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ANNUAL REPORT FOR

NORTHERN GULF OF MEXICO CONTINENTAL SLOPE STUDY

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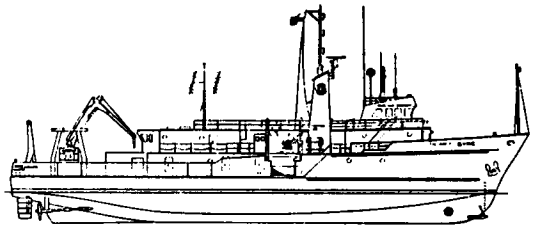
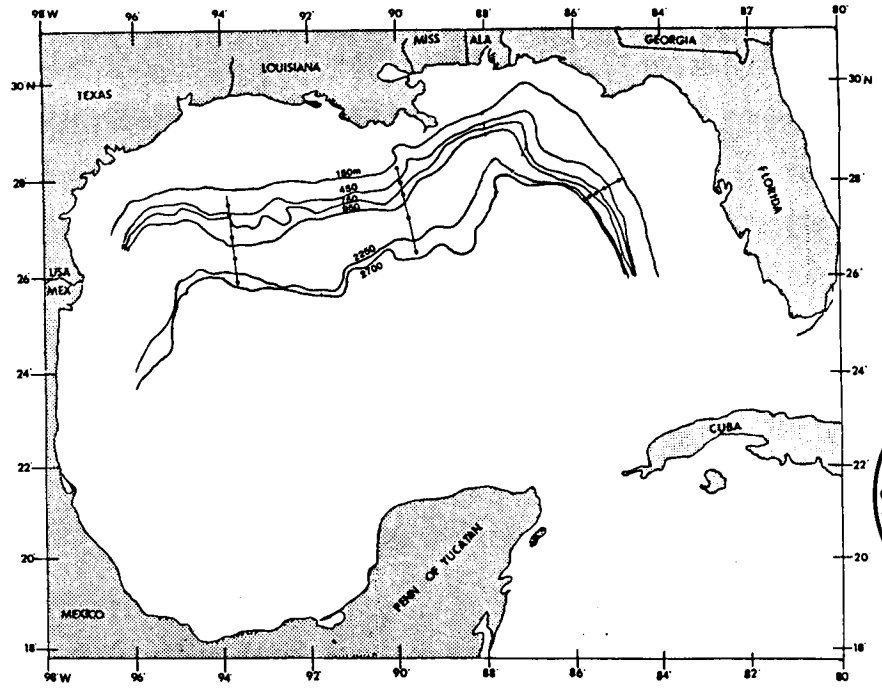


R/V GYRE

PREPARED BY:

LGL ECOLOGICAL RESEARCH ASSOCIATES, INC.

TEXAS A&M UNIVERSITY



SUBMITTED TO:

MINERALS MANAGEMENT SERVICE

GULF OF MEXICO OCS REGIONAL OFFICE

METAIRIE, LOUISIANA

MAY 1985

ANNUAL REPORT

NORTHERN GULF OF MEXICO CONTINENTAL SLOPE STUDY

Prepared For The

Minerals Management Service
Gulf of Mexico OCS Regional Office
3301 N. Causeway Boulevard
Metairie, Louisiana 70003

By

LGL Ecological Research Associates, Inc.
1410 Cavitt Street
Bryan, Texas 77801

And

Texas A&M University
College Station, Texas 77843

Contract No. 14-12-0001-30046

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This report has been reviewed by the Minerals Management Service and approved for publication. Approval does not signify that the contents necessarily reflect the views and policies of the Service, nor does mention of trade names or commercial products constitute endorsement or recommendation for use.

ABSTRACT

This report prepared for the Minerals Management Service (MMS) details the findings of one year of sampling on the continental slope of the Gulf of Mexico. Results of two cruises are presented with information concerning field and laboratory methods and procedures for identifying organisms.

A general overview of the physical and chemical processes in the Gulf of Mexico is presented along with preliminary findings concerning the high molecular weight hydrocarbons in sediments and organisms, sediment texture, organic and carbonate carbon and carbon isotope analysis. Preliminary reports concerning the sigma ^{13}C values for organisms collected in a seep zone are given.

The biological oceanographic section details findings concerning macroeipfauna, fish, meiofauna and macroinfauna including an analysis of zonation patterns in these organisms and comparison of species diversity with previously recorded results.

New analytical procedures for benthic photography are described in detail and results of statistical tests are given for the resulting digitized data set.

ACKNOWLEDGEMENTS

The cooperation and support given by Minerals Management Service personnel Mr. Carroll Day (Contracting Officer) and Dr. Robert Avent (Contracting Officer's Technical Representative) is gratefully acknowledged. The technical consultation provided by the members of the Scientific Advisory Committee has been invaluable to the conception and completion of the project to date. The Scientific Advisory Committee consists of:

Robert Ballard, Ph.D.
Deep Ocean Search and Survey
P.O. Box 373
Woods Hole, MA 02543

Frederick Grassle, Ph.D.
Deep Ocean Search and Survey
P.O. Box 373
Woods Hole, MA 02543

Robert Hessler, Ph.D.
University of California
San Diego
Scripps Institute of Oceanography
La Jolla, CA 92093

Linda H. Pequegnat, Ph.D.
8463 Paseo del Ocaso
La Jolla, CA 92037

Willis Pequegnat, Ph.D.
P.O. Box 2848
College Station, TX 77841

R. Rosenblatt, Ph.D.
University of California
San Diego
Scripps Institute of
Oceanography
La Jolla, CA 92093

Robert Carney, Ph.D.
2382 45th Avenue
San Francisco, CA 94116

We recommend each and every one of them to those looking for consultation on deep-sea research efforts.

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BRACHIOPODA.....Cooper, G. Arthur
BRYOZOA.....Leuterman, A.J.J.
COELENTERATA
Anthozoa
Actiniaria (Sea Anemones).....Fautin, Daphne Dunn
Alcyonaria (Soft Corals).....Lowry, Jennifer
Scleractinia (Stony Corals).....Cairns, Stephen
Hydrozoa.....Calder, Dale

CRUSTACEA
Amphipoda.....McKinney, Larry
Cirripedia (Barnacles).....Spivey, Henry
Cumacea.....Jones, Norman

Decapoda
Anomura: Galatheoidea.....Pequegnats, L. & W.
Anomura: Paguroidea (Hermit Crabs).....McLaughlin, Patsy
Brachyura.....Pequegnat, L. & W.
Macrura (Lobsters, etc.).....Pequegnat, Linda
Natantia (Shrimps).....Pequegnat, Linda
Isopoda.....Wilson, George
Ostracoda.....Kornicker, Louis
Stomatopoda.....Camp, David
Tanaidacea.....Heard, Richard
ECHINODERMATA
Asteroidea.....Pawson, David
Crinoidea.....Messing, Charles
Echinoidea.....Pawson, David
Holothuroidea.....Carney, Robert
Ophiuroidea.....Hendler, Gordon
ECHIURA.....Pilger, John
FISH.....McEachran, John, and Matheson, Edward
MOLLUSCA
Bivalvia.....Rokop, Frank
Propeamusium to be separated out.....Waller, Thomas R.
Cephalopoda.....Roper, Clyde (c/o Michael Sweeney)
Gastropoda.....Bouchet, Philippe, and Waren, Anders
Scaphopoda.....Kraeuter, J.N.
POLYCHAETA.....Hubbard, G. Fain
Ampharetidae.....Zottoli, Robert
Aphroditiforma (Scaled polychaetes).....Pettibone, Marian
Eunicida.....Fauchald, K.
Maldanidae & Spionidae.....Light, William
Oweniidae.....Gardiner, Stephen
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Cruise Participants

LGL

Joshua Baker
Gregory Boland
Bob Fechhelm
Randall Howard

TAMU

Fernando Alcazar
Nancy Andryszak
Larry Bernstein
Scott Chaffey

Cruise Participants (cont'd)

LGL

Larry Martin, Coordinator
Denis Thomson

TAMU

H. Benjamin Cox
Hessein A. Abd El-Reheim
Debra De Freitas
Roger Fay, Coordinator
M. C. Kennicutt
Fred Lane
Dean Merrill
Lauren Sahl
Michelle Schnitzer
Jose Serriano
G. Zhu

Woods Hole
Camera Operations

Earl Young

Laboratory Analyses

LGL

Gregory Boland
Sheron Evans
Robert Hedderman
Randall Howard
  Lab Coordinator
G. Fain Hubbard,
  Lab Coordinator
Larry Martin
Gail Meisner
Ruth Riegel
Duane Sanders
Nancy Tobin

TAMU

Fernando Alcazar
Scott Chaffey
Lauren Sahl
Jose Serricano
DerDuen Sheu

Statistical Analysis/Data Management

LGL

Joshua Baker, Coordinator
Joseph Betor
Lynn Maritzen

Project Management

LGL

John Cole, Executive Vice-President
Benny Gallaway, President and Project Manager
George Lewbel, Biologist
Linda H. Pequegnat, Taxonomic Coordinator

Project Management (cont'd)

LGL

Willis E. Pequegnat, Biological Coordinator
Ian Rosman, Biologist

Report Preparation

Jean Erwin, Coordinator
Diane Bass

To all these and others who have contributed but may have been inadvertently missed, we express our appreciation.

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1.0 INTRODUCTION

In September 1983, LGL Ecological Research Associates, Inc. (LGL) was awarded Contract No. 14-12-0001-30046 by the United States Department of the Interior, Minerals Management Service (MMS) to conduct, in conjunction with Texas A&M University (TAMU), a study of the continental slope of the Gulf of Mexico. Overall, the program is administered under the auspices of the MMS's Outer Continental Shelf (OCS) Environmental Studies Program which has the primary goals of

(1) Obtaining environmental data on the impacts of petroleum and production activities on the OCS, and
(2) Providing relevant information to decision makers in the service's OCS minerals management program.

In light of these goals, the Gulf of Mexico Regional Office recognized the continental slope habitat of the Gulf of Mexico as an area requiring further study. There was, and is, strong indication that this deep-sea region contains significant oil and gas reserves, supported by the fact that industry has steadily extended exploration activities into greater and greater depths with good success in terms of finds. Because of the logistical difficulty in studying deep-sea ecosystems, the state of knowledge for this system lags far behind that for shallow marine communities. In the absence of a data base, the potential effects of man's activities on the deep-sea environment and fauna of the Gulf can, at present, only be inferred based on extrapolations from known effects on shallow water forms. The Continental Slope Study was thereby initiated by the Gulf of Mexico Regional Office of MMS to develop a basic knowledge of the deep (200 to 2600 m) Gulf fauna in advance of pending petroleum development.

1.1 LONG-TERM OBJECTIVES

The overall objectives of this study are:

(1) To determine the abundance, structure, and distribution of animal communities in the deep-sea ir the Gulf of Mexico.

(2) To determine the hydrographic structure of the water column and bottom conditions at selected sites within the study area.

(3) To determine and compare sedimentary characteristics at selected sites within the study area.

(4) To relate differences in biological communities to hydrographic, sedimentary, and geographic variables.

(5) To assess seasonal changes in deep-sea biological communities in terms of abundance, structure, animal size, and reproductive state.

(6) To measure present levels of hydrocarbon contamination in the deep-sea sediments and selected animals prior to, and in anticipation of, petroleum resource development beyond the shelf-slope break.

(7) To compare the biological and non-biological characteristics of the deep Gulf of Mexico with that of other temperate and subtropical deep-sea regions.

(8) To assemble together and synthesize appropriate published and unpublished data with the results of this study, summarizing on a seasonal and spatial basis all biological, habitat, and environmental observations and parameters. Relationships between biological and non-biological 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 syntheses and conclusions.

(9) To conduct an effective quality assurance and quality control program which insures that all data acquired are accurate and repeatable within standards normally required for each type of observation, measurement, or determination.

(10) To critically review, interpret, and analyze all observations and data acquired to redefine as necessary the research program in such a way as to avoid or minimize redundancy and to optimize the efficiency of all field, laboratory, and data management operations for future deep-sea studies sponsored by MMS in the Gulf of Mexico.

(11) To assess the need for and determine the type of studies to be conducted in future program efforts.

The time allowed for accomplishing these objectives is four years. During this period, work in progress will be detailed in bi-monthly reports and preliminary findings will be summarized in three annual reports, this one being the first. The final synthesis report, submitted at the end of the four-year study period will document how well the objectives listed above have been met.

1.2 BACKGROUND ON SELECTED FEATURES OF THE SLOPE ENVIRONMENT

Although the surface waters of the Gulf of Mexico are dynamic in nature due to the seasonal effects of climate, winds, and storms, the Loop Current and rings, tides, etc., much of this dynamism is diminished with depth. A common view is that the deep sea is a tranquil, cold, dark environment where biological systems are greatly limited in terms of energy resources.

This study is directed primarily towards determining the abundance, structure and distribution of animal communities on the continental slope of the Gulf of Mexico at depths between 200 and 2600 m, relating observed differences in biological communities to hydrographic, sedimentary and geographic variables as well as to the degree of hydrocarbon contamination. Below, we provide selected summary background information on the deep-sea environment of the Gulf with emphasis on those factors singled out for study in this program.

1.2.1 Water Mass Properties

The waters of the Gulf of Mexico are layered by distinctive water masses which can be identified by temperature, salinity, and nutrient properties. Figure 1-1 shows a typical winter distribution of temperature (^{o}C), salinity (ppt) and potential density (kg/m^3) with depth for the continental slope region of the northern Gulf of Mexico. Seasonal changes only affect the temperatures in the upper hundred meters with the surface temperatures sometimes increasing to over 30^{o}C in the summer (August). Note that at 500 m the temperature is about 8.3^{o}C and the salinity is almost exactly 35 ppt. Those levels are fairly constant on an annual basis except, as will be discussed below, for small, "event" related effects. The stability of the deep water masses is attributable to a large change in potential density that occurs in a pycnocline centered around 125 m. This highly stratified area inhibits the vertical transfer of momentum and other properties across it.

Typical vertical profiles of oxygen (ml/l), nitrate (µg-at/l), phosphate (µg-at/l), and silicate (µg-at/l) are shown in Figure 1-2. Phosphate, silicate, and nitrate are depleted by biological activity in the near surface waters, but increase with depth to maximum values which are typically associated with the Antarctic Intermediate Water (this water last saw the sea surface about 1000 years ago in the Antarctic convergence zone). An oxygen minimum occurs between depths of 200 and 300 m and is due to the presence of tropical Atlantic Central Water.

Based upon essentially the above diagnostics, Morrison et al. (1983) characterized the vertical distribution and pertinent features of Gulf of Mexico water masses (Table 1-1). Outside the Loop Current and "new" rings, surface or Gulf Common Water extends to a depth of about 250 m. Tropical Atlantic Central Water is present from 300 to 500 m under which lies Antarctic Intermediate Water (500-1000 m). At greater depths a mixture of North Atlantic Deep Water and Caribbean Mid-water occurs which is sometimes referred to as Gulf Deep Water.

The Loop Current and associated rings can influence the vertical distribution of water mass properties, with the effects extending to depths which are being investigated as part of this program (Figs. 1-3, 1-4 and Table 1-1). Figure 1-3 (from Elliott 1979) shows a typical

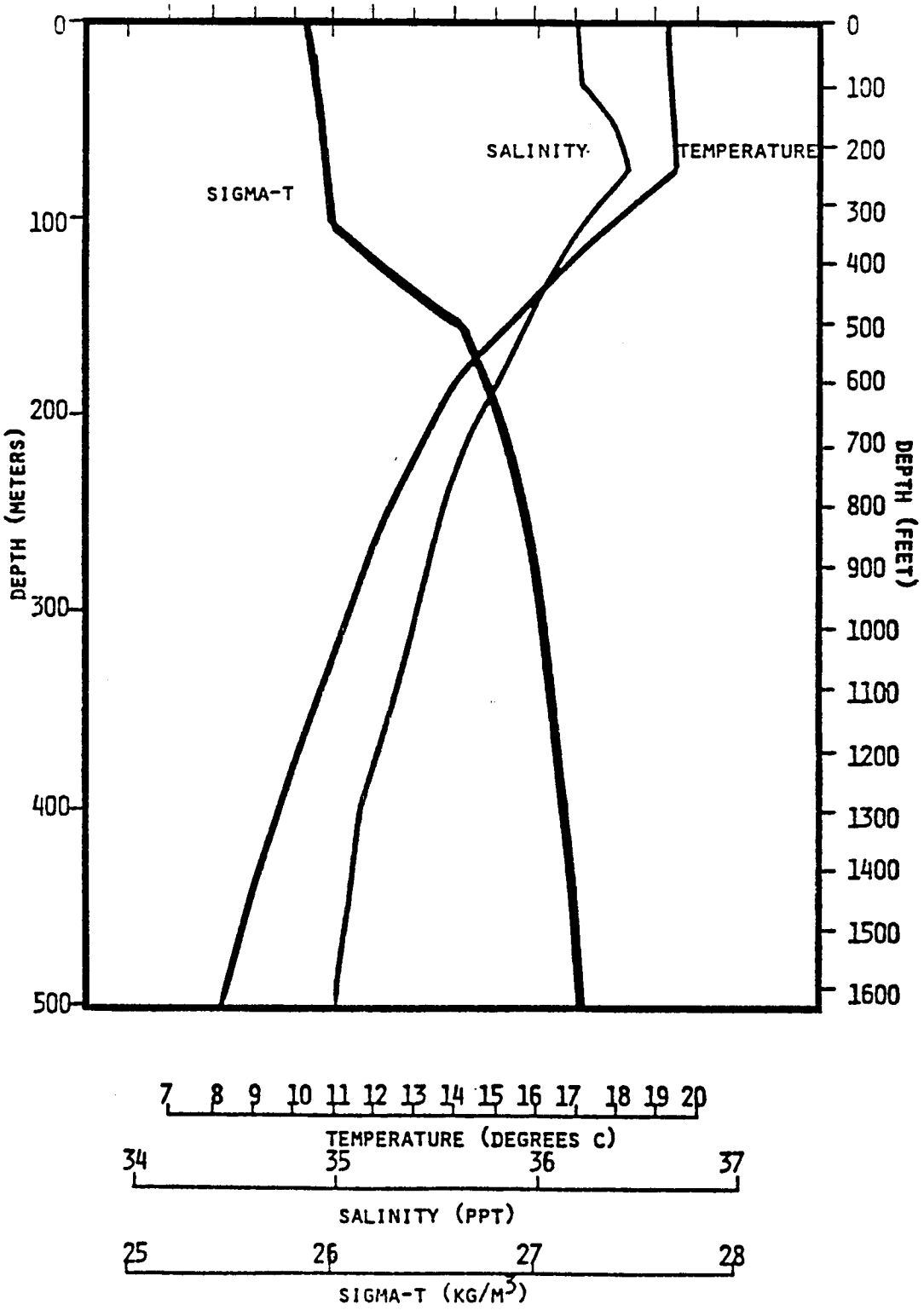


Figure 1-1. Vertical profiles of temperature, salinity, and potential density for a typical Gulf of Mexico station.

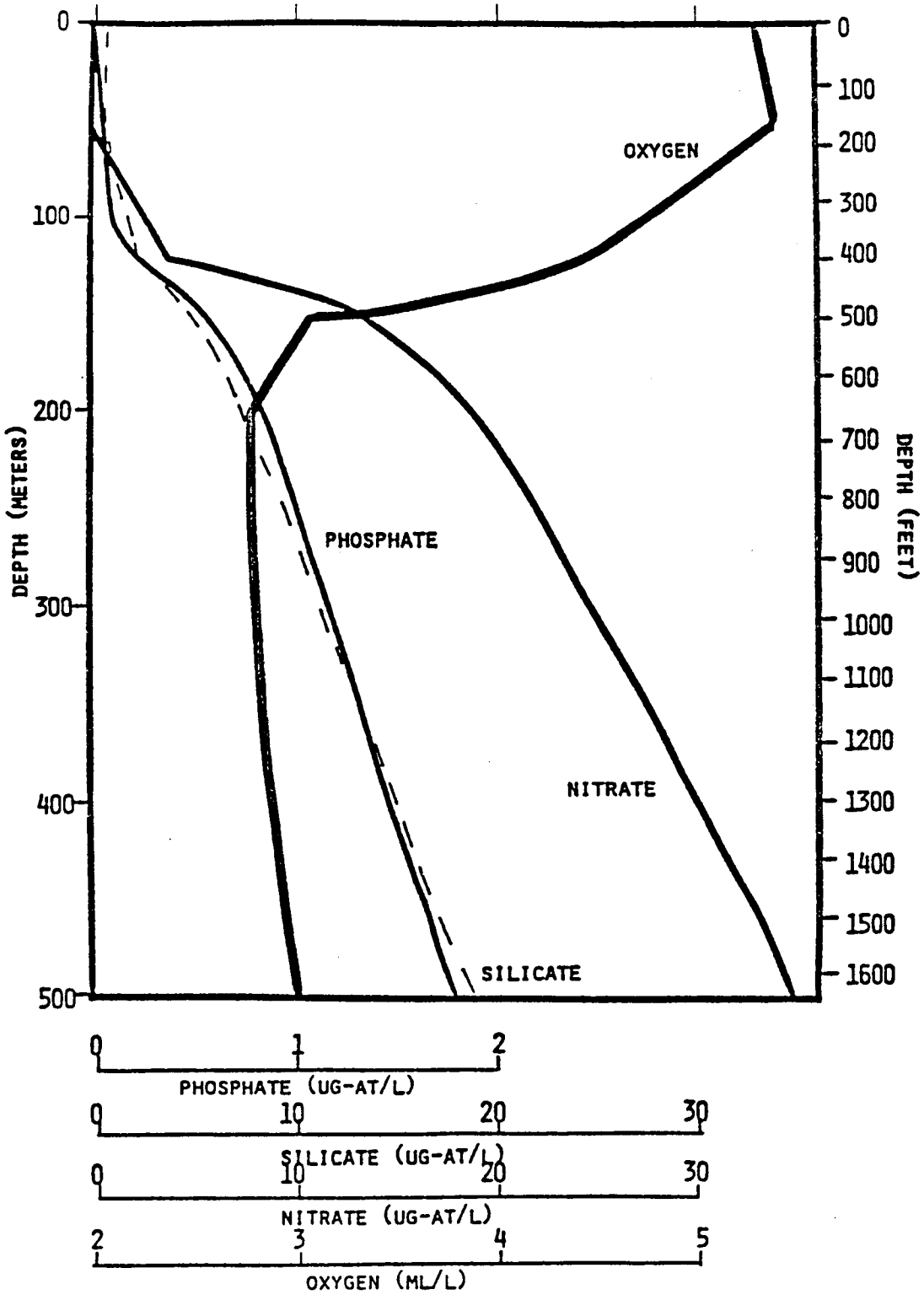


Figure 1-2. Vertical profiles of oxygen, nitrate, phosphate, and silicate for a typical Gulf of Mexico station.

TABLE 1-1

Water Mass Characteristics in the Gulf of Mexico (adapted from Morrison, Merrell, Key and Key, 1983)

Water Mass	Feature	Concentrations	Density Surface $\sigma o (mg/cm^3)$	Approximate Depth(s) (m)
Found in Loop Current and "New" Rings				
Subtropical Underwater	Salinity Maximum	36.7-36.8°/$_{oo}$	25.40	150-250
18°C Sargasso Sea Water	Oxygen Maximum	3.6-3.8 ml/l	26.50	200-400
Found Outside Loop Current and "New" Rings				
Gulf Common Water	Salinity Maximum	36.4-36.5°/$_{oo}$	25.40	0-250
Gulf-Wide				
Tropical Atlantic Central Water	Oxygen Minimum	2.5-3.3ml/l	27.15	300-500
	Nitrate Maximum	29-25 µg-at/l	27.30	500-700
Antarctic Intermediate Water	Phosphate Maximum	1.7-2.5 µg-at/l	27.40	600-800
	Salinity Minimum	34.88-34.89°/$_{oo}$	27.50	700-1000
Caribbean Water	Silicate Maximum	23-28 µg-at/l	27.70	1000-1200

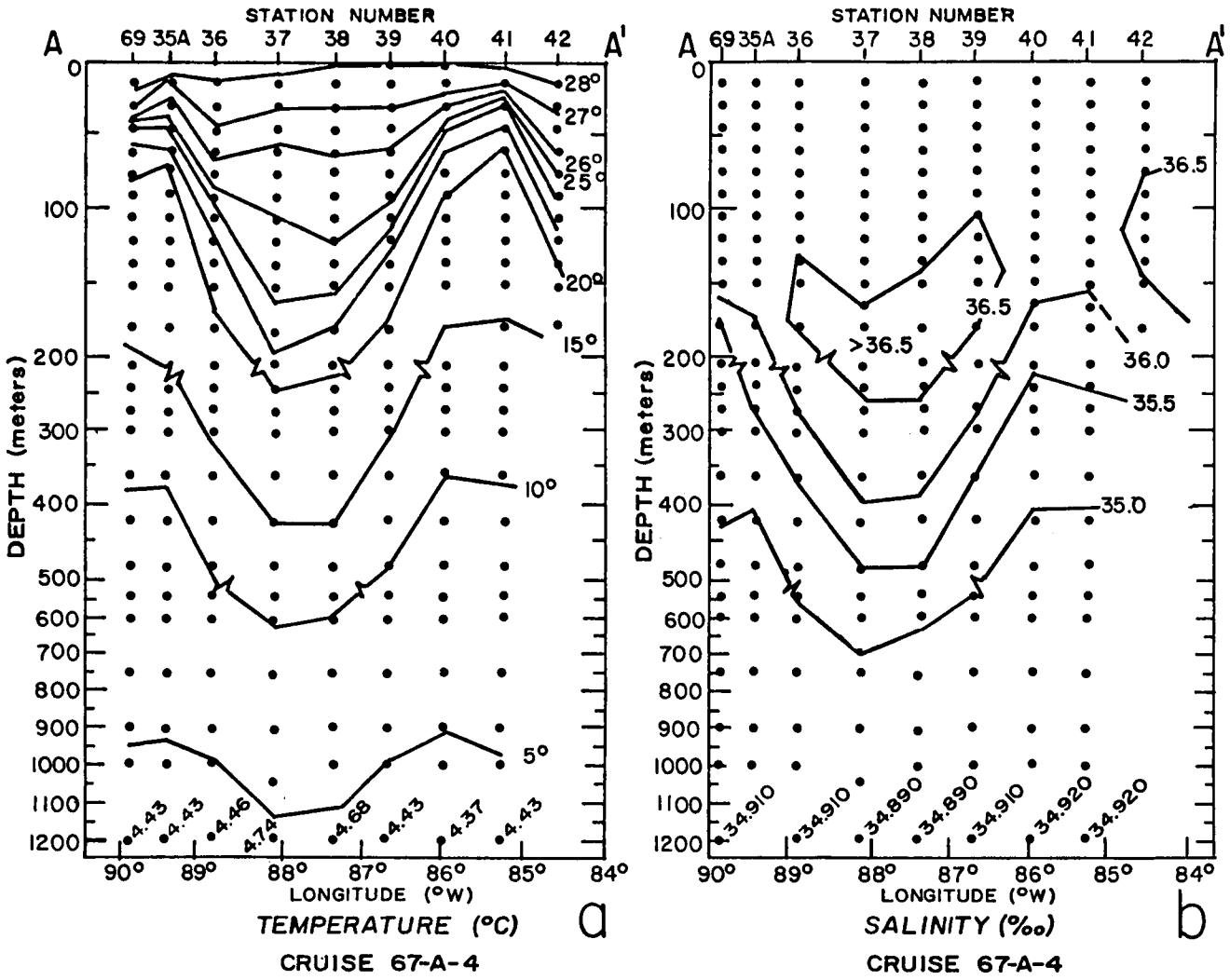


Figure 1-3. Vertical sections of (a) temperature and (b) salinity through an anticyclonic ring. The ratio of the vertical to the horizontal scale is 400:1 and the stations are plotted by longitude so that the section is skewed, stations on the right being further to the east than stations on the left. Note too that there are two scale changes in the depth scale (from Elliott, 1979).

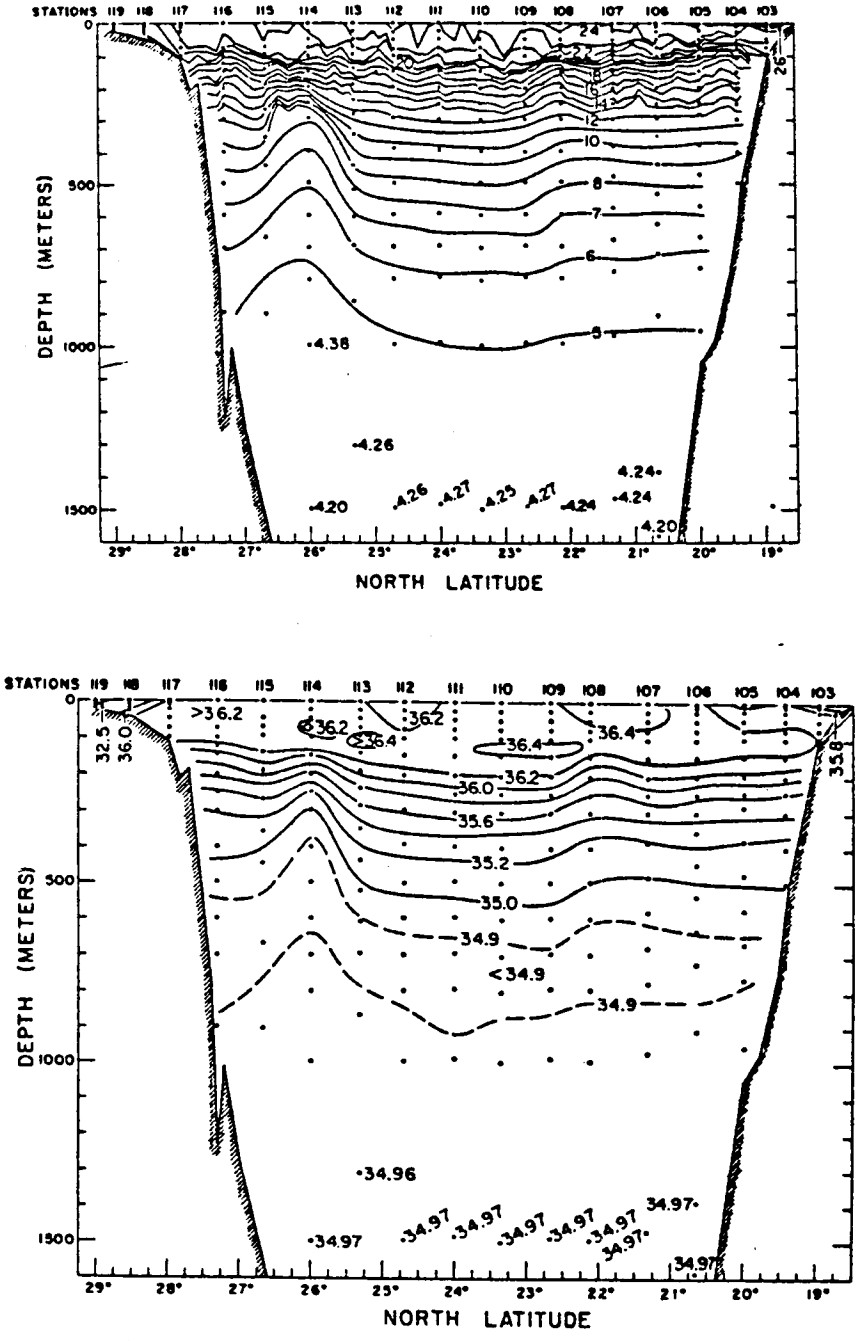


Figure 1-4. Vertical sections of temperature and salinity along 93°W showing a cold core eddy near Station C-4 (from Nowlin, 1971).

section through a warm core ring that had recently separated from the Loop Current. As indicated in Table 1-1, new rings are characterized by slightly higher salinities at about 200 m. Also, they result in some warming and slightly higher salinities at all depths below about 150 m. For example, if a warm core ring passed over, the temperature at 500 m would go from 8.3°C to over 9°C and the corresponding salinity would go from just less than 35 ppt to about 35.1 ppt. Moreover, we would expect some small change in the oxygen distribution at about 300 m, because 18°C Sargasso Sea Water would be present in the Loop/new ring. Finally, just due to geostrophic adjustment (the mechanism that changes the deep temperature and salinity), warm-core rings result in a very small increase in the nutrient values at depths greater than 150 m. Cold core rings produce the opposite effects on deep water characteristics (Fig. 1-4). Whereas the changes are small, they may influence the biota accustomed to a uniform environment.

1.2.2 Deep Ocean Tides

Deep ocean tides in the Gulf of Mexico produce relatively weak barotropic currents (barotropic currents are currents that do not vary with depth). However, as discussed below, they can interact with topography or the density field to produce sheared currents that have tidal periods. Perhaps the most interesting set of these observations is that of who used the motions of a satellite tracked drifting buoy to determine tidal and near-tidal frequencies in the deep Gulf of Mexico. Essentially, their report shows relatively strong motion at 7 hrs (a tidal gravity mode), about 12 hrs (the semi-diurnal tide), about 24 hrs (the diurnal tide), about 26 hrs (inertial oscillations), and 30 hrs (a basin resonance mode).

Molinari and Mayer (1982) report a very low barotropic tidal signal at measurements in 1040 m of water off Mobile (29.11N and 87.92W). In fact, if all the variability in the velocity record were assigned to the barotropic tide, the signal would only be about 1 cm/sec.

The barotropic tide can interact with the topography or density field to produce flows with tidal periods that vary with depth. These are called baroclinic or internal tides. Examination of long-term current

meter records at deep sites in the eastern Gulf, namely the Cognac Platform (28.79N, 89.06W in 1040 m of water) and the OTEC sites (29.11N, 87.92W and 29.19N, 87.64W in 1040 m of water), show no evidence of strong tidal signals at depth. As mentioned earlier, if all the bottom velocity variability at the OTEC sites is related to barotropic tides, the observed tidal signal would be only about 1 cm/sec (Molinari and Mayer 1982). Examination of the deep current meter records shows some weak bursts of less than 10 cm/sec that may be related to internal tides. However, there are no data that suggest the occurrence of strong internal tides in the region of the Northern Gulf Slope.

1.2.3 Observations of Slope and Deep Strong Currents

Figure 1-5 shows the temperature distribution and velocity profiles taken across the Texas shelf/slope in March 1981 in the vicinity of the Flower Garden banks. Velocity vectors to the right are eastward so this section shows a current right out to the shelf break flowing at about two knots towards the east. A strong eastward flow is often observed on the outer Texas shelf/slope. Although there is no proof that such a current extends over to the region offshore of Louisiana, its presence is probable during some times of the year. For example, current meters have been lost on the outer Texas shelf only to turn up east of the Mississippi delta. This seems to be a localized intense current with flows counter to all the pilot charts, etc.

Ebbesmeyer et al. (1982) document the occurrence of strong persistent currents in deep water to the east of the Mississippi delta. Observations were from Cognac platform (28.79N, 89.06W) in 300 m of water and from two potential OTEC sites (29.11N, 87.82W and 29.19N, 87.64W) in 1000 m of water. In 1.8 years of records, they recorded 11 events which had mean speeds of 0.27 to 0.52 m/sec. These events occurred in a depth range of 60 to 180 m and lasted for an average of eight days with the mean interval between events being 30 days.

In summarizing their conclusions, Ebbesmeyer et al. (1982) state the following:

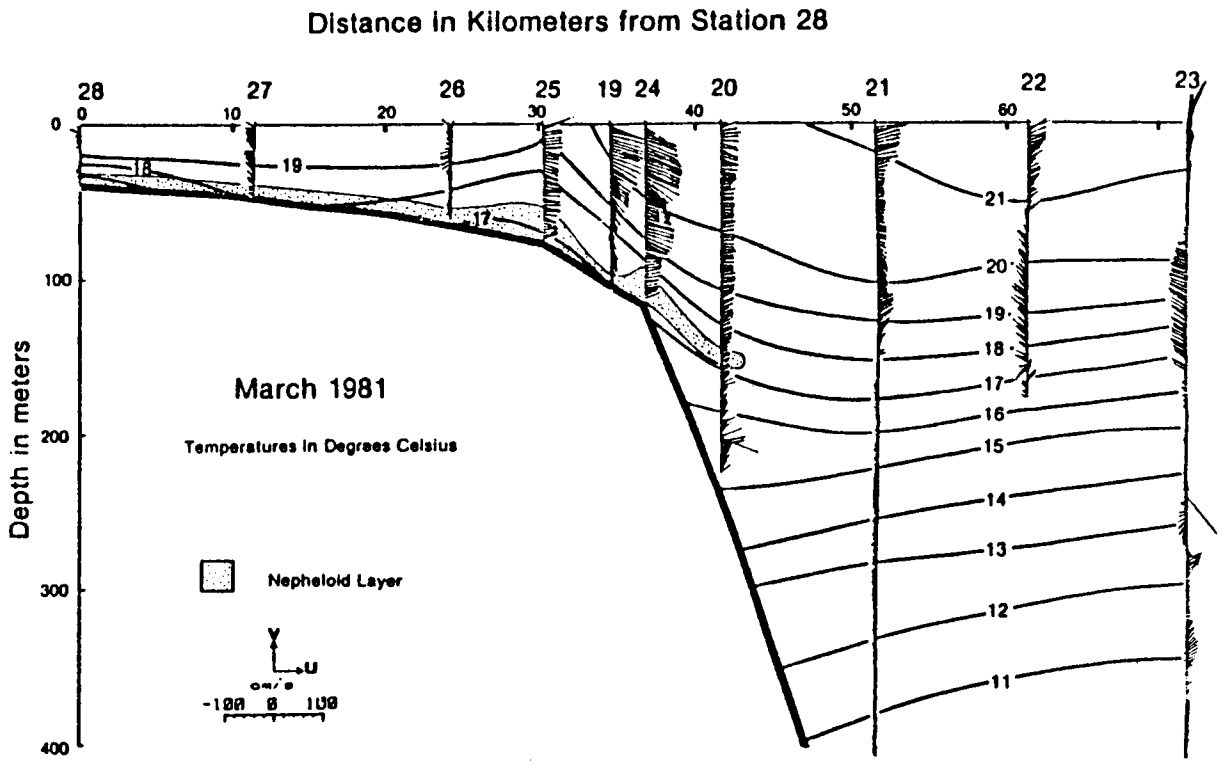


Figure 1-5. Temperature and velocity patterns on the continental shelf/slope near the Flower Gardens Banks.

(1) The average duration of the events is 8-9 days; the longest duration was 25 days.
(2) The interval between the events averages 30 days within a range of 6-76 days.
(3) Events can occur during any season.
(4) During an event the current direction is usually steady and oriented with the bottom contours.
(5) During an event the vertical profile of current velocity can be quite complex with large changes in speed over short depth ranges.
(6) The events most likely are not related to hurricanes or Mississippi River discharge; they probably are connected with activity of the Loop current.

The TAMU Oceanographers working on this project agree that the Loop Current was the probable source of some of the current events observed by Ebbesmeyer et al. (1982). However, they note that the Loop Current did not extend into the region at any time during the observations. It may have come within 60 nm or so of the OTEC sites. Moreover, there is no evidence of a warm-core ring being in the area. Finally, when we look at the mean current vectors from the 11 events, we note that the preferred directions are along lines of constant bathymetry. However, of the 11 events, five have an eastward component, and five have a westward component. The direction of event four was almost due south. The lack of a consistent direction for all the events argues that these currents are not directly associated with the large current rings but are rather due to small eddies, meanders that radiate from the Loop Current. Moreover, at the two OTEC sites which are separated by only 24.5/km, current meters at about the same depth showed no significant coherence of flow. The Texas A&M group believes that wind events may have produced some of the events. Whatever the cause, they note that the strong currents are usually confined to flow along the bathymetric contours.

Molinari and Mayer (1982) have discussed further the data from the OTEC sites described by Ebbesmeyer et al. (1982). In discussing possible forcing mechanisms, they note that there is evidence of a peak in the energy at a period of six to seven days. This coincides with the mean

frequency of northers over the region. Moreover during a period of strong current bursts there was both a tropical storm and a depression in the region. However, the events cannot be tied directly to the wind. In data for an event not presented by Ebbesmeyer et al. (1982), Molinari and Mayer (1982) show that a meander or eddy from the Loop Current caused a reversal in the flow.

In 1980 and 1981, David Brooks (TAMU) had current meters on the outer South Texas shelf and upper slope at depths of 200, 450, and 732 m. The record mean for the 200-m deep mooring was about 20 cm/sec. Most of the currents accounting for the high speeds occurred from about 13 September to 15 November 1980. These currents were due to a warm core ring. At 200 m, Brooks recorded speeds over 80 cm/sec, and, at 450 m, speeds of 40 cm/sec were observed on about 10 August. There was a strong southern surge which lasted about a day. Instantaneous currents were observed as high as 91 cm/sec at 200 m and 15 cm/sec at 732 m. Whitaker (pers. comm.) has related the "bursts" of up to 30 cm/sec shown later in the records to the passage of northers. However, the "bursts" may also be related to the outer velocity structure of a ring.

1.2.4 Bottom Sediments

Pequegnat (1983) compiled the sediment data base for the Gulf of Mexico, presenting the results in map format (Fig. 1-6). Slope and deep Gulf areas are indicated to have bottoms consisting of predominantly silty and clayey muds. It should be noted that the data base is not extensive (e.g., the TerEco Study included data for only 62 sites).

1.2.5 Hydrocarbons

Hydrocarbons are ubiquitous components of the marine environment and have two primary sources--biogenic and thermogenic. Biogenic hydrocarbons are found in many marine and terrestrial organisms, in sediments, and in oceanic waters. Included are the large quantities of methane produced by anaerobic bacteria and the trace quantities of non-volatile hydrocarbons ($>C_{14}$) found in most biological systems. Marine and terrestrial organisms synthesize normal alkanes, branched alkanes, branched alkenes, and

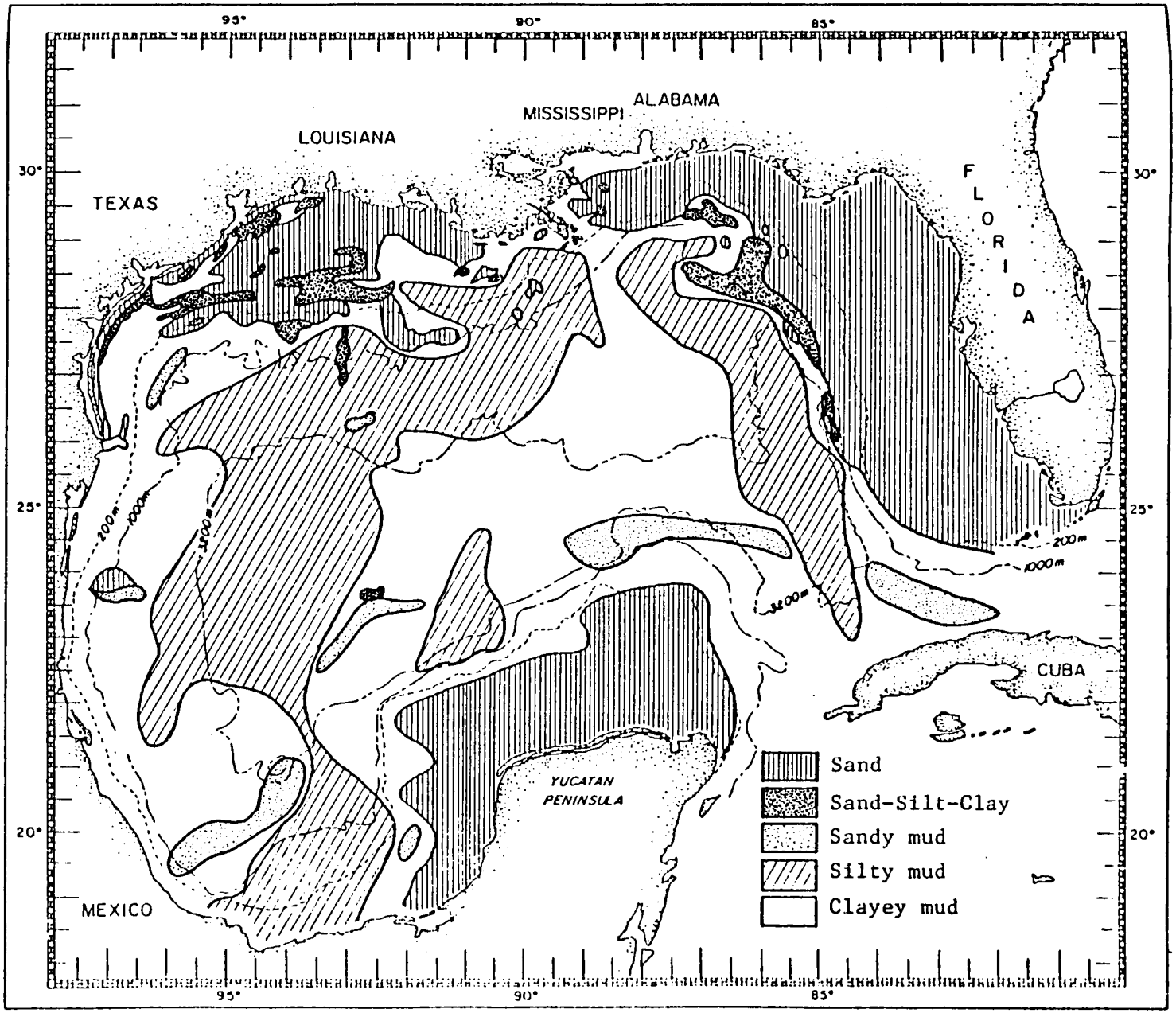


Figure 1-6. Predominant sediment types in the Gulf of Mexico (from Pequegnat 1983).

sometimes small quantities of very specific aromatic compounds. It has been shown that phylogenetically narrow groups of organisms often exhibit characteristic hydrocarbon assemblages (Blumer et al. 1970, Lee et al. 1971, Oro et al. 1967, Meinschein 1969, Ehrhardt and Blumer 1972). Normal, straight chain n-alkanes are the dominant biogenic hydrocarbons in the environment, but alkenes, isoprenoids, cycloalkanes and aromatic hydrocarbons are present in lesser amounts. Phytoplankton are the main source of biogenic hydrocarbons in the marine environment (Saliot 1981). Phytoplankton hydrocarbons are predominantly composed of the C_{15} and/or C_{17} normal alkane (Clark and Blumer 1967, Goutx and Saliot 1980). Goutx and Saliot (1980) determined that n-alkanes account for an average of 20% of the total hydrocarbons in mixed plankton and seawater samples. Isoprenoid hydrocarbons, such as pristane and phytane, are usually found in low levels (Blumer et al. 1971). Unsaturated odd carbon olefins, especially n-$C_{21:6}$, can predominate in certain marine phytoplankton (Blumer et al. 1970, Osterroht and Petrick 1982, Goutx and Saliot 1980). Two to four ring aromatic hydrocarbons detected in phytoplankton are probably due to petroleum contamination.

The presence of long chain alkanes (> n-C_{22}) with a strong odd over even carbon preference is also a useful indicator of terrestrial biogenic hydrocarbons (Eglinton and Hamilton 1963, Kollatukudy and Walter 1973, Gearing et al. 1976, Tullock 1976, Giger and Schaffner 1977, Farrington and Tripp 1977, Giger et al. 1980). These hydrocarbons are derived from the cutin waxes that coat leaves and stems. Surface cuticle waxes, which prevent evaporation in higher plants, are esters of long chain acids and alcohols and produce long chain normal alkanes when degraded (Eglinton and Hamilton 1963, 1967). The composition of higher plants is characterized by a predominance of odd carbon number, high molecular weight n-alkanes from C_{23} to C_{33} (Aizenstat 1973, Tulloch 1976, Wakeham and Farrington 1980). Normal C_{31} is probably the most frequent hydrocarbon while n-C_{29} and n-C_{27} sometimes dominate depending on the specific plant that is the source of the material (Tulloch 1976). Cyclic di- and triterpenoid hydrocarbons occur in considerable amounts in higher plants and have been used as tracers of terrestrial input (Steibl and Herout 1969, Barrick and Hedges 1981, Simoneit 1977). Other hydrocarbons, such as alkenes and

aromatics, occur in low concentrations and are very specific in their chemical structure.

Hydrocarbons generated from thermogenic processes can be distinguished at the molecular level from in situ biogenic hydrocarbons. The parameters used to differentiate thermogenic and biogenic hydrocarbons have been extensively discussed elsewhere and will only be briefly described here (Farrington et al. 1973, Wakeham and Carpenter 1976, Farrington and Tripp 1977, Meyers et al. 1984). A review of hydrocarbon distribution in petroleum are provided by numerous authors (i.e., Wakeham and Farrington 1980, NAS 1975, etc.). Thermogenic hydrocarbons consist of a complex mixture of alkanes, cycloalkanes, branched alkanes, aromatic compounds, polar compounds, and large macromolecular structures. This is in contrast to hydrocarbons derived from biological sources which, as previously discussed, are simple mixtures comprised of only a few hydrocarbons including alkanes ($n\text{-}C_{15}$, $n\text{-}C_{17}$, pristane) and alkenes (Giger et al. 1980). As previously mentioned, plant biowaxes also occur in recent sediments with odd number carbon lengths from 23 to 33 (or greater). Unaltered thermogenic hydrocarbons generally contain a complete suite of normal alkanes with little or no carbon preference, which can be represented by a carbon preference index (CPI), i.e., the ratio of the concentration of odd alkanes to even alkanes over a given carbon range (Wakeham and Carpenter 1976, Farrington and Tripp 1977). Thermogenic hydrocarbons also contain a gas chromatographically unresolved complex mixture (UCM) (Farrington et al. 1973, Farrington and Tripp 1977). Only minor amounts of aromatic hydrocarbons are produced by organisms. Two to five ring aromatic compounds are assumed to be thermogenic in origin.

A number of parameters have been suggested for identifying high molecular weight petroleum hydrocarbons.

These parameters include:

(1) The presence of a gas chromatographically unresolved mixture of hydrocarbons (petroleum contains a tremendously complex mixture of compounds).

(2) A homologous series of compounds in which the sequential members are of approximately equal abundance (i.e.,

compounds with consecutive even and odd numbers of carbon atoms).

(3) The absence of olefinic compounds (except in refined products).

(4) An abundance of both cycloalkanes and aromatic constituents compared to alkanes.

(5) Ratios of pristane/phytane, pristane/C_{17} and phytane/C_{18} (e.g., incorporation of oil within a sample shifts ratios due to increased isoprenoid concentrations).

When analyzing trace quantities of hydrocarbons, it is often difficult to differentiate between compounds of petrogenic and biogenic origin. This differentiation is complicated by weathering, degradation, and the wide variety of component patterns displayed by hydrocarbons from different sources.

The presence of thermogenic hydrocarbons in shallow sediments where neither sufficient temperature nor time has been available to produce hydrocarbons implies either (1) upward migration from deeper sources; (2) anthropogenic inputs (pollution); (3) the incorporation of recycled thermally mature material; and/or (4) low temperature abiotic production. Upward migration and pollution sources can be differentiated on the basis of vertical distributions. The effect of recycled material is difficult to determine and must be examined in relationship to other stratigraphic data. Low temperature abiotic production of hydrocarbons is thought to be minimal.

As with other regions of the world oceans the major inputs of hydrocarbons into the Gulf include biological production, natural seepage, offshore petroleum production and drilling operations, transportation activities, coastal and riverine additions and atmospheric exchange or fallout. To date a number of studies have been directed at establishing baselines for hydrocarbons in the Gulf of Mexico. Most of these studies are restricted to shallow continental shelf areas and/or known point sources of hydrocarbon discharge (i.e., production platform). No data are available on intraslope sediments or organisms to the TAMU's group knowledge. Though the studies summarized here are restricted to shallow

waters they still provide a reference for the comparison of the results produced from the present study.

Biological and Chemical Environmental Studies on the South Texas Outer Continental Shelf (STOCS)

This four-year effort on the south Texas shelf was a consortium program conducted mainly by the University of Texas Marine Science Institute and Texas A&M University for the Bureau of Land Management (BLM). Baseline hydrocarbon measurements were performed to provide BLM with a data base prior to extensive oil and gas exploration (1978/1979). HMWHC were measured in water, zooplankton, and sediment (Parker et al. 1976, 1977a, 1977b, 1978a, 1978b, 1979) and in benthic macroepifauna and macronekton (Giam and Chan 1976, 1977a, 1977b, 1978a 1978b; Giam et al. 1976; Giam 1979). These investigations represented extensive spatial and temporal studies at 25 stations along four transects in the STOCS region.

The results of this study indicated that the area was pristine with respect to anthropogenic inputs of petroleum hydrocarbons. Zooplankton samples obtained by oblique tows were the only component of the ecosystem shown to contain quantities of petroleum hydrocarbons. Petroleum contamination in the zooplankton samples was suggested by n-alkanes in the C_{25}-C_{32} range with a CPI (odd-even preference) near unity and the presence of aromatic hydrocarbons in some samples. Petroleum hydrocarbons in this fraction were attributed to micro-tarballs in the samples. The increase in petroleum hydrocarbons in zooplankton samples during the STOCS study period was most likely due to oil tanker traffic. Macronekton showed no indication of petroleum hydrocarbons. Sediment analyses of both bulk sediment and benthic macroepifauna indicated minimal petroleum pollution. Petroleum pollution, in the form of tarballs observed in the water column, apparently did not contribute measurable quantities to the sediments.

In a special rig monitoring study funded by MMS no petroleum hydrocarbons were detected around an exploration and drilling site on the South Texas shelf.

Mississippi, Alabama, Florida (MAFLA) Outer Continental Shelf Baseline Environmental Survey

BLM studies in the MAFLA lease areas were conducted by the State University System of Florida, Institute of Oceanography (SUSIO) in 1974 and 1975, and by Dames and Moore in 1977/1978. The fundamental goal of this three year study was to establish the variability of selected parameters which might be affected by OCS oil and gas development. The MAFLA area encompasses most of the eastern Gulf of Mexico OCS. Water column HMWHC were measured in the area by Florida State University in 1975/1976 (Calder 1977a, 1977b) and by TAMU in 1977/1978 (Jeffrey 1977; Kennicutt and Jeffrey 1981a, 1981b). Sediments were analyzed by Gulf Coast Research Laboratory (Gearing et al. 1976; Lytle and Lytle 1975, 1977a, 1977b) in 1974-1976 and by Energy Resource Co., Inc. (Boehm 1979a) in 1977/1978. Biota were analyzed by SUSIO in 1974-1976 (Calder 1977b; SUSIO 1975, 1977) and by Virginia Institute of Marine Sciences (Bieri 1979).

MAFLA area sediments were grouped into three geochemical provinces based on the sources of hydrocarbons they contained (Lytle and Lytle 1977a, 1977b). In the nearshore, <50 m depth, West Florida Shelf there was no evidence of anthropogenic or petrogenic hydrocarbons. The deep water areas of the West Florida Shelf are characterized by accumulations of fine sediments of Mississippi River origin. The GC traces from this region are strongly influenced by terrigenous, biogenic compounds added to anthropogenic compounds. A third region lies on the Mississippi-Alabama Shelf and the more offshore areas of the Florida OCS. The sediments of these regions are fine clays and yield hydrocarbon traces which show strong petrogenic, anthropogenic and terrigenous-biogenic influences. Petrogenic sources were inferred from chromatograms with a double "hump" of unresolved compounds and a regular series of n-alkanes peaks. Although there is some temporal instability, the shallow Florida Shelf is characterized as generally being devoid of petrogenic inputs where as the Mississippi-Alabama Shelf is dominated by mixed anthropogenic and biogenic inputs.

Zooplankton, macroepifaunal and demersal fish hydrocarbons were free of petrogenic indicators. The one exception was demersal fish tissues for

winter samples along an upper Florida transect. At these stations, a small UCM and a regular series of n-alkanes suggested a petrogenic source for the tissue hydrocarbons. This area also exhibited strong petrogenic influences in its sediments.

In general, the frequency of detection of petrogenic hydrocarbons in the MAFLA area followed the trend:

sediments > fish > macroinvertebrates > zooplankton > water

None of these components indicated recent local petroleum contamination; rather, the high amounts of terrigenous hydrocarbons indicate riverine transport from terrigenous sources of petrogenic compounds.

Environmental Assessment of an Active Oil Field in the Northwestern Gulf of Mexico

Heavy molecular weight hydrocarbons (HMWHC) were investigated at Buccaneer Oil Field (BOF) 30 miles south of Galveston, Texas, as part of a four-year project funded by the Environmental Protection Agency (EPA) through interagency agreement with the National Oceanic and Atmospheric Administration (NOAA) and managed by the National Marine Fisheries Service (NMFS) (Harper et al. 1976, Jackson 1977, Jackson et al. 1978, Middleditch and West 1979). Most HMWHC results from this project can be found in the literature (Middleditch et al. 1977; Middleditch and Basile 1978, 1979; Middleditch et al. 1978; Middleditch et al. 1979a, 1979b, 1979c, 1979d). Most biota associated with the platforms showed some petroleum contamination. Fouling mats on the platform legs contained low concentrations of oil near the air/sea interface (where periodic exposure to sunlight and air apparently promotes evaporation and degradation), but showed high concentrations of fresh oil at three meters. In contrast to the fouling mat, the barnacles contain weathered oil implying an indirect exposure to oil possibly by filter-feeding on particulates in the water column. Blennies from the platforms contained fresh oil, whereas sheepshead contained weathered oil. This difference between fish species reflects their feeding habits (e.g., the blennies feed on the small

organisms of the fouling mat and the sheepshead eat barnacles). The free-swimming spadefish contained lower concentrations of weathered oil than either the blennies or sheepshead. Individual red snappers exhibited highly variable levels of oil contamination. Some specimens contained no oil, while the mean concentration of oil for all specimens examined was higher than that of the spadefish. The red snapper, in contrast to the other species, is heavily exploited, resulting in a high turn-over rate. Red snapper containing no oil were probably recent arrivals in the region of the BOF, whereas those which had resided longer in the oil field region may have ingested sufficient quantities of contaminated prey to accumulate higher concentrations of oil. Oil contamination was higher in the livers of all fish species than muscle tissue. Shrimp from the BOF were not usually contaminated with oil. Five of nine surface plankton samples collected in BOF contained C_{20}-C_{30} alkanes which were probably derived from petroleum.

The major pool of hydrocarbon contaminants in the BOF area is in the surficial sediments. Although concentration gradients around the platforms were always observed, there was considerable day-to-day changes in these concentrations. This was attributable to periodic resuspension and deposition of surficial sediments. Surficial sediments contain up to 25 ppm of petroleum alkanes. On one occasion concentration gradients of fresh oil were observed in the field at both production platforms extending at least 30 m from the platforms. Alkanes in sediments from 0.7-11 km from the platforms were mostly biogenic in origin. Sediments outside the immediate vicinity of the production platform did not contain petroleum hydrocarbons.

Strategic Petroleum Reserve Brine Disposal Analysis Program

As part of the Energy Policy and Conservation Act of 1975, the Department of Energy (DOE) implemented the Strategic Petroleum Reserve (SPR). This program plans to store one billion barrels of oil in solution-mined salt cavities near existing petroleum distribution facilities along the Gulf of Mexico coast. Because large quantities of leachate and brine will be produced by the operational phase of this program, multidisciplinary environmental studies are currently underway by

NOAA and private firms under contract to DOE at the proposed brine disposal locations. Baseline HMWHC measurements at Big Hill, West Hackberry, Weeks Island, and Chacahoula were performed by Science Applications, Inc. (SAI) (Shokes et al. 1978; Shokes et al. 1979a, 1979b, 1979c) over a 12-14 month period in 1977/1978. As a continuation of these programs, Energy Resources Co., Inc. (Boehm 1979b) through NOAA (NMFS) performed baseline hydrocarbon measurements at these same sites in 1978/1979. A few measurements at Caplin Sector sites (Weeks Island and Chacahoula) were performed by Carbon Systems, Inc. (through TerEco, Corp. and Dames and Moore) in 1978. TAMU (Jeffrey, pers. comm.) is currently measuring HMWHC at the Brian Mound, Big Hill and West Hackberry sites. Considerable baseline hydrocarbon data for shallow nearshore sites have been produced as part of these programs but is not yet available to the public.

Unlike the STOCS and Florida OCS areas which contained few indications of petroleum hydrocarbons, the nearshore brine disposal sites off the Louisiana-Upper Texas coast contained petroleum hydrocarbons in water, biota and sediments. These shallow sites (generally less than 30 m) are influenced by Mississippi-Atchafalya riverine inputs, local hydrocarbon inputs from petroleum operations, transportation activities and biogenic hydrocarbons. At many of the sites, petrogenic hydrocarbons compose the dominant hydrocarbon fraction indicating the effects of large scale petroleum production on the Louisiana shelf.

Analysis of macrocrustaceans from these sites indicated that petroleum contamination is sporadic and not site limited. Petroleum contamination was revealed in many samples by a smooth distribution of n-alkanes, a homologous series of isoprenoid hydrocarbons, and an unresolved complex mixture (UCM). Shrimp HMWHC averaged between 10 to 30 ug/g at most sites. SAI noted that most petrogenic hydrocarbons were not concentrated in the shrimp tail. A strong petrogenic nature was not observed in the fall (from either Texoma or Caplin sites) suggesting contributing compounds may have been excreted during molting as the juveniles obtained adulthood. This petrogenic pattern was not observed for anchovy. Most aromatic compounds had two rings (naphthalenes).

There were large sediment compositional differences between brine disposal sites. Sediment hydrocarbons averaged 1.7, 5.0, 14, and 37 µg/g

at the Chacahoula, Weeks Island, West Hackberry and Big Hill sites, respectively. These differences were also reflected in total organic content. A significant fraction of the sediment hydrocarbons appeared to be of petroleum origin based on a large UCM, low OEP, and prominent occurrence of isoprenoids and aromatics. The UCM mixture in most of these samples comprised 70 to 90% of the HMWHC. Spectrofluorometry and GC/MS techniques revealed that sediments contained aromatic hydrocarbons from two to five rings with a possible mixed source of aromatics from combustion (pyrogenic) and petroleum.

Ecological Investigations of Petroleum Production Platforms in the Central Gulf of Mexico

This one year program in 1978/1979 sponsored by the BLM and managed by Southwest Research Institute (SWRI) was aimed at assessing the long-term cumulative effects of production platform operations on the OCS environment. This study involved investigations at 20 platforms and four control sites extending from the Mississippi River delta to approximately 100 miles offshore and west over 200 miles to a line south of Marsh Island. This area represents both old and new production platforms. Surficial sediments around platforms had a large UCM and detectable amounts of aromatics. Surficial sediments from the study averaged 28.6 µg/g total hydrocarbons, but concentrations as high as 400 µg/g of aromatic hydrocarbon alone were encountered. Implications are that sediment contamination is occurring generally over the entire region with no readily discernable differences between platforms and controls or within samples around a particular platform. Bedinger (1977) suggests that the Mississippi River may be a significant source of petroleum products contaminating the area. Faunal data from the studies indicated no instances of UCM, although aromatic compounds (0.05 ppm or less) were found in some fauna (e.g., spadefish and sheepshead) that live in close association with the platforms. The most common aromatics detected were naphthalene and its derivatives.

Northwest Gulf of Mexico Topographic Features Study

This BLM program conducted through TAMU surveyed and monitored many of the banks on the Texas-Louisiana shelf. Most of these banks are located between the 50 and 200 m isobaths along the OCS region. Biota sampling was restricted to Spondylus and macronekton (Giam and Chan 1978b, 1978c). No indication of petroleum hydrocarbons was found in these samples even though certain banks, such as the Flower Gardens, are close to production operations. Sediments (Parker et al. 1978b) also showed no indication of petroleum contamination. Sediments and biota collected during the Northwest Gulf of Mexico Topographic Features Study by BLM showed no indication of petroleum contamination. Sediments and biota

IXTOC Blowout Studies

In response to concerns over the impact of oil spillage from the IXTOC-I blowout, ERCO, Inc. conducted a study for BLM to assess the extent of, if any, damage produced in offshore Texas benthic environments (Boehm et al. 1983; Boehm and Fiest 1982a, 1982b; ERCO 1981). Sediment and biota were analyzed for petroleum hydrocarbons by spectrofluorometry, GC, and GC/MS. Relying on the data base produced by the STOCS program, no significant increase in hydrocarbon content was observed in surface sediments. Sediments contained chronic, low levels of petroleum dominated by weathered, anthropogenic, saturated hydrocarbons, biogenic n-alkanes, and three to five ring aromatic hydrocarbons (1-100 ng/g of individual components). This is the most complete data base for aromatic compounds in the Gulf of Mexico. Quantitative aromatic hydrocarbon comparisons with STOCS baselines were difficult due to a lack of STOCS data. The presence of low level petroleum pollution in penaeid shrimp was confirmed by GC/MS derived aromatic hydrocarbon searches. Previous STOCS data indicated shrimp contained 10 to 70 ppb aromatic hydrocarbons.

