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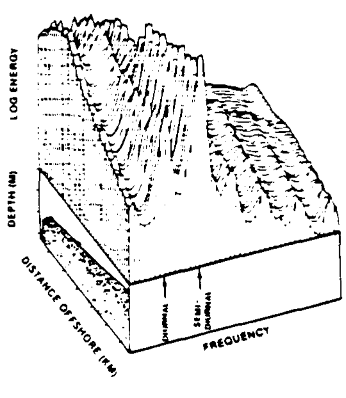
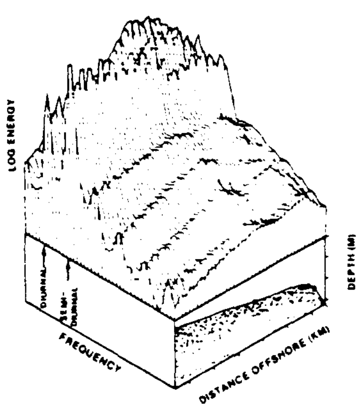
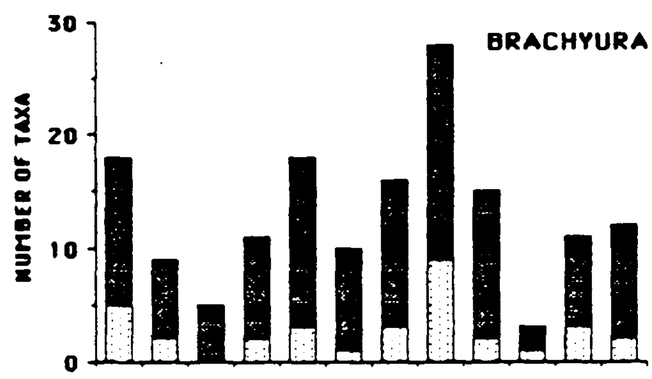
SOUTHWEST FLORIDA SHELF BENTHIC COMMUNITIES STUDY YEAR 5 ANNUAL REPORT

VOLUME II -- TECHNICAL DISCUSSION







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SOUTHWEST FLORIDA SHELF BENTHIC COMMUNITES STUDY YEAR 5 ANNUAL REPORT

Volume II — Technical Discussion

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

Contract No. 14-12-0001-30211

September 1986

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

REPORT AVAILABILITY

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

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

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

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1.0 INTRODUCTION

1.0 INTRODUCTION

This annual report concludes the 2-year Southwest Florida Shelf Benthic Communities Study. This study was part (Years 4 and 5) of the 6-year Southwest Florida Shelf Ecosystems Program scheduled for completion in 1987. The results obtained from the studies conducted in the eastern Gulf of Mexico from December 1983 to December 1985 are presented in this report. Some of the results and a more detailed discussion of the methods were presented in the Year 4 interim report and will not be repeated in this document. This Year 5 annual report includes the final interpretations and conclusions derived from the 2-year field study.

The following sections provide a brief review of sampling completed during the first 3 years of the 6-year program before describing in detail the Year 4 and 5 studies. The field methods and laboratory procedures used are described, and results are presented. Although interpretations and conclusions rely extensively on data collected during Years 4 and 5, data from the previous 3 years have also contributed significantly to the interpretations. The culmination of the Southwest Florida Shelf Ecosystems Program will be the data synthesis report and conceptual model, to be completed in 1987.

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 the Land Management (BLM) [now the Minerals Management Service (MMS)] for the Southwest Florida Shelf Ecosystems Program were as follows:

1. To determine the potential impact of outer continental shelf (OCS) oil and gas offshore activities on live-bottom habitats and communities, which are integral components of the southwest Florida shelf ecosystem.
2. To produce habitat maps that show the location and distribution of various bottom substrates. 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 3 years. 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-m water depth to 200-m water depth. Visual data, combining underwater television and 35-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 corers) 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. A final year (Year 6) was added for synthesis and interpretation of all available data, development of a conceptual model, and impact assessment of offshore oil development.

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 annual report presents the results of this study.

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

Seven other hard-bottom stations, as well as one Group I hard-bottom station, were selected for a more detailed study of biological and physical dynamics. During Year 4, five of these stations, designated Group II and each representing a separate epifaunal community type, were sampled during each of four seasons--fall 1983, winter 1983-1984, spring 1984, and summer 1984. 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.

During Year 4, 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 was equipped with a current meter that measured current speed and direction and temperature; 3 sets of sediment traps at elevations of 0.5 m, 1.0 m, and 1.5 m above the bottom; and 10 sets of substrate plates that were scheduled to be

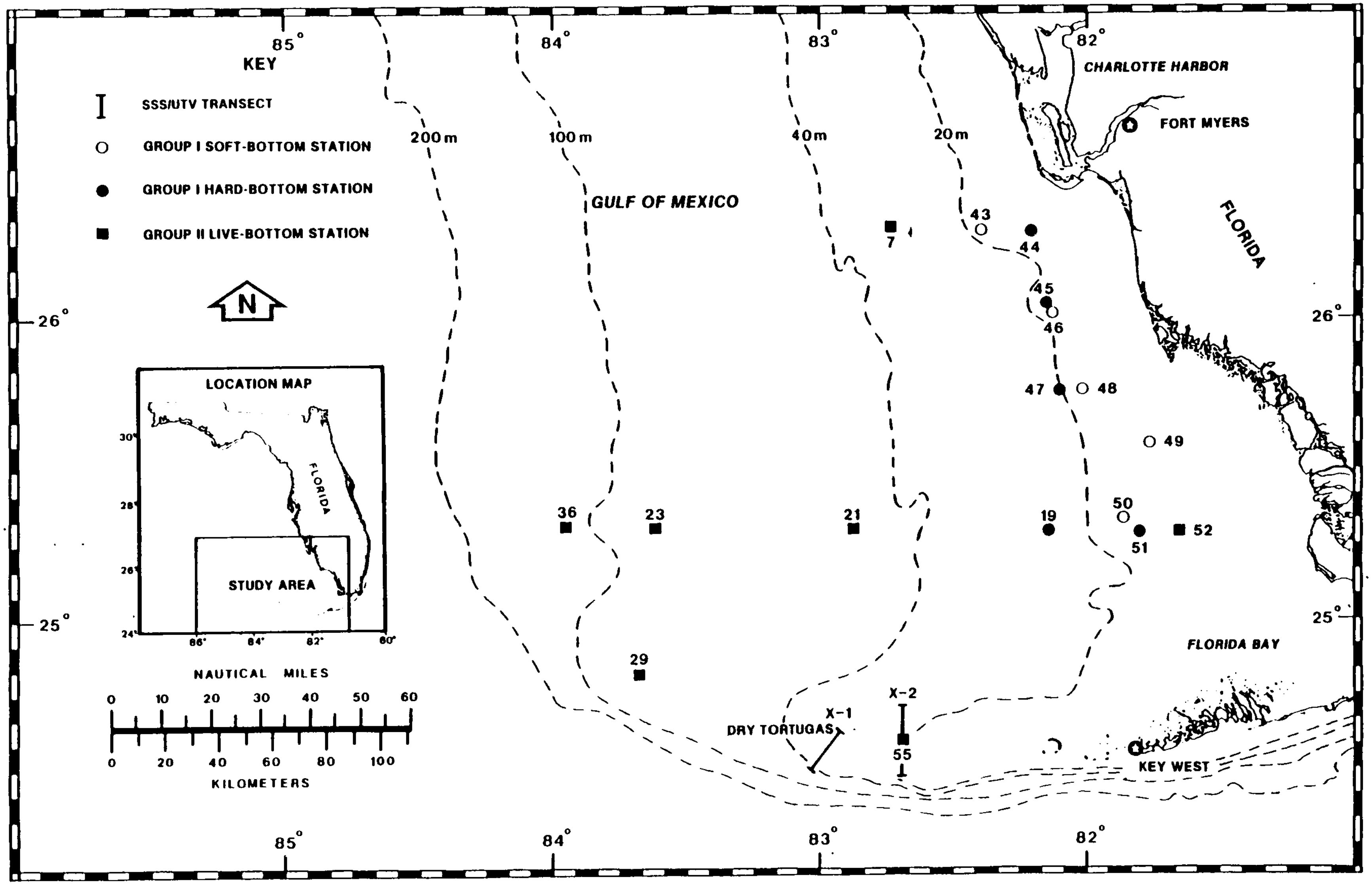

Figure 1.3-1 STATION AND INSTRUMENTED ARRAY LOCATIONS FOR YEARS 4 AND 5

Table 1.3-1. Intensively studied 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
7	32	Middle Shelf	Thin sand over hard substrate	Inner and middle shelf live-bottom assemblage II
44	13	Inner Shelf	Thin sand over hard substrate	Soft coral assemblage I
55	27	Middle Shelf		

retrieved at 3-month intervals over the 2-year study. Also, the arrays at Stations 52 and 21 each contained a wave and tide gage and a time-lapse camera to document sediment transport and biological recruitment. These arrays were serviced quarterly.

During Year 5, intensive quarterly sampling of these five Group II stations continued, and three other stations were added for intensive study (see Figure 1.3-1 and Table 1.3-1). Two of these stations (one was Year 4 Group I hard-bottom Station 44; the other, Station 7) had been sampled previously. The third station (Station 55) situated between the Dry Tortugas and the Marquesas was a new station established during Year 5. This station was chosen primarily because it was at a key location within the boundary of the shelf and would provide valuable information for subsequent modeling efforts. Stations 44 and 7 were selected because they were further north and would provide information on variations in latitude within the study area.

There was some modification to the sampling program during Year 5. Triangle dredge tows were discontinued at the five original stations, and were conducted at only two of the three additional stations (Stations 7 and 55). The third station (Station 44) was sampled only with the instrumented array and CSTD because sufficient underwater television data were already available for similar shallow stations. A second modification was the transfer of the Station 21 wave gage to Station 55 because Station 55 was shallower and would provide better wave measurements. In addition, tide data at Station 55 would be more valuable in providing boundary conditions for subsequent modeling efforts. Also, seven of the eight arrays were equipped with time-lapse cameras; Station 36, the deepest station, was the only array not equipped with a time-lapse camera because it was too deep for the standard camera cases used for the program. Finally, during Year 5, two new transects were surveyed with underwater television and side-scan sonar. Transect X-1 ran from the Tortugas shoals southwest to a depth of 100 m; Transect X-2 ran north- south through Station 55 at an average water depth of 27 m. These transects were added to supplement the habitat mapping studies completed in previous years.

2.0 METHODS

2.0 METHODS

The methods and instrumentation used by the Environmental Science and Engineering, Inc./LGL Ecological Research Associates (ESE/LGL) team to conduct Years 4 and 5 of the Southwest Florida Shelf Benthic Communities Study are discussed in the following sections. The sections are arranged by disciplines as follows:

2.1 PHYSICAL SAMPLING

2.2 BIOLOGICAL SAMPLING

These sections are further subdivided into the specific methods employed to collect data within these categories. In many instances, detailed discussions of methods were presented in the Year 4 annual report. These will not be repeated in the same detail here.

The vessel used by ESE was the Florida Institute of Oceanography's R/V SUNCOASTER. 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. The individual station plots are presented in Appendix A. During any underway sampling, the vessel's LORAN C plotter was used to obtain a continuous track of the survey transects.

2.1 PHYSICAL SAMPLING

Emphasis in Year 5 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 and physical oceanography including 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 eight Year 5 stations. At each station a vertical survey was conducted from surface to bottom. 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. Table 2.1-1 presents the range, time constant, and accuracy of each probe of the CSTD sonde.

The CSTD was lowered to within 1 m off the bottom, then all measurements were manually recorded on ESE Field Data Logs. The sonde was then raised to the next chosen depth and the measurements again manually recorded. The depth and number of manual recordings were decided by the Chief Scientist; however, at least three depths (near-surface, mid-depth, and near-bottom) were always manually recorded.

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

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 msec
Salinity	0-45 ‰	± 0.05	1.4 sec
Temperature	-5-45°C	± 0.05	60 msec
Depth	0-200 m	± 1	50 msec
Dissolved Oxygen	0-40 mg/l	± 0.2	10 sec
pH	2-14 pH	± 0.1	200 msec
Transmissivity	0-100%	± 1	400 msec

Those parameters requiring calibration were corrected using a 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 manually calibrated data against computer calibrations, and (2) comparing calibrated values agains 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.

2.1.2 NISKIN BOTTLE CASTS

A hydrographic cast using a 5-liter (1) 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 reversing thermometer 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 water samples collected near-surface and near-bottom with a Niskin bottle equipped with a 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 and corrected using the temperature measured with the auxiliary thermometer and the standard correction equation presented in Sverdrup et al. (1946).

The salinity samples were obtained from the Niskin bottle, placed in triple-rinsed sample bottles, and returned to the Florida Insitute of Oceanography for analysis. At the Florida Institute of Oceanography, sample salinty 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).

2.1.3 *IN SITU* ARRAY

During Year 5 of the Southwest Florida Shelf Benthic Communities Study, ESE/LGL deployed and maintained an instrumented *in situ* array at eight hard-bottom stations. The arrays (shown in Figure 2.1-1), 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 eight arrays were equipped with settling plates, three sets of sediment traps, and an ENDECO® Model 174MR Current Meter capable of measuring current velocity and temperature. Two of the arrays (Stations 52 and 55) were equipped with Sea Data Model 635-11 Wave and Tide Gages. An ESE/LGL-designed time-lapse camera/strobe system was installed on all but the Station 36 array.

The mooring configuration for the *in situ* array is illustrated in Figure 2.1-2. 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 vessels, the surface float was attached to a weak link that would not support the mooring.

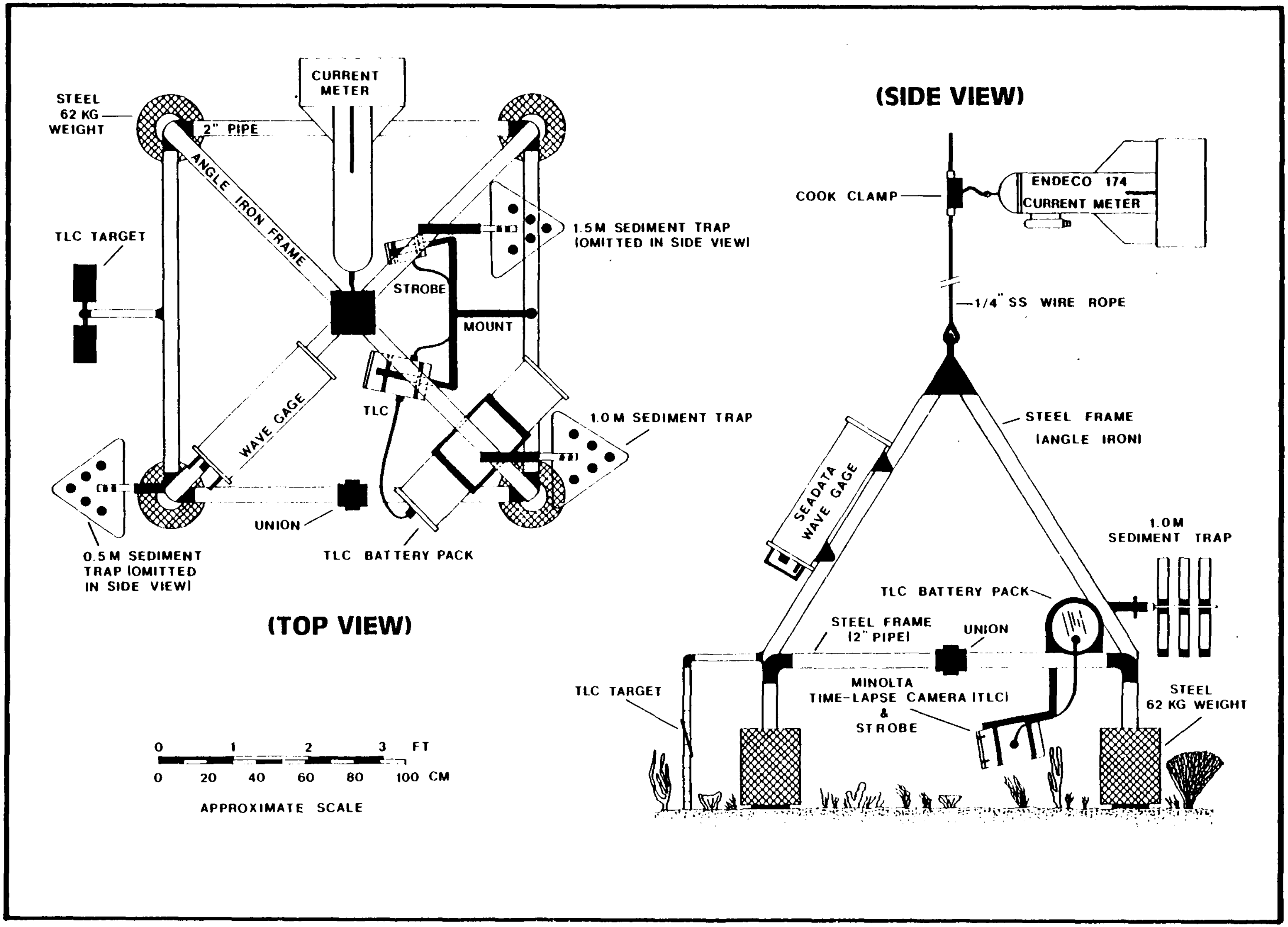

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Figure 2.1-1 *IN SITU* ARRAY (SHOWN WITHOUT SETTLING PLATES FOR CLARITY)

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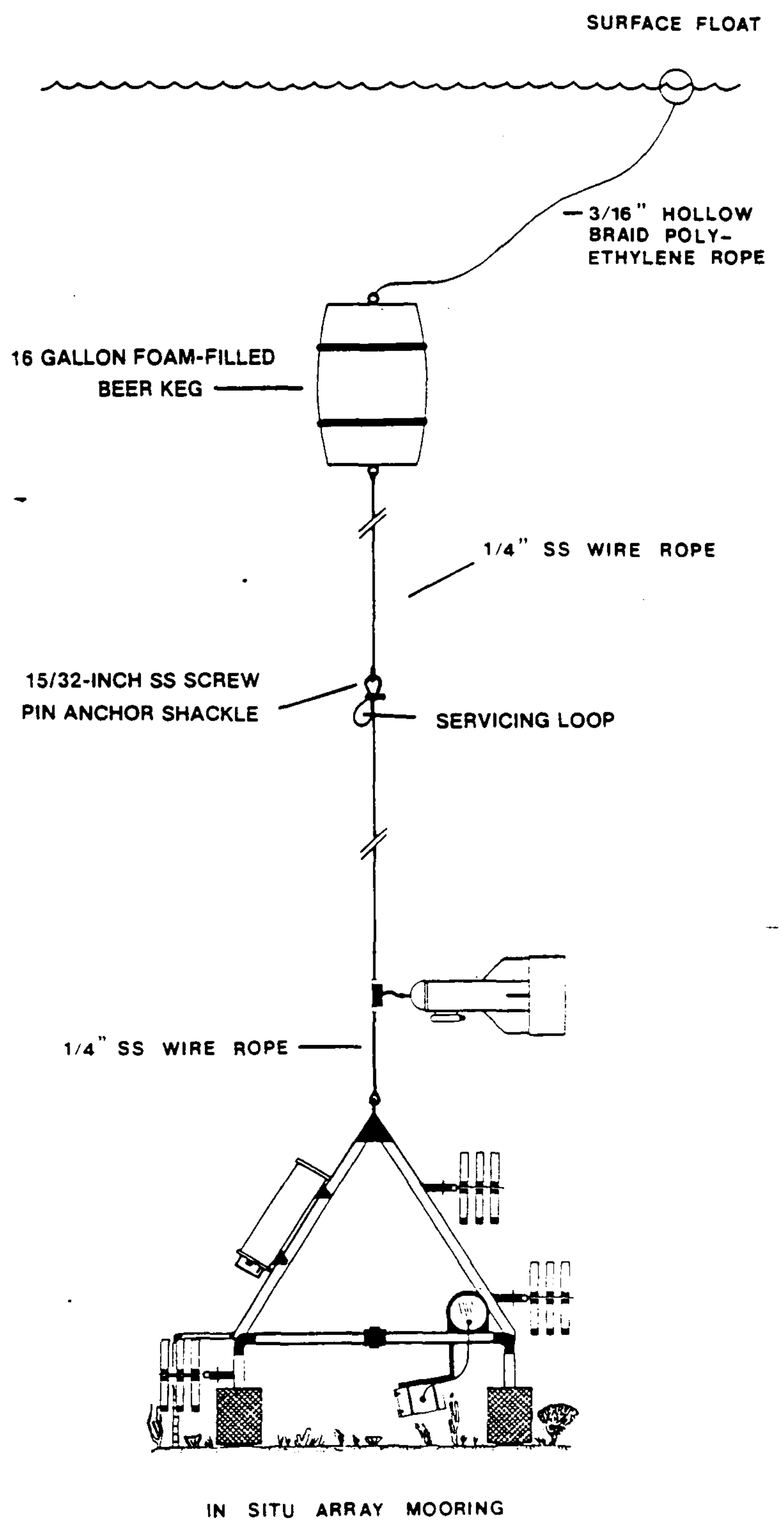

Figure 2.1-2 *IN SITU* ARRAY MOORING CONFIGURATION

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

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 settling plates, the array was not brought onboard. Because of boat motion, the added stress of the heaving 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 forces 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 2.1-3.

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

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

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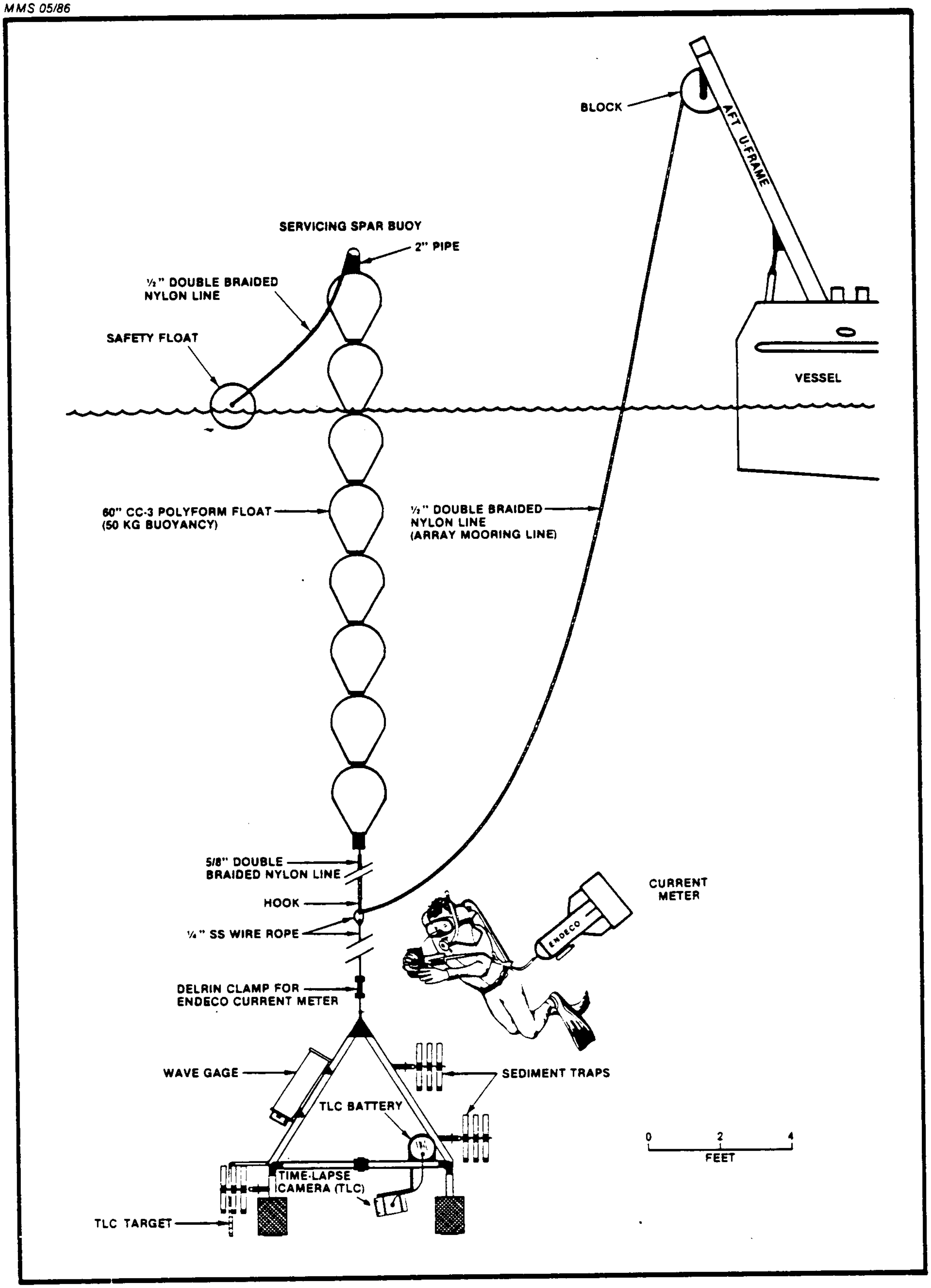

Figure 2.1-3 *IN SITU* ARRAY SERVICING SCHEME FOR DEEP ARRAYS

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. Current velocity data are essential for estimating the transport of pollutants as well as the potential distribution of fish eggs and larvae. Water current data also helped provide estimates of the occurrence and mode of sediment transport at a given station. These data and continuous temperature data are used to estimate the stresses placed on a benthic community. These stresses include swift currents, frequent sediment movement, widely fluctuating temperatures, and the potential for exposure to pollutants transported to the 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 eight stations. The Type 174 current meter is an axial flow, ducted impeller system capable of recording current speed and direction and water temperature, on magnetic tape at predetermined intervals. The accuracy of the speed sensor is ±2.5 centimeter per second (cm/sec); compass - ±7.2 degrees (°); and temperature - ±0.2 degrees Celsius (°C).

The quarterly servicing consisted of removing the current meter from the array for cleaning and inspection; removing and replacing the 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 were again calibrated after final retrieval.

Current data were analyzed to provide information on the fluctuating current characteristics at each station. The current meter records included temperature, current speed, and current direction as a uniformly sampled time series. A sampling interval of 5 minutes (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	Current Speed
Minimum	Alongshore Component of Current (approximately north-south)
Standard Deviation	Cross-Shelf Component of Current (approximately east-west)

These statistics were computed on a monthly, seasonal, and yearly basis for each current meter.

Time-series plots of current speed and direction and temperature were created 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-shelf 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. Principal components analysis to determine the principal 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.

For the initial analysis of the time series record, statistical techniques were used to determine the principal 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 would be required prior to spectral analysis. Comparison of the strengths computed for the x and y components of flow was used to determine the need for further analytical tools such as cross-spectral calculations and cross-correlation analysis.

Numerical computation of energy spectra and cross-spectra 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. Subsets of the time series were prepared for Fourier analysis by using 50% overlap of the data and a 10% cosine bell tapering on each subset. The Fourier analyses were completed on each subset, and the resulting energy at each discrete frequency was averaged to provide the final energy spectral estimate for the seasonal current meter record.

The smallest resolvable frequency can be expressed by:

$$\frac{1}{\Delta tN}$$

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 arrays at Stations 55 and 52 were equipped with Sea Data® Model 635-11 Wave and Tide gages. The 635-11 is a self-contained digital recording wave and tide gage designed for subsurface deployment. The 635-11 measures waves and tides simultaneously by recording water height (pressure) with a resolution of 1:65,000 using a Paros Scientific® Quartz Sensor. The accuracy of the pressure sensor is ±1.5 cm at a depth of 25 m.

The Sea Data® digital wave-tide recorder provided a subsurface pressure record used to calculate a surface wave record from which subsurface orbital velocities associated with wave motion were computed. The contribution of surface waves to turbulence near the bottom was deemed significant for shallow water and was only measured at Stations 52 and 55. Wave data, in particular, are used to estimate the occurrence of wave-induced sediment transport and subsequent stress to the benthic community. In addition, stress associated with wave-induced water motion can be significant for shallow benthic communities. Periods of natural occurrence of high suspended solids were of particular interest for comparison with values that may occur during drilling operation discharges.

The Sea Data® gage records both wave and tide measurements. The tide measurement interval was set to record eight averaged measurements 1/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-sec intervals during the burst. Wave fields characterized by low frequency and long wavelengths, with periods of 8 to 15 sec, 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 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.

The pressure is then determined from the pressure/frequency equation given previously. Because no data are available for barometric pressure at the test site, a standard pressure of 1013.3 millibars (mbars) is assumed. The water height above the sensor is then produced for each pressure reading.

$$H(i) = [(P(i) - 68.947)/98.068] - 10.333$$

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

The Sea Data® instrument uses a Paros 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 according to the dispersion relationship:

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

where: g = gravitational constant, and

ω = wave frequency.

For any frequency ω, the value of k is calculated by an iterative technique, using the Newton-Raphson algorithm to calculate the values of k. An iterative procedure is used to find a new value until the values converge to within ± 0.001.

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 at each station 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 and the frequency of major energy was extracted.

$$P(\omega) = \mathcal{F}\, P(t)$$
$$Y(\omega) = 1/K_p\ P(\omega)$$
$$S(\omega) = Y(\omega)^2/(2\pi T)$$
$$S(\omega) = P(\omega)^2/(2\pi T)/K_p{}^2$$
$$\text{Total energy} = \sum_{n=1}^{N} S(\omega)$$
$$H_s = 4 \times \sqrt{T}$$

where: $\mathcal{F}$ = 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.
T = total energy

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

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 magnitude of the orbital velocity is represented as:

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

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 as with wind-generated waves. Tide readings were converted directly to water level heights for harmonic analysis, low-pass (33-hour) tidal records and spectra analysis.

The continuous direct measurement of water surface displacement primarily resulting from tidal and meteorologial forces was required to determine:

1. Low-frequency energy observed as storm tides (surge),
2. Magnitudes of the various tidal components (harmonic analysis), and
3. Relative energy of tidal frequencies within the spectrum.

After tidal records were preprocessed using the appropriate calibration factors given previously, the continuous tidal data were filtered to isolate the tidal frequencies (bands) using a band pass filter to allow greater resolution over the width of the spectrum containing the most significant energy. The 33-hour low-pass filter (developed at Woods Hole Institute) was used to remove the diurnal and semi-diurnal components of the tide and pass only the slow variations ($\geq$33 hour) in z(t).

Tidal records containing both astronomical and storm tides were separated using a sharp cutoff digital filter of the form:

$$Z_{nt33}(t) = \sum_{n=1}^{n=67} C_n \cdot Z_n(t)$$

After passing the filter over the tidal record primarily only storm signals remain. This is useful for understanding the local response to storm conditions (events) within the Gulf of Mexico and the Straits of Florida. Tidal records of low-frequency forcing will be plotted and analyzed further.

In the analysis of tidal spectra, estimates of tidal energy were computed for both low-pass and unfiltered data collected continuously for a 12-month period. To obtain the necessary confidence interval, long continuous tidal records were required. Where the resolution of discrete spectral lines depends on both a large number of samples (N) and the distance between spectral bands (Δf) in the form:

$$\Delta f = 1/N/\Delta t$$

The data set is segmented using the most appropriate time windows to allow 15 windows in time. The tidal data are then preprocessed to remove the mean and a 10-percent cosine bell tapering is applied. Frequencies which contain significant energy are then analyzed to determine the tidal forcing mechanism (astronomical, seiching, or meteorological).

Characteristics of the tidal record at any location are governed by the dominant tidal components. The observed tidal variations were used to determine the amplitudes of specific tidal components for the most important tidal constituents. These records were resolved into 27 harmonics for which both amplitude and phase angle were computed. This will, in general, allow accurate predictions of tide heights at the location of Stations 52 and 55 on the continental shelf. The total astronomical tide would be computed using the sum of these 27 tidal constituents:

$$Z(t) = \sum_{n-1}^{n=27} A_n \cos \frac{360\ t}{T_n} - \theta_n$$

where: n = individual constituent,

A_n = amplitude of the tidal constituent,

T_n = period (hours) of the tidal constituent, and

O_n = phase-angle of the constituent (degrees).

The spacial variation of the tides resulting from tidal response to changes in the bottom and local boundary conditions will also be evident and addressed in the results/discussion section.

Sediment Traps

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. These methods are described below and in Subsections 2.1.6 and 2.2.5. The *in situ* arrays were equipped with sediment traps and 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 were used to study sediment dynamics at these eight stations. A description of the sediment traps is presented below; time-lapse cameras are discussed in Subsection 2.2.5.

Sediment traps were installed at all eight stations to measure the time-averaged vertical sediment flux at 0.5, 1.0, and 1.5 m above the seabed. Sediment traps were deployed to provide an estimate of sediment resuspension and/or importation to the study area. The sedimentation rate indicates the level of stress to a benthic community and aids in the assessment of the relative effects of drilling muds with respect to the suffocation of epifauna. The sediment traps were simple cellulose acetate butyrate cylindrical tubing with diameters of 4 cm and were 40 cm long. Five traps were mounted at each of the 0.5-, 1.0-, and 1.5-m levels above the bottom to provide replicate samples.

The sediment traps were capped, retrieved, and replaced each time the instrument array was serviced by divers. These sediment samples were then frozen and returned to the laboratory for analysis.

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, 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 occasionally exhibited slight tonal and textural variations that were visually discernible; such laminations, if present, 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. Each sample 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 sample was calculated. The mass was corrected for the contribution made by the soluble salts precipitating in the sediment after evaporation of the water using the known seawater salinity at the station from which the sample was collected.

Once the mass of dry, salt-free sediment was determined, the sediment sample from each tube was carefully mixed and then split into subsamples for grain size, $CaCO_3$ content, and organic carbon content analyses. Preparation of a sample for grain-size analysis involved the oxidation of organic matter within the sediment, flushing of the soluble salts that precipitated in the sediment during evaporation of interstitial seawater, and the dispersal of clay particles that may otherwise have exhibtited a tendency of flocculate.

Organic matter was removed from the sediment grain-size sample by treating it with hydrogen peroxide (H_2O_2) until no further reaction was evident. Following oxidation, the soluble salts and excess H_2O_2 were removed by repetitive washing (with deionized water), centrifugation, and decanting. The sample was then dried and weighed and then mixed with 4% sodium hexametaphosphate solution to inhibit flocculation of clay-sized particles.

Grain-size analysis of sediment trap samples was accomplished using the standard pipette analytical techniques for silt- and clay-sized particles. Because the sediment samples were usually silt- and clay-sized particles during normal periods of current and wave energy, this analysis was usually sufficient; however, the sample was always washed over a 63-um [4 phi (ϕ)] screen to retain any sediments with particle sizes greater than silt. The sample retained, if any, was dried and weighed. If this sample constituted greater than 5% of the original bulk sample weight and was in excess of approximately 10 g, then a seive analysis was conducted.

These size data were entered into the computer and analyzed statistically according to the methods described by Folk and Ward (1957). Folk and Ward's statistical methods were used because frequently the sediments would either demonstrate severe skewing or a bimodal distribution. The statistical parameters (mean, median, standard deviation, skewness, and kurtosis), as well as a cumulative frequency plot were presented for interpretation.

Depending on 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 $CaCO_3$ using hydrochloric acid 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 $CaCO_3$. 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 carbon dioxide (CO_2) in the $CaCO_3$. The structural water existing as hydroxyl groups (OH) with 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.

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 where 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% 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.

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
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 data and sea surface temperature charts available from the NOAA-7 and NOAA-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 2.1-4). The offshore data were collected by NOAA Data Buoy

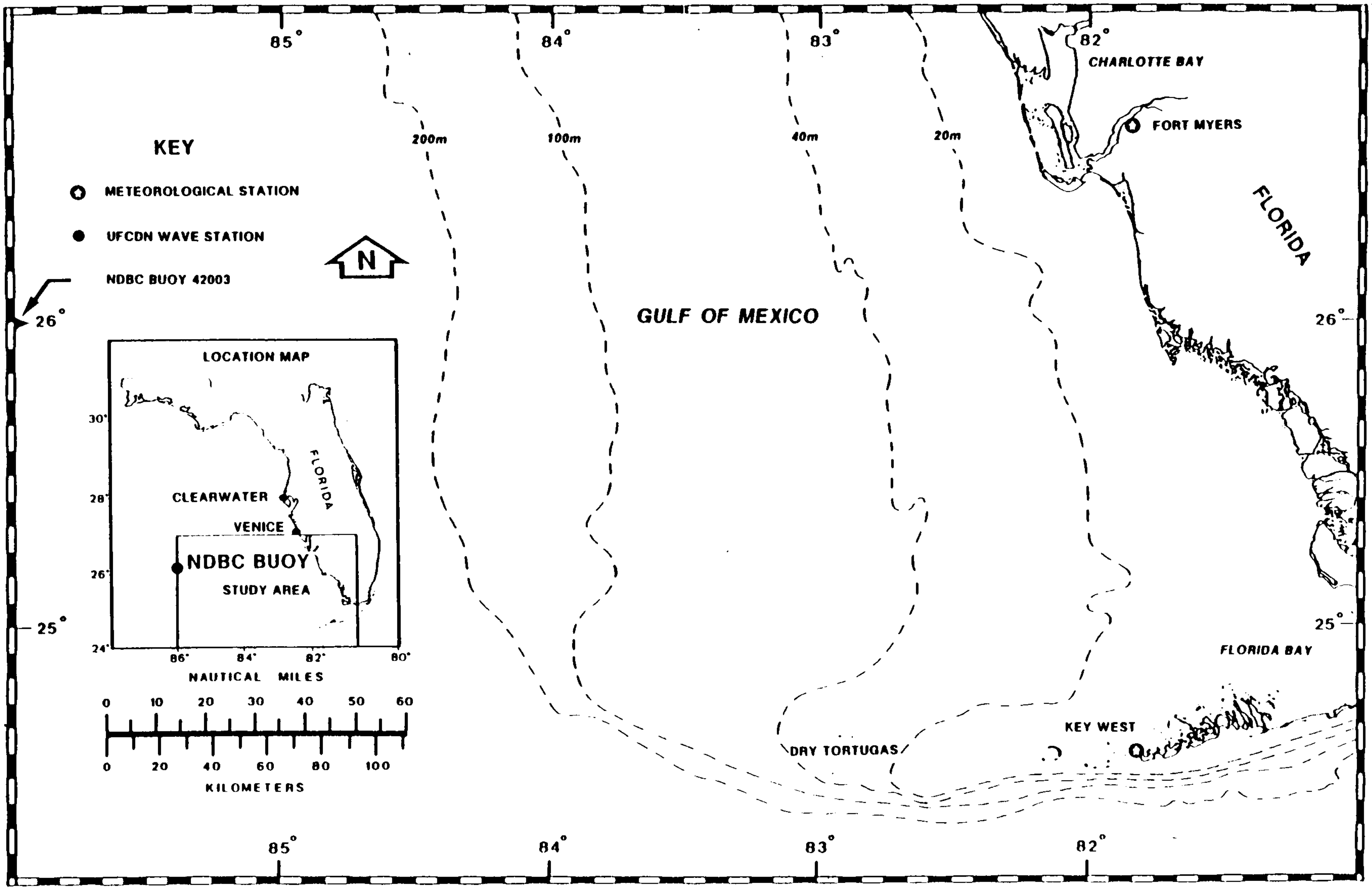

Figure 2.1-4 LOCATIONS OF NDBC BUOY 42003, UFCDN VENICE WAVE GAGE, AND NCDC METEOROLOGICAL STATIONS

Center's (NDBC) Buoy Number 42003 located at latitude-26°00'00"N and longitude-85°53'59"W from November 1983 to December 1985. The nearshore data were obtained from the University of Florida's Coastal Data Network wave stations located offshore of Venice and Clearwater, Florida.

Continuous meteorological data, including wind velocity, air temperature, precipitation, and weather, were obtained from NDBC Buoy Number 42003 and the Local Climatological Data Monthly Summaries published by the National Climatic Data Center (NCDC) for Tampa, Fort Myers, and Key West, Florida.

2.1.6 GRAB SAMPLES

Duplicate bottom sediment samples were collected from each station during the first cruise. Sediment samples were collected with a Smith-McIntyre grab [area = 0.1 square meter (m^2)]. A core subsample was taken from the center or least disturbed area of the Smith-McIntyre grab sample. 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.

These samples were analyzed for grain-size distribution, $CaCO_3$ content, and carbon content as previously described.

2.2 BIOLOGICAL SAMPLING

2.2.1 UNDERWATER TELEVISION

Field Methods

Underwater television surveys along transects near the bottom were performed at Stations 44, 51, 45, 47, 19, 52, 21, 29, 23, and 36 during Year 4, and at Stations 52, 21, 29, 23, 36, 55, and 7 during Year 5 (Table 2.2-1). These surveys were intended to produce quantitative estimates of the abundance of major species, and to characterize benthic habitats.

Surveys took place only during daylight hours, because fish counts made during twilight or dark periods are known to be biased (Starck and Davis, 1966; Collette and Talbot, 1972). Surveys were conducted with black-and-white video equipment remotely operated by a trained observer by direct, hard-wired electrical cable connections from the vessel. Black-and-white cameras were selected because they are more sensitive to low light levels than are color cameras, and because artificial lighting (which would have been required for color definition) was considered likely to interfere with fish behavior. It was possible to use the underwater television system without artificial lighting except at Station 36, where natural light levels were too low to provide an acceptable video image.

The principal components of the underwater television system were twin Sub-Sea Systems® Model CM-8 underwater cameras with Ultricon® picture tubes, and a Sub-Sea Systems® Model ST-1000 stereo control console with multiplexer. The cameras were mounted on a Sub-Sea Systems® Model A50 pan-and-tilt motor fastened inside an LGL Model GSB Mark III steel camera frame. The pan-and-tilt motor also supported a Sub-Sea Systems® 400-watt (w) mercury vapor lamp; a 250-frame Olympus® Model OM-1 single-lens reflex camera (loaded with Ektachrome® ISO/ASA 200 film) in a custom stainless-steel housing; and an Ikelite® Model SS150 underwater strobe. Cameras and lights were mounted adjacent to one another with their optical axes parallel so they could all be pointed together at various subjects by use of the pan-and-tilt motor.

Table 2.2-1 Summary of biological sampling, by cruise and gear type. Time-lapse camera and fouling plate sampling are not included in this table.

PROGRAM:			YEAR 4				YEAR 5			
MONTH/YEAR:			12/83	3/84	5/84	8/84	12/84	3/85	6-7/85	9/85
CRUISE:			1	2	3	4	5	6	7	8
	Group									
Station	YR 4	YR 5								
44	I	N/A	D,U,T*		D,U,T					
51	I		D,U,T		D,U,T					
45	I		D,U,T		D,U,T					
47	I		D,U,T		D,U,T					
19	I		D,U,T		D,U,T					
52	II	II	D,U	D,T	D,U,T	D,U,T	U,T	H,U,T	H,U,T	H,U,T
21	II	II		D,U,T	D,U,T	D,U,T	U,T	U,T	U,T	U,T
29	II	II	D,U,T	D,U,T	D,U,T	D,U,T	U,T	U,T	U,T	
23	II	II	D	D,U,T	D,U,T	D,U,T	U,T	U,T	U,T	
36	II	II	D	D,U,T	D,U,T	D,U,T	U,T	U,T	U,T	
55		II					D,U,T	D,U,T	D,U,T	D,U,T
7		II					D,U,T	D,U,T	D,U,T	D,U,T

*Gear types: U = Underwater Television; T = Trawl; D = Dredge; H = High-resolution Benthic Photography.

Signals from the cameras were transmitted through a dual coaxial cable, permitting signals from either the right or the left camera to be viewed on a single monitor, and to be recorded on a portable Panasonic® Model NV-8410 VHS single-channel videotape recorder. The signals from both cameras could also be multiplexed and viewed simultaneously on the same monitor, and recorded to determine transect dimensions or object sizes (see below). Each 1/2-inch tape cassette recorded up to 2 hours of observations.

To conduct the surveys, the camera frame was lowered on the trawl winch wire over the stern of the vessel, along with the electronic cables required to transmit video signals upward and control signals downward. During descent, these cables were hand-tended and affixed to the trawl wire by means of hose clamps and duct tape. On board the vessel, the observer could trigger the still camera, focus the video cameras, turn the lamp off and on, and operate the pan-and-tilt motor. The frame was lowered to within 1 m of the bottom, and then "flown" by directing a winch operator to raise or lower the system depending on the upcoming terrain seen with the video cameras or on the vessel's echosounder. The camera frame had a vertical stabilization fin to reduce twisting movements and facilitate towing. When wind and weather permitted, the vessel was allowed to drift slowly. Occasionally, it was necessary for the vessel to tow the camera frame by taking its engines in and out of gear at idle speed to maintain an approximate speed of 1 knot.

Upon arrival at each station, a 1-km^2 block was established around the station's center location. The center and margins of the block were marked on the vessel's LORAN C plotter, and the ship's position tracked on the plotter. The camera frame was lowered over the side at the upcurrent or upwind edge of the block. A transect consisted of one pass across the block. In general, the camera frame was raised on deck at the end of each transect, and the vessel repositioned at the upwind or upcurrent side of the block prior to redeployment. When heavy weather or opposing wind and current made it difficult to drift through the block, the camera frame was not brought on deck between transects, and the vessel would pass back and forth through the block, with each pass constituting a transect. A summary of areas transected on each cruise, by station, is given in Table 2.2-2.

A trained observer monitored the view seen by the video camera throughout each survey, taking notes and recording observations by voice on the videotape. Navigation fixes (LORAN C) were taken at 5-min intervals, and at the start and finish of each habitat type traversed. The fixes were audio-dubbed on the videotapes and recorded in the observer's log, along with comments about subjects seen on the monitor at each fix. The 35-mm camera was triggered whenever the observer felt that a high-resolution photograph might be required for laboratory identification of organisms seen on the videotape, or for recording characteristic habitats and biota.

Laboratory Methods

Recorded videotapes were analyzed in LGL's laboratories in Bryan, Texas, using Panasonic® Model 8200 and 1750 VHS videotape players capable of a minimum of 270 lines of monochrome horizontal resolution. The tapes were viewed on a 19-inch Sony® television, with an external video image enhancer for increased resolution and contrast. Sample analysis for each transect followed a two-stage process--initialization followed by evaluation.

Initialization of each transect consisted of determining transect width and drift speed, to permit later calculation of actual areas surveyed. Transect census width was largely a factor of underwater visibility, and was assessed from time to time by operating the video cameras simultaneously. On playback, the multiplexed recording produced a split double image on the monitor screen. Transect census width was determined by measurement of the displacement of recognizable points on these double images.

Table 2.2-2 Area surveyed (m^2) at each station with UTV, by cruise.

Cruise	Station 52	51	44	45	47	29	19	21	23	36	55	7
1	6,760	9,114	2,475	5,605	9,436	5,079	11,424					
2						16,794		4,100	14,888	5,124		
3	9,267	14,940	12,260	22,048	20,368	15,492	16,456	17,908	16,092	4,426		
4	7,640					7,368		8,217	8,316	9,405		
5	2,489					8,427		3,606	3,686	8,333	5,044	12,312
6	7,098					7,665		6,501	6,267	4,688	6,834	4,800
7	2,511					6,498		6,726	5,593	2,253	3,708	4,884
8	3,562							8,430			7,860	7,488
Total:	39,327	24,054	14,735	27,653	29,804	67,341	27,880	55,458	54,842	34,829	23,446	29,484

Total for all stations: 559,510

LORAN C plotter diagrams of video transect start and end positions were then measured to determine total transect length. This length was divided by elapsed time to obtain an overall drift speed. Transect width and drift rate were considered constant throughout each transect, except when unusual changes in visibility or wind velocity had to be considered. The calculated drift rate and the nearest LORAN C fix were used together to determine the position of any given observation along a transect.

Evaluation consisted of determining what sorts of organisms and habitat types were present, and estimating their abundances or relative importance. Since a very large area was surveyed during this program, it was necessary to develop methods for viewing each videotape rapidly and efficiently. Three techniques facilitated rapid scanning: (1) dividing transects into visually homogeneous portions ("habitat type segments"), (2) estimating densities and percentage cover of benthic organisms and substrate types within quadrats or subsamples at the beginning of each segment, and (3) applying those estimates to the entire segment.

At the beginning of a transect, the amount of time it took to cover a 10-m^2 quadrat was calculated, using values for drift rate and transect census width derived during the initialization process. The abundances of benthic organisms and substrate types within three adjacent quadrats were then determined, and the mean of those values was applied to subsequent portions of the videotape (without remeasurement of abundances) until visually distinguishable changes were noted. At that point, one segment was considered to end and another to begin.

The observer then reassessed abundances within three new adjacent quadrats at the beginning of the new segment, and applied the mean of the three new values to subsequent portions of that segment until the next change was observed, and so forth. Changes in substrate percentage cover also could mark the beginning and end of habitat type segments. Any transect could include from one to many habitat type segments, depending on the heterogenity of the bottom in that area. Each segment, therefore, could be different in length and area.

Both density and percentage cover estimates were employed, depending on what was being assessed. Whenever possible, organisms (e.g. fishes, asteroids) were counted individually. However, it was not always feasible to count individual organisms present in extremely high numbers. Under these conditions, their abundance was frequently estimated with ranges that could easily be distinguished from one another (Table 2.2-3). The abundances of some species (e.g. crinoids, gorgonians) varied tremendously, and their densities were estimated with individual counts and ranges. This situation could occur along the same transect.

In some cases, morphological characteristics precluded the enumeration of individuals (e.g., algae, sponges, or *Agaricia* plates). For these organisms, and for substrate types (e.g., sand), percentage cover was used to estimate abundance. Percentage cover was always expressed as a range, except for values of 0% and 100%. Whenever possible, estimates of percentage cover were made when the camera viewed subjects vertically, to minimize the effects of angular distortion.

Visual identifications of organisms were made to the lowest possible taxon and confirmed by specialists as needed. Each identification was assigned a quality index score ranging from one through five, depending on the confidence that could be placed in identification (Table 2.2-4). A score of five indicated that there was virtually no doubt about the identification. A score of one implied that even though a name had been assigned, there was a high degree of uncertainty concerning the identification. The quality index of doubtful identifications was raised whenever possible by using information from the 35-mm photography described above. Quantitative analyses were performed only on data having a score of at least three. Many sections of tape had to be replayed numerous times or viewed at slow speeds to identify or count organisms not distinctly visible.

Table 2.2-3 Scoring system for underwater television abundance data.

1. Density of gorgonians and crinoids:

Score	Density Range
1	$\leq$ 1 per $10m^2$
2	2-10 per $10m^2$
3	11-50 per $10m^2$
4	51-100 per $10m^2$
5	101-200 per $10m^2$

2. Density of fishes and other non-colonial taxa: Flexible range to reflect numbers observed, or non-range (actual count) estimates

2. Percentage cover of sponges, algae, algal nodules (rubble), live agariciid corals, sand, reef rock, and bare patches*:

Score	Range (%)	Score	Range (%)
1	0	6	51-75
2	$\leq$1	7	76-90
3	2-10	8	91-99
4	11-25	9	100
5	26-50		

3. Sponge growth forms:

Score	Types
1	All massive type
2	All branching
3	Approx. equal ratio of branching to massive
4	Predominantly massive, some branching
5	Predominantly branching, some massive

4. Species-specific size categories:

Score	Size
1	Very small
2	Small
3	Medium
4	Large
5	Very large

5. Other significant observations:

Score	Interpretation
1	Apparently dead; e.g., white sand dollar, dead fish
2	Dead gorgonian stalk covered with algae
3	Present, density not recorded

*Hard substrate considered underlying pavement; taxa overlying substrate scored separately for percentage cover.

Table 2.2-4 Scoring system for quality of taxonomic identifications from underwater television data.

Score	Interpretation
1	Best guess
2	Probable
3	Reasonably likely
4	Fairly certain
5	Virtually certain

Each transect was viewed in its entirety. Organisms were considered outside the transect if they were observed more than 5 m above the bottom, or behind an imaginary line through the camera crossing the direction of travel at a 90° angle. Data from each habitat type segment and for the entire tape were first recorded on intermediate preprinted work forms (Table 2.2-5), and then transferred to computer coding forms, entered, and verified.

The underwater television data were used to estimate densities, cover or organisms and substrates, and to place confidence limits on those estimates. In addition, correlation analyses (underway for Year 6) relied on accurate abundance estimates. For consistency, all density estimates are presented in terms of numbers of individuals per hectare, and cover estimates are expressed as a fraction of 100%. The underwater television data set consisted of a continuous record of events or observations along each transect. There were various types of events, such as:

1. Beginning and ending of each transect;
2. Presence of individual fishes or benthic organisms;
3. Beginning of a segment containing organisms whose abundances were considered constant for some distance;
4. End of a segment containing organisms whose abundances were considered constant for some distance;
5. Changes in transect width, depending mainly on visibility.

To use these events to estimate abundances of organisms and substrate types, it was necessary to determine the area transected per event. The process of determining areas required several steps. Each event was encoded with a time and a videotape counter number to permit spatial indexing along each transect. To convert tape counter numbers reliably to distances along transects, each videotape counter was individually calibrated in units of time (i.e., turns per minute).

Table 2.2-5 Information recorded on transect work and coding forms, and in final data records for underwater television transects.

Transect work forms:

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. Densities or percentage coverage of biota; and
6. Time fixes.

Coding forms (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 (to NODC specifications):

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*.

---

*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.

Distances along transects were determined from LORAN C readings taken at the beginning and end points of each transect, as well as from periodic notes made by the observer on board every 5 to 10 minutes, or when particular events were cited.

By starting at a known position and then checking the tape counter reading subsequently, the exact position of each event and the area transected could thus be determined while videotapes were being analyzed in the laboratory.

Both overall (global) and local abundance estimates were calculated, depending on their intended uses. Overall estimates were used for presentations of abundance per transect, per cruise, and per station. They were derived by combining estimates for segments of known areas. Local density estimates were calculated for within-transect correlations of abundances to be presented in the Year 6 report.

Overall estimates for organisms that could be counted on any given cruise at each station were calculated as in the following equation.

$$D_T = (N_T/A) \times 10{,}000 \tag{1}$$

where: D_T = density of taxon T,
N_T = number of individuals of taxon T in all transects together on that cruise, and
A = combined area of all transects surveyed on that cruise.

This estimate was appropriate only when a taxon was completely enumerated, and could not be used when abundances were estimated as ranges. For organisms whose densities were estimated as ranges, it was necessary to use actual start/stop distances within each transect. The estimated density for these organisms was calculated using the following equation.

$$N_T = (T_{stop} - T_{start}) \times W \times D_{scale} \quad (2)$$

where: N_T = number of individuals of taxon T in a given segment,
T_{start} = beginning of a segment within which the density (in m) of individuals in taxon T is estimated to be constant,
T_{stop} = end of that segment, where the density of taxon T changes perceptibly,
W = transect width, and
D_{scale} = estimated abundance of individuals in that segment.

D_{scale} was selected as the median value within a range estimate. For example, for a range of 2 to 10, D_{scale} would be 6. To estimate abundance for an entire transect, N_T estimates for each segment were accumulated, and then calculated per equation (1). Overall estimates of percentage cover (based on ranges) were also calculated from segments using scaled start/stop data as in equation (2), and then divided by total transect area to yield an overall estimate.

Local abundances were calculated by dividing each transect into 50-m-long segments of varying areas. The area within each segment was then calculated based upon transect width, using parallel cameras as described previously. The number of individuals or percentage cover was then determined for each segment by accumulating records linearly by taxon within that segment, using position information from calibrated tape counter records.

Cluster analyses were also performed for fishes censused with underwater television to delineate groups of stations. Both presence/absence (Dice index) and Czekanowski Quantitative (Bray-Curtis) coefficients were used (Boesch, 1977). These analyses are described more fully in Subsection 3.3.4, Cluster Analyses.

2.2.2 TRIANGULAR DREDGE

Field Methods

Triangular dredge samples were collected at Stations 44, 51, 45, 47, 19, 52, 21, 29, 23, and 36 during Year 4, and at Stations 55 and 7 during

Year 5 (Table 2.2-1). Dredging was undertaken mainly to aid in identifying species seen on the underwater television. On each visit to stations sampled, three replicates were taken (weather permitting). The Kahl Scientific Company steel dredge was attached to a three-point chain towing bridle. It had a mesh size of 1.2 cm, its equilateral triangular mouth was 60 cm on each side, and its overall length was 120 cm.

After testing various towing speeds and durations, dredging was standardized at approximately 1 knot ($\simeq$50 cm/sec), for 2 min on the bottom. Once the dredge was back on deck, the sample was dumped, photographed and sorted. Representatives or portions of each visually distinguishable species were retained, relaxed in magnesium sulfate if required, labeled, and preserved in 10% neutral buffered formalin.

Laboratory Methods

Triangular dredge samples were returned to LGL's laboratories in Galveston and Bryan, Texas, for analysis. Samples were first sorted into major taxonomic groups and relabeled for tracking purposes. The specimens in each group 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), to ensure consistency in identifications between samples.

Several major taxa were stored but not identified due to limitations on time and resources. Sponges were the most important organisms in this category. Additionally, polychaetes and smaller crustaceans (e.g., amphipods) were stored but not identified. Sorted specimens to be identified were assigned to the lowest practicable taxon. Specimen identifications were recorded on computer coding forms using standard NODC guidelines and taxonomic codes for entry and verification.

Sorted, labeled, and identified samples of most taxa were then returned to the appropriate fixative (either 10% neutral buffered formalin or

40% isopropyl alcohol) for archival storage, and for use in resolving coding errors detected during the verification process. Some groups (e.g., scleractinians) required special processing such as tissue digestion to reveal skeletal features for identification, and were stored dry.

Data Analysis and Synthesis

The triangular dredge was not considered a quantitative sampling tool for many groups of organisms due to its (1) large mesh size, (2) tendency to clog with large sponges, and (3) ability to take hauls much too large to preserve intact (see Subsection 4.2.2, Methods Evaluation and Recommendations). Consequently, data from the triangular dredge are treated and displayed throughout this report as presence/absence information, rather than as abundance information.

Cluster analyses were performed for invertebrates and plants collected by trawling, in order to delineate groups of stations. The presence/absence (Dice index) was used. This analysis is described more fully in Subsection 3.3.4, Cluster Analyses.

2.2.3 OTTER TRAWL

Field Methods

Trawl samples were collected at Stations 44, 51, 45, 47, 19, 52, 21, 29, 23, and 36 during Year 4, and at Stations 52, 21, 29, 23, 36, 55 and 7 during Year 5 (Table 2.2-1). Trawling was undertaken (1) to help complete a fish species list of each station, (2) to aid in identifying species seen on underwater television, and (3) to provide samples for analysis of fish diet and reproductive state. A single tow was made at each station on each cruise (weather permitting) with a Marinovich® 25-ft (7.6 m) semi-balloon otter trawl equipped with plastic rollers. The trawl was towed at 1 to 2 knots for 10 min on each sampling visit to a station, except at Stations 29 and 23, where rough bottom occasionally necessitated reducing the trawling time to 5 min to minimize damage to the net.

The body of the net, as originally supplied by the manufacturer, had a mesh size of 1-1/2 inches (3.8 cm), and was made of #9 nylon thread. The cod end had a mesh size of 1-1/4 inches (3.2 cm), and was made of #15 nylon thread. To improve the catch, a steel towing bridle and a galvanized tickler chain were attached to the otter doors for Cruise 2. Due to abrasion and heavy hauls, it was necessary to add a polypropylene chafing bag to the outside of the net on Cruise 3. It was also necessary on Cruise 7 to replace a large section of the body and the entire cod end with heavier twine (#12 on body, #30 on cod end) dipped twice in net enamel. The extra weight of these modifications required the 36-inch x 18-inch (91.4-cm x 45.7-cm) "sport doors" originally installed to be replaced with with 48-inch x 24-inch (121.9-cm x 61-cm) gar-type, slotted doors on Cruise 8.

After the net was brought on board, each sample was photographed and sorted. All fish were preserved in 10% neutral buffered formalin, and shipped to LGL for analysis.

Laboratory Methods

Fish collected with the roller otter trawl were returned to LGL's laboratories in Bryan, Texas. 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, drained, and weighed. Sex and state of maturity were then determined by dissection of each specimen. Sex and state of maturity were assessed per NODC protocols (Table 2.2-6). Maturity stages given for synchronous hermaphrodites (species of Serranus, Diplectrum, and Hypoplectrus) were based only on the female gonads. The maturation of male gonads in these species was similar in timing to that of the female gonad (at least in the riper stages), because spawning is usually reciprocal.

Stomach contents were analyzed for eight species of fishes: Haemulon plumieri (the white grunt); Haemulon aurolineatum (the tomtate); Serranus

Table 2.2-6 Categories used to evaluate sex and reproductive condition in fishes collected by trawling.

Sex		Reproductive Condition	
1.	Male	1.	Gonad absent
2.	Female	2.	Gonad immature
3.	Indeterminate	3.	Gonad mature or maturing
4.	Hermaphroditic	4.	Gametes ripening
		5.	Gametes ripe but not spawning
		6.	Spawning
		7.	Spent

atrobranchus (the blackear bass); Serranus phoebe (the tattler); Epinephelus morio (the red grouper); Synodus intermedius (the sand diver); Lactophrys quadricornis (the scrawled cowfish); and Lutjanus synagris (the lane snapper). These species were selected on the basis of numbers collected, ease of dissection, and presumed ecological importance (e.g., relative abundance).

Stomachs were removed from each specimen by dissection (gut from esophagus to duodenum, except for Lactophrys quadricornis) and the contents flushed into a petri dish. Lactophrys stomachs were removed from just below the esophagus to a point approximately 5 cm farther down the gut. The contents were examined under a dissection scope and sorted into major food groups. The volume of stomach contents was estimated using an ordinal system (Hynes, 1950; Griffiths et al. 1975). Stomach fullness was scored from 1 to 20 points, with 20 points representing a full stomach. Food groups were then assigned a portion of those points, depending on what percentage of the total volume they represented.

Specimen identifications, length, weight, sex, state of maturity, and stomach contents (if applicable) were recorded on computer coding forms using standard NODC guidelines and taxonomic codes, entered, and verified. All sorted, labeled, and identified fishes and stomach contents were returned to fixative for archival storage, and for use in resolving coding errors detected during the verification process.

Data Analysis and Synthesis

Diversity (H") and evenness (J') were assessed per Pielou (1975), using natural logs (base e) in the diversity formula. Stomach contents were analyzed using the Index of Relative Importance (IRI) technique (Pinkas et al., 1971) to evaluate the importance of various categories of prey items (e.g., copepods, other fishes, etc.). The index takes into account (1) N, the relative number of individual prey items within each category; (2) V, the relative volume occupied by items within by that prey category; and (3) F, the relative number of specimens within which that prey category occurred.

Each of these factors is expressed as a fraction. For example, if half of the total individual items in one fish's stomach were copepods, N would be 0.5. The maximum value that N can have is 1.0. If those copepods occupied one-fourth of the maximum theoretical volume of that stomach, V would be 0.25. The maximum value that V can have is 1.0. Maximum theoretical volume is determined by comparison to stomachs in other individuals of the same species. If three-fourths of the fish of the same species had copepods in their stomachs, F would be 0.75. The IRI can range from 0 to 2.0, and is calculated as follows:

$$IRI = (N + V) F$$

In the above example, IRI = (0.5 + 0.25) x 0.75 = 0.56.

Cluster analyses were performed for fishes collected by trawling, in order to delineate groups of stations. Both presence/absence (Dice index) and Czekanowski Quantitative (Bray-Curtis) coefficients were used. These analyses are described more fully in Subsection 3.3.4, Cluster Analyses.

2.2.4 SETTLING PLATES

Field Methods

Ceramic tile and steel settling plates were installed at Stations 52, 21, 29, 23, and 36 during Year 4, and at Stations 52, 21, 29, 23, 36, 44, 55, and 7 during Year 5. Although the original sampling scheme required various sets to be immersed for 3, 6, 9, 12, 18, and 21 months and then retrieved when the arrays were serviced, problems in relocating and/or retrieving the arrays altered these "soak" times in some instances. The actual immersion times are presented by station in Table 2.2-7. Settling plates were installed in sets of six on each array, as detailed in the Year 4 Final Report. Plates were collected by divers and transferred to the vessel for individual bagging and preservation in 5% to 10% neutral buffered formalin.

Table 2.2-7 Exposure schedule for settling plates actually retrieved by cruise and station.

```
PROGRAM:              _______YEAR 4________  _______YEAR 5_______

MONTH/YEAR:           12/83 3/84  5/84  8/84  12/84 3/85  6-7/85 9/85

CRUISE:               1     2     3     4     5     6     7     8

STATION 52
  3 month tile:       |-----|-----|-----|-----|-----|-----|-----|
  3 month steel:      |-----|-----|-----|-----|
  6 month tile:       |-----------|-----------|-----------|
  9 month tile:       |-----------------|-----------------|
 12 month tile:*      |-----------------------|
 12 month tile:**     |-----------------------|

STATION 21
  3 month tile:                   |-----|-----|-----|-----|
  3 month steel:                  |-----|-----|
  6 month tile:                   |-----------|-----------|
  9 month tile:       |-----------------|
                                  |-----------------|
                                        |-----------------|
 12 month tile:                   |-----------------------|

STATION 29
  3 month tile:       |-----|-----|-----|     |-----|
  3 month steel:      |-----|-----|-----|
  6 month tile:       |-----------|
  9 month tile:       |-----------------|

STATION 23
  3 month tile:       |-----|-----|           |-----|-----|
  3 month steel:      |-----|-----|
  6 month tile:       |-----------|           |-----------|
  9 month tile:       |-----------------|
  9 month tile:*      |-----------------|
  9 month tile:**     |-----------------|

STATION 36
  3 month tile:                   |-----|-----|-----|-----|
  3 month steel:                  |-----|-----|
  6 month tile:       |-----------|-----------|-----------|
  6 month steel:      |-----------|
  9 month tile:       |-----------------|-----------------|
 12 month tile:       |-----------------------|
 12 month tile:*      |-----------------------|
 12 month tile:**     |-----------------------|
```

Table 2.2-7 (cont'd)

```
PROGRAM:        _______YEAR 4_______________  _______YEAR 5_______________

MONTH/YEAR:     12/83  3/84  5/84  8/84  12/84  3/85  6-7/85  9/85

CRUISE:           1     2     3     4      5      6      7      8

STATION 44
  3 month tile:                                           |-----|
  3 month tile:*                                          |-----|
  9 month tile:                            |-----------------|

STATION 55
  3 month tile                             |-----|
  6 month tile                                   |-----------|

STATION 7
  3 month tile:                            |-----|-----|-----|
  6 month tile:                            |-----------|
  9 month tile:                            |-----------------|
```

* vertically mounted 1.5 m from substrate
** horizontally mounted

Laboratory Methods

Bagged plates were returned to LGL's laboratories in Bryan, Texas. Plates were individually labeled for sample tracking purposes, and both sides gently rinsed in fresh water. The wash water and the fluid from the bag surrounding each plate were combined and sieved with a 0.5-mm screen to retain motile invertebrates and other organisms not firmly attached to the plate. All animals in the wash water and fluid from the bags were identified and counted to the lowest practicable taxon and kept separate from the plate sample. Drained weight (to the nearest 0.1 mg) was determined separately for each taxon with a Sartorius® Model 1202 MP balance.

Because plates had been bolted onto the array in pairs, only the outer (non-facing) side of each plate was assessed. The ceramic plates had grooves on their outer sides; the steel plates did not. Plates were kept immersed in fresh water throughout analysis to keep from drying out organisms. Three types of abundance estimates were made for each plate: percentage cover, density, and drained weight. The type of estimates depended upon each taxon's growth form (Table 2.2-8).

Percentage cover estimates were made for most colonial or encrusting taxa on each plate. Estimates were based upon the point-intercept method, using three acetate overlays, each marked with a different pattern of 100 randomly located dots. Each dot was assumed to represent 1% cover; the number of times a given taxon fell beneath dots was thus multiplied by 1% 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. Density was estimated by counting the number of individuals or colonies 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 by removing and sorting organisms by taxon and then weighing them to the nearest 0.1 mg on a Sartorius® Model 1202 MP balance.

Table 2.2-8 Type of settling plate abundance estimates, by taxon.

TAXON	% Cover	Numerical Counts	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
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

Specimen identifications, densities, 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.

Data Analysis and Synthesis

Since plates collected at Stations 52, 21, 23, 29, and 36 in Year 4 during Cruises 2 and 3 were described in last year's report, they were not included in the Year 5 data analysis and synthesis. Data for settling plates collected on Cruises 4, 5, 6, 7, and 8 were summarized by plate type (e.g., ceramic, steel, bags, vertical or horizontal orientation, and elevation above the bottom) and by method used in the laboratory for calculating the abundance of each group of organisms (e.g., drained weight, number of individuals).

For most groups of organisms, taxonomic identification to the species level was not possible, and diversity indices or other measures of species richness were not computed. Many plates were very sparsely colonized, especially in deep water. Emphasis was therefore placed upon biomass estimates for major taxonomic groups, and graphical summaries such as histograms proved adequate for comparisons among stations and among cruises.

Some motile organisms such as amphipods remained on the plates during preservation, but others fell off into the plastic bags that had been placed around each plate. Transporting plates from the field to the laboratory also detached some sessile animals such as bivalves from the plates. Organisms remaining on the plates were counted only if they were on the front of a plate. The abundances of these organisms could not be compared directly to those in bags, since animals in bags might have come from the front, back, or edges of each plate. The relative proportions of organisms that had been on the front of the plate were not known. Furthermore, the amount of disturbance that occurred during and after preservation varied, and probaby determined what proportion of the individuals of any given species on a plate remained.

2.2.5 TIME-LAPSE CAMERA

Field Methods

Time-lapse camera systems were installed at Stations 52 and 21 during Year 4, and at Stations 52, 21, 29, 23, 55, 7, and 44 during Year 5 (Table 2.2-9). The main function of the time-lapse equipment was to provide continuous information on sediment movement. Several secondary functions of the time-lapse camera included documentation of sessile community formation and monitoring fish presence around artificial structures. Each time-lapse system consisted of a camera, strobe, and battery pack, each in a separate underwater housing (Figure 2.2-1). Housings were hard-wired to one another with four conductor, 16-gauge Crouse-Hinds® underwater electrical cables with Electro-Oceanic® connectors.

Each camera was protected by an Ikelite® underwater housing with a depth limit of 100 m. The housing contained a Minolta® Model XL-401 or 601 Super-8 movie camera and an external, LGL-designed intervalometer (timing device). Standard 50-ft rolls of Kodak Kodachrome® 40 Super-8 film (ASA 40) film (3,600 frames) were used. The intervalometer triggered single-frame exposures every hour, resulting in an apparent time compression of 1:57,600 (i.e., each second of viewing the projected film represented a real elapsed time of 57,600 sec when projected at 16 frames/sec). One day was represented by 24 frames of movie film. There was sufficient film in one cartridge to last up to 5 months, in case it was not retrieved on the usual 3-month schedule. The camera had an f/1.2 zoom lens set on the widest angle possible (either 7.5 or 8.5 mm).

Artificial lighting was provided by a Vivitar® Model 283 strobe in another Ikelite® housing. To minimize battery drain, the strobe was

Table 2.2-9 Numbers of TLC frames exposed following system installation, by station. Zeros denote system failure or array loss; dots indicate that no installation was attempted.

PROGRAM:	YEAR 4			YEAR 5			
MONTH/YEAR:	12/83	3/84	5/84	8/84	12/84	3/85	6-7/85
STARTING CRUISE:	1	2	3	4	5	6	7
Station							
52	986	199	0	829	792	272	1,913
21	0	0	1,775	0	0	253	0
29	.	.	.	.	0	0	0
23	.	.	.	.	768	0	0
55	.	.	.	.	2,536	0	1,956
7	.	.	.	.	731	2,142	1,961
44	.	.	.	.	612	0	0
Total:	986	199	1,775	829	5,439	2,667	5,830

Total for all stations: 17,725

MMSY5ARF 09/86

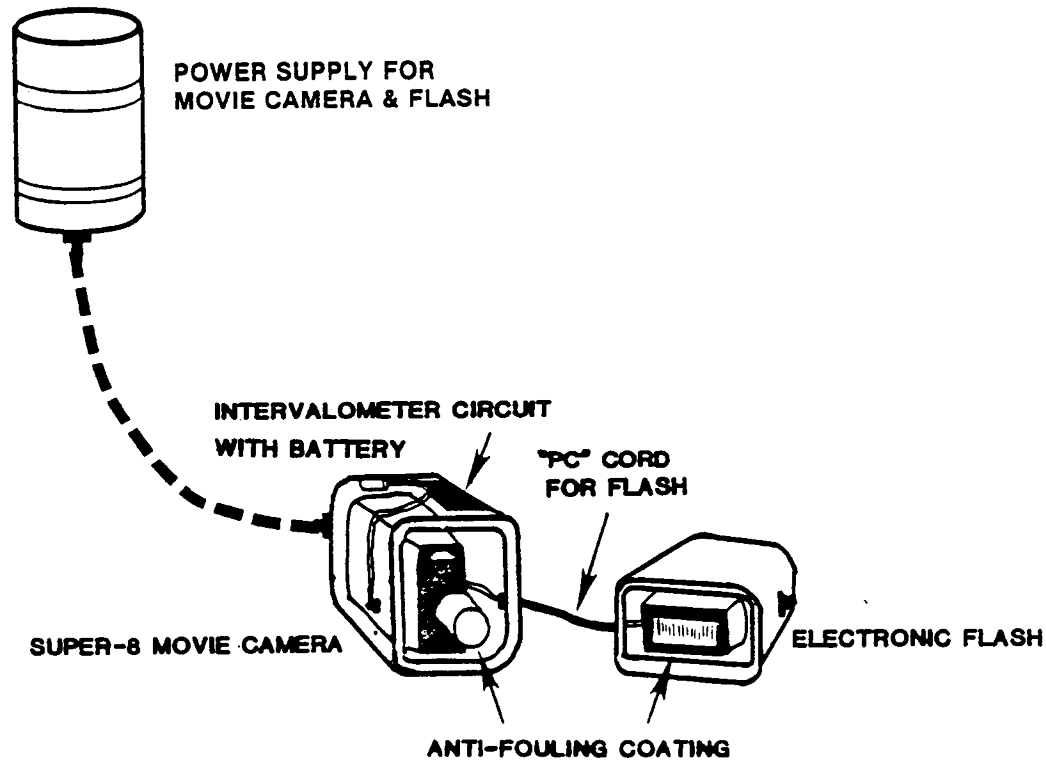

Figure 2.2-1 TIME-LAPSE CAMERA SYSTEM

turned on to charge its capacitors a few seconds before each single-frame exposure, and then turned off immediately after the picture was taken. This task was performed by the intervalometer.

Batteries that ran the intervalometer, camera, and strobe were contained in a custom-built 60-cm x 25-cm aluminum housing, and attached to an instrument array support member. Power requirements for the system were considerable. A 3-month emplacement required batteries with a minimum capacity of 48 amp-hours, but for safety reasons, the batteries installed had an additional 50% capacity beyond this minimum. Sealed lead acid batteries were chosen because: (1) they are truly sealed, with no acid, acid vapor, or water loss during normal use; and (2) they are designed to operate well at temperatures typical of bottom water on the southwest Florida shelf.

Photographic product quality could be degraded rapidly by settling organisms on the camera ports if left untreated. A transparent organometallic (tin-based) polymer specially formulated for optical surfaces was used to prevent biofouling. This polymer was obtained by ESE/LGL from the Department of the Navy, Naval Ship Research and Development Center, Bethesda, Maryland. This material kept camera ports clean for up to 6 months of exposure. A similar technique was also used successfully by Abbott (1979).

To provide a reference point for surficial sediment level, a vertical steel rod was installed in the field of view of each time-lapse camera. The rod extended from the array framework to just below the sediment-water interface. Two steel plates with the same dimensions as the settling plates (see Subsection 2.2.4, Settling Plates) were attached to the sediment rod. The camera was aimed toward these plates and also viewed some of the surrounding substrate.

During each cruise after initial installation, divers serviced the time-lapse system by first retrieving all components. The camera housing was inspected for any water penetration, carefully opened, and inspected. If possible, the film was advanced to prevent any data loss due to exposure of the last few movie frames to light when removing the cartridge. If unexposed film remained, a short segment of handwritten station data was filmed through the movie camera as an integral label.

All equipment was evaluated for damage and integrity. Damaged equipment was replaced, batteries and film renewed, other components serviced, and the intervalometer was initialized for triggering exactly on the hour. The system was allowed to sit on deck until it had operated correctly an hour later. A data slate was placed in the field of view of the camera to record all pertinent information on the first movie frame. Following a successful test, the system was sealed and reinstalled on the array.

Laboratory Methods

After each cruise, Super-8 movie film cartridges were appropriately packaged and mailed to the Kodak® processing laboratory in Rochester, New York. Special arrangements were made with this facility for dealing with these cartridges. For example, provision was made to keep the cropping of leader on the ends of each roll to a minimum, thus preventing any data loss. Kodak® also developed film which had been drenched in seawater, salvaging one cartridge which might have otherwise been ruined.

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

Each time-lapse movie was analyzed in its entirety, using an Elmo® Model 912 manual film editor and a Kodak® Moviedeck Model 475 Super-8 movie projector with variable projection speeds (freeze-frame, 3, 6, 18 and 54 frames/sec). 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 photograph to be accurately determined. The movie projector had higher quality optics, and was 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 sec when seen at 54 frames/sec, apparently 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.

Each movie frame yielded information on numbers of individuals by species of fish and other vertebrates such as sea turtles, turbidity, and occlusion by organisms. Motile invertebrates large enough to see were relatively rare, and were not included in quantitative analyses but instead were 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, to a distance approximately equivalent to that of the two metal settling plate targets. Specific individuals could not be reliably identified from one photograph to the next. 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 zero through four. A score of zero represented unobscured (100%) visibility within the sample area. A score of four represented zero visibility. Each intervening score represented an estimated change of 25% in visibility. Generally, scores of zero, one, or two (relative visibility of 100%, 75%, or 50%) did not interfere with counts or identifications. A score of two occasionally caused smaller fish at the limits of the sample area to be identified only to genus as opposed to species. A visibility score of three (25%) significantly affected fish observations and identifications.

Occlusion by biota was treated separately from water turbidity. Movie frames in which the field of view was obscured by 50% or more by an organism were given a score of five. In the majority of instances this score was used because of a fish located very close to the camera lens, e.g., by the jewfish that took up long-term residence inside some of the arrays.

Data from each time-lapse movie were first transcribed onto preprinted work forms, transcribed onto coding forms, entered, and verified.

Data Analysis and Synthesis

Two summary statistics were derived from time-lapse data: (1) time-series plots of frequency of occurrence of fish, and (2) periodic (hourly) mean frequency of occurrence, or attendance. Although observations ("records") were not necessarily independent of one another due to the likelihood of sighting the same individual repeatedly, it was possible to calculate confidence limits for hourly attendance.

Observations within any given day from one hour to the next appeared to be correlated with one another. Nonetheless, this did not rule out comparisons between means. For most common species, the correlation in sequential hourly means was minimized by summing many days' worth of data. This finding was confirmed by the apparent randomness of residual variability. The larger the number of days involved, the more valid the procedure. In general, a minimum of 20 days of data was sufficient to generate realistic confidence limits. In some cases, sample sizes were smaller; in such instances, the confidence limits for those means were overly conservative (i.e., wide).

2.2.6 HIGH-RESOLUTION BENTHIC PHOTOGRAPHIC SURVEYS

An experimental technique called high-resolution benthic photography surveying was conducted during Year 5, on Cruises 5 through 8. High-resolution benthic photography surveying consisted of a diver equipped with a hand-held video camera-recorder and underwater lighting system swimming along two transects, each 50 m long.

The only purpose of the surveys was to appraise the high-resolution benthic photography surveying methodology itself with regard to evaluating lateral (horizontal) movement of unconsolidated sediments, and assessing the size, recruitment and abundance of sessile organisms too small to identify or count reliably with remotely-operated video systems. Descriptions of the relative strengths and weaknesses of the high-resolution benthic photography surveying method are in Subsection 4.2.6, Methods Evaluation and Recommendations.

The diver-held video system included a housed JVC® Model GR-C1 Video-Movie camcorder (camera-recorder combination) and an underwater lighting system for providing true colors and increased definition. The camcorder was capable of recording 20 min of observations on a TC-20 video cassette. High-resolution benthic photography surveying transects consumed only approximately half this capability. The camcorder was enclosed in an Ikelite® housing that permitted full use of all camcorder controls while underwater. The camcorder housing was also equipped with 1-m-long weighted dropline to help the operator keep it a constant distance above the substrate. Artificial lighting was provided by an Underwater Kinetics Aqua-Sun®, with twin 80-w video lamps in 40° beam angle lamp heads, powered by a tank-mounted, 24-volt battery pack.

Two high-resolution benthic photography surveying transects were established at Station 52. A 52-m polypropylene line marked at 1-m intervals served as a center axis for both transects. The markers were used to describe exact locations along the line. A 0.9-kg cylindrical lead weight was attached to the line every 5 m to keep it from shifting position. The base of one of the array support legs was chosen at random as one end of the transect, and the transect line was stretched away from the array on a relatively straight course. The other end of the line was secured to a heavy weight with spikes welded to it to prevent movement.

To conduct a survey, a diver would swim along the line starting at the array, keeping the end of the dropline barely in contact with the transect line. This kept the elevation of the video camera constant, thus ensuring that an equal area was always kept in the field of view, as well as making it possible to measure repeatably the dimensions of objects seen in videotapes. One meter at each end of the line was considered a buffer zone outside the census area, to avoid problems with installation effects.

Each transect consisted of a 50-m band, parallel and adjacent to the line. The line was kept on the right edge of the video camera's viewfinder to record only one transect at a time. At the distal end of the line, the diver reversed direction and proceeded back toward the array, photographing the transect on the opposite side of the line. Each transect was about 1 m wide, depending on how vertically the camera was held by the diver. Each of the two transects thus included 50 m^2.

Laboratory Methods

Videotapes were viewed on a 63-cm (25-inch) Sony® color television with a Panasonic® Model PV-1730 VHS videotape player, equipped with a special adaptor for TC-20 tapes. The tapes were reviewed for the following information:

1. Habitat characteristics (percent sand, exposed rock, etc.);
2. Percentage cover of dominant organisms, especially those which might show significant changes;
3. Types of sessile organisms;
4. Presence or absence of organisms observed during previous cruises; and
5. Growth of any organisms which could be measured in the same way on more than one cruise.

Data Analysis and Synthesis

Data analysis and synthesis consisted of a subjective evaluation of the effectiveness of the high-resolution benthic photography surveying technique with regard to the parameters mentioned previously. Emphasis was placed on repeatability of measurements. The results of this feasibility study are discussed in detail in Subsection 4.2.6, Methods Evaluation and Recommendations.

3.0 RESULTS AND DISCUSSION

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3.1 PHYSICAL AND CHEMICAL CHARACTERISTICS

A detailed and comprehensive description of the physico-chemical environment and the phenomena that affect this environment is essential to the understanding of an ecosystem. It is difficult to assess the impacts of man's activities, in this case offshore petroleum development, without first understanding the natural processes and perturbations that impact the ecosystem.

The following physico-chemical characterization has been divided into subsections. Subsection 3.1.1 discusses the physico-chemical characteristics of each station individually. This will aid considerably in the interpretation of the biological findings presented in subsequent sections. The remaining subsections present additional regional descriptions of the physico-chemical environment that provide an overview essential for understanding the differences and similarities that arise from intersite comparisons of the biota. In addition, a regional overview is essential for understanding those processes (such as Loop Current intrusions) which occur on scales larger than the individual station scale of 1 km^2. These subsections are arranged thus: Subsection 3.1.2--Hydrographic and Water Chemistry, Subsection 3.1.3--Currents and Circulation, Subsection 3.1.4--Waves and Tides, and Subsection 3.1.5--Sediment Dynamics.

3.1.1 INDIVIDUAL STATION CHARACTERIZATIONS

General station information for the eight Year 5 stations is presented in Table 3.1-1. The information for each station includes the years during which data were collected; the average depth of the station; station location using latitude and longitude, lease block number, and distance from shore; substrate type; and biological assemblage.

Table 3.1-1. General station information for the Year 5 stations

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

*Years during which data were collected.
**CH = Charlotte Harbor.
PR = Pulley Ridge.
DT = Dry Tortugas.
TLL = falls within Three League Line.
***Distance to nearest point of land excluding the Florida Keys.
†TS-HS = thin sand over hard substrate.
AN-S-D = algal nodules over sand with depressions.
TS-HS-D = thin sand over hard substrate with depressions.

††In-Live I = Inner Shelf Live-Bottom Assemblage I.
In-Mid Live II = Inner and Middle Shelf Live-Bottom Assemblage II.
Mid-Algal = Middle Shelf Algal Nodule Assemblage.
Agaricia = _Agaricia_ Coral Plate Assemblage.
Out Crinoid = Outer Shelf Crinoid Assemblage.
†††Location of array.

Characteristics of the sediments obtained as grab samples during Years 4 and 5 are summarized in Table 3.1-2. The characteristics include grain-size statistics based on methods described by Folk and Ward (1957). These statistical methods were chosen because more than 50% of the stations revealed grain-size distributions that were non-normal in that they were either skewed or bimodal. The grain-size statistics expressed in ϕ sizes include median, mean, standard deviation (or sorting), skewness, and kurtosis (or peakedness). Other information includes percent sand, $CaCO_3$ content, and organic carbon content. Caution should be exercised, however, in applying this information to the entire 1-km^2 station because this information is based on, at most, four grab samples. Because these samples were collected during the winter months, seasonal variation in sediment characteristics that may occur with seasonal changes in wave or current climates is not discussed.

The near-bottom hydrographic and water chemistry data collected during the 5-year study for each Year 5 station are summarized in Table 3.1-3. The data are presented as a range for each parameter; these ranges are based on 4 to 12 data points obtained during the various cruises. Temperature is the exception to this being based, not only on data collected during cruises, but on from 1 to 2 years of continuous temperature data collected during Years 4 and 5. In addition to temperature, the other parameters presented include salinity, DO, transmissivity, and light penetration (based on secchi disk readings only). Chlorophyll a, nitrate-nitrite, phosphate, and silicate concentrations, obtained from data from Years 1 and 2 of the program, also are presented (Woodward Clyde Consultants/Continental Shelf Associates, 1983).

Summarized in Table 3.1-4 are some of the more dynamic physical oceanographic data such as average current speed, modal current speed, modal current direction, percentage of time current speeds exceed 20 cm/sec, net current speed, net current direction, and percentage of time wave orbital velocities exceed 20 cm/sec at the bottom. All current

Table 3.1-2. Summary of sediment characteristics for Year 5 stations obtained as grab samples

Station Number	Sediment Size Statistics (ϕ)*					Sand (%)	$CaCO_3$† Content (%)	Organic† Carbon Content (%)
	Median	Mean	Sorting	Skewness	Kurtosis			
44	0.9	0.8	1.4	0.0	1.2	98	88.3	1.8
55	1.1	1.2	1.4	0.1	1.0	92	96.6	3.0
7	1.4	1.3	0.9	-0.3	1.2	98	52.9	1.6
52	0.9	0.9	1.5	0.1	1.1	96	93.6	2.6
21	1.8	1.8	1.0	-0.1	1.2	96	92.1	2.8
23	0.8**	0.8**	1.3	0.1	1.2	98	95.7	3.0
29††	—	—	—	—	—	—	—	—
36	0.7	0.8	1.3	0.2	0.8	98	95.1	2.9

*After Folk and Ward (1957), values given are nominally the average of four replicates.
†Dry weight.
**Range: median ϕ = 2.5 to -1.0; mean ϕ = 2.3 to -1.1.
††*Agaricia* coral pavement precluded sampling any unconsolidated sediment.

Table 3.1-3. Summary of near-bottom hydrographic and water chemistry characteristics for Year 5 stations*

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

*Notes with respect to individual parameters:

Salinity—ranges are based on 4 to 12 data points collected during 1 to 5 years.

Temperature—Ranges are based on periodic measurements as well as continuous measurements over 1 to 2 years.

Dissolved Oxygen—same as salinity.

Transmissivity—same as salinity. Years 4 and 5 data adjusted by cruise so that the maximum was 100 percent.

Light Penetration—calculated using $1.7/D_s$, where secchi readings (D_s) were made during Years 4 and 5.

Chlorophyll a—ranges are based on 4 data points (Years 1 and 2) except for Station 36 (Year 2 only).

NO_3 - NO_2—same as Chlorophyll a.

PO_4—same as Chlorophyll a.

SiO_2—same as Chlorophyll a.

Table 3.1-4. Summary of dynamic physical oceanographic data for Year 5 stations

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

*Estimated using Station 52 wave data.
†Estimated using NDBC Buoy #42003 wave data.

statistics are based on current data collected during one or two years at the individual stations. The wave data, however, were collected for only one year at Stations 52 and 55. Therefore, wave statistics for the other stations are based on the wave fields measured at these two stations or from the National Data Buoy Center's (NDBC) wave buoy.

The remainder of this subsection consists of narrative descriptions of the individual stations. These descriptions are only for the near-bottom environment and discuss only the characteristics within the 1-km^2 station. Discussions of the overlying water column and regional characteristics and processes are discussed in subsequent subsections.

Station 44

Station 44, located in Lease Block Charlotte Harbor #697, was one of the most northern and shallow (13 m) of the Year 5 stations and it was located the closest to land (20 km). This station was chosen for intensive study to ascertain latitudinal variation between stations. The biological assemblage for Station 44 was designated as Inner Shelf Live-Bottom Assemblage I. This station was sampled during Years 3, 4, and 5.

The substrate was designated as thin sand over hard substrate. The sediments at Station 44 are coarse (mean ϕ = 0.8), calcium carbonate (88%) sands that are poorly sorted, symmetrical, and leptokurtic. The organic carbon content of the sediment was lower (1.8%) than all other stations, with the exception of Station 7.

Underwater television surveys revealed a predominantly sand bottom with occasional patches of hard bottom. Transient morphological features such as sand waves and animal tracks were observed.

The near-bottom salinity at Station 44 ranged from 34.8 $^{o}/oo$ to 36.0 $^{o}/oo$. Station 44, along with Station 52, was generally less saline than the other six stations. Presumably, this was because of their proximity to land. The water at these shallow stations was also well mixed regardless of the season.

Near-bottom temperature values ranged from 20.3° to 29.6°C, and Station 44 was generally warmer than the other stations. One of the highest near-bottom dissolved oxygen values (10.1 mg/l) encountered at all stations was observed at Station 44; the minimum value was 5.6 mg/l.

Station 44 was one of the two most turbid stations (Station 52 was the other station) of the eight studied. Transmissivity, measured with a transmissometer mounted on the CSTD, ranged from 77 to 100%. Light extinction coefficients, calculated from limited secchi disk readings, ranged from 0.14 to 0.38. Although 0.38 was relatively high compared to the majority of the stations, it was considerably lower than the 1.13 value measured at Station 52. Turbidity as measured with the time-lapse camera and defined as 75% obscuration, occurred 5.6% of the time. This was relatively frequent compared to all stations except Station 52; however, this value is based primarily on only one month of data.

Currently, there are no chlorophyll _a_ or nutrient data available for Station 44. During the Year 6 Data Synthesis Study, certain historical data may be located or extrapolated from other existing data. Detailed discussion of the hydrographic and water chemistry data, spatial and temporal variability, and distribution throughout the water column are presented in Subsection 3.1.2.

The currents measured at Station 44 revealed a bimodal distribution for current direction indicative of tidally dominated currents. This bimodality was not as pronounced as at the comparable Station 52, but the general east-west setting of the currents was apparent. The average current speed was 8.4 cm/sec, which falls approximately mid-range between the average values calculated for all other stations (5.2 to 10.8 cm/sec). The percent of time the current speed exceeded 20 cm/sec was also approximately mid-range with a value of 4.6%. There is a considerable difference between Stations 44 and 52 with respect to currents. It is possible that this may be due to the proximity of

Station 44 to land, which would keep the station in the lee more often than at Station 52. Although it is recognized that tides are the primary forcing function for the currents, wind, especially in water this shallow, would also have a significant effect on the currents.

The net current calculated over the entire year was 1.4 cm/sec and set to the southeast. This would indicate that suspended sediments or waterborne pollutants would be carried toward shore.

Generally, the current speeds measured at Station 44 were insufficient to resuspend sediments, yet the time-lapse cameras and the sediment traps indicated that sediment was either resuspended or advected into the area. Although advection of sediments is possible, and to some degree likely, sediment resuspension is probably a major source for the sediments trapped. Because the current speeds were insufficient for resuspension, the cause of the sediment movement was wave-induced orbital velocities. A wave orbital velocity of greater than 20 cm/sec would occur 3.0% of the time. This speed added to a current speed of 20 cm/sec, which occurred 4.6% of the time, would produce sufficient energy for sediment resuspension. The Station 44 sediment trap (1 m above the bottom) data measured an average annual sediment deposition rate of 526 $MT/km^2/day$. This deposition rate was the highest measured at any station and was 1.5 times greater than Station 52, 1.9 times greater than the rates measured at Station 55, and 3.6 times greater than the sediment deposition rate measured at Station 7. Detailed discussions of currents, waves, and sediment dynamics are presented in Subsections 3.1.3, 3.1.4, and 3.1.5, respectively.

Station 55

Station 55, located between the Dry Tortugas and the Marquesa's, is the southernmost station and lies within the Three-League Line and, therefore, is not located within a lease block. This station, studied only during Year 5, was chosen because it is located on an important and little understood boundary of the southwest Florida shelf. The average water depth at Station 55 is 27 m, the substrate is designated thin sand over hard substrate, and the biological assemblage is designated as Inner Shelf Live-Bottom Assemblage I. This designation is identical to the shallower (13 m) Stations 44 and 52. Although some differences undoubtedly exist between Station 55 and the other two stations because of greater water depth, the organisms that comprise the community were generally the same.

Underwater television surveys of Station 55 revealed a lush live bottom with occasional patches of bare sand and animal tracks. No sand waves were noted during any of the four cruises.

The Station 55 sediments were finer than those sampled at Stations 44 and 52, with a mean ϕ size of 1.1. Nevertheless, the sediment was still classified as a coarse, calcium carbonate (97%), poorly sorted sand. This grain-size distribution was nearly symmetrical and mesokurtic. The organic carbon content of 3.0% was the highest measured at any station and was equal to that at Station 23. Because of the depth and greater oceanic influence (from the Florida Straits), the salinity at Station 55 was higher than the two shallower stations. The salinity ranged from 35.8 $^{o}/oo$ to 36.5 $^{o}/oo$.

Unlike the salinity distribution, which was homogeneous throughout the water column, temperature, on one occasion, revealed the presence of a thermocline at a depth of 15 m. The temperature ranged from a low of 22.0°C to a high of 28.0°C. The minimum temperature value of 22.0°C was the highest minimum temperature measured at any of the eight stations.

The dissolved oxygen concentration at Station 55 ranged from 5.9 to 9.3 mg/l and was neither the highest nor lowest value measured. The minimum value, however, was lower than the deeper stations, with the exception of Station 36.

In regard to turbidity, Station 55 was similar to the deeper stations with transmissivity values ranging from 83 to 94%. The light extinction coefficients ranged from 0.11 to 0.19. Periods of high turbidity (defined as 75% obscuration as viewed with the time-lapse camera) occurred 3.7% of the time.

There were no chlorophyll a or nutrient data collected during the 5-year study. During the Year 6 Data Synthesis Study, a search of the historical data will be made to provide this information.

The current speeds measured at Station 55 were second only to Station 52 in magnitude. The average current speed calculated for Station 55 was 10.4 cm/sec and set north-northeast and south-southwest. These currents, similar to those at Stations 52 and 44, were predominantly influenced by the tides. The current speed exceeded 20 cm/sec 13.3% of the time. This value, again, was second only to Station 52.

The net current speed was 1.4 cm/sec (identical to Stations 44 and 52) and set almost due south. Suspended sediments or waterborne pollutants on a long-term average would be advected into the Florida Straits and, therefore, out of the study area. This information is important for any modeling considerations because the area lying between the Dry Tortugas and the Marquesa's functions as a sink. Thus water, pollutants, and other constituents are carried off the southwest Florida shelf to the Florida straits.

Similar to other shallow stations, the current speeds at Station 55 occasionally were sufficient to resuspend sediments. Both the time-lapse camera record and the sediment traps indicate that sediment resuspension did occur. The periods of high currents in conjunction with energy were sufficient to produce the sediment movement. The average annual sediment deposition rate was approximately 278 $MT/km^2/day$ according to data collected by the 1-m sediment trap. This was approximately half the rate measured at Station 44, but nearly twice the rate measured at Station 7.

Station 7

Station 7, studied during Years 1, 2, and 5, was located as far north as Station 44 and was deeper (32 m) than Stations 44, 52, or 55. Station 7 was located in Lease Block Charlotte Harbor #686 approximately 58 km from shore. The substrate was designated as thin to thick sand over hard substrate and the biological assemblage was identified as Inner and Middle Shelf Live-Bottom Assemblage II.

Underwater television surveys of Station 7 indicated that the bottom was predominantly sand with occasional rock outcrops and depressions. On the bare sand areas, sand waves were very common and were reported on every transect during Year 5. Some waves appeared to be stabilized with algae, but this was unconfirmed. The slow current speeds and symmetry of the sand waves suggest that those waves result from wave-induced water motion rather than currents.

The sediments at Station 7 were some of the finest (mean ϕ = 1.3) encountered throughout the study area (the only station with finer sediments was Station 21 with a mean ϕ value of 1.8). The sediment was classified as a moderately sorted, negatively skewed (i.e., skewed toward the coarser sizes), leptokurtic sand. The $CaCO_3$ content of the Station 7 sand was 53%, which was less than all other stations which had values greater than 85%. Woodward Clyde Consultants and Continental Shelf Associates (1983) also reported anomalously low values of 72 and 40% at Station 2 located approximately 55 km to the north-northeast of Station 7 and values of 83 and 86% at nearby Station 6. They suggested that the quartz clastics found at Stations 2 and 6 (to a lesser degree) were the result of proximity to the coast and/or sediment transport from the Caloosahatchee River (that drains Lake Okeechobee) and Charlotte Harbor.

The salinity at Station 7 ranged from 35.6 $^{o}/oo$ to 36.5 $^{o}/oo$. This was generally mid-range compared to all other stations. There was a distinct halocline during the spring and summer. This halocline coincided closely with a thermocline, also evident only during the spring and summer. The near-bottom temperatures ranged from 19.1° to 27.8°C. In terms of both salinity and temperature, Station 7 most closely resembled Station 21 (at a depth of 47 m).

Station 7 exhibited the least variability in DO (7.7 to 9.4 mg/l). The dissolved oxygen variability at two of the deepest stations (Stations 29 and 36) was 2.2 mg/l.

Although there were some incidence of high turbidity, as recorded with the time-lapse camera, it was not as frequent (only 1.5%) as Stations 44, 52, and 55. The transmissivity values measured during the cruises ranged from 90 to 99%. The light extinction coefficient ranged from 0.08 to 0.17. These values are more typical of those calculated from the deeper stations (with the exception of Station 21).

Station 7 is the first station discussed for which there are chlorophyll _a_ and nutrient data available. Near-bottom chlorophyll _a_ values ranged from 0.1 to 0.9 mg/m^3. This value can be compared with values of 10 to 40 mg/m^3 for blooms in fertile coastal waters to values of 0.05·mg/m3 for barren tropical waters, as cited by Riley and Chester (1971). Perhaps the most comparable value is that cited by Strickland (1965) for temperate waters of 0.5 mg/m^3. The highest chlorophyll _a_ concentration measured at Station 7 was still well below the fertile range. A discussion of chlorophyll _a_ concentration with respect to space and time will be presented in Subsection 3.1.2.

The nitrate-nitrite concentrations ranged from 0.1 to 0.3 uM; phosphate concentration from less than 0.1 to 0.1 uM; and silicate concentration from 1.0 to 3.0 uM (Woodward Clyde Consultants/Continental Shelf Associates, 1983). Generally, these values fall into the nutrient poor category according to El Sayed _et al._ (1972).

The average current speed calculated for Station 7 (5.2 cm/sec) was the lowest average calculated for any station. Although the influence of the tides on the currents was still evident, the motion had progressed from very nearly rectilinear (similar to that found at Stations 52 and 55) to nearly circular with no pronounced bimodality. The current speeds exceeded 20 cm/sec only 0.6% of the time. Sediment resuspension, however, was evidenced in the data collected by the time-lapse camera and the sediment traps. The time-lapse camera recorded 75% obscuration 1.5% of the time. The average annual sediment deposition rate, as measured with the 1-m sediment trap, was 147 $MT/km^2/day$. Station 7 is ranked as fourth among all eight stations for sediment resuspension. The only stations with higher values were, in ascending order, Stations 55, 52, and 44. All of these stations are shallower and/or higher-energy stations. Wave orbital velocities greater than 20 cm/sec occurred only 1.91% of the time at Station 7.

The net currents measured at Station 7 were among the lowest measured at any of the stations (only the net current at Station 21 was lower). The net current at Stations 7, 55, and 29 was 1.0 cm/sec and set due south.

<u>Station 52</u>

Station 52, located 48 km offshore in Pulley Ridge Lease Block #655, was the easternmost station, and although located more than twice as far offshore as Station 44, the depth (13 m) was identical to Station 44. Station 52 was studied during Years 3, 4, and 5. The biological assemblage was designated Inner Shelf Live-Bottom Assemblage I; the substrate was designated thin sand over hard substrate. Underwater television surveys revealed occasional sand ripples in the sandy areas of Station 52.

The sediments at Station 52 were classified as coarse (mean ϕ = 0.9), calcium carbonate (94%) sand. This sand was poorly sorted, nearly symmetrical, and mesokurtic and closely resembled sediments at one-half of the stations. The organic carbon content of 2.6% was close to the overall average for all stations.

Station 52 exhibited the greatest variability in both salinity and temperature with ranges of 35.1 to 36.3 $^{o}/oo$ and 17.0° to 30.8°C. Although the variability in salinity was the greatest (identical to Station 44), it still was not of a magnitude that would appreciably affect the biota. Temperature, however, with a seasonal variability of 13.8°C could be considered a more stressed environment. This seasonal variability at Station 52 was from 1.5 to 2.0 times greater than the remaining seven stations.

The seasonal differences in DO were not as pronounced as temperature variability and ranged from 6.3 to 9.4 mg/l. The seasonal variability in DO was less than the majority of the stations.

Water clarity was variable at Station 52. Transmissivity values ranged from 67 to 100%; light extinction coefficients ranged from 0.11 to 1.13. The incidence of high turbidity, as measured with the time-lapse camera, was 15%. This means that for 55 days out of the year the transmissivity was reduced to 25%. This, conceivably, would add to the overall stress imposed on the biota at Station 52.

This incidence of high turbidity, primarily the result of resuspended sediments, was reflected in the sediment trap data. The 1.0-m sediment trap indicated an average annual sediment deposition rate of 360 MT/km^2/day. This value was exceeded only by that at Station 44 (526 MT/km^2/day).

This comparatively high incidence of turbidity (or sediment resuspension) was not surprising, given the depth of the station and the current speeds measured at Station 52. The average current speed of 10.8 cm/sec was the highest measured at any of the eight stations. The current speed exceeded 20 cm/sec 13.7% of the time; this, also, was the highest value of any station. Coupled with the wave orbital velocity exceeding 20 cm/sec 3.0% of the time, the incidence of sediment resuspension is not surprising.

The currents at Station 52 were heavily influenced by the tides; this was reflected in the nearly rectilinear east-west motion of the currents. A constant net current setting consistently to the southeast at 1.4 cm/sec was superimposed over this tidal motion. Unlike the other stations which exhibited some seasonal variability in net current direction, the net current direction at Station 52 consistently was toward Florida Bay. Presumably, this water was advected out of Florida Bay through the numerous passes of the Florida Keys, as indicated by the data from Station 55.

No chlorophyll a or nutrient data are available.

Station 21

Station 21 (Pulley Ridge Lease Block #683) was located at the same latitude, but approximately 122 km west of Station 52, 133 km from land, and in 47 m of water. This station was designated as Inner and Middle Shelf Live-Bottom Assemblage II, and the substrate was designated thin sand over hard substrate. Underwater television surveys revealed that the thin sand over hard substrate accounts for 57 to 83%; the remaining 43 to 14% was sand bottom/soft bottom. Small rock outcrops were noted as well as sand waves with wavelengths of approximately 1 m.

The sediment, with a mean ϕ of 1.8, was the finest encountered among the eight stations. The sediment was classified as a medium, $CaCO_3$ (92%), moderately sorted, nearly symmetrical, leptokurtic sand. Other than being somewhat finer than the sediments at the other stations, it was similar in characteristics (with the exception of the quartz clastic sands of Station 7). The organic carbon content was not atypical at 2.8%.

Station 21 more closely resembled the deeper water stations in that the variability in salinity and temperature was not as great as the shallow water stations. Also, unlike the shallow stations, there was consistent evidence of a thermocline and halocline, both occurring between 20 and 30 m. The salinity ranged from 35.9 to 36.7 $^{o}/oo$; the temperature ranged from 19.5° to 27.3°C.

The DO, however, was quite variable (range: 6.1 to 10.3 mg/l). This maximum was the highest near-bottom dissolved oxygen concentration measured at any of the stations.

In addition, Station 21 was second only to Station 52 in the variability of the light extinction coefficient calculated from secchi disk readings with a range of 0.08 to 0.68. This, however, could have been more a reflection of this station's productivity rather than high turbidity resulting from sediment resuspension. The limited chlorophyll a and nutrient data available reveal that Station 21 had the highest concentrations of chlorophyll a with a range of 0.5 to 1.0 mg/m^3. Although this value was not comparable to concentrations measured in blooms in fertile coastal waters, it is above the concentrations normally encountered in temperate waters. The nitrate-nitrite range of 0.1 to 0.3 uM was lower than the near-bottom concentrations measured at the remaining deep-water stations and may have been the result of this increased productivity.

The transmissivity at Station 21 ranged from 82 to 100%. There was no incidence of high turbidity (i.e., greater than 75% obscuration as measured with the time-lapse camera). This would indicate that sediment resuspension was infrequent and of lesser magnitude than any of the stations discussed previously and would support the hypothesis that the occasional instances of higher extinction coefficients were the result of phytoplankton. Some sediment was obtained from the 1.0-m sediment trap (average annual sediment deposition rate was calculated as 22 MT/km^2/day). This value is nearly an order of magnitude less than the values obtained from Stations 44, 55, 7, and 52, but nearly 20 times greater than the values calculated for Stations 23, 29, and 36.

It is unknown whether this sediment was advected into the area or whether it was resuspended. Both current speed and wave data indicate that sediment resuspension is less likely to occur at Station 21 than at the previously discussed stations. The average current speed of 7.2 cm/sec was one of the lowest values calculated and the current speeds exceeded 20 cm/sec only 1.2% of the time (second lowest only to Station 7). The wave orbital velocities exceeded 20 cm/sec only 0.12% of the time.

The net currents measured at Station 21 (0.9 cm/sec setting to the southeast) were the slowest net currents encountered at any of the eight stations.

Station 23

Station 23, located in Pulley Ridge Lease Block #667, was 74 km west of Station 21 and 194 km from land. The average depth was 74 m, but was as shallow as 69 m in 1 km^2 sampling grid. The bottom type was designated as algal nodules over sand with depressions. 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% of the bottom. The sand bottom/soft bottom was present occasionally (0 to 7%), particularly in the northwest corner of the station. No sand waves were observed at this station during the underwater television surveys. The assemblage for Station 23 was designated as Middle Shelf Algal Nodule Assemblage.

The sediments sampled at Station 23 were the most variable sediments sampled at any of the eight stations and, therefore, the mean ϕ and median ϕ values are somewhat deceptive (0.8 ϕ for both). The median ϕ ranged from 2.5 to -1.0; the mean ϕ, from 2.3 to -1.1. This means that the sediments at Station 23 could be classified, according to size, as either fine sand or fine gravel. Regardless of the size classification, the sediment was still carbonaceous ($CaCO_3$ content--96%). The overall average statistics indicated that the sediment also was poorly sorted, nearly symmetrical, and leptokurtic (the variability in average grain sizes must be taken into account). The organic carbon content of 3.0% was the highest encountered and equal to that measured for Station 55.

With respect to salinity and temperature, Station 23 was a typical deep-water station with small ranges and the presence of a thermocline and halocline; however, the halocline was never as pronounced nor as consistent as the thermocline. The salinity ranged from 36.1 to 36.7 $^{o}/oo$, and a halocline occurred with some regularity at a depth ranging from 30 to 40 m. Temperature ranged from 17.5° to 24.3°C with a thermocline generally coincident with the halocline. The maximum temperature of 24.3°C was one of the lowest maximum temperatures encountered, being second only to Station 36, which was considerably deeper.

The dissolved oxygen concentration varied from 6.1 to 9.3 mg/l. This was fairly typical of the deeper stations.

Also typical of the deep-water stations, was the clarity of the water. The transmissivity of the water ranged from 87 to 97%; light extinction coefficient from 0.06 to 0.11; and, according to the time-lapse camera record, there was virtually no incidence of obscuration at the 75% level. Sediment trap data support these observations with the 1.0-m sediment trap recovering only 1.1 MT/km^2/day of sediment. The term, sediment, should be interpreted with caution because at this low level the mass retained by the trap could either be sediment (either resuspended or advected) or it could be the result of organisms that were inhabiting the sediment trap at the time of retrieval. This is true of sediment trap data for the remaining stations (Stations 29 and 36). At these levels, it was difficult to separate out "noise" from real data. One possible confirmation of at least sediment resuspension is the gradual decrease in mass with height of the trap above the bottom. However, this confirmation could be the result of organisms rather than sediment resuspension.

The average current speed at Station 23 was 7.5 cm/sec, which was the second slowest average speed measured. Although tidal effects were evident, they were not as pronounced. The currents moved in a more circular motion rather than a pronounced elliptical or rectilinear type motion. A bimodality was evident in the direction distribution with currents setting east-southeast and west-northwest. The current speeds exceeded 20 cm/sec only 1.8% of the time; wave orbital velocities exceeded 20 cm/sec only 0.01% of the time. These data, the sediment trap data, and water clarity data, suggest that sediment resuspension would occur infrequently, if at all.

Net currents at Station 23 set nearly due west at 3.1 cm/sec. Station 23 was the only station with a pronounced westward component; only Station 7 might have had a very minor westward component (182°true), but this apparent slight westward trend is within the accuracy of the current meter. The net current speed of 3.1 cm/sec was the highest net current speed measured at any of the eight stations. Only net current speed at Station 29 approached this speed; net current speeds measured at other stations were nearly one-half of the Station 23 net current speed.

Chlorophyll a concentration ranged from 0.3 to 0.6 mg/m^3, which is comparable to average temperate waters. Nitrate-nitrite concentrations exhibited some of the greatest variability (second only to Station 36) of any of the five stations for which nutrient data are currently available.

Station 29

Located approximately 55 km south of Station 23 in Dry Tortugas Lease Block #138, Station 29 was the most remote station and was 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. The bottom, designated as algal nodules over sand with depressions, was entirely covered with an algal nodule pavement with occasional depressions and elevations. Less than 1% of the bottom was sand, and no signs of sand waves or bioturbation were observed. The biological assemblage was designated as *Agaricia* Coral Plate Assemblage. This impenetrable coral plate precluded any sediment sampling; therefore, no sediment data exist for this station.

With respect to salinity, temperature, and dissolved oxygen, Station 29 showed the least variability of any station. Even the deeper Station 36 had greater variability in these parameters. Salinity ranged from 36.1 to 36.6 $^o/oo$; temperature, from 17.5° to 26.0°C; and 6.4 to 8.6 mg/l. Similar to Station 23, the existence of a thermocline or halocline between 30 and 40 m was not unusual, and the thermocline was usually more pronounced and consistent than the halocline.

As with the other deep-water stations, Station 29 had very clear water with transmissivity values ranging from 86 to 98%. The calculated light extinction coefficients ranged from 0.07 to 0.19. Unfortunately, no time-lapse camera data were recovered from this station, but it is quite probable that there would have been little or no evidence of turbidity.

The second lowest chlorophyll a and the second highest nitrate-nitrite concentrations measured occurred at Station 29 at 0.1 to 0.6 mg/m^3 and 2.0 to 4.0 uM, respectively. These values would be expected for waters this deep.

Although the average current speeds measured at Station 29 (8.9 cm/sec) were the third highest measured at any station, for several reasons it is unlikely that sediment resuspension would occur. First, current speeds exceeded 20 cm/sec only 4.6% of the time. Second, wave orbital velocities exceeded 20 cm/sec only 0.05% of the time. Third, and most important, because of the virtually continuous algal pavement layer, there would have been little or no unconsolidated sediment available for sediment resuspension. This is confirmed by the 1.0-m sediment trap data which reveals an average annual sediment deposition rate of 0.7 $MT/km^2/day$. As with Stations 23 and 36, at this level it is difficult to differentiate actual sediment trapped versus mass attributable to organisms inhabiting the sediment trap.

Station 36

Station 36, located in Pulley Ridge Lease Block #661, was 219 km from the nearest land. It was located 33 km due west of Station 21 and 60 km north-northwest of Station 29. Station 36, the deepest station, had an average depth of 125 m, with a range of 124 to 127 m. Generally, the bottom sloped downward from east to west. The predominant bottom type was sand bottom/soft bottom (59 to 76%), with lesser coverage (24 to 40%) of thin sand over hard substrate with depressions. Less than 1% rock outcrops were observed. Sand ripples and depressions occasionally were observed. Within the live-bottom patches, 73 to 79% was sand and 13 to 12% was rubble. The biological assemblage at Station 36 was designated as Outer Shelf Crinoid Assemblage.

The coarsest sediments (mean ϕ = 0.8) of the eight stations were located at Station 36. These sediments were classified as very coarse, calcium carbonate (95%), poorly sorted sands. These sands also were classified as being positively skewed (i.e., toward the finer material) and platykurtic. The organic carbon content was 2.9%. A possible explanation for the inordinate amount of coarse material may be caused by a winnowing effect from internal waves breaking on the edge of the continental shelf. This is discussed in greater detail in Subsection 3.1.5.

Salinity, which ranged from 36.1 to 36.7 $^{o}/oo$, was comparable to virtually all deep-water stations. Although the maximum salinity of 36.7 $^{o}/oo$ was high, it was no higher than the salinities measured at Stations 21 and 23. The lowest temperature (15.0°C) was measured at Station 36 as was the lowest maximum temperature (23.8°C). These near-bottom temperatures were approximately 2°C lower than those measured at any other station. Similarly, the lowest dissolved oxygen concentration was measured at Station 36 where the range was only 4.4 to 6.6 mg/l. These values represent the lowest minimum and maximum values measured at any of the eight stations.

Station 36, similar to other deep-water stations, was exceptionally clear with transmissivity values ranging from 88 to 98% and light extinction coefficients ranging from 0.06 to 0.08. This was some of the clearest water measured. Because of the depth and the limitations of the time-lapse camera housings, no time-lapse camera was installed at Station 36.

In regard to water chemistry, chlorophyll a concentrations were the lowest measured (less than 0.1 to 0.1 mg/m^3) and the nitrate-nitrite concentrations were some of the highest measured (5.0 to 10.0 uM). Because it was deeper water, Station 36 near-bottom water was richer in nutrients, but because of the depth, productivity (defined by chlorophyll a concentration) was low.

The average current speed measured at Station 36 (8.9 cm/sec) was identical to that measured at Station 29 and third highest overall. The currents were only slightly influenced by the tides and generally set to the south (i.e., unimodal distribution). The current speed exceeded 20 cm/sec 5.3% of the time; speeds were higher only at Stations 55 and 52. The net currents set nearly due east at 1.8 cm/sec; this was the third highest net current speed (current speed was higher at Stations 23 and 29). Because of the depth, wave orbital velocity never exceeded 20 cm/sec.

There was some evidence for either sediment resuspension or advection based on the data obtained by the sediment traps. Approximately 1.2 MT/km^2/day were caught in the 1.0-m sediment trap. Although this value is low and is within the "noise" level, it is apparent that there was an obvious trend of decreasing mass with height of the trap above the bottom. It is possible that breaking internal waves on the shelf edge may be responsible for sediment resuspension at this station.

3.1.2 HYDROGRAPHY AND WATER CHEMISTRY

The previous subsection presented hydrographic and water chemistry data that were station specific and generally limited to the near-bottom environment. Hydrographic and water quality data (from the 5-year field program and historical data) on a regional scale throughout the water column are presented in this subsection. A comprehensive discussion of the hydrography and water chemistry was presented in Woodward Clyde Consultants (1983); therefore, only those points germane to the specific goals of this fifth year of the project will be discussed in detail.

Prior to discussing the individual hydrographic and water chemistry parameters, a brief overview of the large-scale physical phenomena that affect these parameters on the southwest Florida shelf is presented in the following subsections.

Some of the factors that affect the hydrography and water chemistry of the southwest Florida shelf are large scale and change only gradually. These factors include: incident solar radiation, seasonal wind patterns, terrestrial runoff, and general circulation within the Gulf of Mexico. The effects, in turn, are more predictable; the seasonal changes in salinity and temperature, seasonal stratification and destratification, seasonal changes in wave activity, and net currents are examples.

Other factors that affect the hydrography and water chemistry of the southwest Florida shelf can occur on smaller spatial or temporal scales than those outlined above. Examples of these phenomena include the passage of hurricanes or tropical storms and Loop Current intrusions (discussed in detail in Subsection 3.1.3). Although the spatial and temporal scales of these phenomena are considerably smaller or shorter, their effect on the southwest Florida shelf can be quite pronounced depending on the intensity with which they impact the area. For example, waves produced by the passage of a hurricane or tropical storm can, in shallow water, strip an area of its thin veneer of sediments and uproot and transport sessile epifauna and infauna. This same storm also can introduce inordinate amounts of fresh water to the area thus changing the salinity patterns, which, in turn, can affect the biota. This is especially true of near-shore stations located in water less than 20 m deep. A recent example of this was the destruction or damage to many of Florida's oyster beds caused by several hurricanes in 1985.

Phenomena such as Loop Current intrusions can also have a pronounced effect on the southwest Florida shelf hydrography and water chemistry. Primarily, the effects of the Loop Current occur beyond the 100-m isobath; however, there are occasions when the Loop Current can affect the shallower waters of the southwest Florida shelf. A discussion of these effects, as well as the effects of the other phenomena follows.

Temperature

Temperature is one of the important parameters influencing marine benthic community distributions. Consequently, the Year 4 and 5 studies focused on time-continuous monitoring of near-bottom temperatures. Temperature profiles throughout the water column were only taken quarterly and at only a few stations which did not allow for a detailed description of the overlying water column. During Years 1 and 2, however, near-synoptic temperature profiles were collected on the shelf. These data were collected along Transects A through E (Figure 3.1-1). The distribution of temperature at Transect D during four seasons is presented in Figure 3.1-2. Transect D was chosen to represent conditions of the overlying water because most of the Year 4 and 5 stations were located either on or south of Transect D. The summer temperature distribution along this transect was mixed in the surface waters (depths less than 30 m) and stratified in the deeper waters. The summer temperatures ranged from approximately 18°C at depths greater than 120 m to 30°C near the surface.

The fall temperature distribution indicated a transition between summer and winter as atmospheric cold fronts penetrated the study area,

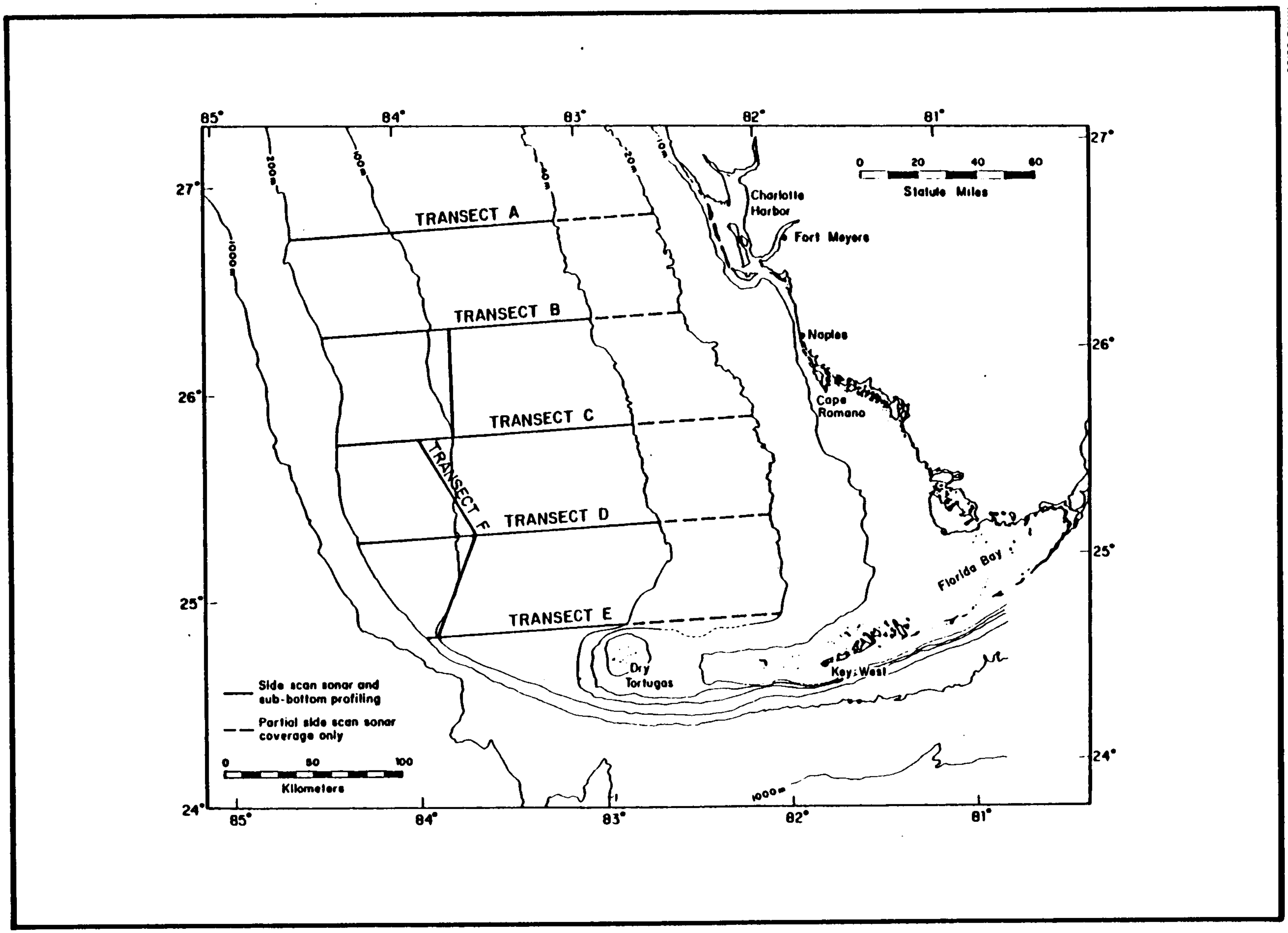

Figure 3.1-1 SAMPLING TRANSECT LOCATIONS DURING YEARS 1 AND 2

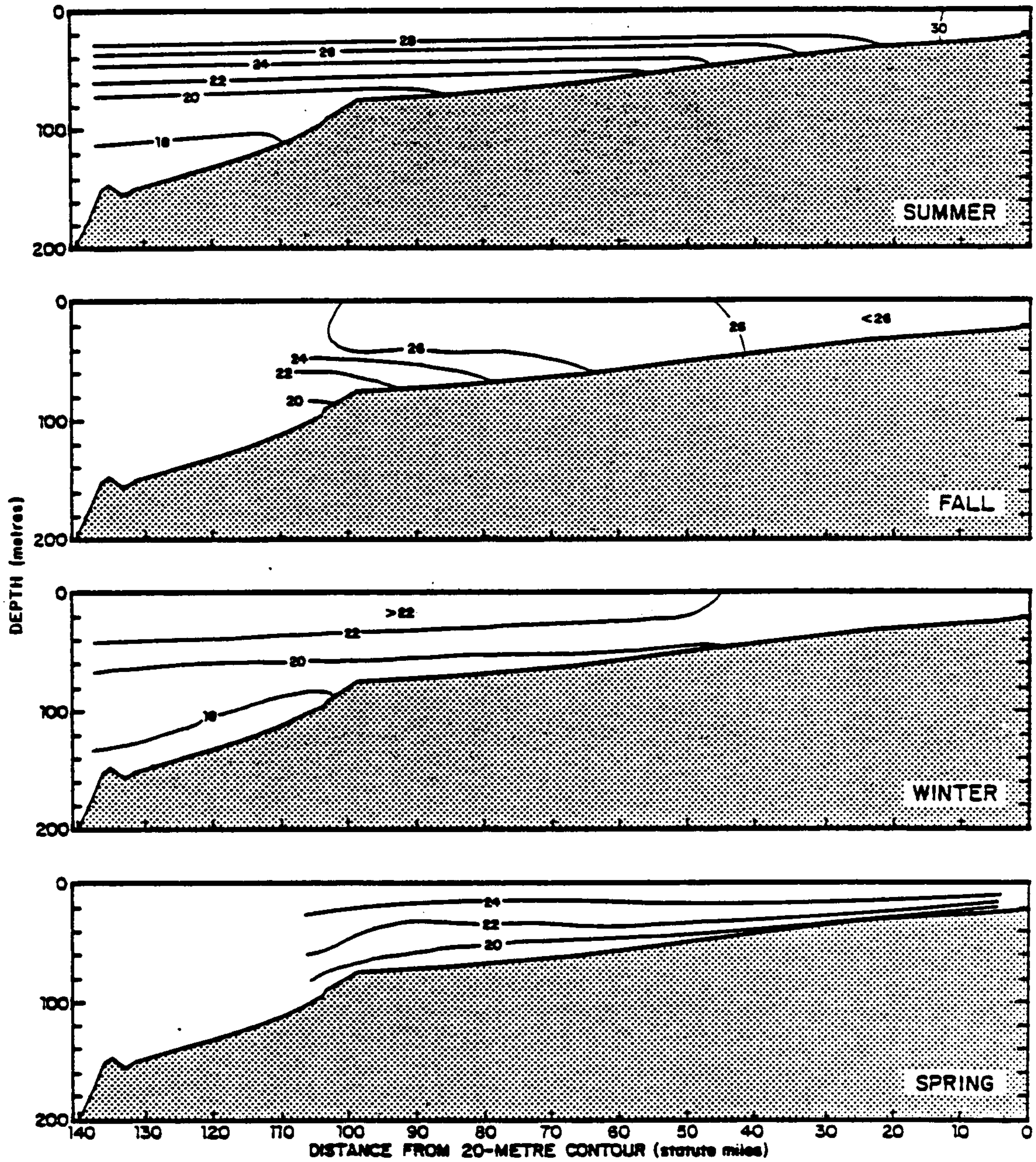

Figure 3.1-2 **SEASONAL TEMPERATURE DISTRIBUTION ALONG TRANSECT D (WOODWARD CLYDE CONSULTANTS, 1983)**

resulting in mixing induced by winds and surface cooling. The effect was to deepen the thermocline to a depth of 40 to 60 m. An additional observation was that the temperature decreased approximately 1.5° to 2.0°C from Transect A in the north to Transect E in the south.

Winter cross-shelf temperature distributions showed a weak thermal stratification (generally less than 4°C in the upper 80 to 100 m), water temperatures of approximately 20°C in shallow water, and a tendency for the water to be slightly warmer seaward.

During the spring, a decrease in turbulent forces (primarily wind induced) and surface warming, resulted in thermocline development (especially nearshore). Another consequence of nearshore warming was the appearance of near-bottom, mid-shelf temperature minima. This was particularly pronounced at Transect E, where warmer oceanic water (possibly the Loop Current) was affecting the offshore stations.

Continuous, near-bottom temperature data were collected at eight stations during Years 4 and 5 (Figure 3.1-3). These data revealed several notable phenomena, the most obvious of which was the seasonal change in temperature. This change was most pronounced at the shallower Stations 44 and 52 where near-bottom temperatures varied as much as 14°C; the deeper stations, for example Station 36, showed a seasonal variability of approximately 9°C.

A shorter-period phenomenon, evident at all but the two shallowest stations, was the intrusion of the Loop Current. A Loop Current intrusion was characterized by an increase in temperature of up to 5°C for periods as long as 10 days. These intrusions were also associated with dramatic changes in the currents (Figure 3.1-4). Although changes in temperature were quite pronounced, it was unlikely that they had a significant effect on benthic biota other than perhaps a slight increase in stress. Perhaps the most important result of a Loop Current intrusion

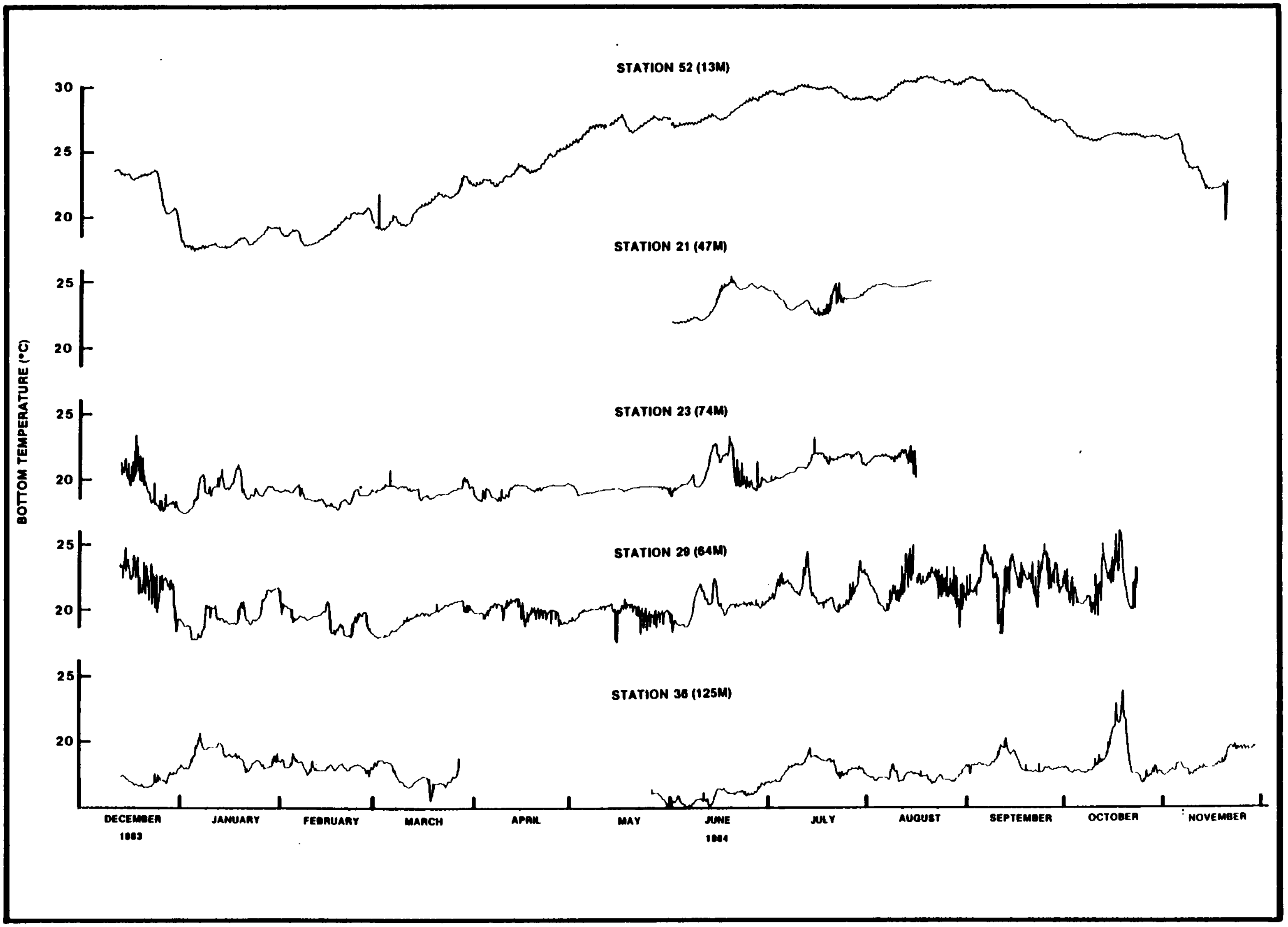

Figure 3.1-3 CONTINUOUS NEAR-BOTTOM TEMPERATURE DATA FOR YEARS 4 AND 5

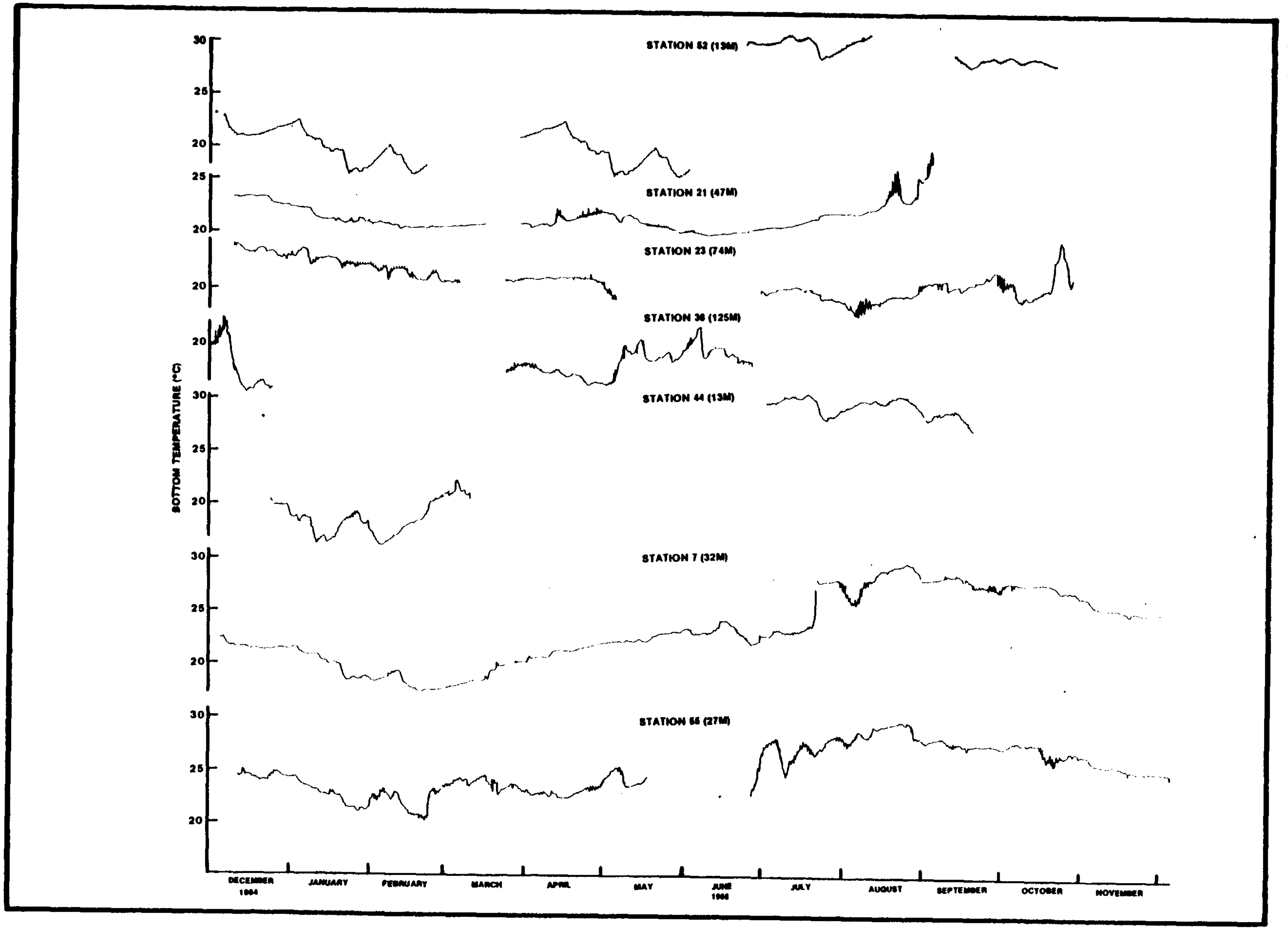

Figure 3.1-3 (cont'd)

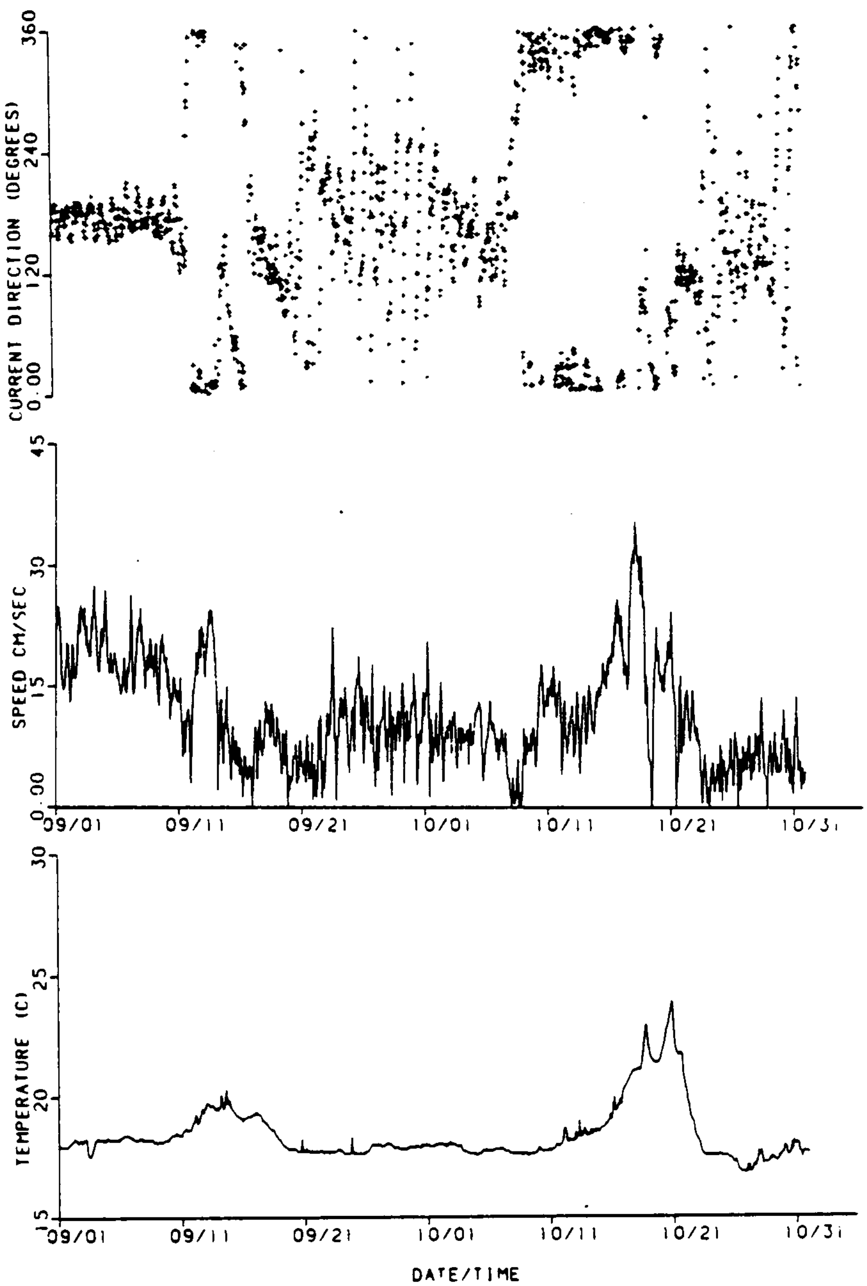

Figure 3.1-4 STATION 36 CURRENT AND TEMPERATURE DATA FOR OCTOBER 1984 SHOWING LOOP CURRENT INTRUSION

is the introduction of relatively nutrient-rich water to an otherwise nutrient-poor environment. This is discussed in greater detail in the nutrient portion of this subsection.