Other Reports

Several miscellaneous reports regarding aromatic hydrocarbons in the Gulf of Mexico have also appeared in the literature. Milan and Whelan (1978) and Milan (1978) found that oysters and mussels assimilated petroleum hydrocarbons when placed in a salt marsh ecosystem exposed to a constant input of oil. Transport of petroleum-contaminated detritus appeared to be the major vector for hydrocarbons into the ecosystem. Oysters from Galveston Bay were found to be severely contaminated with petroleum derived hydrocarbons by Erhardt and Blumer (1972). Aromatic hydrocarbons accounted for 56% of the petroleum load of the oysters. Palacas et al. (1976) and Palacas et al. (1972) found no evidence of petroleum contamination in a coastal sedimentary environment and bay from the northeastern Gulf of Mexico coast. Aromatic hydrocarbons in 60 Gulf of Mexico shelf sediments were reported by Gearing et al. (1976). A large number of peaks were found in the aromatic fraction of sediment extracts though relatively few corresponded with aromatic standards available. No

GC/MS structure confirmation or quantitative aromatic concentrations were provided.

1.3 BACKGROUND ON FAUNAL FEATURES OF THE SLOPE

Most of the deep-sea work in the Gulf of Mexico, both past and recent, has focused on the megafauna and relatively little attention has been directed towards the macroinfauna or the meiofauna (e.g., see Pequegnat 1983). In our study all three groups are being investigated and are defined as follows. The meiofauna and macroinfauna are those which can be sampled effectively with a box core whereas the term megafauna is applied to those large, easily seen organisms, both vertebrate and invertebrate, that one cannot sample effectively with a grab. The megafauna component is being sampled with trawls and photographed.

The distinction between the meiofauna and the macroinfauna is based upon size. The term meiobenthos was introduced by Mare (1942) to apply to benthic organisms that live in soft bottoms and that are intermediate in size between the microfauna and the better known macroinfauna. The upper limit of size of the meiofauna has varied among various studies from 1.0 mm to 0.3 mm, the latter having been selected for use in the present study. The lower limit of size has also been variable, but 0.062 mm is now the more common mesh size employed in sorting screens. Accordingly, in this study meiofauna are those organisms retained on a 62 micron screen; whereas all organisms taken by the grab and retained on a 300 micron sieve are designated as macrofauna.

1.3.1 Meiofauna

The meiofauna is composed of both a permanent and stable set of organisms and a temporary and numerically variable group composed of juvenile macroinfaunal forms. The permanent or true meiofauna differs from the macroinfauna not only in size but also in regard to number, average generation time, and morphological adaptations to their environment. Some protozoans meet the size requirements of the meiofauna (e.g., macrociliates and Foraminifera), but, as Thiel (1975) has pointed out, the latter have been excluded from most investigations on deep-water

meiofauna. Nevertheless, they are included in the present study simply because they are numerically important, ranking third (occasionally second) behind the nematodes and harpacticoid copepods. In some contexts, it is convenient to refer to the metazoan meiofauna as the "true" meiofauna (all of which are permanent) and to lump the forams and temporary meiofauna into a second category. Those who prefer to eliminate the forams in meiofauna studies often justify the deletion because, as protozoans, they have a reproduction mode wholly different from metazoans (Thiel 1966). Another good reason for deleting forams is that it is often difficult to separate living from dead individuals.

As Thiel notes, effective work on offshore meiofauna was started about 20 years ago when Wigley and McIntyre (1964) obtained quantitative samples from a transect on the North American Atlantic shelf and down the slope to about 600 m. In addition, quantitative samples were taken from the slope to the abyss by McIntyre from Discovery (Warwick 1973) and by Thiel from Meteor (Thiel 1966) both in 1964 and 1965 in the Arabian Sea.

The meiofauna has received only minimal attention in the sublittoral of the Gulf of Mexico. Pequegnat and Gettleson (1974) listed the number of individuals in major meiofaunal and macroinfaunal taxa from five stations in the vicinity of Stetson Bank. In 1976, they examined meiofaunal-sediment correlations from 24 stations located on the outer continental shelf of southwest Texas. In the same year, Gettleson and Pequegnat (1976) reported on an intensive study of the wet weight and abundance of the meiofauna and macroinfauna taken from 10 stations on the outer continental shelf of east Texas. More intensive quantitative studies of meiofauna were undertaken on the northern Gulf of Mexico outer continental shelf as a part of the STOCS and Topographic Features Studies (Pequegnat and Sikora 1977, 1978, 1979). Prior to these studies there had been only a limited number of sublittoral studies in which the wet weight and/or abundance of the meiofauna and macroinfauna had been compared.

Meiofaunal studies have been increasing since the early 1970s, especially in Europe. For instance, Guille and Soyer (1974) studied the fauna off the French Banyuls-sur-Mar coast of the Mediterranean Sea; Ankar and Jansson (1973), Elmgren (1972), Ankar and Elmgren (1975), Jansson and Wulff (1977), Cederwall and Elmgren (1980), and Elmgren et al. (1984) have

analyzed meiofaunal and macroinfaunal samples from the Baltic Sea, including the Bothnia Sea and Bothnia Bay.

1.3.2 Macroinfauna

Whereas virtually every major research project conducted on the continental shelf of the Gulf of Mexico has included a strong macroinfaunal research program, quantitative studies of this group have been particularly neglected in the slope and deep-sea Gulf of Mexico. Rowe and Menzel (1971) state that the reason for presenting the results of their study of the deep-sea Gulf infauna was because no quantitative data had been previously published for this region. In summary of their findings, they noted that the benthic fauna of the deep Gulf was depauperate compared to other basins and that biomass and numbers of macroinfauna decreased logarithmically with depth. Rowe et al. (1974) compared biomass estimates for the deep northern Gulf versus the northwestern Atlantic ocean, the results of which supported the previous observation.

Pequegnat (1983) described the results of macroinfaunal sampling from TAMU's R/V Alaminos, sampling which was conducted as part of a comprehensive program in the deep Gulf, over the 1960s. Results were available for the polychaetes and bivalve and scaphopod mollusks, only. The polychaetes were represented by 137 species distributed among 11 orders and 28 families. The bivalve collections contained 73 species and 18 families even though a number of specimens were lost in shipment to a taxonomic specialist. The scaphopod collections contained representatives of 17 species of which 10 species were comprised of live individuals.

This program has placed much emphasis on the collection and study of the macroinfauna. As can be seen from the above, there are few data available from the deep-sea Gulf of Mexico for this most important group.

1.3.3 Megafauna

This study was fortunate in that a comprehensive treatise on the deep sea Gulf of Mexico megafauna had just been completed; namely two reports to MMS prepared by the TerEco Corporation (Pequegnat et al. 1976,

Pequegnat 1983). The first of these reports deals with ecological aspects of the upper continental slope, whereas the most recent one provides a comprehensive treatment of what is presently known about the ecology of the slope dating from the cruises made by U.S. Coast and Geodetic Steamer, Blake during 1877 to 1880 to the present. The quantitative analyses in this report are largely based upon data from 264 stations across the Gulf taken at depths ranging from 150 to 3850 m. This monumental work, primarily descriptive, has set the stage for this study by advancing numerous and sound hypotheses about aspects such as the likely patterns of depth zonation exhibited by characteristic faunal assemblages; the differences between assemblages representative of the eastern Gulf slope versus those representative of the western Gulf slope, and how these differences might relate to general oceanographic patterns; and the trophic organization of the system. The latter are expressed as conceptual models which were supported and evaluated based on preliminary calculations of carbon pools and mass balance. A brief summary of some of TerEco's findings pertinent to this year's LGL work are presented below.

Within the depth range specified for investigation by this study, five faunal assemblages are believed to be represented. A synopsis of some of the salient features of each of these assemblages is provided by the following list.

(1) Shelf/Slope Transition Zone
- depth range 150-450 m; median depth 300 m
- demersal fish predominate, as do predatory asteroids and brachyurans
- very productive with approximately 90 species of demersal fish
- 66 species of the demersal fish reach maximum populations in this zone
- gastropods and polychaetes also prevalent
- Brissopsis urchins extremely abundant
- very few sea cucumbers

(2) Archibenthal Zone - Horizon A
- depth range 475-740 m; median depth 612 m

- demersal fish abundant but represented by only 79 species
- demersal fish species reaching maximum populations in this zone reduced to 45
- asteroids abundant
- sea cucumbers doubled in number
- caridean shrimps also doubled in number
- Brissopsis urchins are almost absent being replaced by Phormosa placenta and Plesiodiadema antillarum

(3) Archibenthal Zone - Horizon B

- depth range 775-950 m; median depth 862 m
- demersal fish numbers reduced only slightly but the numbers reaching maximum populations is less than half of those in Horizon A
- drastic reduction in number of brachyuran crabs
- gastropods and polychaetes still well represented

(4) Upper Abyssal Zone

- depth range 975-2250 meters; median depth 1612 m
- number of demersal fish reduced to half of that in Archibenthal zone
- number of demersal fish attaining maximum populations is over two times that of Horizon B
- major increase in number of species of large sea cucumbers
- number of brachyurans continue to drop (four as compared to 35 in shelf/slope transition zone)
- gastropod and sponge species reach a peak
- polychaetes still abundant

(5) Mesoabyssal - Horizon C

- depth range 2275-2700 m; median depth 2488 m
- very sharp break in fauna of Upper Abyssal and Horizon C of Mesoabyssal

- number of demersal fish with maximum population drops from 49 to three; with only two more species in Horizon D (next depth zone)
- similar reduction in maximum populations noted for other species as well

Faunal assemblages representative of the western Gulf were found to have been characterized by a high degree of endemism whereas little endemism was noted for assemblages in the eastern Gulf. These apparent differences were related to the presence and frequency of gyres, the Loop Current, nutrient and detrital (terrestrial vegetation) inputs from rivers, and depth and substrate characteristics, all of which vary markedly between the eastern and western Gulf regions.

Pequegnat (1983) reported that, unless assimilation of bacteria and meiofauna are unusually high, there are five sources of carbon to the deep-sea areas of the slope, namely dissolved organic matter, deadfalls of animal carcasses, fallout of shallow marine and terrestrial macrophytes, transport of organically rich materials by slumps and turbidity flows, and by active foraging into upper water layers by demersal fish and large benthic crustaceans who gather this material and return to the bottom. There is no evidence to date to support the contention that dissolved organic matter is used as a source of energy by the bacteria and meiofauna. In summary, it can be safely stated that carbon and particle fluxes in the deep-sea region of the continental slope of the Gulf are poorly understood.

The biological zonation patterns and assemblage descriptions provided by Pequegnat (1983) were by necessity, largely based upon the megafauna and macroepifauna because only a moderate amount of data were available for describing the macroinfauna. Typically, the large forms of invertebrates and fishes like those which have been used in the faunal descriptions constitute only a small component of the diversity and numerical abundances of animals living at the deep-sea, sediment-water interface. The animals mainly represented in this habitat are the benthic macroinfauna, and this group, along with the meiofauna thus rightfully constitutes the emphasis of this year's program. The macroinfauna as opposed to the meiofauna will be used as the major basis for the

assemblage characterizations. Beyond the major groups, the taxonomy of the meiofauna is exceedingly poorly known anywhere, much less in the deep sea. Synoptic samples (from the same grabs) of macroinfauna, meiofauna and sediments will be used to establish a better concept of community structure, trophic relationships, and the role of the various physical and chemical features of the habitat as they influence animal abundance and distributional patterns.

1.4 PERFORMING ORGANIZATIONS AND RESPONSIBILITIES

Although LGL is serving as the prime contractor and Program Manager for the Continental Slope studies, other organizations and individuals are performing major tasks, and the research team is guided by a Scientific Advisory Committee (SAC) having established credentials. The SAC serves as a quasi-independent body having two major responsibilities in this program. The first is to advise the program participants and MMS on the quality and nature of ongoing and completed research, and the second is to make recommendations with regards to changes in the program and future research.

In addition to Program Management, LGL personnel are responsible for all biological aspects of the program, including benthic photography. In the conduct of the latter task, the Woods Hole Oceanographic Institution provided underwater photographic equipment and operating staff during Cruise I and have assisted LGL in the development of in-house capabilities in this regard. The project team also includes a number of individual specialists who assist with the identification of various taxonomic groups.

TAMU is the other major participant in the program, having two major areas of responsibility. The first is logistical in nature in that personnel of TAMU have the primary responsibility for providing the research vessel and conducting most at-sea operations. The second area of responsibility for TAMU is the conduct of all phases of the oceanographic and hydrocarbon aspects of the program.

1.5 REPORT ORGANIZATION AND NATURE

In the following sections of this report, we describe the study area and methods of study (2.0); present and discuss the environmental observations made at 15 locations sampled during Year One (3.0); present and discuss the corresponding biological findings (4.0) and provide a summary of program findings (5.0). It should be noted that the program is in its infancy, and few conclusions or definitive statements can (or should) be made at this point.

2.0 STUDY AREA AND METHODS

The Statement of Work for this study limited the program to waters north of 25°N having depths between 200 and 2600 m. It was further specified that (1) stations were to be located in depths likely to delineate faunal zonation or areas of transition and (2) sampling stations were to be located in each of the MMS Western, Eastern, and Central Gulf of Mexico Lease Planning Areas. Guidance was also provided to all potential contractors as to the general level of research effort being anticipated by MMS, the general categories of samples to be collected and the nature of the kinds of laboratory analyses which MMS believed appropriate.

The Statement of Work for the first years' program likewise defined the seasonal allocation of the work--one cruise to the Central Lease Planning Area was to be conducted in the fall-winter of 1983 and all three Lease Planning Areas were to be sampled in the spring or summer of 1985. These requirements provide a context for the study area and methods descriptions provided below.

2.1 STUDY AREA

Our sampling strategy was organized around three, 5-station transects with one located in each of the three Gulf of Mexico Lease Planning Areas (Fig. 2-1). Stations were located along each transect such that one was sited in each of Pequegnat's (1983) faunal zones found within the depth limits of the study, namely the Shelf/Slope Transition Zone; Archibenthal, Horizon A; Archibenthal, Horizon B; Upper Abyssal and Mesoabyssal, Horizon C (see Section 1.3 above). Fine tuning of station locations within each faunal zone was also influenced by water mass distribution (see Section 1.2 above). The shallowest station in each transect was located towards the deeper end of the Shelf/Slope Transition Faunal Zone, below the zone of Gulf Common Water in Tropical Atlantic Central Water. Each of the two stations in the Archibenthal Faunal Zone (Horizon A and B) were located in the Antarctic Intermediate Water mass whereas the two deepest stations were in the Gulf Deep Water. Variation in water mass properties would be

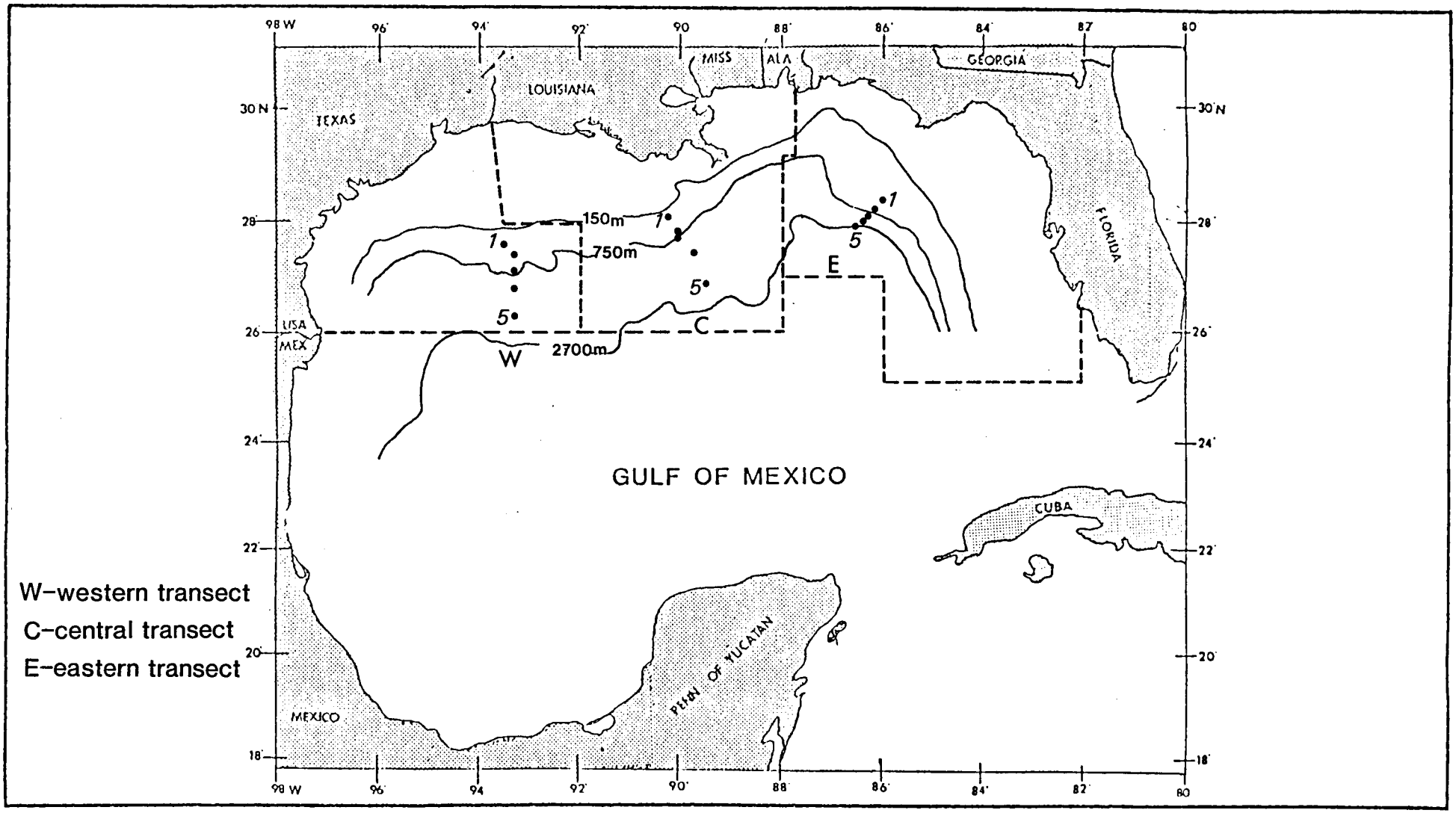


Figure 2-1. Location of transects and stations, within Western (W), Central (C) and Eastern (E) Gulf of Mexico Lease Planning Areas.

expected to be minimal at the deeper stations with the exception of events related to the passage of cold- and warm-core rings from the Loop Current.

The exact location of each station is best defined by the position which was held for taking hydrocasts and conducting the water column and benthic sampling activities. This position more or less represented the center of sampling activity. Upon arrival at a station, the first task was to lower the benthic camera system and shoot a photographic transect, recording position and depths along the transect. Upon completion of this task, the vessel relocated to a position approximating the center of the photographic transect. This position was held during the hydrocasts and water column and benthic sampling activities. Trawling was conducted last. The trawl "track" then attempted to cover some of the photographic "track" based on position determinations. The samples were not, in fact, all taken from the exact same place, but attempting to group the sampling effort as close as possible contributed to better inter-sample comparability.

In this context, station locations for Cruises I and II for Year One box core stations are shown in Table 2-1. The depth and initial on-bottom position of the trawl track is shown in Table 2-2. The exact photography track has not yet been plotted for each cruise.

2.2 CRUISES

During Year One, cruises were conducted on the R/V Gyre (Fig. 2-2), which is operated by the Department of Oceanography of TAMU for the Texas A&M Research Foundation. Specifications include the following features:

Length: 174 ft
Beam: 36 ft
Draft, mean: 12 ft
Tonnage (long tons): 292 gross, 197 net, 946 displacement
Speed: Maximum 11.5 knots cruising, 9.5 knots; minimum, 0 knots
Fuel Capacity: 86,000 gallons
Water Capacity: 8600 gallons

TABLE 2-1

Station Locations for Year One Boxcore Stations

Station	Replicate	Depth	Latitude	Longitude
Cruise I				
C1	1	320	28°03.7'	90°14.1'
	2	320	28°03.7'	90°14.1'
	3	420	28°03.2'	90°15.2'
	4	420	28°03.2'	90°15.2'
	5	356	28°03.4'	90°15.3'
	6	355	28°03.2'	90°15.2'
C2	1	615	27°54.3'	90°05.9'
	2	615	27°54.3'	90°05.9'
	3	603	27°54.4'	90°06.0'
	4	603	27°54.4'	90°06.0'
	5	632	27°54.3'	90°06.0'
	6	610	27°54.3'	90°06.1'
C3	1	845	27°49.2'	90°07.2'
	2	858	27°45.1'	90°08.5'
	3	853	27°49.3'	90°07.0'
	4	853	27°49.3'	90°07.0'
	5	853	27°49.6'	90°06.8'
	6	853	27°49.6'	90°06.8'
C4	1	1440	27°28.3'	89°47.1'
	2	1440	27°28.3'	89°47.1'
	3	1378	27°29.1'	89°46.4'
	4	1378	27°29.1'	89°46.4'
	5	1325	27°29.5'	89°45.6'
	6	1325	27°29.5'	89°45.6'
C5	1	2470	26°58.2'	89°36.9'
	2	2490	26°47.8'	89°31.0'
	3	2490	26°57.8'	89°31.0'
	4	2467	26°58.0'	89°31.8'
	5	2467	26°58.0'	89°31.8'
	6	2468	26°59.4'	89°32.6'

TABLE 2-1
(cont'd)

Station	Replicate	Depth (m)	N. Latitude	W. Longitude
Cruise II				
W1	1	366	27° 35.0'	93° 33.1'
	2	366	27° 35.0'	93° 33.1'
	3	344	27° 35.2'	93° 33.0'
W2	1	605	27° 24.9'	93° 20.5'
	2	603	27° 24.9'	93° 20.4'
	3	603	27° 24.9'	93° 20.5'
W3	1	860	27° 10.6'	93° 19.4'
	2	860	27° 10.6'	93° 19.4'
	3	841	27° 10.3'	93° 19.3'
W4	1	1419	26° 44.1'	93° 19.1'
	2	1405	26° 44.3'	93° 19.1'
	3	1405	26° 44.3'	93° 19.1'
W5	1	2524	26° 17.0'	93° 19.3'
	2	2524	26° 17.0'	93° 19.3'
	3	2470	26° 17.2'	93° 19.2'
C1	1	358	28° 03.3'	90° 15.2'
	2	357	28° 03.3'	90° 15.2'
	3	357	28° 03.3'	90° 15.2'
	4	348	28° 03.3'	90° 15.3'
	5	348	28° 03.3'	90° 15.3'
	6	348	28° 03.3'	90° 15.6'
C2	1	595	27° 54.4'	90° 06.2'
	2	595	27° 54.4'	90° 06.2'
	3	595	27° 54.5'	90° 06.2'
	4	595	27° 54.5'	90° 06.2'
	5	605	27° 54.3'	90° 05.9'
	6	605	27° 54.3'	90° 05.9'
C3	1	834	27° 49.2'	90° 07.1'
	2	834	27° 49.2'	90° 07.1'
	3	840	27° 49.4'	90° 07.0'
	4	840	27° 49.4'	90° 07.0'
	5	841	27° 49.6'	90° 07.1'
	6	841	27° 49.6'	90° 07.1'
C4	1	1390	27° 28.4'	89° 46.8'
	2	1390	27° 28.4'	89° 46.8'
	3	1394	27° 28.3'	89° 47.0'
	4	1394	27° 28.3'	89° 47.0'
	5	1386	27° 28.4'	89° 46.9'
	6	1386	27° 28.4'	89° 46.9'

TABLE 2-1
(cont'd)

Station	Replicate	Depth (m)	N. Latitude	W. Longitude
Cruise II (cont'd)				
C5	1	2377	26° 56.9'	89° 36.7'
	2	2400	26° 57.7'	89° 34.2'
	3	2400	26° 57.7'	89° 34.2'
	4	2377	26° 57.9'	89° 35.1'
	5	2377	26° 57.9'	89° 35.1'
	6	2400	26° 57.6'	89° 35.1'
E1	1	347	28° 27.7'	86° 01.0'
	2	357	28° 27.6'	86° 01.8'
	3	357	28° 27.6'	86° 01.8'
E2	1	625	28° 16.7'	86° 15.1'
	2	625	28° 16.7'	86° 15.1'
	3	650	28° 16.6'	86° 15.2'
E3	1	845	28° 09.6'	86° 25.0'
	2	845	28° 09.6'	86° 25.0'
	3	847	28° 09.5'	86° 26.2'
E4	1	1330	28° 04.3'	86° 34.4'
	2	1358	28° 04.4'	86° 34.8'
	3	1358	28° 04.4'	86° 34.8'
E5	1	2853	28° 00.4'	86° 38.8'
	2	2853	28° 00.4'	86° 38.8'
	3	2800	28° 00.5'	86° 38.9'
	4	2800	28° 04.4'	86° 34.8'

TABLE 2-2

Trawl Locations Sampled During Year One

CRUISE 1 - MMS-NGOMCS - TRAWL STATIONS
November 1983

Station	Sample No.	Depth (m)	On-Bottom N. Latitude	Position W. Longitude	Duration (Hrs:Min)	Remarks
C-1	58	329	28°04.4'	90°17.5'	1:09	
C-2	194	786	27°53.3'	90°05.3'	1:14	
C-3	225	~850	27°48.0'	90°03.3'	2:30	
C-4	347	1440	27°25.4'	89°47.6'	1:21	Small catch
C-5	226	2400	26°56.5'	89°33.2'	5:19	Trawl malfunctioned, minimal catch

CRUISE 2 - MMS-NGOMCS - TRAWL STATIONS
7-19 APRIL 1984

Station	Sample No.	Depth (m)	On-Bottom N. Latitude	Position W. Longitude	Duration (Hrs:Min)	Remarks
W-1	2022	342	27°37.0'	93°33.6'	1:08	Shell Hash (Dead Clams)
W-2	2046	576- 732	27°24.5'	93°18.9'	1:02	
W-3	2048	792- 864	27°08.4'	93°23.6'	2:39	
W-4	2103	1372-1454	26°44.4'	93°18.6'	2:18	Palm Fronds and Sargassum
W-5	2125	2322-2305	26°17.1'	93°28.8'	2:37	
C-1	2168	329- 347	28°03.3'	90°15.0'	1:05	
C-2	2256	603	27°54.4'	90°06.0'	1:04	Many Brittle Stars
C-3	2255	~850	27°49.7'	90°06.7'	2:19	
C-4	2285	1358-1518	27°28.1'	89°43.6'	2:00	
C-5	2335	2412-2390	27°01.4'	89°30.3'	2:16	Poor catch
E-1	2365	375- 358	28°26.5'	86°03.1'	1:17	Good catch
E-2	2387	603- 640	28°17.6'	86°14.8'	0:59	
E-3	2409	~840	28°10.7'	86°25.6'	2:14	
E-4	2429	~1170	28°06.0'	86°35.3'	2:07	
E-5	2458	2881-2834	28°01.9'	86°40.1'	2:12	Poor trawl--Doors probably collapsed

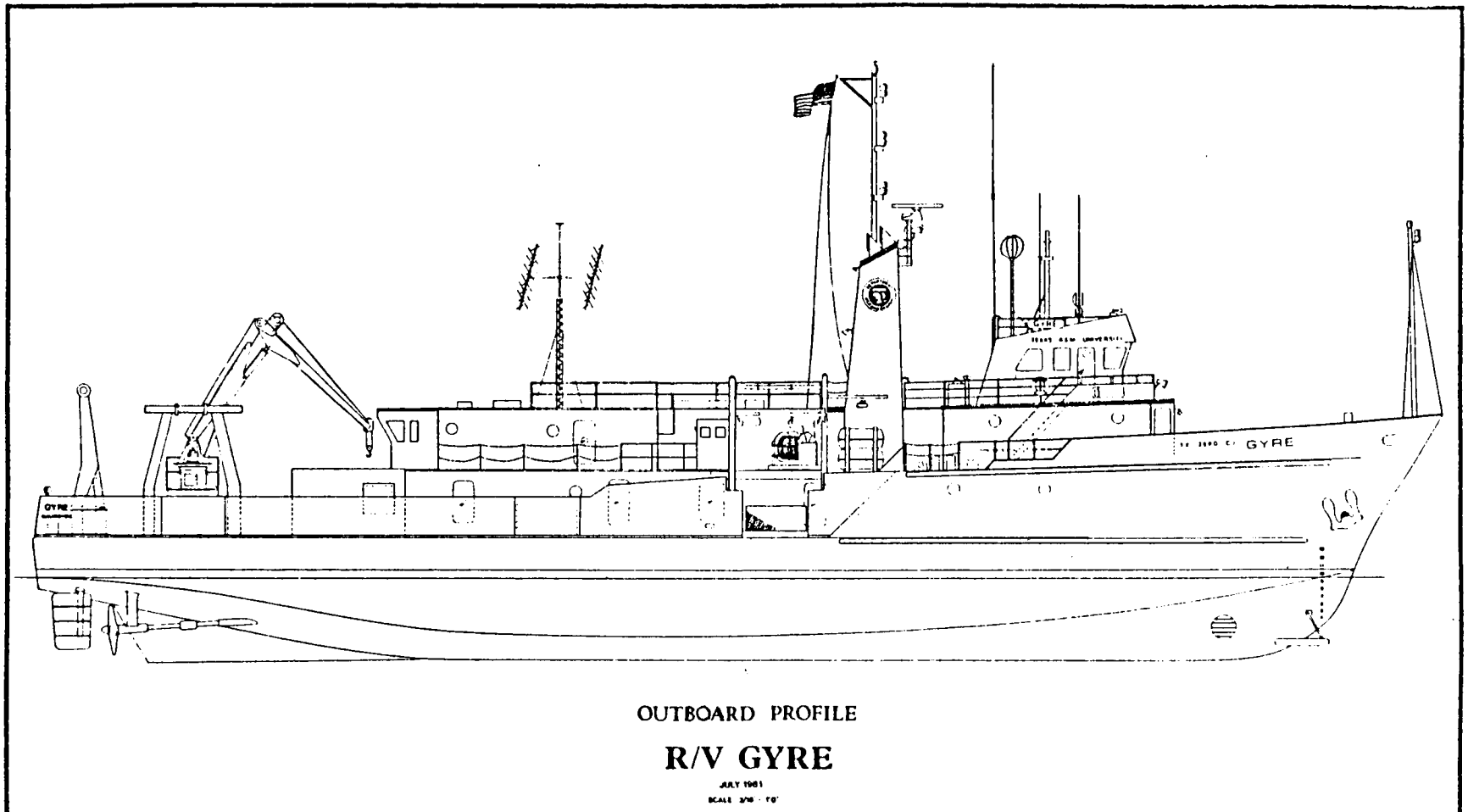


Figure 2-2. R/V Gyre.

Evaporators/desalinators: 5; capacity 60 gallons/hour

Range, Nominal: 8000 miles

Endurance: 21 days nominal; 35 days extended, 60 days emergency

Complement: crew, 10; scientists/technicians, 21

Main propulsion: Twin diesel Caterpillar Model 398D, reduction gear drive to Liaan variable pitch propellers; 850 HP each shaft

Bow Thruster: Electric/hydraulic drive, continuously variable speed, through transverse tunnel forward

Generators: Twin diesel Caterpillar Model 379B, 300 KVA each, giving primary power of 140 VAC, 3^{o}

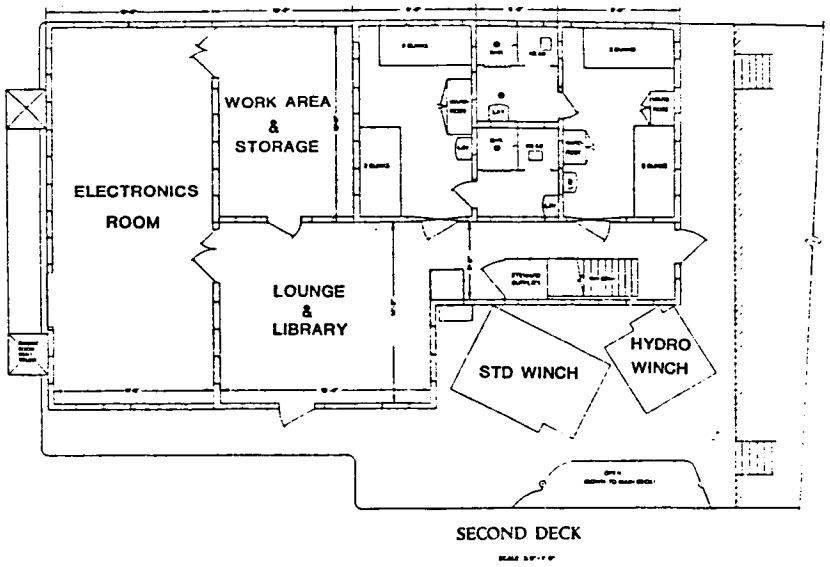
Power Available: 140 VAC 3^{o}; 110 VAC 1^{o} and 3^{o}; 220 AC (very limited). Power isolation and regulation available in main and electronics laboratories for scientific equipment

Vans: One standard van can be carried on the port side of the stern main deck. Several vans are available, or scientistss can provide their own

Clean Water: Tubing is available from the main deck to a point forward of the forefoot of the ship, for taking non-ship contaminated seawater samples

Space for scientific activities on the Gyre is located on the main and upper decks, in and around the after deckhouse (Fig. 2-3). Space in the forward deckhouse and below decks is primarily for operational and housekeeping activities (Fig. 2-4). Light to moderate overside work is performed using winches on the starboard side amid ships; heavier work is conducted off the fantail. On the main deck are the wet lab, main lab, and a technician's workshop; on the upper level are electronics and computer labs and science berthing spaces. Gyre's variable pitch/speed twin screws, and continuously variable speed bow thruster provide excellent maneuvering and station-keeping qualities.

The principal deck machinery of the R/V Gyre is listed below.



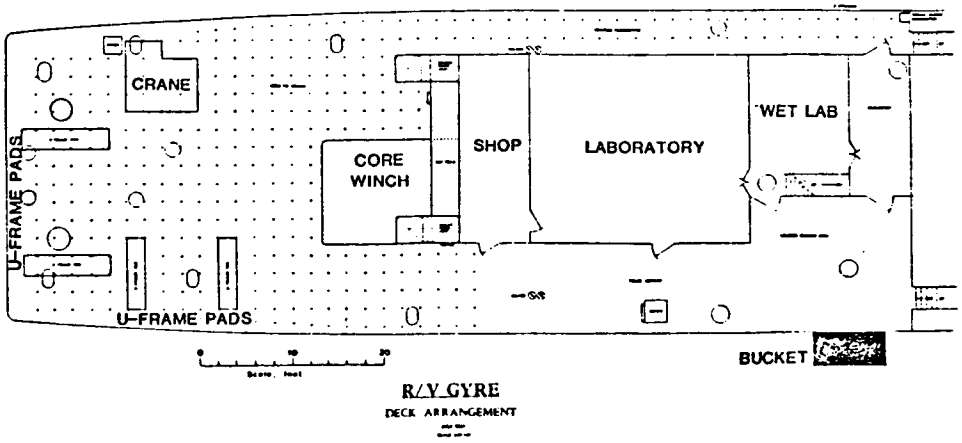
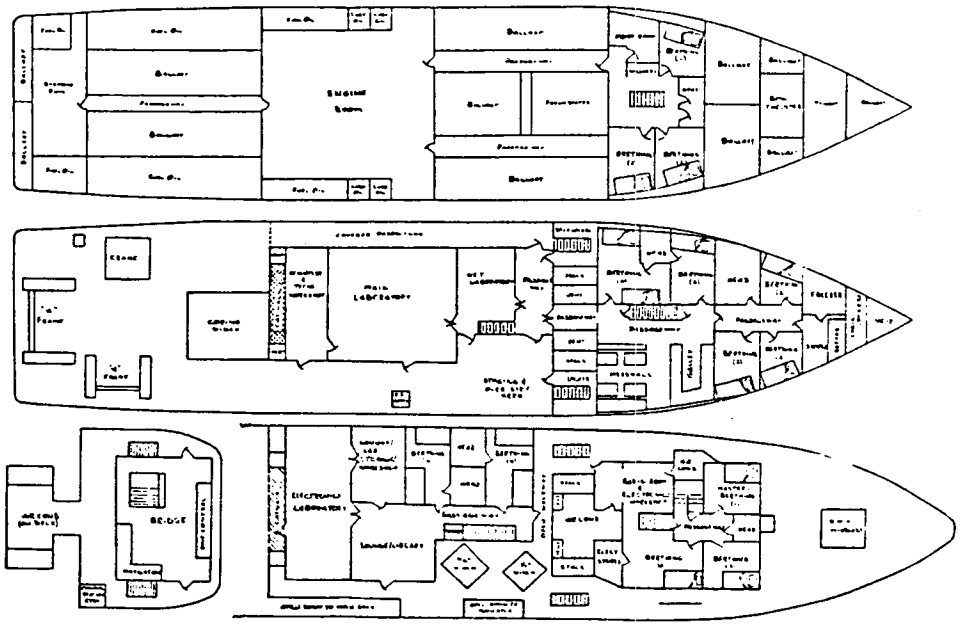


Figure 2-3. R/V Gyre - After Deckhouse.



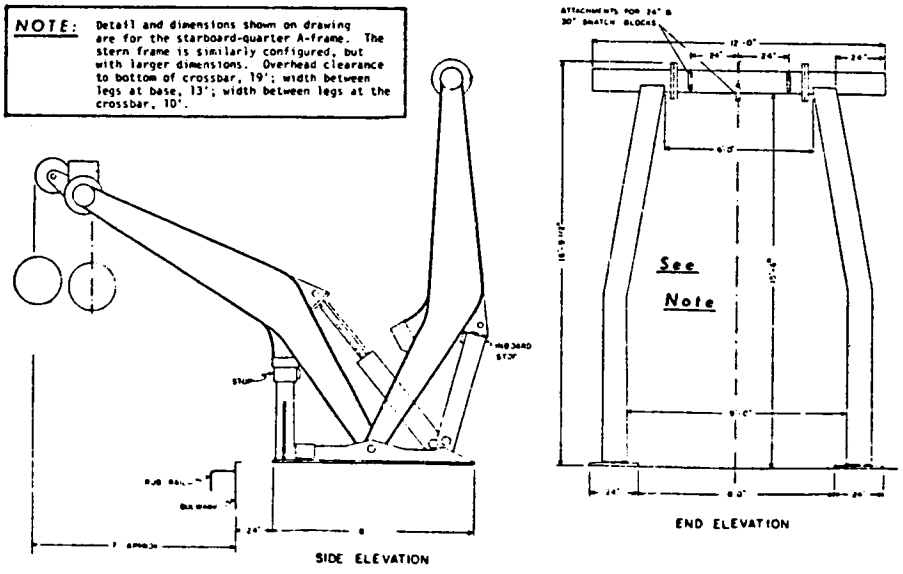


Figure 2-4. R/V Gyre - Forward and below decks.

Winches - One "coring" winch, Northernline Model 3355 EHHOW, spooling 30,000 ft of 1/2 in wire, is located on the main deck aft for stern or starboard quarter heavy operations.

Two "hydro" winches are located on the starboard side amidships, leading overboard through paired hydraulic-powered gallows frames. One spools 30,000 ft of 1/4 in conducter cable; the other spools 23,000 ft of 5/16 in conductor cable. The winches are modifed Northernline Model 3353 EHLOW.

Other specialized winches or handling gear may be available, or can be brought by the scientist if advance arrangements are made.

Cranes - One Nautilus articulated, hydraulically-operated crane is installed on the port side of the stern. It has 360° rotation, and a capacity of 2.5 tons at 36 ft reach (full extension). The load capacity increases closer to the crane base at lesser reeaches.

One Atlas articulated crane is installed in way of the forward hydro winch area to handle scientific gear over the side as well as for general logistics use. It has a capacity of 1.5 tons at 24 ft extension (full extension).

A-Frames - Two heavy-duty A-frames, hydraulically operated, are located on the stern, one facing aft over the stern and the other over the starboard quarter.

Two paired gallows-type frames, hydraulically operated, are located amidships on the starboard side to handle loads from the hydro winches.

Auxiliary Equipment - Air tuggers are available at major over-side handling areas for assistance in moving heavy gear.

Hold-downs - One inch bolt holes to accept bolt-down fittings are installed in decks and laboratories at 2 ft intervals throughout. All machinery and equipment must be bolted down; no welding to decks is permitted.

In addition to winches, cranes, A-frames, and other deck equipment, scientific quality instrumentation is prcvided (or available if requested) for use by scientists. All equipment routinely made available is

maintained by the TAMU marine and electronic technical support groups. Specialized equipment brought by the scientific party is their responsibility, although technicians will assist as much as possible. The following gear is routinely available:

Bathymetry - 3.5 and 12 KHz transceivers; the 3.5 is equipped with a CESP correlator. Transducers are hull-mounted, with the 3.5 units being a matrix of 12 units. A towed 3.5 KHz transducer is available on request. Three Raytheon PDR/LSR recorders are installed in the electronics laboratory.

Wind - Wind speed and relative direction are displayed, but not normally recorded in the laboratory.

Ship Motion - Ship speed through the water and true heading are displayed but not normally recorded in the laboratory.

Expendable Bathytermograph - XBT Launcher/Recorders are installed. Provision of probes is normally the responsibility of the scientist.

The following equipment was also available for use on the Gyre as required.

CTD - One Plessey 9041 (6000 m) and one Neil Brown with oxygen probe (6000 m).

Rosettes - Small Niskin Rosette multisampler, usable with 1.7 or 5 liter Niskin bottles and 9041 CTD. Large Niskin Rosette multisampler, usable with 30 liter Niskin bottles and Neil-Brown CTD.

Reversing Thermometers - An extensive stock of reversing thermometers covering all the commonly-used ranges and scales are available.

Autoanalyzers - A Technicon 4-channel and an Alpken 6-channel autoanalyzer is available. Services of a marine technician for their operation is ordinarily required.

Salinometers - Three salinometers are on hand: Plessy inductive, Guildline conductive and University of Washington

conductive. Services of a marine technician for their operation is usually required.

Oxygen Titration System - Available for use, services of a marine technician for its operation is usually required.

Computer - A HP-2100 computer is installed on-board ship in the computer laboratory. Gyre's electronics technicians are available for routine operation and maintenance. They do not usually have time for special projects, programming and the like.

Data Logging - A SAIL loop for data logging will be available commencing the summer of 1983. This includes interfaces to the commonly-used instrumentss and two hP-25 loggers.

Navigation - A Satnav receiver, Omega receiver, and several Loran A/C receivers are available on-board. The Satnav and Omega are on the bridge, as are some of the Lorans for ship's navigation. Information from these can be provided to the scientists and Loran equipment can be provided in the electronics laboratory or main laboratory.

Prior to conducting each cruise, a planned sampling inventory list was prepared as part of the field logistics plan and included documentation for each replicate of each type of sample which was to be taken. The sample inventory list was prepared as the required First Level Data Inventory form. The sample inventory list was supplemented with preprinted labels for affixing collected samples, which provided an additional quality control check on completing the sampling schedule for each station. The labels had sufficient information to identify the sample to be collected as far as type, date and time of collection, location of collection, gear type used, preservation technique, and the organization to which it was to be transferred for analysis.

Cruise I was part of Cruise 83-G-16 of the Gyre which was conducted during the period 23 November-2 December 1983. Cruise II was part of Gyre Cruise 84-G-4 and was accomplished over the period 3-20 April 1984. On each of the cruises, ship time was shared with National Science Foundation (NSF)-sponsored studies being conducted by Dr. Brooks of TAMU. All

samples planned to have been collected were obtained on each cruise (Table 2-3).

2.3 FIELD SAMPLING PROCEDURES

Field sampling consisted of taking water column measurements, sampling the bottom sediments for physical/chemical characteristics and meio- and macroinfauna, and collecting and photographing megafauna and their habitat.

2.3.1 Hydrographic Measurements

Continuous and discrete measurements of hydrographic parameters were obtained throughout the water column (surface to bottom) at each station as summarized by Table 2-4. A Neil-Brown Mark III CTD/Rosette/Transmissometer System was used to obtain continuous data and discrete water samples. Continuous conductivity (salinity), temperature, depth, and transmission records were provided by the Neil-Brown CTD. A 12-bottle Rosette attached to the CTD was used to collect at least 12 discrete water samples at each station. Bottles were spaced throughout the water column in order to delineate the major water masses at each site. The CTD/Rosette/ Transmissometer system was deployed with a pinger so that the cast could be safely lowered to within a few meters of the bottom. This was done in order to discern whether there were bottom nepheloid layers at each site.

Continuous Measurements

The shipboard Neil-Brown CTD system consisted of a demodulator, digital display and digital-to-analog converters. Digital output of each scan (every 32 ms) was transmitted via armored cable to the shipboard unit in "TELETYPE" format using frequency-shift-keyed modulation designed to transmit up to 127 bytes (8 bits) per scan.

The housing with the conductivity, temperature, and pressure sensors was pressure tested to 10,000 psi for one hour. The accuracy and resolution of the individual sensors is listed in Table 2-5.

TABLE 2-3

Total Sampling Effort for Cruises I and II

Station No. / Gear Type	Cruise I Central 1	2	3	4	5	Cruise II West 1	2	3	4	5	Cruise II Central 1	2	3	4	5	Cruise II East 1	2	3	4	5	Total
Box cores (number)	6	6	6	6	6	3	3	3	3	3	6	6	6	6	6	3	3	3	4	4	90
Meiofauna (tubes)	24	24	24	24	24	12	12	12	12	12	24	24	24	24	24	12	12	12	16	16	432
Sediment (tubes)	6	6	6	6	6	3	3	3	3	3	6	6	6	6	6	3	3	3	4	4	90
Hydrocarbon (tubes)	6	6	6	6	6	3	3	3	3	3	6	6	6	6	6	3	3	3	4	4	90
Trawl (hours)	1.2	1.2	2.5	1.4	5.3	1.1	1.0	2.7	1.3	2.6	1.1	1.0	2.3	2.0	2.3	1.3	1.0	2.2	2.1	2.2	37.8
Camera (frames)	800	800	800	800	800	800	800	800	800	800	800	800	800	800	800	800	800	800	800	800	16,000

TABLE 2-4

Supportive water column analyses.

Parameters	Cruise I 5 Stations	Cruise II 15 Stations	Cruises I & II Total
CTD Casts	5	15	20
Transmissometry Profiles	5	15	20
Dissolved Oxygen	60	180	240
Nutrient[1]			
Phosphate	60	180	240
Nitrate	60	180	240
Silicate	60	180	240
Nitrite	60	180	240
Salinity	60	180	240
POC[1]	60	180	240
Thermometry[2]	20	60	80

[1]Performed during the cruise using available facilities at no extra cost to the project.

[2]Up to 4 sets of thermometers were placed on the Rosette cast to check calibration of the CTD system.

Table 2-5. Neil-Brown Mark III CTD System measurement ranges, accuracy and resolution.

	Range	Accuracy	Resolution
Pressure	0-320 decibar 0-650 decibar 0-1600 decibar 0-3200 decibar 0-6500 decibar	0.1% of FS (standard) 0.5% (optional)	0.0015% FS (all ranges)
Temperature	-32 to +32°C	0.005°C (-3 to +32°C)	0.0005°C
Conductivity	1 to 65 mmhos	0.005 mmhos	0.001 mmhos

Transmission profiles were provided by a Sea Tech Inc. transmissometer interfaced to the CTD system. This instrument has a 25 cm light path with a light emitting diode with a wavelength of 660 nm as a light source. This instrument, described by with proper calibration, provides data with an error less than 0.5% transmission. It has a depth capability of ca. 2500 m.

The data from the CTD/transmissometer were stored both as a hard copy from an X-Y recorder and on magnetic tape. An HP-1000 computer was used aboard the R/V Gyre for data storage.

Discrete Measurements

Discrete measurements of temperature, salinity, dissolved oxygen, nutrients, and particulate organic carbon (POC) were obtained by collecting samples from PVC Niskin bottles mounted on a General Oceanics Rosette sampler. Subsamples for dissolved oxygen were drawn first. All the discrete measurements were performed at sea. Measurements of temperature, salinity, and POC were all performed in duplicate. Ten percent of the oxygen and nutrient samples were also duplicated to establish sampling and analytical precision, and to assure data reliability.

Thermometry

Deep-sea reversing thermometers were attached to Niskin bottles mounted on the Rosette. These thermometers, from Texas A&M University's Department of Oceanography collection, were all precisely calibrated. Most have long histories of calibration to $\pm$ 0.005°C. The thermometers were equilibrated at depth for at least 5 min before tripping. All thermometers were read in duplicate by separate observers. Thermometers were allowed to equilibrate before reading.

Salinity

Samples for salinity were collected in 500-ml citrate bottles that were triple rinsed with sample water before collection. These bottles were air tight. Samples taken from salinity were analyzed using either a Plessey Environmental Systems Model 6230N Laboratory Salinometer or a Guildline Model 8400 Autosal Laboratory Salinometer. The Plessey system utilizes an inductively-coupled conductivity sensor to establish a conductivity ratio between an unknown sample and a standard at approximately 35 ppt salinity. A dual-element platinum thermometer and its associated circuitry senses the temperature of the sample and applies the appropriate compensation. The specifications of the system are as follows:

Range: 0 to 51 ppt
Accuracy: $\pm$ 0.003 ppt
Temperature Compensation: $\pm$ 0.0007 ppt/°C

The Autosal system uses conductivity directly and has better accuracy and precision than the Plessey.

Oxygen

Oxygen samples were always the first drawn from a cast and were drawn as soon as possible. The samples were taken using a length of Tygon tubing with the tip of the tube near the bottom on the flask so that it

could be filled slowly without agitation. The flask was rinsed and air bubbles removed from the tubing with a small amount of sample before the flask was filled. The flask was overflowed one full volume and the stopper inserted to avoid trapping air bubbles.

The technique used for analysis of oxygen was the modified Winkler technique of Carpenter (1965). As soon as possible after collection, the samples are "pickled" by the addition of a divalent manganese solution, followed by strong alkali. The precipitated manganous hydroxide is dispersed evenly throughout the seawater sample which completely fills a stoppered oxygen flask. Any dissolved oxygen rapidly oxidizes an equivalent amount of divalent manganese to basic hydroxides of higher valency states. When the solution is acidified in the presence of iodid, the oxidized manganese again reverts to the divalent state, and iodine, equivalent to the original dissolved oxygen content of the water, is liberated. The iodine is titrated with standardized sodium thiosulfate (Strickland and Parsons 1972). Oxygen samples were analyzed at sea. At least 10% of the oxygen samples taken were and analyzed in duplicate.

Nutrients

Water samples for nutrient analysis (phosphate, nitrate, nitrite, silicate) were drawn into "Whirl-Pak" sampling bags. If samples were not analyzed immediately, they were frozen until analysis later during the cruise. Generally, analyses were performed immediately in the field following the methods outlined by Strickland and Parsons (1972), "A Practical Handbook of Seawater Analysis, (Revised)". Specific methods for each of the nutrients are also given by Technicon Instruments Corporation of Andsley, New York, Industrial Methods Bulletins 100-70W, 98-70W, 161-71WB, and 155-71W.

2.3.2 Sediment Sampling

Box core samples were taken at each station to provide material for macroinfauna and meiofauna identification, sediment grain size determinations, carbon isotope determinations, and hydrocarbon analysis. The samples were subdivided to provide material for each of these

analyses. Six replicate samples were taken at each of the Central Transect stations during both Cruises I and II. Three replicate samples were taken at each station on the Western and Eastern Transect stations during Cruise II (except for Stations E4 and E5, at which four replicates were taken). Box coring devices (a TAMU modified version of the GRAY-O'HARA modification of the J&O box corer [Pequegnat et al. 1981, Fig. 18 & p. C3]) were deployed in yolked pairs, so that a minimum of three casts were required to collect six replicates and two casts for three replicates.

The box coring device used measured 24.5 x 24.5 x 44 cm. It was fitted with hinged upper doors and up to 135 kg of ballast. The doors were opened as the device penetrated the substrate and closed as it was retrieved to prevent wash-out of the sample. Ballast was adjusted to ensure penetration. The device contained six, 3.5-cm i.d. by 43.5 cm metal coring tubes. The tubes were washed with fresh water and then rinsed after each use. During Cruise I, these tubes were mounted in three pairs on a wire rack afixed across the center of the box. This design was improved during Cruise II by mounting all six tubes against one wall of the box and securing them behind a steel septum that extended the full depth of the box. Closing the doors after a core was taken sealed the tubes during retrieval.

Despite precautions, on-board observations suggested that some of the cores had been subject to wash-out. Statistical tests, which were described in detail in the 13 June 1984 MMS Ternary Meeting, compared the contents of the meiofaunal tubes with those of the main portion of the box. These tests were the final arbiter for acceptance of a given box core sample. In the field, the following criteria were used to judge whether a box core was acceptable:

1. The doors should be fully and properly closed.
2. The sediment should fill the box to within 1-2 cm from the top.
3. The sediment in the box should be covered with a thin layer of clear water. Cloudy water suggests mixing of water and sediment during retrieval.

4. The sediment should be level within the box. Sloping sediment suggests faulty angle of penetration.

Coring was continued at each station until the requisite number of replicates met these criteria.

As each box core came on-board, the overlying water was carefully decanted into a 63-micron sieve. Material retained by the sieve was backwashed into the jar in which the meiofauna sample was placed. Four of the tubes were used for meiofauna samples.

The top 5 cm of the samples in the meiofaunal tubes were extruded using a plunger placed directly into a sample jar (glass or plastic). The organisms were then immediately narcotized using an isotonic solution of magnesium sulfate. The sample was covered with the isotonic solution and shaken vigorously for a few seconds. After the sample had set in a cool place out of the sun for about 30 min, the jar was preserved with formalin to make a 5% buffered rose-bengal formalin solution. The jar was gently shaken to achieve a uniform mixture of the preservative. The samples were then stored at ambient temperature.

Undisturbed, uncontaminated sediment samples for analysis of hydrocarbons, grain size, carbonate, and total organic carbon were subsampled from the box core immediately after decantation of overlying water. The subsample for hydrocarbon, carbonate and TOC analyses were stored frozen in a glass jar, while the samples for grain size analysis were placed in whirl-pak bags and refrigerated. All samples were appropriately labeled.

The remainder of the sample containing the infauna was removed in 5 cm increments and seived through a 300 micron screen with a gentle stream of water. Material retained on the screen was placed in suitable containers, labeled, and preserved with 10% buffered formalin to which rose-bengal stain was added. These samples were stored in a cool place as soon as possible following collection.

2.3.3 Megafauna Sampling

Initially we had planned to obtain samples of megafauna for biological analyses using an otter trawl, supplemented by deployment of a

scoop-dredge to obtain samples for hydrocarbon analyses. The scoop-dredging proved unfruitful on Cruise I and was abandoned in favor of longer trawl tows.

The trawl used was a 9 m, semi-balloon net with 60 cm doors, 3.8 cm stretch mesh and 1.3 cm cod-end mesh. The trawl was deployed from the main coring winch and was towed for a target bottom-time interval of 1 h in shallow water and 2 h in deep water. The ratio of trawling cable length to depth was 3:1-4:1 for depths less than 1000 m and 2:1-3:1 for depths greater than 1000 m. Bottom metering wheels and position depth recorders were not deployed during Cruises I and II. As a result, there is some uncertainty about the actual bottom-time intervals for the trawl samples, particularly for the deeper stations.

When the trawl was retrieved, its contents were dumped into large tubes and sorted for specimens of epifaunal, macroinvertebrates and demersal fish for chemical analysis. These specimens were photographed on-board and carefully frozen for laboratory analysis. Care was exercised in processing these specimens so as to prevent contamination by ship-board hydrocarbons. When a minor hydraulic leak occurred on deck during Cruise II, samples of the hydraulic fluid were collected against the possibility of inadvertent contamination. The remaining specimens were cut to ensure internal fixation and then stored in labeled 5 gal buckets containing buffered formalin.

2.3.4 Benthic Photography

Benthic photography during Cruise I was obtained using the Mini-Angus camera system operated by personnel from Woods Hole Oceanographic Institution (WHOI). This system was unavailable for Cruise II, but an improved model was fabricated in conjunction with WHOI personnel who also trained the LGL operator. This system has been named BUCS (Benthic Underwater Camera System) and has performed reliably, and well.

All major components of the BUCS system are manufactured by Benthos Inc. of North Falmouth, Massachusetts. The camera used was the Model 372 having the capacity of taking 800 exposures per loading with standard 35mm film. The lens was a Nikon 28mm f3.5 with a measured underwater viewing angle of 35° x 48.5° when inside the camera housing. A data chamber with

light emitting diode furnished date, time (hours, minutes, seconds) and altitude information in a digital display on each photo frame.

Artificial light necessary at depth was provided by a Benthos Model 383 high intensity flash during Cruise I. This flash is rated at 200 watt-seconds with a flash duration of approximately 1 millisecond. This is adequate to freeze any relative movement between subject and camera during transects. The battery pack has the capacity for over 1600 consecutive flashes--twice the number required for the 800 exposures of film held in the camera. A 100 watt-second strobe was used during Cruise II because the high intensity model was not available. The 200 watt-second model will be available for Cruises III-V.

Positioning information for the camera sled was improved during Cruise II by using a combination of a 12 kHz bottom finding pinger and an inter-communicating altimeter. The altimeter is a precise, short-range acoustic sounding device. Its function is to record the altitude of the camera sled through the camera's data chamber onto each frame of film and to send a signal to the surface from the bottom finding pinger. This signal takes the form of a secondary ping sent between the standard one-second pings. The time delay of the secondary ping is proportional to camera sled altitude and gives a continuous reading of the camera's height above bottom. With components specially modified for the LGL camera system, this time delay can range from 100-500 milliseconds representing only 10 m of altitude above bottom.

On a typical 12 kHz graphic recorder with a paper width of 50 cm, the altitude ping return utilizes 20 cm of space on the paper. Each 1 m of altitude change by the camera near the bottom is reflected by a 2 cm position change of the altitude ping return on the chart paper. This special feature allows very precise altitude maintenance during camera sled transects, which is required to obtain overall consistency and quality throughout the 800 exposures made on each transect. The altimeter data is updated every 0.5 sec and has a resolution of 0.1 meter.

The bottom finding pinger on the LGL camera sled has one additional feature that provides very useful information to the surface chart recorder. This is an additional set of signals transmitted by the pinger as a short series of 5 pings, 20 milliseconds apart each time the flash programmer commands the camera to take a picture. Receiving this signal

at the surface is no guarantee a good photograph is being taken but allows the surface operator to know exactly when photographs should begin, when the film would be exhausted and if there are any malfunctions during the camera transect. These five pings appear close together on the chart paper located immediately after each 1 second base ping return of the bottom and before the secondary enhanced altitude ping.

One additional acoustic profile was continuously recorded when possible using the ship's own 12 kHz transducer providing a depth record for the transect. Using time marks on the chart record and a known constant chart speed, the bottom depths could be correlated to each individual photograph.

The entire system was used in the automatic mode of 1 flash and photograph every 8 seconds as a compromise between ship time conservation and distance traversed. The bottom time for a single 800 exposure transect was then consistently 1 h 47 min with variable wire times from several minutes to over a hour. Typical surface currents and winds during transects have been adequate enough to make subject overlap between successive photographs a rare occurrence.

A bottom contact switch was also incorporated into the system allowing individual photographs to be taken at a precise height above bottom by means of a trigger weight. This capability was not utilized, however, due to the increased time requirements and the success of the altimeter/pinger "flying" technique.

Prior to deployment of BUCS at each station, an estimated descent time was determined and the delay timer set on the flash programmer. This enabled the camera sled to reach the bottom before automatic picture exposures began. Once the sled approached to within 10 m of the bottom, the short range altimeter acoustic information became available and allowed accurate placement of the sled at precise altitudes. The operator then positioned the sled as near to 2 m above bottom as possible. This altitude was determined to be the best compromise between the following: (1) lower altitudes, which allowed better organism identifications, but within a smaller area and with a higher probability of the camera sticking in the mud, and (2) higher altitudes, which permitted more survey area, but inhibited accuracy of identification and size measurement of the

predominant small organisms. An altitude of 2 m resulted in a photographed bottom area of 2.27 m^2.

Photographic film used was the fastest transparency film available in bulk form: Ektachrome professional 5036 with an ASA rating of 200. The ASA was generally increased by 1 f-stop to permit use of a smaller lens aperture. This increased depth-of-field with little sacrifice in picture quality. A test strip of exposed film was developed from each roll while on station to insure that there were no mechanical difficulties. Quality photographs were obtained to the end of each 800 exposure roll.

The camera sled was moved along the transect by allowing the vessel to drift or, when necessary, by motoring very slowly. The camera frame maintained a relatively constant height above the bottom by adjusting the winch in response to readings from the bottom altimeter. This technique was chosen rather than dragging the camera frame along the bottom for several reasons. Safety of the equipment was a consideration, especially in areas with known obstructions on the eastern transect. Most importantly, however, the method permitted photography with the least possible disturbance of the environment.

Motile megafauna captured by photographs from dragged bottom sleds are often seen in flight and may choose to flee in the direction of the oncoming camera. This can yield an excellent photograph, but it certainly will not be a consistent result. It seems likely that any vibration or other disturbance transmitted through bottom sediments by a large device being dragged through the mud in an otherwise extremely stable environment will cause a wide range of behavioral reactions; including flight of motile animals such as fish, or retraction of many types of invertebrates into the substrate. It was believed that the above bottom technique would capture the most undisturbed and complete biological record.

This technique has proven successful in this study. Photographs taken during the first two cruises very rarely showed disturbed sediment plumes caused by animals' avoidance reactions. While the vertical viewing angle is not optimal for identification purposes, it did provide the opportunity for the development of a detailed analysis technique utilizing the known factors of lens viewing angle and altitude, which can be interpreted to give the area of bottom features.

2.4 LABORATORY ANALYSES

Laboratory activities included both physical/chemical and hydrocarbon determinations for sediments and biota; carbon isotope analyses for sediments and biota; sorting, identifying, enumerating and weighing, and measuring biota as well as analyzing their gut contents; and the analyses of photographs for biota and lebensspuren.

2.4.1 Sediment Characterization

Basic sediment characterizations included analyses for grain size, organic carbon and carbonate carbon content. Sea floor sediment texture is an extremely important variable in the evaluation of benthic ecology. The relative proportions of sand, silt, and clay sized material, in conjunction with sediment mineralogy, play an important role in infauna community population size and dynamics (Harper 1977). In order to fully evaluate the slope benthic ecology, it will be essential to delineate the sediment textural characteristics to assess variances noted in both time and space in macroinfauna populations, microbial ecology, and benthic organisms.

In addition to possible biological implications, precise measurements of total organic carbon content are necessary for interpreting trace organic contamination. Carbonate content is useful in deep-sea studies for describing the benthic habitat. Calcium carbonate in slope sediments originates from *in situ* carbonate-containing organisms, turbidity flows carrying shallow-water carbonate to deeper water, the rain of inorganic detritus, and authogenic chemical precipitation of carbonates.

Grain Size

Sediment grain size followed the laboratory procedure of Folk (1974). Samples were homogenized and treated with an aliquot of 30% hydrogen peroxide (H_2O_2) to oxidize organic matter, then washed with distilled water to remove soluble salts. Sodium hexameta phosphate was added to deflocculate each sample. The samples were then wet-sieved using a 62.5

micron (4.0 0) sieve to separate the gravel and sand from the silt-clay fraction.

The total gravel and sand fraction was oven dried (40°C) weighed, and sieved at 1/2 phi intervals (-1.5, -1.0, -0.5, 0.0, 0.5, 1.0, 1.5, 2.0, 2.5, 3.0, 3.5, and 4.0). Each collected fraction was examined for aggregates, disaggregated if necessary, and reweighed by fraction to three significant figures.

The silt-clay fraction was analyzed for particle size distribution by the pipette (settling rate) method at 4.5, 5.0, 5.5, 6.0, 7.0, 8.0, 9.0, and 10.0 0 intervals.

Organic Carbon

Organic carbon determinations were made using a Leco WR-12 Total Carbon System. Sediment subsamples (0.2-0.5 g) were weighed into disposable 5 ml polystyrene beakers and treated with concentrated HCl to remove inorganic carbon (carbonate). Acid was added dropwise until no degassing was observed. The treated samples were then dried at 50°C in a recirculating oven for 24-36 hours to remove excess acid and moisture. After drying, the sample was quantitatively transferred to a sintered crucible. Iron accelerator and tin coated copper catalyst were added and analyzed by total combustion on the Leco instrument. Organic carbon was converted to CO_2 and analyzed with a non-dispersive infrared spectrophotometer. Blanks and standards were run on a daily basis. All samples were analyzed in duplicate and averaged. Periodically samples were combusted at >800°C in a high vacuum Craig-type combustion system as a check on the combustion efficiency of the Leco system.

Carbonate Carbon

Carbonate carbon was determined on the same freeze-dried, homogenized sediment samples that were used for organic carbon and hydrocarbon determinations. Carbonate carbon on Cruise I samples was determined by difference between total carbon and carbonate-free (organic) carbon using the Leco WR-12 Total Carbon System. On Cruise II samples, carbonate carbon was determined

directly by acidification in a carrier stream followed by infrared detection.

2.4.2 Carbon Isotope Analyses

Carbon isotopic analysis were performed on sediments and selected organisms to determine their food source. Stable carbon isotopes have been shown to be useful in delineating the flow of carbon through ecosystems since there is considerable evidence for minimal carbon isotopic fractionation along marine food chains (Parker 1964, Degens et al. 1968, DeNiro and Epstein 1978). Plants preferentially assimilate ^{12}C over ^{13}C during photosynthesis, and the degree of ^{13}C fractionation in plants is dependent on the biochemical pathway used for carbon fixation. Photosynthetically derived carbon from marine algae generally have carbon isotopic values ranging from -19 to -21 ppt. Carbon from terrestrial sources is generally at least 7 ppt lighter (more negative) due to the uptake of CO_2 as opposed to bicarbonate in the sea. However, there are other pathways that can contribute to variations in the organic carbon isotopic content of terrestrial plants.

Organisms that feed on photosynthetically derived carbon from marine algae have carbon isotopic values in the same range as the plankton (-19 to -21 ppt). However, tissue from mussels recovered at the Pacific vents have $\delta^{13}C$ values near -33 ppt (Rau 1981, Rau and Hedges 1979, Williams et al. 1981). The vent communities of the Pacific are based on chemautotrophic bacteria that gain energy from the oxidation of hydrogen sulfide (Karl et al. 1980). In turn, the associated filter feeding organisms feeding on these isotopically light bacteria have similar isotopic values.

Stable carbon isotopes ($\delta^{13}C$ values) were determined on freeze-dried sediment organic carbon and tissue samples. The stable carbon isotopic CO_2 composition derived from combustion of the organic matter was determined on a Nuclide Corporation six inch, 60° sector, isotope ratio mass spectrometer. The carbon isotope values are reported as per mil deviations from the Pee Dee Belemnite (PDB) standard:

$$\delta^{13}C = [(^{13}C/^{12}C)\ \text{sample} - (^{13}C/^{12}C)\ \text{std}/(^{13}C/^{12}C)\ \text{std}] \times 1000$$

2.4.3 High Molecular Weight Hydrocarbons

This study involves the measurement of high molecular weight (HMW) hydrocarbons in macroepifauna, infauna, fishes, and sediments in samples collected on the Gulf of Mexico slope. Sediment samples are screened for aromatic hydrocarbon contamination using total scanning fluorescence, but primary detection and quantification of petroleum contamination is based on high resolution capillary gas chromatography and GC/MS/DS analysis. The purpose of the HWM hydrocarbon analyses are: (1) to determine the suite of HMW hydrocarbons present and their concentration; (2) to determine probable sources of the HMW hydrocarbons as either thermogenic (from natural seepage or anthropogenic sources) or biogenic; (3) to determine the relationship between HMW hydrocarbons and trophic level; (4) to establish the extent of contamination with respect to distance from shore and/or offshore oil/gas production; (5) to determine the relationship, if any, between hydrocarbon chemistry, water depth, major current systems, and sediment physical characteristics; and (6) to compare the findings to known values for shallow water habitats in the Gulf of Mexico and subtropical U.S. Atlantic waters.

Both the sediment and benthic organism analytical schemes are very similar (Figs. 2-5 and 2-6). The HMW hydrocarbon methods for sediments will be described in detail below while only the differences in analytical technique between the sediment scheme and the organism scheme will be noted.

Sediment Hydrocarbon Analyses

A three tier sediment hydrocarbon analysis program has been implemented: extracts of surficial sediments from each box core are analyzed by total scanning fluorescence to determine the presence or absence of aromatic hydrocarbons; detailed saturate and aromatic capillary gas chromatography is performed on individual and/or pooled samples from each station; and selected samples are analyzed by gas chromatography/mass spectrometry (GC/MS) for compound identification and structure confirmation. The total scanning fluorescence method was described in detail in Section 4.2.4 (p. 93-100) of the proposal. The reader is

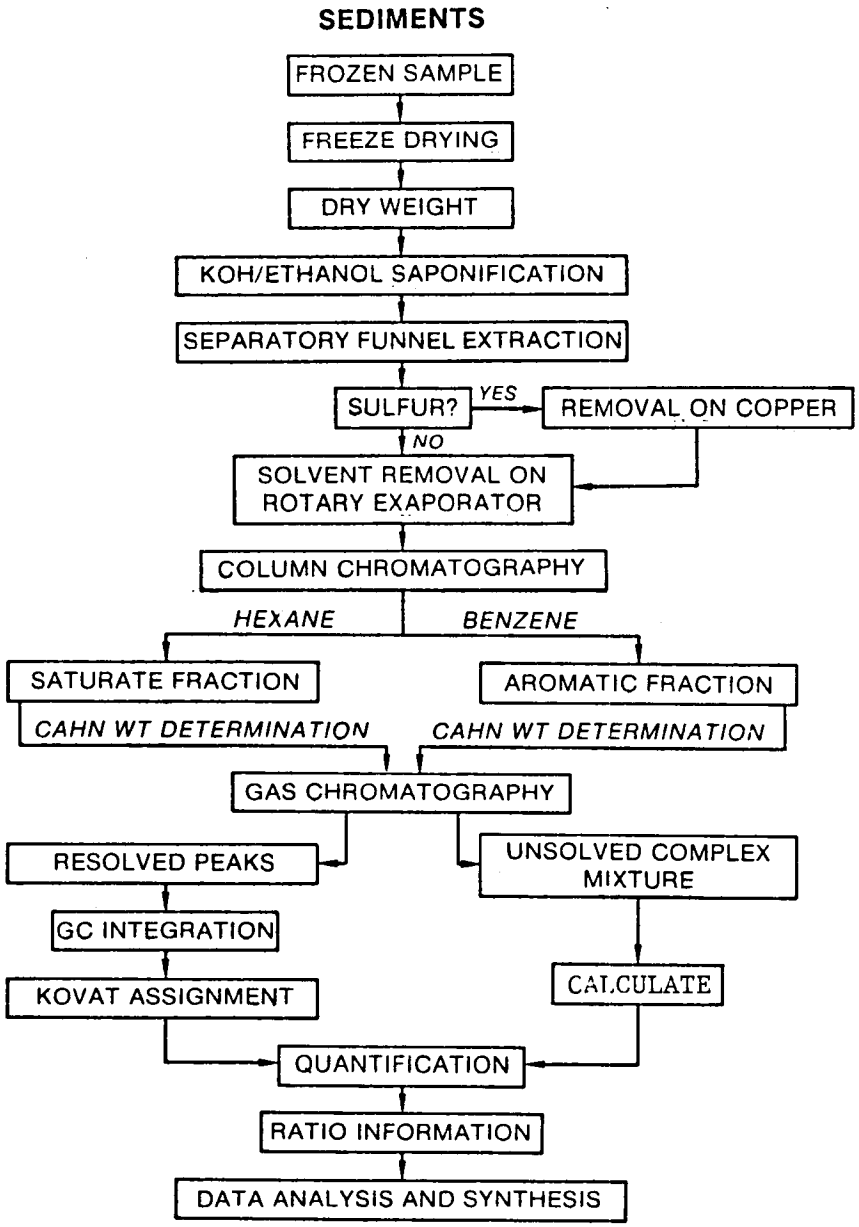


Figure 2-5. Sediment hydrocarbons analytical scheme.

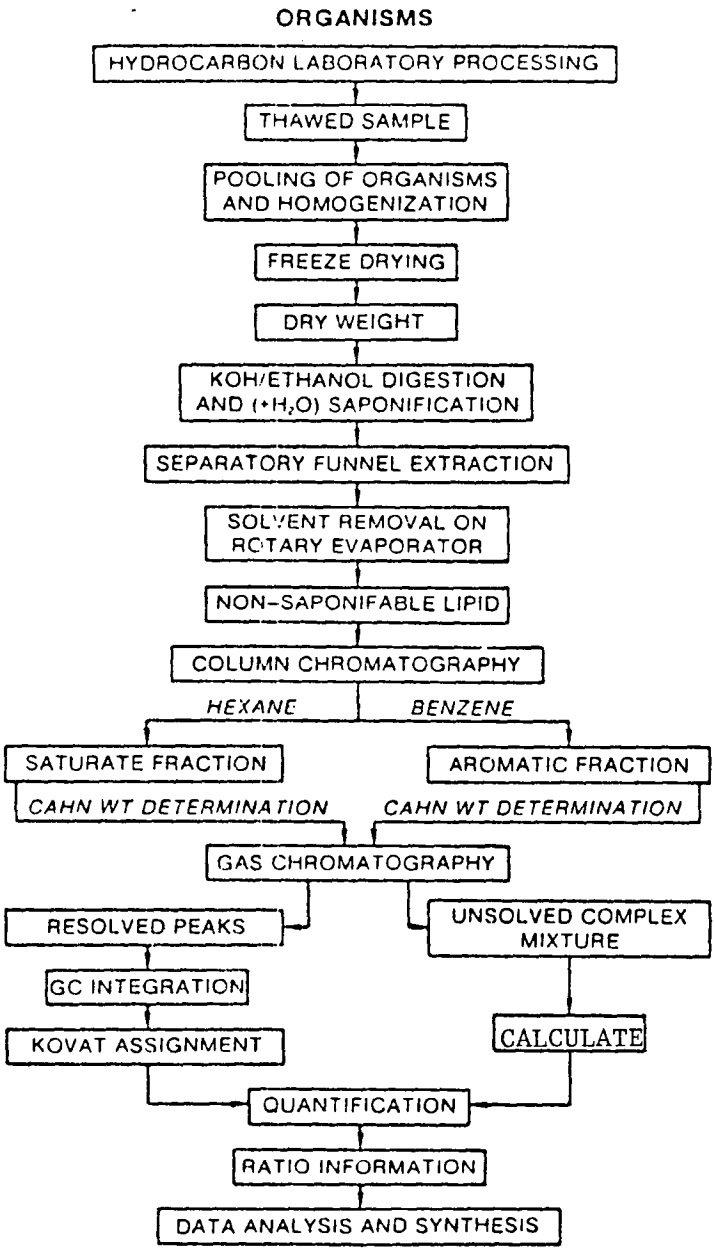


Figure 2-6. Hydrocarbon analysis scheme for organisms.

referred to this section for a description of the methodology and the use of total scanning fluorescence to determine the levels of polynuclear aromatic hydrocarbons in sediments. Sediment samples are obtained from box cores in a clean environment on board ship. A clean stainless steel tube is used to subsample the upper 8-cm of the sediment. Samples are stored in jars that have been solvent-washed and combusted at 450°C. The jars are sealed with teflon-lined caps, labeled, and stored frozen.

The establishment and maintenance of adequate procedural blanks is imperative in trace level hydrocarbon analysis. A quality control and quality assurance program is strictly adhered to. Precleaning of all equipment includes extensive washings with Micro cleaning solution and rinsing with distilled water, acetone, and methylene chloride. All solvents are triple glass-distilled, nanograde purity (Burdick and Jackson, Inc.) or its equivalent. Final rinses are evaluated by gravimetry, gas chromatography and gas chromatography/mass spectrometry. Large volumes (1 L) of solvent are routinely evaporated and tested in a similar manner. When possible all equipment (i.e., glassware) is combusted at 450°C overnight, after the cleaning procedure is completed. Blanks are maintained at negligible levels for all parameters monitored.

Minimum sample handling is stressed to avoid contamination of the samples. Sediment samples are freeze-dried before extraction and a sediment dry weight is obtained. The freeze-dried sample (50 g dry weight) is placed in a round bottom flask (500 ml), with standard taper ground glass neck, and mixed with 95% ethanol (150 ml), 50 ml of hexane, several glass beads or boiling chips, and KOH (10 g). The mixture is refluxed at 80°C for four hours.

Following the KOH/Ethanol reflux, the digested material is transferred to a teflon-stoppered separator funnel (one liter) using distilled H_2O (80 ml) and two portions (50 ml each) of hexane. The mixture is equilibrated for 5 min. by hand shaking, and the solvent and aqueous phases are allowed to separate. Additional hexane is added if the two phases do not separate. The two phases are drained into separate flasks and the aqueous phase is returned to the separatory funnel using a hexane (50 ml) wash. The extraction and separation is repeated a total of three times.

The combined hexane extracts are washed (minimum three times) with aliquots (500 ml each) of distilled H_2O to remove solids and residual alcohol. A saturated salt solution is often used to break the emulsion. To remove any residual water from the hexane extract, anhydrous Na_2SO_4 (2-3 g) is added. Copper turnings are added to the flask and the extract is refluxed for one hour to remove sulfur. The extracts are then roto-evaporated to near dryness and transferred to clean vials with methylene chloride. At all times care is exercised to ensure that the extract does not go to complete dryness to prevent loss of the more volatile components.

The extracts are fractioned into saturate and aromatics/esters fractions on alumina/silica gel columns. The silica gel is activated at 150°C for 16 hours and the alumina is activated at 350°C for 12 hours. The alumina and silica gel are then deactivated with 5% water. Deactivated packings are prepared immediately prior to their use. Ten grams of alumina and 10 g silica gel are hexane slurried individually over a plug of glass wool. The columns are cleaned with 100 ml of hexane which is discarded. The sample extract is dissolved in approximately 1.0 ml of hexane and applied to the surface of the column. A hexane (100 ml) and a benzene:hexane (100 ml, 50:50) fraction is then eluted. Optimum liquid chromatographic conditions and recoveries were tested using authentic standards. After collection each fraction is roto-evaporated, transferred to vials, and dried. The hexane fraction weight is obtained by dissolving the sample in 100 microliters of methylene chloride from which a 20 microliter aliquot is withdrawn and applied to a pre-weighed filter pad. The solvent evaporates and the aliquot is weighed to a tenth of a microgram.

The benzene:hexane fraction is further purified using a Sephadex LH-20 column (25-100 μ mesh). The Sephadex is slurried in the eluting solvent (cyclohexane:methanol:dichloromethane; 6:4:3), allowed to swell overnight and slurry packed in a glass, teflon-stoppered column. Each column is calibrated with authentic aromatic standards to determine the fraction to be collected. The column is pre-rinsed with 200 ml of the eluting solvent, then the sample, dissolved in the eluting solvent, is applied to the top of the column. The first 40 ml of the eluant are discarded while the next 100 ml are collected. This fraction is roto-

evaporated, transferred to a vial, and weighed as described for the hexane fraction.

Each sample is spiked with a known amount of several internal standards to correct for variability in recoveries and extraction efficiencies. Several compounds of similar structure, not naturally occurring, are added for both aliphatic (i.e., 1-chlorooctadecane, polyolefins, or branched alkanes) and aromatic (i.e., hexamethylbenzene, branched aromatics, etc.) analyses. The concentration of the internal standards are in the same range as that encountered for naturally occurring compounds. The compounds chosen must be sufficiently resolved from all sample components. Authentic standards have shown that this analytical procedure provides the desired results.

The aliphatic and aromatic fractions from the columns are quantified by fused silica capillary gas chromatography. Hewlett Packard gas chromatographs (Model 5880) are utilized in a splitless capillary mode. Fused silica capillary columns coated with a bonded phase (BPI/QC2; SGE, Ltd.) are used to attain separation of the extract components. Baseline separation of n-C_{17} and pristane and n-C_{18} and phytane is maintained at all times to insure proper resolution. The columns are 50 m long with an inside diameter of 0.25 mm.

Helium gas is added as a makeup gas between the capillary column and the flame ionization detector. A makeup gas is used to obtain the maximum sensitivity of the detector. The injection port is operated at 300°C and the detector at 350°C. Typical instrumental parameters are shown in Table 2-6.

Table 2-6. Typical program used for the gas chromatographic analysis of hydrocarbons.

Parameter	Setting
Initial temperature	80°C
Initial hold	0 min
Rate	6°C/min

Parameter	Setting
Final temperature	300°C
Final hold	20 min
Injection port temperature	300°C
FID temperature	350°C
Chart speed	0.50 cm/sec

Gas chromatograms are quantified with authentic standards. A combination of commercially available quantitative standards and standrards prepared in our laboratory are used. Sample peaks are identified by comparison of retention times with standards. All peaks are assigned a Kovats Index based on the retention times of a 20-component hydrocarbon standard containing normal alkanes from C_{13} to C_{34}. The alkanes, by definition, are assigned a Kovats Index equal to 100 times the number of carbon atoms they contain (i.e., n-C_{14} K.I. = 1400). The standard is then used to calculate Kovats Index's for other compounds based on interpolation between normal alkanes. All significant peaks in a sample are assigned a Kovats Index. Kovats Index's compensate for daily variations in operating conditions and allows the direction comparison of data run over long periods of time.

The Hewlett Packard gas chromatographs are linked with an HP 1000 data system used for laboratory automation and manipulation of data. Existing analysis packages have the capacity to calculate response factors, which are a measure of the response of the detector versus the area of the peak. From the daily quantitative standard the gas chromatograph is calibrated in an external standard mode. The retention time and amount of each standard peak is used to calculate response factors for the standard compounds and this information is stored on tape and/or hard disk. The output includes the response, the retention time, the Kovats Index and the calculated concentration. The response factor is also used to determine the concentrations of peaks that do not correspond to components in the standard. Every attempt is made to obtain authentic standards for all significant sample components. The unresolved complex

mixture concentrations are calculated based on average n-alkane response over the volatility range covered.

At least 10% of all samples are analyzed by gas chromatography/mass spectrometry (GC/MS) to confirm the identity of the sample components and to identify when possible any unknown compounds. The gas chromatography/mass spectrometry is conducted with a Hewlett Packard 5996 GC/MS system coupled with a Hewlett Packard 1000 data system. Typical operating conditions for the mass spectrometer are listed in Table 2-7. Gas chromatographic columns and conditions are identical to the quantitative GC analyses. A splitless injection technique is used. The total column effluent is routed directly into the ion source of the mass spectrometer. Standard n-alkanes are run daily to confirm Kovats Index's.

Table 2-7. Mass spectrometer conditions.

1.	Source temperature	300°C
2.	Detector gain	2×10^6
3.	Source conditions	
	a. Drawout lens	10 volts
	b. Repeller	22 volts
	c. Ion focus lens	30 volts
	d. Electron energy	70 eV
	e. Xray	3
	f. Electron focus	0
	g. Scanning rate	215 amu/sec
	h. Electron emission	160 uA
	i. Target	160 uA
4.	Calibration with perfluorotributylamine (PFTBA)	

The mass spectrometer is repetitively scanned from m/z 33 to 400 every 2.1 sec. Ionization is accomplished using 70 eV electrons. The ion source temperature is maintained at 300°C. All substantial peaks have their fragmentation patterns hard copied and all data is stored on tape for future reference. Spectral interpretations are added by computer

library searches (in-house and NIH/EPA/CIS), the eight peak index, reference texts, and the periodical literature.

Organism Hydrocarbon Analyses

As mentioned, the organism hydrocarbon analytical scheme is very similar to the one used for sediments (Fig. 2-6). No fluorescence screening is performed. Since organisms do not generally contain large amounts of sulfur, desulfurization with copper is not necessaary. Three tissue types (liver, gonad, and muscle) are analyzed in fish specimens. Only muscle tissue is analyzed in other benthic fauna (shrimp, crabs, etc.). Organisms are frozen at -20°C on board ship. Dissection is performed in a shore-based, clean laboratory. All utensils are pre-cleaned using procedures described in the sediment section. The target sample weight is 15 g wet weight. The method of digestion of tissues is identical to the sediment method. The methods used in column separation, gas chromatography (GC), and gas chromatography/mass spectrometry (GC/MS) are also identical to those used in the sediment analytical scheme.

Hydrocarbon Quality Control/Quality Assurance

Replicate analyses were performed on both a standard sediment and a standard fish muscle tissue sample. Results for alkane analysis are reported in Tables 2-8 through 2-12. Replicate gravimetric analyses were precise within 20 to 30% ($\pm$ 1 σ) at the ppm level (Table 2-8). Replicate analysis of individual n-alkanes varied from ~5 to 50% ($\pm$ 1 σ) at the ppb concentrations in sediments depending on molecular weight (Tables 2-9 and 2-10). Comparison of two analysts processing the same sediment sample is illustrated in Table 2-11 (gravimetric analysis only). Recovery of surrogate standards were generally in the 80-90% range with this percentage reaching a constant value at n-C_{19} (i.e., the lower molecular weight alkanes are lost in roto evaporation, Table 2-12).

Each set of eight analyses contained six samples, one reagent blank, and one reagent blank plus the complete quantitative n-alkane and aromatic standard. All samples were spiked with an aliphatic and an aromatic

TABLE 2-8

Summary of the Precision of Replicate Gravimetric Analyses of Digestion/Fractionation (MMS Analytical Scheme) and its Comparison to Soxhlet Extraction/Fractionation (concentrations in ppm, µg/gm)

Sample	Repl. #	Digestion Extraction		Soxhlet Extraction	
Q.C. Miss. Delta Sediment					
Aliphatic Fractions	1	9.1			
(ppm)	2	8.9	Ave.= 10.3 (9.2)*	25.2	Ave.=31.8
	3	12.0	S.D.= 3.3 (1.4)*	33.0	S.D.= 5.3
	4	17.8*	C.V.= 32.1%(14.9)*	38.1	C.V.=16.8
	5	8.6		30.8	
	6	7.6		---	
	7	9.4		---	
	8	8.6		---	
Aromatic Fraction					
(ppm)	1	9.1		5.2	Ave.= 8.8
	2	6.3	Ave.= 6.7	7.7	S.D.= 3.4
	3	8.4	S.D.= 1.5	13.4	C.V.=39.0
	4	6.3	C.V.= 22.2%	8.9	
	5	5.7		---	
	6	4.5		---	
	7	7.4		---	
	8	6.2		---	
Whitefish Q.C. Tissue					
Aliphatic Fraction					
(ppm)	1	20.1	Ave.=29.4 (24.8)*	45.7	Ave.=48.0
	2	27.7	S.D.=10.7 (3.5)*	43.1	S.D.= 8.8
	3	27.3	C.V.=36.3%(14.2%)	41.0	C.V.=18.4%
	4	24.2		63.2	
	5	47.7*		46.8	
Aromatic Fraction					
(ppm)	1	20.6		66.2	Ave.=54.8
	2	14.0	Ave.= 20.1	38.7	S.D.=14.3
	3	19.4	S.D.= 4.5	60.2	C.V.=26.0%
	4	19.6	C.V.= 22.5%	40.3	
	5	26.7		68.4	

* Calculated excluding the one anomalously high concentration.

TABLE 2-9

Summary of MMS QC sediment digestion/extraction replicate gas chromatographic analyses (concentrations in ppb).

Carbon #	Replicate 1	2	3	4	5	6	Ave.	S.D.**	C.V.***
14	-	-	3.7	3.0	1.9	-	2.9	0.9	31.3
15	-	1.9	3.4	2.4	1.6	-	2.3	0.8	34.3
16	3.7	7.3	19.0	11.9	12.5	7.0	10.2	5.4	53.1
17	11.9	17.4	42.3*	21.8	18.0	16.0	17.0	3.6	21.0
Pristane	17.0	23.9	34.0	25.7	26.3	21.4	26.4	7.3	27.5
18	26.5	30.5	71.9*	40.7	34.8	35.6	33.6	5.4	16.0
Phytane	28.4	36.5	51.1	40.8	38.7	37.8	40.6	5.4	13.2
19	34.1	36.6	83.0*	48.8	39.0	41.9	40.1	5.7	14.1
20	32.5	33.2	74.4*	38.8	33.9	37.0	35.1	2.7	7.7
21	28.2	28.0	64.7*	30.7	28.4	31.5	29.4	1.6	5.5
22	28.4	27.3	58.6*	29.3	27.1	30.3	28.4	1.3	4.8
23	46.4	49.0	74.8*	45.9	45.8	49.2	47.3	1.7	3.6
24	38.4	36.7	56.2*	32.6	32.7	34.6	35.0	2.5	7.2
25	143.1*	108.4	111.4	105.2	100.9	96.9	104.6	5.8	5.5
26	56.9	53.4	68.5*	48.4	51.7	51.9	52.5	3.1	5.9
27	168.1	199.2	203.4	172.2	186.0	185.0	185.7	14.1	7.6
28	73.3	60.7	70.1	53.6	55.4	56.4	61.6	8.2	13.4
29	353.1	330.3	310.2	296.9	294.3	295.2	313.3	23.8	7.6
30	51.8*	40.8	43.7	32.0	35.5	30.1	36.4	5.6	15.8
31	195.3	194.7	189.5	175.8	175.5	186.2	186.2	9.9	5.3
32	6.2	7.2	6.6	6.1	6.9	6.5	6.6	0.4	6.3
Total Resolved Alkanes	1343.3	1323.3	1640.5*	1262.6	1256.9	1250.5	1287.2	42.8	3.3

* values excluded were more than 3 σ from the average.
** S.D. = Standard deviation
*** C.V. = Coefficient of variation (S.D./$\bar{x}$ x 100)

TABLE 2-10

Summary of replicate digestion gas chromatographic analyses of QC Whitefish tissue (concentrations in ppb).

Carbon #	Replicate # 1	2	3	4	5	Ave*	S.D.**	C.V.***
16	--	--	--	--	--			
17	(18.7)	60.8	54.2	40.0	40.0	48.7	10.5	21.5
Pristane	124.4	208.5	186.4	167.6	156.7	168.7	31.6	18.8
18	164.1	193.4	237.4	204.2	204.9	200.8	26.3	13.1
Phytane	200.9	198.5	250.1	226.6	227.7	220.8	21.4	9.7
19	(193.8)	384.3	517.0	463.2	482.5	461.7	56.2	12.2
20	426.4	362.3	491.7	444.2	470.7	439.1	49.6	11.3
21	191.3	154.7	223.9	196.9	221.3	197.6	28.0	14.2
22	103.6	88.6	115.6	115.3	121.3	108.9	13.0	12.0
23	39.7	26.5	58.6	48.4	65.1	47.7	13.7	28.7
Total Resolved Alkanes	1462.9	1677.6	2134.9	1906.4	1990.2	1834.4	265.7	14.5

* Ave. = Average Concentration
** S.D. = Standard Deviation
*** C.V. = Coefficient of Variation ($S.D./\bar{x} \times 100$)

TABLE 2-11

Comparison of the precision of digestion/extraction gravimetric analysis between two different analysts (concentration in ppm, μg/gm)

Sample	Repl. #	Analyst #1	Analyst #2
Q.C. Miss. Delta Sediment			
Aliphatic Fraction	1	9.1	6.3
	2	8.9	12.6
	3	12.0	16.7
	4	17.8	7.1
	5	8.6	13.7
	6	7.6	13.3
	7	9.4	--
	8	8.6	--
		Ave.=10.3	Ave.=11.6
		S.D.= 3.3	S.D.= 4.1
		C.V.=32.1%	C.V.=35.0%
Aromatic Fraction	1	9.1	10.5
	2	6.3	6.1
	3	8.4	7.4
	4	6.3	11.3
	5	5.7	8.3
	6	4.5	7.3
	7	7.4	--
	8	6.2	--
		Ave.= 6.7	Ave.= 8.5
		S.D.= 1.5	S.D.= 2.0
		C.V.=22.2%	C.V.=26.6%

TABLE 2-12

Summary of accuracy experiments for selected n-alkanes (reported as percent recovery of individual compounds).

Carbon#	Replicate # % Recovery 1	2	3	4	Ave.
13	2.6	0.0	0.0	0.0	0.7
14	9.0	1.6	1.4	2.3	3.6
15	16.6	2.3	6.0	39.7	8.7
16	24.6	6.9	13.2	21.0	16.5
17	34.5	23.3	23.0	32.1	28.2
Pristane	42.7	27.7	29.4	36.1	34.0
18	65.4	71.0	52.7	59.5	62.2
Phytane	51.2	51.7	41.4	45.5	47.5
20	88.3	94.9	76.6	76.0	84.0
21	83.6	91.7	75.0	72.5	82.8
22	84.0	95.0	77.1	73.6	82.4
23	85.6	99.9	78.3	76.0	85.0
24	83.2	100.2	77.6	75.0	84.0
25	82.5	114.7	78.9	76.8	88.2

internal standard. All gas chromatographic calculations are corrected for internal standard recoveries but gravimetric data is not.

Diesel oil, lube oil, and bilge water was collected from all ships used in sample collection. Examples are shown in Figure 2-7.

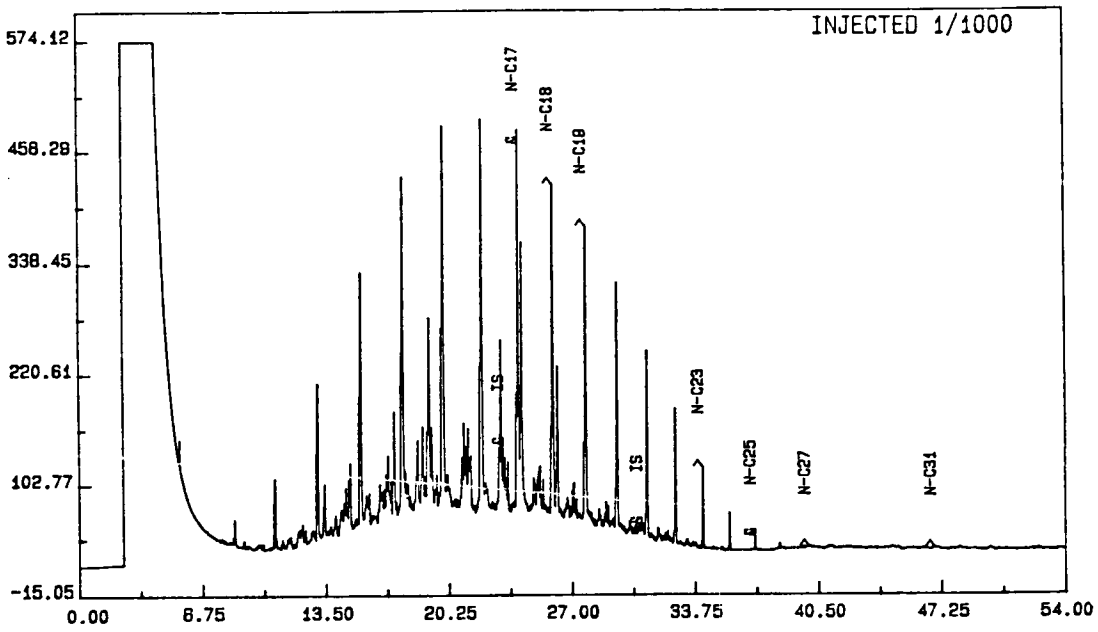
2.4.4 Meiofauna

In the laboratory, meiofaunal samples were gently rinsed through a 300 micron seive to remove macroinfauna, which were later used to evaluate the quality of box core samples (see Section 2.4.5 Macroinfauna below). The material passing through the 300 micron seive was then rinsed on a 63 micron seive to remove preservative. The material retained by the 63 micron seive was next placed, small amounts at a time, in a sorting dish with water. Individuals were sorted by major taxa under a dissecting scope, using an Irwin loop to transfer specimens to vials. The vials were uniquely labeled according to collection date, location, replicate number etc., the taxa represented, and the number of individuals contained in the vial. The contents of each vial were stored and analyzed while in 70% ethanol. Ultimately, biomass will be estimated based upon the number of individuals, their geometric form, and density conversion factor.

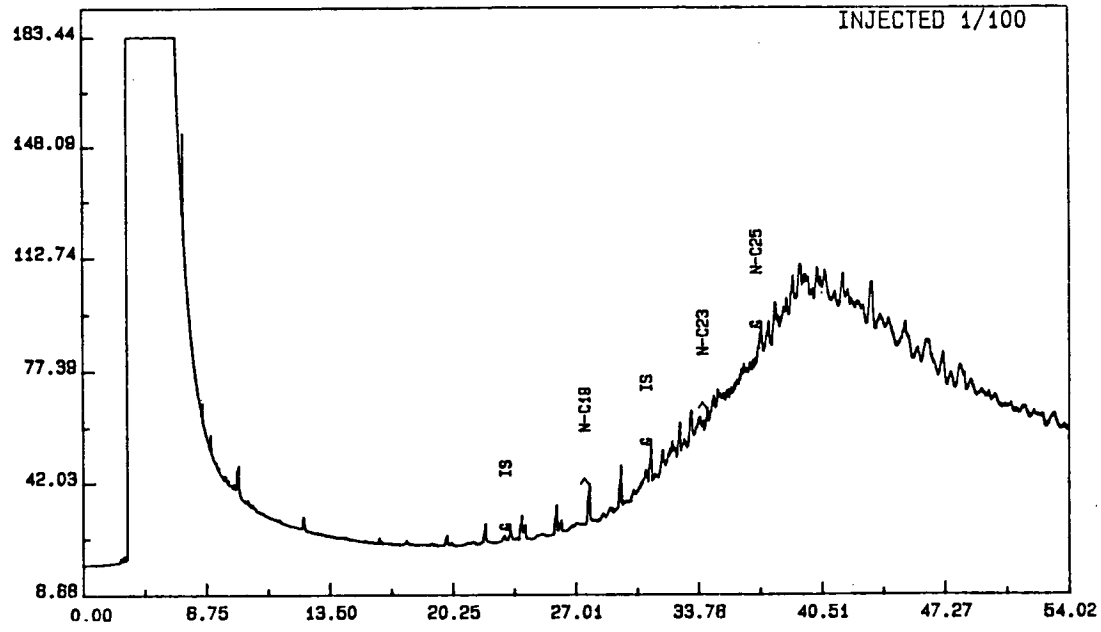
2.4.5 Macroinfauna

In the laboratory, macroinfaunal samples were gently rinsed with water to remove preservative, spread in a laboratory tray and examined under a dissecting microscope. Specimens were removed and sorted into labeled vials by major groups. These were post-fixed and stored in 70% ethanol.

Each major group was next examined using dissecting and light microscopes as necessary to identify each specimen to the lowest taxon possible. Specimens, along with an inventory and supporting data, were sent to taxonomic specialists who either identified or confirmed the LGL identifications, returning the samples to LGL along with the revised inventories. The data and samples were then reconciled to insure all specimens were accounted for. As expected and planned, taxonomic analysis



Fuel Oil



Lube Oil

Figure 2-7. Example gas chromatograms of possible contaminants collected from sampling vessels

for the macroinfauna lags behind other aspects of the project in terms of completion.

Initially, we planned to provide drained wet weight biomass estimates for macroinfaunal taxa. However, since most individuals were minute, weighing proved unfeasible. Also, the handling process was damaging. Weighing was not continued after the initial attempts. Although there are other methods for obtaining biomass levels, they are either destructive or unreliable. This aspect of the project has been dropped from future years' study requirements. Ultimately, biomass will be estimated for the Year One macroinfauna collections using meiofaunal procedures.

As described in Section 2.3.2, the meiofaunal tubes were more protected from wash-out than was the main portion of the box core. Further, the meiofaunal samples were seived in the laboratory, not shipboard. The macroinfauna contained in the meiofaunal tubes thus provided a means for evaluating the "goodness" of the box core samples proper. The results of this quality control procedure, based upon statistical tests of proportions for Cruise I samples, suggested that about 23% of the initial box core samples may have been subject to at least some wash-out. Sampling procedures were improved for Cruise II and a much more rigorous set of field criteria were used in terms of accepting or rejecting box cores.

2.4.6 Megafauna

In the laboratory, megafauna from the trawl samples were removed from the storage containers, rinsed to remove formalin and sorted and identified. Fish and epifaunal invertebrates were then enumerated, weighed to the nearest 0.1 g (drained wet weight) and measured using the standard method for the taxonomic group in question. Where possible, sex and state of maturity were determined externally. Guts of selected representatives of common species were dissected and preserved for later assessment of food habits. Where necessary, specimens requiring identification by specialists were shipped and returned as described for macroinfauna.

2.4.7 Benthic Photography

A new analytical procedure for detailed evaluation of benthic photography was developed for this project. In this procedure, one first calculates the dimensions of the photograph from camera altitude and lens angle. The individual photographs are then projected onto a digitizing palette. Outlining bottom features, organisms and artifacts on the palatte generates a digitized data set of great detail and resolution. Since the dimensions of each photograph are known, the area of bottom features and the size of organisms and artifacts becomes available in a highly refined and detailed form. This procedure represents a marked improvement over standard point-intercept methods for measuring percent of coverage and density.

The apparatus utilizes a modified bulk film strip projector and a first-surface mirror mounted at a 45° angle (Fig. 2-8). The mirror reflects the photographic image directly onto the digitizing palatte. The digitizer used was a Houston Instruments Hi-Pad DT-11YA, driven by an Apple IIe microcomputer using a serial interface card. The computer software that processed the digitized information was developed by LGL. Data were processed and stored on 5.25-in floppy disks and then transferred to the LGL data management system for verification, editing and analysis.

A sample consisting of a roll of 800 photographic frames was obtained for each station. A subsample of 100 frames was selected from this using the systematic sampling technique described by Cochran (1977). Random numbers were correlated with the time of day for each frame and used to select a random starting point within the sequence of 800 frames. Every fourth frame after this starting frame was screened to determine whether it was of acceptable quality (Fig. 2-9). Criteria for acceptable quality were perfect equipment performance and camera altitude in the range of 0.8 to 4.0 m. Preliminary analysis showed that approximately 50% of all frames met these criteria. If the end of the sequence was reached before the subsample of 100 acceptable frames was analyzed, the screening was continued starting with the second frame in sequence until the subsample was complete.

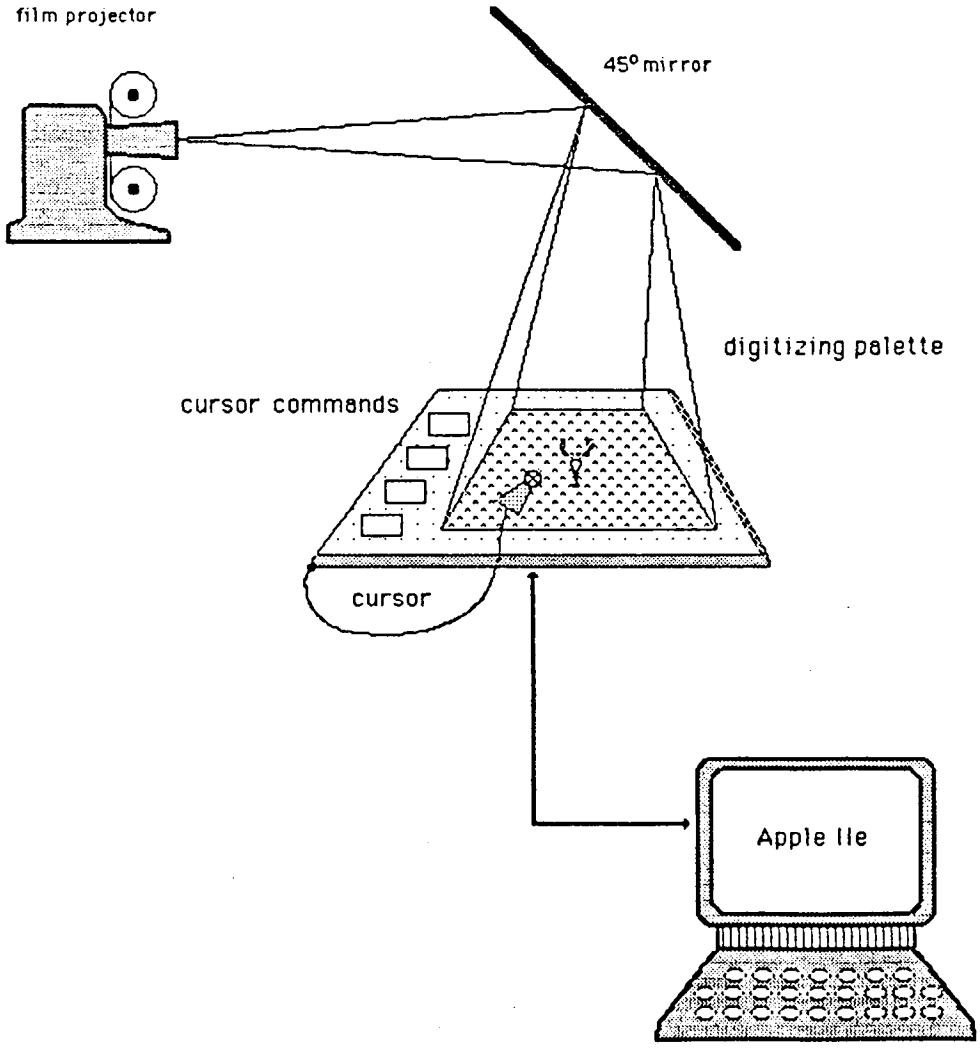


Figure 2-8. Schematic representation of digitizing apparatus used for processing benthic photographs.

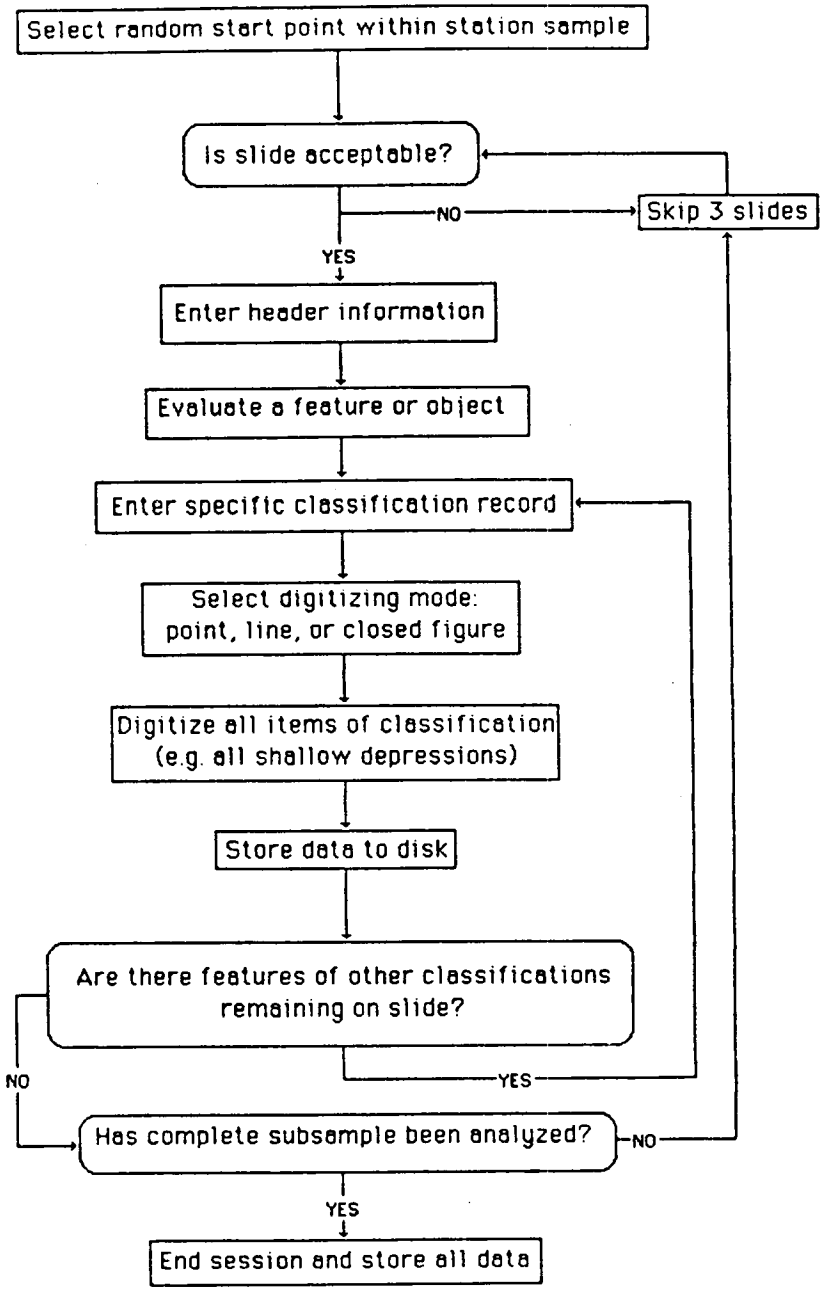


Figure 2-9. Sequence of steps for processing digitizing benthic photographs

Each slide had a unique header record of the following information:

(1) Cruise number
(2) Date (day, month, year)
(3) Station number
(4) Time of day photograph was exposed (hour, minute, second)
(5) Bedform type (deviations from a flat bed)
(6) Sediment color
(7) Bottom type
(8) Camera altitude above bottom
(8) Bottom depth (entered at a later time)

Information regarding date, time and altitude was digitally encoded on the film in the corner of each photograph. Bottom depth was determined from echo returns produced by the ships transducer trace on depth recorder records. The bottom depth for each analyzed photograph was calculated from the transducer record at the exact time each photograph was taken.

Three digitizing procedure options were available for description of any feature or organism seen in a sample photograph. The choice of options was made based upon the judgement of the analyst, who determined whether a given object could best be represented by a point, a line or a closed figure. Each procedure utilized separate software routines, which the analyst could initialize with a curser command.

Closed figures were produced by entering a series of digitized points around the perimeter of an object. The curser of the digitizer was slowly moved around the projected image of each object. A minimum of four points was produced, and typically many more, depending on the size and complexity of each object. Each series of digital data points were later processed into a single two-dimensional shape. The size of the object was determined from the camera altitude and lens angle.

A similar technique was used for measurement of a linear dimension or length. The line format was first selected by a command from the digitizer curser. This was followed by entry of points representing a line on the projected photographic image. For straight objects, only two points were required at the ends of the object. In some instances, numerous digitized points were required to obtain accurate reproduction of a markedly curved object such as a fishes tail.

The third data entry option was single points. These were used in two ways. One use was to record the presence of an object or organism for which a length or area could not be obtained. This could occur when, for example, only a portion of a fish extended into the photographed image, or when a shrimp was located off the bottom and structural details were not distinctly visible. Thus, even when an observation could not be recorded as a two-dimensional shape or line, its presence could still be noted. The other use of point records was to enumerate objects or features too small to be defined by any manipulation of the digitizer curser cross-hairs. In many cases, burrows or depressions were no larger than a single point as displayed on a computer monitor screen.

Types of data records or classifications obtained from photographs included the following:

(1) Numbers of benthic invertebrates, identified to the lowest possible taxon, encoded as points or lines representing appropriate length or width dimensions for each taxon.
(2) Numbers of fish, identified to the lowest possible taxon, encoded as points or lines representing total length.
(3) Man-made artifacts such as cans, bottles, plastic, etc. encoded as points, lines or areas.
(4) Terrigenous or near-shore materials such as sea grass blades encoded as points, lines or areas.
(5) Consolidated materials such as hard rocks, silt stone, etc. generally encoded as a closed figure or area.
(6) Lebensspuren or traces in sediment left by living organisms, encoded as lines or areas if possible, but in some instances points were used and area determined by conversion of the area represented by the minimum resolution of the digitizer.

2.5 DATA MANAGEMENT AND ANALYSES

LGL is responsible for management of all data associatd with the Continental Slope Study and for final transmission of these data to the National Oceanographic Data Center (NODC) in appropriate formats. In this

section we provide a description of the equipment and software which is being used, the data management procedures, the status of Year One data, and a description of the analyses used in this report.

2.5.1 Data Management Equipment and Software

In-house data processing includes the following hardware items:

(1) A 393K-byte Hewlett Packard 9845B portable computer with two accompanying HP9885 8-inch floppy disk drives (500K-byte each) as well as a 217K-byte on-board cassette tape drive and a HP9872C 8-pen incremental plotter,

(2) A 1M-byte LISA Office System with a 10M-byte internal hard disk, a 5M-byte external hard disk, and one .4M-byte internal Sony k3.5" disk drive,

(3) A 1M-byte LISA UNIX System with a 10M-byte internal hard disk and one .4M-byte disk drive,

(4) A 512K-byte Macintosh with a .4M-byte internal Sony 3.5" disk drive,

(5) A 9-track streaming Cipher tape transport (model F880) for in-house data management,

(6) An additional 30M-byte of hard disk storage for the LISAs, and

(7) A 10M-byte hard disk for the Macintosh to enable LGL to transfer most of its data storage, management, and analysis to in-house.

Equipment which is used specifically for data entry and management includes the UNIX System, the LISA 2/10, the Apple IIe microcomputer, a tape backup/transferral system (as mentioned above), a HIPAD DT-114 Digitizer, and seveal CRT work stations, all of which are hardwired to the UNIX system. The Hewlett Packard system was, and will be, used to conduct most of the analyses, using mainframe computers as necessary depending upon the size and complexity of the data set being analyzed.

By having telephone access to large computing centers (mainly the Amdahl 470V/6 at Texas A&M University), LGL has available all commonly

used statistical packages such as BMDP, SAS, IMSL, and SPSS, as well as access to tape and disk drive facilities, making its input/output capabilities compatible with those of almost any other center.

2.5.2 Data Management Procedures

The sequence of data management procedures used by LGL are shown in Figure 2-10. Data received on magnetic tape from TAMU is transferred either to the Amdahl 470V/6 or to the UNIX, depending on which site is to be used for the analysis. Modifications, if any, are made to the data before any analysis is performed. Most of the project data comes to the data management group on coding forms which were designed by the data manager and key project personnel at the outset of the program before any data were collected. Field and laboratory data are coded onto these data forms by laboratory personnel and then entered on the UNIX system by keypunch personnel.

Once the data are entered, they are transferred to project-designated data files on the Amdahl 470V/6. This procedure saves costs in terms of data entry and storage on the mainframe, as well as provides a temporary backup disk. Hard-copy printouts of the data files are obtained via one of the two printers mentioned above. These printouts are then keypunch-verified for entry errors. Corrections are made, and a revised hard-copy printout is obtained and supplied to a project investigator for validation. Errors, if any, are noted by the project investigator and corrections are made on the data files.

A final computerized data validation program is used to test the data for validity. Any inconsistencies found are corrected, producing a final version of the data for analysis. The final version of the data is then transferred to either the UNIX, the LISA 2/10 or the HP9845B for analysis. Any subsequent errors found during analysis are also corrected, such that at time of submission of the data to the NODC, the errors remaining in the data files should be less than one percent.

A copy of the data files is then transferred to magnetic tape which has the following format: unlabeled, 9-track, 1600 bpi, 6160 fixed block format (blocking factor 77), 80 logical record size (blank-filled), EBCIDIC, tape density of 3. This tape is provided to NODC. Data are

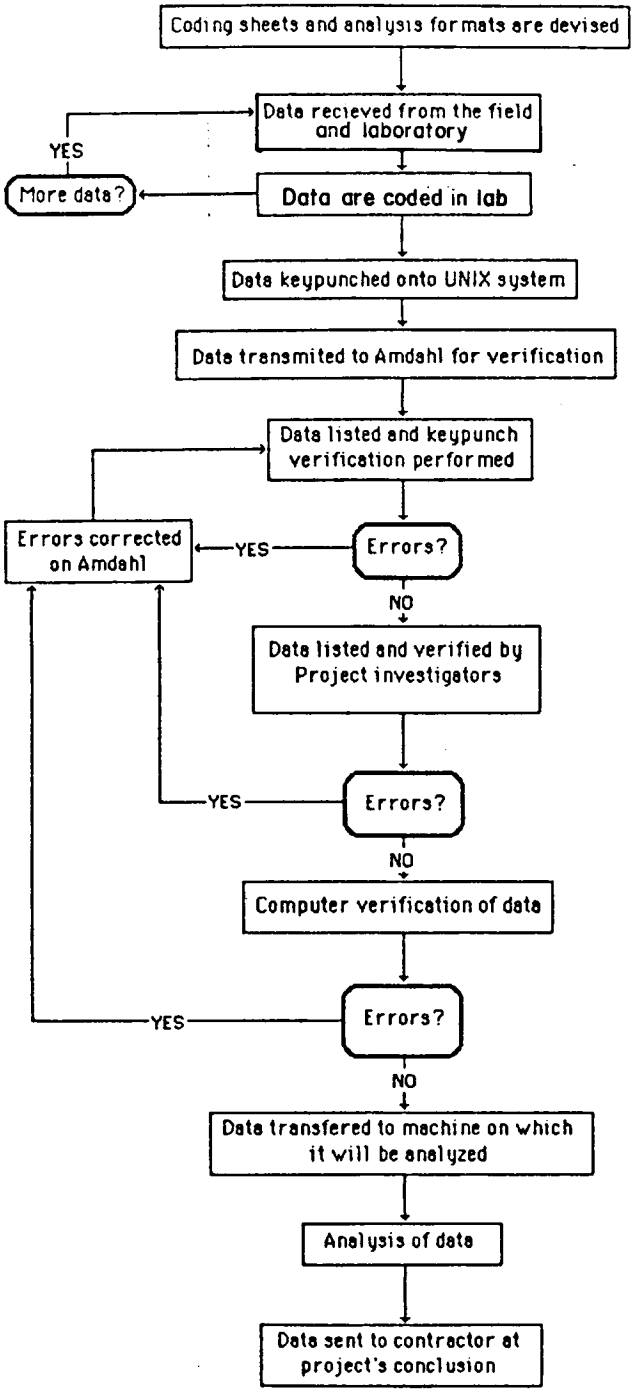


Figure 2-10. Data flow sequence for Continental Slope Study.

fully traceable through the system, with summary reports available at all times to indicate project status. Magnetic tapes containing the data files along with all relevant documentation and accompanying letters of transmittal will all have been provided at the time of draft final report submission.

2.5.3 Status of Year One Data

The status of Year One data is shown in Table 2-13. The data are organized by nine file types. Note that for the macroinfauna there are two file types, reflecting first the rough sort data by major group, and second the final sort where the organisms are identified to the lowest possible taxon.

2.5.4 Data Analyses

Due to the incomplete nature of the data for this reporting period, the analyses presented herein are largely descriptive in nature. More quantitative analyses will be conducted as the data sets are finalized. Progress along these lines is in accord with the anticipated overall project schedule.

Two types of analyses were used for this report, cluster and nodal analyses. Cluster analyses was used to classify station groups by megafauna composition as a basis for evaluating if the preliminary results follow Pequegnat's (1983) faunal zones for this group. The cluster analyses used the Helly-Bray metric with a complete linkage algorithm following Boesch (1977).

Nodal analysis is a procedure that enables one to describe and interpret cells or "nodes" in a two-way table of collection groups vs. species groups (Boesch 1977). Interpretation can be made on the basis of the classic ecological concepts of constancy and fidelity. Constancy compares occurrence of a species group across the collection groups arbitrarily graded as very high, high, medium, low and very low; constancy is an index of how widely distributed a species group is across the collection groups. Algebraically, it is expressed as

TABLE 2-13

Status of data files as of 7 March, 1985.

File Name	Cruise	Received	Coded	Entered	Verified (KP, PI)	QA	Sent To NODC	Total Records
P511								
Meiofauna	1	X	X	X	X	X	X	1047
	2	X	X	X	X	X		2060
								3107
P512								
Macroinfauna	1	X	X	X	X	X	X	1289
	2	X	X	X	X	X		2060
Final sort	1	X	X	X	X	X		1032
								4381
P513 Macroepifauna & Demersal Fish	1	X	X	X	X	X	X	332
	2	X	X	X	X	X		1168
								1500
P514 Benthic Photography	Stations C1, E1, W1 have been digitized and archived at LGL. This data will not be sent to NODC at this time. Total raw data records=42,000; total compressed data records=10,400.							
P515 Ship Position and Depth	1	X	X	X	X	X	X	45
	2	X	X	X	X	X		110
								155
P517								
Sediment	1	X	X	X	X	X		31
	2	X	X	X	X	X		63
								94
P518 Hydrocarbons	Cruise 1 sediment and organisms have been received and verified with a total of 779 data records. Cruise 2 sediment has been received and verified with a total of 464 data records. Total records for both cruises is 1243. Cruise 2 organisms have not been received yet.							
P519								
Hydrography	1	X	X	I/P				
	2	X	X	I/P				

$$C_{ij} = a_{ij}/(n_i n_j)$$

where a_{ij} is the number of occurrences of species group i in collection group j, and n_i and n_j are the respective numbers of group categories. Fidelity compares the constancy of a species in a given collection group with its constancy in all collection groups, i.e.

$$F_{ij} = (a_{ij} \Sigma\ n_j)/(n_j \Sigma a_{ij})$$

The reader is referred to Boesch (1977) for a thorough discussion of this topic.

It should be emphasized that, at this time, the data warrant very little analysis due to their incomplete nature. The analyses conducted were limited to those of a descriptive or classification nature which we believed would enable the best comparisons with historical data.

3.0 ENVIRONMENTAL RESULTS AND DISCUSSION

3.1 WATER COLUMN STRUCTURE

Complete hydrographic data for Cruises I and II are provided in Tables 3-1 and 3-2. Using these data in conjunction with the information contained in Table 1-1, it was confirmed that the water column during sampling consisted of the typical layers of Gulf, Tropical Atlantic Central, Antarctic Intermediate and Gulf Deep Waters (e.g., Fig. 3-1). The uniformity in water mass characteristics across the Gulf is well illustrated by the temperature, salinity, and transmissivity data collected during Cruise II (Fig. 3-2). Only a very shallow mixed layer was present and was associated with a slight decrease in transmission indicating increased suspended particulate matter in the mixed layer. No decrease in light transmission in near-bottom waters was detected at most stations along the sampling transects during either Cruise I or II.

The most notable difference in water quality among the five sampling stations was water temperature. Across all stations and transects, mean depths for near-bottom temperature sampling for each of Stations 1-5 were 346, 634, 863, 1417, and 2567 m, respectively. Mean water temperature at these depths from shallowest to deepest were 10.8, 6.9, 5.4, 4.3, and 4.3°C, respectively. Stations in the Shelf/Slope Transitional Zone were thus markedly warmer than deeper stations; stations in the Archibenthal Zone (Horizons A and B) were intermediate in temperature; and there was little difference in temperature for stations as deep or deeper than 1400 m (Upper Abyssal Zone) down to as much as 2567 m in depth (Mesoabyssal Zone, Horizon C) which were coldest.

3.2 SEDIMENT CHARACTERIZATION

Sediment data for Cruises I and II are provided in Tables 3-3 and 3-4. These analyses are complete except for the carbon isotopic analyses for Cruise II. The carbon isotope data are discussed in the next section as a separate category.

TABLE 3-1

Water column data from Cruise I. Stations without a designated number are NSF stations also collected on the same cruise.