The last phenomenon of note with regard to the continuous temperature data is the presence of some temperature variations occurring at short time scales (hours). The magnitude of these temperature fluctuations was generally less than 1°C. The precise cause of these fluctuations is unknown; however, tidal currents or internal waves are possible explanations. These fluctuations are of insufficient magnitude to affect the biota.

Salinity

The seasonal distribution of cross-shelf salinity is presented in Figure 3.1-5. The overall shelf salinity values were within ± 1 $^{o}/oo$ of 36 $^{o}/oo$. The summer salinity transect, with the exception of a lens of fresher water, shows only slight vertical stratification at a depth of 80 m. This differs markedly from the summer distribution of temperature, which is strongly stratified below 30 m.

Terrestrial runoff is probably the source of the fresher water lens shown in the summer transect. Whether this freshwater source is from local runoff or from rivers farther to the north is unknown. However, Woodward Clyde Consultants (1983) suggest that fresh water from as far north as the Mississippi may become entrained in the Loop Current and reach the study area.

The greatest similarity of isopleths between salinity and temperature distribution occurred at Transect D during the fall. At this time, a salinity minimum was associated with a temperature maximum. The low-salinity, high-temperature signature is not typical of Loop Current or Loop Current Transition Water which is normally warmer and more saline (i.e., in excess of 36.0 $^{o}/oo$) according to Austin (1971) and Molinari

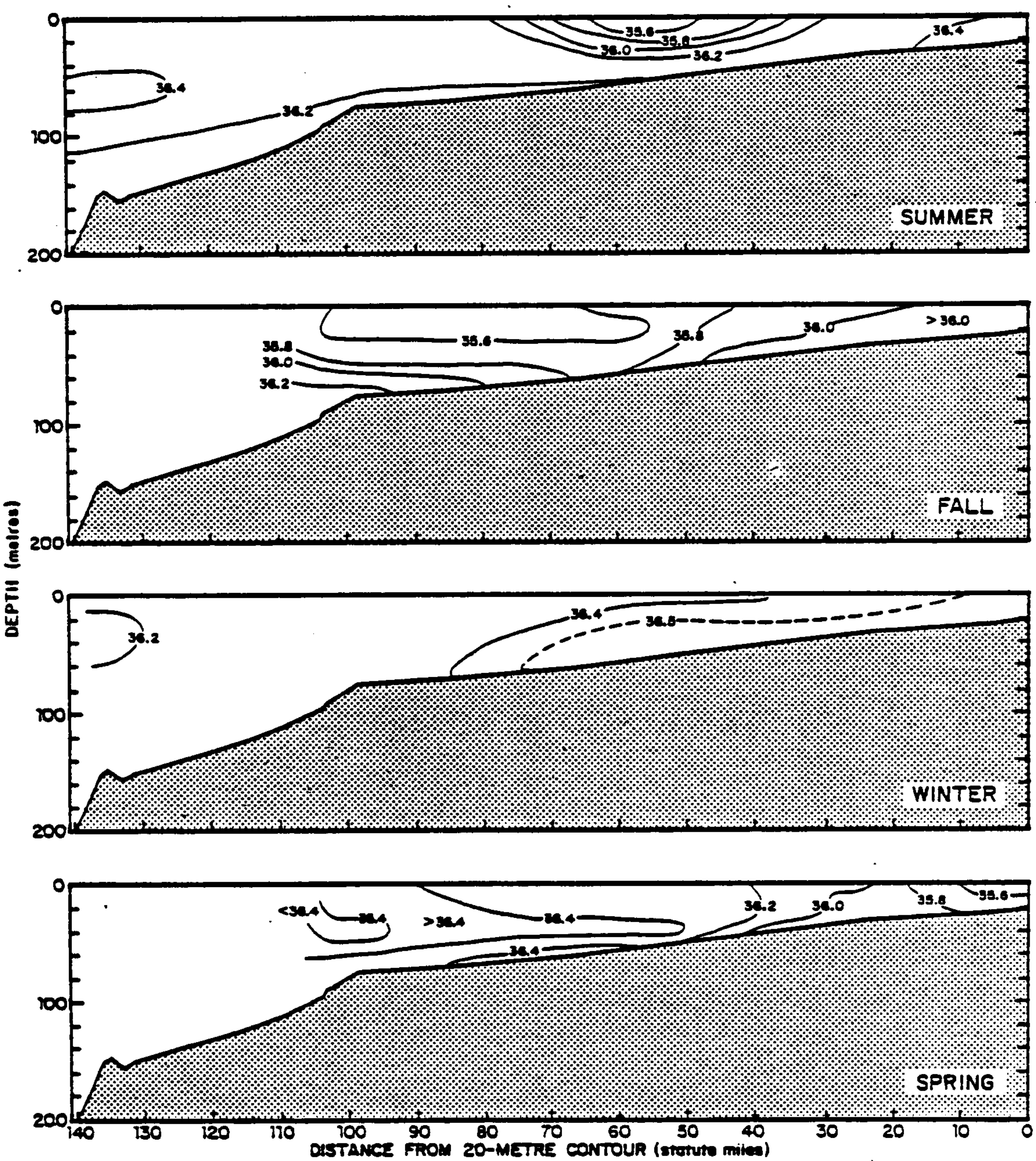

Figure 3.1-5 **SEASONAL SALINITY DISTRIBUTION ALONG TRANSECT D (WOODWARD CLYDE CONSULTANTS, 1983)**

et al. (1975) nor is it typical of Continental Edge Water which is typically colder and fresher (Woodward Clyde Consultants, 1983). The low nutrient concentrations suggest that the water does not originate from the Loop Current. Woodward Clyde Consultants/Continental Shelf Associates (1983), cautioned that their data were non-synoptic and suggested that this feature was evidence of an eddy with a low salinity core. Similar observations had been made by Haddad and Milliken (1980). Alexander et al. (1977) hypothesized that the fresher water results from impingement of Mississippi River water.

The fall salinity distribution also revealed a certain degree of stratification offshore in water depths of approximately 60 m. This stratification also was reflected in the temperature. Nevertheless, both temperature and salinity indicated mixing in nearshore waters with temperature increasing and salinity decreasing seaward.

The winter salinity distribution revealed waters that were nearly homogeneous throughout the water column and across the shelf. Salinity varied by only 0.3 $^{o}/oo$ throughout Transect D and all other transects except Transect C which revealed a subsurface intrusion of higher salinity (as high as 36.8 $^{o}/oo$) water. This intrusion was not evident in the temperature distribution. Several researchers (Chew, 1955; Collier et al., 1958; Maul et al., 1979; Morrison and Nowlin, 1977; Nowlin, 1971; and Wennekens, 1959) have suggested that this high salinity could result from Florida Bay waters, localized extreme evaporation and subsequent sinking. An alternate explanation is intrusion of Loop Current or Subtropical Underwater. Woodward Clyde Consultants/Continental Shelf Associates (1983) favor the hypothesis that the high salinity water originates from Subtropical Underwater. The majority of the researchers consider this to be a transient feature.

The Everglades often have been considered as a source of hypersaline and and fresh water (depending on the time of the year); however, the effect of the Everglades has never been quantified. Schmidt and Davis (1978) reported that salinity values ranging from 40 to 66 $^{o}/oo$ were reported in Florida Bay in 1973 and 1976. Presumably, during times of high precipitation and low evaporation, the waters of Florida Bay could become quite fresh. Schomer and Drew (1982) report salinity values as low as 13 $^{o}/oo$. However, prior to considering Florida Bay as a source of either fresh or hypersaline water, transport studies need to be conducted within the bay proper. Water current data from Station 52, the station nearest Florida Bay, indicated that transport was into rather than out of Florida Bay.

A high salinity (37 $^{o}/oo$) near-bottom lens of water was also evident during the spring cruise at Transect C. Again, the most likely source for this water is the Subtropical Underwater. This feature, if present at all on Transect D, was weak. Generally, the spring salinity distribution showed a decrease in salinity of approximately 1 $^{o}/oo$ within 170 km of shore. There was some evidence of stratification in the deeper (i.e., greater than 80 m) water farther offshore. Nearshore, the waters were vertically well mixed. This differs significantly from the temperature distribution.

Transmissivity

The distribution of transmissivity along Transect D is presented in Figure 3.1-6. Water on the southwest Florida shelf is exceptionally clear overall. There was little evidence of seasonal variation over the major part of the shelf; however, the nearshore areas during the spring and fall appeared more turbid than these areas during the summer and winter (Woodward Clyde Consultants, 1983). According to these same researchers, there was progressively more structure or variability southward. Woodward Clyde Consultants (1983) suggested that the relatively high transmissivity values may be indicative of a lack of significant near-bottom shelf currents capable of resuspending sediments; however, they also strongly urged that near-bottom currents be measured

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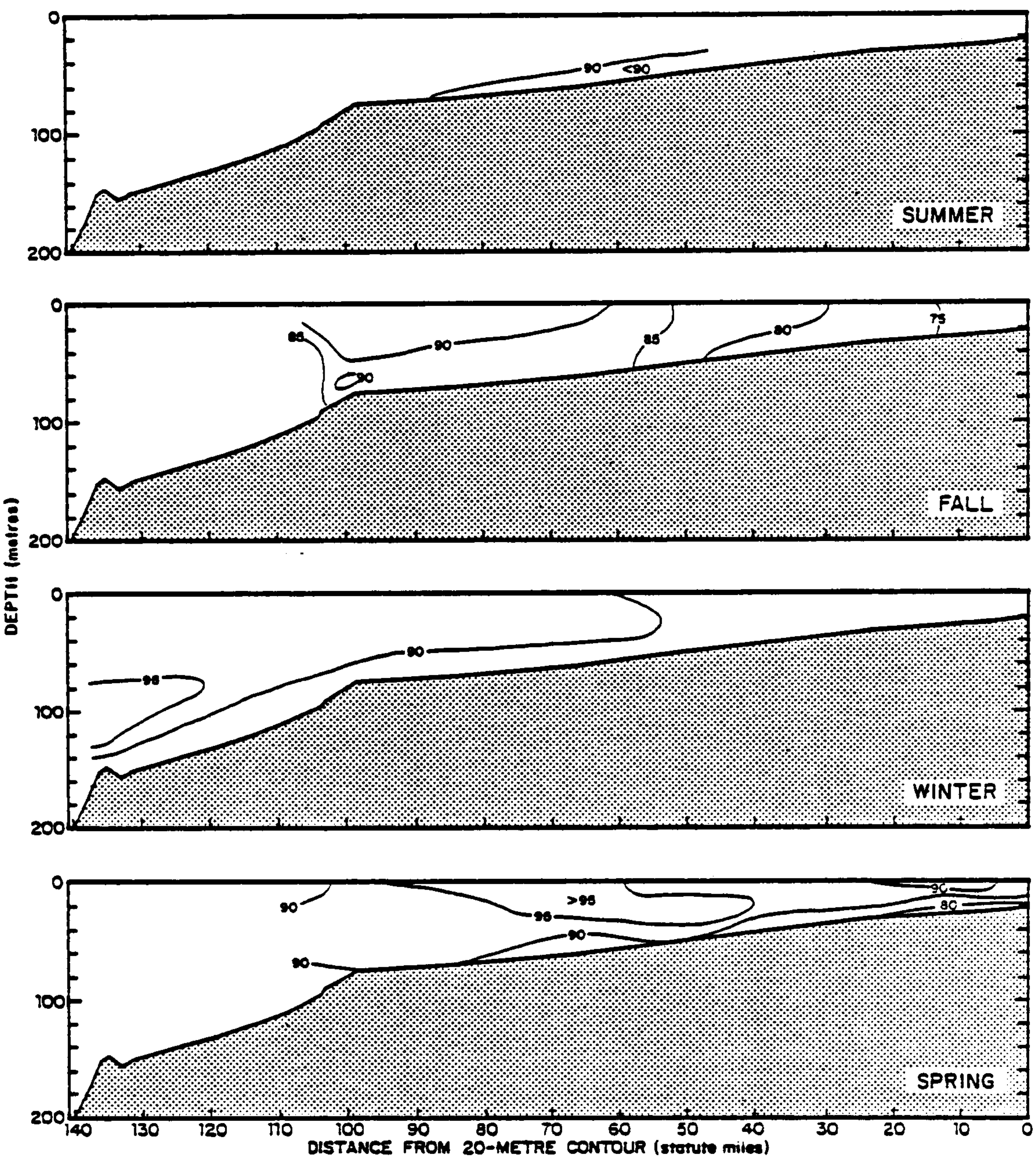

Figure 3.1-6 SEASONAL TRANSMISSIVITY DISTRIBUTION ALONG TRANSECT D (WOODWARD CLYDE CONSULTANTS, 1983)

to either confirm or deny this supposition. Turbidity that did exist was attributed to either limited sediment resuspension or phytoplankton activity.

The summer transmissivity distribution revealed very clear water with transmittance values of approximately 90% (using a 1-m pathlength transmissometer). There was very little evidence of structure.

The transmissivity values reached a minimum during the fall. Values as low as 50% were observed; the lowest transmissivity value obtained along Transect D, however, was 75%. At all transects the trend was toward increasing transmissivity with increasing distance offshore. Generally, the distribution of transmissivity suggested vertical mixing in the nearshore waters (Figure 3.1-6 is a typical example). Nevertheless, Transects A and E did reveal a somewhat stratified distribution. In the case of Transect A, low transmissivity values were found near the surface; at Transect E, the lowest transmissivity values were found near the bottom. The low surface values at Transect A could be the result of terrestrial runoff; the low bottom values at Transect E could be the result of sediment resuspension caused by wave activity. The Year 4 and 5 studies have shown that, generally, the near-bottom currents are too slow to resuspend sediments; however, these currents coupled with wave induced near-bottom orbital velocities in shallow water can resuspend sediments.

The winter transmissivity distribution revealed little structure and generally high transmissivity values (approximately 90%). There were occasional instances of lower transmissivity values, but they did not approach the low values recorded during the fall.

During the spring, the existence of a slightly more turbid layer of bottom water was noted. This layer, with transmissivity values of approximately 90% (usually 5% less than the overlying water), extended out to the 80-m isobath. The layer, as defined by the 90% isopleth, was approximately 20 m thick. Values within 5 m of the bottom were as low as 80%. The exception to this generalization occurred at Transect E, where the distribution was considerably more complicated. On this transect, values as low as 40% occurred nearshore on the bottom (water depth was approximately 20 m). The near-bottom transmissivity values between the 20-m isobath and the 40-m isobath were approximately 90%. A second transmissivity minimum (70%) was encountered beyond the 40-m isobath. This relatively small feature was also reflected as a slightly lower salinity lens along Transect E. Woodward Clyde Consultants/Continental Shelf Associates (1983) stated that nearshore nepheloid layers were more developed along Transects C through E. They also stated that most of the turbidity was associated with phytoplankton (supported with the chlorophyll *a* data). A comparison of transmissivity data with chlorophyll data, however, provides only tenuous support to this hypothesis.

Gelbstoff

Gelbstoff or yellow substance frequently has been used as an indicator of terrestrial influence. It is associated with humic substances resulting from the decomposition of organic matter (e.g., vegetation). Woodward Clyde Consultants/Continental Shelf Associates (1983) reported that the values for Gelbstoff were too close to the limit of detection to prepare any reliable plot of concentration. These extremely low values do suggest, however, that terrestrial influence (including the Everglades) on the southwest Florida shelf is minimal.

Dissolved Oxygen

El Sayed *et al*. (1972) depicted typical dissolved oxygen values of 6.5 to 6.9 mg/l for the upper mixed layer of water and 4.7 to 6.5 mg/l for the depths greater than 100 m. This characterization is representative of DO distribution and variability on the southwest Florida shelf. The overall range of DO concentration observed during Years 4 and 5 of the program was greater (4.4 to 10.3 mg/l) than that previously reported. The lower values (below 5 mg/l), were found in deeper near-bottom water. The higher dissolved oxygen concentrations (greater than 9 mg/l) were found in the surface waters.

Nutrients

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

No nutrient data were collected during Years 4 and 5; however, Woodward Clyde Consultants and Continental Shelf Associates did collect nutrient and plant pigment data during Years 1 and 2 and during the Year 2 Modification as far offshore as the 200-m isobath. The results of the Year 1 and 2 sampling along Transect D are presented in Figures 3.1-7, 3.1-8, and 3.1-9 (nitrate-nitrite, phosphate, and silicate, respectively). Although the fall and spring data collected during 1980 and 1982 (Year 4) extend only to the 100-m isobath, several observations can be made. First, the nutrient values are higher offshore, not only because the water is deeper, but presumably, because the area is in proximity to the Loop Current and its effects. Bogdanov et al. (1969) reported apparent upwelling which was associated with either winds and/or the Loop Current. This upwelling would bring up the more nutrient-rich Subtropical Underwater. Haddad and Carter (1979) reported that Loop Current intrusions do occur on the shelf. Freeberg and Hyle (1978) reported that a Loop Current intrusion occurred within 4 km of shore accompanied with an increase in orthophosphate concentration of 88% and dissolved silicate of 129%.

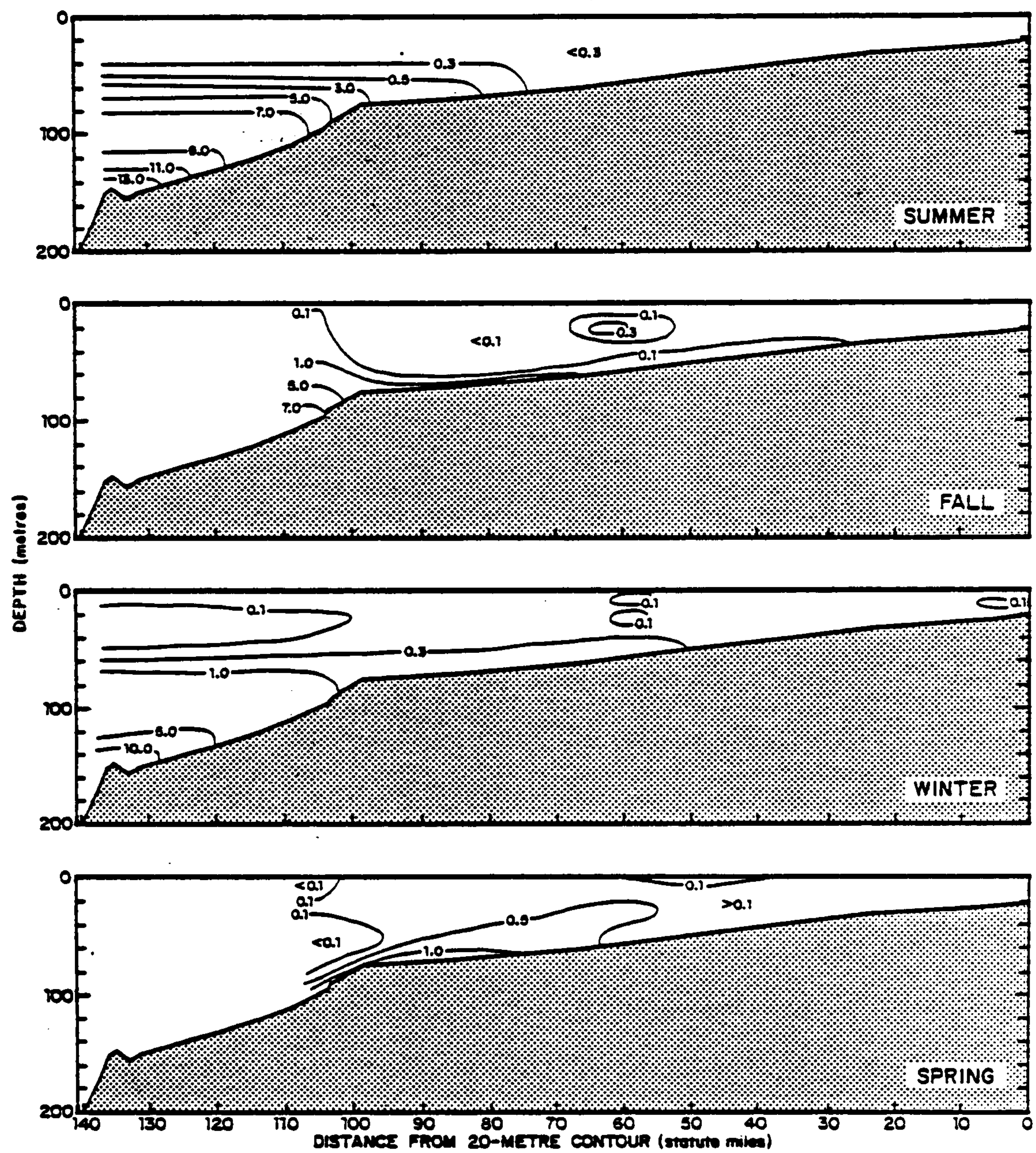

Figure 3.1-7 SEASONAL NITRATE-NITRITE DISTRIBUTION ALONG TRANSECT D (WOODWARD CLYDE CONSULTANTS, 1983)

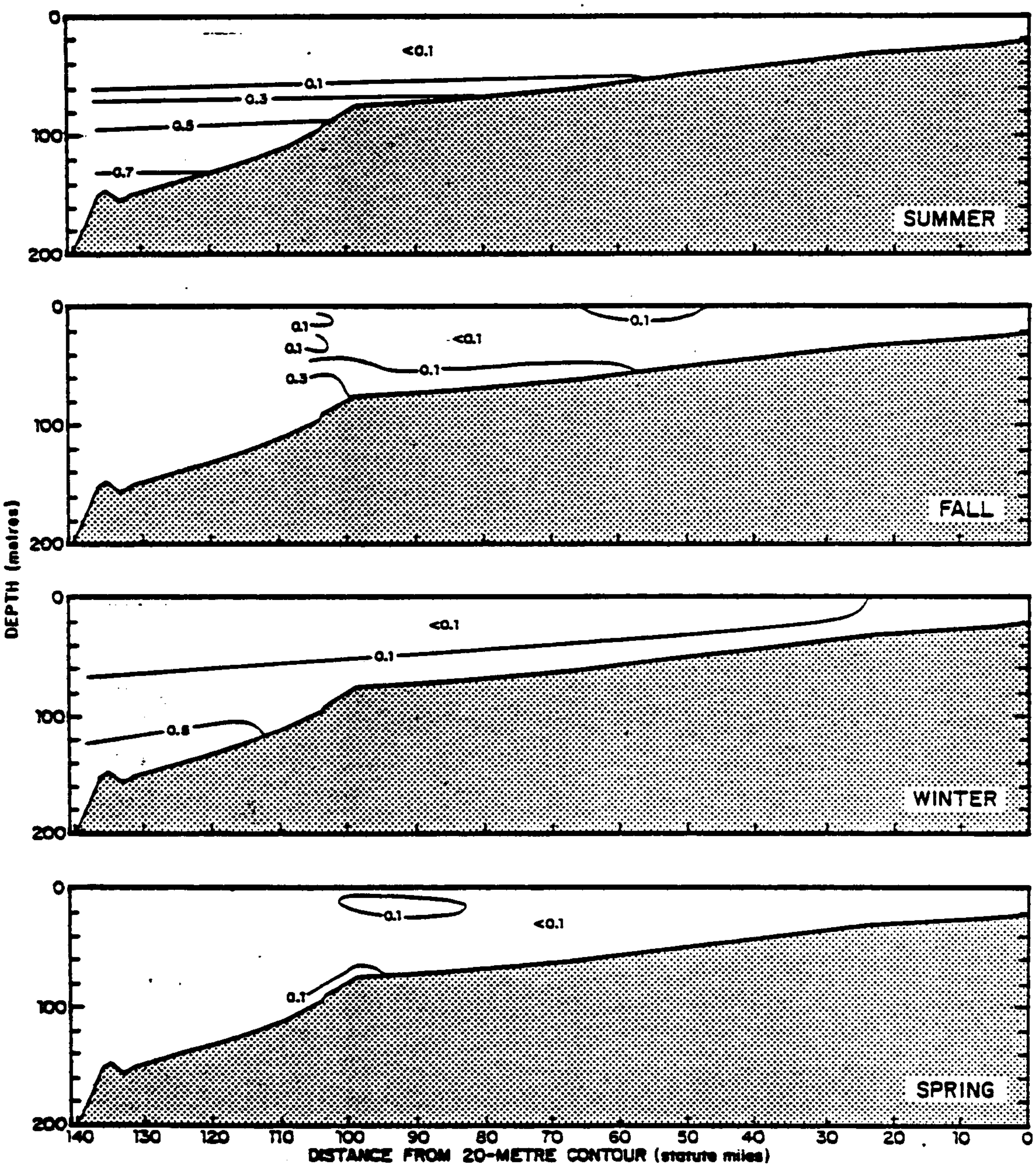

Figure 3.1-8 SEASONAL PHOSPHATE DISTRIBUTION ALONG TRANSECT D (WOODWARD CLYDE CONSULTANTS, 1983)

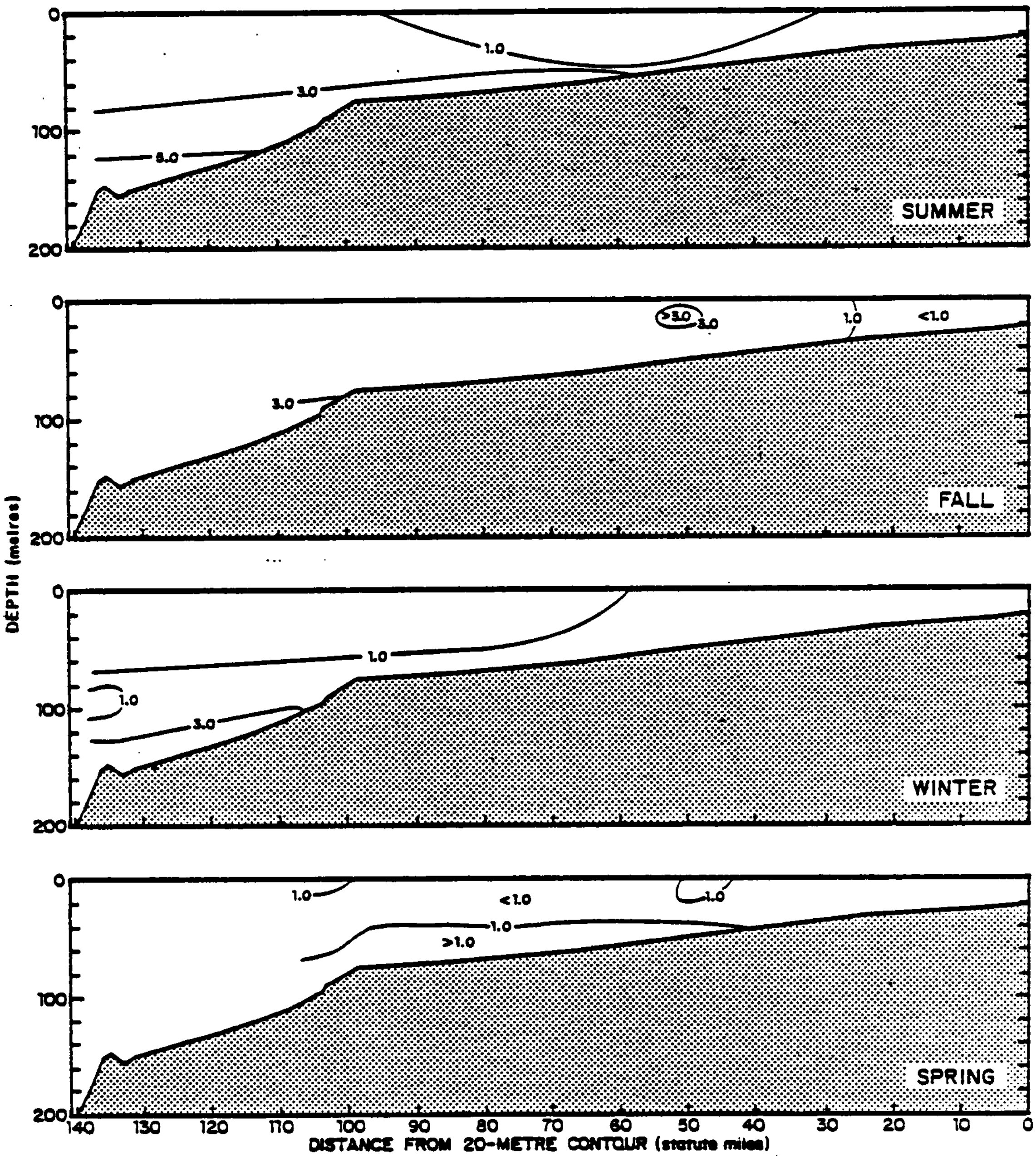

Figure 3.1-9 **SEASONAL SILICATE DISTRIBUTION ALONG TRANSECT D (WOODWARD CLYDE CONSULTANTS, 1983)**

The summer distribution of nutrients generally followed the summer temperature distribution which indicated that the surface layer was well mixed to a depth of 30 m with the water stratified below 40 m. The difference between the nutrient and temperature distribution was that the thermocline extended inshore to the 20-m isobath; the nitracline, however, extended inshore only to the 60-m isobath. A possible explanation is that the nutrients inshore of the 60-m isobath (and within the euphotic zone) are being depleted by phytoplankton. If the explanation were simple turbulent mixing, then the distribution of temperature should closely match the nutrient distribution.

Nitrate-nitrite values as high as 13 uM were found in water as deep as 140 m. Within the surface mixed layer the nitrate-nitrite concentration was less than 0.3 uM. Phosphate and silicate distributions were similar to those of nitrate-nitrite. The absolute values ranged from less than 0.1 to 0.7 uM for phosphate and from 1.0 to 5.0 uM for silicate. As stated in the discussion on salinity, the lens of fresher surface water that occurred on Transect D in the summer was not high in nutrients suggesting that, if this water were originally terrestrial in origin, it was old enough for the nutrients to be depleted by biological activity.

During the fall, the surface mixed layer located inshore was deeper, extending to approximately 60 m, and the nutrient concentrations were even lower than during the summer. Because the sampling did not extend out to the 200-m isobath, it is impossible to say whether the deep water nutrient values were comparable to summer, but the trend evident seemed to suggest the values would be comparable. One feature consistently present for all nutrients was a surface lens of water with slightly higher (1.5 to 2 times) concentrations located near the 60-m isobath. This lens was not readily apparent in the salinity, temperature, or transmissivity. This feature, quite probably based on data collected from a single station, could be an artifact of sampling or analytical technique rather than a real phenomenon. However, because it consistently appears in especially the nitrate-nitrite data suggests that the answer may not be a simple one.

The winter nutrient distribution revealed a nitracline at a depth of 60 m. All nutrient concentrations of the deeper waters were lower than the values observed during the summer. Vertical stratification was evident during the winter.

The spring nitrate-nitrite distribution, similar to the spring salinity distribution, was more complicated. Although the salinity and nutrient distributions did not match exactly, there were certain similarities. Most notable was the intrusion onto the shelf of slightly higher salinity water with slightly higher nutrient concentrations.

Chlorophyll a

The last parameter to be discussed is chlorophyll *a*. Other plant pigments, such as pheophytin, were measured during Years 1 and 2, but chlorophyll *a* is a good indicator of primary productivity and will be the only pigment discussed in this document. Generally, the chlorophyll levels were low (oligotrophic) across the majority of the shelf. This agrees with El Sayed *et al*. (1972) who reported chlorophyll levels of 0.20 ± 0.23 mg/m^3 based on 435 observations for the Gulf of Mexico (Woodward Clyde Consultants, 1983). In contrast, Riley and Chester (1971) report that fertile coastal waters in bloom may exhibit chlorophyll values from 10 to 40 mg/m^3. El Sayed *et al*. (1972) also reported that for the Gulf of Mexico the average surface value for chlorophyll was 0.2 mg/m3 (with a range of 0.05 to 0.3 mg/m^3) and that a chlorophyll maximum coincided with the depth of the euphotic zone.

The seasonal cross-shelf distribution of chlorophyll *a* along Transect D is presented in Figure 3.1-10. The distribution of chlorophyll showed little or no correlation with the other parameters. Considering that the

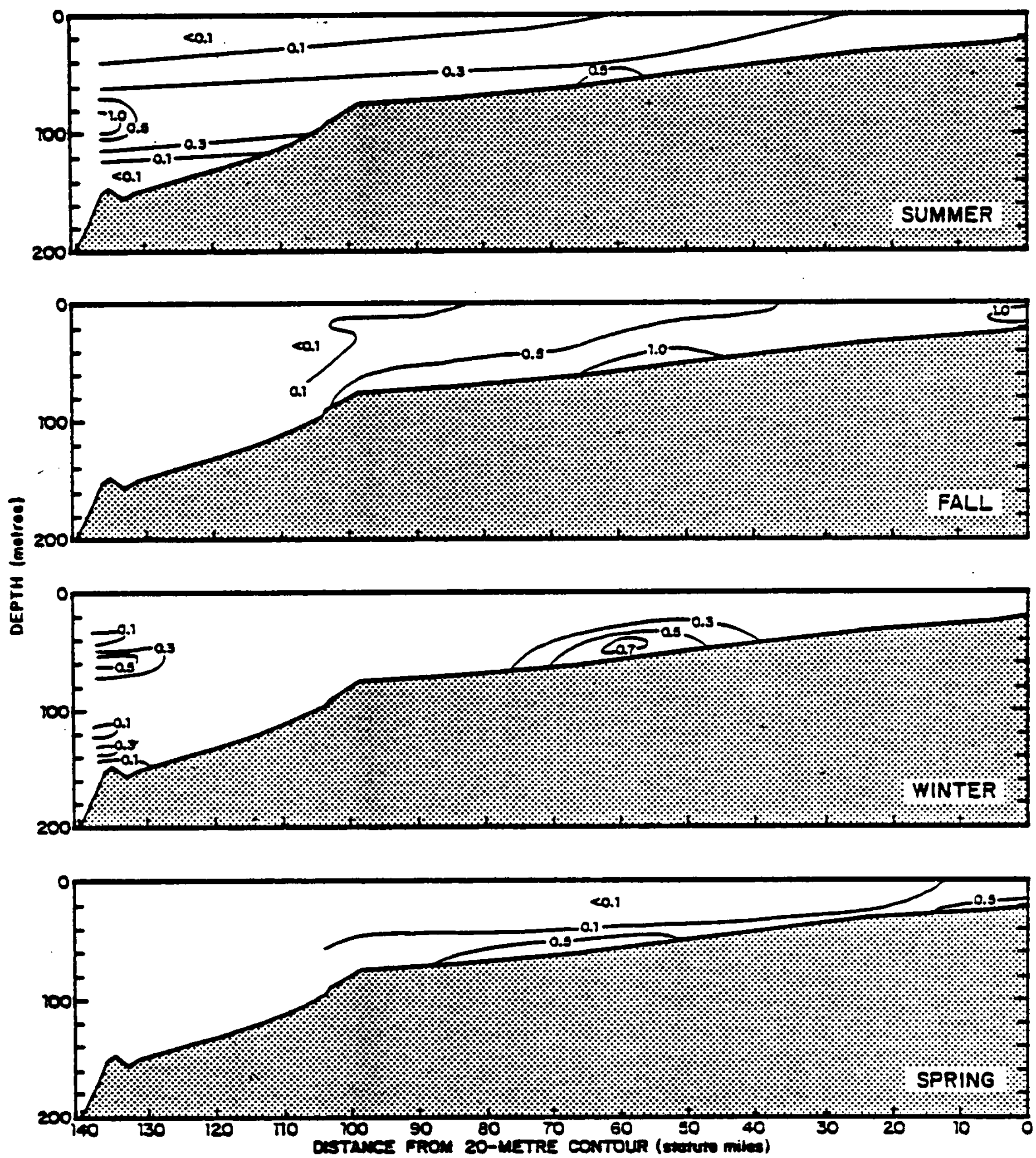

Figure 3-1-10 SEASONAL CHLOROPHYLL *a* DISTRIBUTION ALONG TRANSECT D (WOODWARD CLYDE CONSULTANTS, 1983)

distribution of chlorophyll is a function of a complex relationship between the other parameters, this is not surprising. For example, deep water may have sufficient nutrients to support a bloom, but there is insufficient light available to support photosynthesis; therefore, there is a low amount of primary productivity (and, hence, little chlorophyll is produced). The obverse can be true as well, i.e., plenty of light, but insufficient nutrients. The chlorophyll maximum occurs at the ideal location where there is sufficient light and nutrients to support photosynthesis to the fullest extent.

The summer chlorophyll distribution revealed that the highest chlorophyll values occurred between the depths of 60 and 120 m (as defined by the 0.3 mg/m^3 isopleth). Although relatively nonproductive, the highest productivity occurred across the shelf to a depth of 120 m. One of the highest chlorophyll a values encountered (on the western extreme of Transect D) was 1.0 mg/m^3 which is still an order of magnitude less than the lowest value cited for fertile coastal water in bloom. This value was exceeded only by a value of 1.5 mg/m^3 which occurred nearshore along Transect C during the fall.

During the fall, chlorophyll maxima (1.0 mg/m^3) occurred both mid-shelf and at the eastern extreme of Transect D. The other transects revealed distributions that differed from Transect D and from each other. The transects north of Transect D revealed a chlorophyll distribution that was indicative of mixing, especially inshore of the 50-m isobath. Transect E, located south of Transect D was more vertically stratified and, therefore, similar to Transect D. As stated previously, the highest chlorophyll concentration encountered (1.5 mg/m3) occurred at the eastern extreme of Transect C.

The winter chlorophyll distribution varied with every transect. A near-bottom lens of high-chlorophyll water did occur roughly mid-shelf along

Transect D. There was no analogous structure evident in any of the other parameters. Higher chlorophyll values were also encountered at the western extreme of Transect D and are probably the result of higher nutrient levels resulting from upwelling along the slope.

With regard to water inshore of the 100-m isobath, the lowest chlorophyll values were recorded during the spring and were comparable to the summer values. For both seasons, the inshore chlorophyll values ranged from 0.1 to 0.5 mg/m^3, which was lower than the fall or winter values. This suggests that the phytoplankton bloom had been missed either sometime in the spring or summer. Therefore, it is likely that the maximum values reported during Years 1 and 2 are low and should be considered conservative when estimating the productivity of the shelf water or comparing this productivity with worldwide values.

Summary

Because of the low nutrient and phytoplankton (chlorophyll) concentrations and the high transmissivity, salinity, and temperature values, the southwest Florida shelf is considered a classical tropical-subtropical marine environment (Woodward Clyde Consultants, 1983). The exceptions to this characterization are usually local and transient. For example, there were periods when transmissivity values decreased to as low as 50%. This was not a shelf-wide phenomenon nor was it long lasting and was probably the result of sediment resuspension caused by wave activity and was generally confined to shallow water (less than 50 m).

There were also isolated pockets (lenses) of high- or low-salinity water and high chlorophyll or nutrient concentrations. These phenomena, however, were restricted in time and space. It is likely that the upwelling, induced by winds and/or the Loop Current, was responsible for the introduction of high salinity, high nutrient waters onto the southwest Florida shelf. This water has been variously identified as Loop Current Water or Subtropical Underwater. Either water normally is associated with higher salinity and nutrient values. The effects of the

Loop Current were most obvious farther offshore; however, historical data and data from Years 1 through 5 of this program indicate that the effects can be detected well onto the continental shelf.

The occasional occurrence of lenses of fresher water were also noted on the southwest Florida shelf. Various authors have suggested that this fresh water originates from the Mississippi River, is entrained by a southward flowing branch of the Loop Current, and can eventually be impinged in Loop Current eddies thus producing the phenomenon observed. Whether the source is the Mississippi River or west coast Florida rivers, the effect is generally the same, i.e., the introduction of fresher water. However, limited nutrient, Gelbstoff, and transport data indicate that local runoff, either from Florida rivers or the Everglades, does not play a significant role in the overall hydrography of the southwest Florida shelf.

3.1.3 CURRENTS

The principal objectives of the current monitoring program were to help define the physical environment on the southwest Florida shelf and evaluate the interactions of the physical environment with the benthic community. The stresses that may be imposed on the biota either directly or indirectly through sediment resuspension or transport of eggs and larvae are of particular interest. Descriptions of current energy distributions, transport directions, and importance to sediment dynamics are emphasized in this section. Additional analysis of the data regarding overall shelf circulation will be completed by the Physical Oceanography Program under a separate MMS contract.

Numerous studies have been conducted on the currents in the Gulf of Mexico, either directly through current velocity measurement or indirectly through hydrographic surveys or satellite imagery [e.g., Leipper (1970), Vukovich and Maul (1985), Ichiye (1962), Brooks and Legeckis (1982), Kirwan, et al. (1984), etc.]. The majority of these studies, however, centered on examining the Gulf-wide circulation and the effects of the Loop Current; only a few studies examined the currents on the southwest Florida shelf.

The first recorded study of currents in the study area was conducted in 1914 by Vaughan (1935). Measurements were made with an Ekman Current Meter in several of the passes around the Florida Keys in an attempt to explain the distribution of sediments and the configuration of the keys. Currents as high as 130 cm/sec during flood tide were reported.

A more recent study in the area was conducted by Rehrer et al. (1966). In this study, drifters were used to investigate the bottom currents in the shrimp grounds north of the Marquesas. Of the 590 bottom drifters released, 151 were recovered and were used to describe the bottom currents in the area. The results indicated that currents were generally to the west and south and averaged between 1 and 10 miles per day for the two seasons studied. The authors concluded that larval shrimp from this area could not be transported directly to the Everglades nursery area by eastward currents but must follow a circuitous route. These results were compared with direct current measurements in the area by Rinkel and Dunlop (1962) who measured current drifts of 3 to 9 miles per day.

The remaining intensive water current study completed in the area was conducted between 1965 and 1967 and was part of the Hourglass Cruises (Williams et al., 1977). As one task of the program, 4,460 drift bottles were released during a 28-month period. The results of the 1,415 drifters that were recovered were used to estimate water circulation on the southwest Florida shelf. The results for a typical winter and summer release are shown in Figure 3.1-11. The results for the winter releases indicated a persistent flow to the south, whereas spring and summer releases indicated drifter returns from the south and north. This scatter in returns was interpreted as the result of northerly longshore currents as well as entrainment in northerly flowing Loop Current eddies.

The present MMS-funded study is one of the first to use moored current meters in the study area to examine the time-dependent structure of the currents. The current meters were maintained for 2 years at five stations (Stations 21, 23, 29, 36, and 52) and for 1 year at three additional stations (Stations 7, 44, and 55), as shown in Figure 1.3-1. Lost equipment and various instrument malfunctions reduced the data recovery; however, an extensive data base describing the current regime in the area was obtained.

Speed-Direction Plots

The first step in the data analysis following the final editing and calibration of the current meter time-series data was to produce speed-direction plots of the data. All speed-direction plots and associated progressive vector plots for 1985 (Year 5) are presented in Appendix B (1984 data are presented in the Year 4 annual report). Representative

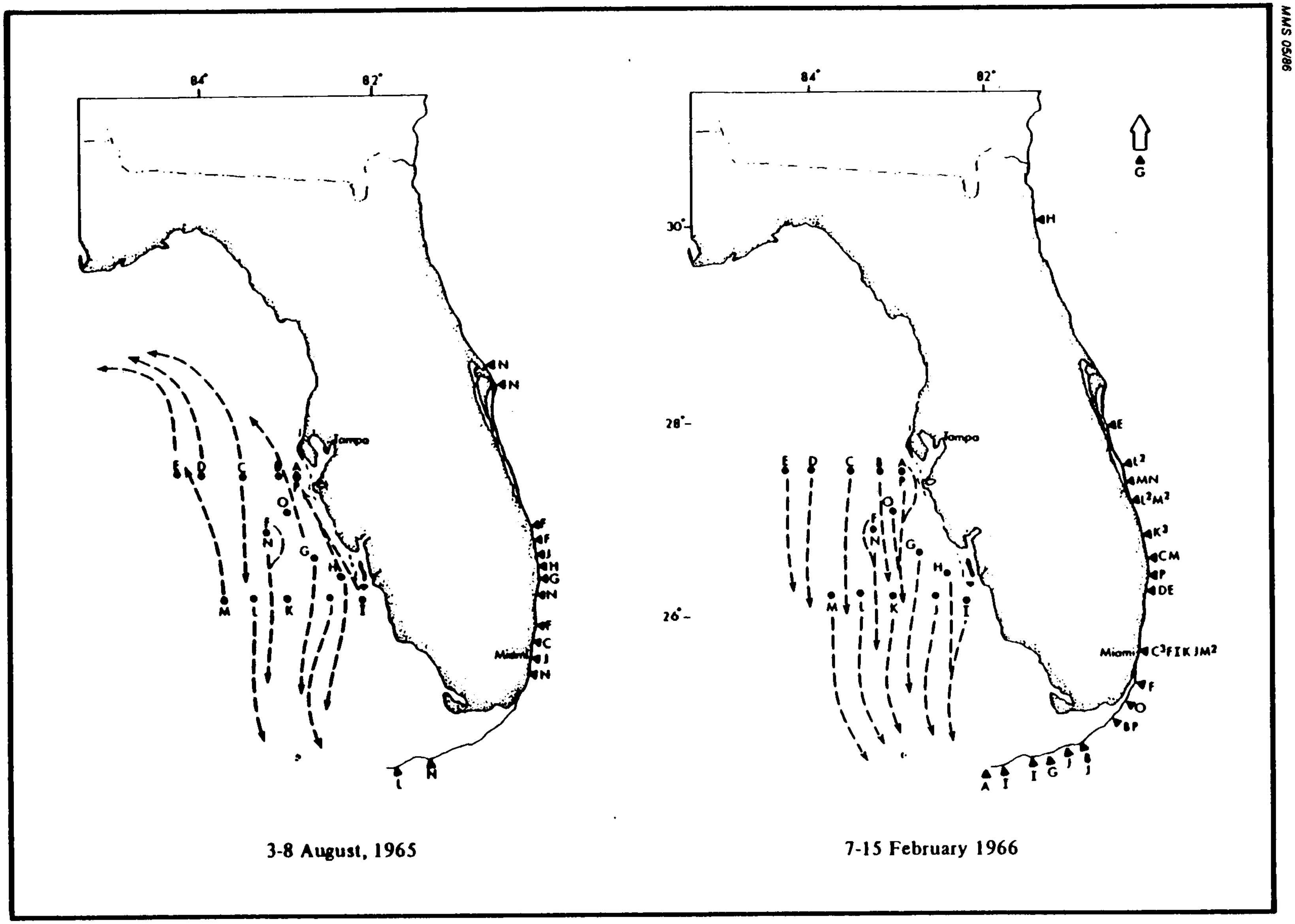

Figure 3.1-11 **TYPICAL SUMMER AND WINTER DRIFTER RETURNS FROM HOURGLASS CRUISES (WILLIAMS *et al*, 1977)**

samples of the plots for Stations 52, 7, 23, and 55 are shown in Figures 3.1-12 and 3.1-13. The results for Station 52 (13.5 m) show the dominant east-west flow in this shallow water zone. The current speed data indicate there is primarily a semidiurnal tide with maximum speeds of approximately 30 cm/sec occurring every 6 hours during flood and ebb tides. The data also show the spring and neap tides with maximum and minimum speed ranges occurring at a 2-week interval. The progressive vector plot for Station 52 indicates that although the maximum speeds were in the east-west direction, the net transport was to the southeast toward Florida Bay. This finding was consistent for the 2 years of data examined for this station.

The results from Station 7 (32 m) and Station 23 (74 m) illustrate the gradual change in tides from semidiurnal to diurnal and from linear in the east-west direction to more elliptical with increasing depth. The major peaks in current speed occur every 12 hours with only small peaks at the 6-hour interval. Also, the uniform appearance of the tidal influence in the current speed observed at Station 52 becomes less apparent in deeper water as other forces become more important. At Station 23, the tidal peaks in the speed record are apparent, but the speed does not drop to near zero at slack tide as it did in shallower water. The maximum speeds also are less, and reached approximately 15 cm/sec at flood and ebb tide. The direction varies more uniformly between 0 and 360° because of the tidal elliptical trajectories.

The speed-direction plot for Station 55 indicates a tidally dominated velocity field with speeds to 45 cm/sec. The tidal flow is oriented north-south as the currents flush through the gap between the Tortugas and the Marquesas. The tides are mixed in this region; the diurnal tides are dominant. The spring and neap tide effects also are apparent in the speed record with increasing tidal currents occurring at 2-week intervals.

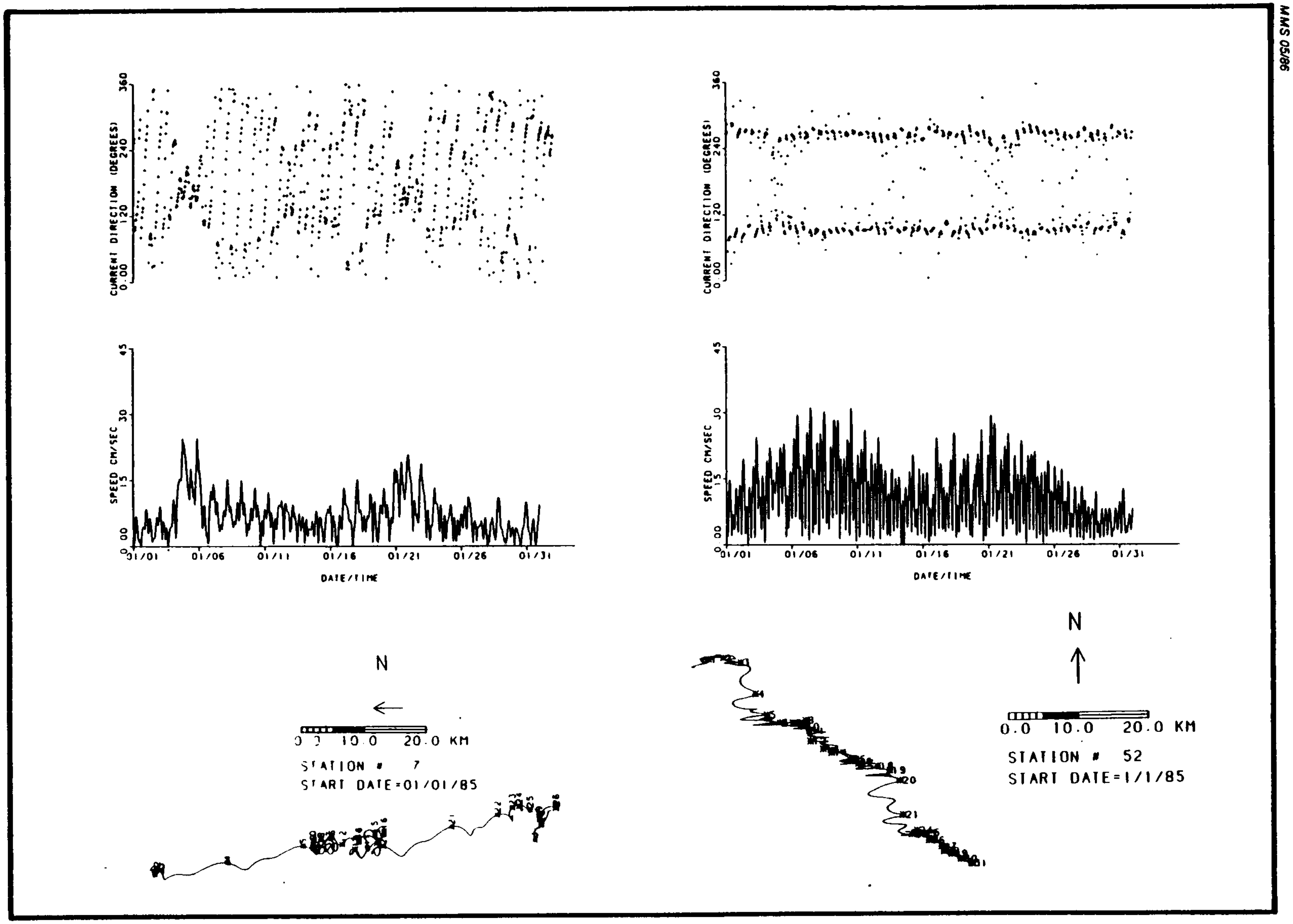

Figure 3.1-12 STATIONS 7 AND 52 CURRENT SPEED, DIRECTION AND PROGRESSIVE VECTOR PLOTS – JANUARY 1985

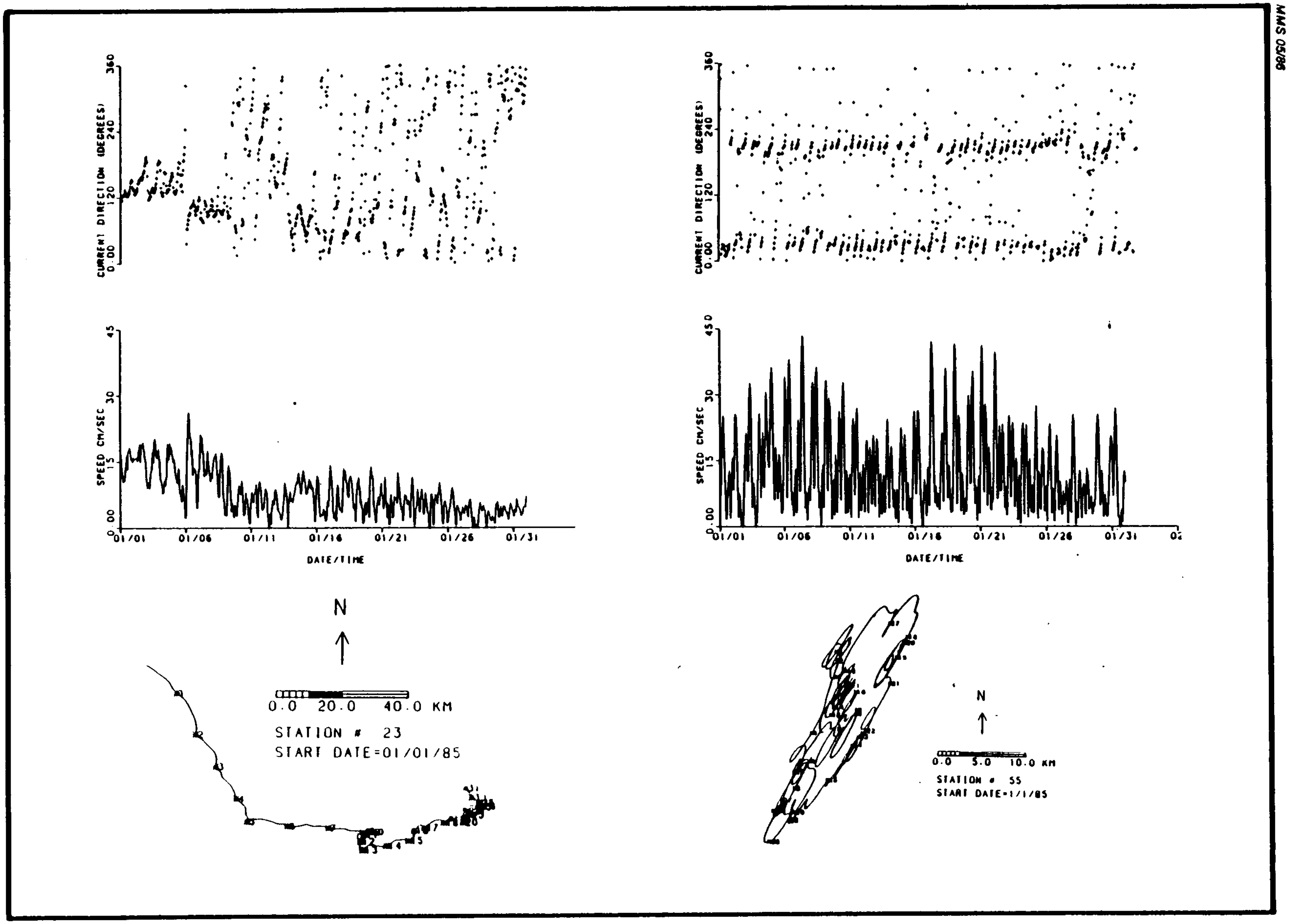

Figure 3.1-13 STATIONS 23 AND 55 CURRENT SPEED, DIRECTION AND PROGRESSIVE VECTOR PLOTS – JANUARY 1985

Power Spectra Analysis

Power spectra analysis was conducted on many of the current meter records to examine energy frequency concentration and to identify how the water current energy changes throughout the study area. Spectral estimates from Stations 52 and 55 are provided in Figure 3.1-14; additional examples of the power spectra are provided in Appendix B. The spectra from Stations 52 and 55 illustrate tidal dominance. As also shown in the speed-direction plots for Station 52, the current energy is primarily at the semidiurnal tidal frequency (approximately 0.08 hour^{-1}) with the majority of the energy in the east-west component (offshore component). At Station 55, the north-south component is dominant at the semidiurnal frequency, but there also is energy in the east-west component indicating that tidal currents are elliptical. The spectra from both stations indicate a second energy concentration at the diurnal frequency. This energy concentration typically had two peaks: one at the diurnal tidal frequency and the other at the local inertial frequency. Because these frequencies were approximately the same at the latitude within the study area, it frequently was difficult to distinctly separate the two energy bands and the energy appeared as one broad peak. This is illustrated in the spectra from Stations 29 and 36 presented in Figure 3.1-15. These spectra show not only a single broad peak near the diurnal frequency but also that the energy at the diurnal frequency is becoming dominant as the water depth increases. Also, the energy is approximately equal in both components, whereas it was totally dominated by the east-west component in the shallow water at Station 52.

To illustrate the change in energy with depth, three-dimensional illustrations of the energy spectra were prepared. The depth relationship of Stations 52, 21, 29, 23, and 36 that are nearly aligned along an east-west transect is presented in Figure 3.1-16. To generate the three-dimensional plots, the power spectra were plotted with frequency in the x-direction, energy in the z-direction, and distance offshore in the y-direction. The gaps along the offshore direction between the discrete

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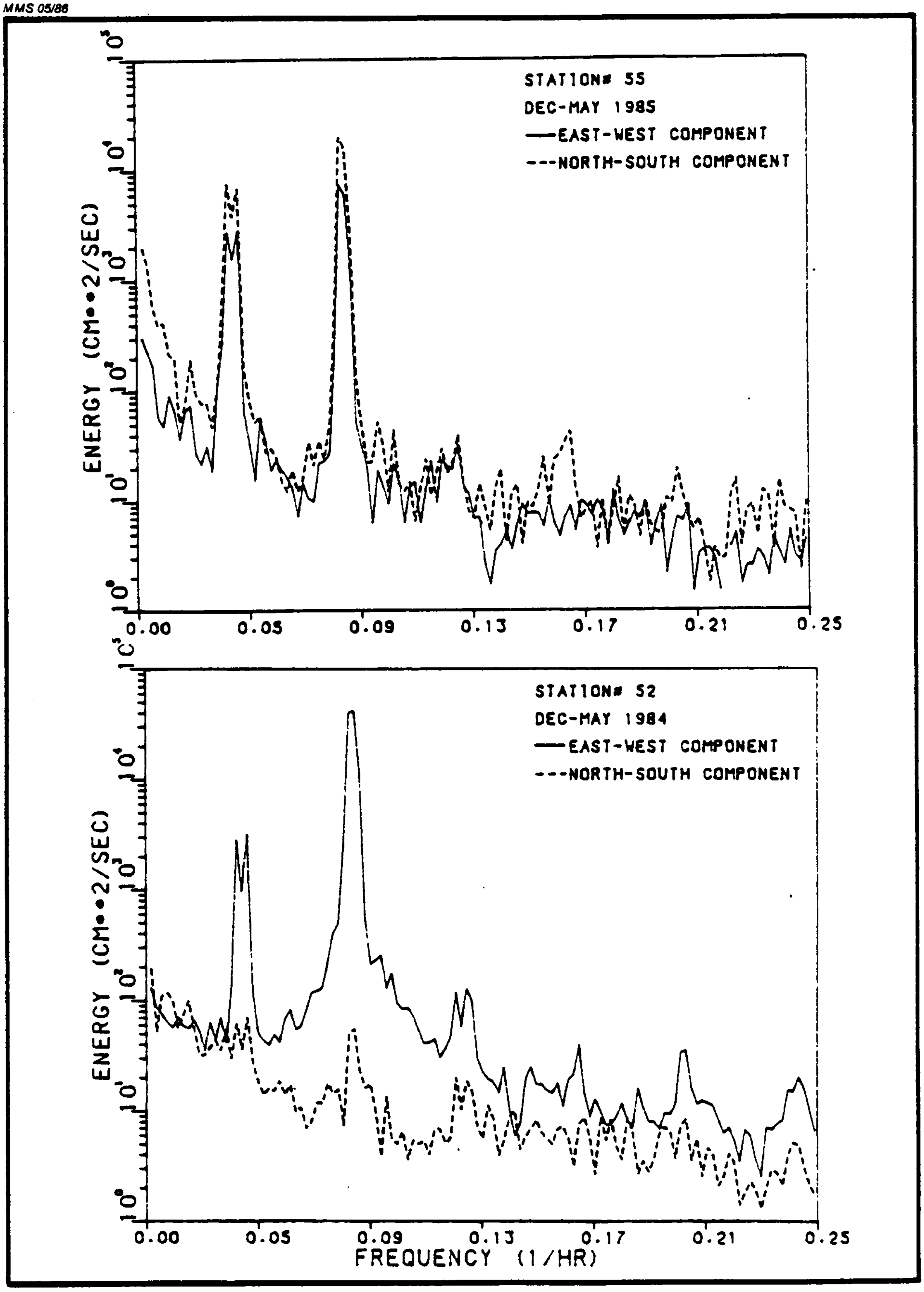

Figure 3.1-14 ENERGY SPECTRA FOR STATIONS 52 AND 55

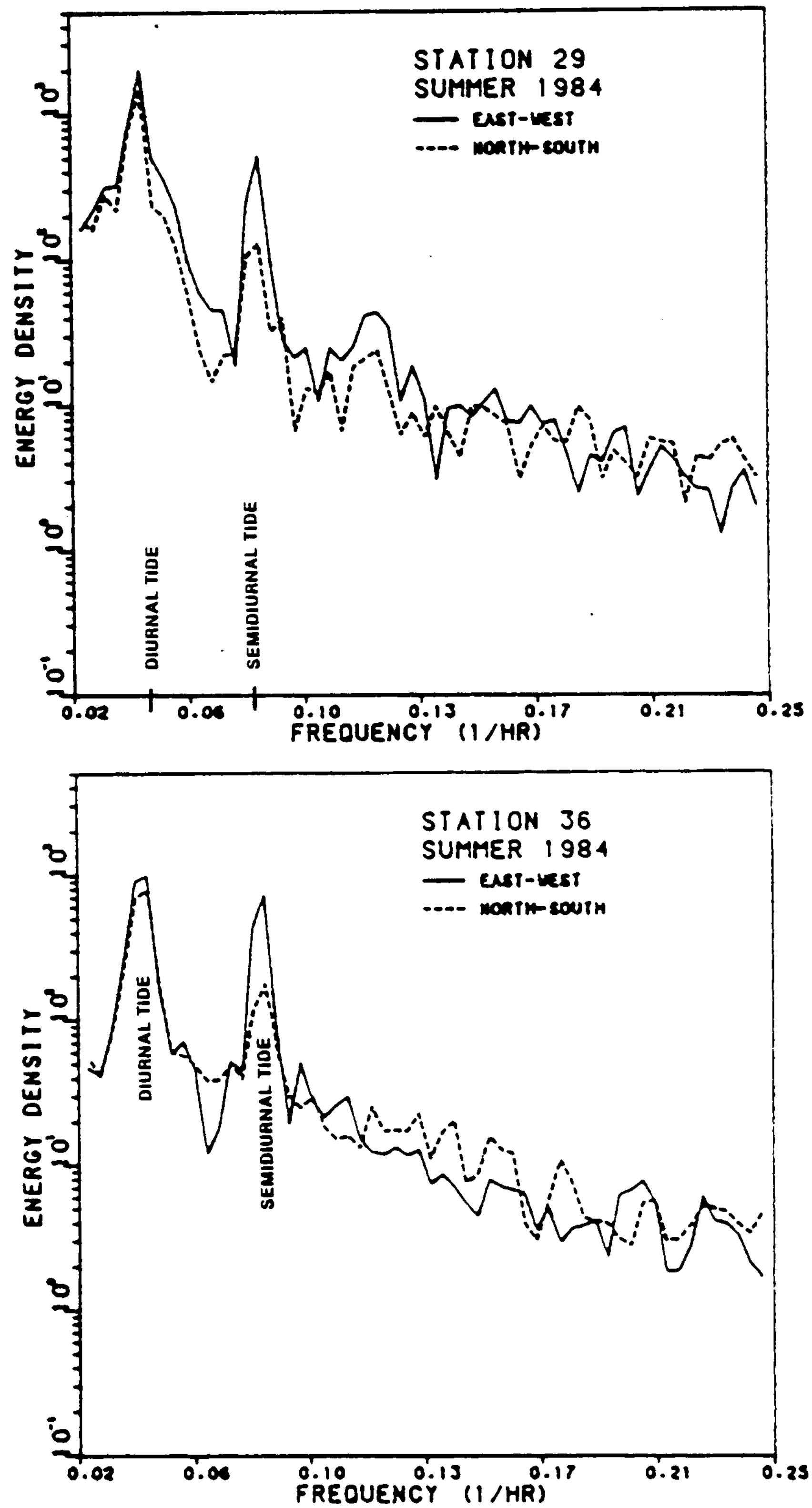

Figure 3.1-15 ENERGY SPECTRA FOR STATIONS 29 AND 36

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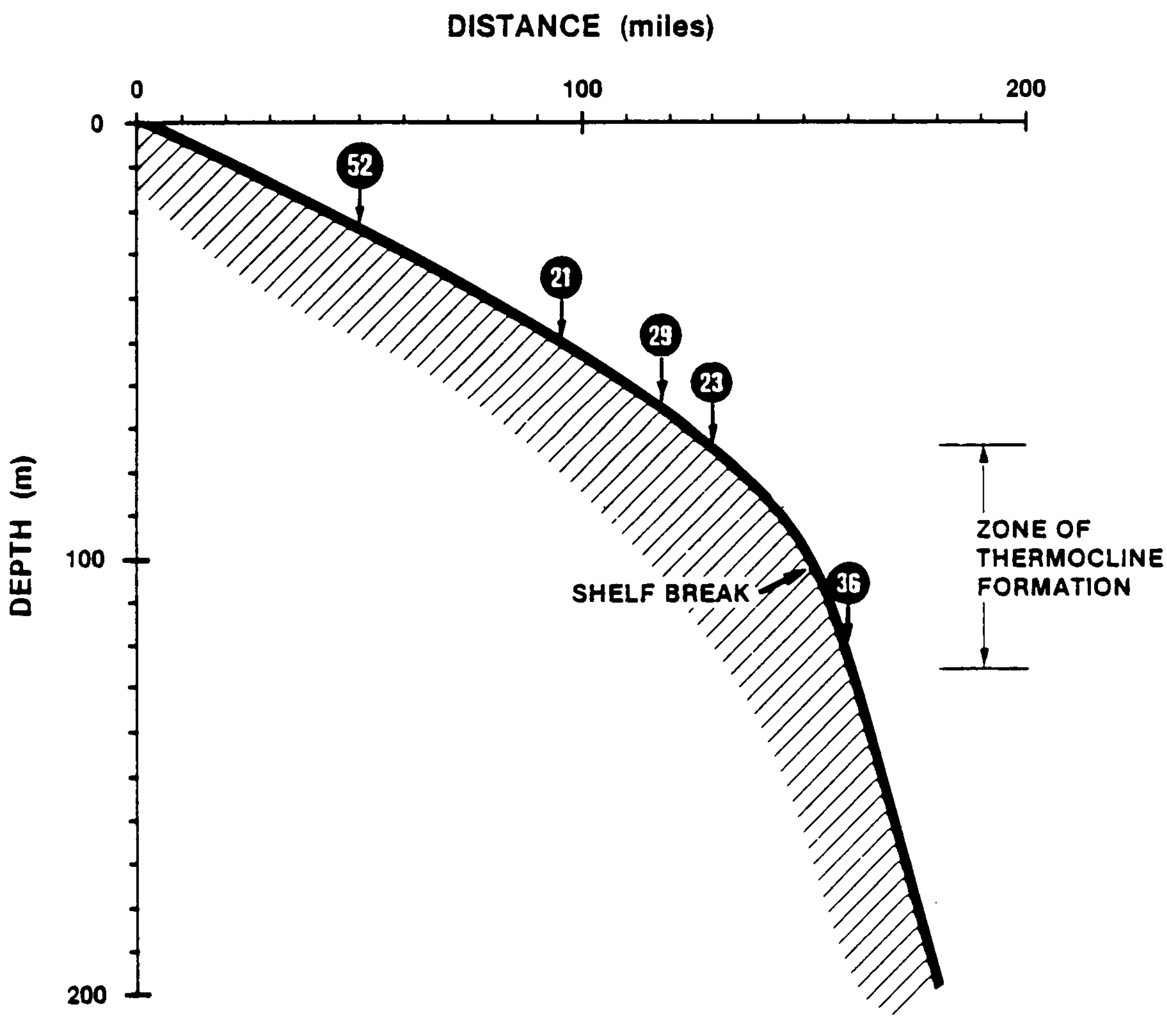

Figure 3.1-16 FLORIDA SHELF PROFILE SHOWING STATION DEPTHS

station locations were filled by an interpolation routine to provide the final three-dimensional representation. In other words, five power spectra estimates were used to produce the plots; energy peaks between the spectra are an artifact of the interpolation routine. A sample of the results for the east-west component of current data collected during the summer is presented in Figure 3.1-17. Two different views of the same data are presented in this figure. The results illustrate the two dominant peaks in the energy at the tidal frequencies with the semidiurnal tidal component containing the greatest energy in shallow water (Station 52). The energy at the semidiurnal frequency decreased slightly with distance offshore as the energy at the diurnal tidal (and inertial) frequency increased. At Station 21 (47 m), the magnitudes were approximately equal, and at Station 29 (64 m) the diurnal component became dominant. Also illustrated in the figure is the increase in energy with depth at the low-frequency end of the spectra. This is the result of long-period currents in deeper water that frequently dominated the tides. The tidal component in deep water frequently appeared as speed fluctuations superimposed on larger ambient currents. At Station 52 in shallow water, however, the tidal currents dominated, and the current speed frequently dropped to zero at slack tide. Consequently, there was little net drift or low-frequency energy in the shallow water to contribute energy to that part of the spectra.

The north-south component of the water currents in the summer were considerably different than the east-west component as compared in Figure 3.1-18. In shallow water, there was little energy in the north-south component because the flow was dominated by the onshore-offshore tidal currents. The energy in both tidal components for the north-south flow increased with depth as the tidal trajectories became more elliptical rather than nearly linear in shallow water. At Station 29 (64 m) and deeper, the energy at the diurnal frequency was approximately equal in both direction components; however, energy at the semidiurnal frequency was always greater in the east-west component. The

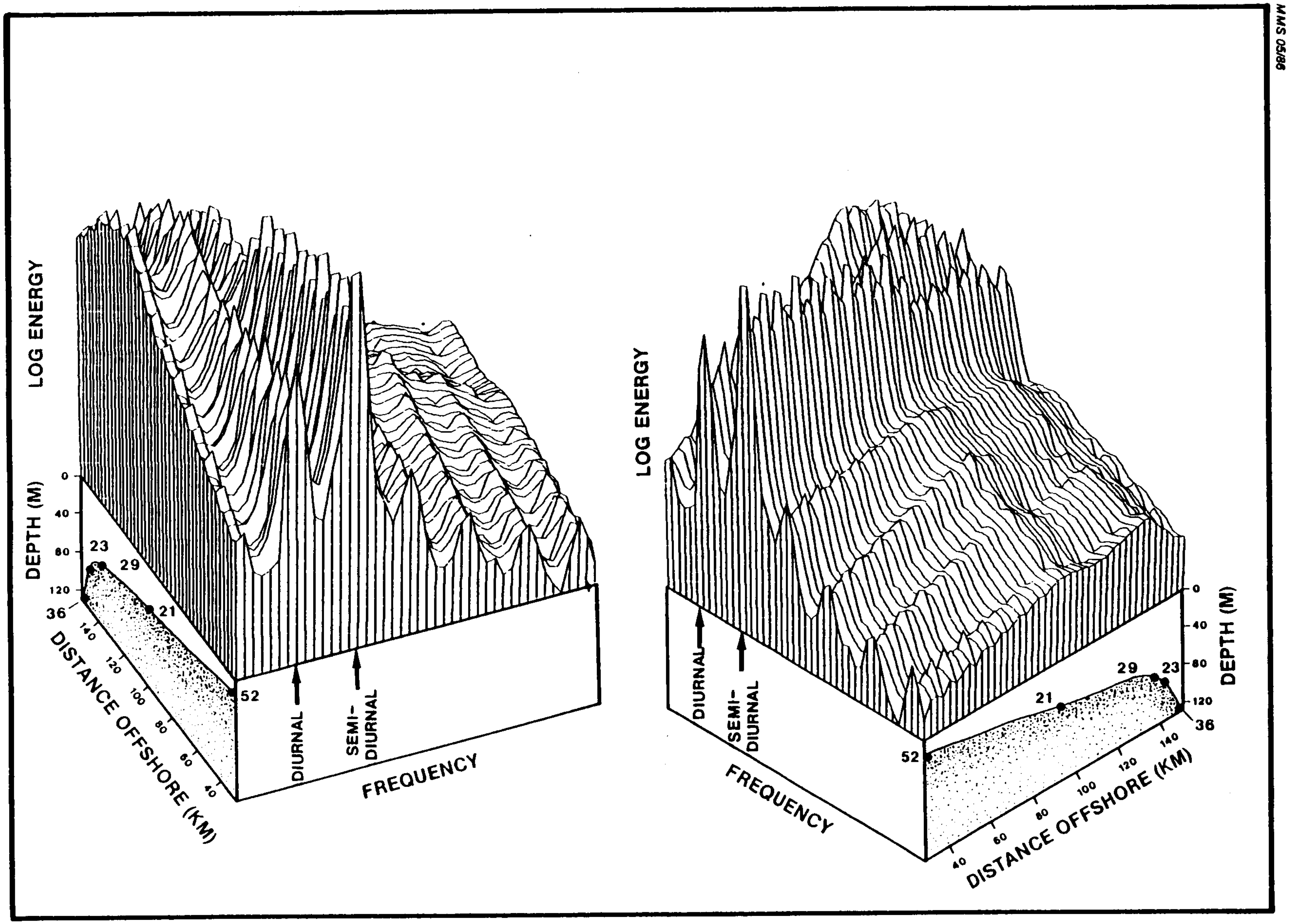

Figure 3.1-17 TWO VIEWS OF 3-D SUMMER (1984) ENERGY SPECTRA, EAST-WEST COMPONENT

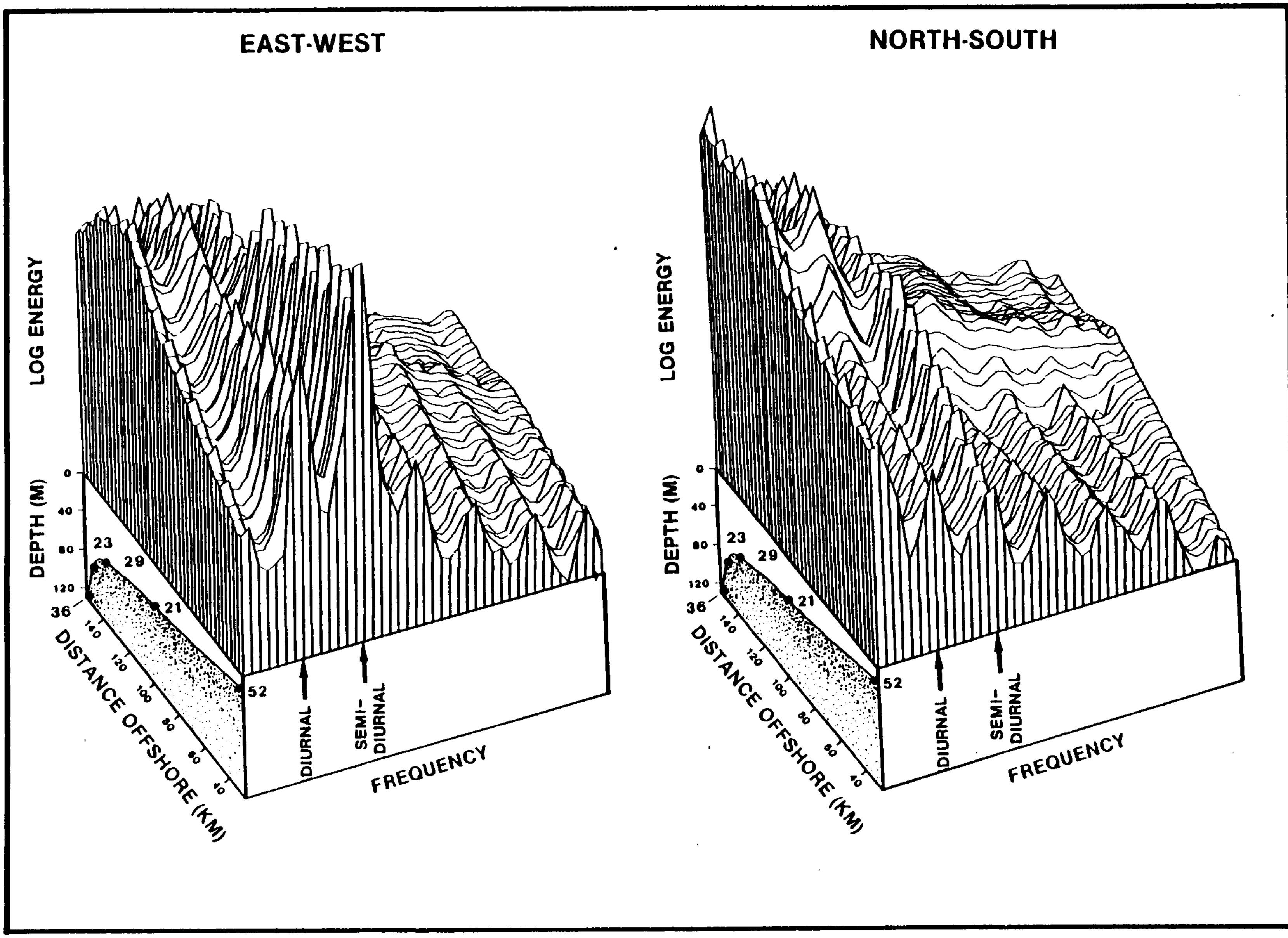

Figure 3.1-18 3-D SUMMER (1984) ENERGY SPECTRA, EAST-WEST AND NORTH-SOUTH COMPONENT

low-frequency energy in deep water in the north-south component was greater than the east-west component as a result of strong net flows parallel to the depth contours in deeper water. In addition, frequent strong currents to the north that were the result of Loop Current eddies on the shelf contributed to the low-frequency energy in the north-south component.

The power spectra for the summer currents and the winter currents were similar. The differences are illustrated in Figure 3.1-19. Energy levels in the diurnal component in deeper water were higher in the summer than in the winter, probably as a result of increased energy at the inertial frequency because inertial currents generally are much stronger in the summer when there is a thermocline (Mortimer, 1971; Danek, 1976). The winter spectra, however, had higher energy levels at the low-frequency components. This was a direct result of the higher average current speeds in the winter that were produced by the stronger winter winds.

Current Distribution

Other statistical analyses were performed on the current meter data including Joint Frequency Distribution Tables. Annual and seasonal Joint Frequency Distribution Tables computed from all available current data are presented in Appendix B; an example of a Joint Frequency Distribution Table from Station 52 for the winter is presented in Figure 3.1-20. The results show that the average current speed for the winter for Station 52 was 13.1 cm/sec with the current direction being primarily east-west as a result of the dominant tidal currents. The maximum speeds recorded were between 60 and 65 cm/sec, and 61.2% of the 23,413 speed readings were below 15 cm/sec.

Principal Component Analysis also was conducted on the current meter data to determine the long-term net current speeds and flow direction. All data collected during the 2-year study were used in this analysis, and a

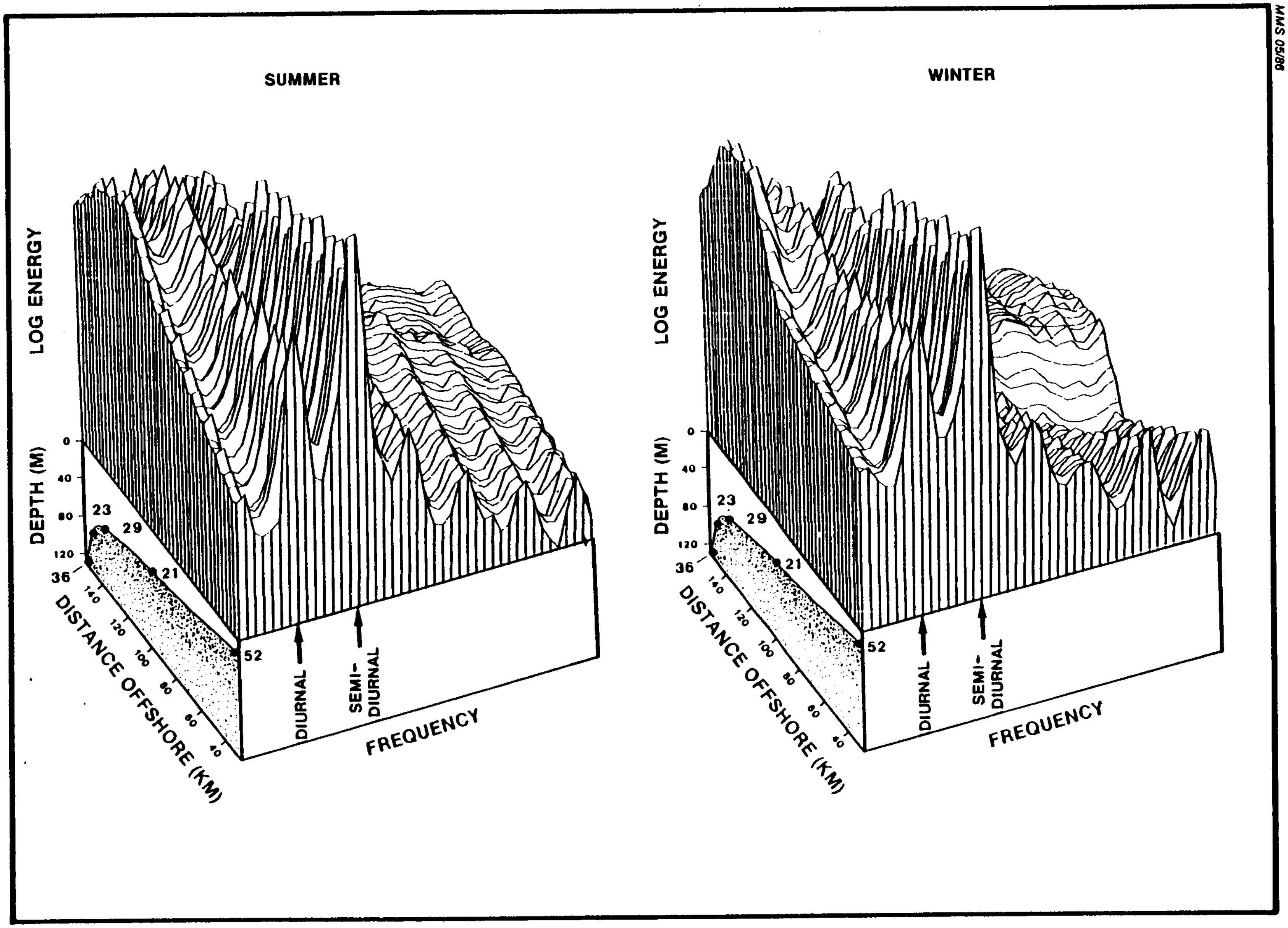

Figure 3.1-19 3-D SUMMER (1984) AND WINTER (1983-84) ENERGY SPECTRA, EAST-WEST COMPONENT

JOINT FREQUENCY DISTRIBUTION TABLE OF CURRENT SPEED AND DIRECTION AT STATION 52
FROM 12/01/83 TO 02/29/84 REPORT DATE: WED, MAY 07 1986

DIRECTIONS ARE DEGREES TRUE

SPEED CM/S	0	22	45	67	90	112	135	157	180	202	225	247	270	292	315	337	360	TOTAL	PERCENT
0	87	82	150	312	456	356	200	180	191	222	392	555	351	126	84	59		3803	16.2
5		1	29	457	1085	348	102	73	58	129	303	1207	665	25				4482	19.1
10			2	651	2072	208	37	13	14	66	269	1789	935	11				6067	25.9
15			1	494	1976	133	17	3		26	162	1333	654	8		1		4808	20.5
20			1	273	1423	55	1			2	37	707	300	3				2802	12.0
25				161	632						1	280	116					1190	5.1
30			1	58	139							28	26					252	1.1
35				1	1							2						4	0.0
40																		0	0.0
45				1	1													2	0.0
50					1													1	0.0
55					1													1	0.0
60				1														1	0.0
65																		0	0.0
70																		0	0.0
75																		0	0.0
80+																		0	0.0
TOTAL	87	83	184	2409	7787	1100	357	269	263	445	1164	5901	3047	173	84	60		23413	
PERCENT	0.37	0.35	0.79	10.29	33.26	4.70	1.52	1.15	1.12	1.90	4.97	25.20	13.01	0.74	0.36	0.26			100.00

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Figure 3.1-20 EXAMPLE OF A JOINT FREQUENCY DISTRIBUTION TABLE summary of the results are presented in Table 3.1-5. The highest average speeds recorded were at two of the shallowest stations (Stations 52 and 55) and exceeded 10 cm/sec. Stations 44 and 7 were of comparable depth; however, these stations were located more than 100 km to the north where the tidal currents were reduced which resulted in the two lowest average speeds of the eight stations. The current speed at Station 7 exceeded 20 cm/sec only 0.6% of the time. This indicates that currents are probably not a constant mechanism for sediment transport. The speed of 20 cm/sec was used as a criterion because that is the approximate minimum current speed that can initiate motion in unconsolidated ocean sediments (Wimbush and Lesht, 1979). At Stations 52 and 55, the currents exceeded 20 cm/sec more than 13% of the time, indicating that these areas are more susceptible to sediment movement. The current speeds at Station 36 (125 m) exceeded 20 cm/sec 5.3% of the time; however, virtually no sediment was collected in the sediment traps. Consequently, the currents may have been strong enough to initiate sediment movement in the form of bed load transport but were not strong enough to resuspend the sediments.

To illustrate the relative strength of the currents monitored, the average seasonal current speeds are plotted in Figure 3.1-21 for those stations that had sufficient seasonal data. Also, the net seasonal currents provided in Table 3.1-5 are illustrated in Figure 3.1-22. The seasonal vectors illustrate that there is considerable variability in the net flow at the majority of stations. There are, however, a few notable patterns. The currents at Station 52, although dominated by east-west tidal currents, had a consistent net current for all seasons to the southeast toward Florida Bay at less than 2 cm/sec. The currents at Station 55 also exhibited a consistent flow to the south between the Tortugas and Marquesas, except for a small net current to the northeast during the winter. The flows at Stations 23 and 36 were somewhat consistent and exhibited net currents typically to the south, probably as a result of the Loop Current. The currents at Stations 21 and 29 were variable but

Table 3.1-5. Water current statistics

Station	Number of Data Points	Average Speed (cm/sec)	Percent >20 cm/sec	Net Currents Winter SPD	Winter DIR	Spring SPD	Spring DIR	Summer SPD	Summer DIR	Fall SPD	Fall DIR
52	171,777	10.8	13.7	2.0	134	1.8	124	1.0	127	0.9	130
21	97,931	7.2	1.2	1.7	285	3.6	158	0.4	162	0.9	024
23	143,826	7.5	1.8	4.0	169	1.1	174	0.5	315	ID	ID
29	114,916	8.9	4.6	4.7	221	1.0	258	5.3	311	2.1	203
36	118,513	8.9	5.3	5.6	161	1.1	166	1.7	223	1.9	151
7	103,981	5.2	0.6	2.3	157	2.1	130	0.6	337	3.0	063
44	52,720	8.4	4.6	ID	ID	ID	ID	2.2	298	1.3	130
55	91,438	10.4	13.3	0.5	034	2.4	174	0.9	128	2.6	192

ID = insufficient data.

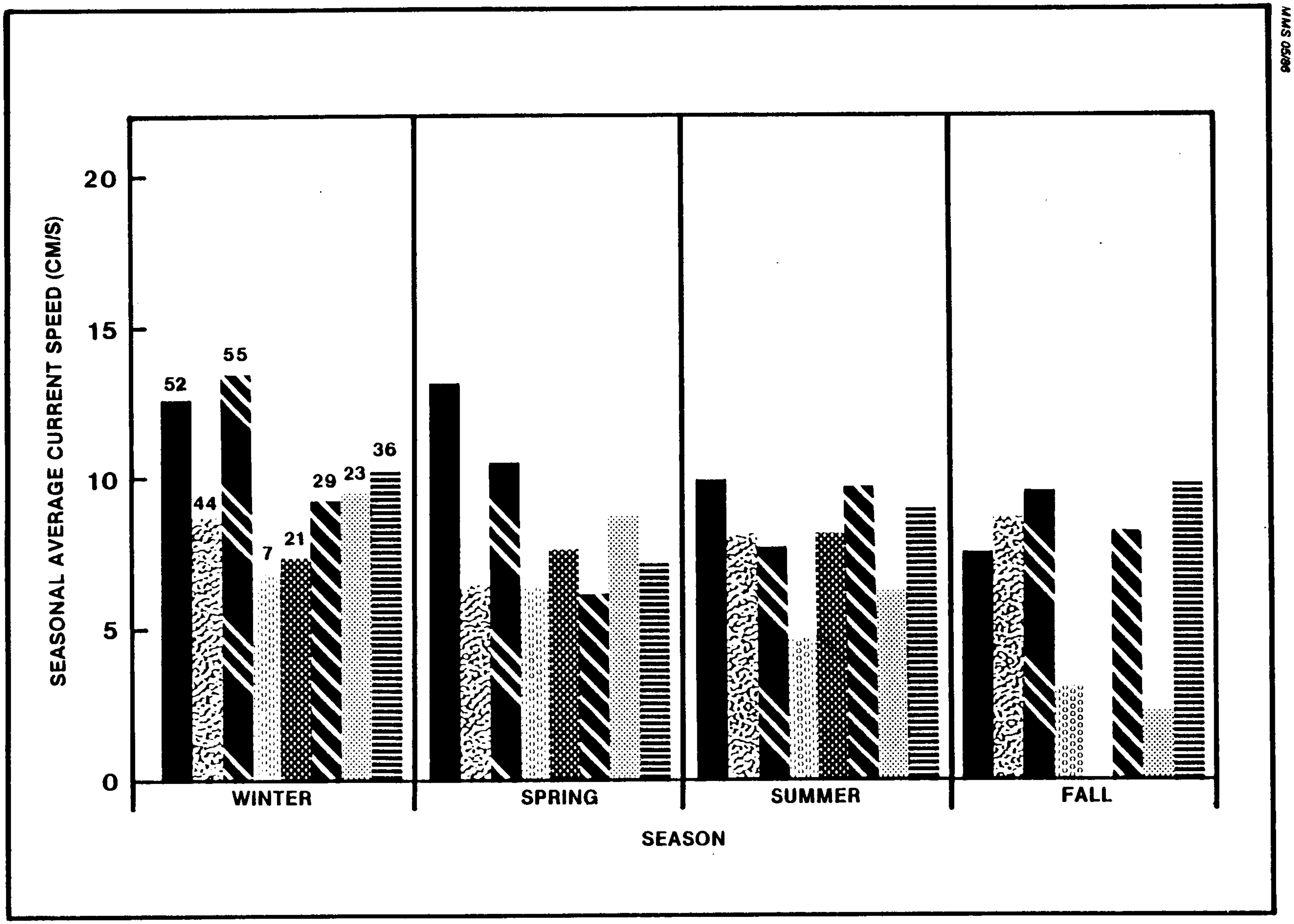

Figure 3.1-21 SEASONAL AVERAGE SPEEDS COMPUTED FROM AVAILABLE 1984 AND 1985 DATA

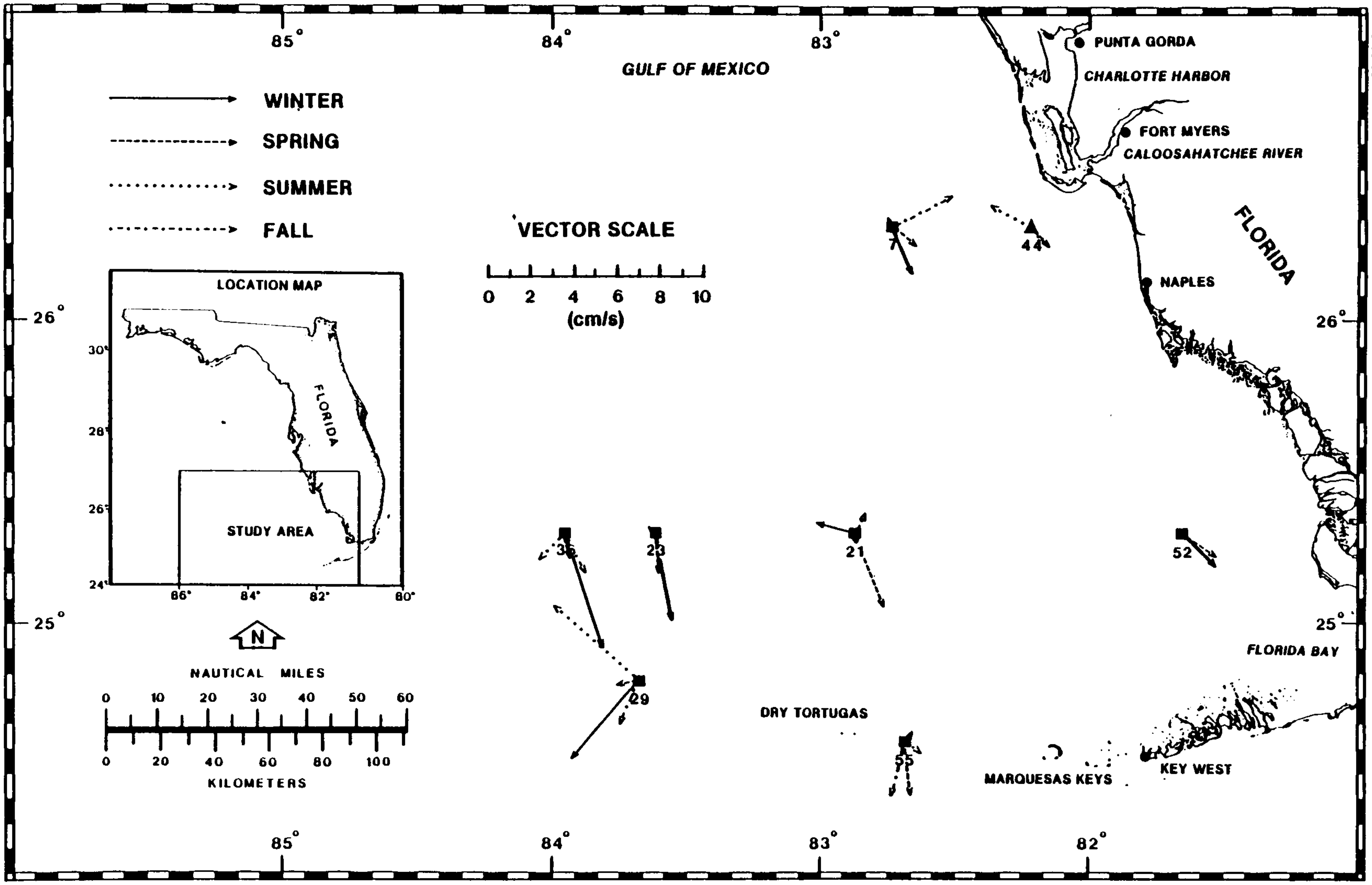

Figure 3.1-22 SEASONAL AVERAGE VELOCITIES COMPUTED FROM AVAILABLE 1984 AND 1985 DATA

typically had an offshore velocity component indicating the currents were generally flowing off the southwest Florida shelf in these areas. The net currents at Stations 7 and 44 were small and variable with no obvious flow patterns.

Event Analysis

The major events noticeable in the current records were caused by Loop Current intrusions near the edge of shelf at Stations 23, 29, and 36. The Loop Current intrusions typically were identified by a 2° to 4°C rise in temperature, as discussed in Subsection 3.1.2. Two examples of Loop Current eddy intrusions that were measured at Station 36 in September and October 1984 are shown in Figure 3.1-23. The intrusions are identified by the temperature rises beginning September 11 and October 11, 1984. The effects on the currents were similar during both events. Prior to the intrusions, the currents were to the south, but as the Loop Current eddy intruded on the shelf, the current changed to northerly with an increase in speed. The events lasted approximately 5 days in September and approximately 10 days in October. Two similar events were observed at Station 29 in June and July 1984, as illustrated in Figure 3.1-24. The events were again identified by an increase in temperature with increasing currents and flow reversals to the north.

The extent of these eddy intrusions on the shelf was identified by examining the temperature records. The available temperature records for the events discussed previously are plotted in Figure 3.1-25. The eddy intrusions that occurred in June and July can be seen in the temperature records at Stations 21, 23, and 29. The eddy reached Station 29 (the southernmost station) on June 10, but did not reach Station 23 until June 14, or Station 21 until June 16, 1984. The effects of the eddy, however, were apparent across the majority of the southwest Florida shelf, although the eddy did not reach Station 52. Also, for this event, the eddy was not detected at Station 36 (125 m) indicating the northward-flowing tongue of warm water that comprised the eddy remained shoreward

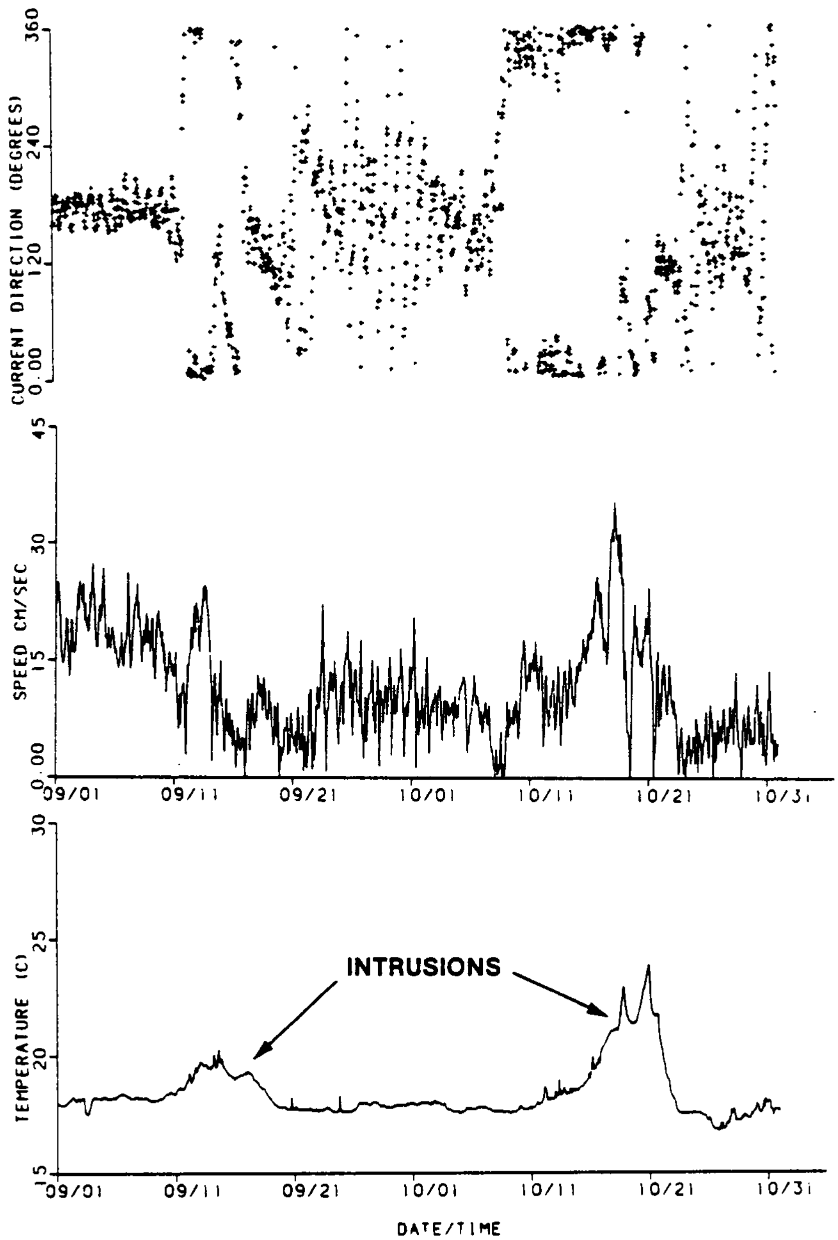

Figure 3.1-23 STATION 36 CURRENT AND TEMPERATURE DATA SHOWING LOOP CURRENT INTRUSION

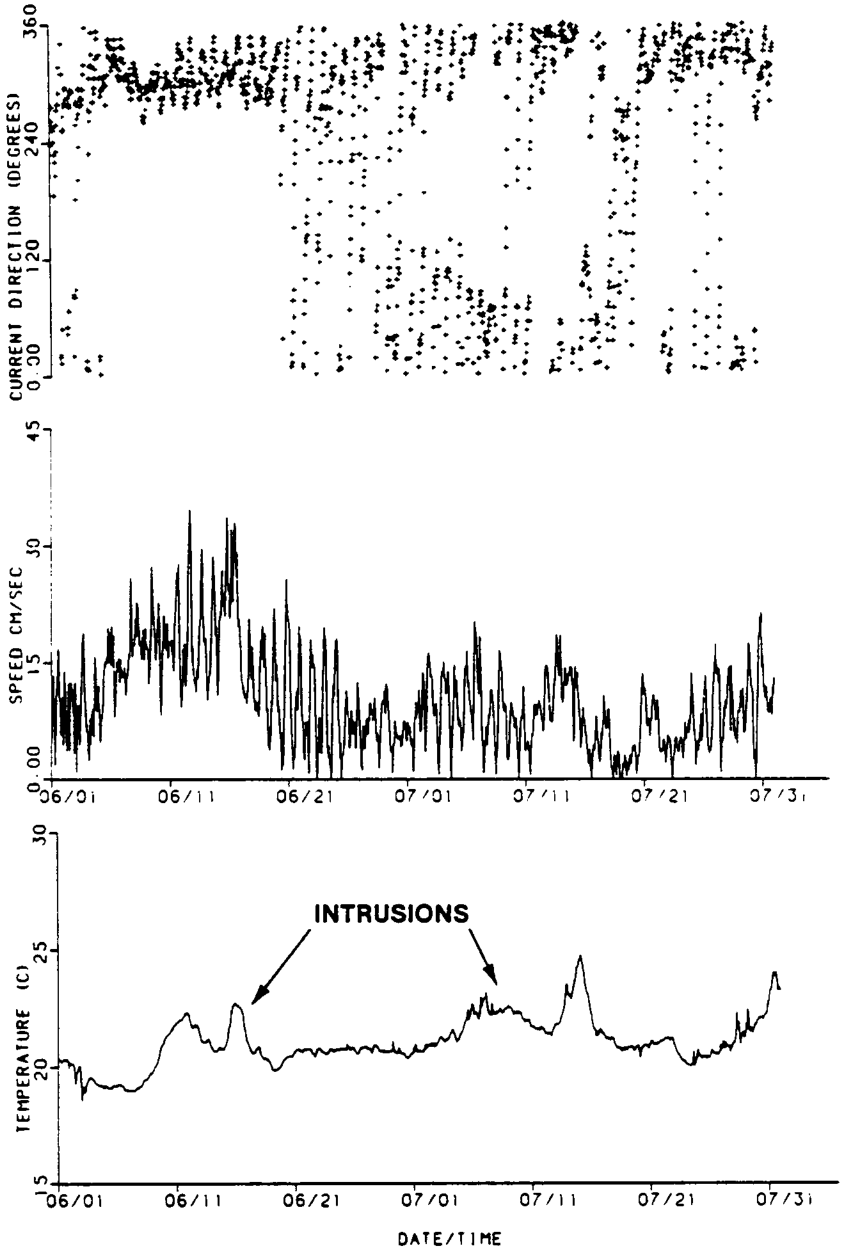

Figure 3.1-24 STATION 29 CURRENT AND TEMPERATURE DATA SHOWING LOOP CURRENT INTRUSION

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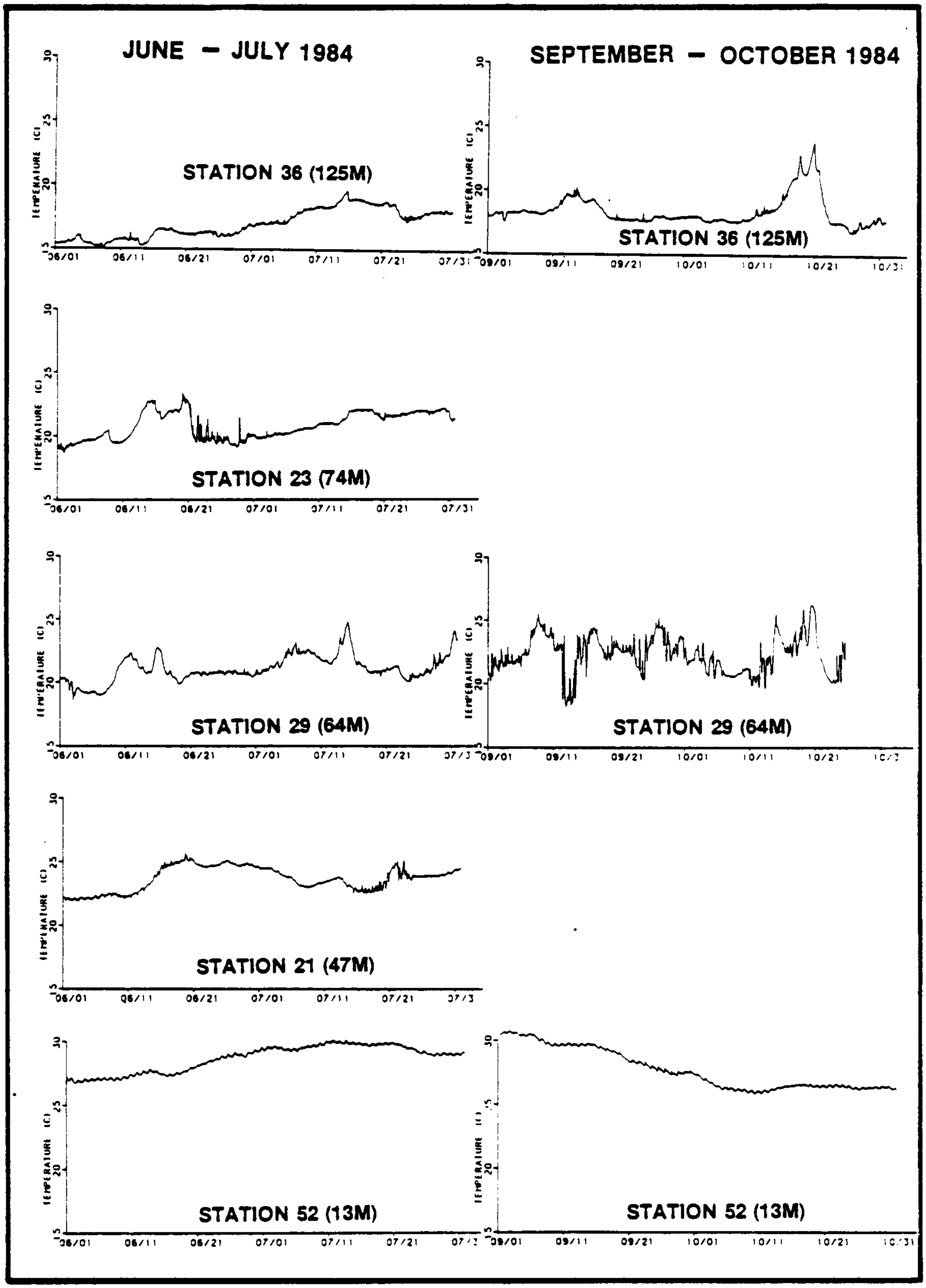

Figure 3.1-25 CONTINUOUS TEMPERATURE PLOTS SHOWING LOOP CURRENT EDDY INTRUSIONS

of the 125-m depth contour. The September and October 1984 eddy intrusions apparent at both Stations 36 and 29, however, indicated there is considerable lateral variability in the extent of the warm water intrusions. The intrusion, however, did not reach as far inshore as Station 52.

An example of the velocity shear at the edge of these Loop Current eddies that propagate on the southwest Florida shelf occurred on December 4, 1984. The USS America, during refueling with a tanker north of Station 23, experienced an emergency breakaway. During the refueling process, the two ships were pulled apart. The ship's helmsman noticed a north-south frontal line at the scene, and subsequent passes indicated a 5°F temperature difference across the line, as observed on the ship's intake temperature recorder. Upon crossing the line, the ship experienced a 10° to 15° course deviation to the north. It is concluded that during the refueling process, one ship was in southwest Florida shelf water and the other was in the swift northward flowing Loop Current eddy that separated the ships. The frontal zone was so sharp that it could actually be seen as a discontinuity in the sea state.

Other events apparent in the current records were storm passages that occurred in 1985. Tropical Storm Bob passed near the site in July, as shown in Figure 3.1-26. The storm system became a tropical storm on July 22, 1985, as the winds reached 36 knots. The storm moved onshore between Naples and Fort Myers on July 23. Naples reported sustained winds of 35 knots as the storm center passed to north of the city. The resulting high winds produced increased current speeds at several of the current meter stations as indicated in Figure 3.1-27. The most severe effects were at Stations 7 and 44 nearest the center of the storm. The current speeds increased from an average of less than 10 cm/sec to peak speeds of approximately 60 cm/sec. Flow directions at both stations during the storm were to the northwest. The effects of the storm at Stations 21 and 23 were apparent, although the stations were more than

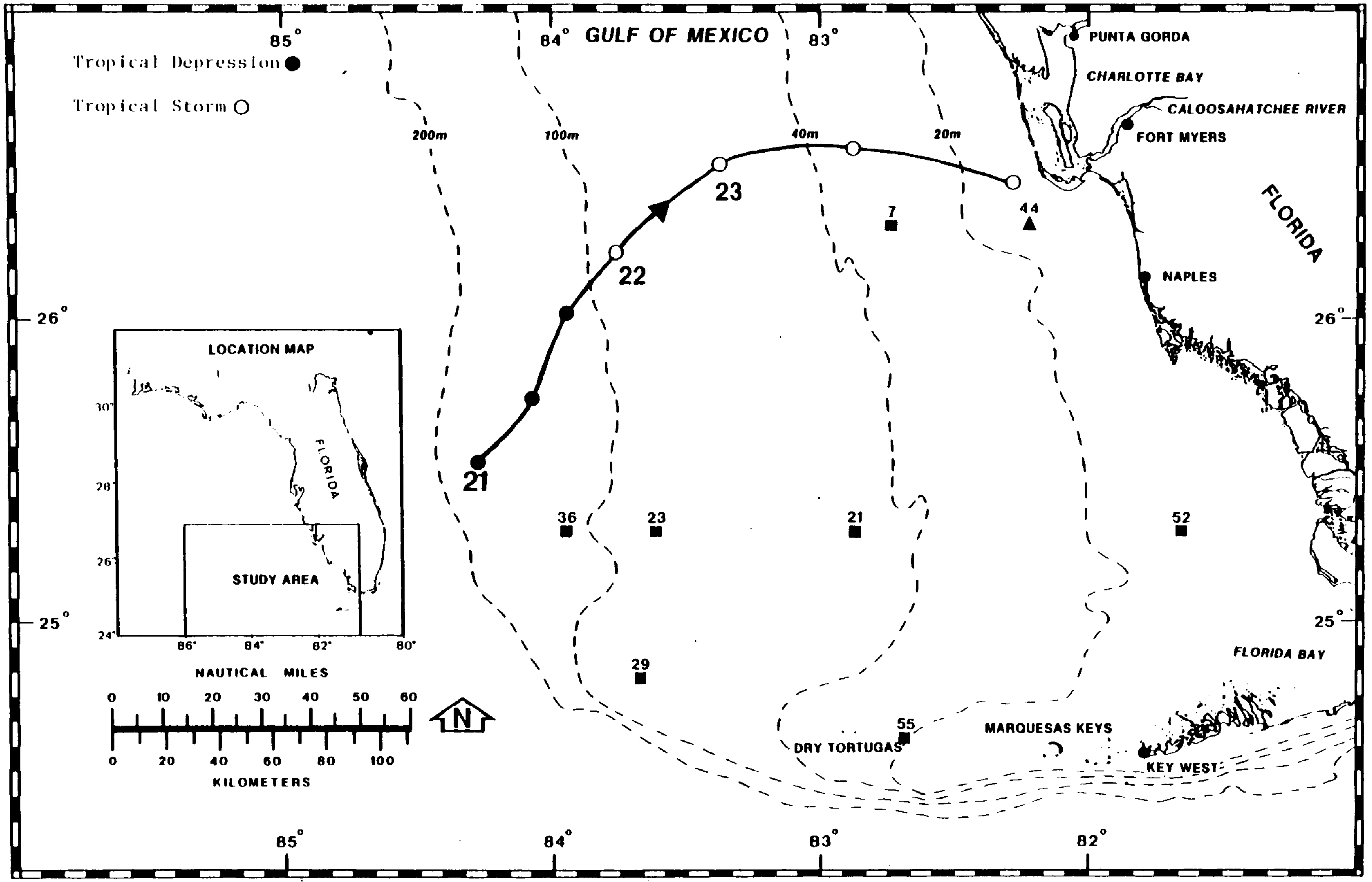

Figure 3.1-26 STORM TRACK FOR TROPICAL STORM BOB – JULY 1985

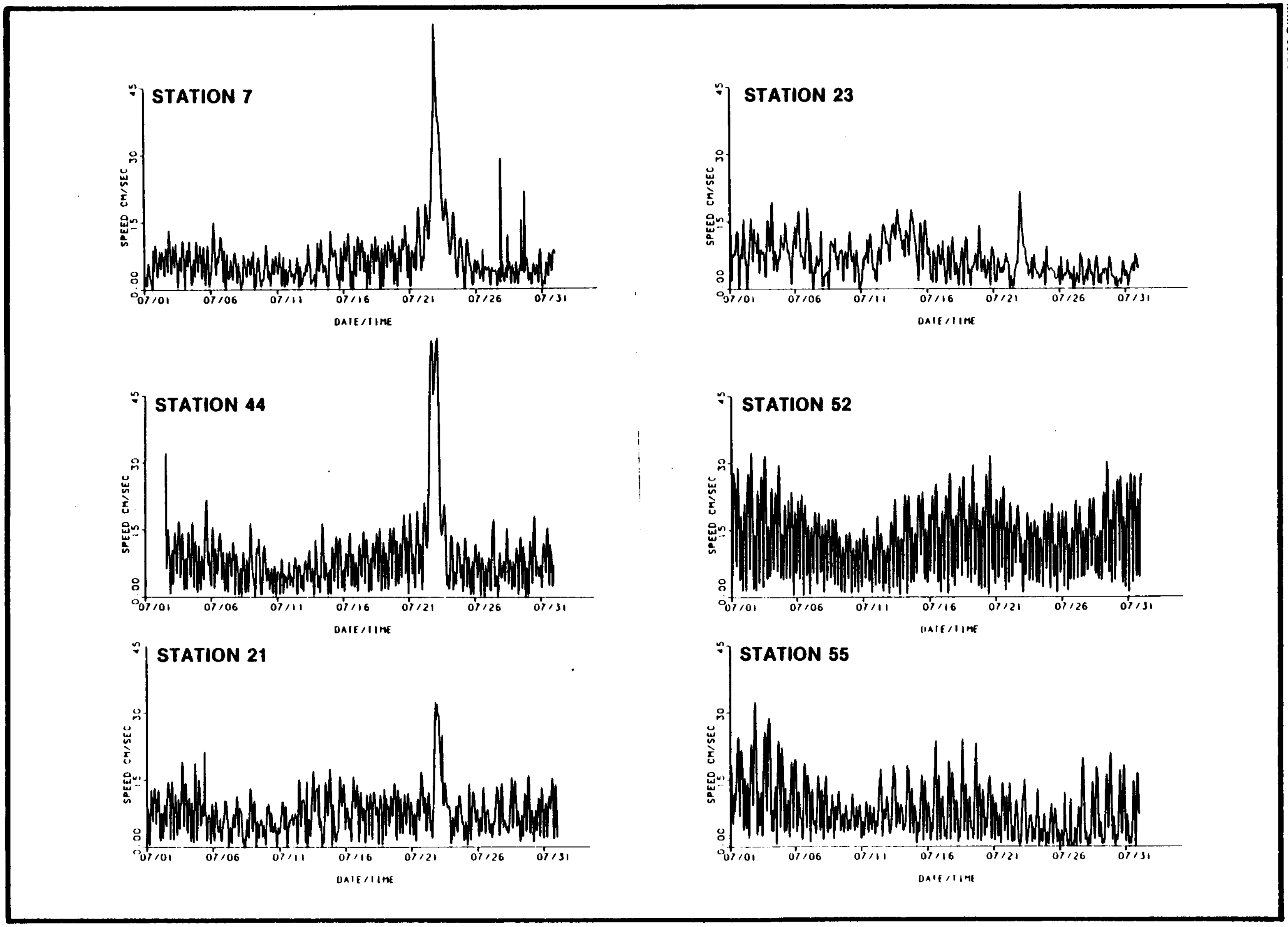

Figure 3.1-27 CURRENT SPEEDS RESULTING FROM TROPICAL STORM BOB - JULY 1985

120 km to the south. The current speed increases observed were more pronounced in shallower water at Station 21 than at Station 23. Farther to the south and shoreward at Stations 52 and 55, the effects were nearly undetectable.

Hurricane Elena passed through the Gulf of Mexico during the study period. The hurricane spent the majority of its energy further to the north in late August and, although effects were apparent in the current meter records, the effects were not as pronounced. The area most affected was near Station 55, where speeds increased higher than 50 cm/sec as Hurricane Elena entered the Gulf of Mexico through the Straits of Florida.

3.1.4 WAVES AND TIDES

Tides

The tides of the Gulf of Mexico are weakly developed, and usually their observed range does not exceed 0.7 m (Durham and Reid, 1967). Semi-diurnal (twice daily) tides are generally small; therefore, overall tides in the Gulf are considered diurnal (daily) in character. The diurnal tides of the Atlantic Ocean influence the tides in the Gulf through the Yucatan Channel. A single oscillating system with a nodal line extending from western Haiti to Nicaragua is formed by the Gulf of Mexico and the Caribbean Sea. This causes the tides of the Gulf to be simultaneous. The Gulf and the Caribbean Sea are viewed as a single oscillating body with a period of nearly 24 hours (Grace, 1932). Tidal regimes for the Gulf of Mexico [as displayed by Eleuterius (1974) in Figure 3.1-28] indicate that the study area is a region of mixed tides (i.e., has both diurnal and semi-diurnal tidal components).

To monitor the tides, waves, and other water-level fluctuations, subsurface, pressure-type, water-level recorders were installed at Stations 52 and 55 and were operational from December 1984 to December 1985. The results of the water-level measurements with the tidal components

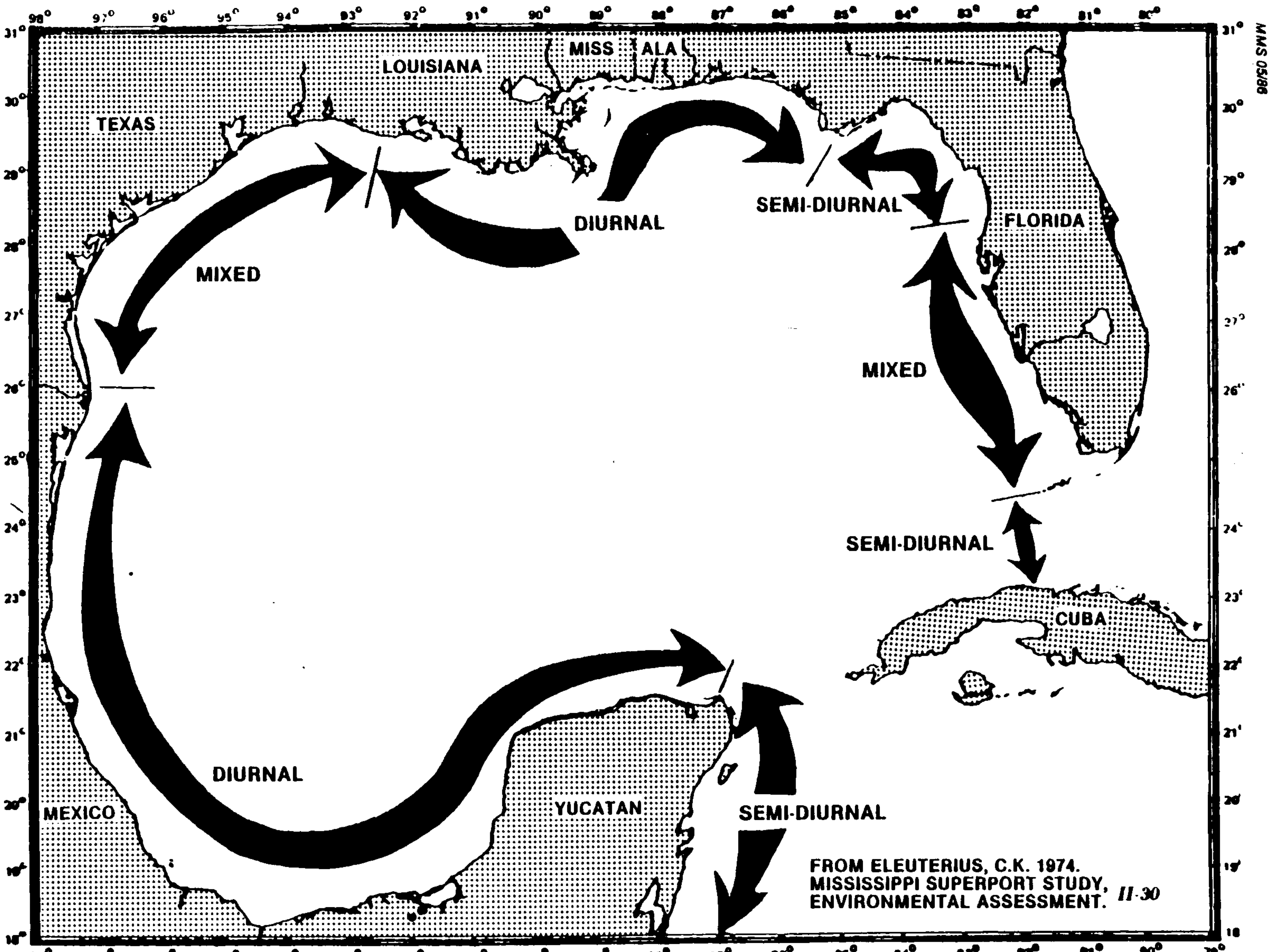

Figure 3.1-28 GULF OF MEXICO TIDAL REGIMES (BLM, 1978)

removed, i.e., low-pass (33-hour) filtered, are presented in Appendix B. An example of the tidal fluctuations observed at Station 52 is presented in Figure 3.1-29. The tidal record clearly shows that the tides are mixed with both a semi-diurnal and diurnal component. The spring and neap tides are also apparent with an increasing tidal amplitude at two-week intervals. The tidal range is about 1.5 m during spring tides and 0.7 m during neap tides. The tidal ranges at Station 55 were only about one-half of those observed at Station 52.

Figure 3.1-29 also shows the results of a low-pass filter (33-hour) of the same tidal record. The effects of two storm systems that were not evident in the raw data are quite apparent in the filtered data. Even though these were major storms, the maximum range in water level variation was less than 0.4 m at Station 52 and less than 0.2 m at Station 55. The results of two other storm passages (Tropical Storms Juan and Kate) are shown in Figure 3.1-30 with the impact again being the greatest at Station 52 but still less than a range of 0.5 m. The results from both storms exhibit the characteristic decrease in water level as the storm approaches followed by an increase in water level.

Harmonic analysis was completed on the tidal records to determine the contribution of the major tidal components to the observed water level fluctuations. The results of the analysis for Stations 52 and 55 are presented in Table 3.1-6. Ten of the major components used in the analysis are identified in Table 3.1-7. The results show that on the average the tidal components are twice as large at Station 52. The M_2 and S_2 components are the largest components at Station 52 and are both at the semi-diurnal frequency. The O_1 and M_2 components are the two largest components at Station 55; one is diurnal, whereas the other is semi-diurnal, indicating the tides are more mixed at Station 55, but predominantly semi-diurnal at Station 52.

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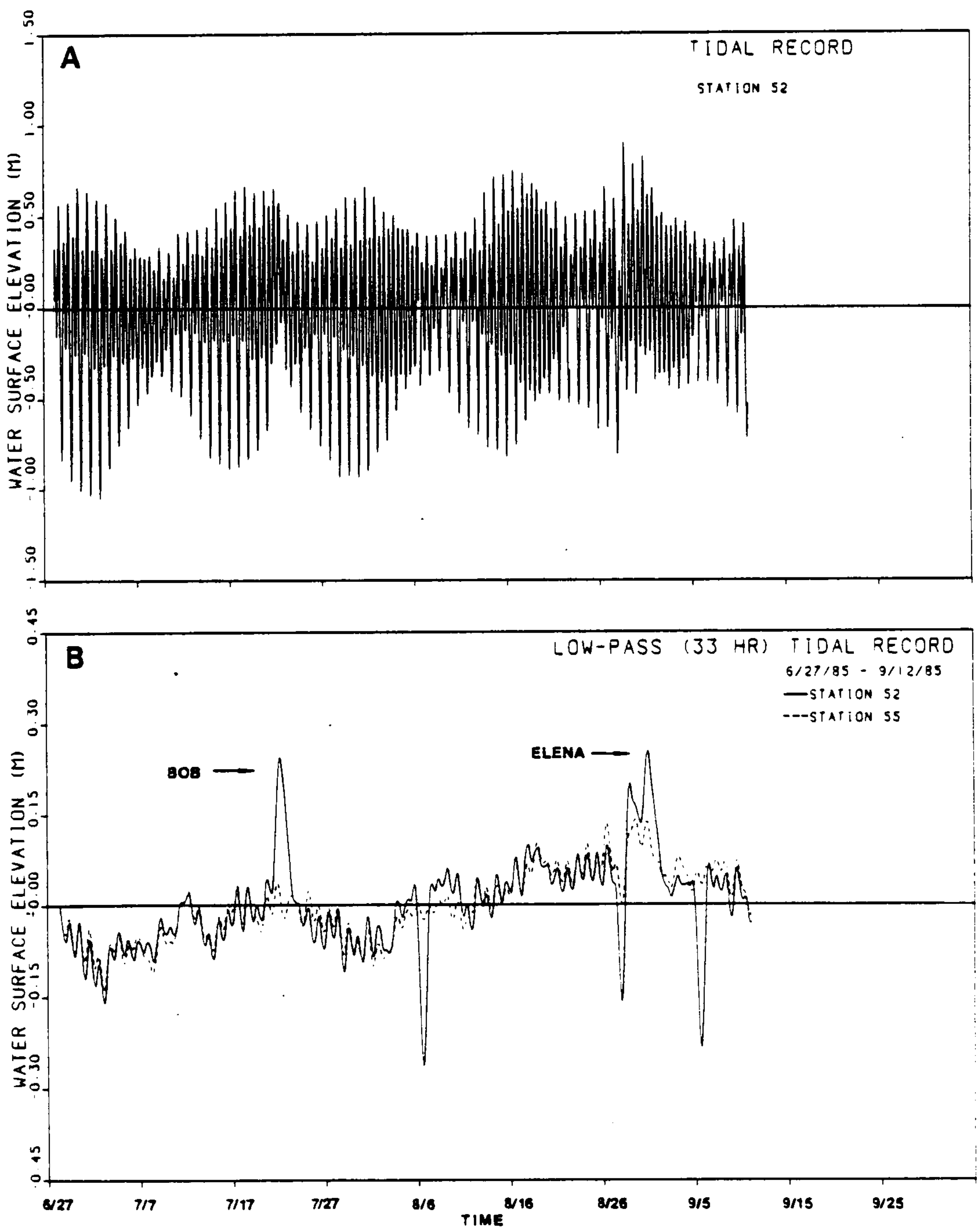

Figure 3.1-29 UNFILTERED (A) AND LOW-PASS FILTERED (B) TIDAL RECORD SHOWING THE IMPACT OF TROPICAL STORM BOB AND HURRICANE ELENA

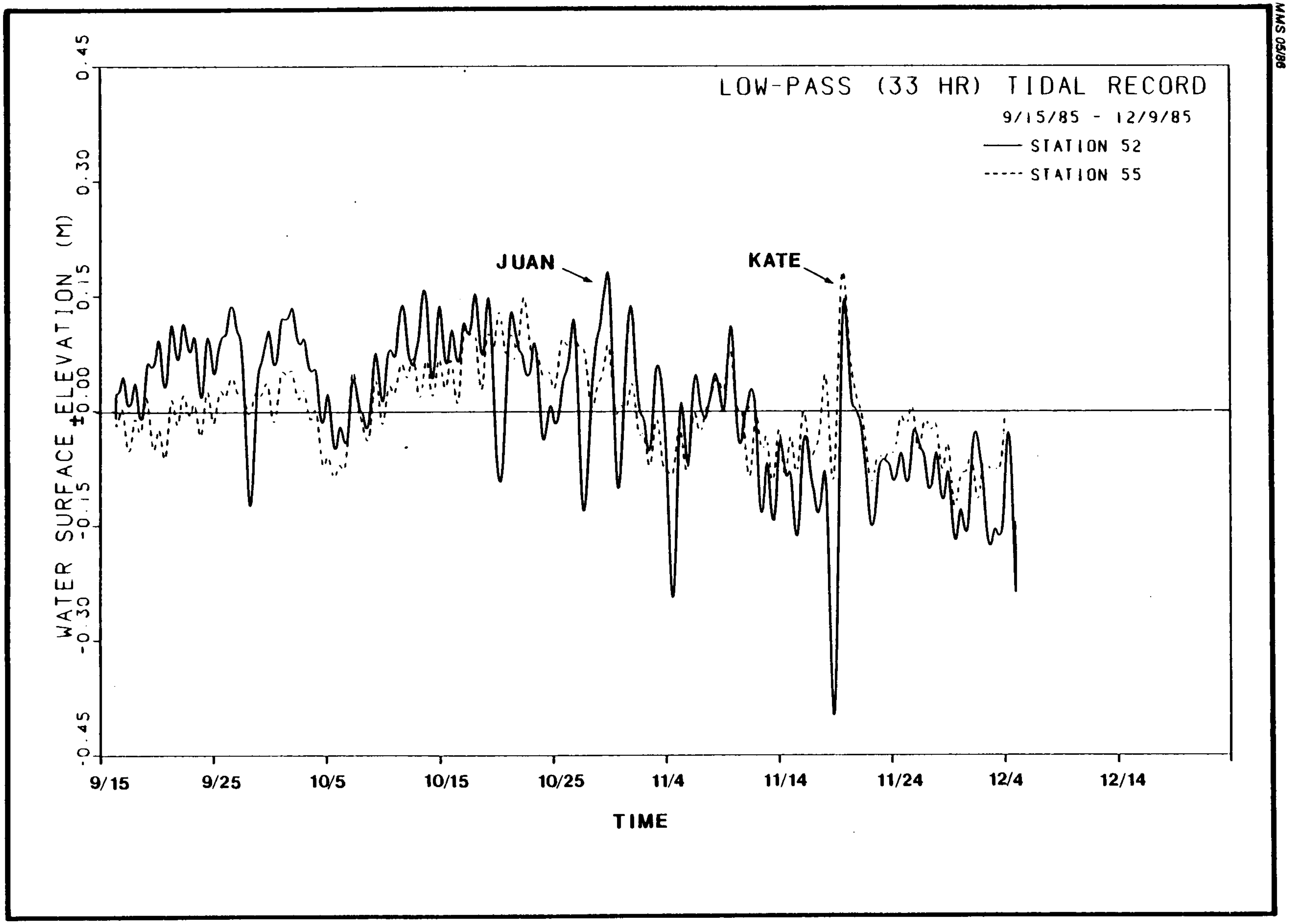

Figure 3.1-30 FILTERED WATER LEVEL RECORD SHOWING IMPACT OF STORMS JUAN AND KATE

Table 3.1-6. Amplitude and phase of major tidal harmonic components

Tidal Constituents*	Period (hours)	Station 52 Amplitude (cm)	Station 52 Phase (Degree)	Station 55 Amplitude (cm)	Station 55 Phase (Degree)
M_2	12.4	25.61	188.2	7.45	130.6
S_2	12.0	11.64	166.6	1.60	133.5
O_1	25.8	9.95	70.9	8.12	351.7
K_1	23.9	5.65	53.2	4.61	66.1
P_1	24.1	5.41	82.5	3.60	258.1
a	12.0	5.25	94.9	5.02	325.3
a	12.6	4.46	354.6	0.78	152.0
N_2	12.7	3.57	68.4	1.20	116.0
a	23.8	3.26	318.3	3.55	105.4
a	24.1	3.04	71.0	3.35	144.1
a	763.5	2.66	137.6	1.03	298.3
M_{sf}	354.4	2.15	179.3	1.11	15.4
K_2	11.7	1.98	325.5	1.06	48.2
a	12.2	1.66	230.7	0.69	195.6
M_f	327.9	1.53	192.5	0.69	51.5
a	26.9	1.43	327.3	3.08	336.7
a	12.9	1.40	276.8	0.19	52.1
Mm	661.3	1.22	63.9	0.60	35.7
a	12.2	1.22	121.1	0.62	255.5
a	219.2	1.17	70.2	0.35	258.8

*Tidal constituents are defined in Table 3.1-7.

a = unnamed.

Table 3.1-7. Dominant tidal harmonics

Tidal Constituent	Symbol	Period (hours)
Main Lunar	M_2	12.42
Main Solar	S_2	12.00
Lunar Elliptic	N_2	12.66
Lunisolar	K_2	11.97
Lunisolar	K_1	23.93
Main Lunar	O_1	25.82
Solar	P_1	24.07
Lunar Fortnightly	M_f	327.86 (13.66 days)
Luni-Solar Fortnightly	M_{sf}	354.36 (14.77 days)
Lunar Monthly	M_m	661.30 (27.56 days)

Power spectra analyses of the water level records were also completed, and the results are presented in Figure 3.1-31. The spectrum of the high frequency portion of the tidal record (i.e., periods less than 33 hours) shows the energy distribution of the diurnal and semi-diurnal components. Even though these components are frequently lumped into the two major categories (diurnal and semi-diurnal), it is apparent that each consists of several components. It is also apparent that there is more energy at the semi-diurnal frequency at Station 52 than at the diurnal frequency and there is more energy at Station 52 than at Station 55. The semi-diurnal energy at Station 55 is comparable to the diurnal energy, indicating the area is a mixed tide region. The low-pass (33 hours) spectra for both stations indicate that there are no major concentrations of energy in periods greater than 26 hours. Both stations show small peaks near 2.5 days (frequency = 0.016 $hour^{-1}$) which may be meteorological, but the energy concentrations are small. The only other peaks are near 25 hours (frequency = 0.04 $hour^{-1}$) which are probably the result of leakage from the diurnal tidal component.

Waves

The goal of the wave program was to document the magnitudes and frequency of occurrence of large waves whose energy could penetrate to the bottom. The objective was to determine the stress applied to the benthic community primarily through sediment resuspension. Two wave gages were in operation from December 1984 to December 1985; one each at Stations 52 and 55. The instruments recorded wave conditions every 6 hours during the 12-month deployment. The results of the measurements for both stations include time and date of measurement, significant wave height, and dominant wave period. The results are presented in Appendix B in both tabular and graphic form. In addition to the wave gage data, data from NDBC Buoy 42003 (located 200 km west-northwest of Station 36) were obtained, and daily summary results are also presented in Appendix B.

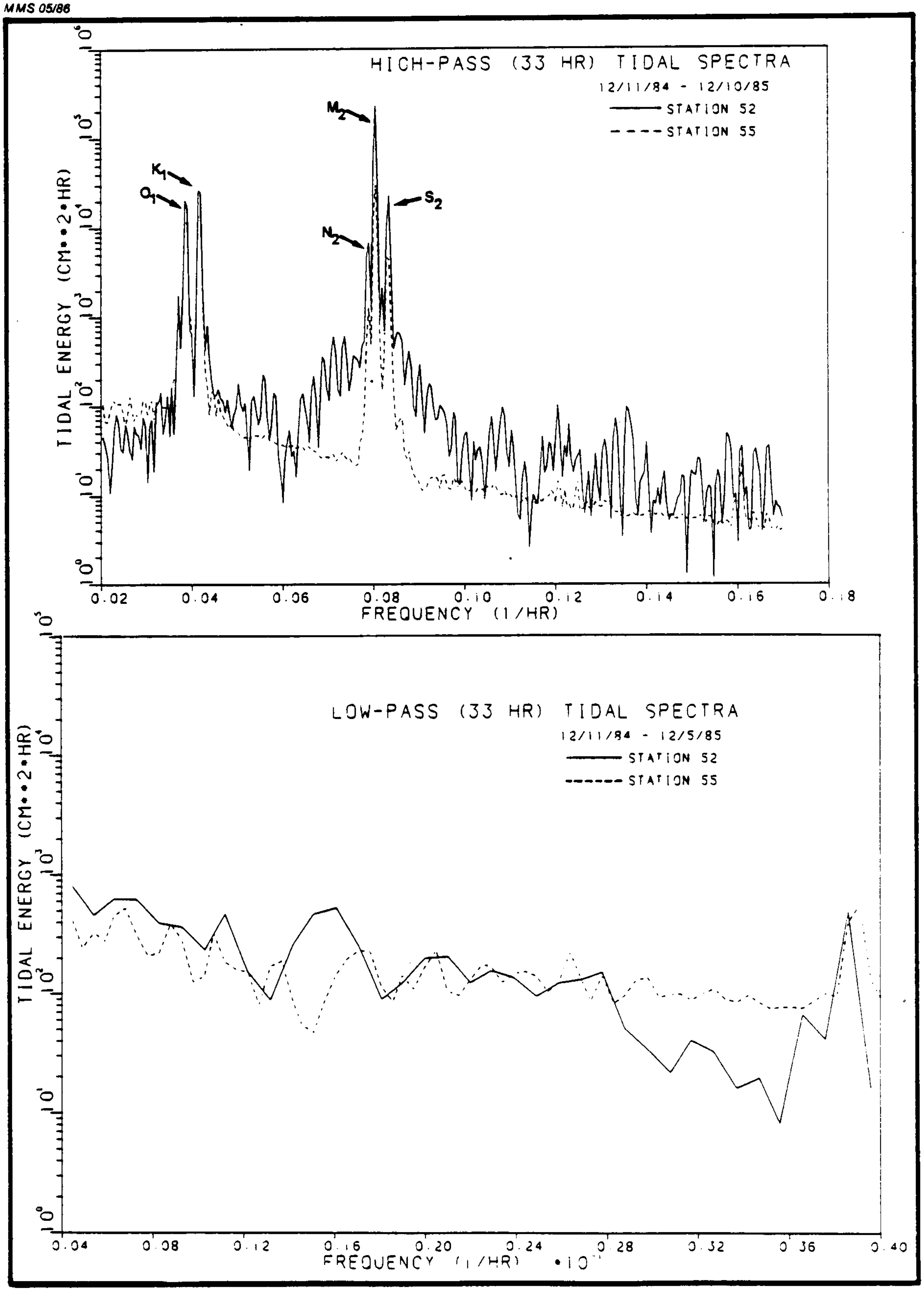

Figure 3.1-31 POWER SPECTRA ESTIMATES OF WATER LEVEL RECORDS FOR HIGH PASS AND LOW PASS FILTERED DATA

A sample of the method of presenting the data for November 1985 from Station 55 is illustrated in Figure 3.1-32. All four daily measurements of wave height and wave period are plotted to illustrate the changing wave field. The figure shows the impact of Tropical Storm Kate as the significant wave height reached 4.7 m on November 19, 1985. The figure also indicates that the wave period never decreases below about 6 sec. This is an artifact of the analysis technqiue that was required because a pressure sensor gage was used and because the water was 27 m deep. Since wave energy attenuates with depth, waves with periods less than 6 sec could not be reliably detected at this depth. Consequently, the energy from that end of the spectrum did not contribute to computing the significant wave height. This resulted in a dramatic underestimation of the waves for episodes when the wave periods were generally less than 6 sec and less than 1 m high. However, the goal of the wave program was to document episodes of large waves whose energy penetrated to the bottom and applied stress to the benthic community. For this purpose the pressure sensor was ideal because it could measure only the wave energy that penetrated to the bottom. Consequently, detailed information on the wave field was sacrificed, but monitoring of waves sufficient to impact the benthic community was successfully completed. Similarly, at Station 52 (depth 13 m), wave energy for waves with periods less than 3 sec could not be measured.