DATE	MMS STATION #	TIME START	TIME FINISH	POSITION LAT	LONG	LORAN X	LORAN Y	DEPTH PDR (m)	MEASURED DEPTH (m)	TEMP (°C)	SAL (o/oo)	SIGMA-t	DO (ml/l)	TRANS (volts) (5v=100%)	PO4 (uM)	NO3 (uM)	NO2 (uM)	SILICA (uM)	POC (ug C/l)
11/24		0700		2757.3	9357.6	25830	46716	95	0		36.252		4.39	4.27	0.24	7.1	0.08	5.6	
11/24		0940	1012	2743.3	9345.7	25825	46677	271	250	13.66	35.624	26.75	4.15	4.35	1.04	21.8	0.51	10.3	25.0
11/24		1319	1414	2726.4	9337.6	25835	46627	570	600	7.98	34.988	27.29	3.87	4.39	1.78	29.5	0.15	19.9	11.2
11/25		1418	1509	2747.2	9129.7	27223	46300	580	572	7.94	34.974	27.27	3.89	4.39	1.68	30.8	0.06	19.8	13.6
11/25		1418	1509	2747.2	9129.7	27223	46300	580	574	7.93	34.977	27.28	4.17	4.39	1.63	30.9	0.03	19.8	18.4
11/25		1418	1509	2747.2	9129.7	27223	46300	580	576	7.88	34.973	27.28	3.87	4.39	1.60	30.9	0.03	19.9	16.7
11/25		1418	1509	2747.2	9129.7	27223	46300	580	578	7.89	34.974	27.28	3.99	4.39	1.66	30.8	0.02	19.8	18.3
11/25		1418	1509	2747.2	9129.7	27223	46300	580	580	7.87	34.969	27.28	4.05	4.39	1.63	30.8	0.03	20.0	25.1
11/26	C-1	0339	0455	2803.5	9014.2	28050	46594	298	2	22.62	34.909	23.99	4.99	4.20	0.00	0.0	0.01	1.4	58.1
11/26	C-1	0339	0455	2803.5	9014.2	28050	46594	298	25	22.63	34.943	23.99	4.98	4.20	0.00	0.0	0.01	1.2	61.6
11/26	C-1	0339	0455	2803.5	9014.2	28050	46594	298	50	23.32	35.545	24.27	4.64	4.27	0.00	0.3	0.22	2.1	43.6
11/26	C-1	0339	0455	2803.5	9014.2	28050	46594	298	75	20.54	36.291	25.61	3.63	4.35	0.18	4.9	0.05	4.6	15.5
11/26	C-1	0339	0455	2803.5	9014.2	28050	46594	298	100	18.74	36.348	26.14	3.15	4.31	0.44	9.6	0.04	5.8	17.3
11/26	C-1	0339	0455	2803.5	9014.2	28050	46594	298	125	17.99	36.336	26.32	3.15	4.39	0.48	11.2	0.03	5.2	17.4
11/26	C-1	0339	0455	2803.5	9014.2	28050	46594	298	150	16.09	36.100	26.59	3.11	4.35	0.82	14.2	0.03	6.9	15.9
11/26	C-1	0339	0455	2803.5	9014.2	28050	46594	298	175	15.51	36.005	26.64	3.00	4.35	0.91	15.4	0.04	7.7	20.2
11/26	C-1	0339	0455	2803.5	9014.2	28050	46594	298	200	14.73	35.918	26.75	2.93	4.23	1.00	16.7	0.05	8.8	26.8
11/26	C-1	0339	0455	2803.5	9014.2	28050	46594	298	250	13.38	35.686	26.85	2.85	4.23	1.16	19.3	0.05	10.7	24.4
11/26	C-1	0339	0455	2803.5	9014.2	28050	46594	298	275	12.54	35.543	26.92	2.77	4.35	1.27	20.9	0.05	11.7	32.4
11/26	C-1	0339	0455	2803.5	9014.2	28050	46594	298	297	11.63	35.431	27.00	2.75	4.31	1.46	22.6	0.08	13.1	14.2
11/26	C-2	1840	2023	2754.3	9005.7	28087	46548	622	2	22.89	35.307	24.22	4.96	4.12	0.00	0.0	0.00	0.8	83.0
11/26	C-2	1840	2023	2754.3	9005.7	28087	46548	622	60	21.70	36.282	25.28	3.87	4.35	0.07	3.0	0.04	3.4	48.5
11/26	C-2	1840	2023	2754.3	9005.7	28087	46548	622	100	18.95	36.363	26.10	3.18	4.39	0.42	10.3	0.00	5.0	28.2
11/26	C-2	1840	2023	2754.3	9005.7	28087	46548	622	150	16.63	36.134	26.49	3.05	4.35	0.69	14.4	0.00	6.4	26.4
11/26	C-2	1840	2023	2754.3	9005.7	28087	46548	622	200	14.42	35.814	26.73	2.97	4.39	0.98	18.1	0.00	8.5	27.4
11/26	C-2	1840	2023	2754.3	9005.7	28087	46548	622	250	12.66	35.574	26.92	2.83	4.39	1.17	20.9	0.00	10.8	27.3
11/26	C-2	1840	2023	2754.3	9005.7	28087	46548	622	300	11.63	35.459	27.02	2.73	4.39	1.33	22.7	0.00	12.5	24.6
11/26	C-2	1840	2023	2754.3	9005.7	28087	46548	622	400	9.52	35.152	27.17	2.70	4.39	1.63	26.4	0.00	17.0	18.0
11/26	C-2	1840	2023	2754.3	9005.7	28087	46548	622	500	8.33	35.015	27.26	2.75	4.35	1.75	27.6	0.01	20.1	21.4
11/26	C-2	1840	2023	2754.3	9005.7	28087	46548	622	600	7.55	34.942	27.30	2.87	4.39	1.87	28.2	0.02	21.9	
11/26	C-2	1840	2023	2754.3	9005.7	28087	46548	622	613	7.51	34.928	27.30	2.91	4.39	1.82	28.2	0.04	22.2	25.3
11/27	C-3	0828	1025	2748.4	9006.6	28053	46525	860	5	22.88	35.437	24.30	4.90	4.39	0.11	0.3	0.05	1.2	71.5
11/27	C-3	0828	1025	2748.4	9006.6	28053	46525	860	50	22.91	36.132	24.82	4.20	4.39	0.11	0.7	0.11	2.9	60.5
11/27	C-3	0828	1025	2748.4	9006.6	28053	46525	860	100	18.19	36.333	26.26	3.14	4.39	0.50	10.5	0.03	5.3	69.8
11/27	C-3	0828	1025	2748.4	9006.6	28053	46525	860	150	15.58	36.005	26.62	2.98	4.39	0.83	16.6	0.02	7.5	21.8
11/27	C-3	0828	1025	2748.4	9006.6	28053	46525	860	200	13.86	35.797	26.85	2.85	4.39	1.03	19.4	0.06	9.3	39.2
11/27	C-3	0828	1025	2748.4	9006.6	28053	46525	860	300	11.72	35.450	27.01	2.71	4.39	1.34	24.0	0.04	12.9	30.5
11/27	C-3	0828	1025	2748.4	9006.6	28053	46525	860	400	9.67	35.174	27.16	2.68	4.39	1.61	27.2	0.04	16.6	22.9
11/27	C-3	0828	1025	2748.4	9006.6	28053	46525	860	500	7.92	34.969	27.28	2.81	4.39	1.77	29.3	0.06	20.3	25.7
11/27	C-3	0828	1025	2748.4	9006.6	28053	46525	860	600	7.05	34.902	27.32	3.03	4.39	1.77	29.0	0.05	22.7	46.3
11/27	C-3	0828	1025	2748.4	9006.6	28053	46525	860	700	6.27	34.883	27.43	3.30	4.39	1.82	29.2	0.05	24.4	31.2
11/27	C-3	0828	1025	2748.4	9006.6	28053	46525	860	800	5.74	34.900	27.52	3.54	4.39	1.70	28.2	0.70	25.5	36.9
11/27	C-3	0828	1025	2748.4	9006.6	28053	46525	860	851	5.47	34.887	27.54	3.75	4.39	1.70	26.2	0.06	25.8	31.5

TABLE 3-1
(cont'd)

DATE	MMS STATION #	TIME START	TIME FINISH	POSITION LAT	LONG	LORAN X	LORAN Y	DEPTH PDR (m)	MEASURED DEPTH (m)	TEMP (°C)	SAL (o/oo)	SIGMA-t	DO (ml/l)	TRANS (volts) (5v=100%)	PO4 (uM)	NO3 (uM)	NO2 (uM)	SILICA (uM)	POC (ug C/l)
11/29	C-4	1835	2031	2728.7	8946.7	28153	46418	1440	50	22.98	35.413	24.27	4.87	4.27	0.01	0.0	0.03	1.5	29.0
11/29	C-4	1835	2031	2728.7	8946.7	28153	46418	1440	100	19.79	36.401	25.90	3.35	4.35	0.32	7.7	0.06	4.0	16.9
11/29	C-4	1835	2031	2728.7	8946.7	28153	46418	1440	200	13.31	35.679	26.87	2.96	4.35	1.00	21.2	0.02	9.3	20.3
11/29	C-4	1835	2031	2728.7	8946.7	28153	46418	1440	300	10.73	35.315	27.09	2.69	4.35	1.33	26.6	0.02	13.4	19.8
11/29	C-4	1835	2031	2728.7	8946.7	28153	46418	1440	400	9.15	35.114	27.20	2.70	4.35	1.51	29.5	0.01	16.7	20.6
11/29	C-4	1835	2031	2728.7	8946.7	28153	46418	1440	500	7.86	34.964	27.29	2.88	4.35	1.66	31.3	0.01	19.9	18.1
11/29	C-4	1835	2031	2728.7	8946.7	28153	46418	1440	600	6.78	34.900	27.39	3.10	4.35	1.68	31.4	0.02	22.9	13.7
11/29	C-4	1835	2031	2728.7	8946.7	28153	46418	1440	700	6.13	34.898	27.48	3.34	4.35	1.64	30.8	0.02	23.9	11.7
11/29	C-4	1835	2031	2728.7	8946.7	28153	46418	1440	800	5.60	34.899	27.54	3.66	4.39	1.59	29.3	0.02	24.8	20.9
11/29	C-4	1835	2031	2728.7	8946.7	28153	46418	1440	900	5.30	34.922	27.60	3.91	4.35	1.54	28.0	0.03	25.4	17.7
11/29	C-4	1835	2031	2728.7	8946.7	28153	46418	1440	1200	4.53	34.959	27.72	4.55	4.35	1.41	25.1	0.03	25.4	45.7
11/29	C-4	1835	2031	2728.7	8946.7	28153	46418	1440	1364	4.37	34.962	27.74	4.73	4.35	1.33	24.1	0.03	25.3	26.7
11/28	C-5	1540	1900	2655.3	8932.9	28125	46254	2535	10	24.44	34.996	23.53	4.81	4.35	0.03	0.1	0.07	2.0	36.8
11/28	C-5	1540	1900	2655.3	8932.9	28125	46254	2535	50	24.44	35.951	24.25	4.82	4.35	0.01	0.2	0.05	2.0	32.7
11/28	C-5	1540	1900	2655.3	8932.9	28125	46254	2535	100	20.79	36.419	25.65	3.63	4.39	0.21	4.9	0.10	3.4	19.0
11/28	C-5	1540	1900	2655.3	8932.9	28125	46254	2535	300	13.32	35.697	26.89	2.93	4.39	1.06	18.6	0.05	10.0	18.6
11/28	C-5	1540	1900	2655.3	8932.9	28125	46254	2535	500	9.29	35.114	27.18	2.72	4.39	1.55	21.7	0.05	17.7	
11/28	C-5	1540	1900	2655.3	8932.9	28125	46254	2535	800	6.06	34.896	27.48	3.31	4.39	1.77	26.8	0.04	25.7	9.9
11/28	C-5	1540	1900	2655.3	8932.9	28125	46254	2535	1000	5.02	34.927	27.64	4.01	4.39	1.62	24.3	0.03	27.2	30.6
11/28	C-5	1540	1900	2655.3	8932.9	28125	46254	2535	1400	4.30	34.966	27.75	4.84	4.39	1.40	21.2	0.03	26.6	15.7
11/28	C-5	1540	1900	2655.3	8932.9	28125	46254	2535	1800	4.22	34.977	27.77	5.02	4.39	1.33	20.2	0.02	26.2	28.3
11/28	C-5	1540	1900	2655.3	8932.9	28125	46254	2535	2200	4.22	34.977	27.77	5.07	4.39	1.35	20.1	0.04	26.0	39.3
11/28	C-5	1540	1900	2655.3	8932.9	28125	46254	2535	2400	4.23	34.975	27.76	5.03	4.39	1.34	20.1	0.03	25.9	26.5
11/28	C-5	1540	1900	2655.3	8932.9	28125	46254	2535	2535	4.24	34.974	27.76	5.08	4.39	1.36	20.0	0.03	26.2	40.9

TABLE 3-2

Water column data from Cruise II. Stations designated S-1 are NSF stations collected on the same cruise.

DATE	MMS STATION #	TIME START	POSITION LAT	LONG	DEPTH PDR (m)	MEASURED DEPTH (m)	TEMP (°C)	SAL (o/oo)	SIGMA-t	DO (ml/l)	Trans (volts) (5v=100%)	SIO4 (uM)	PO4 (uM)	NO3 (uM)	NO2 (uM)	POC (ugC/l)	DOC (mgC/l
4/4	W-1	0257	2739.8	9346.5	340	24	20.36	35.852	25.33	5.17	4.35	1.0	0.04	0.0	0.11	40.8	1.11
4/4	W-1	0257	2739.8	9346.5	340	49	20.40	36.123	25.53	4.77	4.39	1.0	0.02	0.0	0.12	18.8	0.96
4/4	W-1	0257	2739.8	9346.5	340	74	19.95	36.231	25.73	4.30	4.39	2.1	0.18	3.2	0.26	37.2	0.96
4/4	W-1	0257	2739.8	9346.5	340	100	19.28	36.270	25.94	3.95	4.43	2.7	0.30	5.9	0.20	10.8	0.84
4/4	W-1	0257	2739.8	9346.5	340	124	18.18	36.304	26.24	2.98	4.43	4.8	0.70	12.5	0.20	7.9	0.83
4/4	W-1	0257	2739.8	9346.5	340	173	15.76	36.050	26.63	2.89	4.43	6.8	1.05	10.5	0.70	6.9	0.75
4/4	W-1	0257	2739.8	9346.5	340	225	14.10	35.805	26.81	2.78	4.43	8.3	0.74	19.9	0.90	7.9	0.89
4/4	W-1	0257	2739.8	9346.5	340	275	12.79	35.611	26.93	2.72	4.41	10.9	1.58	23.0	0.25	8.8	0.82
4/4	W-1	0257	2739.8	9346.5	340	334	11.55	35.425	27.02	2.69	4.39	12.8	1.92	25.4	0.20	10.2	0.84
4/4	W-1	0257	2739.8	9346.5	340	345	11.30	35.397	27.05	2.62	4.43	13.1	2.01	25.7	0.28	9.3	0.88
4/4	W-1	0257	2739.8	9346.5	340	345	11.30	35.369	27.03	2.66	4.43	13.4	2.06	26.0	0.19	15.1	0.74
4/4	W-1	0257	2739.8	9346.5	340	345	11.30	35.364	27.02	2.75	4.43	13.4	2.17	26.2	0.25	16.5	0.76
4/7	W-2	2345	2724.9	9320.9	654	5	20.48	36.001	25.42	5.28	4.43	1.1	0.18	0.0	0.29	29.1	1.06
4/7	W-2	2345	2724.9	9320.9	654	20	20.48	36.186	25.56	3.99	4.43	2.6	0.34	4.9	0.38	19.6	0.87
4/7	W-2	2345	2724.9	9320.9	654	60	20.38	36.224	25.61	4.14	4.39	2.2	0.31	3.8	0.38	19.5	0.87
4/7	W-2	2345	2724.9	9320.9	654	101	18.90	36.207	25.99	3.33	4.45	5.6	0.68	14.0	0.14	19.6	0.67
4/7	W-2	2345	2724.9	9320.9	654	149	16.87	35.890	26.25	2.84	4.47	8.3	1.00	17.7	0.26	14.8	0.64
4/7	W-2	2345	2724.9	9320.9	654	199	14.89	35.643	26.51	2.80	4.43	10.2	1.22	20.9	0.14	22.0	0.62
4/7	W-2	2345	2724.9	9320.9	654	250	13.02	35.492	26.79	2.72	4.45	11.8	1.34	22.3	0.13	12.0	0.66
4/7	W-2	2345	2724.9	9320.9	654	300	12.03	35.215	26.77	2.59	4.47	15.2	1.63	25.7	0.09	8.6	0.66
4/7	W-2	2345	2724.9	9320.9	654	397	10.09	35.053	27.00	2.78	4.47	18.1	1.80	28.1	0.06	16.7	0.69
4/7	W-2	2345	2724.9	9320.9	654	484	8.83	34.908	27.09	3.29	4.47	24.8	1.93	29.6	0.04	25.3	0.60
4/7	W-2	2345	2724.9	9320.9	654	635	6.31	34.908	27.46	3.38	4.47	25.2	1.94	29.8	0.22	21.5	0.68
4/7	W-2	2345	2724.9	9320.9	654	647	6.25	34.876	27.44	3.37	4.47	25.2	1.97	29.8	0.35	27.2	0.79
4/8	W-3	1150	2710.6	9319.5	880	28	20.77	35.001	24.58	5.19	4.39	1.4	0.15	0.2	0.09	37.5	1.04
4/8	W-3	1150	2710.6	9319.5	880	50	20.22	36.204	25.64	4.39	4.43	2.6	0.27	3.9	0.10	13.5	0.88
4/8	W-3	1150	2710.6	9319.5	880	102	19.03	36.219	25.96	2.97	4.43	5.8	0.66	12.6	0.11	16.3	0.77
4/8	W-3	1150	2710.6	9319.5	880	150	17.03	35.802	26.14	2.80	4.47	8.2	1.03	17.4	0.15	23.5	0.60
4/8	W-3	1150	2710.6	9319.5	880	225	14.10	35.485	26.56	2.70	4.46	11.3	1.34	20.4	0.10	25.7	0.66
4/8	W-3	1150	2710.6	9319.5	880	300	11.97	35.205	26.77	2.69	4.47	14.9	1.62	24.2	0.13	24.0	0.65
4/8	W-3	1150	2710.6	9319.5	880	398	9.90	35.016	27.00	2.78	4.47	18.0	1.83	26.3	0.12	13.6	0.65
4/8	W-3	1150	2710.6	9319.5	880	499	8.42	34.929	27.17	2.97	4.47	21.6	1.88	29.3	0.11	30.7	0.73
4/8	W-3	1150	2710.6	9319.5	880	600	7.25	34.895	27.32	3.42	4.47	24.5	1.92	31.8	0.11	19.8	0.58
4/8	W-3	1150	2710.6	9319.5	880	725	6.11	34.924	27.50	3.98	4.47	26.2	1.73	29.3	0.14	27.7	0.54
4/8	W-3	1150	2710.6	9319.5	880	864	5.13	34.935	27.63	4.07	4.47	25.6	1.70	29.6	0.08	13.6	0.55
4/8	W-4	2202	2643.9	9319.2	1464	52	20.17	36.096	25.57	5.20	4.39	1.4	0.03	0.1	0.01	30.9	1.27
4/8	W-4	2202	2643.9	9319.2	1464	99	18.79	36.290	26.08	3.73	4.43	3.7	0.46	6.3	0.08	19.4	0.83
4/8	W-4	2202	2643.9	9319.2	1464	175	15.50	36.061	26.70	3.08	4.47	6.5	0.90	14.2	0.02	13.2	0.84
4/8	W-4	2202	2643.9	9319.2	1464	275	12.52	35.532	26.92	2.85	4.47	10.8	1.28	20.9	0.02	14.2	0.79
4/8	W-4	2202	2643.9	9319.2	1464	401	9.79	35.158	27.13	2.72	4.47	15.6	1.63	26.2	0.01	17.8	0.68
4/8	W-4	2202	2643.9	9319.2	1464	772	5.78	34.896	27.52	3.57	4.47	25.2	1.47	27.0	0.13	14.2	0.62
4/8	W-4	2202	2643.9	9319.2	1464	899	5.23	34.916	27.60	3.96	4.47	25.7	1.52	26.2	0.03	14.3	0.70
4/8	W-4	2202	2643.9	9319.2	1464	1101	4.58	34.949	27.70	4.52	4.47	26.0	0.35	23.8	0.02	14.2	0.57

TABLE 3-2
(cont'd)

DATE	MMS STATION #	TIME START	POSITION LAT	LONG	DEPTH PDR (m)	MEASURED DEPTH (m)	TEMP (°C)	SAL (o/oo)	SIGMA-t	DO (ml/l)	Trans (volts) (5v=100%)	SIO4 (uM)	PO4 (uM)	NO3 (uM)	NO2 (uM)	POC (ugC/l)	DOC (mgC/l)
4/8	W-4	2202	2643.9	9319.2	1464	1300	4.30	34.965	27.75	4.85	4.47	25.8	1.42	23.9	0.07	17.4	0.83
4/8	W-4	2202	2643.9	9319.2	1464	1448	4.23	34.971	27.76	4.92	4.47	25.5	1.34	25.1	0.17	8.3	0.80
4/8	W-4	2202	2643.9	9319.2	1464	1458	4.23	34.970	27.76	4.84	4.47	25.8	1.23	23.9	0.13	17.4	0.77
4/9	W-5	1705	2616.8	9318.8	2460	25	20.79	36.058	25.38	5.21	4.39	1.0	0.12		0.00	36.8	0.95
4/9	W-5	1705	2616.8	9318.8	2460	75	19.13	35.996	25.77	4.95	4.39	1.3	0.18	1.1	0.27	26.0	0.84
4/9	W-5	1705	2616.8	9318.8	2460	150	15.52	36.037	26.67	3.96	4.47	5.0	0.75	10.0	0.04	33.3	0.82
4/9	W-5	1705	2616.8	9318.8	2460	300	10.86	35.287	27.04	2.55	4.47	14.3	1.57	23.8	0.01	11.2	0.68
4/9	W-5	1705	2616.8	9318.8	2460	500	7.49	34.951	27.33	2.85	4.47	20.6	1.91	28.0	0.00	13.0	0.67
4/9	W-5	1705	2616.8	9318.8	2460	1100	4.48	34.951	27.72	4.59	4.47	25.3	1.57	23.0	0.00	12.2	0.65
4/9	W-5	1705	2616.8	9318.8	2460	1501	4.22	34.974	27.76	4.93	4.47	24.7	1.50	21.9	0.00	9.4	0.70
4/9	W-5	1705	2616.8	9318.8	2460	1901	4.21	34.971	27.76	5.03	4.47	24.5	1.47	21.1	0.00	8.2	0.62
4/9	W-5	1705	2616.8	9318.8	2460	2300	4.24	34.979	27.77	5.09	4.47	24.4	1.46	20.1	0.00	9.8	0.70
4/9	W-5	1705	2616.8	9318.8	2460	2441	4.25	34.981	27.77	5.03	4.47	24.1	1.50	19.4	0.00	25.2	0.90
4/9	W-5	1705	2616.8	9318.8	2460	2451	4.25	34.993	27.78	5.04	4.47	23.8	1.42	18.7	0.01	30.6	0.83
4/11	S-1	0150	2742.7	9131.2	690	632	6.44	34.896	27.43	3.27	4.47	23.8	1.68	29.4	0.02	8.3	0.65
4/11	S-1	0150	2742.7	9131.2	690	632	6.44	34.896	27.43	3.27	4.47	23.8	1.68	29.4	0.02		
4/11	S-1	0150	2742.7	9131.2	690	657	6.23	34.900	27.47	3.32	4.47	24.3	1.68	29.3	0.03	18.9	0.78
4/11	S-1	0150	2742.7	9131.2	690	657	6.23	34.900	27.47	3.32	4.47	24.3	1.68	29.3	0.03		
4/11	S-1	0150	2742.7	9131.2	690	672	6.15	34.899	27.48	3.39	4.47	24.6	1.69	29.5	0.06	11.4	0.65
4/11	S-1	0150	2742.7	9131.2	690	672	6.15	34.899	27.48	3.39	4.47	24.6	1.69	29.5	0.06		
4/11	S-1	0150	2742.7	9131.2	690	676	6.12	34.900	27.48	3.38	4.47	24.6	1.68	29.7	0.06	17.6	0.80
4/11	S-1	0150	2742.7	9131.2	690	676	6.12	34.900	27.48	3.38	4.47	24.6	1.68	29.7	0.06		
4/11	S-1	0150	2742.7	9131.2	690	680	6.03	34.899	27.49	3.40	4.47	24.7	1.69	29.8	0.05	14.5	0.72
4/11	S-1	0150	2742.7	9131.2	690	680	6.03	34.898	27.49	3.40	4.47	24.7	1.69	29.8	0.05		
4/11	S-1	0150	2742.7	9131.2	690	682	6.02	34.892	27.49	3.39	4.47	24.5	1.70	29.9	0.00	21.0	0.87
4/11	S-1	0150	2742.7	9131.2	690	682	6.02	34.892	27.49	3.39	4.47	24.5	1.70	29.9	0.00		
4/11	C-1	1033	2801.8	9013.9	384	10	19.29	35.633	25.59	5.63	4.23	1.3	0.10	0.5	0.21	40.4	1.21
4/11	C-1	1033	2801.8	9013.9	384	25	19.01	35.821	25.78	5.34	4.27	1.0	0.06	0.0	0.04	41.9	1.19
4/11	C-1	1033	2801.8	9013.9	384	49	19.20	35.974	25.83	5.18	4.31	1.2	0.06	0.4	0.23	39.2	1.20
4/11	C-1	1033	2801.8	9013.9	384	76	18.27	36.102	26.18		4.29	2.6	0.13	4.0	0.08	19.2	1.04
4/11	C-1	1033	2801.8	9013.9	384	100	17.26	36.250	26.32	3.12	4.43	5.0	0.46	13.2	0.05	17.3	0.94
4/11	C-1	1033	2801.8	9013.9	384	124	16.23	36.104	26.48	2.98	4.39	7.3	0.61	15.7	0.07	19.4	0.86
4/11	C-1	1033	2801.8	9013.9	384	149	15.45	35.995	26.57	3.02	4.26	7.3	0.68	17.1	0.05	25.0	0.82
4/11	C-1	1033	2801.8	9013.9	384	175	14.53	35.885	26.68	2.96	4.39	8.4	0.75	18.5	0.08	11.9	0.81
4/11	C-1	1033	2801.8	9013.9	384	225	13.82	35.764	26.69	2.86	4.31	9.9	0.83	20.1	0.08	12.8	0.72
4/11	C-1	1033	2801.8	9013.9	384	275	12.60	35.582	26.67	2.79	4.33	11.6	1.03	22.8	0.09	12.7	0.69
4/11	C-1	1033	2801.8	9013.9	384	370	10.07	35.233	27.18	2.75	4.43	15.1	1.33	27.6	0.07	8.8	0.72
4/11	C-1	1033	2801.8	9013.9	384	380	10.06	35.227	27.45	2.73	4.43	15.4	1.32	27.8	0.07	7.9	1.00
4/11	C-2	2129	2754.9	9005.7	630	10	20.14	35.662	25.25	5.44	4.25	1.0	0.06	0.0	0.03	32.0	1.07
4/11	C-2	2129	2754.9	9005.7	630	20	19.62	36.127	25.74	4.67	4.27	2.1	0.14	3.0	0.08	34.4	1.18
4/11	C-2	2129	2754.9	9005.7	630	59	18.80	36.311	26.07	2.97	4.35	4.5	0.50	13.0	0.07	10.2	1.02
4/11	C-2	2129	2754.9	9005.7	630	100	17.75	36.051	26.16	3.03	4.44	6.3	0.72	16.3	0.04	10.4	0.66

TABLE 3-2
(cont'd)

DATE	MMS STATION #	TIME # START	POSITION LAT	LONG	DEPTH PDR (m)	MEASURED DEPTH (m)	TEMP (°C)	SAL (o/oo)	SIGMA-t	DO (ml/l)	Trans (volts) (5v=100%)	SIO4 (uM)	PO4 (uM)	NO3 (uM)	NO2 (uM)	POC (ugC/l)	DOC (mgC/l)
4/11	C-2	2129	2754.9	9005.7	630	149	15.62	35.838	26.50	2.96	4.46	6.7	0.83	19.3	0.04	5.9	1.30
4/11	C-2	2129	2754.9	9005.7	630	200	14.27	35.598	26.61	2.80	4.42	9.0	1.08	22.6	0.05	9.0	0.80
4/11	C-2	2129	2754.9	9005.7	630	249	12.81	35.481	26.82	2.74	4.42	10.5	1.22	24.4	0.05	10.3	0.80
4/11	C-2	2129	2754.9	9005.7	630	299	11.93	35.162	26.75	2.62	4.35	14.7	0.93	28.3	0.05	11.9	0.90
4/11	C-2	2129	2754.9	9005.7	630	400	9.68	34.978	27.01	2.86	4.44	18.5	1.67	30.5	0.05	6.2	0.72
4/11	C-2	2129	2754.9	9005.7	630	499	8.16	34.902	27.19	3.10	4.47	21.4	1.75	30.5	0.05	6.1	0.61
4/11	C-2	2129	2754.9	9005.7	630	614	6.77	34.919	27.41	3.18	4.43	21.2	1.71	29.7	0.06	14.9	0.66
4/11	C-2	2129	2754.9	9005.7	630	625	6.69	34.909	27.41	3.18	4.43	21.5	1.74	30.6	0.07	11.3	0.81
4/12	C-3	1022	2749.2	9006.8	870	25	19.66	35.761	25.45	5.47	4.23	1.2	0.09	0.0	0.01	46.5	1.18
4/12	C-3	1022	2749.2	9006.8	870	?	?	35.731	--	5.23	4.47	1.7	0.09	0.6	0.42	29.9	1.29
4/12	C-3	1022	2749.2	9006.8	870	50	19.24	36.080	25.80	5.01	4.24	1.8	0.14	1.2	0.12		
4/12	C-3	1022	2749.2	9006.8	870	102	17.99	36.284	26.28	3.45	4.43	5.0	0.43	9.6	0.06	10.8	0.96
4/12	C-3	1022	2749.2	9006.8	870	149	15.93	36.066	26.60	3.28	4.47	6.1	0.67	13.3	0.06	12.0	0.83
4/12	C-3	1022	2749.2	9006.8	870	224	14.04	35.788	26.81	3.04	4.47	8.6	0.92	17.2	0.08	10.0	1.20
4/12	C-3	1022	2749.2	9006.8	870	299	11.84	35.467	27.00	2.87	4.47	11.9	1.22	22.0	0.06	24.2	0.75
4/12	C-3	1022	2749.2	9006.8	870	500	8.25	35.001	27.26	2.85	4.47	20.0	1.55	27.8	0.13	13.7	0.81
4/12	C-3	1022	2749.2	9006.8	870	599	7.16	34.917	27.35	3.05	4.47	22.7	1.74	29.0	0.13	10.1	0.63
4/12	C-3	1022	2749.2	9006.8	870	724	5.89	34.898	27.51	3.54	4.43	25.9	1.72	27.9	0.09	21.3	0.60
4/12	C-3	1022	2749.2	9006.8	870	856	5.26	34.920	27.60	3.96	4.43	26.8	1.58	26.4	0.16	16.0	0.61
4/12	C-3	1022	2749.2	9006.8	870	868	5.21	34.894	27.59	3.96	4.43	26.6	1.58	26.5	0.14	7.8	0.74
4/13	C-4	0326	2728.7	8945.5	1430	51	19.85	36.122	25.68	5.29	4.39	1.1	0.09	0.0	0.02	44.7	1.09
4/13	C-4	0326	2728.7	8945.5	1430	100	18.66	36.352	26.16	3.43	4.43	4.0	0.40	9.9	0.06	12.4	0.78
4/13	C-4	0326	2728.7	8945.5	1430	174	15.40	35.985	26.66	3.05	4.47	6.8	0.71	17.0	0.06	4.1	0.89
4/13	C-4	0326	2728.7	8945.5	1430	274	12.20	35.499	26.96	2.90	4.47	11.0	1.12	24.9	0.06	7.8	0.80
4/13	C-4	0326	2728.7	8945.5	1430	400	9.69	35.131	27.13	2.81	4.47	16.7	1.50	30.7	0.05	4.5	0.66
4/13	C-4	0326	2728.7	8945.5	1430	574	7.34	34.899	27.31	3.03	4.47	22.4	1.74	33.2	0.09	2.0	0.76
4/13	C-4	0326	2728.7	8945.5	1430	775	5.77	34.871	27.50	3.68	4.47	26.0	1.74	32.0	0.09	1.7	0.63
4/13	C-4	0326	2728.7	8945.5	1430	900	5.23	34.891	27.58	3.99	4.47	26.5	1.63	29.9	0.07	12.8	0.72
4/13	C-4	0326	2728.7	8945.5	1430	1100	4.59	34.924	27.68	4.50	4.47	26.6	1.54	27.5	0.06	9.3	0.79
4/13	C-4	0326	2728.7	8945.5	1430	1300	4.34	34.938	27.72	4.83	4.47	26.2	1.47	26.2	0.09	5.0	0.67
4/13	C-4	0326	2728.7	8945.5	1430	1422	4.32	34.940	27.73	4.50	4.47	24.9	1.48	26.8	0.07	7.3	0.63
4/13	C-4	0326	2728.7	8945.5	1430	1431	4.32	34.940	27.73	4.59	4.47	25.3	1.50	27.1	0.06	25.7	0.89
4/14	C-5	0138	2658.2	8933.4	2503	26	20.61	36.185	25.52	5.20	4.39	1.3	0.07	0.0	0.00	32.4	1.23
4/14	C-5	0138	2658.2	8933.4	2503	75	19.46	36.114	25.77	5.12	4.39	1.0	0.06	0.2	0.01	28.4	1.00
4/14	C-5	0138	2658.2	8933.4	2503	150	17.45	36.241	26.38	3.04	4.47	4.8	0.41	11.7	0.02	12.3	0.76
4/14	C-5	0138	2658.2	8933.4	2503	300	12.66	35.566	26.92	2.81	4.47	10.0	0.90	20.9	0.00	13.9	0.75
4/14	C-5	0138	2658.2	8933.4	2503	500	8.70	35.019	27.20	2.78	4.47	17.5	1.33	27.9	0.01	16.7	0.70
4/14	C-5	0138	2658.2	8933.4	2503	800	5.82	34.872	27.50	3.50	4.47	24.8	1.35	28.1	0.00	11.1	0.69
4/14	C-5	0138	2658.2	8933.4	2503	1500	4.26	34.944	27.74	4.93	4.47	24.8	1.17	22.8	0.00	16.8	0.70
4/14	C-5	0138	2658.2	8933.4	2503	1899	4.22	34.949	27.74	5.07	4.47	24.5	1.14	22.2	0.00	17.7	0.59
4/14	C-5	0138	2658.2	8933.4	2503	2300	4.23	34.952	27.75	5.14	4.43	24.2	1.13	21.8	0.00	7.3	0.66
4/14	C-5	0138	2658.2	8933.4	2503	2485	4.24	34.952	27.74	5.07	4.35	24.2	1.13	22.0	0.00	11.5	0.63
4/14	C-5	0138	2658.2	8933.4	2503	2495	4.24	34.952	27.74	4.99	4.35	23.8	1.09	21.9	0.01	11.9	0.77

TABLE 3-2
(cont'd)

DATE	MMS STATION #	TIME START	POSITION LAT	LONG	DEPTH H PDR (m)	MEASURED DEPTH (m)	TEMP (°C)	SAL (o/oo)	SIGMA-t	DO (ml/l)	Trans (volts) (5v=100%)	SIO4 (uM)	PO4 (uM)	NO3 (uM)	NO2 (uM)	POC (ugC/l)	DOC (mgC/l)
4/15	E-1	2055	2827.8	8601.6	368	11	19.27	35.430	25.30	5.26	4.27	0.7	0.11	0.0	0.00	50.4	1.10
4/15	E-1	2055	2827.8	8601.6	368	25	19.58	36.070	25.71	5.40	4.35	0.7	0.09	0.0	0.00	28.5	1.16
4/15	E-1	2055	2827.8	8601.6	368	51	19.13	36.190	25.91	5.23	4.39	0.6	0.07	0.0	0.09	37.2	1.12
4/15	E-1	2055	2827.8	8601.6	368	75	18.49	36.237	26.12	4.91	4.43	1.2	0.16	1.1	0.03	20.1	0.97
4/15	E-1	2055	2827.8	8601.6	368	100	18.22	36.253	26.19	4.83	4.47	1.5	0.21	1.7	0.03	12.7	1.26
4/15	E-1	2055	2827.8	8601.6	368	125	17.74	36.273	26.33	3.96	4.47	3.0	0.39	5.8	0.03	6.7	0.87
4/15	E-1	2055	2827.8	8601.6	368	151	16.74	36.154	26.48	3.77	4.47	4.8	0.48	7.5	0.02	10.6	0.80
4/15	E-1	2055	2827.8	8601.6	368	176	16.00	36.091	26.60	3.15	4.47	6.2	0.69	11.4	0.02	12.9	0.83
4/15	E-1	2055	2827.8	8601.6	368	225	14.26	35.826	26.79	2.89	4.47	8.8	0.93	15.5	0.03	19.1	0.73
4/15	E-1	2055	2827.8	8601.6	368	274	12.07	35.475	26.96	2.75	4.46	11.6	1.18	20.2	0.02	14.4	0.69
4/15	E-1	2055	2827.8	8601.6	368	356	10.31	35.246	27.11	2.73	4.39	15.4	1.40	23.8	0.03	19.5	1.16
4/15	E-1	2055	2827.8	8601.6	368	360	10.23	34.246	27.12	2.71	4.39	15.4	1.41	24.4	0.02	19.9	0.86
4/16	E-2	2101	2816.5	8615.6	655	11	19.31	35.839	25.60	5.39	4.35	0.9	0.03	0.0	0.01	32.5	1.13
4/16	E-2	2101	2816.5	8615.6	655	20	19.32	35.838	25.60	5.15	4.35	1.2	0.02	0.8	0.28	35.6	1.01
4/16	E-2	2101	2816.5	8615.6	655	60	18.84	35.965	25.82	4.48	4.39	2.3	0.14	4.4	0.06	14.1	0.91
4/16	E-2	2101	2816.5	8615.6	655	100	18.08	36.241	26.22	3.66	4.47	4.6	0.33	10.1	0.06	10.1	0.86
4/16	E-2	2101	2816.5	8615.6	655	149	17.29	36.227	26.40	3.09	4.47	7.2	0.60	15.7	0.06	8.7	0.87
4/16	E-2	2101	2816.5	8615.6	655	200	15.50	36.001	26.65	2.87	4.47	9.0	0.84	19.1	0.04	9.2	0.74
4/16	E-2	2101	2816.5	8615.6	655	244	14.05	35.790	26.80	2.77	4.47	12.3	1.12	22.9	0.07	4.1	0.60
4/16	E-2	2101	2816.5	8615.6	655	300	11.85	35.444	26.98	2.73	4.47	16.3	1.36	26.4	0.07	11.3	0.64
4/16	E-2	2101	2816.5	8615.6	655	403	9.57	35.128	27.14	2.82	4.47	19.4	1.53	28.1	0.09	17.2	0.78
4/16	E-2	2101	2816.5	8615.6	655	498	8.55	35.006	27.21	2.93	4.47	22.9	1.65	28.9	0.11	18.5	0.66
4/16	E-2	2101	2816.5	8615.6	655	641	7.30	34.896	27.32	3.30	4.43	23.2	1.68	28.6	0.08	10.5	0.65
4/16	E-2	2101	2816.5	8615.6	655	651	7.29	34.896	27.32	2.98	4.43	23.0	1.66	28.5	0.11	25.8	0.74
4/17	E-3	0125	2809.5	8625.2	875	27	21.84	36.285	25.26	3.62	4.39	0.8	0.04	0.0	0.00	19.8	0.83
4/17	E-3	0125	2809.5	8625.2	875	51	19.98	36.322	25.79	3.71	4.39	1.8	0.11	2.6	0.20	18.4	1.04
4/17	E-3	0125	2809.5	8625.2	875	100	18.03	36.307	26.28	3.37	4.47	4.0	0.34	9.1	0.03	7.2	0.75
4/17	E-3	0125	2809.5	8625.2	875	150	16.29	36.141	26.58	3.02	4.47	5.5	0.56	13.1	0.01	7.3	0.60
4/17	E-3	0125	2809.5	8625.2	875	225	13.90	35.726	26.79	2.74	4.47	9.0	0.87	18.3	0.01	6.9	0.78
4/17	E-3	0125	2809.5	8625.2	875	300	11.74	35.405	26.97	2.79	4.47	12.3	1.15	22.4	0.01	4.2	0.66
4/17	E-3	0125	2809.5	8625.2	875	400	9.87	35.158	27.12	2.87	4.47	16.2	1.41	25.8	0.04	7.8	0.58
4/17	E-3	0125	2809.5	8625.2	875	500	8.43	34.988	27.22	3.01	4.47	19.9	1.50	27.8	0.04	8.3	0.65
4/17	E-3	0125	2809.5	8625.2	875	601	7.10	34.881	27.33	3.33	4.47	23.2	1.59	26.8	0.04	10.6	0.58
4/17	E-3	0125	2809.5	8625.2	875	727	6.05	34.859	27.46	3.58	4.47	24.9	1.54	26.4	0.04	16.2	0.58
4/17	E-3	0125	2809.5	8625.2	875	857	5.67	34.870	27.51	4.46	4.47	26.7	1.46	27.1	0.04	11.2	0.62
4/17	E-3	0125	2809.5	8625.2	875	867	5.65	34.871	27.52	5.00	4.47	24.8	1.42	26.9	0.04	5.9	0.64
4/17	E-4	1824	2804.2	8634.6	1420	51	18.98	35.940	25.76	5.23	4.33	1.0	0.00	0.2	0.12	26.6	0.98
4/17	E-4	1824	2804.2	8634.6	1420	100	17.86	36.300	26.32	3.68	4.46	3.6	0.24	10.1	0.03	2.7	0.84
4/17	E-4	1824	2804.2	8634.6	1420	174	15.65	36.033	26.64	2.66	4.47	5.8	0.41	16.0	0.02	7.4	0.62
4/17	E-4	1824	2804.2	8634.6	1420	275	12.69	35.570	26.91	2.90	4.47	10.0	0.77	23.4	0.03	6.6	0.67
4/17	E-4	1824	2804.2	8634.6	1420	400	9.93	35.171	27.12	2.70	4.47	15.0	1.18	29.2	0.01	6.6	0.67
4/17	E-4	1824	2804.2	8634.6	1420	573	7.63	34.919	27.29	2.89	4.47	20.6	1.43	32.4	0.02	4.3	0.62
4/17	E-4	1824	2804.2	8634.6	1420	775	5.79	34.864	27.49	3.63	4.47	24.5	1.40	31.1	0.02	1.8	0.59

TABLE 3-2
(cont'd)

DATE	MMS STATION #	TIME START	POSITION LAT	POSITION LONG	DEPTH PDR (m)	MEASURED DEPTH (m)	TEMP (°C)	SAL (o/oo)	SIGMA-t	DO (ml/l)	Trans (volts) (5v=100%)	SIO4 (uM)	PO4 (uM)	NO3 (uM)	NO2 (uM)	POC (ugC/l)	DOC (mgC/l)
4/17	E-4	1824	2804.2	8634.6	1420	901	5.26	34.886	27.58	4.16	4.47	25.1	1.34	29.5	0.02	6.1	0.68
4/17	E-4	1824	2804.2	8634.6	1420	1100	4.78	34.913	27.65	4.38	4.47	25.2	1.23	27.5	0.03	10.7	0.60
4/17	E-4	1824	2804.2	8634.6	1420	1299	4.41	34.931	27.71	4.68	4.47	24.6	1.12	25.7	0.03	3.9	0.58
4/17	E-4	1824	2804.2	8634.6	1420	1402	4.31	34.937	27.73	4.94	4.47	24.5	1.08	25.2	0.03	3.9	0.56
4/17	E-4	1824	2804.2	8634.6	1420	1415	4.31	34.937	27.73	4.71	4.47	24.1	1.06	25.7	0.03	4.3	0.64
4/18	E-5	1047	2801.4	8638.3	2990	26	20.34	36.112	25.54	5.19	4.29	0.7	0.00	0.1	0.00	28.2	0.90
4/18	E-5	1047	2801.4	8638.3	2990	100	17.91	36.205	26.23	4.34	4.43	2.6	0.07	6.5	0.02	12.5	0.82
4/18	E-5	1047	2801.4	8638.3	2990	200	14.69	35.892	26.74	3.09	4.47	6.9	0.52	17.9	0.01	4.0	0.80
4/18	E-5	1047	2801.4	8638.3	2990	400	9.81	35.153	27.12	2.73	4.47	15.1	1.10	28.5	0.01	12.1	0.67
4/18	E-5	1047	2801.4	8638.3	2990	600	7.23	34.888	27.32	2.99	4.47	22.2	1.44	32.1	0.01	1.7	0.85
4/18	E-5	1047	2801.4	8638.3	2990	900	5.11	34.895	27.60	4.01	4.47	26.0	1.34	28.7	0.01		0.53
4/18	E-5	1047	2801.4	8638.3	2990	1300	4.33	34.938	27.73	4.81	4.47	25.4	1.18	24.8	0.01		0.58
4/18	E-5	1047	2801.4	8638.3	2990	1700	4.25	34.944	27.74	4.97	4.47	25.1	1.10	23.9	0.02	8.2	0.72
4/18	E-5	1047	2801.4	8638.3	2990	2100	4.25	34.947	27.74	4.97	4.47	24.8	1.10	23.3	0.01	2.9	0.75
4/18	E-5	1047	2801.4	8638.3	2990	2499	4.27	34.948	27.74	4.98	4.49	24.7	1.10	22.8	0.01	1.4	0.63
4/18	E-5	1047	2801.4	8638.3	2990	2976	4.30	34.951	27.74	5.10	4.47	25.1	1.07	22.3	0.01	3.7	0.83
4/18	E-5	1047	2801.4	8638.3	2990	2986	4.30	34.951	27.74	4.77	4.47	23.2	1.02	22.8	0.01	14.2	1.41

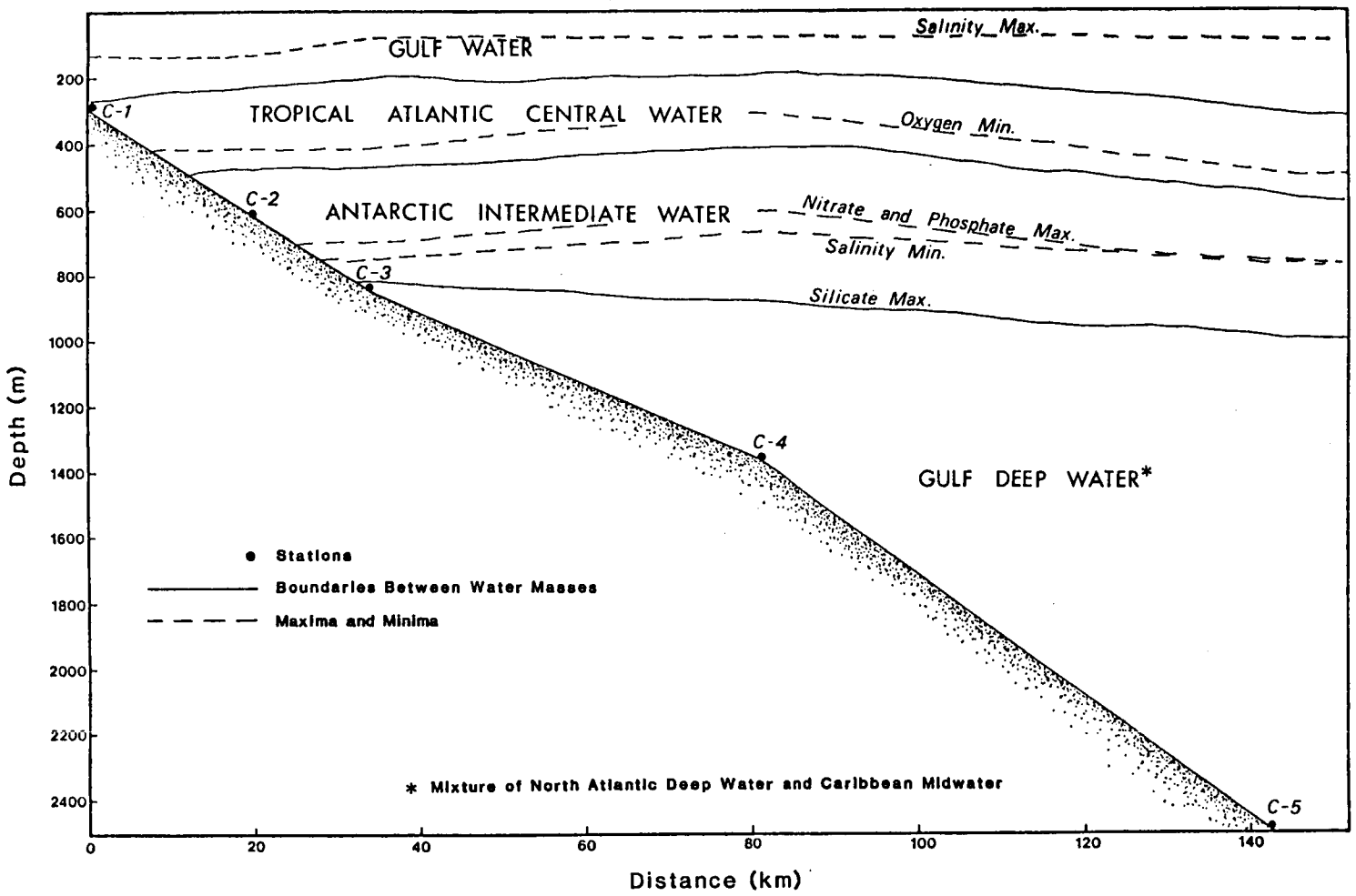


Figure 3-1. Water masses along the Central Transect during Cruise I. A similar distribution was observed for Cruise II.

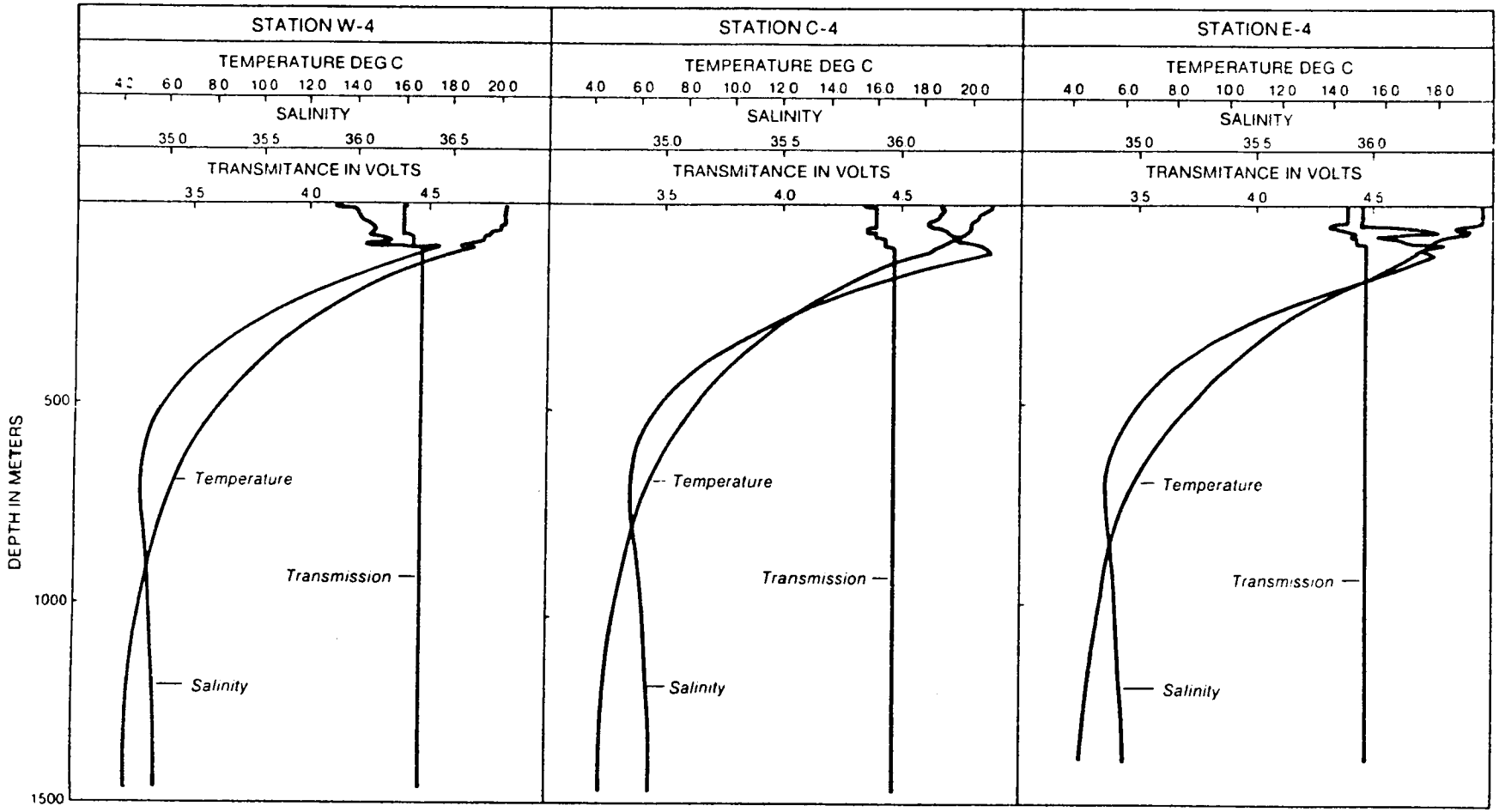


Figure 3-2. Vertical distribution of temperature, salinity, and light transmission at stations on the West, Central and East Transects during Cruise II.

TABLE 3-3

Sediment characteristics of Cruise I stations. Station 7 was an NSF station sampled on the same cruise.

DATE	STATION#	DEPTH (m)	BOXCORE CAST	REP #	POSITION LAT	LONG	FRACTIONS SAND %	SILT %	CLAY %	MEANS ARITHM	MEANS GEOMTRIC	STATISTICAL PARAMETER KURTOSIS	STATISTICAL PARAMETER SKEWNESS	ORG C %	CaCO3 %	DEL 13-C	WATER %
11/26/83	C-1	320	1	1	2803.7	9014.1	5.0	16.0	79.0					0.88	3.1	-21.6	59.4
11/26/83	C-1	320	1	2	2803.7	9014.1	3.7	17.6	78.7	9.3	9.0	6.8	-1.8	0.75	2.7	-21.7	64.9
11/26/83	C-1	420	2	1	2803.2	9015.2	2.0	16.0	82.0					0.90	1.4	-21.7	60.9
11/26/83	C-1	420	2	2	2803.2	9015.2	2.0	16.0	82.0					0.70	1.9	-21.8	61.3
11/26/83	C-1	356	3	1	2803.4	9015.3	1.0	16.0	83.0					0.81	2.4	-21.5	63.1
11/26/83	C-1	355	3	2	2803.2	9015.2	2.0	15.0	83.0					0.63	2.2	-21.7	69.1
11/26/83	C-2	615	1	1	2754.3	9005.9	4.5	16.4	79.1	9.3	9.0	7.1	-2.0	0.59	4.6	-21.5	59.3
11/26/83	C-2	615	1	2	2754.3	9005.9	4.0	17.0	79.0					0.47	5.5	-21.8	64.1
11/26/83	C-2	603	2	1	2754.4	9006.0	5.4	16.1	78.6	9.3	8.9	6.7	-2.0	0.25	3.3	-21.9	58.
11/26/83	C-2	603	2	2	2754.4	9006.0	6.0	16.0	78.0					0.41	4.0	-22.2	64.4
11/26/83	C-2	610	3	1	2754.3	9006.1	4.8	17.1	78.1	9.3	8.9	7.1	-2.0	0.45	6.1	-20.2	59.7
11/26/83	C-2	610	3	2	2754.3	9006.1	7.4	15.8	76.9	9.1	8.7	6.3	-1.9			-20.4	61.8
11/26/83	C-2	632	4	1	2754.3	9006.0	6.2	15.1	78.7	9.2	8.8	6.4	-1.9	0.30	4.9	-20.8	59.6
11/27/83	C-3	845	1	1	2749.2	9007.2	3.0	16.0	81.0					0.46	3.9	-21.6	56.3
11/27/83	C-3	858	2	2	2749.2	9007.0	3.0	14.0	83.0					0.38	3.6	-21.6	58.5
11/30/83	C-3a	853	1	1	2749.3	9007.0	3.0	17.0	80.0					0.48	3.0	-21.2	65.7
11/30/83	C-3a	853	1	2	2749.3	9007.0	3.0	18.0	79.0					0.62	3.0	-21.4	66.1
11/30/83	C-3a	853	2	1	2749.6	9006.8	2.0	16.0	83.0					0.58	5.0	-21.7	62.6
11/30/83	C-3a	853	2	2	2749.6	9006.8	2.0	17.0	81.0					0.31	4.6	-21.4	65.8
11/29/83	C-4	1440	1	1	2728.3	8947.1	9.9	19.1	71.1	8.8	8.2	5.6	-1.7	0.22	7.6	-21.4	61.8
11/29/83	C-4	1440	1	2	2728.3	8947.1	8.3	19.4	72.3	8.9	8.3	5.7	-1.7	0.11	4.8	-21.8	59.1
11/30/83	C-4	1378	2	1	2729.1	8946.4	24.6	15.8	59.6	7.3	6.1	2.5	-0.5	0.09	9.6	-20.9	55.6
11/30/83	C-4	1378	2	2	2729.1	8946.4	19.6	17.0	63.4	8.5	7.4	4.1	-1.5	0.01	9.5	-21.1	53.5
11/30/83	C-4	1325	3	1	2729.5	8945.6	40.2	11.5	48.4	7.3	5.2	1.9	-0.8	0.60	7.6	-20.7	53.4
11/30/83	C-4	1325	3	2	2729.5	8945.6	37.1	12.7	50.2	7.5	5.6	2.0	-0.8	0.01	10.1	-20.0	53.0
11/28/83	C-5	2470	1	1	2658.2	8931.9	3.0	26.0	71.0					0.39	4.0	-22.3	63.8
11/28/83	C-5	2490	2	1	2657.8	8931.0	3.0	26.0	71.0					0.50	6.6	-22.7	62.4
11/28/83	C-5	2490	2	2	2657.8	8931.0	3.0	25.0	72.0					0.38		-22.8	57.4
11/28/83	C-5	2467	3	1	2658.0	8931.8	3.0	27.0	70.0					0.37	9.4	-21.5	58.1
11/28/83	C-5	2467	3	2	2658.0	8931.8	3.0	26.0	71.0					0.26	7.0	-21.6	59.7
11/28/83	C-5	2468	4	2	2659.4	8932.6	5.3	26.9	67.8	8.9	8.4	4.1	-1.3	0.32	7.1	-22.6	56.7
11/25/83	7	570	1	1	2746.9	9130.2	1.0	16.0	83.0					0.41	1.9	-21.4	61.1
11/25/83	7	570	1	2	2746.9	9130.2								0.55	3.0	-22.4	69.3

TABLE 3-4

Sediment characteristics of Cruise II stations.

STN #	DEPTH (m)	BOXCORE CAST	BOXCORE REP #	POSITON LAT	POSITON LONG	**** FRACTION **** SAND %	SILT %	CLAY %	---- MEANS --- ARITHM	GEOMTRIC	STATISTICAL PARAMETER KURTOSIS	SKEWNESS	ORG C %	CaCO3 %	WATER %
W1	385	1	2	2735.0	9333.1	37.1	21.2	41.7	6.8	5.5	1.8	-0.5	0.60	40	47.0
W1	385	1	1	2735.0	9333.1	38.3	14.8	46.9	7.0	5.6	1.7	-0.5	0.63	33	50.3
W1	344	2	1	2735.2	9333.0	34.4	20.5	45.1	7.1	5.9	1.8	-0.5	0.64	27	49.2
W2	605	1	1	2724.9	9320.5	18.1	12.1	69.8	8.6	7.6	4.8	-1.7	0.72	35	55.9
W2	603	2	1	2724.9	9320.4	20.5	18.1	61.4	8.0	6.8	2.5	-1.0	0.62	36	53.7
W2	603	3	1	2724.9	9320.5	21.7	17.8	60.5	7.9	6.9	3.3	-1.2	0.64	34	53.5
W3	860	1	1	2710.6	9319.4	9.0	22.3	68.8	8.4	7.9	6.3	-1.7	0.57	26	59.4
W3	860	1	2	2710.6	9319.4	9.4	18.2	72.4	8.6	8.1	7.3	-2.0	0.58	31	57.0
W3	841	2	2	2710.3	9319.3	15.3	16.3	68.5	8.6	7.6	4.9	-1.7	0.63	37	57.8
W4	1419	1	1	2644.1	9319.1	9.4	22.1	68.5	8.1	7.6	7.2	-1.9	0.61	34	57.4
W4	1405	2	2	2644.3	9319.1	12.4	16.5	71.2	8.1	7.4	7.8	-2.2	0.50	31	55.6
W4	1405	2	1	2644.3	9319.1	10.5	15.1	74.5	8.1	7.5	7.3	-2.0	0.47	37	50.6
W5	2652	1	2	2617.0	9319.3	37.6	13.8	48.6	6.9	5.2	1.9	-0.7	0.40	43	48.4
W5	2524	1	1	2617.0	9319.3	27.7	14.9	57.4	7.2	5.9	2.9	-1.1	0.36	41	49.5
W5	2470	2	1	2617.2	9319.2	28.3	18.7	53.0	7.4	6.1	3.1	-1.1	0.38	46	52.9
C1	358	1	1	2803.3	9015.2	1.3	22.6	76.2	9.2	9.0	5.8	-1.5	0.93	8	60.2
C1	357	2	1	2803.3	9015.2	1.7	20.2	78.1	9.2	9.0	6.1	-1.6	0.92	10	60.2
C1	357	2	2	2803.3	9015.2	1.4	19.5	79.2	9.2	9.0	5.4	-1.5	0.92	10	57.3
C1	358	3	1	2803.3	9015.3	2.3	25.2	72.5	9.0	8.7	5.9	-1.5	0.96	8	61.1
C1	348	3	2	2803.3	9015.3	1.0	22.1	76.9	9.1	8.9	4.7	-1.3	0.92	5	62.4
C1	348	4	1	2803.3	9015.6	1.2	18.8	80.0	9.3	9.1	6.1	-1.6	0.87	8	63.1
C2	595	1	1	2754.4	9006.2	8.6	17.2	74.2	8.9	8.3	6.6	-1.9	0.63	42	56.8
C2	595	1	2	2754.4	9006.2	13.1	20.1	66.8	8.5	7.7	5.1	-1.6	0.79	35	58.9
C2	595	2	2	2754.5	9006.2	15.8	19.1	65.1	8.6	7.9	4.6	-1.5	0.84	16	56.6
C2	595	2	1	2754.5	9006.2	11.2	22.2	66.7	8.6	7.9	5.3	-1.6	0.78	19	54.6
C2	605	3	1	2754.3	9005.9	5.8	19.5	74.7	9.0	8.6	6.6	-1.8	0.88	16	59.4
C2	605	3	2	2754.3	9005.9	6.7	19.5	73.6	8.9	8.4	6.0	-1.7	0.85	17	55.5
C3	834	1	1	2749.2	9007.1	2.7	21.6	75.7	9.1	8.8	5.9	-1.6	0.78	12	55.8
C3	834	1	2	2749.2	9007.1	15.9	23.5	60.5	8.3	7.6	4.1	-1.3	0.79	14	56.9
C3	840	2	2	2749.4	9007.0	25.5	21.5	53.0	7.5	6.1	3.2	-1.2	0.80	14	59.3
C3	840	2	1	2749.4	9007.0	2.6	22.7	74.7	9.1	8.8	6.0	-1.5	0.80	13	60.7
C3	841	3	2	2749.6	9007.1	2.7	25.9	71.4	9.0	8.7	6.2	-1.5	0.76	12	60.3
C3	841	3	1	2749.6	9007.1	2.6	27.5	69.9	8.8	8.5	5.9	-1.4	0.90	13	63.4
C4	1390	1	2	2728.4	8946.8	15.6	16.2	68.3	8.3	7.5	6.3	-1.9	0.56	41	59.2
C4	1390	1	1	2728.4	8946.8	13.1	17.7	69.2	8.1	7.5	7.4	-2.0	0.48	28	59.5
C4	1394	2	1	2728.3	8947.0	9.2	17.6	73.3	8.4	7.9	7.4	-1.9	0.54	24	57.9

TABLE 3-4
(cont'd)

STN #	DEPTH (m)	BOXCORE CAST	REP #	POSITON LAT	POSITON LONG	**** FRACTION **** SAND %	SILT %	CLAY %	---- MEANS --- ARITHM	GEOMTRIC	STATISTICAL PARAMETER KURTOSIS	SKEWNESS	ORG C %	CaCO3 %	WATER %
C4	1394	2	2	2728.3	8947.0	14.0	26.3	59.7	8.4	7.6	5.3	-1.6	0.66	23	57.3
C4	1386	3	1	2728.4	8946.9	12.5	20.4	67.0	8.6	7.7	5.9	-1.8	0.61	23	57.4
C4	1386	3	2	2728.4	8946.9	16.0	24.4	59.6	8.1	7.1	4.0	-1.3	0.52	26	57.6
C5	2377	1	1	2656.9	8936.2	10.1	39.3	50.7	7.5	6.8	6.5	-1.8	0.63	22	57.6
C5	2400	2	2	2657.7	8934.2	11.7	28.0	60.4	8.3	7.7	3.5	-1.1	0.83	19	54.8
C5	2400	2	1	2657.7	8934.2	7.1	27.0	65.9	8.6	9.2	4.8	-1.4	0.76	26	57.1
C5	2377	3	2	2657.9	8935.1	11.5	25.0	63.5	8.2	7.6	4.6	-1.4	0.69	25	58.6
C5	2377	3	1	2657.9	8935.1	9.9	30.7	59.4	8.0	7.4	5.1	-1.4	0.72	26	59.7
C5	2400	4	1	2657.6	8935.1	5.4	32.2	62.4	8.5	8.1	3.8	-1.0	0.56	27	60.7
E1	347	1	1	2827.7	8601.0	36.3	34.2	29.5	6.2	5.1	1.9	-0.2	0.62	59	55.2
E1	357	2	1	2827.6	8601.8	35.8	25.9	38.3	6.7	5.6	1.8	-0.3	0.59	100	54.9
E1	357	2	2	2827.6	8601.8	39.2	33.0	27.7	6.0	4.9	1.9	-0.1	0.65	63	55.5
E2	625	2	2	2816.7	8615.1	30.9	27.8	41.3	6.8	5.6	2.3	-0.7	0.57	62	55.8
E2	625	2	1	2816.7	8615.1	29.4	22.5	48.1	7.1	5.9	2.5	-0.8	0.47	69	57.8
E2	630	4	1	2816.6	8615.2	27.2	19.1	53.7	7.3	6.2	2.7	-1.0	0.46	100	54.6
E3	845	1	1	2809.6	8625.0	27.2	43.7	29.1	6.9	6.1	3.3	-1.0	0.45	62	56.8
E3	845	1	2	2809.6	8625.0	34.3	25.2	40.5	6.9	5.9	2.5	-0.8	0.44	70	60.4
E3	847	2	1	2809.5	8625.2	26.1	26.5	47.5	7.2	6.0	3.1	-1.1	0.43	74	58.7
E4	1330	1	1	2804.3	8634.4	31.3	22.3	46.4	7.1	6.1	3.3	-1.2	0.45	98	58.3
E4	1410	3	1	2804.3	8634.8	30.4	16.9	52.8	7.3	6.0	2.4	-0.8	0.32	99	57.1
E4	1335	2	1	2804.1	8634.4	31.3	22.3	46.4	7.0	6.0	2.7	-0.9			59.5
E4	1358	4	1	2804.4	8634.8	27.6	23.4	49.1	7.3	6.1	2.5	-0.8	0.43	60	59.1
E4	1358	4	2	2804.4	8634.8	26.5	24.4	49.1	7.2	6.4	3.4	-1.1	0.36	62	56.5
E5	2853	1	1	2800.4	8638.8	23.3	20.2	56.5	7.4	6.3	3.7	-1.3	0.47	80	54.5
E5	2853	1	2	2800.4	8638.8	22.7	17.8	59.5	7.6	6.4	3.8	-1.4	0.65	41	59.9
E5	2800	2	2	2800.5	8638.9	23.8	14.8	61.4	7.7	6.8	4.8	-1.6	0.71	53	59.2
E5	2800	2	1	2800.5	8638.9	24.0	16.4	59.6	7.6	6.3	3.5	-1.3	0.41	89	58.5

3.2.1 Sediment Texture

Summaries of sediment grain size are shown in Figure 3-3 (Cruise I) and Figure 3-4 (Cruise II). On Cruise I, bottom sediments collected at Stations C1, C2, and C3 were all comprised of clay-sized particles grading to sandy and/or silty clays at Stations C4 and C5. On Cruise II, five of the six samples collected at Station C1 were once more classified as clay, but at Stations C2 and C3 either all or most of the replicates were silty clays. Sediments taken at the deeper stations on the Central Transect (C4, C5) during Cruise II were again dominated by silty clays. Whether the differences in grain size composition observed for Stations C2 and C3 between cruises represents a seasonal affect or one of spatial variability is unknown. Based upon other data presented below, the former is more likely.