Comparisons of the results of the wave measurements at Stations 52 and 55 with the NDBC data are presented in Figures 3.1-33 and 3.1-34. To generate these plots, each data point from the wave gages was matched with the simultaneous measurement from the NDBC buoy and the matched pairs were plotted for each season. The results show that the summer months were the calmest with the significant wave heights rarely exceeding 2 m at any of the three monitoring points. The winter months had the highest percentage of waves above 2 m, but the largest waves were measured in the fall because of hurricanes. The largest hourly average significant wave height recorded at the NDBC buoy was 10.7 m on

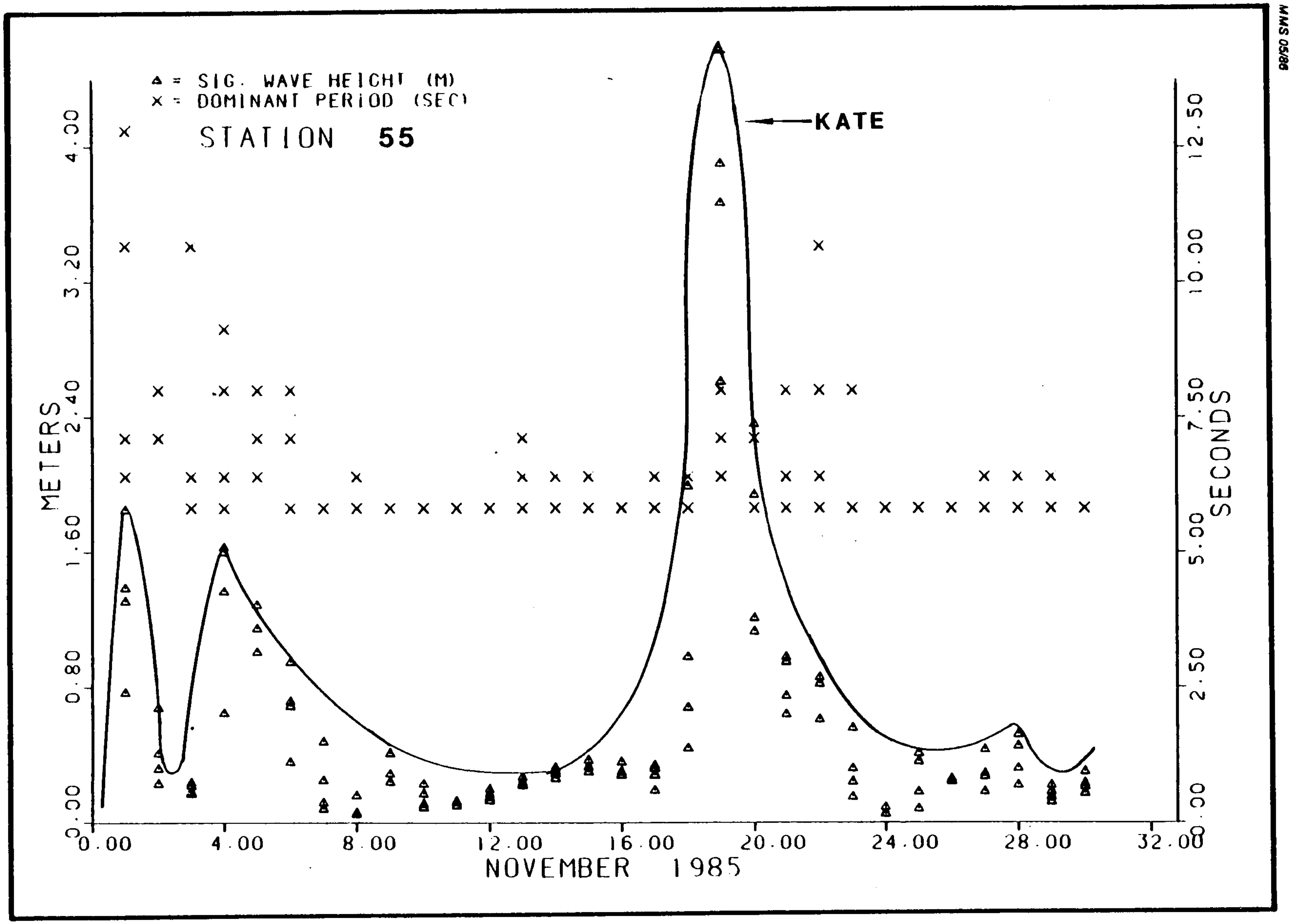

Figure 3.1-32 EXAMPLE OF THE METHOD OF PRESENTING THE WAVE RESULTS SHOWING THE EFFECTS OF TROPICAL STORM KATE

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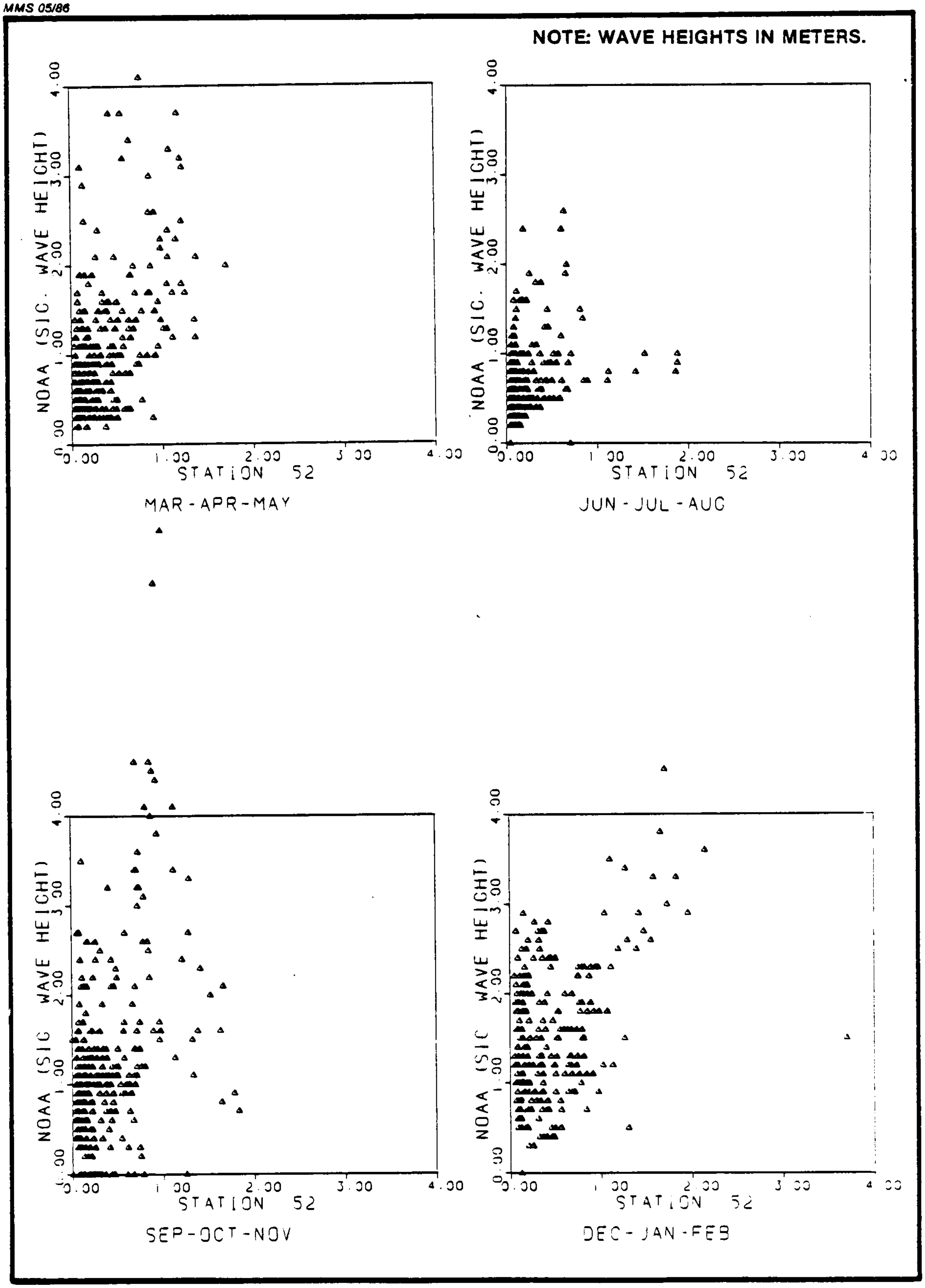

Figure 3.1-33 SEASONAL WAVE HEIGHT COMPARISONS FROM STATION 52 AND THE NDBC DATA

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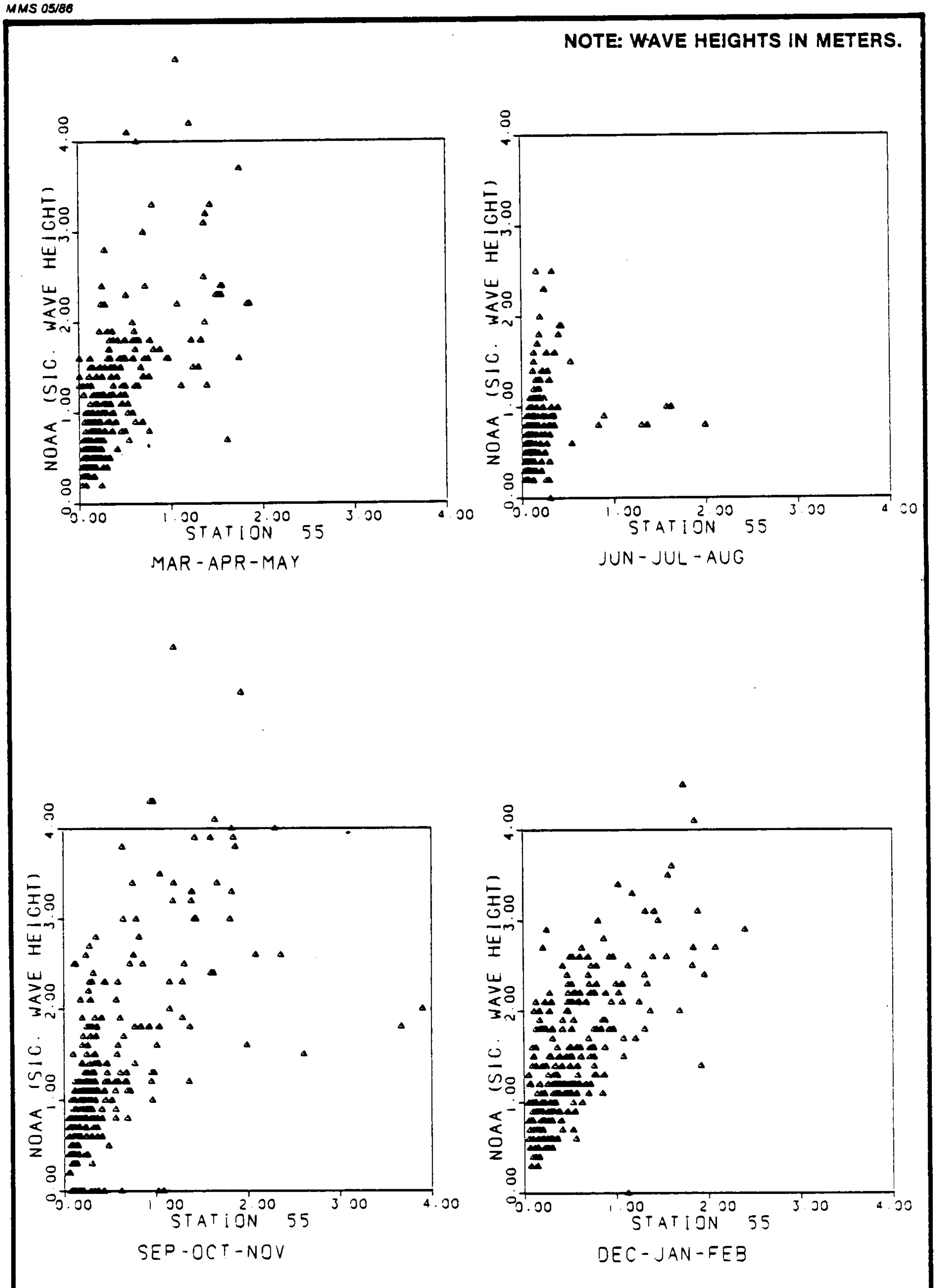

Figure 3.1-34 SEASONAL WAVE HEIGHT COMPARISONS FROM STATION 55 AND THE NDBC DATA

November 20, 1985, during Tropical Storm Kate (the buoy was inoperative during Hurricane Elena).

The figures also show that the waves in deeper water (at the NDBC buoy) are larger than at Stations 52 and 55. This occurs because the buoy is essentially unsheltered (i.e., large fetch) which allows for larger wave fields to develop. In addition, there is some biasing toward smaller waves at the two pressure sensor stations as discussed above, whereas the NDBC buoy, an accelerometer-type gage, can measure all surface waves. To compare the data, the maximum waves measured each month and the percentage of occurrence of various wave heights for all three data sets were computed, and the results are presented in Figure 3.1-35. The NDBC buoy recorded the largest waves with 19.9% of the waves greater than 1.5 m and 3.3% greater than 3.0 m. Most of the waves at Stations 52 and 55 were less than 0.6 m with only 1.5% at Station 52 and 3.4% at Station 55 above 1.5 m.

The primary goal of the wave studies was to determine the amount of energy penetrating to the bottom and the potential for sediment resuspension. Consequently, the next step was to use the wave data to estimate the wave energy at the water sediment interface (as described in Section 2.1). Wave energy dissipates quite rapidly with depth as illustrated in Figure 3.1-36. This figure illustrates the estimated wave orbital velocities at the water-sediment interface for various sized waves. It shows that a 3 m wave with a period of 5 sec will create bottom velocities of about 25 cm/sec in 20 m of water. Also, the energy from a 10-m wave will dissipate to velocities of about 10 cm/sec in 70 m of water. Consequently, it is unlikely that any wave energy will penetrate to the bottom at Station 36 (125 m).

The theory used to calculate these curves was applied to the wave data for all three data sets to compute the wave orbital velocities that occur at the water sediment interface. The results of the analysis are

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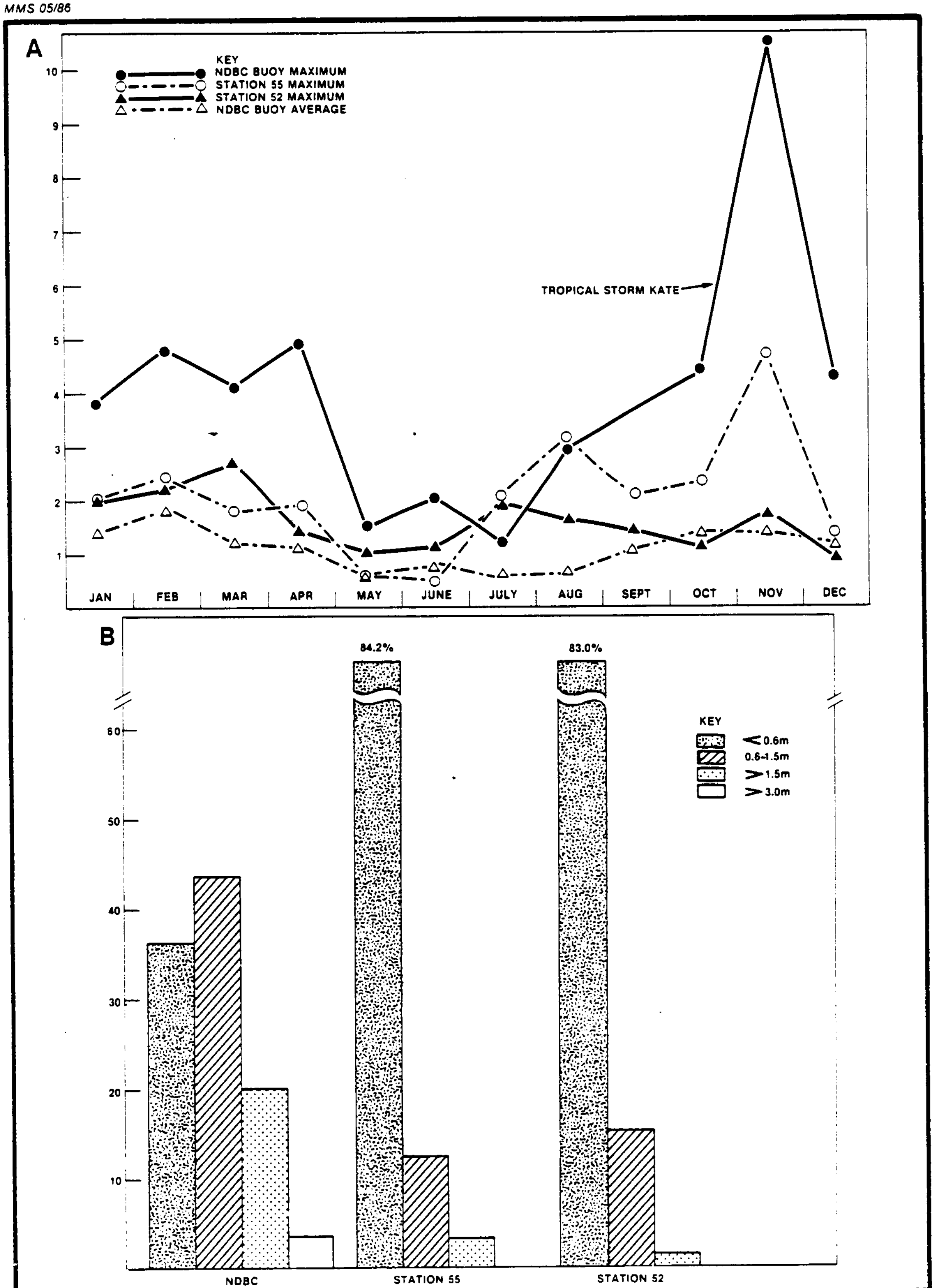

Figure 3.1-35 MONTHLY MAXIMUM OBSERVED WAVES (A) AND PERCENTAGES OF OCCURRENCE (B) FOR STATION 52, STATION 55, AND THE NDBC DATA

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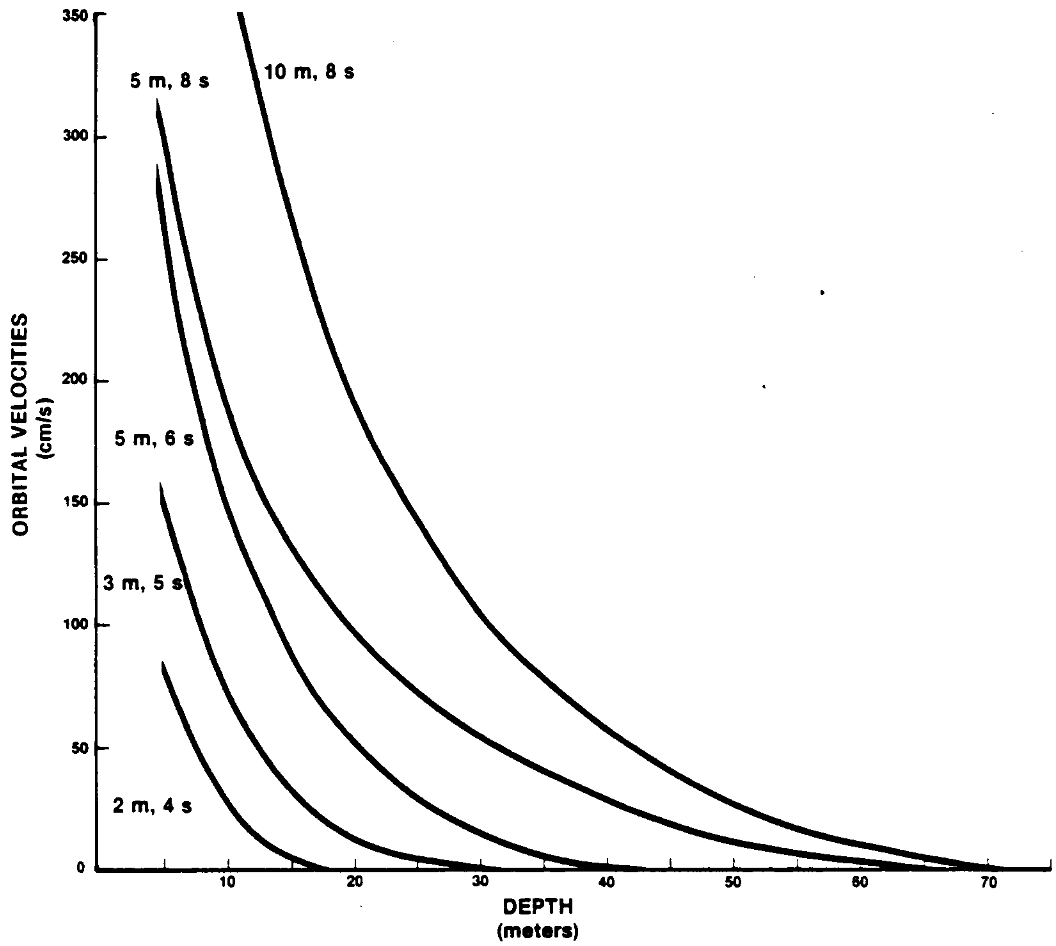

Figure 3.1-36 ESTIMATED BOTTOM WAVE ORBITAL VELOCITIES VERSUS DEPTH FOR SEVERAL DIFFERENT WAVES

presented in Table 3.1-8. Because three wave fields were used for the estimates, three different results are provided for each station. The Station 52 data are, of course, most applicable to Station 52 because they were measured at that station. The NDBC buoy data are most applicable to Stations 21, 23, 29 and 36 because these stations are unsheltered and relatively deep. The Station 55 data are provided as an intermediate estimate from wave data collected in 27 m of water in a partially sheltered area.

The results show that essentially no wave energy penetrated to the bottom at Station 36 and very little reached the bottom at Stations 29 and 23. An occurrence of one percentage point equates to 88 hours over the year. Consequently, the results indicate the wave energy was greater than 10 cm/sec at Station 29 less than 9 hours during the year. The amount of energy penetrating to the bottom was greater at Station 21, but still small compared to Station 52. At Station 52, the orbital velocity exceeded 10 cm/sec nearly 840 ($\simeq$10%) hours during the year and it exceeded 20 cm/sec 262 hours. Consequently, the wave energy at Station 52 can readily penetrate to the bottom and is important in contributing to sediment resuspension. The waves are much less important at the other stations and probably only contribute to sediment resuspension during extreme weather conditions such as hurricanes. It is unlikely that wave energy ever penetrates to the bottom at Station 36.

Table 3.1-8. Estimates* of occurences of bottom wave orbital velocities using linear wave theory and the three available data sets

Station	Depth (m)	Speed ≥10 cm/sec (%)			Speed ≥20 cm/sec (%)			Speed ≥30 cm/sec (%)			Speed ≥40 cm/sec (%)		
		NDBC	52 Data	55 Data	NDBC	52 Data	55 Data	NDBC	52 Data	55 Data	NDBC	52 Data	55 Data
52	13	50.4	9.55†	24.0	27.7	2.99†	10.1	16.8	0.81†	6.45	11.4	0.16†	3.03
21	47	0.34†	—	1.17	0.12†	—	0.39	0.1†	—	—	0.05†	—	—
29	64	0.10†	—	0.54	0.05†	—	—	0.04†	—	—	—	—	—
23	74	0.05†	—	0.39	0.01†	—	—	—	—	—	—	—	—
36	125	—	—	—	—	—	—	—	—	—	—	—	—

*Using the three wave fields measured, bottom orbital velocities were estimated using linear wave theory for each of the five stations. For example, if the wave field measured by the NDBC buoy were to occur at Station 52, the bottom orbital velocity would exceed 10 cm/sec 50.4% of the time.

†Values are the best estimates for each station.

3.1.5 SEDIMENT DYNAMICS

Introduction

One of the objectives of Year 5 of the Southwest Florida Shelf Ecosystems Program was to estimate resuspension and transport of sediments on the shelf and relate these findings to changes in the live bottom communities studied. The various methods used included: multi-level sediment traps, underwater television, time-lapse cameras, current meters, wave gages, bottom sediment sampling, and near-bottom transmissivity measurements. In addition, a literature search was begun that will continue into Year 6 of the program to further refine our description of sediment dynamics on the southwest Florida shelf.

Sediment is transported as bed load, suspended load, or a combination of the two processes. The process involved depends on numerous factors including sediment particle size, sediment particle density, density and viscosity of the water, motion of the water (either unidirectional or oscillatory), and roughness of the bottom. Bed load is the mode of transport that is initiated with the least energy and initially consists of intermittent rolling and sliding of individual grains. The random nature of turbulence in fluid flow is reflected in the random motion of the particle. As the flow increases, the number of particles moved increases and particles are lifted off the bed executing short trajectories before falling back. This process, called saltation, is an indication that the bed load mode of transportation has reached a more advanced stage. Finally, if the velocity of the water continues to increase, some of the sediment particles are lifted off of the bottom and remain aloft. This is referred to as suspended load transport. Specific bed forms can be associated with the dominant mode of sediment transport. Figure 3.1-37 (from Shepard, 1973) is a schematic representation of the various modes of transport, types of grain motion, and the bed forms associated with each mode of sediment transport.

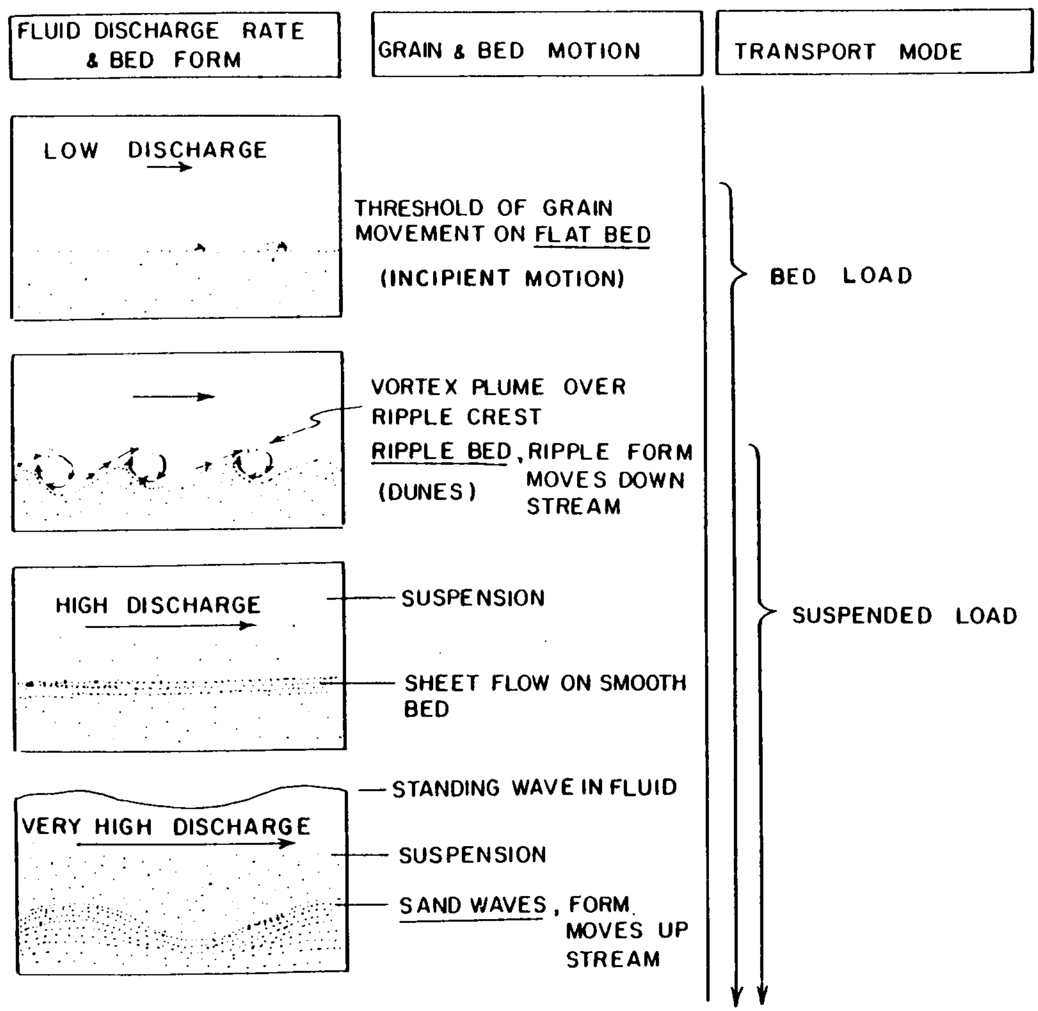

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Figure 3.1-37 **SCHEMATIC REPRESENTATION OF THE VARIOUS MODES OF TRANSPORT AND TYPES OF GRAIN MOTION (SHEPARD, 1973)**

This figure suggests a straightforward understanding of sediment transport; prediction of the processes as they occur in nature are, however, considerably more complex, and quantification is very difficult or impossible. Komar (1976a) summarized the state of knowledge as follows:

> Sediment transport on continental shelves can be divided into three types according to the processes as (1) resulting from unidirectional currents alone, (2) produced by wave action alone, and (3) caused by unidirectional currents superimposed on wave action. Of the three, only in the first case are we in a position to make quantitative estimates of sediment transport rates, given the required current measurements. Even there we are only able to estimate the bed load transport, not the suspended load transport. Waves alone apparently can cause an onshore transport of coarse sediment that moves only during wave-crest passage. This has not been adequately studied nor have any attempts been made at quantifying the process. Most commonly, case (3) of waves with superimposed unidirectional currents is important in shelf sediment transport. We have seen that this depends heavily on the ripple geometry, and the net transport is a complex function of the interaction of this geometry with the wave and current motions. Because of these complications, in spite of many studies on transport of sand under waves, we are nowhere near a state of art that permits quantitative predictions of sediment transport.
>
> Sediment transport by steady, uniform flows in open channels (rivers) has been the subject of intense study for more than a century. After all these investigations there is still no consensus of agreement as to an analytical framework, and quantitative estimates may be in error by as much as a factor of 10.

Although this statement sounds quite pessimistic, it should be remembered that the predictions are based on indirect methods such as current and wave measurements combined with some knowledge of the sediment characteristics. Better estimates of sediment resuspension and transport may be made using sediment trap, underwater television, and time-lapse camera data.

Numerous papers exist discussing the methods for the prediction of sediment transport (either bed load or suspended load). Some of these methods were used in this study to (1) determine if sediment transport can occur and (2) estimate the quantity of sediment transported. The results of these analyses are presented first. The importance of the sediment dynamics findings will then be discussed in light of the biological communities involved and the effects that offshore oil development may have on sediment dynamics as it relates to these communities.

Bed Load Transport

Bed load transport occurs when shear stress at the bottom boundary exceeds a critical value; this is called the threshold or critical boundary shear stress. There are several methods for estimating boundary shear stress including: Reynold's stress or eddy correlation, velocity profile determination, and the quadratic stress law. The application of the quadratic stress law as described by Sternberg (1972) was used to estimate bed load transport. The velocity profile method would be preferable, but requires a minimum of three current velocity measurements within 1.5 m of the bottom which is difficult to obtain.

There are several limitations or assumptions associated with using the quadratic stress law method as described by Sternberg (1972). These include:

1. The method is used for sediment sizes between 2.38 ϕ to 0.93 ϕ (medium to coarse sand); however, extrapolation to coarser grain sizes is considered acceptable;
2. The method assumes a logarithmic velocity distribution;
3. For this method a roughness element of less than 5 cm is assumed; and
4. The method is based on the assumption that there are little or no suspended sediments. The presence of suspended sediments can significantly affect the drag coefficient and, hence, the estimation of critical boundary shear stress.

A final point to be made regarding the application of this method is that it should not be used to estimate suspended sediment transport.

The first step in the prediction and description of sediment transport is to estimate the current velocity 100 cm above the bed (U_{100}). The current velocity during Years 4 and 5 of this study was measured at a nominal height of 300 cm above the bed. Assuming a logarithmic distribution of current velocity with depth, U_{100} was estimated to be 85% of the current velocity measured 300 cm (U_{300}) above the bed. This correction factor was used to adjust the measured currents to U_{100}.

Wimbush and Lesht (1979) conducted sediment transport studies in the Florida Straits at a depth of 710 m using a series of current meters and stereo time-lapse cameras to detect incipient sediment motion and mode of transport. The results of their study are presented in Table 3.1-9. The current meter data presented on this table were obtained from a current meter located 0.7 m above the bottom. The carbonaceous sediment at this location was somewhat finer than the majority of the sediments on the southwest Florida shelf (1.5 ϕ versus an average grain size of 1 ϕ, respectively). Nevertheless, these data can be used to estimate incipient sediment motion and mode of transport. Initiation of grain motion occurred at hour-averaged current speeds of 15.6 $\pm$ 1.7 cm/sec; sediment suspension occurred at 23.2 $\pm$ 3.6 cm/sec. Termination of these processes occurred at 14.3 $\pm$ 5.4 cm/sec and 26.7 $\pm$ 3.9 cm/sec, respectively.

The studies of Sternberg (1972), Wimbush and Lesht (1979), and others, suggest that incipient sediment motion should occur with speeds of approximately 16 to 17 cm/sec 100 cm above the bed. This is approximately equivalent to speeds of 20 cm/sec measured 300 cm above the bed ($0.85 * U_{300}$). Therefore, the percentage of the time current speeds exceed 20 cm/sec provides some indication of how often sediment transport can be expected.

Current speeds in excess of 20 cm/sec occurred at every station sometime during the 2-year study. This does not, however, imply that bed load

Table 3.1-9. Critical values of various parameters for initiation and termination of sediment motion (Wimbush and Lesht, 1979)

	Parameter			
	U_c (cm/sec)	$\hat{U}_c$ (cm/sec)	$u*$ (cm/sec)	$\hat{u}*$(cm/sec)
Crest movement				
Initiation	12.2 ± 1.9	14.1 ± 1.8	0.8 ± 0.5	1.4 ± 0.7
Termination	13.7 ± 3.8	15.3 ± 4.1	1.2 ± 0.5	1.6 ± 0.7
Grain motion				
Initiation	15.6 ± 1.7	17.3 ± 1.1	1.0 ± 0.2	1.3 ± 0.2
Termination	14.3 ± 5.4	17.5 ± 5.3	1.2 ± 0.3	1.5 ± 0.5
Ripple migration				
Initiation	19.1 ± 1.8	22.2 ± 2.4	1.6 ± 0.4	2.0 ± 0.5
Termination	17.2 ± 2.0	19.1 ± 2.0	1.7 ± 0.4	2.0 ± 0.5
Suspension				
Initiation	23.2 ± 3.6	29.4 ± 3.8	2.3 ± 0.5	2.9 ± 0.7
Termination	26.7 ± 3.9	30.0 ± 4.2	2.6 ± 0.5	3.0 ± 0.5

Note: Parameters are determined by averaging data from frames associated with observed motion. Caret over symbol denotes the hourly maximum (of ½-hour averaged samples). U_c is hour-averaged speed at current meter C, and $u*$ is friction velocity computed from U_{a1} and U_{a2}.

transport was an important process on the southwest Florida shelf. Using Sternberg's (1972) method for estimating bed load transport, it was apparent that, although sediment motion can be initiated at speeds of 20 cm/sec (U_{300}), bed load transport is extremely low at that speed. Even with U_{300} values of 40 cm/sec, the sediment transported as bed load was nearly negligible. The greatest estimated amount of sediment transported as bed load was less than 10 kilograms per kilometer per day (kg/km/day) during the fall (1985) at Station 44. Estimates in excess of 1 kg/km/day also were calculated for Station 52 during the spring (1984 and 1985), summer (1985), fall (1984), and winter (1985). The highest value, about 4 kg/km/day, occurred during the winter at Station 52. Sediment transport rates in excess of 1 kg/km/day also occurred occasionally at Stations 55 and 36 during certain seasons, but these values are very low and indicate minimal sediment movement.

It is apparent from these estimates that sediment transport as bed load, resulting from currents only, is negligible on the southwest Florida shelf. The addition of wave energy probably enhances bed load transport, but there currently is no method to estimate the effects of the currents coupled with the waves. The sediment trap data presented later in this subsection, however, indicate that suspended sediment transport is important, particularly at the shallower stations.

Suspended Sediment Deposition Rate

As stated previously, there is currently no means of indirectly estimating the amount of sediment transported as suspended load using wave and current data. Figure 3.1-38 does, however, provide some guidance with regard to initiation of sediment transport as suspended load and the relative concentration of suspended sediments that could be expected for a given grain size and mean velocity. This figure also indicates the region defined by grain size and mean velocity for which bed load transport estimations become unreliable (stippled area). Thus far, only methods for estimating sediment transport caused by

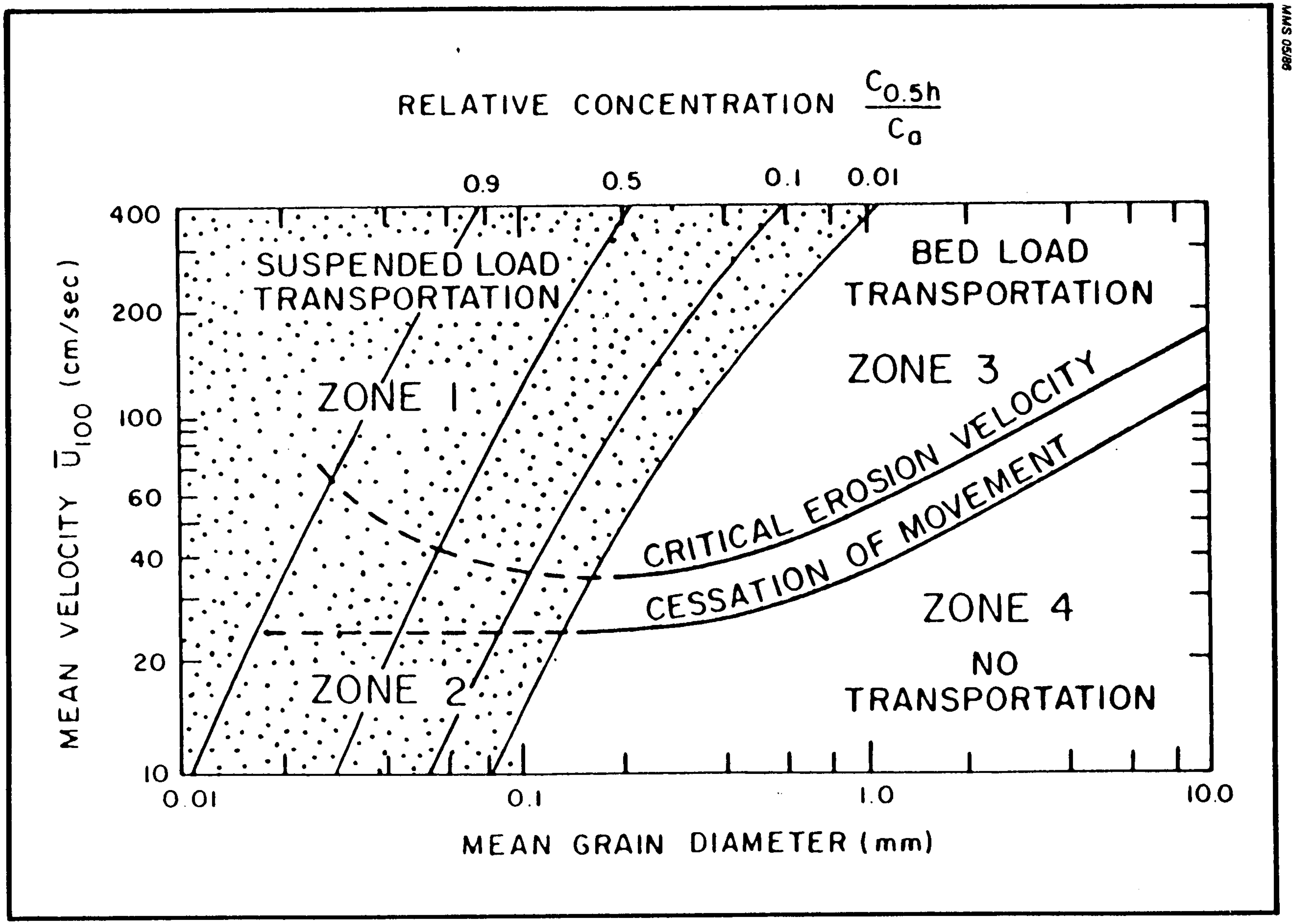

Figure 3.1-38 **THE RELATION BETWEEN VELOCITY, GRAIN SIZE, AND STATE OF SEDIMENT MOVEMENT (STERNBERG, 1972)**

unidirectional flow have been discussed. There is some disagreement among researchers as to whether unidirectional or oscillatory motion is more important on the continental shelf. Nevertheless, oscillatory motion such as that induced by tidal currents, internal waves, and surface waves most certainly is also responsible for sediment transport. Komar (1976b) has reported evidence that suggests that surface wave action is important on the continental shelf out to a depth of 125 m or greater. Teleki (1972), although stating that the effect of waves in deep water (specifically the continental shelves) is negligible, concedes that wave motion could play a role in sediment resuspension, especially if coupled with a weak current. In addition to surface waves, internal waves are thought to contribute to the transport of sediments on the continental shelf. Southard and Cacchione (1972) conducted tank studies of sediment transport of internal waves and concluded that, although non-quantifiable, there was definite evidence that internal waves can transport sediment, particularly in the breaking zone. This zone of breaking could occur on the southwest Florida shelf near the shelf break in the vicinity of Station 36.

Because suspended sediment transport is difficult to accurately estimate, sediment traps were used to provide information on the degree of sediment resuspension that could be expected on the southwest Florida shelf. The sediment deposition rate was determined by first measuring the salt-free dry weight of the sediment collected in the traps and dividing by the area of the trap opening to determine the deposition per square centimeter. This value was then multiplied by the number of square centimeters in a square kilometer and divided by the number of days the sediment trap was in place to determine the sedimentation rate in metric tons per square kilometer per day. The results of these calculations for the 1985 sediment trap data for each season are presented in Figure 3.1-39. The figure also shows the water current energy presented as the percentage of time the currents exceeded 20 cm/sec and the estimated wave energy presented as the percentage of

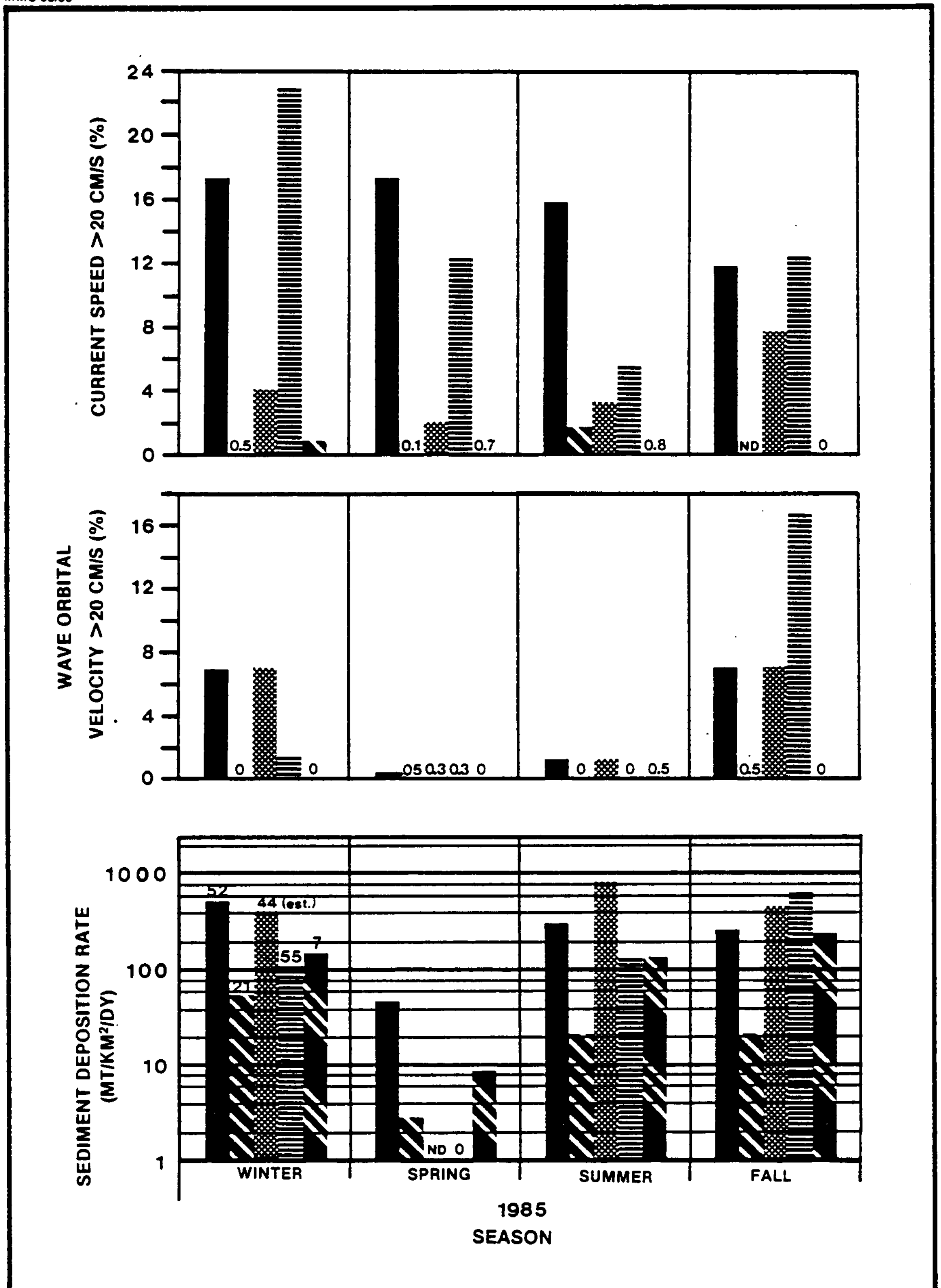

Figure 3.1-39 SEASONAL WATER CURRENTS, WAVE ORBITAL VELOCITIES, AND SEDIMENTATION RATES FOR 1.0-M SEDIMENT TRAPS FOR 1985 DATA

time the wave orbital velocity at the bottom exceeded 20 cm/sec. Only the results for Stations 52, 21, 44, 55, and 7 are presented; the results from Stations 23, 29, and 36 are not presented because these stations were in deeper water and the sedimentation rates were very low (typically about 1 $MT/km^2/day$). The results are presented only for the sediment collected in the 1.0-m trap (i.e., 1.0 m above the bottom); the sediment traps at the 0.5 m from the bottom typically collected 61% more sediment than at 1.0 m and the traps at 1.5 m collected 23% less than the traps at 1.0 m.

This large gradient indicates that the sediments could not be readily transported throughout the water column, but rather were limited to the near-bottom zone. Approximately twice as much sediment reached the 0.5-m level than reached the 1.5-m level. Undoubtedly much of the finer material was dispersed throughout the water column during storms, but most of the activity was limited to within a few meters of the bottom. The difference measured at these levels also suggests the sediment collected originated from the near vicinity of the traps. Had the material traveled long distances, there would have been a more uniform fallout from the water column and the sediment deposition rate values would have been more consistent.

The sedimentation results indicate that the shallowest stations (52 and 44) were generally the most active. The highest sedimentation rate measured in 1985 was 848 $MT/km^2/day$ at Station 44 during the summer. Station 55 recorded the most sedimentation during the fall even though it was much deeper than Stations 52 and 44. This was the result of hurricanes near that station during the fall that produced a few episodes of strong currents and high waves that resuspended large volumes of sediments. The high sedimentation rate in the summer was also the result of passages because the winds are typically calmer during the summer except for a few storms. The high sedimentation in the winter, however, was produced by higher winds resulting from frontal passages that are characteristic of this area during the winter. The spring months produced the lowest sedimentation because spring is a season of calm winds prior to the hurricane season.

The wave and current data also shown in Figure 3.1-39 are presented to illustrate the relationship between sedimentation and wave and current energy. The comparison suggests that wave energy is more important than current energy in sediment resuspension. For example, at Station 55 high currents occurred much more often in the winter than in the fall, but the sedimentation was much greater in the fall (621 versus 109 MT/km^2/day) because the wave energy was greater in the fall. Also, the currents in the spring were comparable to those in the summer and fall, but the sedimentation was very low in the spring primarily because the wave energy at the bottom was almost nil. Further evidence of the importance of wave energy is provided from the deeper stations (23, 29, and 36). The currents at these stations at times were as great as the currents in shallow water however there was essentially no sediment resuspension because no wave energy could penetrate to those depths.

To further illustrate the relationship of sedimentation to waves and currents, the values are plotted in Figure 3.1-40 (only sedimentation rates $>$ 10 MT/km^2/day are presented). The figure shows that there is a general correlation ($r = 0.534$ for currents and $r = 0.667$ for waves) of currents and waves with sedimentation, but there is considerable scatter in the results. Much of the scatter probably results from using seasonal average sedimentation rates (the sediment traps were retrieved every 3 months). If individual episodes of sedimentation could be compared with currents and waves, the correlations would probably be much stronger. Layering in some of the sediment traps retrieved in 1984 indicated that most of the sedimentation occurred during only a few episodes within the season. Consequently, the sedimentation rate during storm activity could be 10 times greater than the calculated seasonal

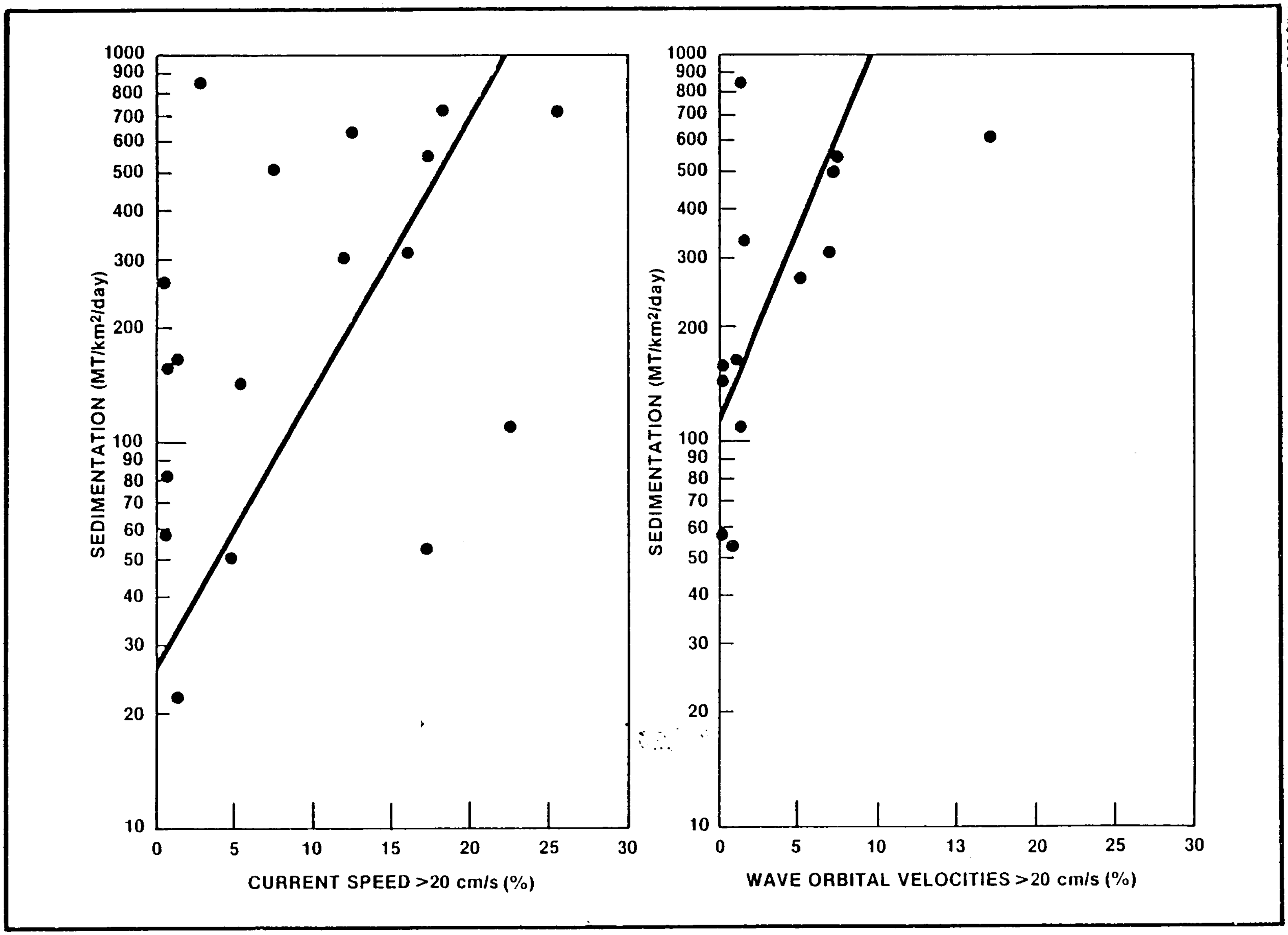

Figure 3.1-40 COMPARISON OF SEDIMENTATION RATES WITH OCCURRENCES OF HIGH CURRENT SPEEDS AND HIGH WAVE ORBITAL VELOCITIES

averages. It is apparent, however, that sediment resuspension depends on both currents and waves, but generally will not occur without wave energy.

To illustrate the decrease in sedimentation rate with depth, the seasonal values are plotted in Figure 3.1-41. The two curves (log curve and power curve) illustrating the decrease in sediment activity are similar to the curves illustrating the decrease in wave energy with depth (see Figure 3.1-36). All curves show a very sharp decline with depth which again illustrates the importance of wave energy in sediment resuspension. In addition, correlation coefficients as high as 0.8 suggest that depth of water and, therefore, the frequency with which waves affect the bottom, are important factors. Another point illustrated in the figure is the slight increase in sedimentation at Station 36. There are three possible reasons for this slight increase:

1. Frequent Loop Current intrusions at Station 36 produced stronger currents that may have resuspended some sediments;
2. Station 36 is located on the slope near the permanent thermocline and the sedimentation may be the result of breaking internal waves; or
3. Stations 23 and 29 are covered by algal nodule pavements that may reduce sediment resuspension relative to that observed at Station 36.

Suspended Sediment Characteristics

The preceding discussions have emphasized the transport of sediments, either as bed load or suspended load, on the southwest Florida shelf. What follows is a discussion of the physical and chemical characteristics of the suspended sediments and comparison of these characteristics with those of the bottom sediments (discussed in Subsection 3.1.1). It is important to note in the following discussion that the descriptions of sediment characteristics are based on the shallower stations (those less than 47 m). Sediment traps at the deeper stations had insufficient quantities of sediment for detailed analysis. A summary of the trapped sediment characteristics, including mean diameter, percent silt and clay, MMS ABS 08/86

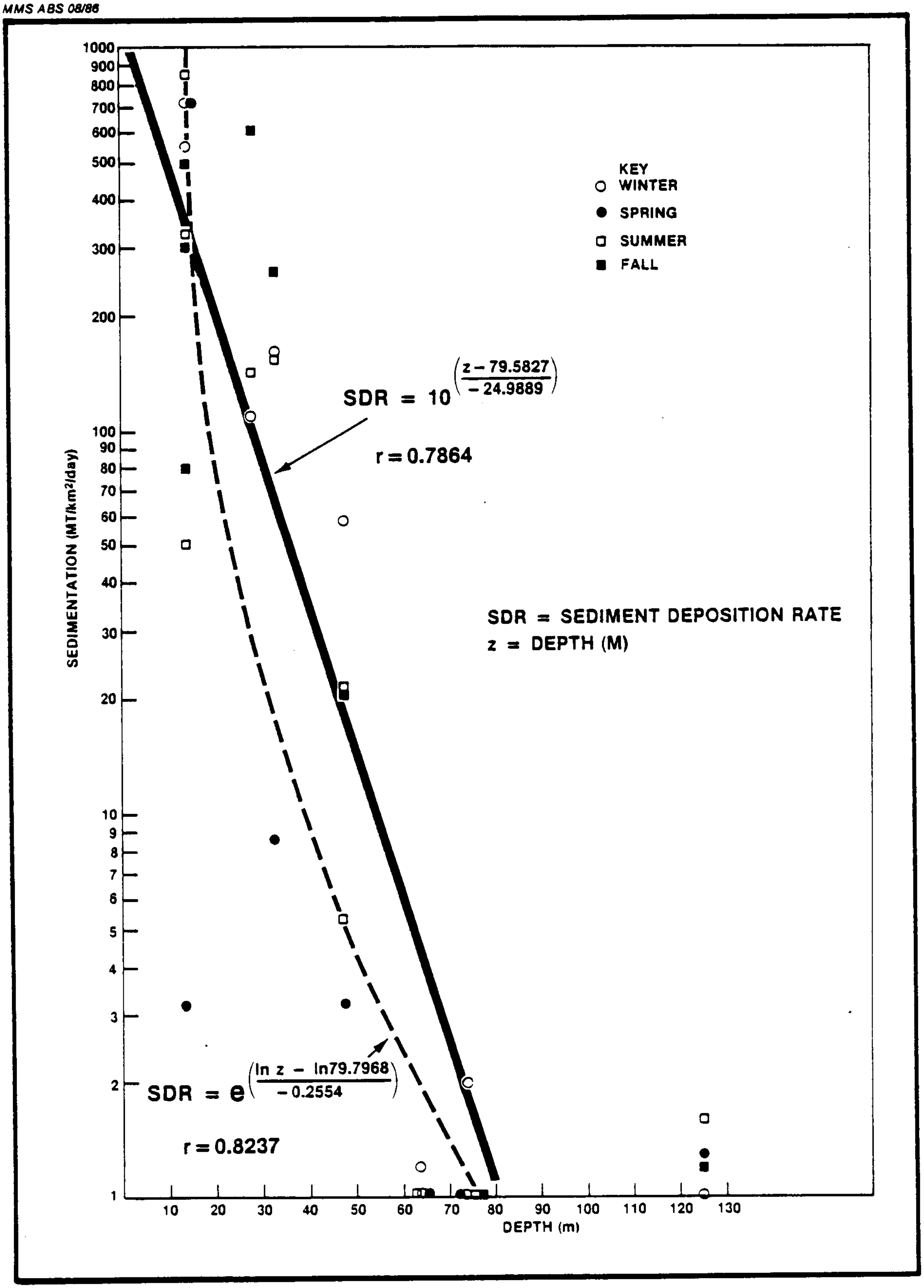

Figure 3.1-41 SEDIMENTATION RATES FROM SEDIMENT TRAPS VERSUS DEPTH

percent organic carbon and $CaCO_3$, as well as deposition rate and various other physical parameters, is presented in Table 3.1-10. To simplify the presentation, only the characteristics of the sediment from the 1.0-m trap are presented (except in rare instances when the 1.0-m trap was not recovered, in which case, the 1.5-m trap sediments were reported). There are some differences in the sediments with height of the trap; these differences are discussed below and the individual trap data are presented in Appendix D.

Particle size distributions were determined for trapped sediments from Stations 52, 44, 55, 7, and 21 (in order of increasing depth) for four seasons. The sediment grain sizes of the 1.0-m sediment trap samples ranged from a mean ϕ of 4.2 (0.054 mm) to 7.6 (0.005 mm). The sediments from the traps were considerably finer than the finest sediments recovered from the bottom grab samples [Station 21 - 1.8 ϕ (0.288 mm)]. The overall average percentages (by weight) of sand, silt, and clay in all of the trapped sediments for all seasons were 14, 56, and 30%, respectively. By contrast, bottom sediments in the study area are predominantly sand sized, comprising 97% of the bottom grab samples. These results suggest that kinetic energy at the sea floor is rarely intense enough to resuspend sand-size particles (at least to a height of 0.5 m above the bed), although frequently intense enough to resuspend silt and clay sizes. Consequently, the currents and waves selectively resuspend the finer materials that result in the high sedimentation rates observed in shallow water.

Generally, the mean diameter of trapped sediments decreased with increased height of the sediment trap. The greatest difference observed between the 0.5-m and 1.5-m sediment trap was 1.7 ϕ, although this was not the norm. Generally the difference was more on the order of 0.5 ϕ units or less. Occasionally sediment diameter actually increased with the height of the trap, although the difference was very close to the accuracy of the analytical measurement.

Table 3.1-10. Seasonal sediment dynamics and characteristics (blank spaces indicate either no data or insufficient sample for detailed sediment analysis)

			Bed Load		Suspended Load							
Sta. No.	Bottom Depth (m)	Season	Mean Sed. Dia. (mm)	U_{300} ≥20 cm/sec (%)	Wave OV ≥20 cm/sec (%)	U_{300} ≥20 cm/sec (%)	Sed. Dep. Rate ($MT/km^3/day$)	Mean Dia. (mm)	Silt (%)	Clay (%)	Org. Carbon (%)	$CaCO_3$ (%)
52	13	Win 84	0.54	18.2		1.1	716.2	0.007	50	39	17.3	84.3
		Spr 84		25.1		21.6	716.2	0.005	48	44	11.3	70.0
		Sum 84		4.3		0.1	50.9				20.3	59.0
		Aut 84		0.6		0.1	80.7	0.006	50	39	15.2	69.5
		Win 85		17.3	7.05	3.4	548.0	0.009	53	40	11.5	81.8
		Spr 85		17.5	0.28	3.4	53.2	0.012	36	26	16.5	80.8
		Sum 85		15.8	1.20	2.2	327.7	0.017	60	22	9.0	23.6
		Aut 85		11.9	7.02	0.5	309.6	0.008	49	33	12.5	34.9
21	47	Win 84	0.29									
		Spr 84										
		Sum 84					5.3					
		Aut 84					21.2	0.007	58	34	21.0	59.2
		Win 85		0.5	0*	0.0	57.8	0.007	61	34	12.0	85.0
		Spr 85		0.1	0.05*	0.0	3.2					
		Sum 85		1.8	0*	0.4	21.6	0.008	60	34	11.4	36.7
		Aut 85			0.48*							
29	64	Win 84	—	11.2		0.3	1.2					
		Spr 84		1.6		0.2	0.5					
		Sum 84		6.1		0.7	0.8					
		Aut 84		3.5		0.3						
		Win 85		3.6	0*	0.0	0.2					
		Spr 85			0*							
		Sum 85			0*							
		Aut 85			0.21*							
23	74	Win 84	0.57	5.6		0.2	2.0					
		Spr 84		1.3		0.1	0.5					
		Sum 84		1.2		0.0						
		Aut 84										

Table 3.1-10. (con't)

Sta. No.	Bottom Depth (m)	Season	Bed Load: Mean Sed. Dia. (mm)	Bed Load: U_{300} $\geq$20 cm/sec (%)	Suspended Load: Wave OV $\geq$20 cm/sec (%)	U_{300} $\geq$20 cm/sec (%)	Sed. Dep. Rate (MT/km^3/day)	Mean Dia. (mm)	Silt (%)	Clay (%)	Org. Carbon (%)	$CaCO_3$ (%)
		Win 85		1.1	0*	0.0	0.9					
		Spr 85		2.7	0*	0.0	0.9					
		Sum 85		0.4	0*	0.0	1.0					
		Aut 85		0.0	0.05*	0.0	1.0					
36	125	Win 84	0.57	7.0		0.6						
		Spr 84		0.1		0.0						
		Sum 84		6.6		0.4						
		Aut 84		7.5		0.9	1.2					
		Win 85		3.2	0*	0.2	0.6					
		Spr 85		1.8	0*	0.1	1.3					
		Sum 85		7.7	0*	2.9	1.6					
		Aut 85			0*							
44	13	Win 85	0.57	4.2	7.05†	0.6						
		Spr 85		1.9	0.28†	0.1						
		Sum 85		3.3	1.20†	1.6	847.7	0.025	49	16		
		Aut 85		7.8	7.02†	5.4	504.6	0.016	60	22	9.0	30.4
55	27	Win 85	0.44	22.8	1.11	6.8	109.2	0.007	57	41	9.5	89.1
		Spr 85		12.4	0.27	3.5						
		Sum 85		5.2	0.0	0.9	142.0	0.008	55	30	6.4	29.4
		Aut 85		12.5	16.76	3.0	621.4	0.010	58	24	7.2	36.9
7	32	Win 85	0.41	1.0	0.83*	0.0	159.7	0.012	68	26	11.0	80.5
		Spr 85		0.1	1.91*	0.0	8.7					
		Sum 85		0.8	0.05*	0.5	156.1	0.025	69	13	7.5	22.9
		Aut 85		0.0	4.86*	0.0	262.1	0.015	58	23	7.8	33.6

*Wave orbital velocity calculated using NDBC Buoy #42003 wave data.
†Wave orbital velocity calculated using Station 52 wave data.

There was no apparent relationship between the mean diameter of the trapped sediments and the distance offshore, depth of the station, or season. With the exception of Station 21, sediments at the individual stations generally ranged from approximately 0.005 to 0.020 mm. Only at Station 21 did the sediments remain consistently around 0.007 mm during all seasons. The finer material collected at this deeper station (47 m) suggests the source of the material may have been in shallow water and the finer material remained in the water column longer before reaching Station 21 and settling out.

The $CaCO_3$ and organic carbon content (as percent weight) of the trapped sediments (nominally from the 1.0-m trap) from Stations 52, 44, 55, 7, and 21 are summarized in Table 3.1-10. $CaCO_3$ content was variable in the trap sediments with values ranging from 23 to 89%. This was unlike the bottom sediments which were consistently above 85%, with the exception of Station 7 (53%). There was no readily apparent relationship between $CaCO_3$ content and depth of station, mean grain size, mass of sediment trapped, or season with the exception that the $CaCO_3$ content appeared to be higher during the more energetic winter season. There also was no apparent relationship between the $CaCO_3$ content and the height of the trap.

As with $CaCO_3$ content, there were no apparent relationships between organic carbon content and other parameters. One observation apparent from Table 3.1-10 is that the organic carbon content at Station 52 was consistently higher than the other stations. This could result from a higher carbon content in resuspended sediments, but is probably due partially to the large amounts of sessile organisms of the sediment traps that occurred regularly at Station 52.

During 1984 the sediment trap data were examined in more detail. 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.

Also during 1984 the layering that was observed in the sediment traps was examined in detail. 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 3.1-42 and 3.1-43. The vertical axis for all these graphs (fraction of total depositon) 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 from 1984 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.

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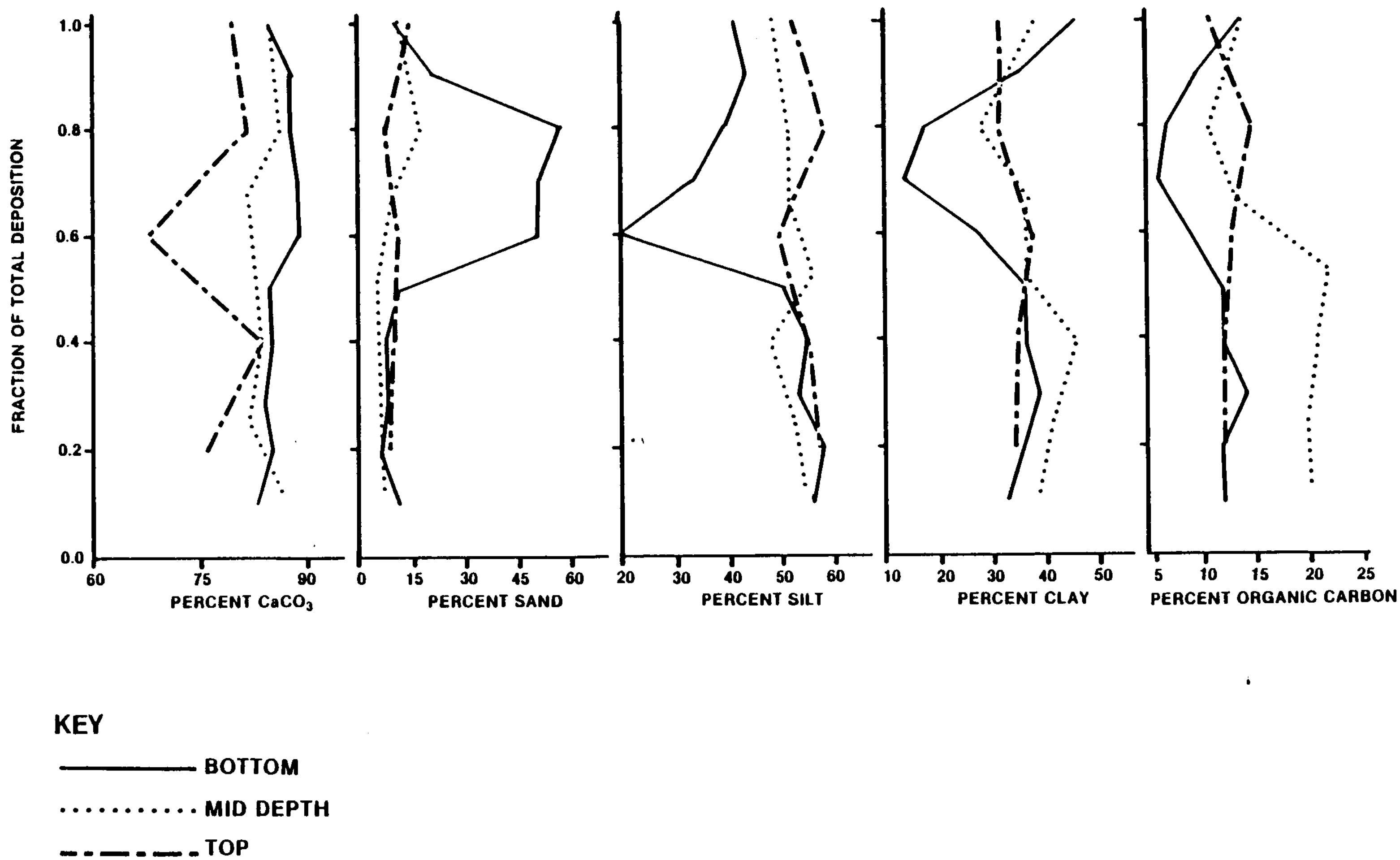

Figure 3.1-42 SEDIMENT CHARACTERISTICS FOR STATION 52 *IN SITU* ARRAY TRAPS FROM DECEMBER 10, 1983, TO MARCH 2, 1984

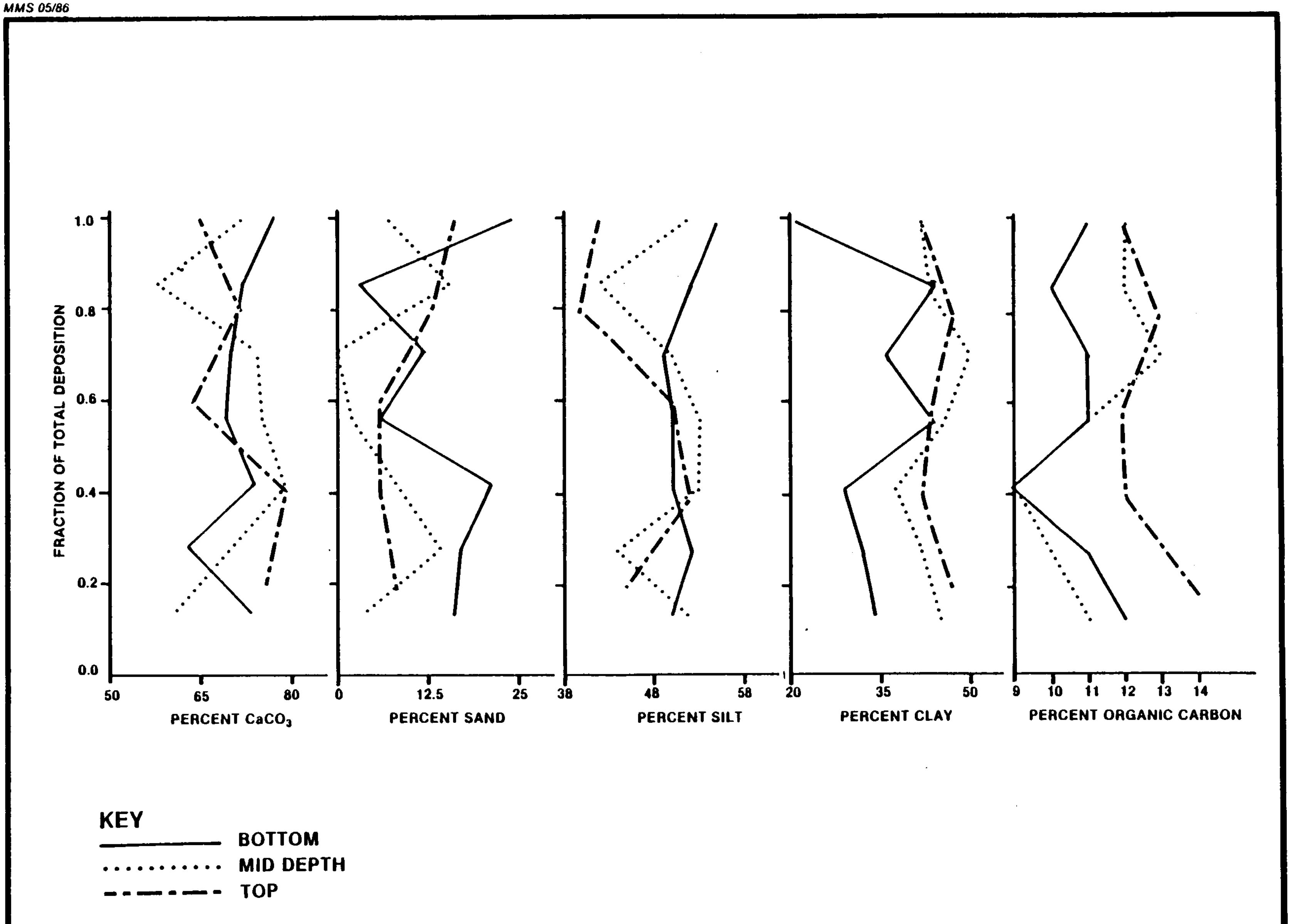

Figure 3.1-43 SEDIMENT CHARACTERISTICS FOR STATION 52 *IN SITU* ARRAY TRAPS FROM MARCH 2, 1984, TO MAY 12, 1984

The most interesting results were obtained from the winter sampling period (Figure 3.1-42). During the middle of the period, several sections from the bottom sediment trap had high levels of sand (up to 58%). No other samples from sediment traps had more than 35% 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 Section 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 resuspension event of Year 4 was not intense enough to lift significant quantities of sand more than about 1 m off the sea floor.

3.2 BIOLOGICAL CHARACTERISTICS

3.2.1 STATION DESCRIPTIONS

Introduction

During Year 4, all stations were designated as belonging either to Group I or Group II (Figure 3.2-1). Group I stations were intended to extend the Year 3 program's seasonal information, and included some soft bottom and some live bottom stations. Group II stations were all believed to have live bottom communities. Sampling intensity for biota at Group I stations was approximately half that at Group II stations, with Group I stations sampled semiannually and Group II stations sampled quarterly. Sampling gear used at all live bottom stations included underwater television, triangular dredge, and otter trawl (Tables 2.2-1 and 2.2-2). In addition, two Group II stations (Stations 52 and 21) had time-lapse camera systems during Year 4, and all Group II stations had settling plates installed on arrays (Tables 2.2-9 and 2.2-7).

For each station, mean abundances were calculated by cruise for numerically dominant taxa observed frequently enough with underwater television to test for significant differences among cruises. Means were estimated by averaging densities within successive 50-m-long sections of each transect, in order to permit the calculation of confidence limits (see subsection 3.3, Intersite Comparisons and Community Dynamics). These means and confidence interval bars are plotted graphically in each station description. These means may differ slightly from the density estimates in Appendix G, which were calculated by dividing the number of individuals seen on each cruise by the total area surveyed.

During Year 5, all Group I stations (with the exception of Station 44) were dropped from the sampling program; an array was installed at Station 44; and two new stations (Stations 7 and 55) were added (Figure 3.2-1). All stations were sampled quarterly during Year 5, although dredging was discontinued at the old Group II stations (Stations 52, 21, 29, 23, and 36) because previous dredged samples from these stations were considered

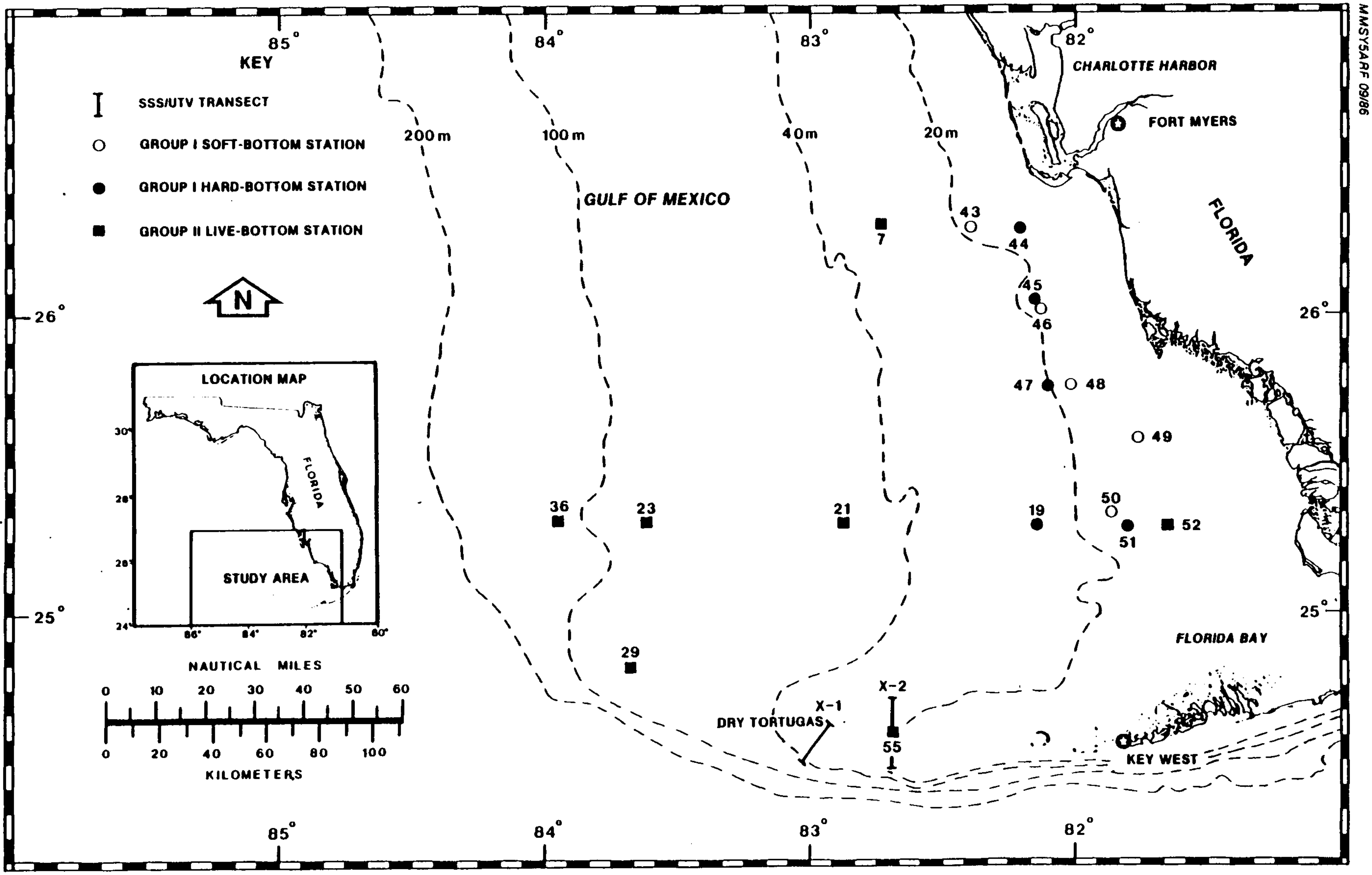

Figure 3.2-1 STATION AND INSTRUMENTED ARRAY LOCATIONS FOR YEARS 4 AND 5

adequate. Time-lapse cameras and settling plates were emplaced at all stations during Year 5 except at Station 36, which had settling plates but was too deep for the camera housings.

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. For common species, presence/absence data are relatively insensitive to this unbalanced sampling design. However, rarer species are certainly less likely to have been collected at Group I stations. Comparisons of numbers of species or related parameters between stations should not be made without taking into account differences in sampling intensity. Further discussion of this subject is provided in Subsection 3.2.3, Intersite Comparisons.

Descriptions of inter-cruise or seasonal differences within stations must be made with caution. Sampling effort using the underwater television varied with area transected at any given station, for example. Comparisons between seasons are provided in this report for data from underwater television, time-lapse camera, trawl, and settling plates. In many cases, the data have been normalized (e.g., using density estimates such as number per hectare or per 10-min trawl) to facilitate such comparisons.

Dredge data were converted into presence/absence scores because the dredge is a non-quantitative sampler. Furthermore, methods for selecting those specimens to be preserved from massive dredge hauls were non-repeatable, even though every attempt was made to collect a representative sample from each haul. Although field methods were consistent with the goal of dredging, i.e., to facilitate underwater television identifications, they did make statistical comparisons of numbers of individuals or numbers of taxa inappropriate. A checklist of species collected with the dredge on a cruise-by-cruise basis for each station is provided in Appendix E. Differences in numbers of taxa between cruises or stations undoubtedly reflect sampling limitations as well as natural variability. Although many sponges were collected with the dredge, none of them was identified in the laboratory because it was agreed that previous taxonomic work on sponges was adequate for the area. Consequently, sponges do not appear on any dredge table or figure in this report.

Stations are discussed individually below in order of increasing depth. Historical information from Years 1 and 2 is provided if available. Results for each station are separated by gear types. Station descriptions have been written to stand alone, to increase their usefulness to readers interested only in specific locations. Whenever possible, scientific names have been supplemented with common names. Common names in this report are excerpted from taxonomic references as well as general works (e.g., Kaplan, 1982; Colin, 1978; Greenberg and Greenberg, 1977; Robins et al, 1980).

Although Group I live bottom stations (except for Station 44) were not sampled during Year 5, data for all gear types (except settling plates, which are treated separately in Appendix I) at all live bottom stations from Years 4 and 5 are included in this report. This is necessary because much of the data was preliminary in the Year 4 Final Report. Time-lapse narratives for Year 4 are not included, because they were discussed in detail in the Year 4 Final Report, but time-lapse narratives for Year 5 are included. No discussion is provided for soft bottom stations, which were addressed in the Year 4 Final Report and were not resampled during Year 5.

Station 52

Historical Notes

Station 52 [depth 13 m, in the Inner Shelf Depth Zone (Woodward Clyde Consultants/Continental Shelf Associates, 1983)] was designated a live bottom station in the Year 3 Final Report by Continental Shelf Associates (R. Avent, MMS, pers. comm., 1984). However, no historical data on Station 52 are available at this time.

Station 52 was surveyed as a Group II station by ESE/LGL during Years 4 and 5 on Cruise 1 (December 1983), Cruise 3 (May 1984), Cruise 4 (August 1984), Cruise 5 (December 1984), Cruise 6 (March 1985), Cruise 7 (June/July 1985), and Cruise 8 (September 1985).

Underwater Television Results

The total area surveyed with underwater television was 39,327 m^2 (Table 2.2-2). Station 52 was a low-relief, flat area dominated by patches of sponges, algae, and dense stands of gorgonians projecting from underlying hard substrate through carbonate sand.

The most abundant benthic organisms were algae, sponges, and gorgonians (Figure 3.2-2, Tables 3.2-1 and 3.2-2). Algae and demosponges averaged 21 and 8% cover, respectively. Unidentified gorgonians had an overall density of 28,237 per hectare (ha = $10^4 m^2$). Other numerical dominants were the sponge *Ircinia campana* (405/ha); the gorgonian *Pterogorgia guadalupensis* (118/ha); the sponge *Ircinia strobilina* (51/ha); unidentified hydroids (49/ha); and unidentified asteroids (15/ha).

Forty-four fishes were recognized at Station 52 (Table 3.2-3). The fishes counted most frequently were the white grunt, *Haemulon plumieri* (278/ha); the hogfish, *Lachnolaimus maximus* (39/ha); the red grouper, *Epinephelus morio* (19/ha); the blue runner, *Caranx crysos* (17/ha); the pigfish, *Orthopristis chrysoptera* (13/ha); the jackknife-fish, *Equetus lanceolatus* (11/ha); the bar jack, *Caranx ruber*; the lane snapper, *Lutjanus synagris*; the sheepshead, *Archosargus probatocephalus*; and various porgies (all 4/ha); and the porkfish, *Anisotremus virginicus* (3/ha) (see Figure 3.2-3). Overall diversity (H") and evenness (J') for fishes censused with underwater television were 1.49 and 0.40, respectively, for all cruises together at Station 52.

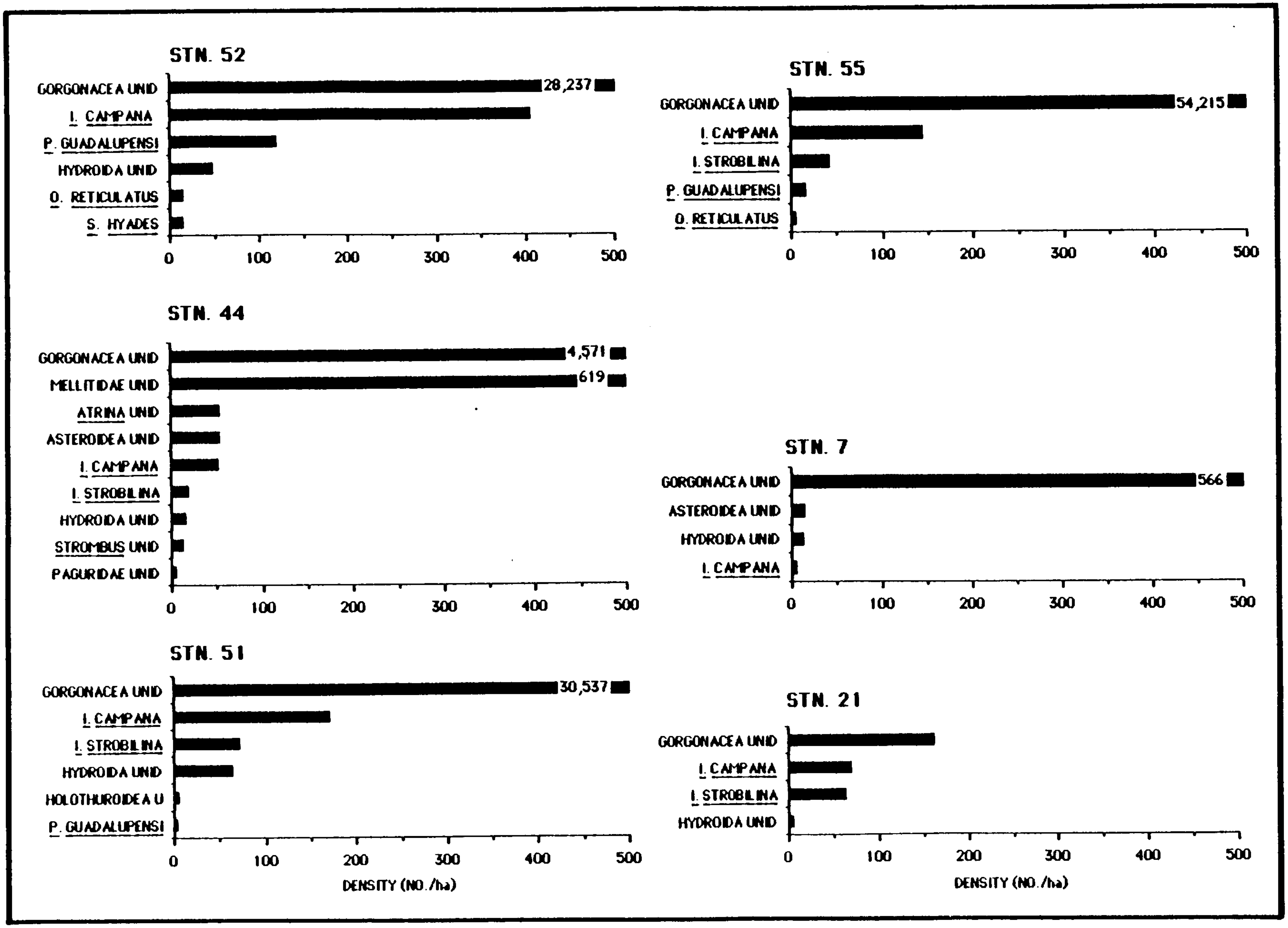

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Figure 3.2-2 OVERALL DENSITY OF NUMERICALLY DOMINANT (≥3/ha) BENTHIC INVERTEBRATES SURVEYED WITH UTV (FOR ALL CRUISES TOGETHER, BY STATION)

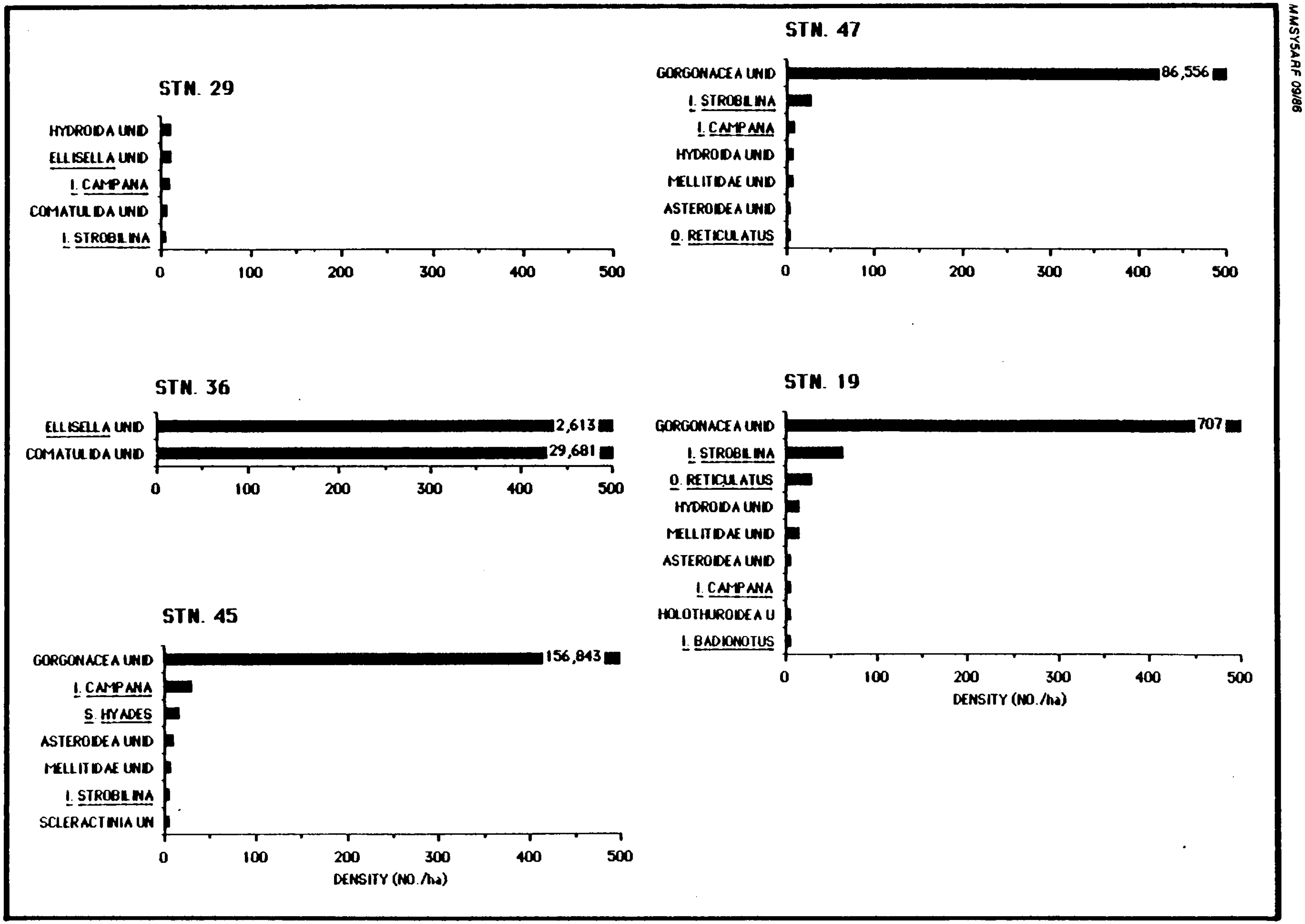

Figure 3.2-2 (Con't)

Table 3.2-1 Cover (%) of benthic invertebrates and plants seen in UTV, by cruise and station. Dots indicate no survey.

	Cruise 1	2	3	4	5	6	7	8	Overall Cover
Station 52									
ALGAE UNIDENT.	23.8	.	1.6	48.2	17.3	11.5	37.2	17.7	20.7
Sargassum UNIDENT.	<.1	.							<.1
DEMOSPONGIAE*	6.7	.	1.6	1.7	14.3	15.8	16.7	17.1	8.4
Station 44									
ALGAE UNIDENT.		.	1.1	.	.	.	.	.	0.9
DEMOSPONGIAE*	7.3	.	0.5	.	.	.	.	.	1.6
Station 51									
ALGAE UNIDENT.	34.9	.	23.4	.	.	.	.	.	27.8
DEMOSPONGIAE*	4.5	.	5.1	.	.	.	.	.	4.9
Station 45									
DEMOSPONGIAE*	8.2	.	4.9	.	.	.	.	.	5.6
Station 47									
Caulerpa UNIDENT.	15.4	.		.	.	.	.	.	4.9
DEMOSPONGIAE*	3.3	.	5.3	.	.	.	.	.	4.7
Station 19									
ALGAE UNIDENT.	27.8	.	1.7	.	.	.	.	.	12.4
Sargassum UNIDENT.	<.1	.		.	.	.	.	.	<.1
DEMOSPONGIAE*	2.8	.	3.8	.	.	.	.	.	3.4
Station 55									
ALGAE UNIDENT.	.	.	.	.	11.6	27.8	31.0	15.2	20.6
DEMOSPONGIAE*	.	.	.	.	17.7	24.0	13.4	11.3	16.7
Station 7									
ALGAE UNIDENT.	.	.	.	.	32.9	5.3	27.7	18.5	23.9
Halimeda UNIDENT.	.	.	.	.			6.5		1.1
Caulerpa UNIDENT.	.	.	.	.	<.1				<.1
Sargassum UNIDENT.	.	.	.	.	<.1		3.6		0.6
AGARICIIDAE UNIDENT.	.	.	.	.	<.1				<.1
DEMOSPONGIAE*	.	.	.	.	21.0	4.7	12.6	14.4	15.3
Station 21									
ALGAE UNIDENT.	.		66.9	30.3	16.9	5.4	36.4	24.1	35.9
DEMOSPONGIAE*	.	6.4	35.2	4.5	25.2	18.6	23.3	23.4	22.7
Station 29									
ALGAE UNIDENT.					6.0	6.4	6.0	.	2.1
Anadyomene menziesii	24.3	18.0	18.0	18.0	38.0	19.1	33.4	.	22.6
AGARICIIDAE UNIDENT.	14.4	11.1	18.0	21.0	38.0	6.7	12.1	.	17.0
DEMOSPONGIAE*	0.6	1.3	6.0	0.5	6.0	6.4	6.0	.	3.9
Station 23									
ALGAE UNIDENT.	.		15.6		18.0	5.7	12.0	.	7.6
Anadyomene menziesii	.	2.9	17.5	0.5	32.9	5.7	19.7	.	10.9
DEMOSPONGIAE*	.	0.5	16.5	0.5	6.0	17.0	9.7	.	8.4
Station 36									
DEMOSPONGIAE*	.	0.1	<.1				0.1	.	<.1

*Includes counted _Ircinia_ spp. and unidentified forms.

Table 3.2-2 Mean and overall densities (no. per hectare) and frequency of benthic invertebrates which could be counted on UTV, for all cruises together, by station.

Taxon	Station 52	44	51	45	47	19	55	7	21	29	23	36	Overall Density	Frequency
ECHINODERMATA														
ASTEROIDEA														
Astropecten UNIDENT.					0.3								<.1	1
Oreaster reticulatus	0.3				3.7	28.0	4.3	0.7					2.4	5
ASTEROIDEA UNIDENT.	14.7	52.3	1.2	9.0	3.7	5.4	0.4	13.6	0.4		0.5	2.0	5.6	11
OPHIUROIDEA														
OPHIUROIDEA UNIDENT.												0.9	0.1	1
ECHINOIDEA														
Diadema antillarum			0.4										<.1	1
Meoma ventricosa								0.3					<.1	1
MELLITIDAE UNIDENT.	0.5	618.9		5.8	5.7	13.6		1.7	0.7			0.3	23.2	8
Clypeaster UNIDENT.		0.7										1.7	0.2	2
ECHINACEA UNIDENT.												0.6	<.1	1
HOLOTHUROIDEA														
Isostichopus badionotus	0.5	1.4	0.4	2.9	1.7	3.9	0.4	0.3	0.9				0.8	9
HOLOTHUROIDEA UNIDENT.	1.8		4.2	2.2	1.0	3.9		0.7	2.9				1.3	7
CRINOIDEA														
**COMATULIDA UNIDENT.										5.8		29681	2431.6	2
CNIDARIA														
HYDROIDA														
HYDROIDA UNIDENT.	48.6	15.6	62.8	1.1	6.4	14.7		13.2	4.9	11.4		1.4	13.4	10
ZOANTHARIA														
Solenastrea hyades	13.5		1.7	15.2	0.7								2.4	4
Mussa angulosa				1.8	0.3								0.1	2
SCLERACTINIA UNIDENT.				5.1	0.7								0.4	2
ACTINIARIA UNIDENT.	0.5		0.4			0.4				0.6			0.2	4
Madracis UNIDENT.										0.4			0.1	1
ALCYONARIA														
Pterogorgia guadalupensis	118.2		3.3	1.1		0.4	16.2						12.0	5
**GORGONACEA UNIDENT.	28237	4571.1	30537	156843	86556	707.0	54215	565.9	161.6	0.1			23620	10
Thesea UNIDENT.										0.1			<.1	1
***Ellisella* UNIDENT.							1.3		0.2	11.0		2613.0	215.8	4
PORIFERA														
Ircinia strobilina	51.1	19.0	70.7	5.1	27.5	62.1	42.2		62.0	4.2	0.7		26.7	10
***Ircinia campana*	404.7	50.9	170.0	30.0	8.7	4.7	143.7	4.4	69.1	9.5	1.3		67.2	11

Table 3.2-2 (cont'd)

Taxon	Station 52	44	51	45	47	19	55	7	21	29	23	36	Overall Density	Frequency
MOLLUSCA														
BIVALVIA														
Atrina UNIDENT.		52.3											1.8	1
GASTROPODA														
Strombus UNIDENT.		12.2			0.3	0.4							0.5	3
CEPHALOPODA														
TEUTHOIDEA UNIDENT.								0.3				0.9	0.1	2
XIPHOSURA														
Limulus polyphemus					0.3								<.1	1
CRUSTACEA														
BRACHYURA														
Calappa UNIDENT.		0.7	0.4										<.1	2
PORTUNIDAE UNIDENT.		0.7				0.7							0.1	2
ANOMURA														
PAGURIDAE UNIDENT.	0.3	5.4			0.3						1.1		0.4	4
PALINURA														
Scyllarides UNIDENT.									0.2				<.1	1
Panulirus argus									0.2		0.2		<.1	2

** Estimate based on individual counts and range estimates. See text for explanation.

Table 3.2-3 Mean and overall densities (no. per hectare) of fishes seen on UTV, by station.

Taxon	Station 52	44	51	45	47	19	55	7	21	29	23	36	Overall Density	Frequency
ORECTOLOBIDAE														
Ginglymostoma cirratum										0.1			<.1	1
RHINOBATIDAE														
Rhinobatos lentiginosus				0.4									<.1	1
CLUPEIDAE														
CLUPEIDAE UNIDENT.	2.0												0.2	1
SYNODONTIDAE														
Synodus intermedius	0.3		0.4	0.4					0.4			0.3	0.1	5
SYNODONTIDAE UNIDENT.	0.3					0.7						0.6	0.1	3
Synodus UNIDENT.	0.5											4.0	0.4	2
Trachinocephalus myops												0.3	<.1	1
Synodus poeyi												7.5	0.6	1
OGCOCEPHALIDAE														
Ogcocephalus corniger												0.6	<.1	1
SCORPAENIDAE														
SCORPAENIDAE UNIDENT.	0.3	0.7										0.9	0.1	3
PERCIFORMES														
PERCIFORMES UNIDENT.	0.3			0.7		4.3							0.3	3
SERRANIDAE														
Diplectrum formosum				0.7									<.1	1
Mycteroperca interstitialis				0.4									<.1	1
Epinephelus guttatus				0.4									<.1	1
Diplectrum UNIDENT.	2.8	0.7	7.5		0.7	13.3		6.8	0.4				2.1	7
Serranus subligarius						0.4							<.1	1
Epinephelus morio	19.1		11.2	1.1	2.7	2.2	0.9	1.7	12.8	1.0	2.0		5.0	10
Liopropoma eukrines						0.4				0.4			0.1	2
Epinephelus/*Mycteroperca* UNIDENT.		1.4		0.4		0.4		1.4		3.6	2.4	0.6	1.1	7
Hypoplectrus unicolor									0.4	0.1			0.1	2
Serranus UNIDENT.	0.3							0.7	1.1	46.6	10.8	2.6	9.1	6
Hemanthus UNIDENT.										294.9			46.3	1
Serranus annularis										0.3	0.2		0.1	2
Epinephelus fulvus											0.2		<.1	1
Mycteroperca phenax											0.5		0.1	1
ANTHINAE UNIDENT.									2.2	67.9	2.2	130.1	21.8	4
Serranus phoebe									3.6	8.0	16.8	10.6	4.7	4
Holanthias martinicensis												0.3	<.1	1
Serranus atrobranchus												0.9	0.1	1
Anthias UNIDENT.												7.2	0.6	1

Table 3.2-3 (cont'd)

Taxon	Station 52	44	51	45	47	19	55	7	21	29	23	36	Overall Density	Frequency
GRAMMISTIDAE														
Rypticus maculatus	0.5												<.1	1
PRIACANTHIDAE														
Pristigenys alta									0.4				<.1	1
Priacanthus UNIDENT.									0.4				<.1	1
Priacanthus arenatus							0.4		2.0		0.2	0.9	0.4	4
Priacanthus cruentatus											0.4		<.1	1
APOGONIDAE														
Apogon pseudomaculatus									0.5		0.2		0.1	2
MALACANTHIDAE														
Malacanthus UNIDENT.												0.3	<.1	1
ECHENEIDAE														
Echeneis naucrates	0.3												<.1	1
CARANGIDAE														
Caranx ruber	4.3												0.4	1
Caranx hippos	1.0												0.1	1
Caranx bartholomaei	0.3												<.1	1
Caranx crysos	17.3	5.4	10.0	4.7	0.7	2.5			2.7				3.2	7
Decapterus punctatus		24.4	1.7	1.4					4.5		911.7		118.2	5
Decapterus UNIDENT.								10.5	180.3				24.0	2
Seriola dumerili	1.0					0.4			4.7	4.3	1.5		1.6	5
CARANGIDAE UNIDENT.										0.1			<.1	1
EMMELICHTHYIDAE														
Inermia vittata										97.3	2.7		15.6	2
LUTJANIDAE														
Lutjanus apodus				0.4	1.7								0.1	2
Lutjanus griseus	0.3						6.4						0.4	2
Lutjanus synagris	3.6	1.4	0.8	0.7	1.0	0.7	0.4		0.2				0.6	8
Lutjanus mahogoni						0.7							<.1	1
Lutjanus UNIDENT.	0.8	3.4							0.2		0.7		0.3	4
GERREIDAE														
Eucinostomus UNIDENT.			1.7										0.1	1
HAEMULIDAE														
Orthopristis chrysoptera	13.2		0.4										1.2	2
Haemulon UNIDENT.		1.4	0.4	0.7		0.4							0.1	4
Anisotremus virginicus	2.8		0.4				0.4						0.3	3
Haemulon plumieri	278.4	1.4	248.2	4.3	13.1	36.9	4.3	0.3					43.3	8
Haemulon aurolineatum	0.3	9.5	1.7	4.3	1.3	3.2		13.6	5.0				2.6	8

Table 3.2-3 (cont'd)

Taxon	52	44	51	45	47	19	55	7	21	29	23	36	Overall Density	Frequency
	Station													
SPARIDAE														
Archosargus probatocephalus	4.1												0.4	1
Calamus UNIDENT.	6.1		1.7	4.3	0.3	5.0	4.7	1.4	8.1	0.3	0.9		2.8	10
SCIAENIDAE														
Equetus UNIDENT.				5.4									0.3	1
Equetus lanceolatus	10.9	3.4	7.9		8.7	3.9		15.9			12.2		5.1	7
Equetus umbrosus			10.8		2.7						0.4		0.8	3
MULLIDAE														
Pseudupeneus maculatus							0.4						<.1	1
Mulloidichthys martinicus								0.3					<.1	1
MULLIDAE UNIDENT.												0.3	<.1	1
EPHIPPIDAE														
Chaetodipterus faber	1.0			0.4									0.1	2
CHAETODONTIDAE														
Chaetodon UNIDENT.				0.4									<.1	1
Pomacanthus arcuatus			2.1	1.8	0.3	2.9	3.4		0.9	0.3	0.7		0.9	8
Pomacanthus UNIDENT.	0.5					0.4					0.4		0.1	3
Holacanthus UNIDENT.			1.2			2.2			0.2	0.3			0.3	4
Holacanthus ciliaris				1.4						0.4			0.2	2
Holacanthus bermudensis						0.7	2.1	3.1	4.0	1.6	2.9		1.5	6
Chaetodon sedentarius	0.5	0.7				1.8	0.9	0.3	6.0	15.1	5.3	0.3	4.1	9
CHAETODONTIDAE UNIDENT.								0.3	0.2	0.1			0.1	3
Chaetodon aculeatus							4.7				0.4		0.3	2
Holacanthus tricolor										5.0			0.8	1
Chaetodon ocellatus										0.3	0.4		0.1	2
Chaetodon aya												5.5	0.4	1
POMACENTRIDAE														
Pomacentrus UNIDENT.			1.2										0.1	1
Pomacentrus variabilis						0.4							<.1	1
Pomacentrus partitus					1.3					12.5			2.1	2
Chromis UNIDENT.					0.3				2.3	1.9			0.6	3
Chromis enchrysurus									114.0	518.0	221.0		124.3	3
POMACENTRIDAE UNIDENT.									0.4	3.7	0.5		0.7	3
Pomacentrus leucostictus										3.9			0.6	1
Chromis scotti										133.1			20.9	1
Chromis insolatus										0.6	2.4		0.4	2
SPHYRAENIDAE														
Sphyraena barracuda						0.4							<.1	1

Table 3.2-3 (cont'd)

Taxon	52	44	51	45	47	19	55	7	21	29	23	36	Overall Density	Frequency
	Station													
LABRIDAE														
Lachnolaimus maximus	38.7	0.7	6.7	1.4			0.4						4.1	5
Halichoeres caudalis						2.9					0.2		0.2	2
Halichoeres UNIDENT.	1.0								2.0	0.1	21.7		3.1	4
Bodianus pulchellus										8.5	0.4		1.4	2
BOTHIDAE														
Bothus UNIDENT.								0.3	0.4			0.3	0.1	3
BALISTIDAE														
Monacanthus ciliatus	0.3												<.1	1
Aluterus scriptus			0.4										<.1	1
Monacanthus UNIDENT.	0.5				0.3	0.7							0.1	3
Cantherhines macrocerus			0.4			0.4							<.1	2
Aluterus schoepfi	1.8		0.4					0.3					0.2	3
Aluterus UNIDENT.	0.5							0.3					0.1	2
Monacanthus hispidus						0.4							<.1	1
Cantherhines pullus						0.4							<.1	1
BALISTIDAE UNIDENT.						0.4							<.1	1
Balistes capriscus	0.3		0.4			0.4				0.1	0.9		0.2	5
OSTRACHIDAE														
Lactophrys UNIDENT.	0.3		0.8				0.4			0.3			0.1	4
Lactophrys quadricornis	1.8	2.0	0.8	1.1		1.1			0.2	0.1	0.2		0.5	8
TETRAODONTIDAE														
TETRADONTIDAE UNIDENT.	0.3												<.1	1
Sphoeroides UNIDENT.			0.4						0.2				<.1	2
Sphoeroides spengleri	0.8										0.2		0.1	2
DIODONTIDAE														
Chilomycterus schoepfi		0.7											<.1	1
Diodon UNIDENT.								0.3	0.2	0.1			0.1	3
HOLOCENTRIDAE														
Holocentrus UNIDENT.									0.4	0.1			0.1	2
HOLCENTRIDAE UNIDENT.									0.2	0.6	0.2		0.1	3
Holocentrus rufus							0.4		0.2		0.2	0.3	0.1	4
SYNGNATHIDAE														
Hippocampus UNIDENT.						0.4							<.1	1
GOBIIDAE														
Ioglossus calliurus						3.2		41.4	10.6				4.4	3
Number of fish taxa :	40	15	26	23	14	33	15	18	36	37	35	21		
Number of fish families :	18	10	14	13	9	16	10	11	17	12	15	10		
Total number of fish taxa :	116													
Total number of fish families :	34													

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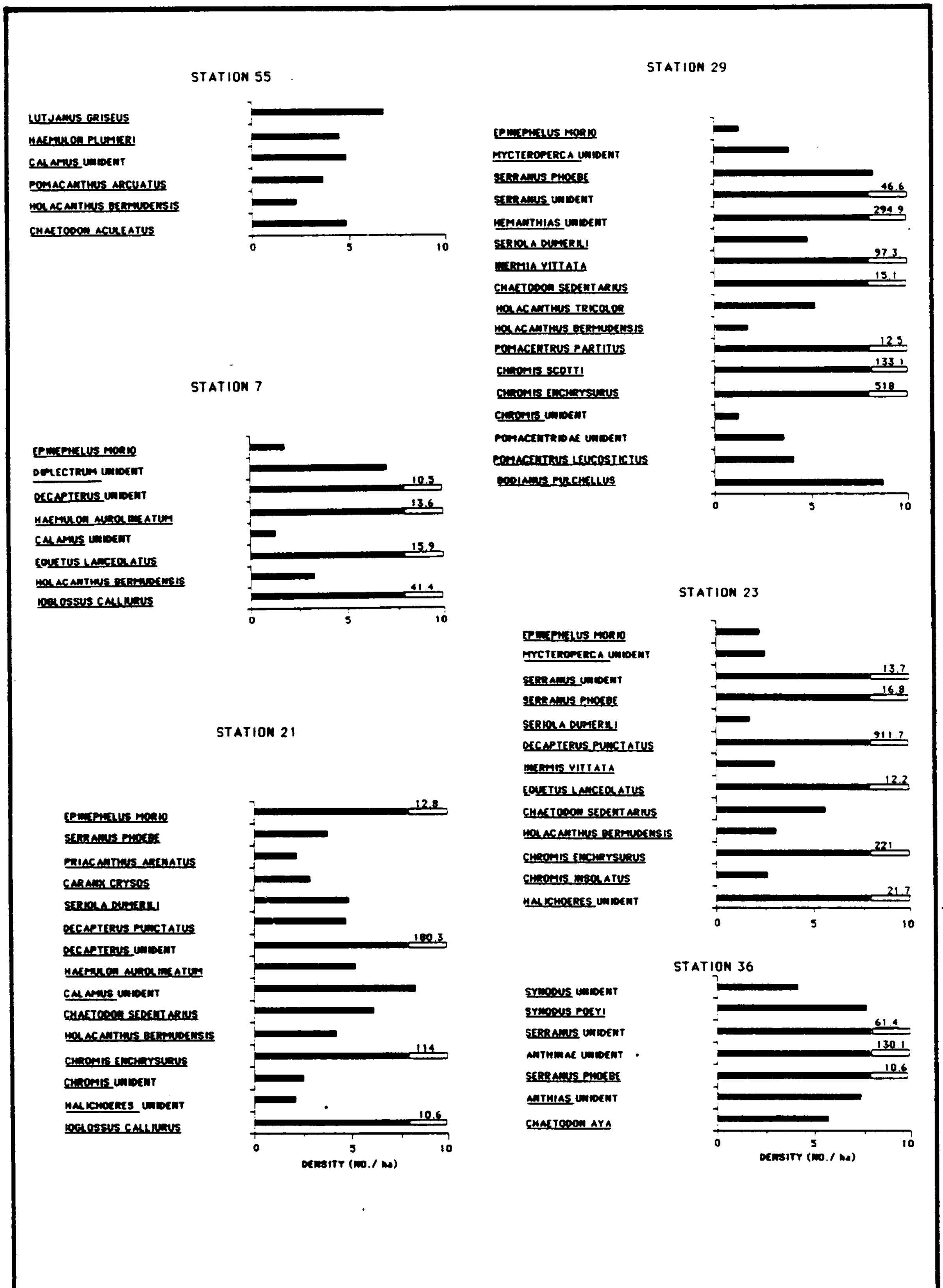

Figure 3.2-3 OVERALL DENSITY OF NUMERICALLY DOMINANT (≥1/ha) FISHES SURVEYED WITH UTV, FOR ALL CRUISES TOGETHER, BY STATION

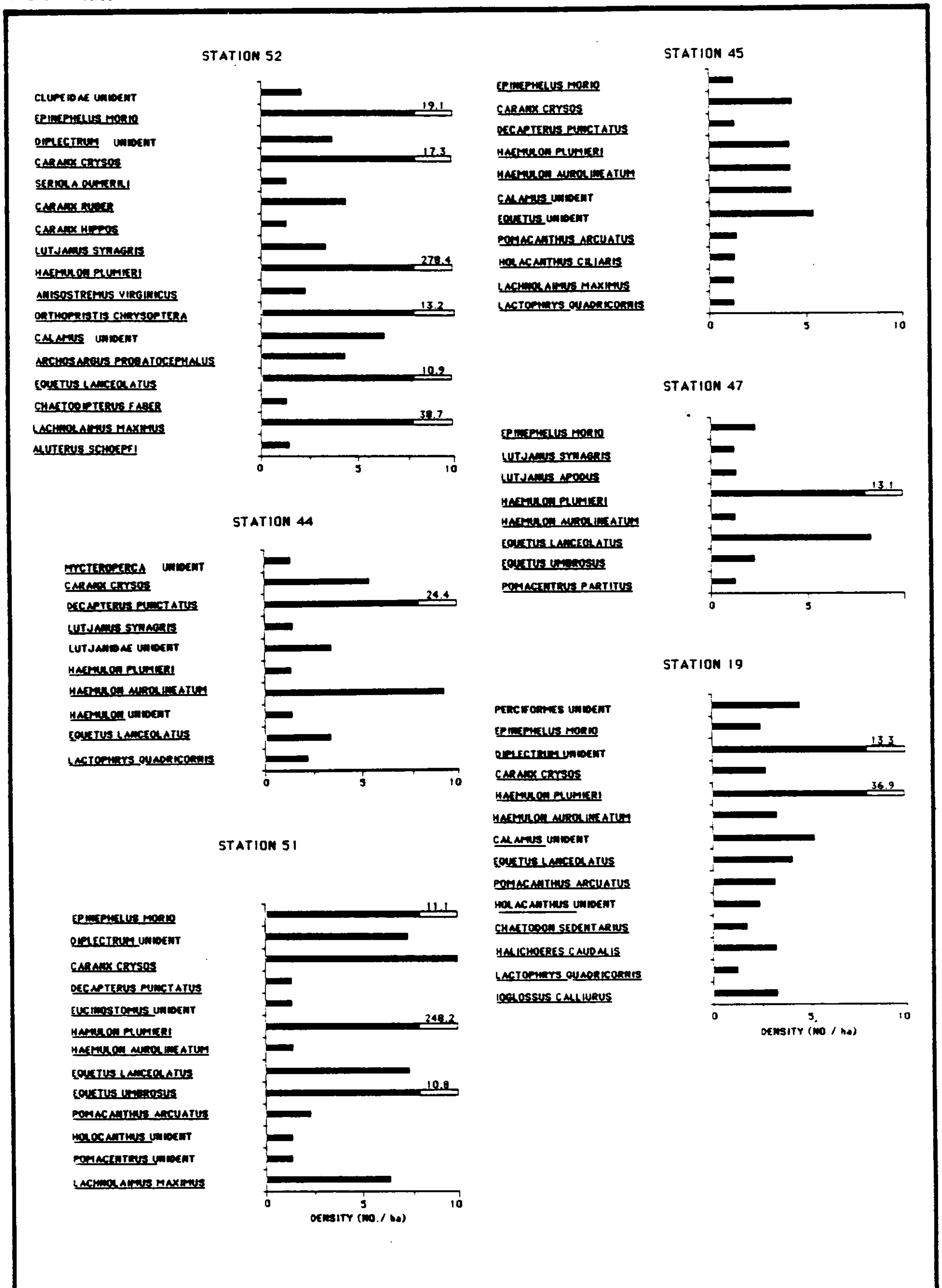

Figure 3.2-3 (cont'd)

The only visible substrate type on all cruises at Station 52 was sand. Sponges and gorgonians were the most abundant invertebrates on most cruises (Table 3.2-1). Average cover by demosponges ranged from 2% to 17%. The sponge *Ircinia campana* ranged from 227 to 542/ha, and *Ircinia strobilina* ranged from 10 to 128/ha. Gorgonian densities ranged from 10,108 to 69,107/ha. Asteroids were also abundant on all cruises, ranging from 3 to 42/ha. Despite the changes from cruise to cruise in the mean abundances of benthic organisms observed on underwater television at Station 52, none of the differences in density or percentage cover was statistically significant.

Pronounced seasonal blooms were noted in some of the more ephemeral organisms, such as algae and hydroids. Algae covered more than a third of the bottom on two cruises. Based on high-resolution benthic photography survey results (see below), these are believed to have been species of the brown alga *Dictyopteris*.

Algal coverage was lowest in the spring, very high in the summer and early fall, and intermediate in the late fall and winter. Values were less than 2% on Cruise 3 (May 1984), and 12% on Cruise 6 (March 1985), but averaged 24% on Cruise 1 (December 1983), 48% on Cruise 4 (August 1984), and 37% on Cruise 7 (June/July 1985). Late fall and winter coverage was 17 percent to 18% (Cruises 5 and 8, December 1984 and September 1985, respectively). Hydroids also bloomed in spring, achieving their highest densities on Cruises 3 and 6 (67 and 175/ha, respectively).

Many fishes at Station 52 were common on every cruise surveyed. Such species included the red grouper, *Epinephelus morio* (density range from 6 to 60/ha); the white grunt, *Haemulon plumieri* (8 to 618/ha); and the jackknife-fish, *Equetus lanceolatus* (3 to 35/ha). The hogfish, *Lachnolaimus maximus*, was not seen on Cruise 5, but was seen on all other cruises surveyed (2 to 135/ha). For most numerically dominant species

(*Diplectrum*, *Cabanx crysos*, *Lutjanus synagris*), there were no statistically significant differences in abundance between cruises ($p > 0.05$).

For *Haemulon plumieri*, no clear seasonal trends could be deduced, due to overlapping confidence intervals for mean densities. The greatest number of individuals was collected on Cruise 4 (August 1984), and the fewest on Cruise 5 (December 1984). However, only on Cruise 5 were there significant differences in abundance ($p < 0.05$) from all other cruises. Although the density of *Haemulon plumieri* was highest on Cruise 4, it did not differ significantly from densities on Cruise 1 (December 1983), Cruise 3 (May 1984), Cruise 6 (March 1985), Cruise 7 (June/July 1985), or Cruise 8 (September 1985).

For *Lachnolaimus maximus*, the results suggested lower densities in spring compared to summer, fall, and winter. The greatest densities were observed on Cruises 7 and 8; however, these did not differ statistically from one another, nor from Cruise 1 or Cruise 4. Densities were significantly lower on Cruises 3 and 6 than on all other cruises.

For *Epinephelus morio*, the results suggested higher densities in summer and fall than in spring and winter. Cruises 7 and 8 (higher densities) differed significantly from Cruises 3, 5, and 6 (lower densities), but Cruises 1 and 4 (intermediate densities) statistically overlapped both Cruises 7 and 8, and Cruises 3, 5, and 6.

For *Equetus lanceolatus*, overlapping confidence limits obscured any seasonal trends that might have been present. Mean density was highest on Cruise 7, but it did not differ significantly from densities on any other cruise except for Cruise 3 (lowest density).

On the other hand, quite a few fishes were abundant on only one or two cruises. Striking examples included the pigfish, *Orthopristis* *chrysoptera* (59/ha on Cruise 4); the blue runner, *Caranx crysos* (75 /ha on Cruise 4); and the lane snapper, *Lutjanus synagris* (37/ha on Cruise 8). Cruises 4 (August 1984) and 8 (September 1985) seemed particularly "rich," both in terms of numbers of fish species identified and in numbers of individuals for many species. This observation cannot be attributed simply to sample size; even though Cruise 4 ranked second in area transected (7,640 m^2), Cruise 8 ranked fifth in area transected (3,562 m^2) (Table 2.2-2). Furthermore, during Cruise 3, when the largest area was surveyed (9,267 m^2), there were fewer than half of the fish taxa identified on Cruise 4.

Triangular Dredge Results

A total of 109 invertebrates (excluding sponges) was identified in 12 triangular dredge samples from Station 52 (Table 3.2-4). Dredge samples confirmed underwater television evidence that the bottom at Station 52 was mainly unconsolidated sediment and gorgonian beds overlying low-profile hard substrate, with some isolated coral heads. Only three scleractinians were taken: the lobed star coral *Solenastrea hyades*; the ahermatypic coral *Phyllangia americana*; and the smooth starlet coral, *Siderastrea siderea*.

Most of the common gorgonian genera in Florida were represented (e.g., *Pseudoplexaura*, *Leptogorgia*, *Plexaurella*, *Muricea*, *Pterogorgia*, *Eunicea*) among the 13 species collected. *Pseudoplexaura fusifera* and *Leptogorgia medusae* were unique to Station 52, not having been collected at any other station during Years 4 or 5.

A very rich molluscan fauna was found at Station 52. Twenty-four gastropods were collected. Larger species included the queen conch, *Strombus gigas*; the Florida fighting conch, *Strombus alatus*; the banded tulip shell, *Fasciolaria lilium* (= *Fasciolaria distans*); the horse conch, *Pleuroploca gigantea*; the West Indian murex, *Murex brevifrons*, the lace murex, *M. florifer*; and the measled cowry, *Cypraea zebra*. Numerous

Table 3.2-4 Presence (+) and frequency of benthic invertebrates collected by dredging, for all cruises together, by station.

Taxon	Station 52	44	51	45	47	19	55	7	21	29	23	36	All	Frequency
Number of reps:	12	6	6	6	6.	6	12	12	9	12	12	12	111	
CNIDARIA														
ALCYONARIA														
<u>Pseudoplexaura</u> <u>fusifera</u>	+													1
<u>Leptogorgia</u> <u>virgulata</u>		+												1
<u>Leptogorgia</u> <u>medusae</u>	+													1
<u>Lophogorgia</u> <u>hebes</u>		+												1
<u>Plexaurella</u> <u>pumila</u>	+			+										2
<u>Pseudoplexaura</u> <u>wagenaari</u>	+			+										2
<u>Pseudopterogorgia</u> <u>rigida</u>				+										1
<u>Leptogorgia</u> <u>setacea</u>				+										1
<u>Muricea</u> <u>elongata</u>	+	+		+			+							4
<u>Eunicea</u> <u>asperula</u>	+	+		+	+		+							5
<u>Plexaurella</u> <u>nutans</u>	+			+			+							3
<u>Pterogorgia</u> <u>guadalupensis</u>	+	+		+	+	+	+							6
<u>Pseudoplexaura</u> <u>porosa</u>	+			+	+		+							4
<u>Eunicea</u> UNIDENT.	+			+	+		+							4
<u>Eunicea</u> <u>knighti</u>	+						+							2
<u>Plexaurella</u> <u>fusifera</u>	+						+							2
<u>Eunicea</u> <u>calyculata</u>	+						+							2
<u>Plexaurella</u> <u>fusca</u>			+				+							2
<u>Eunicea</u> <u>fusca</u>				+			+							2
<u>Muricea</u> <u>pinnata</u>				+			+							2
<u>Pseudopterogorgia</u> <u>acerosa</u>				+	+	+	+							4
<u>Plexaurella</u> <u>dichotoma</u>					+		+							2
<u>Lophogorgia</u> <u>punicea</u>						+	+							2
<u>Eunicea</u> <u>tourneforti</u> forma <u>atra</u>							+							1
<u>Plexaura</u> <u>flexuosa</u>							+							1
<u>Plexaura</u> <u>homomalla</u>							+							1
<u>Eunicea</u> <u>pinta</u>							+							1
<u>Pterogorgia</u> <u>citrina</u>							+							1
<u>Pterogorgia</u> <u>anceps</u>							+							1
<u>Iciligorgia</u> <u>schrammi</u>							+							1
<u>Lophogorgia</u> <u>barbadensis</u>							+							1
<u>Muriceopsis</u> <u>flavida</u>							+							1
<u>Muricea</u> <u>pendula</u>							+							1
<u>Pseudoplexaura</u> <u>crusis</u>							+							1
<u>Pseudoplexaura</u> <u>flagellosa</u>							+							1
<u>Muricea</u> <u>laxa</u>							+							1
<u>Eunicea</u> <u>clavigera</u>							+							1
<u>Eunicea</u> <u>laciniata</u>							+							1
<u>Eunicea</u> <u>succinea</u> forma <u>plantaginea</u>							+							1
<u>Pseudopterogorgia</u> <u>americana</u>							+							1
<u>Eunicea</u> <u>palmeri</u>							+							1
<u>Eunicea</u> <u>laxispica</u>							+							1
<u>Plexaurella</u> <u>grisea</u>							+							1
<u>Nicella</u> <u>schmitti</u>							+				+			2
<u>Thesea</u> UNIDENT.										+		+		2
Caliacis nutans												+		1
<u>Thesea</u> <u>parviflora</u>												+		1
<u>Ellisella</u> <u>barbadensis</u>												+		1
<u>Ellisella</u> <u>elongata</u>												+		1
<u>Nidallia</u> <u>occidentalis</u>												+		1
Number of taxa:	13	5	1	13	6	3	36	0	0	1	1	6	50	
ZOANTHARIA														
<u>Porites</u> <u>divaricata</u>				+										1
<u>Isophyllia</u> <u>multiflora</u>				+										1
<u>Solenastrea</u> <u>hyades</u>	+	+		+	+		+	+						6
<u>Phyllangia</u> <u>americana</u>	+	+					+	+						4
<u>Cladocora</u> <u>arbuscula</u>		+		+	+		+	+						5
<u>Siderastrea</u> <u>siderea</u>	+	+		+	+		+	+	+					7
<u>Meandrina</u> <u>meandrites</u>							+							1
<u>Dichocoenia</u> <u>stokesii</u>							+							1

Table 3.2-4 (cont'd)

Taxon	Station 52	44	51	45	47	19	55	7	21	29	23	36	All	Frequency
ZOANTHARIA (continued)														
Oculina UNIDENT.							+							1
Solenastrea bournoni							+	+						2
Oculina diffusa		+					+	+	+					4
Stephanocoenia michelini				+			+	+	+					4
Mussa angulosa				+			+	+	+					4
Scolymia lacera				+				+	+					3
Cladocora debilis								+						1
Isophyllia sinuosa								+						1
Oculina varicosa							+	+	+					3
Agaricia lamarcki				+			+			+				3
Scolymia UNIDENT.							+	+	+	+				4
Madracis decactis							+			+				2
Agaricia fragilis							+			+				2
Helioseris cucullata							+			+				2
Montastrea cavernosa							+			+				2
Manicina areolata								+		+				2
Agaricia agaricites										+				1
Porites astreoides										+				1
Madracis formosa										+				1
Madracis mirabilis										+				1
Madracis asperula										+	+			2
Paracyathus pulchellus												+		1
Javania caillati												+		1
Coenosmilia arbuscula												+		1
Madrepora carolina												+		1
Flabellum fragile												+		1
Balanophyllia UNIDENT.												+		1
Dendrophyllia cornucopia												+		1
Number of taxa:	3	5	0	9	3	0	18	14	7	12	1	7	37	
MOLLUSCA														
GASTROPODA														
Terebra sp. 1	+													1
Crepidula fornicata	+													1
Polystira UNIDENT.	+													1
Latirus infundibulum	+													1
Crepidula convexa	+													1
Cancellaria reticulata		+												1
Crepidula maculosa	+	+												2
Lucapina sowerbii	+	+												2
Pisania tincta	+													1
Cantharus cancellarius	+													1
Cerithium algicola	+													1
Terebra dislocata	+			+										2
Crepidula plana	+		+	+										3
Murex pomum			+											1
Cerithium atratum				+										1
FASCIOLARIIDAE UNIDENT.				+										1
Ocenebra interfossa				+										1
Latirus angulatus				+										1
Diodora cayenensis	+	+				+								3
Diodora listeri	+			+			+							3
Crepidula aculeata	+	+		+	+	+	+							6
Strombus gigas	+			+	+		+							4
Conus jaspideus stearnsi					+									1
Pseudostomatella erythrocoma					+									1
Cypraea zebra	+						+							2
Strombus pugilis		+				+	+							3
Oliva sayana	+						+	+						3
Strombus alatus	+						+	+						3
Oliva reticularis						+								1
Vexillum gemmatum							+							1
Conus floridanus							+							1

Table 3.2-4 (cont'd)

Taxon	Station 52	44	51	45	47	19	55	7	21	29	23	36	All	Frequency
GASTROPODA (continued)														
Cerodrillia perryae							+							1
Mitra nodulosa							+							1
Conus spurius							+	+						2
Murex cabritii							+	+						2
Vermicularia knorri	+								+					2
Strombus costatus				+					+					2
Latirus cariniferus				+					+					2
Trivia pediculus				+					+					2
Drillia UNIDENT.								+						1
Calliostoma jujubinum								+						1
Murex brevifrons	+				+	+					+			4
Phalium granulatum					+				+					2
Calliostoma javanicum						+			+					2
Murex florifer	+			+				+	+		+			5
Pleuroploca gigantea	+										+			2
Astraea phoebia				+							+			2
Cypraea cinerea							+			+				2
Crassispira tampaensis									+					1
Polystira albida									+					1
Scaphella junonia									+					1
Conus villepini									+					1
Xenophora conchyliophora									+					1
Serpulorbis decussatus									+					1
Calliostoma pulchrum									+					1
Distorsio clathrata							+				+			2
Turbo castanea								+			+			2
Fasciolaria lilium	+					+		+				+		4
Cypraea UNIDENT.										+				1
Conus daucus										+				1
Siliquaria squamata										+	+			2
Haliotis pourtalesii											+			1
Sthenorytis pernobilis												+		1
Number of taxa:	24	6	2	14	6	7	15	9	14	4	8	2	64	
BIVALVIA														
Anadara UNIDENT.	+													1
Lioberus castaneus	+													1
Ostrea permollis	+													1
Pinctada radiata	+													1
Solen obliquus	+													1
Chlamys UNIDENT.	+													1
Barbatia candida		+												1
Barbatia tenera	+													1
Chama florida	+													1
Chama sp. 1	+													1
Arca zebra	+	+		+										3
Pinctada imbricata	+	+	+	+										4
Pteria UNIDENT.	+			+										2
Pteria colymbus	+		+	+										3
Anadara notabilis	+	+		+	+									4
Lithophaga aristata				+										1
Barbatia domingensis				+										1
Spondylus ictericus				+	+									2
Arca imbricata				+	+									2
Arcinella cornuta		+				+								2
Chione cancellata	+					+								2
Lithophaga bisulcata	+	+		+				+						4
Arcinella UNIDENT.					+									1
Aequipecten acanthodes					+	+								2
Chione paphia					+	+								2
Laevicardium laevigatum					+	+	+							3
Tellina aequistriata						+								1
Spondylus americanus	+		+	+			+	+	+					6

Table 3.2-4 (cont'd)

Taxon	52	44	51	45	47	19	55	7	21	29	23	36	All	Frequency
	Station													
BIVALVIA (continued)														
Chama macerophylla	+			+					+					3
Lima scabra							+							1
Lima lima							+							1
Arca secticostata							+							1
Lima pellucida							+							1
Aequipecten gibbus						+	+	+						3
Macrocallista maculata						+	+	+						3
Pecten ziczac							+	+						2
Trachycardium isocardia								+						1
Semele bellastriata								+						1
Tellina alternata								+						1
Chione latilerata								+						1
Aequipecten muscosus						+	+	+			+			4
Eucrassatella speciosa								+	+					2
Chama congregata	+										+			2
Periglypta listeri									+					1
Pododesmus UNIDENT.									+					1
Nemocardium peramabile									+					1
Arca UNIDENT.										+				1
Chlamys benedicti											+			1
PECTINIDAE UNIDENT.											+			1
Number of taxa:	19	6	3	12	7	9	10	11	6	1	4	0	51	
CEPHALOPODA														
Octopus UNIDENT.	+						+							2
Number of taxa:	1	0	0	0	0	0	1	0	0	0	0	0	1	
CRUSTACEA														
ISOPODA														
FLABELLIFERA UNIDENT.				+										1
Paracerceis caudata		+		+		+								3
Number of taxa:	0	1	0	2	0	1	0	0	0	0	0	0	2	
PENAEIDEA														
Penaeus setiferus		+												1
Penaeus duorarum	+													1
Penaeus aztecus		+	+											2
Sicyonia laevigata	+				+	+								3
Metapenaeopsis goodei			+					+						2
Sicyonia typica					+			+						2
Solenocera atlantidis								+						1
Parapenaeus politus									+					1
Sicyonia brevirostris									+					1
Number of taxa:	2	2	2	0	2	1	0	3	2	0	0	0	9	
CARIDEA														
PALAEMONIDAE UNIDENT.		+												1
Periclimenaeus caraibicus	+													1
Hippolyte UNIDENT.	+													1
ALPHEIDAE UNIDENT.		+												1
Periclimenes americanus	+			+				+						3
Synalpheus minus	+		+	+			+		+					5
Synalpheus fritzmuelleri						+								1
Synalpheus brooksi							+							1
Leptochela serratorbita							+							1
Alpheus normanni				+	+				+					3
Alpheus floridanus								+						1
Leptochela carinata								+						1
Leptochela papulata								+						1
Synalpheus townsendi	+		+	+		+	+	+	+	+	+			9
Synalpheus longicarpus	+						+	+			+			4
Anchistioides antiguensis	+										+			2
Lysmata rathbunae										+				1
Synalpheus goodei											+			1
Palaemonetes intermedius											+			1
Number of taxa:	7	2	2	4	1	2	5	6	3	2	5	0	19	
STENOPODIDEA														
Stenopus scutellatus									+					1
Number of taxa:	0	0	0	0	0	0	0	0	1	0	0	0	1	

Table 3.2-4 (cont'd)

Taxon	Station 52	44	51	45	47	19	55	7	21	29	23	36	All	Frequency
PALINURA														
Scyllarus chacei								+						1
Scyllarus americanus								+						1
Scyllarides nodifer									+					1
Number of taxa:	0	0	0	0	0	0	0	2	1	0	0	0	3	
ANOMURA														
Petrolisthes UNIDENT.	+													1
Porcellana sayana	+													1
Megalobrachium soriatum	+	+		+										3
Paguristes tortugae	+			+										2
Petrolisthes galathinus	+	+	+	+	+	+	+							7
Paguristes sericeus	+	+		+	+	+	+	+	+					8
Paguristes moorei						+								1
Paguristes triangulatus							+							1
Pachycheles rugimanus							+							1
Paguristes lymani							+							1
Pagurus carolinensis								+						1
Upogebia affinis								+						1
Pagurus longicarpus								+						1
Pagurus arcuatus								+						1
Pagurus defensus							+		+					2
Dardanus fucosus							+	+	+		+			4
Pagurus acadianus								+			+			2
Galathea rostrata									+		+			2
Pagurus impressus						+						+		2
Munida pusilla									+	+	+	+		4
Manucomplanus corallinus								+				+		2
Munida UNIDENT.												+		1
Pagurus politus												+		1
Cancellus ornatus												+		1
Number of taxa:	6	3	1	4	2	4	7	8	5	1	4	6	24	
BRACHYURA														
Portunus gibbesii	+													1
Euryplax nitida	+													1
Panopeus turgidus	+													1
Pilumnus lacteus	+													1
Portunus depressifrons		+												1
Panoplax depressa	+													1
Hypoconcha arcuata		+												1
Mithrax hispidus	+		+	+										3
Mithrax furceps				+										1
Pilumnus floridanus				+										1
Pilumnus dasypodus	+		+	+	+	+								5
Lobopilumnus agassizi				+	+									2
Calappa sulcata		+				+								2
Pitho lherminieri	+					+								2
Mithrax forceps		+		+			+							3
Pilumnus sayi	+	+		+	+	+		+						6
Portunus spinimanus					+									1
Metoporhaphis calcarata					+									1
Homola UNIDENT.					+									1
Panopeus occidentalis	+						+							2
Hypoconcha sabulosa	+			+	+			+						4
Pilumnus pannosus			+				+							2
Portunus anceps		+			+			+						3
Macrocoeloma camptocerum	+				+	+		+						4
Pitho UNIDENT.			+		+			+						3
Portunus floridanus	+							+						2
Mithrax pleuracanthus	+	+		+	+	+	+	+	+					8
Portunus UNIDENT.						+								1
Dromidia antillensis	+			+	+			+	+					5
Iliacantha intermedia					+	+	+	+						4
Macrocoeloma trispinosum	+			+	+		+	+	+					6

Table 3.2-4 (cont'd)

Taxon	Station 52	44	51	45	47	19	55	7	21	29	23	36	All	Frequency
BRACHYURA (continued)														
Dissodactylus crinitichelis							+							1
Cycloes bairdii							+							1
Macrocoeloma UNIDENT.							+							1
Micropanope nuttingi							+	+						2
Eurypanopeus abbreviatus								+						1
Aepinus septemspinosus								+						1
Speocarcinus carolinensis								+						1
Ranilia muricata								+						1
Mithrax holderi								+						1
Symethis variolosa								+						1
Raninoides loevis								+						1
Collodes trispinosus								+						1
Osachila semilevis								+						1
Calappa flammea					+			+	+					3
Podochela sidneyi	+	+	+		+		+					+		6
Stenorynchus seticornis	+	+			+	+	+	+	+			+		8
Callidactylus asper								+	+					2
Parthenope granulata								+	+					2
Mithrax UNIDENT.	+										+			2
Raninoides louisianensis									+					1
Speloeophorus nodosus									+					1
Paractaea rufopunctata nodosa							+	+	+	+	+			5
Mithrax acuticornis							+	+	+	+	+			5
Portunus ordwayi							+		+		+			3
Stenocionops furcata						+	+	+	+			+		5
Microphrys UNIDENT.										+				1
Podochela riisei					+							+		2
Euchirograpsus americanus											+			1
Palicus faxoni											+			1
Nibilia antilocapra											+			1
Macrocoeloma eutheca											+			1
Pyromaia UNIDENT.											+			1
Calappa angusta								+				+		2
Palicus alternatus									+		+	+		3
Portunus spinicarpus									+			+		2
Micropanope spinipes										+	+	+		3
Parthenope fraterculus											+	+		2
Iliacantha subglobosa											+	+		2
Parthenope pourtalesii												+		1
Anasimus UNIDENT.												+		1
Number of taxa:	19	9	5	11	18	10	16	28	15	4	13	12	71	
STOMATOPODA														
Meiosquilla schmitti							+							1
Gonodactylus bredini	+			+	+	+	+	+	+	+	+			9
Gonodactylus UNIDENT.	+					+				+	+			4
Eurysquilla plumata									+					1
Gonodactylus torus										+				1
Squilla prasinolineata											+			1
Number of taxa:	2	0	0	1	1	2	2	1	2	3	3	0	6	
ECHINODERMATA														
ASTEROIDEA														
Astropecten americanus			+											1
Echinaster UNIDENT.				+										1
Echinaster spinulosus	+	+	+	+		+		+						6
Astropecten articulatus					+									1
Astropecten comptus					+	+		+						3
Astropecten duplicatus		+	+		+	+	+	+	+					7
Luidia alternata			+		+			+	+					4
Astropecten nitidus	+								+					2
Oreaster reticulatus							+		+					2
Echinaster modestus	+										+			2
Poraniella regularis										+	+			2
Luidia barbadensis											+			1

Table 3.2-4 (cont'd)

Taxon	52	44	51	45	47	19	55	7	21	29	23	36	All	Frequency
	Station													
ASTEROIDEA (continued)														
Narcissia trigonaria											+			1
Linckia nodosa											+			1
Henricia antillarum											+			1
Tosia parva											+	+		2
Rosaster alexandri												+		1
Pectinaster gracilis												+		1
Sclerasterias contorta												+		1
Number of taxa:	3	2	4	2	4	3	2	4	4	1	7	4	20	
OPHIUROIDEA														
Ophiostigma isacanthum	+													1
Amphipholis squamata			+											1
Astrocyclus caecilia					+	+								2
Ophiolepis elegans					+		+	+						3
Ophiothrix lineata		+			+				+					3
Ophiactis sp. 1							+							1
Ophiothrix angulata	+	+	+	+	+	+		+	+	+	+			10
Ophiactis savignyi	+	+	+				+			+	+			6
Ophioderma brevispina	+	+					+	+	+	+	+			7
Ophiopsila UNIDENT.								+		+				2
Ophioderma rubicundum				+						+	+			3
Ophionereis UNIDENT.										+				1
Ophionereis reticulata										+				1
Ophionereis olivacea										+				1
Ophiactis UNIDENT.										+				1
OPHIOMYXIDAE UNIDENT.										+				1
Ophiocoma UNIDENT.										+				1
Ophiomyxa flaccida										+	+			2
Ophiothrix suensonii				+						+	+	+		4
Ophioderma UNIDENT.											+			1
Macrophiothrix UNIDENT.											+	+		2
Asteroschema nuttingii												+		1
Astroporpa annulata												+		1
OPHIURIDAE UNIDENT.												+		1
Ophiopaepale UNIDENT.												+		1
Ophiozona UNIDENT.												+		1
Ophiura UNIDENT.												+		1
Number of taxa:	4	4	3	3	4	2	4	4	3	13	8	8	27	
ECHINOIDEA														
Clypeaster rosaceus	+													1
Encope michelini		+				+								2
Encope aberrans		+			+			+						3
Clypeaster subdepressus	+	+	+		+		+	+	+					7
Lytechinus variegatus	+	+	+				+	+	+					6
Clypeaster UNIDENT.								+						1
Meoma ventricosa							+	+	+					3
Diadema antillarum		+								+				2
Arbacia punctulata	+			+			+		+	+	+			6
Eucidaris tribuloides	+						+			+	+			4
Lytechinus euerces											+			1
Lytechinus callipeplus											+			1
Stylocidaris affinis										+	+	+		3
Clypeaster ravenelii												+		1
Coelopleurus floridanus												+		1
Stylocidaris lineata												+		1
Echinolampas depressa												+		1
Number of taxa:	5	5	2	1	2	1	5	5	4	4	5	5	17	
HOLOTHUROIDEA														
Isostichopus badionotus	+			+		+								3
Thyonella pervicax						+								1
Thyonella gemmata										+				1
Number of taxa:	1	0	0	1	0	2	0	0	0	1	0	0	3	
CRINOIDEA														
COMATULIDA UNIDENT.										+		+		2
Comactina UNIDENT.												+		1
Number of taxa:	0	0	0	0	0	0	0	0	0	1	0	2	2	
Number of invertebrate taxa :	109	50	25	77	56	47	121	96	67	48	59	53	405	

smaller gastropods also were taken, including many sessile or semi-sessile forms such as slipper shells (*Crepidula maculosa*, *C. convexa*, *C. fornicata*, *C. aculeata*, *C. plana*) and limpets (*Diodora cayenensis*, *D. listeri*).