On the Western Transect, sediments at Stations W1 and W2 graded from sand-silt-clay mixtures at W1 to sandy clays at Station W2. Silty clay predominated at both of Stations W3 and W4; but at Station W5, sediments were all sandy clay. On the Eastern Transects, sand-silt-clay mixtures were predominant at each of Stations E1 through E4. At the deepest Station, E5, two of the samples were comprised of sandy clay and one was sand-silt-clay. Sediments on both the Eastern and Western Transects, particularly the former, contained a higher proportion of sand-sized particles than was found on the Central Transect.

3.2.2 Organic Carbon

Mean organic carbon levels in the bottom sediments by cruise, transect and station are depicted in Figure 3-5. Levels of organic carbon in the sediments on the Central Transect were higher on Cruise II (April 1984) than on Cruise I (November 1983) with the degree of difference being least for Station C1. In general, organic carbon levels were slightly higher at the most shoreward stations along the transects, highest on the Central Transect at all sampling depths, and lowest on the East Transect at all sampling depths, except at the deepest station (e.g., compare W5 and E5 levels, Fig. 3-5). The lower organic carbon levels on the East

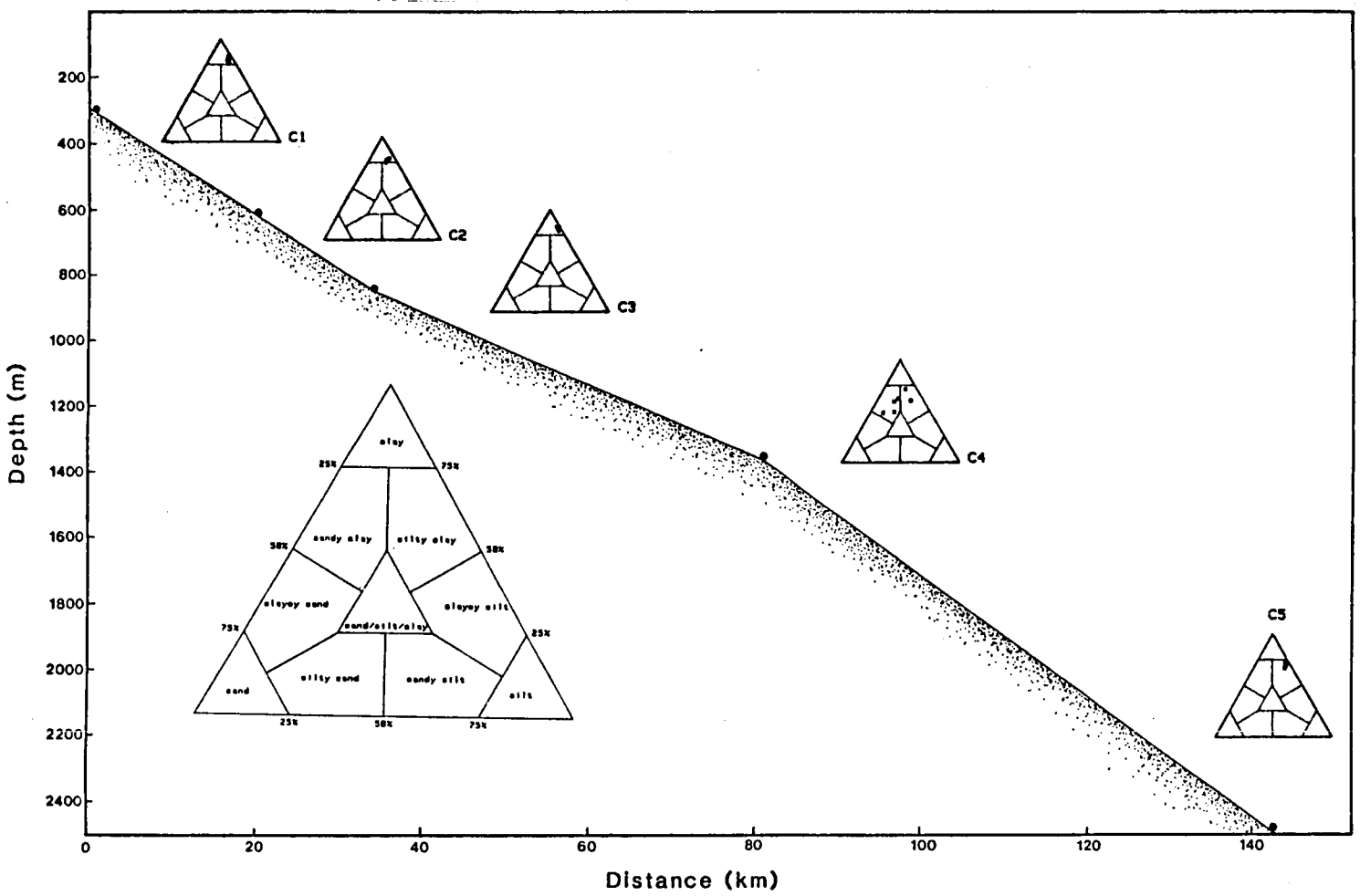


Figure 3-3. Sediment grain sizes at Cruise I sampling stations.

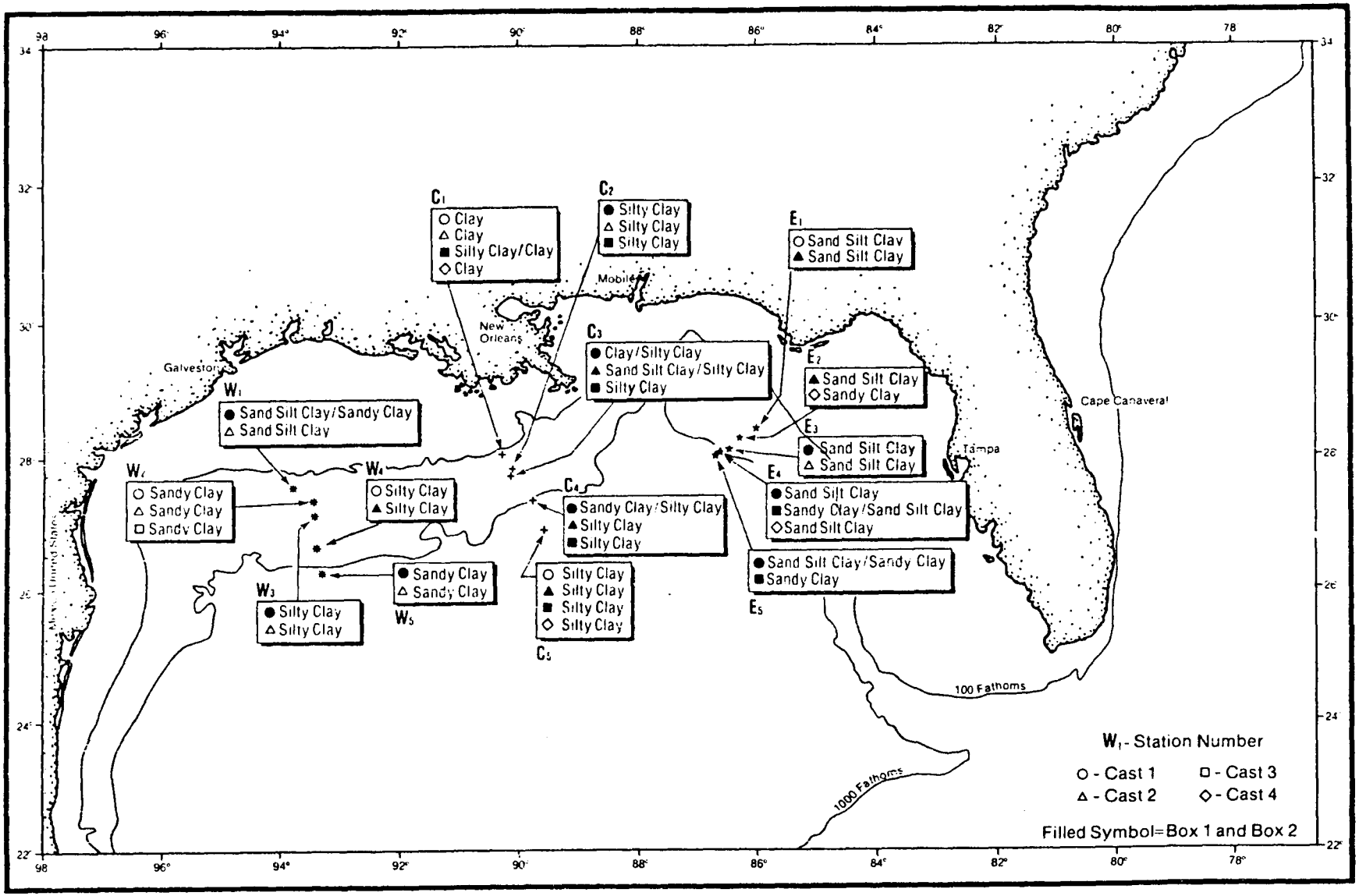


Figure 3-4. Grain size types (after Folk, 1974) at Cruise II stations.

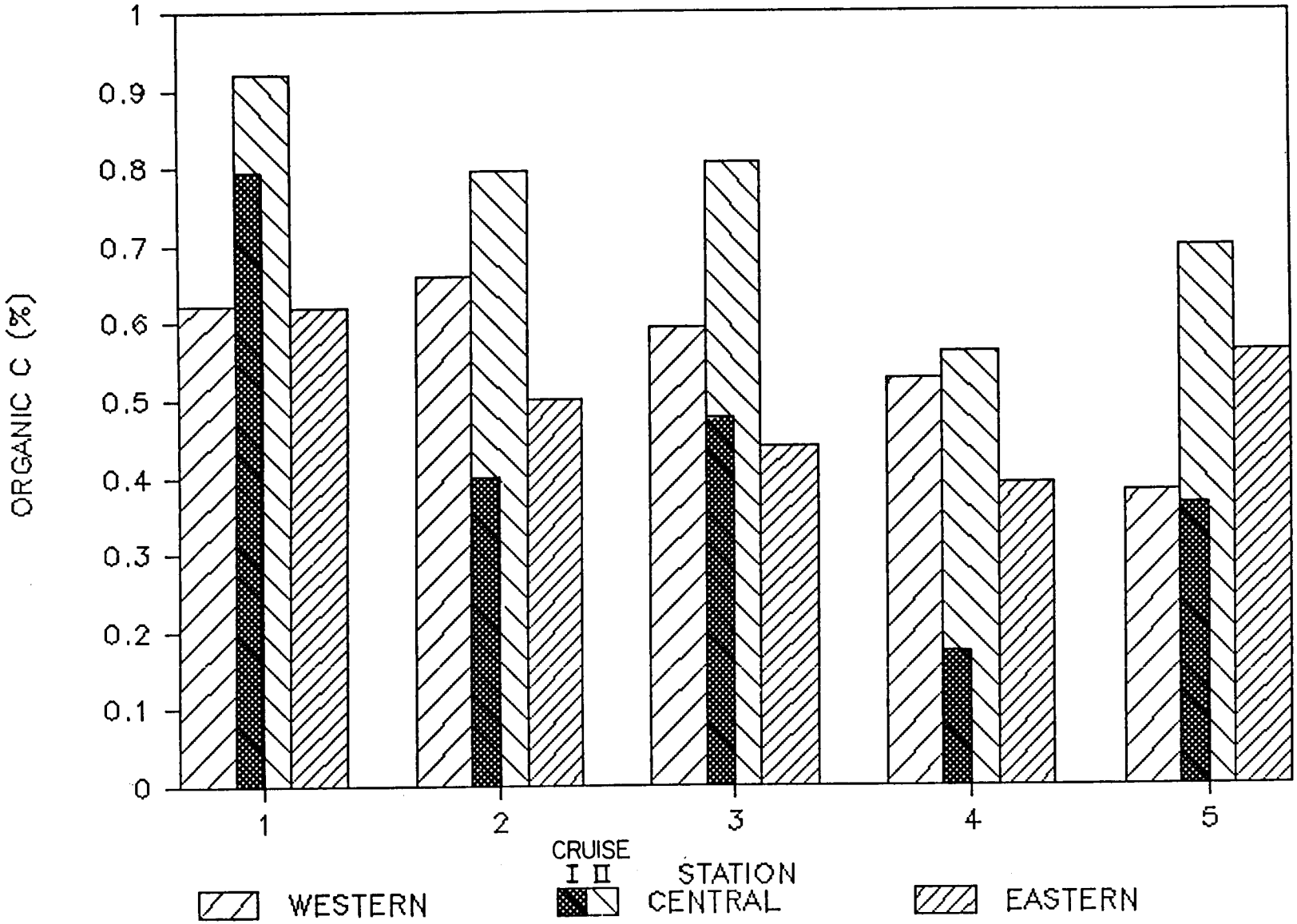


Figure 3-5. **Average percent organic carbon for stations along the West, Central, and East Transects,** Cruises I and II.

Transect were associated with higher percent sand/silt and carbonate-containing sediments.

3.2.3 Calcium Carbonate

Calcium carbonate levels in sediments at stations along the Central Transect were lower in the samples taken in November 1983 than in samples obtained from the same areas during April 1984 (Fig. 3-6). Central Transect levels were lowest of the three areas sampled, Western Transect levels were intermediate and the Eastern Transect was characterized by sediments of high carbonate content.

3.3 CARBON ISOTOPE ANALYSES

Results of these analyses are available for Cruise I sediments (see Table 3-3) and selected organisms collected during Cruise II (Table 3-5). The sediment organic carbon values observed for Cruise I are characteristic of planktonic-algae-derived organic carbon, and there are no discernable trends with regards to depth or distance from shore.

Table 3-5 shows the carbon isotopic values of organisms collected from the Gulf of Mexico slope during Cruise II. The organisms from the seep areas were not collected as part of this study but are presented here for comparison. All but one organism from the non-seep areas (our study) have values that are characteristic of deep-sea organisms that derive their energy from sinking photosynthetic carbon. In the hydrocarbon seep regions on the Louisiana slope, carbon isotopic analysis of freeze dried mantle and foot tissue of bivalves from a trawl had $o^{13}C$ values of -31 to -35 ppt. This indicates that the food source of these organisms came from chemosynthesis, and not from terrestrial or marine photosynthetic organic carbon. These isotopic values provide supporting evidence that the food source of the bivalves are sulfur or hydrocarbon oxidizing bacteria in a hydrocarbon/sulfide-rich environment. The bivalves smelled strongly of hydrogen sulfide during dissection. Bacterial biomass could also be enhanced by heterotrophic, hydrocarbon degrading bacteria. The vestimentiferan worms and their tubes collected in a seep area have $o^{13}C$ values of -27 and -28 ppt, respectively. In comparison, tube worms

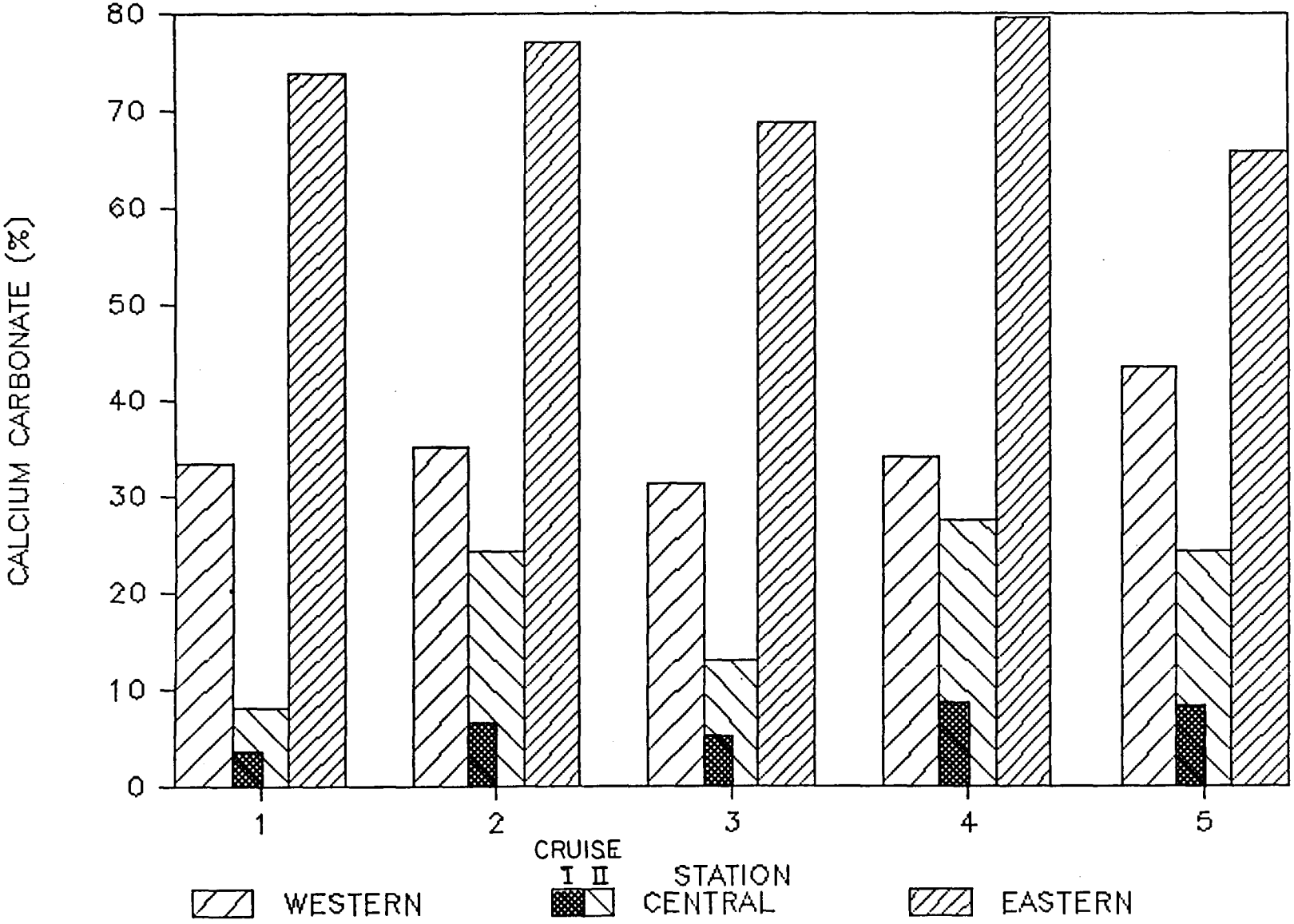


Figure 3-6. Average percent calcium carbonate for stations along the West, Central, and East Transects.

TABLE 3-5

Carbon isotopic values($\delta^{13}C$ in $^{o}/_{oo}$ relative to PDB) for organisms obtained from trawls on the Gulf of Mexico continental slope.

Organism	Description	Station	Depth[1]	$\delta^{13}C$	Position		Comment
Geryon quinquedens	crab	E-1	390	-17.2	28°24'N	85°58'W	
Bembrops gobioides	fish	E-1	390	-17.8	28°24'N	85°58'W	
Synaphobranchus brevidorsalis	eel	E-3	840	-18.1	28°11'N	86°26'W	
Geryon quinquedens	crab	E-3	840	-23.1	28°11'N	86°26'W	
Synaphobranchus brevidorsalis	fish	E-4	1225	-19.2	28°07'N	86°36'W	
Bathypterois guadrifilis	fish	E-4	1225	-18.6	28°07'N	86°36'W	
Synaphobranchus oregoni	eel	E-4	1225	-19.5	28°07'N	86°36'W	
Nematocarcinus rotundus	shrimp	E-4	1225	-18.2	28°07'N	86°36'W	
Acanthephyra eximia	shrimp	E-4	1225	-18.3	28°07'N	86°36'W	
Geryon quinquedens	crab	E-4	1225	-19.3	28°07'N	86°36'W	
Synaphobranchus oregoni	fish	C-1	347	-19.6	28°03'N	90°15'W	
Geryon quinquedens	crab	C-4	1390	-17.4	27°28'N	89°44'W	
Bathygadus macrops	fish	W-2	550	-17.5	27°25'N	93°19'W	
Monomitopus sp.	fish	W-3	791	-18.1	27°08'N	93°24'W	
Dicrolene sp.	fish	W-3	791	-18.3	27°08'N	93°24'W	
Halosaurus guentheri	fish	W-3	791	-17.5	27°08'N	93°24'W	
Stereomastis sculpta	shrimp	W-4	1390	-17.0	26°44'N	93°19'W	
Calyptogena ponderosa (2 specimens)	clam	GC-272	600	-35.4 -35.3	27°40'N	91°32'W	Seep area
Lucinoma atlantis (2 specimens)	clam	GC-272	600	-31.2 -33.0	27°40'N	91°32'W	Seep area
Unidentified neogastropod	snail	GC-272	600	-31.5	27°40'N	91°32'W	Seep area
Lamellibrachia sp.	tubeworm flesh	43	600	-27.0	27°45'N	91°14'W	Seep area
Lamellibrachia sp.	tube worm	43	600	-28.1	27°45'N	91°14'W	Seep area
Nezumia aequalis	fish[2]	GC-272	600	-17.6	27°40'N	91°32'W	Seep area
Monomitopus sp.	fish	GC-272	600	-17.9	27°40'N	91°32'W	Seep area
Chaunax pictus	fish	GC-272	600	-17.9	27°40'N	91°32'W	Seep area
Coryphaenoides colon	fish	43	600	-17.2	27°45'N	91°14'W	Seep area

[1]Depths are approximate since many areas of the slope are steep.
[2]Fish were not necessarily collected in the immediate vicinity of the seeps. They could have been collected at other areas during the trawl.

(Riftia pachyptila) sampled from the Galapagos Rift had considerably heavier isotopic values (-11 ppt, Rau 1981). One explanation for these heavier isotopic values is that symbiotic chemosynthesis limits the supply of CO_2 thus reducing isotopic fractionation. The oil seep tube worms must also have a mechanism of carbon assimilation that reduces isotopic fractionation relative to the bivalves.

An interesting observation in Table 3-5, is the isotopically light (-23.1 ppt) value obtained from a crab at Station E3. This value (analyzed in duplicate) is considerably lighter than any of the other non-seep organisms. It is possible that this may represent a contribution of chemosynthetic carbon at this station. In any case, this organism was composed of carbon produced from a source other than marine algae.

3.4 HYDROCARBON ANALYSES

3.4.1 Sediments

Central Transect -Cruise I

Gravimetrically determined aliphatic and aromatic hydrocarbon concentrations ranged from 9.4 to 49.8 and 3.3 to 11.5 ppm (Table 3-6). Hydrocarbon concentrations at Stations C2 to C5 were similar and were highest at the shallowest station (C1). The gas chromatographically derived unresolved complex mixture (UCM) ranged from 19.3 to 29.8 ppm. The UCM accounted for 67 to 100% of the aliphatic hydrocarbons. The remainder is accounted for by resolved normal and isoprenoid alkanes. The UCM had a bimodal distribution. The UCM centered at ~n-C_{28} was generally dominant over the lower molecular weight UCM by a factor of 2.5 to 6.7 (Table 3-6).

Molecular level hydrocarbon distributions are consistent with mixed biogenic (predominantly terrestrial) and thermogenic sources (Fig. 3-7). A biogenic terrestrial source is suggested by the strong odd carbon preference in the C_{23} to C_{32} normal alkanes (i.e., CPI = 2.4 to 3.6). The complete suite of normal alkanes that is seen suggests the presence of low level thermogenic compounds. N-C_{15}, n-C_{17}, and pristane can result from a thermogenic and/or planktonic source. Hydrocarbon concentrations in the

TABLE 3-6

Summary of selected hydrocarbon parameters during Cruises I and II at the Central Transect [Ali-aliphatic; Aro-aromatic; UCM-unresolved complex mixture; $<C_{23}$-UCM $<n\text{-}C_{23}$; $>C_{23}$-UCM $>n\text{-}C_{23}$; % n-alkanes = 100 x Σ n-alkanes/(UCM + Σn-alkanes); % UCM = (Total UCM/Ali) x 100; Ave-average of replicate box cores, Std. ± 1σ]

STA		EXTRACTABLE ORGANIC MATTER (ppm) ALI.	ARO.	TOTAL	ALIPHATIC UCM (ppm) <C23	>C23	TOTAL	% N-ALKANES	% UCM
CRUISE I									
C1	AVE.	49.8	11.5	61.4	5.7	24.1	29.8	5.7	67.4
	STD.	23.7	4.7		2.5	9.4			
C2	AVE.	23.4	4.3	27.7	2.5	16.8	19.3	6.3	82.5
	STD.	16.7	2.2		0.8	10.2			
C3	AVE.	10.7	5.5	16.2	4.6	19.2	23.8	5.9	100.0
	STD.	4.7	4.3		3.9	6.4			
C4	AVE.	9.4	4.5	13.9	4.4	19.9	24.3	5.1	100.0
	STD.	4.7	1.8		2.2	12.6			
C5	AVE.	19.6	3.3	22.8	5.5	13.9	19.4	9.8	98.9
	STD.	10.9	1.6		3.5	7.7			
CRUISE 2									
C1	AVE.	21.3	1.5	22.8	3.0	4.3	7.4	19.6	34.7
	STD.	4.1	0.9		1.5	3.7			
C2	AVE.	18.0	1.1	19.1	4.0	4.5	8.5	17.5	47.2
	STD.	4.7	0.4		3.8	3.5			
C3	AVE.	16.1	1.9	18.0	2.3	6.4	8.7	16.5	54.0
	STD.	2.2	0.8		1.1	2.2			
C4	AVE.	23.0	2.9	25.8	5.7	8.3	14.0	10.8	60.9
	STD.	13.0	1.5		1.9	2.2			
C5	AVE.	19.4	3.2	22.6	2.0	4.1	6.0	21.1	30.9
	STD.	2.2	0.7		0.7	2.3			

STA	CPI	TOT ALK	SUM ALK	% PRIS+PHYT	PRIS/ N-C18	PRIS/ N-C17	PRIS/ PHYT	UCM<C23/ UCM>C23
CRUISE I								
C1	3.2	1806.7	1755.4	2.9	0.9	1.1	1.0	4.2
C2	3.5	1308.2	1270.5	3.0	1.0	1.1	1.3	6.7
C3	3.5	1603.4	1546.4	3.7	1.3	1.2	1.7	4.2
C4	3.3	1318.7	1284.4	2.7	0.9	1.0	0.9	4.5
C5	2.4	2090.1	2020.3	3.5	1.2	1.2	1.3	2.5
CRUISE II								
C1	4.3	1797.3	1699.1	5.8	1.2	1.7	1.7	1.4
C2	4.3	1756.4	1573.5	11.6	1.1	1.7	1.1	1.1
C3	4.5	1719.2	1622.0	6.0	0.9	1.6	0.9	2.7
C4	3.6	1662.5	1548.3	7.4	0.8	0.9	0.9	1.5
C5	3.4	1593.7	1537.1	3.7	0.6	0.5	0.7	2.1

[CPI = carbon preference index from $n\text{-}C_{23}$ to $n\text{-}C_{32}$; Tot. Alk - resolved n-alkanes plus pristane and phytane; Sum Alk - Σ n-Alkanes; Pris - Pristane; Phyt-phytane; % Pris+Phyt - pris+phyt/(Totl Alk x 100)].

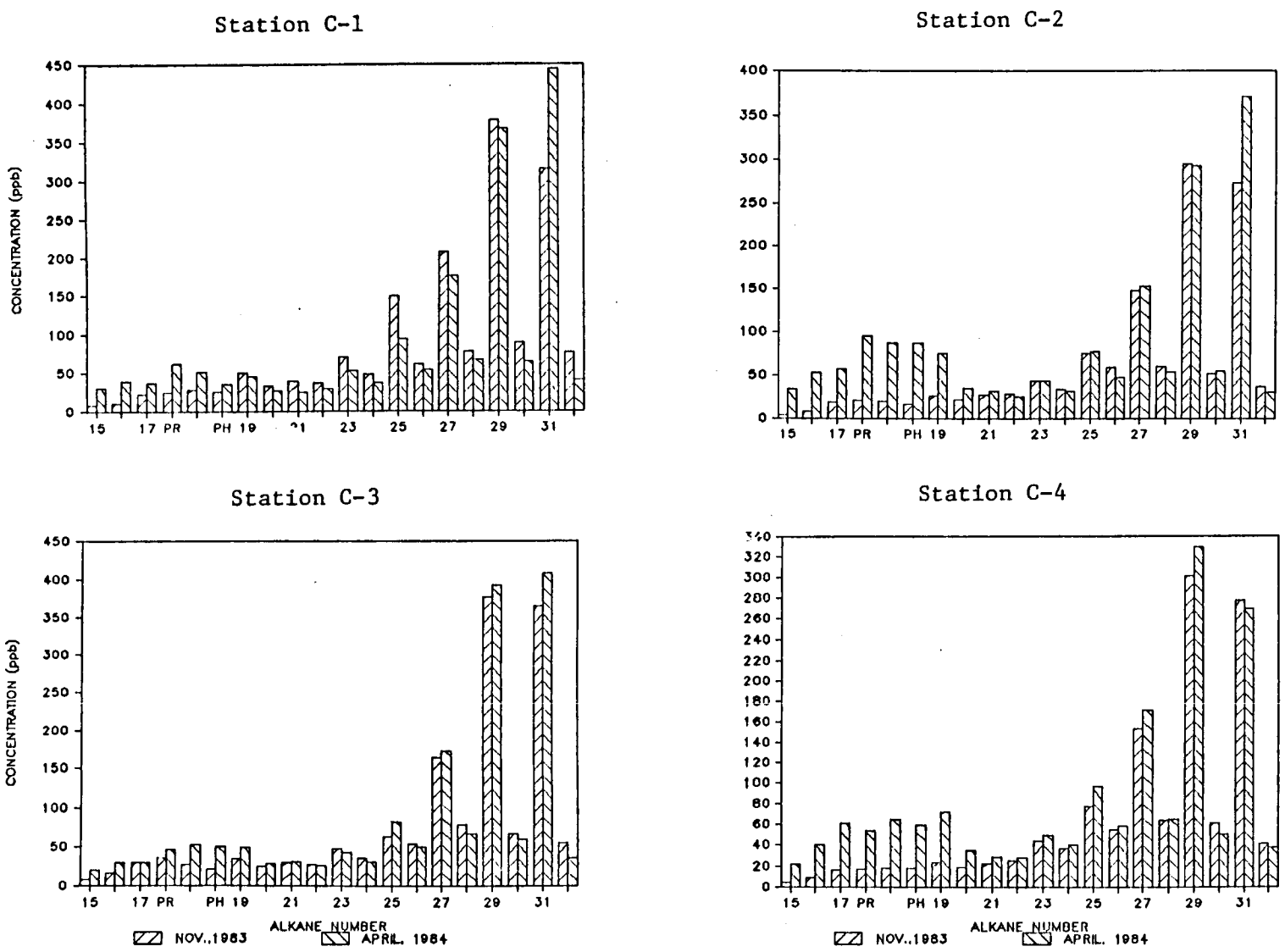


Figure 3-7. Molecular level distributions for sediment hydrocarbons from the Central transect stations.

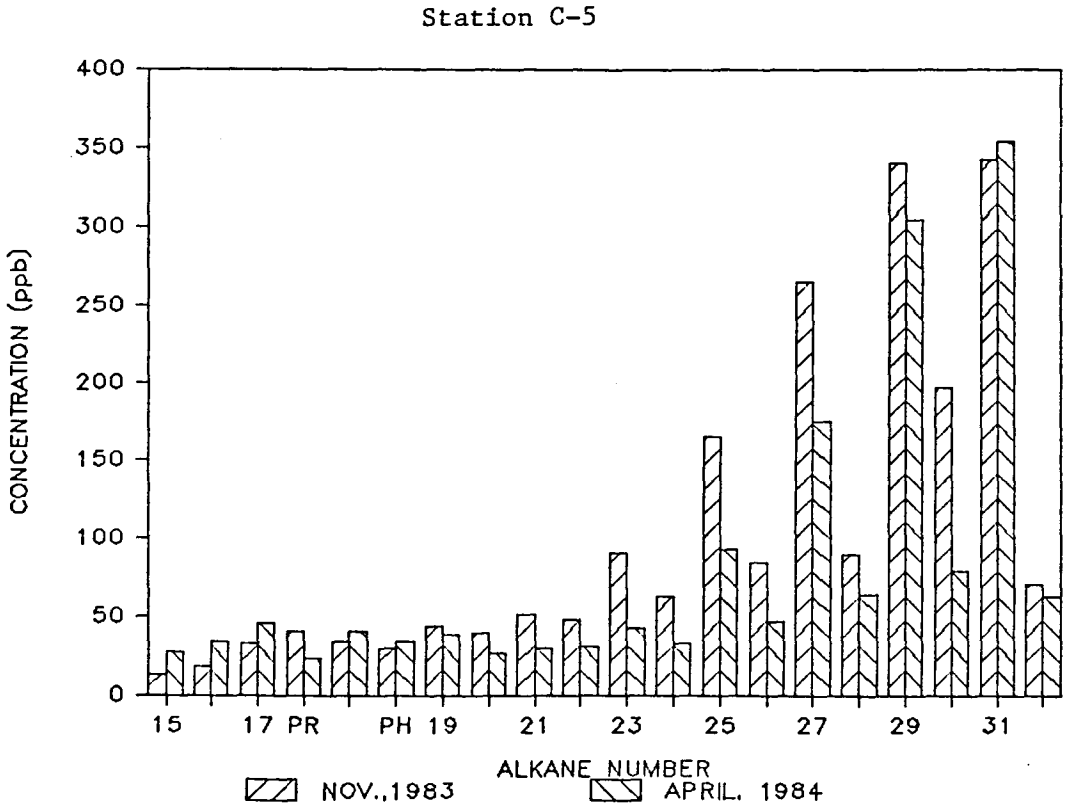


Figure 3-7 (cont'd)

n-C_{15} to n-C_{23} range were generally less than 50 ppb. The relative contribution of sources to the n-C_{15} to n-C_{23} hydrocarbons is difficult to determine at these low levels. Hydrocarbons in the n-C_{23} to n-C_{32} ranged from <100 to >400 ppm (Fig. 3-7, Table 3-7). As previously mentioned, concentrations of the odd, normal alkanes were highest. The dominant alkanes were n-C_{29} and n-C_{31} (Table 3-8). Molecular level distributions and concentrations were uniform over the transect. Most of the variability was within the analytical reproducibility (± 20-30%).

Table 3-8. Dominant alkanes.

	Central-I		Central II		Western		Eastern	
	$<C_{23}$	$>C_{22}$	$<C_{23}$	$>C_{22}$	$<C_{23}$	$>C_{22}$	$<C_{23}$	$>C_{22}$
1	19,21	29,31	Pr*,18	31,29	Pr,16	29,31	17,16	31,29
2	22,21	29,31	Pr,18	31,29	Pr,17	31,29	Pr,19	31,29
3	Pr,19	31,29	Pr,Ph	31,29	Pr,17	31,29	17,16	29,31
4	22,19	29,31	18,17	29,31	17,Pr	31,29	16,17	31,29
5	21,22	29,31	17,18	31,29	16,17	31,29	Pr,19	29,31

*Ph - Phytane, Pr - Pristane

Only trace amounts (<0.1 ppb) of aromatic hydrocarbons were detected by GC/MS analysis. Two to four ring compounds and their C_1 and C_2 akylated analogues were present sporadically. The presence of aromatic compounds was also confirmed by total scanning fluorescence spectra.

Central Transect - Cruise II

Gravimetrically derived aliphatic and aromatic hydrocarbon concentrations ranged from 16.1 to 23.0 and 1.1 to 3.2 ppm, respectively. Concentrations generally overlapped at ± 1σ. No trend with water depth was apparent. The gas chromatographically derived aliphatic UCM ranged from 6.0 to 14.0 ppm (Table 3-9). The UCM accounted for 80-90% of the

TABLE 3-7

Summary of the individual alkane concentrations in sediments from Cruises I and II along the Central Transect (ppb, ng/g dry wt of sediment; Ave. - average of replicate boxcores, std. ± 1σ).

STA		N-C15	N-C16	N-C17	PRISTANE	N-C18	PHYTANE	N-C19	N-C20	N-C21	N-C22
CRUISE I											
C1	AVE.	8.2	10.5	22.8	25.3	28.8	26.0	50.6	32.8	39.8	36.4
	STD.	8.6	6.3	5.2	19.4	5.1	6.8	21.9	7.0	11.2	11.9
C2	AVE.	3.9	8.1	19.0	21.0	20.3	16.7	26.7	21.6	27.9	28.8
	STD.	2.5	2.2	4.4	6.6	5.9	3.7	7.5	5.5	7.6	9.3
C3	AVE.	8.7	15.8	29.6	35.7	27.9	21.3	34.5	24.2	29.8	27.9
	STD.	5.4	7.9	19.1	21.1	13.7	9.4	12.5	6.0	7.3	6.5
C4	AVE.	4.0	9.1	16.3	16.6	18.2	17.7	23.5	19.2	22.1	25.2
	STD.	4.1	3.2	3.5	7.5	4.4	8.9	10.1	5.0	5.1	7.4
C5	AVE.	12.6	17.9	32.6	39.9	33.2	29.9	43.7	39.4	50.5	47.8
	STD.	9.9	12.0	16.9	22.3	16.1	14.0	21.4	18.1	23.5	21.2
CRUISE II											
C1	AVE.	30.4	39.7	36.8	62.0	51.2	36.2	45.7	27.4	25.1	29.5
	STD.	5.7	13.2	24.7	44.7	29.0	23.0	17.5	4.1	7.0	4.1
C2	AVE.	34.2	52.9	57.1	95.5	87.4	87.5	75.6	34.7	31.3	25.3
	STD.	21.3	52.1	42.1	116.5	120.1	129.5	93.2	26.4	9.0	2.9
C3	AVE.	19.8	29.4	29.9	46.6	52.9	50.5	48.8	28.7	30.9	25.5
	STD.	3.4	9.6	16.4	45.7	27.0	30.0	21.9	10.2	5.8	4.3
C4	AVE.	21.4	40.7	61.7	54.4	65.3	59.8	72.0	34.9	28.8	28.0
	STD.	4.5	16.3	48.0	27.4	53.0	53.7	40.2	12.1	7.8	9.1
C5	AVE.	27.6	34.0	45.5	23.1	40.6	33.6	38.1	26.7	29.8	30.2
	STD.	14.0	17.6	16.2	20.9	14.7	12.2	19.4	4.4	6.6	8.0

STA		N-C23	N-C24	N-C25	N-C26	N-C27	N-C28	N-C29	N-C30	N-C31	N-C32
CRUISE 1											
C1	AVE.	69.7	47.7	148.9	61.0	207.0	77.7	379.1	89.6	315.5	75.9
	STD.	32.6	22.8	88.0	26.0	156.7	45.2	181.7	36.7	103.1	34.7
C2	AVE.	43.5	33.5	75.4	59.2	147.3	60.2	294.8	51.7	273.6	36.6
	STD.	12.7	13.3	26.1	37.4	58.4	35.7	128.5	18.1	82.2	7.2
C3	AVE.	47.5	36.2	62.7	53.0	163.4	78.6	377.6	66.4	365.0	54.9
	STD.	12.2	7.2	30.0	11.1	39.0	25.7	303.9	50.3	386.6	51.2
C4	AVE.	44.5	36.9	77.6	54.6	152.9	64.3	301.5	61.8	277.7	41.3
	STD.	13.8	13.2	35.2	17.4	58.4	17.9	89.8	21.1	132.8	29.2
C5	AVE.	90.2	62.0	164.4	83.5	264.9	89.0	340.5	196.7	342.2	70.3
	STD.	38.1	25.6	71.0	34.9	102.6	35.1	108.6	273.4	100.5	16.7
CRUISE II											
C1	AVE.	52.6	37.1	94.8	53.8	175.8	67.4	367.8	63.9	444.4	41.0
	STD.	8.4	9.7	16.4	15.1	27.1	13.5	76.6	18.2	104.0	16.0
C2	AVE.	43.4	31.7	77.6	48.1	153.6	54.2	292.1	55.1	371.2	30.9
	STD.	3.5	1.2	5.3	2.5	42.6	14.5	84.4	23.0	79.9	15.0
C3	AVE.	42.3	30.7	82.5	49.5	172.0	66.8	393.0	59.7	408.0	35.7
	STD.	6.5	4.8	15.9	8.2	15.4	9.2	66.2	10.7	57.7	5.8
C4	AVE.	49.8	40.0	97.0	58.4	170.5	64.9	329.1	50.6	269.6	37.6
	STD.	16.3	16.8	35.3	25.2	60.6	29.8	112.1	18.8	127.8	17.4
C5	AVE.	42.4	32.3	92.1	46.8	174.0	64.1	304.6	78.9	354.6	62.5
	STD.	14.1	5.3	20.7	7.4	30.3	20.3	99.9	40.7	160.7	35.7

TABLE 3-9

Summary of selected hydrocarbon parameters for sediments from the Central, Western and Eastern Transects during Cruise II (for abbreviations see Table 3-6).

STA		EXTRACTABLE ORGANIC MATTER (ppm) ALI.	ARO.	TOTAL	ALIPHATIC UCM (ppm) <C23	>C23	TOTAL	% N-ALKANE	% UCM
C1	AVE.	21.3	1.5	22.8	3.0	4.3	7.4	19.6	34.7
	STD.	4.1	0.9		1.5	3.7			
C2	AVE.	18.0	1.1	19.1	4.0	4.5	8.5	17.5	47.2
	STD.	4.7	0.4		3.8	3.5			
C3	AVE.	16.1	1.9	18.0	2.3	6.4	8.7	16.5	54.0
	STD.	2.2	0.8		1.1	2.2			
C4	AVE.	23.0	2.9	25.8	5.7	8.3	14.0	10.8	60.9
	STD.	13.0	1.5		1.9	2.2			
C5	AVE.	19.4	3.2	22.6	2.0	4.1	6.0	21.1	30.9
	STD.	2.2	0.7		0.7	2.3			
W1	AVE.	48.7	6.5	55.2	7.3	24.1	31.4	4.0	64.4
	STD.	1.1	0.9		1.3	2.5			
W2	AVE.	18.5	2.4	20.9	0.6	5.6	6.2	11.8	33.5
	STD.	0.3	0.4		0.2	3.0			
W3	AVE.	19.4	2.4	21.9	1.1	5.4	6.5	13.3	33.5
	STD.	1.2	1.2		0.3	2.6			
W4	AVE.	15.2	2.3	17.5	0.8	4.4	5.2	16.1	34.2
	STD.	1.3	1.0		0.2	2.2			
W5	AVE.	12.6	2.0	14.6	1.2	5.4	6.6	14.3	52.4
	STD.	2.2	1.4		0.4	0.6			
E1	AVE.	7.8	0.9	8.7	2.4	4.9	7.3	7.6	93.5
	STD.	2.1	0.4		2.1	0.6			
E2	AVE.	6.2	1.4	7.6	1.9	1.3	3.2	13.5	51.6
	STD.	0.5	0.3		1.0	1.0			
E3	AVE.	7.2	1.6	8.7	2.3	2.4	4.7	11.3	65.3
	STD.	1.9	0.8		0.6	1.5			
E4	AVE.	6.1	1.6	7.7	3.9	2.2	6.1	11.6	100.0
	STD.	3.7	0.5		2.9	0.6			
E5	AVE.	7.4	2.8	10.1	3.2	2.6	5.8	14.7	78.4
	STD.	2.5	2.9		2.9	1.0			

STA	CPI	TOT ALK (ppm)	SUM ALK (ppm)	% PRIS+PHYT	PRIS/ N-C18	PRIS/ N-C17	PRIS/ PHYT	UCM>C23/ UCM<C23
C1	4.3	1797.3	1699.1	5.8	1.2	1.7	1.7	1.4
C2	4.3	1756.4	1573.5	11.6	1.1	1.7	1.1	1.1
C3	4.5	1719.2	1622.0	6.0	0.9	1.6	0.9	2.7
C4	3.6	1662.5	1548.3	7.4	0.8	0.9	0.9	1.5
C5	3.4	1593.7	1537.1	3.7	0.6	0.5	0.7	2.1
W1	2.0	1367.0	1266.1	8.0	2.9	3.4	4.1	3.3
W2	2.3	799.4	769.3	3.9	1.5	1.1	1.8	8.9
W3	3.7	1017.1	983.8	3.4	1.5	1.2	2.3	4.7
W4	2.8	1063.5	1041.9	2.1	1.1	0.9	2.1	5.7
W5	2.7	1106.0	1068.8	3.5	0.9	0.8	1.3	4.4
E1	2.8	649.2	609.3	6.5	1.4	0.5	2.2	2.0
E2	2.9	547.4	507.0	8.0	1.6	2.0	3.0	0.7
E3	3.3	637.0	601.9	5.8	0.9	0.5	1.5	1.0
E4	3.4	873.6	812.8	7.5	1.1	1.0	2.0	0.6
E5	3.9	1037.0	971.8	6.7	1.5	1.4	2.1	0.8

total GC-derived hydrocarbons (UCM + total resolved alkanes). The remainder (10-20%) was accounted for by normal and isoprenoid alkanes (Table 3-9). The UCM was biomodally distributed and was nearly equally divided between the two maxima (Fig. 3-8).

Molecular level concentrations suggest a mixed biogenic and thermogenic source (Fig. 3-9). Individual compounds in the n-C_{15} to n-C_{23} were again less than 50 ppm with the main exception being Station C2 (Table 2.8-4). At Station C2 n-C_{17} to n-C_{19} compounds approached 100 ppm. Compounds from n-C_{23} to n-C_{32} ranged from <50 ppm to >400 ppm (Table 3-7). The dominant n-alkanes were again n-C_{29} and n-C_{31} (Fig. 3-9). Molecular level concentrations and distributions were very similar at all water depths.

Only trace amounts of two to four ring aromatic compounds and their alkylated analogues were detected. The presence of aromatic compounds was again confirmed by total scanning fluorescence.

Western Transect - Cruise II

Gravimetrically determined concentrations of the aliphatic and aromatic hydrocarbons ranged from 12.6 to 48.7 ppm and 2.0 to 6.5 ppm, respectively (Table 3-9). Gravimetrically determined concentrations were more than two-fold higher at Station W1 than at Stations W2 through W5. The GC derived aliphatic UCM paralleled the gravimetric concentrations ranging from 5.2 to 31.4 ppm. The UCM accounted for 84 to 96% of the total GC derived hydrocarbons. The higher molecular weight UCM was three to nine times higher than the low molecular weight UCM (Table 3-9). The normal and isoprenoid alkanes were a higher percentage of the total hydrocarbons as the water depth increased. Molecular level compositions again indicated a mixed assemblage of biogenic and thermogenic hydrocarbon (Fig. 3-9). Individual compound concentrations from n-C_{15} to n-C_{22} were less than 30 ppb, whereas compounds from n-C_{23} to n-C_{32} were present in concentrations from <30 ppb to >300 ppb (Table 3-10). The dominant normal alkanes were n-C_{29} and n-C_{31} (see Table 3-8). Only trace amounts of aromatic hydrocarbons were detected by GC/MS and confirmed by total scanning fluorescence spectra.

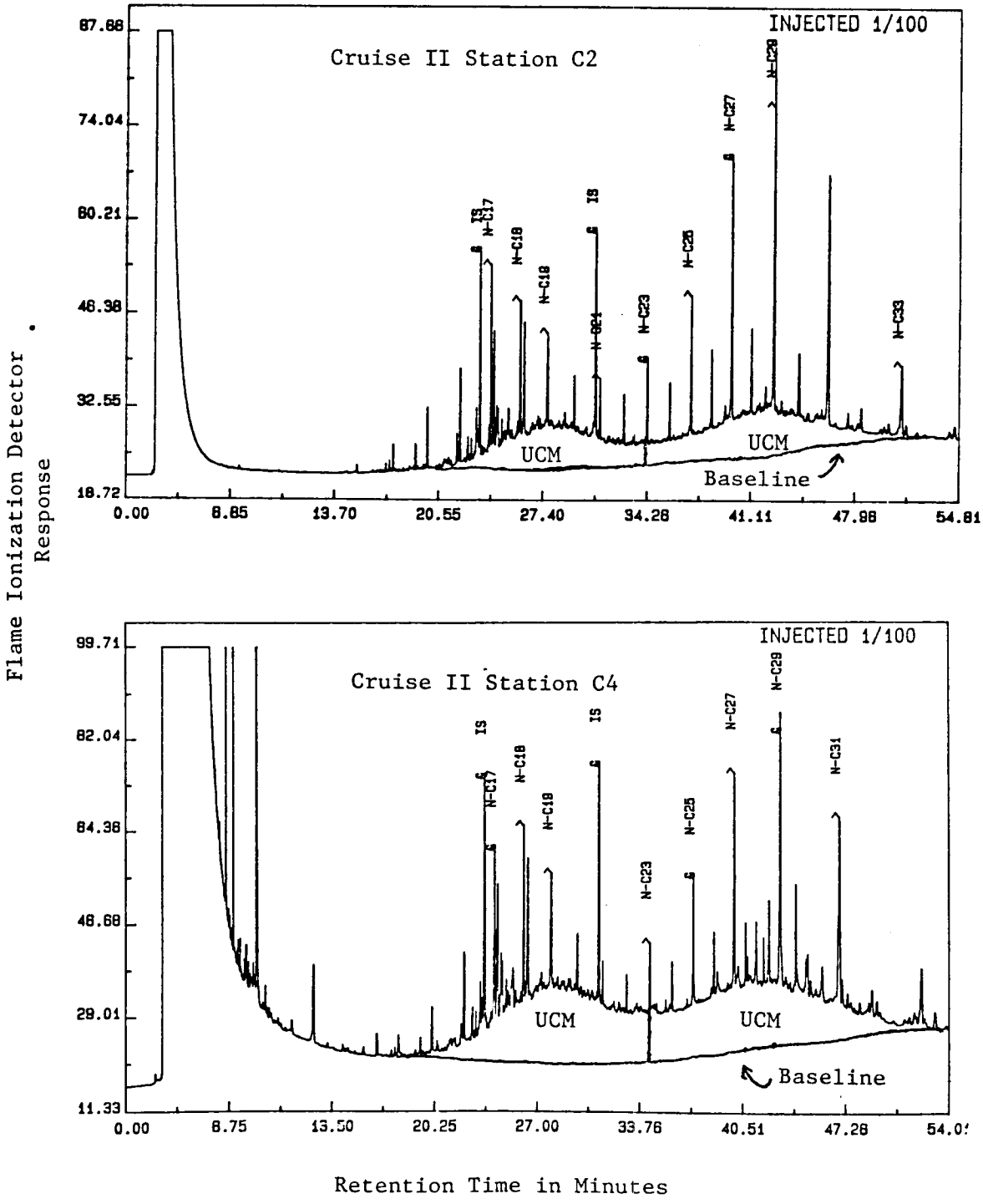


Figure 3-8. Representative gas chromatographic patterns of sediment hydrocarbons from the Central Transect during Cruise II.

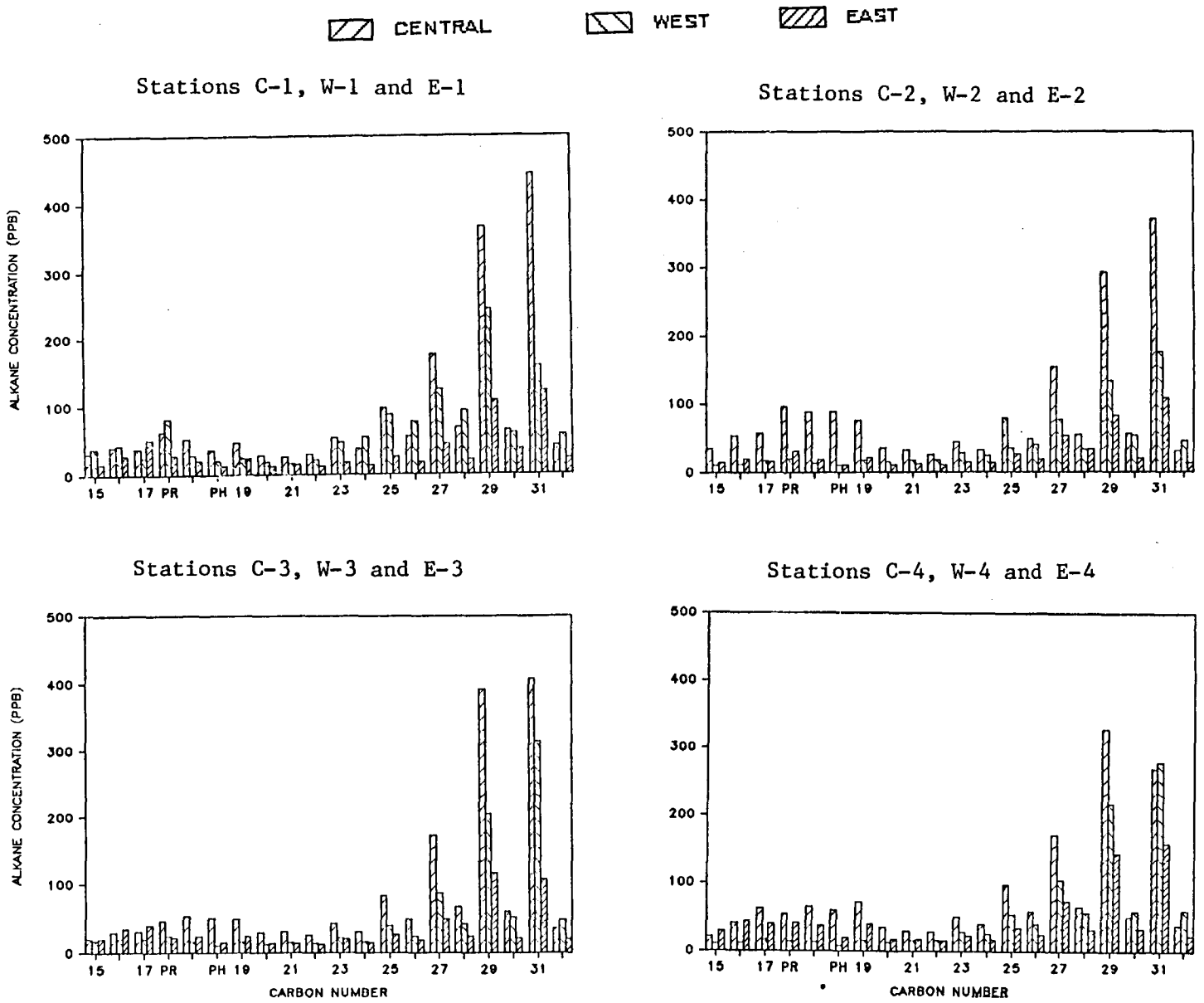


Figure 3-9. Molecular level distributions for sediment hydrocarbons from Cruise II.

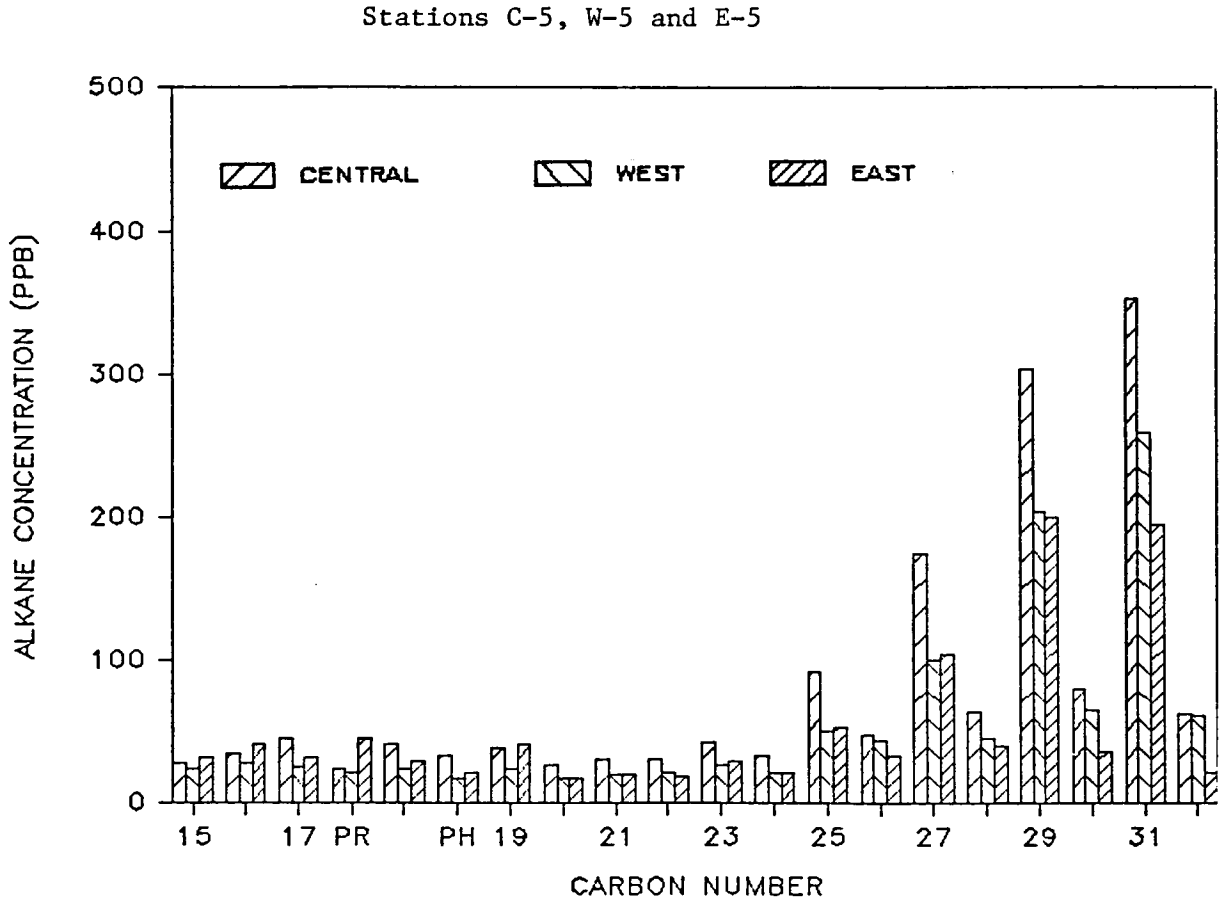


Figure 3-9 (cont'd)

TABLE 3-10

Summary of the individual alkane concentrations in sediments from the Central, Western and Eastern Transects during Cruise II (ng/g).

STA		N-C15	N-C16	N-C17	PRIS	N-C18	PHYT	N-C19	N-C20	N-C21	N-C22
C1	AVE.	30.4	39.7	36.8	62.0	51.2	36.2	45.7	27.4	25.1	29.5
	STD.	5.7	13.2	24.7	44.7	29.0	23.0	17.5	4.1	7.0	4.1
C2	AVE.	34.2	52.9	57.1	95.5	87.4	87.5	75.6	34.7	31.3	25.3
	STD.	21.3	52.1	42.1	116.5	120.1	129.5	93.2	26.4	9.0	2.9
C3	AVE.	19.8	29.4	29.9	46.6	52.9	50.5	48.8	28.7	30.9	25.5
	STD.	3.4	9.6	16.4	45.7	27.0	30.0	21.9	10.2	5.8	4.3
C4	AVE.	21.4	40.7	61.7	54.4	65.3	59.8	72.0	34.9	28.8	28.0
	STD.	4.5	16.3	48.0	27.4	53.0	53.7	40.2	12.1	7.8	9.1
C5	AVE.	27.6	34.0	45.5	23.1	40.6	33.6	38.1	26.7	29.8	30.2
	STD.	14.0	17.6	16.2	20.9	14.7	12.2	19.4	4.4	6.6	8.0
W1	AVE.	37.1	42.4	23.6	81.1	27.7	19.8	24.2	18.4	15.1	20.9
	STD.	25.0	35.1	8.3	21.4	18.1	12.5	6.3	2.3	1.7	5.6
W2	AVE.	10.7	11.0	17.2	19.3	12.8	10.8	16.5	13.8	16.2	16.6
	STD.	4.2	1.6	2.7	12.7	2.4	3.9	3.4	3.0	4.2	4.5
W3	AVE.	16.8	19.3	20.2	23.3	16.0	10.0	16.1	12.2	14.6	13.4
	STD.	4.8	8.6	7.5	1.7	6.0	7.8	1.8	0.9	0.1	0.7
W4	AVE.	10.3	11.6	16.2	14.7	13.0	7.0	15.4	12.6	15.1	16.1
	STD.	2.9	2.7	5.4	8.8	3.2	5.3	1.5	1.3	0.6	2.5
W5	AVE.	23.7	27.3	24.9	20.9	23.6	16.3	22.9	17.4	19.9	20.4
	STD.	2.7	7.1	4.4	16.1	2.1	4.7	1.3	2.5	3.6	3.5
E1	AVE.	15.8	28.1	50.6	27.5	19.2	12.4	22.7	11.6	14.4	10.8
	STD.	15.8	26.1	35.1	16.3	8.4	13.1	4.4	0.9	1.3	0.8
E2	AVE.	14.5	19.4	15.2	30.2	18.9	10.1	20.4	10.6	11.5	10.0
	STD.	4.6	6.0	2.5	16.4	5.2	3.0	9.6	1.0	1.6	1.6
E3	AVE.	19.5	33.8	39.0	21.1	23.5	14.0	24.3	13.0	13.1	12.1
	STD.	8.8	15.3	20.5	5.3	6.4	2.8	7.2	2.8	1.4	3.7
E4	AVE.	28.6	44.0	40.0	40.5	37.4	20.3	39.5	17.6	16.9	16.0
	STD.	12.2	27.3	19.1	43.7	30.0	10.2	12.3	4.4	3.9	4.2
E5	AVE.	31.8	41.2	31.2	44.3	29.4	20.8	41.3	17.0	19.5	18.3
	STD.	30.5	43.7	28.0	17.5	20.3	17.7	25.0	6.8	5.1	4.4

TABLE 3-10
(cont'd)

STA		N-C23	N-C24	N-C25	N-C26	N-C27	N-C28	N-C29	N-C30	N-C31	N-C32
C1	AVE.	52.6	37.1	94.8	53.8	175.8	67.4	367.8	63.9	444.4	41.0
	STD.	8.4	9.7	16.4	15.1	27.1	13.5	76.6	18.2	104.0	16.0
C2	AVE.	43.4	31.7	77.6	48.1	153.6	54.2	292.1	55.1	371.2	30.9
	STD.	3.5	1.2	5.3	2.5	42.6	14.5	84.4	23.0	79.9	15.0
C3	AVE.	42.3	30.7	82.5	49.5	172.0	66.8	393.0	59.7	408.0	35.7
	STD.	6.5	4.8	15.9	8.2	15.4	9.2	66.2	10.7	57.7	5.8
C4	AVE.	49.8	40.0	97.0	58.4	170.5	64.9	329.1	50.6	269.6	37.6
	STD.	16.3	16.8	35.3	25.2	60.6	29.8	112.1	18.8	127.8	17.4
C5	AVE.	42.4	32.3	92.1	46.8	174.0	64.1	304.6	78.9	354.6	62.5
	STD.	14.1	5.3	20.7	7.4	30.3	20.3	99.9	40.7	160.7	35.7
W1	AVE.	45.9	53.7	86.0	75.4	122.4	91.0	244.5	59.6	158.7	56.6
	STD.	11.9	21.2	24.4	33.8	32.3	32.1	47.4	40.4	7.4	11.4
W2	AVE.	27.1	24.2	33.9	39.9	76.7	33.5	133.0	52.7	175.5	45.3
	STD.	8.1	10.5	11.2	20.5	7.7	6.3	47.9	33.9	10.9	27.9
W3	AVE.	20.9	15.4	39.3	23.3	85.7	41.7	202.8	51.7	313.6	47.7
	STD.	0.7	0.5	3.2	3.5	5.5	4.3	25.2	11.7	83.6	17.9
W4	AVE.	27.5	25.3	54.6	39.2	103.8	57.0	216.9	57.9	278.9	60.2
	STD.	5.7	7.8	10.0	10.3	11.7	9.1	22.6	5.6	78.2	14.4
W5	AVE.	26.3	21.1	50.1	42.9	99.3	45.5	203.8	65.2	259.9	61.2
	STD.	5.0	3.0	9.9	10.7	21.3	15.3	82.9	18.1	111.4	20.7
E1	AVE.	17.3	12.7	25.2	17.1	43.5	21.4	105.6	36.4	119.7	22.6
	STD.	2.2	1.9	4.3	2.2	3.4	2.5	4.6	17.3	35.6	2.2
E2	AVE.	14.0	13.3	26.6	18.5	52.1	33.0	82.2	20.2	107.3	13.0
	STD.	2.4	3.0	9.9	4.2	26.5	25.8	38.3	6.6	29.9	1.4
E3	AVE.	19.9	14.6	26.8	17.7	49.5	24.0	115.2	21.2	105.8	19.5
	STD.	6.7	5.3	6.4	4.2	8.7	7.0	20.7	5.1	35.7	3.5
E4	AVE.	22.1	17.3	34.8	24.0	73.4	31.9	143.9	33.5	158.1	21.7
	STD.	2.9	2.3	3.6	3.9	10.8	2.4	13.1	8.1	12.8	4.5
E5	AVE.	29.4	20.9	53.5	32.4	103.4	39.9	200.1	35.8	194.5	20.9
	STD.	5.2	3.7	13.9	8.0	21.2	8.8	35.1	5.8	48.5	2.8

Eastern Transect - Cruise II

Gravimetrically derived aliphatic and aromatic hydrocarbon concentrations ranged from 6.1 to 7.8 ppm and 0.9 to 2.8 ppm, respectively. No trend with water depth was observed. The GC-derived aliphatic UCM ranged from 3.2 to 7.3 ppm and also showed no trend with depth of water. Molecular level compositions suggest a mixed biogenic and thermogenic hydrocarbon assemblage (Fig. 3-9). Concentrations of individual alkanes in the n-C_{15} to n-C_{23} range were generally less than 30 ppb. Pristane and n-C_{17} were often the dominant alkanes in this molecular weight range (Table 3-8). Alkanes from C_{23} to C_{32} ranged from <30 ppb to >250 ppb. N-C_{29} and n-C_{31} were the dominant normal alkanes (Table 3-8). No aromatic compounds were detected by GC/MS analysis, but their presence at very low levels was inferred from total scanning fluorescence (<0.01 ppb).

Comparison of Central Transect Samples from Cruises I and II

As can be seen in Figure 3-7, Table 3-6 and Table 3-7, molecular level concentrations and distributions were very similar in both Cruise I and Cruise II samples of the Central Transect. The same two normal alkanes were dominant (n-C_{29}, n-C_{31}), though the most dominant alkane varied during the same sampling period and between cruises (Table 3-8).

The aliphatic hydrocarbon (gravimetric) and aliphatic UCM (GC-derived) concentrations at Station C1 were more than two times as great in Cruise I samples as they were in Cruise II samples (Fig. 3-10). Gravimetric aliphatic hydrocarbons at Station C2 to C5 were comparable in both samples. In contrast, the aliphatic UCM was substantially decreased at all Cruise II stations. The aliphatic hydrocarbons were a combination of biogenic and thermogenic sources (biowaxes and petroleum). It is presumed that the aliphatic UMC was solely due to thermogenic hydrocarbons. Thus, the decrease in aliphatic hydrocarbons at Station C1 Cruise II samples was the result of dilution with low-UCM organic matter. Biodegradation may also have contributed to this effect.

The total resolved alkanes remained fairly constant in both samples (Fig. 3-10). Since the resolved alkanes were dominated by the biowaxes,

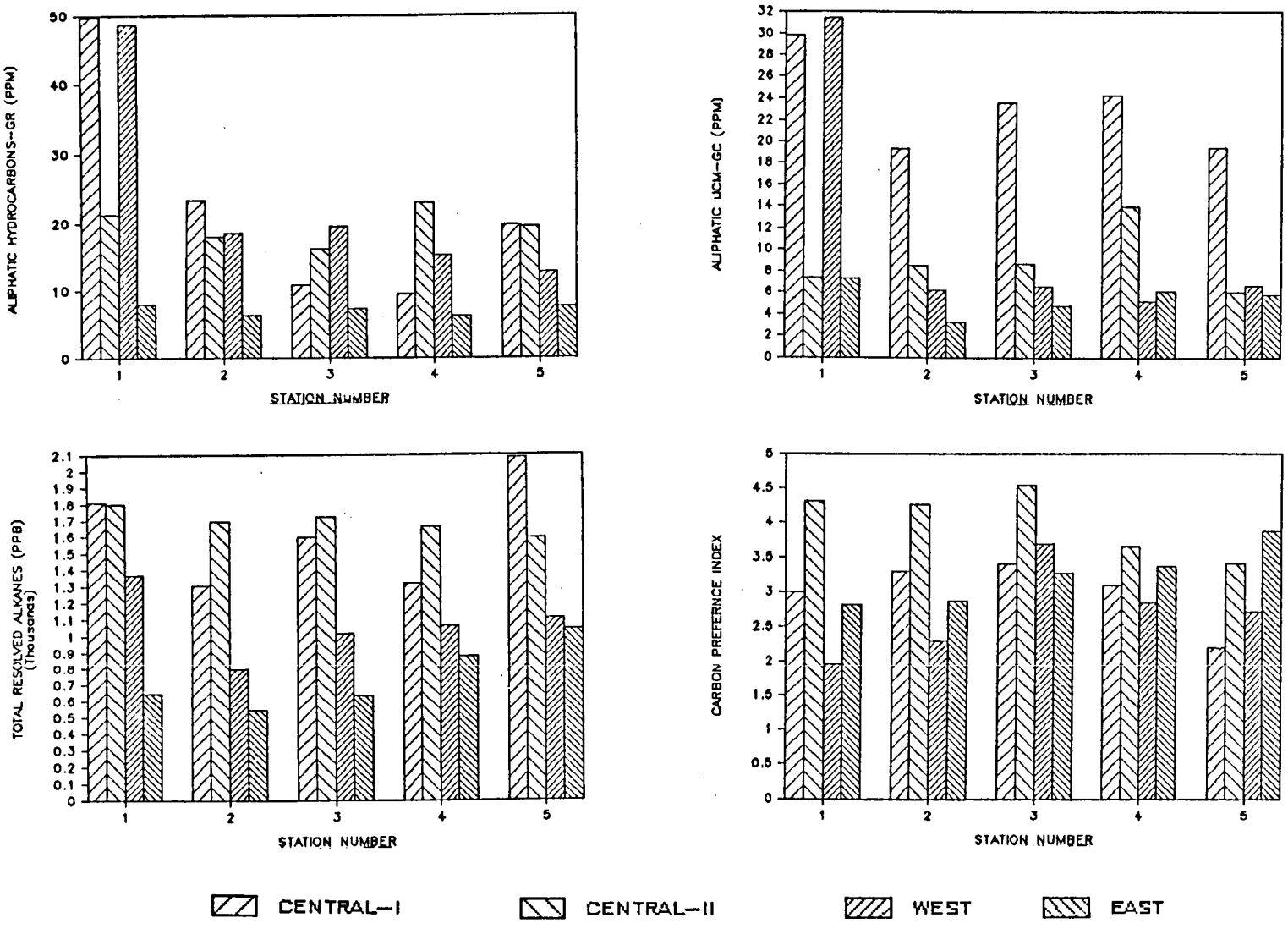


Figure 3-10. Comparison of selected sedimentary hydrocarbon parameters from Cruises I and II.

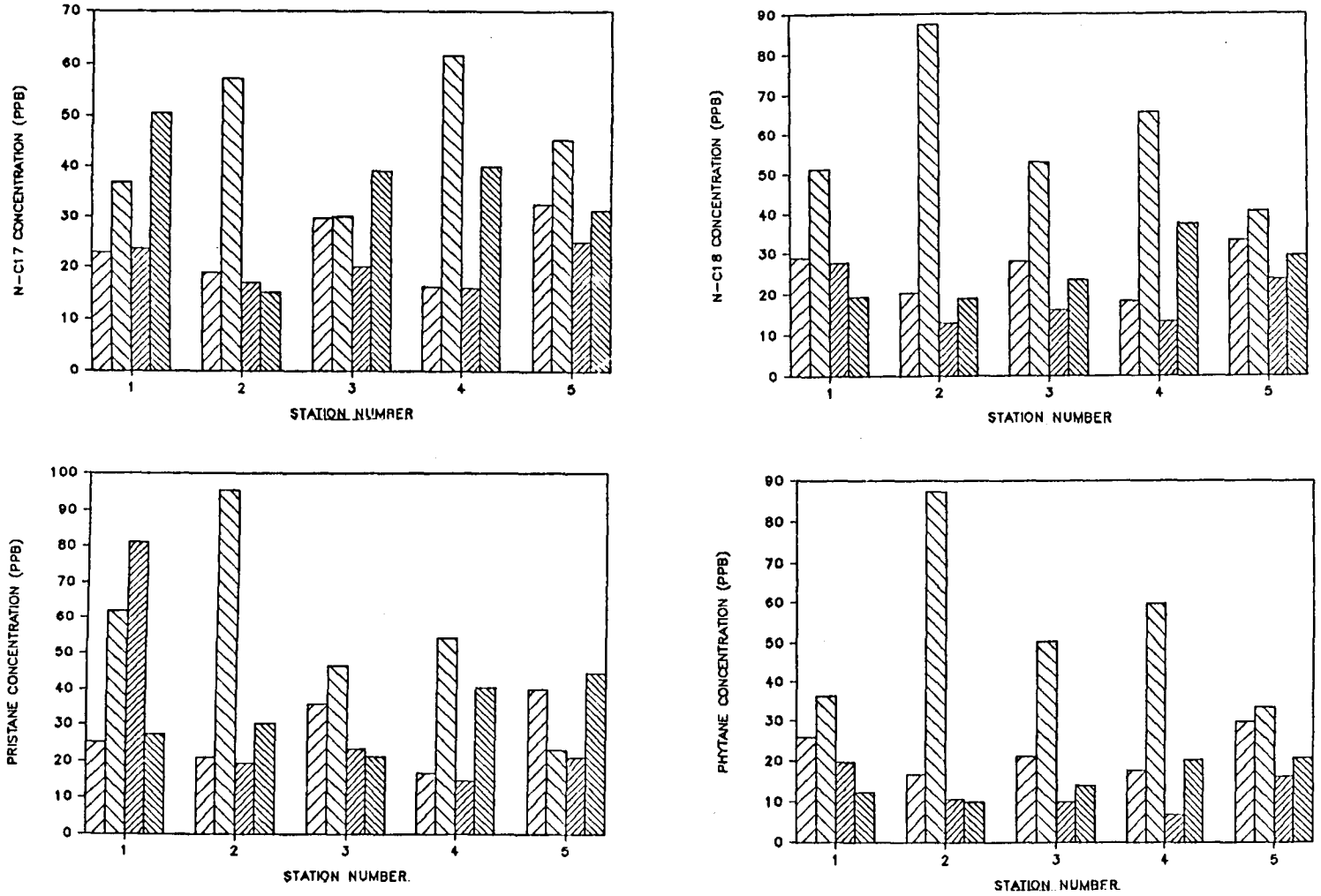
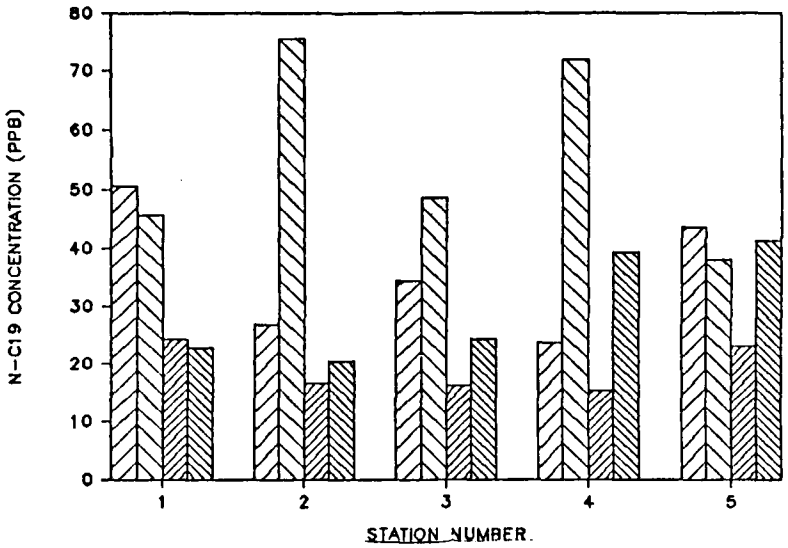
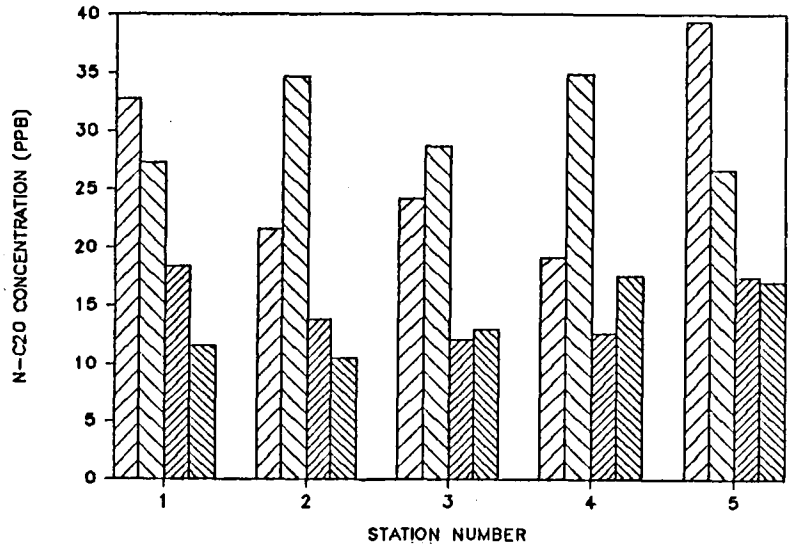


Figure 3-10 (cont'd)





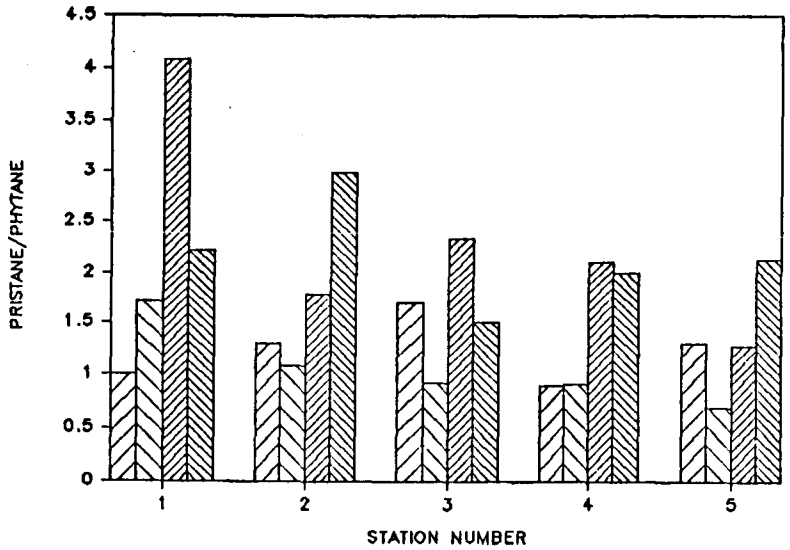


Figure 3-10 (cont'd)

this suggests a relatively constant delivery of terrigenous material to the site. The carbon preference index was more elevated during Cruise II than Cruise I, perhaps also due to a recent influx of low UCM terrigenous material. This suggests that the majority of the thermogenic components are not associated with the terrigenous input and that the UCM increases once the sediment is in place. This could be caused by the upward migration of petroleum hydrocarbons in the sediments or the deposition of anthropogenic hydrocarbons from the overlying water. There was a general increase in pristane, phytane, n-C_{17}, n-C_{18}, and n-C_{19} in Cruise II samples (Fig. 3-9). The terrigenous material must transport a low level lower molecular weight UCM. As can be seen in Table 2.8-6, the ratio of the high molecular weight UCM to the low UCM was greatly reduced in Cruise II samples.

The primary differences between samples from the two cruises is in the n-C_{15} to n-C_{22} hydrocarbons. Samples from Cruise I were dominated by C_{19} to C_{22} alkanes, while those from Cruise II were dominated by n-C_{17}, n-C_{18}, pristane, and phytane (Table 3-8 and Fig. 3-10).

In conclusion, the molecular level concentrations and distributions were similar in samples from both cruises, and suggest a mixed biogenic and thermogenic origin for the observed hydrocarbons. Differences between the two cruises can be explained by a complex interplay of the upward migration of thermogenic hydrocarbons in the sediments and the transported input of the water mass. In general, Cruise I samples appeared to be more highly degraded and older whereas, Cruise II samples appeared to be fresher and more terrigenous in nature.

Comparison - Central, Western, Eastern Transects

Aliphatic hydrocarbons (gravimetric) at the East Transect were reduced by more than a factor of two when compared with the West and Central Transects (Table 3-9, Fig. 3-10). Presumably, this is due to much smaller terrigenous and thermogenic hydrocarbon inputs to the East Gulf of Mexico. Station W1 was anomalously high though not higher than Station C1 from Cruise I. Aliphatic hydrocarbon concentations of Stations C2 to C5 and W2 to W5 were similar in concentration (Fig. 3-10). At all times the Cruise I, Central Transect had the highest aliphatic UCM concentrations

suggesting that, of the areas sampled, this is the most active area of hydrocarbon seepage.

The aliphatic UCM showed a more variable pattern (Fig. 3-10). The hydrocarbon distributions at C1 (Cruise I) were very similar to those at Station W1 (Cruise II). This may be due to the reduced river influence at Station W1. This would also confirm that the difference between Station C1 (Cruise I) and C1 (Cruise II) is also the result of decreased river activity prior to the Cruise I sampling and increasing activity between Cruises I and II. At the deeper stations, the UCM was relatively constant regardless of the transect. Again Station W1 was anomalously high.

In general, the East Transect had the lowest UCM concentration at a given depth. Total resolved alkanes showed a very regular decrease from Central to West to East. These three parameters [aliphatic hydrocarbons (biogenic and thermogenic), aliphatic UCM (petrogenic) and total resolved alkanes (predominately terrestrial, biogenic)] confirm the interpretation that the majority of the reduction in hydrocarbons in the East Transect is primarily due to the much lower input of terrigenous and petrogenic material.

Also apparent from the pristane, n-C_{17} and n-C_{19} distributions is that the phytoplanktonic input is more pronounced in the East Transect. This is the most likely due to the dilution of planktonic debris in the western Gulf with river-derived terrigenous debris. The East Transect also contains significant amounts of non-normal, non-isoprenoid aliphatics in the n-C_{16} to n-C_{19} range (Fig. 3-10). These types of compounds have been identified in benthic marine algae.

Summary

Sediments at all three transects had a mixture of thermogenic, terrigenous, and planktonic hydrocarbons. Two samplings at the Central Transect suggested the influx of low UCM terrigenous material between Cruises I and II. This terrigenous material consisted primarily of bulk organic matter and plant biowaxes. The material being transported to this area appeared to be compositionally constant with time. The biowaxes were accompanied by a low molecular weight UCM and by n-C_{15} to n-C_{19} compounds. The higher molecular weight UCM appeared to accumulate in place and was

much more highly degraded than the terrigenous material. Piston coring in the Gulf of Mexico intraslope has demonstrated that this is an area of active natural oil seepage. Piston cores sampled at these sites generally showed an increase in hydrocarbons with depth. This suggests that the source of the high molecular weight UCM in the sediments is upward migration, though transport of anthropogenic hydrocarbons to the sediment by water column particulates can not be ruled out.

The influence of riverborne material decreased from the Central to the West to the East Transect. The reduced hydrocarbon levels in the East Transect were primarily due to smaller terrigenous and thermogenic inputs. Planktonic and algal inputs were difficult to discern in the West and Central Transects, but were readily apparent in the East Transect as shown by the numerous alkenes detected. This may be due to the more rapid sedimentation rates at the Central and West Transects and/or the large input of riverine material causing rapid dilution of oceanic detritus. Elevated microbial activity in the sediments and/or in the water column may also assist in removing the more labile marine debris.

In general, hydrocarbons were only present in low concentrations, especially at the East Transect. Aliphatic hydrocarbon levels ranged from ~10 to 50 ppm. Aliphatic hydrocarbon levels recorded in the literature range from 1 to 3000 ppm. The low concentrations generally occur in very sandy areas, whereas the high concentrations occur in polluted, shallow waters. In areas of pervasive seepage on the Gulf of Mexico slope, aliphatic hydrocarbons have been measured in excess of 100,000 ppm.

3.4.2 Organisms

Possible Contamination of Samples

Preliminary data presented at the MMS Information Transfer Meeting in November suggested that some organisms collected from Cruise I had elevated levels of apparent petrogenic hydrocarbons. At that time it was noted that the occurrence was sporadic not only within a station but also within a given species. The molecular composition of the observed hydrocarbons was also somewhat suspicious in that it covered a very narrow molecular weight range that would be indicative of a refined product

(Fig. 3-11). Closer scrutiny of the data and additional analyses suggested that this pattern may have been an artifact introduced during sample processing and analysis. It was quickly realized that the majority of the samples (>80%) that exhibited this pattern had been processed during a single three day period. Examination of complete procedural blanks run during this time period revealed no contamination (Fig. 3-11). This would eliminate reagent contamination as a possible source. Furthermore, samples of the same species from the same trawl did not have this fingerprint, which suggests that on-board sampling was not the cause of the contamination. Organisms were stored whole, frozen, and were not dissected until they were returned to a clean laboratory onshore. Examination of samples of lube oil, bilge water and diesel taken from the ship showed that these contaminants had patterns very different from the pattern observed in the organisms (see Section 2.4.3 under Hydrocarbon Quality Control/Quality Assurance). Analysis of all fluids in our laboratory (pump oil, greases, etc.) has so far been unable to find this particular type of hydrocarbon signature. At this point we have to assume that this fingerprint was introduced sometime during sample preparation and is not representative of petrogenic hydrocarbons. The following discussion excludes any organism analyses suspected of containing this artifact fingerprint.

Cruise I

The trawl catches from Cruise I were small. Consequently, there were few specimens available for analysis. This small data set makes it difficult to assess trophic level variations. Variations with water depth were likewise not resolved with such a small sample set.

Analyses were limited primarily to shrimp and fish tissues (Table 3-11). Hydrocarbon concentrations in organisms were low level as compared with hydrocarbon levels noted in the literature. The dominant alkanes present were generally pristane, n-C_{17}, n-C_{15} and occasionally n-C_{19}. These hydrocarbons are presumed to have planktonic origin. No hydrocarbons above n-C_{21} were detected. The gravimetrically determined parameters were dominated by indigenous biogenic compounds. Gas chromatography revealed a bimodal distribution of hydrocarbons. The first

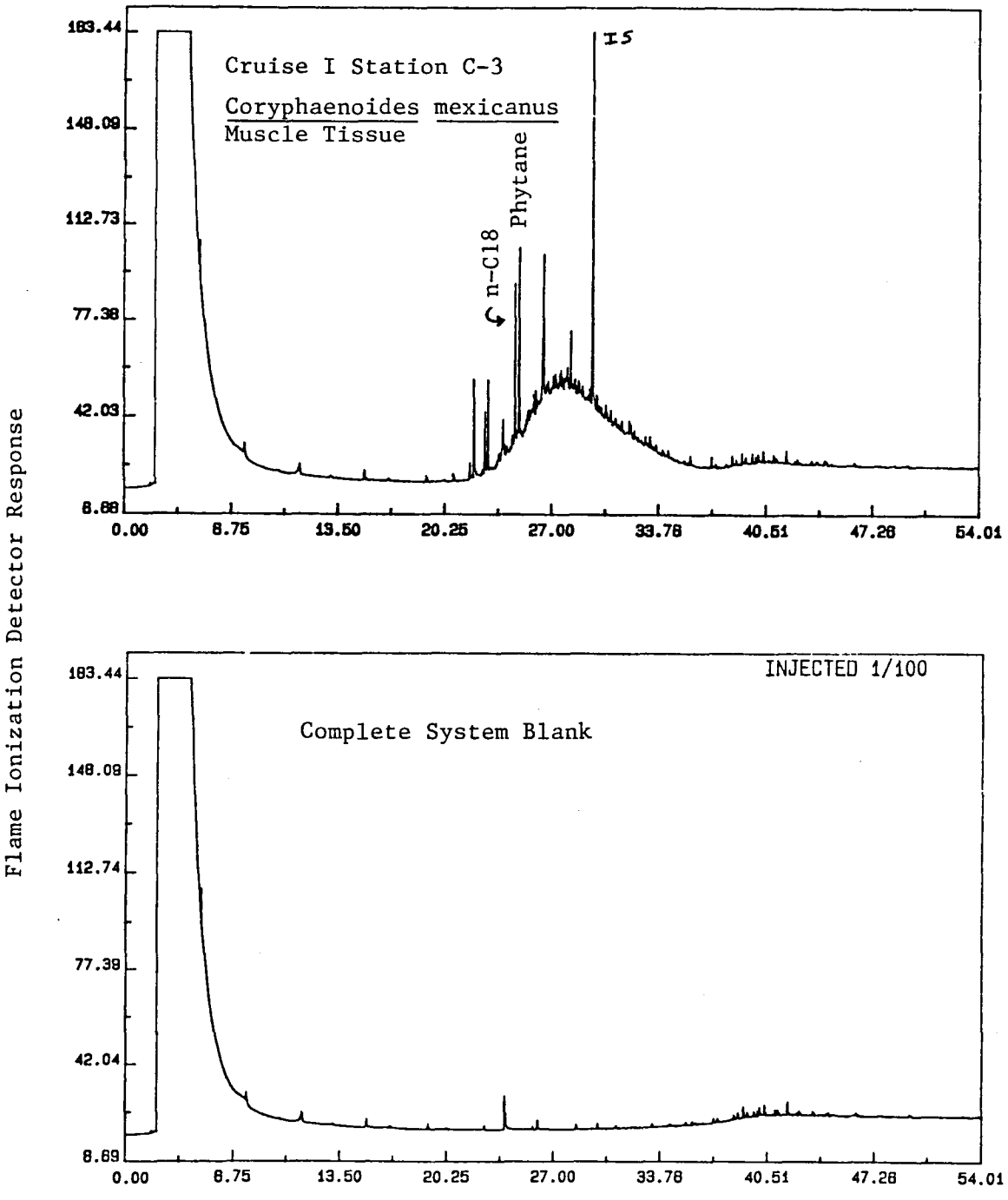


Figure 3-11. Possible contaminant fingerprint and a system blank processed in the same set of samples.

TABLE 3-11

Summary of Cruise I Organism Hydrocarbon Data.

STN	SPECIES	# OF	TISSUE	EOM (ppm) ALIPH	EOM (ppm) AROM	EOM (ppm) TOT EOM	ALIPH (ppm) ALI UCM	N-C15	N-C16	N-C17	PRISTANE	N-C18	PHYTANE	N-C19	N-C20	N-C21
C1	Urophycis cirrata	1	muscle	3.6	1.5	5.1	2.6	573.0	143.2	137.7	1103.4	221.7	167.5	218.1	0.0	0.0
C1	Urophycis floridanus	1	muscle	11.0	1.2	12.2	24.7	0.0	0.0	9.2	41.4	7.8	9.7	0.0	0.0	0.0
C1	Coelorhynchus caribbaeus	8	muscle	15.3	1.8	17.1	15.1	0.0	4.0	17.7	11.7	25.9	19.7	29.9	0.0	0.0
C1	Urophycis floridanus	1	muscle	12.4	1.4	13.9	3.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
C1	Urophycis floridanus	1	muscle	16.1	2.7	18.8	11.9	5.6	3.1	32.8	74.9	5.6	6.2	4.7	0.0	0.0
C1	Urophycis cirrata	1	liver	95.0	21.6	116.6	55.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
C1	Coelorhynchus caribbaeus	8	liver	451.0	36.8	487.8	438.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
C1	Urophycis cirrata	2	liver	918.4	18.4	936.7	139.6	626.2	254.2	119.4	557.6	335.5	347.8	360.5	0.0	0.0
C1	Urophycis floridanus	1	gonad(b)	7.6	1.9	9.4	8.4	0.0	0.0	0.0	30.7	7.5	10.8	0.0	0.0	0.0
C1	Urophycis floridanus	1	gonad(a)	7.2	2.7	10.0	13.6	0.0	0.0	0.0	56.4	16.8	19.9	0.0	0.0	0.0
C1	Urophycis cirrata	1	gonad	8.2	5.1	13.3	3.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
C1	Urophycis floridanus	1	gonad	174.8	124.3	299.1	35.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
C1	Penaeid sp.	14	muscle	15.4	7.2	22.6	34.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
C1	Penaeopsis megalops	5	muscle	75.5	75.5	151.1	33.7	21.2	31.3	87.9	47.5	58.6	40.7	37.2	0.0	0.0
C2	Nezumia aequalis	1	muscle	32.2	6.7	38.9	44.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
C2	Chaunax pictus	1	muscle	4.8	11.0	15.8	1.9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
C2	Chaunax pictus	1	liver	316.3	7.1	323.4	266.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
C2	Acanthephyra armata	1	muscle	115.1	207.6	322.7	60.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
C3	Trichopeltarium nobile	1	muscle	28.0	12.4	40.4	110.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	49.1	0.0
C3	Geryon quinquedens	2	muscle	5.4	14.6	20.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
C3	Benthesicumus bartletti	7	muscle	70.3	93.1	163.4	70.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
C3	Synaphobranchus brevidorsalis	1	liver	70.7	34.8	105.5	74.3	50.2	35.0	189.5	299.1	31.1	53.3	46.7	0.0	0.0
C3	Coryphaenoides mexicanus	1	muscle	21.3	1.4	22.7	9.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	14.3	0.0
C3	Monomitopus sp.	2	muscle	34.1	3.8	37.9	22.9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	19.7	0.0
C3	Nematocarcinus rotundus	5	muscle	44.6	39.0	83.6	40.9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
C4	Cataetyx sp.	1	muscle	47.3	6.3	53.6	13.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

peaks are due to the hydrocarbons mentioned above and the second set of peaks were tentatively identified as C_{28} to C_{30} endogenous steroidal compounds (Fig. 3-12). When hydrocarbons were detected in fish, the concentrations were highest in liver tissue. Generally no hydrocarbons were detected in gonad tissue.

No two to five ring aromatic hydrocarbons were detected by GC/MS. Hydrocarbons listed in Table 3-11 as aliphatic and aromatic occurred in the extractable organic material and can be primarily attributed to biogenic compounds.

Cruise II

Cruise II organism analyses are approximately one-half complete and should be completed within one month (Table 3-12). Preliminary results are very similar to Cruise I results. Gravimetric weights are extremely variable and appear to be predominantly biogenic in origin. At a molecular level, the dominant hydrocarbons are pristane, n-C_{17}, and n-C_{15} indicative of a planktonic or algal origin. Also as during Cruise I, other hydrocarbons accompanied the dominant compounds including phytane, n-C_{16}, n-C_{18} and n-C_{20}. Few or no hydrocarbons were generally detected above n-C_{21}. The analytical data base needs to be more extensive and complete before generalizations as to trophic level, geographic, and contamination (pollution) effects can be ascertained. In general, all hydrocarbon species in organisms appeared to be pristine.

One exception was a pooled sample of shrimp (Nematocarcinus rotundus, five individuals) from Station E3. The complete suite of alkanes and the unresolved complex mixture strongly suggested petroleum contamination (Fig. 3-13). Bottom tars were also collected in this trawl. The shrimp may have become contaminated in the trawl, but one would expect that contamination during sampling would be confined to the exterior hard parts.

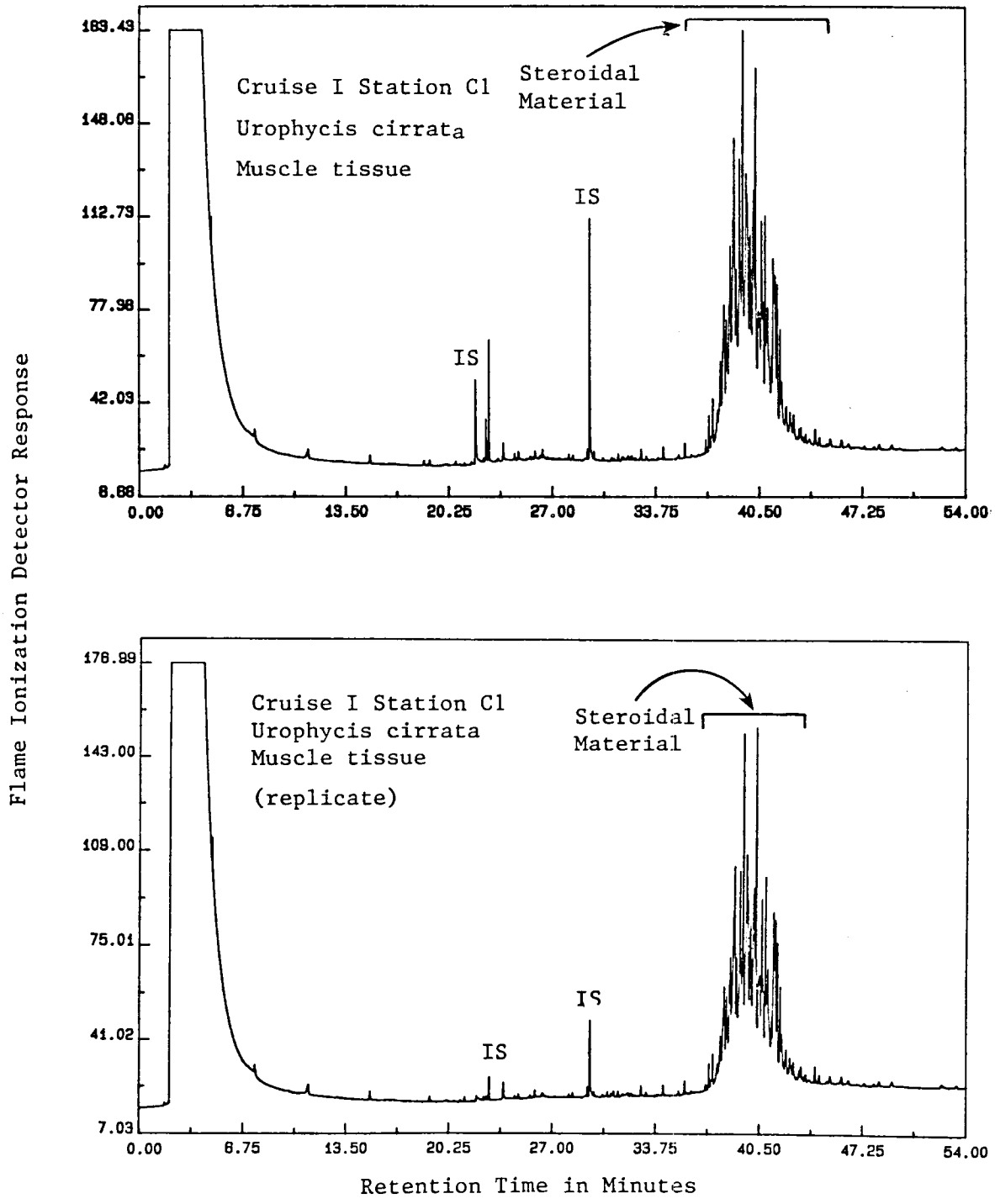


Figure 3-12. Selected examples of organism aliphatic hydrocarbon gas chromatograms.

TABLE 3-12

Summary of Cruise II organism hydrocarbon data completed to date.

STN	SPECIES	# OF IND	TISSUE	EOM (ppm) ALIPH	AROM	TOT EOM	N-C15	N-C16	N-C17	PRISTANE	N-C18	PHYTANE	N-C19	N-C20	N-C21
W1	Penaeopsis serrata	31	muscle	8.1	3.5	11.6	26.9	197.6	31.4	66.2	33.9	18.4	9.8	8.0	0.0
W2	Bathygadus macrops	2	muscle	35.3	6.0	41.3									
W3	Geryon quinquedens	2	muscle	78.0	7.1	85.1									
W3	Munidopsis spinosa	6	muscle	6.6	3.1	9.6									
W3	Synaphobranchus brevidorsalis	3	muscle	67.2		67.2									
W3	Synaphobranchus brevidorsalis	1	muscle	51.0	46.9	97.9									
W3	Synaphobranchus brevidorsalis	1	liver	907.6	38.5	946.0									
W3	Synaphobranchus brevidorsalis	3	liver	331.3		331.3									
W3	Synaphobranchus brevidorsalis	1	gonad	214.7	37.3	252.0									
W3	Synaphobranchus brevidorsalis	3	gonad	68.8		68.8									
W3	Dicrolene sp.	1	muscle	333.3	65.2	398.5									
W3	Monomitopus sp.	3	muscle	107.4	23.7	131.0									
W3	Coryphaenoides mexicanus	2	muscle	30.9	48.5	79.5									
W3	Halosaurus guentheri	2	muscle	38.5	401.7	440.2									
W3	Bathygadus macrops	2	liver	893.7	71.3	965.0									
W3	Coryphaenoides mexicanus	2	liver	1225.7	106.8	1332.4									
W3	Nematocarcinus rotundus	13	muscle	23.0	1.9	24.9	0.0	0.0	51.6	2118.8	51.7	0.0	39.9	22.4	0.0
W3	Glyphocrangon aculeata	10	muscle	23.1	16.1	39.1									
W3	Stereomastis sculpta	12	muscle	33.5	6.4	39.9	0.0	87.6	55.3	328.0	41.7	16.9	23.3	14.7	0.0
W4	Stereomastis sculpta	2	muscle	143.8	42.4	186.2									
W4	Penaeopsis serrata	10	muscle	114.6		114.6									

STN	SPECIES	# OF IND	TISSUE	EOM (ppm) ALIPH	AROM	TOT EOM	N-C15	N-C16	N-C17	PRISTANE	N-C18	PHYTANE	N-C19	N-C20	N-C21
C1	Synaphobranchus oregoni	1	muscle	102.2	56.5	158.7									
C1	Synaphobranchus oregoni	1	liver	611.7	41.5	653.2									
C1	Poecilopsetta beani	5	muscle	58.6		58.6									
C1	Urophycis cirratus	3	muscle			0.0									
C1	Urophycis cirratus	3	liver			0.0									
C2	Trichopeltarium nobile	3	muscle	238.5	36.0	274.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
C2	Bathygadus melanobranchus	1	muscle			0.0									
C2	Nezumia aequalis	4	muscle	40.1		40.1									
C2	Etmopterus schultzi	2	muscle			0.0									
C2	Bathygadus melanobranchus	1	liver	717.0		717.0									
C2	Etmopterus schultzi	2	liver			0.0									
C2	Nezumia aequalis	4	liver			0.0									
C3	Synaphobranchus oregoni	2	muscle	25.2		25.2									
C3	Synaphobranchus brevidorsalis	1	muscle	12.0		12.0									
C3	Synaphobranchus brevidorsalis	1	liver	9556.4		9556.4									
C3	Synaphobranchus oregoni	2	liver	147.8		147.8									
C3	Synaphobranchus oregoni	2	gonad	37.5		37.5									
C3	Stereomastis sculpta	6	muscle	24.3	6.8	31.0	17.5	84.9	40.9	412.4	31.4	13.7	24.8	9.8	0.0
C4	Geryon quinquedens	2	muscle	219.8	19.5	239.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

TABLE 3-12
(cont'd)

STN	SPECIES	# OF IND	TISSUE	EOM (ppm) ALIPH	EOM (ppm) AROM	EOM (ppm) TOT EOM	N-C15	N-C16	N-C17	PRISTANE	N-C18	PHYTANE	N-C19	N-C20	N-C21
E1	Geryon quinquedens	1	muscle	11.7	8.0	19.7									
E1	Bembrops gobioides	5	muscle	33.6	13.3	46.9									
E1	Bembrops gobioides	5	liver	580.4	1322.5	1902.9									
E1	Penaeopsis serrata	15	muscle	4.4	3.4	7.7									
E2	Nematocarcinus rotundus	12	muscle	11.0	4.7	15.6									
E3	Geryon quinquedens	1	muscle	73.4	9.5	82.9									
E3	Synaphobranchus brevidorsalis	1	muscle	33.3	12.3	45.6	0.0	2.7	29.2	221.6	32.1	10.5	9.7	0.0	0.0
E3	Synaphobranchus brevidorsalis	1	liver	138.1	50.0	188.1									
E3	Synaphobranchus brevidorsalis	1	gonad	55.8	5.5	61.3									
E3	Stereomastis sculpta	6	muscle	21.1	10.1	31.2									
E3	Glyphocrangon aculeata	3	muscle	62.7	26.0	88.6									
E3	Nematocarcinus rotundus	5	muscle	87.4	7.3	94.7									
E4	Geryon quinquedens	1	muscle	77.7	6.0	83.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
E4	Synaphobranchus brevidorsalis	1	muscle	70.6	29.4	100.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
E4	Synaphobranchus oregoni	1	muscle	30.3	1.9	32.1	0.0	47.7	100.5	764.3	136.8	218.9	303.8	129.4	111.5
E4	Synaphobranchus brevidorsalis	1	liver	255.0	233.5	488.5	15.3	52.6	25.6	309.6	18.0	0.0	17.4	0.0	0.0
E4	Synaphobranchus oregoni	1	liver	131.5	12.9	144.4									
E4	Synaphobranchus oregoni	1	gonad	60.9	9.8	70.7									
E4	Bathypterois quadrifilis	5	muscle	56.4	16.9	73.3									
E4	Dicrolene sp.	1	muscle	43.3	30.4	73.7	103.0	83.8	239.9	444.1	50.2	29.7	53.8	35.5	0.0
E4	Acanthephyra eximia	4	muscle	158.2	15.9	174.1	1410.8	544.0	202.9	5025.0	51.9	98.0	53.2	0.0	0.0
E4	Nematocarcinus rotundus	8	muscle	48.7	12.2	60.9	96.9	28.7	71.3	21.1	29.3	33.1	9.4	0.0	0.0

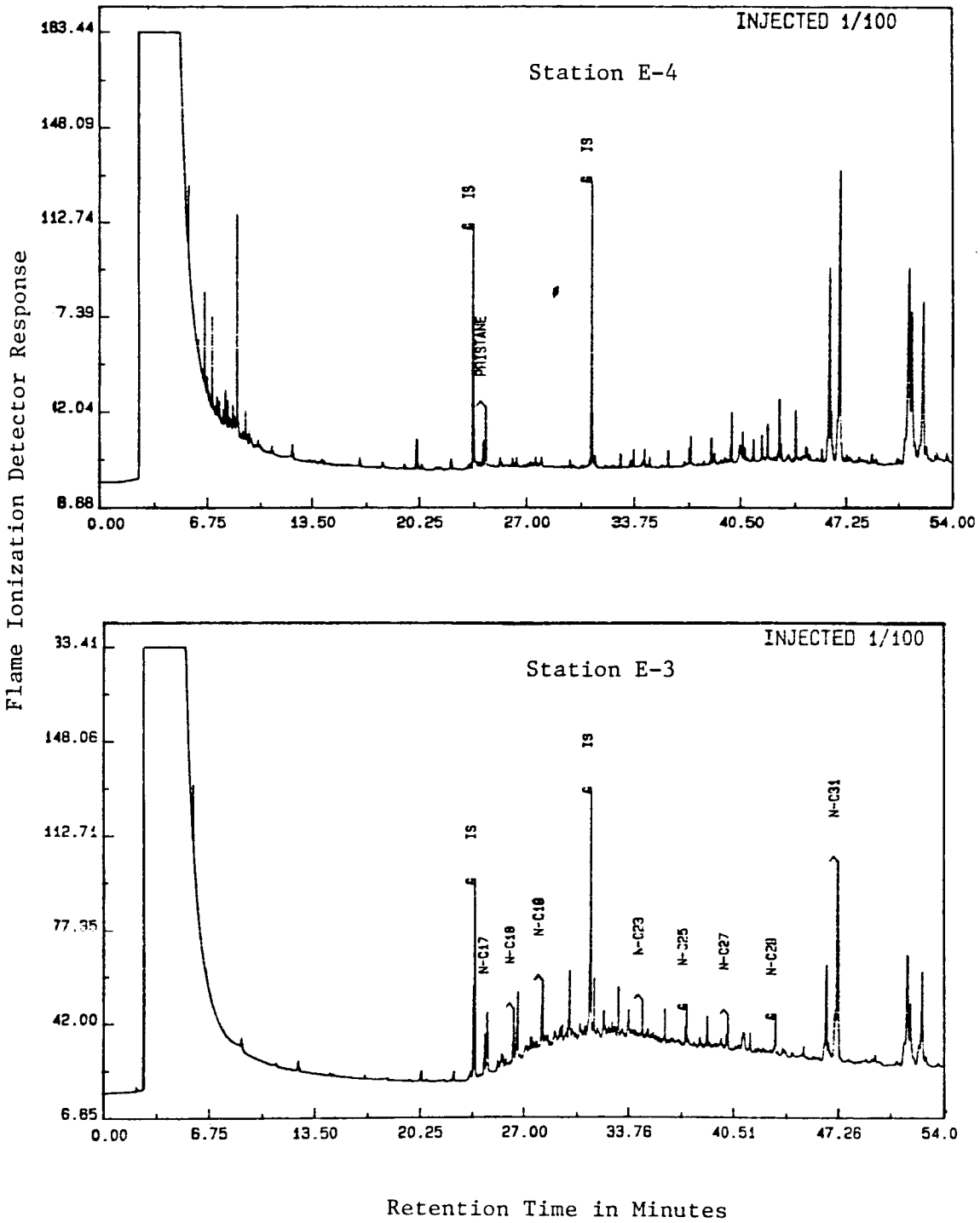


Figure 3-13. Aliphatic hydrocarbon gas chromatograms of of *Nematocarcinus rotundus* from Stations E-3 and E-4 of Cruise II.

4.0 BIOLOGICAL RESULTS AND DISCUSSION

Most of the data presented herein are presented in summary format. Complete listings of taxa and counts by station are subject to considerable change upon completion of the taxonomic analyses and are not provided at this stage in the program.

4.1 MEIOFAUNA

A total of some 74,445 meiofaunal organisms were enumerated in the Cruise I and II samples with the specimens representing about 36 major groups. Of these, representatives of five taxa of permanent meiofauna (Nematoda, Harpacticoidea, Polychaeta, Ostracoda, and Kinorhyncha) along with the protozoan Foraminifera and naupliar larvae (temporary meiofauna) comprised over 99% of the collections (Table 4-1). All groups were most abundant on the Central Transect.

Table 4-1. Total counts of dominant meiofauna for all five stations on each transect by cruise.

	Transects				
	West	Central		East	
Taxon	Cruise II	Cruise I	Cruise II	Cruise II	Totals
Nematoda	2785	13,261	15,145	3578	34,769
Foraminifera	251	2269	13,764	286	16,570
Harpacticoida	1256	5372	4786	1226	12,640
Polychaeta	219	656	1036	275	2186
Ostracoda	123	474	513	146	1256
Kinorhyncha	63	251	322	48	684
TOTALS	4697	22,283	35,566	5559	68,105
Percent of Total	0%	33%	52%	8%	100%
Naupliar larvae	619	1732	2443	590	5384
	12%	32%	45%	11%	100%

Considering only the permanent metazoan forms, nematodes and harpacticoids were by far the most abundant organisms. Without exception, the nematode worms are the most abundant metazoan component of the meiofauna in the marine environment. In fact, with only occasional exceptions, the nematodes outrank even the benthic Foraminifera which, of course, are protozoans that possess entirely different population and reproductive characteristics. In spite of their abundance, the taxonomy of the nematodes is poorly known. Hence it is difficult to obtain reliable identifications to the species level. As a result, considerable attention has been given in the literature to grouping nematodes into feeding types based on the morphology of the buccal cavity, as originally proposed by Wieser (1953). Because it has been thought that differences in the nematode fauna of sandy and silty clay habitats may be due to differences in the type of food present, several authors have studied the distribution of feeding types in different habitats (Coull 1970, Boucher 1974, Juario 1975). It is, however, difficult to believe that any positive correlations between a feeding type and sediment type result directly from the sediment. For instance, it is known that subtidal areas of similar sediment composition are not generally dominated by nematodes of the same feeding types (Boucher 1974, Juario 1975). Nevertheless, Wieser's (1953) feeding groups are instructive:

(a) Without oral cavity. Selective deposit feeders.
(b) With large unarmed oral cavity. Non-selective deposit feeders.
(c) With relatively weak oral armament. Epigrowth feeders, i.e., feed on alga adnate to sediment grains.
(d) With heavy oral armament. Predators and omnivores.

Juario (1975) found that epigrowth feeders, on a numerical basis, were almost always dominant, with the non-selective deposit feeders ranking second. It was noted, however, that whenever epigrowth feeder populations declined, there was an increase in non-selective deposit feeders and vice versa. As might be expected, the selective deposit feeders and predators were low in abundance at all times.

It is hoped that in the future the distribution of feeding types can be analyzed for the Central Transect when the data from all cruises are in hand. Perhaps such a study will shed some light on the roles of sediment type and organic matter in determining the distribution of food and feeding types in deep water.

The predominantly benthic Harpacticoida is one of several orders of the subclass Copepoda of the class Crustacea. As a rule, the harpacticoids are small, ranging in size from 0.2 to 2.5 mm, and the majority of species are found in the marine benthic environment (Venn 1980). Without exception in the present study they are the second most abundant metazoan component of the meiofauna in the deep-Gulf environment. Except for two results from the Central Transect stations during Cruise II, the harpacticoids outnumbered even the Foraminifera at all depths. It is possible that the large numbers of forams present on the Central Transect during Cruise II could have resulted from a recently completed peak in recruitment (see Tables 4-2 and 4-3). This seems plausible because such large numbers did not occur at any depth on other transects during Cruise II, nor at any depth on the Central Transect during Cruise I.

4.1.1 Density

Density data (no/10 cm^2) for meiofauna are graphed in Figures 4-1 and 4-2, with supporting tabular data provided in Tables 4-2 and 4-3 (density) and Tables 4-4 and 4-5 (percentages). The densities of meiofauna found in the present study can be compared with those obtained in other studies with the usual caveats that sampling and preparation procedures differ slightly among the studies. For instance, Pequegnat (1979) found that populations tended to decrease with increasing depth between 10 and 134 m; however, this trend was not uniform. Populations of meiofauna ranged from 925/10 cm^2 at 10-m depths to 128/10 cm^2 at 134 m off the coast of Texas. We found that populations in the present study ranged from a high of 1136/10 cm^2 to a low of 126/10 cm^2 at a depth of 2530 m. Juario (1975) working in the German Bight obtained a value of 3914/10 cm^2 at a depth of 35 m; whereas Boucher (1972) calculated populations as high as 4480/10 cm^2 at 35-m depth in the Mediterranean. It should be noted, however, that

TABLE 4-2

Densities of Meiofauna During Cruise I (No./10 cm^2)

Taxa	Stations: Central Transect Only*				
	C1	C2	C3	C4	C5
Nematoda	278.3	274.7	227.1	168.8	199.5
Harpacticoida	115.5	132.6	97.7	69.0	50.4
Nauplii	32.9	36.6	34.6	20.8	25.2
Foraminifera	71.8	40.3	42.5	18.7	23.2
Polychaeta	22.8	11.2	8.7	9.4	4.8
Other Taxa	24.2	23.7	21.1	14.7	10.4
Average (x)	90.09	86.5	71.9	50.2	52.3
Harpacticoida/Nematode ratio =	0.42	0.48	0.43	0.41	0.25

*Station depths from 1 to 5 are in order 348, 657, 839, 1341, and 2530 m.

TABLE 4-3

Densities of Meiofauna During Cruise II (No./10 cm^2)

	Stations*														
	1			2			3			4			5		
Taxa/Transect	W	C	E	W	C	E	W	C	E	W	C	E	W	C	E
Nematoda	164.9	481.8	121.4	95.6	253.1	107.7	106.8	228.5	115.7	68.2	203.1	94.8	64.6	145.1	111.3
Harpacticoida	84.7	108.8	27.9	35.3	108.5	42.6	47.8	88.2	40.5	31.5	68.7	36.1	26.2	40.4	39.9
Nauplii	36.7	60.2	14.5	21.5	43.1	21.3	16.8	46.4	20.3	18.0	41.7	13.4	16.9	20.1	21.2
Foraminifera	22.9	420.7	12.6	7.3	223.4	7.4	6.8	215.1	6.4	2.4	240.8	5.5	5.2	55.9	11.8
Polychaeta	15.2	29.4	9.0	6.1	29.8	11.3	8.5	14.0	11.4	6.2	12.3	7.7	3.3	4.2	4.3
Other Taxa	26.6	35.1	13.9	10.9	19.7	7.9	7.7	20.4	10.4	7.1	15.7	9.6	9.5	8.1	7.3
Average by Transect	58.5	189.3	33.2	29.5	112.9	33.0	32.5	108.1	34.1	22.2	97.1	27.9	21.0	45.6	32.6
Harpacticoid/ Nematode Ratio	0.51	0.23	0.23	0.37	0.43	0.40	0.45	0.39	0.35	0.46	0.34	0.38	0.41	0.28	0.36

*Station depths from 1 to 5 are in order 348, 657, 839, 1341, and 2530 m.

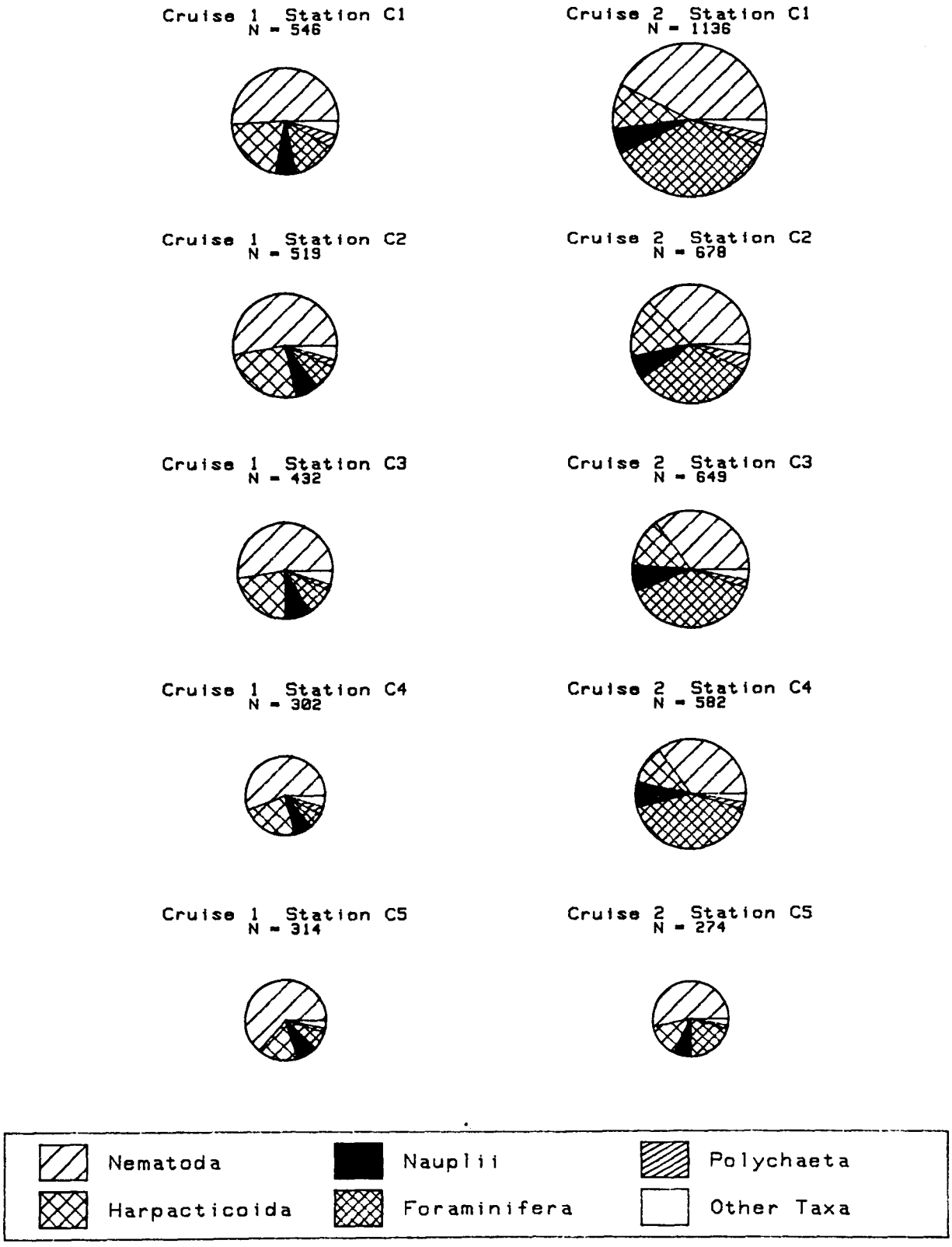


Figure 4-1. Comparison of meiofauna densities (no./10 cm^2) between Cruises I (November 1983) and II (April 1984). Note the large increase of forams in Cruise II diagrams. Comparisons can be made on both axes.

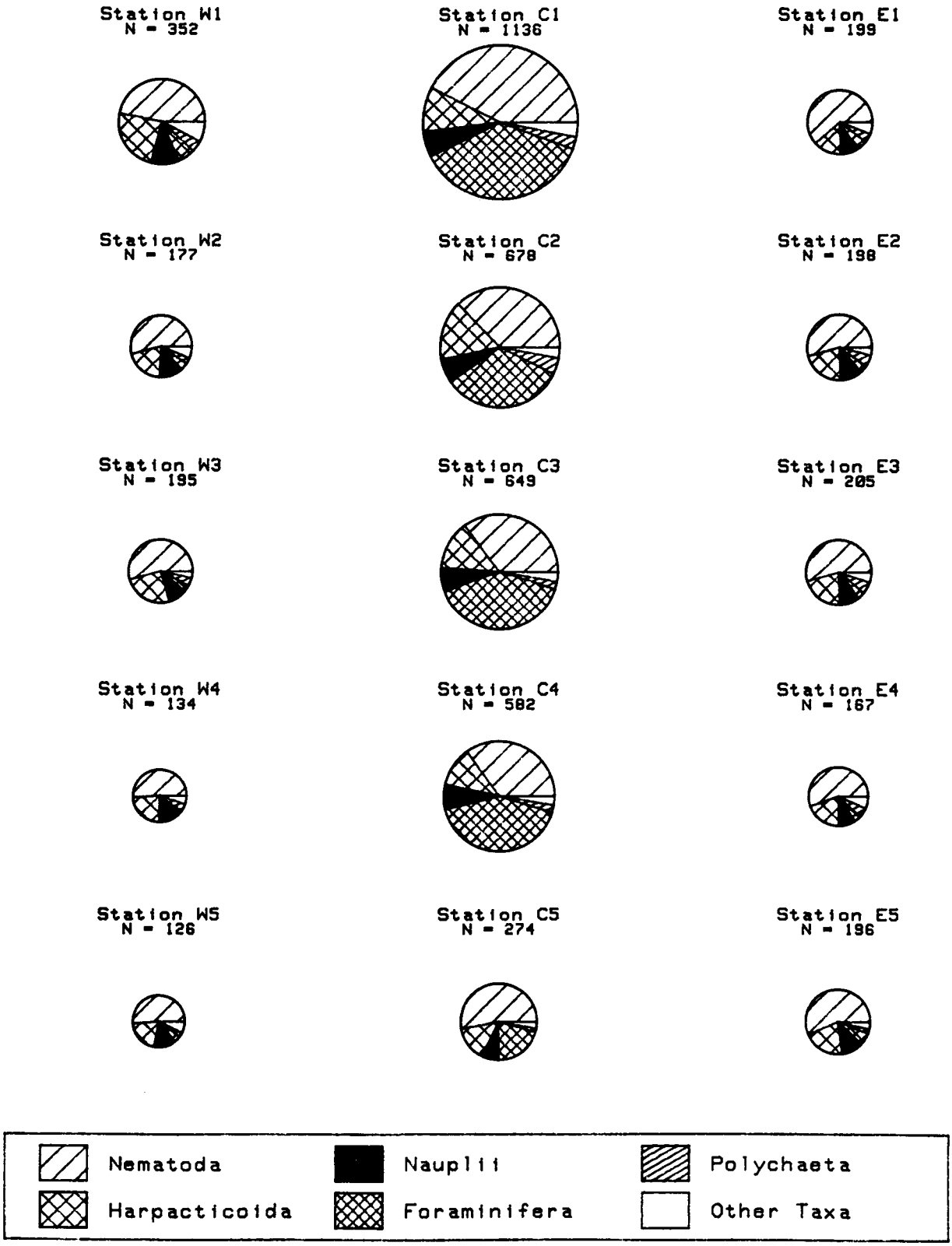


Figure 4-2. Comparison of meiofauna densities (no./cm^2) obtained during Cruise II (April 1984). Comparisons can be made on both axes.

TABLE 4-4

The Percentages of the Total Populations of Meiofauna Found at the Five Stations of the Central Transect During Cruise I (November 1983) and Cruise II (April 1984). Results are directly comparable with Figure 4-1

STATIONS:	1		2		3		4		5		Averages All Stations	
Taxa/Cruise	I	II	I	II	I	II	I	II	I	II	Cruise I	Cruise II
Nematoda	53.4	43.8	55.5	38.5	55.3	36.4	58.9	35.8	65.8	54.6	57.8	41.8
Harpacticoida	22.2	9.9	26.8	16.5	23.8	14.0	24.1	12.1	16.6	15.2	22.7	13.5
Nauplii	6.3	5.5	7.4	6.6	8.4	7.4	7.2	7.4	8.3	7.6	7.5	6.9
Foraminifera	13.8	38.2	8.1	34.0	10.4	40.0	6.5	42.5	7.7	21.1	9.3	35.2
Polychaeta	4.4	2.7	2.3	4.5	2.1	2.2	3.3	2.2	1.6	1.6	2.7	2.6
Other Taxa	4.6	3.2	4.8	3.0	5.1	3.2	5.1	2.8	3.4	3.0	4.6	3.0

Note: 1) Nematodes comprised a lower percentage of the total meiofauna on the Central Transect during Cruise II than I at all stations.
2) The same is true of the harpacticoid copepods: $\bar{X}$ = 22.70 on Cruise I; 16.22 on Cruise II.
3) Foraminifera were just the reverse, averaging 9.3 on I and 35.15 on II.
4) The percentage of nematodes on the Central Transect during Cruise I tends to increase with increasing depth; this trend is not as uniform on Cruise II, but the percentage at Station 5 (54.6%) is higher than at Station 1 (43.8%). This trend is not observed in the other groups. In fact, it is more or less reversed in the forams and polychaetes.