Eight gastropods were collected only at Station 52: *Crepidula convexa*, *C. fornicata*, *Cantharus cancellarius* (the cancellate cantharus), *Pisania tincta* (the tinted cantharus), *Latirus infundibulum* (the brown-lined latirus), *Cerithium algicola* (the ivory cerith), and unidentified species of *Polystira* and *Terebra*.

Nineteen bivalves were taken in the dredge. Quite a few species were those typically found attached to hard substrate, such as oysters, jewel boxes, and ark shells. Samples included the winged oyster, *Pteria colymbus*; the Atlantic pearl oyster, *Pinctada imbricata* (= *Pinctada radiata*); the Atlantic thorny oyster, *Spondylus americanus*; the Florida spiny jewel box, *Arcinella cornuta*; the leafy jewel box, *Chama macerophylla*; the little corrugated jewel box, *C. congregata*; the Florida jewel box, *C. florida*; Bale's ark, *Barbatia tenera*; the turkey wing, *Arca zebra*; and the eared ark, *Anadara nobilis*.

Eight bivalves were found only at Station 52, including unidentified species of *Anadara*, *Chlamys*, and *Pteria*; Say's chestnut mussel, *Lioberus castaneus*; *Chama florida* and an unidentified congener; the jackknife clam, *Solen obliquus*; and the sponge oyster, *Ostrea permollis*.

Many typically soft-bottom crustaceans were collected, including penaeids, carideans, and mantis shrimps. Penaeids included the pink shrimp, *Penaeus duorarum* (found only at Station 52); and a rock shrimp, *Sicyonia laevigata*. Seven caridean shrimps were collected, including several species usually associated with sponges or anemones, e.g., *Periclimenaeus caraibicus* and an unidentified *Hippolyte* (both unique to Station 52) and *P. americanus*, as well as several pistol shrimps, *Synalpheus minus*, *S. townsendi*, and *S. longicarpus*. Two stomatopods were also taken, *Gonodactylus bredeni* and an unidentified congener.

A large number of anomuran and brachyuran crabs often associated with coral reefs and sponges were found in triangular dredge samples. Among the anomurans were *Paguristes sericeus*, *P. tortugae*, *Petrolisthes galathinus* and an unidentified congener, *Porcellana sayana* (unique to Station 52), and *Megalobrachium soriatum*.

The 18 brachyurans included the arrow crab, *Stenorhynchus seticornis*; several majiid crabs (*Mithrax hispidus*, *M. pleuracanthus*, and *M. turceps*); and the lesser sponge crab, *Dromidia antillensis*. Four species of *Pilumnus* were collected, including the hairy crab, *P. sayi*, the small hairy crab, *P. lacteus*; *P. dasypodus* and *P. gibbsi*. Two portunid crabs, *Portunus gibbesi* and *P. floridanus*, also were taken. Five of the brachyurans (*Portunus gibbesi*, *Euryplax nitida*, *Panopeus turgidus*, *Pilumnus lacteus*, and *Panoplax depressa*) were found only at Station 52.

Three soft-bottom asteroids were collected in triangular dredges at Station 52: the brown spiny sea star, *Echinaster spinulosus*; the sand star, *Astropecten nitidus*; and *Echinaster modestus*. Soft-bottom echinoids included the flat sea biscuit, *Clypeaster subdepressus* and the inflated sea biscuit, *Clypeaster rosaceus* (taken only at Station 52); and the green sea urchin, *Lytechinus variegatus*. Two urchins more often seen on hard substrate were the pencil urchin, *Eucidaris tribuloides*, and the brown rock urchin, *Arbacia punctulata*.

Four ophiuroids were taken, including the thorny brittle star, *Ophiostigma isacanthum*; the angular brittle star, *Ophiothrix angulata*; Savigny's ophiactis, *Ophiactis savignyi*; and the short-spined brittle star, *Ophioderma brevispina*. Of these, only *Ophiostigma isacanthum* was unique to Station 52.

Twenty-two algae were identified in triangular dredge samples from Station 52 (Table 3.2-5). All were rhodophytes except for two green algae (Caulerpa sertularoides and Udotea flabellum) and three brown algae (Dictyota linearis, D. bartayresii, and Dictyopteris membranacea). Eleven of the red algae (two species of Gracilaria and nine unidentified forms) and Dictyota linearis were unique to Station 52.

Otter Trawl Results

Station 52 was sampled with the trawl on Cruises 2, 3, 4, 5, 6, 7, and 8 (March 1984, May 1984, August 1984, December 1984, March 1985, June/July 1985, and September 1985, respectively). Seven trawl hauls collected 498 individual fish, an average of 71 individuals per 10-minute tow (Table 3.2-6). Thirty-eight fishes were recognized, belonging to 24 families. The best represented families in terms of numbers of species present were the sparids (porgies, four species), and the serranids (groupers and basses), haemulids (grunts), and balistids (triggerfish) (three species each).

The most abundant species overall were the white grunt, Haemulon plumieri (19.1 individuals/tow); the hogfish, Lachnolaimus maximus (11/tow); the scrawled cowfish, Lactophrys quadricornis (7.1/tow); the silver jenny, Eucinostomus gula (6.1/tow); the sand perch, Diplectrum formosum; (4.6/tow); the jackknife-fish, Equetus lanceolatus (3.7/tow); the lane snapper, Lutjanus synagris (3.3/tow); and the grass porgy, Calamus arctifrons (2.9/tow). Other common species included the bandtail puffer, Sphoeroides spengleri (1.3/tow); the sand diver, Synodus intermedius, and the red grouper, Epinephelus morio (both 1.1/tow); and the fringed filefish, Monacanthus ciliatus (1/tow) (Figure 3.2-4). Overall diversity (H") and evenness (J') for fishes collected by trawling were 2.58 and 0.71, respectively, for all cruises together at Station 52.

Table 3.2-5 Presence (+) and frequency of benthic plants collected by dredging, for all cruises together, by station.

Taxon	Station 52	44	51	45	47	19	55	7	21	29	23	All	Frequency
CHLOROPHYCEAE													
Halimeda monile			+	+									2
Halimeda simulans			+		+								2
Caulerpa sertularioides	+				+	+							3
Caulerpa mexicana					+								1
Udotea cyathiformis				+		+	+						3
Udotea conglutinata			+		+	+		+					4
Codium isthmocladum				+	+		+	+					4
Udotea flabellum	+						+	+					3
Caulerpa peltata				+				+					2
Halimeda tuna				+				+					2
Halimeda discoidea				+			+	+					3
Halimeda UNIDENT.							+						1
Caulerpa taxifolia							+						1
Halimeda gracilis							+	+					2
Udotea spinulosa							+	+					2
Pseudocodium floridanum									+				1
Caulerpa racemosa v. *macrophysa*									+				1
Pseudotetraspora antillarum										+	+		2
Anadyomene menziesii										+	+		2
Number of taxa:	2	0	3	6	5	3	8	8	2	2	2	19	
PHAEOPHYCEAE													
Dictyota linearis	+												1
Dictyopteris membranacea	+		+	+									3
Dictyopteris UNIDENT.			+										1
Dictyota bartayresii	+			+	+	+			+				5
Sargassum filipendula				+				+					2
SPOROCHNACEAE UNIDENT.							+						1
Dictyota divaricata							+						1
Sargassum cf. *hystrix*				+	+				+				3
Rosenvingea intricata							+	+					2
Sporochnus bolleanus								+					1
Sargassum UNIDENT.								+					1
Dictyota cervicornis								+					1
Sporochnus pendunculatus								+	+				2
Nerstetia tropica									+				1
PHAEOPHYTA sp. 1									+				1
Lobophora variegata										+			1
PHAEOPHYTA sp. 2										+	+		2
Dictyopteris sp. 1											+		1
Number of taxa:	3	0	2	4	2	1	3	6	5	2	2	18	
RHODOPHYCEAE													
RHODOPHYTA sp. 13	+												1
Gracilaria sp. 1	+												1
Laurencia sp. 1	+												1
RHODOPHYTA sp. 8	+												1
Gracilaria foliifera	+												1
RHODOPHYTA sp. 6	+												1
RHODOPHYTA sp. 5	+												1
RHODOPHYTA sp. 4	+												1
RHODOPHYTA sp. 15	+												1
RHODOPHYTA sp. 16	+												1
RHODOPHYTA sp. 14	+												1
RHODOPHYTA sp. 17	+		+										2
Gracilaria verrucosa			+										1
RHODOPHYTA sp. 19				+									1
Laurencia gemmifera				+									1
Laurencia cf. *obtusa*				+									1
RHODOPHYTA sp.18				+									1
Spyridia filamentosa	+		+		+								3
RHODOPHYTA sp. 7				+									1
RHODOPHYTA sp. 3				+									1

Taxon	Station 52	44	51	45	47	19	55	7	21	29	23	All	Frequency
RHODOPHYCEAE (continued)													
RHODOPHYTA sp. 2				+									1
RHODOPHYTA sp. 1				+									1
Eucheuma nudum		+		+	+								3
RHODOPHYTA sp. 9		+			+								2
Botryocladia occidentalis	+	+		+	+			+					5
Gracilaria UNIDENT.					+								1
Jania pumila					+								1
Wrightiella tumanowiczi					+								1
Laurencia intricata				+				+					2
Lithothamnium occidentale						+							1
Champia parvula	+				+	+			+				4
Gracilaria armata					+		+	+					3
Gracilaria cylindrica	+				+				+				3
Solieria tenera							+						1
Cryptonemia luxurians							+						1
Halymenia floresia							+	+					2
Gracilaria blodgetti							+	+					2
Gracilaria mammillaris		+							+				2
Agardhiella ramosissima	+								+				2
Polysiphonia UNIDENT.				+					+				2
Dasya baillouviana								+					1
Rhodymenia rhizoides								+					1
Eucheuma isiforme								+					1
Rhodymenia sp. 2								+					1
Eucheuma acanthocladum								+					1
Rhodymenia sp. 1								+					1
RHODOPHYTA sp. 10					+				+				2
Fauchea hassleri									+				1
Kallymenia westii									+				1
Hypoglossum tenuifolium									+				1
RHODOPHYTA sp. 11									+				1
RHODOPHYTA sp. 12									+				1
Peyssonnelia rubra orientalis										+			1
Peyssonnelia UNIDENT.										+			1
Number of taxa:	17	4	3	12	11	2	5	11	11	2	0	54	
ANGIOSPERMAE													
Halophila baillonis						+							1
Number of taxa:	0	0	0	0	0	1	0	0	0	0	0	1	
Number of plant taxa:	22	4	8	22	18	7	16	25	18	6	4	92	

Table 3.2-6 Mean and overall density (no. per 10-min tow) and frequency of fishes collected by trawling, for all cruises together, by station.

Taxon	Station 52	44	51	45	47	19	55	7	21	29	23	36	Overall Density	Frequenc
MURAENIDAE														
Gymnothorax moringa							0.3						<0.1	1
Gymnothorax saxicola								0.3					<0.1	1
Gymnothorax nigromarginatus			0.5		0.5			1.3			0.7	0.3	0.3	5
MURAENESOCIDAE														
Paraxenomystax bidentatus											0.2		<0.1	1
CLUPEIDAE														
Harengula jaguana	0.7												0.1	1
ENGRAULIDAE														
ENGRAULIDAE UNIDENT.		6.5											0.3	1
SYNODONTIDAE														
Synodus foetens	0.1			0.5		0.5		3.5	0.4				0.4	5
SYNODONTIDAE UNIDENT.		1.5							0.1				0.1	2
Synodus intermedius	1.1		1.0	1.5	0.5	0.5	0.3	1.8	2.1		3.6	0.3	1.2	10
Saurida sp.								0.3	0.1				<0.1	2
Synodus synodus										0.4	0.7		0.1	2
Synodus poeyi								7.5	0.7		5.1	23.5	4.2	4
Saurida brasiliensis								0.5	1.3		0.2	0.2	0.3	4
Trachinocephalus myops								0.8				0.5	0.1	2
Saurida normani												0.5	0.1	1
Saurida UNIDENT.												6.3	0.8	1
ARIIDAE														
Arius felis	0.1												<0.1	1
BATRACHOIDIDAE														
Opsanus pardus						1.0							<0.1	1
Porichthys plectrodon									0.1				<0.1	1
GOBIESOCIDAE														
Gobiesox strumosus									0.7				0.1	1
Gobiesox cf. *punctulatus*										0.2			<0.1	1
LOPHIIDAE														
Lophiodes reticulatus											0.2		<0.1	1
ANTENNARIIDAE														
Antennarius ocellatus									0.1				<0.1	1
Antennarius radiosus												0.5	0.1	1
OGCOCEPHALIDAE														
Ogcocephalus pantostictus				0.5		0.5							<0.1	2
Ogcocephalus cubifrons					0.5			0.3					<0.1	2
Ogcocephalus parvus											0.7	0.5	0.1	2
Halieutichthys aculeatus											1.3	1.7	0.3	2
Ogcocephalus corniger												2.0	0.3	1
OPHIDIIDAE														
OPHIDIIDAE UNIDENT.									0.1				<0.1	1
HOLOCENTRIDAE														
Holocentrus poco									0.3				<0.1	1
Holocentrus bullisi									1.1	0.2			0.2	2
Adioryx coruscus										0.4			<0.1	1

Table 3.2-6 (cont'd)

Taxon	Station 52	44	51	45	47	19	55	7	21	29	23	36	Overall Density	Frequenc
ZEIDAE														
Zenopsis conchifera												0.2	<0.1	1
CAPROIDAE														
Antigonia capros												0.3	<0.1	1
AULOSTOMIDAE														
Aulostomus maculatus							0.3						<0.1	1
SYNGNATHIDAE														
Hippocampus erectus	0.1				1.0			0.3		0.2			0.1	4
Cosmocampus alucens											0.2		<0.1	1
SCORPAENIDAE														
Scorpaena calcarata	0.1							0.5					0.1	2
Scorpaena brasiliensis	0.3								0.1		0.2		0.1	3
Scorpaena plumieri									0.3				<0.1	1
Scorpaena dispar									0.4	0.6	6.2		0.7	3
Scorpaena elachys											0.2		<0.1	1
Scorpaenodes tredecimspinosus											0.2		<0.1	1
Scorpaena agassizi											0.4	3.3	0.5	2
Pontinus rathbuni												0.5	0.1	1
TRIGLIDAE														
Prionotus scitulus	0.9												0.1	1
Prionotus martis	0.1												<0.1	1
Prionotus roseus								0.5					<0.1	1
Prionotus ophryas									0.1				<0.1	1
Bellator egretta											0.2	7.8	1.0	2
Bellator militaris											0.2	0.2	<0.1	2
Prionotus stearnsi												10.0	1.3	1
Bellator brachychir												1.7	0.2	1
SERRANIDAE														
Serranus subligarius	0.3												<0.1	1
Epinephelus morio	1.1		0.5	0.5	0.5		1.4	0.3	1.7				0.6	7
Diplectrum formosum	4.6		0.5		0.5	1.0		3.5	0.3				1.1	6
Diplectrum bivittatum									0.6				0.1	1
Hypoplectrus puella									1.6				0.2	1
Mycteroperca phenax									0.1				<0.1	1
Hypoplectus unicolor									0.4				0.1	1
Serranus annularis							0.3		0.1	1.0	1.8		0.3	4
Serranus tortugarum										0.4			<0.1	1
Schultzea beta										0.2			<0.1	1
Gonioplectrus hispanus										0.2			<0.1	1
Centropristis philadelphica											0.2		<0.1	1
Serranus phoebe									4.6		36.0	3.7	4.6	3
Hemanthias vivanus										0.2		0.3	0.1	2
Serranus atrobranchus											9.1	32.5	5.0	2
Plectranthias garrupellus												0.5	0.1	1
Holanthias martinicensis												1.5	0.2	1
GRAMMISTIDAE														
Rypticus maculatus	0.6			1.0									0.1	2
Rypticus bistrispinus											1.3		0.1	1
PRIACANTHIDAE														
Priacanthus arenatus									0.3				<0.1	1
Pristigenys alta									0.3			0.7	0.1	2
Priacanthus cruentatus											0.2	0.2	<0.1	2

Table 3.2-6 (cont'd)

Taxon	52	44	51	45	47	19	55	7	21	29	23	36	Overall Density	Frequency
	Station													
APOGONIDAE														
Astrapogon alutus									0.3				<0.1	1
Apogon quadrisquamatus									2.1				0.3	1
Apogon affinis									0.1				<0.1	1
Apogon pseudomaculatus									5.1				0.8	1
Apogon aurolineatus									1.9		0.4		0.3	2
Apogon UNIDENT.												0.8	0.1	1
ECHENEIDAE														
Echeneis neucratoides	0.1												<0.1	1
CARANGIDAE														
Caranx crysos	0.3												<0.1	1
LUTJANIDAE														
Lutjanus synagris	3.3				1.5	1.5		0.3	0.3				0.7	5
Lutjanus griseus							2.3		0.3				0.2	2
GERREIDAE														
Eucinostomus gula	6.1												0.9	1
Eucinostomus jonesi									0.1				<0.1	1
HAEMULIDAE														
Anisotremus virginicus	0.6		0.5										0.1	2
Haemulon plumieri	19.1		4.0	7.0	2.5	1.0	1.1						3.5	6
Haemulon aurolineatum	0.3	1.0		2.0	1.5			0.8	1.4				0.5	6
SPARIDAE														
Lagodon rhomboides	0.6												0.1	1
Calamus arctifrons	2.9												0.4	1
Calamus cf. *leucosteus*	0.3												<0.1	1
Calamus UNIDENT.	0.1		1.0										0.1	2
Calamus bajonado				1.0									<0.1	1
Calamus penna				0.5									<0.1	1
Calamus calamus				0.5					0.3				0.1	2
Calamus nodosus							0.6		0.4				0.1	2
Calamus pennatula									0.7				0.1	1
Calamus sp. 1									0.1				<0.1	1
SCIAENIDAE														
Equetus lanceolatus	3.7		0.5		1.0			3.5	0.7				1.0	5
Equetus umbrosus									0.3				<0.1	1
MULLIDAE														
MULLIDAE UNIDENT.					0.5								<0.1	1
Pseudupeneus maculatus	0.1						0.3		0.1				0.1	3
EPHIPPIDAE														
Chaetodipterus faber	0.9			10.0									0.6	2
CHAETODONTIDAE														
Pomacanthus arcuatus	0.1				1.5		0.9						0.1	3
Chaetodon ocellatus	0.1						0.6		1.9				0.3	3
Holacanthus bermudensis				1.0			0.9	0.3	0.4				0.2	4
Chaetodon sedentarius									2.6	0.6			0.4	2
Chaetodon aculeatus										0.2			<0.1	1
Chaetodon ava												1.5	0.2	1

Table 3.2-6 (cont'd)

Taxon	Station 52	44	51	45	47	19	55	7	21	29	23	36	Overall Density	Frequency
POMACENTRIDAE														
Chromis UNIDENT.									0.1				<0.1	1
Chromis enchrysurus									0.6	6.7	1.1		0.9	3
Chromis insolatus										0.2			<0.1	1
Pomacentrus partitus										0.2			<0.1	1
Chromis scotti										11.2		0.2	1.2	2
LABRIDAE														
Halichoeres bivittatus				3.0									0.1	1
Lachnolaimus maximus	11.0		0.5	1.5			0.6						1.8	4
Bodianus pulchellus										0.2			<0.1	1
Halichoeres bathyphilus												0.2	<0.1	1
LABRIDAE UNIDENT.												0.2	<0.1	1
Decodon puellaris												0.7	0.1	1
SCARIDAE														
Sparisoma aurofrenatum							0.3						<0.1	1
Nicholsina usta	0.1			1.5				0.3	0.1				0.1	4
Sparisoma chrysopterum							0.6						<0.1	1
Sparisoma UNIDENT.									0.4				0.1	1
Sparisoma atomarium									0.1	0.6	0.2		0.1	3
Cryptotomus roseus										0.2			<0.1	1
Sparisoma radians										0.6			0.1	1
OPISTOGNATHIDAE														
Opistognathus UNIDENT.												0.2	<0.1	1
BLENNIIDAE														
Parablennius marmoreus						0.5			0.3				0.1	2
CLINIDAE														
Stathmonotus hemphilli							0.3						<0.1	1
Emblemaria caldwelli									0.4				0.1	1
Starksia UNIDENT.									0.1				<0.1	1
Nemaclinus atelestos									0.1				<0.1	1
GOBIIDAE														
Gobiosoma horsti							0.3						<0.1	1
Risor ruber							0.3						<0.1	1
GOBIIDAE UNIDENT.									0.1				<0.1	1
Evermannichthys UNIDENT.									0.1				<0.1	1
Evermannia UNIDENT.									0.1				<0.1	1
ACANTHURIDAE														
Acanthurus bahianus							0.3						<0.1	1
BOTHIDAE														
Citharichthys macrops		0.5											<0.1	1
Bothus ocellatus								0.5	0.1				0.1	2
Syacium papillosum							0.6	8.3	5.3		0.9	1.8	1.8	5
Cyclopsetta fimbriata					0.5				0.1			0.2	0.1	3
Citharichthys gymnorhinus												0.5	0.1	1
Citharichthys dinoceros												0.2	<0.1	1
Ancylopsetta dilecta												0.5	0.1	1
Citharichthys cornutus												8.3	1.1	1
Citharichthys UNIDENT.												0.5	0.1	1
SOLEIDAE														
Achirus lineatus		0.5											<0.1	1

Taxon	Station 52	44	51	45	47	19	55	7	21	29	23	36	Overall Density	Frequency
TRIACANTHODIDAE														
Parahollardia lineata												1.3	0.2	1
BALISTIDAE														
Balistes capriscus					1.0			0.3					0.1	2
Monacanthus hispidus	0.9				1.0		0.3	1.0	0.3				0.3	5
Aluterus schoepfi	0.3						0.6		0.3				0.1	3
Monacanthus ciliatus	1.0				1.0	2.5			0.1	0.4	9.1		1.2	6
Aluterus heudeloti									0.3				<0.1	1
Monacanthus UNIDENT.									0.1				<0.1	1
Monacanthus tuckeri										0.2			<0.1	1
OSTRACIIDAE														
Lactophrys quadricornis	7.1	2.0	1.5	2.5	0.5		3.4		0.3	0.2			1.7	8
Lactophrys polygonia									0.1		0.7		0.1	2
TETRAODONTIDAE														
Sphoeroides nephelus	0.1												<0.1	1
Canthigaster rostrata							0.3			0.2			<0.1	2
Sphoeroides spengleri	1.3			2.5				0.5	0.6			0.5	0.5	5
DIODONTIDAE														
Chilomycterus schoepfi	0.3			1.5		0.5							0.1	3
Diodon holocanthus							0.3		0.6	0.2	0.2		0.1	4
Overall density per station :	71.1	12.0	10.5	38.5	16.0	9.5	17.1	36.5	48.9	25.7	82.0	117.2		
Number of taxa :	38	6	10	18	17	10	25	24	69	26	30	42		
Number of families :	24	6	8	13	13	9	19	15	28	14	18	18		
Total number of taxa :	166													
Total number of families :	49													

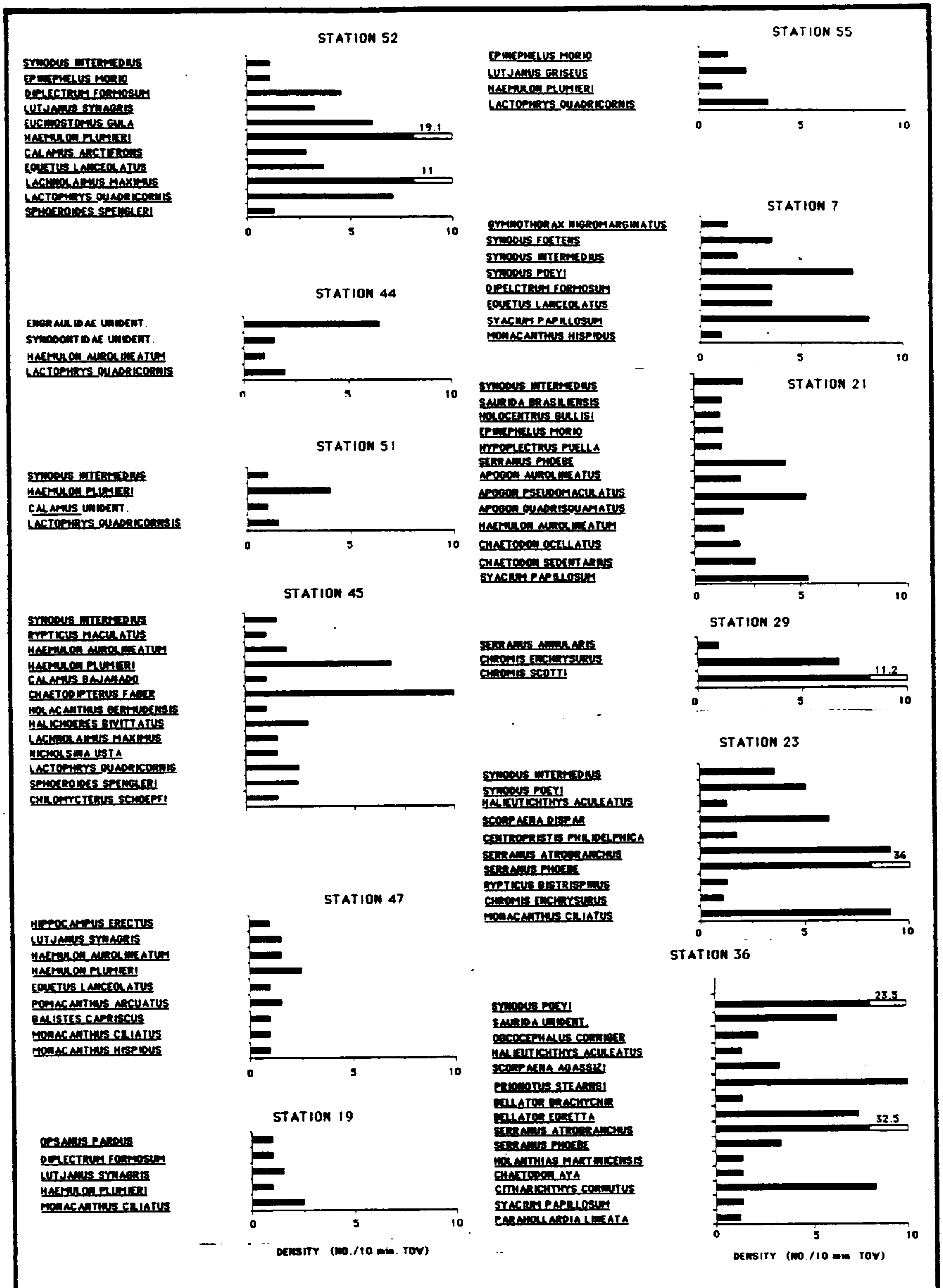

Figure 3.2-4 OVERALL DENSITY OF NUMERICALLY DOMINANT ($\geq$ 1/tow) FISHES COLLECTED BY TRAWLING, FOR ALL CRUISES TOGETHER, BY STATION

Thirteen species were collected only at Station 52, including the scaled sardine, Harengula jaguana; the hardhead catfish, Arius felis; the smoothhead scorpionfish, Scorpaena calcarata; the leopard searobin, Prionotus scitulus; the barred searobin, Prionotus martis; the belted sandfish, Serranus subligarius; the whitefin sharksucker, Echeneis neucratoides; the blue runner, Caranx crysos; the pinfish, Lagodon rhomboides; the whitebone porgy, Calamus leucosteus; the southern puffer, Sphoeroides nephelus; Eucinostomus gula; and Calamus arctifrons.

Fishes seen most frequently were Lactophrys quadricornis and Lachnolaimus maximus (all seven cruises); Haemulon plumieri (six out of seven cruises); the sand diver, Synodus intermedius, the red grouper, Epinephelus morio, and the planehead filefish, Monacanthus hispidus (five cruises each). The fringed filefish, Monacanthus ciliatus, the bandtail puffer, Sphoeroides spengleri, the spadefish, Chaetodipterus faber, the sand perch, Diplectrum formosum, and the leopard searobin, Prionotus scitulus, each were collected on four cruises.

Hauls were highly variable from one cruise to the next although some species were taken repeatedly. The best hauls were obtained on Cruise 8 (September 1985, 119 individuals taken) and Cruise 5 (December 1984, 116 individuals). Cruise 4 (August 1984) was notably poor in terms of numbers of fish collected; only six specimens were taken with the trawl. Analyses of stomach contents, maturation state, length and weight for some of the species collected at Station 52 (Epinephelus morio, Haemulon plumieri, Lactophrys quadricornis) are presented in Subsection 3.2.2, Species Accounts.

Time-Lapse Camera

Overview

The array at Station 52 was first installed during Cruise 1 (December 1983). Time-lapse camera results from Cruises 1 through 5 were described in the Year 4 Annual Report, and are not repeated here.

Results presented below are derived from time-lapse camera installations on Cruises 5, 6, and 7.

Shallow water at this station permitted all array servicing to be done on the bottom, without moving the array. The settling plate targets were also part of the original array. At the beginning of Cruise 5 (December 1984), the sessile community on the right-hand, undisturbed target had been growing for 362 days. The left-hand target was scraped clean by divers during each cruise.

The area in view of the time-lapse camera was quite similar to that seen in underwater television transects. Sessile organisms included gorgonians, sponges and algae. These were attached to rocky substrate covered in most places by thin sand, whose thickness (10 to 40 mm) was measured by divers. Scouring was noted by divers under the array. Other than directly below the array, there was no apparent sediment movement or change in thickness throughout the year.

Cruises 5 and 6 (December 1984 to March 1985)

Between Cruises 5 and 6, the time-lapse camera was fully functional but recorded useful information for only 33 days (792 hourly records). The camera was installed on December 6, 1984, but was shifted out of position on January 8, 1985. The shift was believed to be caused by jewfish, Epinephelus itajarra, or loggerhead sea turtles, Caretta caretta, both of which commonly appeared in the time-lapse records for Cruises 5, 6, and 7.

The water was slightly turbid for most of the period. Most frames (60.6%) exhibited slight turbidity (relative visibility 75%). The remaining frames were scored as 25% visibility (6.3%) and zero visibility (14.9%). Jewfish occluded 6.4% of the frames.

There were two major turbidity storms, one at the beginning and another at the end of the period. The first reduced visibility to 25% or less, and began at 2000 hours on the first day of installation (December 6). It extended for 3 days, to 1700 hours on December 9. The second turbidity storm began at 1600 hours on January 4, and continued for at least 4 days.

Only a portion of the left settling plate target (cleaned) was in the field of view at the beginning of the period. After Day 4, when the camera shifted in position, it was no longer possible to see the plate targets. The camera shifted again on Day 6 to nearly a 90° tilt from its original orientation, making fish records very difficult to analyze.

The settling community seen on the target plates was extensive. The organisms on the array were, in fact, responsible for some data loss. The octocoral Telesto was by far the most conspicuous organism. It grew on nearly all surfaces of the array. From the beginning, growth of Telesto partially obscured the camera's view. As the camera shifted in position, the problem grew progressively worse. By Day 34 (when the camera was shifted again), dense mats of Telesto hanging down from the array completely blocked the view.

Cycles of expansion and contraction of Telesto polyps were observed. These cycles were apparently not correlated with diurnal or tidal cycles. The polyps usually remained expanded or contracted for 2 to 6 hours.

The time-lapse camera recorded 952 fish observations. Few fishes were seen until 2 days after installation, due to very high turbidity (Figure 3.2-5). There were only five different fishes sighted (Table 3.2-7). The fish recorded most frequently was the gray snapper, Lutjanus griseus (817 observations). Gray snappers were seen almost exclusively during daylight (0700 to 1900 hours) (Figure 3.2-5). Since

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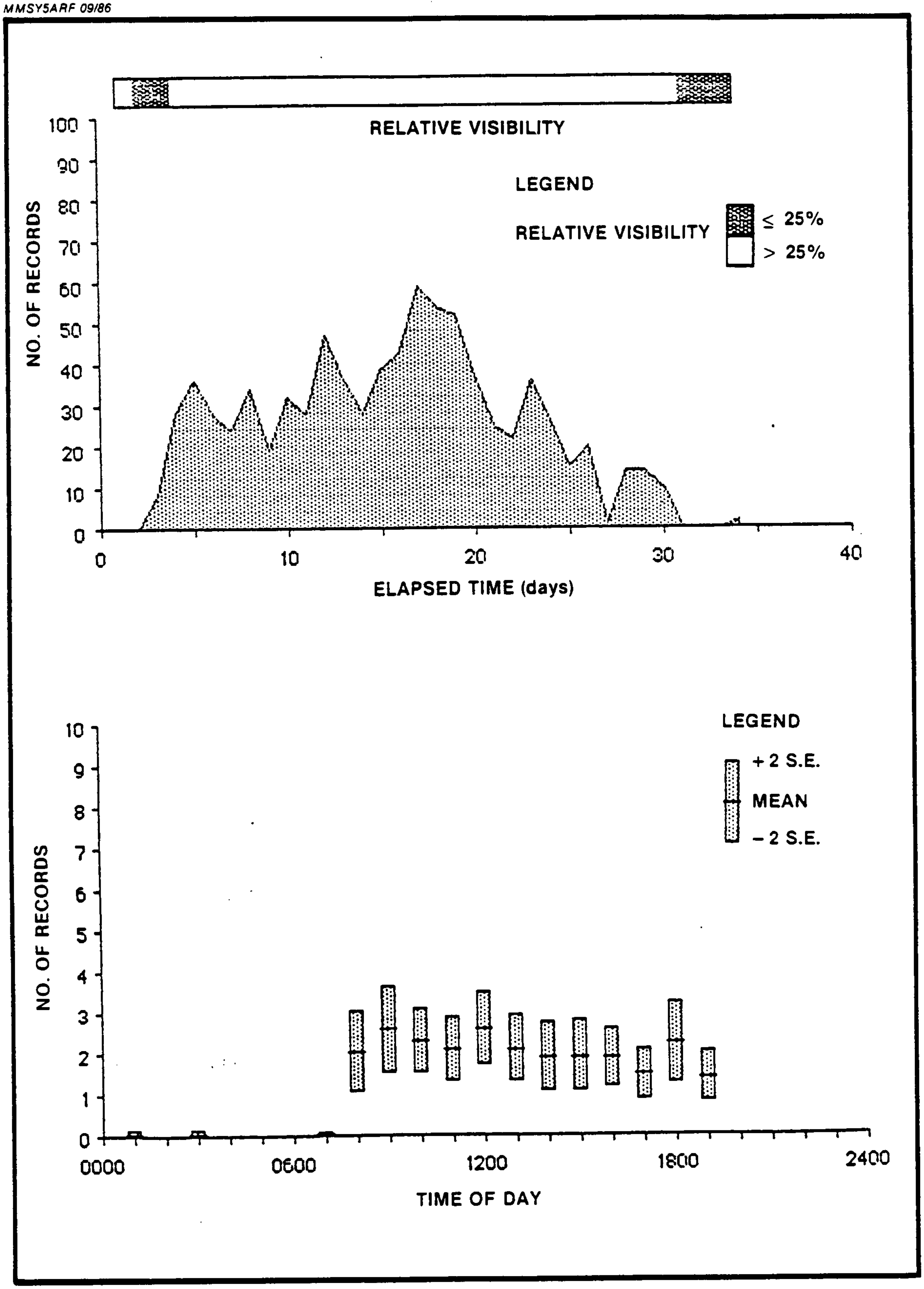

Figure 3.2-5 ACTIVITY PATTERNS FOR *Lutjanus griseus* AT STATION 52, FROM TLC, DECEMBER 6, 1984 — JANUARY 8, 1985

Table 3.2-7 Total number of fish and turtle sightings (records) observed by time-lapse camera at Station 52, by exposure period

Taxon	Exposure Period 12/84-1/85 Sightings	3/85-4/85 Sightings	6/85-9/85 Sightings	Total Sightings
Haemulon aurolineatum	0	1	4104	4105
Lutjanus griseus	817	162	1078	2057
Perciformes unident.	0	0	507	507
Epinephelus itajara	96	36	213	345
Anisotremus virginicus	24	48	185	257
Caretta caretta	11	11	55	77
Lutjanus synagris	0	55	0	55
Ginglymostoma cirratum	0	0	34	34
Mycteroperca sp.	0	0	15	15
Pomacanthus arcuatus	2	1	9	12
Haemulon plumieri	0	7	1	8
Chaetodon ocellatus	0	0	8	8
Archosargus probatocephalus	1	0	5	6
Lachnolaimus maximus	0	0	5	5
Apogonidae	0	0	4	4
Selene vomer	0	0	2	2
Calamus unident.	0	0	2	2
Caranx crysos	0	0	2	2
Equetus lanceolatus	0	0	1	1
Epinephelus morio	0	0	1	1
Epinephelus unident.	1	0	0	1
Seriola dumerili	0	0	1	1
Dasyatidae unident	0	0	1	1
Number of Sightings	952	321	6233	7506
Total Frames Exposed	792	272	1913	4991

gray snappers are primarily nocturnal feeders (Randall, 1967), they may have left the array at dusk to feed in surrounding areas, returning after sunrise.

The second most frequently recorded fish was Epinephelus itajarra, the jewfish. Most observations were repeated sightings of the same individual(s). Jewfish probably increased in number during this period, compared to the previous study year. At least three jewfish were reported by divers during Cruises 4 and 5; at least five individuals were sighted by divers during Cruises 6 through 8. After Cruise 5, jewfish appeared in time-lapse records from the very first day of installation, with peaks in frequency of observations every 3 to 4 days (Figure 3.2-6). Hourly means of attendance showed wide variations, with sighting at every hour of the day except 1800 hrs. There was a peak in attendance at night, between 1900 and 0600 hrs.

The remaining fish observations included 24 records of porkfish, Anisotremus virginicus; two records of gray angelfish, Pomacanthus arcuatus;, and a single observation of sheepshead, Archosargus probatocephalus. Porkfish were observed only sporadically until Day 17 and later reached a peak of eight sightings on Day 27 (Figure 3.2-7). Most porkfish were seen during daylight hours (0900 to 1900 hour). The porkfish is also primarily a nocturnal feeder (Randall, 1967), explaining its absence inside the array at night.

The fourth most frequently observed animal overall was a loggerhead sea turtle, Caretta caretta (11 observations). Generally only the shell was seen inside the array. The turtle was usually lying flat on the bottom. The turtle was only recorded at night between 2100 and 0600 hours.

Cruises 6 and 7 (March 1985 to June/July 1985)
The time-lapse system was serviced during Cruise 6 and reinstalled on March 30, 1985. The system again experienced problems due to large fish

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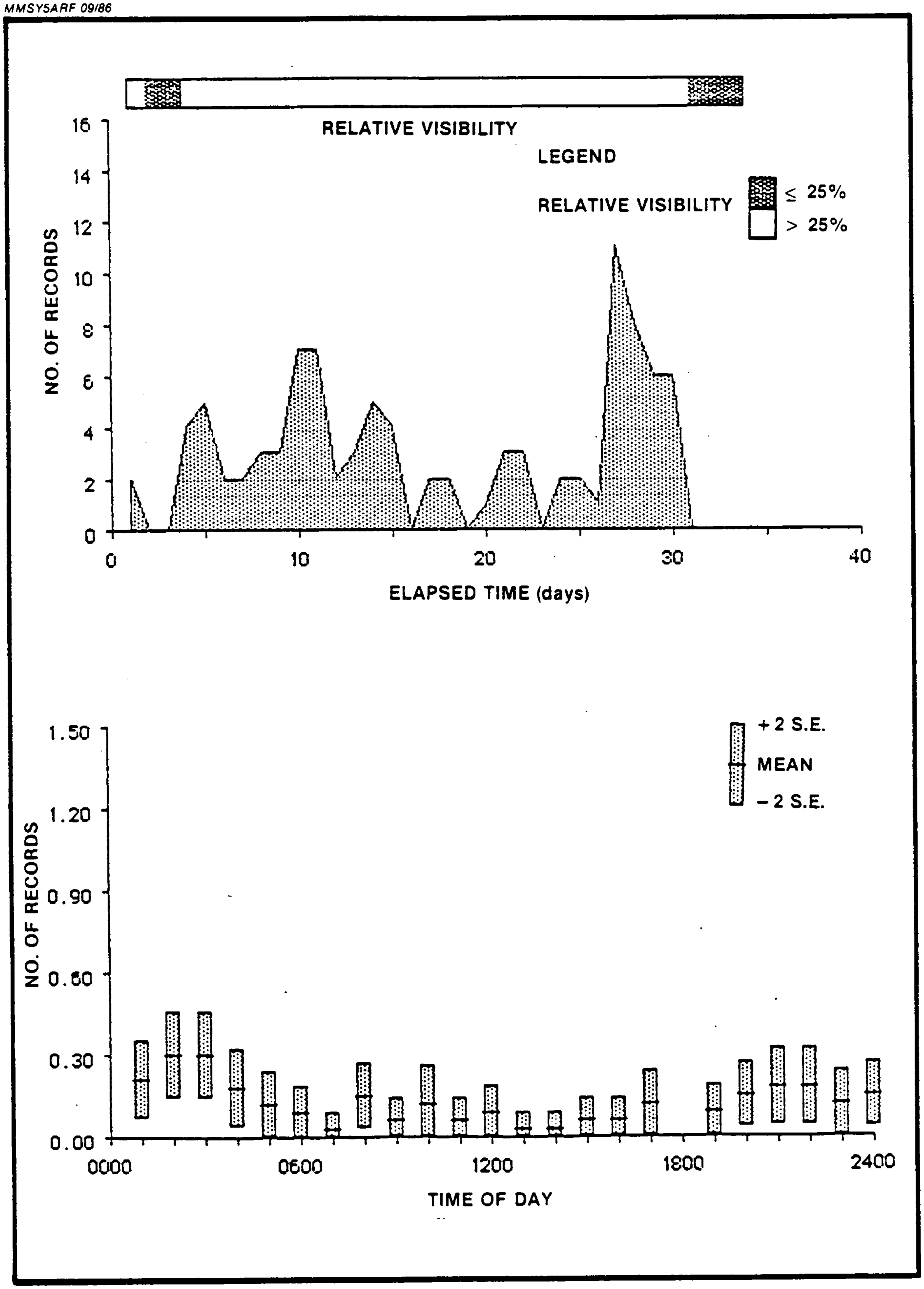

Figure 3.2-6 ACTIVITY PATTERNS FOR *Epinephelus itajara* AT STATION 52, FROM TLC, DECEMBER 6, 1984 – JANUARY 8, 1985

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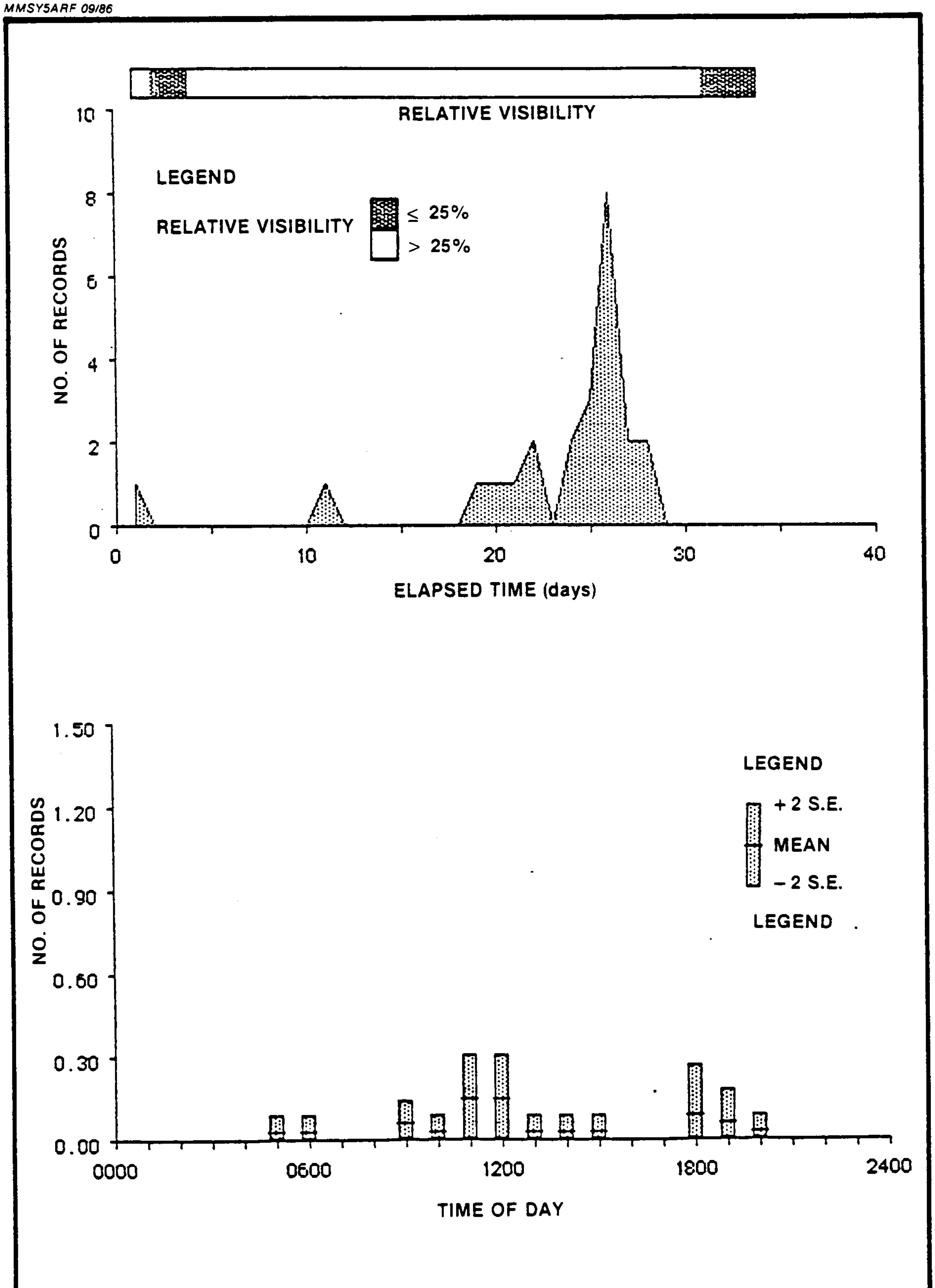

Figure 3.2-7 ACTIVITY PATTERNS FOR *Anisotremus virginicus* AT STATION 52, FROM TLC, DECEMBER 6, 1984 – JANUARY 8, 1985

or turtles causing misalignment of the camera. Within the first 12 hours of operation, the camera was bumped twice, and a large jewfish appeared in five frames and a large loggerhead turtle in another frame. Due to these collisions, the time-lapse camera took only 271 useful frames (during 11 days and 7 hours of real time) by April 10, 1985. Thereafter, its view was obscured by Telesto.

Most (72.8%) of the frames permitting an unobstructed view of the area were taken in clear water (100% relative visibility). Just after installation, there was a brief period of several days of high turbidity (Figure 3.2-8). Four days in the middle of the period provided no useful data, because the camera's view was completely obscured by settling organisms, and 9.9% of the frames were occluded by jewfish.

The settling plate targets were only visible for a short time, and there were no visible changes in the community on the right-hand plate, and no apparent colonization of the cleaned left-hand target. Fishes and turtles were recorded 321 times (Table 3.2-7). The most frequently sighted fish was the gray snapper (162 records). The same pattern of hourly attendance patterns seen during the previous period was seen, except that there were more observations shortly after dark. The departure of gray snappers from the array was delayed by several hours compared to the previous period. Gray snappers were observed at 2000 and 2100 hours inside the array, although none was recorded at these hours between Cruises 5 and 6.

The second most frequently recorded fish was the lane snapper, *Lutjanus synagris* (55 observations). Lane snappers were seen only during this sampling period. A figure is not presented for lane snappers; however, their hourly attendance patterns were similar to those of the gray snapper, another nocturnal feeder.

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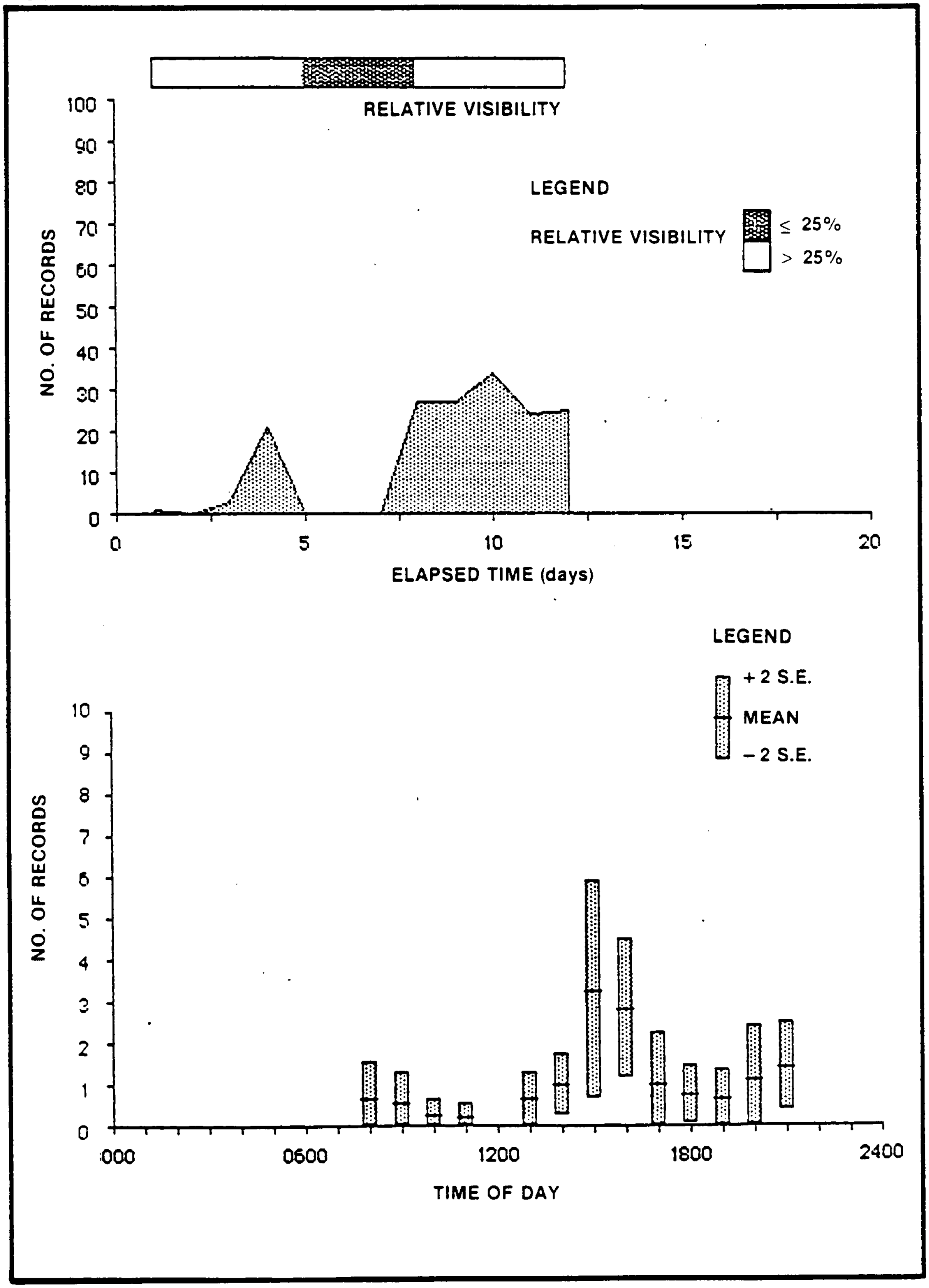

Figure 3.2-8 **ACTIVITY PATTERNS FOR *Lutjanus griseus* AT STATION 52, FROM TLC, MARCH 30 – APRIL 10, 1985**

The third most frequently seen fish was the porkfish. Abundance patterns and hourly attendance means are shown in Figure 3.2-9. The pattern of hourly attendance was very similar to that of the previous period, with most observations during daylight (0800 and 2000 hours).

The other four fishes seen included the jewfish (36 observations), the white grunt, Haemulon plumieri (seven records); and the tomtate, Haemulon aurolineatum; and gray angelfish, Pomacanthus arcuatus (one observation each). Jewfish were most often seen after dark (Figure 3.2-10), whereas during the previous period, observations were relatively evenly dispersed. However, limited sample size make such conclusions tentative.

Loggerhead sea turtles were recorded 11 times, and included at least two individuals. One especially large turtle was photographed during the daytime (1300 hours) with its head adjacent to the settling plate target. Using the target as a size reference, the head of this turtle was calculated to be approximately 175 mm long, with an eye socket about 50 mm in diameter. All sea turtle records but this one were obtained after dark (between 2100 and 0400 hours).

Cruises 7 and 8 (June/July 1985 to September 1985)

The time-lapse camera was serviced during Cruise 7 and reinstalled on June 25, 1985. This time, the apparatus functioned until nearly the next cruise. It operated for 79 days and 17 hours (1913 hourly records). The sea floor was hard to see during this period, partly because of turbidity but primarily because the camera was aimed slightly upward.
High-resolution benthic photography survey results during Cruise 7 showed a tremendous bloom of the foliose brown alga Dictyopteris, which covered up to 75% of the substrate along the high resolution benthic photography survey transects, where it was previously very rare. Although the high-resolution benthic photography survey transects were near the array, Dictyopteris was not abundant directly under and surrounding the array. This observation was confirmed by divers servicing the array. The lack

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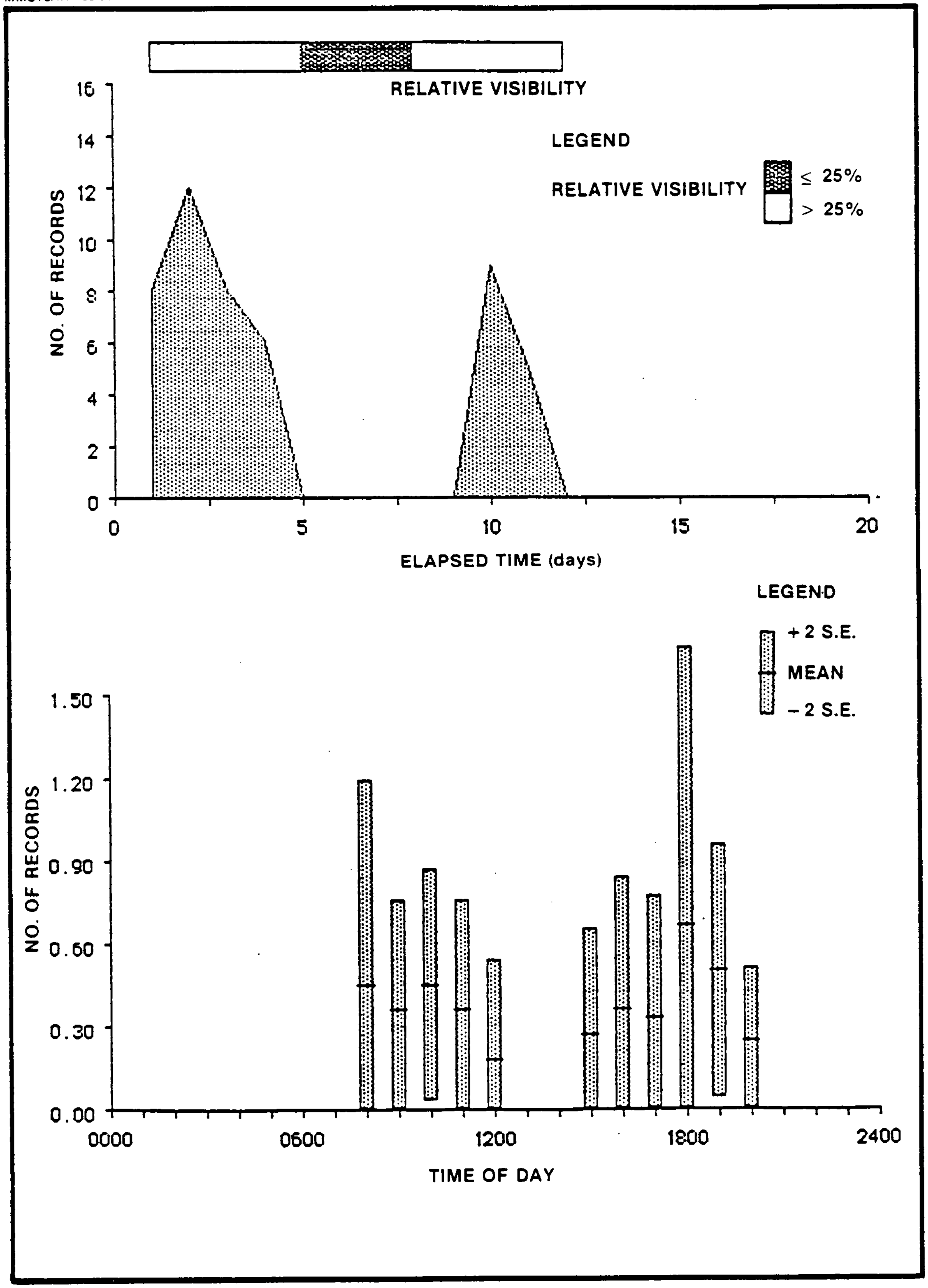

Figure 3.2-9 ACTIVITY PATTERNS FOR *Anisotremus virginicus* AT STATION 52, FROM TLC, MARCH 30 — APRIL 10, 1985

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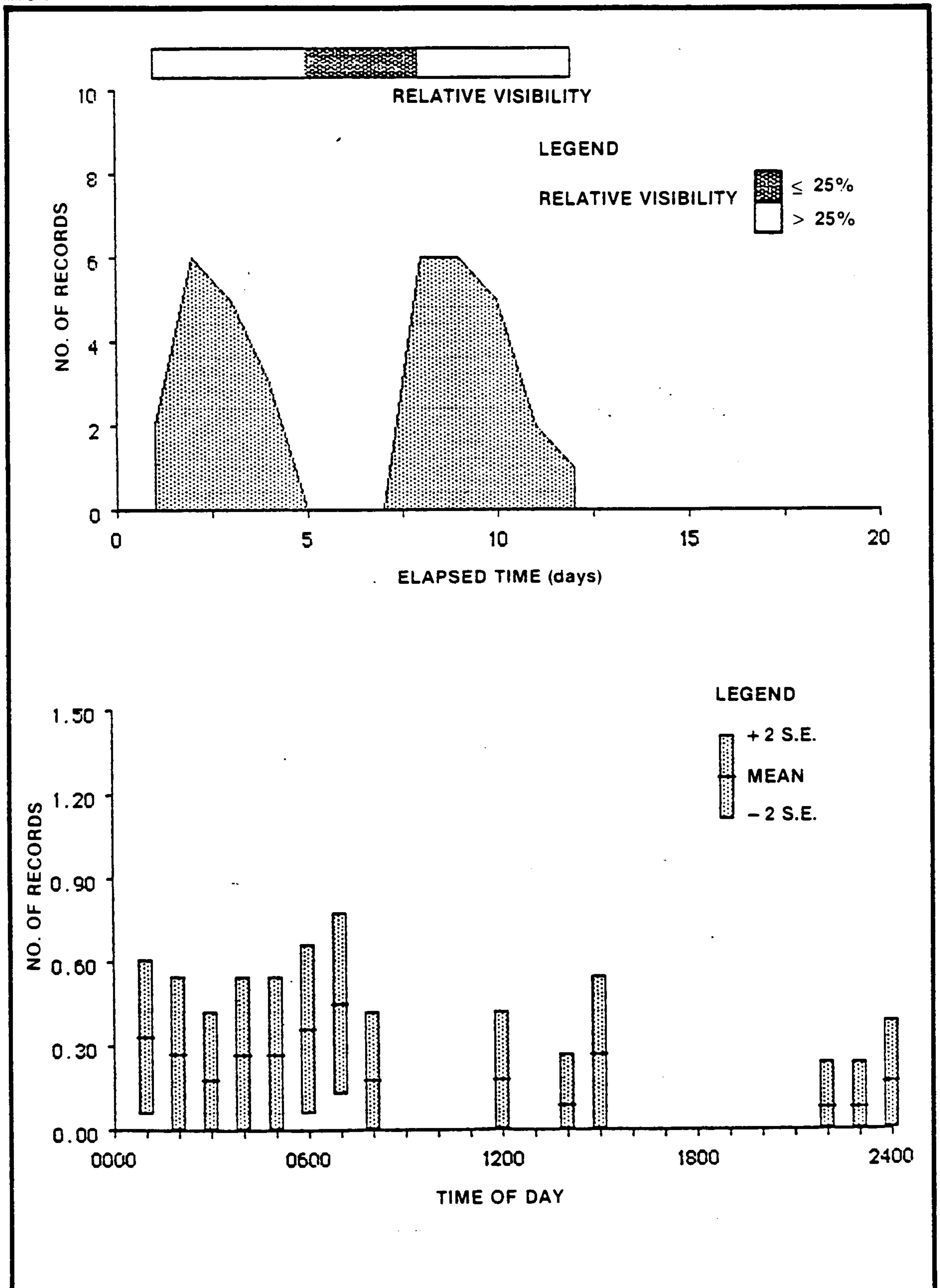

Figure 3.2-10 ACTIVITY PATTERNS FOR *Epinephelus itajara* AT STATION 52, MARCH 30 — APRIL 10, 1985

of algal coverage may have been due to scouring by water currents altered by the array, but was more probably caused by elevated biological activity by herbivorous fishes near the array.

Loggerhead turtles, jewfish, and nurse sharks were observed resting on the bottom nearly every day during this period. These animals may have been responsible for the removal of the sand directly underneath the array. Bare rock was exposed directly under the array, in contrast to the 10- to 40-mm thick layer of sand covering virtually all the surrounding bottom.

Water clarity during this period was highly variable, but predominantly good (100% and 75% relative visibility for 33.6 and 54.3% of the frames exposed, respectively). Smaller percentages of the 1913 frames were classified under conditions of higher water turbidity. A total of 5.1% of the frames was taken in water with 50% relative visibility, and the remaining frames were taken under conditions of 25% and zero visibility (3.1 and 3.9%, respectively, of the frames).

Turbidity storms greatly reduced visibility on two occasions. The first began around 2100 hours on July 22, and the water did not clear substantially until two days later at 1700 hours on July 24. Visibility remained reduced for an additional 17 days, until August 10. The second turbidity storm began at 1200 hours on August 30, and continued for about 4 1/2 days.

The field of view was blocked by jewfish in 2.5% of the total frames during this period. Unfortunately, the settling plate targets were only visible for the first few hours of Day 1. Just 4 hours after the time-lapse camera system was installed by divers, a large loggerhead turtle was observed; in the next frame, the plate targets and sediment transport measurement rod had been knocked completely out of the field of view.

Some supplementary observations were made on other substrates brought into view as a result of camera position shifts on Day 6. A horizontal pipe in the array was visible throughout the remainder of the 80-day period. Organisms living on this pipe could have been growing since the array was originally installed (December, 1983) and might be considered a mature "climax" community. Two organisms were abundant: the octocoral Telesto, and hydroids. Telesto stalks were estimated to be approximately 12 mm in length when first measured, and increased noticeably in length during the period.

Fishes and sea turtles were more frequently recorded during this period, due to the increased number of frames exposed. A total of 6,233 fish and sea turtle observations were made; 19 taxa were represented (Table 3.2-7). Five different fishes were recorded more than 180 times. The most frequently recorded fish taxa was the tomtate, Haemulon aurolineatum (4,104 observations, almost four times those of any other taxon). Most of the tomtates were juveniles. Figure 3.2-11 illustrates tomtate frequency and attendance patterns. Frequency of observations remained relatively low for the first 70 days of the 80-day period. A large increase in frequency of observations was due to juvenile tomtates, beginning on Day 71 and reaching a peak (540 records) on the last day of the period. The hourly mean attendance pattern of tomtates closely resembled that of the porkfish (another nocturnal feeding grunt); nearly all observations occurred during the day (0800 to 2000 hrs) (Figure 3.2-12).

The second most frequently recorded fish was the gray snapper. During this period, 1,078 grey snapper observations were recorded (Figure 3.2-13). Frequency of sightings was highly variable, with a peak between Days 20 and 40 (50 records on 2 days). Hourly attendance patterns were very similar to those of the previous periods. Fish were at the array primarily between 0800 and 2100 hours.

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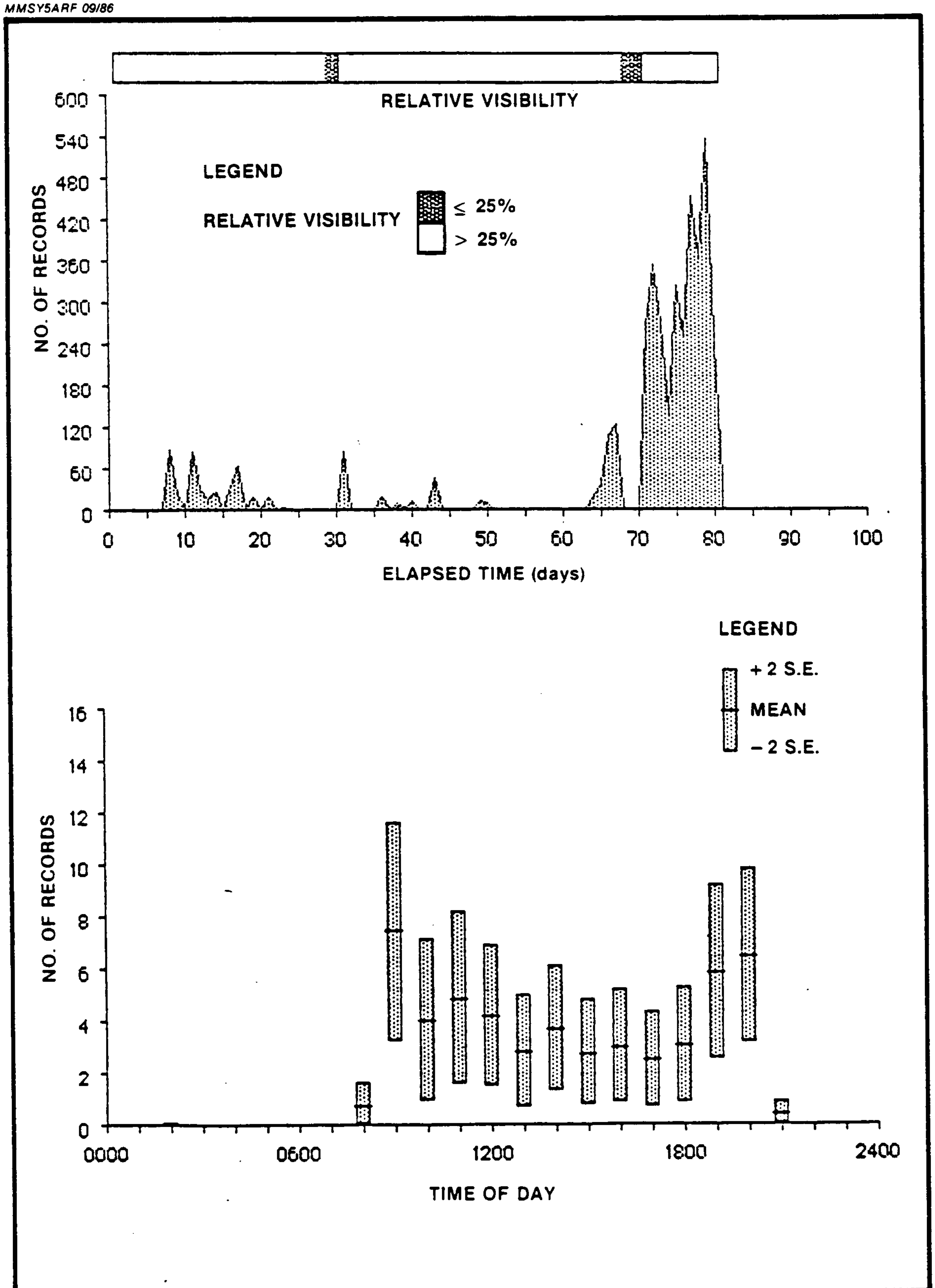

Figure 3.2-11 ACTIVITY PATTERNS FOR *Haemulon aurolineatum* AT STATION 52, FROM TLC, JUNE 25 — SEPTEMBER 13, 1985

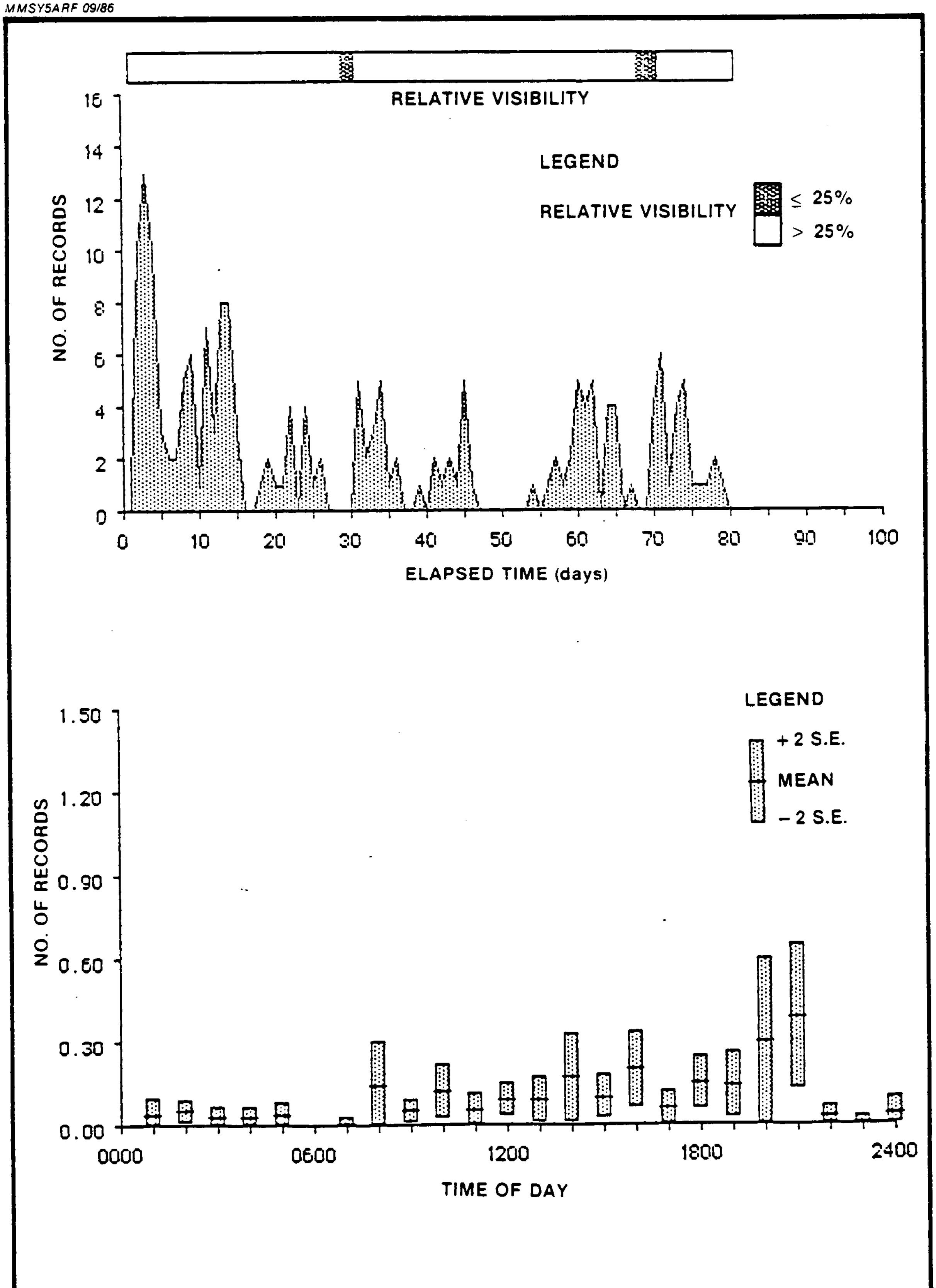

Figure 3.2-12 ACTIVITY PATTERNS FOR *Anisotremus virginicus* AT STATION 52, FROM TLC, JUNE 25 – SEPTEMBER 13, 1985

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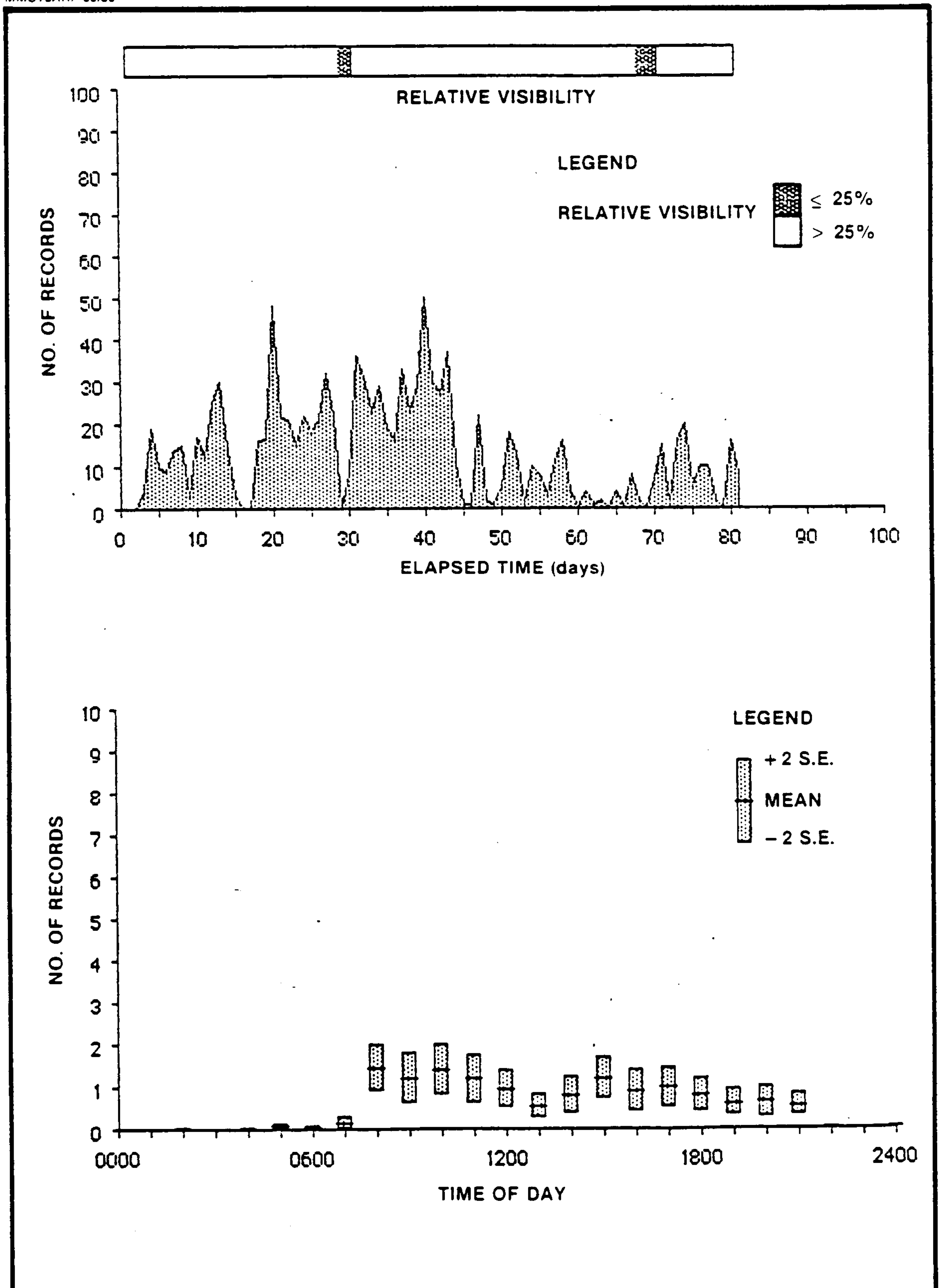

Figure 3.2-13 **ACTIVITY PATTERNS FOR *Lutjanus griseus* AT STATION 52, FROM TLC, JUNE 25 – SEPTEMBER 13, 1985**

The third most frequently recorded fishes (507 observations) were small individuals that could not be identified beyond order Perciformes. Most of these fishes were probably juvenile tomtate or other haemulids. Some were thought to be scad (family Carangidae).

Other frequently seen fishes were jewfish (213 observations), and porkfish (185 records). Jewfish showed an interesting pattern of attendance (Figure 3.2-14). It was a similar pattern to that between Cruises 5 and 6 (Figure 3.2-6), but much more pronounced. Jewfish were observed during every hour of the day but there was a statistically significant trend of elevated abundance between 2200 and 0300 hours. Randall (1967) reported that groupers feed both during the night and day, but are most active at dawn and dusk. Our observations suggest that jewfish may not always rely heavily on night feeding, at least between Cruises 5 and 8 (December to July) at Station 52.

Activity patterns of porkfish are shown in Figure 3.2-12. The peak in the daily total number of observations was on the second day (13 records). Subsequent peaks in sightings ranged between 5 and 8 observations, at intervals of 10 to 12 days. An interesting pattern of mean hourly abundance is also shown in Figure 3.2-12. In contrast to previous periods when night observations of the porkfish were rare, porkfish were recorded in 23 of the 24 possible hours. The highest hourly mean was also at night (2100 hours).

Two other fishes were recorded more than 10 times: the nurse shark, Ginglymostoma cirratum (34 observations) and a grouper of the genus Mycteroperca (15 records). Nurse sharks were observed beginning Day 4 at 2200 hours, and continuing sporadically throughout the period. A majority of records were made during the night (25 records between 1900 and 0600 hours). All records were apparently of the same individual. Each time a nurse shark was observed, it appeared to be the same size and

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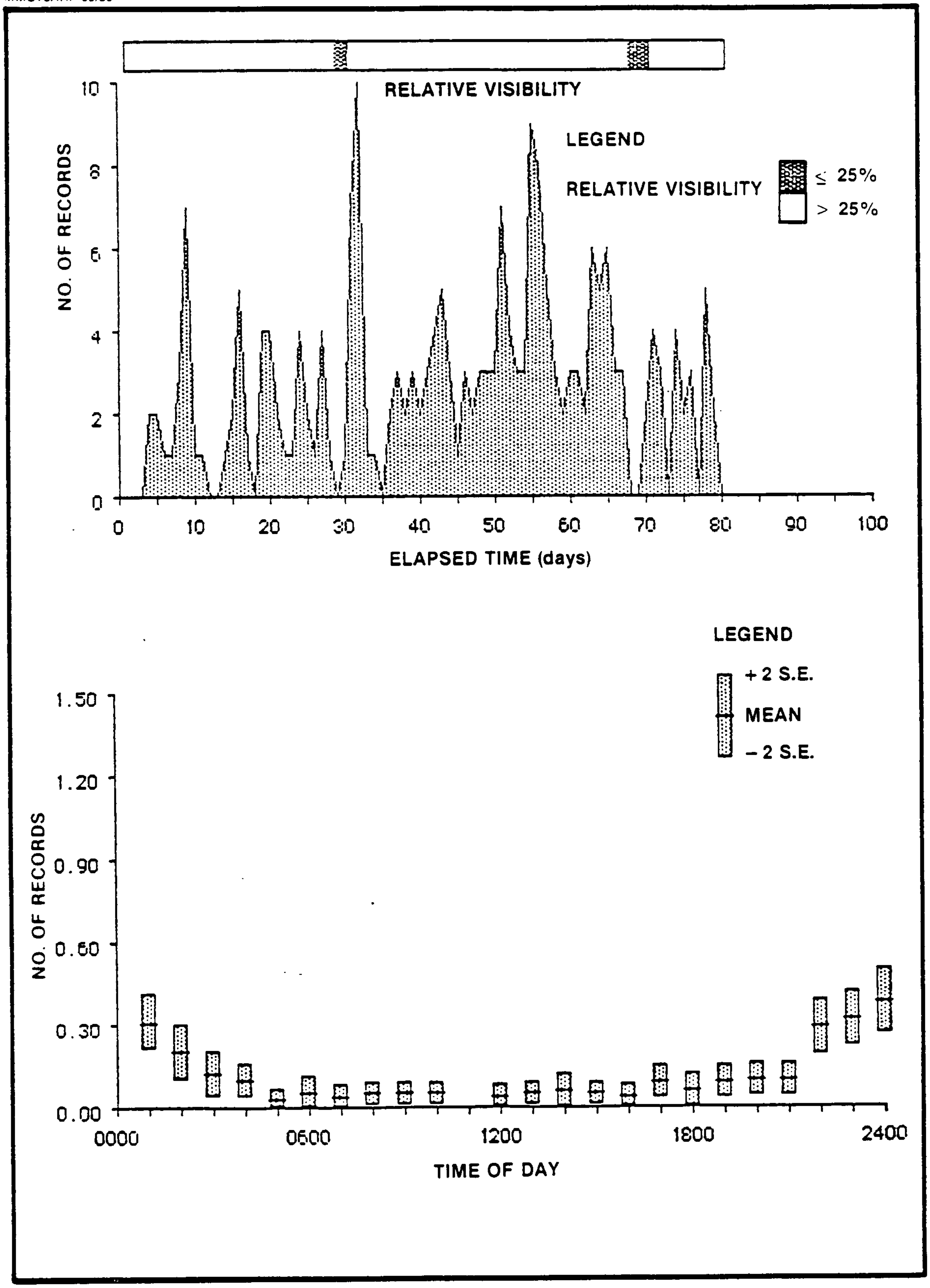

Figure 3.2-14 ACTIVITY PATTERNS FOR *Epinephelus itajara* AT STATION 52, FROM TLC, JUNE 25 – SEPTEMBER 13, 1985

was in virtually the same position just outside the array with its head pointing inside the array. Table 3.2-7 lists 13 other fish taxa recorded at Station 52.

One of the 55 sea turtle records was thought to be a photograph of a leatherback turtle, Dermochelys coriacea. A portion of the characteristic shell of a leatherback turtle was seen in a single frame on July 10 at 2300 hours. This was the only record of a sea turtle other than a loggerhead.

High-Resolution Benthic Photographic Survey Results

High-resolution benthic photographic survey results were obtained from Cruises 6 through 8, though not from Cruise 5 (when the transect was installed) due to severe weather. On Cruise 6 (March 30, 1985), the bottom was almost entirely covered with coarse, calcareous sand, although divers had observed a good deal of benthic algae during previous cruises. The dominant organisms along the transect were sponges. Several major morphological types could be differentiated:

1. Massive, barrel-shaped forms such as the loggerhead sponge, Ircinia strobilina;
2. Massive, vase-shaped forms such as Ircinia campana;
3. Encrusting or low-relief sponge clumps; and
4. Branching sponges or those with cylindrical stalks projecting from the substrate.

Low relief sponges covered much of the transect, accounting for 30 to 40% cover in several 10- to 20-m segments. Throughout the entire 100 m^2 area (both transects combined), the average cover for all sponge types was approximately 20%.

Four vase and five loggerhead-type sponges were recorded in the transects. Their densities (400 and 500 individuals/ha, respectively) were somewhat lower than those obtained by underwater television results

(382 and 51/ha for Ircinia campana and I. strobilina, respectively). Densities obtained in high resolution benthic photography survey transects would be expected to be more variable than underwater television densities, since the 100 m^2 high resolution benthic photography survey area is a great deal smaller.

Gorgonian densities were very difficult to determine due to morphological features (many stalks) which made it hard to recognize individual colonies in video samples. There were approximately 35 colonies in the 100 m^2 area, representing a density of 3,500/ha. This number is considerably lower than the underwater television estimate for gorgonians (overall density 26,000/ha), but again the smallness of the area surveyed is probably the source of the differences, since extrapolations from such small actual sample sizes are certainly questionable.

One gorgonian species, Pseudopterogorgia guadalupensis, was readily identifiable and could easily be counted individually in high-resolution benthic photography survey transects. Four separate P. guadalupensis colonies were counted along the 100 m^2 transects, representing a density of 400/ha. The underwater television estimate was 118/ha.

High-resolution benthic photography survey techniques for measuring the sizes of benthic objects were evaluated on this cruise. Sizes were estimated by comparison with objects with known dimensions (e.g., settling plates, transect lines) as calibration aids, and by direct measurement of screen (projected) size on video monitors.

For example, the heights of 15 gorgonian colonies were measured. Their heights could be estimated when surge or currents forced them to lie roughly parallel to the bottom, presenting a two-dimensional view. The measured colonies ranged from 20 to 75 cm high, with a mean of 37 cm. It was not possible to estimate sponge heights, but it was possible to determine their diameters. Fortuitously, the projected size of objects on the high resolution benthic photography survey video monitor (63-cm diagonal screen) very closely approximated their true sizes. A discussion of sponge growth based on these measurements is presented below.

Only two other invertebrates were observed along the high-resolution benthic photography survey transects during Cruise 6. At two locations, a filamentous, colonial organism--probably a hydroid--was noted. Its bushy colonies were approximately 20 cm in diameter. A conch (Strombus sp.) was also observed, at the end of its track in the sand.

On Cruise 7 (June 25, 1985), there was an obvious change in biota. The bottom was dominated (50 to 75% cover) by foliose brown algae of the genus Dictyopteris. During the previous cruise, virtually no attached algae were seen. Other community components remained similar. All of the large sponges recognized on Cruise 6 were present and showed no measurable changes in size. Several gorgonians which could be recognized by their distinctive sizes and shapes were present and apparently unchanged from Cruise 6. Some gorgonian stalks belonging to colonies whose bases were outside the transects were pushed by water motion into the field of view of the camera but were excluded from density estimates.

One observation of special note was a small (10 by 20 cm) excavated depression inside the transect during both Cruise 6 and Cruise 7. This bare patch was surrounded by sand, and the underlying bedrock was fully exposed. Apparently, this odd feature persisted for more than 3 months, although there was a great deal of water motion at this shallow station during this period. The longevity of this may be related to ongoing biological activity. For example, nocturnal fish may return to the same place to feed every night, as documented with time-lapse photography elsewhere in this report.

On Cruise 8 (September 13, 1985), Dictyopteris was still conspicuous, but at a reduced density (5 to 15% cover). Sand comprised most of the substrate, and the larger sessile animals observed during previous cruises were still present, including all identifiable gorgonians and sponges.

Between Cruises 6 and 8, some larger sponges showed detectable increases in size. For example, one vase sponge (probably Ircinia campana) had originally measured 8.5 cm in diameter on the television monitor. Its diameter increased by 1.5 cm (18%) to 10 cm during the following 6 months. Based on preliminary calculations (1:1 correspondence between screen size and actual size), this sponge would have an expected growth rate of approximately 3 cm in diameter per year.

A massive, loggerhead-type sponge (probably Ircinia strobilina was measured for growth between Cruises 7 and 8. During the 3-month interval, the sponge increased in diameter approximately 2.5 cm (15%), from 16 to 17 cm on Cruise 7 to 19 cm on Cruise 8. If a linear increase in diameter is assumed to occur over a longer period of time, this sponge would be expected to increase 10 cm in diameter per year.

The high-resolution benthic photography survey method did not permit the measurement of heights of objects. Consequently, it was not possible to determine the increase in overall size for this sponge. However, by making some general assumptions that are consistent with other observations, it is possible to estimate total volumetric increase. Loggerhead sponges are typically cylindrical, with diameters similar to their heights. It is probably reasonable to assume that an increase in diameter is reflected by a similiar increase in height, meaning that volume can be modeled roughly by a cylinder of equal height and diameter. If so, the loggerhead sponge mentioned above would have a volume of 3,528 cm^3. A quarterly increase of 2.5 cm in diameter and height would change its volume to 5,387 cm^3, an overall increase of 53%. At this rate, its volume could double in less than 6 months.

This number should not be taken too seriously, for two reasons. First, there are many uncertainties and assumptions in the calculations; and second, loggerhead sponges--as well as most other species--seem to have a maximum size, implying that growth rates slow asymptotically as that size is approached. However, the calculation does suggest that sponges may recover very rapidly from damage, if a portion of the original sponge remains after destructive activities cease. This conclusion is consistent with high growth rates described in the literature for other sponges. For example, Stevely et al. (1978) reported annual increases in the sizes of commercial sponges in Florida ranging from 77 to over 225% in either diameter or volume, depending on the species' growth form.

Station 44

Historical Notes

Station 44 [depth 13 m, in the Inner Shelf Depth Zone (Woodward Clyde Consultants/Continental Shelf Associates, 1983)] was designated a live bottom station in the Year 3 Final Report by Continental Shelf Associates (R. Avent, MMS, pers. comm., 1984). It was selected for further study to provide a more northern station to compare with Station 52.

Station 44 was surveyed as a Group I station by ESE/LGL during Year 4, on Cruises 1 and 3 and as a modified Group II station (settling plates and time-lapse camera samples only) during Year 5 (Table 2.2-2).

Underwater Television Results

The total area surveyed was 14,735 m^2. The bottom at Station 44 was mainly carbonate sand, with scattered dense gorgonian beds, corals, sponges, and algae. The only substrate type reported was sand. Tracks produced by burrowing echinoids were conspicuous features.

Among benthic invertebrates, the highest mean densities were recorded for gorgonians (4,571/ha); mellitid sand dollars (616/ha), bivalves of the genus *Atrina* (52/ha), the sponge *Ircinia campana* (51/ha), unidentified asteroids (52/ha), and hydroids (16/ha) (Figure 3.2-2, Table 3.2-2). As a group, demosponges accounted for 2% cover (Table 3.2-1).

The most frequently counted fishes in underwater television transects at Station 44 were the round scad, *Decapterus punctatus* (24/ha); the tomtate, *Haemulon aurolineatum* (10/ha); the blue runner, *Caranx crysos* (5/ha); the jackknife-fish, *Equetus lanceolatus*; and various unidentified lutjanid snappers (both 3/ha) (Figure 3.2-3, Table 3.2-3).

There were major differences in the underwater television data for benthic organisms and between Cruise 1 (December 1983) and Cruise 3 (May 1984), probably due to the patchy nature of benthic substrates at this station. During Cruise 3, approximately five times more area was surveyed than on Cruise 1 (Table 2.2-2). The area covered on Cruise 1 thus was more likely to have been atypical of the block in general. Although the only substrate type reported at Station 44 was sand, whether or not large sessile organisms were present ("live bottom") probably depended on how deeply the sand covered underlying hard substrate. It appears that thin sand over hard substrate made up much of the area surveyed on Cruise 1, and that fewer such areas were seen on Cruise 3.

Benthic invertebrates associated with hard substrates were recorded at very high densities on Cruise 1 (Table 3.2-1). For example, the most common benthic organisms were gorgonians (23,133/ha), sponges such as Ircinia campana (303/ha) and I. strobilina (109/ha), and hydroids (77/ha). Demosponges as a group accounted for 7% coverage (Table 3.2-1), and unidentified asteroids were very abundant (43/ha).

During Cruise 3, the fauna was more typical of soft bottom. The density of Ircinia strobilina was estimated less than 1/ha, and Ircinia campana was not observed at all. Perentage cover of demosponges as a group was low (less than 1%). The density of mellitid sand dollars was 20 times higher (737/ha) than it had been on Cruise 1 (36/ha), and gorgonian density was almost two orders of magnitude lower (824/ha). Asteroids were even more abundant (52/ha), but hydroids were much less abundant (3/ha). Furthermore, conchs (Strombus), which are generally found on sand, were common on Cruise 3 (15/ha), but not seen at all on Cruise 1.

Despite the changes from Cruise 1 to Cruise 3 in the mean abundances of benthic organisms observed on underwater television at Station 44, none of the differences in density was statistically significant. However, there was a significant decrease ($p < 0.05$) in the percentage cover of demosponges from Cruise 1 to Cruise 3.

The differences in fish seen on Cruise 1 versus Cruise 3 further suggest that areas differed, at least in terms of the kinds of animals (sponges and gorgonians) that usually produce vertical relief. Most of the fishes recorded from Cruise 1 were those typically associated with larger bottom features. The most common species were the tomtate, Haemulon aurolineatum (57/ha); the jackknife-fish, Equetus lanceolatus and unidentified lutjanid snappers (both 20/ha); the scrawled cowfish, Lactophrys quadricornis (12/ha); and the lane snapper, Lutjanus synagris; white grunt, Haemulon plumieri; and groupers (Mycteroperca or Epinephelus) (all 8/ha). None of these was seen on Cruise 3. In fact, the only two fish species seen on Cruise 3 were two jacks: the round scad, Decapterus punctatus (29/ha), and the blue runner, Caranyx crysos (7/ha). Neither of these fishes was observed on Cruise 1.

Overall diversity (H") and evenness (J') for fishes censused with underwater television were 1.96 and 0.72, respectively, for all cruises together at Station 44.

The only statistically significant differences in fish abundances calculated from underwater television data for Cruises 1 and 3 at Station 44 were for Decapterus punctatus and Haemulon aurolineatum ($p < 0.05$). Decapterus was abundant in the spring (Cruise 3), while Haemulon was abundant in winter (Cruise 1).

Triangular Dredge Results

Fifty invertebrate taxa (excluding sponges) were identified in six triangular dredge samples from Station 44 (Table 3.2-4). The fauna included a mixture of organisms usually associated with hard substrate and coral reefs, and other species more commonly found on unconsolidated sediment, reflecting the mosaic nature of the area.

Five scleractinian corals were collected: the lobed star coral, Solenastrea hyades; the smooth starlet coral, Siderastrea siderea; the ahermatypic coral, Phyllangia americana; a bush coral, Oculina tenella; and the ivory tube coral, Cladocora arbuscula. Five species of gorgonians were also present, including Leptogorgia virgulata, Lophogorgia hebes, Muricea elongata, Eunicea asperula, and Pterogorgia guadalupensis. Leptogorgia virgulata and Lophogorgia hebes were unique to Station 44.

Other typical coral reef species included the long-spined sea urchin, Diadema antillarum; and the arrow crab, Stenorhynchus setosus. Several portunid crabs were taken, including Portunus depressifrons (unique to Station 44) 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). The brachyuran Hypoconcha arcuata was unique to Station 44.

Six gastropods were collected at Station 44. Of these, four were sessile or semi-sessile forms found only on hard substrate such as coral or discarded molluscan shells: the spotted slipper-shell, Crepidula maculosa; the spiny slipper-shell, Crepidula aculeata; Sowerby's fleshy limpet, Lucapina sowerbii; and the Cayenne keyhole limpet, Diodora cayenensis. The only gastropod unique to Station 44 was the common nutmeg, Cancellaria reticulata, a soft bottom form. The fighting conch, Strombus pugilis, also was taken.

All six bivalves from Station 44 were attached species. These included the Florida spiny jewel box, Arcinella cornuta; the eared ark, Anadara nobilis; the Atlantic pearl oyster, Pinctada imbricata; the turkey wing, Arca zebra; the white bearded ark, Barbatia candida (unique to Station 44); and a boring clam, the mahogany date mussel, Lithophaga bisulcata.

Many echinoderms usually found on soft bottom were collected, including the spiny beaded sea star, Astropecten duplicatus; the brown spiny sea star, Echinaster spinulosus; the sand dollars Encope aberrans and E. michelini; the flat sea biscuit, Clypeaster subdepressus; the green sea urchin, Lytechinus variegatus. Several soft-bottom crustaceans were taken, including brown and white shrimps, Penaeus aztecus and P. setiferus; and the portunid crabs Portunus depressifrons and P. anceps.

Ophiuroids collected at Station 44 included several species 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 (Table 3.2-5): Botryocladia occidentalis, Eucheuma nudum, Gracilaria mammilaris, and an unidentified rhodophyte.

Otter Trawl Results

Station 44 was sampled on Cruises 1 (December 1983) and 3 (May 1984). Trawl samples were quite sparse (Table 3.2-6). An average of 12 individuals were collected per tow. Only six taxa belonging to six families were recognized. The most common were unidentified engraulids (6.5/tow); synodontids (1.5/tow); the scrawled cowfish, Lactophrys quadricornis (2/tow); and the tomtate, Haemulon aurolineatum (1 per tow) (Figure 3.2-4). Of the 24 fish that were taken, 22 were collected on Cruise 1 (December 1983). The best represented family was the Haemulidae (grunts, two species). Three fishes were taken only at Station 44: the unidentified engraulids; the spotted whiff, Citharichthys macrops; and the lined sole, Achirus lineatus.

Analyses of stomach contents, maturation state, length, and weight for Lactophrys quadricornis are presented in Subsection 3.2.2, Species Accounts.

Overall diversity (H") and evenness (J') for fishes collected by trawling were 1.36 and 0.76, respectively, for both cruises together at Station 44.

Time-Lapse Camera

Overview

The array at Station 44 was first installed during Cruise 5 (December 1984), in an area of relatively dense sponges and other large benthic organisms. The sediment transport measurement rod was located directly behind a massive, grey-colored sponge approximately 20 cm tall and other brown branching sponges. The area in view of the camera was half covered with biota, and half with exposed sand. Divers servicing the array measured the thickness of unconsolidated sediment at 0 to 5 mm. No major sediment transport was observed, but the movements of sessile organisms such as hydroids and algae revealed semidiurnal tidal cycles. All of the algae and hydroids remained in the field of view appeared unchanged in density throughout the period.

Cruise 5-8 (December 1984 to September 1985)

Due to problems in relocating the array, the camera installed during Cruise 5 on December 5, 1984, was not recovered until over 9 months later during Cruise 8, on September 20, 1985. Surprisingly, the camera and strobe were in relatively good condition, but completely detached from the array. Time-lapse camera data were available for 25.5 days from December 5 to December 31, 1984 (612 hourly observations).

None of the frames was taken in clear water (100% visibility), but 92.2% of the frames were exposed under slightly turbid conditions (relative visibility 75%). 1.8% of the frames were shot under conditions of 50% relative visibility, 2.5% of the frames during 25% relative visibility, and the remaining 3.6% of the frames were taken in zero visibility. The only major sediment resuspension ("turbidity storm") began on Day 2 (6 December) at 1600 hours, reducing visibility to zero by 2000 hours. These conditions persisted for 2 days, after which the water clarity returned to its previous level (25% relative visibility). None of the frames was occluded by biota.

A small coral colony (probably *Siderastrea siderea*), was in the field of view of the camera. This presented an excellent opportunity to observe the effects of sedimentation on the dark-colored coral. It was flush against the bottom, presumably attached to hard substrate, and surrounded by a thin layer of sand on all sides. The surface of the coral turned a lighter color when sediment covered it.

Very little sediment was seen on the coral immediately after the turbidity storm. On several other occasions, the colony was covered with varying amounts of coarse sediment. The coral generally required 8 to 12 hours to remove all visible sediment. In one instance, the colony was completely buried, but required only 4 hours to clear itself.

Branching sponges adjacent to the sediment measuring rod also provided an opportunity to observe small-scale sediment dynamics. Coarse sediments accumulated between the sponge stalks in such a way that the edge of the sediment piles were plainly visible against the dark background of the sponges. The piles of sediment moved up and down the sponge stalks. No regular cycle was apparent, but the interval between high points of sediment accumulation was usually several days. Much of the sediment appeared to be coming from the sponges themselves. Small clumps of white material--probably composed of sediment-laden mucus--were located temporarily at the tips of sponge stalks. This material appeared to originate from the terminal osculum of the sponges. During the entire period, relative visibility never exceeded 75%.

The settling plate targets were both new at the beginning of this period. There was no visible settling growth during the period. Fish observations included 92 individual records, comprising 13 taxa (Table 3.2-8). Lack of sightings during the first 43 hours were due to the turbidity storm (Figure 3.2-15). Only three fishes accounted for more than 10 observations. The most numerous fish (35 records) was *Diplectrum*, either *D. bivittatum* or *D. formosum*. Figure 3.2-15 shows

Table 3.2-8 Total number of fish sightings by time-lapse camera at Station 44, during December 1984

Taxon	Sightings
Diplectrum unident.	35
Equetus lanceolatus.	25
Perciformes unident.	12
Epinephelus itajara.	5
Serranus subligarius.	3
Apogonidae unident.	3
Epinephelus morio.	2
Haemulon aurolineatum.	2
Sparisoma unident.	1
Archosargus probatocephalus.	1
Haemulon plumieri.	1
Rypticus unident.	1
Carangidae unident.	1
Number of Sightings	92
Total Frames Exposed	612

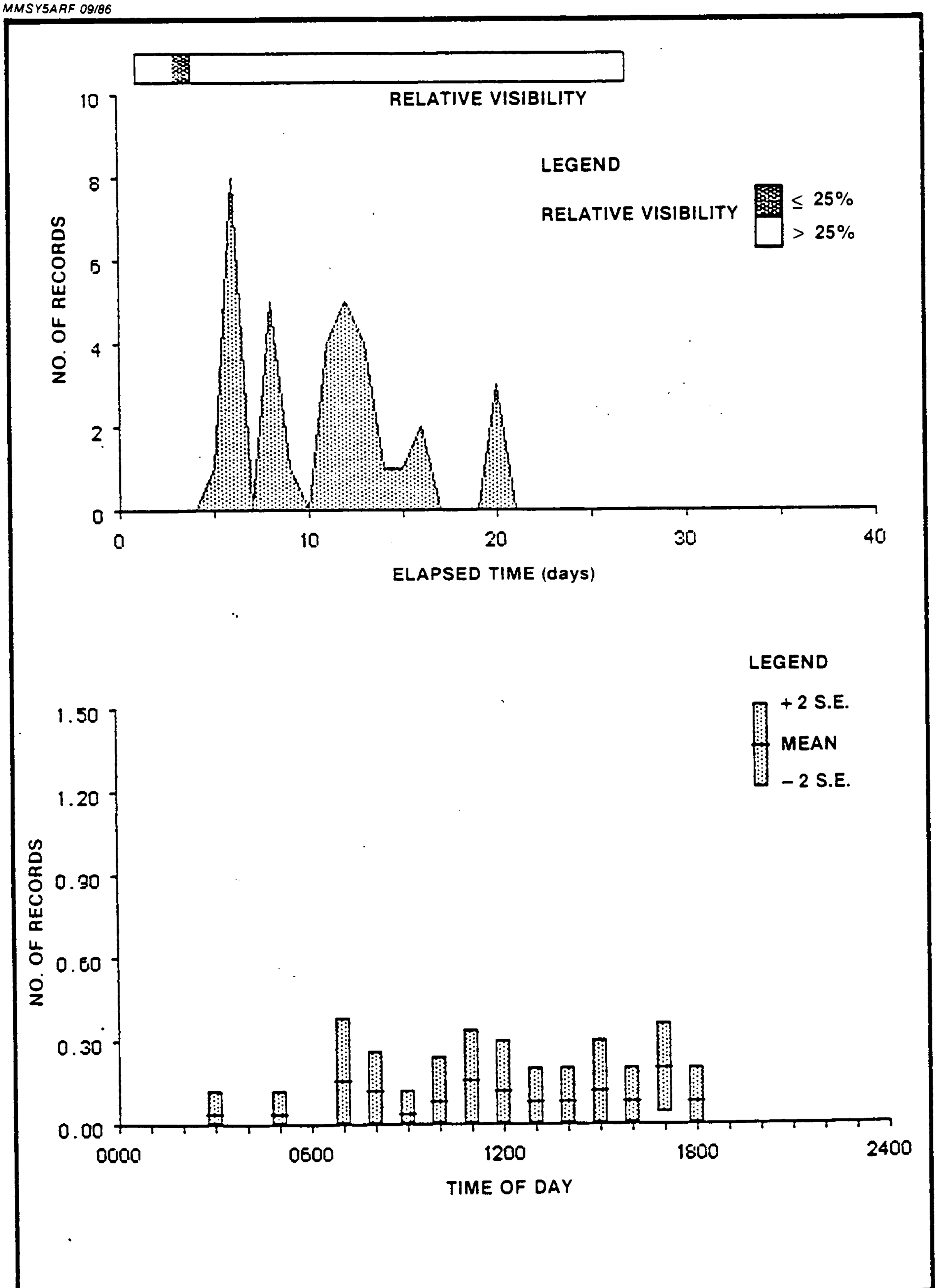

Figure 3.2-15 ACTIVITY PATTERNS FOR *Diplectrum* sp AT STATION 44, FROM TLC, DECEMBER 5 – 31, 1984

both daily frequency of observations and mean hourly attendance for Diplectrum. Diplectrum was observed immediately after the water cleared. Diplectrum was also commonly seen by divers in the surrounding area. The maximum daily frequency of observations (eight records) occurred on Day 7. Attendance was primarily during daylight (0700 to 1800 hours), with a few observations at 0500 and 0300 hours. Hourly means showed no apparent peak.

The second most frequently sighted fish was the jackknife-fish, Equetus lanceolatus (25 records). Jackknife-fish were not observed until 9 days after installation (Figure 3.2-16). The third most frequently recorded fishes (12 records) was too small to identify, and were grouped as Perciformes. Most of them were probably juvenile tomtate (Haemulon aurolineatum). Jewfish (Epinephelus itajarra) were recorded in only five frames of this period, at 1400, 1900, and 2100 to 2300 hours.

Cruise 7-8 (June/July 1985 to September 1985)
Since we could not relocate the original array during both Cruises 6 and 7, a new array was deployed during Cruise 7. To assemble a new time-lapse camera system, it was necessary to utilize all the backup time-lapse equipment on board. The standard 1-hour intervalometer was not available, making the intervalometer inside the movie camera the only option. Its maximum interval was only 1 min 28 sec, which reduced the exposure period to about 3 days, compared to over 5 months at the standard 1-hour interval.

The make-shift strobe failed within 30 min of operation, but ambient light was adequate to expose frames properly during daylight hours. During the first day, an odd object moved back and forth in the background. It seemed to be an urchin covered with pieces of shell and other debris. It moved across the field of view twice (around 1900 hours), appearing on seven frames, or about 10-1/2 min of real time. Its speed was calculated to be about 0.2 m/min.

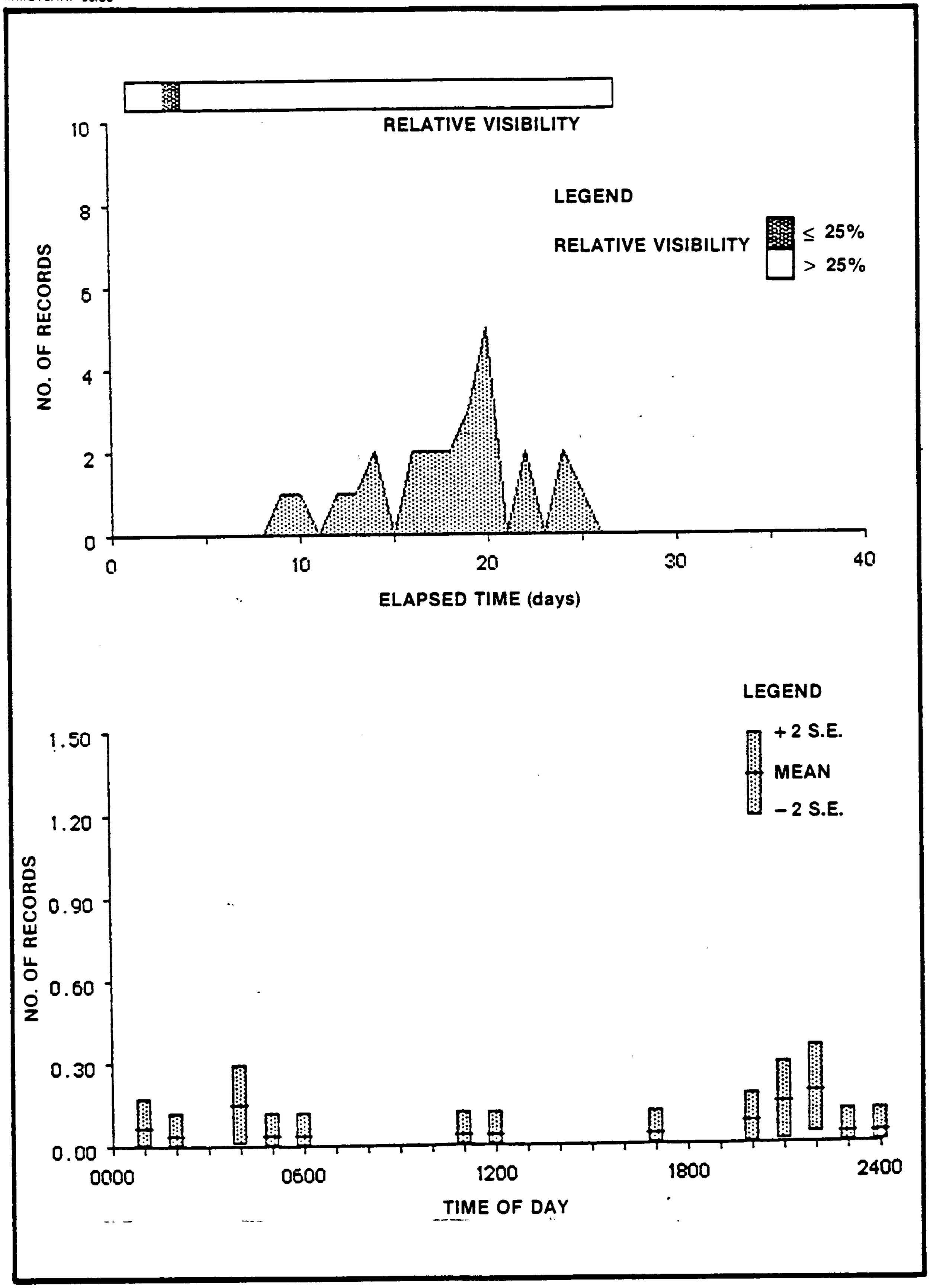

Figure 3.2-16 ACTIVITY PATTERNS FOR *Equetus lanceolatus* AT STATION 44, FROM TLC, DECEMBER 5 – 31, 1984

Fish were rarely seen during daylight. During the second day, an adult jack-knife fish was seen twice around midday. Several small, cryptic fish were noticed darting in and around a clump of sponges throughout the day. These were probably damselfishes, or possibly serranids. These fishes were most active in the morning between 0800 and 1000 hours. Just after daylight (0800 hour) a small ray (Dasyatidae) moved across the bottom towards the camera and then out of sight. The movement was slow and steady, and the ray remained in contact with the bottom as if it were feeding in the sand. The journey lasted 12 frames (about 18 min of real time).

When the third daylight period began, the camera had been dislodged from its bracket and was pointing into open water. No other useful frames were obtained. The film ran out during the fourth day.

Station 51

Historical Notes

Station 51 [depth 15 m, in the Inner Shelf Depth Zone (Woodward Clyde Consultants/Continental Shelf Associates 1983)] was designated a live bottom station in the Year 3 Final Report by Continental Shelf Associates (R. Avent, MMS, pers. comm., 1984). Station 51 was surveyed by ESE/LGL during Year 4 as a Group I station, on Cruises 1 and 3 (December 1983 and May 1984, respectively.

Underwater Television Results

A total area of 24,054 m^2 was surveyed with underwater television. Station 51 was mainly a flat carbonate sand bottom with ripple marks and attached algae, and patches of gorgonians and sponges. Sand was the only substrate type reported from Station 51.

The most abundant invertebrates observed were gorgonians, sponges, and algae (Figure 3.2-2, Tables 3.2-1 and 3.2-2). Unidentified gorgonians were extremely numerous (30,537/ha) as were the sponges *Ircinia campana*

(170/ha) and _I. strobilina_ (71/ha), and unidentified hydroids (63/ha). Algae accounted for 33% cover, and demosponges as a group for another 6%. Other common invertebrates included various holothuroids (4/ha), and the gorgonian _Pterogorgia guadalupensis_ (3/ha).

The most frequently counted fishes in underwater television transects at Station 51 were the white grunt, _Haemulon plumieri_ (248/ha); the red grouper, _Epinephelus morio_; and the cubbyu, _Equetus umbrosus_ (both 11/ha); the blue runner, _Caranx crysos_ (10/ha); the jackknife-fish, _Equetus lanceolatus_; and unidentified sand perches of the genus Diplectrum (both 8/ha); and the hogfish, _Lachnolaimus maximus_ (7/ha) (Figure 3.2-3, Table 3.2-3).

Overall diversity (H") and evenness (J') for fishes censused with underwater television were 1.11 and 0.34, respectively, for all cruises together at Station 51.

Cruise 1 (December 1983) underwater television data were very similar to Cruise 3 (May 1984) data for most abundant benthic organisms (Table 3.2-1). Approximately 50% less area was covered on Cruise 1 (9,114 m^2) than on Cruise 3 (14,940 m^2) (Table 2.2-2).

Algal cover was high on both cruises (35% and 24% cover, respectively). Demosponges accounted for about 5% on both cruises. The sponge _Ircinia campana_ had a mean density of 81/ha on Cruise 1, and 224/ha on Cruise 3. _Ircinia strobilina_ had densities of 99/ha (Cruise 1) and 54/ha (Cruise 3). On both cruises, transects crossed dense gorgonian beds, with recorded densities of 15,801 and 39,527/ha at Station 51 for Cruises 1 and 3, respectively. The gorgonian _Pterogorgia guadalupensis_ was noted on Cruise 1 (9/ha), though not on Cruise 3. Hydroids bloomed between Cruises 1 and 3; they were not observed on Cruise 1, but were extremely common (101/ha) on Cruise 3.

Despite the changes from cruise to cruise in the mean abundances of benthic organisms observed on underwater television at Station 51, none of the differences in density or percentage cover was statistically significant.

Most of the fishes seen at Station 51 on Cruise 1 were also abundant on Cruise 3. On Cruise 1, the most abundant species was the white grunt, *Haemulon plumieri*, 521/ha. Other common fishes included the cubbyu, *Equetus umbrosus* (26/ha); the jackknife-fish, *E. lanceolatus* (21/ha); the red grouper, *Epinephelus morio* (19/ha); the hogfish, *Lachnolaimus maximus* (11/ha); and the gray angelfish, *Pomacanthus arcuatus* (7/ha).

On Cruise 3, *Haemulon plumieri* was still the overwhelming numerical dominant (82/ha), followed by the blue runner, *Caranx crysos* (14/ha); sand perch, either *Diplectrum formosum* or *D. bivittatum* (11/ha); the red grouper, *Epinephelus morio* (7/ha); and the hogfish, *Lachnolaimus maximus* (4/ha).

The only fish censused with underwater television at Station 51 which differed significantly ($p < 0.05$) in density between cruises was *Equetus lanceolatus*. *Equetus* was abundant only in December (Cruise 1).

Triangular Dredge Results

Dredge samples from Station 51 were relatively sparse in terms of numbers of species. Numerous sponges were taken, but were not identified. Only 25 invertebrate taxa (excluding sponges) were identified in six samples (Table 3.2-4). Few invertebrates associated with hard substrates were collected. No scleractinians were found, and only one gorgonian (*Plexaurella fusca*) was captured by the triangular dredge, although some dense gorgonian beds were observed on underwater television.

Just three bivalves (the Atlantic thorny oyster, *Spondylus americanus*; the winged oyster, *Pteria colymbus*; and the Atlantic pearl oyster, Pinctada imbricata) were taken by triangular dredge. The two gastropods collected were the apple murex, Murex pomum (unique to Station 51) and the eastern white slipper-shell, Crepidula plana). Five small brachyurans (Pilumnus dasypodus, P. pannosus, Mithrax hispidus, Podochela sidneyi, and an unidentified Pitho), one anomuran (Petrolisthes galathinus) and two pistol shrimps (Synalpheus minus and S. townsendi) were also collected at Station 51.

A number of taxa collected by the dredge were more typical of soft bottom than of hard bottom. These included two penaeids (the brown shrimp, Penaeus aztecus, and the prawn Metapenaeopsis goodei). There were also four sea stars (the American sand star, Astropecten americanus, unique to Station 51; the spiny beaded sea star, Astropecten duplicatus; the limp sea star, Luidia alternata; and the brown spiny sea star, Echinaster spinulosus) and two echinoids (the flat sea biscuit, Clypeaster subdepressus, and the green sea urchin, Lytechinus variegatus). Three ophiuroids were collected: Savignyi's ophiactis, Ophiactis savignyi; the angular brittle star, Ophiothrix angulata; and Amphipholis squamata (taken only at Station 51).

Eight plants were taken at Station 51 (Table 3.2-5): three green algae (Halimeda monile, H. simulans, and Udotea conglutinata), two brown algae (Dictyopteris membranacea and an unidentified congener), and three red algae [Spiridia filamentosa, Gracilaria verrucosa (unique to Station 51), and an unidentified rhodophyte].

Otter Trawl Results

Trawl samples were taken at Station 51 on Cruises 1 (December 1983) and 3 (May 1984) (Table 2.2-1). Only 21 individuals were collected from the two hauls at Station 51, an average of 10.5 per 10-minute tow (Table 3.2-6). The most abundant fishes were the white grunt, Haemulon plumieri (4/tow), and the scrawled cowfish, Lactophrys quadricornis (1.5/tow, Figure 3.2-4).

Overall diversity (H") and evenness (J') for fishes collected by trawling were 1.96 and 0.85, respectively, for both cruises together at Station 51.

There were 10 species belonging to eight families in trawl samples. Of these, only one (Haemulon plumieri) was present on both cruises. On Cruise 1, only the blackedge moray, Gymnothorax nigromarginatus, and H. plumieri (six individuals) were found in the trawl. On Cruise 3, 14 individuals were taken, representing nine species.

Analyses of stomach contents, maturation state, length and weight for Haemulon plumieri are presented in Subsection 3.2.2, Species Accounts.

Station 45

Historical Notes

Station 45 [depth 16 m, in the Inner Shelf Depth Zone (Woodward Clyde Consultants/Continental Shelf Associates, 1983)] was designated a live bottom station in the Year 3 Final Report by Continental Shelf Associates (R. Avent, MMS, pers. comm., 1984). Station 45 was surveyed as a Group I station by ESE/LGL during Year 4, on Cruises 1 and 3 (Table 2.2-1).

Underwater Television Results

A total area of 27,653 m^2 was surveyed with underwater television. The bottom at Station 45 consisted of carbonate sand over hard bottom, with scattered communities of corals, gorgonians, sponges, and algae. The only substrate type reported was sand. The topography of Station 45 was generally flat, with ripple marks and a few detectable depressions or valleys 1 to 2 m deep.

There were huge numbers of unidentified gorgonians (156,842/ha) observed at Station 45 (Table 3.2-2). Other abundant invertebrates included the sponge Ircinia campana (30/ha); the coral Solenastrea hyades (15/ha), the unidentified asteroids (9/ha); mellitid sand dollars (6/ha); the sponge

Ircinia strobilina and unidentified corals (both 5/ha); and the holothuroid Isostichopus badionotus (3/ha) (Figure 3.2-3). Demosponges accounted for 6% cover (Table 3.2-1).

The most frequently counted fishes in underwater television transects at Station 45 were the blue runner, Caranx crysos, and an unidentified drum--probably the jackknife-fish but identified only to genus--Equetus sp. (both 5/ha); and unidentified porgies of the genus Calamus, the tomtate, Haemulon aurolineatum; and the white grunt, H. plumieri (all 4/ha) (Figure 3.2-3, Table 3.2-3).

Overall diversity (H") and evenness (J') for fishes censused with underwater television were 2.70 and 0.86, respectively, for all cruises together at Station 45.

During Cruise 1 (December 1983), 5,605 m^2 were surveyed. On Cruise 3 (May 1984), 22,048 m^2 were surveyed, four times the area seen on Cruise 1 (Table 2.2-2). The abundances of most common benthic invertebrates were similar from Cruise 1 to Cruise 3 (Table 3.2-1). Gorgonians were numerically dominant on both cruises (106,644 and 169,604/ha on Cruises 1 and 3, respectively). The density of the sponge Ircinia campana was relatively constant (34 and 29/ha). Although rarer on Cruise 1 (fewer than 2/ha), the sponge Ircinia strobilina was frequently seen on Cruise 3 (6/ha). As a group, demosponges accounted for 8 and 5% cover on Cruises 1 and 3, respectively.

During Cruise 1, underwater television transects apparently crossed a large area of coral, as evidenced by very high densities of the lobed star coral, Solenastrea hyades (57/ha); other unidentified scleractinians (20/ha); and the large flower coral, Mussa angulosa (9/ha). Corals were rarer (4.5/ha for Solenastrea hyades, others 1.4/ha) on Cruise 3, although the total area transected on Cruise 1 was one-fourth of that transected on Cruise 3. This suggests that the coral patch seen on Cruise 1 was not typical of the area overall. Mellitid sand dollars were also observed on Cruise 1 (29/ha), but not on Cruise 3, when unidentified sea stars were more common (11/ha).

None of the benthic invertebrates censused with underwater television at Station 45 differed significantly ($p < 0.05$) in density between cruises.

The fish seen during Cruise 1 may also reflect differences in the type of area transected compared to Cruise 3. During Cruise 1, the most abundant species were the tomtate, *Haemulon aurolineatum* (13/ha), and the hogfish, *Lachnolaimus maximus* (4/ha). The seven taxa identified had densities exceeding 1/ha.

During Cruise 3, far more fishes were sighted (20 taxa) than on Cruise 1 (7 taxa), probably as a result of covering such a large area on Cruise 3, but they were not as concentrated. Eleven of them had densities lower than 1/ha, and all but five of them [the blue runner, *Caranx crysos*, and unidentified sciaenids of the genus *Equetus* (almost certainly either *E. lanceolatus*, the jackknife-fish, or *E. umbrosus*, the cubbyu), both 6/ha; the white grunt, *Haemulon plumieri*, and unidentified porgies of the genus *Calamus*, both 5/ha] had densities lower than 3/ha.

The only statistically significant difference ($p < 0.05$) between cruises in mean density of fishes observed on underwater television at Station 45 was for *Haemulon aurolineatum*, most abundant in the winter Cruise 1 (December 1983).

Triangular Dredge Results

Seventy-seven invertebrate taxa (not counting sponges) were collected in six triangular dredge samples at Station 45 (Table 3.2-4). The fauna of Station 45 included many species typical of shallow-water coral reefs, and numerous unidentified sponges.

Nine scleractinian corals were found: the lobed star coral, Solenastrea hyades; the ahermatypic coral, Phyllangia americana; the ivory tube coral, Cladocora arbuscula; the solitary disc coral, Scolymia lacera; the smooth starlet coral, Siderastrea siderea; the small finger coral, Porites divaricata; the large flower coral, Mussa angulosa; the blushing star coral, Stephanocoenia michelini; and the cactus coral, Isophyllia multiflora (= I. sinuosa forma multiflora). Porites divaricata and Isophyllia were not collected from any other station.

Thirteen species of gorgonians were identified, representing seven genera (Plexaurella, Pseudoplexaura, Pseudopterogorgia, Leptogorgia, Muricea, Eunicea, and Pterogorgia). Two species, Leptogorgia setacea and Pseudopterogorgia rigida, were unique to Station 45.

Twelve bivalves were present at Station 45. Most of the bivalves were attached forms found on hard substrates, such as oysters, arc shells, and jewel boxes. Larger species included the Atlantic pearl oyster, Pinctada imbricata; the winged oyster, Pteria colymbus and an unidentified congener; the turkey wing, Arca zebra; the eared ark, Anadara notabilis; the white miniature ark, Barbatia domingensis; the mossy ark, Arca imbricata; the leafy jewel box, Chama macerophylla; and two spiny oysters, Spondylus americanus and the digitate spiny oyster, S. ictericus. Two boring clams were also present: the scissor date mussel, Lithophaga aristata, and the mahogany date mussel, Lithophaga bisulcata. Lithophaga aristata and Barbatia domingensis were unique to Station 45.

There were 14 gastropods collected with the triangular dredge. Both sessile or semi-sessile and highly motile species were found. Attached forms included slipper shells (e.g., the eastern white slipper-shell, Crepidula plana, and the spiny slipper shell, Crepidula aculeata) and limpets (e.g., Lister's keyhole limpet, Diodora listeri). Several large soft-bottom gastropods were present, such as pink and milk conchs, *Strombus gigas* and *S. costatus*; the lace murex, *Murex florifer*; and the long-spined star-shell, *Astraea phoebia*. Species unique to Station 45 included Carpenter's dwarf triton, *Ocenebra interfossa* (probably a misidentification, because the species has been reported previously from the Pacific Ocean); the short-tailed latirus, *Latirus angulatus*; the Florida cerith, *Cerithium atratum*; and an unidentified fasciolariid.

Crustaceans taken at Station 45 included many forms typically found on coral reefs. Eleven brachyuran crabs were collected, including the lesser sponge crab, *Dromidia antillensis*, four majiids (*Mithrax turceps, M. forceps, M. hispidus*, and *M. pleuracanthus*), and others. *Mithrax turceps* and *Pilumnus floridanus* were not collected at any other station.

A cleaner shrimp, *Periclimenes americanus*, and three pistol shrimps, (*Alpheus normanni*, *Synalpheus minus*, and *S. townsendi*) were also collected with the triangular dredge, along with four anomurans, including hermit crabs (*Paguristes tortugae*, *P. sericeus*), and porcelain crabs (*Petrolisthes galathinus, Megalobrachium soriatum*). *Megalobrachium* has been collected in elsewhere conjunction with *Oculina* and *Ircinia* (Williams, 1984). A stomatopod, *Gonodactylus bredeni*, also was collected.

Several echinoderms were present in dredge samples. Two sea stars were found: the brown spiny sea star, *Echinaster spinulosus*, and an unidentified congener. Three ophiuroids collected were the angular brittle star, *Ophiothrix angulata*; Suenson's brittle star, *Ophiothrix suensonii*; and the ruby brittle star, *Ophioderma rubicundum*. *Ophiothrix suensonii* is often reported from the inside of sponges or from gorgonians. One urchin (the brown rock urchin, *Arbacea punctulata*) and one one sea cucumber (the three-rowed sea cucumber, *Isostichopus badionotus*) also were taken by the triangular dredge.

A diverse algal flora was present at Station 45. Twenty-two algae were identified in dredge samples from Station 45 (Table 3.2-5). Six green algae (Halimeda monile, H. tuna, H. discoidea, Udotea cyathiformis, Codium isthmocladum, and Caulerpa peltata), four brown algae (Dictyopteris membranacea, Dictyota bartayresii, Sargassum filipendula, and S. cf. hystrix), and 12 rhodophytes were reported.

The only red algae that could be identified to genus were Eucheuma nudum, Botryocladia occidentalis, three species of Laurencia (L. gemmifera, L. cf. obtusa, and L. intricata), and a Polysiphonia. Many of the red algae at Station 45 were not found at any other station, including Laurencia gemmifera, L. cf. obtusa, and six other unidentified species.

Otter Trawl Results

Station 45 was sampled on Cruise 1 (December 1983) and Cruise 3 (May 1984) (Table 3.2-1). Seventy-seven individuals were collected in the two hauls, for an average of 38.5 individuals per 10-minute tow (Table 3.2-6). Eighteen fishes were recognized, belonging to 13 families. The best represented family from the standpoint of numbers of species present was Sparidae, the porgies (three species).

The most abundant species overall were the Atlantic spadefish, Chaetodipterus faber (10/tow); the white grunt, Haemulon plumieri (7/tow); the slippery dick, Halichoeres bivittatus (3/tow); the scrawled cowfish, Lactophrys quadricornis and the bandtail puffer, Sphoeroides spengleri (both 2.5/tow); and the tomtate, Haemulon aurolineatum (2/tow) (Figure 3.2-4, Table 3.2-6). Other common species included the whitespotted soapfish, Rypticus maculatus; the jolthead porgy, Calamus bajonado; and the blue angelfish, Holacanthus bermudensis (all 1/tow). Overall diversity (H") and evenness (J') for fishes collected by trawling were 2.44 and 0.84, respectively, for both cruises together at Station 45.

Three fishes were collected only at Station 45: *Calamus bajonado*; the sheepshead porgy, *Calamus penna*; and *Halichoeres bivittatus*.

Many species were present during both Cruises 1 and 3, when 32 and 45 individuals, respectively, were taken. Species found on both cruises included the sand diver, *Synodus intermedius*; the tomtate, *Haemulon aurolineatum*; *Chaetodipterus faber*; the hogfish, *Lachnolaimus maximus*; *Lactophrys quadricornis*; *Rypticus maculatus*; and *Sphoeriodes spengleri*.

Analyses of stomach contents, maturation state, length and weight for some of the fishes taken at Station 45 (*Lactophrys quadricornis*, *Synodus intermedius*, *Haemulon plumieri*, and *Epinephelus morio*) are presented in Subsection 3.2.2, Species Accounts.

Station 47

Historical Notes

Station 47 [depth of 20 m, in the Inner Shelf Depth Zone (Woodward Clyde Consultants/Continental Shelf Associates, 1983)] was designated a live bottom station in the Year 3 Final Report by Continental Shelf Associates (R. Avent, MMS, pers. comm., 1984). Station 47 was surveyed by ESE/LGL during Year 4, on Cruises 1 (December 1983) and 3 (May 1984) (Table 2.2-1).

Underwater Television Results

Total area surveyed was 29,804 m^2 (Table 2.2-2). Ripple-marked carbonate sand characterized the bottom at Station 47. The only substrate type reported was sand. There were also patches of gorgonians, sponges, and algae observed on the underwater television.

The most abundant invertebrates at Station 47 were various unidentified gorgonians (86,556/ha); the sponges *Ircinia strobilina* (28/ha) and *I. campana* (9/ha); hydroids and mellitid sand dollars (both 6/ha); the reticulated sea star, *Oreaster reticulatus*, and other unidentified asteroids (both 4/ha) (Figure 3.2-2, Table 3.2-2). Green algae of the genus Caulerpa and demosponges as a group each accounted for 5% cover (Table 3.2-1).

Fourteen fishes were recognized at Station 47. The most frequently counted fishes in underwater television transects were the white grunt, Haemulon plumieri (13/ha); the jackknife-fish, Equetus lanceolatus (9/ha); the cubbyu, Equetus umbrosus and the red grouper, Epinephelus morio (both 3/ha) (Figure 3.2-3, Table 3.2-3). Overall diversity (H") and evenness (J') for fishes censused with underwater television were 1.94 and 0.73, respectively, for all cruises together at Station 47.

On Cruise 1 (December 1983), a total of 9,436 m^2 was surveyed in underwater television transects (Table 2.2-2). The most abundant benthic invertebrates were gorgonians (19,718/ha) and the sponges Ircinia strobilina (69/ha) and Ircinia campana (16/ha) (Table 3.2-2). Over 15% cover was occupied by the green alga Caulerpa. Corals were present (e.g., Scolymia lacera and Solenastrea hyades), though at densities of less than 2/ha. Demosponges as a group accounted for 3% cover (Table 3.2-1). Various echinoderms associated with sand were present, including mellitid sand dollars (10/ha); the reticulated sea star, Oreaster reticulatus (5/ha); and sea cucumbers, such as Isostichopus badionotus (1/ha).

On Cruise 3 (May 1984), 20,368 m^2 were surveyed in underwater television transects. Caulerpa was gone, and a modest hydroid "bloom" was evident (10/ha). Transects passed over extremely dense beds of gorgonians (117,519/ha). By comparison to Cruise 1, the sponges Ircinia strobilina and I. campana were less frequently noted (8 and 5/ha, respectively). Coverage by demosponges was 5%. The densities of asteroids, holothuroids, and sand dollars were fairly similar to those recorded on Cruise 1. Even less coral was observed; the only species reported was Solenastrea hyades (less than 1/ha). The horseshoe crab, Limulus polyphemus, was present though rare (fewer than 1/ha).

None of benthic organisms censused with underwater television at Station 47 differed significantly ($p > 0.05$) in density or percentage cover between cruses.

The most abundant fishes observed on Cruise 1 were the jackknife-fish, *Equetus lanceolatus* (10/ha); the cubbyu, *Equetus umbrosus* (8/ha); the red grouper, *Epinephelus morio* (5/ha); and the white grunt, *Haemulon plumieri* (4/ha). On Cruise 3, most fishes were present at very low densities, although more taxa were observed than on Cruise 1. Perhaps this reflected the greater area covered on Cruise 3. The only fishes whose densities exceeded 3/ha were *Haemulon plumieri* (17/ha) and *Equetus lanceolatus* (8/ha).

None of fishes observed with underwater television at Station 47 differed significantly ($p > 0.05$) in density between cruises.

Triangular Dredge Results

Triangular dredge samples for Station 47 included relatively few corals and gorgonians, although many sponges were present (Table 3.2-4). Fifty-six invertebrates (not counting sponges) were identified. In general, samples suggested a high proportion of unconsolidated sediment to hard bottom.

The only three scleractinians collected were the lobed star coral, *Solenastrea hyades*; the ivory tube coral, *Cladocora arbuscula*; and the smooth starlet coral, *Siderastrea siderea*. Six gorgonians were taken: *Eunicea asperula* and an unidentified congener, *Pterogorgia guadalupensis*, *Pseudoplexaura porosa*, *Pseudopterogorgia acerosa*, and *Plexaurella dichotoma*.

Six gastropods were found at Station 47. Most of the gastropods collected were soft-bottom species, such as the fighting conch, *Strombus gigas*; Stearn's cone, *Conus jaspideus stearnsi*; the Scotch bonnet, Phalium granulatum; and the West Indian murex, Murex brevifrons. Two species, Conus jaspideus stearnsi, and Dall's false stomatella, Pseudostomatella erythrocoma, were not collected at any other station.

The seven bivalves collected by dredging at Station 47 included several which attach to hard substrates, e.g., ark shells (the mossy ark, Arca imbricata; the eared ark, Anadara notabilis; and an unidentified Arcinella unique to Station 47), and the digitate spiny oyster, Spondylus ictericus. Free-living or semi-sessile bivalves were also collected, including the king venus, Chione paphia; the thistle scallop, Aequipecten acanthodes; and the common egg cockle, Laevicardium laevigatum.

Many crustaceans were present at Station 47. Although only two anomurans were found (the porcellanid Petrolisthes galathinus and the hermit crab Paguristes sericeus), 18 brachyurans were identified in triangular dredge samples. Some of the larger forms were portunid crabs (Portunus anceps and P. spinimanus); majiids (the arrow crab, Stenorhynchus seticornis, and Mithrax pleuracanthus); xanthids (Pilumnus dasypodus, P. sayi, Lobopilumnus agassizi); the sponge crab, Dromidia antillensis; and the box crab, Calappa flammea. Three brachyurans, Portunus spinimanus, Metoporhapis calcarata, and an unidentified Homola, were found only at Station 47. One mantis shrimp, Gonodactylus bredeni, and two rock shrimps, Sicyonia laevigata and S. typica, were also collected.

The four sea stars collected by triangular dredge at Station 47 were species typically found only on unconsolidated sediment. Three species of Astropecten were present: the beaded sea star, A. articulatus, unique to Station 19; the spiny beaded sea star, A. duplicatus; and A. comptus. The limp sea star, Luidia alternata, was also taken. Four species of ophiuroids were collected, including the lined brittle star, Ophiothrix lineata; the angular brittle star, Ophiothrix angulata; Ophiolepis elegans; and Astrocyclus caecilia. Several sand dollars were also taken, including Encope aberrans and the flat sea biscuit, Clypeaster depressus.

Eighteen algae were identified in triangular dredge samples from Station 47 (Table 3.2-5). There were five green algae (Halimeda simulans, Caulerpa sertularoides, C. mexicana, Udotea conglutinata, Codium isthmocladum) and two browns (Dictyota bartayresii and Sargassum cf. hystrix). Caulerpa mexicana was unique to Station 47.

The remaining 10 algae were rhodophytes (Spyridia filamentosa, Eucheuma nudum, Botryocladia occidentalis, Graciliaria cylindrica, G. armata, an unidentified Graciliaria, Jania pumila, Wrightiella tumanowiczi, Champia parvula, and another which could not be unidentified to genus). Jania pumila, Wrightiella tumanowiczi, and an unidentified Gracilaria were not found at any other station.

Otter Trawl Results

Station 47 was sampled with the trawl on Cruises 1 (December 1983) and 3 (May 1984) (Table 2.2-1). The two hauls took 32 individuals, an average of 16 per 10-minute tow (Table 3.2-6). Seventeen species and 13 families of fishes were identified in the trawl hauls. The best represented family in terms of numbers of species collected was the Balistidae, the triggerfishes (three species). Overall diversity (H") and evenness (J') for fishes collected by trawling were 2.69 and 0.95, respectively, for both cruises together at Station 47.

The most abundant fishes were the white grunt, Haemulon plumieri (2.5/tow); and the lane snapper, Lutjanus synagris, the tomtate, Haemulon aurolineatum; and the gray angel, Pomacanthus arcuatus (all 1.5/tow) (Figure 3.2-4). Most (24) of the fish were taken on Cruise 3. The only species present on both cruises were Haemulon plumieri and Lutjanus synagris. These and Haemulon aurolineatum constituted the entire haul of eight fishes from Cruise 1.

Analyses of stomach contents, maturation state, length, and weight for some of the fishes collected at Station 47 (Haemulon plumieri, Lutjanus synagris, Lactophrys quadricornis, Synodus intermedius, the sand diver, and Epinephelus morio, the red grouper) are presented in Section 3.2.2, Species Accounts.

Station 19

Historical Notes

Station 19 (depth 24 m, within the Inner Shelf Depth Zone) was surveyed by Woodward-Clyde Consultants and Continental Shelf Associates, Inc., during Year 1 and Year 2. Its substrate was categorized as Sand Bottom/Soft Bottom (about 65%) and Thin Sand over Hard Substrate (about 35%). No rock outcrops or exposed hard bottom were observed. About 35% of the area surveyed was estimated to be live bottom, representative of Inner Shelf Live Bottom Assemblage I, dominated by sponges and large gorgonians, but also including patches of algae, ascidians, corals, hydroids (Woodward Clyde Consultants/Continental Shelf Associates, 1983; 1984). Station 19 was surveyed by ESE/LGL as a Group I station during Year 4, on Cruises 1 and 3 (Table 2.2-1).

Underwater Television Results

The total area surveyed was 27,880 m^2 (Table 2.2-2). The bottom at Station 19 was mainly carbonate sand, marked with ripples, and patches of gorgonians, sponges, and algae. The only substrate type reported was sand. In general, epibenthic invertebrates and fishes were relatively low in density compared to shallower live bottom communities.

The most abundant invertebrates observed in underwater television transects were gorgonians (707/ha); the sponge Ircinia strobilina (62/ha); the reticulated sea star, Oreaster reticulatus (28/ha); hydroids (15/ha); mellitid sand dollars (14/ha); the sponge Ircinia campana, and unidentified asteroids (both 5/ha); and holothuroids (Isostichopus badionotus and others) (4/ha) (Figure 3.2-2, Table 3.2-2). Demosponges as a group averaged 3% cover (Table 3.2-1). Unidentified algae accounted for 12% cover.

Thirty-three fishes were observed with underwater television at Station 19, more than at any of the stations inshore of Station 19. Although Station 19 is only slightly deeper than they are, it is located about 50 km to the west of Station 52. The most abundant fishes were the white grunt, Haemulon plumieri (37/ha); a serranid identified as Diplectrum, but almost certainly either the dwarf sand perch (D. bivitattum) or the sand perch (D. formosum) (13/ha); various unidentified porgies, Calamus spp. (5/ha); the jackknife-fish, Equetus lanceolatus (4/ha); unidentified perciform fishes (4/ha); and the gray angel, Pomacanthus arcuatus, the blue runner, Caranx crysos, the goby, Ioglossus calliurus, and the painted wrasse, Halichoeres caudalis (all 3/ha) (Figure 3.2-3, Table 3.2-3). Overall diversity (H") and evenness (J') for fishes censused with underwater television were 2.40 and 0.69, respectively, for all cruises together at Station 19.

On both Cruise 1 (December 1983) and Cruise 3 (May 1984), very large areas were surveyed (11,424 m^2 and 16,456 m^2, respectively) (Table 2.2-2). Many of the most abundant benthic organisms seen on Cruise 1 were also common on Cruise 3.

On Cruise 1, the numerical dominants were gorgonians (285/ha); Ircinia strobilina (123/ha) and Ircinia campana (9/ha); and soft-bottom echinoderms such as the reticulated sea star, Oreaster reticulatus, and mellitid sand dollars (both 33/ha); holothuroids (10/ha) and unidentified asteroids (9/ha). Demosponges as a group accounted for 2.8% cover (Table 3.2-1).

On Cruise 3, gorgonians (1,000/ha), Ircinia strobilina (20/ha), and Oreaster (24/ha) were again abundant, as were holothuroids (Isostichopus badionotus, 7/ha). In contrast to Cruise 1, hydroids were common (25/ha) on Cruise 3, but no sand dollars were observed.

Major changes in algal abundance took place between Cruises 1 and 3 (Table 3.2-1). On Cruise 1, algal cover was 28%; algal cover declined to less than 2% on Cruise 3.

None of the benthic invertebrates censused with underwater television at Station 19 differed statistically ($p > 0.05$) in density between cruises. Unidentified demosponges accounted for significantly more cover ($p > 0.05$) on Cruise 1 than on Cruise 3.

Virtually all of the fishes recorded from Station 19 were observed on Cruise 1 (31 of 33 taxa). The most abundant fishes recorded from Cruise 1 were the white grunt, _Haemulon plumieri_ (90/ha) and sand basses of the genus _Diplectrum_ (23/ha). Other common species included the jackknife-fish, _Equetus lanceolatus_, and unidentified porgies of the genus _Calamus_ (both 9/ha); the blue goby, _Ioglossus calliurus_ (8/ha); the gray angelfish, _Pomacanthus arcuatus_, and the painted wrasse, _Halichoeres caudalis_ (both 7/ha); the reef butterflyfish, _Chaetodon sedentarius_ (4/ha); and the scrawled cowfish, _Lactophyrs quadricornis_ (3/ha). The only species seen on Cruise 3 were _Diplectrum_ (7/ha); the blue runner, _Caranx crysos_ (4/ha); _Calamus_ (3/ha); and the whitespotted filefish, _Cantherhines macrocerus_ (fewer than 1/ha).

Differences were statistically significant ($p < 0.05$) between cruises in the densities of _Diplectrum_, _Haemulon plumieri_, _H. aurolineatum_, and _Ioglossus calliurus_ at Station 19. For all four fishes, densities were higher in the winter on Cruise 1 (December 1983) than in the spring on Cruise 3 (May 1984).

Triangular Dredge Results

Station 19 had a low-relief community dominated by sponges. Forty-seven taxa of invertebrates (excluding sponges) were identified in 6 triangular dredge samples (Figure 3.2-2, Table 3.2-4). There were no scleractinian corals found, and only three gorgonians (_Pterogorgia guadalupensis_, *Pseudopterogorgia acerosa*, and *Plexaurella dichotoma*) were found. Most species were soft-bottom types.

Seven gastropods were taken by the dredge. Larger forms included the banded tulip, *Fasciolaria lilium*; the West Indian murex, *Murex brevifrons*; the fighting conch, *Strombus pugilis*; and the netted olive, *Oliva reticularis* (unique to Station 19). Two species found on hard substrates were the spiny slipper-shell (*Crepidula aculeata*) and the Cayenne keyhole limpet (*Diodora cayenensis*).

Nine bivalves were collected at Station 19. All but one (*Arcinella cornuta*, the Florida spiny jewel box) were species usually found in unconsolidated sediment: the cross-barred venus, *Chione chancellata*; the king venus, *C. paphia*; the thistle scallop, *Aequipecten acanthodes*; the common egg cockle, *Laevicardium laevigatum*; the Lintea tellin, *Tellina aequistriata* (unique to Station 19); the calico clam, *Macrocallista maculata*; the calico scallop, *Aequipecten gibbus*; and the rough scallop, *Aequipecten muscosus*.

There were four anomurans taken, including several hermit crabs [*Pagurus impressus*, *Paguristes sericeus* and *P. moorei* (unique to Station 19)]; and the porcelain crab *Petrolisthes galathinus*. Ten brachyuran crabs were present, including majids such as the arrow crab, *Stenorhynchus seticornis*, which is often associated with sponges, several xanthids (*Pilumnus dasypodus* and *P. sayi*), and the box crab *Calappa sulcata*. Two stomatopods, *Gonodactylus bredeni* and an unidentified congener; a rock shrimp, *Sicyonia laevigata*; and two pistol shrimps, *Synalpheus fritzmuelleri* (found only at Station 19) and *S. townsendi*, were also collected.

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

Only six algae were found in triangular dredge samples from Station 19 (Table 3.2-5). There were three green algae (Caulerpa sertularoides, Udotea cyathiformis, U. conglutinata), one brown (Dictyota bartayresii), and two reds (Lithothamnion occidentalis, unique to Station 19, and Champia parvula). A trachaeophyte, the sea grass Halophila baillonis, was also found only at Station 19.

Otter Trawl Results

Station 19 was sampled with the otter trawl on Cruise 1 (December 1983) and Cruise 3 (May 1984) (Table 2.2-1). Fish were not particularly abundant in trawl samples; only 18 individuals (9.5 fish per 10-minute tow) were collected (Table 3.2-6). Ten species were present, belonging to 9 families. The only family represented by more than one species was the lizardfishes (Synodontidae, 2 species). Overall diversity (H") and evenness (J') for fishes collected by trawling were 2.13 and 0.92, respectively, for both cruises together at Station 19.

The most abundant species at Station 19 was the fringed filefish, Monacanthus ciliatus (2.5 individuals per tow) (Figure 3.2-4). Other common species (all 1/tow) were the lane snapper, Lutjanus griseus (1.5/tow); and the sand perch, Diplectrum formosum, the white grunt, Haemulon plumieri, and the leopard toadfish, Opsanus pardus (the only species unique to Station 19). All of these fishes were collected on both cruises. Nine specimens were taken on Cruise 1; 10 were taken on Cruise 3.

Analyses of stomach contents, maturation state, length, and weight for Haemulon plumieri are presented in Subsection 3.2.2, Species Accounts.

Station 55

Historical Notes

Station 55 [depth 72 m, within the Inner Shelf Zone (Woodward Clyde Consultants/Continental Shelf Associates, Inc., 1983)], was surveyed by ESE/LGL as a Group II station during Year 5, on Cruise 5 (December 1984), Cruise 6 (March 1985), Cruise 7 (June/July 1985), and Cruise 8 (September 1985) (Table 2.2-1).

Underwater Television Results

A total of 23,446 m^2 was surveyed (Table 2.2-2). The only substrate type reported was sand, which must have been overlying hard substrate, given the assortment of sessile epibiota present.

The most abundant benthic invertebrates in underwater television surveys were gorgonians and sponges (Figure 3.2-2). Gorgonians were present at very high densities (54,214/ha for unidentified species, 16/ha for Pterogorgia guadalupensis) (Table 3.2-2). Demosponges as a group were responsible for 17% cover; the sponges Ircinia campana and Ircinia strobilina had densities of 144/ha and 42/ha, respectively. The reticulated sea star, Oreaster reticulatus, was seen frequently (4/ha). Unidentified algae were very important, accounting for 21% cover (Table 3.2-1).

Scuba divers at Station 55 noted that low-lying sponges were intermingled with many small colonies of scleractinian corals, especially Solenastrea hyades. Since these scleractinians could not be separated visually from sponges in underwater television videotapes, they were grouped together as unidentified demosponges during sample analysis. However, many corals were collected in triangular dredge samples from Station 55 (see subsequent paragraphs).

Fish were rather sparse at Station 55 (Figure 3.2-3, Table 3.2-3). The most abundant fishes were gray snappers, Lutjanus griseus (6/ha); porgies of the genus Calamus and the longsnout butterflyfish, Chaetodon aculeatus (both 5/ha); the white grunt, Haemulon plumieri (4/ha); and the gray angel, Pomacanthus arcuatus (3/ha).

The abundances of most benthic organisms were similar from one cruise to the next at Station 55. Areas transected varied from 3,708 to 7,860 m^2 (Table 2.2-2). Unidentified gorgonians and Ircinia were recorded from every cruise. Gorgonian densities ranged from 36,667 to 71,295/ha. The density of Ircinia campana was 109 to 167/ha; Ircinia strobilina was consistently less abundant (32 to 67/ha).

The reticulated sea star, Oreaster reticulatus, was abundant on Cruise 6 (March 1985) and Cruise 7 (6/ ha and 14/ha, respectively), although absent on Cruise 5 (December 1984) and scarce (1/ha) on Cruise 8 (September 1985). The effects of patchiness upon sampling were clearly evident from the underwater television results for the gorgonian Pterogorgia guadalupensis, which was highly abundant (103/ha) on Cruise 7 but not recorded from any other cruise. The gorgonian Ellisella also was observed only on one cruise, Cruise 5 (6/ha).

The only benthic invertebrates whose density or cover differed significantly ($p < 0.05$) between cruises at Station 55 were gorgonians. Gorgonian density was highest on Cruise 5 (December 1984), and differed from lower densities on Cruises 6, 7, and 8 (March, June/July, and September 1985, respectively).

Demosponges as a group were major contributors to bottom cover on every cruise, ranging from 11 to 24% cover (Table 3.2-1). Algae were also very important throughout the study, though least abundant on Cruise 5 in December 1985 (12% cover) and most abundant on Cruise 6 in March 1985 (28% cover) and Cruise 7 (31% cover).

Almost twice as many fishes were recognized from Cruise 5 (10 taxa) than from any other cruise, even though the area surveyed on Cruise 5 was only 5,044 m^2. Among the fishes, only porgies (genus *Calamus*) and the white grunt, *Haemulon plumieri*, were seen on all four cruises. *Calamus* densities ranged from 3/ha (Cruise 8) to 10/ha (Cruise 5); *H. plumieri* was only abundant on Cruise 5 (14/ha, with densities of 1 to 3/ha on other cruises). Overall diversity (H") and evenness (J') for fishes censused with underwater television were 2.25 and 0.83, respectively, for all cruises together at Station 55.

Other species seen two or three times included the longsnout butterfly-fish, *Chaetodon aculeatus* (Cruise 5, 8/ha; Cruise 7, 11/ha; Cruise 8, 4/ha); the gray snapper, *Lutjanus griseus* (18/ha on Cruise 5, 8/ha on Cruise 8); and the blue angelfish, *Holacanthus bermudensis* (2/ha on Cruise 5, 11/ha on Cruise 7). Fishes seen only once but at fairly high densities included the gray angelfish, *Pomacanthus arcuatus* (12/ha on Cruise 6); the reef butterflyfish, *Chaetodon sedentarius* (5/ha on Cruise 7); and the red grouper, *Epinephelus morio* and the longspine squirrelfish, *Holocentrus rufus* (both 3/ha on Cruise 7). None of the fishes censused with underwater television at Station 55 differed significantly ($p > 0.05$) in density between cruises.

Triangular Dredge Results

A total of 121 invertebrates were identified in 12 triangular dredge samples from Station 55 (Table 3.2-4). Most of these were gorgonians, scleractinian corals, gastropods, bivalves, and brachyuran crabs.

Station 55 had a particularly diverse gorgonian fauna. Of the 50 taxa of gorgonians identified in this study, 36 were collected by dredging at Station 55. Twenty of these were unique to Station 55. Eleven genera were recognized: *Muricea*, *Eunicea*, *Plexaurella*, *Pseudopterogorgia*, *Pseudoplexaura*, *Lophogorgia*, *Plexaura*, *Pterogorgia*, *Iciligorgia*, *Muriceopsis*, and *Nicella*.

Although scleractinians were hidden from view among sponges and could not be recognized in underwater television surveys, they were very well represented in triangular dredge samples. Eighteen corals were identified. Larger forms included including the lobed star coral, Solenastrea hyades; the smooth star coral, Solenastrea bournoni; the smooth starlet coral, Siderastrea siderea; the butterprint brain coral, Meandrina meandrites; the elliptical star coral, Dichocoenia stokesii; the ivory bush coral, Oculina diffusa; two other bush corals, Oculina varicosa and an unidentified congener; the blushing star coral, Stephanocoenia michelini; Lamarck's sheet coral, Agaricia lamarcki; the fragile saucer coral, Agaricia fragilis; the green cactus coral, Madracis decactis; the saucer coral, Helioseris cucullata; and the mountainous star coral, Montastrea cavernosa.

Smaller and ahermatypic forms included an unidentified solitary coral, Scolymia (probably S. lacera); the ahermatypic coral Phyllangia americana; the ivory tube coral, Cladocora arbuscula; and the large flower coral, Mussa angulosa. Three corals (Dichocoenia stokesii, Meandrina meandrites, and an unidentified Oculina) were collected only from Station 55.

Fifteen gastropods were collected by dredging at Station 55. Some sessile or hard-substrate species were taken (e.g., Lister's keyhole limpet, Diodora listeri, and the spiny slipper-shell, Crepidula aculeata), but the majority of gastropods were larger, more motile forms. Conspicuous species included three conchs (the pink conch, Strombus gigas; the fighting conch, Strombus pugilis; and the Florida fighting conch, Strombus alatus); two cowries (the measled cowrie, Cypraea zebra; the Atlantic gray cowrie, Cypraea cinerea); two cone shells (the alphabet cone, Conus spurius, and the Florida cone, Conus floridanus); and Cabrit's murex, Murex cabritii.

Olive shells, which are commonly found in sand (Abbott, 1974) were represented by two species: the netted olive, Oliva reticulata, and the lettered olive, Oliva sayana. The little gem miter, Vexillum gemmatum; Conus floridanus; the beaded miter, Mitra nodulosa; and Perry's drillia, Cerodrillia perryae, were collected only at Station 55.

Ten bivalves were found in dredge samples from Station 55. Some attached forms were taken, such as thorny oysters (e.g., the Atlantic thorny oyster, Spondylus americanus) and ark shells (identified as Anadara secticostata but probably the cut-ribbed ark, Anadara floridana). Most of the bivalves were those associated with soft bottoms, such as the calico clam, Macrocallista maculata; the common egg cockle, Laevicardium laevigatum; the calico scallop, Aequipecten gibbus; the zigzag scallop, Pecten ziczac. Anadara secticostata and three swimming clams, Lima scabra (the rough lima), Lima lima (the spiny lima), and Lima pellucida (the Antillean lima) were taken only at Station 55. Swimming clams are most often found beneath coral rubble and under rocks.

Five caridean shrimps were collected. Of these, one was a pasaphaeaid (Leptochela serratorbita) known from "coral, shells, and compact sand," (Williams, 1984), and not taken at any other station. The remainder were pistol shrimps [Synalpheus minus, S. brooksi (unique to Station 55), S. townsendi, and S. longicarpus] often associated with large sponges or coral reefs.

Seven anomurans were found at Station 55, including porcelain crabs (Petrolisthes galathinus, Pachycheles rugimanus) and hermit crabs (Paguristes sericeus, P. triangulatus, P. lymani, Pagurus defensus, and Dardanus fucosus). Paguristes triangulatus, P. lymani, and Pachycheles rugimanus were unique to Station 55.

Sixteen brachyurans were collected, including arrow crabs (Stenorhynchus setosus) an other majids (Mithrax acuticornis, M. pleuracanthus, M.

forceps), xanthids (*Micropanope nuttingi*, *Panopeus occidentalis*, *Pilumnus pannosus*), iliacanthids (*Iliacantha intermedia*), portunids (*Portunus ordwayi*), and others. Three brachyurans were collected only at Station 55: *Dissodactylus crinitichelis*, *Cycloes bairdii*, and an unidentified *Macrocoelma*. The mantis shrimps *Meiosquilla schmitti* and *Gonodactylus bredeni* were also taken. *Meiosquilla schmitti* was not collected at any other station.

Only two sea stars were taken at Station 55: the reticulated sea star, *Oreaster reticulatus*, and the spiny beaded sea star, *Astropecten duplicatus*. Other echinoderms were more diverse. There were four ophiuroids in dredge samples: *Ophiolepis elegans*; the short-spined brittle star, *Ophioderma brevispina*; Savignyi's ophiactis, *Ophiactis savignyi*; and an unidentified *Ophiactis* unique to Station 55. Five echinoids were collected, including soft bottom forms (the flat sea biscuit, *Clypeaster subdepressus*; the green sea urchin, *Lytechinus variegatus*; the sea pussy, *Meoma ventricosa*), and other species usually found on hard substrate (the brown rock urchin, *Arbacea punctulata*, and the pencil urchin, *Eucidaris tribuloides*).

Sixteen algae were collected with the triangular dredge at Station 55 (Table 3.2-5). Half the algae were greens: *Udotea cyathiformis*, *U. flabellum*, *U. spinulosa*, *Codium isthmocladum*, *Halimeda discoidea*, *H. gracilis* and an unidentified congener, and *Caulerpa taxifolia*. Three browns (*Dictyota divaricata*, *Rosenvingea intricata*, and an unidentified sporochnacean) and five reds (*Gracilaria armata*, *G. blodgetti*, *Solieria tenera*, *Cryptonemia luxurians*, and *Halymenia floresia*) were also taken.

Several of the algae found at Station 55 were not collected at any other station. These species included *Caulerpa taxifolia*, *Dictyota divaricata*, *Soliera tenera*, and *Cryptonemia luxurians*.

Otter Trawl Results

Station 55 was sampled with the trawl on Cruises 5 through 8 (December 1984, and March, June/July, and September 1985) (Table 2.2-1). The four hauls collected a total of 60 individuals, for an average of 17.1 fish per 10-minute tow (Table 3.2-6). Twenty-five species were recognized, belonging to 19 families. The best represented families in terms of numbers of species present were the butterflyfishes (Chaetodontidae), with three species collected.

The most abundant fishes were the scrawled cowfish, *Lactophrys quadricornis* (3.4/tow), and the gray snapper, Lutjanus griseus (2.3/tow) (Figure 3.2-4). Other common species included the red grouper, *Epinephelus morio* (1.4/tow); and the white grunt, *Haemulon plumieri* (1.1/tow).

The most specimens (23) were taken on Cruise 7, and the fewest (10) on Cruise 8. Only six species were collected on more than one cruise. *Epinephelus morio*, *Lactophrys quadricornis*, and *Haemulon plumieri* were each taken on three cruises. The spotfin butterflyfish, *Chaetodon ocellatus*; the hogfish, *Lachnolaimus maximus*; and the redtail parrotfish, *Sparisoma chrysopterum* were each taken on two cruises.

Eight fishes were collected only at Station 55. These species included the spotted moray, *Gymnothorax moringa*; the trumpetfish, *Alostomus maculatus*; the redband parrotfish, *Sparisoma aurofrenatum*; redtail parrotfish, *Sparisoma chrysopterum*; the blackbelly blenny, *Stathmonotus hemphilli*; the yellowline goby, *Gobiosoma horsti*; the tusked goby, *Risor ruber*; and the ocean surgeon, *Acanthurus bahianus*.

Overall diversity (H") and evenness (J') for fishes collected by trawling were 2.85 and 0.88, respectively, for all cruises together at Station 55.

Analyses of stomach contents, maturation state, length and weight for some of the species collected at Station 55 [Epinephelus morio, Haemulon plumieri, Lactophrys quadricornis, and Synodus intermedius (the sand diver)] are presented in Section 3.2.2, Species Accounts.

Time-Lapse Camera Results

Overview

An array with time-lapse camera system was installed at this station during Cruise 5 and recovered during Cruise 7. A new array was installed during Cruise 7 (complete with another time-lapse camera) near the original array and retrieved on Cruise 8. The area surrounding the arrays was dominated by gorgonians. The substrate was carbonate rock covered by sand. The sediment next to the array was approximately 5 mm thick, as measured by divers.

Cruises 5 and 6 (December 1984 to March 1985)

The camera was installed on December 12, 1984, and operated for 105 days and 16 hours (2,536 frames) before retrieval on Cruise 6. The majority of the frames (75.1%) was exposed in clear water (relative visibility 100%). Some frames were taken in more turbid water (16.6% in relative visibility of 75%, and 4.7% in 50% relative visibility). Turbidity was high (25% relative visibility) on January 6 and 7. Another (and more severe) turbidity period began on Day 63 (February 12), when relative visibility dropped in 9 hours from 100% to zero, where it remained for several days. No major sediment transport by currents was observed throughout the period.

Two percent of the frames were occluded by a jewfish, Epinephelus itajara.

The first noticeable settling growth appeared as a slight texturing on the surface of the targets during the fourth week of immersion. On Day

35, a thin, whitish mat completely covered both targets. During the next 2 weeks, there was not much change. On Day 49, the white fuzzy mat degenerated, exposing the darker, underlying plate surface over more than 75% of the plate area. The complete change occurred within 60 hours, suggesting that it may have been caused by grazing activity or predation. The settling community returned to its former density in approximately 10 days. The appearance of the two targets on Day 59 was similar to the appearance on Day 49.

During the following weeks, some areas of both plates were again cleared or grazed, but other areas developed a substantial mat. Around Day 75, stalks (probably hydroids) approximately 5 mm in length appeared along the edges of both plates. These stalks reached approximately 10 mm in length at the end of the period; their growth rate averaged approximately 0.16 mm/day. Two small patches (probably hydroids also) appeared around Day 75 and developed into bushy orange colonies approximately 25 mm in diameter. The longer stalks were approximately 10 mm long.

The taller gorgonians in the background bent in response to semidiurnal tidal cycles. They usually leaned toward one side of the frame for 4 to 5 hours, straightened out, and leaned toward the opposite side for 4 to 5 hours.

Gorgonians 20 to 30 mm long were monitored during the first 60 days of the period. Very distinctive and regular cycles of extension and retraction were observed. Polyps usually extended approximately 0800 hours, and retracted at around 1800 hours or 1900 hours. The extension and retraction was a gradual process requiring several hours.

A plume of sediment was observed on Day 86 at 1700 hours along with a spotted goatfish, <u>Mulloidichthys</u> <u>maculatus</u>. Water visibility was reduced from 100 to 50% in this single frame, and returned to 100% immediately afterward. Particles were resuspended at least 0.5 m off the bottom.

On Day 97, the reticulated sea star, Oreaster reticulatus, was observed from 1700 to 1900 hours. During this time, it moved approximately 75 cm. More fishes were observed with the time-lapse camera at Station 55 than at any other station. Between Cruises 5 and 6, 26 taxa (317 observations) were recorded (Table 3.2-9). Nine fishes were noted 10 or more times. The most frequently recorded fish was the jewfish, Epinephelus itajara (63 observations). The jewfish was not seen until 50 days after array installation. Jewfish were also most frequently seen near the time of their first appearance (on Day 51, 11 observations). Jewfish were recorded intermittently thereafter; by the end of the period, only single observations were made on Days 100 and 105. Jewfish were recorded at every hour of the day except 0800 and 2000 hours (Figure 3.2-17). Attendance decreased around dawn and dusk, and increased at mid-day and midnight. These observations are consistent with the feeding habits of groupers (Randall, 1967), which feed during the day and night, but generally increase feeding activities at dawn and dusk. This same trend in attendance was also observed at Station 52.

The second most frequently recorded fish was the white grunt, Haemulon plumieri (56 observations). White grunts were not observed until Day 20, and showed major peaks in daily abundance on Days 72 and 68 (27 observations at 0800 hours and 15 observations at 1000 hours, respectively). Apparently a small school of white grunts formed a daytime resting aggregation (cf. Meyer and Schultz 1985) near the array.

Two angelfishes were recorded frequently: the gray angelfish, Pomacanthus arcuatus (30 observations) and the blue angelfish, Holocanthus bermudensis (28 observations) (Figure 3.2-18). Blue angelfish were first seen on Day 12. Blue angelfish were seen throughout the day, with no apparent peaks in hourly means.

Lutjanus griseus, the gray snapper, appeared in limited numbers during this period (17 observations). Gray snappers were not seen until 80 days

Station 55, by cruise.

Taxa	Start Cruise 5	7	Total
Perciformes	0	270	270
Haemulon aurolineatum	0	237	237
Lutjanus griseus	17	179	196
Epinephelus morio	9	75	84
Holacanthus bermudensis	28	50	78
Epinephelus itajara	63	9	72
Haemulon plumieri	56	4	60
Pomacanthus arcuatus	30	28	58
Anisotremus virginicus	22	35	57
Decapterus sp.	0	46	46
Thalassoma bifasciatum	0	43	43
Ocyurus chrysurus	24	9	33
Apogon sp.	14	3	17
Caranx crysos	12	0	12
Chaetodon ocellatus	3	8	11
Caranx sp.	9	0	9
Sparisoma sp.	4	3	7
Calamus sp.	2	5	7
Sphyraena barracuda	5	1	6
Mulloidichthys maculatus	3	3	6
Pomacanthus paru	3	2	5
Lactophrys quadricornis	3	1	4
Ginglymostoma cirratum	0	3	3
Aulostomus maculatus	0	2	2
Halichoeres sp.	2	0	2
Epinephelus sp.	2	0	2
Aluterus schoepfi	1	0	1
Seriola dumerili	0	1	1
Caretta caretta *	0	1	1
Chaetodon sedentarius	0	1	1
Rachycentron canadum	1	0	1
Eupomacentrus sp.	0	1	1
Mycteroperca sp.	0	1	1
Eucinostomus sp.	0	1	1
Labridae	0	1	1
Equetus umbrosus	0	1	1
Equetus acuminatus	1	0	1
Sciaenidae	1	0	1
Calamus nodosus	1	0	1
Epinephelus guttatus	1	0	1
Number of Observations	317	1024	1341
Total Frames	2536	1956	4492

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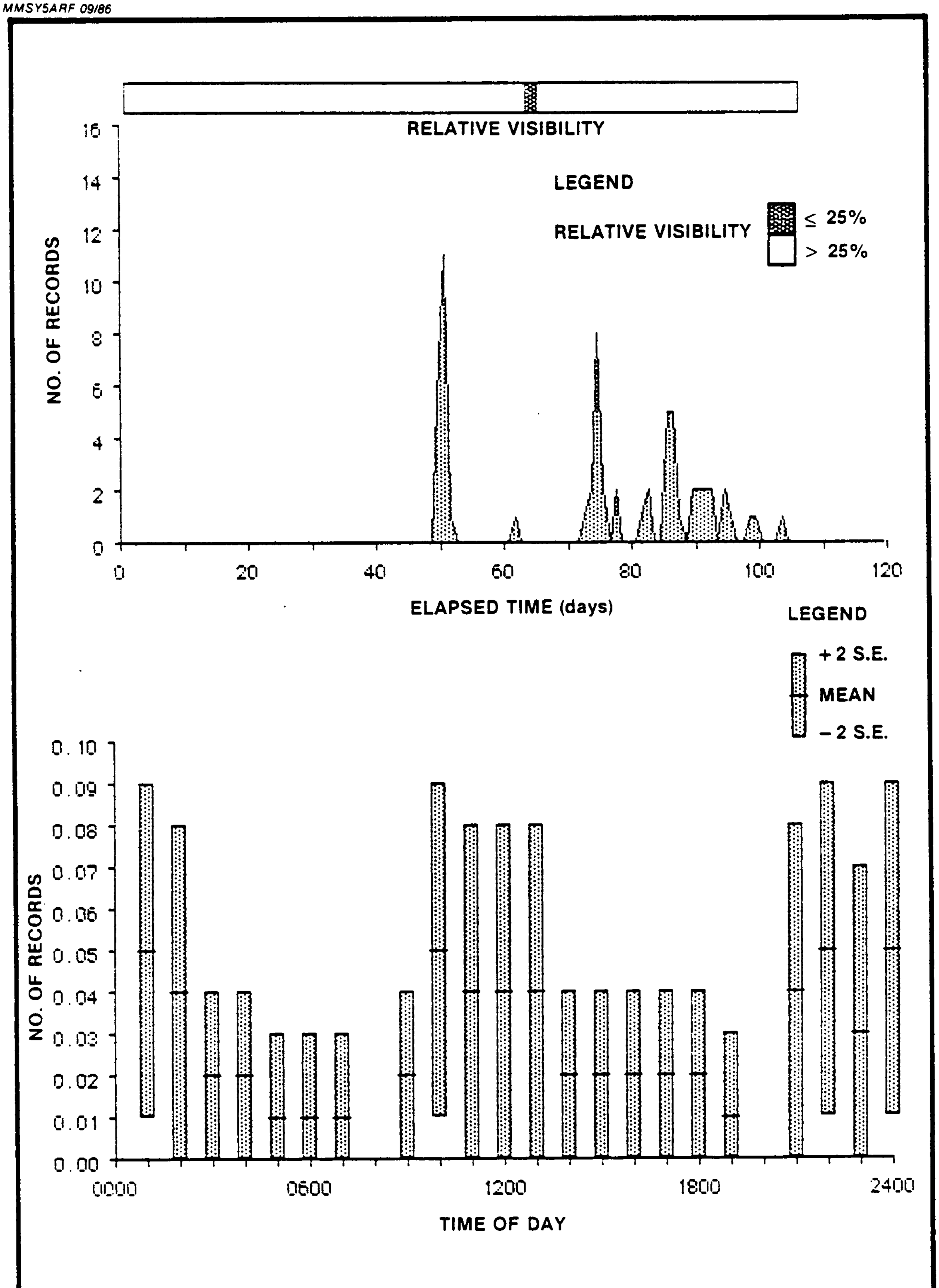

Figure 3.2-17 TOTAL DAILY ABUNDANCE AND HOURLY ABUNDANCE IN TIME-LAPSE RECORDS FROM STATION 55, DECEMBER 12, 1984 – MARCH 27, 1985 — *Epinephelus itajara*

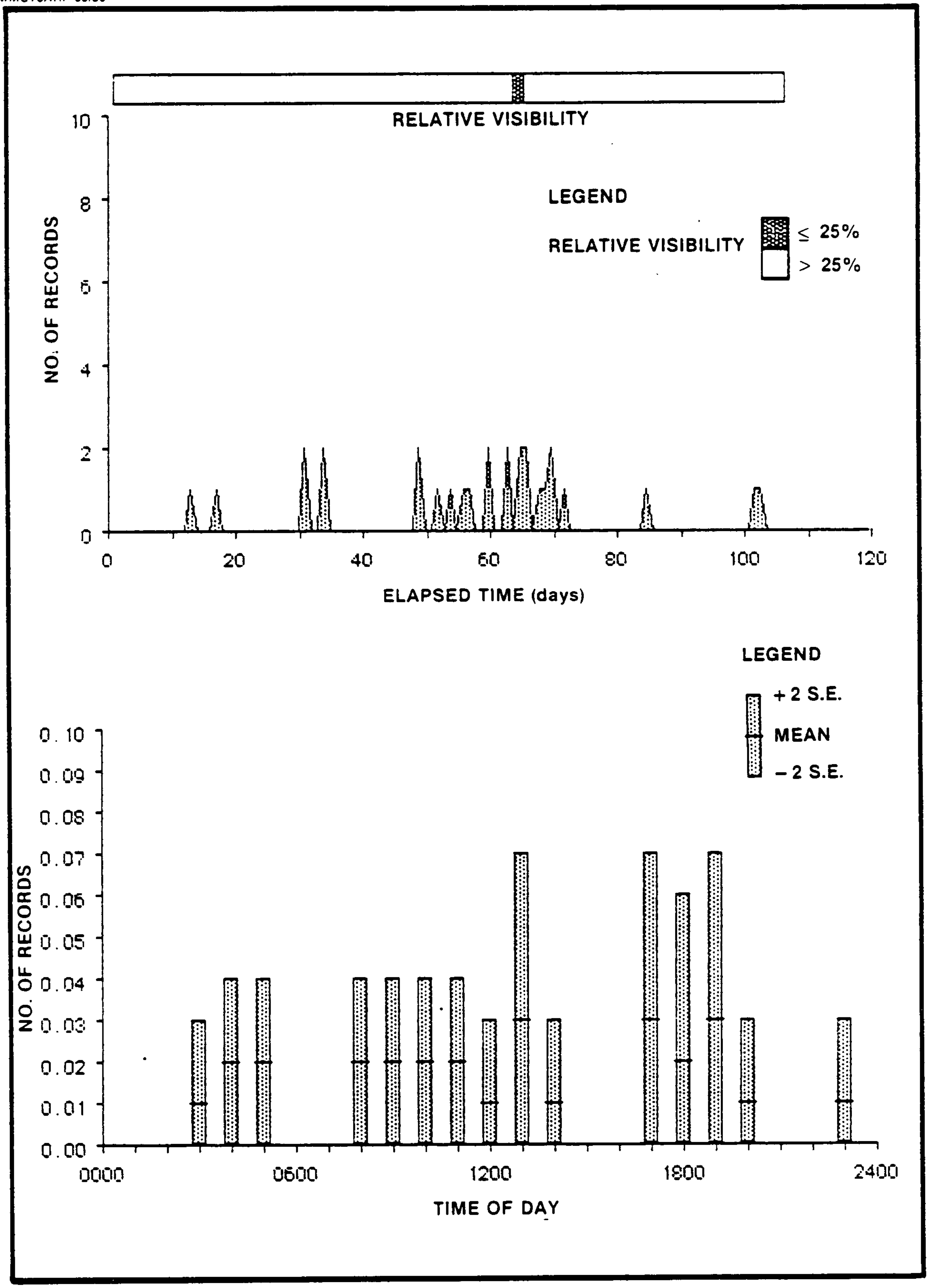

Figure 3.2-18 **TOTAL DAILY ABUNDANCE AND HOURLY ABUNDANCE IN TIME-LAPSE RECORDS FROM STATION 55, DECEMBER 12, 1984 – MARCH 27, 1984 —** ***Holacanthus bermudensis***

after array installation (Figure 3.2-19). An extended delay before gray snappers were attracted to the array was also evident at other arrays. For example, at Station 52, gray snappers did not appear until 28 days after installation. The hourly attendance pattern of gray snappers at Station 55 was similar to that at Station 52; fish were recorded primarily during daylight hours (0800 hours to 2000 hours) with a few observations at 2300 hours (Figure 3.2-19).

Other fishes frequently observed included the yellowtail snapper, *Ocyurus chrysurus* (24 records), and the porkfish, *Anisotremus virginicus* (22 records).

Cruises 7 and 8 (June/July 1985 to September 1985)

The time-lapse data recovered from this period were from a new array installed during Cruise 7 on June 27, 1985. The array that had been serviced during Cruise 6 could not be found on Cruise 7. The time-lapse camera emplaced on Cruise 7 was recovered on September 17, 1985, after operating for 81 days 13 hours (1,957 frames). Most frames (82.6%) were taken under clear water conditions (100% relative visibility), 8.6% under 75% visibility conditions, 3.4% in 50% visibility, 3.2% in 25% visibility and 2.1% in zero visibility.

Three turbidity storms reduced relative visibility to 25% or less. The first storm began on Day 64 (August 29), and lasted for 30 hours. A second storm began on Day 66 (August 31), and extended for 67 hours (September 3). The final storm reduced visibility to 25% or zero on Day 81 (September 15), but lasted only 5 hours. In four frames, the field of view was occluded by fish. Water movement had no apparent effect on the depth or coverage of bottom sediments.

Two days after installation, the settling plate targets took on a whitish color due to a thin layer of growth, probably a bacterial mat. This covering did not change visibly for 20 days. On Day 22, stalked

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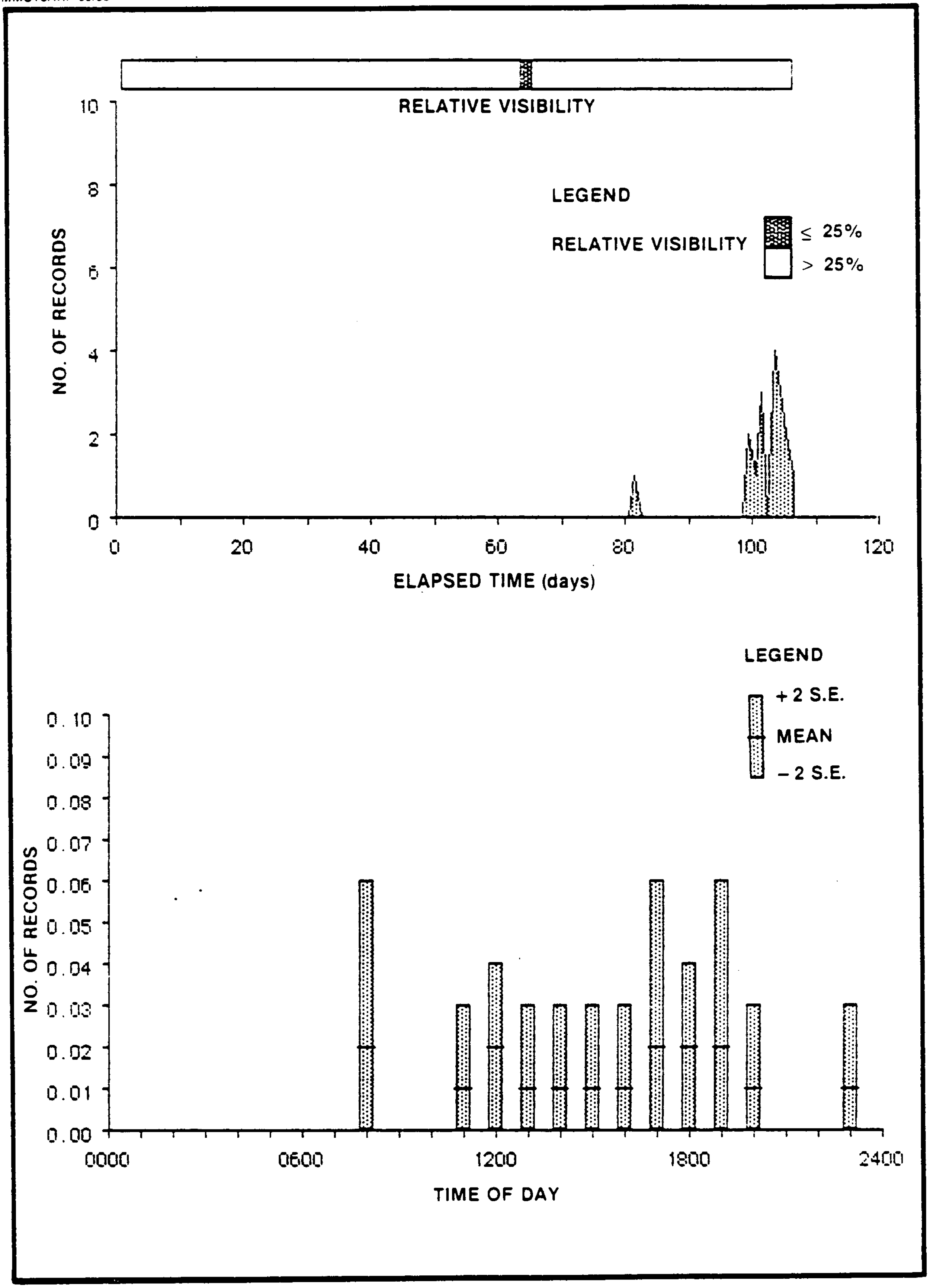

Figure 3.2-19 TOTAL DAILY ABUNDANCE AND HOURLY ABUNDANCE IN TIME-LAPSE RECORDS FROM STATION 55, DECEMBER 12, 1984 – MARCH 27, 1985 — *Lutianus griseus*

organisms were visible along the top edge of the plates. The stalks appeared to be hydroids and grew approximately 5 mm in length during the next 22 days. Between Day 50 and the end of the period (Day 83), some stalks decreased in length, while others grew more robust and increased in length. Near the end of the period the maximum length of these stalks was 10 to 15 mm. Most of the plates' surfaces did not show much growth, although between Day 60 and Day 83 some hydroid patches reached heights of about 10 mm. No motile animals were observed on the targets and there was no evidence of grazing activity throughout the period.

On Day 32, a reticulated sea star, Oreaster reticulatus, appeared at 1800 hours. It moved slowly away, covering about 2 m in 7 hours.

Gorgonian polyps exhibited a fairly regular pattern of extension and retraction. In general, the polyps extended during daylight hours and retracted at night; however, several gorgonians extended their polyps during the dark period of each 24-hour cycle. On some occasions, entire colonies kept their polyps retracted for several days. Storms did not seem to have any effect on polyp extension or retraction. As soon as the water cleared sufficiently to see gorgonians, their polyps seemed to be following the same cycle observed during periods with excellent water clarity.

Another interesting event occurred beginning on Day 74. A spherical orange sponge approximately 3 cm in diameter suddenly appeared at 0800 hours at the base of a gorgonian. It remained stationary for the next 110 hours, and then moved 0.5 m during the next 3 hours. Ten hours later, it moved out of sight. No major currents were noted at this time, as evidenced by the vertical position of gorgonian stalks. The sponge was probably attached to a crab. However, it is curious that the crab (if one was present) did not move for over 4-1/2 days.

The attached algae changed dramatically. At the beginning of the period, a thick mat of filamentous and foliose algae (probably Dictyopteris) completely covered depressions and spaces between gorgonians and other objects. Beginning around Day 12 (July 8), the algae began to deteriorate. By Day 30 (July 26), there was very little remaining algae. Only minor bioturbation was seen in the sand after it became exposed.

The fish observed were even more diverse (Table 3.2-9) than in the previous period. Twenty-nine fishes were seen (1,023 records). Even though this period was 24 days shorter than the previous period, the number of records was more than three times greater. Nine taxa were observed at least 25 times. The most numerous fishes (270 records) were not identified beyond order Perciformes, due to their small size. It is believed that the majority of these individuals was haemulids (grunts), probably tomtate (Haemulon aurolineatum). A large proportion of the fish actually identified as tomtates were small juveniles.

The second most frequently observed fish was the tomtate (237 observations) (Figure 3.2-20). The tomtates first appeared on Day 25 and reached a daily peak of 34 observations on Day 48. The hourly attendance pattern was much the same as at Station 52, with most observations during daylight, between 0600 hours and 2000 hours. Records from Station 52 began about 2 hours later (0800 hours), however, during the same period. Perhaps higher water clarity at Station 55 allowed dawn light to reach the bottom sooner than at Station 52, resulting in reformation of resting schools earlier at Station 55.

The gray snapper, Lutjanus griseus, was the second most frequently observed fish (179 records), in contrast to only 17 records during Cruises 5 and 6. The first gray snapper appeared on Day 10 after Cruise 7, and the peak daily total (10 records) occurred on Day 37 (Figure 3.2-21). Gray snappers were observed primarily during daylight, but also during dark periods, near dawn and dusk (0500 hours to

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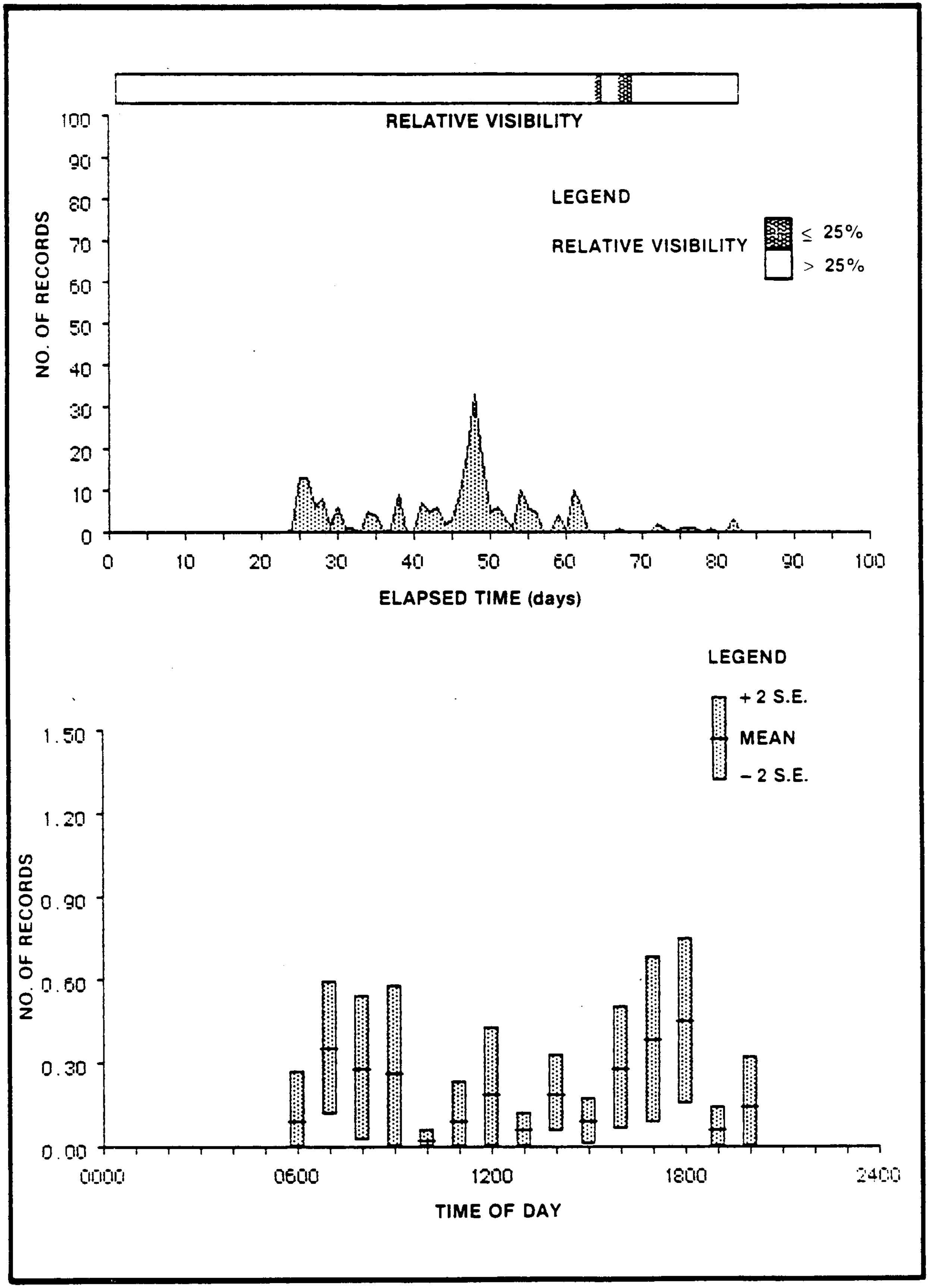

Figure 3.2-20 **TOTAL DAILY ABUNDANCE AND HOURLY ABUNDANCE IN TIME-LAPSE RECORDS FROM STATION 55, JUNE 27 – SEPTEMBER 17, 1985 —** *Haemulon aurolineatun*

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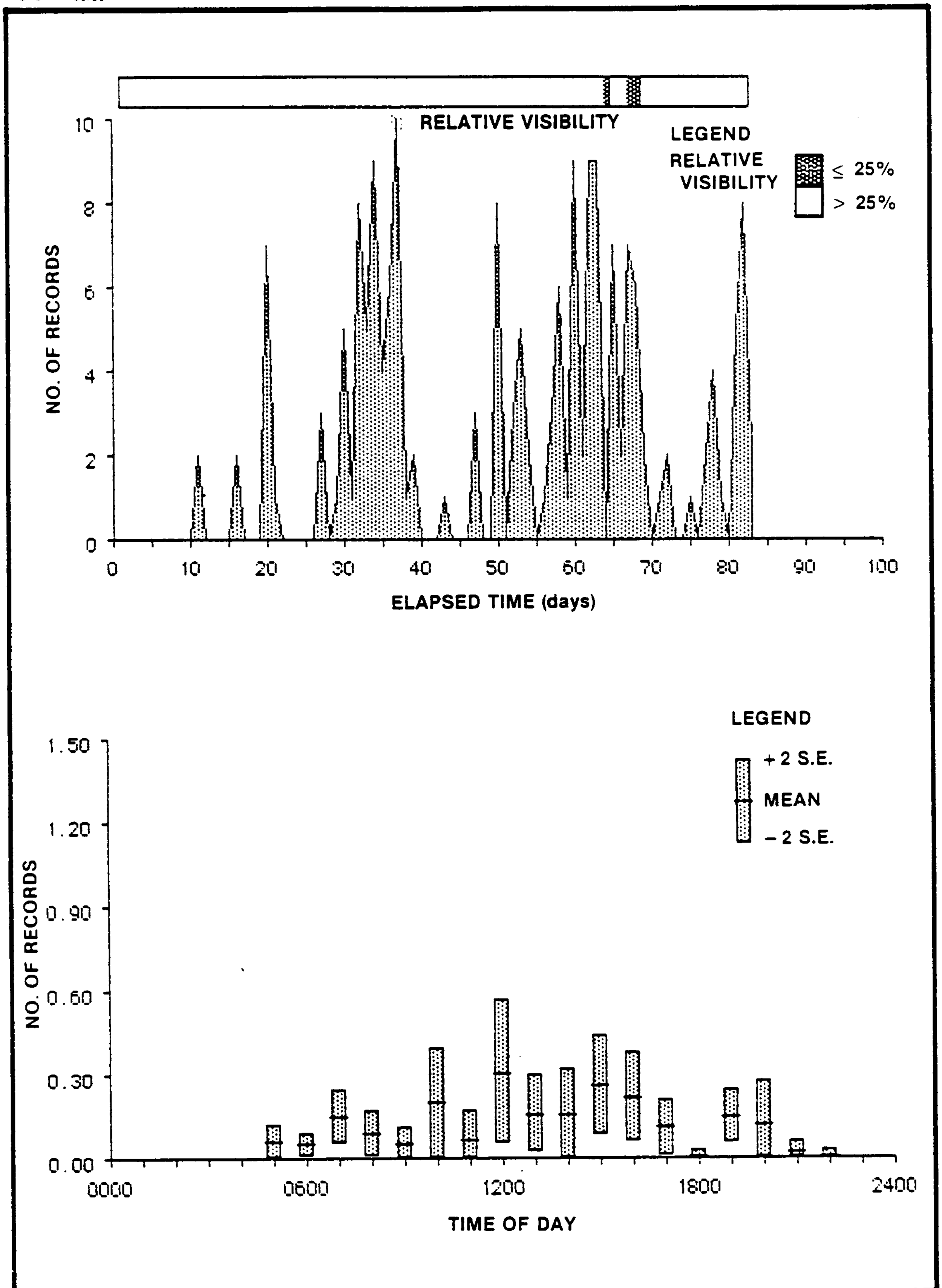

Figure 3.2-21 TOTAL DAILY ABUNDANCE AND HOURLY ABUNDANCE IN TIME-LAPSE RECORDS FROM STATION 55, JUNE 27 – SEPTEMBER 17, 1985 — *Lutjanus griseus*

2200 hours). There was a peak in attendance near mid-day, but none of the hourly means were significantly different.

The red grouper, Epinephelus morio, was frequently observed during this period (75 observations). Red groupers were observed at the array from the first day of this period, and reached a peak (8 observations) just one day later (Figure 3.2-22). Daily attendance was variable but without major gaps throughout the period. Hourly attendance was restricted to daylight hours (0600 and 2100 hours).

Two angelfishes were prominent: the blue angelfish, Holacanthus bermudensis (50 records) (Figure 3.2-23), and the gray angelfish, Pomacanthus arcuatus (28 observations). Blue angelfishes were observed fairly early in the period (Day 8). They were seen during every hour of the day except for 0100, 0200, 0400, and 2300 hours.

Other fishes frequently observed included unidentified scads of the genus Decapterus (46 records); bluehead wrasses, Thalassoma bifasciatum (43 records); and the porkfish, Anisotremus virginicus (35 records). The jewfish, Epinephelus itajara was only observed nine times, mostly between 1800 hours and 0600 hours. The remaining 19 fishes in Table 3.2-9) were observed fewer than 20 times. A lone sea turtle, probably the loggerhead (Caretta caretta), was observed in a single frame at 0500 hours on July 20.

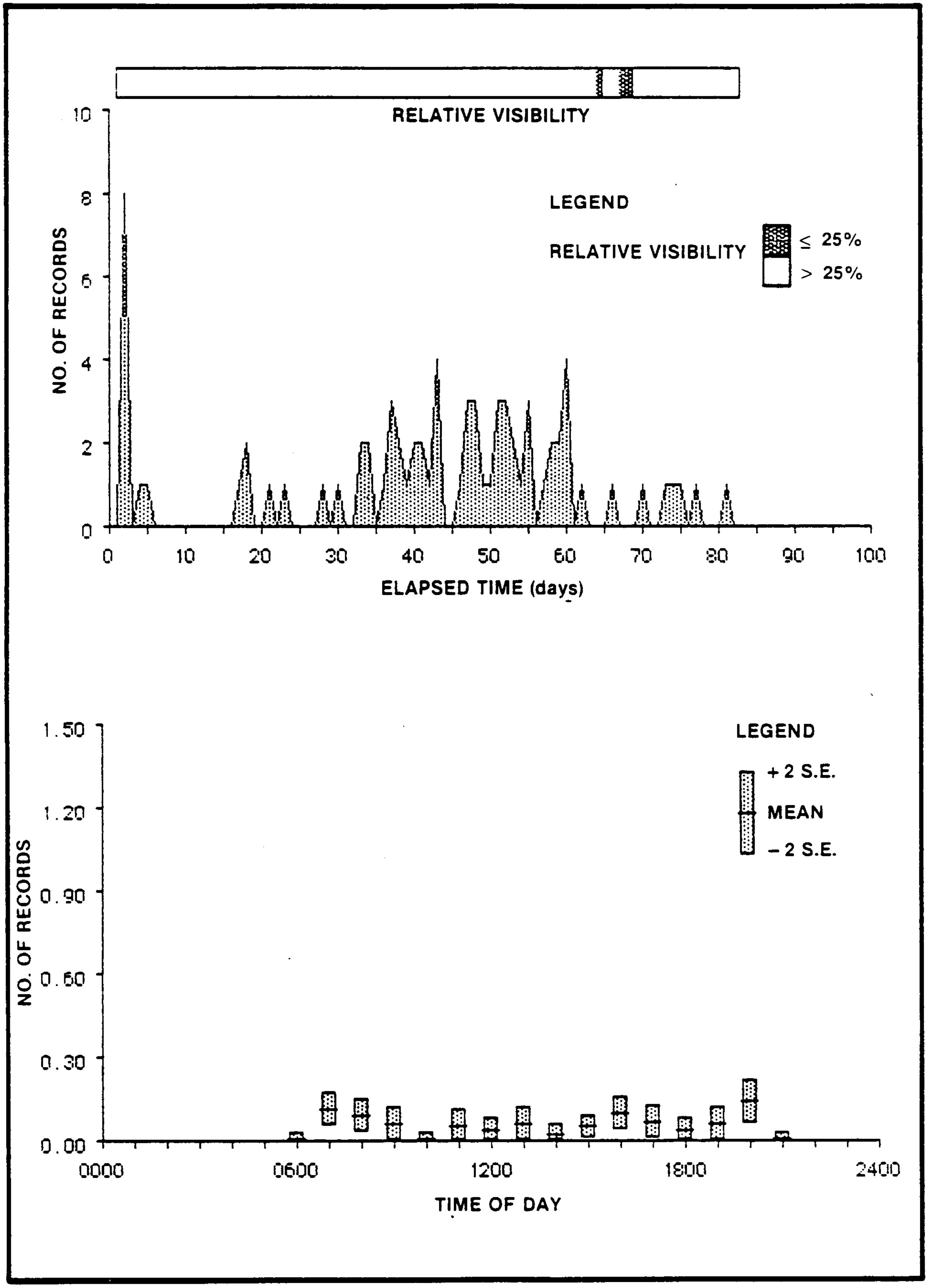

Figure 3.2-22 TOTAL DAILY ABUNDANCE AND HOURLY ABUNDANCE IN TIME-LAPSE RECORDS FROM STATION 55, JUNE 27 – SEPTEMBER 17, 1985 — *Epinephelus morio*

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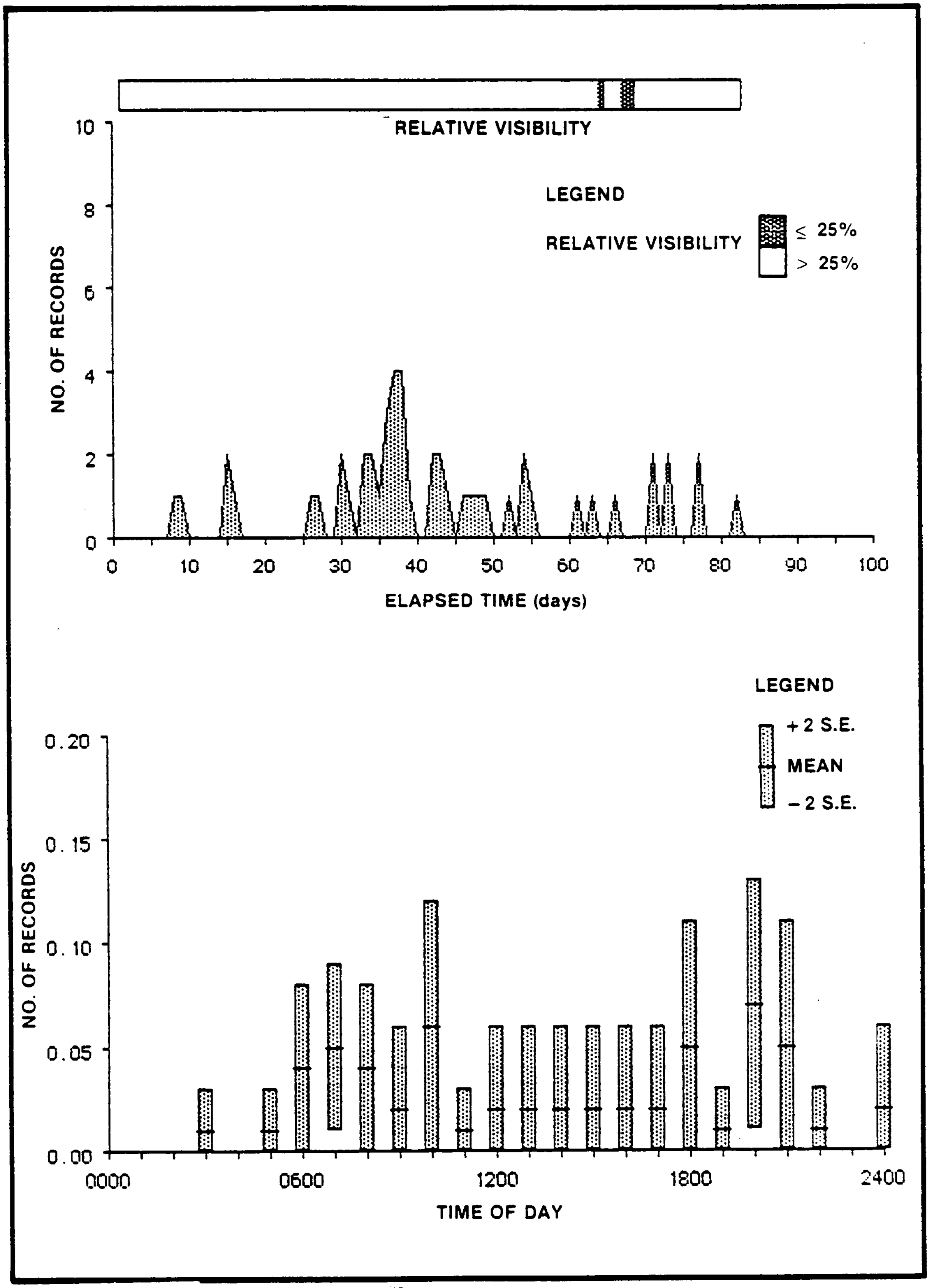

Figure 3.2-23 **TOTAL DAILY ABUNDANCE AND HOURLY ABUNDANCE IN TIME-LAPSE RECORDS FROM STATION 55, JUNE 27 – SEPTEMBER 17, 1985 —** *Holacanthus bermudensis*

Station 7

Historical Notes

Station 7 (depth 32 m, within the Inner Shelf Depth Zone) was surveyed by Woodward-Clyde Consultants and Continental Shelf Associates, Inc., during Year 1 and Year 2. Its substrate was categorized as mostly Sand Bottom/ Soft Bottom (16 to 90%), and Thin Sand over Hard Substrate (10 to 39%), with occasional rock outcrops and calcareous rubble. Live bottom patches were common (29% cover), with the major community type described as Inner Shelf Live Bottom Assemblage II, dominated by algae, ascidians, bryozoans, scleractinians, small gorgonians, hydroids, and many sponges (Woodward Clyde Consultants/Continental Shelf Associates, Inc., 1983, 1984). Station 7 was surveyed by ESE/LGL as a Group II station during Year 5, on Cruises 5 (December 1984), 6 (March 1985), 7 (June/July 1985), and 8 (September 1985). It was selected for further study as a northern comparison to the biological assemblage at Station 21.

Underwater Television Results

The total area transected was 29,484 m^2 (Table 2.2-2). The surficial substrate was almost entirely sand (99%), with some small patches of shell hash (1.5%) and scattered rock outcrops (less than 1%).

The most abundant benthic organisms were gorgonians (566/ha), unidentified demosponges (15% cover), and algae (24% cover) (Figure 3.2-2; Tables 3.2-1, 3.2-2). Other common invertebrates included unidentified asteroids (14/ha); hydroids (13/ha); sea urchins (echinaceans) (8/ha); and the sponge *Ircinia campana* (4/ha).

Fishes most often seen in underwater television transects at Station 7 included the blue goby, *Ioglossus calliurus* (41/ha); the jackknife-fish, *Equetus lanceolatus* (16/ha); the tomtate, *Haemulon aurolineatum* (14/ha); scad of the genus *Decapterus* (11/ha); sand perches, either *Diplectrum bivittatum* or *D. formosum* (7/ha); and the blue angelfish, *Holacanthus bermudensis* (3/ha) (Figure 3.2-3, Table 3.2-3). Overall diversity (H") and evenness (J') for fishes censused with underwater television were 1.84 and 0.64, respectively, for all cruises together at Station 7.

Substrate type was fairly constant from cruise to cruise (sandy), implying that the same sorts of areas were transected, except during Cruise 6, when 9% of the substrate was covered with shell hash.

Several benthic organisms were seen on every cruise. Asteroids were observed on all four cruises at densities varying from 4/ha to 22/ha, with the highest density on Cruises 6 and 7 (21 and 23/ha, respectively). The sponge Ircinia campana was also seen on every cruise, at densities ranging from 3/ha to 6/ha. Hydroids were present on every cruise. Their abundance was relatively constant on Cruises 5, 7, and 8 (6/ha to 8/ha), but was considerably higher (46/ha) on Cruise 6.

Demosponges as a group were present throughout Year 5, but their cover was high on Cruises 5, 7, and 8 (21%, 13%, and 15%, respectively), and lowest (5%) on Cruise 6 (Table 3.2-1). Some benthic invertebrates such as gorgonians and urchins appeared to be much more patchy. Gorgonians were not observed at all on Cruises 5 and 8, but were very abundant on Cruises 6 and 7 (54/ha and 3,363/ha, respectively). Echinaceans (urchin-like echinoids as opposed to sand-dollar-like echinoids) were seen only on Cruise 5, for example (18/ha).

Unidentified algae were very abundant on Cruises 5, 7, and 8 (33%, 28%, and 19% cover), although lower cover (5%) was reported on Cruise 6 (Table 3.2-1). The brown alga Sargassum and the green alga Halimeda were also common on Cruise 7 (4 and 7% cover, respectively), although they were not reported from any other cruise.

None of the benthic organisms censused with underwater television at Station 7 differed significantly in density or cover ($p > 0.05$) among cruises.

Fish densities varied considerably between cruises. The blue goby, Ioglossus calliurus, was extremely abundant on Cruise 6 (83/ha) and Cruise 7 (120/ha), and very common on Cruise 5 (19/ha), but completely absent on Cruise 8. The jackknife-fish, Equetus lanceolatus, had densities of 25/ha and 33/ha on Cruises 5 and 7, respectively, but was not seen on either Cruise 6 or Cruise 8. Scad (Decapterus) and tomtate (Haemulon aurolineatum) were dense on Cruise 8 (41/ha and 53/ha, respectively), though not present on any other cruise. The red grouper, Epinephelus morio was seen only on Cruise 5 (4/ha). Other groupers (either Mycteroperca or Epinephelus) were seen on Cruise 5 (2/ha) and Cruise 7 (4/ha).

The only fishes censused with underwater television at Station 7 whose densities differed significantly ($p < 0.05$) among cruises were Decapterus (taken only in the fall on Cruise 8) and Ioglossus calliurus. The densities of Ioglossus calliurus were high in spring and summer [Cruises 6 (March 1985) and 7 (June/July 1985)] and did not differ from one another, but differed significantly from lower values in the winter and fall [Cruises 5 (December 1984) and 8 (September 1985)].

Twice as many fishes (13 taxa) were seen on Cruise 5 than on any other cruise, perhaps reflecting the greater area surveyed on Cruise 5 (12,312 m^2) as opposed to 4,800 m^2 on Cruise 6; 4,884 m^2 on Cruise 7; and 7,488 m^2 on Cruise 8. More than half of these species were seen only on Cruise 5. The only fish seen on all four cruises was the blue angelfish, Holacanthus bermudensis, whose density ranged from 1 to 4/ha.

Triangular Dredge Results

At Station 7, 96 invertebrates (excluding sponges) were identified in 12 triangular dredge hauls (Table 3.2-4). Fourteen of these were scleractinians, even though corals were not observed with the underwater television; conversely, among the most abundant invertebrates seen with underwater television were gorgonians, yet no gorgonians were ever taken with the dredge at Station 7.

Scleractians collected at Station 7 included the lobed star coral, Solenastrea hyades; the smooth star coral, S. bournoni; the ahermatypic coral Phyllangia americana; the ivory tube coral, Cladocora arbuscula; another tube coral, Cladocora debilis; the ivory bush coral, Oculina diffusa; another bush coral, Oculina varicosa; the smooth starlet coral, Siderastrea siderea; the blushing star coral, Stephanocoenia michelini; the large flower coral, Mussa angulosa; the solitary disc coral, Scolymia lacera and an unidentified congener; the sinuous cactus coral, Isophyllia sinuosa; and the rose coral, Manicina areolata. Cladocora debilis and Isophyllia sinuosa were not found at any other station.

Nine gastropods were taken at Station 7. Most species were those usually found on soft bottoms (Abbott, 1974; Abbott and Dance, 1983) such as olives (the lettered olive, Oliva sayana), conchs (the Florida fighting conch, Strombus alatus), murexes (the lace murex, Murex florifer; Cabrit's murex, M. cabritii), tulips [the banded tulip, Fasciolaria lilium (= Fasciolaria distans)], and cones (the alphabet cone, Conus spurius). Other species more often found on or under hard substrates were present (e.g., the chestnut turban, Turbo castanea, and the coffee bean trivia, Trivia pedicula). Two of the gastropods were unique to Station 7: the jujube top-shell, Calliostoma jujubinum; and an unidentified Drillia.

Most of the 12 bivalves found in triangular dredge samples from Station 7 were soft-bottom or unattached forms such as scallops, venuses, semeles, tellins, and cockles. Species included the calico clam, Macrocallista maculata; the calico scallop, Aequipecten gibbus; the zigzag scallop, Pecten ziczac; the rough scallop, Aequipecten muscosus; the imperial venus, Chione latilirata; the alternate tellin, Tellina alternata; the cancellate semele, Semele bellastriata; the even cockle, Trachycardium isocardia (= Cardium isocardia); the common egg cockle, Laevicardium laevigatum (= Laevicardium serratum); and Gibbes's crassatella, Eucrassatella speciosa. Four of the bivalves (Chione latilerata, Tellina alternata, Semele bellastriata, and Trachycardium isocardia) were collected only at Station 7.

Three penaeids (Metapenaeopsis goodei, Sicyonia typica, and Solenocera atlantidis) and two slipper lobsters (Scyllaris chacei and Scyllaris americanus) were collected at Station 7, along with the mantis shrimp Gonodactylus bredeni. Six carideans were also present, including pistol shrimps (Synalpheus townsendi, S. longicarpus, Alpheus floridanus); two pasiphaeids (Leptochela carinata and L. papulata); and Periclimenes americanus. Solenocera atlintidis, Alpheus floridanus, the two slipper lobsters, and the two pasiphaeids were not collected at any other station.

Station 7 had eight anomurans, including many hermit crabs (Paguristes sericeus, Pagurus carolinensis, P. longicarpus, P. arcuatus, P. acadianus, Dardanus fucosus, and Manucomplanus corallinus); and the mud shrimp, Upogebia affinis. Of these anomurans, four (Pagurus carolinensis, P. longicarpus, P. arcuatus, and Upogebia affinis) were unique to Station 7.

The most diverse group of benthic invertebrates collected at Station 7 was the brachyurans. Twenty-eight taxa were identified in triangular dredge hauls, including many families: xanthids (e.g., Pilumnus sayi, Micropanope nuttingi, and Eurypanopeus abbreviatus), arrow crabs (Stenorynchus seticornis), and other majids (Collodes trispinosus, Mithrax pleuracanthus, M. holderi, and M. acuticornis), box crabs (Calappa flammea and C. angusta), goneplacids (Speocarcinus carolinensis), portunids (Portunus anceps and P. floridanus), and others.

Nine brachyurans were unique to Station 7, including Eurypanopeus abbreviatus, Aepinus septemspinosus, Speocarcinus carolinensis, Ranilia muricata, Mithrax holderi, Symethis variolosa, Raninoides loevis, Osachila semilevis, and Collodes trispinosus.

Four sea stars typically found on soft bottom were collected, including the brown spiny sea star, Echinaster spinulosus; two sand stars, Astropecten comptus and the spiny beaded sea star, A. duplicatus; and the limp sea star, Luidia alternata. Four ophiuroids were also taken: Ophiolepis elegans; the angular brittle star, Ophiothrix angulata; the short-spined brittle star, Ophioderma brevispina; and an unidentified Ophiopsila.

The five echinoids collected by dredging at Station 7 were all soft-bottom forms, including the flat sea biscuit, Clypeaster subdepressus; the green sea urchin, Lytechinus variegatus; the sea pussy, Meoma ventricosa; the sand dollar Encope abberans; and an unidentified Clypeaster.

Station 7 had 25 algae in 12 triangular dredge hauls (Table 3.2-1). Eight of these were green algae (Udotea conglutinata, U. flabellum, U. spinulosa, Codium isthmocladum, Caulerpa peltata, Halimeda tuna, H. discoidea, and H. gracilis). There were six browns, including Sargassum filipendula and an unidentified congener, Rosenvingea intricata, Sporochnus bolleanus, S. pendunculatus, and Dictyota cervicornis. Dictyota cervicornis and Sporochnus bolleanus were unique to Station 7. The remaining 11 algae were reds, including Botryocladia occidentalis; Laurencia intricata; Graciliaria armata and G. blodgetti; Halymenia floresia; Dasya baillouviana; Rhodymenia rhizoides and two unidentified congener; and Eucheuma isiformes, E. acanthocladum and an unidentified congener. Over half of the red algae (Dasya baillouviana, all three species of Rhodymenia, Eucheuma isiforme, and E. acanthocladum were collected only at Station 7.

Trawl Results

Station 7 was sampled with the trawl on Cruises 5 through 8 (December 1984, and March, June/July, and September 1985) (Table 2.2-1). The trawl was an effective tool at Station 7; 146 individuals were taken in four hauls, an average of 36.5 fish per 10-minute tow (Table 3.2-6). Twenty-four species were recognized, belonging to 15 families. The best represented family in terms of numbers of species present was the Synodontidae (lizardfishes), with six species. Overall diversity (H") and evenness (J') for fishes collected by trawling were 2.46 and 0.77 respectively, for four cruises together at Station 7.

The most abundant fishes were the dusky flounder, Syacium papillosum (8.3/tow); the offshore lizardfish, Synodus poeyi (7.5/tow); the inshore lizardfish, Synodus foetens; the sand perch, Diplectrum formosum, and the jackknife-fish, Equetus lanceolatus (all 3.5/tow) (Figure 3.2-4). Other common fishes included the sand diver, Synodus intermedius (1.8/tow); the blackedge moray, Gymnothorax nigromarginatus (1.3/tow); and the planehead filefish, Monacanthus hispidus (1/tow).

Half of the species collected at Station 7 were found on more than one cruise. Synodus foetens and Diplectrum formosum were collected on all four cruises. Synodus intermedius, Gymnothorax nigromarginatus, and Syacium papillosum were taken three times. Synodus poeyi, Trachinocephalus myops (the snakefish), Haemulon aurolineatum (the tomtate), Equetus lanceolatus, Bothus ocellatus (the eyed flounder), Monacanthus hispidus, and Sphoeroides spengleri (the bandtail puffer) were all taken twice. Overall abundance varied by a factor of two from one cruise to the next. On Cruises 5 and 8, 25 fish each were taken. On Cruises 6 and 7, 42 and 54 individuals were collected, respectively.

Only two species collected by trawling were unique to Station 7: the ocellated moray, Gymnothorax saxicola, and the bluespotted searobin, Prionotus roseus.

Analyses of stomach contents, maturation state, length, and weight for various fishes collected at Station 7 [Synodus intermedius, Epinephelus morio (the red grouper), and Lutjanus synagris (the lane snapper)] are presented in Subsection 3.2.2, Species Accounts.

Time-Lapse Camera Results

Overview

The array and time-lapse camera at Station 7 were first installed during Cruise 5. The habitat visible to the time-lapse camera was somewhat barren. The biological community was similar to that described from underwater television observations. The substrate was predominantly sand overlying carbonate rock. Significant changes in sediment depth were not seen by the time-lapse camera, but a great deal of bioturbation caused by echinoids was recorded. Settling communities experienced both growth and major regression periods.

Cruises 5 and 6 (December 1984 to March 1985)

The time-lapse period beginning on December 5, 1984, lasted for a total of 30 days and 13 hours. Relative water visibility during this period ranged from 0 to 100%. The majority of frames (68.5%) was taken in relatively clear water (100% relative visibility). Of the remaining frames, 28.9% were scored as 75% relative visibility. The proportion of frames recorded under conditions of 25% relative visibility and zero visibility was 0.1 and 2.2%, respectively. One major turbidity storm was recorded during the last day. Beginning at 0900 on Day 31, relative visibility dropped from 100% to 0% in 1 hour, and remained that way for at least 16 hours. Visibility was still zero when the time-lapse camera failed.

Settling growth on the newly installed target plates began after just a few days. The plates turned a milky white, possibly due to bacterial mats. No other growth was observed until around Day 30, at which time the plates became more highly textured, possibly due to colonization by hydroids.

One of the most remarkable aspects of this period was the extent of bioturbation evident in the time-lapse camera frames. Bioturbation greatly altered the surficial sediment. Echinoids (either sea biscuits or sand dollars) were visible as mounds on the surface of the sediment. Mounds moved in various directions, leaving distinctive trails 10 to 15 cm wide. These movements took place almost exclusively at night (between 1700 and 0500 hours). In general, the distance traveled by a single individual did not exceed 4 to 5 m in a single night. For example, one echinoid slowly plowed along under the sediment for 15 hours, covering approximately 2 m. It remained stationary for another 12 hours (from 0500 to 1700 hours), and then returned to its original position in 6 hours.

The gill filaments of a sabellid fan-worm were also seen. The extension and retraction of these filaments were correlated with the 12-hour light/dark cycle. The gills were extended between 0800 hours and 1800 hours, and withdrew below the sediment surface from around 1900 hours to 0600 or 0700 hours. This worm hole and others did not seem to be adversely affected by the passage of echinoids directly over their openings. The worm described above showed the same periodicity of extension and retraction after an echinoid passed directly over it. The sediment above the worm burrow was reworked no fewer than six times by burrowing animals, without apparent effect on the worm.

Records of fishes included 22 species and 227 observations (Table 3.2-10). The most frequently observed fish was the planehead filefish, Monacanthus hispidus. At night, this species maintained fixed locations for long periods of time. Monacanthus hispidus and the orange filefish, Aleuterus schoepfi (12 observations) were only seen at night (1900 hours to 0600 hours) and seemed to be attracted to the settling plate targets and the sediment transport rod. The planehead filefish first appeared on the second night of the period, while the orange filefish did not arrive until 26 days after installation. On numerous occasions, a planehead filefish oriented itself nose-first, adjacent to the sediment rod for up to 12 or 13 hours at a time without moving more than a few centimeters.

by cruise.

Taxa	Start Cruise 5	6	7	Total
Haemulon aurolineatum	1	42	1139	1182
Lutjanidae	0	2	1043	1045
Perciformes	0	0	508	508
Seriola dumerili	0	83	173	256
Chaetodipterus faber	11	196	10	217
Decapterus sp.	4	0	178	182
Monacanthus hispidus	103	9	4	116
Lutjanus synagris	5	62	38	105
Equetus lanceolatus	3	15	40	58
Sphoeroides spengleri	37	0	0	37
Epinephelus morio	1	14	22	37
Lutjanus griseus	0	0	28	28
Diplectrum sp.	13	1	3	17
Calamus sp.	9	2	4	15
Apogon sp.	1	4	8	13
Mycteroperca sp.	0	4	8	12
Aluterus schoepfi	12	0	0	12
Caranx sp.	0	3	8	11
Holacanthus bermudensis	10	0	0	10
Sparisoma sp.	0	7	2	9
Epinephelus itajara	0	0	7	7
Antennarius ocellatus	0	0	5	5
Labridae	0	0	4	4
Caretta caretta *	0	1	3	4
Scorpaena sp.	4	0	0	4
Haemulon plumieri	0	0	3	3
Centropristis ocyurus	1	2	0	3
Holocentrus sp.	3	0	0	3
Ginglymostoma cirratum	0	0	3	3
Chilomycterus schoepfi	0	0	3	3
Lactophrys quadricornis	1	3	0	4
Chaetodon sp.	2	0	0	2
Caranx crysos	0	0	2	2
Monacanthus ciliatus	2	0	0	2
Haemulon sp.	0	2	0	2
Eucinostomus sp.	2	0	0	2
Chromis enchrysura	1	0	0	1
Pomacanthus arcuatus	0	0	1	1
Urophycis sp.	1	0	0	1
Lutjanus sp.	0	0	1	1
Hypoplectrus sp.	0	1	0	1
Number of Observations	227	453	3248	3928
Total Frames	731	2142	1961	4834

The second most frequently recorded fish (37 observations) was the bandtail puffer, Sphoeroides spengleri. This species also remained in view of the time-lapse camera at night (between 1800 hours and 0600 hours). The bandtail puffer was first observed 11 days after installation. One individual occupied the bottom of a small depression for up to 10 hours on several occasions, separated by as much as 8 days.

Other fishes observed included sand perch, Diplectrum sp. (13 records, first observed on Day 6); the Atlantic spadefish, Chaetodipterus faber (11 records, beginning on Day 21); and the blue angelfish, Holacanthus bermudensis (10 records, first seen on Day 4). All of the remaining 16 fishes were recorded fewer than 10 times. On Day 14 at 0500 hours, a hake, Urophycis sp., appeared to be feeding, with its mouth very close to the sediment and tail elevated. This was the only record of this species at Station 7.

Cruises 6 and 7 (March 1985-June/July 1985)

The time-lapse camera was serviced and reinstalled on March 22, 1985. The time-lapse camera operated until June 20, 1985, for 89 days and 6 hours (2,142 frames). Virtually all of the frames (94.9%) were exposed in relative visibility of 75%. The turbidity did not detrimentally affect fish censuses. The remaining 5.1% of the frames were scored at a relative visibility of 50%. No turbidity storms were seen during this period, and none of the frames was occluded by animals.

The array was raised from the bottom (32 m) to approximately 10 m during servicing on Cruise 6. The left target was intended to be cleaned at this time, but a few patches of gray-colored hydroids were left along the edges. Several weeks passed before any changes were observed on either target. Around Days 25 to 27, bare spaces on the left target began to fill with filamentous, gray-colored hydroids similar to those on the edge of the target. They also covered the undisturbed right target.

Regression, as well as growth, was observed on the targets. On several occasions, hydroids several centimeters long disappeared in a few hours. On some occasions, grazing by animals was observed. For example, on Day 7, a hermit crab moved around on the right target for 5 hours (between 2300 hours and 0300 hours). A wire attached to the array was heavily colonized by hydroids along most of its length during the early part of this period. On Day 29, at 0700 hours, hydroids 2 to 3 cm long began to disappear in a linear progression down the wire. By 1600 hours, the entire wire had been nearly cleared of hydroids. It is not known what organism or process was responsible, but grazing is likely.

A series of very interesting observations concerning the movement of an unattached sponge was made. A small, brown-colored, bulbous sponge appeared on Day 25 at 0500 hours and rolled around for another 12 days. During this period the sponge appeared to be alive, its sides pulsating when viewed at projection speeds. Each pulsation cycle took 2 to 3 hours.

On Day 50, a spherical yellow sponge approximately 8 cm in diameter suddenly appeared on the front of a settling plate target where it remained for 29 hours. It may have been Cinachyra kuekenthali, which is reported to occur in the area. It was probably attached to a crustacean (e.g., a decorator crab), but none was seen.

A sea star, probably Echinaster spinulosus, also made the 20- to 30-cm journey from the substrate onto the targets. On Day 78 at 1600 hours, it appeared on the target, apparently having crawled up the sediment measuring rod during the previous hour. It remained there for 3 hours, and then disappeared.

On two occasions, mounds of sediment developed. One began to form at 2300 hours, and continued to build in size for 6 hours until it was approximately 20 cm in diameter and 10 cm high. A similar mound appeared at 1500 hours, and reached its maximum size after only 2 hours.

Eighteen fishes and one turtle were recorded during this period (453 observations) (Table 3.2-10). Six fishes were observed more than 10 times. The most frequently observed fish was the Atlantic spadefish, *Chaetodipterus faber* (196 observations). Although very few spadefish were observed at this station during the previous sampling period (11 records), they were present from the beginning of this period (Day 2), reaching a maximum daily frequency (16 observations) on Day 4 (Figure 3.2-24). Hourly attendance patterns showed a distinct peak just before sunrise (0500 hours). There was also a distinct gap in attendance at the array around mid-day.

The second most frequently observed fish (not reported at all during the previous period) was the amberjack, *Seriola dumerili* (83 observations). This species was seen within the first few days of the period, but intermittently thereafter (Figure 3.2-25). Its maximum daily frequency occurred on Day 74 (25 records). Most observations were made around 1800 hours and 2300 hours. Another small attendance peak occurred just after sunrise (0700 hours to 0800 hours). Most of the greater amberjacks were small. Randall (1967) reports that jacks are generally diurnal feeders, which implies that amberjacks at the array at night were probably not there to feed.

The third most frequently recorded fish was the lane snapper, *Lutjanus synagris* (62 observations). This species was present from the very first day after array servicing, and intermittently throughout the period (Figure 3.2-26). The maximum daily frequency was five observations on Day 12. There were no distinct trends in hourly attendance. Lane snappers were recorded during every hour of the day with the exception of 1300 hours. The highest mean hourly attendance was at 1600 hours, but it did not differ significantly ($p>0.05$) from any other hourly mean.

Other frequently observed fishes included tomtate, *Haemulon aurolineatum* (42 records); the jackknife-fish, *Equetus lanceolatus* (15 records); and

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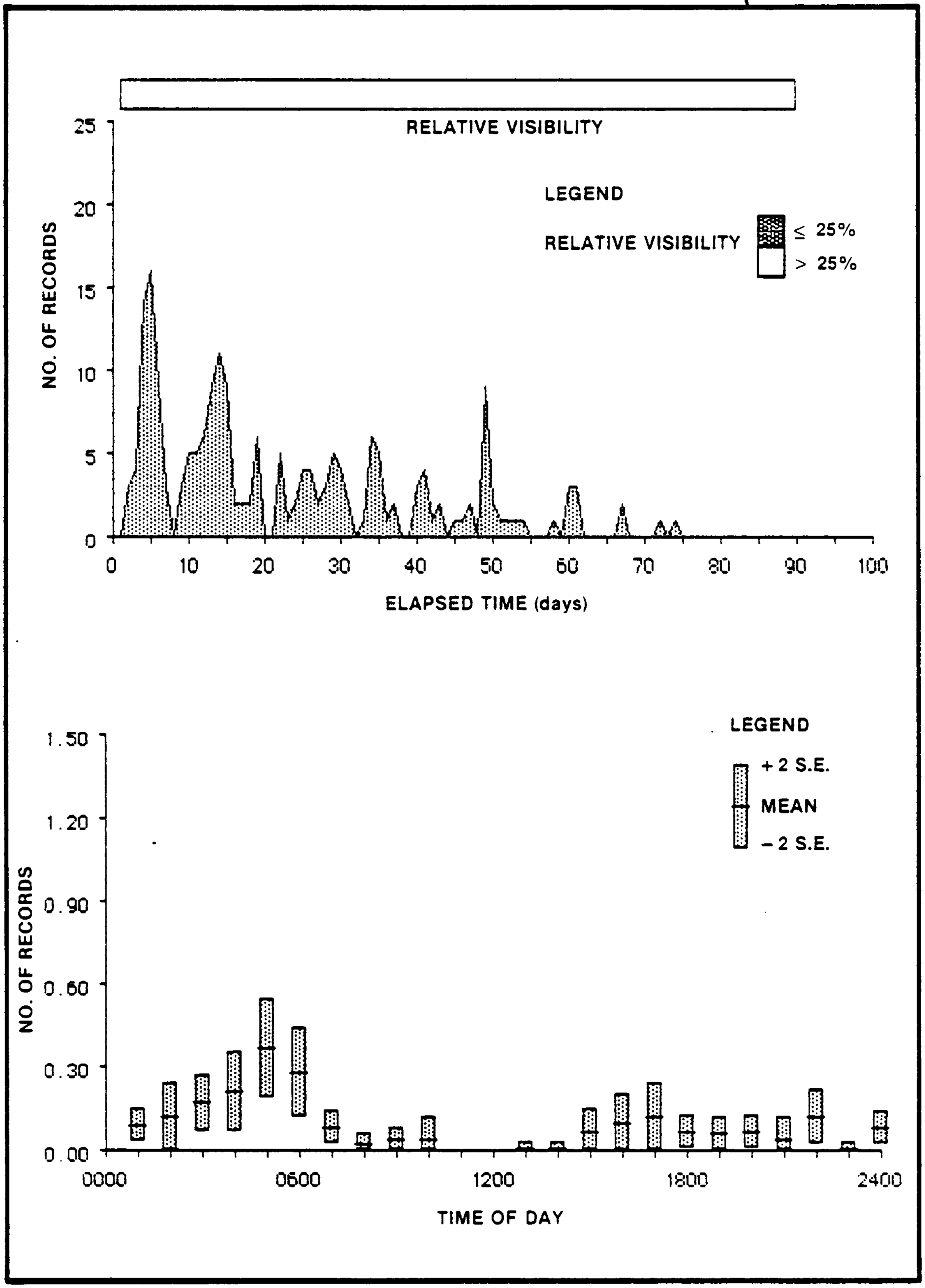

Figure 3.2-24 **TOTAL DAILY ABUNDANCE AND HOURLY ABUNDANCE IN TIME-LAPSE RECORDS FROM STATION 7, MARCH 22 – JUNE 20, 1985 —** *Chaetodipterus faber*

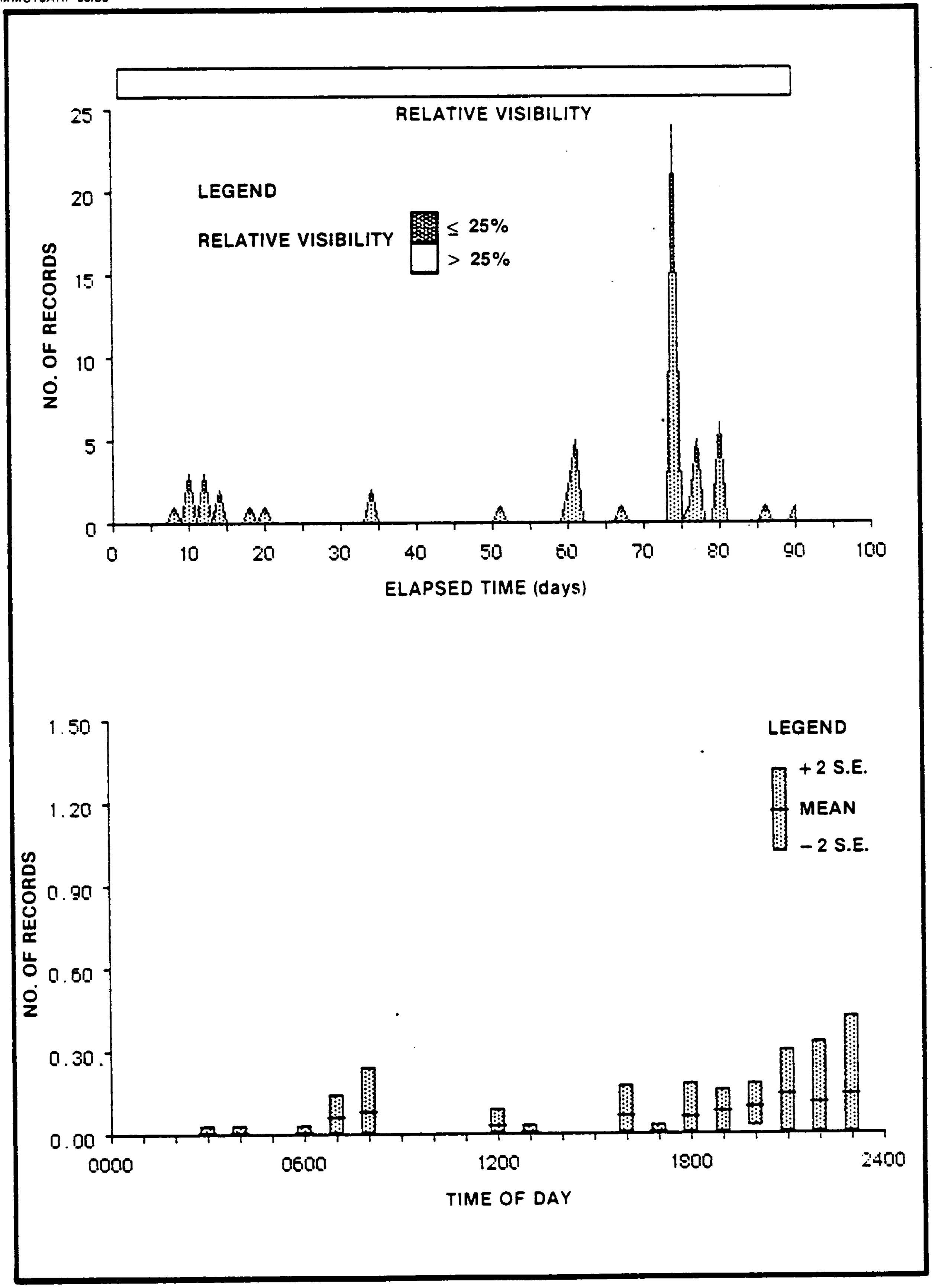

Figure 3.2-25 TOTAL DAILY ABUNDANCE AND HOURLY ABUNDANCE IN TIME-LAPSE RECORDS FROM STATION 7, MARCH 22 – JUNE 20, 1985 — *Seriola dumerili*

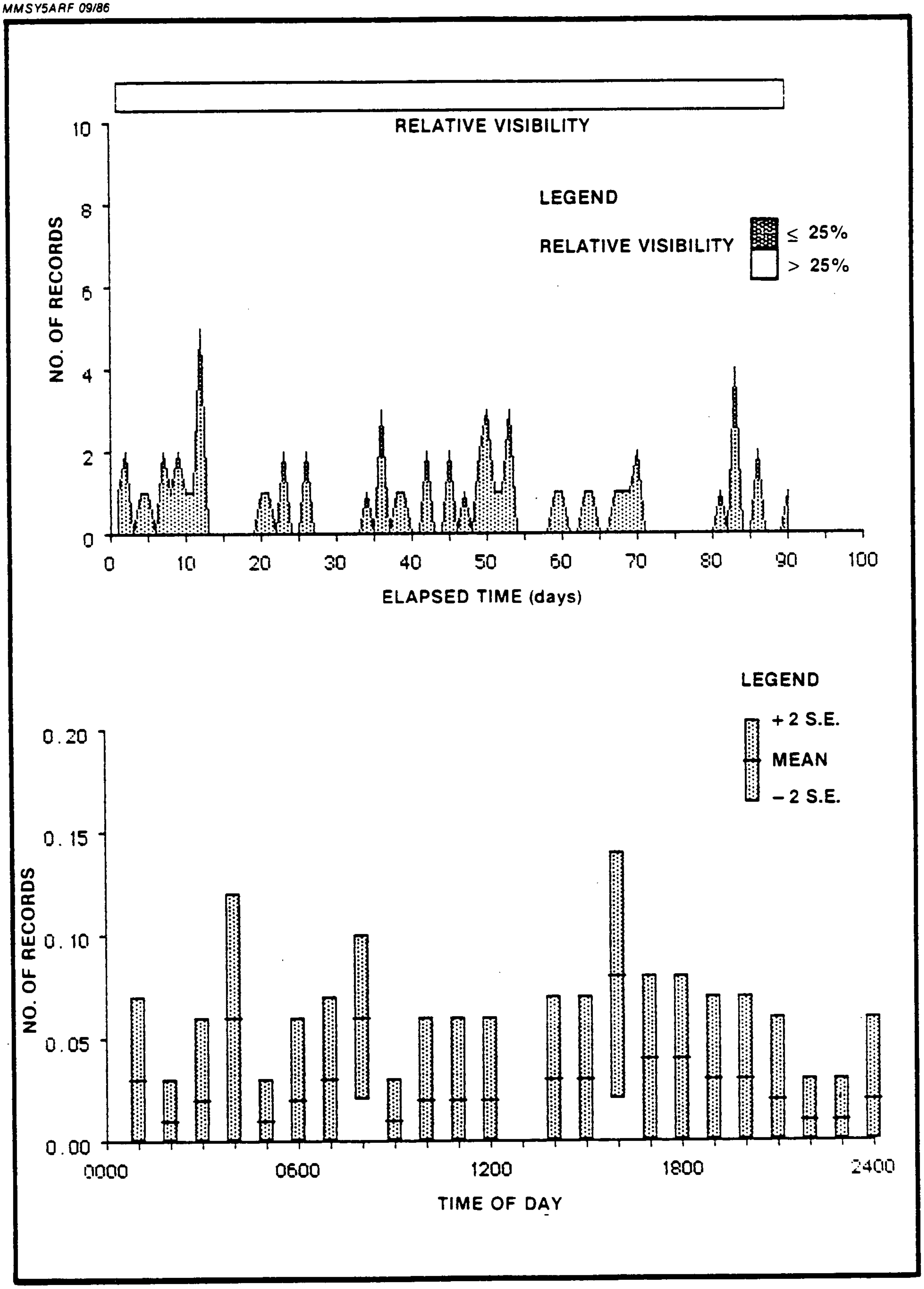

Figure 3.2-26 **TOTAL DAILY ABUNDANCE AND HOURLY ABUNDANCE IN TIME-LAPSE RECORDS FROM STATION 7, MARCH 22 – JUNE 20, 1985 —** *Lutjanus synagris*

the red grouper, *Epinephelus morio* (14 records). The tomtate was observed very early in the period with intermittent daily peaks of one or two observations per 24-hour period. In contrast to Stations 52 and 55 during this period, tomtate attendance at Station 7 was dispersed over a much greater range of hours (Figure 3.2-27). Of the top six fishes ranked by frequency of observations, only one (Atlantic spadefish) was common to both Cruises 5 and 6 and Cruises 6 and 7 data sets.

A loggerhead sea turtle, *Caretta caretta*, was seen on Day 58 at 1800 hours.

Cruises 7 and 8 (June/July 1985 to September 1985)
The time-lapse apparatus functioned properly for 81 days and 17 hours, from July 1, 1985, to September 21, 1985 (1,961 frames). None of the frames was occluded by fish. Most (85.1%) of the frames were exposed with a relative visibility of 100%. The remaining 10.9% of the frames were taken in relative visibility of 75%, and 1.2% of the frames were taken in 50% relative visibility. On two occasions, turbidity storms reduced the visibility to 25% or zero. The first of the storms occurred on Day 21 (July 21) and lasted from 1600 hours to 0300 hours on Day 22. Another storm began at 0700 hours on Day 61 (August 30) and lasted 46 hours, until 0500 hours on Day 63. Just before the first storm, a mound of sediment approximately 10 cm high was seen just outside the array. After the storm, the mound was no longer there. This was the only visible evidence of sediment movement. Little bioturbation was evident. The camera shifted out of position after two days, precluding further benthic observations.

The right target at the beginning of this period had a settling community which had been developing for 208 days, while the left target had been scraped clean by divers during servicing. The right target was extremely covered with tan-colored hydroids 4 to 5 cm long. The time-lapse camera strobe failed at the end of Day 4, and ambient light was not sufficient

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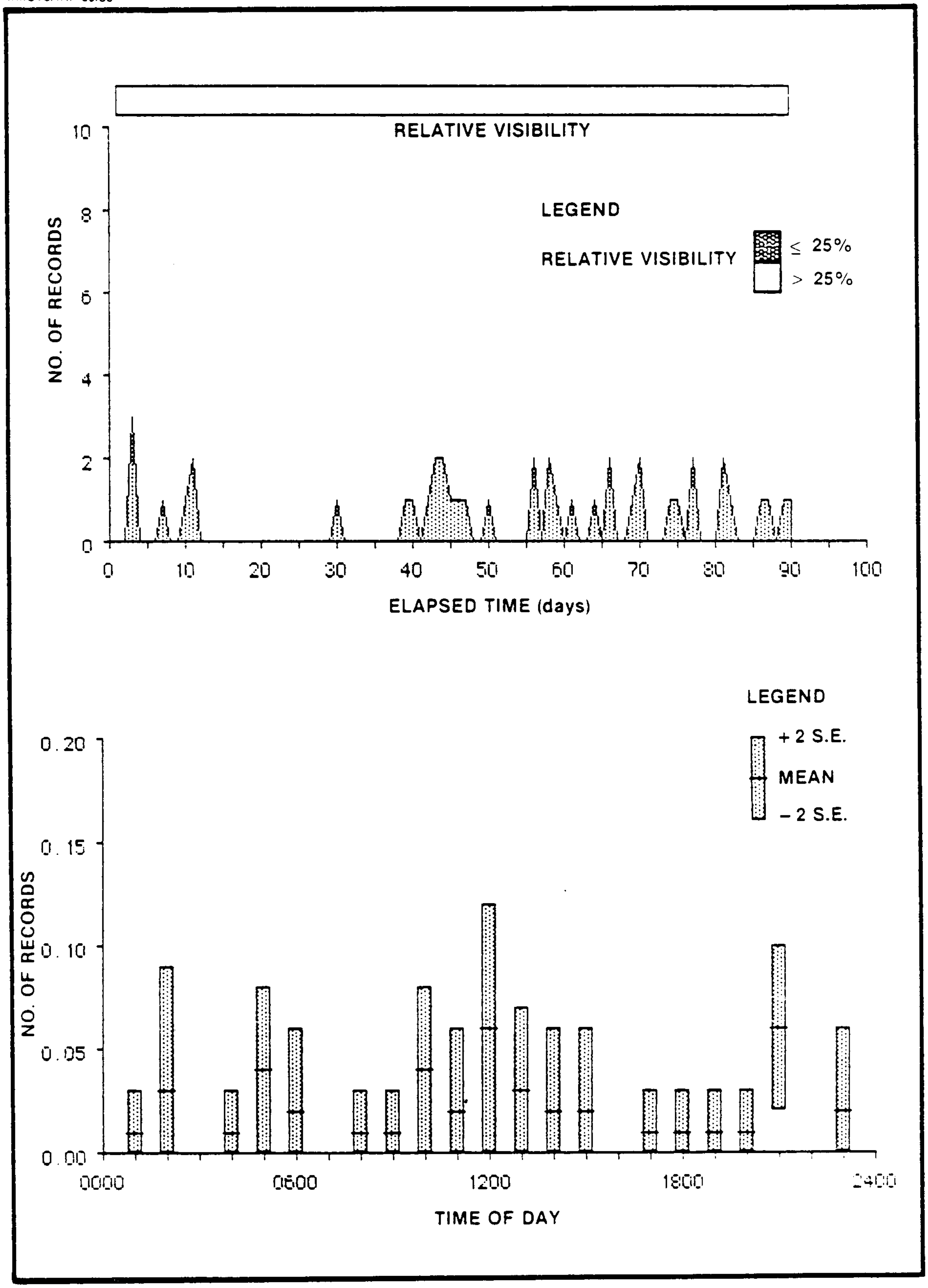

Figure 3.2-27 TOTAL DAILY ABUNDANCE AND HOURLY ABUNDANCE IN TIME-LAPSE RECORDS FROM STATION 7, MARCH 22 – JUNE 20, 1985 — *Haemulon aurolineatum*

to observe the targets. The strobe began to function again on Day 17, by which time the left target had already developed a substantial mat of organisms. The mat had hydroid stalks 1 to 2 cm long. The mat on this plate did not undergo any apparent further growth. On Day 63, after the second storm, the community on the right target (now submerged for 8 months) was seen to be deteriorated so that both targets looked similar to one another. This similarity persisted until the end of the period, 20 days later.

Due to the position shift of the camera, a horizontal array member was visible from Day 2 to the end of the period. Its settling community was well-established, having been underwater for almost 7 months. The biota appeared to be primarily hydroids, resembling those on the targets. The hydroids on the array were approximately 2 cm in length and did not appear to change in size during the period.

Motile epifauna such as arrow crabs, hermit crabs, and sea stars frequently appeared on the targets. One hermit crab was observed on the plates for 40 consecutive hours, remaining in one position for 10 hours. On most occasions, hermit crabs were on the plates for only a few hours, and changed positions frequently.

On Day 67 at 2200 hours, an ocellated frogfish, <u>Antennarius</u> <u>ocellatus</u>, took up temporary residence on top of one of the targets, leaving at 0200 hours on Day 68. This same fish may have taken up residence inside the array; a large frogfish of similar description was reported by divers servicing the array during Cruise 8.

An arrow crab, <u>Stenorhynchus</u> <u>seticornis</u>, was first seen on Day 44, and was observed on most nights throughout the remainder of the period. It moved between the top of the array cross member to the back of the sediment rod and to the front and back of the settling plate targets.

Only a single sea star (probably Echinaster spinulosus) was observed. It was visible on Day 72 for 17 hours, and again for 3 hours on Day 73.

During Cruises 7 and 8, there were 26 fishes seen (3,245 observations) (Table 3.2-10). Nine species were recorded more than 10 times. The most frequently observed fish was the tomtate, Haemulon aurolineatum (1,139 observations). This represented a substantial increase from the previous two cruises. Tomtates were not observed until 18 days after array servicing (Figure 3.2-28). The peak in daily frequency occurred on Day 27 (57 records). Tomtates were seen frequently throughout the period except when water visibility precluded fish observations. Tomtates were most often seen during daylight (between 0800 hours and 2100 hours) with a peak at 1500 hours. This activity pattern was consistent with the literature (Randall 1967, Meyer and Schultz 1985), which indicates that tomtates (and grunts in general) are primarily nocturnal feeders.

The second most frequently recorded fishes were unidentified small individuals (<10 cm) believed to be in the family Lutjanidae. All fishes were seen in a densely packed school within 13 hours (from 0800 hours to 2000 hours) on Day 22. As many as 160 individuals appeared in a single frame.

Another group of small unidentified fishes was the third ranking taxon. These fishes were not identifiable other than as order Perciformes. They were very small in size (around 5 cm), and most of them were believed to be tomtates. This asumption was supported by divers, who reported large groups of very small tomtates inside the array. Some of the fishes were believed to be scad, probably of the genus Decapterus.

The fourth most frequently recorded fishes (178 records) were scad, Decapterus sp. Most observations were of large groups (10 to 25 individuals) within single frames. The maximum daily total was on Day 63 (28 observations). All observations were made during daylight hours (0700 hours to 200 hours).

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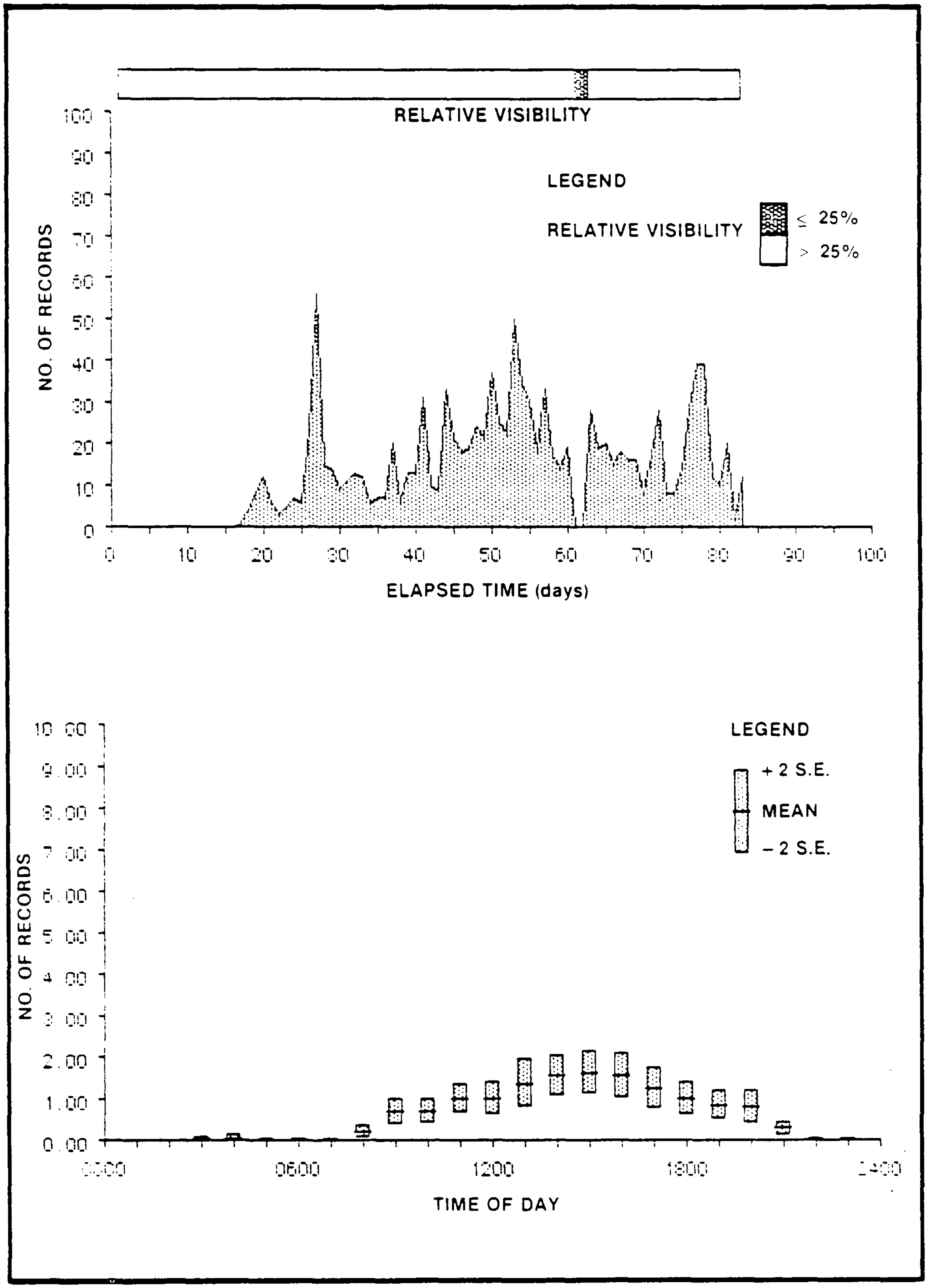

Figure 3.2-28 TOTAL DAILY ABUNDANCE AND HOURLY ABUNDANCE IN TIME-LAPSE RECORDS FROM STATION 7, JULY 1 – SEPTEMBER 21, 1985 — *Haemulon aurolineatum*

The fifth most frequently seen fish was the greater amberjack, Seriola dumerili (173 observations). Greater amberjacks were also recorded during the previous two periods. Greater amberjacks were not recorded in this period until 17 days after array servicing (Figure 3.2-29). All of the greater amberjacks were relatively small (20 to 30 cm), and observed primarily inside the array framework. Hourly attendance patterns were similar to those of the previous period. The hourly means were more widely distributed, possibly due to the greater number of observations. Amberjacks were recorded at every hour of the day except 0100 hours and 2300 hours. Two peaks occurred approximately 2 hours after sunrise and sunset, as during the previous period (Figure 3.2-25).

The jackknife-fish, Equetus lanceolatus, and the lane snapper, Lutjanus synagris (40 and 38 records, respectively) were also observed during previous cruise periods. Lane snappers appeared between Days 30 and 70, reaching a peak of six records on Day 34 (Figure 3.2-30). Hourly attendance was more restricted than in the previous period (Figure 3.2-26). The lane snapper was observed only during daylight hours (between 0700 hours and 2100 hours) during this period.

The gray snapper, Lutjanus griseus (28 observations), was not previously reported at this station. The lack of gray snapper observations from previous periods suggested an extended delay in recruitment to the array. Interestingly, gray snappers were not captured by trawling or counted on underwater television transects during any cruise at Station 7; perhaps this species is not normally abundant in the vicinity. No gray snappers were recorded until 53 days after array servicing (Figure 3.2-31). The peak daily total was six records on Day 66. Gray snappers were observed to the end of the period. Hourly attendance was dispersed, with the only major gap between 0400 hours and 0800 hours.

A total of three sea turtle records was obtained: 0600 hours on Day 45; 2100 hours on Day 49; and on 1700 hours on Day 81. The turtles were

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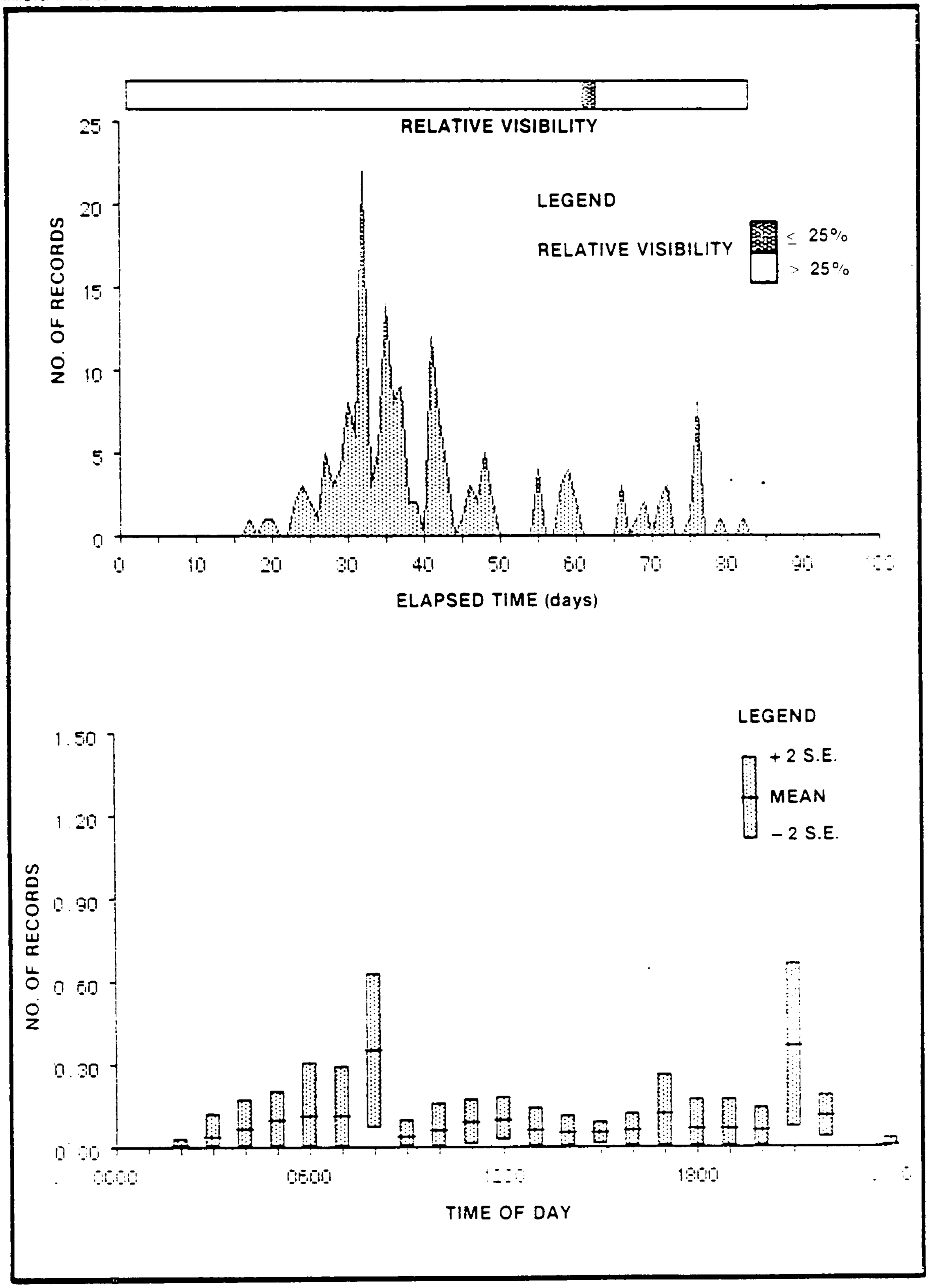

Figure 3.2-29 TOTAL DAILY ABUNDANCE AND HOURLY ABUNDANCE IN TIME-LAPSE RECORDS FROM STATION 7, JULY 1 – SEPTEMBER 21, 1985 — *Seriola dumerili*

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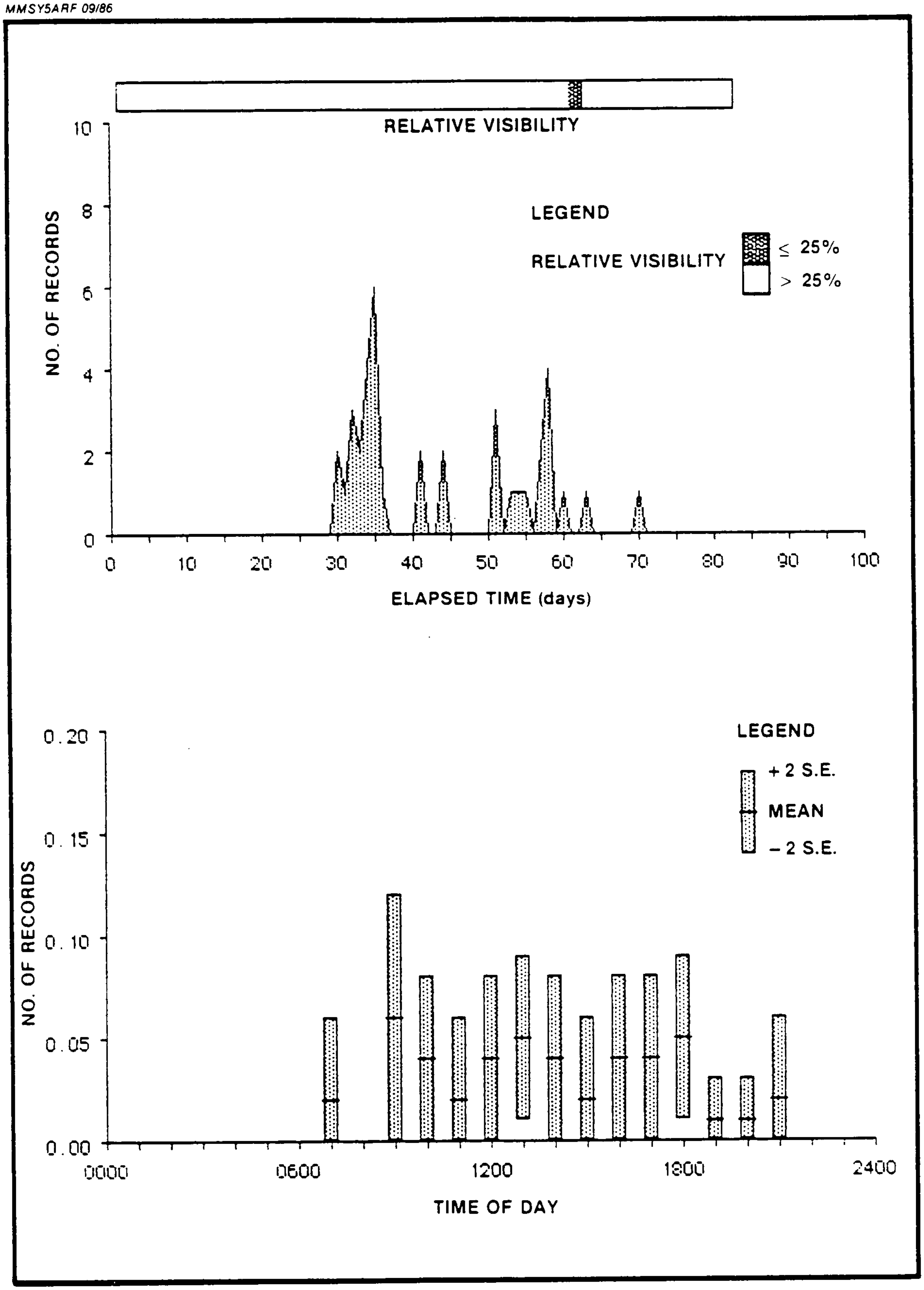

Figure 3.2-30 **TOTAL DAILY ABUNDANCE AND HOURLY ABUNDANCE IN TIME-LAPSE RECORDS FROM STATION 7, JULY 1 – SEPTEMBER 21, 1985 —** *Lutjanus synagris*

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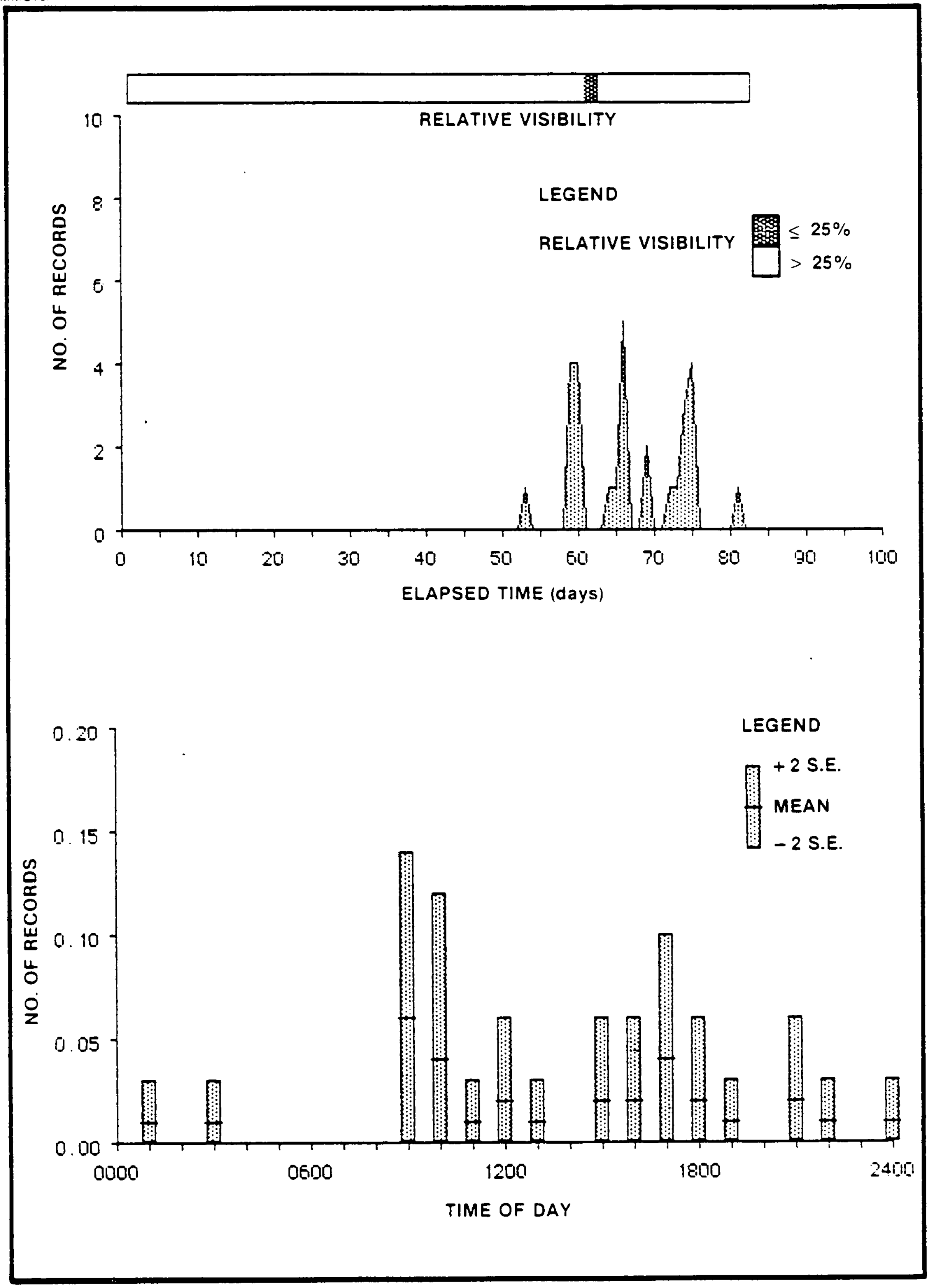

Figure 3.2-31 TOTAL DAILY ABUNDANCE AND HOURLY ABUNDANCE IN TIME-LAPSE RECORDS FROM STATION 7, JULY 1 – SEPTEMBER 21, 1985 — *Lutjanus griseus*

lying flat on the bottom with the top portion of the shells visible. They were all large, and appeared to be loggerheads (*Caretta caretta*).

One final observation of special interest was a fairly large (close to 2 m) nurse shark (*Ginglymostoma cirratum*) seen on Days 47 and 48 from 2300 hours to 0100 hours. The shark was lying on the bottom just outside the settling plate targets.

Station 21

Historical Notes

Station 21 (depth 47 m, within the Middle Shelf Depth Zone) was surveyed by Woodward-Clyde Consultants and Continental Shelf Associates, Inc. during Year 1 and Year 2. Its substrate was categorized as mainly Thin Sand over Hard Substrate (57 to 83%) with occasional rock outcrops and patches of Sand Bottom/Soft Bottom (14 to 43%). The most prominent benthic organisms at Station 21 were sponges, but algal blooms were also a major feature. About 74% of the total area was considered live bottom, representative of the Inner and Middle Shelf Live Bottom Assemblage II, which has a lower biomass per unit area than the Inner Shelf Live Bottom Assemblage I, though many of the same species are present in both assemblage types. The Inner and Middle Shelf Live Bottom Assemblage II typically is dominated by algae, ascidians, bryozoans, corals, small gorgonians, hydroids, and many sponge species (Woodward Clyde Consultants/ Continental Shelf Associates, 1983, 1984). Station 21 was surveyed by ESE/LGL as a Group II station during Years 4 and 5, on Cruises 2, 3, 4, 5, 6, 7, and 8 (March 1984, May 1984, August 1984, December 1984, June/July 1985, and September 1985) (Table 2.2-1).

Underwater Television Results

Total area surveyed was 55,488 m^2 (Table 2.2-2). Station 21 consisted mainly of coarse, carbonate sand, with patches of algae and sponges interspersed. The topography was flat, and ripple marks and evidence of bioturbation could be seen in the sand. Sand cover averaged over 99%.

The most common invertebrates at Station 21 were unidentified gorgonians (162/ha), the sponges *Ircinia campana* (69/ha) and *I. strobilina* (62/ha), hydroids (5/ha), and unidentified holothuroids (3/ha) (Figure 3.2-2, Table 3.2-2). Unidentified algae and demosponges were very important benthic community components (36% and 23% coverage, respectively) (Table 3.2-1).

The most abundant fishes in underwater television transects at Station 21 were unidentified scad of the genus *Decapterus* (180/ha); the yellowtail reeffish, *Chromis enchrysurus* (114/ha); the red grouper, *Epinephelus morio* (13/ha); unidentified porgies of the genus *Calamus* (8/ha); the blue goby, *Ioglossus calliurus* (7/ha); the reef butterfly fish, *Chaetodon sedentarius* (6/ha); the tomtate, *Haemulon aurolineatum*, the amberjack, *Seriola dumerili*, and the round scad, *Decapterus punctatus* (all 5/ha); the blue angelfish, *Holacanthus bermudensis* (4/ha); and the blue runner, *Caranx crysos* (3/ha) (Figure 3.2-3). Fishes were often seen closely associated with large sponges. Overall diversity (H") and evenness (J') for fishes censused with underwater television were 1.62 and 0.45, respectively, for all cruises together at Station 21.

The amount of area surveyed per cruise at Station 21 ranged from 3,606 to 17,908 m^2 (Table 2.2-2). On all cruises, the predominant substrate was sand, representing from 98 to 100% coverage, relieved only by occasional outcrops of reef rock.

The benthic community was, in general, rather similar from one cruise to the next. The areas surveyed were consistently dominated by sponges and (on most cruises) algae. Densities of *Ircinia campana* ranged from 26/ha (Cruise 8) to 146/ha (Cruise 2); *Ircinia strobilina* densities were typically a bit lower, ranging from 30 to 101/ha. Demosponges accounted for 5 to 35% coverage (Table 3.2-1).

Pronounced fluctuations in algal cover were recorded from Station 21, with the lowest values in late winter or early spring (March) followed by a dramatic rise in late spring or early summer (May/June), and a gradual decrease in the fall. Algae were not observed in March 1984, but in May 1984 they accounted for 67% cover. Algal abundance decreased in fall and winter (30% cover on Cruise 4 in August 1984, 17% cover on Cruise 5 in December), reaching another low (5%) in March 1985 (Cruise 6). Their coverage rose to 36% in June/July 1985 (Cruise 7), and was 24% in September 1985 (Cruise 8).

Gorgonian beds were not common at Station 21, although isolated patches were present in the area. On Cruise 3, a dense bed of gorgonians was transected (500/ha), but gorgonians were either rare or absent on all other cruises. Hydroids were seen on most cruises but were common only in the spring (7/ha on Cruise 2 in March 1984, 11/ha on Cruise 3 in May 1984). Mellitid sand dollars were also observed on Cruise 2 (10/ha), but not seen on subsequent cruises. Holothuroids were present on every cruise, with densities ranging from less than 1/ha (Cruise 3, May 1984) to 8/ha (Cruise 5, December 1984).

The only benthic organisms censused with underwater television at Station 21 whose abundance differed statistically ($p < 0.05$) among cruises were gorgonians and demosponges. Gorgonian density on Cruise 3 (May 1984) was higher than on any other cruise; none of the other cruise means differed from one another. Demosponge cover was highest on Cruise 2 (March 1984), and differed significantly from low values for cover on Cruise 3 (May 1984), Cruise 7 (June/July 1985), and Cruise 8 (September 1985). However, mean percentages for cover on Cruises 3 through 8 did not differ significantly from one another.

The only fish sighted on all cruises at Station 21 was the reef butterflyfish, *Chaetodon sedentarius*. However, the yellowtail reeffish, *Chromis enchrysurus*; the red grouper, *Epinephelus morio*; and unidentified porgies (*Calamus*) were also representative of the site, reported from six out of seven cruises.

Most fishes were relatively scarce at Station 21 on Cruises 2 and 3, both in terms of density and of numbers of species sighted. On Cruise 2, when 4,100 m^2 were surveyed, only five taxa were recognized. The only species whose density exceeded three/ha was the reef butterflyfish, *Chaetodon sedentarius* (five/ha). On Cruise 3, 17,908 m^2 were transected, but only 10 taxa were sighted, and most of these were present at very low densities. The most abundant fishes were the blue runner, *Caranx crysos* (eight/ha); unidentified species of Chromis (seven/ha); and the red grouper, Epinephelus morio (four/ha).

By fall (Cruise 4, August 1984), fish were considerably more common in underwater television transects. Even though the area transected ($8,217\ m^2$) was less than half that viewed on Cruise 3, 17 taxa were reported. Numerically dominant species included the yellowtail reeffish, Chromis enchrysurus, which was present at extremely high densities (181/ha); the blue goby, Ioglossus calliurus (49/ha); Epinephelus morio (20/ha); unidentified wrasses (13/ha); porgies of the genus Calamus and amberjacks, Seriola dumerili (both 12/ha); the blue angelfish, Holacanthus bermudensis (10/ha); the reef butterflyfish, Chaetodon sedentarius (9/ha); and the tattler, Serranus phoebe (5/ha).

The fishes reported from Cruise 5 (December 1984) were similar to those on Cruise 4 in many respects. A total of $3,606\ m^2$ was surveyed, and 11 taxa were reported. Chromis enchrysurus and Epinephelus morio were still very numerous (219 and 22/ha, respectively). Other abundant fishes included porgies (14/ha), Chaetodon sedentarius, Holacanthus bermudensis, and Ioglossus calliurus (all 6/ha).

On Cruise 6 (March 1985), $6,501\ m^2$ were surveyed with underwater television, but only eight fishes were observed. The most abundant species were Chromis enchrysurus (85/ha), Chaetodon sedentarius (20/ha); Epinephelus morio (14/ha); the bigeye, Priacanthus arenatus (12/ha); and Holacanthus bermudensis (8/ha). Other common species included the twospot cardinalfish, Apogon pseudomaculatus (five/ha); and various squirrelfishes of the genus Holocentrus, and porgies, Calamus (both three/ha).

On Cruise 7 (June/July 1985), 14 fishes were identified in a survey area of $6,726\ m^2$. High densities were recorded for Chromis enchrysurus (332/ha); Epinephelus morio (34/ha); Ioglossus calliurus (24/ha);

Serranus phoebe (22/ha); and unidentified anthinids (probably species of the serranids Hemanthias and Plectranthias) (18/ha). The round scad, Decapterus punctatus, and the tomtate, Haemulon aurolineatum, were also abundant on Cruise 7 (37 and 42/ha, respectively). Haemulon aurolineatum was not reported from on any other cruises at this station. Decapterus punctatus was not noted on other cruises, but it is possible that the extremely dense schools of Decapterus on Cruise 8 were D. punctatus, though identification to the species level was not possible in that instance.

On Cruise 8 (September 1985), 8,430 m^2 were surveyed, but only eight taxa were identified. As on Cruises 2 and 3, the fish fauna appeared sparse compared to other cruises. Several of the most abundant fishes were those which could be considered pelagic, rather than reef residents [e.g., Decapterus (1,186/ha) and Seriola dumerili (19/ha)]. Other common fishes more closely associated with benthic habitats included Chromis enchrysurus (143/ha), Epinephelus morio (10/ha); and Calamus (4/ha).

There were four fishes censused with underwater television at Station 21 whose densities differed significantly ($p \leq 0.05$) among cruises.

There were no clear seasonal differences in the densities of Epinephelus morio. The 95% confidence intervals for mean densities overlapped on Cruises 3 through 8, although Cruise 3 (May 1984) was significantly lower than that on Cruise 4 (August 1984). The density of Epinephelus morio (zero) on Cruise 2 (March 1984) differed significantly from densities recorded on all other cruises.

Confidence intervals for mean densities of Chaetodon sedentarius overlapped one another, obscuring seasonal differences. Densities did not differ statistically from one another except for Cruise 6 (March 1985), which was significantly higher than densities on Cruise 3 (May 1984) or Cruise 8 (September 1985).

Densities of Chromis enchrysurus had overlapping confidence intervals for all cruises except for Cruises 2 and 3 (spring 1984), whose low values differed significantly from higher densities on Cruises 4 through 8.

The results for Ioglossus calliurus suggest possible seasonal differences, with increased densities during the summer. Ioglossus had zero densities on Cruises 2, 3, and 6 (March 1984, May 1984, and March 1985). These zero values did not differ significantly from low densities on Cruises 5 and 8 (December 1984 and September 1985), but did differ from higher densities on Cruises 4 and 7 (August 1984 and June/July 1985).

Triangular Dredge Results

Sixty-seven invertebrates (excluding sponges) were identified in nine triangular dredge samples from Station 21 (Table 3.2-4). There were many unidentified sponges.

No gorgonians were collected at Station 21, but seven species of scleractinian corals were found, including the smooth starlet coral, Siderastrea siderea; the ivory bush coral, Oculina diffusa; another bush coral, Oculina varicosa; the blushing starlet coral, Stephanocoenia michelini; the large flower coral, Mussa angulosa; and the solitary disc coral, Scolymia lacera and an unidentified congener.

Fourteen gastropods were collected at Station 21. There were several sessile forms found on hard substrates, such as the Florida worm-shell, Vermicularia knorri, and the decussate worm-shell, Serpulorbis decussatus. Most of the gastropods were more typical of soft bottoms, such as cones, conchs, and murexes. Larger species included the Atlantic carrier shell, Xenophora conchyliophora; Villepin's cone, Conus villepinii; the white giant turrid, Polystira albida; the Tampa turrid, Crassispira tampaensis; the milk conch, Strombus costatus; the trochlear latirus, Latirus cariniferus; the Scotch bonnet, Phalium granulatum; the chocolate-lined top, Callistoma javanicum; another top shell, C. pulchrum; and the lace murex, Murex florifer.

Six of the gastropods were unique to Station 21, including Crassispira tampaensis; the jujonia, Scaphella junonia; Conus villepinii; the Atlantic carrier-shell, Xenophora conchyliophora; Serpulorbis decussatus; and Calliostoma pulchrum.