TABLE 4-5

The Percentages of the Total Populations of Meiofauna Found at the Five Stations on the Three Transects on Cruise II. The values are directly comparable with Figure 4-2

STATION:	1			2			3			4			5		
Taxa/Transect	W	C	E	W	C	E	W	C	E	W	C	E	W	C	E
Nematoda	50.8	43.8	65.4	57.7	38.5	56.6	57.2	36.4	58.4	54.0	35.8	59.3	55.6	54.6	59.1
Harpacticoida	26.1	9.9	15.1	21.3	16.5	22.4	25.6	14.0	21.9	24.9	12.1	21.1	22.5	15.2	21.2
Nauplii	11.3	5.5	8.6	13.0	6.6	11.2	9.0	7.4	9.9	14.2	7.4	9.9	14.6	7.6	11.2
Foraminifera	7.0	38.2	6.1	4.4	34.0	3.9	3.7	40.0	3.6	1.9	42.5	4.0	4.5	21.1	6.3
Polychaeta	4.7	2.7	4.8	3.7	4.5	5.9	4.6	2.2	6.2	4.9	2.2	5.6	2.8	1.6	2.3
Other Taxa	8.4	3.2	6.4	6.6	3.0	4.2	4.1	3.2	6.1	5.6	2.8	7.1	8.2	3.0	3.9

Note: 1) That the percentage of nematodes on Cruise II tends to be higher on the Eastern Transect than on the other two, and is consistently higher on the Western Transect than on the Central. This is not true of the harpacticoids which are relatively more abundant on the Western Transect than on the other two, and is consistently higher on the Eastern Transect than on the Central Transect.
2) The Foraminifera on the other hand during Cruise II were significantly higher on the Central Transect than on the other two, but exhibited no uniform trend between the East and West Transects.
3) Unlike the findings on the Central Transect the percentage of nematodes on the Western Transect although higher at Station 5 than Station 1 is even higher at the intermediate stations, i.e., there is no uniform trend of increasing percentage with depth. The Eastern Transect does not project this trend at all. In fact, the percentage is higher at Station 1 than at Station 5, but it should be noted that Station 5 of the Eastern Transect has proportionally more nematodes than do the other transects.
4) As might be expected, the harpacticoids on the Western Transect are proportionally more abundant at Station 1 than at Station 5, but are more abundant at Station 5 than at 1 on the Eastern Transect.

these were exceptions on the high end of the scale. Values of other investigators studying in the German Bight at depths of 25 and 33 m were 823 and 1083/10 cm^2, respectively. At 146 m in the North Sea, McIntyre (1964) found 1959/10 cm^2 of total meiofauna.

Depth Comparisons

Except for Stations 3 and 5 on the East Transect (vertical axis on Fig. 4-2) and Station 3 on the West Transect, a very marked trend of decreasing density with depth increase seems to occur. This is particularly marked on the Central and West Transects where the densities at Station C5 are a fraction of that at C1. The exception noted for the East Transect is primarily accounted for by substantial increases in nematodes, harpacticoids, naupliar larvae, and forams between Station E3 (the low point) and Station E5. Interestingly, polychaetes, ostracods, and kinorhychs exhibit a reduction between these same stations.

Sampling Period Comparisons

Overall, the major difference in the November 1983 and April 1984 meiofaunal samples from the Central Transect was the marked increase in the relative abundance of Foraminifera in April as compared to samples taken in November (Fig. 4-1, Table 4-4). This increase corresponded to decreases in the relative abundance of both nematodes and harpacticoids. Also on Cruise I, nematode relative abundance increased with depth, whereas this pattern was not as evident during Cruise II.

As described in Section 3.0, there was evidence that considerable changes occurred in the benthic environment on the Central Transect between the two cruises; namely a change in sediment composition towards coarser sediments and increased amounts of organic carbon including terrigenous plant materials. This input of materials was apparently associated with a bloom or recruitment of Foraminifera in the sediments. The observed blooms likely also contributed to the marked increase in sediment levels of calcium carbonate in April.

Transect Comparisons

Meiofaunal densities on the Central Transect in April 1984 were markedly higher than densities observed for the transects to the east and west (Fig. 4-2, Table 4-5). The relative abundance of Foraminifera was much higher on the Central Transect than on either the Eastern or Western Transects. The percentage of the collections represented by nematodes was higher on the Eastern Transect than on the other two, and was consistently higher for stations on the Western Transect as compared to the Central Transect. In contrast, harpacticoids were relatively more abundant on the Western Transect than on the other two, and were consistently more abundant on the Eastern than on the Central Transect. These and other differences noted on Table 4-5 are most likely related to the sediment grain size differences between the transects as described in Section 3.0.

The Eastern Transect contained higher levels of sand and calcium carbonate than the other transects, with the Western Transect having coarser sediments and higher levels of calcium carbonate than the Central Transect.

4.1.2 Noteworthy Collections of Rare Groups

Since publication by Linnaeus of his Xth edition of the "Systema Naturae", in 1758, the accepted foundation of modern taxonomy, several new phyla of metazoan animals were described up to and including the first decade or two of the 20th century. Most of the discoveries dealt with sizable macrofaunal organisms. It was not until the 1920s that a new era of discovery began when Remane began an organized study of the assemblage of microscopic metazoans living in the interstitial environment created by marine sediments and associated pore waters. Interest in this assemblage increased after publication of a comprehensive paper on the fauna of intertidal sediments in an English estuary by Mare in 1942. It was in this paper that Mare separated and named the meiobenthos, separating it from the micro- and macrobenthos. In 1969, Kristensen, while studying the interstitial fauna of shelly gravel of Danish estuaries, isolated an undescribed animal which, in 1983, he described as a representative of a new phylum, the Loricifera. Later he found representatives of this group

in Greenland (to depths of 110 m), France (30 m), the Azores (480 m), North Carolina, and Florida (15 m). Beyond doubt, one life stage or another of the Loricifera have been seen by numerous biologists who were studying interstitial assemblages, but all failed to perceive their unique set of characteristics that set them apart from the Rotifera and Kinorhyncha with which Loriciferans might easily be confused. It is therefore a matter of great interest that the present LGL study has discovered a rich source of Loricifera in the northern Gulf of Mexico at considerably greater depths than previously known.

Through Cruise II, 43 specimens of the phylum Loricifera were collected at nine sampling stations distributed among the three vertical transects (Table 4-5a).

Table 4-5a. LGL collection of Loricifera from the northern Gulf of Mexico, Cruise II, April 1984.

Transect/Station	Depth (m)	Number of Individuals	
W1	348	4	
W2	657	2	6
C3	839	1	
C4	1341	15	
C5	2530	3	19
E1	348	1	
E2	657	2	
E3	839	8	
E4	1341	7	18
	TOTAL		43

The depth distribution clearly shows that the Loricifera are certainly not shallow-water meiofauna. In fact, as seen in Table 4-6, they appear in the northern Gulf of Mexico to be most common at depths ranging between

800 and 1400 m, or from the Archibenthal Zone (Horizon B) into the Upper Abyssal Zone.

Table 4-6. Depth distribution of Loricifera collected by LGL, Cruise II, April 1984.

Depth (m)	Number of Individuals
348	5
657	4
839	9
1341	22
2530	3
TOTAL	43

At present, we are uncertain as to how many genera and species are represented in this collection beyond the new genus designate studied by R.P. Higgins of the Smithsonian Institution. On 15 January 1985, in a letter addressed to Fain Hubbard of LGL, Higgins advised that the single Loriciferan sent to him (collected at a depth of approximately 800 m) represents a new genus in the family Nanaloricidae.

As is now known, the Loricifera are related to the Kinorhyncha, which represents another group of poorly known meiofauna. On Cruises I and II, representatives of the Kinorhyncha were collected from all sampling depths and from all transects (Table 4-7).

Table 4-7. LGL collection of Kinorhyncha from the northern Gulf of Mexico, Cruise I, November 1983, and Cruise II, April 1984.

Transect/Station	Depth (m)	Number of Individuals
W1	348	40
W2	657	3

Transect/Station	Depth (m)	Number of Individuals	
W3	839	5	
W4	1341	5	
W5	2530	10	63
C1	348	287	
C2	657	78	
C3	839	99	
C4	1341	54	
C5	2530	55	573
E1	348	18	
E2	657	3	
E3	839	9	
E4	1341	11	
E5	2530	7	48
	TOTAL		684

As a result from these cruises, we now possess 684 individuals representing an unknown number of kinorhynch species. As seen in Table 4-7, the largest numbers by far were collected from the Central Transect. Depthwise, combining all transects, the kinorhynchs occur from Station 1 at 348 m down to Station 5 at 2530-m depth. However, they appear to be most abundant at 348 m (345 specimens), which places them as markers of the Shelf/Slope Transition Zone.

When the collections of both the Kinorhyncha and Loricifera have been studied more intensively by Dr. Higgins and the assemblage of new species is known and correlated with the depth distribution of the group, we shall be in a better position to discuss their ecological attributes. Even so, we can say at this time that the MMS program has one of the largest, if not the largest, collections of both Loricifera and Kinorhyncha in existence today. And undoubtedly, both will be increased substantially when the results of Cruises III, IV, and V are available. We can say now

that whereas Kristensen connected the Loricifera with coarse, often shelly, sediments, the MMS collections reveal that they are also abundant in fine sediments. Moreover, it is equally important to note that the kinorhynchs are far more abundant and extend far deeper into the marine environment that was thought prior to the appearance of the MMS samples.

4.1.3 Harpacticoid/Nematode Ratio (H/N Ratio)

The possibility of using the ratio of benthic copepods (harpacticoids) to nematodes as an index of pollution, as proposed by Parker (1975), or as an indicator of any significant environmental perturbation has been proposed in previous studies (Gettleson and Pequegnat 1976; Pequegnat and Sikora 1977, 1979, and 1980). As indicated above, nematodes and harpacticoids are generally the two most abundant true meiofaunal components in the Gulf of Mexico. The concept undergirding use of the ratio between the two taxa is much the same as that associated with percentages of fauna represented, with the exception that in a ratio of two components each with different critical environmental responses, one might be able to more readily decipher the cause of a perturbation. Thus, in Gulf of Mexico studies to date, abundance of nematodes has been consistently found to be correlated with the coarseness of the sediment, whereas the abundance of harpacticoids has not (Gettleson and Pequegnat 1976; Rogers and Darnell 1971; Pequegnat and Sikora 1977, 1979). Harpacticoids appear to increase in numbers in some proportion with increases in available organic matter in the sediment. Nematodes have been shown to increase dramatically when sand increased beyond 60%, whereas harpacticoids decrease; probably not because of the sediment change but because sands tend to be less rich in available organics than do silts and some clays.

The first attempts to apply the H/N Ratio to the LGL deep-water studies are shown in Tables 4-2 and 4-3 above. For the first four stations on the Central Transect, the ratios are remarkably close, ranging from 0.41 to 0.48, but the ratio at Station 5 is about half that of the others. The reason is readily evident in that nematodes increased at Station 5 over Station 4, whereas the harpacticoids continued to drop in density.

The results of Cruise II are quite complicated showing no definitive patterns. Except at Station 2 on the Central Transect, the highest ratios are found on the Western Transect. In fact, all of the ratios of 0.41 to 0.51 were found there. The reason is more a substantial decrease in nematode density (Table 4-3) than in increases in harpacticoids. As yet, however, correlations with the sediment texture and organic carbon data presented in foregoing sections of the report have not been considered to be fruitful. One reason for this is simply that texture and chemical analyses were run on individual replicates and the biological data are presently tabulated for the composite sample at a station.

4.2 MACROINFAUNA

Macroinfauna from Cruises I and II have been completely sorted and enumerated according to the major taxonomic groups (Tables 4-8 through 4-11). In all but one collection (Station 5, Cruise I), the most abundant taxonomic group represented in the macroinfauna was the polychaete worms. At all but three stations (C1, C3, and C5, Cruise I), the nematodes were second highest in abundance. The next five most abundant groups were the harpacticoid copepods, isopods, bivalves, ostracods, and tanaidaceans. Each of the latter five groups varied in order of abundance at the different stations.

Most of the dominant groups of the Cruise I macroinfauna have been identified to the species level, including representatives of the Isopoda, Bivalvia, Tanaidacea, Amphipoda, Bryozoa, Ophuiroidea, Gastropoda, Scaphopoda, Ascidiacea, and myodocopan Ostracoda. The Polychaeta, Sipuncula, and Cumacea identifications were not completed in time for inclusion in this report. The nematode worms and harpacticoid copepods were not scheduled for more specific identifications.

4.2.1 Density

Overall densities of macroinfauna at the sampling stations (Tables 4-8 through 4-11) ranged from a low of 2435/m^2 (W5, April 1984) to a high of 8628/m^2 (C2, April 1984). With the exception of Rowe and Menzel (1971), there are few comparative data for the Gulf for this depth range (348 to

TABLE 4-8

Density of macroinfauna from Cruise I ordered by overall numerical dominance (no./m^2).

Taxon	Station C1	C2	C3	C4	C5	OVERALL DENSITY
POLYCHAETA	2035.7	2270.1	1874.6	2252.5	1022.3	1891.0
NEMATODA	539.0	697.1	386.6	1221.4	1534.9	875.8
HARPACTICOIDA	225.5	430.6	240.2	503.8	263.6	332.7
OSTRACODA	84.9	392.5	650.3	234.3	61.5	284.7
ISOPODA	588.8	172.8	187.5	169.9	90.8	241.9
BIVALVIA	143.5	96.7	199.2	266.5	149.4	171.1
TANAIDACEA	117.2	316.3	181.6	205.0	49.8	174.0
AMPHIPODA	193.3	137.7	84.9	52.7	8.8	95.5
BRYOZOA	14.6	23.4	38.1	278.3	2.9	71.5
NEMERTINEA	58.6	32.2	55.7	67.4	46.9	52.1
APLACOPHORA	55.7	52.7	58.6	26.4	11.7	41.0
SIPUNCULA	17.6	5.9	23.4	17.6		12.9
GASTROPODA	73.2	43.9	43.9	76.2	5.9	48.6
OPHIUROIDEA	26.4	11.7	35.1	43.9	23.4	28.1
CUMACEA	90.8	23.4	23.4	49.8	5.9	38.7
PORIFERA	5.9	5.9	5.9	26.4	55.7	19.9
SCAPHOPODA	11.7	26.4	41.0	64.4	41.0	36.9
HYDROZOA	8.8	2.9	2.9	23.4		7.6
HOLOTHUROIDEA	2.9		8.8	14.6		5.3
ASCIDIACEA		2.9	14.6	55.7		14.6
SCYPHOZOA	20.5			2.9		4.7
UNKNOWN	5.9		5.9	20.5		6.4
ECHINOIDEA	2.9		2.9	2.9	20.5	5.9
ANTHOZOA	2.9	5.9		8.8		3.5
BRACHIOPODA		8.8				1.8
PRIAPULIDA						0.0
KINORHYNCHA	2.9		5.9	8.8		3.5
ECHIURA						0.0
DECAPODA		2.9				.6
UNKNOWN CRUSTACEA	2.9	5.9		5.9		2.9
HALACARIDAE						0.0
TURBELLARIA			2.9			.6
OLIGOCHAETA						0.0
UNKNOWN COELENTERATA						0.0
MYSIDACEA				2.9		.6
CEPHALOCHORDATA				2.9		.6
ZOANTHARIA					5.9	1.2
PYCNOGONIDA				2.9		.6
CRINIODEA						0.0
ASTEROIDEA						0.0
GASTROTRICHA						0.0
Total	4332.2	4768.6	4182.8	5708.8	3400.7	4478.6

TABLE 4-9

Density of macroinfauna from Cruise II by numerical dominance (no./m^2).

Taxon	Station C1	C2	C3	C4	C5	OVERALL DENSITY
POLYCHAETA	4322.8	5010.5	3680.7	3382.5	1414.0	3562.1
NEMATODA	603.5	940.4	786.0	1147.4	1273.7	950.2
HARPACTICOIDA	168.4	705.3	435.1	807.0	322.8	487.7
OSTRACODA	35.1	512.3	515.8	315.8	182.5	312.3
ISOPODA	221.1	410.5	256.1	449.1	129.8	293.3
BIVALVIA	228.1	164.9	270.2	386.0	182.5	246.3
TANAIDACEA	77.2	424.6	284.2	207.0	49.1	208.4
AMPHIPODA	80.7	168.4	171.9	84.2	24.6	106.0
BRYOZOA	59.6	42.1	42.1	200.0	14.0	71.6
NEMERTINEA	52.6	56.1	84.2	45.6	45.6	56.8
APLACOPHORA	91.2	21.1	52.6	49.1	10.5	44.9
SIPUNCULA	42.1	28.1	17.5	56.1	24.6	33.7
GASTROPODA	63.2	10.5	52.6	42.1	17.5	37.2
OPHIUROIDEA	66.7	28.1	28.1	31.6	56.1	42.1
CUMACEA	10.5	66.7	28.1	42.1	14.0	32.3
PORIFERA			3.5	24.6	3.5	6.3
SCAPHOPODA	3.5		17.5	24.6	66.7	22.5
HYDROZOA	10.5	10.5	24.6	31.6		15.4
HOLOTHUROIDEA		7.0	17.5	10.5	3.5	7.7
ASCIDIACEA	3.5	3.5	14.0	56.1		15.4
SCYPHOZOA	7.0		7.0	3.5	14.0	6.3
UNKNOWN	3.5		7.0	14.0		4.9
ECHINOIDEA			3.5	14.0	14.0	6.3
ANTHOZOA	7.0		3.5	7.0		3.5
BRACHIOPODA	7.0	10.5	3.5		24.6	9.1
PRIAPULIDA	3.5		3.5	3.5	28.1	7.7
KINORHYNCHA				7.0		1.4
ECHIURA			3.5			.7
DECAPODA	3.5	3.5				1.4
UNKNOWN CRUSTACEA			3.5			.7
HALACARIDAE				10.5		2.1
TURBELLARIA					7.0	1.4
OLIGOCHAETA						0.0
UNKNOWN COELENTERATA						0.0
MYSIDACEA		3.5				.7
CEPHALOCHORDATA			3.5			.7
ZOANTHARIA						0.0
PYCNOGONIDA						0.0
CRINIODEA				3.5		.7
ASTEROIDEA						0.0
GASTROTRICHA						0.0
Total	6171.9	8628.1	6821.1	7456.1	3922.8	6600.0

TABLE 4-10

Density of macroinfauna from Cruise II by numerical dominance (no./m^2).

Taxon	Station E1	E2	E3	E4	E5	OVERALL DENSITY
POLYCHAETA	4336.8	3705.3	3838.6	2647.4	1147.4	2989.5
NEMATODA	1691.2	1894.7	1789.5	1405.3	773.7	1461.3
HARPACTICOIDA	343.9	294.7	456.1	494.7	305.3	381.4
OSTRACODA	182.5	154.4	308.8	347.4	173.7	236.5
ISOPODA	56.1	112.3	203.5	257.9	184.2	169.7
BIVALVIA	449.1	231.6	329.8	326.3	84.2	274.9
TANAIDACEA	63.2	175.4	266.7	205.3	78.9	156.0
AMPHIPODA	7.0	70.2	105.3	31.6	10.5	42.1
BRYOZOA	98.2	14.0	77.2	73.7	26.3	57.0
NEMERTINEA	56.1	35.1	42.1	21.1	21.1	33.4
APLACOPHORA	182.5	91.2	28.1	36.8	5.3	63.2
SIPUNCULA	161.4	98.2	56.1	73.7	36.8	81.7
GASTROPODA	84.2		35.1	36.8	21.1	34.7
OPHIUROIDEA	56.1	21.1	84.2	15.8	5.3	33.4
CUMACEA	35.1	7.0	84.2	47.4	36.8	42.1
PORIFERA		35.1	14.0	26.3	300.0	85.4
SCAPHOPODA	35.1		7.0	42.1		17.3
HYDROZOA	203.5	14.0	49.1	26.3	5.3	54.5
HOLOTHUROIDEA	21.1	56.1	42.1	89.5		42.1
ASCIDIACEA		7.0	28.1		10.5	8.7
SCYPHOZOA	105.3		42.1	15.8	10.5	32.2
UNKNOWN	14.0		7.0	5.3	10.5	7.4
ECHINOIDEA		7.0		5.3	5.3	3.7
ANTHOZOA			49.1	5.3		9.9
BRACHIOPODA		7.0				1.2
PRIAPULIDA			14.0			2.5
KINORHYNCHA	35.1					6.2
ECHIURA	63.2					11.1
DECAPODA		14.0		5.3	5.3	5.0
UNKNOWN CRUSTACEA						0.0
HALACARIDAE			7.0		5.3	2.5
TURBELLARIA	7.0					1.2
OLIGOCHAETA	28.1					5.0
UNKNOWN COELENTERATA						0.0
MYSIDACEA	7.0					1.2
CEPHALOCHORDATA						0.0
ZOANTHARIA						0.0
PYCNOGONIDA						0.0
CRINIODEA						0.0
ASTEROIDEA						0.0
GASTROTRICHA						0.0
Total	8322.8	7045.6	7964.9	6242.1	3263.2	6354.2

TABLE 4-11

Density of macroinfauna from Cruise II by numerical dominance (no./m^2).

	Station					
Taxon	W1	W2	W3	W4	W5	OVERALL DENSITY
POLYCHAETA	4140.4	3375.4	1838.6	1536.8	666.7	2311.6
NEMATODA	666.7	1396.5	1235.1	322.8	547.4	833.7
HARPACTICOIDA	203.5	280.7	456.1	231.6	484.2	331.2
OSTRACODA	14.0	203.5	168.4	77.2	126.3	117.9
ISOPODA	168.4	252.6	161.4	189.5	49.1	164.2
BIVALVIA	245.6	119.3	196.5	189.5	84.2	167.0
TANAIDACEA	105.3	112.3	168.4	119.3	98.2	120.7
AMPHIPODA	21.1	63.2	49.1	28.1	14.0	35.1
BRYOZOA	98.2	7.0	49.1	21.1	168.4	68.8
NEMERTINEA	98.2	98.2	70.2	28.1	7.0	60.4
APLACOPHORA	77.2	14.0	49.1	7.0	21.1	33.7
SIPUNCULA	189.5	49.1	21.1	28.1	14.0	60.4
GASTROPODA	14.0	7.0	21.1		7.0	9.8
OPHIUROIDEA	28.1	77.2	133.3	7.0		49.1
CUMACEA	28.1	21.1	56.1	7.0	7.0	23.9
PORIFERA		7.0	7.0	7.0	98.2	23.9
SCAPHOPODA	14.0		28.1	7.0	14.0	12.6
HYDROZOA	14.0	7.0	42.1		7.0	14.0
HOLOTHUROIDEA		56.1	14.0			14.0
ASCIDIACEA	14.0	14.0			7.0	7.0
SCYPHOZOA			7.0			1.4
UNKNOWN	21.1		7.0		14.0	8.4
ECHINOIDEA			7.0			1.4
ANTHOZOA	14.0					2.8
BRACHIOPODA				7.0		1.4
PRIAPULIDA			7.0			1.4
KINORHYNCHA						0.0
ECHIURA						0.0
DECAPODA		7.0				1.4
UNKNOWN CRUSTACEA						0.0
HALACARIDAE						0.0
TURBELLARIA						0.0
OLIGOCHAETA						0.0
UNKNOWN COELENTERATA	28.1					5.6
MYSIDACEA						0.0
CEPHALOCHORDATA						0.0
ZOANTHARIA						0.0
PYCNOGONIDA	7.0					1.4
CRINIODEA						0.0
ASTEROIDEA						0.0
GASTROTRICHA						0.0
Total	6210.5	6168.4	4793.0	2814.0	2435.1	4484.2

2530 m). Rowe and Menzel (1971) sampled over a depth range from 185 to 3770 m, using an anchor dredge to obtain samples. The samples were seived through a 0.42 mm screen as compared to the 0.30 mm screen used in this program. Densities reported by Rowe and Menzel (1971) ranged from 13/m^2 (3440 m) to a high of 1095/m^2 (270-295 m). Their collections in the 1000- to 2000-m depth range typically contained some 300 to 400 organisms/m^2.

The overall density data for the macroinfauna are graphed by station, cruise, and transect in Figures 4-3 and 4-4, and elaborated below.

Depth Comparisons

Samples taken on Cruise I at the Central Transect stations demonstrated fairly constant population densities among the depths or stations, with the values ranging from 3401/m^2 at Station C5 to 5709/m^2 at Station C4. Station C5 was characterized by the highest density of nematodes, being the only station where nematodes of macroinfaunal size outranked the polychaetes in numerical abundance. The densities of macroinfauna taken on Cruise II at the Central Transect were also fairly constant among stations, except for Station C5 which had a relatively low density of 3923/m^2 (Fig. 4-3 and Table 4-9). Densities at the other stations ranged from 6172/m^2 at C1 to 8628/m^2 at C2. Station C5, the deepest, also had the highest concentration of macroinfaunal-size nematodes, as was the case during Cruise I in November.

On the Eastern Transect (Fig. 4-4), the deepest station (E5) also had the lowest total population density (3263/m^2), with other stations having more or less similar population densities (from 6242/m^2 at E4 to 8323/m^2 at E1).

Population densities varied more among stations on the Western Transect than at any of the others. The lowest densities were at the deeper stations, W5 and W4, being 2433/m^2 and 2813/m^2, respectively. Highest macroinfaunal populations at this transect occurred at the shallowest stations, W1 and W2, where densities were 6211 and 6168/m^2, respectively. Intermediate population densities (4793/m^2) were found at W3.

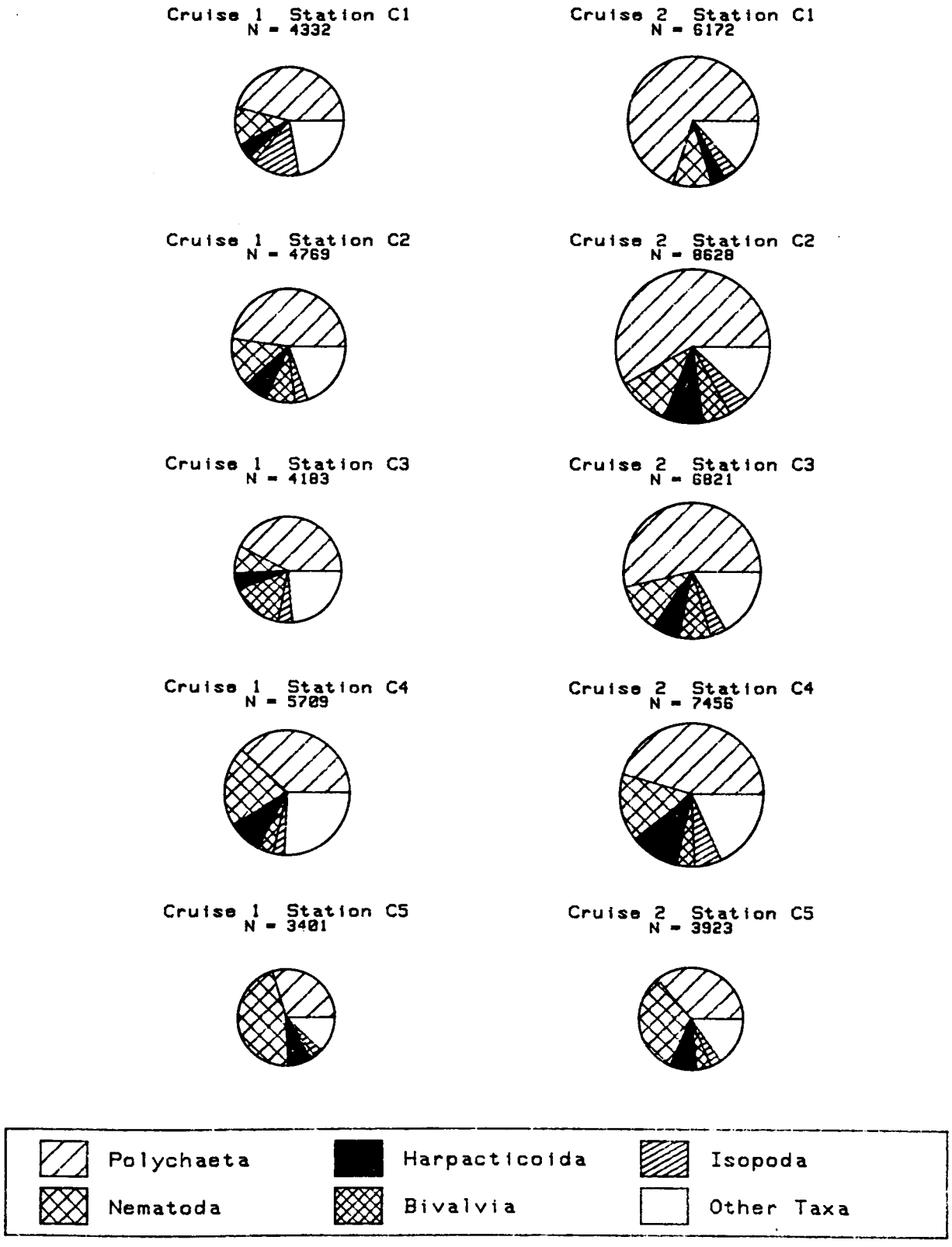


Figure 4-3. Comparison of macroinfauna densities (no/m^2) between Cruise I (November 1983) and Cruise II (April 1984) stations.

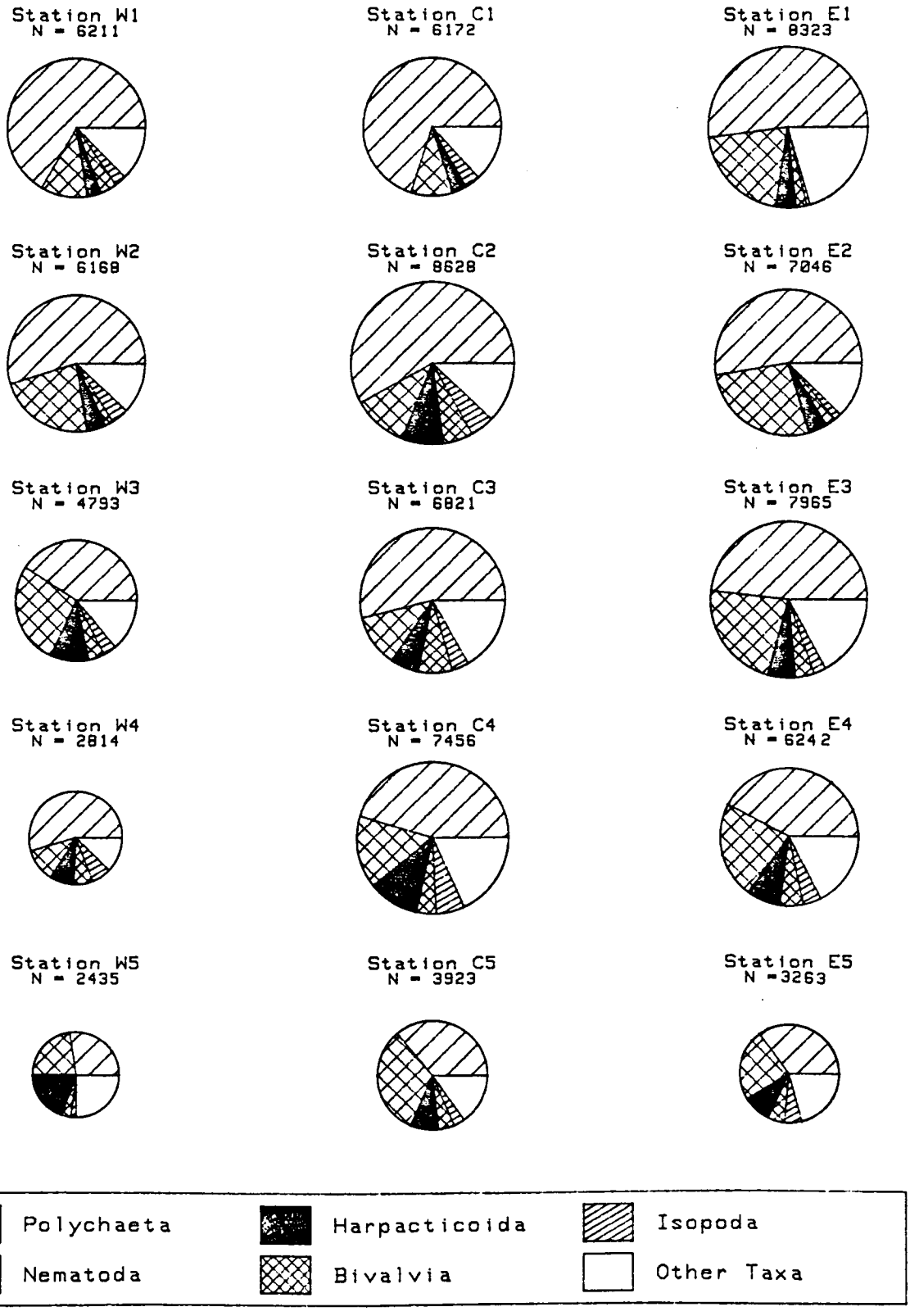


Figure 4-4. Comparison of macroinfaunal densities (no./m^2) obtained during Cruise II (April 1984).

Sampling Period Comparisons

With the possible exception of certain taxonomic groups at Station C5 (primarily the nematodes), abundance of macroinfauna was greater over the entire depth range of the Central Transect in April 1984 as compared to the November 1983 levels (Fig. 4-3, Table 4-12). Whether these differences represent true seasonal differences is conjectural, but consistently lower overall densities were encountered in all seven of the dominant macroinfaunal groups during the November sampling period as compared to the April samples. Increases in polychaete abundance accounted for the greatest amount of the observed differences (Table 4-12).

Table 4-12. Densities of major taxonomic groups of macroinfauna from the central transect in November and April (No./m^2 = mean density for five stations).

Taxon	November 1983 No./m^2	April 1984 No./m^2
Polychaeta	1891	3562
Nematoda	876	950
Harpacticoida	333	488
Ostracoda	285	312
Isopoda	242	293
Bivalvia	171	246
Tanaidacea	174	208
TOTAL MACROINFAUNA	4479	6600

Transect Comparisons

The Western Transect differed from the other two in two primary ways. First, abundance of macroinfauna was typically lower and; second, abundance exhibited a steady decline with depth (Fig. 4-4). At the

Western Transect, four of the five stations exhibited the lowest population densities when compared to the same-depth stations at the other two transects. The abundance pattern across transects was consistent for each of the major groups of taxa (Table 4-13), with the Western Transect showing lowest densities for all of the major taxonomic groups.

Table 4-13. Comparison of densities of major taxonomic groups of macroinfauna among the three transects in April 1984 (No./m^2 = mean density for five stations).

	Central	Eastern	Western
Total Macroinfauna	6600	6354	4484
Polychaeta	3562	2989	2312
Nematoda	950	1461	834
Harpacticoida	488	381	331
Ostracoda	312	236	118
Isopoda	293	169	164
Bivalvia	246	275	167
Tanaidacea	208	159	121

4.2.2 Analysis of the Macroinfauna by Taxonomic Groups

Polychaeta

Polychaete worms were the most numerically abundant group at all macroinfaunal stations sampled except at Station C5, Cruise I. They ranged from densities of 667/m^2 at Station W5 to 5011/m^2 at Station C2. Polychaete abundance tended to decrease with depth at each transect, with the deepest station at all transects showing the lowest polychaete counts as well as the lowest total macroinfauna counts. Polychaete populations were markedly lower at the Central Transect during November as compared to April (see Table 4-12). Due to the large numbers of polychaetes encountered, identifications to the species level were not completed in

time for this report. A more complete treatment of macroinfaunal polychaetes at the species level will be presented in a later report.

Nematoda

Nematode worms are the second most abundant group in the macroinfauna at all stations sampled except two (Stations C1 and C3 on the November 1983 cruise). They ranged in density from 323/m^2 at Station W4 to 1895/m^2 at Station E2.

Harpacticoida

Harpacticoid copepods in the macroinfaunal samples ranged in density from 168/m^2 at Station C1, to 807/m^2 at Station C4. Abundance showed no particular increase or decrease with depth along a transect. Harpacticoids were most numerous at Station 4 at all transects except the Western Transect, where they were most abundant at Station W5.

Ostracoda

Ostracod densities ranged from 14/m^2 at Station W1, to 650/m^2 at Station C3. Originally it was not intended to identify the ostracods to the species level, but because a taxonomist at the Smithsonian Institution was interested in the Gulf of Mexico myodocopan ostracods and offered to identify them at no cost to the project, the myodocopans have been identified to the species level. We have not as yet found a specialist to identify the podocopan ostracods.

Nine species of myodocopan ostracods were identified from Cruise I macroinfauna samples and are listed by depth of maximum populations in Table 4-14. The two most abundant species, Euphilomedes sp. A and Philomedes sp. A were found only at Station 2 (657 m). It is interesting to note that four of the myodocopan species have not been previously reported from the Gulf of Mexico and only one of the myodocopan species reported previously from northern Gulf continental shelf collections is in the slope collection from Cruise I. However, it should also be noted that most of the previous shelf material was taken in the western Gulf of

Mexico whereas Cruise I slope collections in this study were limited to the Central Transect.

Table 4-14. Abundance of ostracod species from the Central Transect (Cruise I), arranged in order of abundance by depths of maximum populations.

Species	Total individuals at all stations	Number of stations where species dominate	Occurrence on Transects	Depth range (m)	Depth of Max. Pop.
OSTRACODA					
HARBANSUS SP.B	6	0	C	348	348
CYLINDROLEBERIDINAE	2	0	C	348 - 839	348
EUPHILOMEDES SP.A	47	0	C	657	657
PHILOMEDES SP.A	16	0	C	657	657
SCLERANER SP.A	5	0	C	657	657
PSEUDOPHILOMEDES SP.A	1	0	C	657	657
PODOCOPA SPP.	367	5	C	348 - 2530	839
HARBANSUS SP.A	9	0	C	839	839
ANGULOROSTRUM SP.A	8	0	C	348 - 1341	1341
SPINACOPIA SP.A	2	0	C	1341	1341

Podocopan ostracods have not been identified to the species level. The podocopans as a group, although ranging throughout all of the depths sampled along the Central Transect, attained their maximum populations at C4 (839 m).

Isopoda

Isopods ranged in density from 49/m^2 at Station W5 to 589/m^2 at Station C1. The isopods were a very diverse group in the Cruise I macroinfauna (58 species have been identified, most of which are new species). The species are listed in Table 4-15 according to their depth of maximum population.

The two most abundant species, Gnathia sp. 201 and Prochelator sp. 202, occurred only at Station C1, while the third most abundant species, Prochelator sp. 209, ranged in depth between 657-2530 m (Stations 2-5). However, its depth of maximum population was at 657 m (Station C2). The species ranking fourth in abundance, Whoia sp. 225, ranged from 839-2530 m

TABLE 4-15

Abundance of isopod species from the Central Transect (Cruise I), arranged in order of abundance by depths of maximum poulations.

Species	Total individuals at all stations	Number of stations where species dominate	Occurrence on Transects	Depth range (m)	Depth of Max. Pop.	
ISOPODA						
GNATHIA SP.201	139	1	C	348	348	
PROCHELATOR SP.202	28	0	C	348	348	
CONILERA SP.214	17	0	C	348	348	
GNATHIA SP.211	5	0	C	348	348	Sta 1
EUGERDA SP.203	5	0	C	348	348	
GNATHIA SP.210	2	0	C	348	348	
CHELATOR SP.212	2	0	C	348	348	
EURYCOPIDAE NEW GENUS Y	1	0	C	348	348	
NANNONISCIDAE N. GEN. SP.213	1	0	C	348	348	
PROCHELATOR SP.209	27	1	C	657 - 2530	657	
ISOPODA SPP.	8	0	C	657 - 839	657	
EUGERDA SP.215	8	0	C	657 - 1341	657	
LEPTANTHURA SP.219	6	0	C	657 - 1341	657	
HAPLOMESUS SP.207	5	0	C	657	657	
ISCHNOMESUS SP.208	4	0	C	657	657	
WHOIA SP.216	3	0	C	657 - 839	657	Sta 2
DESMOSOMATIDAE	3	0	C	657	657	
NOTOXENOIDES SP.206	3	0	C	657	657	
REGABELLATOR SP.221	1	0	C	657	657	
LEPTANTHURA SP.205	1	0	C	657	657	
BELONECTES SP.220	1	0	C	657	657	
ISCHNOMESUS SP.222	1	0	C	657	657	
WHOIA SP.225	15	0	C	839 - 2530	839	
MACROSTYLUS SP.223	11	1	C	657 - 1341	839	
NANNONISCUS SP.233	4	0	C	839 - 1341	839	
EUGERDA SP.236	4	0	C	839 - 1341	839	
ISCHNOMESUS SP.227	3	0	C	839 - 1341	839	
PROCHELATOR SP.238	3	0	C	839	839	
PROCHELATOR SP.228	3	0	C	839	839	
GNATHIA SP.226	2	0	C	839	839	Sta 3
HAPLONISCUS SP.234	2	0	C	839	839	
PANETELA SP.224	1	0	C	839	839	
EXILINISCUS SP.232	1	0	C	839	839	
NANNONISCOIDES SP.229	1	0	C	839	839	
EURYCOPIDAE NEW GENUS G	1	0	C	839	839	
CHELATOR SP.237	6	0	C	839 - 1341	1341	
EURYCOPIDAE NEW GENUS H	5	1	C	1341	1341	
ILYARACHNA SP.218	4	0	C	657 - 1341	1341	
NANNONISCUS SP.242	3	0	C	1341 - 2530	1341	
THAMBEMA SP.243	3	0	C	1341	1341	
ACANTHOCOPE SP.231	3	0	C	839 - 1341	1341	
ISCHNOMESUS SP.247	2	0	C	1341	1341	
HAPLOMESUS SP.239	2	0	C	1341	1341	
DESMOSOMA SP.248	2	0	C	1341	1341	Sta 4
BALBIDOCOLON SP.253	1	0	C	1341	1341	
KATIANIRA SP.244	1	0	C	1341	1341	
CHELATOR SP.251	1	0	C	1341	1341	
DENDROTION SP.246	1	0	C	1341	1341	
DENDROMUNNA SP.249	1	0	C	1341	1341	
EUGERDELLA SP.241	1	0	C	1341	1341	
MIRABILICOXA SP.252	1	0	C	1341	1341	
NANNONISCOIDES SP.250	1	0	C	1341	1341	
NANNONISCONUS SP.240	1	0	C	1341	1341	
CRYPTONISCIDAE	1	0	C	1341	1341	
MACROSTYLUS SP.256	7	1	C	2530	2530	
PROCHELATOR SP.235	4	0	C	839 - 2530	2530	
EXILINISCUS SP.255	3	0	C	2530	2530	
PANETELA SP.225	1	0	C	2530	2530	Sta 5
MIRABILICOXA SP.254	1	0	C	2530	2530	

(Stations C3-C5) in depth, with its depth of maximum population at C3 (839 m). More isopod species (19 species or 32%) reached depths of maximum populations at Station C4 (1341 m) than at any other station. Stations C2 and C3 each had 13 isopod species or 22% reaching maximum populations at those depths (657 and 839 m).

Tanaidacea

The tanaidacean crustaceans ranged in density from 49/m^2 at Station C5 to 425/m^2 at Station C2. They typically showed lowest densities at the shallowest and deepest stations on all transects, and generally had highest densities at Stations 2, 3, and 4 at all transects.

A total of 59 species of tanaidaceans has been identified from Cruise I macroinfauna samples alone (Table 4-16). These specimens represent many new species. Of the 10 most dominant species, six of them reach their depth of maximum populations at Station 2 (657 m), two at Station 1 (348 m), and one each at Stations 3 (839 m) and 4 (1341 m).

As was the case with the Isopoda, more species of Tanaidacea, i.e., 21 species (35%), reach their depth of maximum populations at Station C4 (1341 m) than at any other depth, followed by Station 2 with 17 species (28%).

Bivalvia

Bivalve mollusks ranged in density from 84/m^2 at Station W5 to 449/m^2 at Station E1. A total of 40 bivalve species were identified from Cruise I macroinfauna samples (Table 4-17). The most abundant species, Vesicomya sp. A, ranged between 348-1341 m (Stations 1-4), but achieved its depth of maximum population at Station 3 (839 m). Of the ten dominant bivalve species, four had maximum populations at Station C4 (1341 m), three at Station 1 (348 m) and two at C5 (2530 m). More species (13 or 33%) reached their maximum populations at Station C4 (1341 m) than at any other station. Station C1 followed with 11 species (28%) and then Station C3 with 9 species (23%). Only two bivalve species had maximum populations at Station C2. Bivalves were more predominant at the deepest Station, C5,

TABLE 4-16

Abundance of tanaidacean species from the Central Transect (Cruise I), arranged in order of abundance by depths of maximum poulations.

Species	Total individuals at all stations	Number of stations where species dominate	Occurrence on Transects	Depth range (m)	Depth of Max. Pop.	
TANAIDACEA						
LEPTOGNATHIA SP.2	9	1	C	348 - 839	348	
TYPHLOTANAIS SP.3	8	0	C	348	348	
LEPTOGNATHIA SP.3	6	0	C	348 - 657	348	
LEPTOGNATHIA SP.1	5	0	C	348 - 657	348	Sta 1
TYPHLOTANAIS SP.2	4	0	C	348 - 657	348	
LEPTOGNATHIIDAE	2	0	C	348 - 657	348	
LEPTOGNATHIA SP.4	1	0	C	348	348	
APSEUDIDAE SP.1	20	1	C	657 - 1341	657	
PSEUDOTANAIS SP.1	18	0	C	348 - 657	657	
LEPTOGNATHIA SP.8	16	0	C	657 - 1341	657	
PARATANAIDAE SP.1	13	0	C	657 - 839	657	
LEPTOGNATHIA SP.9	12	0	C	657 - 1341	657	
NEOTANAIS SP.1	12	0	C	657 - 1341	657	
PARANARTHRURA SP.1	6	0	C	657 - 839	657	
LEPTOGNATHIA SP.5	3	0	C	657	657	
ROBUSTOCHELIA SP.1	3	0	C	657 - 839	657	Sta 2
PARANARTHRURA CF. INSIGNIS	3	0	C	348 - 657	657	
TYPHLOTANAIS SP.1	2	0	C	657	657	
PSEUDOTANAIDAE	2	0	C	657 - 839	657	
LEPTOGNATHIA SP.6	2	0	C	657	657	
LEPTOGNATHIA SP.7	2	0	C	657	657	
LEPTOGNATHIA SP.12	2	0	C	657 - 839	657	
LEPTOGNATHIA SP.11	1	0	C	657	657	
LEPTOGNATHIA SP.10	1	0	C	657	657	
LEPTOGNATHIA SP.15	9	1	C	839	839	
LEPTOGNATHIA SP.	5	0	C	657 - 1341	839	
TANAIDACEA SPP.	4	0	C	657 - 839	839	
TYPHLOTANAIS SP.4	3	0	C	839	839	
LEPTOGNATHIA SP.18	3	0	C	839	839	
TYPHLOTANAIS SP.5	2	0	C	839	839	Sta 3
ANARTHRURIDAE SP.1	2	0	C	839	839	
LEPTOGNATHIA SP.14	1	0	C	839	839	
LEPTOGNATHIA SP.16	1	0	C	839	839	
LEPTOGNATHIA SP.13	1	0	C	839	839	
PSEUDOTANAIDAE GENUS A	1	0	C	839	839	
PSEUDOTANAIS SP.2	11	1	C	839 - 1341	1341	
LEPTOGNATHIA SP.24	7	0	C	1341	1341	
LEPTOGNATHIIDAE GENUS A	6	0	C	839 - 1341	1341	
PARANARTHRURA SP.3	5	0	C	1341	1341	
LEPTOGNATHIA SP.23	4	0	C	1341	1341	
TYPHLOTANAIS SP.6	4	0	C	1341	1341	
TYPHLOTANAIS SP.7	4	0	C	1341	1341	
LEPTOGNATHIA SP.19	4	0	C	1341	1341	
LEPTOGNATHIA SP.17	3	0	C	839 - 1341	1341	
PSEUDOTANAIS SP.3	2	0	C	1341 - 2530	1341	Sta 4
AGATHOTANAIS SP.1	2	0	C	1341	1341	
LEPTOGNATHIA SP.25	2	0	C	1341	1341	
APSEUDES SP.1	1	0	C	1341	1341	
ANARTHRURIDAE SP.2	1	0	C	1341	1341	
LEPTOGNATHIA SP.22	1	0	C	1341	1341	
LEPTOGNATHIA SP.20	1	0	C	1341	1341	
LEPTOGNATHIA SP.21	1	0	C	1341	1341	
LEPTOGNATHIA SP.26	1	0	C	1341	1341	
PSEUDOTANAIS SP.	1	0	C	1341	1341	
PARANARTHRURA SP.2	1	0	C	1341	1341	
LIBANIUS	1	0	C	1341	1341	
LEPTOGNATHIA SP.29	3	1	C	2530	2530	
TYPHLOTANAIS SP.8	2	0	C	2530	2530	
LEPTOGNATHIA SP.27	2	0	C	2530	2530	Sta 5
LEPTOGNATHIA SP.28	1	0	C	2530	2530	

TABLE 4-17

Abundance of bivalve species from the Central Transect (Cruise I), arranged in order of abundance by depths of maximum poulations.

Species	Total individuals at all stations	Number of stations where species dominate	Occurrence on Transects	Depth range (m)	Depth of Max. Pop.	
BIVALVIA						
TELLINA SP.A	13	0	C	348 - 657	348	
EULAMELLIBRANCH SP.F	13	0	C	348 - 657	348	
THYASIRA SP.B	10	1	C	348	348	
PECTEN SP.B	4	0	C	348	348	
MALLETIA SP.B	3	0	C	348 - 657	348	
EULAMELLIBRANCH SP.E	2	0	C	348	348	Sta 1
NUCULANIDAE SP. INDET.	2	0	C	348	348	
NUCULANIDAE (NUCULANA) SP.D	2	0	C	348	348	
CUSPIDARIA SP.A	1	0	C	348	348	
ACAR ASPERULA	1	0	C	348	348	
EULAMELLIBRANCH SP.G	1	0	C	348	348	
NUCULA SP.B	6	0	C	348 - 657	657	
CYCLOPECTEN SP.A	5	0	C	657 - 1341	657	Sta 2
VESICOMYA SP.A	39	2	C	348 - 1341	839	
DACRYDIUM SP.A	7	0	C	839 - 1341	839	
NUCULANIDAE SP.C	7	0	C	839	839	
NUCULA SP.A	4	0	C	657 - 1341	839	
NUCULANIDAE (TINDARIA) SP.G	3	0	C	839	839	
EULAMELLIBRANCH SP.D	3	0	C	839	839	Sta 3
TELLINA SP.B	1	0	C	839	839	
PECTEN SP.A	1	0	C	839	839	
NUCULANIDAE SP.H	1	0	C	839	839	
BIVALVIA SP.INDET.	22	0	C	348 - 2530	1341	
LIMA SP.A	22	1	C	839 - 1341	1341	
EULAMELLIBRANCH SP.	15	0	C	839 - 2530	1341	
EULAMELLIBRANCH SP.B	12	0	C	1341 - 2530	1341	
NUCULANIDAE SP.A	10	0	C	1341	1341	
NUCULANIDAE SP.B	7	0	C	1341	1341	
PRONUCULA SP.A	6	0	C	839 - 2530	1341	
BATHYARCA SP.A	4	0	C	1341	1341	Sta 4
NUCULA SP.C	2	0	C	1341	1341	
ARCA SP.A	2	0	C	1341	1341	
PROTOBRANCH SP.	1	0	C	1341	1341	
MALLETIA SP.	1	0	C	1341	1341	
ASTARTE SP.A	1	0	C	1341	1341	
THYASIRA SP.A	16	1	C	2530	2530	
MALLETIA SP.A	13	0	C	2530	2530	
EULAMELLIBRANCH SP.A	3	0	C	2530	2530	
NUCULANIDAE (TINDARIA) SP.F	1	0	C	2530	2530	Sta 5
EULAMELLIBRANCH SP.C	1	0	C	2530	2530	

than most other macroinfaunal groups. Five species reached maximum populations at this depth.

Amphipoda

Amphipods ranged in density from 7/m^2 at Station E1 to 193/m^2 at Station C1. They tended to show higher densities at Stations 2 and 3 on all transects except the Central Transect in November (Cruise I) where they were most abundant at Stations 1 and 2. Lower densities were mostly at Stations 4 and 5 on all transects.

A total of 43 species of amphipods was identified from Cruise I macroinfauna samples (Table 4-18). Eighteen (or 41%) had their depth of maximum populations at Station 1 (348 m). This is in contrast to the other crustacean groups, the isopods and tanaidaceans, which showed the greatest species diversities at the deeper stations, especially Station 4 at 1341 m. In contrast, only three amphipod species had maximum populations at C4, compared to 19 and 21 species respectively for the isopods and tanaidaceans. Of the nine numerically dominant amphipod species, six reached maximum populations at Station 1 (348 m) and three reached maximum populations at Station 2 (657 m).

Bryozoa

With colonial animals like bryozoans, it is nearly impossible to enumerate individual specimens. As a practical solution to this problem, our numbers of bryozoans from this project are counts of bryozoan pieces. These counts ranged from 3/m^2 at Station C5 to 278/m^2 at Station C4. Bryozoan counts are remarkably consistent between the Novembver and April sampling periods at the Central Transect; i.e., high counts at C4, low counts at C5, and intermediate counts at C2 and C3. Station C1 had higher counts of Bryozoa in April (60/m^2) than in November (15/m^2).

A total of 11 species was identified from the Cruise I macroinfauna samples, most of which (8 species or 73%) had maximum populations at Station C4 (1341 m). This station also had the highest density of bryozoans of all the Central Transect stations (Table 4-19).

TABLE 4-18

Abundance of amphipod species from the Central Transect (Cruise I), arranged in order of abundance by depths of maximum populations.

Species	Total individuals at all stations	Number of stations where species dominate	Occurrence on Transects	Depth range (m)	Depth of Max. Pop.	
AMPHIPODA						
HARPININAE	20	1	C	348 - 2530	348	
AMPHIPODA	19	3	C	348 - 1341	348	
MAYERELLA CF. REDUNCA	8	0	C	348	348	
LYSIANASSIDAE N.SP.1	7	0	C	348 - 657	348	
AMPELISCA CF. PACIFICA	5	0	C	348	348	
AMPELISCIDAE	5	0	C	348 - 1341	348	
BYBLIS N.SP.1	4	0	C	348	348	
PARAMETOPELLA N.SP.1	3	0	C	348	348	St
OEDICEROPSIS	3	0	C	348 - 839	348	
MELITIDAE SP.1	3	0	C	348 - 839	348	
LEPTOPHOXUS N.SP.A	3	0	C	348 - 839	348	
BATHYMEDON N.GEN.	3	0	C	348	348	
MAYERELLA REDUNCA	2	0	C	348	348	
MELITIDAE	2	0	C	348 - 657	348	
LEPTOPHOXUS	2	0	C	348 - 839	348	
COROPHIIDAE SP.1	1	0	C	348	348	
MELITIDAE SP.3	1	0	C	348	348	
LEPECHINELLIDAE	1	0	C	348	348	
PARDISYNOPIA N.SP.1	99	1	C	657 - 1341	657	
PHOXOCEPHALUS A N.SP.	5	0	C	657 - 1341	657	
PHOXOCEPHALUS B	5	0	C	348 - 657	657	
METAPHOXUS P	2	0	C	657	657	
LYSIANASSIDAE SP.2	2	0	C	657	657	
BYBLIS SP.2	1	0	C	657	657	S
PHOXOCEPHALIDAE SP.1	1	0	C	657	657	
METAPHOXUS N.SP.	1	0	C	657	657	
HAUSTORIIDAE	1	0	C	657	657	
SYNOPIIDAE SP.2	1	0	C	657	657	
GAMMAROPSIS SP. 1	3	0	C	839	839	
METAPHOXUS A	3	0	C	348 - 839	839	
MELITIDAE SP.2	2	0	C	839	839	
CARANGOLIA N.SP.1	2	0	C	839 - 1341	839	
METAPHOXUS SP.2	1	0	C	839	839	
LYSIANASSIDAE N.GEN.SP.1	1	0	C	839	839	
COROPHIIDAE UNKNOWN	1	0	C	839	839	S
ACANTHONOTOZOMATIDAE N.SP.1	1	0	C	839	839	
SYNOPIIDAE N.GEN.1	1	0	C	839	839	
METAPHOXUS	1	0	C	839	839	
MELITIDAE SP.4	1	0	C	839	839	
MELITA N.SP.	1	0	C	839	839	
JEDDO N.SP.1	2	0	C	1341	1341	
COROPHIOIDEA N.SP.1	1	0	C	1341	1341	S
METAPHOXUS B	1	0	C	1341	1341	
LYSIANASSIDAE	1	0	C	2530	2530	St

TABLE 4-19

Abundance of bryozoan species from the Central Transect (Cruise I), arranged in order of abundance by depths of maximum populations.

Species	Total individuals at all stations	Number of stations where species dominate	Occurrence on Transects	Depth range (m)	Depth of Max. Pop.	
BRYOZOA						
SPHAERULOBRYOZOON SPP.	2	0	C	839	839	Sta 3
CHEILOSTOMATA SP. D	1	0	C	839	839	
CHEILOSTOMATA SP. B	1	0	C	839	839	
CHEILOSTOMATA SP. A	8	2	C	657 - 1341	1341	
EUGINOMA CAVALIERI	8	2	C	348 - 2530	1341	
BIFAXARIIDAE SP.F	5	1	C	1341	1341	
CHEILOSTOMATA SP. C	3	0	C	839 - 1341	1341	
CHEILOSTOMATA SP. E	3	0	C	1341	1341	Sta 4
MEMBRANIPORA SPP.	2	0	C	1341	1341	
PSEUDALCYONIDIUM BOBINAE	1	0	C	1341	1341	
SCRUPOCELLARIA SPP.	1	0	C	1341	1341	

TABLE 4-20

Abundance of gastropod species from the Central Transect (Cruise I), arranged in order of abundance by depths of maximum populations.

Species	Total individuals at all stations	Number of stations where species dominate	Occurrence on Transects	Depth range (m)	Depth of Max. Pop.	
GASTROPODA						
CRENILABIUM SP.	3	1	C	348	348	
CIMA SP.	3	1	C	348 - 1341	348	
CORINNAETURRIS SP.	2	0	C	348	348	
CHRYSALLIDA SP.	1	0	C	348	348	Sta 1
MANGELIINAE	1	0	C	348	348	
BENTHOMANGELIA SP.	1	0	C	348	348	
TORNUS EXQUISITUS	1	0	C	348	348	
TARANIS MALMI	1	0	C	348	348	
EULIMA SP.	1	1	C	657	657	Sta 2
SKENEIDAE	2	0	C	839	839	
GASTROPODA SPP.	2	1	C	839	839	
MELANELLA	2	1	C	839 - 2530	839	
LISSOSPIRA SP.	1	0	C	839	839	Sta 3
ALVANIA XANTHIAS	1	0	C	839	839	

It is interesting to note that the only species occurring at Station C1 and at Station C5 was Euginoma cavalieri, which ranged throughout all depths at the Central Transect (348-2530 m) and was one of the dominants in these samples, tying with Cheilostomata sp.A for most abundant bryozoan. Only one other species, Cheilostomata sp. C, occurred at more than one station. The other eight species were confined to one station--either Station C3 or C4. It is also interesting to note that, from Cruise I macroinfaunal samples alone, there were at least six new species (Cheilostomata sp. A-F), four of which are new genera.

Gastropoda

Gastropod densities ranged from 0/m^2 at Stations E2 and W4 to 84/m^2 at Station E1. Gastropod densities tended to be highest at the shallowest station, Station 1, on all transects except the West Transect, where they were also relatively abundant at Station W3.

Thirteen species of Gastropoda were identified from Cruise I macroinfauna samples, most of which (8 species or 62%) achieved maximum populations at the shallowest station, C1, at 348 m (Table 4-20). Four species had maximum populations at Station C3 (839 m). Only one species, Melanella sp., ranged as deep as Station C5 (2530 m), and only one species, Cima sp., was taken at Station C4 (1341 m). Thus, it can be said that the gastropod mollusks predominate at the upper slope depths, in contrast to the bivalves, which are more dominant at lower slope depths.

Scaphopoda

Scaphopod mollusks attained densities ranging from 0/m^2 (at Stations C2, E2, W2, and E5) to 67/m^2 at Station C5 in April. Their consistent absence from Station 2 at all transects sampled in April is interesting to note. They were present in modest numbers, however, at Station C2 in November.

Seven scaphopod species were identified from Cruise I macroinfauna samples (Table 4-21). Most of the specimens were very small and extremely difficult to identify. All of the species except for the unidentifiable Scaphopoda had maximum populations at the three deeper stations, i.e., at

TABLE 4-21

Abundance of scaphopod species from the Central Transect (Cruise I), arranged in order of abundance by depths of maximum populations.

Species	Total individuals at all stations	Number of stations where species dominate	Occurrence on Transects	Depth range (m)	Depth of Max. Pop.	
SCAPHOPODA						
SCAPHOPODA (UNIDENTIFIABLE)	7	2	C	348 - 1341	348	Sta 1
SIPHONODENTALIIDAE	9	2	C	657 - 1341	839	Sta 3
EPISIPHON SP.	5	0	C	657 - 2530	839	
DENTALIIDAE	5	0	C	348 - 1341	1341	
CADULUS SP.	4	0	C	1341 - 2530	1341	Sta 4
HETEROSCHIZMOIDES CALLITHRIX	3	0	C	1341	1341	
EPISIPHON DIDYMUM	4	1	C	2530	2530	Sta 5
DENTALIUM PERLONGUM	1	0	C	2530	2530	

TABLE 4-22

Abundance of ophiuriod species from the Central Transect (Cruise I), arranged in order of abundance by depths of maximum populations.

Species	Total individuals at all stations	Number of stations where species dominate	Occurrence on Transects	Depth range (m)	Depth of Max. Pop.	
OPHIUROIDEA						
OPHIUROIDEA JUVENILE SP.B	5	1	C	348 - 1341	348	
OPHIUROIDEA JUVENILE SP.C	3	1	C	348 - 839	348	
AMPHIURA SEMIERMIS	1	0	C	348	348	Sta 1
OPHIUROIDEA JUVENILE SP.G	1	0	C	348	348	
OPHIUROIDEA JUVENILE SP.I	1	0	C	348	348	
OPHIERNUS SP.	1	0	C	657	657	
OPHIACANTHIDAE JUVENILE SP.J	1	0	C	657	657	Sta 2
OPHIOSTRIATUS SP.	1	0	C	657	657	
OPHIOTHOLIA SP.	11	2	C	839 - 1341	839	
OPHIACANTHIDAE JUVENILE SP.K	2	0	C	839 - 1341	839	Sta 3
OPHIUROIDEA JUVENILE SP.A	5	0	C	839 - 1341	1341	
OPHIUROIDEA JUVENILE SP.D	4	0	C	1341 - 2530	1341	
OPHIUROIDEA JUVENILE SP.E	2	0	C	1341	1341	Sta 4
OPHIUROIDEA JUVENILE SP.F	1	0	C	1341	1341	
AMPHILEPIS SP.	7	1	C	2530	2530	
OPHIUROIDEA JUVENILE SP.H	1	0	C	2530	2530	Sta 5

839 m and deeper: C3 (two species), C4 (three species) and C5 (two species), a reverse situation to that of the more shallow-occurring gastropod mollusks.

Ophiuroidea

Ophiuroids ranged in density from 0/m^2 at Station W5 to 133/m^2 at Station W3. Sixteen species of ophiuroids were identified from Cruise I macroinfauna samples, most of which were very small juvenile specimens that were extremely difficult to identify. The dominant species, Ophiotholia sp. reached maximum populations at Station C3 (839 m) (Table 4-22). However, more species, most of which were juveniles, reached maximum populations at Station C1 (348 m) and C4 (1341 m). Two species were found exclusively at the deepest station, C5, at 2530 m. They are Amphilepis sp. and Ophiuroidea juvenile sp.H.