Six bivalves were present in dredge hauls. There were three sessile bivalves, including the Atlantic thorny oyster, Spondylus americanus; the leafy jewel box, Chama macerophylla; and an unidentified jingle, Pododesmus. Unattached forms included Gibbes's crassatella, Eucrassatella speciosa; the cockle Nemocardium peramabile; and Lister's venus, Periglypta listeri. Nemocardium peramabile, Periglypta listeri, and Pododesmus were collected only at Station 21.

Five anomurans were found in triangular dredge samples, including three hermit crabs (Paguristes sericeus, Pagurus defensus, and Dardanus fucosus) and two galatheids (Galathea rostrata and Munida pusilla).

Brachyurans were much more diverse, with 15 taxa collected. Dredge hauls included box crabs (Calappa flammea); the arrow crab (Stenorhynchus seticornis) and other majiids (Mithrax pleuracanthus, M. acuticornis); portunid crabs (Portunus ordwayi and P. spinicarpus); the lesser sponge crab, Dromidia antillensis; and many others. Species collected only at Station 21 included Raninoides louisianensis and Speloeophorus nodosus.

Other crustaceans included two penaeids, both unique to Station 21 (the rock shrimp, Sicyonia brevirostris, and Parapenaeus politus); a stenopodidan shrimp (Stenopus scutellatus); a slipper lobster not collected at any other station (Scyllarides nodifer); and three pistol shrimps (Synalpheus minus, S. townsendi, and Alpheus normanni). The mantis shrimps Gonodactylus bredeni and Eurysquilla plumata (unique to Station 21) were also collected.

Four species of sea stars usually associated with soft bottoms were collected with the triangular dredge: the reticulated sea star, Oreaster reticulatus; the limp sea star, Luidia alternata; the spiny beaded sea star, Astropecten duplicatus; and Astropecten nitidus. Three ophiuroids were found in samples from Station 21, including the striped brittle star, Ophiothrix lineata; the angular brittle star, Ophiothrix angulata; and the short-spined brittle star, Ophioderma brevispina.

Four 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, Clypeaster rosaceus; the brown rock urchin, Arbacea punctulata; and the sea pussy, Meoma ventricosa.

Eighteen algae were recognized in triangular dredge samples (Table 3.2-5). They included two greens (Caulerpa racemosa var. macrophysa and Pseudotetraspora antillarum), both collected only at Station 21. Five browns were taken (Dictyota bartayresii, Sargassum cf. hystrix; Sporchnus penduncúlatus; Nerstetia tropica, and another which could not be identified to genus); the last two species were unique to Station 21.

Eleven red algae were found at Station 21: Champia parvula, Gracilaria cylindrica, G. mammilaris, Aghardiella ramosissima, an unidentified Polysiphonia, Fauchea hassleri, Kallymenia westii, Hypoglossum tenuifolium, and three forms which could not be identified to genus. Species not collected at any other station included Faucheria hassleri, Kallymenia westii, Hypoglossum tenuifolium, and two of the three unidentified rhodophytes.

Otter Trawl Results

Station 21 was sampled with the trawl on Cruises 2 through 8 (March, May, August, and December 1984, and March, June/July, and September 1985, respectively) (Table 2.2-1). A total of 342 individuals was collected in the seven hauls, an average of 48.9 fish per 10-minute tow (Table 3.2-6).

Sixty-nine taxa were recognized, belonging to 28 families. The best represented family in terms of numbers of fishes collected were the serranids (basses and groupers, eight species); the lizardfishes (Synodontidae) and balistids (triggerfishes), at least five species each; and the scorpaenids (scorpionfishes), apogonids (cardinalfishes), chaetodontids (butterflyfishes), scarids (parrotfishes), clinids, and bothids (lefteye flounders), three species each. Overall diversity (H") and evenness (J') for fishes collected by trawling were 3.53 and 0.83, respectively, for all cruises together at Station 21.

The most abundant species were the dusky flounder, *Syacium papillosum* (5.3/tow); the twospot cardinalfish, *Apogon pseudomaculatus* (5.1/tow); the tattler, *Serranus phoebe* (4.6/tow); the reef butterflyfish, *Chaetodon sedentarius* (2.6/tow); the sawcheek cardinalfish, *Apogon quadrisquamatus*, and the sand diver, *Synodus intermedius* (both 2.1/tow) (Figure 3.2-4).

Other common species included the spotfin butterflyfish, *Chaetodon ocellatus*, and the bridle cardinalfish, *Apogon aurolineatus* (both 1.9/tow); the red grouper, *Epinephelus morio* (1.7/tow); the barred hamlet, *Hypoplectrus puella* [probably a color morph of *Hypoplectrus unicolor* (Thresher, 1978; Graves and Rosenblatt, 1980, from Robins *et al.* 1980.)] (1.6/tow); the tomtate, *Haemulon aurolineatum* (1.4/tow); the largescale lizardfish, *Saurida brasiliensis* (1.3/tow); and the deepwater squirrelfish, *Holocentrus bullisi* (1.1/tow).

Several species were collected with high frequency. Fishes present on six out of seven cruises were *Synodus intermedius*, *Serranus phoebe*, and *Syacium papillosum*. *Chaetodon ocellatus* was taken on five cruises, and *Epinephelus morio*, *Hypoplectrus puella*; and the offshore lizardfish, *Synodus poeyi* were each present on four cruises. *Apogon pseudomaculatus*, Chaetodon sedentarius; the balloonfish, Diodon holocanthus; the sheepshead porgy, Calamus penna; and the yellowtail reeffish, Chromis enchrysurus were each collected on three cruises.

The abundance of these and most other fishes was highly variable between cruises. For example, the trawl on Cruise 5 (December 1984) produced almost 10 times as many fish (212 individuals, 47 species) as on other cruises. Cruise 6 (March 1985) was particularly poor for fish (only eight specimens taken). Many species were present at low densities. For example, 41 species (more than half the total) were represented by only one or two specimens during the entire study.

At least 22 fishes were collected only at Station 21. These species included the Atlantic midshipman, Porichthys plectrodon; the ocellated frogfish, Antennarius ocellatus; the skilletfish, Gobiesox strumosus; an unidentified ophidiid cusk eel; the saddle squirrelfish, Holocentrus poco; the bandtail searobin, Prionotus ophryas; the dwarf sand perch, Diplectrum bivittatum; Hypoplectrus puella; the scamp, Mycteroperca phenax; the bigeye, Priacanthus arenatus; the bronze cardinalfish, Astropogon alutus; the bigtooth cardinalfish, Apogon affinis; Apogon quadrisquamatus, A. pseudomaculatus, and A. aurolineatus; the slender mojarra, Eucinostomus jonesi; Calamus penna; the cubbyu, Equetus umbrosus; the threadfin blenny, Nematoclinus atelestos and several other clinids (Emblemaria caldwelli, an unidentified Starksia), several gobies (Evermannichthys and unidentified members of various genera (Monacanthus, Chromis, Calamus).

Analyses of stomach contents, maturation state, length and weight for Synodus intermedius, Epinephelus morio, Serranus phoebe, Lutjanus synagris, and Lactophrys quadricornis are presented in Subection 3.2.2, Species Accounts.

Time-Lapse Camera

Overview

Time-lapse camera apparatus was originally installed at Station 21 on Cruise 1. However, due to array loss and equipment malfunction, data were recovered only from a second array, installed on Cruise 3 and retrieved on Cruise 6. Data obtained from the Cruise 3 installation was presented in the Year 4 Annual Report. Cruises 6 and 7 observations are reported below.

Cruises 6 and 7 (March 1985 to June/July 1985)

The second array at this station was installed during Cruise 3 on May 28, 1984, and was brought on deck for repairs during Cruise 4 and then re-installed. Sessile organisms on target plates recorded between Cruise 6 and Cruise 7 thus were undisturbed for 7 months, although those organisms which may have survived the exposure to air during Cruise 4 had been growing for about 10 months when photographed after Cruise 6.

The area in view of the camera at Station 21 was similar to that described from underwater television transects. Most of the substrate was bare sand with a few massive-type sponges and some attached algae. Due to the depth of 47 m, divers were not able to measure the thickness of sediment at the time-lapse camera site, although hard substrates were occasionally seen exposed in underwater television transects.

Time-lapse camera data were available for only 10 days and 13 hours from March 29 to April 9, 1985 (253 hourly observations). The termination of camera operation was due to battery failure. Virtually all (99.6%) of the frames were exposed in clear water (100% relative visibility). A single frame had a relative visibility index of 50%, possibly due to the activities of a benthic feeding fish which resuspended bottom sediments. The sediment in view of the time-lapse camera was not visibly altered by either bioturbation or water movement.

Many frames (22.5% of the total) were occluded by jewfish. Large fish may take up temporary residence inside the array either because of the spatial orientation the array provides, or possibly because smaller fish attracted to the array offer a concentrated food supply.

The settling plate targets included both a freshly scraped plate on the left, and an unscraped plate on the right. The flat surface of the cleaned plate remained visibly unchanged during the 11 days of the time-lapse period, but the edges of this plate did exhibit some growth. Along the edges of the left plate, hydroid stalks became apparent very near the beginning of the period and grew to a length of approximately 10 mm. The edges of this target probably had not been cleaned as completely as the flat surface, perhaps leaving hydroid stolons on the edges where they could regrow rapidly.

The undisturbed target did not show any visible changes in cover by biota, but there were some noticeable movements of organisms when viewed at accelerated projection speeds. A yellow colonial ascidian measuring approximately 3 cm in diameter expanded and contracted a few millimeters in size at irregular intervals throughout the period. The cycle from expansion to contraction and back to an expanded state usually took 3 to 4 frames (i.e. 3 to 4 hours of real time).

A great deal of unexpected movement in sponges was also observed. An unidentified yellow, knobby sponge radically altered its size and shape between adjacent movie frames (at 1-hour intervals). Its diameter changed from about 3 cm to 2 cm and back again on several occasions. Other sponge also exhibited volume changes. Also, a hermit crab (?) with a shell covered with sponges and other sessile organisms moved around 10 to 20 cm/hour for about 48 hours.

Observations of fishes included only seven taxa and 136 observations (Table 3.2-11). The two most abundant taxa were recorded at a similar

Table 3.2-11. Total number of fish sightings by time-lapse camera at Station 21, during March and April 1985

Taxon	Sightings
Perciformes	58
Epinephelus itajara	57
Chaetodon ocellatus	10
Mycteroperca Unident.	5
Lutjanidae	2
Seriola dumerili	2
Calamus Unident.	2
Number of Sightings	136
Total Frames Exposed	253

frequency: Unidentified Perciformes, and jewfish (58 and 57 records, respectively). Figure 3.2-32 illustrates daily abundance totals and hourly attendance patterns for jewfish. All of the sightings were probably one or two individuals. Jewfish were seen soon after installation (Day 4), and may have been in residence at the array during the previous period, although no time-lapse data could be checked for that period. Jewfish were seen in a single 5-day block of time between Day 4 and Day 8. Jewfish were not seen during the last several days of the period. Hourly attendance is shown in Figure 3.2-32; only 1 hour of the day (0600 hours) lacked jewfish observations. Fewer jewfish were recorded between 0500 and 0700 hours, possibly suggesting feeding activity away from the array.

The third most frequently recorded fish was the spotfin butterflyfish, *Chaetodon ocellatus* (10 observations). This fish was observed on Days 5 and 9, with a peak of six records on Day 11. Spotfin butterflyfishes were observed primarily in the evening between 1600 and 2000 hours. Another grouper (an unidentified *Mycteroperca*) appeared a total of five times. The remaining fishes included unidentified snappers (Lutjanidae), porgies of the genus *Calamus*, and the greater amberjack, *Seriola dumerili* (two records each).

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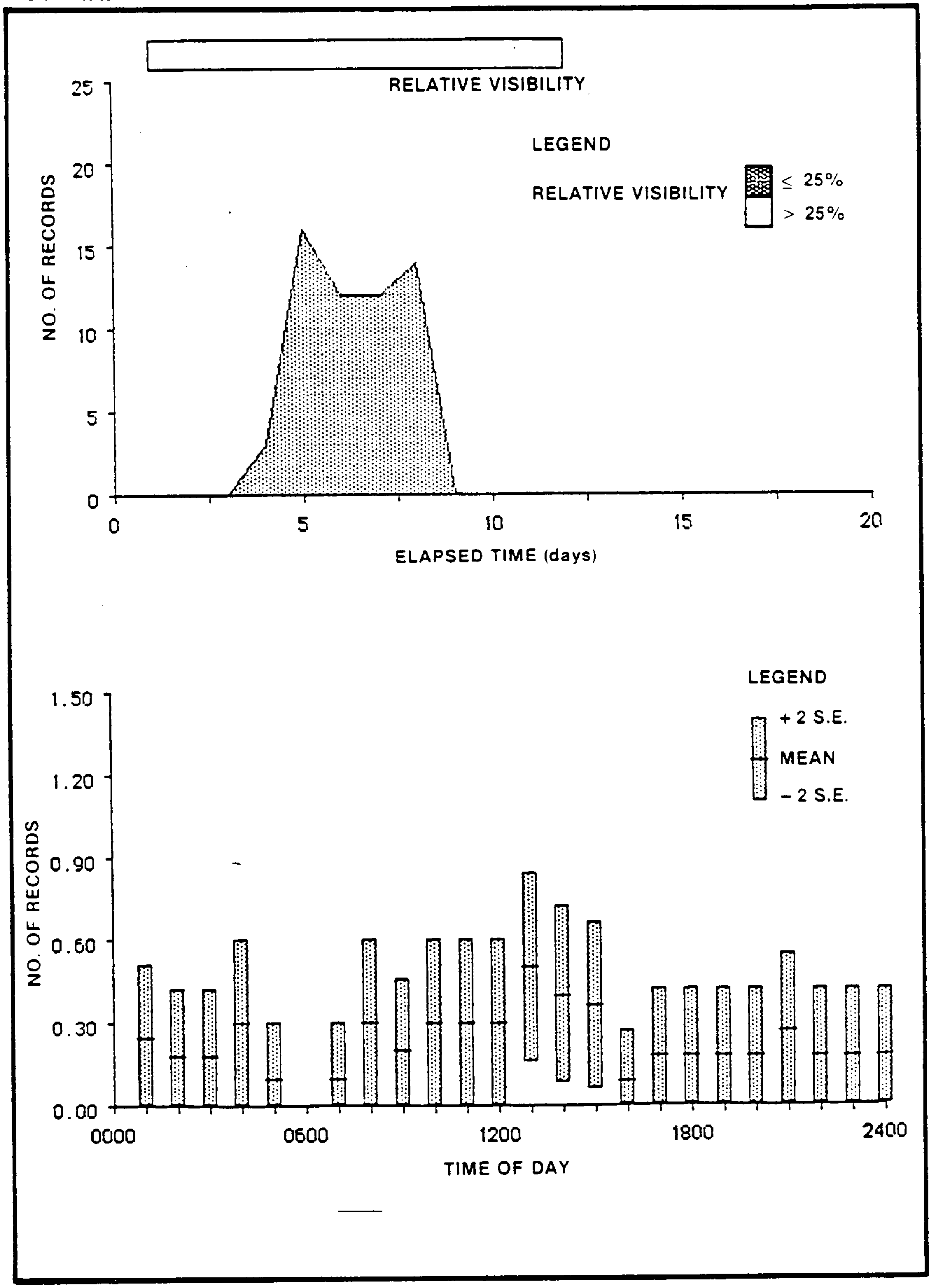

Figure 3.2-32 ACTIVITY PATTERNS FOR *Epinephelus itajara* AT STATION 21, MARCH 29 – APRIL 1985

Station 29

Historical Notes

Station 29 (depth 64 m, within the Middle Shelf Depth Zone) was surveyed by Woodward-Clyde Consultants and Continental Shelf Associates, Inc., during Year 1 and Year 2. Its substrate was categorized as Algal Nodule Pavement with Agaricia Accumulations, i.e., a layer of fused coralline algal nodules and hermatypic coral reef structures made up of living and dead colonies of Agaricia (97% of the bottom area surveyed). Live bottom coverage was reported as 100% of the area surveyed, and consisted of Agaricia Coral Plate Assemblage, dominated by the alga Anadyomene menziesii, live corals, gorgonians, and sponges. The biological community was described as "tropical-reefal in character," (sic) due to the presence of Agaricia and the large number of fishes typically associated with Caribbean coral reef (Woodward Clyde Consultants/Continental Shelf Associates, 1983, 1984). Station 29 was surveyed by ESE/LGL as a Group II station during Years 4 and 5, on Cruises 1, 2, 3, 4, 5, 6, and 7 (Table 2.2-1).

Underwater Television Results

The total area surveyed was 67,323 m^2 (Table 2.2-2). The bottom at Station 29 consisted of an irregular pavement of well-consolidated coralline algae, and living and dead agariciid corals (84% cover) that formed a complex substrate of plates, mounds, and cavities. The topography was mostly flat, with some depressions and low hill-like areas.

The most common invertebrates observed in underwater television transects at Station 29 were Agaricia (17% cover), gorgonians of the genus Ellisella and unidentified hydroids (both 11/ha), the sponge Ircinia campana (10/ha), comatulid crinoids (6/ha), and the sponge Ircinia strobilina (4/ha) (Figure 3.2-2, Tables 3.2-1, 3.2-2). The green alga Anadyomene (menziesii) was the clear dominant compared to other algae (23% versus 2% cover). Unidentified demosponges accounted for another 4% cover.

Station 29 was particularly rich in fishes (Table 3.2-3), which were often concentrated near topographic features such as mounds or depressions. The most frequently counted fishes in underwater television transects were the yellowtail reeffish, Chromis enchrysurus (518/ha); an unidentified serranid of the genus Hemanthias (295/ha); the purple reeffish, Chromis scotti (133/ha); unidentified anthinids (68/ha) and other serranids of the genus Serranus (probably Serranus phoebe or Serranus annularis) (47/ha); the boga, Inermia vittata (97/ha); the reef butterflyfish, Chaetodon sedentarius (15/ha); the bicolor damselfish, Pomacentrus partitus (12/ha); the spotfin hogfish, Bodianus pulchellus (9/ha); the tattler, Serranus phoebe (8/ha); the rock beauty, Holanthias tricolor (5/ha); and the amberjack, Seriola dumerili, unidentified serranids of the genus Mycteroperca, the beaugregory, Pomacentrus leucostictus, and an unidentified damselfish (all 4/ha) (Figure 3.2-3). Overall diversity (H") and evenness (J') for fishes censused with underwater television were 1.75 and 0.49, respectively, for all cruises together at Station 29.

The area surveyed on each cruise at Station 29 ranged from 5,079 m^2 to 16,794 m^2 (Table 2.2-2). The substrate was reported consistently as a fused or broken pavement of algal/coral aggregate (80 to 100% cover), with some small pockets of sand visible in depressions. Anadyomene ranged from 18% cover on Cruises 2, 3, and 4, (March, May, and August 1984, respectively) to 38% cover on Cruise 5 (December 1984) (Table 3.2-1). Living Agaricia was reported as varying from 7 to 21% cover, although it was often hard to differentiate living corals from dead.

Other characteristic benthic organisms varied considerably in abundance from one cruise to the next (Table 3.2-1). Although the benthic invertebrates censused with underwater television at Station 29 differed significantly in density ($p > 0.05$) among cruises; demonsponges had significantly higher percentage cover on Cruise 2 (March 1984) than on any of the five subsequent cruises. Cover by demosponges on Cruise 1 was intermediate, and did not differ either from Cruise 2 cover or from cover on Cruises 3 through 7. Variable high densities (9 to 35/ha) were recorded for Ircinia campana on Cruises 1 (December 1983), 2, 4, and 7 (June/July 1985), but on Cruises 3, 5, its density was $\leq$1/ha, and it was not reported on Cruise 6. Similarly, Ircinia strobilina was common on Cruises 1 through 4 (densities 3 to 9/ha), but rare or absent on Cruises 6 and 7. The abundance of demosponges as a group ranged from 1 to 6%, with the highest values reported on Cruise 6.

The density of the most common gorgonian, Ellisella, varied widely, ranging from 6 to 22/ha (Cruises 5 and 1, respectively). Patches of comatulid crinoids were viewed on Cruises 3 and 4 only (densities 17 and 19/ha, respectively). Hydroids also fluctuated in densities (absent or less than 3/ha on Cruises 1, 2, and 7; 10 to 32/ha on Cruises 3 through 6).

A number of fish species were present at Station 29 on every cruise, often at very high densities. These fishes included the yellowtail reeffish, Chromis enchrysurus (137 to 1,586/ha); the purple reefish, Chromis scotti (5 to 390/ha); unidentified Serranus species (0 to 153/ha); the reef butterflyfish, Chaetodon sedentarius (9 to 31/ha); the rock beauty, Holacanthus tricolor (2 to 8/ha); and the spotfin hogfish, Bodianus pulchellus (1 to 17/ha).

Other fishes seen less frequently, but at high densities when present, included an unidentified Hemanthias (2,357/ha on Cruise 5); the boga, Inermia vittata (887/ha on Cruise 4); the tattler, Serranus phoebe (30/ha on Cruise 3); the bicolor damselfish, Pomacentrus partitus (65/ha on Cruise 4); the beaugregory, Pomacentrus leucostictus (31/ha on Cruise 5); the amberjack, Seriola dumerili (16/ha on Cruise 3); and the red grouper, Epinephelus morio (8/ha on Cruise 87).

Two of the fishes censused with underwater television at Station 29 differed significantly in density ($p \leq 0.05$) among cruises. The mean density of *Chromis enchrysurus* was highest on Cruise 5 (December 1984), and differed significantly from densities on all other cruises. No clear seasonal differences were obvious. Both the highest densities and lowest densities were recorded from winter cruises. The low densities on Cruise 1 (December 1983) and Cruise 2 (March 1984) differed significantly from higher densities on Cruise 7 (June/July 1985). Cruise 6 (March 1985) had an intermediate density whose confidence intervals overlapped those of Cruises 1, 3, 4, and 7, but differed from those for Cruise 2.

No clear seasonal differences were evident for *Chromis scotti*, either. *Chromis scotti* had high mean densities on Cruises 4, 5, 6, and 7 which did not differ significantly from one another. Very low mean densities for Cruises 1 and 2 differed ($p \leq 0.05$) from those on all other cruises except Cruise 6. Cruise 3 had an intermediate density, and its confidence intevals overlapped those of Cruises 5, 6, and 7.

The number of taxa identified on Cruises 1 through 5 ranged from 14 to 17, even though the total area transected on each cruise varied from 5,079 m^2 to over three times that figure, 16,794 m^2. A comparative decrease in species richness was evident on Cruise 6 (7,665 m^2, 10 taxa) and on Cruise 7 (6,498 m^2, eight taxa). In some senses, Cruise 4 was particularly "rich" for fish fauna, since 17 taxa were identified although only 7,368 m^2 were surveyed.

Triangular Dredge Results

Forty-eight invertebrates (excluding sponges) were collected in 12 triangular dredge hauls from Station 29 (Table 3.2-4). The samples were dominated by agariciid coral rubble and by the green alga, *Anadyomene menziesii*.

Twelve species of scleractinians were recorded. Four agariciids were present, including Lamarck's sheet coral, *Agaricia lamarcki*; the fragile saucer coral, *Agaricia fragilis*; leaf coral, *Agaricia agaricites*, and the saucer coral, *Helioseris cucullata*. Four species of *Madracis* were collected: the green cactus coral, *M. decactis*; the yellow pencil coral, *M. mirabilis*; and *M. asperula* and *M. formosa*. Other scleractinians included the cavernous star coral, *Montastrea cavernosa*; the rose coral, *Manicina areolata*; the mustard hill coral, *Porites astreoides*; and an unidentified disc coral, *Scolymia* (probably *S. lacera*). The corals *Agaricia agaricites*, *Porites astreoides*, *Madracis formosa*, and *M. mirabilis* were collected only at Station 29.

Only one gorgonian was collected from Station 29, an unidentified species of *Thesea*.

Only one bivalve--an unidentified ark shell, *Arca*--was found at Station 29. Four gastropods were taken with the dredge: the Atlantic gray cowry, *Cypraea cinerea* and an congener; the carrot cone, *Conus daucus*; and the slit worm-shell, *Siliquaria squamata*, a symbiote found embedded in sponges (Abbott, 1974). The *Arca*, *Conus daucus*, and *Siliquaria squamata* were all found only at Station 29.

Just two carideans were collected: the pistol shrimp *Synalpheus townsendi*, and the cleaning shrimp, *Lysmata rathbunae* (unique to Station 29). Three species of stomatopods were taken, *Gonodactylus bredeni*, *G. torus* (found only at Station 29), and an unidentified congener. Three brachyuran crabs (a xanthid, *Paractaea rufopunctata nodosa*, and two majiids, *Mithrax acuticornis* and an unidentified *Microphrys* unique to Station 29) and a single anomuran, the galatheid *Munida pusilla*, were collected with the triangular dredge.

Only one asteroid, *Poraniella regularis*, was present at Station 29. On the other hand, Station 29 was particularly rich in ophiuroids. Thirteen species were collected, representing seven genera: Ophiactis (Savignyi's ophiactis, O. savignyi, and an unidentifed congener), Ophiothrix (the angular brittle star, O. angulata; Suenson's brittle star, O. suensoni) Ophioderma (the short-spined brittle star, O. brevispina, and the ruby brittle star, O. rubicundum), Ophionereis (the reticulated brittle star, O. reticulata; the olive brittle star, O. olivacea; and an unidentified congener), Ophiopsila (an unidentified species), Ophiomyxa (the slimy brittle star, O. flaccida), Ophiocoma (an unidentified species), and an unidentified ophiomyxid.

Six of the ophiuroids (Ophionereis reticulata, O. olivacea, and the unidentified Ophionereis, Ophiactis ophiocoma, and ophiomyxid) were taken only at Station 29.

There were four species of echinoids in dredge hauls, the long-spined sea urchin, Diadema antillarum; the brown rock urchin, Arbacia punctulata; the pencil urchin, Eucidaris tribuloides; and Stylocidaris affinis. A single holothuroid unique to Station 29 was collected, Thyonella gemmata, as well as an unidentified comatulid crinoid.

Six species of algae were recorded from triangular dredges at Station 29 (Table 3.2-5). The most striking of these was the large green alga, Anadyomene menziesii. Another green, Pseudotetraspora antillarum was also collected, along with two browns, Lobophora variegata (unique to Station 29) and another phaeophyte which could not be identified to genus. Only two reds were present, Peysonnelia rubra orientalis, and an unidentified congener, both found only at Station 29.

Otter Trawl Results

Station 29 was sampled with the trawl on Cruises 1 through 7 (December 1983; March, May, August, and December 1984; and March, and June/July 1985, respectively) (Table 2.2-1). The trawl was routinely shredded by the Agaricia coral bottom at Station 29, and there may have been some losses through holes in the net. In seven samples, 131 fish were collected, an average of 25.7/10-minute tow (Table 3.2-6). There were 26 taxa identified, belonging to 14 families. The best represented families in terms of numbers of species were the serranids (basses and groupers, five species), the pomacentrids (damselfishes, five species), and the scarids (parrotfishes, three species). Overall diversity (H") and evenness (J') for fishes collected by trawling were 2.00 and 0.61, respectively, for all cruises together at Station 29.

The most abundant species were damselfishes: the purple reeffish, Chromis scotti (11.2/tow), and the yellowtail reeffish, C. enchrysurus (6.7/tow) (Figure 3.2-4). A small serranid, Serranus annularis (the orangeback bass) was also common (1.0/tow). Most other fishes were present at very low densities; in fact, 18 species were represented by only one or two specimens.

There were seven species taken on more than one cruise. Fishes observed frequently included Chromis scotti (six cruises), C. enchrysurus (five cruises), and Serranus annularis (three cruises). Other fishes seen on two cruises included the hunchback scorpionfish, Scorpaena dispar; the reef butterflyfish, Chaetodon sedentarius; the greenblotch parrotfish, Sparisoma atromarium, and the fringed filefish, Monacanthus ciliatus.

Considerable differences in density were noted between cruises. On Cruises 1 through 4, 5 or fewer specimens were collected/haul. Seventy-seven specimens were taken on Cruise 5, mainly Chromis enchrysurus and C. scotti. Sixteen and 20 fish were collected on Cruises 6 and 7, respectively.

Almost half of the fishes (at least 10 species) collected with the trawl at Station 29 were not taken at any other station. These species included a gobiesocid believed to be the stippled clingfish, Gobiesox punctulatus; the reef squirrelfish, Adioryx coruscus (= Holocentrus coruscus); the school bass, Schultzea beta; the chalk bass, Serranus tortugarum; the Spanish flag, Gonioplectrus hispanus; the longsnout butterflyfish, Chaetodon aculeatus; the sunshinefish, Chromis insolatus; the bicolor damselfish, Chromis partitus; the spotfin hogfish, Bodianus pulchellus; the bluelip parrotfish, Chryptotomus roseus; and the bucktooth parrotfish, Sparisoma radians.

Analyses of stomach contents, maturation state, length and weight for Lactophrys quadricornis, which was collected at Station 29, are presented in Subsection 3.2.2, Species Accounts.

Station 23

Historical Notes

Station 23 (depth 74 m, in the Middle Shelf Depth Zone) was surveyed during Year 1 and Year 2 by Woodward-Clyde Consultants and Continental Shelf Associates, Inc. Its substrate type was categorized as Coralline Algal Nodule Layer over Sand, (93 to 100% coverage), with some small areas of thick sand substrate exposed (0 to 7%), and occasional rock outcrops. Live bottom was reported to cover 97% of the area surveyed, and was classed as Middle Shelf Algal Nodule Assemblage, consisting of loose or fused coralline algal nodules and rubble, with some corals and small sponges present (Woodward Clyde Consultants/Continental Shelf Associates, 1983, 1984). Station 23 was surveyed by ESE/LGL as a Group II station during Years 4 and 5, on Cruises 2, 3, 4, 5, 6, and 7 (Table 2.2-1).

Underwater Television Results

The total area surveyed was 54,842 m^2 (Table 2.2-2). The bottom at Station 23 consisted of patches of loose to lightly consolidated algal nodules on a base of carbonate sand. The topography was predominantly flat, with some low relief. Substrate types included nodules and algal rubble (74% cover) and sand (26% cover). The most visible benthic organism--other than the coralline algal nodules themselves--was the green alga Anadyomene menziesii. The ichthyofauna was diverse but patchy. Those fish that were observed were usually associated with shallow depressions or prominences on the bottom.

The most abundant benthic invertebrates were small sponges. Large sponges were rarely observed (Figure 3.2-2, Table 3.2-1). Unidentified demosponges accounted for 8% cover (Table 3.2-2). Other invertebrates were seen occasionally, including unidentified asteroids; the spiny lobster, Panulirus argus, the sponges Ircinia strobilina and I. campana, and an unidentified pagurid hermit crab (all fewer than 2/ha). Coverage by Anadyomene menziesii averaged 1%, while other unidentified algae accounted for another 8%.

The most common fishes in underwater television transects at Station 23 were the round scad, Decapterus punctatus (912/ha); the yellowtail reeffish, Chromis enchrysurus (221/ha); various unidentified wrasses of the genus Halichoeres (22/ha); the tattler, Serranus phoebe (17/ha); the jackknife fish, Equetus lanceolatus (12/ha); unidentified serranids of the genus Serranus (11/ha); the reef butterflyfish, Chaetodon sedentarius (5/ha); and the blue angelfish, Holacanthus bermudensis (3/ha) (Figure 3.2-3, Table 3.2-3). Overall diversity (H") and evenness (J') for fishes censused with underwater television were 0.90 and 0.25, respectively, for all cruises together at Station 23.

Relatively few benthic invertebrates were observed on any cruise at Station 23 because the bottom was covered with algal nodules. Sandy patches were present wherever algal rubble was not. Nodules were reported as the substrate type 71% to 92% of the time, except on Cruise 6 (March 1985), when more sandy areas were transected (nodules 53%). The sponge Ircinia campana was observed on Cruise 2 (March 1984), Cruise 4 (August 1984), and Cruise 5 (December 1984) at densities lower than 4/ha. Ircinia strobolina was seen only on Cruise 4 (5/ha). Cover by all demosponges taken together ranged from 1% (Cruises 2 and 4) to 17% (Cruise 3 and Cruise 6). Asteroids (5/ha), and pagurid crabs (8/ha), were reported only on Cruise 6. Only Ircinia campana and pagurid crabs were recorded on more than one cruise.

The abundance of Anadyomene menziesii was highly variable. Low values were recorded on Cruise 2 (March 1984), Cruise 4 (August 1984), and Cruise 6 (3%, 1%, and 6%, respectively) (Table 3.2-1). Anadyomene was extremely abundant in May 1984, on Cruise 3 (18% cover); in December 1984 (33% cover); and in June 1985, on Cruise 7 (20% cover). Other unidentified algae showed similar variability, with lower values (<6%) on Cruises 2, 4, and 6, and higher values on Cruises 3 (16%), 5 (18%), and 7 (12%).

None of the benthic invertebrates censused with underwater television at Station 23 differed significantly in diversity or cover ($p > 0.05$) among cruises.

Most of the fishes observed at Station 23 were seen only on one or two cruises, alhough frequently in large numbers (Figure 3.2-4). For example, the round scad, *Decapterus punctatus*, was observed only on Cruise 4 (6,013/ha). The jackknife-fish, *Equetus lanceolatus*, was seen only on Cruises 3 and 6, at high densities (22 and 51/ha, respectively). The boga, *Inermia vittata*, was recorded only on Cruise 4 (18/ha). The red grouper, *Epinephelus morio*, was seen on Cruises 3, 4, and 5, but exceeded 3/ha only on Cruise 5 (16/ha). Wrasses of the genus *Halichoeres* were abundant (22.8/ha) on Cruise 4, and very abundant on Cruise 5 (271/ha).

Some fishes were present consistently at Station 23. The only species recorded on all cruises were the yellowtail reeffish, *Chromis enchrysurus*, and the tattler, *Serranus phoebe*. Several other species were seen on four or five of the six cruises to Station 23: the blue angelfish, *Holacanthus bermudensis*; reef butterflyfish, *Chaetodon sedentarius*; and various serranids. Densities for *Chromis enchrysurus* were lowest on Cruise 2 (81/ha) and Cruise 3 (33/ha) but ranged from 316 to 567/ha on subsequent cruises. *Serranus phoebe* was uncommon on Cruise 3 (1/ha), although its density was greater than 12/ha on other cruises.

Compared to other cruises, a particularly diverse fish fauna was observed on Cruise 4. Twenty-one taxa were identified, though the total area covered (8,316 m^2) was toward the low end of the scale (Table 2.2-2). For instance, Cruises 2 and 3 surveyed 14,888 m^2 and 16,092 m^2, respectively. Fewer than 13 taxa were recognized on any other cruise.

The only fish censused with underwater television at Station 23 whose densities differed significantly ($p < 0.05$) among cruises was *Serranus* phoebe. No clear pattern of seasonality was evident. Although the low density recorded on Cruise 3 (May 1984) differed significantly from higher densities on Cruises 4 (August 1984) and 6 (March 1985), the confidence limits for density on Cruise 3 overlapped those for Cruises 2, 5, and 7 (March 1984, December 1984, and June/July 1984), as did the confidence limits for mean densities on Cruises 4 and 6.

Triangular Dredge Results

Fifty-nine invertebrates (excluding sponges) were identified in 12 triangular dredge hauls from Station 23 (Table 3.2-4). Dredges were filled mainly with calcareous nodules of coralline algae, to which the green alga Anadyomene menziesii was often attached. Only a single scleractinian coral (Madracis asperula) and a single gorgonian (Nicella schmitti) were collected.

Four bivalves were collected: the rough scallop, Aequipecten muscosus; the little corrugated jewel box, Chama congregata; Benedict's scallop, Chlamys benedicti; and an unidentified pecten. These last two species were unique to Station 23.

Eight gastropods were found in triangular dredge samples. These included several large species, such as the West Indian murex, Murex brevifrons, and the lace murex, Murex florifer; the horse conch, Pleuroploca gigantea; and the star turban, Astraea phoebia. A rare abalone, Haliotis pourtalesii, was collected only at Station 23. Haliotis was found inside a small depression on the underside of a chunk of calcareous rubble. Other gastropods included a cymatiid triton, Distorsio clathrata (the Atlantic distorsio); the chestnut turban, Turbo castanea; and the slit worm-shell, Siliquaria squamata.

Several pistol shrimps were found among the nodules, including Synalpheus townsendi, S. longicarpus, and S. goodei. Other carideans included the pontoniid shrimp Anchistoides antiguensis, and the palaemonid

Palaemonetes intermedius. Synalpheus goodei and Palaemonetes intermedius were taken only at Station 23. Three mantis shrimps were found: Gonodactylus bredeni and an unidentified congener, and Squilla prasinolineata (unique to Station 23).

Four anomurans were collected, including two galatheids (Munida pusilla and Galathea rostrata) and two hermit crabs (Pagurus acadianus and Dardanus fucosus). Many families of crabs were represented by the 13 brachyurans found in dredge samples from Station 23. There were majiids (Mithrax acuticornis, M. turceps, an unidentified Mithrax, Nibilia antilocapra, Macrocoeloma eutheca, and an unidentified Pyromaia), xanthids (Paractea rufopunctata nodosa, Micropanope spinipes), portunids (Portunus ordwayi), grapsids (Euchirograpsus americanus), palicids (Palicus faxoni, Palicus alternatus), parthenopids (Parthenope fraterculus), and iliacanthids (Iliacantha subglobosa). Five brachyurans (Euchirograpsus americanus, Palicus faxoni, Nibilia antilocapra, Macrocoeloma eutheca, and Pyromaia) were collected only at Station 23.

A diverse assortment of asteroids (seven species) and ophiuroids (eight taxa) was collected with the triangular dredge at Station 23. Asteroids included Tosia parva; Echinaster modestus; Poraniella regularis; Luidia barbadensis (unique to Station 23); Linckia nodosa; Narcissia trigonaria; and Henricia antillarum. The last four of these species were found only at Station 23.

Ophiuroids in dredge samples included the angular brittle star, Ophiothrix angulata; Savigny's ophiactis, Ophiactis savignyi; the short-spined brittle star, Ophioderma brevispina; the ruby brittle star, Ophioderma rubicundum; Suenson's brittle star, Ophiothrix suensonii; the slimy brittle star, Ophiomyxa flaccida; and unidentified species of Macrophiothrix and Ophioderma (unique to Station 23).

There were five echinoids collected at Station 23, including the brown rock urchin, Arbacia punctulata; the pencil urchin, Eucidaris tribuloides; Lytechinus euerces; L. callipeplus; and Stylocidaris affinis. Both species of Lytechinus were collected only at Station 23.

There were only four algae collected at Station 23 (Table 3.2-5). Two greens were present (Anadyomene menziesii and Pseudotetraspora antillarum). The only other algae were Dictyopteris sp. 1 (unique to Station 23) and another brown not identified to genus.

Otter Trawl Results

Station 23 was sampled with the trawl on Cruises 2 through 7 (March, May, August, and December 1984; and March and June/July, 1985) (Table 2.2-1). Fish density was high, averaging 82 specimens per 10-minute tow (369 fishes collected) (Table 3.2-6). Thirty species belonging to 18 families were taken in the six samples. The most important families in terms of numbers of species were the scorpionfishes (Scorpaenidae), represented by five species; and the lizardfishes (Synodontidae) and basses and groupers (Serranidae), each with four species. Overall diversity (H") and evenness (J') for fishes collected by trawling were 2.10 and 0.74, respectively, for all cruises together at Station 23.

The overwhelming numerical dominant was the tattler, Serranus phoebe (36 individuals/tow) (Figure 3.2-4). Abundant species included the blackear bass, Serranus atrobranchus, and the fringed filefish, Monacanthus ciliatus (both 9.1/tow); the hunchback scorpionfish, Scorpaena dispar (6.2/tow); the offshore lizardfish, Synodus poeyi (5.1/tow); and the sand diver, Synodus intermedius (3.6/tow). Other common species were the orangeback bass, Serranus annularis (1.8/tow); the freckled soapfish, Rypticus bistrispinus, and the pancake batfish, Halieutichthys aculeatus (both 1.3/tow); and the yellowtail reeffish, Chromis enchrysurus (1.1/tow).

With the exception of Cruise 7, overall density of fishes was remarkably consistent between cruises, averaging between 82 and 109 per 10-minute tow. Serranus phoebe was the most abundant specimen on nearly every cruise, often accounting for more than half the fish collected. Only 19 specimens were collected on Cruise 7, and except for five, all of these were Serranus phoebe.

Many of these species were taken on more than one cruise. For example, Serranus phoebe was present on all six cruises; Synodus intermedius, on five cruises; Synodus poeyi, Scorpaena dispar, Serranus atrobranchus, and Monacanthus ciliatus, on four cruises; Rypticus bistrispinus, Serranus annularis, and Chromis enchrysurus on three cruises; and Halieutichthys aculeatus on two cruises.

Seven species were collected only at Station 23: the pike-conger, Paraxenomystax bidentatus; the reticulated goosefish, Lophiodes reticulatus; the pipefish Cosmocampus alucens; the dwarf scorpionfish, Scorpaena elachys; the deepreef scorpionfish, Scorpaenodes tredecimspinosus; the rock sea bass, Centropristis philadelphica; and Rypticus bistrispinus.

Analyses of stomach contents, maturation state, length and weight for some of the species collected at Station 23 (Serranus phoebe, S. atrobranchus, Synodus intermedius) are presented in Subsection 3.2.2, Species Accounts.

Time-Lapse Camera

Overview

A time-lapse camera was first installed at Station 23 on Cruise 5. It was successful in recovering time-lapse data, but equipment failure occurred on all subsequent installations. The area in view of the camera was visually homogeneous and similar to that observed on underwater television transects at this station. The substrate was made up of a solid pavement of algal nodules. The only conspicuous sessile organism was the green alga, _Anadyomene menziesii_. There were no breaks in the nodule pavement, and unconsolidated sediment was not observed on the surface of the nodules.

Cruises 5 and 6 (December 1984 to March 1985)
The time-lapse equipment was installed on December 9, 1984 and recovered on Cruise 6. The camera functioned from December 9, 1984, to January 10, 1985, for 32 days and 1 hour (793 hourly records). Nearly all (92.6%) of the frames were recorded under conditions of 100% relative visibility. Actual visibility was slightly less than 100% in these frames, but was not low enough to classify as 75% relative visibility. A very small amount of suspended particulate material was always visible, often appearing to spiral through the array. Perhaps a vortex causing resuspension of bottom sediments was created by the array. A few of the data frames were taken during periods of higher turbidity; 7.2% of the frames were recorded in 75% relative visibility, and the remaining 0.3% were taken in 50% relative visibility.

Although the array had been submerged for 1 year prior to the first time-lapse installation, both settling plate targets were new. The targets did not show any development of settling organisms during the period.

The only conspicuous attached organism was the alga _Anadyomene menziesii_. Six large algal blades were located within view of the camera. The blades were oriented in different directions and inclined at an acute angle to the substrate. The blades moved back and forth with water movement. Some of the blades cycled on a 6-hour basis, suggesting some tidal influence, but most cycles were unpredictable. Most blades remained in one position for several days. None of the algal blades disappeared or was detached from the substrate throughout the period.

One other observation was of particular interest. A spiny lobster, Panulirus argus, was the only lobster seen during the study. It was observed in a single frame on Day 18 (26 December) at 2000 hours.

Sixteen fishes were observed (97 records) (Table 3.2-12). The dominant fishes were unidentified damselfishes of the genus Chromis (50 records). The records probably included both the yellowtail reeffish, Chromis enchrysurus, and the purple reeffish, Chromis scotti, which closely resemble each other during part of their life histories. The first Chromis appeared on the second day after installation, with a peak (10 records) on Day 17 (Figure 3.2-33). No other Chromis were observed throughout the remainder of the period. The hourly attendance pattern was very peaked, with all observations occurring between 1000 and 1900 hours, and a peak on either side of 1500 hours.

None of the other fishes was recorded more than 10 times. They included the gray angelfish, Pomacanthus arcuatus (nine records), an unidentified squirrelfish of the genus Holocentrus, and the spotfin butterflyfish, Chaetodon ocellatus (both six records). The remaining fishes seen at this station had a frequency of five records or fewer.

A single loggerhead sea turtle (Caretta caretta) was seen on Day 26 (3 January) at 1600 hours.

Table 3.2-12. Total number of fish and turtle sightings by time-lapse camera at Station 23 during December 1984 and January 1985

Taxon	Sightings
Chromis Unident.	50
Pomacanthus arcuatus	9
Holocentrus Unident.	6
Chaetodon ocellatus	6
Equetus lanceolatus	5
Holacanthus bermudensis	4
Epinephelus Unident.	3
Caranx crysos	3
Apogon Unident.	3
Balistes capriscus	2
Caretta caretta	1
Epinephelus morio	1
Epinephelus guttatus	1
Caranx Unident.	1
Scorpaena sp.	1
Serranus pheobe	1
Urophycis Unident.	1
Number of Sightings	98
Total Frames Exposed	768

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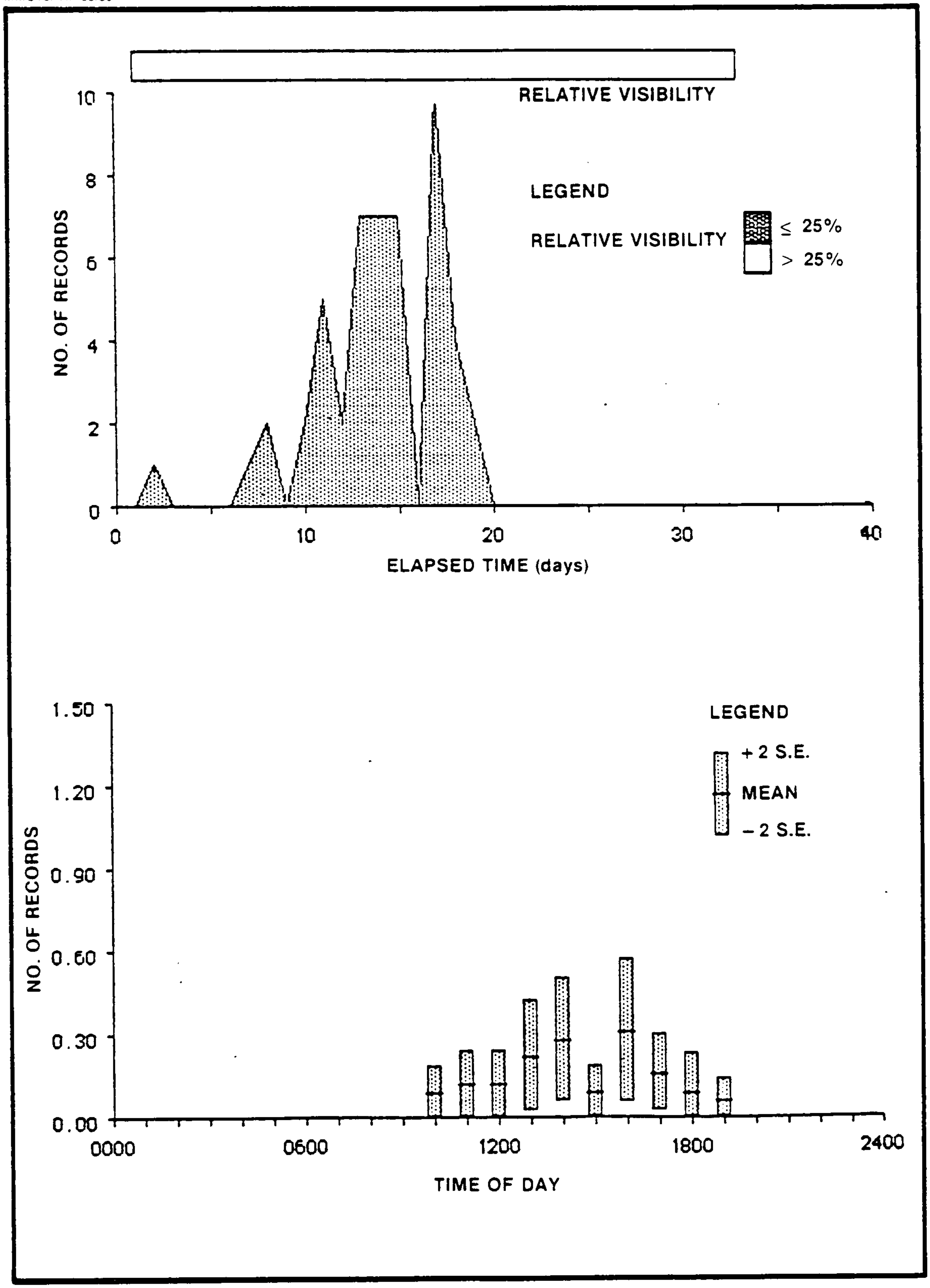

Figure 3.2-33 ACTIVITY PATTERNS FOR *Chromis* sp. AT STATION 23, FROM TLC, DECEMBER 9, 1984 — JANUARY 10, 1985

Station 36

Historical Notes

Station 36 (depth 125 m, in the Outer Shelf Depth Zone) was surveyed by Woodward-Clyde Consultants and Continental Shelf Associates, Inc., in Years 1 and 2. The substrate was categorized as Sand Bottom/Soft Bottom (59 to 76%), and Thin Sand over Hard Substrate (24 to 40%). Live bottom was estimated to cover 32% of the area surveyed, and consisted of Outer Shelf Crinoid Assemblage, which is dominated by large numbers of comatulid crinoids on sand or rock rubble (Woodward Clyde Associates/ Continental Shelf Associates, 1983, 1984). Station 36 was surveyed by ESE/LGL as a Group II station during Years 4 and 5, on Cruises 2, 3, 4, 5, 6, and 7 (Table 2.2-1).

Underwater Television Results

The total area transected was 34,229 m^2 (Table 2.2-2). 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. Sand accounted for over 99% cover, with occasional rock outcrops.

Comatulid crinoids (23,681/ha) and sea whips of the genus Ellisella (2,613/ha) were by far the most conspicuous fauna observed by the underwater television (Figure 3.2-2, Tables 3.2-1, 3.2-2). Other benthic invertebrates included various unidentified asteroids, ophiuroids and hydroids (all two or less/ha).

The most common fish seen in video transects included various unidentified small anthinids (130/ha); the tattler, Serranus phoebe (11/ha); the offshore lizardfish, Synodus poeyi (8/ha); serranids of the genus Anthias (7/ha); the bank butterflyfish, Chaetodon aya (6/ha); and lizardfishes of the genus Synodus (4/ha) (Figure 3.2-3, Table 3.2-3).

Overall diversity (H") and evenness (J') for fishes censused with underwater television were 1.13 and 0.37, respectively, for all cruises together at Station 36.

On all cruises, the predominant substrate type was sand, although isolated rocky outcrops were sighted on Cruise 6. The only invertebrates seen all cruises were comatulid crinoids and *Ellisella*. Crinoids were extremely abundant, with densities ranging from 10,604/ha (Cruise 6, March 1985) to 47,314/ha (Cruise 5, December 1984). The distribution of *Ellisella* was highly patchy, with densities ranging from 2/ha (Cruise 6) to 8,464/ha (Cruise 5).

Unidentified asteroids were seen on Cruises 3, 6 and 7 (4 to 8/ha); various echinaceans on Cruise 3 (14/ha); *Clypeaster* on Cruises 3 and 7 (45/ha and 18/ha, respectively); and hydroids on Cruises 2, 3, and 7 (2/ha on Cruises 2 and 3, rising to 13/ha on Cruise 7). Unidentified demosponges were reported at densities less than one/ha (Table 3.2-1) on Cruises 2, 3, and 7, but neither *Ircinia campana* nor *I. strobilina* was noted. Squids were also sighted on Cruise 3 (seven/ha).

None of the benthic invertebrates censused with underwater television at Station 36 differed significantly in density ($p > 0.05$) among cruises.

Considerable variability characterized fish counts between cruises. None of the fishes was seen on every cruise at Station 36. The bank butterflyfish, *Chaetodon aya*, was present on all cruises except for Cruise 4, but was abundant only on Cruise 3 (20/ha), Cruise 6 (13/ha), and Cruise 7 (9/ha). Other frequently sighted species included unidentified lizardfish of the genus *Synodus* (Cruises 2, 3, and 7; densities 21, 2, and 9/ha, respectively); and the tattler, *Serranus phoebe* (Cruises 2, 3, 4, and 7; densities 63, 7, 1, and 4/ha, respectively). Unidentified anthinids were very abundant on Cruises 3 through 6, with densities ranging from 24/ha (Cruise 5) to 288/ha (Cruise 6).

Other species were seen only once or twice, though often at high densities. Examples include a large school of small, unidentified perciform fishes (266/ha on Cruise 4); the offshore lizardfish, *Synodus poeyi* (55/ha on Cruise 6); serranids of the family Anthinae (53/ha on Cruise 6); the blackear bass, *Serranus atrobranchus* (13/ha on Cruise 7); the horned batfish, *Ogcocephalus corniger* (9/ha on Cruise 7); and the bigeye, *Priacanthus arenatus* (7/ha on Cruise 3). Besides these species, most other fishes observed at Station 36 were seen infrequently and at relatively low densities. Of the 21 taxa recorded, 11 were present on only one cruise, and mostly at densities lower than 2/ha.

The only fish censused with underwater television at Station 36 whose densities differed significantly ($p < 0.05$) among cruises was *Serranus phoebe*. No clear pattern of seasonality was evident. The highest mean density was recorded on Cruise 2 (March 1984), and differed from all other cruises, but none of the densities on subsequent cruises differed statistically from one another. Both the highest and the lowest densities occurred during the spring, since values not differing significantly from zero were recorded during Cruise 3 (May 1984) and Cruise 6 (March 1985).

Triangular Dredge Results

Fifty-three invertebrates (excluding sponges) were collected in 12 triangular dredge samples from Station 36 (Table 3.2-4). Dredge hauls were dominated by comatulid crinoids. Most of these could be assigned to the genus *Comactina*.

There were seven ahermatypic corals collected, including *Javania cailleti*, *Madrepora carulina*, *Paracyathus pulchellus*, *Coehosmilia arbuscula*, *Flabellum fragile*, *Dendrophyllia cornucopia*, and an unidentified *Balanophyllia*. None of these scleractinians was taken at any other station.

Six gorgonians were found in dredge samples, including Thesea parviflora and an unidentified congener, Calliacis nutans (= Thesea nutans), Ellisella barbadensis, E. elongata, and Nidalia occidentalis. Except for Calliacis nutans, all of these were unique to Station 36.

No bivalves were found at Station 36, and the only gastropods that were collected were the noble wentletrap, Sthenorytis pernobilis (unique to Station 36), and the banded tulip, Fasciolaria lilium.

No penaeids, stomatopods, or carideans were dredged up at Station 36. Six anomurans were taken in dredge hauls. There were four hermit crabs, Pagurus impressus, P. politus, Manucomplanus corallinus, and Cancellus ornatus (a nearly symmetrical species that does not use shells, but is often associated with silicious sponges and calcareous rock) (Williams 1984). Two galatheids were also collected, Munida pusilla and an unidentified Munida. Pagurus politus, Cancellus ornatus, and the unidentified Munida were not taken at any other station.

Brachyurans were diverse, with many families represented among the 13 species collected. Hauls included majids [Stenorhynchus seticornis (the arrow crab), Stenocionops furcata, Mithrax acuticornis, Podochela riisei, and an unidentified Anasimus], portunids (Portunus spinicarpus), box crabs (Calappa angusta), palicids (Palicus alternatus), xanthids (Micropanope spinipes), parthenopids (Parthenope fraterculus and P. pourtalesii), and iliacanthids (Iliacantha subglobosa). Parthenope pourtalesi and Anasimus were unique to Station 36.

Four asteroids were found at Station 36, including Tosia parva, Sclerasterias contorta, Rosaster alexandri, and Pectinaster gracilis. All of these except for Tosia were collected only at Station 36.

Eight ophiuroids were present, including Suenson's brittle star, Ophiothrix suensonii; Astroporpa annulata; Asteroschema nuttingii; and five others (Macrophiothrix, Ophiura, Ophiozona, Ophiopaepale, Ophioderma) that could be identified only to genus. All of these except for Macrophiothrix and Ophiothrix suensonii were unique to Station 36.

The five echinoids taken in triangular dredges included Stylocidaris affinis, Clypeaster ravenelii, Stylocidaris lineata, Echinolampas depressa, Coelopleurus floridanus. The last three of these were taken only at Station 36. Crinoids included Comactina and others which were not identified.

There were no algae identified in triangular dredge hauls at Station 36.

Otter Trawl Results

Station 36 was sampled with the trawl on Cruises 2 through 7 (March, May, August, and December 1984; and March and June/July 1985 (Table 2.2-1). A total of 703 individuals was collected in six hauls, averaging 117 specimens per 10-min tow (Table 3.2-6). The most important families in terms of numbers of species present were the lefteye flounders (Bothidae, at least seven species), the lizardfishes (Synodontidae, six species), the basses and groupers (Serranidae, five species), and the searobins (Triglidae, four species). Overall diversity (H") and evenness (J') for fishes collected by trawling were 2.53 and 0.68, respectively, for all cruises together at Station 36.

The most abundant species overall were the blackear bass, Serranus atrobranchus (32.5/tow); the offshore lizardfish, Synodus poeyi (23.5/tow); the shortwing searobin, Prionotus stearnsi (10/tow); the horned whiff, Citharichthys cornutus (8.3/tow); the steamer searobin, Bellator egretta (7.8/tow); an unidentified lizardfish, Saurida (6.3/tow); the tattler, Serranus phoebe (3.7/tow); the longfin scorpionfish, Scorpaena agassizi (3.3/tow); and a batfish, Ogcocephalus corniger (2/tow) (Figure 3.2-3).

Other common species included the dusky flounder, *Syacium papillosum* (1.8/tow); the pancake batfish, *Halieutichthys aculeatus*, and the shortfin searobin, *Bellator brachychir* (both 1.7/tow); the roughtongue bass, *Holanthias martinicensis*, and the bank butterflyfish, *Chaetodon aya* (both 1.5/tow); and the jambeau, *Parahollardia lineata* (1.3/tow).

With the exception of Cruise 4 (when 335 specimens were taken, almost half the total collected at Station 36), hauls were similar in numbers of fish taken from one cruise to the next. The average catch ranged from 57 to 97 fish per 10-min tow. Some species did vary widely in abundance; for instance, *Synodus poeyi* ranged from 0 (Cruise 7) to 112 (Cruise 4)/tow.

Many species were consistently represented in the trawl samples from cruise to cruise. For example, *Halieutichthys aculeatus*, *Prionotus stearnsi*, *Bellator egretta*, and *Serranus atrobranchus* were all collected on every cruise. *Synodus poeyi*, *Scorpaena agassizi*, and *Serranus phoebe* were present on five out of six cruises. *Chaetodon aya*, *Syacium papillosum*, and *Parahollardia lineata* were found on four of the cruises.

Twenty-two fishes--more than half the total--were identified only from Station 36. Species collected just at Station 36 included *Parahollardia lineata*; five bothids (*Citharichthys cornutus*; *C. gymnorhinus*; *C. dinoceros*; *Ancylopsetta dilecta*; and an unidentified *Citharichthys*); an unidentified jawfish, *Opistognathus*; three labrids (the red hogfish, *Decodon puellaris*, the greenband wrasse, *Halichoeres bathyphilus*, and another unidentified labrid); *Chaetodon aya*; an unidentified cardinalfish, *Apogon*; two serranids (*Holanthias martinicensis* and the apricot bass, *Plectranthias garrupellus*); two searobins (*Prionotus stearnsi* and *Bellator egretta*); the highfin scorpionfish, *Pontinus rathbuni*; the deepbody boarfish, *Antigonia capros*; the buckler dory, *Zenopsis conchifera*; *Ogcocephalus corniger*; the singlespot frogfish, *Antennarius radiosus*; the shortjaw lizardfish, *Saurida normani*; and another unidentified *Saurida*.

Analyses of stomach contents, maturation state, length and weight for some of the species collected at Station 36 (*Synodus intermedius*, *Serranus atrobranchus*, and *S. phoebe*) are presented in Subsection 3.2.2, Species Accounts.

3.2.2 SPECIES ACCOUNTS

Introduction

During Years 4 and 5, 167 fishes were collected by trawling. Most of them were present at very low densities (see Subsection 3.2.1, Station Descriptions). All of the specimens in good condition (intact after capture) were measured and weighed (see Subsection 2.3.3, Methods). However, summaries of length and weight data for most species were not particularly informative because they were based on only a few specimens. It was necessary to pool length and weight data across stations for most species in order to include sufficient numbers of individuals. Length and weight summaries for all species represented by 10 or more individuals (pooled data) are presented in Appendix F. Length and weight information for these fishes is presented in Appendix F, except for the species described below.

Eight of the most abundant and/or widespread species were selected for assessment of reproductive condition, in addition to the length and weight measurements mentioned above. These species were *Serranus atrobranchus*, the blackear bass; *S. phoebe*, the tattler; *Epinephelus morio*, the red grouper; *Haemulon plumieri*, the white grunt; *H. aurolineatum*, the tomtate; *Lutjanus synagris*, the lane snapper; *Synodus intermedius*, the sand diver; and *Lactophrys quadricornis*, the scrawled cowfish. All specimens were examined for sex and gonad maturation, although in some cases gonads were too small to characterize. Sex ratios are not provided for serranids because serranids are simultaneous hermaphrodites. Gut content analysis was performed on random samples of at least 10 individuals of each of the 8 species. The Index of Relative Importance (IRI) used to evaluate stomach contents is described in Subsection 2.2.3, Otter Trawl Data Analysis and Synthesis. Each of these species is discussed individually in the following sections.

Serranus phoebe

Two species of the genus Serranus were selected: the blackear bass, Serranus atrobranchus, and the tattler, Serranus phoebe. Literature regarding the natural history of S. atrobranchus and S. phoebe is scarce. Both species inhabit deeper water (Figure 3.2-34) and are found most commonly between 55 and 185 m. They prefer sandy or mud bottoms to coral zones (Robins and Starck, 1961).

Serranus phoebe was collected during Years 4 and 5 at Station 21 (depth 47 m), Station 23 (74 m), and Station 36 (125 m). The 216 specimens of S. phoebe ranged in length from 47 to 166 mm, with a mean of 106.3 mm. Their weight ranged from 1.2 to 81.4 g, with a mean of 24.5 g. Length/weight relationships for S. phoebe are presented in Figure 3.2-35).

The stomachs of 105 tattlers collected during Cruises 2 through 7 were examined. The contents included items derived from 19 different taxa. There was little variation between cruises in the relative proportions of contents (Figure 3.2-36). The main source of nutrition (IRI = 0.725) was shrimp-like decapods, which represented 59.3% of the identified prey organisms (Table 3.2-13). These decapods were also dominant in terms of volume and frequency of occurrence.

The next highest IRI (0.124) was calculated for unidentified crustaceans. It is quite likely that a portion of this material is of decapod origin. Copepods were found in seven stomachs and represented 10.3% of the prey items ingested. Small brachyuran and anomuran crabs accounted for an IRI of 0.011. This value may underestimate the true dietary importance of crabs, because some crab pieces may have been included in the unidentified crustacean category.

These findings are consistent with previous reports. For example, Robins and Starck (1961) examined the stomachs of six tattlers and found the contents to be primarily crustacean; 90% appeared to be shrimp, 9% was crab, and 1% was bivalve mollusc.

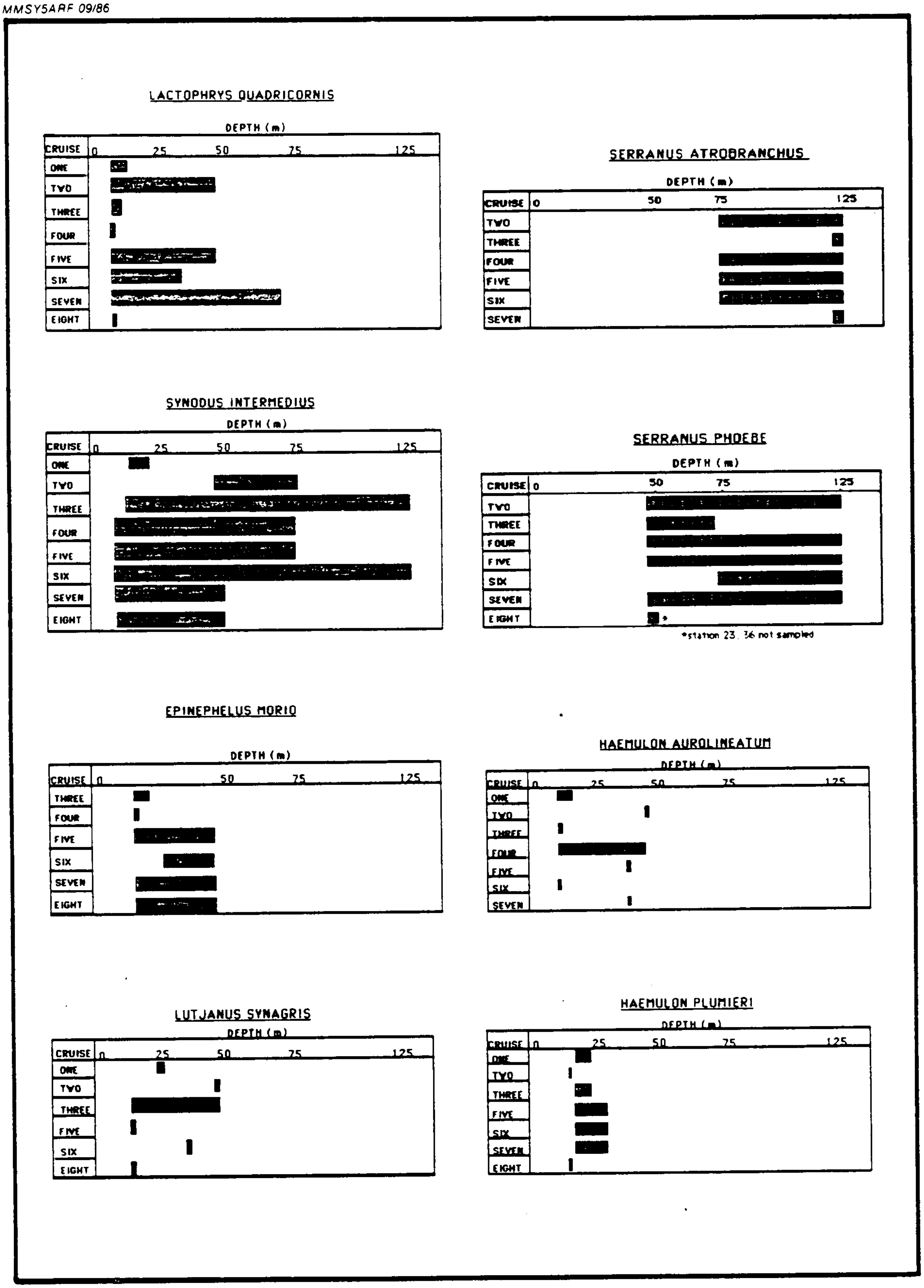

Figure 3.2-34 DEPTH RANGES FOR SELECTED FISHES COLLECTED BY TRAWLING, FOR ALL STATIONS TOGETHER, BY CRUISE

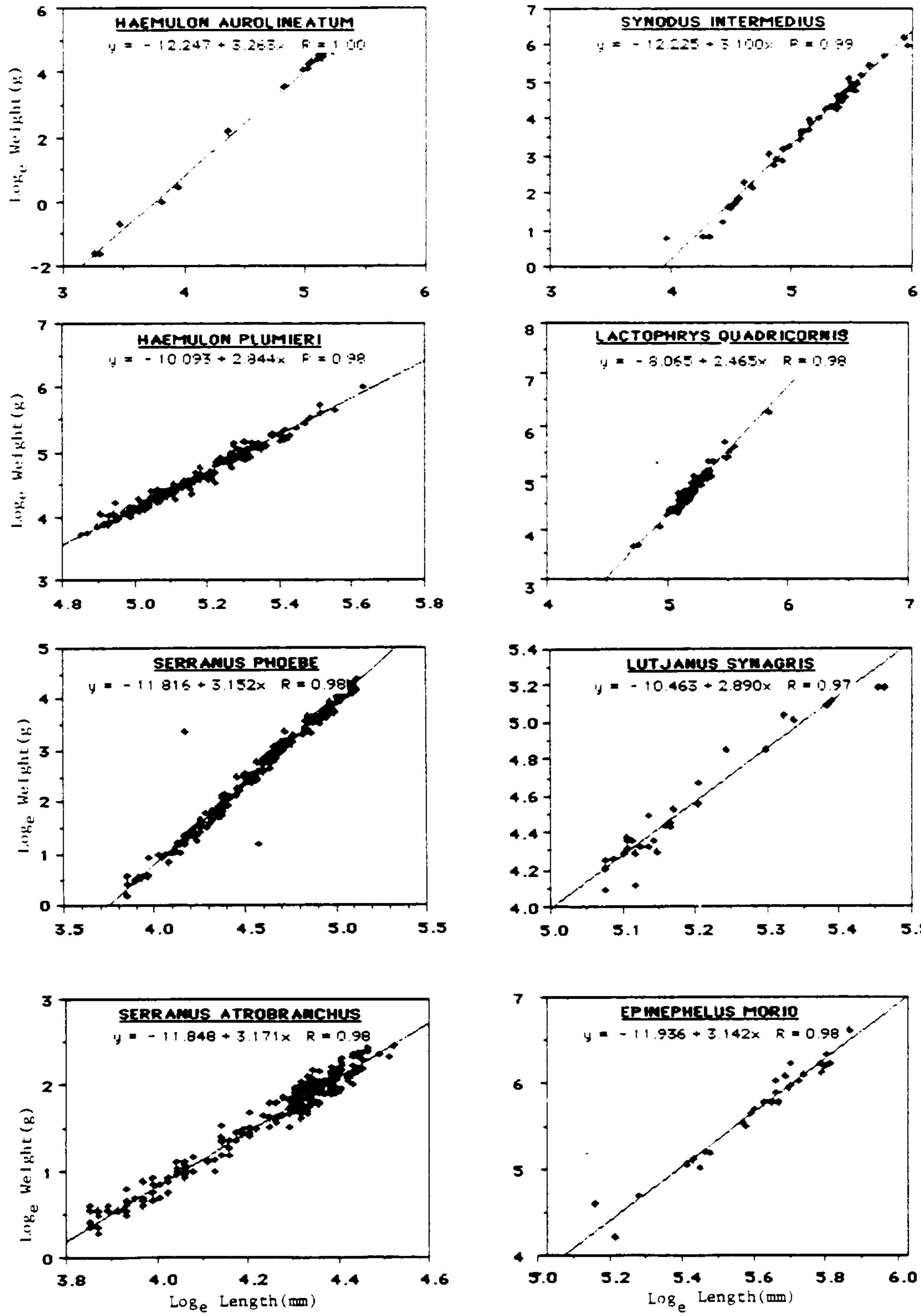

Figure 3.2-35 LENGTH-WEIGHT REGRESSIONS FOR SELECTED FISHES COLLECTED BY TRAWLING, FOR ALL CRUISES AND STATIONS TOGETHER, BY SPECIES

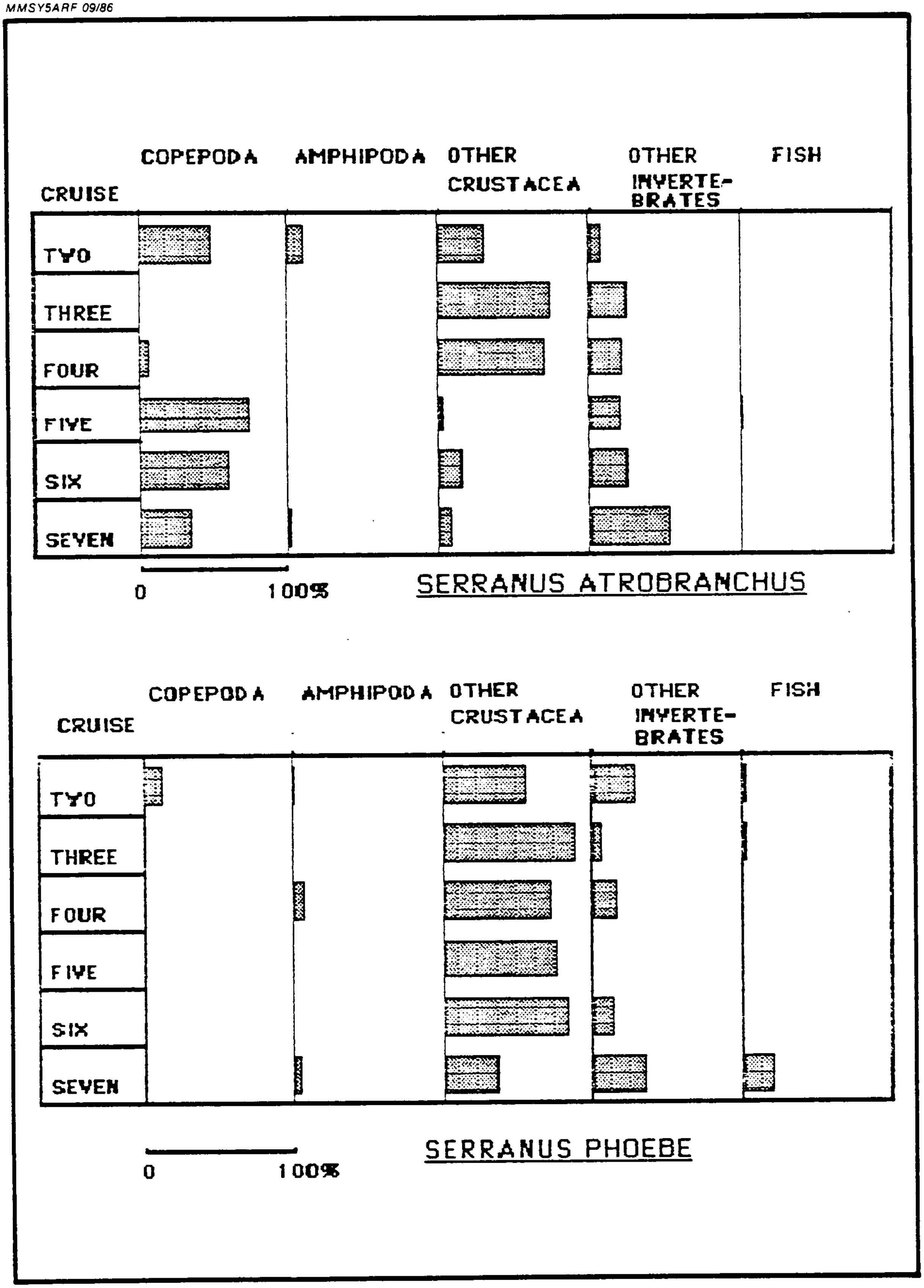

Figure 3.2-36 STOMACH CONTENTS (% OF TOTAL ITEMS) OF *Serranus atrobranchus* AND *S. phoebe* COLLECTED BY TRAWLING, FOR ALL STATIONS TOGETHER, BY CRUISE

Table 3.2-13 Serranus phoebe stomach contents.

Prey	Average % of Stomach Volume	Frequency	Number of Items	IRI*
Nematoda	0.01	1	1	0.000
Polychaeta	1.00	6	6	0.002
Thecosomata	0.01	1	2	0.000
Bivalvia	0.19	1	1	0.000
Cephalopoda	0.91	1	1	0.000
Copepoda	0.25	7	50	0.007
Isopoda	0.01	1	1	0.000
Amphipoda	0.57	8	10	0.002
Decapoda	25.56	71	286	0.725
Anomura	0.20	1	3	0.000
Brachyura	2.64	13	19	0.011
Stomatopoda	1.68	4	5	0.002
Other Crustacea	11.66	42	44	0.124
Bryozoa	0.02	1	1	0.000
Ophiuroidea	0.10	2	2	0.000
Comatulida	0.00	1	1	0.000
Synodontidae	0.33	2	2	0.000
Antennariidae	0.91	1	1	0.000
Perciformes	2.13	6	6	0.003
Unidentified items	5.27	40	40	0.069
TOTAL	53.45		482	0.945

Total number of stomachs: 105

*Index of Relative Importance (Pinkas et al., 1971).

Fish do not appear to be important in _S. phoebe_'s diet. Only nine fish in as many stomachs were found, including one large frogfish (Antennaridae). Tattlers generally reside near a burrow in the sand or under rocks (Robins and Starck, 1961), and it is possible that the fish found in the stomachs were ingested as the result of some territorial dispute rather than as food.

At Station 21, 32 tattlers were collected during Cruises 4, 5, and 7 (August 1984, December 1984, and June/July 1985). They ranged in length from 53 to 159 mm. All contained inactive or immature gonads.

At Station 23, 162 tattlers were collected. The 22 tattlers from Cruise 5 had a length range of 53 to 164 mm (Figure 3.2-37). Fourteen of these were 100 mm or less in length and contained inactive or immature gonads. The remaining eight contained ripening gonads. The 71 tattlers collected during Cruises 2 (March 1984) and 6 (March 1985) were 47 to 163 mm long. Immature tattlers (29% of the total) were all less than or equal to 97 mm in length. Those with inactive gonads (43%) had the greatest length range (79 to 159 mm). Tattlers with ripening gonads (22%) were 128 to 163 mm long. Mature gonads were found in one fish 142 mm long. With only two exceptions, tattlers from 47 to 145 mm long that were collected during Cruises 3 (May 1984), 4, and 7 had inactive or immature gonads.

At Station 36, 19 _S. phoebe_ were taken during Cruises 2, 5, 6, and 7. These were all larger fish, 149 to 166 mm. Six fish were sexually mature. One tattler from Cruise 7, and all the tattlers from Cruise 2, contained ripening gonads. The overall pattern of gonad maturation by season is shown in Figure 3.2-38.

Serranus atrobranchus

Serranus atrobranchus, the blackear bass, is a smaller fish than the tattler. Both species overlapped in depth range during this study

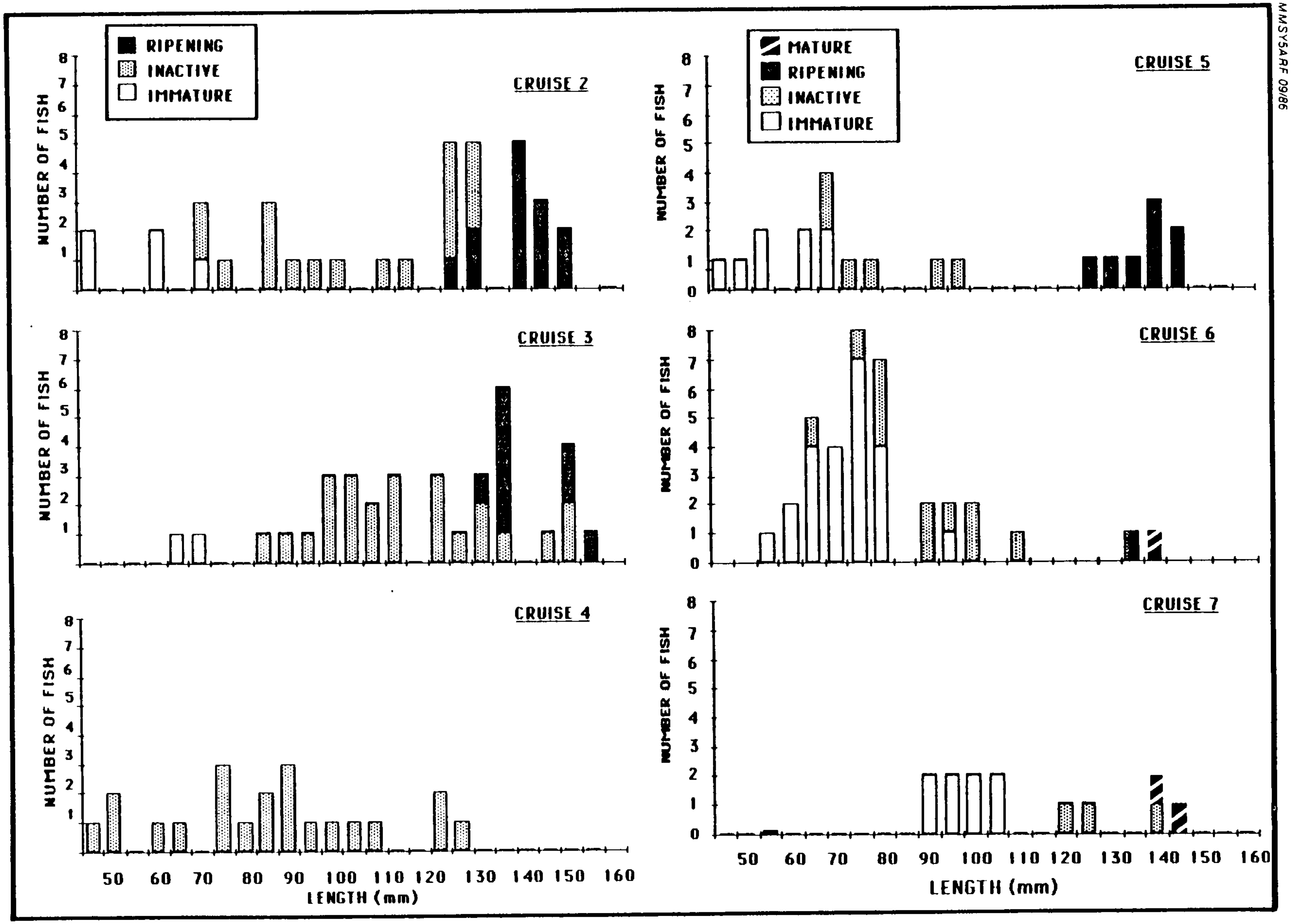

Figure 3.2-37 MATURATION STATES AND LENGTHS OF *Serranus phoebe* COLLECTED BY TRAWLING AT STATION 23, BY CRUISE

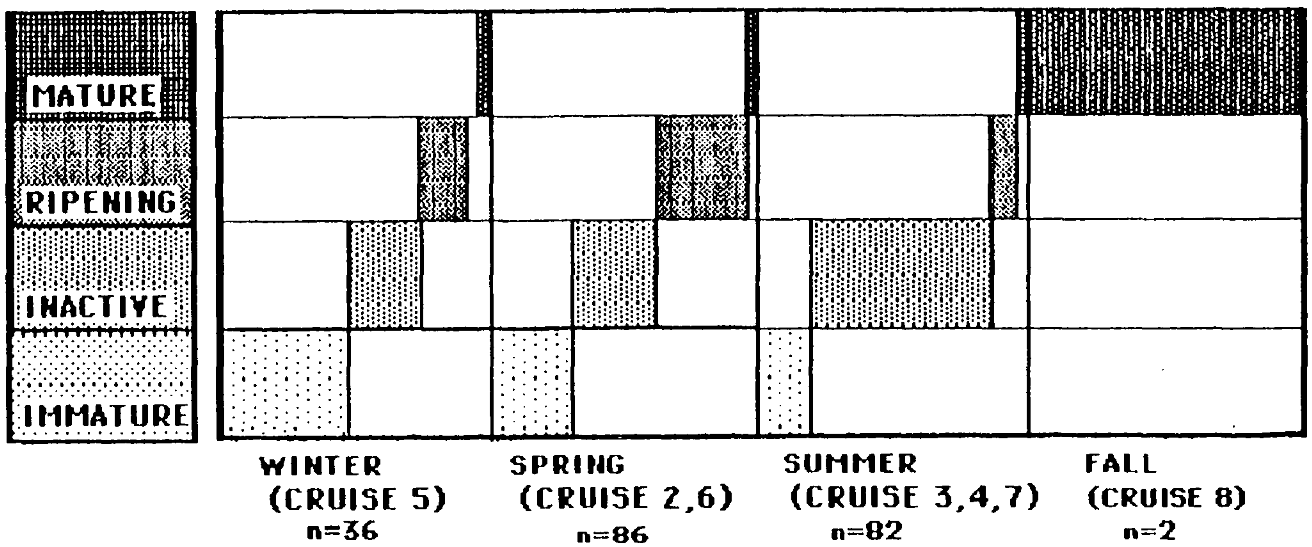

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Figure 3.2-38 PROPORTIONS OF INDIVIDUALS OF *Serranus phoebe* IN VARIOUS MATURATION STATES, COLLECTED BY TRAWLING AT STATION 36, BY SEASON

(Figure 3.2-34). Serranus atrobranchus was taken at Station 23 (depth 74 m) and Station 36 (125 m). There was also some overlap in major dietary components, implying possible competition for food. Serranus atrobranchus was found at Station 23 during Cruises 2, 4, 5, and 7 (March 1984, August 1984, December 1984, and June 1985, respectively), and at Station 36 during Cruises 2, 4, 5, 6 (March 1985), and 7.

Serranus atrobranchus ranged in length from 47 to 92 mm, with a mean of 71.5 mm. Its weight ranged from 1.3 to 11.5 g, with a mean of 5.9 g.

Stomachs of 72 blackear bass were examined. Unidentified decapods earned the highest IRI, 0.227 (Table 3.2-14). Copepods were nearly equal in importance (IRI = 0.163). There was little variability in stomach contents between cruises (Figure 3.2-36).

Thirty-three blackear bass from Station 23 were examined for sexual maturity. Three contained ripening gonads, but the remaining 30 were immature. Their mean length was 53.4 mm (Figure 3.2-39), and their mean weight was 2.2 g.

At Station 36, 194 blackear bass were collected. Their mean length and weight (75 mm and 6.6 g, respectively) were greater than those of fish taken at Station 23. The difference in size implies a movement to deeper water as blackear bass age. Alternatively, differential mortality could also be responsible for the difference, although it is a more complicated explanation than offshore movement with increasing size.

Blackear bass taken at Station 36 during Cruise 5 were 55 to 90 mm in length, and all were mature. Blackear bass collected during Cruises 2 and 6 ranged in length from 47 to 92 mm. Some gonads were immature (11% of the individuals), but more were ripening (67%) and mature (24%) (Figure 3.2-39). Blackear bass collected during Cruises 4 and 7 had a length range of 48 to 84 mm with gonad maturation states of immature

Table 3.2-14 <u>Serranus atrobranchus</u> stomach contents.

Prey	Average % of Stomach Volume	Frequency	Number of Items	IRI*
Polychaeta	0.88	1	1	0.000
Ostracoda	0.01	1	1	0.000
Copepoda	3.26	29	107	0.163
Tanaidacea	0.01	1	1	0.000
Isopoda	0.02	2	3	0.000
Amphipoda	0.50	4	5	0.002
Decapoda	11.95	25	119	0.227
Brachyura	0.99	2	2	0.001
Other Crustacea	9.94	20	24	0.088
Sipuncula	0.09	1	1	0.000
Ophiuroidea	2.42	6	12	0.008
Miscellaneous fishes	0.94	1	1	0.000
Unidentified items	9.77	38	52	0.210
TOTAL	40.78		329	0.699
Total number of stomachs: 72				

*Index of Relative Importance (Pinkas <u>et</u> <u>al</u>., 1971).

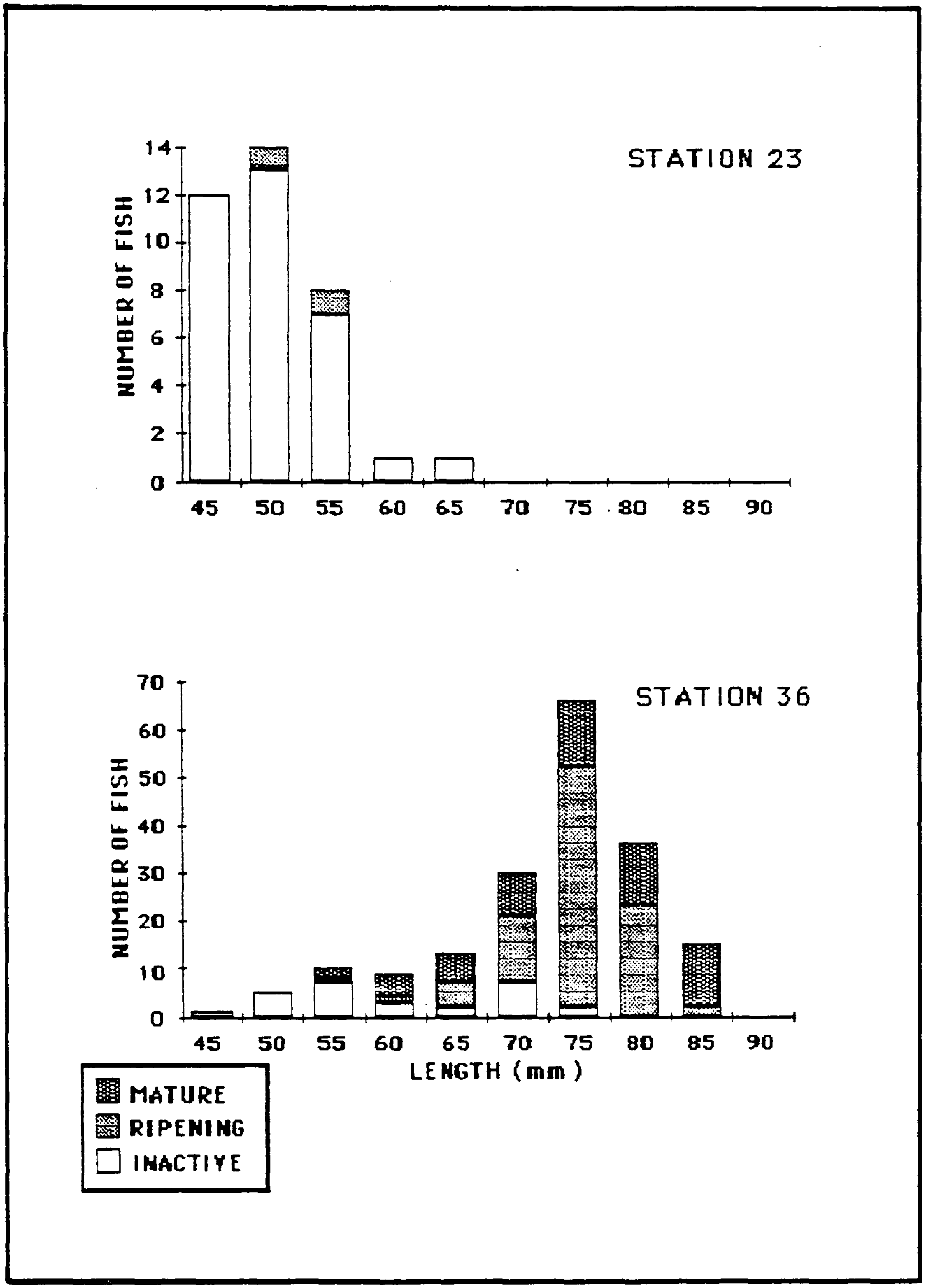

Figure 3.2-39 MATURATION STATES AND LENGTHS OF *Serranus atrobranchus* COLLECTED BY TRAWLING AT STATIONS 23 AND 36, FOR ALL CRUISES TOGETHER

(36%), ripening (58%), and mature (6%). Gonad maturation is shown by season in Figure 3.2-40.

That fish with mature gonads spanned a wide range of lengths suggests that they remain in deep waters to spawn. This finding is consistent with the serranid literature. Houde and Chitty (1976) determined that serranid eggs were most abundant in the eastern Gulf of Mexico at depths of greater than 50 m in February, and larvae were most abundant during the spring and summer months. Eggs and larvae were assumed to be transported to shallower water in spring and summer by a southeasterly current.

Epinephelus morio

The red grouper, Ephinephelus morio, was at one time the most abundant grouper of the Tortugas (Longley, 1929). The species is highly prized as a food and sport fish throughout its geographical range, forming the bulk of Florida's commercial reef catch (Manooch, 1984). Studies of the feeding habits of red grouper show that invertebrates (particularly crustaceans) are preyed upon more than other available choices (Moe, 1969; Randall, 1965; and Longley, 1929).

Red groupers were collected by trawling over a wide depth range (13 to 47 m) during Years 4 and 5 (Figure 3.2-34). A total of 24 specimens were taken at Stations 52, 51, 45, 47, 55, 7, and 21. Their mean length was 276.5 mm (range = 174.0 to 354.0 mm). Their mean weight was 337.8 g (range = 67.4 to 743.9 g). Length/weight relationships for red groupers are provided in Figure 3.2-35.

Stomach contents of all but nine specimens were lost when their stomachs everted upon trawl ascent. With the exception of one cephalopod, all contents were crustaceans (Table 3.2-15). Brachyurans and decapods were found in the largest numbers, with the crabs dominant in terms of volume and occurrence.

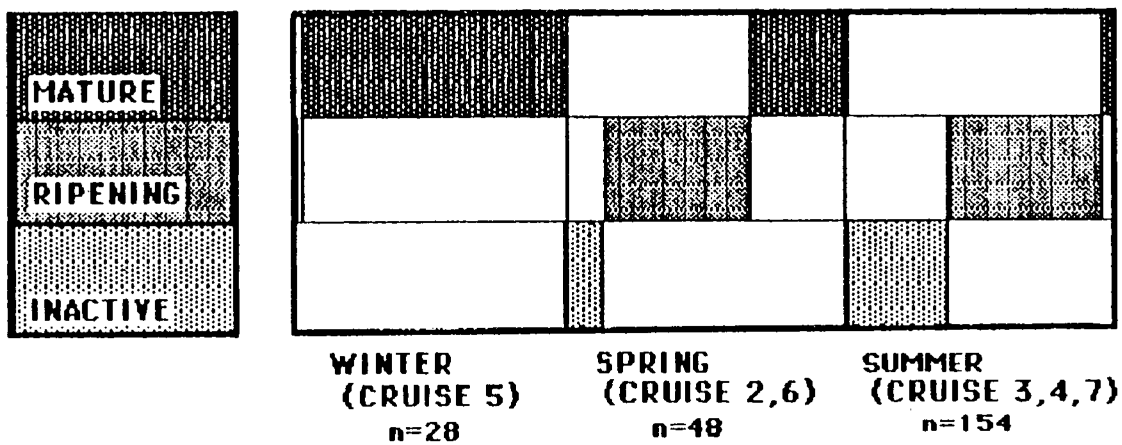

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Figure 3.2-40 PROPORTIONS OF INDIVIDUALS OF *Serranus atrobranchus* IN VARIOUS MATURATION STATES, COLLECTED BY TRAWLING AT STATION 36, BY SEASON

Table 3.2-15 *Epinephelus morio* stomach contents.

Prey	Average % of Stomach Volume	Frequency	Number of Items	IRI*
Cephalopoda	5.56	1	1	0.026
Decapoda	4.22	2	6	0.109
Brachyura	13.00	3	5	0.237
Other Crustacea	6.11	2	2	0.070
Unidentified items	2.22	3	3	0.083
TOTAL	31.11		17	0.525

Total number of stomachs: 9

*Index of Relative Importance (Pinkas *et al.*, 1971).

Seventy-five percent of the red groupers examined had inactive gonads. The remaining six specimens had gonads ranging from immature to post-spawning stages. Ripening and mature fish were collected on Cruises 5, 6, and 7 (December 1984, March 1985, and June/July 1985), and a post-spawning specimen was taken on Cruise 8 (September 1985). Too few specimens were collected to accurately delineate reproductive seasonality; the data suggest that spawning may take place in winter, spring, or summer.

Haemulon plumieri

The white grunt, *Haemulon plumieri*, schools on reefs during the daytime, and feeds strictly at night away from the reefs (Hobson, 1973). The white grunt mainly eats invertebrates, rarely taking other fish (Randall, 1965). At twilight, the grunts aggregate into large schools and migrate to nearby grassbeds and sandy areas, where they disperse and feed on a wide variety of prey choices (Meyer and Schultz, 1985; Hobson, 1973). A study of the gut contents of 22 white grunts by Randall (1965) identified 16 taxa in the diet. Crabs (*Mithrax* sp.) represented 26% of the contents volume, polychaetes, 14.5%; echinoids, 12.4%; and sipunculids, 8.3%. Other invertebrates contributed 7% or less per taxon.

White grunts were collected during Years 4 and 5 at Stations 52, 51, 45, 47, and 55. Their depth range was 13 to 27 m (Figure 3.2-34). The 142 specimens examined had a mean length of 178.5 mm (range = 128.0 to 279.0 mm), and a mean weight of 112.4 g (range = 40.8 to 405.3 g). Length/weight relationships for white grunts are provided in Figure 3.2-35.

Twenty prey taxa were identified in the contents of 130 stomachs examined (Table 3.2-16). Polychaetes were the dominant prey by volume and frequency of occurrence (IRI = 0.199), while amphipods were most important in terms of numbers of items (IRI = 0.147). Shrimp-like decapods, sipunculids, and ophiuroids were present but less important (IRI's from

Table 3.2-16 *Haemulon plumieri* stomach contents.

Prey	Average % of Stomach Volume	Frequency	Number of Items	IRI*
Nematoda	0.06	6	6	0.001
Polychaeta	7.35	56	79	0.200
Polyplacophora	0.88	2	2	0.001
Bivalvia	0.09	2	2	0.000
Ostracoda	0.02	2	2	0.000
Copepoda	0.03	6	11	0.001
Mysidacea	0.01	2	2	0.000
Tanaidacea	0.00	1	1	0.000
Isopoda	0.01	1	1	0.000
Amphipoda	1.14	43	159	0.147
Decapoda	1.51	22	34	0.024
Brachyura	0.01	1	1	0.000
Stomatopoda	0.50	2	2	0.000
Other Crustacea	5.87	23	23	0.048
Sipuncula	3.03	16	21	0.020
Brachiopoda	0.11	2	2	0.000
Ophiuroidea	1.88	24	30	0.027
Echinoidea	0.01	1	1	0.000
Holothuroidea	0.19	1	2	0.000
Unidentified items	10.90	89	93	0.429
TOTAL	33.60		474	0.898

Total number of stomachs: 108

*Index of Relative Importance (Pinkas *et al*., 1971).

0.027 to 0.048). Because most prey were presumably taken at night, and the white grunts were captured in the daytime, stomach contents in specimens were often decomposed by digestive processes. Semi-digested masses of unidentifiable origin accounted for 16.8% (by volume) of the contents of white grunt stomachs.

The reproductive cycle appeared to be annual, with spawning occurring in late fall (Figure 3.2-41). The sex ratio (males:females) was 0.84:1, with females outnumbering males by 77 to 65. Of the gonads examined from white grunts collected during Cruise 5 (December 1984), 50% had previously spawned, 20% were immature, and 30% were inactive. Seventy-six% of the white grunts examined from Cruises 2 and 6 (March 1984 and 1985, respectively) had inactive gonads. The remaining 24% was divided equally between fish with ripening and mature gonads. Cruises 3 and 4 (May and August 1984, respectively) produced white grunts which were advancing toward spawning, with 53% of the gonads ripening, 41% mature, 3% spawning, and 3% inactive. During Cruise 8 (September 1985), white grunts with inactive gonads accounted for 53% of the individuals collected. Ripening gonads were found in 24% of the fish. Mature gonads were found in 14%, and 9% of the individuals were spawning.

Haemulon aurolineatum

Haemulon aurolineatum, the tomtate, is one of the smaller grunts found in the Gulf of Mexico (Manooch, 1984). Previous studies have shown its diet to include shrimps, polychaetes, crabs, amphipods, copepods, gastropods, pelecypods, tanaids, scaphopods, and isopods (Randall, 1965).

Tomtates were collected by trawling during Years 4 and 5 from the same stations as were white grunts (Stations 52, 51, 45, 47, and 55). In addition, tomtates were taken at Station 21, suggesting a greater depth range than white grunts have (Figure 3.2-34).

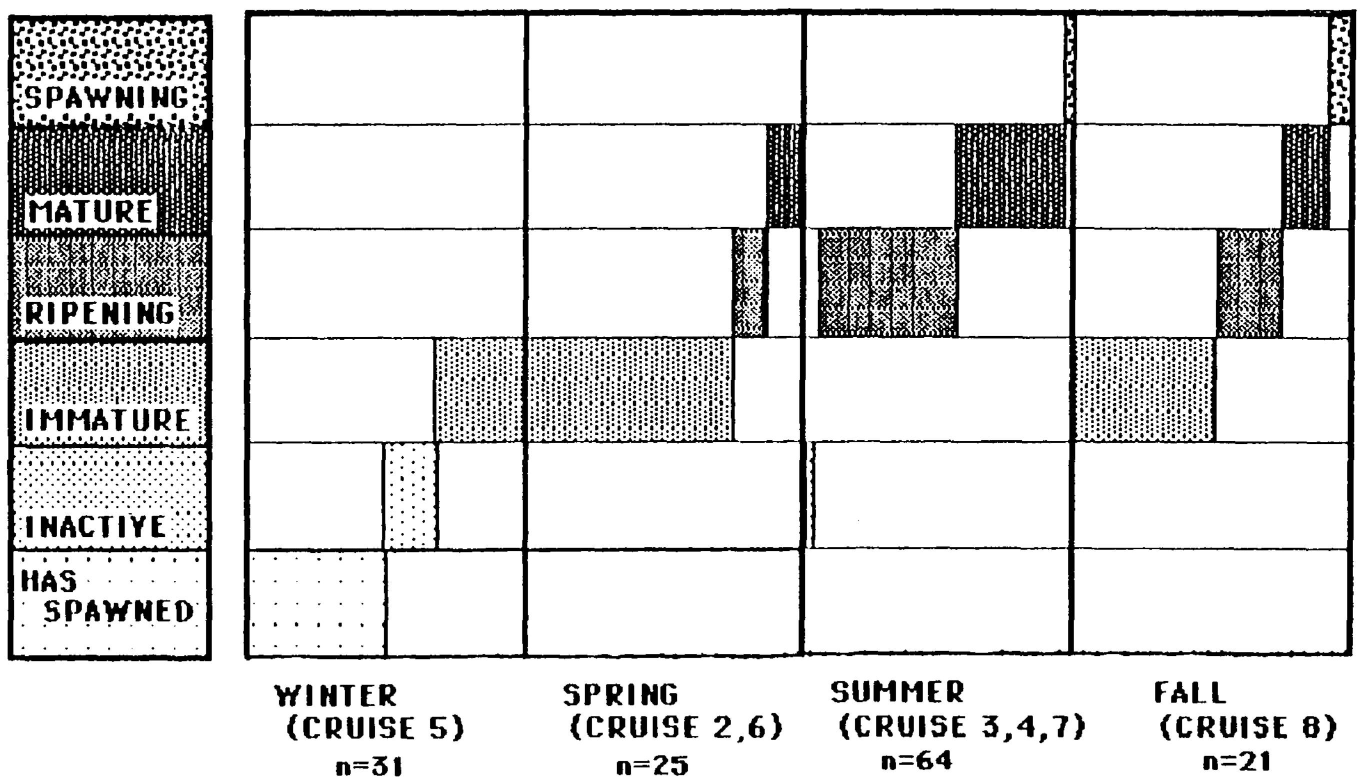

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Figure 3.2-41 PROPORTIONS OF INDIVIDUALS OF *Haemulon plumieri* IN VARIOUS MATURATION STATES, COLLECTED BY TRAWLING, FOR ALL STATIONS TOGETHER, BY SEASON

The mean length of the 24 tomtates examined was 137.0 mm (range = 26 to 198.0 mm). Their mean weight was 68.1 g (range = 0.2 to 124.9 g). Length/weight relationships for tomtates are provided in Figure 3.2-35.

Gonad maturation state for the 10 males and 7 females whose gonads were large enough to stage are shown in Table 3.2-17; sex ratio for this small sample was 1.4:1.

Seven tomtate stomachs contained 20 polychaetes and 18 shrimp-like decapods which, when totaled, represented 76% of the organisms found. Three or fewer copepods, mysidaceans, amphipods, sipunculids, and fish were present (Table 3.2-18).

Lutjanus synagris

Lutjanus synagris, the lane snapper, is an important game and food fish that is popular in Florida (Manooch, 1984). Like the white grunt, it is primarily a nocturnal bottom feeder which migrates at night from reef areas to nearby grass flats and sandy zones (Manooch, 1984; Longley, 1922). The diet of the fish will change with age, with juveniles feeding on copepods, amphipods, and small shrimp. The adult lane snapper's diet changes to crabs, fishes, and penaeid shrimps (Manooch, 1984). Although no polychaetes were found in lane snapper stomachs during this study, Longley (1922) indicated that polychaetes are a popular food choice of the lane snapper.

Thirty-two *Lutjanus synagris* were collected during Years 4 and 5, at Stations 52, 47, 19, 7, and 21, spanning a depth range of 13 to 47 m (Figure 3.2-34). Their distribution was very similar to that of the tomtate, *Haemulon aurolineatum*. Their mean length was 181.6 mm (range = 160 to 236 mm). Their mean weight was 100.9 g (range = 59.8 to 185.1 g). Length/weight relationships for lane snappers are illustrated in Figure 3.2-35.

Table 3.2-17 Gonad maturation states for fishes collected by trawling, for all stations together, by species and cruise. Tabulated numbers include all individuals examined.

	Maturation State				
	Immature	Inactive	Ripening	Mature	Spawning
Haemulon aurolineatum					
Cruise 1		3	3	1	
2		1		1	
3			1	1	
5		1	1	2	
6				1	
8		1	1		
Lutjanus synagris					
Cruise 1		1	1	1	
2		1			
3		1	3	2	
5		19			
6			1		
8				2	
Synodus intermedius					
Cruise 1		1	1		
2		3			
3	1	3	3	1	
4		3	3		
5	2	4	2		
6	1	3	1	5	
7			3		
8	1		3		1
Lactophrys quadricornis					
Cruise 1		5	1		
2		1	1		
3		8	10		
4			1		
5	5	10			2
6	1	6	2	1	
7		2	2	5	
8		6		5	

Table 3.2-18 *Haemulon aurolineatum* stomach contents.

Prey	Average % of Stomach Volume	Frequency	Number of Items	IRI*
Polychaeta	5.00	4	20	0.328
Copepoda	0.07	1	2	0.006
Mysidacea	0.89	1	1	0.007
Amphipoda	0.76	2	3	0.025
Decapoda	12.89	4	18	0.463
Sipuncula	5.00	1	1	0.028
Miscellaneous fishes	0.18	1	1	0.004
Unidentified items	3.89	4	4	0.123
Total	28.68		50	0.984

Total number of stomachs: 7

*Index of Relative Importance (Pinkas, *et al.*, 1971)

The sex ratio of lane snappers was 1.9:1, with males outnumbering females 21 to 11. Their gonad maturation states are shown in Table 3.2-17. Four lane snapper stomachs were examined. One crab (*Pilumus sayi*), one brachyuran crab, and one unidentified crustacean were found; one in each of three stomachs. A total of 14 shrimp-like decapods occurred in three of the four stomachs.

Synodus intermedius

The sand diver, *Synodus intermedius*, is a demersal carnivore that prefers clear water and is generally found on sand or mud bottoms. This lizardfish rests on the bottom, and when potential prey passes above, swims rapidly upward to seize the prey (Randall, 1965).

Sand divers were found throughout the study area during Years 4 and 5. Fifty-six specimens were collected at Stations 52, 51, 45, 47, 19, 55, 7, 21, 23, and 36. They ranged in depth from 13 to 125 m (Figure 3.2-34). Their mean length was 182.0 mm (range = 7 to 387 mm). Their mean weight was 83.8 g (range = 2.1 to 487.4 g). Length/weight relationships for sand divers are illustrated in Figure 3.2-35.

The sex ratio for fish large enough to characterize was 1.3:1, with males outnumbering females 23 to 18. Gonad maturation states for these fish are shown in Table 3.2-17. Fifteen fish were too small to sex.

Fishes were found in 24 of the 36 sand diver stomachs examined (Table 3.2-19). The IRI for all fish prey together was 0.187. Six identifiable groups of prey fishes were recorded. Sand divers preyed heavily on other members of the family Synodontidae (IRI = 0.108). Although sand divers showed a preference for fish, their stomachs also contained cephalopods, shrimp, and other crustaceans.

Lactophrys quadricornis

The scrawled cowfish, *Lactophrys quadricornis*, is the most common and widespread of the trunkfishes, with a distribution throughout the

Table 3.2-19 *Synodus intermedius* stomach contents.

Prey	Average % of Stomach Volume	Frequency	Number of Items	IRI*
Hydrozoa	0.14	1	1	0.001
Nematoda	0.03	1	1	0.001
Cephalopoda	5.56	2	2	0.008
Decapoda	2.01	3	3	0.009
Other Crustacea	0.64	2	2	0.003
Synodontidae	13.73	8	11	0.108
Saurida	2.78	1	1	0.002
Perciformes	13.33	6	6	0.061
Serranidae	2.78	6	6	0.002
Balistidae	3.61	2	2	0.006
Miscellaneous fishes	5.56	2	2	0.008
Unidentified items	9.03	11	11	0.125
TOTAL	59.20		43	0.334
Total number of stomachs:	36			

*Index of Relative Importance (Pinkas *et al.*, 1971)

Caribbean from Bermuda to Brazil (Bohlke and Chaplin, 1968; Randall, 1968). This cowfish is found mainly over seagrass beds and sandy areas. It feeds on polychaetes, sponges, tunicates, shrimps, amphipods, and other invertebrates (Randall, 1965).

There were 78 scrawled cowfishes taken during Years 4 and 5, at Stations 52, 44, 51, 45, 47, 55, 21, and 29, spanning a depth range of 13 to 64 m (Figure 3.2-34). Their mean length was 187.8 mm (range = 112.0 to 452.0 mm). Their mean weight was 140.9 g (range = 38.4 to 1178.1 g). Length/weight relationships for scrawled cowfish are provided in Figure 3.2-35.

Lactophrys quadricornis had a sex ratio of 0.85:1, with females outnumbering males 39 to 33. Gonad maturation states for these fishes are shown in Table 3.2-17. Sex was not determinable for six specimens.

Twenty-four gut sections of L. quadricornis were examined, and 16 invertebrate taxa were recognized inside them. Amphipods were the most important prey, with 138 items recorded (IRI = 0.363) (Table 3.2-20). Polychaetes were the second most important prey (IRI = 0.035), with 37 items recorded. Remaining organisms totaled less than 25 items per category. Much of the unidentified material was composed of sand, shell fragments, and plants.

Table 3.2-20 *Lactophrys quadricornis* stomach contents.

Prey	Average % of Stomach Volume	Frequency	Number of Items	IRI*
Hydrozoa	0.13	3	3	0.002
Anthozoa	0.08	2	3	0.001
Nematoda	0.21	5	8	0.007
Polychaeta	0.25	6	37	0.035
Gastropoda	0.13	3	3	0.002
Bivalvia	0.04	1	1	0.000
Ostracoda	0.04	1	3	0.001
Copepoda	0.17	4	5	0.004
Cumacea	0.04	1	1	0.000
Tanaidacea	0.17	4	4	0.003
Isopoda	0.08	2	2	0.001
Amphipoda	0.76	17	138	0.363
Decapoda	0.19	5	12	0.010
Other Crustacea	0.13	3	3	0.002
Bryozoa	1.24	8	8	0.017
Ascidiacea	0.08	2	22	0.007
Unidentified items	52.42	24	24	1.020
TOTAL	56.16		277	1.475

Total number of stomachs: 24

*Index of Relative Importance (Pinkas *et al.*, 1971)

3.3 INTERSTATION COMPARISONS AND COMMUNITY DYNAMICS

3.3.1 INTRODUCTION

Nearly every biological study covering a large area eventually results in the production of one or more zonation schemes or maps. All such schemes depend strongly on what community components are mapped or measured (e.g., fish vs. benthic features), and what gear was used to collect samples. Rather than present a single scheme, several alternatives are presented and are related whenever possible to previous work in the area. Each scheme can be considered one view of the "real" community through a "window" (gear type) on the study area. Each window presents a somewhat different view of the same community or location. The more overlap between such views, the more comprehensive and accurate the conclusions will be. Lack of overlap implies the existence of data gaps of unknown magnitude.

Comparisons are made in the following section among Stations 52, 44, 51, 45, 47, 19, 55, 7, 21, 29, 23, and 36 for samples collected by ESE/LGL during Years 4 and 5, along with comments and speculation about community dynamics. Emphasis is placed on summary measures such as diversity, depth ranges, numbers of taxa, dissimilarity indices, and other means of comparing and contrasting stations. For more detailed information concerning individual stations and organisms, please refer to Subsections 3.2.1, Station Descriptions, and 3.2.2, Species Accounts.

These stations were selected for sampling because (1) they had been characterized during Years 1 through 3 as "live bottom" stations (Woodward Clyde Consultants/Continental Shelf Associates, 1983 and 1984; and R. Avent, MMS, pers. comm., 1985), and (2) because they represented several distinctive habitat types across depth contours, and thus included a spectrum of benthic communities of the southwest Florida shelf. Since they were known *a priori* to be different from one another, it would have been a waste of effort to demonstrate statistically that stations were different. In fact, most interstation differences were patently obvious. Both these differences and some similarities are highlighted below. Unless otherwise noted, estimates of abundance represent overall averages for all cruises together. Based on underwater television samples, there was no obvious temporal variability in the abundance of most benthic organisms--except for algae--at most stations. The majority of seasonal differences could be attributed to sampling variability, which was extremely high. Since most benthic organisms visible on underwater television were large and presumably long-lived (e.g., corals, barrel sponges), one would not expect differences in their densities between seasons. Intensive synoptic surveying for these organisms would therefore probably have been more cost-efficient than seasonal surveying, effort being equal.

3.3.2 STATISTICAL CONSIDERATIONS

Sampling intensities within gear types during Years 4 and 5 differed from cruise to cruise and from station to station, both as a result of program design, and of unexpected events such as heavy weather and equipment failure (see Subsection 3.2.1, Station Descriptions, and Section 4.2, Methods Evaluation). The kinds of statistical estimates which are usually sensitive to unequal sampling efforts are those that attempt to compare stations or groups of taxa based on abundance data, which often exhibit explosive variances. This is one reason that presence/absence summaries were used frequently in this report. As in any field program, some species were undoubtedly not sampled, due to natural variability, gear bias, or inadequate replication. The study area was extremely patchy. Patchiness increased the chances of missing species, or, for that matter, entire communities. How many species were missed cannot, of course, be determined directly. However, the issue was examined indirectly with species-area graphs. These graphs depict the number of species (or individuals/species) taken with successive samples. More samples take more species, until (theoretically) every species in the environment has been collected. The approach of these curves to asymptotic values is usually taken to mean that further sampling would bring diminishing returns, at least with regard to the compilation of a species list.

Organisms collected by dredging were identified to the species level for most taxonomic groups. Comparisons of total numbers of species (all taxa pooled) would not be meaningful, because sponges were not identified, even though they may have included more species than all other taxa put together. Other taxa were identified to the species level. Numbers of taxa within major taxonomic groups added during successive visits to the same stations are presented in Figure 3.3-1. Only stations sampled at least three times (three replicates/visit), and groups including at least 10 taxa at each station are shown.

Within most major taxonomic groups--even sessile forms such as corals and gorgonians--numbers of taxa added had not begun to level off, even after 12 or more replicates on successive cruises. Comparisons between cruises and stations for numbers of taxa or other measures of species richness would therefore be inappropriate. They could be easily misinterpreted as indicating real differences in benthic diversity, rather than sampling variability. Depth range graphics and cluster analyses based on presence/absence were thus chosen to delineate patterns of similarity and differences between stations with respect to dredge samples.

The reader should keep in mind that the delineation of zones or clusters of stations is subjective, and that the true situation is almost certainly a continuum rather than a division into discrete zones. Even if zones had distinct boundaries, the actual locations of those could lie anywhere between stations. As a convention, boundaries are shown approximately half-way between stations, since no information is available from intermediate points. The number of fishes sampled by trawling and with the underwater television had not approached asymptotic values at most stations by the end of the ESE/LGL sampling program (Figures 3.3-2 and 3.3-3). Direct comparisons of numbers of species and other community

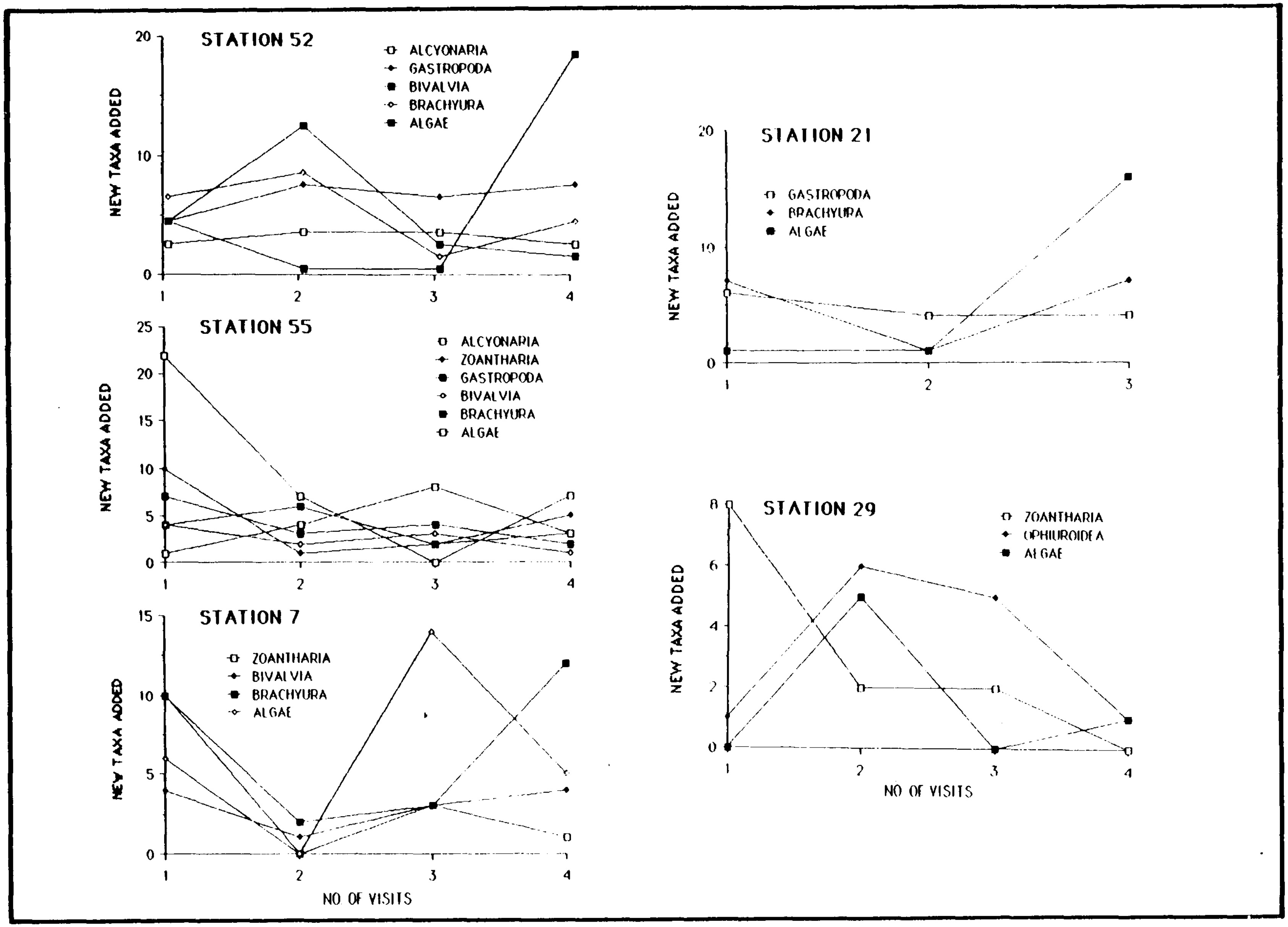


Figure 3.3-1 INCREASES IN THE CUMULATIVE LIST OF INVERTEBRATES COLLECTED BY DREDGING AT STATIONS 52, 55, 7, 21, AND 29 ON SUCCESSIVE CRUISES TO

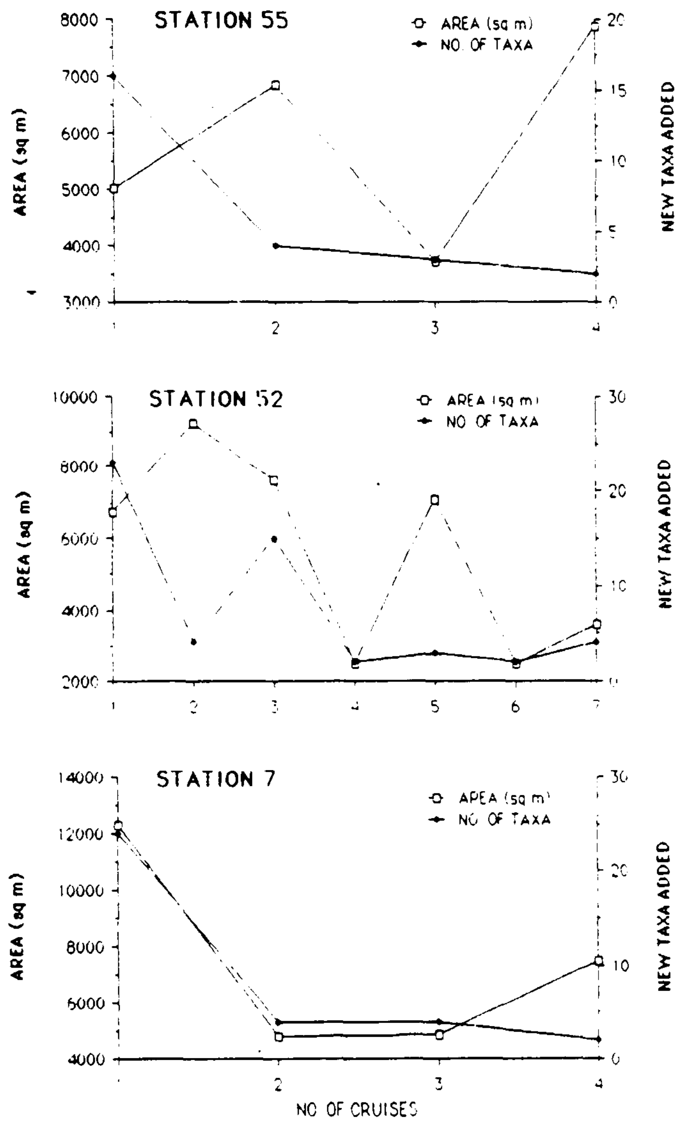
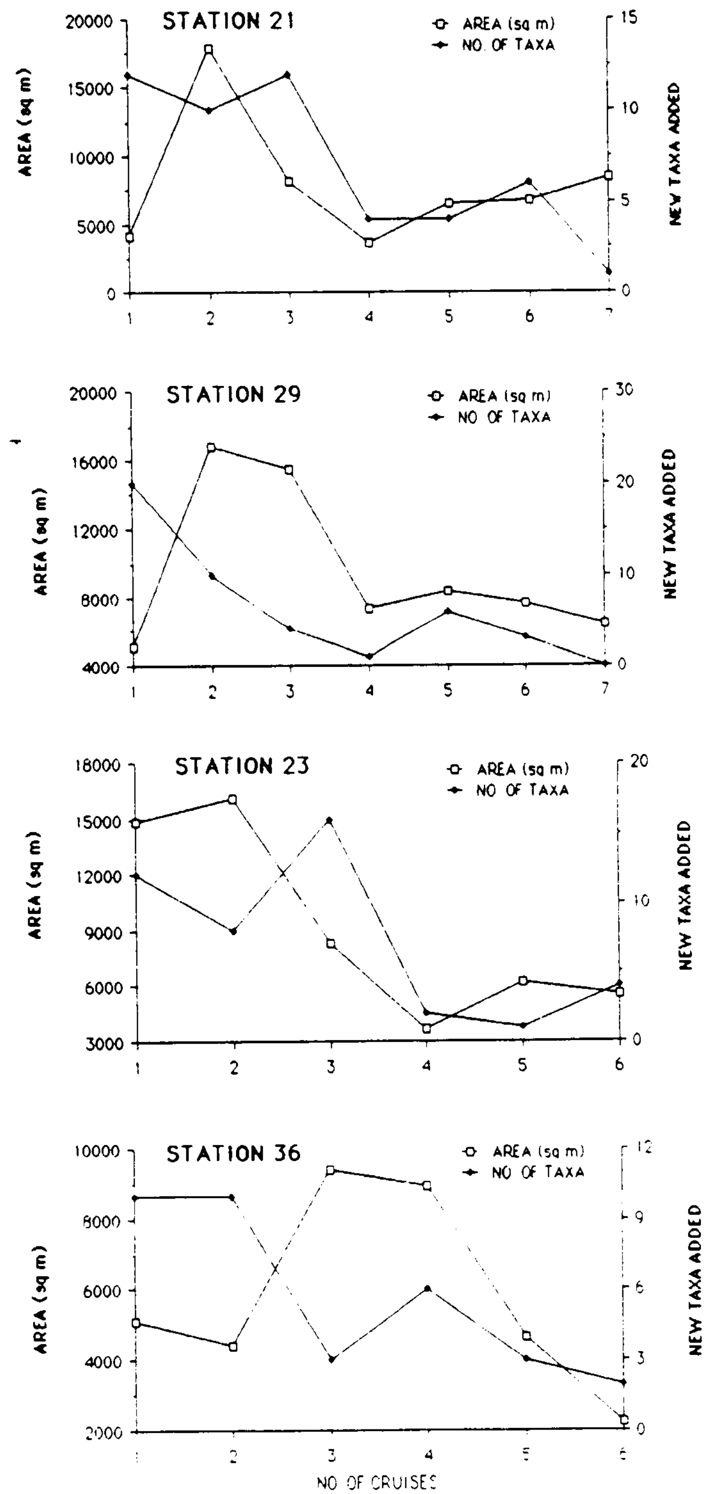


Figure 3.3-2 INCREASES IN THE CUMULATIVE LIST OF FISHES CENSUSED WITH UTV AT STATIONS 55, 52, 7, 21, 29, 23, AND 36 ON SUCCESSIVE CRUISES TO EACH STATION, AND AREA TRANSECTED ON EACH CRUISE



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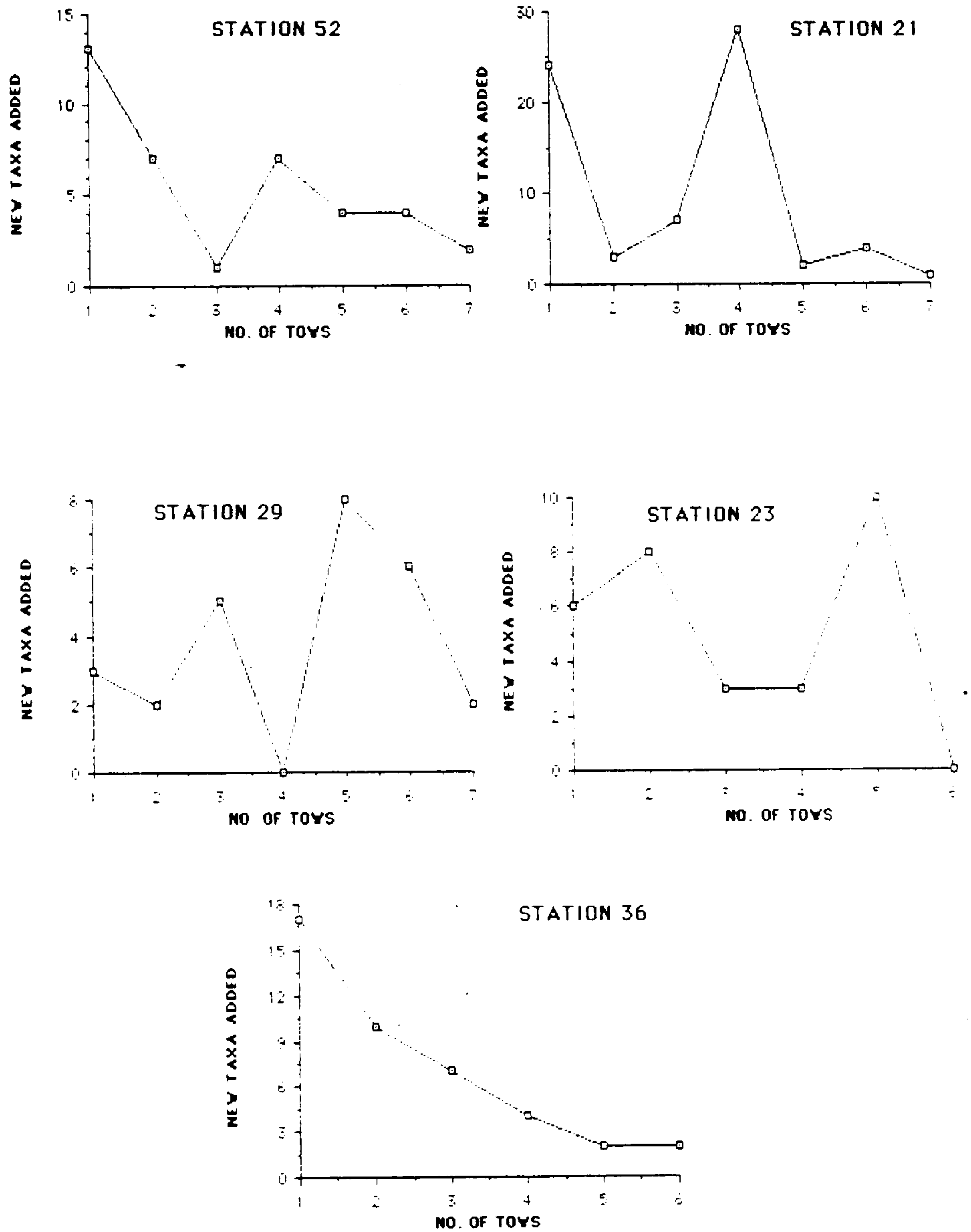

Figure 3.3-3 INCREASES IN THE CUMULATIVE LIST OF FISHES COLLECTED BY TRAWLING AT STATIONS 52, 21, 29, 23, AND 36 ON SUCCESSIVE CRUISES TO EACH STATION

summary statistics among all stations were therefore difficult to justify statistically for these gear types, although comparisons among stations with approximately equal sampling effort were valid.

Some stations appeared to be "undersampled" for fishes compared to others. For example, the number of taxa added by trawling on successive visits to Stations 21, 29, and 23 approached zero after three or four tows. Had the sampling program at those stations terminated at that point, all of the species identified from subsequent samples would have been entirely missed. This would not be a minor loss; the species list nearly doubled in size at Station 21 on the fourth visit, and similar increases were noted at Stations 29 and 23 on the fifth visit. Only Station 36 exhibited an exponential decrease in numbers of taxa with successive tows.

Quantitative comparisons based on abundant species (e.g., diversity indices) are relatively insensitive to omissions of rare species, but they are strongly influenced by natural variability and replication. The unbalanced sampling design used in this program posed serious statistical difficulties (e.g., extremely wide confidence limits on measures of central tendency) with respect to comparisons within species between stations. Inter-cruise comparisons were therefore stressed for fishes of particular interest (see Subsection 3.2.1, Station Descriptions), and between-station statistical comparisons were de-emphasized. In order to make any comparisons that depend on numbers of taxa or relative abundance, organisms must be identified to comparable levels of resolution, preferably at the lowest possible taxon. The level of taxonomic resolution for benthic invertebrates and plants seen with underwater television was not adequate for comparisons of numbers of species or abundance.

Comparisons of abundance between stations for individual species could be made by pooling the data for those species across cruises, in the same way that overall estimates of abundance were made for those species.

However, whether or not stations could be compared using pooled data depended upon (1) the existence of sufficient numbers of replicate samples, as well as (2) demonstrating a lack of heterogeneity (i.e., statistically significant differences) between samples from different cruises. The trawl data failed to meet the first criterion, since in most cases only a few hauls were available to pool, and they could not in any sense be considered replicates because they were each taken on a different cruise. The underwater television data for fishes and benthic organisms were screened on a species-by-species basis for each station, to determine whether significant inter-cruise differences would cause such comparisons to fail the second criterion. Only species meeting both criteria were compared statistically between stations.

3.3.3 ZONATION BY DEPTH

Depth range graphics were used to help delineate faunal boundaries from dredge, underwater television, and trawl samples. Continuity of distributions are not to be inferred from the graphics. Given the mosaic nature of the study area, one or more stations within a species' depth range may not have had that species present. In some cases, depth ranges for the same organism differed from one gear type to the next. These differences must be resolved in favor of the widest depth range, regardless of gear type. For instance, if a narrower depth range was shown for one species with the trawl than with the underwater television, the most conservative conclusion is that the trawl was a less effective sampler at some locations than the underwater television. The best representation of a species' actual depth range was the widest recorded with any gear type.

Triangular Dredge Results

The most detailed taxonomic information on benthic community composition can be derived from triangular dredge samples, although abundance information was lacking. Figures 3.3-4 and 3.3-5 illustrate the range of depths from which benthic invertebrates and plants were collected. Only the shallowest and deepest stations at which each species was taken are

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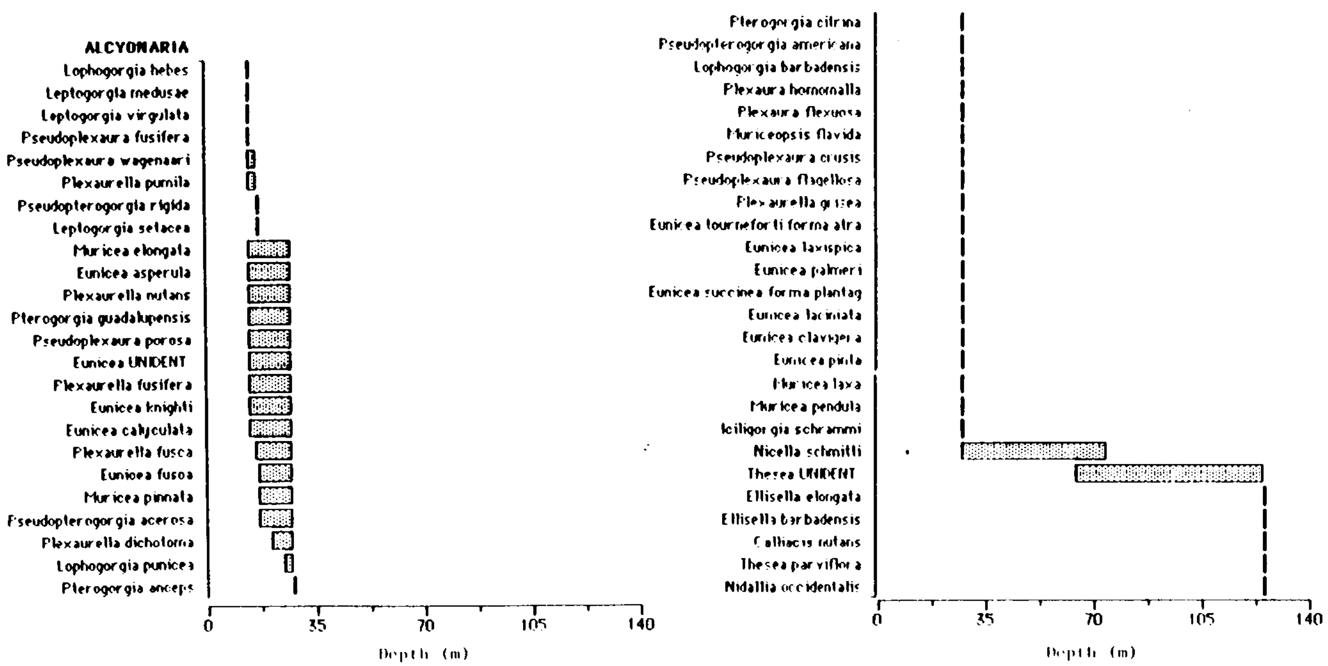

Figure 3.3-4 DEPTH RANGES FOR BENTHIC INVERTEBRATES COLLECTED BY DREDGING, FOR ALL STATIONS AND CRUISES TOGETHER

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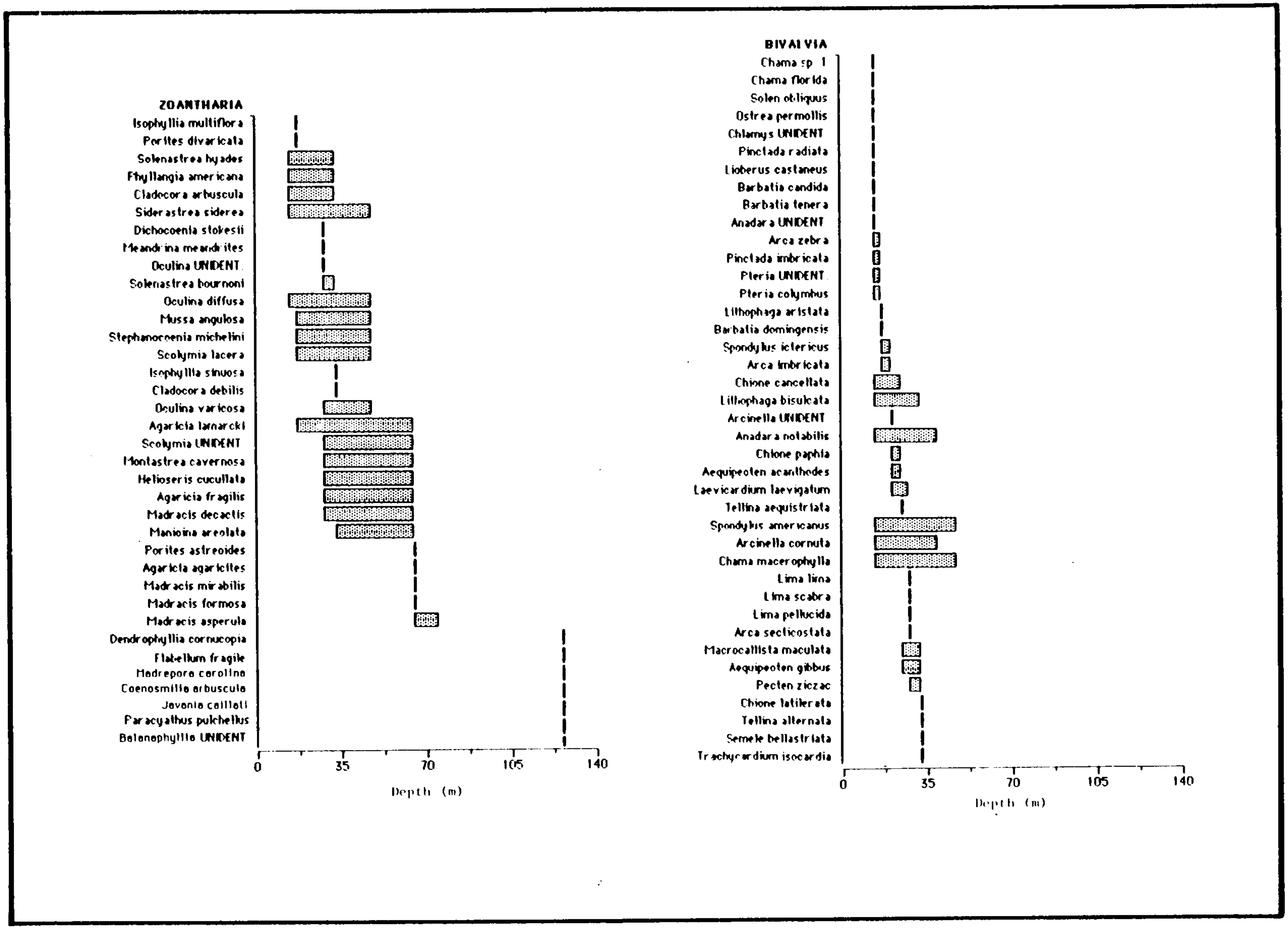

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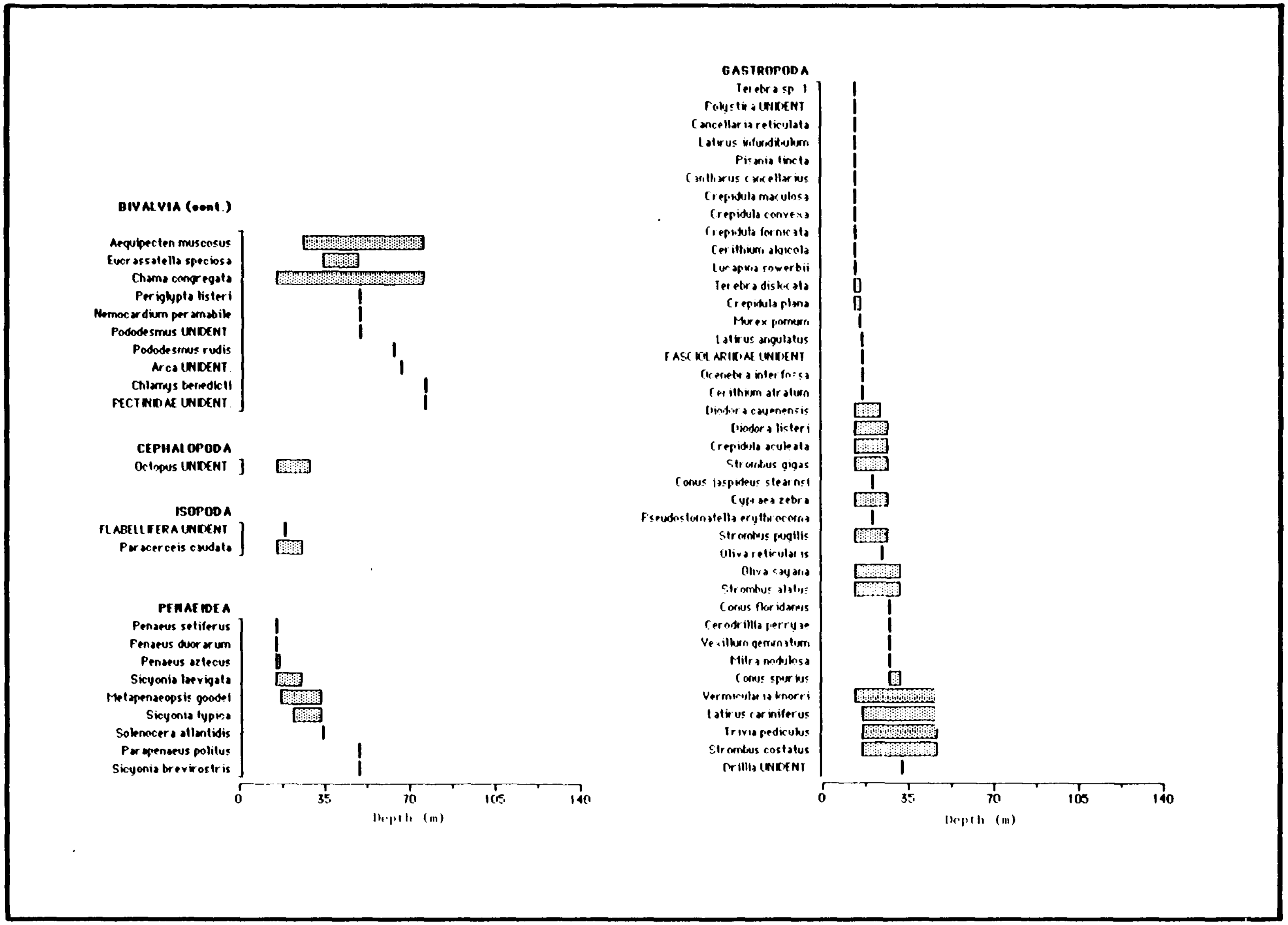

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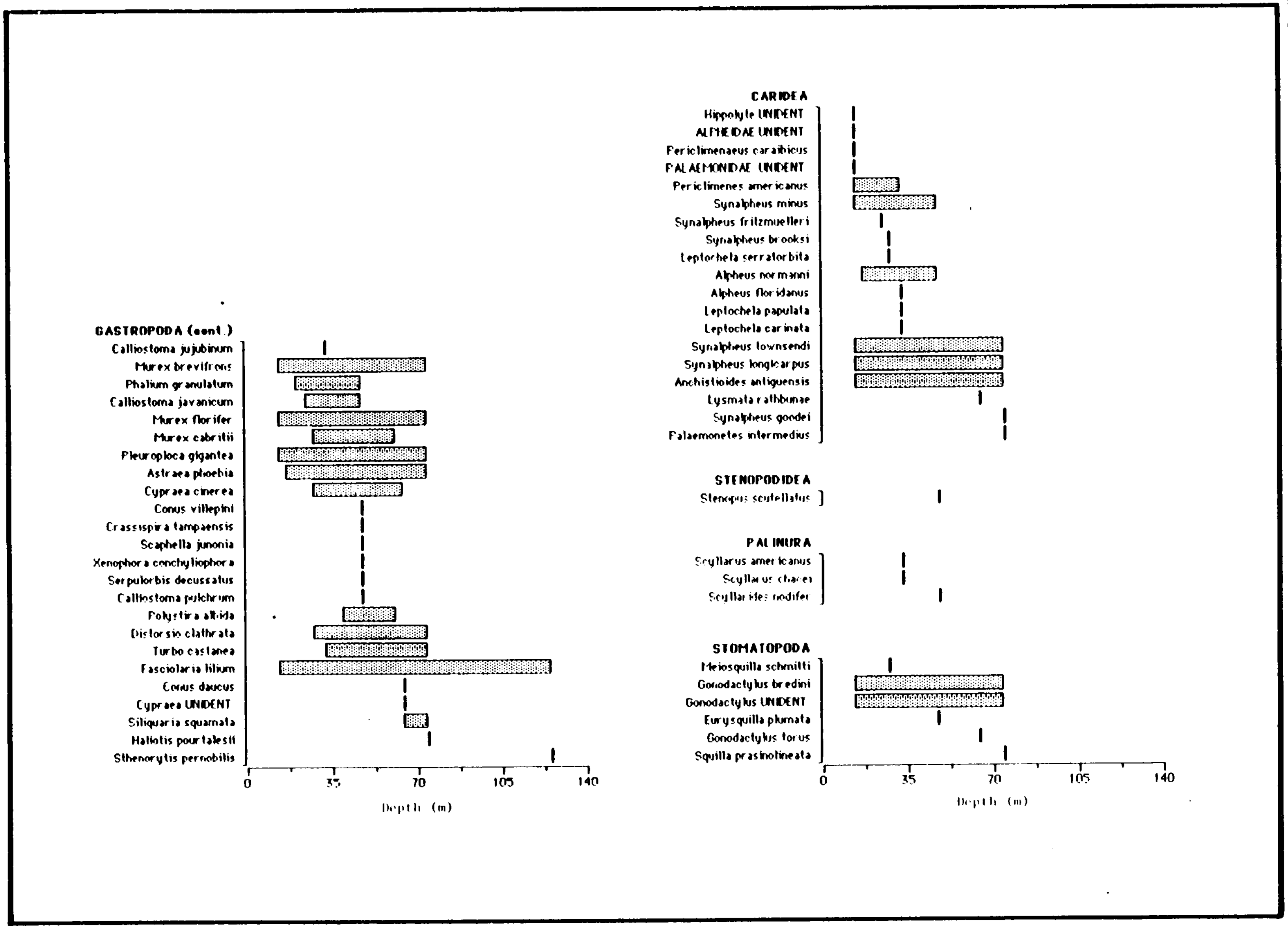

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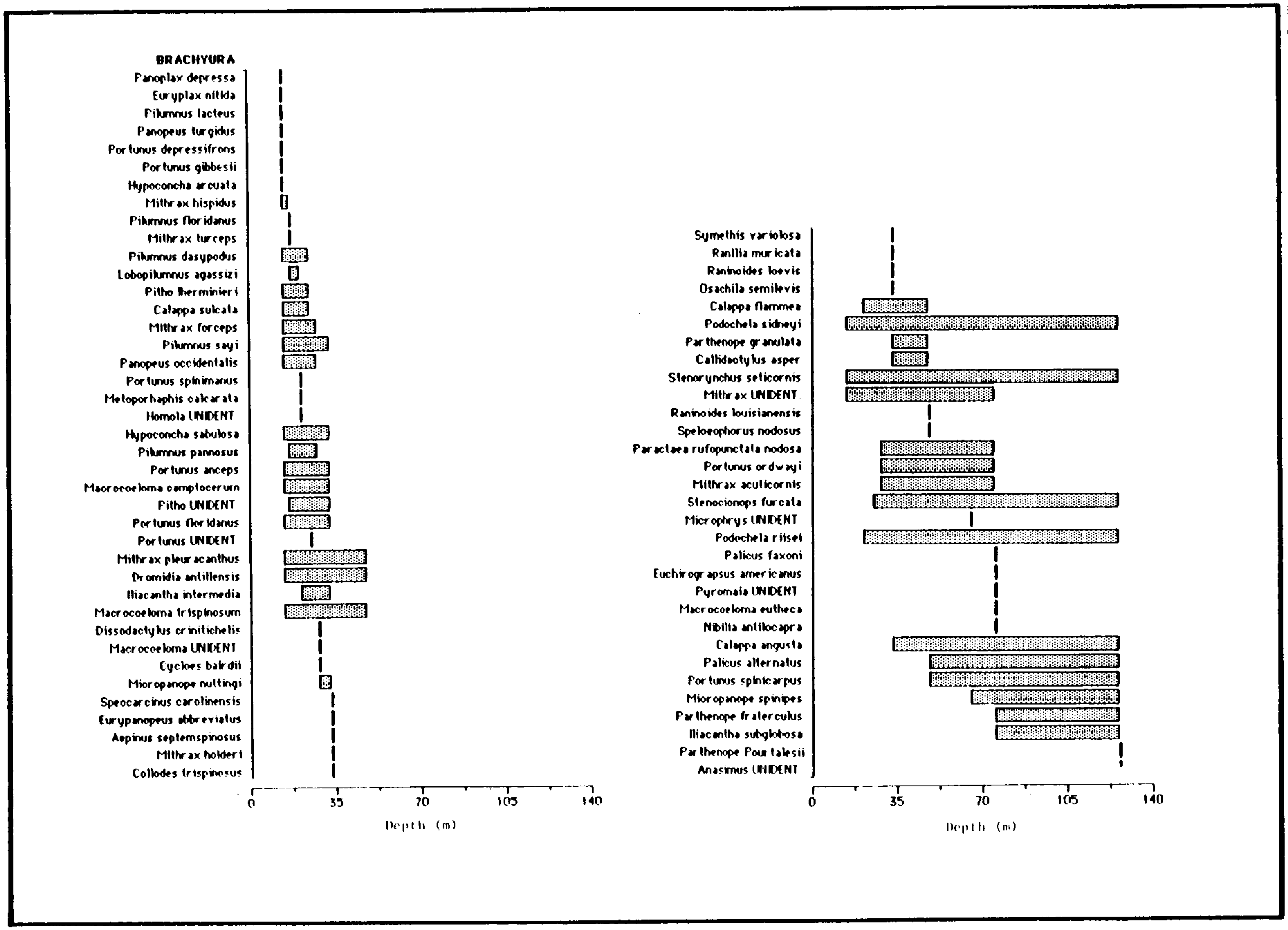

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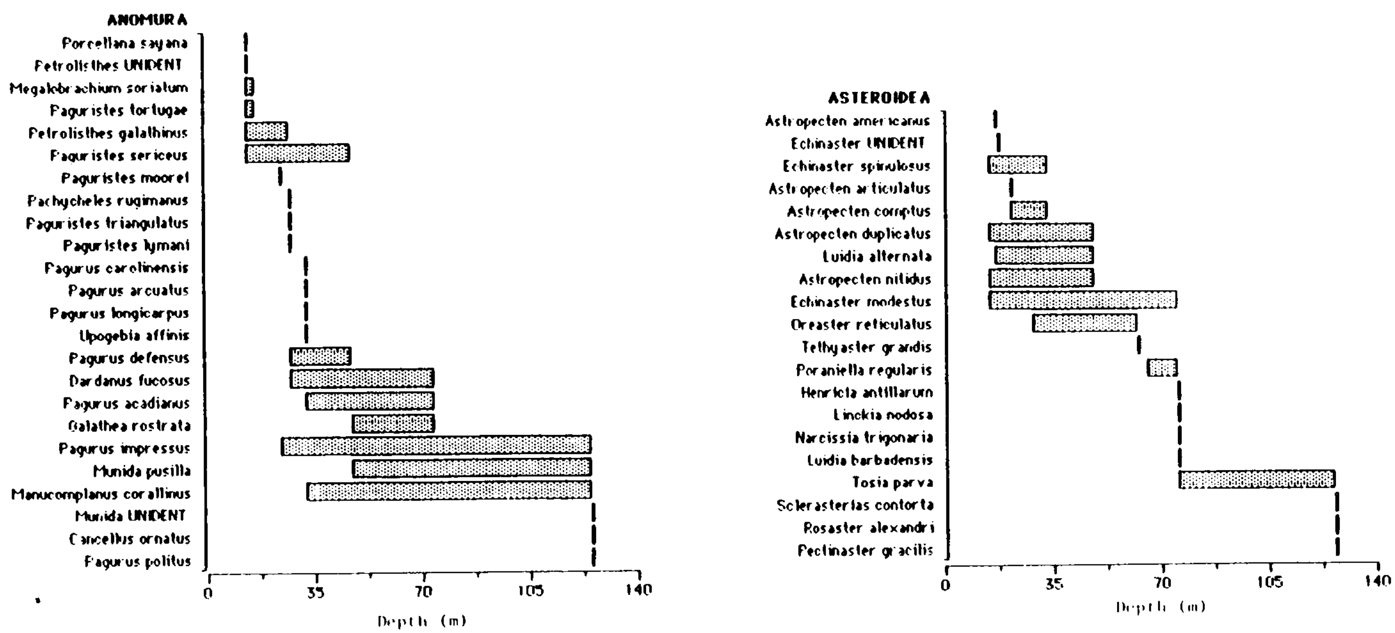

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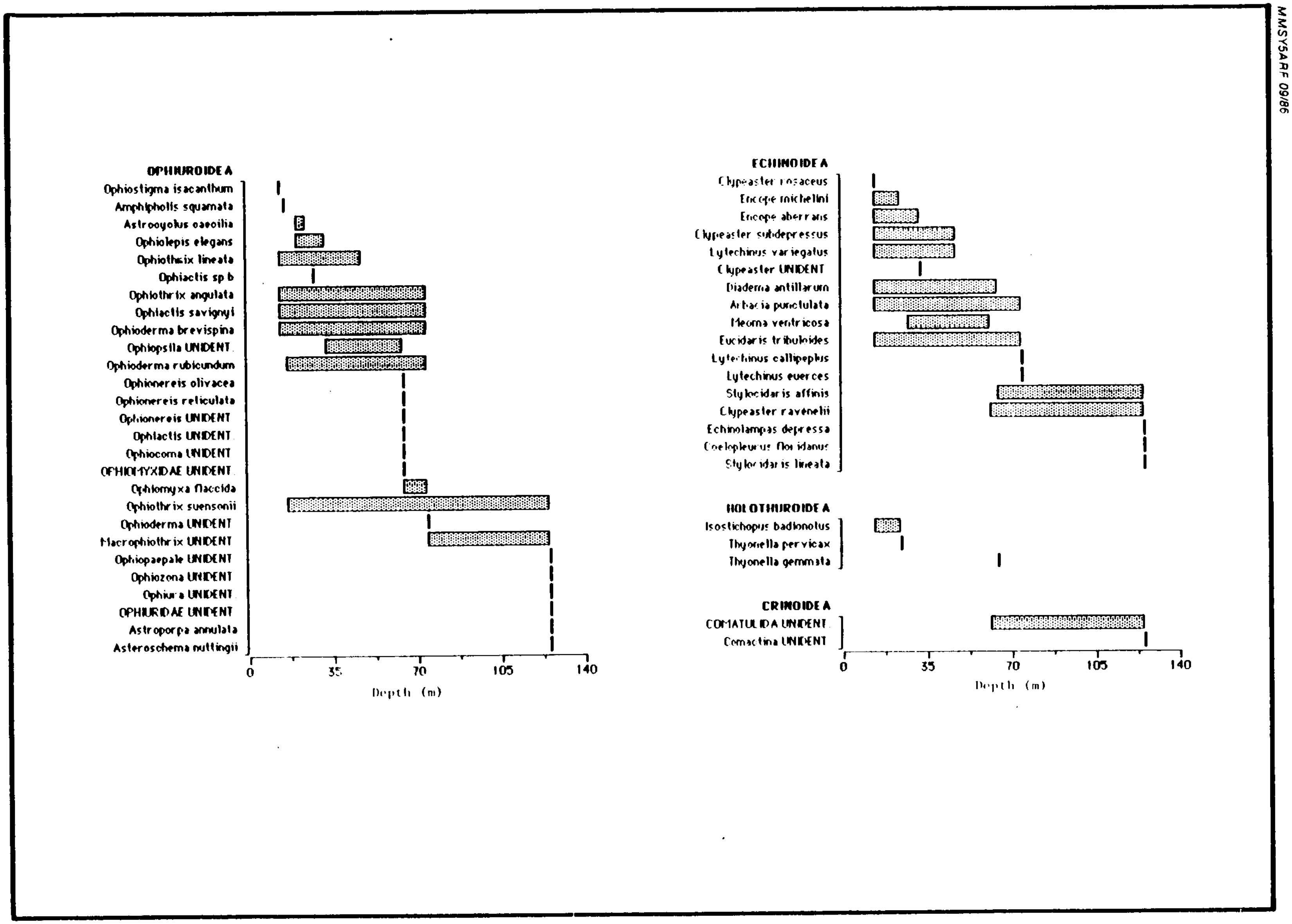

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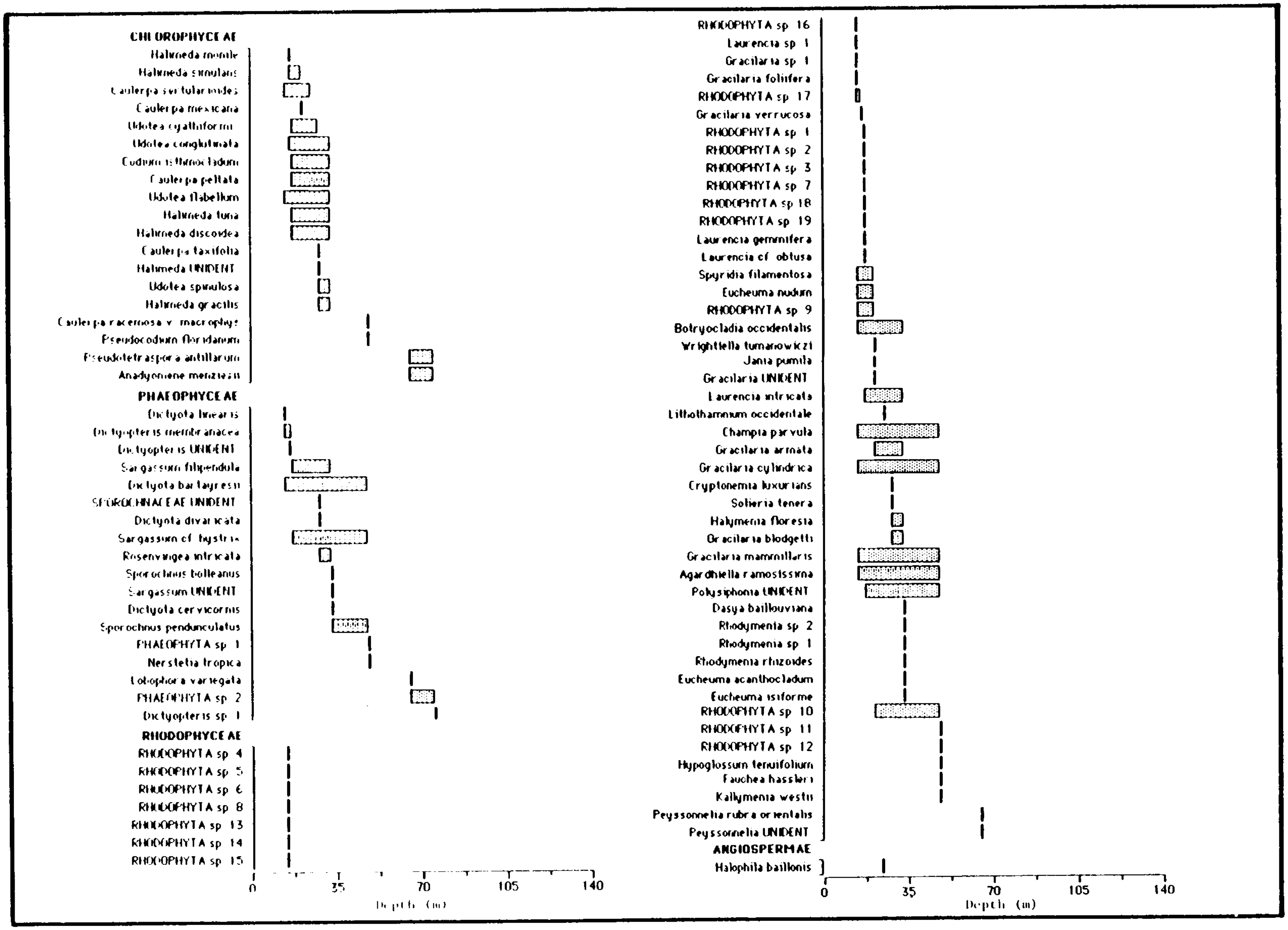

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Figure 3.3-5 DEPTH RANGES FOR ALL BENTHIC PLANTS COLLECTED BY DREDGING, FOR ALL STATIONS AND CRUISES TOGETHER shown by bars in the figures. The figures do not indicate whether or not any given species was collected at stations lying between those minimum and maximum depths; those data can be found in Appendix E. The figures were designed to show the "acceptable" or "suitable" depth range by species, in order to help elucidate faunal zonation by depth. Of course, substrate type would be most likely to determine whether or not a given species would be present at any particular location or station within its acceptable depth range. For most major groups of benthic organisms, there were obvious shifts in community composition with depth, especially for sessile forms. In several cases, there were distinct suites of shallow-water species, some transitional species, and other distinct deep-water suites of species. The main focus of interest was the larger, habitat-forming organisms. The majority of other species depend upon them for shelter, food, and vertical relief on an otherwise flat, rather featureless shelf. Gorgonians, corals, and plants are discussed in the following section, as well as in the section on underwater television results. Sponges are discussed in the underwater television section, since they were not identified to species from dredge samples (except for Ircinia), and could not therefore be used to discern depth zones or other faunal boundaries. Important factors known to influence the distribution of gorgonians and corals include temperature, illumination, salinity, suitable substrate, water movement, and interspecific competitive exclusion.

Gorgonians and corals usually flourish in temperatures of 25 to 29°C (Wells, 1956, 1957; Stoddard, 1969), but healthy and diverse reef populations are found at average temperatures of 18.9°C in Bermuda (Bayer, 1961). These figures pertain to shallow-water species, and are within the range determined for Station 21 and those lying farther inshore. The temperature requirements of deeper water forms are probably somewhat narrow and hence restrict their distribution to a limited bathymetric range (Bayer, 1961). Salinity tolerance in scleractinian corals ranges from 17.5 to 40 ‰ (Vaughan, 1919; Edmonson, 1924; Wells, 1957; and Kinsman, 1964). Most octocorals are found in areas of relatively small salinity fluctuation (Bayer, 1961). Data from the southwest Florida study area indicated rather minor differences in bottom salinity among stations.

Bathymetric distributions of corals and gorgonians seem to follow phylogenetic lines; some genera are restricted to moderate depths while others occupy intermediate to rather deep ranges. The controlling factor appears to be illumination (Gardiner, 1930).

Nearly all of the gorgonians and corals found in this study harbor zooxanthellae. Some research suggests that zooxanthellae provide most, if not all, of the nutrients of some gorgonians and corals (Gohar, 1940; Kinzie, 1970; Goreau, 1959; Jaap, 1979). For this reason, they would be expected to be highly influenced by the availability of sufficient light to meet their nutritional requirements.

Other corals (e.g., Scolymia) and gorgonians (e.g., Ellisella) found in this study do not possess zooxanthellae, and are predominant in deep water and aphotic habitats (Cairns, 1979). These forms were represented in this study by members of several families: Caryophyllidae, Flabellidae, and Dendrophyllidae. The bathymetric distribution of Caryophyllidae and Flabellidae is littoral to abyssal; Dendrophyllidae are found from the littoral to the bathyal zones (Wells, 1956).

Suitable substrate availability plays a major role in coral distribution (Cary, 1914). It is also considered the single most important factor controlling the distributions of shallow-water gorgonians (Bayer, 1961; Kinzie, 1970). Within the study area, shallow water gorgonians and corals were found mainly on hard bottom (exposed rock, or rock underlying a thin sand veneer) or within coralline algal nodule zones. In these areas, competition with other sessile forms would be expected to be an important determinant of community composition. Although hard substrate provides a rigid support to which gorgonians can attach, sand may also have had a positive role in the maintenance of existing gorgonian beds. Sand movement can interfere with the settlement and growth of many other organisms, and it is likely that many low-profile species (possible competitors with gorgonians) would be excluded from sand-covered areas. In addition, light reflected from flat, sandy bottoms is appreciably brighter (up to 4.8 times as bright) than that reflected upward from other substrates (Kinzie, 1970). A few ahermatypic corals and gorgonians were present in deeper sand, and apparently not attached to underlying hard substrates. Most of these were solitary corals or single whip-like colonies (e.g., Ellisella). These free living forms are either limited to low energy environments or are resistant to this abrasion (Bayer, 1961).

Nearly all of the gorgonians (Alcyonaria) were collected in water less than 27 m deep (Station 55 and shoreward). All of these species have zooxanthellae, and are believed largely dependent on high light levels for photosynthetic nutrition (J. Wheaton, Florida Department of Natural Resources, pers. comm., 1985). Only one of the species (Nicella schmitti) found in shallow water also extended into deeper water (beyond 70 m). There were five deep water gorgonians found only at Station 36 (125 m), and another (an unidentified Thesea) that spanned the depth range between Station 29 (64 m) and Station 23 (74 m); none of these has zooxanthellae.

Based on the gorgonian data, three distinctive biological zones could be distinguished, corresponding to depth range patterns. The first zone included most photosynthetic forms, and extended from 13 m to near the 30-m depth contour. There appeared to be a transition zone (or, rather, a barren zone, since only two gorgonian species were present) from about 30 m to about 125 m. There was also a deep zone in which only non-photosynthetic gorgonians were present, including the 125-m contour and possibly extending into deeper or shallower water. Detailed sampling at more intermediate depths would be required to delineate the actual zonal boundaries, since there were considerable gaps in depth between some stations.

Species associated either with gorgonians directly or with soft substrate (through which gorgonians were attached to hard substrate) followed similar distribution patterns. For example, many soft-bottom gastropods (e.g., species of Oliva, Conus, and Strombus) were taken mainly in the shallow zone mentioned above. Many unattached bivalves (Tellina, Trachycardium) and most of the penaeids (e.g., Penaeus setiferus, P. duorarum, Sicyonia spp.) also had similar depth ranges to those of the gorgonians.

Scleractinian corals (Zoantharia) presented a somewhat different pattern. Most species had broader depth ranges than did most gorgonians. There were two recognizable groups of corals, each with progressively greater depth ranges. The shallow group of corals included species that possess zooxanthellae, such as Montastrea cavernosa and Stephanocoenia michelini. Toward the deeper side of this group were many photosynthetic forms that can tolerate low light levels, such as Agaricia fragilis, Helioseris cucullata, and Agaricia agaricites. There was also a distinctive set of eight non-photosynthetic, mainly solitary corals (e.g., Dendrophyllia cornucopia, Javania cailleti) present only at Station 36.

The distributions by depth of many other types of organisms commonly found in coral reefs were similar to those found for corals. For example, various pistol shrimps (Synalpheus spp.), hermit crabs (Pagurus and Paguristes spp.), brachyurans (Mithrax spp., Pilumnus spp.), sessile gastropods and bivalves (Crepidula spp., Spondylus americanus, Arca spp.) had depth ranges which closely matched those of the photosynthetic corals.

A reasonable working scheme for depth zonation based on the coral collection would include two discontinuous zones. A shallow zone, in which photosynthetic forms were dominant, extended from the 13-m contour into deeper water, ending about the 64-m contour (Station 29). Within this zone, some species were found toward the shallow side (e.g., Porites divaricata, Isophyllia multiflora), and others toward the deeper side (e.g., Madracis mirabilis, M. formosa, M. asperula). A deep zone including only non-photosynthetic corals would include the 125-m depth contour (Station 36), and might extend in either direction into deeper or shallower water.

Within other major taxa, most forms were rather restricted in depth, although some spanned extremely broad depth ranges. Many of the widely-distributed species were generalistic predators or omnivores known to have highly flexible dietary requirements (e.g., the gastropods Murex brevifrons and Fasciolaria lilium) (Abbott, 1979), or habitat preferences. For example, all of the stomatopods identified to species were quite restricted in depth except for Gonodactylus bredini. Gonodactylus bredini lives in burrows in coral reefs, sponges, and similar habitats (Camp, 1973) that would be common throughout the study area. Sand dollars, ophiuroids, and other soft-bottom species such as sea stars (e.g., Astropecten duplicatus, A. nitidus, Oreaster reticulatus) were also widespread across depth contours, as were the unconsolidated substrates from which they were taken.

Figure 3.3-5 illustrates depth ranges for plants collected with the dredge. Nearly all of the green algae (Chlorophyceae) were restricted to Station 7 (depth 32 m) and shallower locations. Only four species (Pseudocodium floridanum, Caulerpa racemosa var. macrophysa, Pseudotetraspora antillarum, and Anadyomene menziesii) were present at deeper stations (Stations 21, 29, and 23). No plants were collected at Station 36.

The brown algae (Phaeophyceae) included species that spread out over a slightly greater depth range than did the greens. However, only three browns were collected in water greater than 47 m: *Lobophora variegata*, *Dictyopteris* sp. 1, and an unidentified phaeophyte, at Station 23 (depth 74 m).

The depth distribution pattern of red algae (Rhodophycea) resembled, for the most part, those of the browns and greens, although there was a relatively higher proportion of reds collected only at a single depth or a single station. Many species were restricted to water 13 to 20 m deep (Stations 52, 44, 45, and 47). There was also a large suite of species that ranged from the shallowest stations to Station 21, at 47 m. Only two forms (both *Peysonnelia* species) were collected from deeper water, at Station 29 (depth 64 m).

Underwater Television Results

Figure 3.3-6 illustrates depth ranges for benthic organisms surveyed with the underwater television. Although most taxa spanned much wider ranges than were evident in the equivalent figures for animals and plants collected with the dredge, the difference between the two sets of figures can be interpreted as a methodological artifact due to inequalities in taxonomic resolution. The taxonomic resolution of underwater television data was much lower than that for dredge samples of benthic organisms.

Most of the taxa seen in Figure 3.3-6 were identified only to genus or higher categories which included various numbers of species that could not be differentiated from one another. Individual species' depth ranges may have been narrow, but a sufficient number of ranges overlapped, resulting in a broad depth range for the group as a whole. For example, mellitid echinoids were observed on underwater television over the entire depth range from 13 to 125 m. Individual mellitids (e.g., *Clypeaster*, *Encope*) were collected with the dredge within various (much narrower) depth ranges, spanning the 13 to 125 m spread. Similarly, demosponges were present at every station, but were known to include an extremely large number of species.

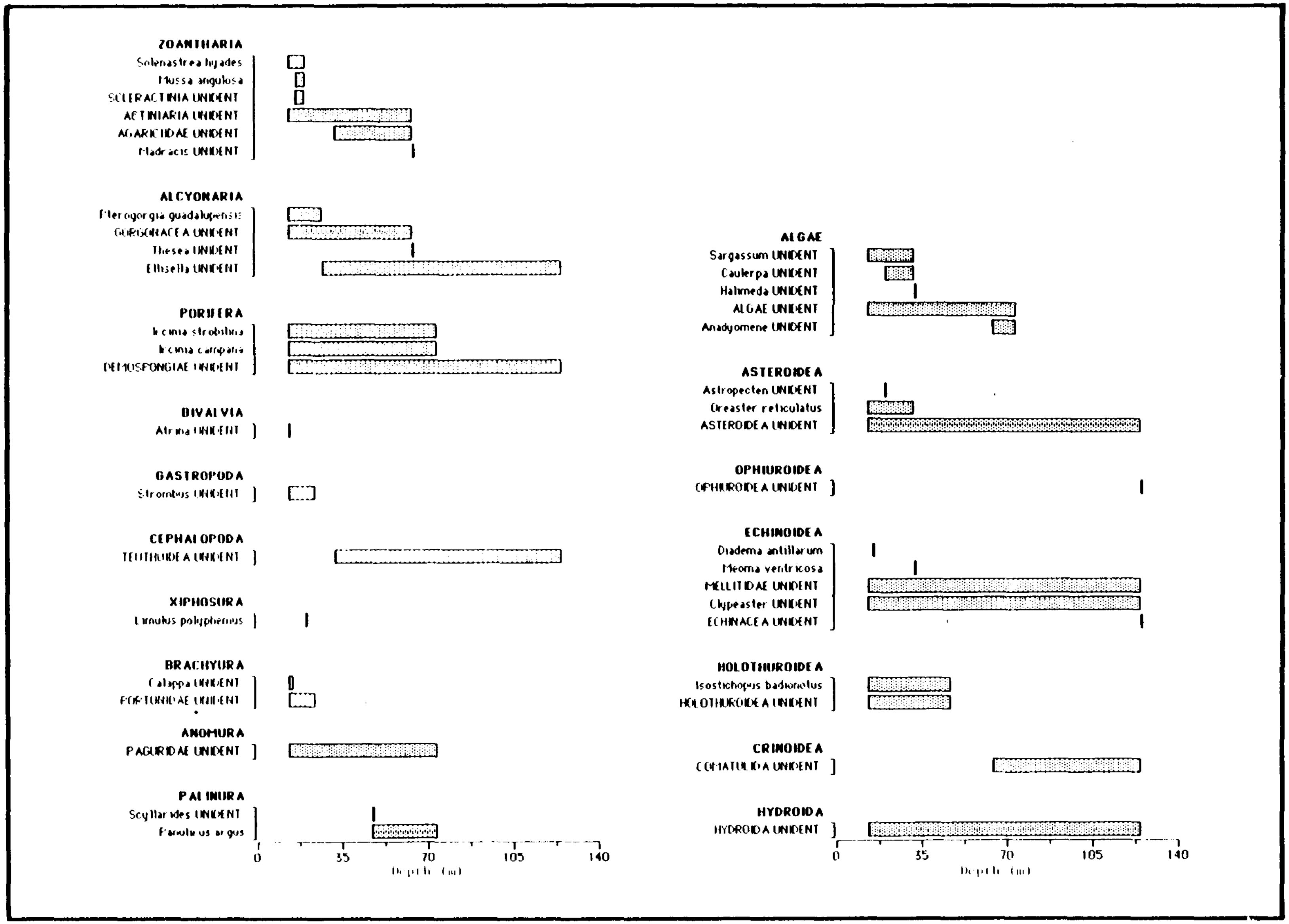

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Figure 3.3-6 DEPTH RANGES FOR BENTHIC ORGANISMS SURVEYED WITH UTV, FOR ALL STATIONS AND CRUISES TOGETHER

It was therefore not feasible to deduce zonation or depth range patterns from underwater television data for most benthic taxa at the species level. There was good agreement, in general, between depth ranges from underwater television and dredge data at higher taxonomic levels. For example, the maximum depth for all algae visible with underwater television was 74 m (Station 23), matching the maximum depth range recorded for algae collected with the dredge. Crinoids were collected by dredging from 64 m (Station 29) to 125 m (Station 36), and viewed on underwater television over the same depth range.

The taxonomic resolution of underwater television data for fishes was excellent. Depth ranges for fishes censused with underwater television are presented in Figure 3.3-7. Some species (e.g., *Synodus intermedius*, *Chaetodon sedentarius*) were observed from 13 to 125 m. Others were restricted to a single depth or very narrow range. Several groups could be distinguished, but the depth zones pertaining to those groups were less distinct, and included much more overlap than there was between zones derived from trawl data.

The shallowest suite of species extended from 13 to 47 m. Many species were observed with underwater television only at the shallowest stations (13 to 20 m), while others such as *Lutjanus synagris* and *Haemulon aurolineatum* ranged from 13 to 47 m. A second group of species was found mainly from 47 m to 75 m, and included species such as *Chromis enchrysurus*, *Chromis scotti*, and *Chromis insolatus*. A third group of species (e.g., *Serranus atrobranchus*, *Chaetodon aya*) was observed only in deep water (125 m). Many species (e.g., *Epinephelus morio*, *Lactophrys quadricornis*) overlapped both the first and second groups, extending from 13 to 75 m. Similarly, a few species such as *Holocentrus rufus* and *Serranus phoebe* overlapped the second and third groups.

Otter Trawl Results

Three general groups of species could be delineated on the basis of depth range from trawl data, although there was some overlap between these

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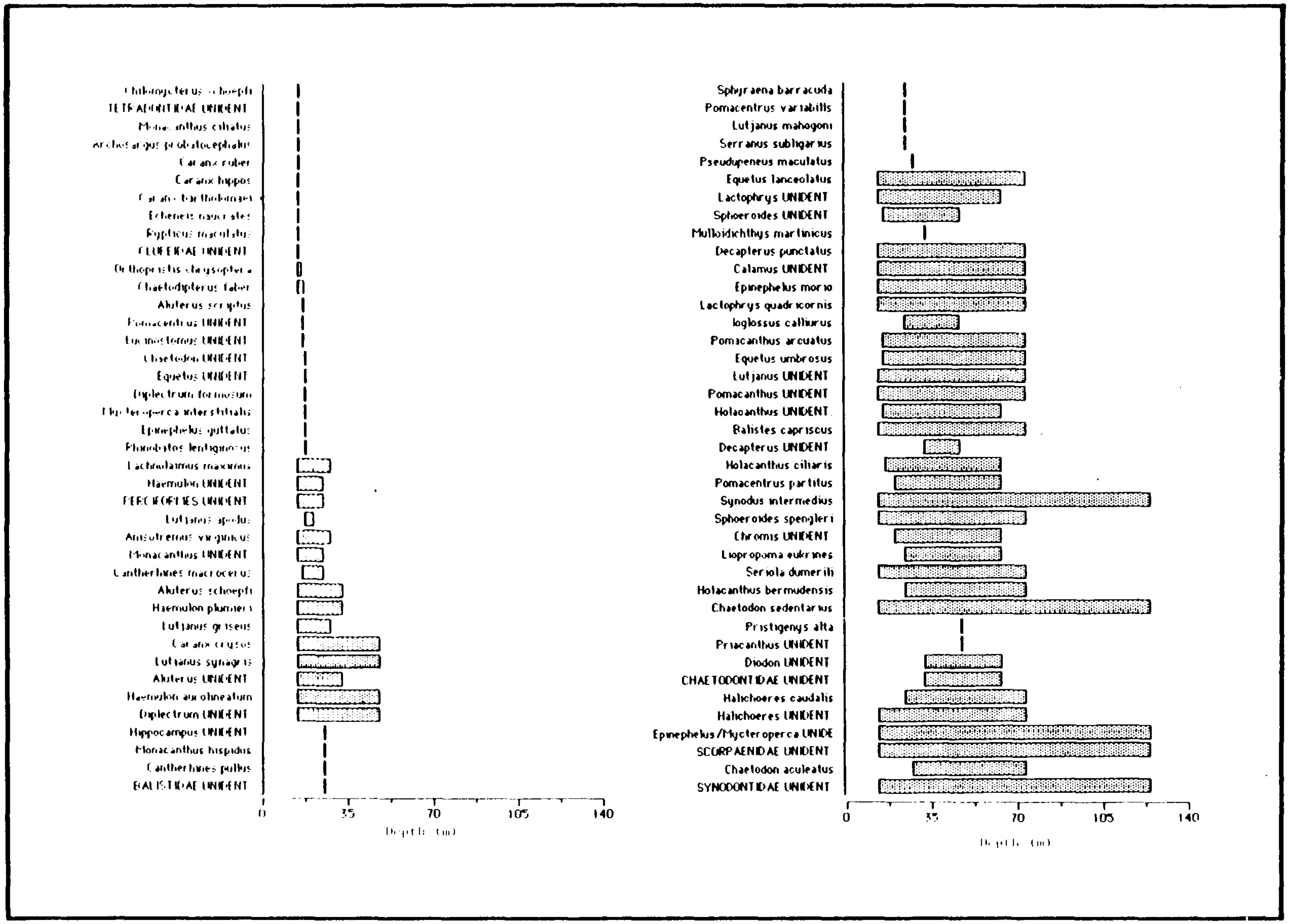

Figure 3.3-7 DEPTH RANGES FOR FISHES SURVEYED WITH UTV, FOR ALL STATIONS AND CRUISES TOGETHER

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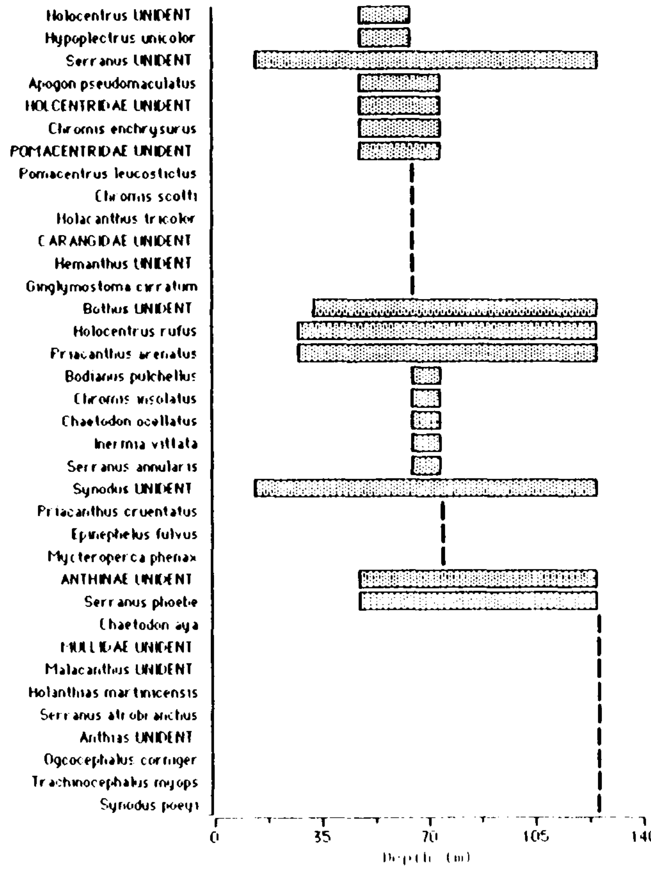

Figure 3.3-7 (cont'd)

groups, and a few species (e.g., *Synodus intermedius*, *S. poeyi*, *Gymnothorax nigromarginatus*, and *Sphoeroides spengleri*) covered the entire depth range from 13 to 125 m (Figure 3.3-8).

Fishes occupying the shallowest zone ranged in depth from 13 m (Station 52) to about 47 m (Station 21). Within this and the other zones were some species that were collected only at one or two depths (e.g., several species of *Prionotus* and *Calamus*), as well as others that spanned most or all of the depth range from 13 to 47 m (e.g., *Haemulon plumieri* and *H. aurolineatum*).

A second group of fishes was most frequently collected between 47 m and 74 m (Station 23) (e.g., *Chromis enchrysurus*, *Chaetodon sedentarius*, and *C. aculeatus*). A third group was found mainly in deeper water (74 to 125 m), such as *Serranus atrobranchus*, and *Chromis scotti*.

It was possible to compare depth ranges for trawl samples versus underwater television samples on a species-by-species basis. Many species had depth ranges in underwater television samples which matched or closely paralleled those in trawl samples (e.g., *Lachnolaimus maximus*, *Haemulon aurolineatum*). On the other hand, most species had much wider depth ranges as determined from underwater television samples than trawl samples. For example, *Pomacanthus arcuatus*, *Equetus lanceolatus*, *Holacanthus bermudensis*, and *Epinephelus morio* all extended into deeper water than trawl samples would suggest. This was not always true, though. For example, *Trachinocephalus myops* and *Synodus poeyi* were recorded only from deep water underwater television samples (125 m), but they were collected with the trawl at much shallower stations as well.

3.3.4 CLUSTER ANALYSES

Cluster analyses per Boesch (1977) of dredge data were performed using the Dice similarity index for presence/absence information, to group stations. Cluster analyses to group stations on the basis of underwater

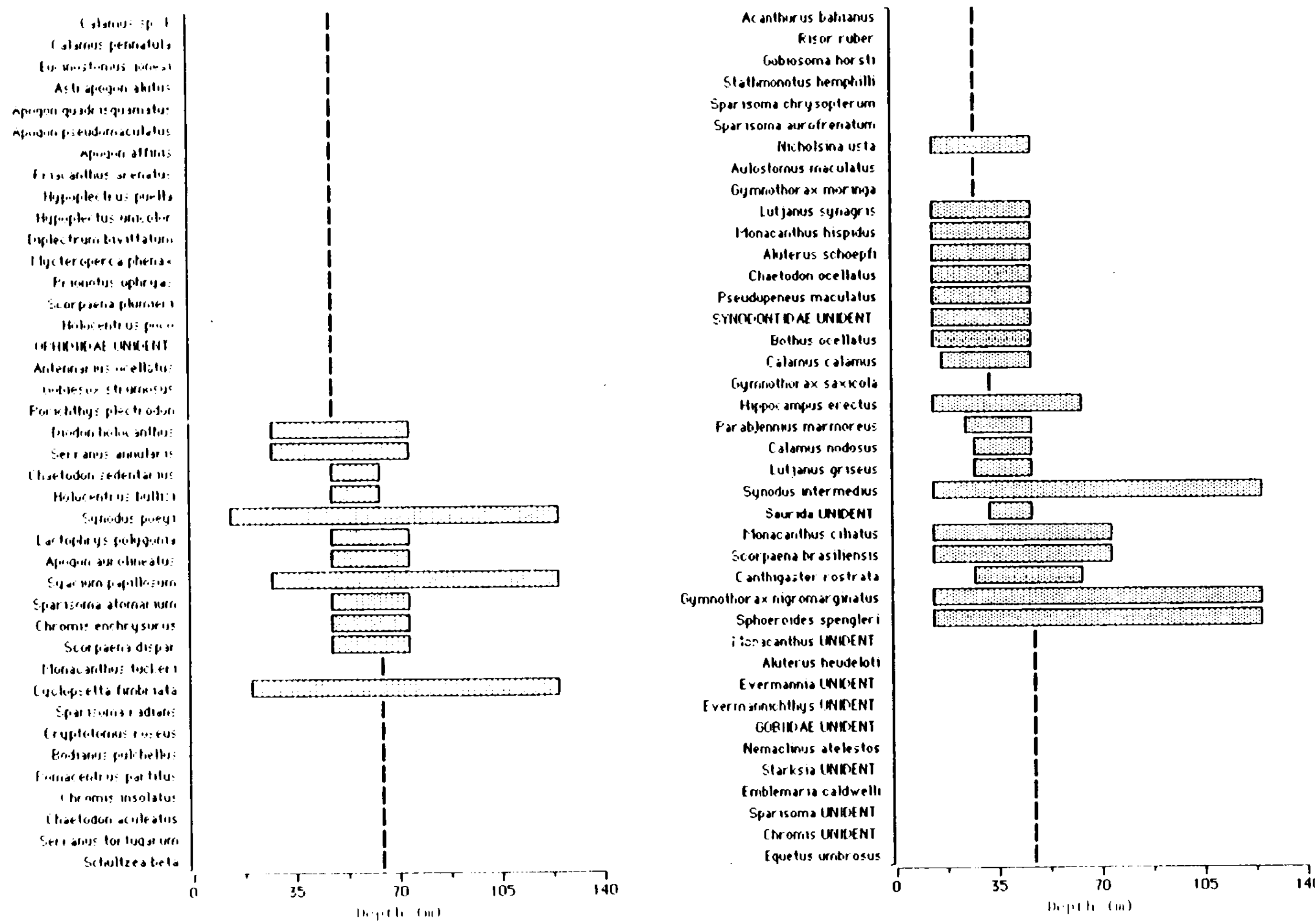

Figure 3.3-8 DEPTH RANGES FOR FISHES COLLECTED BY TRAWLING, FOR ALL STATIONS AND CRUISES TOGETHER

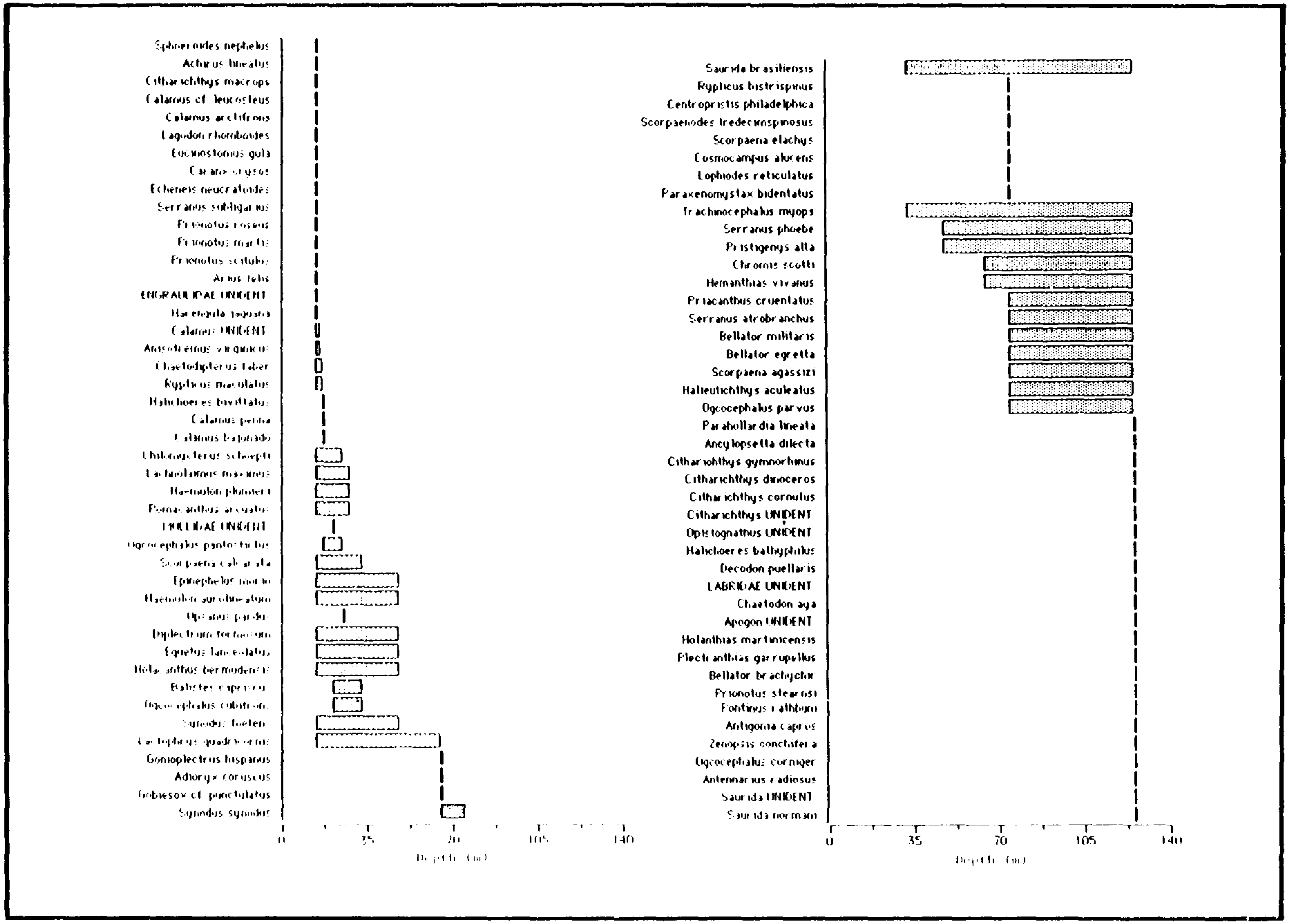

Figure 3.3-8 (cont'd)

television and trawl fish data were performed using the Bray-Curtis (Czechanowski Quantitative) Index. The Bray-Curtis Index takes into account relative abundance, grouping stations by sets of species sharing high densities, and vice versa. The Dice Index disregards relative abundance, and groups stations more simply by co-occurrence (presence/absence). For each type of analysis, both the dendrogram and a schematic map of stations grouped within clusters are shown. Each schematic map shows two levels of dissimilarity in order to avoid implying that one of the many possible splits or groupings seen on the dendrogram is the "correct" one. Levels were chosen arbitrarily based on major splits in the dendrograms, to produce three to six groups.

Triangular Dredge Results

Cluster analysis of benthic invertebrates and plants collected by dredging divided stations into several sets lying roughly parallel to depth contours (Figure 3.3-9).

Station 36 differed from other stations at the 0.887 level. Previous work (Woodward Clyde Consultants/Continental Shelf Associates, 1983, 1984) has categorized this station as lying within the Outer Shelf depth zone, with benthic biota matching the Outer Shelf Crinoid Assemblage (see Subsection 3.2-1, Station Descriptions).

Stations 29 and 23 closely resembled one another, and were grouped at the 0.624 level. Both Stations 29 and 23 lie within the Middle Shelf depth zone. Station 29 was categorized as having an *Agaricia* Coral Plate Assemblage, whereas benthic organisms at Station 23 were classified as belonging to the Middle Shelf Algal Nodule Assemblage.

Stations 7, 45, 21, 55, and 52 were grouped at the 0.787 level. Within this group, Station 21 was least similar to the other stations. Station 21 lies within the Middle Shelf depth zone, and its biota has been categorized as Inner and Middle Shelf Live Bottom Assemblage II.

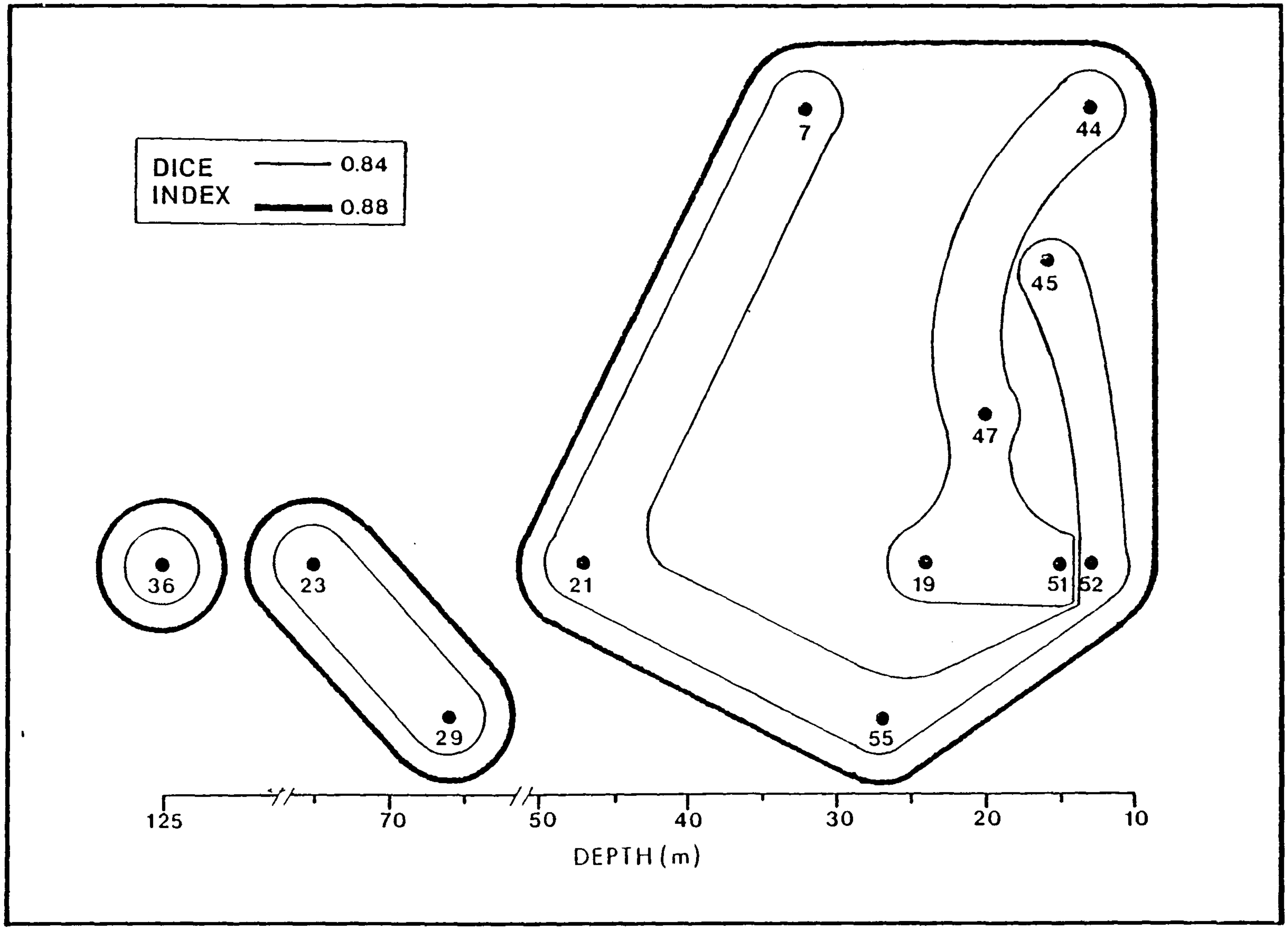

Figure 3.3-9 RESULTS OF CLUSTER ANALYSIS OF DREDGE DATA, USING THE DICE INDEX OF DISSIMILARITY TO GROUP STATIONS AT TWO LEVELS (INSET)

Stations 7, 45, 55, and 52 lie within the Inner Shelf depth zone. The biota at Station 7 have been classified as Inner and Middle Shelf Live Bottom Assemblage II. No previous biotic classification is available for Stations 45, 52, or 55.

Stations 51, 44, 47, and 19 were clustered at the 0.84 level. Within this group, Station 51 was least similar to the other three stations. All of these stations lie within the Inner Shelf depth zone. The biota at Station 19 has been categorized as Inner Shelf Live Bottom Assemblage I. No previous biotic classification is available for Stations 51, 44, or 47.

Trawl Results

Stations were clustered based both on abundance of fishes collected by trawling (Czechanowski or Bray-Curtis Index of similarity) and on simple co-occurence (Dice Index). Although the two patterns were similar, there were some differences between them (see Figure 3.3-10).

Using the Dice Index for trawl data, four station groupings emerged at the 0.843 level of dissimilarity (Figure 3.3-10). Although the groupings crossed depth contours, stations farther offshore (e.g., Stations 36 and 23) were highly dissimilar to any other station groups (0.962 level).

Station 44 differed from all other stations at the 0.938 level. Stations 23 and 36 clustered together at the 0.639 level, and were highly dissimilar to all other station groupings (0.962 level). Stations 21, 29, and 55 grouped together at the 0.843 level, with Station 29 less similar to Stations 21 and 55 than the latter two were to one another. Stations 7, 45, 47, 19, 51, and 52 all were clustered together at the 0.765 level; within this group, Stations 7 and 47 were most like one another (0.463), as well as most dissimilar to the remaining stations in the group.

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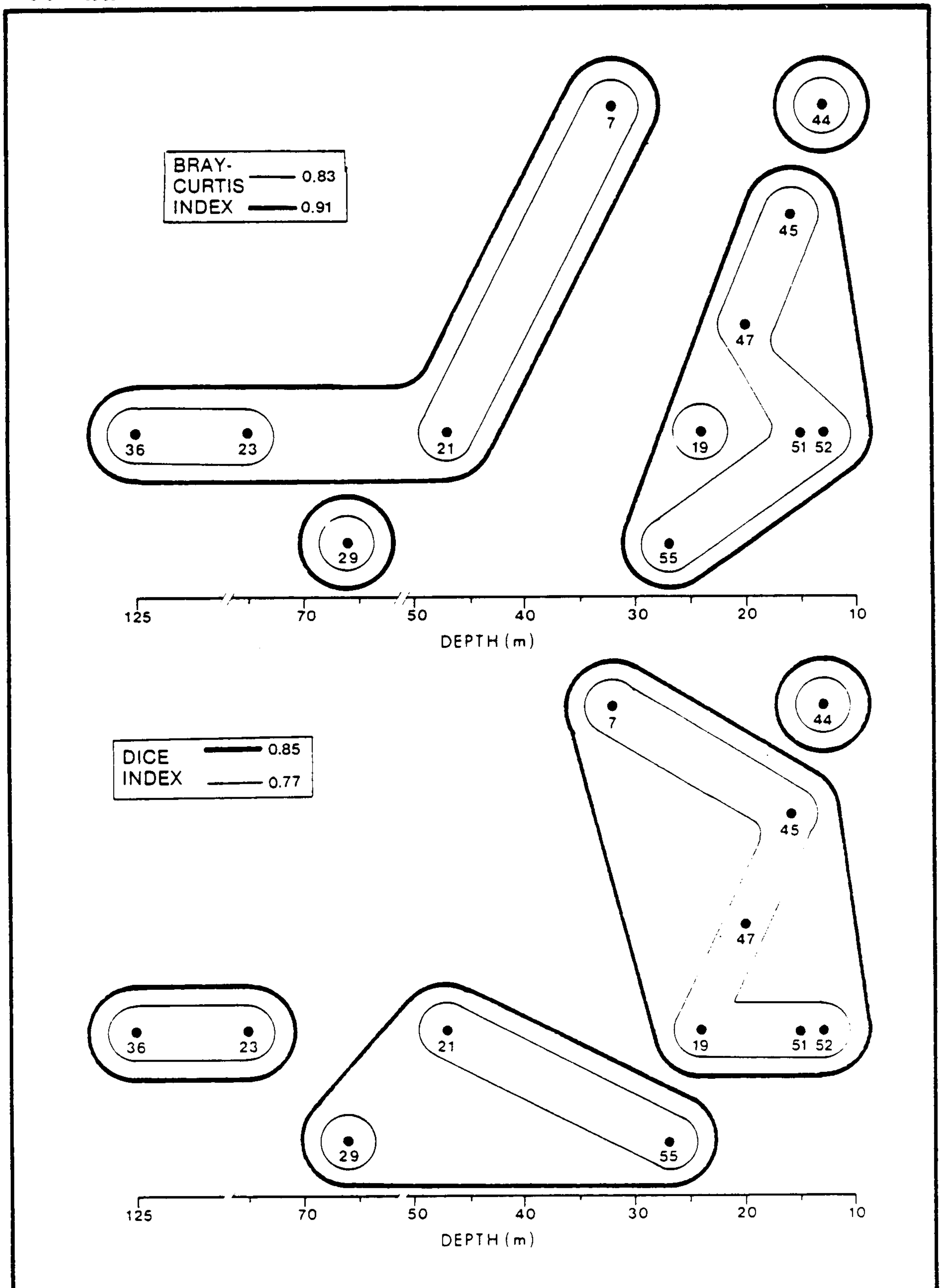

Figure 3.3-10 RESULTS OF CLUSTER ANALYSES OF TRAWL DATA, USING BRAY-CURTIS (TOP) AND DICE (BOTTOM) INDICES OF DISSIMILARITY TO GROUP STATIONS AT TWO LEVELS (INSET)

Underwater Television Results

Using the Bray-Curtis Index at the 0.95 level of dissimilarity, three major groups of stations emerged (Figure 3.3-11): a nearshore group, including all stations shallower than 32 m (Stations 7, 44, 45, 47, 19, 55, 51, and 52); an intermediate group of stations lying in depths of 47 to 74 m (Stations 21, 29, and 23); and Station 36 (125 m depth). Within the inshore group, Stations 51 and 52 were most similar to one another (0.208 level), and least like any of the other stations (0.931 level) (Figure 3.3-12). The inshore group of stations was further subdivided at the 0.83 level of dissimilarity into three sub-groups: Station 44 and Station 7 clustered together, as did Stations 51 and 52, and Stations 47, 19, 45, and 55 were split into a separate sub-group.

The Dice Index at the 0.76 level of dissimilarity (Figures 3.3-12 and 3.3-13) produced the same three inshore, intermediate, and offshore station groupings seen with the Bray-Curtis Index at the 0.83 level. Within the inshore group, Stations 51 and 47 were most similar (0.500 level) to one another, and Station 55 was least like the others (0.708 level). Within the intermediate group, Stations 29 and 23 were most similar to one another (0.417 level). The inshore stations could be further divided into two sub-groups at the 0.71 level.

3.3.5 DIVERSITY AND ABUNDANCE

Diversity and abundance are discussed in the following section. Emphasis is placed on major taxonomic groups and particularly abundant species or groups of species at each station using pooled information from various cruises. For information about less common species, or detailed cruise-by-cruise results, please refer to Appendices E, F, and G.

The Shannon-Weaver diversity index [H" using Napierian (base e) logs] and evenness (J') were calculated only for fishes collected with the trawl and for fishes identified in underwater television transects, since nearly all of the taxa in these data sets were identified to the species

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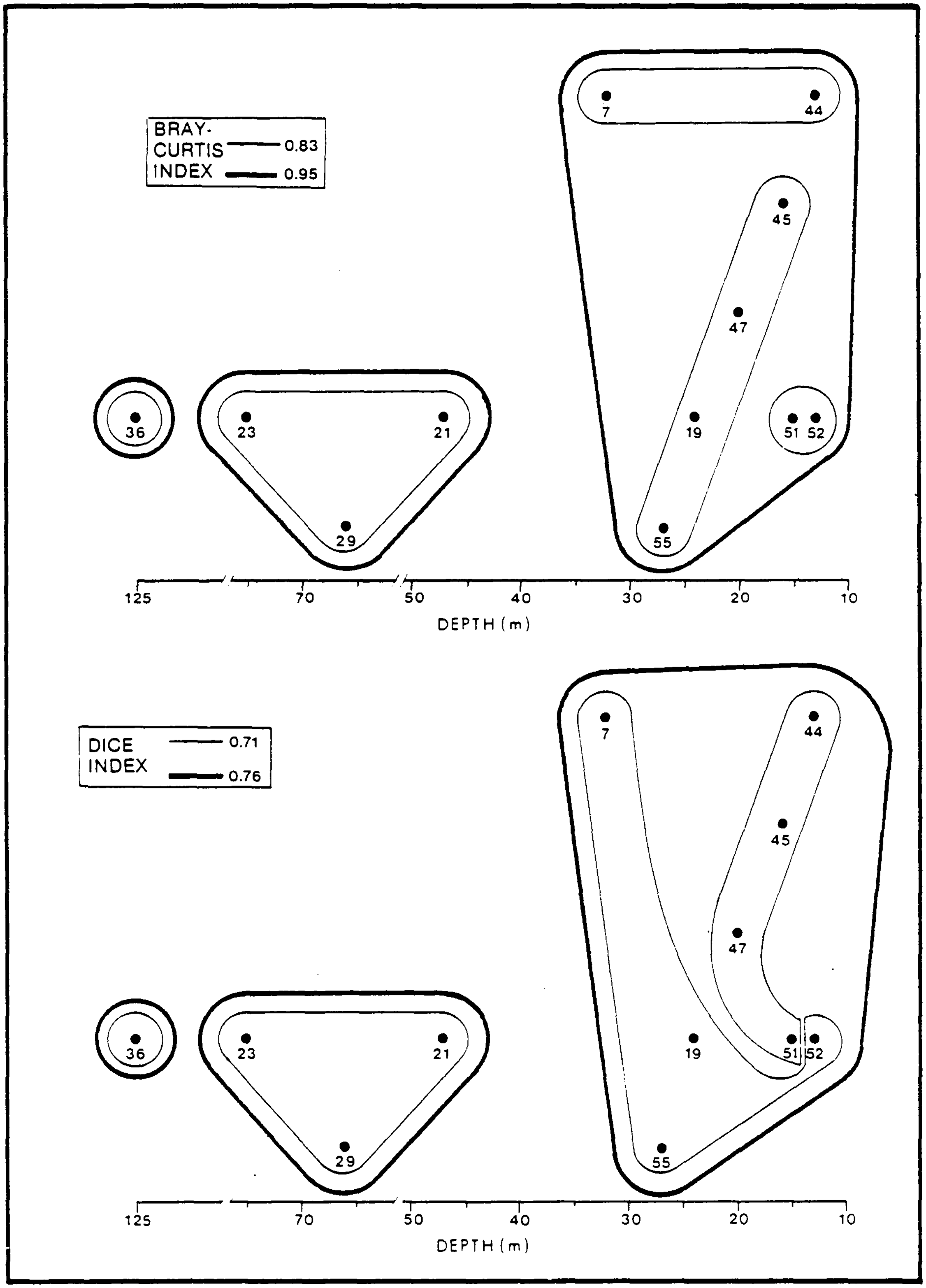

Figure 3.3-11 RESULTS OF CLUSTER ANALYSES OF UTV DATA FOR FISHES, USING BRAY-CURTIS (TOP) AND DICE (BOTTOM) INDICES OF DISSIMILARITY TO GROUP STATIONS AT TWO LEVELS (INSET)

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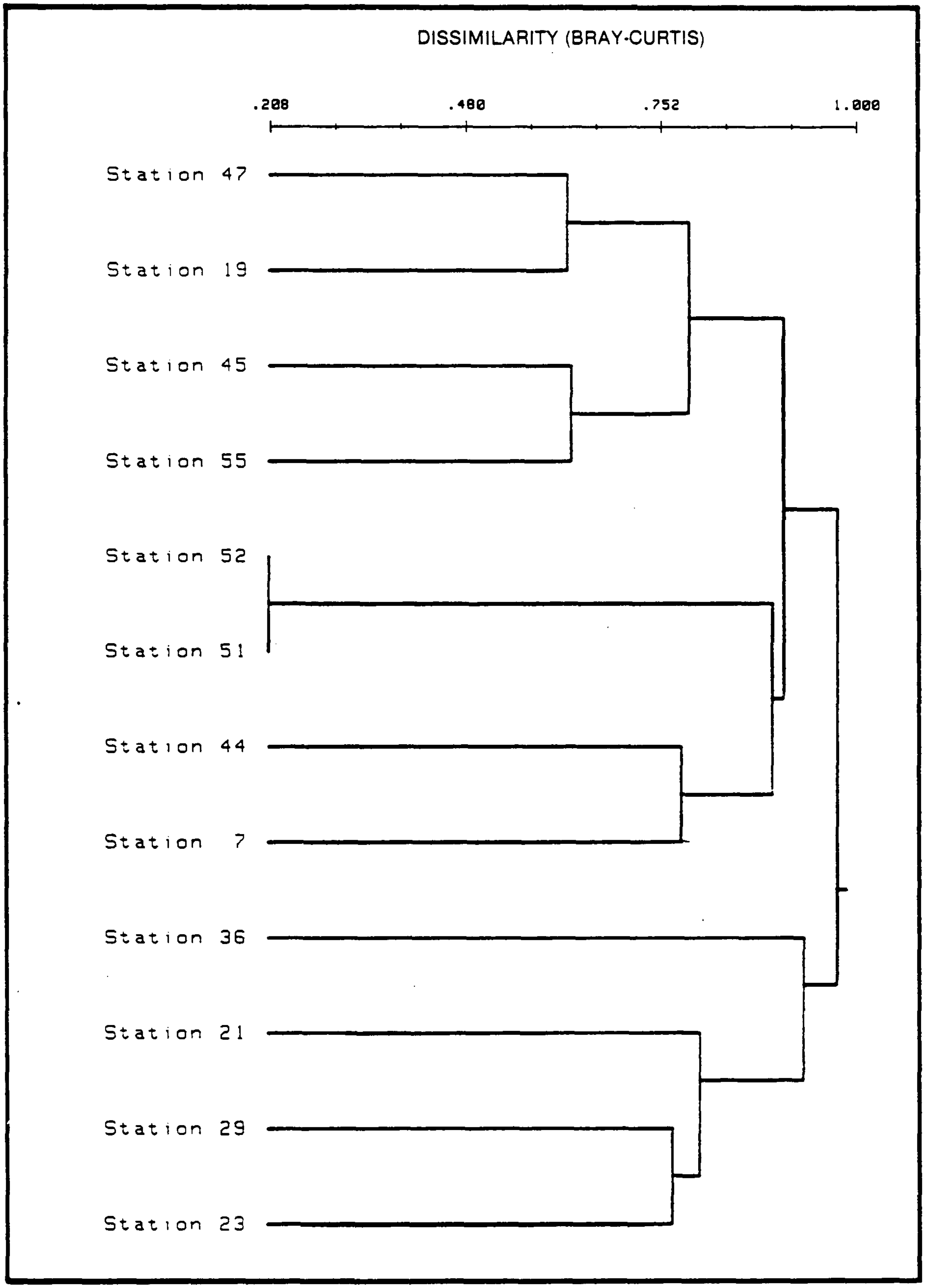

Figure 3.3-12 **DENDROGRAM OF STATION CLUSTERS BASED ON UTV DATA FOR FISHES, FOR ALL CRUISES TOGETHER, USING THE BRAY-CURTIS DISSIMILARITY**

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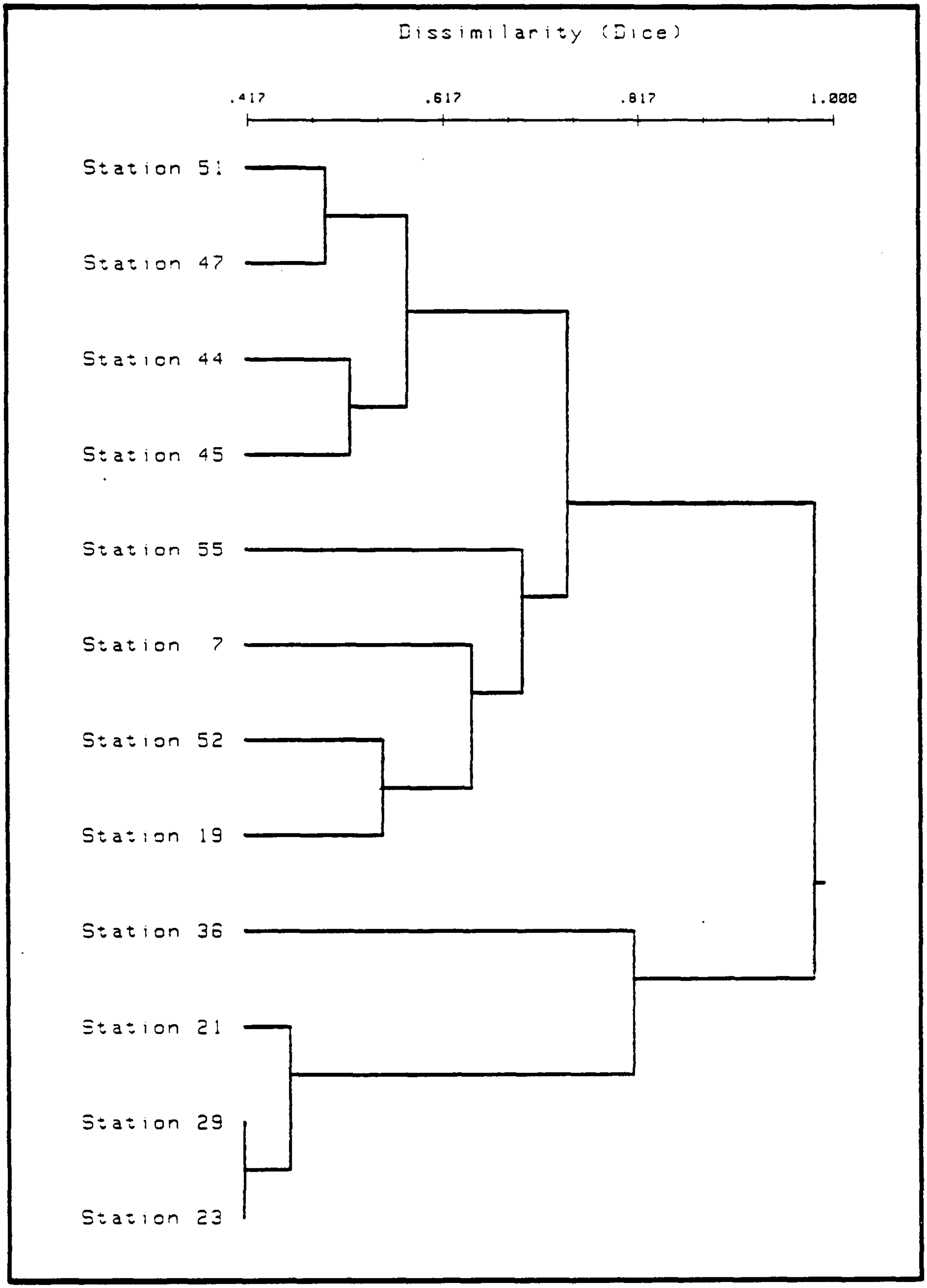


Figure 3.3-13 DENDROGRAM OF STATION CLUSTERS BASED ON UTV DATA FOR FISHES, FOR ALL CRUISES TOGETHER, USING THE DICE INDEX OF DISSIMILARITY

level. Diversity indices can be compared in a meaningful fashion only when applied to groups of organisms identified at equivalent taxonomic levels, and whose abundances have been reliably estimated. *Ad hoc* fusions of more than a few species into higher taxonomic levels (e.g., "demosponges" in the underwater television benthic invertebrate data set) disrupt the indices to such an extent as to make them useless, since the indices cannot differentiate between fusions of two species or two hundred species. Similarly, presence/absence data (dredge) or non-independent samples (time-lapse camera data) were unsuitable for H" or J' calculations.

Triangular Dredge Results

As described above, quantitative or statistical comparisons between stations in terms of numbers of taxa would be inappropriate. For most taxonomic groups, the species list was still increasing when sampling was discontinued.

At all stations together, 405 invertebrates and 92 plants were identified (Tables 3.2-4 and 3.2-5). The most important groups of invertebrates in terms of overall numbers of taxa were the brachyurans (71 taxa) gastropods (64 taxa), gorgonians and bivalves (50 and 51 taxa, respectively), corals (37 taxa), ophiuroids (27 taxa), anomurans (24 taxa), asteroids (20 taxa), carideans (19 taxa), and echinoids (17 taxa). Among plants, there were more than twice as many red algae identified (54 taxa) than browns (19 taxa) or greens (18 taxa). Many invertebrates and plants were collected from a number of stations. For example, 31 taxa were taken at five or more stations. These widespread species are listed in decreasing order of frequency of occurrence in Table 3.3-1.

Stations 52, 55, 7, 29, 23, and 36 were each sampled on four cruises (three replicate tows/cruise). About twice as many invertebrates were collected in shallow water at Stations 55, 52, and 7 (121, 109, and 96 taxa, respectively) than in deeper water at Stations 29, 23, or 36 (48,

Table 3.3-1 Benthic organisms collected by dredging at five or more stations.

Taxon	No. of Stations
ALCYONARIA	
Pterogorgia guadalupensis	6
Eunicea asperula	5
ZOANTHARIA	
Siderastrea siderea	7
Solenastrea hyades	6
Cladocora arbuscula	5
GASTROPODA	
Crepidula aculeata	6
BIVALVIA	
Spondylus americanus	6
CARIDEA	
Synalpheus townsendi	9
Synalpheus minus	5
ANOMURA	
Paguristes sericeus	8
Petrolisthes galathinus	7
BRACHYURA	
Mithrax pleuracanthus	8
Stenorhynchus seticornis	8
Podochela sidneyi	6
Macrocoeloma trispinosum	6
Pilumnus sayi	6
Dromidia antillensis	5
Pilumnus dasypodus	5
Paractaea rufopunctata nodosa	5
Mithrax acuticornis	5
STOMATOPODA	
Gonodactylus bredeni	9
ASTEROIDEA	
Astropecten duplicatus	7
Echinaster spinulosus	6
OPHIUROIDEA	
Ophiothrix angulata	10
Ophioderma brevispina	7
Ophiactis savignyi	6
ECHINOIDEA	
Clypeaster subdepressus	7
Lytechinus variegatus	6
Arbacea punctulata	6
ALGAE	
Dictyota bartayresii	5
Botryocladia occidentalis	5

59, and 53 taxa, respectively). This pattern was repeated with regard to plants; far more taxa were collected in shallow water at Stations 52, 7, and 55 (22, 25, 16, respectively) than at Stations 29, 23, or 36 (6, 4, and 0, respectively).

Stations 44, 51, 45, 47, and 19 were each sampled on two cruises (three replicate tows/cruise). Among these stations, Station 45 had the most diverse sample in terms of numbers of taxa identified (77 invertebrates, 22 plants), followed by Station 47 (56 invertebrates, 18 plants), Stations 19 (47 invertebrates, seven plants) and 44 (50 invertebrates, four plants), and Station 51 (25 invertebrates, eight plants).

A summary of numbers of taxa identified within major groups by station is provided in Figure 3.3-14, which also illustrates the relative proportions of those taxa that were identified only at a given station as a qualitative indication of local endemism. Of course, the more taxa seen within a major group at any one station, the more likely it would be that some of those taxa would be unique to that station. Quantitative comparisons should not, therefore, be made between stations with respect to percentages of unique taxa.

Nonetheless, some general trends were clearly visible. Various groups of organisms differed considerably in their habitat specificity. For example, although relatively few gorgonians and corals were collected by dredging at Station 36, nearly all of them were unique to that station. Bivalves and gastropods seem to have been quite station-specific; at more than half of the stations, approximately half the bivalves and gastropods present were collected only at those specific stations. Asteroids, echinoids, and ophiuroids were even more likely to be station-specific. At every station except for one, more than half of the taxa collected were unique to that station. On the other hand, anomuran and brachyuran crabs were much more cosmopolitan.

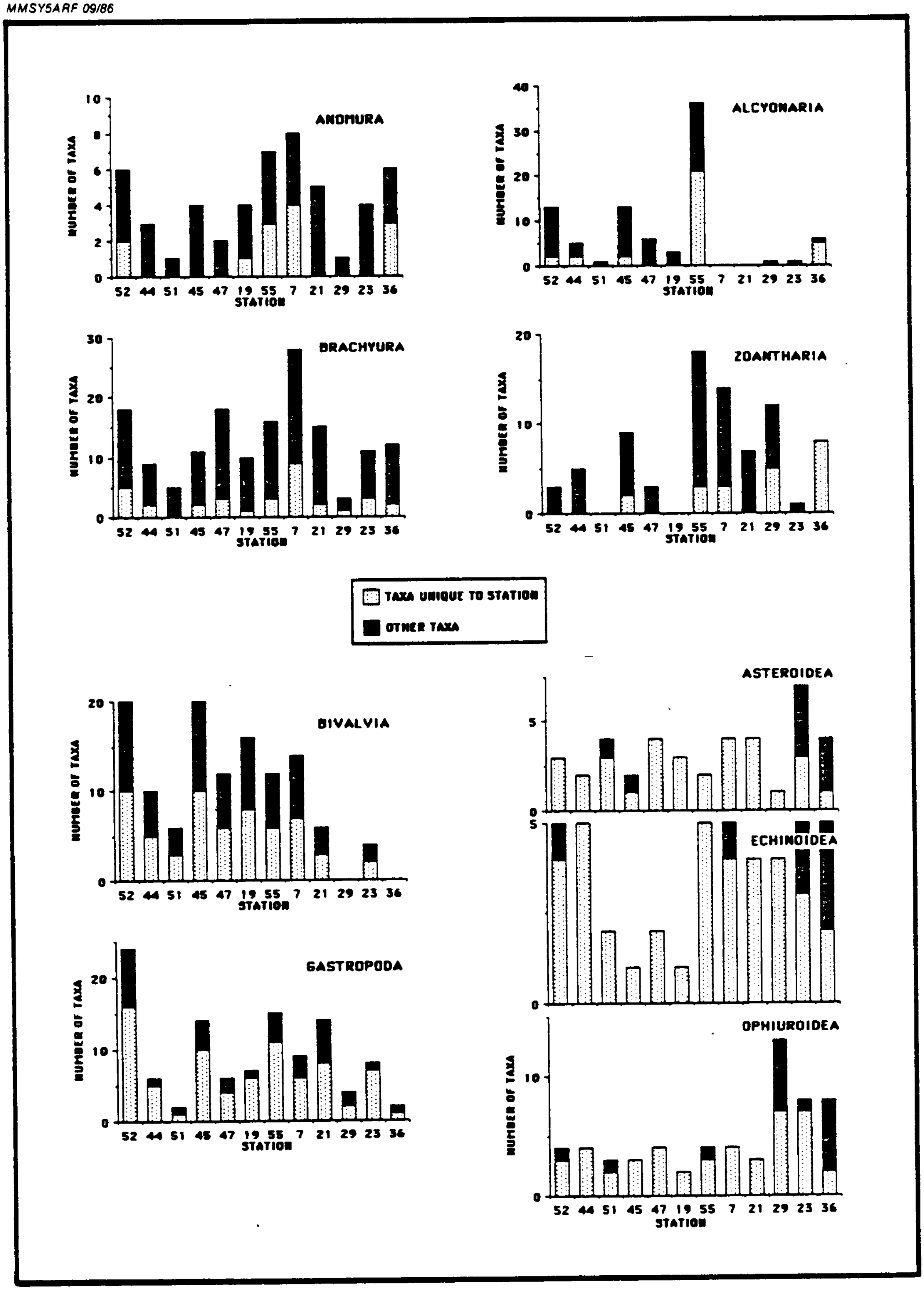


Figure 3.3-14 NUMBER OF INVERTEBRATE TAXA COLLECTED BY DREDGING AT MORE THAN ONE STATION (DARK STIPPLING) AND AT ONLY ONE STATION (LIGHT STIPPLING), BY STATION AND MAJOR TAXONOMIC GROUP

Otter Trawl Results

A summary of overall densities (all cruises together) at each station for fishes collected by trawling is provided in Table 3.2-6.

For all stations and cruises together, 166 fishes were identified, representing 49 families. All but 13 taxa were identified at the species level. The most abundant fishes overall were Serranus atrobranchus (5/ha); Serranus phoebe (4.6/ha); Synodus poeyi (4.2/ha); Haemulon plumieri (3.5/ha); Syacium papillosum and Lachnolaimus maximus (both 1.8/ha); Lactophrys quadricornis (1.7/ha); Prionotus stearnsi (1.3/ha); and Synodus intermedius, Chromis scotti, and Monacanthus ciliatus (all 1.2/ha).

High overall densities can arise from large collections at a few stations, rather than high densities throughout the study area. Several of the species mentioned above fit this description. For example, Prionotus stearnsi was taken only at one station; Serranus atrobranchus and Chromis scotti at two stations; Serranus phoebe at three stations; and Synodus poeyi and Lachnolaimus maximus at four stations.

Many fishes were collected from several stations. Fourteen species were taken at five or more stations; these are listed in decreasing order of frequency of occurrence in Table 3.3-2.

In terms of species richness, Station 21 had more fishes (69 taxa) identified in trawl hauls than did any other station. Other particularly diverse sites included Station 36 (42 taxa), Station 52 (38 taxa), and Station 23 (30 taxa).

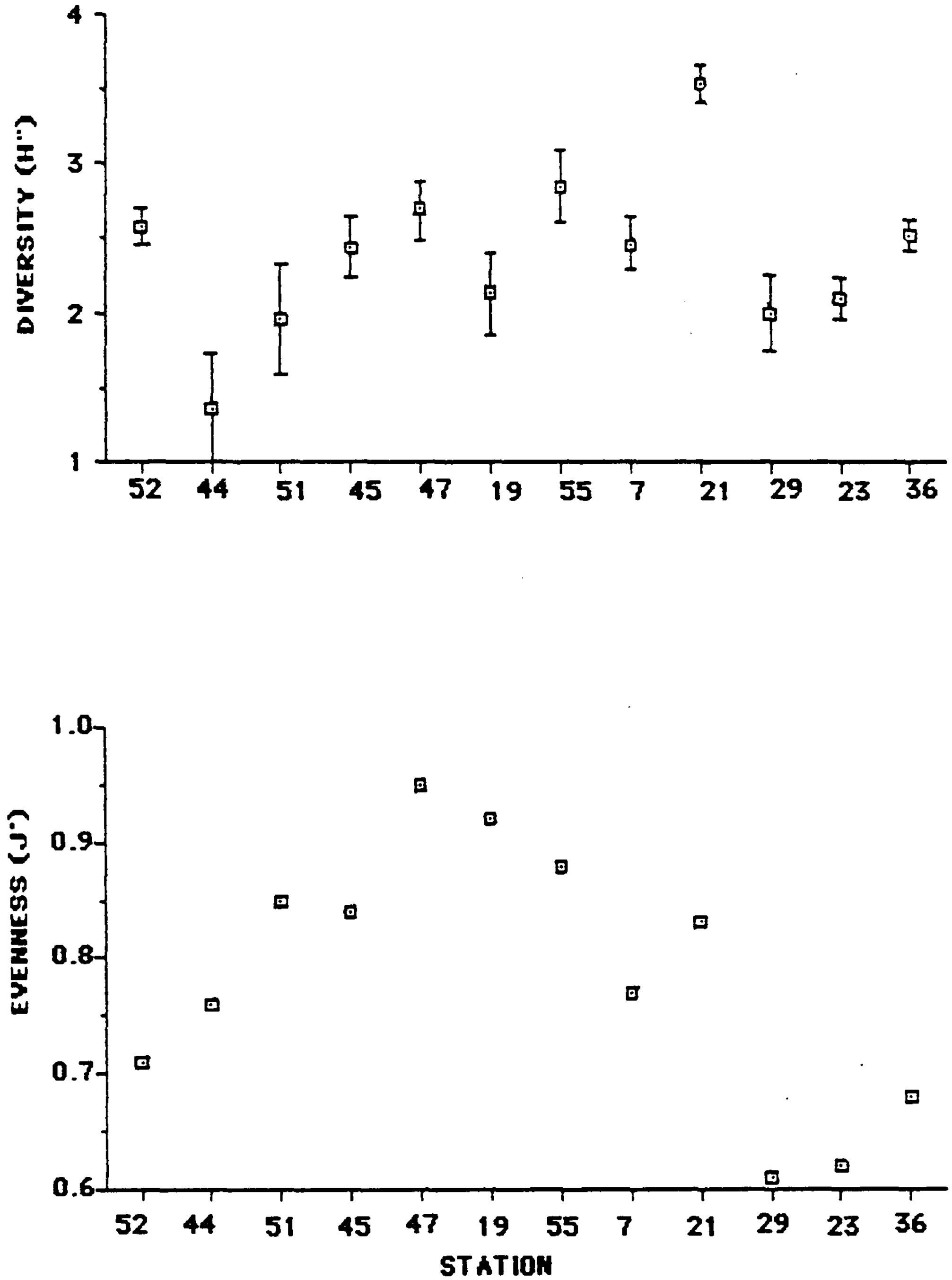
H" values for nearly all of the stations did not differ significantly ($p > 0.05$) from one another when comparing stations with equal numbers of tows (Table 3.3-3 and Figure 3.3-15). There was no statistically significant correlation between depth and diversity ($tau = 0.29$, $p > 0.20$), nor

Table 3.3-2 Fishes collected by trawling at five or more stations.

Taxon	No. of Stations
Synodus intermedius	10
Lactophrys quadricornis	8
Epinephelus morio	7
Diplectrum formosum	6
Monacanthus ciliatus	6
Haemulon plumieri	6
Haemulon aurolineatum	6
Gymnothorax nigromarginatus	5
Lutjanus synagris	5
Equetus lanceolatus	5
Syacium papillosum	5
Sphoeroides spengleri	5
Monacanthus hispidus	5
Synodus foetens	5

Table 3.3-3 Community summary statistics for fishes collected by trawling, for all cruises together, by station.

	Station											
	52	44	51	45	47	19	55	7	21	29	23	36
Diversity (H") :	2.58	1.36	1.96	2.44	2.69	2.13	2.85	2.46	3.53	2.00	2.10	2.53
Std. error of H" :	.056	.180	.188	.107	.095	.137	.116	.089	.062	.132	.074	.051
Evenness (J') :	.71	.76	.85	.84	.95	.92	.88	.77	.83	.61	.62	.68
Total abundance :	498	24	21	77	32	19	60	146	342	131	369	703
Total number of taxa :	38	6	10	18	17	10	25	24	69	26	30	42



NOTE: VERTICAL BARS REPRESENT 95% CONFIDENCE LIMITS FOR H"

Figure 3.3-15 DIVERSITY (H") AND EVENNESS (J') FOR FISHES COLLECTED BY TRAWLING, FOR ALL CRUISES TOGETHER, BY STATION between trawling effort and diversity (tau < 0.19, $p > 0.50$). Two stations stood out in terms of diversity: Station 44, with very low diversity, and Station 21, with very high diversity.

Only 24 specimens were collected at Station 44, representing six taxa. While the low H" (1.36) for Station 44 may, in part, reflect minimum sampling effort (only two tows), other stations with equivalent samples did not show such low diversity. For example, Stations 51, 45, 47, and 19 each had two tows. Of these, all had higher diversity, and every one of them but Station 51 differed significantly ($p < 0.05$) in diversity from Station 44. Evenness (J') at Station 44 was 0.76, lower than that of any of the other four stations. Furthermore, the mean number of specimens collected/tow at Station 44 the third lowest of any station. Compared to other stations, Station 44 was depauperate in terms of fishes.

By comparison, Station 21 was particularly rich in terms of fishes caught in trawls. The catch included 342 fishes, representing 69 taxa. The diversity index (3.53) for Station 21 was the highest recorded, and differed significantly from those of all other stations. Intense sampling may account in part for the plethora of fishes at Station 21, since seven tows were taken there. Nonetheless, this was not the entire cause of the high diversity observed at Station 21; the mean number of specimens collected/tow was 48.9, the third highest of any station. Diversity and evenness (J' = 0.83) for Station 21 may be compared directly only with that at Station 52, where seven tows were also taken. At Station 52, H" was 2.58, and J' was somewhat lower (0.71).

Although the three deepest stations (29, 23, and 36) were intermediate in diversity indices (2.00, 2.10, and 2.53, respectively) compared to other stations, the three lowest evenness indices (0.61, 0.62, 0.68) were recorded from these three stations. The low values reflect numerical dominance by a few extremely abundant taxa (e.g., *Chromis scotti*, *Chromis enchrysurus*, *Serranus phoebe*, *Serranus atrobranchus*, *Synodus poeyi*) collected at these stations. H" was significantly higher ($p < 0.05$) at Station 36 than at Station 23 or Station 29, and J' was higher at Station 36. However, somewhat more time was spent on the bottom trawling at Station 36 than at either of the other two stations (60 min vs. 45 and 50 min, respectively), where net damage sometimes reduced tow length.

Evenness was highest (0.95) at Station 47, where no one species was particularly abundant among the 32 specimens collected, even though 17 taxa were present.

An alternative measure of species diversity is based on rarefaction analysis (Sanders, 1968). Figure 3.3-16 illustrates a series of rarefaction curves for fishes collected by trawling, by station. The end points on each curve are determined by the entire catch for all cruises at that station, while intermediate points are calculated based on relative proportions of individuals of each species in the entire catch. The higher the curve is for any station, the greater its relative diversity. For example, the curve for Station 21 lies above that for Station 29; if a sample taken at both stations included an equal number of individuals (e.g., 90 individuals), one would expect that the sample from Station 21 would have approximately twice the number of species present than the sample from Station 29.

Rarefaction analyses produced visually separable curves for trawl data, dividing stations into approximately four sets. Station 21 was clearly more diverse than any other station. Stations 47 and 55 were somewhat less diverse than Station 21. Stations 52, 23, 29, 7, 51, 45, 19, and 36 were all approximately equal in diversity. Station 44 was clearly less diverse than any other station. These results are quite similar to those shown in Table 3.3-3 and Figure 3.3-15 for H" for the same samples.

Underwater Television Results

Thirty-three different taxa of benthic invertebrates and plants were counted to estimate their densities in underwater television transects

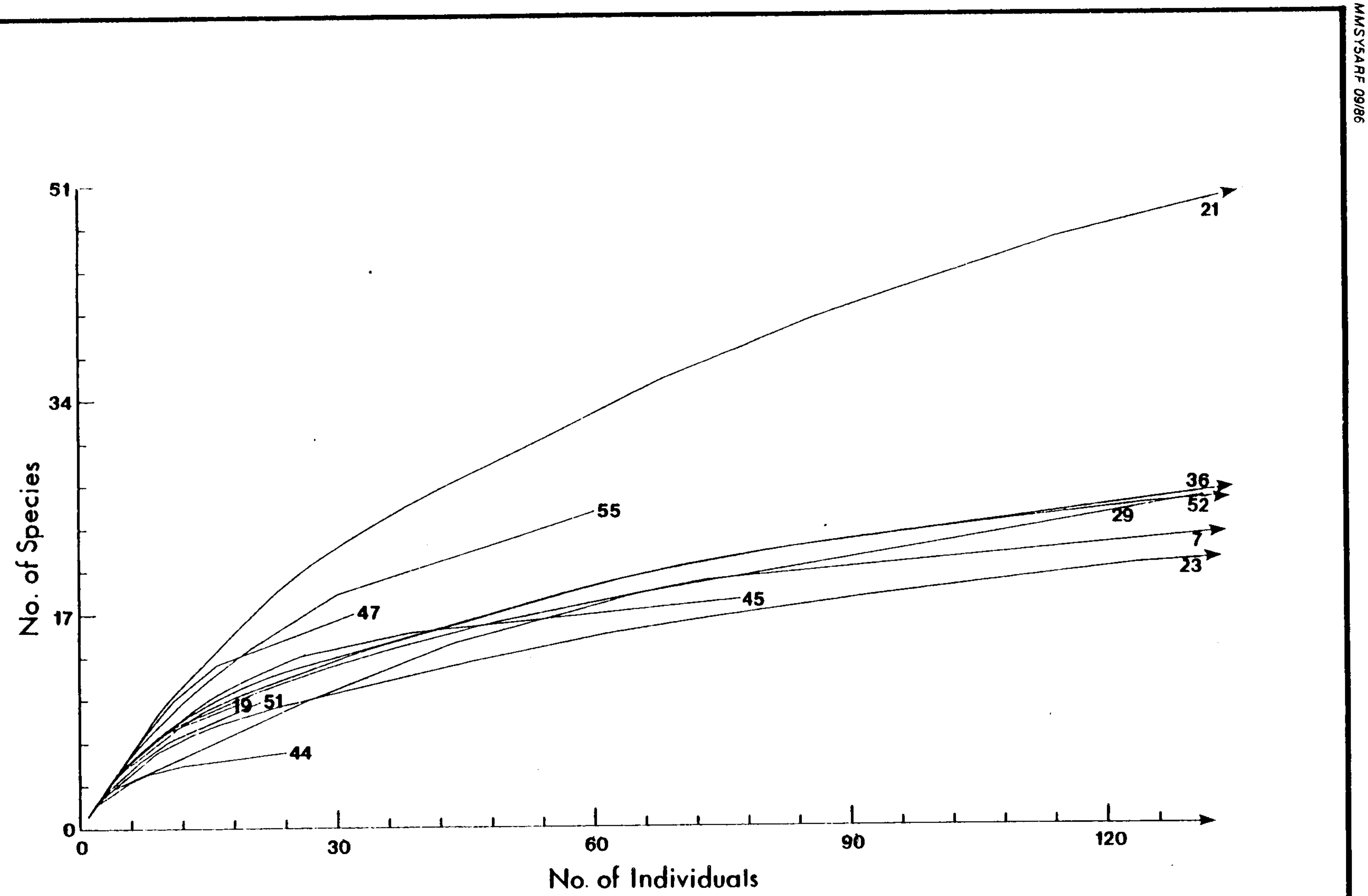


Figure 3.3-16 RESULTS OF RAREFACTION ANALYSIS FOR FISHES COLLECTED BY TRAWLING, BY STATION

(Table 3.2-1); the abundances of an additional seven taxa were estimated as percentage cover (rather than counts) (Table 3.2-2).

Overall, the most abundant counted benthic taxa were various unidentified gorgonians (23,620/ha); comatulid crinoids (2,432/ha); the gorgonian Ellisella (216/ha); the sponge Ircinia campana (67/ha); its congener, Ircinia strobilina (27/ha); various mellitid sand dollars (23/ha); hydroids (13/ha), and asteroids (6/ha).

Most of these taxa had very broad distributions, probably as a result of their including many species which could not be separated taxonomically through visual means. For example, unidentified asteroids and Ircinia campana were observed at 11 stations; Ircinia strobilina, unidentified gorgonians, and hydroids at 10 stations each; and mellitids at 8 stations. Ellisella and the comatulids were exceptions, being observed only at three and two stations each, respectively.

The most abundant organisms whose abundance was estimated as percentage cover were unidentified algae (13% for all stations and cruises together), demosponges (9%), the green alga Anadyomene menziesii (5%), and agariciid corals (3%). Demosponges were observed at every station, though their overall cover was less than 1% at Station 36, and only 2% at Station 44. Unidentified algae were recorded at nine stations, with the highest cover at Station 21 (38%), Station 51 (33%), Station 7 (27%), Station 55 (24%), and Station 52 (21%). Anadyomene was recorded only at Stations 29 and 23 (24% and 12% cover, respectively), and agariciids were abundant (18% cover) only at Station 29.

All of the 116 fishes seen with underwater television were counted, and nearly all of them were identified to the species level (Table 3.2-3). There were 34 families represented. Station 52 had the largest species list, with 40 taxa belonging to 18 different families. Stations 29, 21, 23, and 19 were also rich in numbers of taxa (37, 36, 35, and 33 taxa each, respectively).

The most abundant fishes, for all stations and cruises together, were Chromis enchrysurus (124/ha); Decapterus punctatus (118/ha) and unidentified congeners (24/ha); anthinid serranids of the genus Hemanthus (46/ha) and various unidentified forms (22/ha); Haemulon plumieri (43/ha); Chromis scotti (21/ha); Inermia vittata (16/ha); Epinephelus morio and Serranus phoebe, and Equetus lanceolatus (all 5/ha); and Chaetodon sedentarius (4/ha).

Many fishes had very widespread distributions. For example, 19 species were censused at five or more stations. A list of these fishes in decreasing order of frequency of occurrence is presented in Table 3.3-4.

A few fishes with high overall abundances were observed at only a few stations, though in great numbers. For example, Hemanthus was reported only from Station 29. Chromis enchrysurus was censused at three sites (Stations 21, 29, and 33); and Chromis scotti only at Station 29; Inermia vittata only at Stations 29 and 23. Conversely, some fishes with low overall distributions were widely distributed.

3.3.6 STATISTICAL COMPARISONS BETWEEN STATIONS FOR SELECTED SPECIES

Rather different patterns of diversity and evenness characterized the underwater television fish data versus the trawl data (Table 3.3-5, Figure 3.3-17). At 10 out of 12 stations, H" and J' for trawl data were higher than H" or J' for underwater television data, even though the underwater television surveys covered a much larger area and a broader range of habitat types. For trawls, H" ranged from 1.36 to 3.53; J' ranged from 0.61 to 0.95. For underwater television, H" ranged from 0.90 to 2.70, and J' ranged from 0.25 to 0.86.

The H" and J' values for underwater television were lower than those for trawl samples, probably as a result of species fusions into higher taxonomic categories in underwater television data. Despite this factor, the underwater television may actually have viewed a greater number of

Table 3.3-4 Fishes observed with UTV at five or more stations.

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

Table 3.3-5 Community summary statistics for fishes seen on UTV, for all cruises together, by station.

	Station											
	52	44	51	45	47	19	55	7	21	29	23	36
Diversity (H") :	1.49	1.96	1.11	2.70	1.94	2.40	2.25	1.84	1.62	1.75	.90	1.13
Std. error of H" :	.083	.155	.094	.141	.182	.148	.149	.113	.077	.034	.038	.116
Evenness (J') :	.40	.72	.34	.86	.73	.69	.83	.64	.45	.49	.25	.37
Overall density (no./ha) :	419	57	307	37	35	94	30	99	372	1232	1224	174
Total number of taxa :	40	15	26	23	14	33	15	18	36	37	35	21

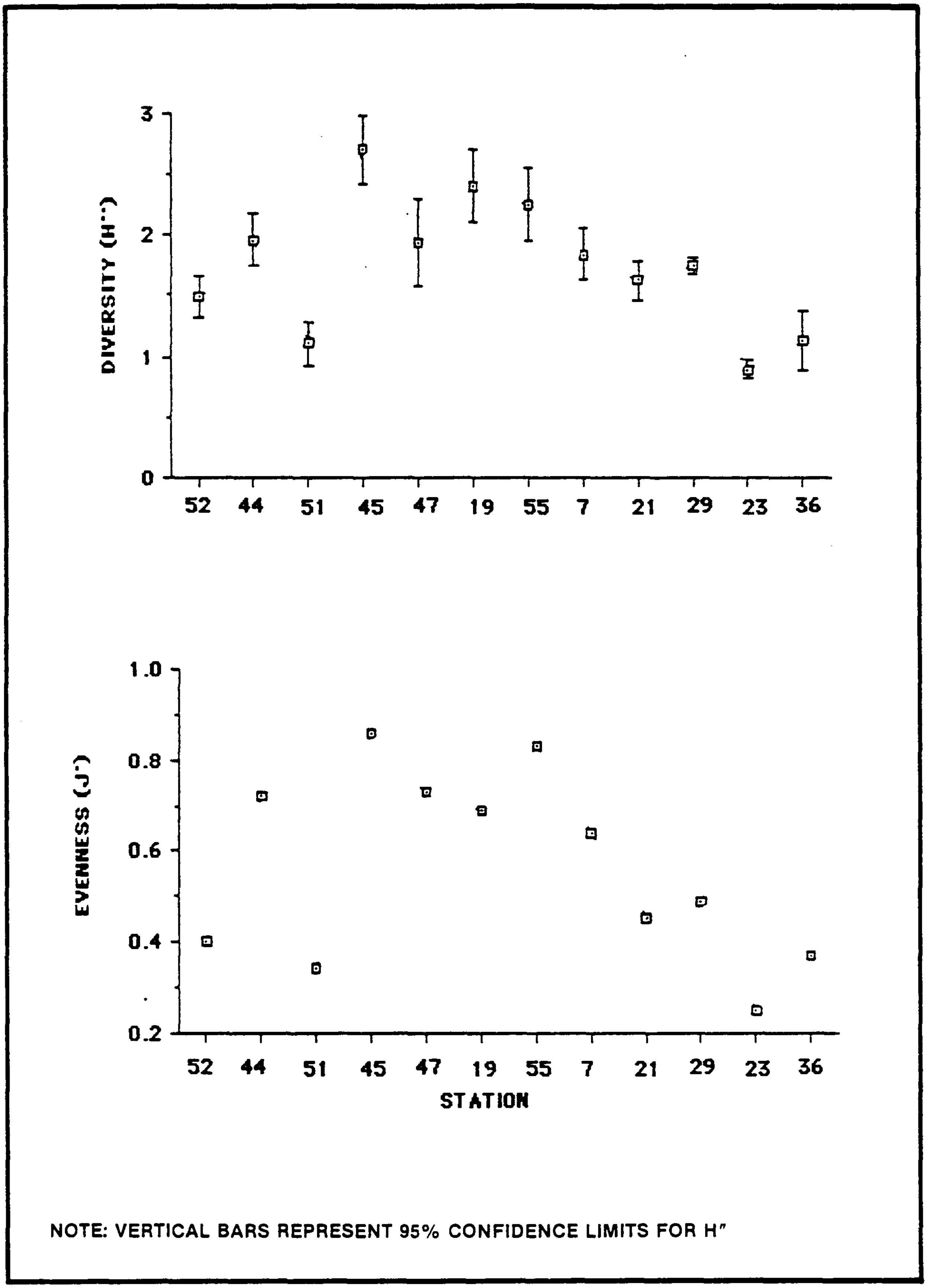


Figure 3.3-17 DIVERSITY (H") AND EVENNESS (J') FOR FISHES SURVEYED WITH UTV, FOR ALL CRUISES TOGETHER, BY STATION

species than the trawl caught. The trawl took fishes close to the bottom in relatively unobstructed areas, whereas the underwater television censused fishes on the bottom, those higher in the water column, and among outcrops and other rough terrain. The underwater television also recorded some fish that were able to avoid the trawl.

As for the trawl, statistically valid comparisons between stations can be made only for stations with approximately equal sampling effort. Stations differed widely in total area surveyed, thus making it difficult to compare them except within groups of similar area. Furthermore, there was no statistically significant correlation between area surveyed and diversity (tau = -0.26, $p > 0.20$), nor between diversity and depth (tau = -0.29, $p > 0.20$). For comparisons, stations were divided into the following groups, within each of which stations did not differ in area surveyed by more than one ha:

Area (ha):	14.7	23.5-24	27.7-27.8	29.5-29.8	34.8	39.3	54.8-55.5	67.3
Stations:	44	55, 51	45, 19	7, 47	36	52	23, 21	29

Stations 55 and 51 differed significantly ($p < 0.05$) in diversity, based on underwater television data. Station 51 had the second-lowest H" and J' values (1.11 and 0.34, respectively), whereas Station 55 had the third highest H" (2.25) and the second highest J' (0.83) values. Although Station 51 had 26 taxa as compared to 15 taxa at Station 55, overall abundance at Station 51 was much higher (307/ha) than at Station 55 (30/ha); the high ratio of numbers of taxa to numbers of individuals at Station 55 explains its high diversity and evenness indices.

The differences in diversity and evenness between Stations 51 and 55 can probably be attributed to differences in bottom types at the two stations. Both stations had a lot of sand, relieved by occasional dense patches of gorgonians (see Subsection 3.2.1, Station Descriptions). However, Station 55 apparently had a much more complex assemblage of large benthic organisms capable of attracting and sheltering fishes. For example, at Station 51, sponges accounted for 6% cover, and attached algae for another 33%. No scleractinian corals were taken by the dredge. At Station 55, sponges mixed with scleractinian corals covered 17% of the bottom, and 18 species of corals were collected by dredging. Gorgonians at Station 55 were the third most abundant (54,215/ha) observed during Years 4 and 5, about 77% denser than those at Station 51 (30,537/ha).

Diversity did not differ significantly between Stations 45 and 19, although H" values were higher at Station 45 (2.70) and Station 19 (2.40) than at other stations. Evenness at Station 45 (0.86) was the highest recorded; J' at Station 19 was moderate (0.69). At Station 45, 23 taxa were observed, though overall density (37/ha) was the third lowest of any station. At Station 19, 33 taxa were present; overall density was 94/ha.

The high diversity recorded for fishes at Station 45 may have been, in part, due to the relief provided by extremely dense gorgonian beds. Gorgonians had a density of 156,843/ha at Station 45, greater than at any other station. This argument cannot be made for Station 19, however, where gorgonian abundance was much lower (707/ha), and sponge cover was also minimal (3.4%).

Station 7 and Station 47 did not differ significantly in diversity (H" = 1.84 and 1.94, respectively), although evenness at Station 47 was higher (J' = 0.73) than at Station 7 (0.64), probably as a result of dominance by several abundant species such as *Syacium papillosum* and *Synodus poeyi* at Station 7.

Stations 23 and 21 differed significantly in diversity ($p < 0.05$). Station 23 had the lowest diversity (H" = 0.90) and evenness (J' = 0.25) of any station, while Station 21 had moderate diversity (1.62) and somewhat higher evenness (0.45). At Station 23, overall density was the highest recorded (1,232/ha), but only 35 taxa were observed. By contrast, overall density at Station 21 was a third of that (372/ha), but more taxa (36) were observed.

Although the amount of area surveyed differed between Station 29 and 23--meaning that quantitative comparisons were probably inappropriate--there were conspicuous differences between their patterns of diversity and evenness. H" and J' were much lower at Station 23 than at Station 29, despite their physical proximity to one another.

Both Stations 29 and 23 had very similar overall fish densities (1,232 and 1,224/ha, respectively) and numbers of taxa (37 and 35, respectively). However, underwater television samples from Station 23 included only two species whose densities exceeded 25/ha: *Decapterus punctatus* (912/ha) and *Chromis enchrysurus* (221/ha). Underwater television samples from Station 29 included a more even distribution of species with high densities, such as *Hemanthus* (295/ha); *Chromis enchrysurus* (518/ha); *Chromis scotti* (133/ha); and *Inermia vittata* (97/ha); unidentified anthinids (68/ha); etc. H" and J' reflected these differences with higher values for Station 29.

The higher fish diversity and evenness at Station 29 probably reflects its greater physical relief. Station 29 had a rough bottom made up of *Agaricia* and associated organisms, while Station 23 was a relatively smooth pavement of fused algal nodules. The complexity of the bottom at Station 29 would provide many more kinds and sizes of hiding places for fish than would the comparatively uniform bottom at Station 23. A similar argument can be made for the differences in H" for fishes between Station 21 and Station 23. The bottom at Station 21 was dominated by sponges (23% cover vs. 8% cover at Station 23), and was visually much more complex than Station 23.

An alternative presentation of diversity of fishes observed with the underwater television is provided as a set of rarefaction curves in Figure 3.3-18. Rarefaction analyses indicated that Stations 19 and 45 had the greatest diversity; Stations 55, 44, 47, 7, 52, 21, 51, 29, and 36 were similar in diversity; and Station 23 had the lowest diversity. These results closely paralleled the distribution of H" by station for the same underwater television samples.

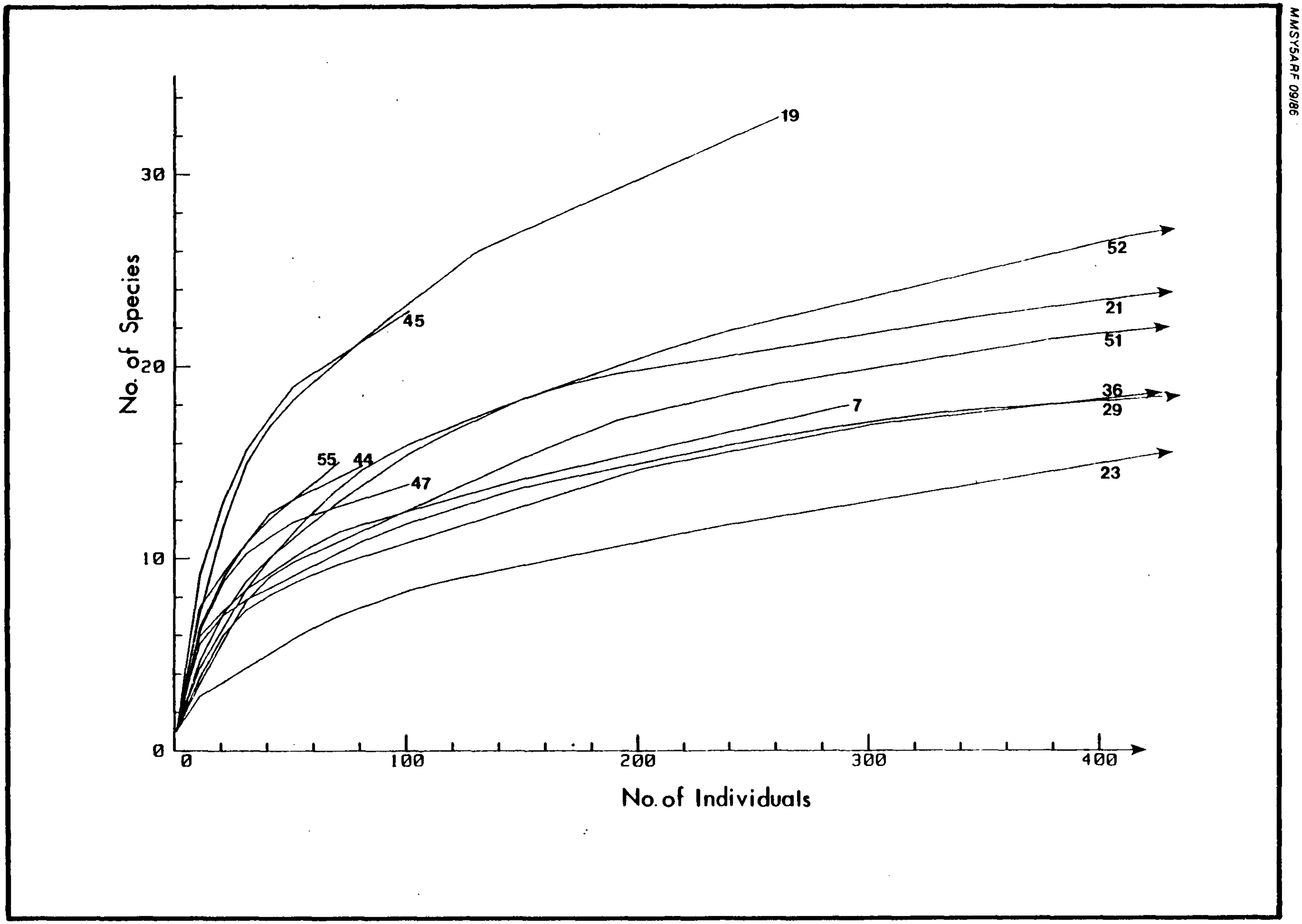


Figure 3.3-18 RESULTS OF RAREFACTION ANALYSIS FOR FISHES CENSUSED WITH UTV, BY STATION

3.3.7 SETTLING PLATE RESULTS

Introduction

Settling plates were installed and collected at Stations 52, 21, 29, 23, and 36 during both Year 4 (Cruises 1 to 4) and Year 5 (Cruises 5 to 8); and at Stations 44, 55, and 7 only during Year 5. The schedule included exposure periods of 3, 6, 9, and 12 months, although not every station had plates exposed for every time period. For example, the longest exposure period possible was 9 months for plates installed at the beginning of Year 5.

Both tile (ceramic) and steel plates were installed during Year 4. No steel plates were installed during Year 5, because they proved unsatisfactory during Year 4 due to the flaking of rusty surfaces (Danek et al., 1985). Consequently, only the results from tile plates are described herein.

At each station, tile plates were mounted vertically in racks 30 cm above the substrate. These are described below as "standard" plates. At Stations 52, 44, 23, and 36, another rack held a small number of tile plates vertically 1.5 m above the substrate to assess the effect of increased elevation from the bottom. These are described below as "1.5-m plates." At Stations 52, 23, and 36, an additional rack held a few tile plates horizontally 30 cm above the substrate to examine the effect of plate orientation. These are described below as "horizontal plates."

Seventy-four sets of plates were collected during Years 4 and 5, with each set representing one combination of station x exposure period x plate type. Most sets included five replicate plates, each of which was accompanied by a bag of material that was washed off the plates during preservation (see Subsection 2.2.4, Methods, Settling Plates). In some sets, fewer than five plates and bags were collected. Losses were due to breakage, e.g., by jewfish (see Subsection 2.2.5, Time-Lapse Camera). There were 656 samples (328 plates + 328 bags) altogether.

For the front (corrugated) surface of each plate, three different measurements were made: (1) percentage cover by taxon, (2) wet weight by taxon, and (3) number of individuals by taxon. For each bag, two types of measurements were made: (1) wet weight by taxon, and (2) number of individuals by taxon.

This report briefly summarizes results by station, exposure period, plate type, and measurement type. Major taxa within each sample set are highlighted. However, no attempt is made to describe the data set fully, since this would require far more space than is available in this report. The entire data set is available in standard format from NODC.

Stations are ordered in figures and tables by increasing depth:

Station:	52	44	55	7	21	29	23	36
Depth (m):	13	16	27	32	47	66	75	125

Standard 3-Month Plates

Exposure periods and stations where standard 3-month plates retrieved were as follows:

Cruise:	1	2	3	4	5	6	7	8
Month/Year:	12/83	3/84	5/84	8/84	12/84	3/85	6-7/85	12/85
Station								
52,29,23	-C1-C2-							
52,29,23		-C2-C3-						
52,21,29,36			-C3-C4-					
52,21,36				-C4-C5-				
52,21,29,23,36,55,7					-C5-C6-			
52,21,23,36,7						-C6-C7-		
52,44,7							-C7-C8-	

A summary of values for percentage cover, wet weight, and density (numbers of individuals) on standard 3-month plates and in bags is provided in Table 3.3-6. Figure 3.3-19 illustrates percentage cover on standard plates by dominant taxa. Figure 3.3-20 shows wet weight. Figure 3.3-21 portrays density.

Table 3.3-6 includes only those taxa accounting for at least 1% cover, one individual/plate or bag, or 0.1 g wet weight/plate or bag. Sets not meeting at least one of these criteria after rounding are not shown in the table. Dots indicate which (if any) criteria were not met. Means were calculated by summing values for sets together and dividing by the number of sampling periods, without using cutoffs. Cutoffs for figures were 1% cover, or three individuals/plate or bag, or one gram wet weight/plate or bag.

There was a pronounced decrease in percentage cover, wet weight, and numbers of individuals by settling organisms with increasing station depth. The shallowest stations, Stations 52 and 44, had the highest values. Cover at these stations averaged 41 and 50%, respectively; mean wet weight, 13.8 and 40.8 g; and density, 94 and 108 individuals/plate.

Table 3.3-6. Mean wet weights, densities, and cover of organisms on sets of plates and in bags, by station, exposure period, and plate type. Dashes (-) indicate mean weights, densities, or cover less than 0.1 gram, one individual, or one percent (respectively) per plate. Period means (3-month, 6-month, etc.) are averages of set means. Exposure periods are shown by cruise number (e.g., C1-C2 denotes plates installed on Cruise 1 and collected on Cruise 2), month, and year.

Station, Plate Type & Exposure	Plates			Bags	
	Weight (g/plate)	Density (no./plate)	Cover (%)	Weight (g/bag)	Density (no./bag)
STATION 52					
Standard, 3 Months					
C1-C2, 12/83-3/84	2.9	115	19	0.5	758
C2-C3, 3/84-5/84	12.6	200	68	0.4	1271
C3-C4, 5/84-8/84	10.0	69	41	0.7	340
C4-C5, 8/84-12/84	49.4	163	52	0.7	174
C5-C6, 12/84-3/85	5.8	43	26	0.1	378
C6-C7, 3/85-6&7/85	1.3	59	60	-	136
C7-C8, 6&7/85-9/85	14.5	8	23	-	32
3-month mean:	13.8	94	41	0.3	441
Standard, 6 Months					
C1-C3, 12/83-5/84	23.8	290	71	1.0	931
C3-C5, 5/84-12/84	17.8	134	55	1.9	285
C5-C7, 12/84-6&7/85	174.1	119	66	-	171
6-month mean:	71.9	181	64	1.0	462
Standard, 9 Months					
C1-C4, 12/83-8/84	119.5	304	59	0.7	212
C4-C7, 8/84-6&7/85	273.6	146	46	0.7	218
9-month mean:	196.5	225	53	0.7	215
Steel, 3 Months					
C1-C2, 12/83-3/84	1.4	54	8	0.3	292
C2-C3, 3/84-5/84	6.9	100	28	0.4	1254
C3-C4, 5/84-8/84	6.0	51	16	0.3	246
C4-C5, 8/84-12/84	10.1	84	13	0.4	176
3-month mean:	6.1	72	17	0.4	492
1.5-m, 12 Months					
C1-C5, 12/83-12/84	334.8	349	79	9.8	686
12-month mean:	334.8	349	79	9.8	686

Table 3.3-6 (con't)

Station, Plate Type & Exposure	Plates			Bags	
	Weight (g/plate)	Density (no./plate)	Cover (%)	Weight (g/bag)	Density (no./bag)
STATION 52 cont'd.					
Horiz., 12 Months					
C1-C5, 12/83-12/84	289.7	270	71	2.9	1500
12-month mean:	289.7	270	71	2.9	1500
STATION 44					
Standard, 3 Months					
C7-C8, 6&7/85-9/85	40.8	108	50	-	542
3-month mean:	40.8	108	50	-	542
Standard, 9 Months					
C5-C8, 12/84-9/85	252.8	303	71	1.4	127
9-month mean:	252.8	303	71	1.4	127
1.5-m, 3 Months					
C7-C8, 6&7/85-9/85	83.3	410	58.8	2.1	788
3-month mean:	83.3	410	58.8	2.1	788
STATION 55					
Standard, 3 Months					
C5-C6, 12/84-3/85	7.6	82	18	0.2	64
3-month mean:	7.6	82	18	0.2	64
Standard, 6 Months					
C6-C8, 3/85-9/85	7.7	34	8	-	27
6-month mean:	7.7	34	8	-	27
STATION 7					
Standard, 3 Months					
C5-C6, 12/84-3/85	2.6	19	11	0.1	99
C6-C7, 3/85-6&7/85	1.7	72	20	0.7	39
C7-C8, 6&7/85-9/85	0.6	20	7	0.2	48
3-month mean:	1.6	37	13	0.3	62

Table 3.3-6 (con't)

Station, Plate Type & Exposure	Plates			Bags	
	Weight (g/plate)	Density (no./plate)	Cover (%)	Weight (g/bag)	Density (no./bag)
STATION 7 cont'd.					
Standard, 6 Months					
C5-C7, 12/84-6&7/85	9.2	50	28	0.3	50
6-month mean:	9.2	50	28	0.3	50
Standard, 9 Months					
C5-C8, 12/84-9/85	67.9	201	58	-	69
9-month mean:	67.9	201	58	-	69
STATION 21					
Standard, 3 Months					
C3-C4, 5/84-8/84	0.7	51	9	0.4	7
C4-C5, 8/84-12/84	1.4	50	10	-	3
C5-C6, 12/84-3/85	0.5	4	8	-	2
C6-C7, 3/85-6&7/85	0.1	2	9	-	-
3-month mean:	0.7	27	9	0.1	3
Standard, 6 Months					
C3-C5, 5/84-12/84	3.8	158	23	1.2	15
C5-C7, 12/84-6&7/85	4.2	19	43	-	1
6-month mean:	4.0	88	33	0.6	8
Standard, 9 Months					
C3-C6, 5/84-3/85	20.3	57	43	0.1	6
C4-C7, 8/84-6&7/85	45.2	57	66	-	5
9-month mean:	32.8	57	54	-	5
Standard, 12 Months					
C3-C7, 5/84-6&7/85	50.1	67	71	-	1
12-month mean:	50.1	67	71	-	1
Steel, 3 Months					
C3-C4, 5/84-8/84	0.5	7	3	0.1	16
C4-C5, 8/84-12/84	0.3	16	6	1.2	-
3-month mean:	0.4	12	5	0.7	8

Table 3.3-6 (con't)

Station, Plate Type & Exposure	Plates			Bags	
	Weight (g/plate)	Density (no./plate)	Cover (%)	Weight (g/bag)	Density (no./bag)
STATION 29					
Standard, 3 Months					
C1-C2, 12/83-3/84	-	8	-	-	2
C2-C3, 3/84-5/84	-	16	-	-	7
C3-C4, 5/84-8/84	1.0	41	16	0.3	26
C5-C6, 12/84-3/85	-	21	3	-	-
3-month mean:	0.3	21	5	0.1	9
Standard, 6 Months					
C1-C3, 12/83-5/84	0.3	36	3	0.1	38
6-month mean:	0.3	36	3	0.1	38
Standard, 9 Months					
C1-C4, 12/83-8/84	7.4	55	34	0.7	29
9-month mean:	7.4	55	34	0.7	29
Steel, 3 Months					
C2-C3, 3/84-5/84	-	-	-	-	1
C3-C4, 5/84-8/84	0.3	25	2	0.7	57
3-month mean:	0.1	8	1	0.2	19
STATION 23					
Standard, 3 Months					
C1-C2, 12/83-3/84	0.1	13	1	-	9
C2-C3, 3/84-5/84	-	7	-	-	13
C5-C6, 12/84-3/85	-	18	1	-	1
C6-C7, 3/85-6&7/85	0.3	25	2	-	4
3-month mean:	0.1	16	1	-	7
Standard, 6 Months					
C1-C3, 12/83-5/84	0.3	38	5	-	21
C5-C7, 12/84-6&7/85	2.0	74	15	-	22
6-month mean:	1.2	56	10	-	22
Standard, 9 Months					
C1-C4, 12/83-8/84	1.0	45	11	-	-
9-month mean:	1.0	45	11	-	-

Table 3.3-6 (con't)

Station, Plate Type & Exposure	Plates			Bags	
	Weight (g/plate)	Density (no./plate)	Cover (%)	Weight (g/bag)	Density (no./bag)
STATION 23 cont'd.					
Steel, 3 Months					
C1-C2, 12/83-3/84	-	1	-	-	-
C2-C3, 3/84-5/84	-	1	-	0.1	3
3-month mean:	-	1	-	0.1	2
1.5-m, 9 Months					
C1-C4, 12/83-8/84	1.1	-	12	-	-
9-month mean:	1.1	-	12	-	-
Horiz., 9 Months					
C1-C4, 12/83-8/84	0.8	41	6	-	-
9-month mean:	0.8	41	6	.	.
STATION 36					
Standard, 3 Months					
C3-C4, 5/84-8/84	0.1	5	1	-	-
C5-C6, 12/84-3/85	-	-	-	-	1
C6-C7, 3/85-6&7/85	-	1	-	-	-
3-month mean:	0.1	1	-	-	-
Standard, 6 Months					
C1-C3, 12/83-5/84	0.1	6	-	0.1	4
C3-C5, 5/84-12/84	0.4	5	-	-	1
C5-C7, 12/84-6&7/85	0.6	6	1	-	1
6-month mean:	0.4	6	-	-	2
Standard, 9 Months					
C1-C4, 12/83-8/84	0.8	14	2	-	-
C4-C7, 8/84-6&7/85	-	13	3	-	1
9-month mean:	0.4	13	3	-	1
Standard, 12 Months					
C3-C7, 5/84-6&7/85	1.2	23	3	-	8
12-month mean:	1.2	23	3	-	8

Table 3.3-6 (con't)

Station, Plate Type & Exposure	Plates			Bags	
	Weight (g/plate)	Density (no./plate)	Cover (%)	Weight (g/bag)	Density (no./bag)
STATION 36 cont'd.					
Steel, 6 Months					
C1-C3, 12/83-5/84	-	-	-	-	1
6-month mean:	-	-	-	-	1
1.5-m, 12 Months					
C1-C5, 12/83-12/84	6.5	13	3	-	7
12-month mean:	6.5	13	3	-	7
Horiz., 12 Months					
C1-C5, 12/83-12/84	3.8	15	2	0.1	37
12-month mean:	3.8	15	2	0.1	37

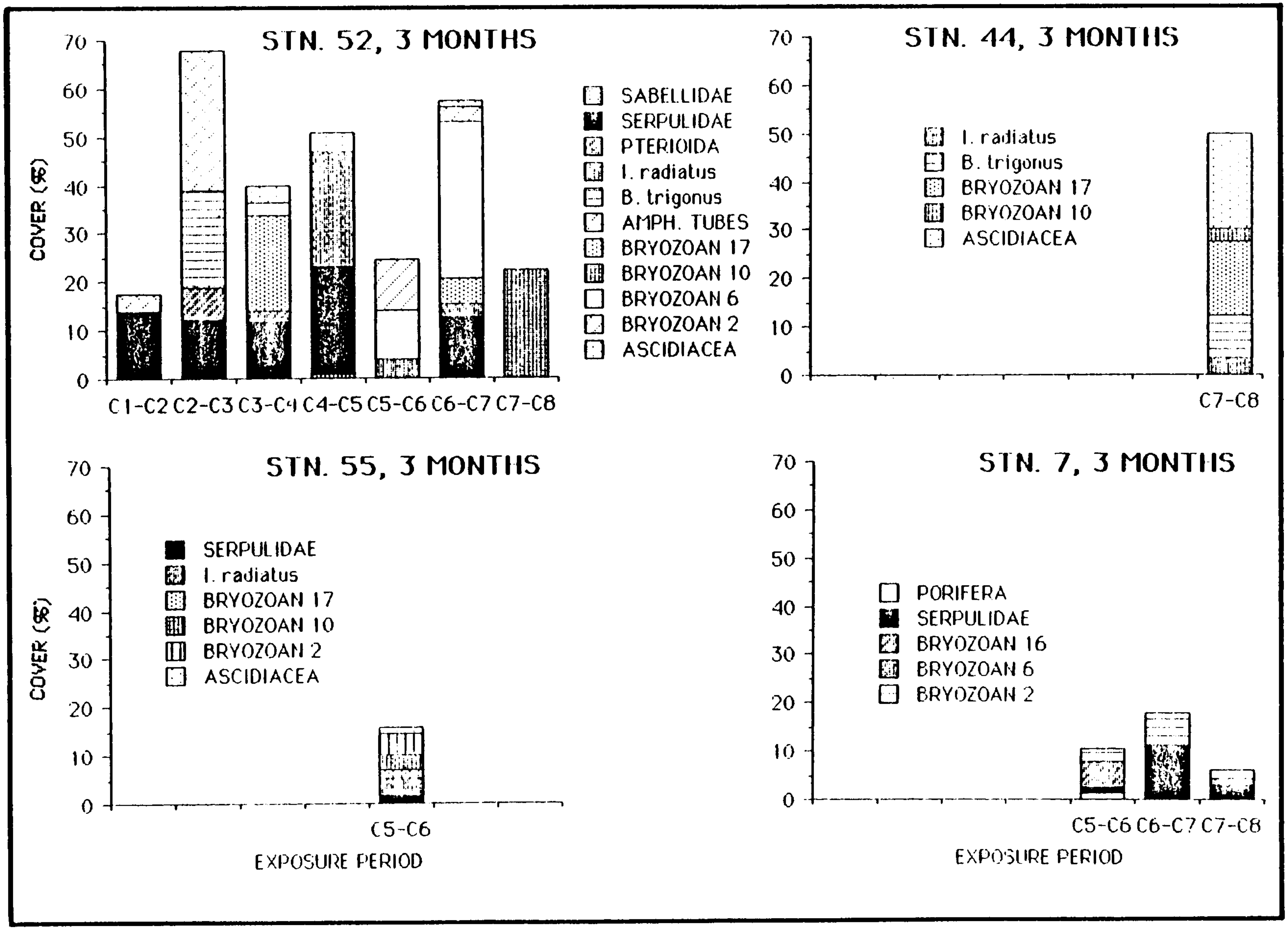


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Figure 3.3-19 **COVER BY MAJOR TAXA OF SETTLING ORGANISMS ON STANDARD 3-MONTH PLATES, BY EXPOSURE PERIOD AND STATION**

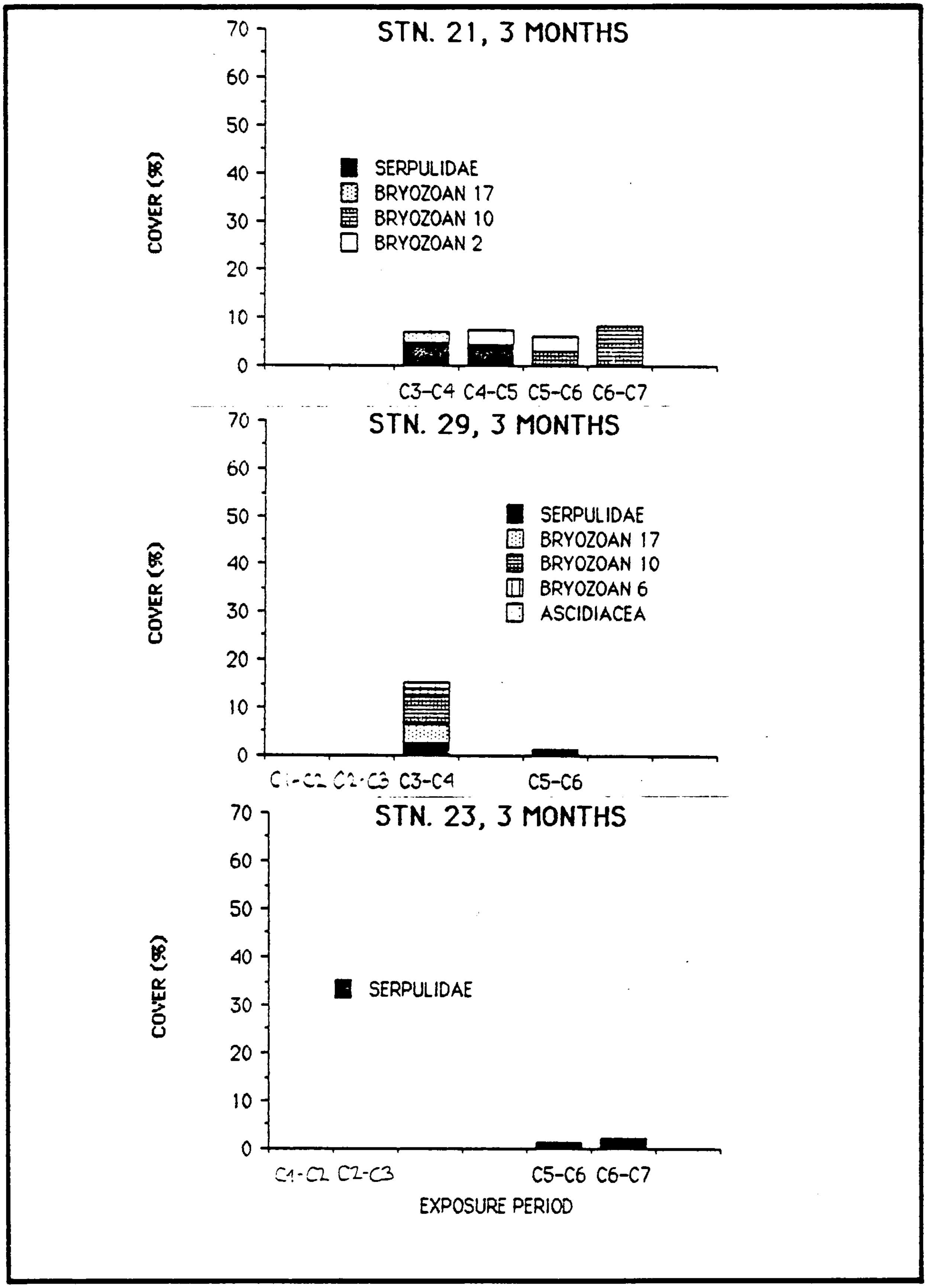

Figure 3.3-19 (Con't)

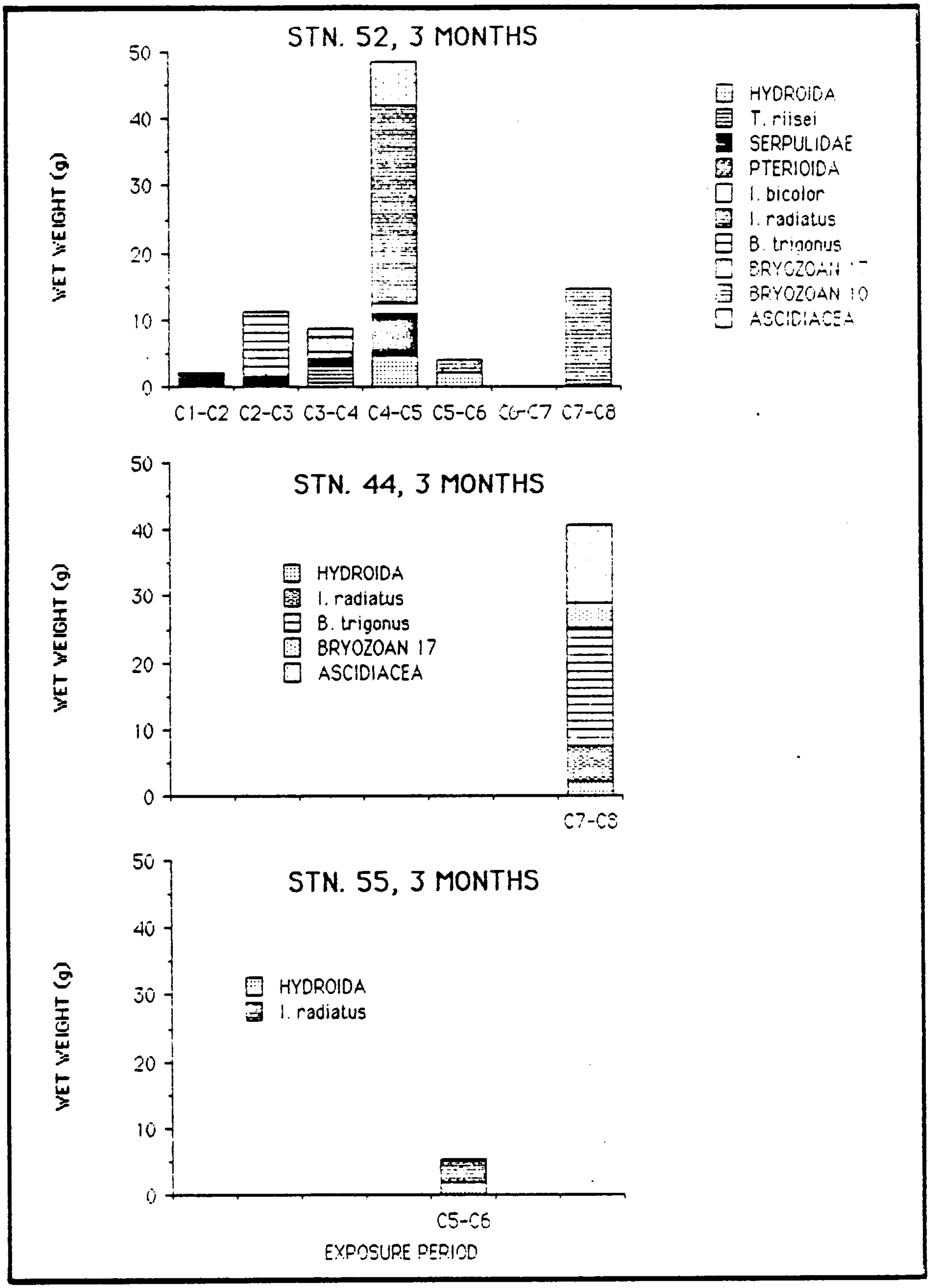

Figure 3.3-20 WET WEIGHT BY MAJOR TAXA OF SETTLING ORGANISMS ON STANDARD 3-MONTH PLATES, BY EXPOSURE PERIOD AND STATION

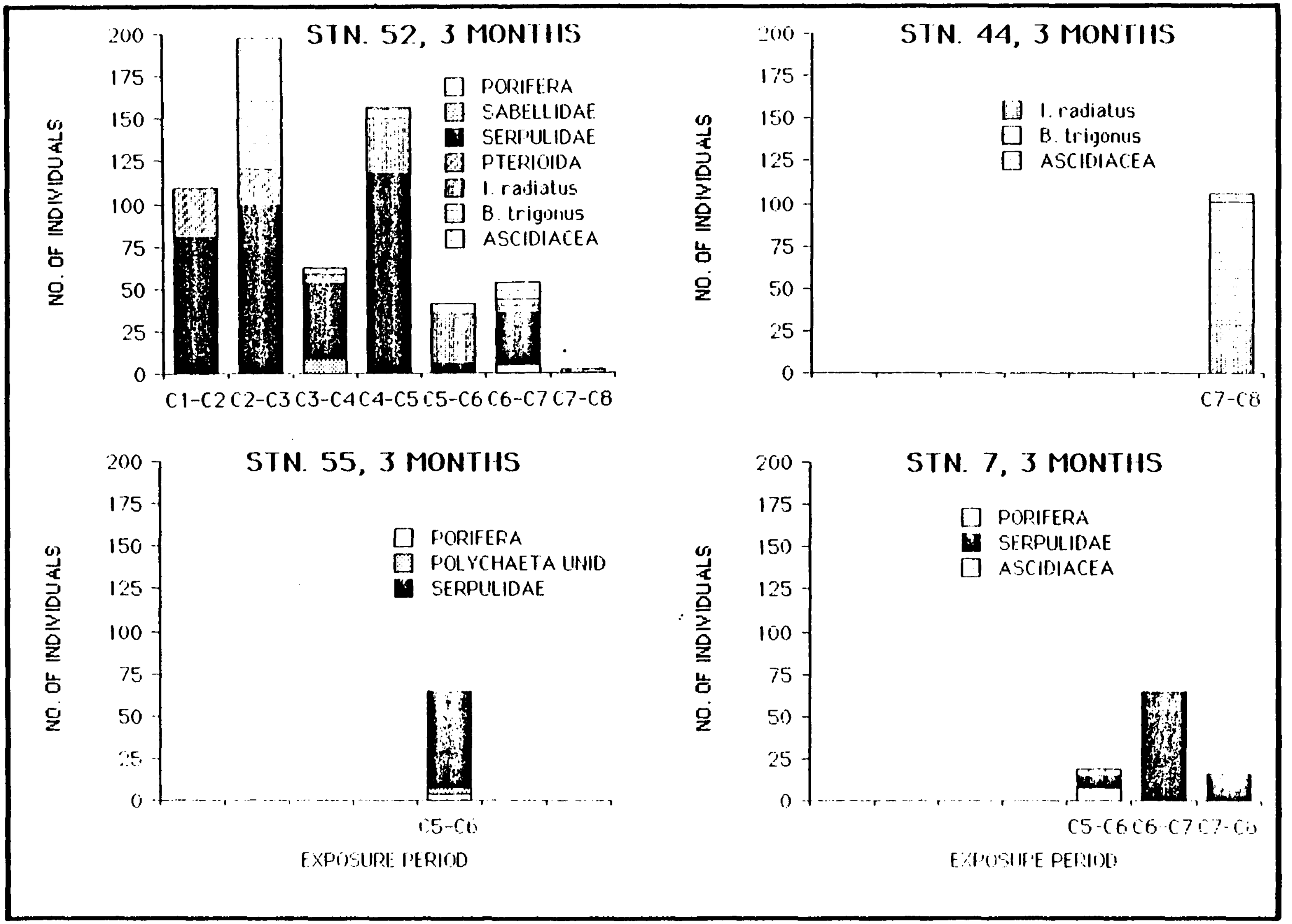

Figure 3.3-21 DENSITY BY MAJOR TAXA OF SETTLING ORGANISMS ON STANDARD 3-MONTH PLATES, BY EXPOSURE PERIOD AND STATION

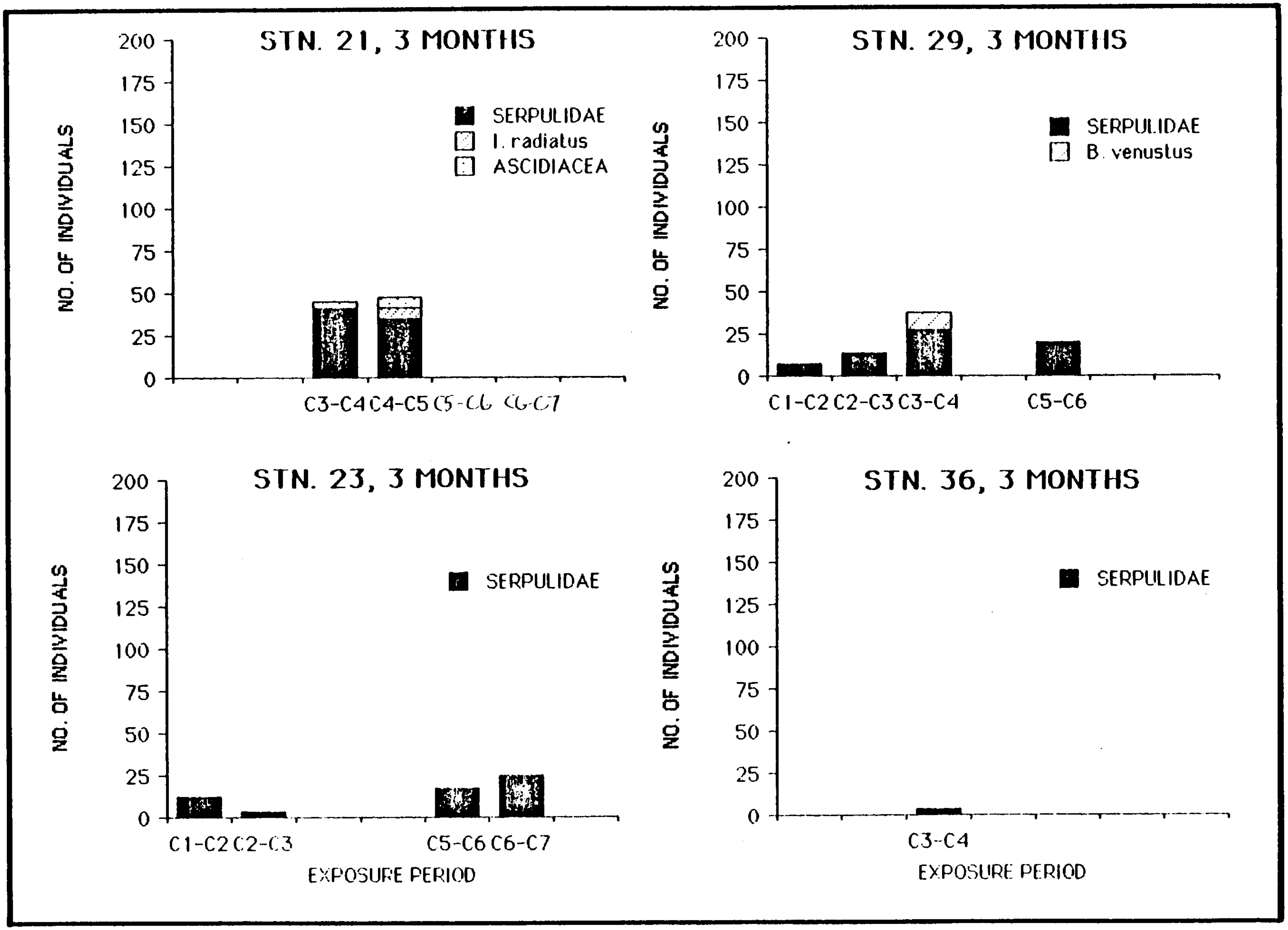

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Figure 3.3-21 (Con't)

At Station 52, standard plates were exposed for every 3-month period between Cruise 1 and Cruise 8. The dominant forms in terms of cover were serpulid polychaetes and bryozoans. There was considerable variation between periods; for example, amphipod tubes and the barnacle *Balanus trigonus* were particularly abundant from Cruise 2 to Cruise 3, while Lister's tree oyster, *Isognomon radiatus*, was most common from Cruise 4 to Cruise 5. A bryozoan was most abundant from Cruise 7 to Cruise 8. In terms of wet weight, most of the biomass was made up of *B. trigonus* (Cruise 2-3), *I. radiatus* (Cruise 4-5), and bryozoans (Cruise 7-8). Much more biomass was collected from Cruise 4 to Cruise 5 (August to December 1984) than during any other period, and most of the increase was due to *I. radiatus*. The numerical dominants in nearly every exposure period were serpulids. Other frequently counted organisms included *B. trigonus* (Cruise 2-3), *I. radiatus*, and pterioid oysters too small to identify.

At Station 44 from Cruise 7 to Cruise 8 (the only period in which standard 3-month plates were collected at both Stations 52 and 44), cover, wet weight, and density were higher than at Station 52. Most of the cover and biomass consisted of *B. trigonus*, ascidians, bryozoans, and *I. radiatus*. Ascidians and *B. trigonus* accounted for the greatest number of individuals.

At Station 55, standard 3-month plates were exposed only from Cruise 5 to Cruise 6. Cover (18%) was lower than at Station 52 (26%) during the same exposure period, but mean wet weight (7.6 g) and density (50 individuals) were somewhat higher (5.8 g and 43 individuals) during the same period. Mean cover, wet weight, and density at Station 55 were also lower than at Station 44. *Isognomon radiatus*, bryozoans, and serpulids were most important in terms of cover, while *I. radiatus* and hydroids accounted for most of the weight. Serpulid polychaetes were numerically dominant. By comparison, serpulids were relatively unimportant at Station 52 during the same period.

At Station 7, standard 3-month plates were exposed for three periods: from Cruise 5 to Cruise 6, from Cruise 6 to Cruise 7, and from Cruise 7 to Cruise 8. Mean cover was 13%, lower than mean cover at either Station 52 or Station 55. During the same sampling periods, cover at Station 7 was lower in each case than at shallower stations. Serpulids and bryozoans accounted for the most cover at Station 7. The most frequently counted organisms were serpulid polychaetes. Wet weights and mean numbers of individuals at Station 7 were also lower than those at Stations 52, 44, or 55. Wet weight averaged less than 1 g/plate for any taxon.

At Station 21, standard 3-month plates were exposed for four periods: from Cruise 3 to Cruise 4, from Cruise 4 to Cruise 5, from Cruise 5 to Cruise 6, and from Cruise 6 to Cruise 7. The average cover was 9%; plates averaged 27 individuals; and mean weight was 0.7 g/plate. Each of these values was less than at any shallower station. During the first two periods, serpulids dominated both cover and counts. During the last two periods, bryozoans almost completely replaced serpulids in terms of percentage cover.

At Station 29, standard 3-month plates were exposed for four periods: from Cruise 1 to Cruise 2, from Cruise 2 to Cruise 3, from Cruise 3 to Cruise 4, and from Cruise 5 to Cruise 6. Average cover was 5%; density was 21 individuals/plate; and wet weight averaged only 0.3 g/plate. Bryozoans and serpulids were the most important contributors to cover. Nearly all of the individuals counted at Station 29 were serpulids, except from Cruise 3 to Cruise 4, when the barnacle *Balanus venustus* was common.

At Station 23, standard 3-month plates were exposed for four periods: from Cruise 1 to Cruise 2, from Cruise 2 to Cruise 3, from Cruise 5 to Cruise 6, and from Cruise 6 to Cruise 7. Mean wet weight was

0.1 g/plate. Cover averaged 1%, with a mean of only 16 individuals. Serpulids dominated the sparse samples, both in cover and in number of individuals.

At Station 36, standard 3-month plates were exposed from Cruise 3 to Cruise 4. Plates looked almost the same after immersion as before. The only organisms averaging more than three individuals/plate were serpulids. Mean density was one/plate, cover was <1%, and wet weight averaged only 0.1 g/plate.

Standard 6-Month Plates

Exposure periods and stations where standard 6-month plates retrieved were as follows:

Cruise:	1	2	3	4	5	6	7	8
Month/Year:	12/83	3/84	5/84	8/84	12/84	3/85	6-7/85	12/85
Station								
52,29,23,36		----C1-C3----						
52,21,36				----C3-C5----				
52,21,23,36,7						----C5-C7----		
55							-----C6-C8-----	

A summary of values for percentage cover, wet weight, and density on standard 6-month plates and in bags is provided in Table 3.3-6 and Figures 3.3-22 through 3.3-24.

At Station 52, standard 6-month plates were exposed for three periods: from Cruise 1 to Cruise 3, from Cruise 3 to Cruise 5, and from Cruise 5 to Cruise 7. Mean weight (71.9 g) was over five times as high as on 3-month plates from the same station. Mean cover (64%) was one-and-a-half times that on 3-month plates. Mean density (181 individuals/plate) was twice that on 3-month plates.

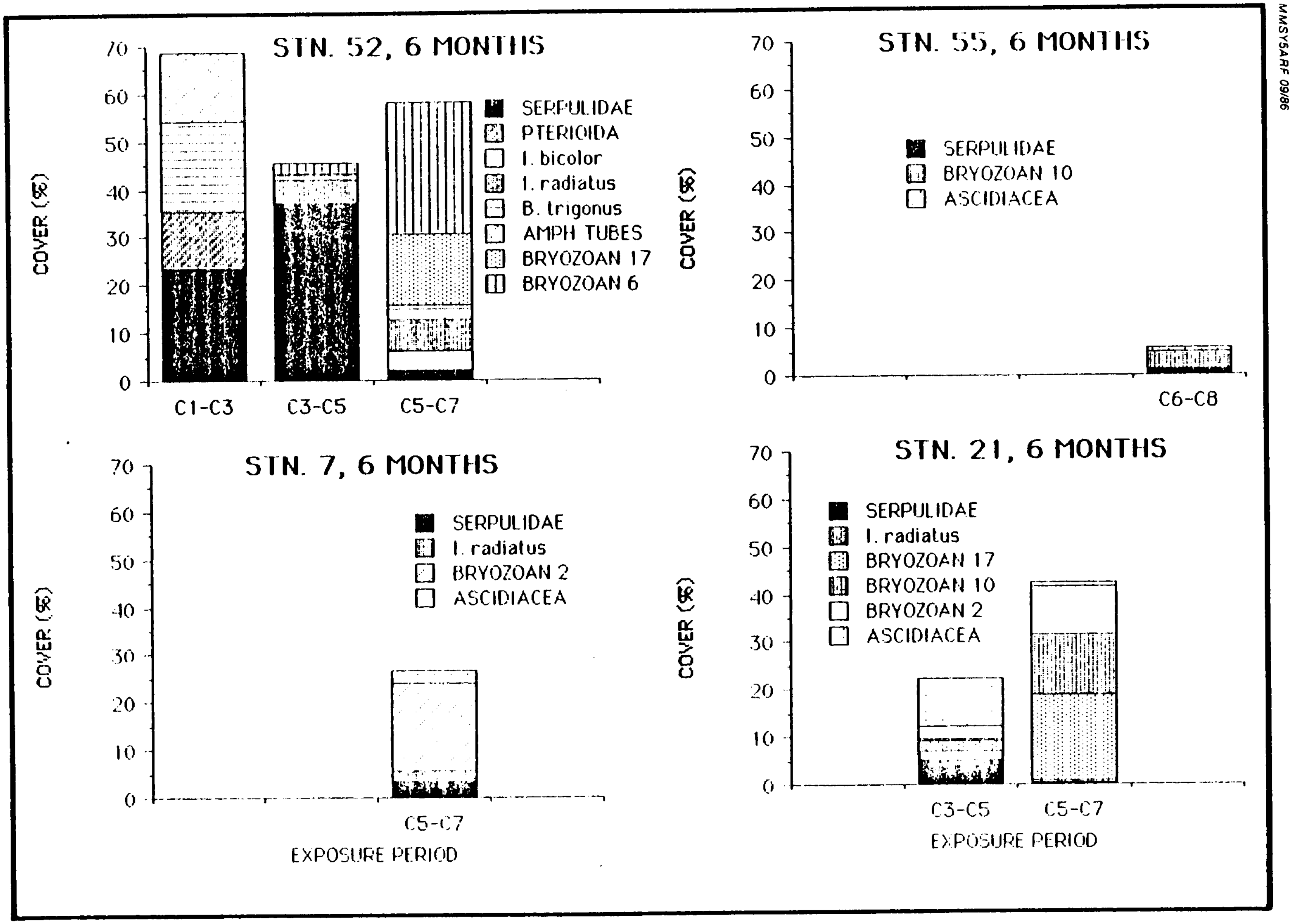


Figure 3.3-22 **COVER BY MAJOR TAXA OF SETTLING ORGANISMS ON STANDARD 6-MONTH PLATES, BY EXPOSURE PERIOD AND STATION**

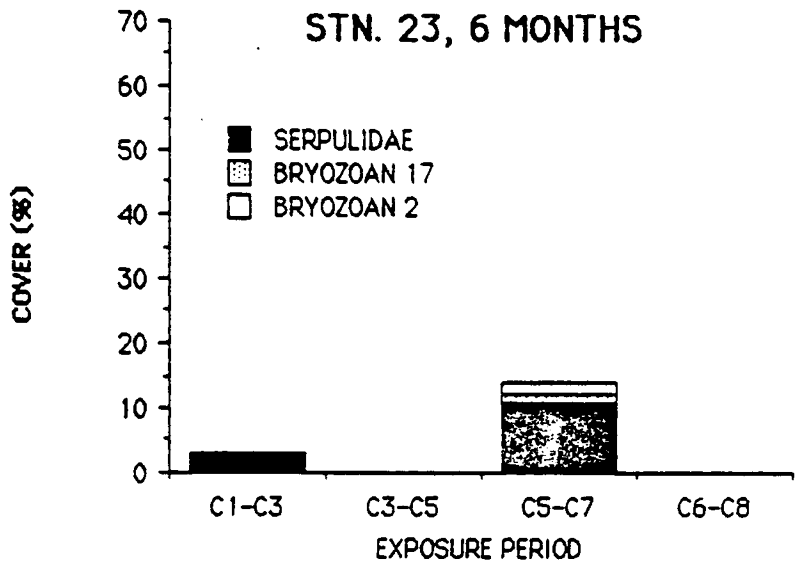


Figure 3.3-22 (Con't)

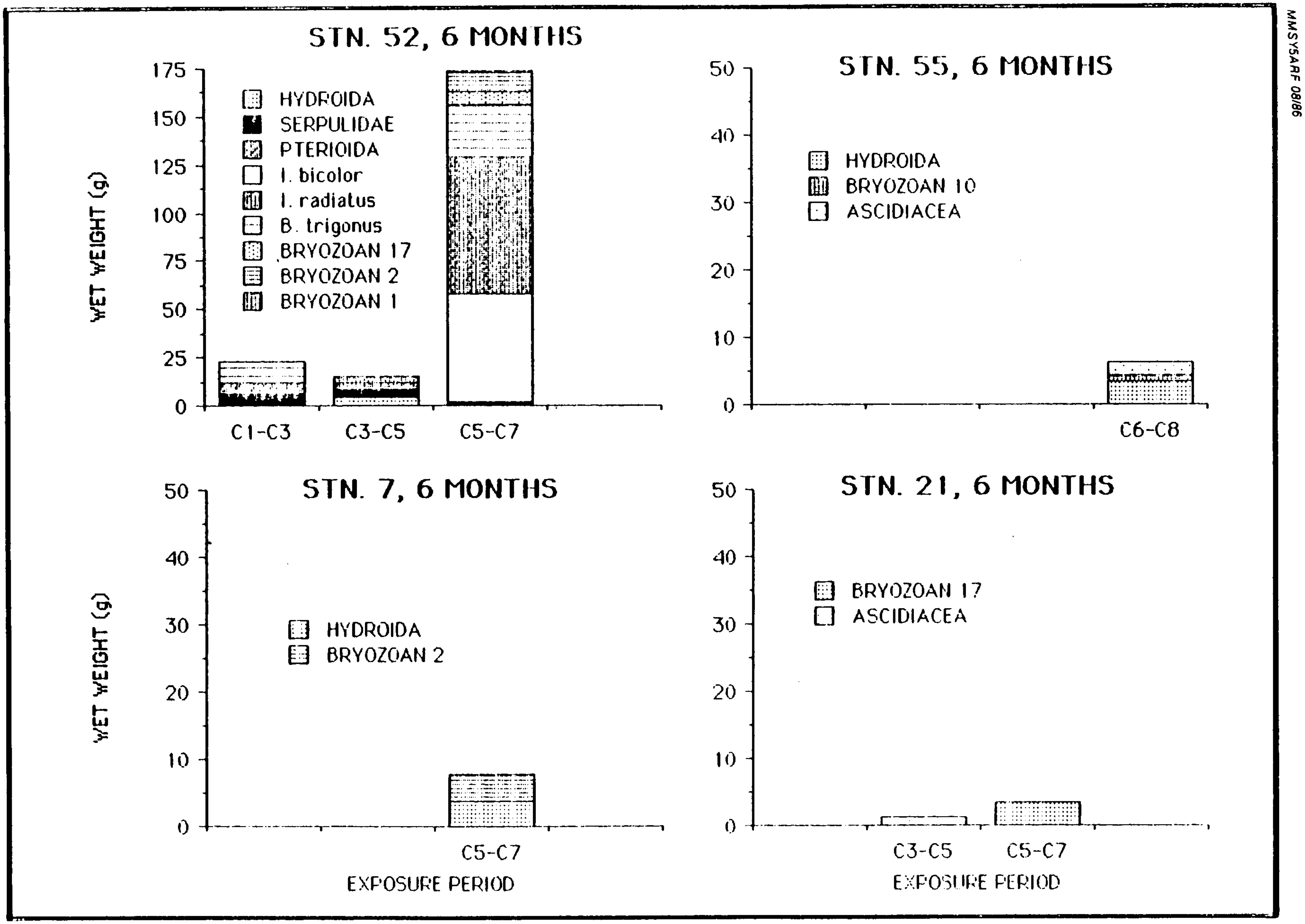


Figure 3.3-23 **WEIGHT BY MAJOR TAXA OF SETTLING ORGANISMS ON STANDARD 6-MONTH PLATES, BY EXPOSURE PERIOD AND STATION**

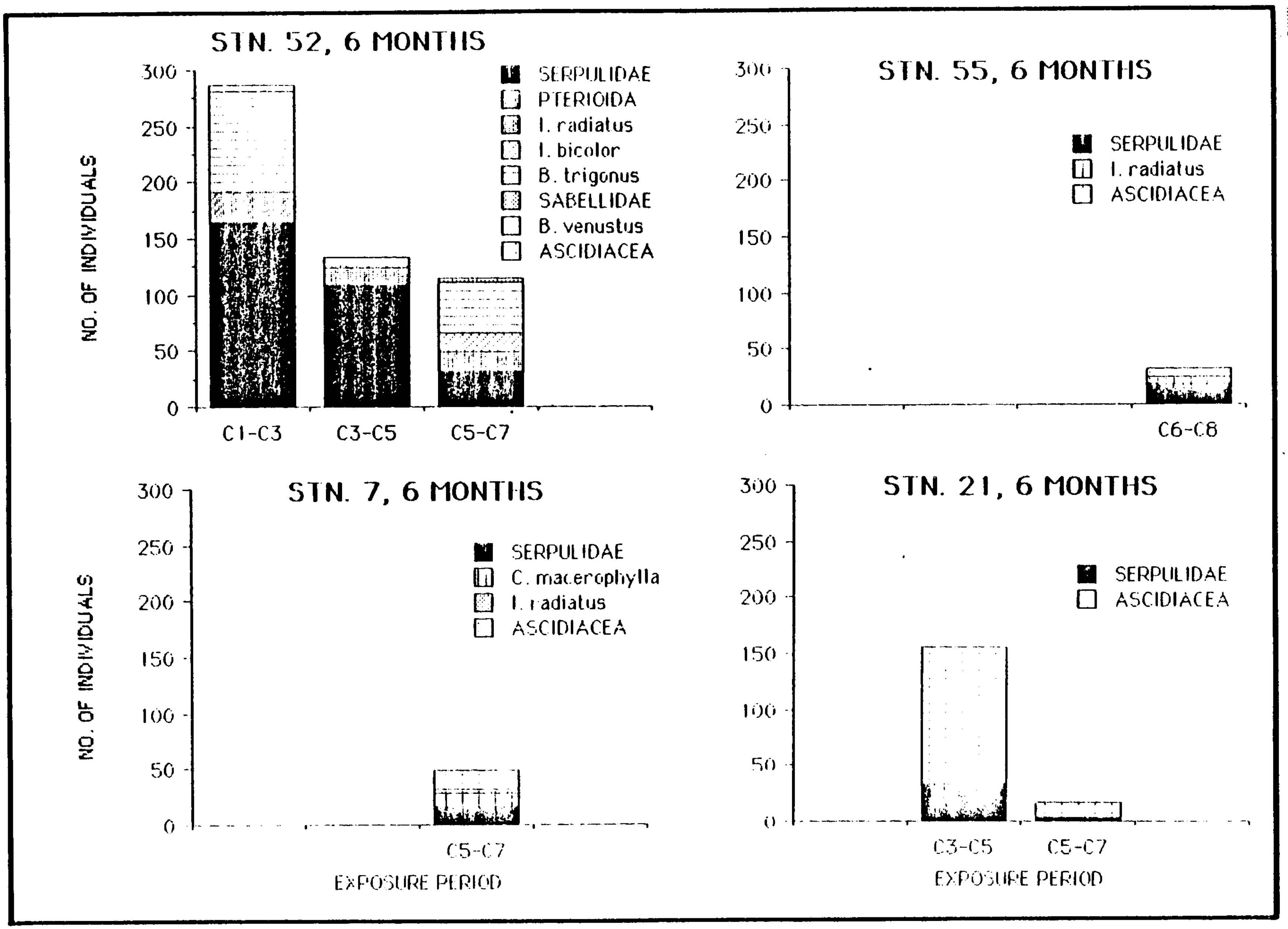


Figure 3.3-24 DENSITY BY MAJOR TAXA OF SETTLING ORGANISMS ON STANDARD 6-MONTH PLATES, BY EXPOSURE PERIOD AND STATION

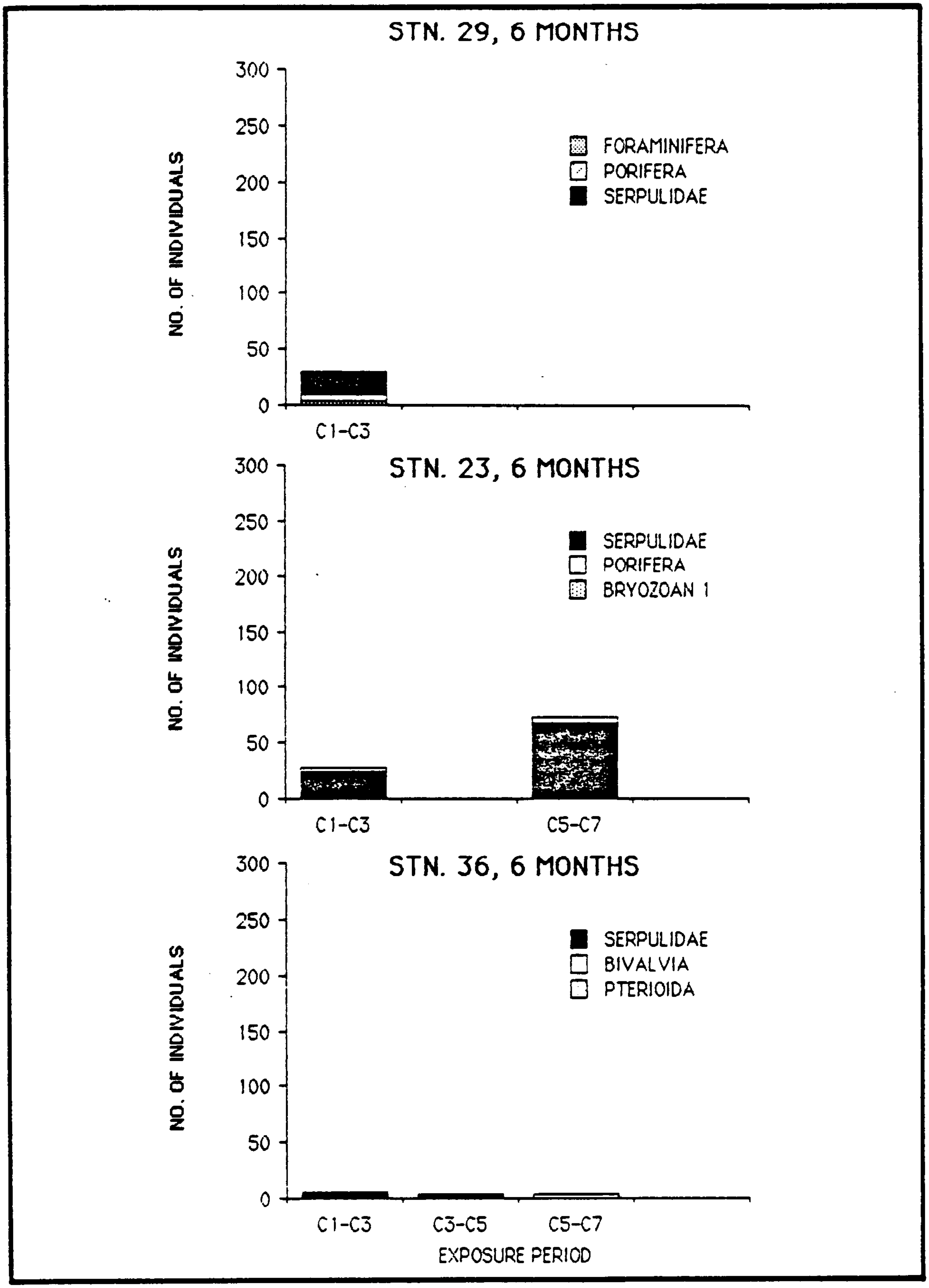


Figure 3.3-24 (Con't)

Species composition on standard 6-month plates changed considerably among periods. Serpulids, pterioid oysters, _Balanus trigonus_, and amphipod tubes were most important in terms of cover during the first period. During the second period, serpulids were dominant. During the third period, bryozoans accounted for most of the cover. During the first two periods, wet weights averaged 23.8 and 17.8 g/plate, respectively, and were made up mainly of serpulids, pterioids, and barnacles. Wet weight then increased between Cruise 5 and 7 by almost an order of magnitude, to 174 g/plate. Most of the increase in biomass was due to the growth of _Isognomon radiatus_ and _I. bicolor_, the bicolor tree oyster. Most of the individuals settling on standard 6-month plates were serpulids and _B. trigonus_. The number of individuals decreased from one exposure period to the next, largely reflecting a drop in the settlement of serpulids from Cruise 3 to Cruise 5, and from Cruise 5 to Cruise 7.

At Station 55, standard 6-month plates were exposed only from Cruise 6 to Cruise 8. Cover averaged 8%, one-eighth of that of 6-month plates from Station 52, in shallower water. Most of the cover was attributed to a bryozoan. Average wet weight was 7.7 g/plate, one-tenth of that at Station 52. Hydroids and ascidians accounted for most of the weight. The mean density was 34 individuals/plate, of which serpulids were most frequently counted. This density was about a fifth of that at Station 52 for 6-month plates.

At Station 7, standard 6-month plates were exposed only from Cruise 5 to Cruise 7. Cover averaged 28%, most of which was made up by a bryozoan. Mean cover was less than half that at Station 52, but much higher than that at Station 55, although the periods of exposure were not the same for Stations 7 and 55 and should not be compared directly. During the same period, cover, wet weight, and density at Station 52 were all much higher (66%, 174.1 g, 119 individuals) than at Station 7 (28%, 9.2 g, and 50 individuals). At Station 7, hydroids and bryozoans accounted for most of the weight. Mean wet weight on 6-month plates at Station 7 was almost six times that on 3-month plates at Station 7, and a bit higher than that on 6-month plates at Station 55. The majority of individuals counted were serpulids, ascidians, and the leafy jewel-box, *Chama macerophylla*.

At Station 21, standard 6-month plates were exposed for two periods: from Cruise 3 to Cruise 5, and from Cruise 5 to Cruise 7. Average cover was 33%. Cover at Station 21 was approximately half that at Station 52 during the same exposure period from Cruises 3 to 5 (23% and 55%, respectively), and about two-thirds that at Station 52 from Cruises 5 to 7 (43% and 66%, respectively). However, average biomass at Station 21 was more than an order of magnitude lower than at Station 52 (4 vs. 181 g/plate), and less than half of that at Station 7 during the same periods. The biomass at Station 21 was made up primarily of ascidians during the first period, and a bryozoan during the second period. The average density at Station 21 was 88 individuals/plate, but the first exposure period had far more (159/plate) than did the second (19/plate). Most of the individuals during both periods were ascidians, though serpulids were also abundant. Mean weight, density, and cover on 6-month plates at Station 21 were much higher than on 3-month plates.

At Station 29, standard 6-month plates were exposed only from Cruise 1 to Cruise 3. Wet weight averaged only 0.3 g--the same as on standard 3-month plates--and density (36 individuals/plate) and cover (5%) on 6-month plates were only slightly higher than on 3-month plates. The only organisms that averaged at least 1 g/plate were hydroids, and only serpulids accounted for at least one percent cover. Average density was 36 individuals/plate, much lower than on any shallower station. Serpulids were more numerous than any other taxon. Station 29 had about an order of magnitude fewer individuals, and almost two orders of magnitude less cover and weight than Station 52 for the same period.

At Station 23, standard 6-month plates were exposed for two periods: from Cruise 1 to Cruise 3, and from Cruise 5 to Cruise 7. Average cover was 10%, an order of magnitude more than that on 3-month plates from the same station. Serpulids accounted for the greatest cover during both periods. Mean weight was 1.2 g/plate. Hydroids were the only organisms whose weight averaged at least 1 g/plate. Average density was 56 individuals/plate, of which nearly all were serpulids. About twice as many serpulids were counted during the second period than during the first. Wet weight, cover, and number of individuals were quite similar between Station 23 and Station 29 for the same (first) period.

At Station 36, standard 6-month plates were exposed for three periods: from Cruise 1 to Cruise 3, from Cruise 3 to Cruise 5, and Cruise 5 to Cruise 7. As in 3-month plates, 6-month plates were practically bare. Mean cover did not reach 1%, and mean wet weight was only 0.4 g/plate. Mean density was less than one individual/plate. The only common organisms were small serpulids, pterioids, and unidentified bivalves.

Standard 9-Month Plates

Exposure periods and stations where standard 9-month plates retrieved were as follows:

Cruise:	1	2	3	4	5	6	7	8
Month/Year:	12/83	3/84	5/84	8/84	12/84	3/85	6-7/85	12/85
Station								
52,29,23,36	-------C1-C4-------							
21			---------C3-C6-------					
52,21,36				---------C4-C7--------				
44,7					----------C5-C8--------			

A summary of values for percentage cover, wet weight, and density (numbers of individuals) on standard 9-month standard plates and in bags is provided in Table 3.3-6 and Figures 3.3-25 through 3.3-27.

At Station 52, standard 9-month plates were exposed for two periods: from Cruise 1 to Cruise 4, and from Cruise 4 to Cruise 7. Mean wet

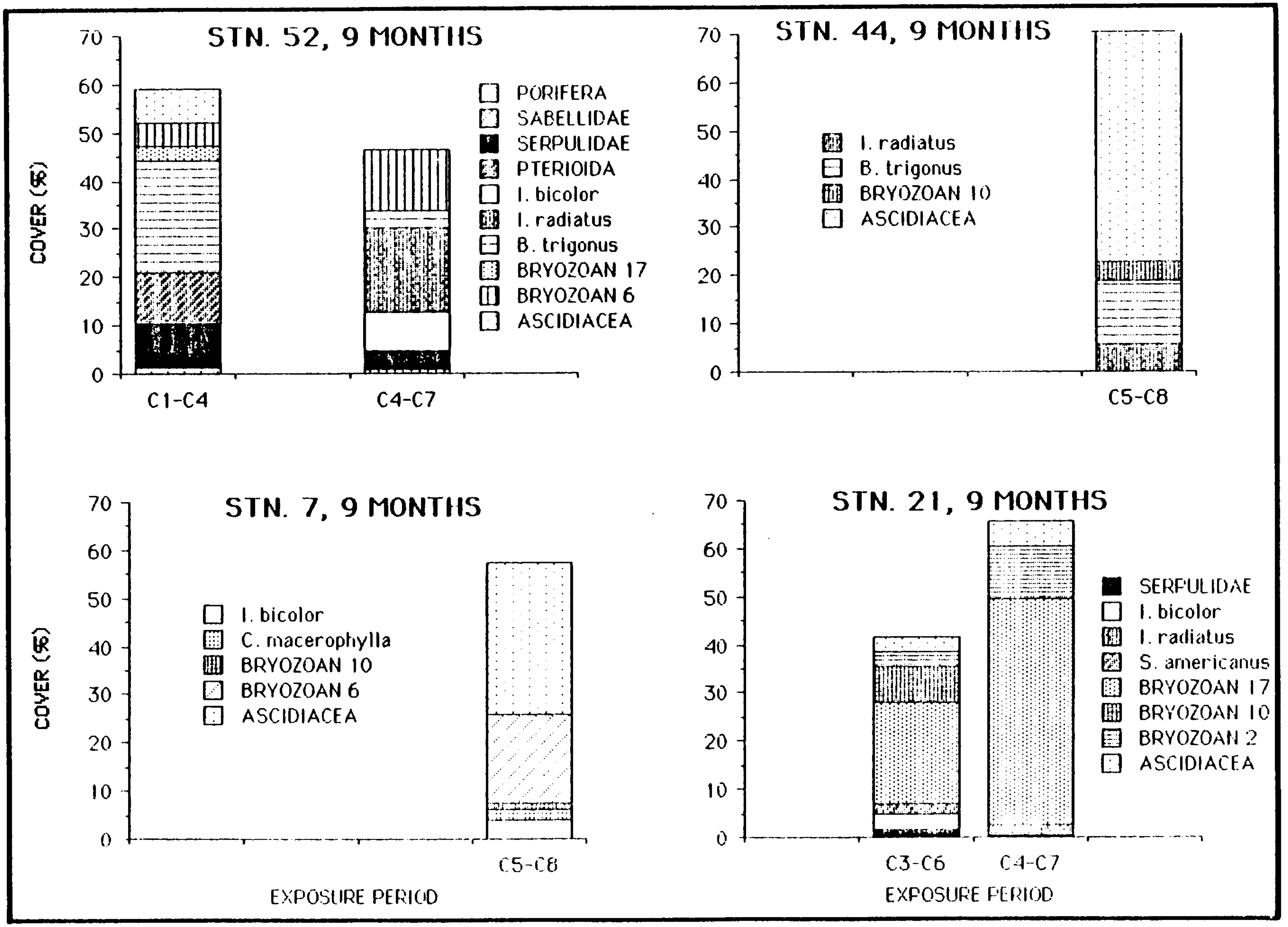


Figure 3.3-25 COVER BY MAJOR TAXA OF SETTLING ORGANISMS ON STANDARD 9-MONTH PLATES, BY EXPOSURE PERIOD AND STATION

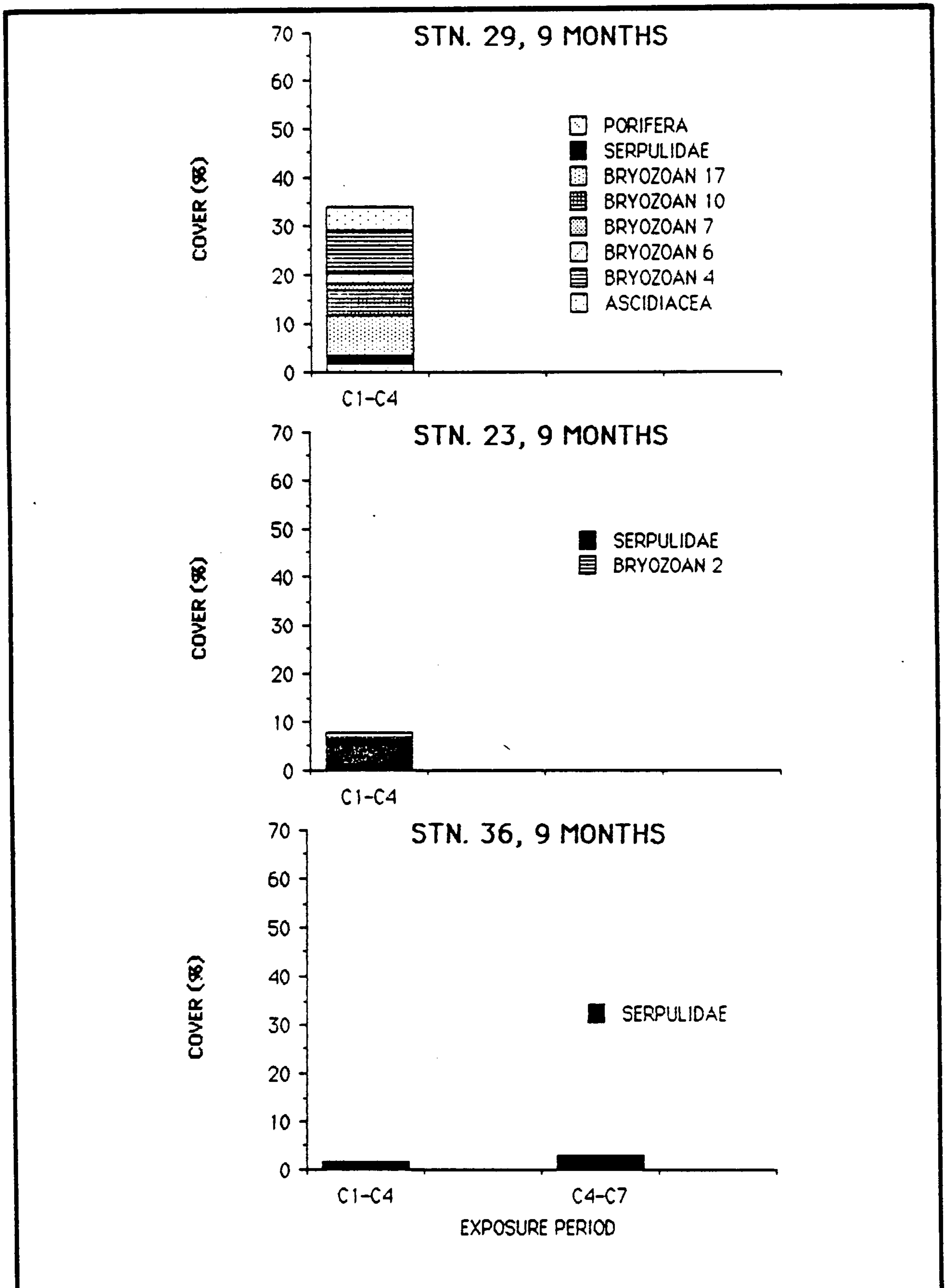


Figure 3.3-25 (Con't)

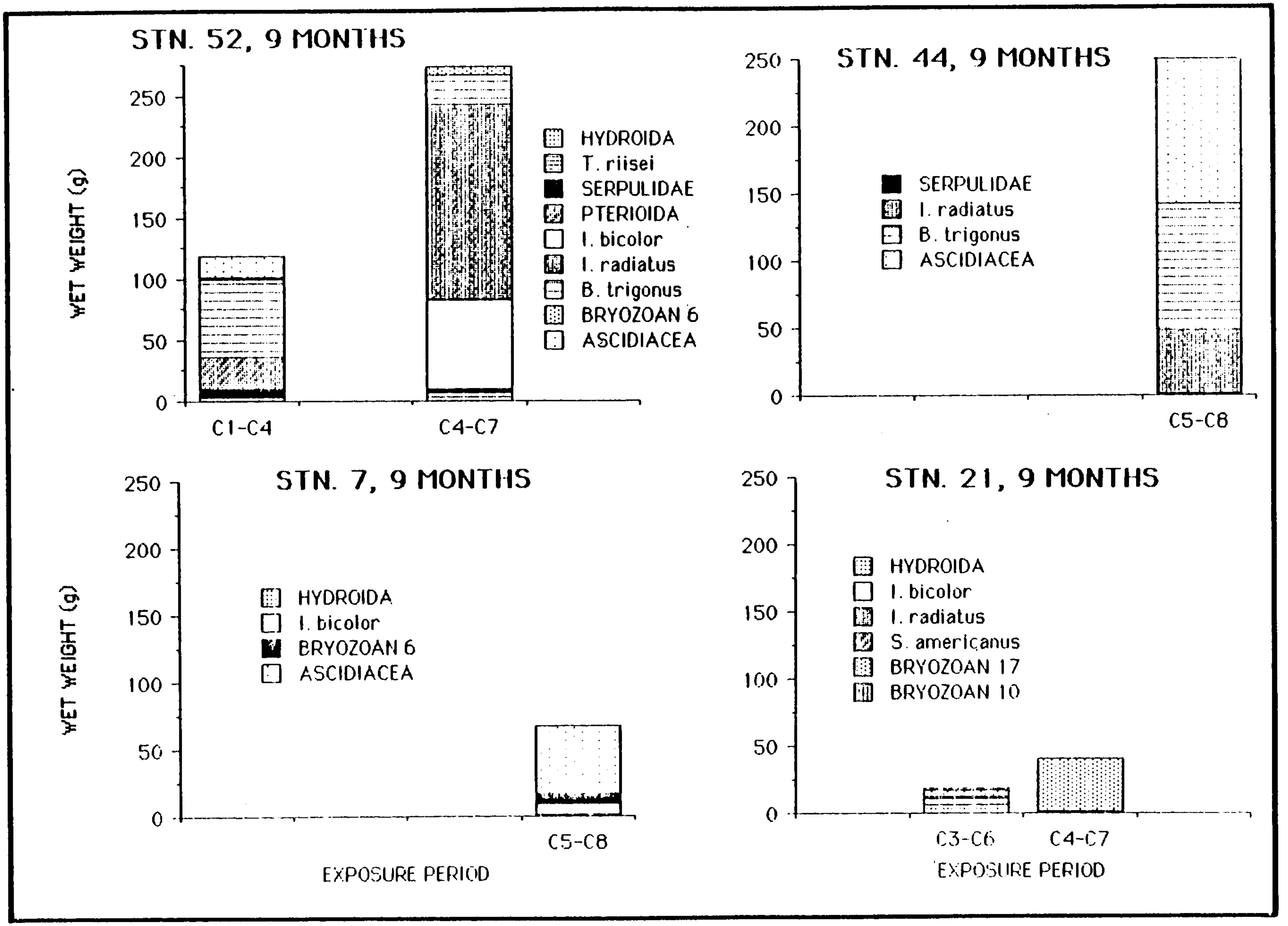


Figure 3.3-26 **WEIGHT BY MAJOR TAXA OF SETTLING ORGANISMS ON STANDARD 9-MONTH PLATES, BY EXPOSURE PERIOD AND STATION**

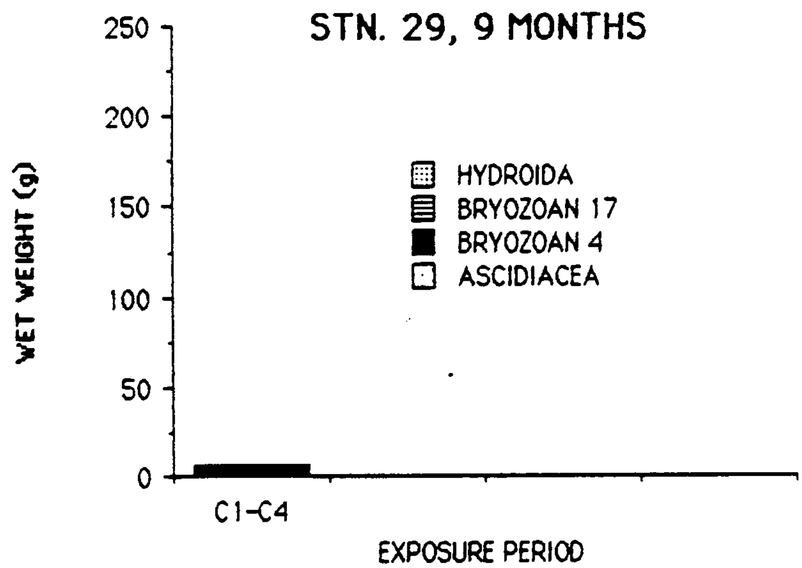


Figure 3.3-26 (Con't)

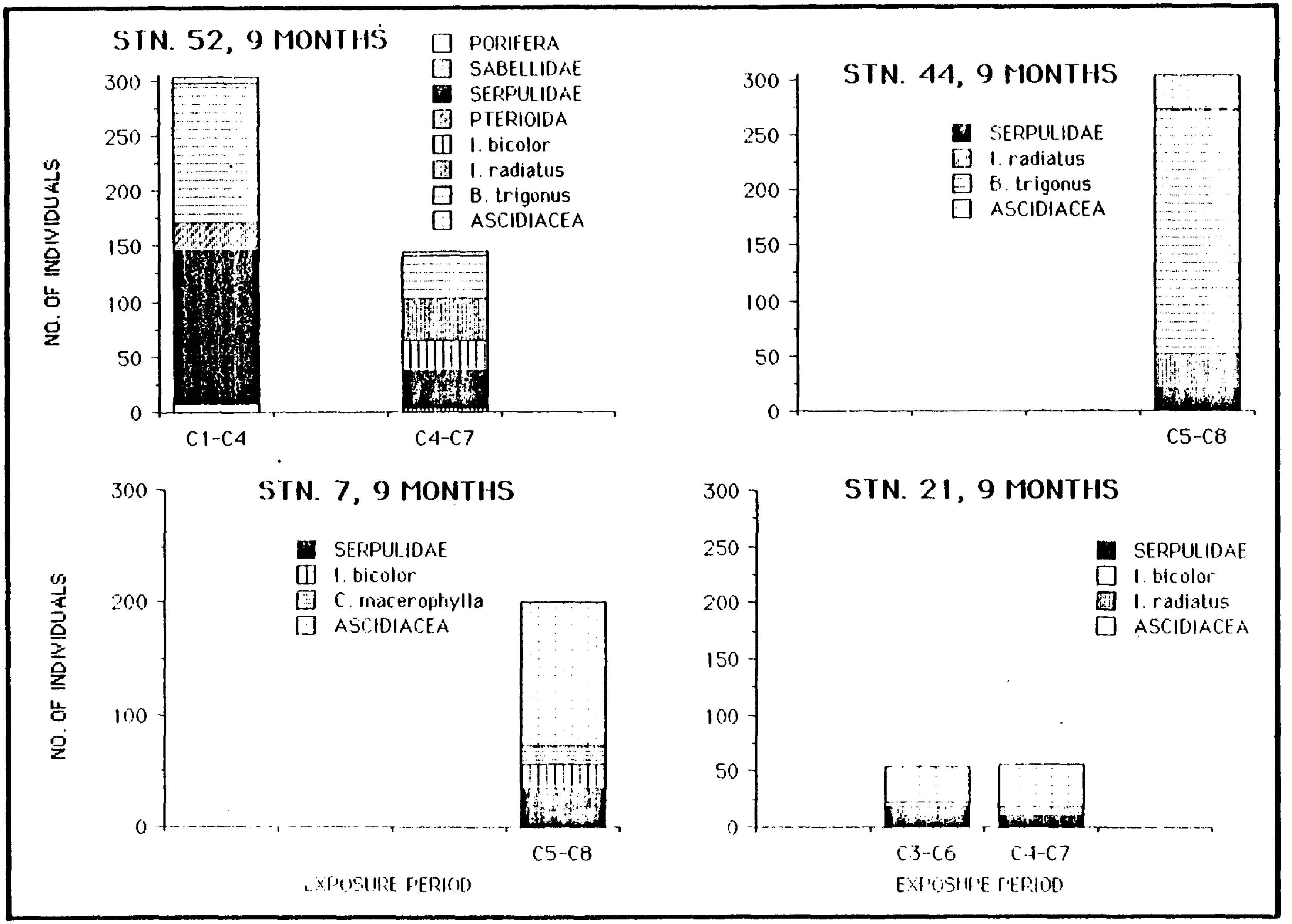


Figure 3.3-27 DENSITY BY MAJOR TAXA OF SETTLING ORGANISMS ON STANDARD 9-MONTH PLATES, BY EXPOSURE PERIOD AND STATION

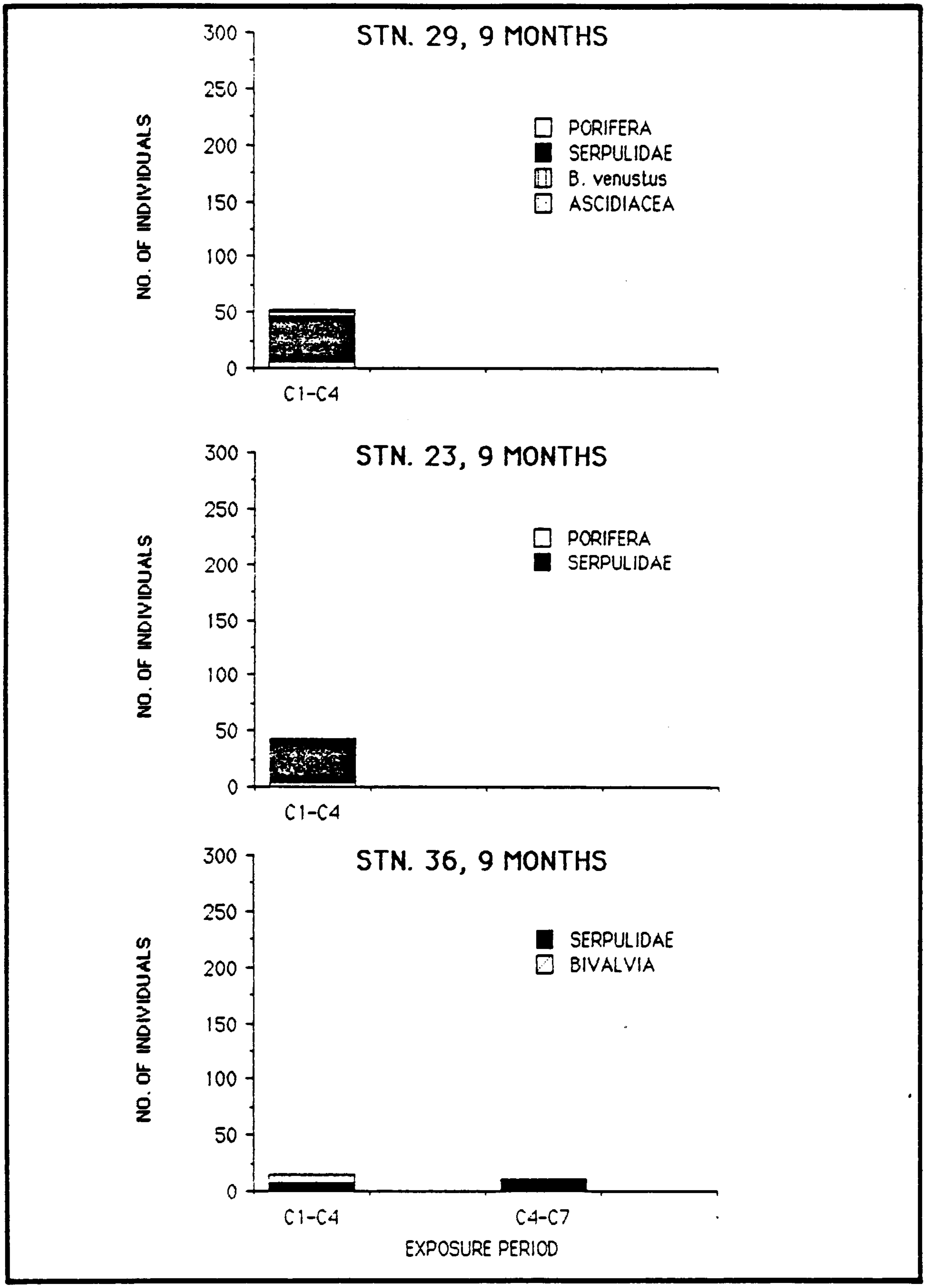


Figure 3.3-27 (Con't)

weight was 196.5 g/plate; mean density, 225 individuals/plate; and mean cover, 53%. Mean weight and density were higher than on 6- or 3-month plates from Station 52, although cover had an intermediate value. Most of the cover could be attributed to *Balanus trigonus*, bryozoans, unidentified pterioids, and *Isognomon radiatus*. *Balanus trigonus* accounted for most of the weight during the first period, and *I. radiatus* for most of the weight during the second period. Mean wet weight from Cruises 1 to 4 (119.5 g) was less than half that from Cruise 4 to 7 (273.6 g), even though twice the individuals were present during the first period (density 304/plate) than during the second period (density 146/plate). Most of the individuals during the first period were serpulids and *Balanus trigonus*, which were not as heavy as individuals of *Isognomon*.

At Station 44, standard 9-month plates were exposed from Cruise 5 to Cruise 8. Mean wet weight was 252.8 g/plate, six times that on standard 3-month plates from the same station. Mean density was 303 individuals/plate, three times that on 3-month plates, and mean cover was 71%, about half again that on 3-month plates. All of the 6-month means from Station 44 were higher than those at Station 52 (as were those of 3-month plates), but since the exposure periods for 6-month plates were not the same, direct comparisons should not be made. Most of the cover and weight at Station 44 were made up of ascidians, *B. trigonus*, and *I. radiatus*, though *B. trigonus* was the numerical dominant.

At Station 7, standard 9-month plates were exposed from Cruise 5 to Cruise 8. Mean wet weight was 67.9 g/plate; mean density was 201 individuals/plate; and cover was 58%. Each of these values was much greater than those on standard 3-month and 6-month plates from the same station. During the same exposure period, wet weight at Station 7 was only a fourth of that at Station 44, and density and cover were also lower at Station 7. The majority of the individuals counted on plates at Station

7 were ascidians, serpulids, *Isognomon bicolor*, and *Chama macerophylla*. Ascidians, bryozoans, and *I. bicolor* accounted for most of the cover and wet weight.

At Station 21, standard 9-month plates were exposed for two periods: from Cruise 3 to Cruise 6, and from Cruise 4 to Cruise 7. Mean wet weight was 32.8 g/plate; mean density was 57 individuals/plate; and mean cover was 54%. Each of these values was lower than those at shallower stations (Stations 52, 44, and 7). Mean wet weight and cover were both higher than on standard 6-month and 3-month plates from the same station. During the same exposure period, wet weight (45.2 g/plate) at Station 21 was only a sixth of that at Station 52 (273.6 g/plate). Most of the individuals at Station 21 were ascidians and serpulids, but most of the weight and cover were made up of bryozoans.

At Station 29, standard 9-month plates were exposed from Cruise 1 to Cruise 4. Mean wet weight was 7.4 g/plate; mean density, 55 individuals/plate; and mean cover, 34%. Density and cover were somewhat higher than on standard 3-month and 6-month plates from the same station, while mean wet weight was more than 20 times greater. Nonetheless, mean wet weight was much lower than that at any shallower station. During the same exposure period, wet weight at Station 29 was only one-sixteenth of that at Station 52 (119.5 g). Bryozoans accounted for most of the cover and wet weight at Station 29, but serpulids were numerically dominant.

At Station 23, standard 9-month plates were exposed from Cruise 1 to Cruise 4. Mean wet weight was only 1 g/plate; mean density, 45 individuals/plate; and mean cover, 11%. Mean wet weight and cover were an order of magnitude greater than on standard 3-month plates from the same station, but very similar to those for standard 6-month plates (1.2 g and 10%, respectively. All three values were less than those at any shallower station; for example, wet weight was less than a seventh of that on standard 9-month plates exposed for the same period at Station 29. Most of the organisms present were serpulids.

At Station 36, standard 9-month plates were exposed for two periods: from Cruise 1 to Cruise 4, and from Cruise 4 to Cruise 7. Mean wet weight was 0.4 g; mean density, 13 individuals/plate; and mean cover, 3%. These very low values were higher than those on standard 3-month and 6-month plates from Station 36, but much lower than those at any other station. Most of the organisms were serpulids.

Standard 12-Month Plates

Exposure periods and stations where standard 12-month plates retrieved were as follows:

	Cruise:	1	2	3	4	5	6	7	8
	Month/Year:	12/83	3/84	5/84	8/84	12/84	3/85	6-7/85	12/85
Station									
21,36				------------		C3-C7		-----------	

At both Stations 21 and 36, standard 12-month plates were exposed from Cruise 3 to Cruise 7. A summary of values for percentage cover, wet weight, and density (numbers of individuals) on 12-month standard plates and in bags is provided in Table 3.3-6 and Figure 3.3-28.

At Station 21, mean wet weight was 50.1 g/plate; density, 67 individuals/plate; and mean cover, 71%. Wet weight and cover were much higher than on standard 3-month, 6-month, and 9-month plates from the same station. Most of the individuals were ascidians, serpulids, and *Isognomon radiatus*, although bryozoans were responsible for the most weight and cover.

At Station 36, mean wet weight was 1.2 g/plate; density, 23 individuals, and cover 3%. These values were higher than those of standard 3-month, 6-month, and 9-month plates from the same station, although much lower than those from Station 21 during the same exposure period. Nearly all of the organisms present were serpulids.

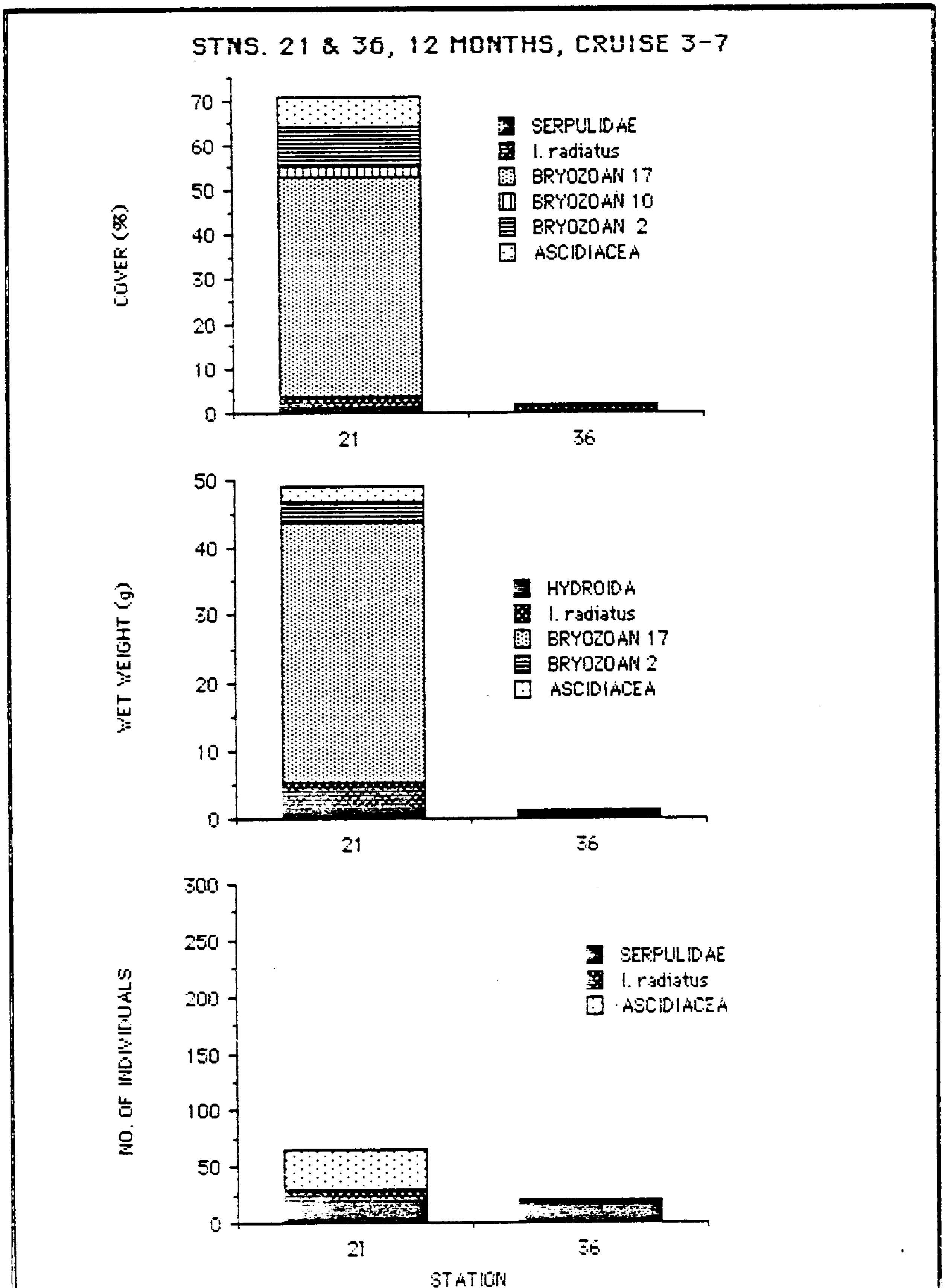


Figure 3.3-28 COVER, WEIGHT, AND DENSITY OF MAJOR TAXA OF SETTLING ORGANISMS ON STANDARD 12-MONTH PLATES FROM CRUISES 3 TO 7 AT STATIONS 21 AND 36

1.5-m Plates

Exposure periods and stations [in brackets] where 1.5-m plates retrieved were as follows:

Cruise:	1	2	3	4	5	6	7	8
Month/Year:	12/83	3/84	5/84	8/84	12/84	3/85	6-7/85	12/85
Exposure Period								
3 months:							--C7-C8-- [Station 44]	
9 months:	-------C1-C4------- [Station 23]							
12 months:	----------C1-C5---------- [Stations 52,36]							

A summary of values for percentage cover, wet weight, and density (numbers of individuals) on 1.5-m plates and in bags is provided in Table 3.3-6 and Figures 3.3-29 through 3.3-31.

At Station 44, 1.5-m plates were exposed for 3 months, from Cruise 7 to Cruise 8. Mean wet weight was 83.3 g/plate; mean density, 410 individuals/plate; and mean cover, 58.8%. All of these values were greater than on standard 3-month plates exposed for the same period at Station 44. Wet weight on 1.5-m 3-month plates was over twice as high, and density was four times greater than on standard 3-month plates. The most important organism in terms of cover, weight, and density on the 1.5-m plates was *Balanus venustus*, which was not present on standard 3-month plates from the same period. *Balanus trigonus*, a major component on standard 3-month plates, was also important on 1.5-m 3-month plates.

At Station 23, 1.5-m plates were exposed for 9 months, from Cruise 1 to Cruise 4. Mean wet weight was 1.1 g/plate; mean density, 62 individuals/plate; and mean cover, 12%. These values were slightly higher than corresponding values from standard 9-month plates from the same period at Station 23. Nearly all of the individuals collected by 1.5-m 9-month plates and standard 9-month plates were serpulids.

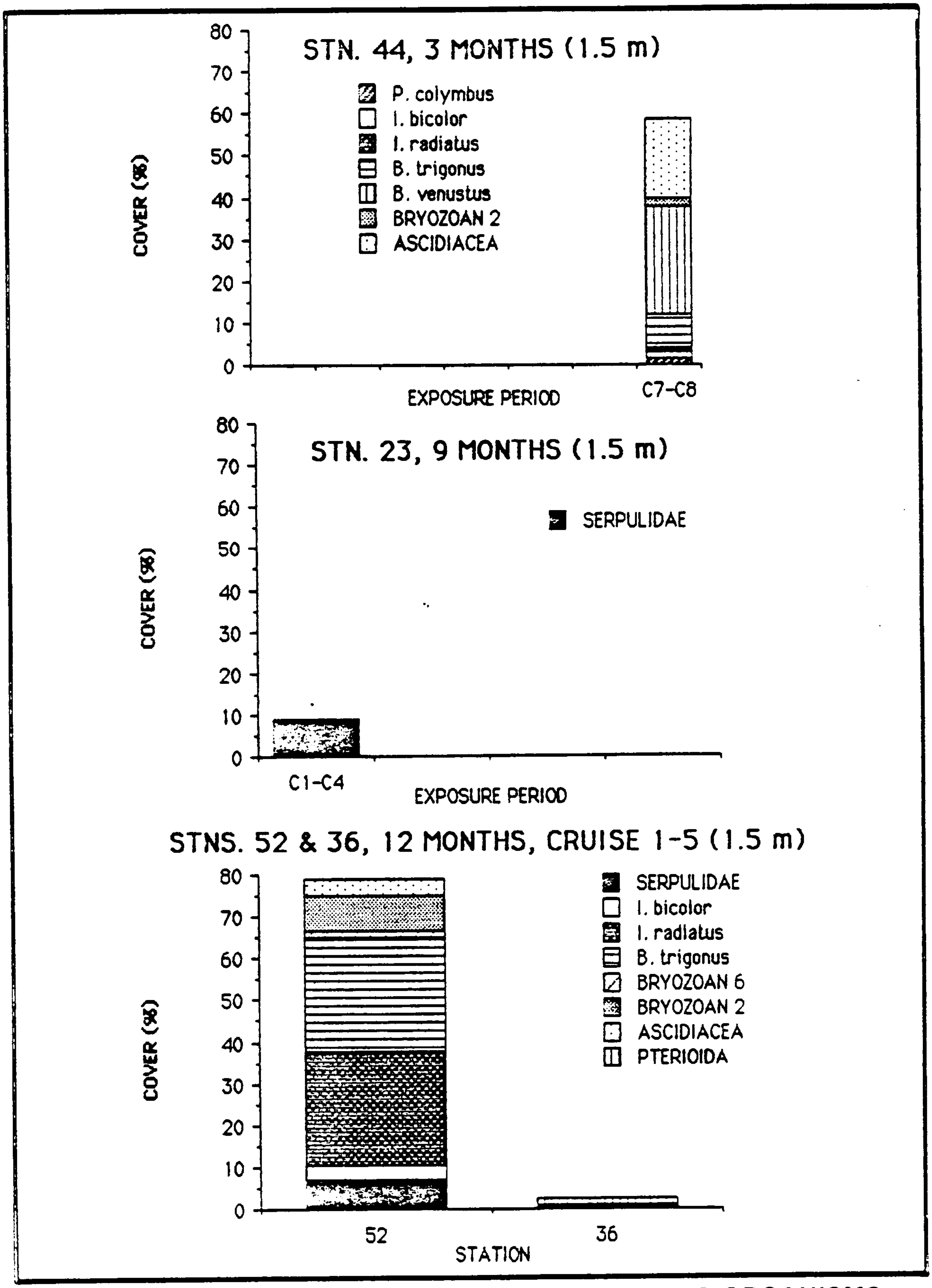
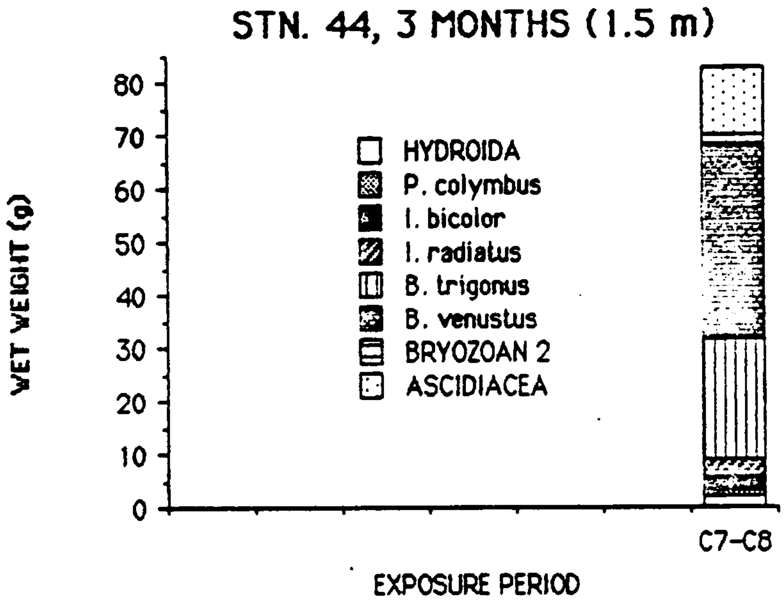


Figure 3.3-29 COVER BY MAJOR TAXA OF SETTLING ORGANISMS ON 1.5-m PLATES, BY EXPOSURE PERIOD AND STATION



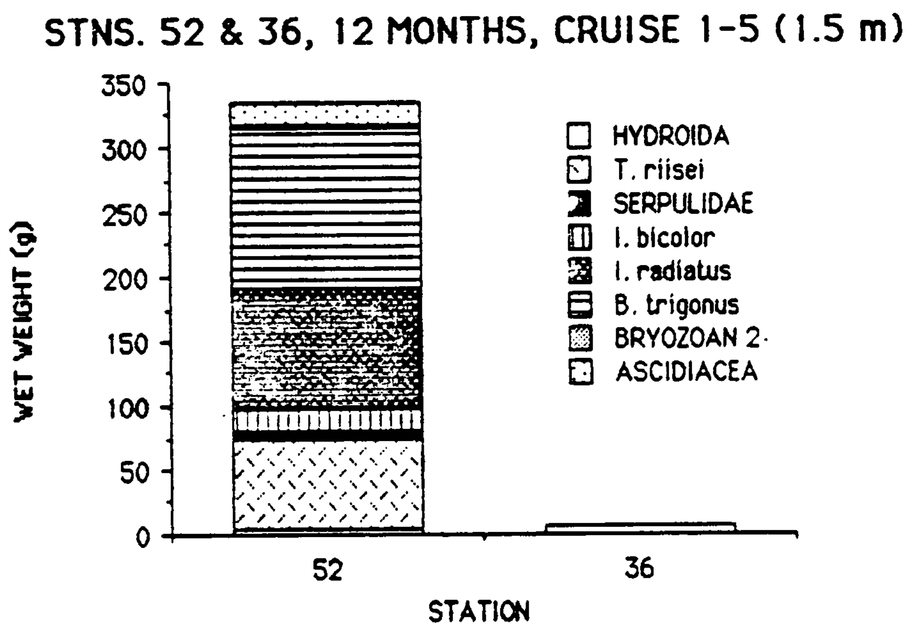


Figure 3.3-30 WEIGHT BY MAJOR TAXA OF SETTLING ORGANISMS ON 1.5-m PLATES, BY EXPOSURE PERIOD AND STATION

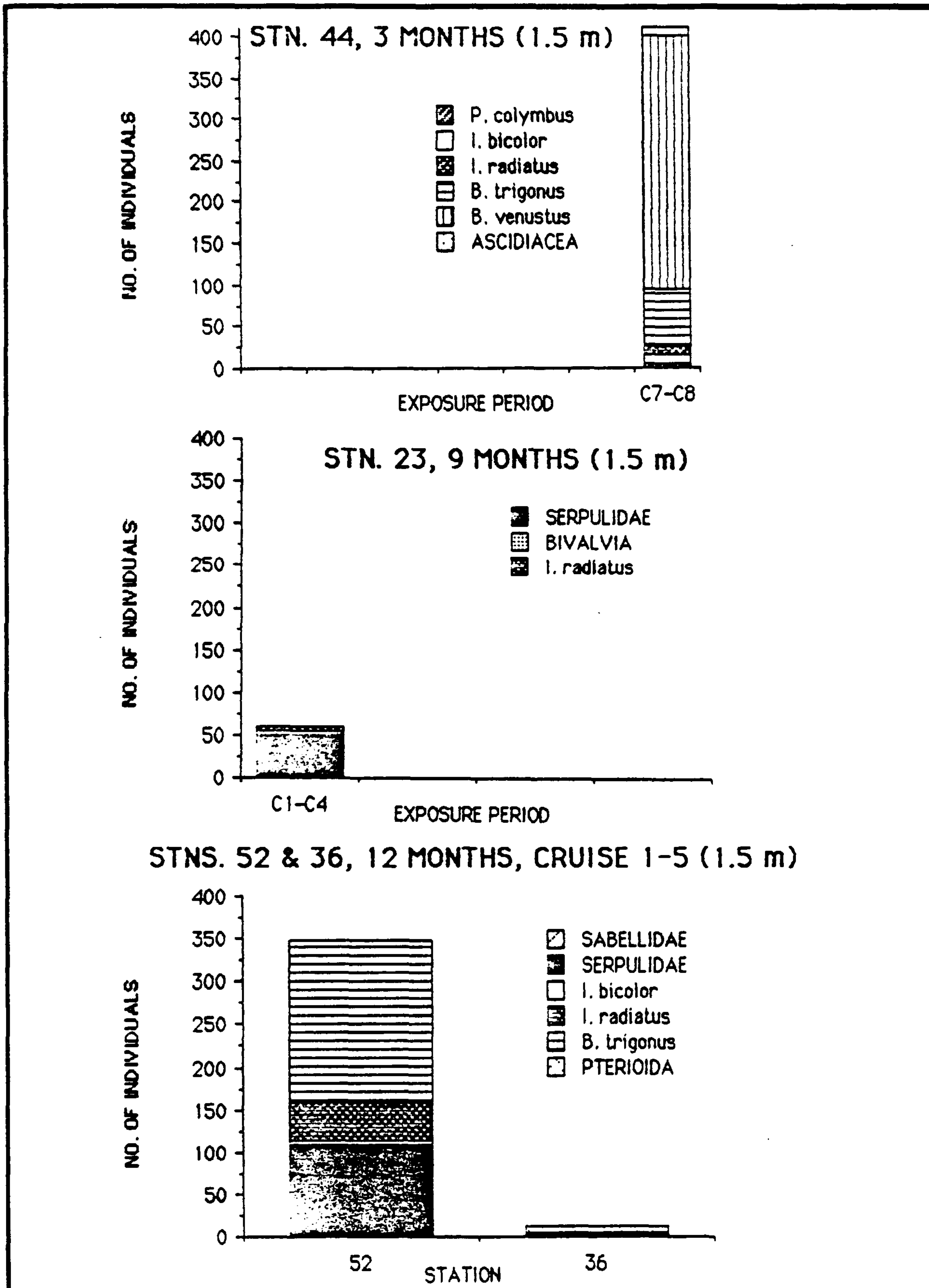


Figure 3.3-31 DENSITY BY MAJOR TAXA OF SETTLING ORGANISMS ON 1.5-m PLATES, BY EXPOSURE PERIOD AND STATION

At Station 52, 1.5-m plates were exposed for 12 months, from Cruise 1 to Cruise 5. Mean wet weight was 334.8 g/plate; mean density, 349 individuals/plate; and mean cover, 79%. No standard 12-month plates were collected from Station 52, thereby precluding comparison. Mean wet weight, density, and cover for 1.5-m 12-month plates were all greater than on standard plates exposed for less time at Station 52. Most of the cover was made up of *Isognomon radiatus* and *Balanus trigonus*, serpulids, and bryozoans. The majority of the individuals counted were *B. trigonus* and serpulids. *Isognomon radiatus*, *B. trigonus*, and the octocoral *Telesto riisei* accounted for most of the wet weight on 1.5-m 12-month plates.

At Station 36, 1.5-m plates were exposed for 12 months, from Cruise 1 to Cruise 5. Mean wet weight was 6.5 g/plate; mean density, 13 individuals/plate; and mean cover, 3%. Wet weight was over five times higher than that on standard 12-month plates at Station 36. Cover was identical and density was a bit lower on 1.5-m 12 month plates than on standard plates. However, the exposure periods were not the same and should not be compared directly. All values for 1.5-m 12 month plates at Station 36 were a fraction of those at Station 52 for the same exposure period. Most of the wet weight at Station 36 was made up of masses of hydroid colonies, although small pterioids and serpulids were the most numerous individual organisms counted.

Horizontal Plates

Exposure periods and stations [in brackets] for horizontal plates retrieved were as follows:

Cruise:	1	2	3	4	5	6	7	8
Month/Year:	12/83	3/84	5/84	8/84	12/84	3/85	6-7/85	12/85

Exposure Period

9 months:	-------C1-C4------- [Station 23]
12 months:	---------C1-C5--------- [Stations 52,36]

A summary of values for percentage cover, wet weight, and density (numbers of individuals) on horizontal plates and in bags is provided in Table 3.3-6 and Figures 3.3-32 through 3.3-34.

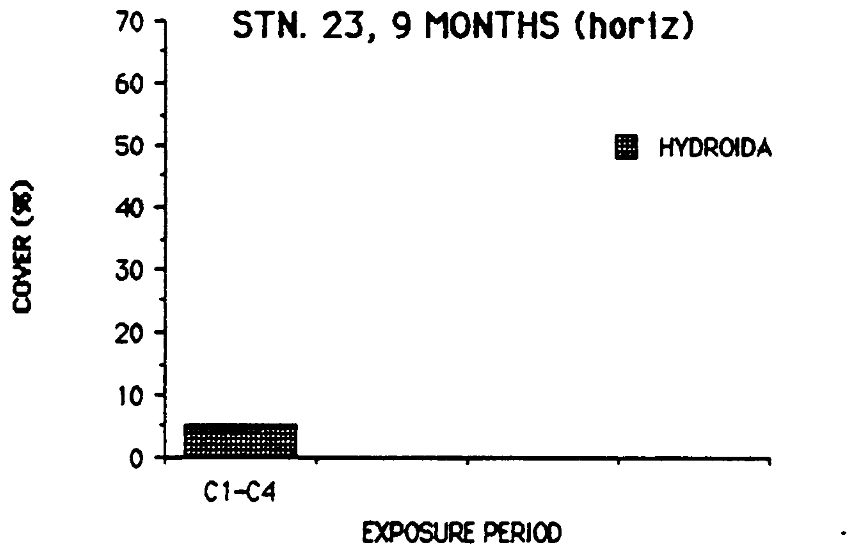
At Station 23, horizontal plates were exposed for 9 months, from Cruise 1 to Cruise 4. Mean wet weight was 0.8 g/plate; mean density, 41 individuals/plate; mean over, 6%. These values were less than those for 1.5-m or standard plates exposed during the same period. Hydroids accounted for the most cover, and serpulids were most frequently counted.

At Station 52, horizontal plates were exposed for 12 months, from Cruise 1 to Cruise 5. Mean wet weight was 289.7 g/plate; mean density, 270 individuals/plate; and mean cover, 71%. These values were about 10% to 23% lower than corresponding values from 12-month, 1.5-m plates exposed during the same period. Most of the individuals were _Balanus trigonus_, serpulids, and _Isognomon radiatus_, which also accounted for most of the cover. The greatest portion of the wet weight was made up of _I. radiatus_, _Chama macerophylla_, and _Telestó riisei_.

At Station 36, horizontal plates were exposed for 12 months, from Cruise 1 to Cruise 5. Mean wet weight was 3.8 g/plate; mean density, 15 individuals/plate; and mean cover, 2%. Wet weight was thus about half that on 1.5-m plates exposed during the same period, while cover and density were very similar. Most of the individuals counted were serpulids, which also were responsible for the greatest cover, though hydroids made up most of the wet weight.

Bag Samples

Bag samples contained mainly small gammarid and caprellid amphipods, and other motile fauna. The weight of bag samples was usually negligible (less than a gram/bag), but the number of individuals was often very high (Table 3.3-6). The number of individuals in sets of bags generally



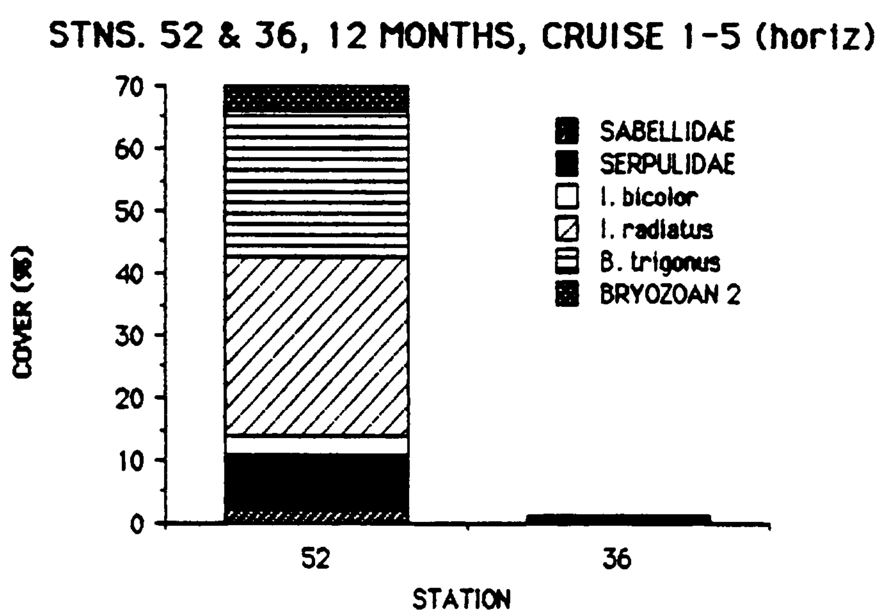


Figure 3.3-32 COVER BY MAJOR TAXA OF SETTLING ORGANISMS ON HORIZONTAL PLATES, BY EXPOSURE PERIOD AND STATION

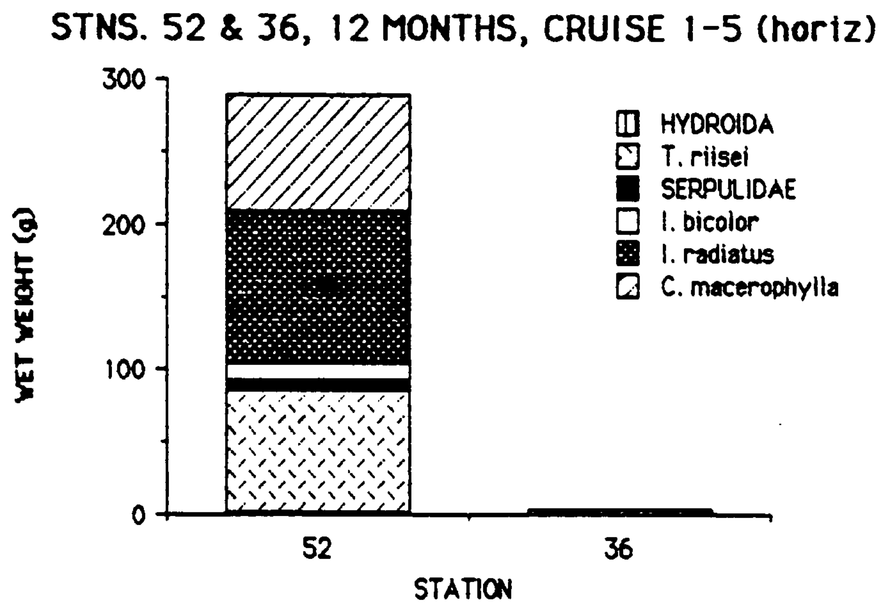


Figure 3.3-33 WEIGHT BY MAJOR TAXA OF SETTLING ORGANISMS ON HORIZONTAL PLATES BY EXPOSURE PERIOD AND STATION

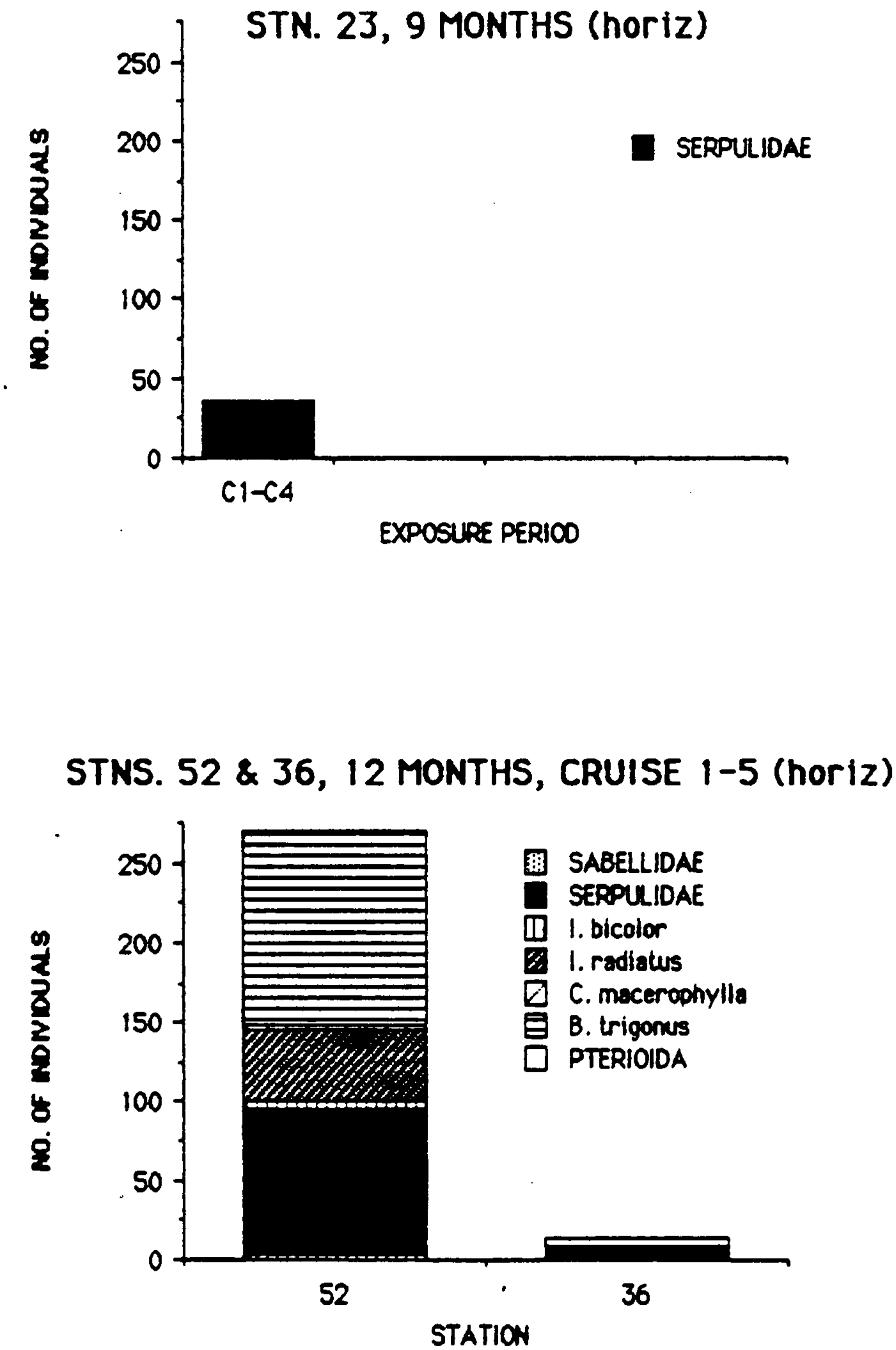


Figure 3.3-34 DENSITY BY MAJOR TAXA OF SETTLING ORGANISMS ON HORIZONTAL PLATES BY EXPOSURE PERIOD AND STATION

exceeded the number on corresponding sets of plates by several times, especially at shallow stations (Figure 3.3-35). It was not possible to determine whether organisms in bags had fallen off the front, back, or edges of each plate, so their numbers and weights cannot fairly be compared to those of animals on plates.

Furthermore, plates were placed in bags on deck after being hauled up from depth, since it was not possible to install the bags around the plates *in situ*. It is virtually certain that there were losses *en route*, but the amount of loss was unknown. It is also probable that the loss was taxon-specific, since some animals such as gastropods usually release their hold on substrates and drop when disturbed, while others such as caprellids grip more tightly. Consequently, taxon-specific data for bag samples were considered unreliable, and only totals for all species together are reported.

Discussion and Conclusions

The most common organisms in shallow water were hydroids, barnacles (*Balanus trigonus*), bivalves (*Isognomon bicolor* and *I. radiatus*), bryozoans, ascidians, and serpulids. In deeper water, serpulids were most abundant. Standard plates collected less material (from the standpoint of wet weight) than did 1.5-m plates exposed during the same period at the same station, while horizontal plates usually had intermediate amounts.

Any of the parameters measured (biomass, density, cover) for the settling community could be used to examine differences and similarities between stations and exposure periods. However, biomass was considered the most suitable in this study, in that it was least subject to errors due to morphological differences between species. For example, density estimates omitted colonial hydroids, which are not easily counted but often made up the bulk of material on the plate. Similarly, cover

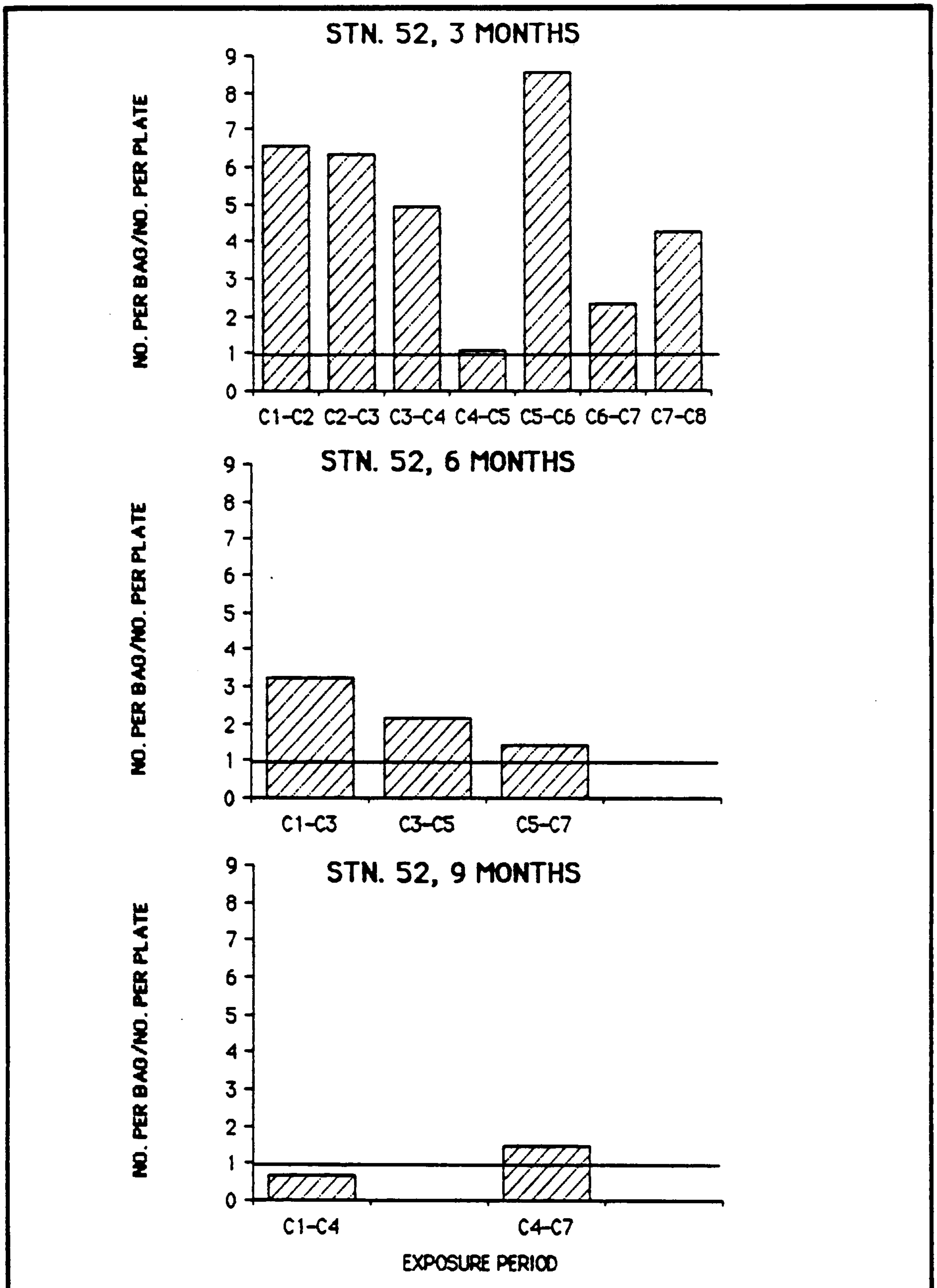


Figure 3.3-35 MEAN DENSITY OF SETTLING ORGANISMS IN BAGS VS. CORRESPONDING PLATES AT STATION 52, BY EXPOSURE PERIOD (HORIZONTAL LINE DENOTES EQUAL NUMBERS)

estimates excluded motile organisms. By comparison, all taxa were weighed. Consequently, this section emphasizes weight estimates (biomass) rather than cover or density.

In general, at any given station, the longer plates were exposed, the more biomass was found on them (Figure 3.3-36). In addition, for a given exposure period, the deeper the station, the less biomass was present. Biomass decreased drastically at stations located below 47 m (Stations 29, 23, and 36, at 66, 75, and 125 m, respectively).

Seasonal patterns of settlement and growth could be resolved most effectively with unbroken 3-month series of plates within stations. Such series existed at Station 52, where seven successive periods were represented on standard tile plates; and at Station 7 (three successive periods); Station 21 (four successive periods). Longer exposure periods provided information on total biomass accumulation with time, but were not intended to elucidate seasonal patterns.

Unfortunately, there was an inverse relationship between the survivability of plates and the amount of material growing on them. In shallow water, where intense settlement and rapid growth took place, plates were much more frequently found smashed on the bottom. As a result, the number of replicates recovered in shallow water was typically too low for statistical analysis. For instance, only three of the seven sets of 3-month plates retrieved from Station 52 had more than two intact plates in them, and for two periods, only one plate was recovered. Consequently, conclusions based on these partial sets must be considered qualitative. Deeper stations often showed excellent replication, but had extremely low biomass values (e.g., <1 g). Station 36, for example, had a consecutive series of sets of five 3-month standard plates recovered, but none of these sets had a mean biomass exceeding 0.6 g/plate. Drained weights of less than a gram are not particularly accurate, because the amount of water retained by each specimen during the weighing process varies with

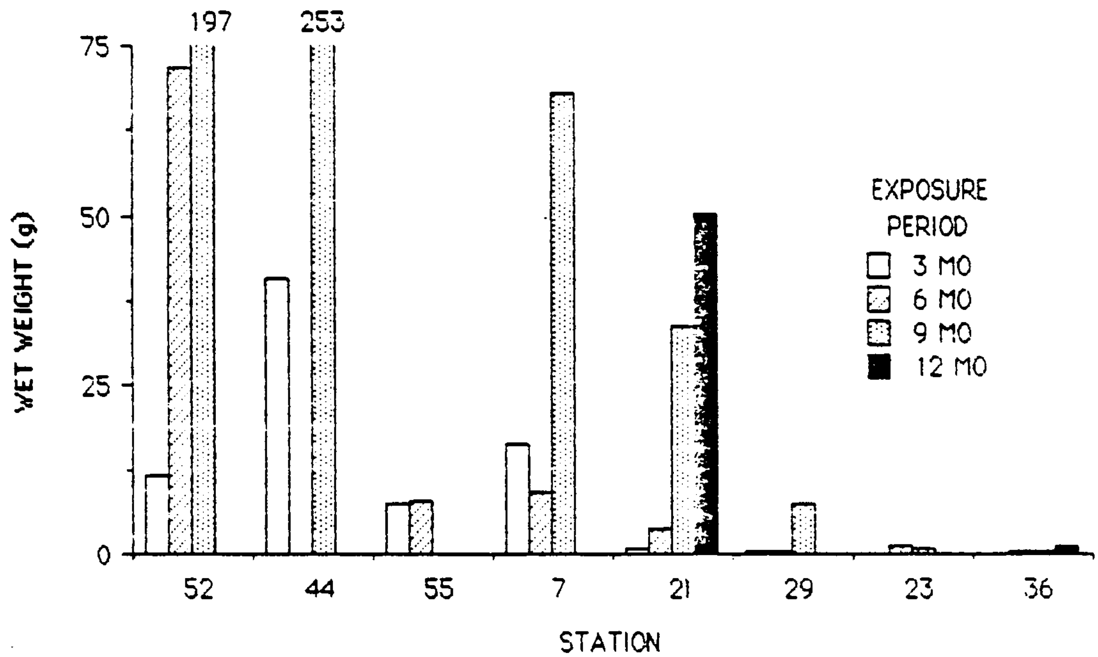


Figure 3.3-36 MEAN WET WEIGHTS ON STANDARD PLATES FOR ALL CRUISES TOGETHER, BY EXPOSURE PERIOD AND STATION

the degree of dessication and the length of draining. In many cases, the weight of water retained probably equalled or exceeded the weight of small specimens.

At Station 52 (depth 13 m), biomass was lowest on plates exposed from winter to early summer (i.e., from December 1983 to March 1984; from December 1984 to March 1985; and from March 1985 to June/July 1985). Biomass was highest on plates exposed from early summer to winter (from June/July 1985 to September 1985, and from August 1984 to December 1984). Plates apparently may experience either light or heavy growth in the spring; although the lowest values at Station 52 were recorded from March 1985 to June/July 1985, the third highest value was recorded between March and May in 1984.

At Station 21 (depth 47 m), a similar pattern was observed. The highest biomass was recorded from late summer to winter (August to December 1984), and the lowest from spring to early summer (March 1985 to June/July 1985). Although full sets (five plates each) were recovered, the range of weights was so low (only 0.1 to 1.4 g/plate) that any conclusions about seasonality must be considered tentative.

At Station 7 (depth 32 m), the pattern was the opposite of that observed at Stations 52 and 21. Biomass was lowest on plates exposed in early summer and fall [from June/July to September (Cruise 7 to Cruise 8)] and highest on plates exposed from winter to spring [December to March (Cruise 5 to Cruise 6)]. Mean biomass was also very low on these plates (range = 0.6 to 2.6 g/plate), although four to five plates were retrieved from each period.

A consecutive series of three sets of 6-month standard plates was also collected at Station 52. In contrast to the 3-month plates at the same station, the greatest mean biomass was present on plates exposed from winter to early summer (December 1984 to June/July 1985), and lowest on plates exposed from spring to winter (May to December 1984). Biomass on plates exposed from winter 1983 to spring 1984 (December to May) was intermediate, but totaled less than one-seventh of that during the corresponding period in the following year. Although biomass was high on plates exposed from December 1984 to June/July 1985, the mean value was based on only two plates retrieved. Biomass on 3-month plates exposed from December 1984 to March 1985, and from March 1985 to June/July 1985 was quite low. The reason that 6-month plates had such high biomass during the same period that 3-month plates had relatively low biomass (compared to other exposure periods) is unknown.

The results of this study suggest that biofouling on petroleum structures will be heavy in shallow water near shore, and light in deeper water offshore, confirming the premise of DePalma (1971) who predicted equivalent results regardless of geographic location. The results also were similar in many respects to those of several other eastern Gulf of Mexico studies on artificial substrates (Pequegnat and Pequegnat, 1972). The Pequegnats suspended plastic floats at depths from 4 to 44 m on buoys at three stations off Panama City, Florida, and sampled them at various intervals ranging from 2 weeks to 1 year. These studies are probably most relevant to the southwest Florida study, since other artificial substrate work in the Gulf of Mexico has mainly been farther west or closer to shore (e.g., Thomas, 1975).

Since the Pequegnats reported dry weight rather than wet weight, and because at Panama city, floats sampled the settling community above the bottom as well as near the bottom, their data cannot be compared directly to this study. Within their stations, biomass was lowest near the bottom. Although the principal settling organisms were similar in both areas (barnacles, hydroids, polychaetes, especially caprellids and tubicolous gammarids), the species composition differed somewhat between areas. For example, near Panama City, *Balanus venustus* was a prominent settler, and *Balanus trigonus* was not reported there. By comparison, *Balanus trigonus* was the most important barnacle off southwest Florida, and *B. venustus* was rare. The absence of *Balanus trigonus* from the

Pequegnats' floats was probably due to its relatively recent introduction to the Gulf of Mexico (Gittings et al., 1986). In general, the Pequegnats' results resembled those of this study: the longer substrates were exposed, the more material grew on them, and biomass decreased with increasing water depth (i.e., distance from shore).

Because virtually none of the organisms examined on settling plates was identified in benthic samples, specific comparisons and predictions are precluded. The lack of comparability in species lists was expected, since dredges and television cameras do not sample microscopic organisms on the bottom. Furthermore, settling communities typically include many "founder" species that are not competitive dominants, and are therefore not well represented in mature communities.

Additionally, nearly all of the plates were installed in a vertical orientation, stacked close to one another. This type of installation provides excellent information about the kinds of organisms that would settle on other vertical surfaces (e.g., petroleum platforms), but the applicability of the results to horizontal natural bottom is questionable. Light levels on vertical plates--especially plates within stacks--are a fraction of what they would be on horizontal surfaces, for instance. This is probably why photosynthetic gorgonians, which are extremely abundant at most stations, were never seen to have settled on plates. Even on plates exposed for 9 to 12 months at shallow stations, major benthic species such as sponges were only minor components of the settling community.

There were some sets of horizontally mounted, 12-month plates installed at Stations 52 and 36, and 9-month plates at Station 23. The plates from Stations 23 and 36 were nearly bare, as were the vertical plates. By comparison, the horizontal plates at Station 52 were heavily overgrown with Chama macerophylla, Telesto riisei, and Isognomon radiatus. None of these species is a major benthic community component, although Chama was taken with the dredge. The most reasonable conclusion from these results is that settling plates are a useful tool for studying the settling community, but the results are very difficult to apply to natural bottom!

Nonetheless, there are several management implications of both the current findings and the earlier studies of biofouling in the eastern Gulf of Mexico. Damaged hard substrates in shallow water will probably be recolonized rapidly by settling organisms. In deeper water, colonization will take much longer (perhaps years). In the absence of further disturbance, natural succession on recolonized substrates may eventually produce a mature community if the substrate previously supported one. There is an excellent chance that the post-impact community would not closely resemble the pre-impact community. A mosaic of different communities side-by-side is one of the most distinctive features of the southwest Florida shelf; it may be difficult or impossible to predict which groups of suitable organisms would come to dominate a recolonized area. Furthermore, some low-lying areas of the shelf are frequently disturbed due to periodic burials and extinctions by sand movement, especially in shallow water. Repeated defaunation of an area may retain an immature ("pre-climax") community pattern. The effects of development in these areas may be indistinguishable from natural processes, so far as the settling community is concerned.

The organisms of greatest concern in this region are not settling species, but long-lived forms that represent mature communities, such as corals, gorgonians, and large sponges. Artificial substrate studies may therefore not have any real value in predicting benthic community recovery from damage, unless substrates are exposed for long periods of time, i.e., 1 year or more. Even so, many benthic species may be sufficiently specific in their habitat requirements that they may not settle on artificial substrates.

In addition, faunal differences between standard and 1.5-m plates in this study, and between the floats at various depths in the Panama City study, make it clear that plates should be exposed immediately above or on the bottom if they are to be useful in predicting community recovery. While artificial substrates mounted higher above the bottom reveal a great deal about the fouling communities that may settle on petroleum platforms, they tell very little about benthic recovery.

Artificial structures such as petroleum platforms in shallow water near shore will certainly be thoroughly fouled unless protected by anti-fouling coatings or other measures. Long-term buildup will probably be heavy almost all the way down to the sediment line. Based on this study, fouling growth may exceed 9 kg wet weight/m^2 near the bottom in water depths of 13 m or less, extrapolating from vertical 9-month plates at Stations 44 and 52.

In water between 13 m and 47 m deep, long-term biofouling buildup will be slower, but still considerable on the lower portions of platforms. Twelve-month plates at Station 21 (47 m) collected 2.2 kg wet weight of fouling organisms/m^2. At greater depths, buildup will be minimal or negligible. At Station 29 (64 m), 9-month plates collected 325 g/m^2 wet weight, but at Station 23 (74 m), 9-month plates collected only 44 g/m^2, and at Station 36 (125 m), 12-month plates averaged only 53 g/m^2.

Whether or not the upper portions of platforms will be heavily fouled is not known, since this study did not examine biofouling other than near the bottom. Previous work offshore in the Gulf of Mexico (Lewbel et al. in press) has shown that for some platforms farther to the west, there is a substantial buildup of bivalves near the surface, with a decrease toward the bottom.

3.3.8 THE LIVE BOTTOM CONCEPT

In general, the results of the Year 4 and Year 5 studies were similar to those provided by other contractors for the same stations during the first years of the Southwest Florida Shelf Ecosystem Program. Stations that differed substantially in depth also differed substantially from one another in flora and fauna. The Inner Shelf stations in shallow water resembled one another in many respects. However, the utility of the "live bottom" definition was questionable for many stations, especially those in shallower water. "Live bottom areas" are defined by MMS as those areas which contain biological assemblages consisting of such sessile invertebrates as sea fans, sea whips, hydroids, anemones, ascidians, sponges, bryozoans, seagrasses, or corals living upon and attached to naturally occurring hard or rocky formations with rough, broken, or smooth topography; or whose lithotope favors the accumulation of turtles, fishes, and other fauna.

Based on previous reports, half of the Group I stations were expected to be live bottom, and the remainder to be soft bottom. The distinction between the two types was vague at best. Most stations had wide areas of carbonate sand interspersed with low-relief outcrops of coral or rock, and sponges and gorgonians that projected through sediment. Many of these sponges were very large (e.g., 1 m in height), confirming previous findings that despite the presence of soft sediment, the hard substrate beneath was not deeply buried.

Hard substrate must be exposed at some time in order for settlement of invertebrate larvae to take place. Whether or not organisms that settle on hard substrate can survive subsequent inundation by sand depends upon the length and timing of exposure, as well as growth rate and their own resistance to sand scour and partial or complete burial. Invertebrates projecting through sand have grown to sufficient size to resist burial, and offer points of attraction to other fauna such as fish. Fish were often seen concentrated in gorgonian beds or associated with large sponges on soft bottoms.

Furthermore, local densities of many species along transects were highly clumped, producing overall confidence limits for abudances that frequently included zero. This demonstrated that measures of central tendency (e.g., mean density) may be inappropriate or inadequate to describe the true situation for this study area. The problem of local density differences could be solved with larger areas, but those used in this program--at least, for underwater television transects--were already greater than those in most other biological surveys.

These observations call into question the current concept of live bottom, at least for this study area. An area classified either as live bottom or soft bottom can probably change from one into the other rather easily, especially where the sediment overburden is not deep. Areas of soft bottom alternate with live bottom in a patchwork fashion in many locations, and sampling variability can account for major differences between transects a few meters apart. These findings militate strongly against categorizing extensive areas of the bottom--or stations--as either live or soft bottom, even if one accepts the jargon; the dichotomy is frankly inadequate to describe the biological situation, and perpetuates misunderstanding.

4.0 CONCLUSIONS AND RECOMMENDATIONS

4.0 CONCLUSIONS AND RECOMMENDATIONS

This section summarizes major conclusions regarding potential impacts of petroleum exploration and development on the southwest Florida continental shelf, based primarily on results of the Years 4 and 5 Southwest Florida Shelf Benthic Communities Study. A brief review of pertinent background information precedes a discussion of management implications and their rationale. The section ends with recommendations for future applied ecological research in the area.

During Year 6, information collected in Years 1 through 5 will be synthesized into an overview of the shelf ecosystem. The definition and selection of Valuable Ecosystem Components (i.e., species and habitats of special concern and/or protection by virtue of their ecological roles, economic or recreational value, legislative status, or other characteristics) will be emphasized. Until the Year 6 synthesis has been completed, the conclusions, their implications, and the recommendations that follow must be considered tentative.

Petroleum activities postulated to affect marine ecosystems include construction, installation, and operation of offshore rigs and pipelines; release of effluents such as drilling fluids and production or formation water; increased boat traffic; attraction of fishermen and sport divers to rigs; and oil spills (Clark and Terrell, 1978; Gallaway, 1981; Gallaway and Lewbel, 1981; Middleditch, 1981). These activities and their possible effects on the southwest Florida shelf are considered below.

4.1 POTENTIAL IMPACTS OF PETROLEUM EXPLORATION AND DEVELOPMENT

4.1.1 ENVIRONMENTAL CONDITIONS

The southwest Florida continental shelf is a broad (approximately 200 km), flat limestone platform with relatively few areas of high relief. The shelf slopes gently to the west. In most locations, low-lying, hard substrates either alternate with or are covered by a thin veneer of coarse sand. This sand is primarily calcareous, with percentages of $CaCO_3$ exceeding 90% in most locations, indicating that the sand is derived primarily from coral, calcareous algae, and the erosion of bedrock.

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

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

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

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

A summary of the physical data collected during the MMS Program and from literature sources is presented in Figure 4.1-1 for the five major Group II Stations. This figure is presented not only to provide a description of the physical environment as it changes with depth, but also to illustrate the stresses or ranges in the physical parameters that help determine the composition of the biological communities. The parameters that are summarized in the figure include:

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

4.1.2 BIOLOGICAL CONCERNS

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

On hard substrate in shallow water, sessile animals dependent upon sunlight (e.g., corals and gorgonians) and sponges are dominant. Low-

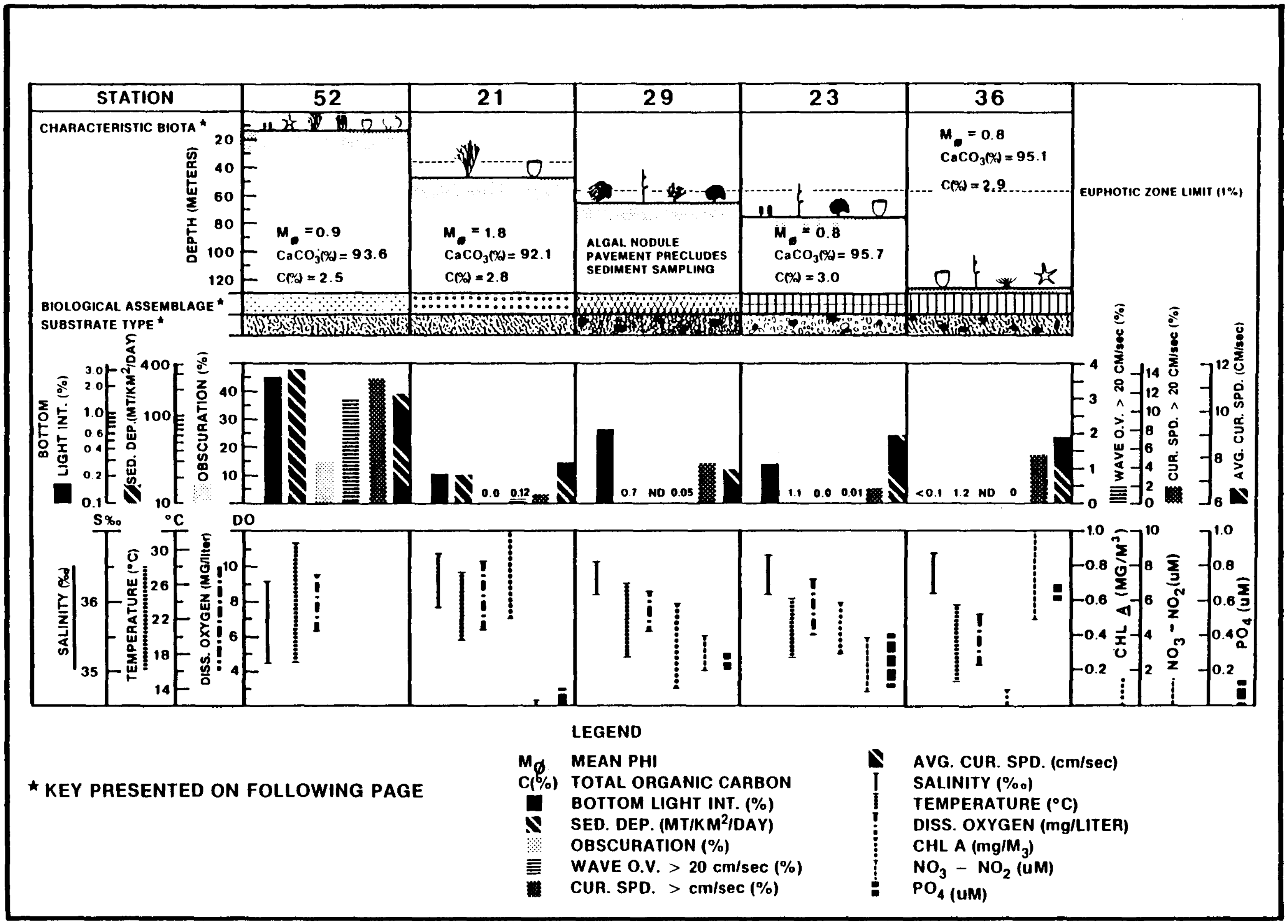


Figure 4.1-1 CROSS-SHELF BIOLOGICAL, PHYSICAL, AND CHEMICAL STATION CHARACTERIZATION OF SELECT GROUP II STATIONS

SUBSTRATE TYPES

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

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

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

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

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

BIOLOGICAL ASSEMBLAGES

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

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

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

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

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

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

CHARACTERISTIC BIOTA

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

SOFT BOTTOM BIOTA

MACROPHYTIC ALGAE

ASTEROIDS

CRINOIDS

SCATTERED ATTACHED EPIFAUNA, MOSTLY SMALL SPONGES

LIVE BOTTOM BIOTA

Halimeda spp.	ALGAE
Anadyomene menziesii	ALGAE
	HYDROZOANS
Muricea elongata, *Pseudoplexaura* spp., *Eunicea* spp., *Pseudopterogorgia* spp.	GORGONIANS
Antipatharia spp.	GORGONIANS
Agaricia spp.	HARD CORALS
Siderastrea spp.	HARD CORALS

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Figure 4.1-1 (cont'd)

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

Several hundred different fishes have been identified on the southwest Florida shelf, including grunts, snappers, groupers, and other species of potential commercial and recreational interest. Much of the area is unsuitable for trawling due to outcrops of hard substrate, masses of sponges, or other bottom features, and must be fished either with traps or by hook and line. There also are several deep (perhaps >1,000 m) "holes" (subsidence or solution holes) near the edge of the shelf; these deep holes are reported to harbor large numbers of fish, especially snappers, and may be of great commercial and scientific interest.

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

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

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

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

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

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

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

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

4.1.3 MANAGEMENT IMPLICATIONS

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

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

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

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

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

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

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

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

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

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

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

4. Petroleum platforms and other structures will almost certainly concentrate settling species, fishes, turtles, and other organisms. Offshore structures will provide outstanding fishing and recreational diving. Some species (e.g., valued ecosystem components and species

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

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

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

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

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

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

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

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

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

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

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

The environmental concerns listed above are the most likely to be of importance on the southwest Florida shelf. Numerous studies have amassed information concerning potential environmental hazards from oil- and gas-related activities including Darovec _et al_. (1975); Darnell, Defenbaugh, and Moore (1983); Darnell and Kleypas (1986); Jaap (1984); McCoy (1981); Schomer and Drew (1982); Wolfenden (1983); and Zieman (1982). A listing of potential hazards indentified in these studies, their causative activities and agents, and potential effects are summarized in Table 4.1-1. These hazards and potential are in general agreement with those identified for the southwest Florida shelf.

4.2 METHODS EVALUATION AND RECOMMENDATIONS

The use of several types of gear to sample the same kinds of organisms resulted in a broader understanding of the communities surveyed, as well

Table 4.1-1. Preliminary listing of environmental hazards potentially resulting from oil and gas related activities on the Southwest Florida Shelf, their causes, and their valued ecosystem component effects

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

Table 4.1-1. (cont'd)

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

as of the advantages and limitations of each type of gear. Underwater television, trawls, and time-lapse camera all provided data on fishes. Underwater television, dredges, and high-resolution benthic photography surveys all were used to survey benthic invertebrates and plants. Fouling plates and time-lapse cameras sampled newly settled organisms, which are often ignored in conventional sampling programs even though they described aspects of community dynamics which cannot be studied by any other technique. Each of these techniques is reviewed in turn in the following section, followed by a brief discussion of the main areas of overlap of the various gear types.

4.2.1 UNDERWATER TELEVISION

Underwater television surveys were extremely useful in describing benthic communities, mainly because a very large area (15,000 to 67,000 m^2) was surveyed at every site. Taxonomic resolution of underwater television data depended on the type of organisms seen. The underwater television was probably the single most effective gear for surveying fishes and assessing their densities. Fishes in underwater television samples were relatively easy to identify to species. At the majority of sites, more fishes were identified in underwater television samples than with trawling. Some species [e.g., the porkfish, *Anisotremus virginicus*; half the damselfishes; and half the serranids (groupers and basses)] were sampled only with underwater television.

Unfortunately, the underwater television was not sufficient in resolution for species-level identifications of most benthic organisms such as sponges, corals, and gorgonians. Underwater television could be used effectively to define habitat types and to characterize benthic substrates (e.g., "live bottom"), but it seriously underestimated the abundances of low-profile or cryptic taxa. In some cases it was necessary to accept less resolution (i.e., a higher taxonomic level) in identification in order to compare results from several observers. This resulted in the loss of some data, but made it possible to compare data sets between observers. Invertebrates and plants often could not be identified beyond the family level. Nevertheless, large-area estimates of the abundance of such multi-species groupings using underwater television were undoubtedly more reliable than those obtained through any other means.

Most results demonstrated that it is a great deal easier to collect underwater television data than it is to interpret it correctly. A superficial analysis of underwater television data is as likely to mislead as to inform. It is particularly subject to inconsistencies as a result of varying levels of observer expertise.

Surprisingly, the experience of an observer is not necessarily correlated with more species-level identifications. In fact, the more knowledgeable the observer, the less likely he may be to render specific identifications of benthic organisms. These kinds of inconsistencies can be extremely troublesome to resolve, because it is not a simple task to look back over hours of videotape to locate and confirm an identification of a particular fish. By comparison, examining a trawl specimen from a jar for taxonomic verification is a trivial matter.

For example, gorgonians (sea fans, sea whips, and sea rods) provide a case in point. Two well-trained biologists scored most of our videotapes. Both biologists had been on cruises and were familiar with the communities involved. One biologist--who had also been responsible for identification of gorgonians from the dredge samples--turned out to be much more reluctant to assign species names to gorgonians than did the other observer. The first observer knew that many taxonomic features of gorgonians depend on morphological traits (e.g., spicule shape) not visible on television. The second observer was not as familiar with gorgonians and was more inclined to assign specific names, based on literature reports and limited dredge samples.

By comparison, the converse was true for fishes. The second observer was more knowledgeable and more likely to assign species names to fishes. He was able to differentiate between species based on behavioral traits such as position in the water, swimming speed, schooling, etc., as well as appearance. In general, we have assigned specific names whenever possible, balancing the risk of misidentification against the advantage of making the correct "guess," especially when trawl or dredge samples provided the ground truth.

The ground-truthing process was crucial on the southwest Florida shelf for underwater television samples at many locations. Diver observations or trawl and dredge samples must be taken whenever possible to determine if important species are hidden from view by an overstory of other organisms.

An excellent example was found in the underwater television and dredge data from Station 55. The only abundant benthic invertebrates visible in videotapes were gorgonians and sponges. Underwater television samples showed 11% to 24% cover by assorted demosponges; and corals were not reported by the observer. However, dredge samples produced 18 species of corals. The discrepancy between results from the two gear types could not be resolved until cruise logs were consulted. While servicing the array at Station 55, divers noted that many low-lying coral colonies could be found among the sponges; however, these small corals were not visible in videotapes.

The underwater television sample analysis process was designed to provide maximum resolution of temporal and spatial differences in benthic organisms; many such differences were seen. However, the organisms most frequently assessed were long-lived species such as huge sponges and gorgonians, which would not be expected to change seasonally. Any differences in abundance of these organisms were most likely the result of surveying different areas on different cruises, rather than to actual seasonal changes in abundance. The underwater television data on these organisms are, therefore, valuable as an indication of patchiness and heterogeneity in distribution, rather than of seasonal changes.

Finally, all ESE/LGL underwater television transects were performed during daylight hours. Although most sessile organisms would be unaffected by the use of lights, some fishes would. These fishes either would be attracted to the lights, or avoid them; either situation would misrepresent actual densities. In addition, most species of fishes appear to be diurnal rather than nocturnal, and it is likely that many of them would not be observed at night or that their densities would differ greatly from night to day. Compared to previous underwater television surveys in the same areas (Woodward Clyde Consultants/Continental Shelf Associates 1983) which were surveyed only after dark, higher densities and more species usually were observed in this study.

4.2.2 TRIANGULAR DREDGE

The triangular dredge was an extraordinarily effective piece of field sampling gear for some kinds of biota, in terms of quantity of sample collected. It removed virtually everything projecting above the bottom. In underwater television transects that crossed dredge tracks at several stations, clear-cut swaths could be seen where the dredge had been used.

Unfortunately, the triangular dredge was not effective as a quantitative sampling tool. Because it had a fairly large mesh size, it undoubtedly lost many smaller organisms through its holes. It was readily clogged by large sponges, and it took so much material that even in a very short tow, it often came on deck completely full or overflowing. Consequently, tow length had to be kept short (2 min). Samples were thus especially prone to variability due to patchiness, since the dredge could not be towed along the bottom long enough to cover a large area without the dredge overflowing.

In addition, the abundance of organisms in tows could not be compared to one another by using densities based on tow length and dredge width, because the time on the bottom may have been unrelated to haul quantity. For example, if a dredge came up full, it was not possible to determine whether it filled up during the first 30 sec, or during the last few seconds on the bottom.

As a result of these factors--and the practical impossibility of analyzing complete samples from the triangular dredge--it was necessary to treat the dredge results as presence/absence data. This caused a loss of information on the density of organisms collected by the dredge, but avoided giving the misleading impression that samples from the dredge were quantitative. Because members of each visually distinct species were chosen randomly on deck for preservation, the length and weight data for invertebrates also may be non-representative, but are presented in Appendix E for completeness.

It might be possible to consider data quantitative for species collected by dredging in future studies, but only if several conditions were met:

1. The dredge would have to come on deck unclogged by large organisms such as loggerhead sponges;
2. The dredge would have to be less than completely full when returned to the deck, so that one could assume that the entire dredge track was sampled (rather than the area covered until the dredge filled); and
3. Complete dredge hauls would have to be preserved and analyzed in the laboratories. Although some hauls came closer than others to meeting these criteria, the results were not consistent.

   Even if all these conditions were satisfied, abundance data for species small enough to be winnowed by the coarse mesh of the dredge would have to be disregarded.

4.2.3 OTTER TRAWL

Trawl samples were most useful for facilitating the identification of fishes seen on underwater television, for expanding the taxonomic checklist for each station, and for analysis of stomach contents and life history parameters.

On the whole, however, the otter trawl was a difficult tool to use on the southwest Florida shelf at many stations. The irregularity of the bottom meant that a great deal of time was spent mending nets on board. When the stock bridle and doors were replaced with a more heavy-duty version (see Subsection 2.3.3, Methods), and anti-chafing mesh was added to the net, its durability was considerably enhanced. It is recommended that these modifications be made at the beginning of any future study for which trawling in hard bottom areas is required.

Although an extensive fish list was compiled at many stations, it would have been very useful to have more than one trawl sample per cruise. Replication would have made it possible to conduct detailed statistical analyses of fish abundance, for comparison to underwater television estimates. Although point estimates (single trawls) of fish densities from trawling can be compared to underwater television estimates, the value of those comparisons would have been greatly enhanced by an understanding of the variability in trawl catches within cruises at each station. Trawls did miss many species seen with underwater television, and vice versa. Trawl data were extremely variable between cruises and stations, and without replicate samples, it was not possible to determine the source of such variability.

For example, point estimates routinely give misleading impressions of overall densities for species in which schooling affects catchability. For these species, whether or not the trawl passes through a school strongly affects the results. Without replication within stations on the same cruise, it is not possible to delineate these sources of variation, nor to compare seasonal data other than qualitatively. Because a short amount of ship time was required for each tow, it probably would have been economic to take three tows at each station on each cruise.

Several comments are pertinent regarding the analysis of stomach contents of fish collected with the trawl. Various factors can bias the results. Many of these cannot be eliminated, but should be taken into account when evaluating the results.

Due to the depths at which collections were made, some of the fish regurgitated part or all of their stomach contents while the trawl was being raised. When fish were retrieved from deeper stations, their gas bladders sometimes expanded, forcing their stomachs toward the mouth. In the case of physoclistic fishes such as Serranus phoebe, S. atrobranchus, and Epinephelus morio, stomachs were sometimes fully everted into the mouth. This can result in a underestimate of prey volume. On the other hand, some fishes may have much fuller stomachs in the trawl than they had before they were captured. Piscivorous fishes taken early in the trawl are known to prey upon organisms in the trawl which they might not ordinarily catch, or to gorge themselves on an unnatural abundance of food (Randall, 1965).

In addition, the proportions of various prey items in stomachs of fish collected in trawls may differ significantly from the actual proportions in the diet. These artifacts depend upon differential digestion rates as well as the timing of capture. For example, small crustaceans or worms, even in large amounts, will be assimilated before other prey such as fish that may take longer to digest (Hyslop, 1980). Different species of fish feed at different times. A fish that feeds at night but is captured in the late afternoon may contain the well-digested remains of the previous night's feeding, or have entirely digested its prey by the time of capture. In such cases, the data will be biased in favor of prey that is digested more slowly (Randall, 1965). Therefore, fish taken during or shortly after their feeding periods will contain a more representative sample of their actual diets. Finally, when capturing prey, a fish may swallow nonfood items such as stones or pieces of algae, which may affect the analysis (Randall, 1965).

Finally, summary indices used to represent the importance of food items can be most useful for an overview, but may not always portray the dietary value of specific food items. Nearly all indices ignore the caloric value of food items. Indices based solely on numbers of items in the stomach can underestimate the relative importance of a few large items if many smaller items are present. Indices based strictly on volumetric measurements are strongly affected by different rates of digestion of various items (Pinkas et al., 1971). Analysis based on frequency of occurrence (numbers of fish having a particular type of prey in their stomachs) "may give little indication of the relative amount or bulk of each food category present in the stomach" (Hyslop, 1980). The use of all three values certainly supplies a more representative view (Windell, 1971). The IRI used in this study (see Subsection 2.3.3, Methods) takes each of these factors into account, and is one of the better indices available.

4.2.4 SETTLING PLATES

Settling plates are a standard, well-accepted method for collecting information about larval settlement and growth of marine organisms. As such, they were very effective in this program. Ceramic tile plates collected a much wider variety of species than did steel plates, which shed bubbles and flakes of rust, and were very difficult to analyze.

If the buildup of settling organisms on artificial structures is a major concern of future programs (e.g., affecting design criteria for offshore structures), our findings suggest that plates are ideal for such considerations. It may not be cost-effective to install plates in water depths exceeding 75 m, however, due to very low settlement growth rates.

This finding alone is of interest. On the other hand, rapid buildup may be expected in water depths of 20 m or less, and plates are an excellent tool for predicting the types and quantities of sessile organisms to be expected there.

Whether or not settling plates can be useful in assessing the possible long-term effects of damage to benthic communities is a key question that remains unanswered. Rapid recruitment to plates in shallow water implies that benthic communities may recover--or at least, be repopulated with sessile species--within a reasonable length of time following mechanical damage. There is no question that in shallow water, bared substrate would be quickly recolonized by settling species. This conclusion is confirmed by the biomass figures for settling plates at Station 52, for example.

Whether or not plate results can be extrapolated to natural bottom is unclear, however. Most of the species seen on plates were not major benthic community components such as large sponges, corals, gorgonians, etc. but were typical "opportunists," which settle on bared substrate (e.g., plates, buoys, or anchor lines) and are often replaced by superior competitors as a community matures. Perhaps a very long period of exposure (years) could resolve the matter, but previous work has demonstrated that plates usually reveal settlement patterns on artificial substrates, rather than on natural substrates.

4.2.5 TIME-LAPSE CAMERA

Time-lapse camera samples provided excellent long-term data for fishes attracted to arrays. The time-lapse camera records revealed relative species abundance, interspecies associations, arrival times, and residence times, as well as diurnal activity patterns. Although it was impossible to separate multiple records of the same individuals from single sightings, the data could be analyzed statistically through the use of repeated measures procedures. Most species showed surprisingly rapid arrival times (often within hours of installation of arrays) and pronounced differences in abundance from one day to the next. Time-lapse camera films also documented turbidity conditions on the bottom and sediment movements in a graphic fashion. These dynamic processes could not have been observed synoptically by any other sampling method. Furthermore, valuable observations of settling community development were made with the time-lapse camera.

There were some problems with data recovery from time-lapse camera systems. Losses occurred due to mechanical failures of camera or strobe housings. Small water leaks caused some systems to fail before the full roll of film was exposed. Electrolytic damage to latches, and stress fractures in the commercially-purchased underwater housings were responsible for the leaks. New, improved housings were installed at all time-lapse stations during Cruise 5 (Year 5), greatly reducing but not eliminating these sources of failure. Other data losses resulted from camera or strobe failure, development errors at Kodak®, or total loss of the instrument array.

There was another unexpected source of problems. Large fishes and turtles damaged a number of time-lapse camera systems. For example, at Station 52, at least three jewfish, *Epinephelus itajara*, took up residence inside or near the array. Two of these were estimated by divers to be almost 2 m long, and probably weighed over 100 kg each. These large groupers broke settling plates and support rods, abraded electrical cables, and took several time-lapse camera systems out of operation by causing flooding or misalignment of the camera. Improvised barriers (e.g., rope) were ineffective, and future arrays should be designed to exclude large animals.

4.2.6 HIGH-RESOLUTION BENTHIC PHOTOGRAPHIC SURVEYS

The high-resolution benthic photography survey technique using a diver-held camera provided the ability to observe a relatively large area in some detail. The technique, therefore, is potentially useful for the evaluation of long-term changes such as growth and succession. Returning to the same location would not have been feasible with a towed or drifted video system. Major changes in the relative abundance of various organisms could be estimated in a repeatable manner with high-resolution benthic photography survey, and sessile organisms could be monitored for temporal stability and growth. In general, these tasks were accomplished with this method.

There were two major disadvantages of the methodology:

1. Lack of resolution (in spite of the name high-resolution benthic photography survey), and
2. Inconsistent spatial orientation of the video camera. The poor resolution of freeze-frame video images precluded detailed measurements of most taxonomic groups.

In addition, small changes in the camera's altitude changed the apparent dimensions of benthic objects. Although a weighted line was used to maintain the camera at a constant distance from the bottom, it was not always possible to maintain the same distance from the bottom at all times, especially in a strong current. A small change in camera altitude between surveys would result in spurious size changes of the same objects. Variations in camera angle created different perspectives, making it impossible to compare the abundances of many organisms.

Based on this preliminary methodology test, we find little to recommend the high-resolution benthic photography survey technique over the use of 35-mm still cameras in fixed jigs (Rezak and Bright, 1981), except for the ability to cover a larger area per unit time with video cameras. This would be especially important in water deep enough to restrict divers' bottom time.

To maximize the results obtained either from the high-resolution benthic photography survey method or from still photography, several additional suggestions are pertinent. It would be very helpful in future studies in similar areas to:

1. Mark and measure (with conventional techniques) any individual organisms selected for repeated observations;
2. Install marked rods through the sediment into the underlying carbonate rock, so that sediment depth could be evaluated photographically; and
3. Mark band transects with boundary lines (rather than just center lines, as in this study), or install a center line of measurable width on photographic images, so that minor differences in camera height or perspective would not adversely affect the data.

4.3 RECOMMENDATIONS FOR FURTHER WORK

In some senses, making recommendations is premature at this stage in the project. Once the Year 6 synthesis is complete and an overview of the previous 5 years has been presented, recommendations will be more meaningful. In fact--if there were not a planned Year 6 synthesis--the strongest recommendation that ESE and LGL could make would be for a year of synthesis of the extensive database collected during the 5-year program.

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

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

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

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

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

To represent the data more accurately, it was necessary to calculate local abundances within transects. The local abundances, rather than whole-transect estimates, were then collected iteratively along transects to generate mean and variance estimates. The confidence limits calculated from these estimates were nearly always so wide as to guarantee that interseason differences for the majority of species were not significant. In other words, patchiness at most locations and for most species made it impossible to differentiate between seasonal differences and spatial differences. It is probably fortunate for biologists that local distributions cannot be revealed by dredge or trawl samples!

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

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

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

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

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

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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 fifth year of the 6-year multi-disciplinary program was provided under MMS Contract No. 14-12-0001-30211.

This Year 5 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; the late Dr. William Behrens, Dr. Murice Rinkel, Mr. Dean Milliken, 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

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John D. Bonds, Ph.D. (University of Alabama, Analytical Chemistry, 1969)--Quality Assurance Manager.

The following people assisted in the field sampling and laboratory analysis: Edward Kellar, Gary Dalbec, Daniel Doebler, Jim Barnes, John Maxwell, Gary Tourtellotte, and George Foster.

Preparation of the Annual Report was directed by Melissa Burke, Cynthia Thompson, and Leslie Burges (Document Coordinators) with assistance from Carolyn Granger (Word Processing Department Manager), and Shane Edmond (Graphics Department Manager).

LGL Ecological Research Associates, Inc.--Subcontractor

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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, Charlie R. Chandler, Stephen T. Viada, 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 Virginia McCarter.

Side Scan Sonar Consultants

The following individuals provided side scan sonar services during this study.

Martin Gierlach (East Port International) and Henry Holm (Holm and Resta, Inc.).

Finally, we would like to thank those unnamed individuals who contributed their skills as word processors, artists, accountants, and contracts personnel.

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. The includes fostering the wisest use of our land and water resources, protecting our fish and wildlife, 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 assure that their development is in the best interest of all our people. The Department also has a major responsibility for American Indian reservation communities and for people who live in Island Territories under U.S. Administration.