Sipuncula

Sipunculan worms ranged in density from 0/m^2 at Station C5 to 189/m^2 at Station W1. They tended to decrease in density with depth, except for Stations C3, C4, and E4 which showed highest densities. The shallowest stations (1) had the highest mean density of sipunculans (103/m^2) while the deepest stations (5) had the lowest (22/m^2). The sipunculans had not been identified to species levels in time for the deadline for this report.

Ascidiacea

Tunicates (ascidiaceans) ranged in density from 0/m^2 (at Stations C1, E1, W3, W4, E4, and C5) to 56/m^2 at Station C4 in April and in November. Two species were identified from Cruise I macroinfauna samples, both of which reached maximum populations at Station C4 (1341 m) (Table 4-23).

TABLE 4-23

Abundance of ascidiacean species from the Central Transect (Cruise I), arranged in order of abundance by depths of maximum populations.

Species	Total individuals at all stations	Number of stations where species dominate	Occurrence on Transects	Depth range (m)	Depth of Max. Pop.	
ASCIDIACEA						
DICARPA SIMPLEX	13	2	C	839 - 1341	1341	Sta 4
PYURIDAE SP.	1	0	C	1341	1341	

TABLE 4-24

Abundance of echinoid species from the Central Transect (Cruise I), arranged in order of abundance by depths of maximum populations.

Species	Total individuals at all stations	Number of stations where species dominate	Occurrence on Transects	Depth range (m)	Depth of Max. Pop.	
ECHINOIDEA						
HEMIASTER EXPERGITUS LOVEN	7	5	C	348 - 2530	2530	Sta 5
SCHIZASTER ORBIGNYANUS	1	0	C	2530	2530	

Echinodidea

Sea urchins (echinoids) were absent from nearly half of the macroinfauna stations sampled during Cruises I and II. They ranged in density from 0/m^2 (at Stations C1, C2, E1, E3, W1, W2, W4, and W5) to 21/m^2 at Station C5. Two species were identified, both of which attained maximum populations at the deepest station, C5, at 2530 m (Table 4-24).

4.3 MEGAFAUNA

The decapod crustacean, echinoderm and demersal fish components of the trawl collections taken during Cruises I and II have been identified and enumerated (Appendices A, B and C). Data for other groups as well as the biomass, size and food habit data will be reported in subsequent annual reports.

4.3.1 Decapod Crustacea

Seventy-eight benthic species of macroepifaunal decapod crustaceans were collected by LGL along the three transects on the northern slope of the Gulf. The anomurans, including hermit crabs and galatheid rock-crabs, yielded the most species, followed by carideans and brachyurans (Table 4-25). Four groups stand out as containing truly deep-water species, viz., carideans, pagurans, Munidopsis, and nephropids, in which over two-thirds of the species occur at or below the 1000-m isobath* (Table 4-25). The brachyuran crabs and the galatheids of the genus Munida, on the other hand, have closer affinities with the upper slope and the outer continental shelf, as is demonstrated by the fact that only a third of their species are found as deep as 1000 m.

As is well known, there are important differences in the physicochemical characteristics of the water column and the sediment bed between the eastern and western Gulf. It is, therefore, of more than

*The isobath of 1000 m is considered to be significant because it is the depth of separation between the Archibenthal Zone and the Upper Abyssal Zone which can be considered to be the beginning of the deep sea.

TABLE 4-25

Macroepifaunal Decapod Crustaceans Collected During Cruises I and II

	No. of Species	% of all Decapods	Number of Species at or below 839 m	% of Species below 1000 m
Penaeidea	8	10	4	50
Caridea (& Stenopodidea)	19	24	13	68
Anomura	27			
Paguridae etc. (12)		15	8	67
Galatheidae				
Munida (6)		8	2	33
Munidopsis (9)		12	6	67
Macrura	5			
Polychelidae (2)		3	1	50
Nephropidae (3)		4	2	67
Brachyura	17	22	6	35
Other Macrura	2			
Scyllaridae (1)		1	0	0
Axiidae (1)		1	0	0
	78	100	42	54

TABLE 4-26

Numbers of Macroepifaunal Species of Decapods Achieving Maximum Depth Penetration on a Given Transect

	Transect		
	West	Central	East
Carideans	3	7	9
Brachyurans	2	12	3
Pagurids	3	6	3
Munidopsis	2	0	7
Penaeids	3	3	2
Munida	2	1	3
Nephropids	0	0	3
Polychelids	1	0	1
Scyllarids	1	0	0
Axiids	0	0	1
TOTALS	17	29	32

academic interest to ascertain whether there are discernable biotic differences between the east and west. One approach to this issue is found in Table 4-26 where we see that nearly twice as many macroepifaunal species of Decapoda occur deeper on the eastern transect than on the west. Indeed, the present data, although admittedly very preliminary, seem to warrant the observation of a deepening trend from west to east. Furthermore, both the carideans and Munidopsis galatheids, which have substantial numbers of deep-sea species, have three or more times as many deep individuals on the east as West Transect. On the other hand, the brachyurans and Munida galatheids, which are noted for their shallow-water affinities, have more nearly equal numbers of deep-occurring species on the west and east transects (Table 4-26). These observations should not, however, overshadow the fact that relatively large numbers of species of carideans, pagurids, and brachyurans in particular have numerous species that achieve their greatest depth penetration on the Central Transect. No explanation of this tentative observation is readily available, but one can speculate that the Mississippi River may have significant influences over the region of the Central Transect while the Loop Current affects the East Transect. If the above observations are warranted by future sampling effort, one might wish to offer ideas as to the nature of these influences.

Natantia:Caridea

Eighteen species of benthonic caridean shrimp were collected from the three transects during Cruises 1 and 2 (Table 4-27). They were taken from Stations 1 through 5 at depths ranging from 348 to 2530 m. Ten of these species (56%) occur at depths below 1000 m. This compares closely with previous studies by TerEco Corporation (Pequegnat et al. 1983) where 48% of the carideans occurred at depths in excess of 1000 m. It is interesting to note that four of the six numerical dominants belong to only two genera, viz., Nematocarcinus and Glyphocrangon. Although there is a slight difference in rank order, all six of these dominants were also listed in the TerEco study. There is also a close correspondence between the depths of maximum populations of the leading species in the LGL and TerEco studies. Present data, which admittedly are only preliminary,

TABLE A-27

(I) Caridea found on the northern Continental Slope - Gulf of Mexico*

(II) Numerical dominants in rank order

Cruises 1 and 2

(I) Inventory of carideans in the Gulf of Mexico arranged by depth of maximum population

Species Name	Total Indiv. at all Stations	Sum of Stations where Species Dominant	Depth Range (m)	Depth of Max. Pop. (m)	Occurrence on Transects	Transect of Deepest Occurrence
Parapandalus willisi	15	3	348	348	E, C, W	C
Heterocarpus ensifer	2	0	348	348	_, _, W	W
Pontocaris caribbaeus	1	0	348	348	_, C, _	C
Plesionika holthuisi	230	3	657-839	657	E, C, W	C
Glyphocrangon alispina	20	0	657-839	657	E, C, _	C
Glyphocrangon longleyi	5	0	657	657	_, C, _	W
Pricnocrangon pectinata	2	0	657	657	_, C, _	C
Paralidopus barbouri	1	0	657	657	_, C, _	C
Acanthephyra armata	3	0	657-1341	839	E, C, W	E
Nematocarcinus rotundus	397	5	657-1341	1341	E, C, W	E
Glyphocrangon aculeata	100	1	839-2530	1341	E, C, W	E
Glyphocrangon nobilis	20	1	657-2530	1341	E, C, W	W
Pontophilus gracilis	19	0	657-2530	1341	E, C, _	E
Acanthephyra eximia	19	0	1341	1341	E, _, _	E
Heterocarpus oryx	13	0	1341	1341	E, C, _	E
Bathypalaemonella serratipalma	3	0	1341	1341	E, _, _	E
Bathypalaemonella texana	1	0	1341	1341	E, _, _	E
Nematocarcinus ensifer	3	1	2530	2530	_, _, W	W

(II) Dominant carideans presented in rank order

Species	Number of Individuals Times Stations (x5) Where Species Dominant**	Depth and Transect of Peak Populations
Nematocarcinus rotundus	9925	1341 m on East Transect
Plesionika holthuisi	3950	657 m on East Transect
Glyphocrangon aculeata	500	1341 m on East Transect
Parapandalus willisi	225	348 m on Central Transect
Glyphocrangon nobilis	100	1341 m on Central Transect
Nematocarcinus ensifer	15	2530 m on West Transect

*As will be true of all of the two-part tables in this section of the report, there are several important biological factors presented. First, we see the inventory of species and the relative numbers of individuals collected. In the third column, one can observe the number of collecting stations where a given species outranked in numbers all other Carideans. Column 4 shows the range of depth exhibited by each species. In many cases the species was collected only at one depth. Column 5 displays the transect or transects on which the species was collected. Some evidence has been accumulated that reveals that there may not only be more decapod species in the eastern Gulf than the western, but also that they may penetrate deeper there. Evidence on this issue is presented in Columns 5 and 6.

**The x5 is only an arbitrary multiplier intended to emphasize the number of occurrences of numerical dominance possessed by a species. Numbers of individuals alone are not as significant as numbers over a bathymetric and/or geographic range. For instance, even though more individuals of Pontophilus gracilis than of Parapandalus willisi were taken, it was not considered to be among the dominant penaeids because it was not dominant at any station and occurred on only one transect. The 225 after Parapandalus willisi is obtained by taking number of individuals collected (15) times the product of the number of stations where it was dominant (3) times the multiplier (5). Thus we have 15 x 15 = 225.

indicate the possibility that carideans are more abundant and penetrate deeper on the Eastern Transect than on the other two (Table 4-26). Thus, of the eight species that reach maximum populations below 1000 m, seven are found deepest on the East Transect, only two on the West Transect, and none reached their deepest occurrence on the Central Transect.

Natantia:Penaeidea

Cruises 1 and 2 yielded eight species of benthonic penaeid shrimps (Table 4-28). Essentially this group represents the upper part of the bathymetric range of the 22 species collected in the TerEco study. Thus, three species were limited to 348 m (Station 1), one each was found no deeper than 659 and 839 m, and only two penetrated as deep as 1341 m. Moreover, four species were found to have their peak populations at 348 m; this includes the numerical dominant, Penaeopsis serrata. The second most abundant species, Benthesicymus bartletti, was found to be most abundant along the 1341 m isobath. It is interesting to note that the LGL and TerEco studies found the rank order of the top three numerical dominants to be the same, and there were only minor differences in position of the next three. The agreement in regard to depths of maximum populations were also remarkably close, considering the limited number of sampling depths in the LGL study. For instance, TerEco found the maximum population of Penaeopsis serrata to be 300 m, LGL shows 348 m--its shallowest sampling depth; Benthesicymus bartletti is 1050 m in TerEco and 1341 m in LGL (it was also taken at 839 m); and Parapenaeus longirostris is 250 m in TerEco and 348 m in LGL. The additional sampling depths employed in Cruise 3 may well bring these depths even closer together.

The rather close agreement in findings thus far achieved seems to indicate that we may soon be in a position to predict with considerable accuracy the species that will be encountered along selected isobaths. This is tantamount to defining the faunal assemblages that one can expect to find at given depths in various parts of the Gulf.

TABLE 4-28

(I) Penaeidea found on the northern Continental Slope - Gulf of Mexico*

(II) Numerical dominants in rank order

Cruises 1 and 2

(I) Inventory of penaeids in the Gulf of Mexico arranged by depth of maximum population

Species Name	Total Indiv. at all Stations	Sum of Stations where Species Dominant	Depth Range (m)	Depth of Max. Pop.	Occurrence on Transects	Transect of Deepest Occurrence
Penaeopsis serrata	752	2	348	348	E, _, W	W
Parapenaeus longirostris	41	1	348	348	E, C, _	C
Hymenopenaeus robustus	2	0	348-657	657	_, _, W	W
Solenocera necopina	1	0	348	657	_, C, _	C
Hymenopenaeus debilis	4	1	657-1341	657	E, _, W	E
Plesiopenaeus edwardsianus	4	1	657-839	839	E, C, W	W
Benthesicymus bartletti	56	6	839-1341	1341	E, C, W	E
Hymenopenaeus aphoticus	1	0	1341	1341	_, C, _	C
Spongicoloides sp.	1	0	1341	1341	E, _, _	E

(II) Dominant penaeids presented in rank order

Species	Number of Individuals Times Stations (x5) Where Dominant**	Depth and Transect of Peak Population
Penaeopsis serrata	7520	348 m on the West Transect
Benthesicymus bartletti	1680	1341 m on the East Transect
Parapenaeus longirostris	205	348 m on the Central Transect
Hymenopenaeus debilis	20	1341 m on the East Transect
Plesiopenaeus edwardsianus	20	839 m on the West Transect

*See explanation on Table 4-27.
**See explanation on Table 4-27.

Anomura

The Anomura are represented in the LGL collection of the deep Gulf by the following five families: (1) the Galatheidae (so-called rock-crabs) with the genera Munida and Munidopsis, (2) the Paguridae or hermit crabs that are represented here primarily by the genera Pagurus and Parapagurus, (3) the Chirostylidae (galatheid-like crustaceans that live on branching gorgonian corals) represented by the genera Uroptychus and Gastroptychus, (4) the Lithodidae represented by the spiny crab-like genus Lithodes with a single species here, and (5) the Porcellanidae which has the species Porcellana sigsbeiana that has a flattened crab-like shape.

The galatheids have very marked bathymetric limits and are therefore good signature species of faunal zones. In Table 4-29 we note that four of the six species of Munida are found no deeper than Station 2 (657 m), one spans Stations 2 to 4, and the sixth occurs only at Stations 4 and 5. The separation becomes sharper if one refers to the depths of maximum population--four species attain such at 348 m, one species at 657 m, and the sixth at 1341 m. Thus, we can say that species of the genus Munida tend to inhabit the upper slope. Species of the genus Munidopsis on the other hand are known to penetrate into deeper waters of the Sigsbee Deep. Four of the nine species of this genus have maximum populations at 1341 m, one at 839 m, one at 657 m, and only two at 348 m.

It is interesting to compare the galatheid numerical dominants between the LGL (data from all transects) and TerEco studies, even though the former is as yet preliminary:

Galatheid Numerical Dominants

LGL (All Transects)	TerEco (All Transects)
Munida valida	Munida longipes
Munida longipes	Munidopsis sigsbei
Munidopsis robusta	Munida valida
Munidopsis spinosa	Munidopsis simplex
Munidopsis longimanus	Munidopsis longimanus
Munidopsis simplex	

TABLE 4-29

(I) Galtheidae found on the northern Continental Slope - Gulf of Mexico*

(II) Numerical dominants in rank order

Cruises 1 and 2

(I) Inventory of galatheids in the Gulf of Mexico presented by depth of maximum population

Species Name	Total Indiv. at all Stations	Sum of Stations where Species Dominant	Depth Range (m)	Depth of Max. Pop. (m)	Occurrence on Transects	Transect of Deepest Occurrence
Munida irrasa	1	0	348	348	_, _, W	W
Munida forceps	3	0	348	348	_, C, _	C
Munida longipes	65	2	348	348	_, C, W	W
Munida sp.	2	0	348-657	348	E, _, _	E
Munidopsis polita	3	0	348-1341	348	E, _, W	E
Munidopsis robusta	26	1	348-657	348	E, _, W	W
Munida valida	123	4	657-1341	657	E, C, W	E
Munidopsis alaminos	1	0	657	657	E, _, _	E
Munidopsis erinaceus	9	0	657	657	E, _, _	E
Munidopsis spinosa	8	1	839	839	_, _, W	W
Munida microphthalma	2	1	1341-2530	1341	E, C, _	E
Munidopsis abbreviata	2	0	1341	1341	E, _, _	E
Munidopsis longimanus	7	1	657-1341	1341	E, C, _	E
Munidopsis sigsbei	7	0	839-1341	1341	E, _, W	E
Munidopsis simplex	6	1	1341	1341	E, _, W	E

(II) Dominant galatheids presented in rank order

Species	Number of Individuals Times Stations (x5) Where Species Dominant**	Depth and Transect of Peak Populations
Munida valida	2460	657 m on East Transect
Munida longipes	480	348 m on Central Transect
Munidopsis robusta	130	348 m on West Transect
Munidopsis spinosa	40	839 m on West Transect
Munidopsis longimanus	35	1341 m on East Transect
Munidopsis simplex	30	1341 m on East Transect

*See explanation on Table 4-27.
**See explanation on Table 4-27.

The comparison is very close indeed so far as species components are concerned, particularly in view of the fact that the TerEco study sampled both deeper and shallower than LGL. One might expect that since species of Munidopsis occur deeper than Munida they would have fewer representatives among the numerical dominants. This could follow from the assumption that food supplies would decrease with increasing depth. In actuality, we see that Munidopsis has more species in both lists. This is simply a reaffirmation of the assertion that reduction of food supplies tends to reduce populations, not the number of species (diversity), until, of course, it becomes extreme, and species do drop out.

The Paguridae is a very complex group. Fortunately, their systematics has been studied in considerable depth in the last two years or so. Accordingly, we are now able to assign names (Table 4-30) to species of the genus Parapagurus whereas previously one had to refer to the genus as a complex. This genus, in particular, is thought to be characterized by species with broad feeding proclivities (i.e., scavengers, carnivores, and omnivores). As such, they replace in deeper waters the roles played by brachyuran crabs. As will be noted again later, the Brachyura with a few exceptions are confined to the shelf and upper slope, whereas the pagurids occur in the mid-slope region.

The representative of the Lithodidae, Lithodes agassizii, resembles a majid brachyuran crab, but it is not very closely related. A closer look reveals that whereas the brachyurans have five pairs of "walking legs", this lithodid has only four pairs. As is true of most anomurans, the fifth pair is markedly reduced and is carried under or alongside of the carapace. This trait plus its crab-like morphology, among other characteristics, belies that this species is closely related to the King Crab of Alaskan waters and Giant Crab of northern Japan waters, which are themselves lithodids. The Lithodes agassizii in the LGL collections are all juvenile specimens.

The Porcellanidae is a moderately large family of anomurans that again have undergone convergent evolution to resemble some brachyurans. Most of the porcellanid species occur in shallow water, even up to and including the intertidal where, with their flattened shape, they occur in narrow crevices under rocks. The deep water Gulf species, Porcellana sigsbeiana is the only offshelf species to be found here.

TABLE 4-30

(I) Anomura (except galatheidas) found on the northern continental slope - Gulf of Mexico*

(II) Numerical dominants in rank order

Cruises 1 and 2

(I) Inventory of Paguridae, Lithodidae, Chirostylidae, and Porcellanidae in the Gulf of Mexico arranged by depth of maximum population.

Species Name	Total Indiv. at all Stations	Sum of Stations where Species Dominant	Depth Range (m)	Depth of Max. Pop. (m)	Occurrence on Transects	Transect of Deepest Occurrence
Porcellana sigsbeiana	3	1	348	348	_, C, _	C
Pagurus rotundimanus	2	1	348	348	_, _, W	W
Parapagurus pictus	3	2	348-2530	348	_, _, W	W
Paguristes sp.	1	0	348	348	_, C, _	C
Uroptychus nitidus	26	3	657-1341	657	E, _, W	E
Parapagurus pilosimanus	7	1	657-1341	657	E, C, _	E
Lithodes agassizii	3	2	839-1341	839	_, C, _	C
Parapagurus bicristatus	1	0	839	839	_, C, _	C
Parapagurus n. sp.	3	2	839-1341	839	_, C, W	W
Uroptychus sp.	2	0	1341	1341	E, _, _	E
Catapaguroides microps	2	1	839-1341	1341	_, C, _	C
Gastroptychus spinifer	1	1	2530	2530	_, C, _	C

(II) Numerical dominants in rank order

Species	Number of Individuals Times Stations (x5) Where Species Dominant**	Depth and Transect of Peak Populations
Uroptychus nitidus	390	1341 m on Central Transect
Parapagurus pilosimanus	35	657 m on Central Transect
Parapagurus pictus	30	348 m on West Transect
Lithodes agassizii	30	839 m on Central Transect
Parapagurus n. sp.	30	839 m on Central Transect
Porcellana sigsbeiana	15	348 m on Central Transect

*See explanation on Table 4-27.

**See explanation on Table 4-27.

The Chirostylidae, which obviously have evolved from a stock containing the galatheids, are represented by several species in the Gulf. The two species in deep water are Uroptychus nitidus, which lives only in gorgonian corals (e.g., Chrysogorgia elegans and Acanella arbuscula), and Gastroptychus spinifer whose habits are utterly unknown.

Brachyura

The Brachyura are represented by 17 species in the present collection (Table 4.31). In spite of the fact that this is a small percentage of the species known to occur in the offshelf waters of the northern Gulf, all of the numerically important species are in the collection, as seen below:

Numerical Dominants	
LGL (All Transects)	TerEco (All Stations)
Bathyplax typhla	Bathyplax typhla
Lyreidus bairdii	Lyredus bairdii
Benthochascon schmitti	Geryon quinquedens
Geryon quinquedens	Acanthocarpus alexandri
Acanthocarpus alexandri	Benthochascon schmitti

This is a remarkably close comparison. Furthermore, additional study reveals that bathymetric limits are also very close.

Macrura

The macruran decapod crustaceans are represented by seven species in the LGL collection. As anticipated, the polychelids and nephropids are most numerous followed by a single scyllarid and a single axiid.

Among the polychelids or "flatback lobsterettes" the species Stereomastis sculpta is by far the most abundant (Table 4-32), as was the case with the TerEco study. This species has a very wide bathymetric range (657-2530 m), but in spite of its widespread distribution and numerical abundance, we know very little about its habits. It has been

TABLE 4-31

(I) Brachyura found on the northern Continental Slope - Gulf of Mexico*

(II) Numerical dominants in rank order

Cruises 1 and 2

(I) Inventory of crabs in the Gulf of Mexico presented by depth of maximum population

Species Name	Total Indiv. at all Stations	Sum of Stations where Species Dominant	Depth Range (m)	Depth of Max. Pop. (m)	Occurrence on Transects	Transect of Deepest Occurrence
Stenocionops spinimana	1	0	348	348	_, _, W	W
Chacellus filiformis	1	0	348	348	_, C, _	C
Collodes leptochela	1	0	348	348	_, C, _	C
Acanthocarpus alexandri	8	0	348	348	_, C, W	C
Bathynectes superba	4	0	348	348	_, C, W	C
Thalassoplax angusta	3	0	348	348	_, C, _	C
Palicus gracilis	5	0	348	348	_, C, W	C
Ethusa microphthalma	14	0	348-657	348	_, C, _	C
Pyromaia arachna	36	0	348	348	E, C, W	C
Lyreidus bairdii	67	2	348	348	_, C, W	W
Benthochascon schmitti	96	1	348-839	348	E, C, W	E
Trichopeltarion nobile	7	0	657	657	_, C, _	C
Rochinia crassa	13	0	348-1341	657	E, C, W	E
Bathyplax typhla	177	5	348-1341	657	E, C, W	C
Rochinia umbonata	1	0	839	839	_, C, _	C
Geryon quinquedens	17	3	348-1341	839	E, C, W	E
Brachyura sp.	2	0	839	839	_, C, _	C

(II) Dominant brachyurans presented in rank order

Species	Number of Individuals Times Station (x5) Where Species Dominant**	Depth and Transect Of Peak Populations
Bathyplax typhla	4425	657 m on the East Transect
Lyreidus bairdii	670	348 m on the West Transect
Benthochascon schimitti	480	348 m on the East Transect
Geryon quinquedens	255	839 m on the East Transect

*See explanation on Table 4-27.
**See explanation on Table 4-27.

TABLE 4-32

(I) Polychelidae and Nephropidae found on the northern Continental Slope - Gulf of Mexico*

(II) Dominant species in rank order

Cruises 1 and 2

(I) Inventory of the polychelids and nephropids in the Gulf of Mexico presented by depth of maximum population

Species Name	Total Indiv. at all Stations	Sum of Stations where Species Dominant	Depth Range (m)	Depth of Max. Pop. (m)	Occurrence on Transects	Transect of Deepest Occurrence
Polychelidae						
Polycheles typhlops	2	1	348-657	?	_, C, W	W
Stereomastis sculpta	114	9	657-2530	1341	E, C. W	E
Nephropidae						
Nephropsis aculeata	8	2	348-657	348	E, C, _	E
Nephropsis agassizii	3	1	839-1341	839	E, _, W	E
Nephropsis rosea	5	2	657-1341	657	E, C, _	E

(II) Dominant polychelid and nephropid crustaceans presented in rank order

Species	Number of Individuals Times Stations (x5) Where Species Dominant**	Depth and Transect of Peak Population
Polychelidae		
Stereomastis sculpta	10,260	1341 m on the East Transect
Polycheles typhlops	10	348 m on the Central & West transects
Nephropidae		
Nephropsis aculeata	80	348 m on the East Transect
Nephropsis rosea	50	657 m on the Central Transect
Nephropsis agassizii	15	839 m on the West Transect

*See explanation on Table 4-27.
**See explanation on Table 4-27.

found in the stomach of the synaphobranchid eel. The fact that the eel is not a particularly fast swimmer suggests that Stereomastis may bury itself partially in sediments where it might be captured by the eel. Polycheles typhlops is far less abundant and being shallower appears not to overlap to a great extent the bathymetric range of Stereomastis.

The nephropids or deep-sea lobsters are represnted by the single genus Nephropsis and the three species aculeata, rosea, and agassizi, in that numerical order. Little is known about these crustaceans, but it is suspected that they are burrowers. Interestingly, they achieve maximum populations at 348 (aculeata), 657 (rosea), and 839 m (agassizi).

Scyllarus chacei (a scyllarid lobster) is referred to as a shovel-nosed lobster. Only one individual was taken at a depth of 348 m. This small representation suggests that this species lives in burrows and is known to prefer areas around hard substrate.

4.3.2 Echinodermata

During Cruises 1 and 2, some 33 species of echinoderms have been collected and identified. As can be seen in Table 4.-33 this total does not include the brittle stars and serpent stars (Ophiuroidea), which have been collected but not yet identified. From previous experience we would expect this class to add a substantial number of species to the above total. In fact, they will very likely rank second in species numbers behind the asteroids or true starfish.

Table 4-33. Number of species (exclusive of Ophiuroidea) in echinoderm classes and their bathymetric distributions. LGL Cruises I and II).

	No. of Species	% of all Echinoderm spp.	No. of Species at and below 839 m	% of Group below 839 m
Asteroidea	18	55	12	67
Holothuroidea	8	24	7	88
Echinoidea	5	15	2	40

Crinoidea	2	6	1	50
	33	100	22	

Asteroidea

In spite of the fact that only 18 species of asteroids have been collected (Table 4-34) as compared with 61 species in the TerEco report (Pequegnat et al. 1983), three species not previously reported are included in the list--Astropecten comptus, found only at Station 1 (Central Transect), Pectinaster gracilis, and Henricia antillarum. One might be tempted to suspect different taxonomic interpretations as the basis for the previous omissions, particularly in the case of the Astropecten, except for the fact that the three species were either taken primarily on the Central or Eastern Transects, which are areas not sampled by Pequegnat (1983). These identifications will be carefully checked, particularly as additional sampling is done in the central area.

Holothuroidea

The numbers in Table 4-33 bear out very clearly that the sea cucumbers (Holothuroidea), as a group, are the true markers of the deep sea among the echinoderms. Those species that occur deepest generally either skim the surface film of detritus off the bottom or actually engulf sediments and extract organic inclusions in the gut. The starfishes (asteroids) are also well represented below 1000* m but only 67% achieve maximum populations below that depth as compared with 88% of the sea cucumbers (Table 4-35). The difference becomes even wider upon comparing depths of maximum population. Only 39% of the asteroid species achieve maximum populations at either Station 4 (1341 m) or Station 5 (2530 m), as compared with 63% of the sea cucumbers (see Tables 4-34 and 11). This, of course, is commensurate with the fact that the majority of asteroids are carnivores. We would expect, therefore, that as the production of their prey (frequently palaeotaxodont bivalves) goes down with increasing depth

*See explanation on page 177.

TABLE 4-34

(I) Asteroidea found on the northern continental slope - Gulf of Mexico*

(II) Numerical dominants in rank order

Cruises 1 and 2

(I) Inventory of asteroids in the Gulf of Mexico arrangd by depth of maximum population

Species Name	Total Indiv. at all Stations	Sum of Stations where Species Dominant	Depth Range (m)	Depth of Max. Pop. (m)	Occurrence on Transects	Transect of Deepest Occurrence
Astropecten americanus	12	1	348	348	_, C, W	C
Odontaster hispidus	2	1	348	348	_, _, W	W
Astropecten comptus	1	0	348	348	_, C, _	C
Astropectinidae	1	0	348	348	_, C, _	C
Pectinaster gracilis	30	2	657-839	657	E, C, W	C
Persephonaster echinulatus	14	2	657	657	E, C, _	E
Plinthaster dentatus	6	0	657-839	657	E, C, _	C
Hymenaster sp.	3	0	657-1341	657	E, _, W	E
Hymenasteridae	1	0	657	657	E, _, _	E
Goniopecten demonstrans	4	0	839	839	_, C, _	C
Goniasteridae	1	0	839	839	_, C, _	C
Plutonaster intermedius	11	1	839-1341	1341	_, C, _	C
Nymphaster arenatus	6	0	657-1341	1341	_, C, W	C
Dipsacaster sp.	4	1	839-2530	1341	E, C, W	W
Ceramaster grenadensis	1	0	1341	1341	_, C, _	C
Henricia antillarum	1	0	1341	1341	E, _, _	E
Zoraster fulgens	2	1	1341	1341	E, _, _	E
Pseudarchaster sp.	3	1	2530	2530	_, _, W	W

(II) Dominant asteroids presented in rank order

Species	Number of Individuals Times Stations (x5) Where Species Dominant**	Depth and Transect of Peak Populations
Pectinaster gracilus	300	657 m on West Transect
Persephonaster echinulatus	140	657 m on East Transect
Plutonaster intermedius	110	1341 m on Central Transect
Astropecten americanus	60	348 m on Central Transect
Dipsacaster sp.	40	1341 m on East Transect
Pseudarchaster sp.	30	2530 m on West Transect
Zoraster fulgens	20	1341 m on East Transect
Odontaster hispidus	10	348 m on West Transect

*See explanation on Table 4-27.
**See explanation on Table 4-27.

TABLE 4-35

(I) Holothuroidea found on northern continental slope - Gulf of Mexico*

(II) Numerical dominants in rank order

Cruises 1 and 2

(I) Inventory of holothuroids in the Gulf of Mexico arranged by depth of maximum population

Species Name	Total Indiv. at all Stations	Sum of Stations where Species Dominant	Depth Range (m)	Depth of Max. Pop. (m)	Occurrence on Transects	Transect of Deepest Occurrence
Molpadia cubana	1	1	348	348	_, C, _	C
Mesothuria lactea	37	3	657-1341	839	E, C, _	E
Molpadia barbouri	7	1	839-1341	1341	E, C, W	E
Molpadia musculus	7	1	1341	1341	E, _, _	E
Echinocucumis hispida	3	1	1341	1341	_, C, _	C
Molpadia blakei	2	0	839-1341	1341	_, C, _	C
Pseudostichopus sp. A	6	1	1341-2530	2530	_, C, W	W
Pseudostichopus sp. B	3	0	2530	2530	_, _, W	W

(II) Numerical dominants in rank order

Species	Number of Individuals Times Stations (x5) Where Species Dominant**	Depth and Transect of Peak Populations
Mesothuria lactea	555	839 m on Central Transect
Molpadia musculus	35	1341 m on East Transect
Molpadia barbouri	35	1341 m on East Transect
Pseudostichopus sp. A	30	2530 m on West Transect
Echinocucumis hispida	15	1341 m on Central Transect

*See explanation on Table 4-27.
**See explanation on Table 4-27.

that these predators would also suffer population reductions and the dropping out of species. We have already observed that the brachyurans or true crabs, which are also mostly carnivores or omnivores, do not penetrate into the deep sea in appreciable numbers.

Echinoidea

The sea-urchins are not well represented in the present collection, only five species having been taken as compared with 31 species in the TerEco study (Table 4-36). Curiously also, echinoids have only been taken from the Central Transect. Two bathymetric groups are represented, the Brissopsis complex that lives on the outer continental shelf and upper slope to depths around 350 m, and the Plesiodiadema/Phormosoma assemblage that predominates from 650 to 1400 m depth. It is well known that echinoids are "nomadic", moving in herds that consume much of the appropriate organic matter in their path. These aggregations are well shown in bottom photographs, but this "clustering" also makes it more likely that a trawl can sweep an area without sampling more than the most abundant species. In this connection, it is interesting to note that Plesiodiadema, Phormosoma, and Brissopsis were the predominant species reported by Pequegnat et al. (1983), as in the LGL study.

The sea-urchins also undergo interesting ecological changes with increasing depth (Table 4-36). In the present collection, which is not as yet representative of the slope urchin fauna, two species attain maximum populations below 839 m. However, these two have undergone considerable morphological and physiological changes to adapt to a deep-sea mode of life. Thus, Phormosoma placenta has lost all of the heavily calcified test (globular skeleton) so typical of shallow water species (e.g., Brissopsis alta), presenting only a soft bag-like body. Also, in the absence of plant material, it is adapted to extracting its food from sediments. Plesiodiadema antillarum still retains a globular body, but it is only a few millimeters in diameter and the test is only weakly calcified.

It is well known that the carbonates of which most echinoderm skeletons are constructed are much more soluble in cold water than warm and under high pressure. It is for this reason, in part, that the

TABLE 4-36

(I) Echinoidea found on the northern continental slope - Gulf of Mexico*

(II) Numerical dominants in rank order

Cruises 1 and 2

(I) Inventory of echinoids in the Gulf of Mexico arranged by depth of maximum population

Species Name	Total Indiv. at all Stations	Sum of Stations where Species Dominant	Depth Range (m)	Depth of Max. Pop. (m)	Occurrence on Transects	Transect of Deepest Occurrence
Brissopsis sp.	10	1	348	348	_, C, _	C
Brissopsis alta	4	0	348	348	_, C, _	C
Brissopsis atlantica	1	0	348	348	_, C, _	C
Plesiodiadema antillarium	18	2	657-1341	1341	_, C, _	C
Phormosoma placenta	4	0	1341	1341	_, C, _	C

(II) Dominant echinoids presented in rank order

Species	Number of Individuals Times Stations (x5) Where Species Dominant**	Depth and Transect of Peak Populations
Plesiodiadema antillarum	160	1341 m on Central Transect
Brissopsis sp.	50	348 m on Central Transect

*See explanation on Table 4-27.
**See explanation on Table 4-27.

successful deep-sea echinoderm species, including the sea cucumbers and some of the echinoids and ophiuroids, have lost most or all of their carbonate skeletons.

Crinoidea

It is not surprising that only two species of crinoids have been collected up to now (Table 4-37). Few crinoids occur in the northern Gulf, compared to other classes of echinoderms, and very few are part of the deep Gulf fauna. Present collections were taken only at depths between 657 and 1341 m. The dominant species in the present collection, Atelecrinus balanoides taken at 657 m, was the second most abundant species in the TerEco report, reaching maximum population between 500 and 1400 m depth. The second LGL species, Democrinus brevis collected at depths between 657 and 1341 m, may well be the TerEco Democrinus sp. that was exceedingly common between depths of 150 and 1050 m depth.

Comparison With Previous Studies

The comparisons shown in Table 4-38 are close enough to indicate that upon completion of the LGL study, we should be able to predict the composition of faunal assemblages along isobaths on the continental slope of the northern Gulf of Mexico.

4.3.3 Fish

A total of 94 species of demersal or benthopelagic fish in 42 families was collected on the three sampling transects during Cruises 1 and 2. This compares with 206 species in 47 families collected and reported upon in the TerEco study (Pequegnat 1983).

The Macrouridae or grenadiers, represented by 19 species, led the list of demersal fish collections, followed by the Rajidae (skates) with only five species, the Ophidiidae (cusk-eels and Brotulas), Synaphobranchidae (eels), and Halosauridae (Halosaurs) with 4 species (Table 4-39). The species in these five families accounted for 38% of the total collected. In other words, over a third of the demersal fish

TABLE 4-37

Crinoidea found on the northern continental slope - Gulf of Mexico

Cruises 1 and 2

Inventory of Crinoidea in the Gulf of Mexico arranged by depth of maximum population

Species Name	Total Indiv. at all Stations	Sum of Stations where Species Dominant	Depth Range (m)	Depth Max. Pop. (m)	Occurrence on Transects	Transect of Deepest Occurrence
Atelecrinus balanoides	12	1	657	657	_, _, W	W
Democrinus brevis	17	2	657-1341	1341	E, C, W	E

TABLE 4-38

Comparison of the top numerical dominant species in four classes of the phylum Echinodermata between the present study and the TerEco study (Pequegnat et al. 1983). The TerEco species are limited to those found in LGL sampling depths

	Echinodermata	
Classes	LGL (All Transects)	TerEco (All Stations)
Asteroidea	Astropecten americanus Pectinaster gracilis Persephonaster echinulatus Plutonaster intermedius Nymphaster arenatus	Nymphaster arenatus Plutonaster intermedius Astropecten americanus Others too deep or too shallow
Echinoidea	Plesiodiadema antillarum Brissopsis sp. Phormosoma placenta	Plesiodiadema antillarum Phormosoma placenta Brissopsis sp.
Holothuroidea	Mesothuria lactea Echinocucumis hispida Molpadia barbouri Molpadia musculus	Mesothuria lactea Molpadia musculus Molpadia barbouri Echinocucumis hispida
Crinoidea	Atelecrinus balanoides Democrinus brevis	Democrinus sp. Caryometra cf. alope Atelecrinus balanoides

TABLE 4-39

Number of Species Collected in the Fish Taxa and Their Bathymetric Distribution from all Stations on all Transects

Family	No. of Species	% of all Fish spp.	No. Species below 1000 m	% of Group below 1000 m
Macrouridae	19	21	10	53
Rajidae	5	5	1	20
Ophidiidae	4	4	3	75
Synaphobranchidae	4	4	3	75
Halosauridae	4	4	3	75
Gadidae	3	3	0	-
Bathypteroidae	3	3	3	100
Triglidae	3	3	1	33
Scorpaenidae	3	3	0	-
Apogonidae	3	3	0	-
Nettastomidae	2	2	1	50
Congridae	2	2	1	50
Thirty other families	39	41	8	21
TOTAL	94	100	34	x 42

species thus far collected belong to only an eighth of the families represented in the LGL collection.

Reference to Table 4-39 reveals several interesting points: (1) 30 undesignated families on the bottom lines house 39 of the total species collected (averaging only 1.3 species per family); (2) only 21% of these species occur below a depth of 1000* m, i.e., at Stations 4 and/or 5, and (3) this compares with an average of 44% of the species in the most specious families occurring below 1000-m depth.

Study of the last column in Table 4-39 shows that the fish families containing the most species are divisible into two bathymetric groups. The deep-slope group is composed of the five families in which over 50% of the species occur below a depth of 1000 m. Contrariwise, the shallow-slope group contains seven families in which from 50 to 100% of the species occur at slope depths less than 1000 m. Interestingly, 34 of the 55 species contained in the 12 families designated in Table 4.1-15 belong to the deep group and only 21 to the shallow group.

The families containing the greatest number of species of the deep-group are the Macrouridae (19 spp.), Ophidiidae (4 spp.), Synaphobranchidae (4 spp.), Halosauridae (4 spp.), and the Bathypteroidae (3 spp.). The principal families of the shallow-group are the Rajidae (skates and rays), Gadidae (codfishes), Scorpaenidae, Apogonidae (Cardinal fishes), and the Triglidae (sea robins).

The macrourids (see Table 4-40) were taken at Stations 1 through 4 (348 to 1341 m). Five species of this family, of which Coelorinchus carribaeus is the numerical dominant, attain maximum populations around 348-m depth; four species, led by Nezumia aequalis, are most numerous at depths around 657 m; four species, led by Coryphenoides mexicanus, reach maximum populations at depths around 839 m; five species dominated by Gadomus longifilis, are most numerous around 1341 m. It is not surprising that four of the eight fish species shown to be overall numerical dominants are macrourids (Table 4-40).

The cusk eels (Ophidiidae) were collected from Stations 2, 3, and 4 (657-1341 m). However, two of the four species, Dicrolene sp. and

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*See explanation on page 177

TABLE 4-40

(I) Fishes found on the northern continental slope - Gulf of Mexico*

(II) Numerical dominants in rank order

Cruises 1 and 2

(I) Inventory of fishes in the Gulf of Mexico arranged by depth of maximum population

Species Name	Total Indiv. at all Stations	Sum of Stations where Species Dominant	Depth Range (m)	Depth of Max. Pop.	Occurrence on Transects	Transect of Deepest Occurrence
Coelorinchus caribbaeus	114	2	348-657	348	_, C, W	C
Bembrops gobioides	74	0	348-1341	348	E, C, W	E
Poecilopsetta beani	72	0	348-1341	348	E, C, W	C
Setarchus guentheri	65	1	348	348	E, C, W	W
Urophycis cirrata	60	0	348	348	E, C, W	C
Chlorophthalmus agassizi	51	0	348	348	E, C, W	W
Epigonus pandionis	32	0	348-839	348	E, C, W	W
Hymenocephalus italicus	30	1	348	348	E, _, W	E
Malacocephalus occidentalis	23	0	348	348	C, W, E	C
Parasudis truculenta	23	0	348-1341	348	E, C, W	E
Peristedion greyae	20	0	348-1341	348	E, C, W	E
Coelorinchus coelorhynchus	17	0	348	348	E, C, W	C
Merluccius albidus	11	0	348-657	348	E, C, W	W
Urophycis floridana	7	0	348	348	_, C, _	C
Hemanthias leptus	7	0	348	348	_, C, W	C
Pontinus longispinus	6	0	348	348	_, C, W	C
Lophiodes monodi	5	0	348-657	348	E, _, _	E
Argentina striata	5	0	348	348	_, C, W	C
Bromisculus imberbis	5	0	348	348	_, _, W	W
Gnathagnus egregius	4	0	348	348	_, C, W	W
Peristedion mineatum	4	0	348	348	_, C, W	C
Hoplostethus occidentalis	3	0	348	348	E, C, W	W
Gurgesiella sinusmexicanus	3	0	348	348	_, _, W	W
Polymetme corythaeola	3	0	348	348	_, C, W	C
Polymixia lowei	2	0	348	348	_, C, _	C
Synagrops bella	2	0	348	348	E, _, _	E
Steindachneria argentea	2	0	348	348	_, C, _	C
Helicolenus dactylopterus	1	0	348	348	E, _, _	E
Raja garmani	1	0	348	348	_, C, _	C
Macrorhamphosa scolopax	1	0	348	348	_, C, _	C
Prionotus stearnsi	1	0	348	348	_, C, _	C
Raja lentiginosa	1	0	348	348	_, _, W	W
Symphurus marginatus	1	0	348	348	E, _, _	E
Synagrops spinosa	1	0	348	348	_, _, W	W
Dibranchus atlanticus	45	3	657-839	657	E, C, W	C
Nezumia aequalis	29	2	657-1341	657	E, C, W	C

TABLE 4-40
(cont'd)

Species Name	Total Indiv. at all Stations	Sum of Stations where Species Dominant	Depth Range (m)	Depth of Max. Pop.	Occurrence on Transects	Transect of Deepest Occurrence
Bathygadus macrops	17	0	657-1341	657	E, C, W	E
Chaunax pictus	16	0	657-839	657	E, C, W	C
Neoscopelus macrolepidotus	10	0	657-839	657	E, C, W	W
Diplacanthopoma sp.	9	0	657-839	657	_, C, W	W
Pseudophichthys laterodorsalis	7	0	657	657	E, C, _	C
Laemonema barbatulum	5	0	657	657	E, _, W	E
Coryphenoides colon	5	0	348-657	657	E, C, W	C
Etmopterus schultzi	4	0	657	657	E, C, _	C
Yarella blackfordi	4	0	657-839	657	_, C, W	C
Barathronus bicolor	3	0	657-839	657	E, C, _	C
Nezumia sp.	2	0	657-839	657	_, _, W	W
Cruriraja rugosa	1	0	657	657	_, C, _	C
Decapturus punctatus	1	0	657	657	_, C, _	C
Synaphobranchus sp.	1	0	657	657	E, _, _	E
Ophichthus cruentifera	1	0	657	657	_, _, W	W
Nettastoma melanura	1	0	657	657	_, _, W	W
Halosaurus ovenii	1	0	657	657	_, C, _	C
Macrouridae	1	0	657	657	_, _, W	W
Hoplunnis sp.	1	0	657	657	_, _, W	W
Synaphobranchus brevidorsalis	57	3	657-1341	839	E, C, W	E
Synaphobranchus oregoni	28	0	839-1341	839	E, C, W	W
Monomitopus sp.	23	0	839-1341	839	E, C, W	E
Coryphenoides mexicanus	10	0	839-1341	839	E, C, W	E
Bathygadus melanobranchus	10	0	657-839	839	E, C, W	E
Nezumia suilla	9	0	839-1341	839	E, _, W	E
Halosaurus guentheri	8	0	839-1341	839	E, _, W	E
Lepophidium brevibarbe	3	0	348-839	839	_, C, _	C
Epigonus macrops	2	0	839	839	_, _, W	W
Gadomus arcuatus	2	0	839-1341	839	E, _, _	E
Bathyuroconger vicinus	1	0	839	839	_, C, _	C
Hydrolagus sp.	1	0	839	839	_, _, W	W
Leptoderma macrops	1	0	839	839	E, _, _	E
Epigonus occidentalis	1	0	839	839	_, C, _	C
Apristurus parvipinnis	1	0	839	839	_, C, _	C
Bathypterois viridescens	2	0	839-1341	839	E, _, W	E
Gadomus longifilis	37	1	839-1341	1341	E, C, _	E
Stephanoberyx monae	34	1	1341	1341	E, _, W	E
Dicrolene sp.	26	0	657-1341	1341	E, C, W	E
Nezumia cyrano	13	0	839-1341	1341	E, _, _	E
Ilyophis brunneus	13	0	839-1341	1341	E, _, _	E
Bathygadus favosus	10	0	1341	1341	E, _, _	E
Venefica procera	9	0	1341-2530	1341	E, C, _	E
Bathypterois quadrifilis	9	0	1341	1341	E, _, _	E
Aldrovandia affinis	6	0	1341	1341	E, _, W	E
Conocara sp.	6	0	1341	1341	E, _, _	E
Bathypterois phenax	4	0	1341	1341	E, _, _	E

TABLE 4-40
(cont'd)

Species Name	Total Indiv. at all Stations	Sum of Stations where Species Dominant	Depth Range (m)	Depth of Max. Pop.	Occurrence on Transects	Transect of Deepest Occurrence
Cataetyx sp.	2	0	1341-2530	1341	E, C, _	C
Acromycter perturbata	1	0	1341	1341	E, _, _	E
Aldrovandia gracilis	1	0	1341	1341	E, _, _	E
Apistrurus laurissonii	1	0	1341	1341	E, _, _	E
Bathophilus sp.	1	0	1341	1341	_, C, _	C
Bembrops anatirostris	1	0	1341	1341	E, _, _	E
Coelorinchus sp.	1	0	1341	1341	E, _, _	E
Ipnops murrayi	1	0	1341	1341	_, _, W	W
Malacoraja purpuriventralis	1	0	1341	1341	_, C, _	C
Squalogadus modificatus	1	0	1341	1341	E, _, _	E
Trachonurus villosus	1	0	1341	1341	E, _, _	E
Xyelacyba myersi	1	0	1341	1341	E, _, _	E

(II) Dominant fishes presented in rank order

Species	Number of Individuals Times Stations (x5) Where Species Dominant**	Depth and Transect of Peak Populations
Coelorinchus caribbaeus	1130	348 m on Central Transect
Synaphobranchus brevidorsalis	855	839 m on East Transect
Dibranchus atlanticus	675	657 m on West Transect
Setarchus guentheri	325	348 m on West Transect
Nezumia aequalis	290	657 m on East Transect
Gadomus longifilis	185	1341 m on East Transect
Stephanoberyx monae	170	1341 m on East Transect
Hymenocephalus italicus	150	348 m on East Transect

*See explanation on Table 4-27.
**See explanation on Table 4-27.

Monomitopus sp., reach maximum populations at 839 m, and the other two (viz., Lepophidium brevibarbe and Xyelacyba myersi) at 1341 m.

Four species of synaphobranchid eels were collected. Five species are known to exist in the Gulf. One of the eels, which is not assignable to a species at this time, may prove to be a new species. Only one specimen was taken at Station 2 on the East Transect. Synaphobranchus brevidorsalis and S. oregoni reach maximum populations at 839 m, whereas Ilyophis brunneus is most abundant at 1341 m. These eels are common subjects in bottom photographs taken at these depths. It is possible that the unassigned species is S. affinis, which is common on the shelf but rare on the continental slope.

The four species of Halosauridae reach maximum populations at three different depths. Halosaurus ovenii is found at 657 m; the much more common Halosaurus guentheri occurs in large numbers at 839 m; whereas Aldrovandia affinis (common) and Aldrovandia gracilis (rare) have so far only been taken at 1341 m. Both H. guentheri and A. affinis are reasonably common in bottom photographs.

Three species of the family Scorpaenidae (scorpion fishes) were collected in the study. All three attain their maximum populations at 348 m. One species, Setarchus guentheri, is the fourth most abundant fish species collected thus far. It is particularly common on the West Transect. Pontinus longispinis is more common on the Central Transect. Helicolenus dactylopterus is little known; so far as we are aware it has not been collected in the northern Gulf before. The single specimen collected was taken at Station 1 of the East Transect.

Table 4-41 shows the results of a comparison of listings of the most commonly collected fish species and their depth of maximum population between the LGL and TerEco studies. The comparison is exceedingly close; note that the species that do not agree are at LGL's shallowest stations where their sampling was very efficient and at TerEco's intermediate sampling depths where the giant trawl used by the latter group had excellent sampling characteristics.

The comparison of depths of maximum populations are also judged to be very good, particularly if it is remembered that the stated depths have plus or minus deviations of something between 25 and 50 m.

TABLE 4-41

Comparison of Most Abundant Species of Fish Between the LGL and TerEco Studies. Arranged in Order of Simple Abundance For Convenience of Comparison

LGL (All Transects)		TerEco (All Stations)	
Species	Depth of max. Pop. (m)	Species	Depth of max. Pop. (m)
Poecilopsetta beani	348	Poecilopsetta beani	250
Bembrops gobiodes	348	Bembrops gobiodes	400
Coelorinchus caribbaeus	348	Coelorinchus caribbaeus	300
Hymenocephalus italicus	348	Hymenocephalus italicus	450
Urophycis cirrata	348	Urophycis cirrata	450
Dibranchus atlanticus	657	Dibranchus atlanticus	650
Nezumia aequalis	657	Nezumia aequalis	900
Synaphobranchus sp.	839	Synaphobranchus sp.	1000
Gadomus longifilis	1341	Gadomus longifilis	1050
Monomitopus sp.	839	Monomitopus sp.	1050
Dicrolene sp.	1341	Dicrolene sp.	1200
Stephanoberyx monae	1341	Stephanoberyx monae	1200
Parasudis truculenta	348	Parasudis truculenta	250
Setarchus guentheri	348	Pontinus longispinus	200
Chlorophthalmus agassizii	348	Yarella blackfordi	650
Epigonus pandionis	348	Bathygadus melanobranchus	900
Malacocephalus occidentalis	348	Aldrovandia gracilis	1450
Peristedion greyae	348	Halosaurus guentheri	900

4.3.4 Zonation and Macroepifaunal Assemblages

Zonation

Attempts to discern and define significant changes in the composition of the fauna proceeding from the outer continental shelf to the abyss have been made by several investigators (Menzies et al. 1973, Rowe and Haedrich 1979, Pequegnat et al. 1976, Gardiner and Haedrich 1978). Considering the early stage of the LGL sampling program, it is perhaps appropriate to consider only the Gulf of Mexico and not attempt to relate the work to date to other seas. Accordingly, the ensuing discussion will be limited to considerations of the present LGL findings and comparisons of these to the faunal zone scheme for the northern Gulf of Mexico devised by and found in Pequegnat et al. (1983):

Gulf of Mexico Zones (Pequegnat 1983)		LGL Sampling Stations
Shelf/Slope Transition	(150-450 m)	Station 1 (348 m)
Archibenthal Zone		
Horizon A	(475-750 m)	Stations 2 (657 m)
Horizon B	(775-950 m)	Stations 3 (839 m)
Upper Abyssal	(975-2250 m)	Stations 4 (1341 m)
Mesoabyssal		
Horizon C	(2275-2700 m)	Stations 5 (2530 m)

Faunal zones can be based upon any one or a combination of ecological animal types. The zones noted above and to be discussed in the following paragraphs are based upon three benthic megafaunal groups, viz., decapod Crustacea, echinoderms, and demersal fishes.

It can be readily seen in the above that the LGL sampling stations fall safely into four faunal zones of which one has two relevant horizons thereby making five station-to-zone equivalents. One must remember when interpreting any statistical technique for picturizing zones that it is

their biotic nature to be different. Accordingly any measure of similarity should display low values among stations in different zones and somewhat higher values between stations within the bathymetric limits of a given zone. Unfortunately, during Cruises I and II only one station was mounted per zone; hence we should expect rather low indices of similarity throughout; however, in Cruise III some additional stations were visited within a given zone. These findings will be discussed in a subsequent report.

The dendrogram presented in Figure 4-5 is based upon the most populous species among all of the decapods, echinoderms, and demersal fishes presented in foregoing sections of the report. In general, species represented by less than three individuals were not used in the clustering procedure. Moreover, the dendrogram is based upon a combining of the relevant data from the three transects discussed throughout this report. The dendrogram seems to show from data gathered from all transects that Station 5 (2530 m), which is in Horizon C of the Mesoabyssal Zone, stands well apart from the other stations. This is a logical expectation from the fact that the station is at an extreme of the bathymetric sampling range. Furthermore, it is just below a major faunal break. Thus, it is too deep for development of the typical slope fauna and too shallow for full development of the faunal populations that form the true abyssal group in the Lower Abyssal Zone.

For unlike but parallel reasons, Station 1 in the Shelf/Slope Transition Zone is nearing the lower limit for species that spread from the outer shelf down the slope while, at the same time, it is at or near the upper limit for some slope species that find shallow limits in the zone. As we sample in the areas occupied by the more typical slope fauna, we can anticipate a somewhat more uniform distribution of species and consequently a moderate increase in the similarity indices.

Thus far, the dendrogram in Figure 4-5 seems to support the faunal zones proposed in the TerEco report (Pequegnat et al. 1983).

Every effort will be made to improve this mode of sampling in the future. Meanwhile, between now and the next report data from such aberrant samplings will be deleted from the data base used for computation of faunal zone dendrograms. Thus far, however, the dendrogram in Figure 4-5 is supportive of the faunal zones proposed in Pequegnat et al. (1983).

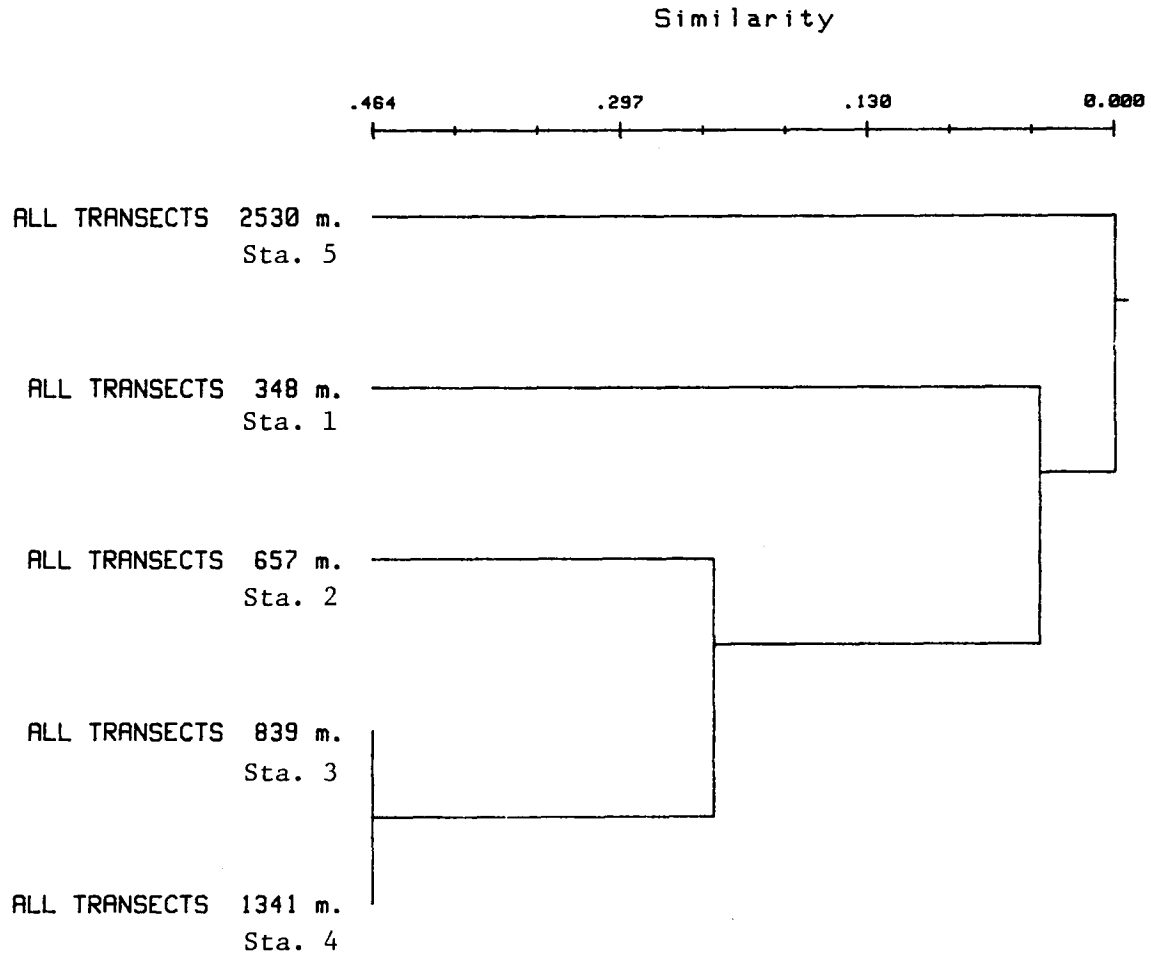


Figure 4-5. Dendrogram showing similarity by station (or depth) at all transects. Based upon clustering of the most abundant macroepifaunal species of decapods, echinoderms, and fish.

Species Composition of the Faunal Assemblages

In order to understand the significance of faunal assemblages, it is necessary to conceptualize how the megafaunal species involved are distributed over the continental slope. In the first place, it must be expected that some but not all species that can be considered typical of a faunal assemblage will be limited in distribution to the vertical limits of the proposed zone. Since species have been used to construct zones, we can expect that assemblages are congruent with zones. All species have bathymetric ranges, i.e., they range from shallow to deep or, to put it another way, one species starts at a given point on the slope and stops at another, another starts shallower but doesn't go as deep as the first, still another, starts and stops deeper than the first two. So that when we plot the vertical starts and stops of tens of species we see that distinct clustering of species emerge. These are the faunal assemblages. Some species may overlap into one or another assemblage, but generally it achieves its maximum populations in a single zone. Some species that characterize a zone usually will be bathymetrically limited to that zone.

Shelf/Slope Transition Zone Assemblage (150-450 m)--Obviously the LGL sampling does not cover the full extent of this zone; hence the faunal assemblage will lack some of those species components that range into the area of the upper slope from the outer shelf. Nevertheless, the comparison of the fish species with that taken by TerEco is reasonably good. Among the asteroids, there is very little similarity because the bulk of the species in the TerEco list for this zone came from the upper part of the slope and the shelf. Generally the decapod crustaceans in the LGL and TerEco reports are reasonably close.

Demersal Fishes

Species with Maximum Population in Zone
(First 10 species in Rank Order)

1. *Coelorinchus caribbaeus*
2. *Setarchus guentheri*
3. *Hymenocephalus italicus*
4. *Bembrops gobioides*
5. *Poecilopsetta beani*
6. *Urophycis cirrata*

Shelf/Slope Transition Zone Assemblage (150-450 m)--continued

7. Chlorophthalmus agassizii
8. Epigonus pandionis
9. Malacocephalus occidentalis
10. Parasudis truculenta
11. Argentina striata
12. Bromisculus imberbis
13. Coelorinchus coelorhynchus
14. Gnathagnus egreguis
15. Gurgesiella sinusmexicanus
16. Helicolenus dactylopterus
17. Hemanthias leptus
18. Hoplostethus occidentalis
19. Lophiodes monodi
20. Macrorhamphosa scolopax
21. Merluccius albidus
22. Peristedion greyae
23. Peristedion mineatum
24. Polymetme corythaeola
25. Polymixia lowei
26. Pontinus longispinus
27. Prionotus stearnsi
28. Raja garmani
29. Raja lentiginosa
30. Symphurus marginatus
31. Synagrops bella
32. Synagrops spinosa
33. Steindachneria argentea
34. Urophycis floridana

Other Species that Live in the Zone

35. Coryphenoides colon
36. Lepophidium brevibarbe

Asteroidea

Species with Maximum Population in Zone

(Species in Rank Order)

1. Astropecten americanus
2. Odontaster hispidus
3. Astropecten comptus
4. Astropectinidae

(no other asteroid species found in the zone)

Holothuroidea

Species with Maximum Population in Zone

1. Molpadia cubana

(no other holothuroid species found in the zone)

Echinoidea

Species with Maximum Population in Zone
(Species in Rank Order)

1. Brissopsis sp.
2. Brissopsis alta
3. Brissopsis atlantica

(no other echinoid species found in the zone)

Crinoidea

(none collected in the zone)

Penaeidae

Species with Maximum Population in the Zone
(Species in Rank Order)

1. Penaeopsis serrata
2. Parapenaeus longirostris
3. Hymenopenaeus robustus
4. Solenocera necopina

(no other species were found in the zone)

Caridea

Species with Maximum Population in Zone
(Species in Rank Order)

1. Parapandalus willisi
2. Heterocarpus ensifer
3. Pontocaris caribbaeus

(no other species were found in the zone)

Anomura-Galatheidae

Species with Maximum Population in Zone
(Species in Rank Order)

1. Munida longipes
2. Munidopsis robusta
3. Munida forceps
4. Munidopsis polita

5. Munida sp.
6. Munida irrasa

(no other species were found in the zone)

Anomura Except Galatheidae

Paguridae

Species with Maximum Population in Zone

(Species in Rank Order)

1. Parapagurus pictus
2. Pagurus rotundimanus
3. Paguristes sp.

(no other species were found in the zone)

Porcellanidae

Species with Maximum Population in Zone

1. Porcellana sigsbeiana

Chirostylidae and Lithodidae

(no species collected in this zone)

Brachyura

Species with Maximum Population in the Zone

(Species in Rank Order)

1. Lyreidus bairdii
2. Benthochascon schmitti
3. Pyromaia arachna
4. Ethusa microphthalma
5. Acanthocarpus alexandri
6. Palicus gracilis
7. Bathynectes superba
8. Thalassoplax angusta
9. Stenocionops spinimana
10. Collodes leptochela
11. Chacellus filiformis

Other Species that Live in the Zone

12. Bathyplax typhla
13. Geryon quinquedens
14. Rochinia crassa

Shelf/Slope Transition Zone Assemblage (150-450 m)--continued

Macrura

Polychelidae

Other Species that Live in the Zone

1. Polycheles typhlops

Nephropidae

Maximum Population in Zone

1. Nephropsis aculeata

Archibenthal Zone-Horizon A (475-750 m)--The species of the faunal assemblage characterizing this zone are as follows:

Demersal Fishes

Species with Maximum Population in Zone

(First 10 Species in Rank Order)

1. Dibranchus atlanticus
2. Nezumia aequalis
3. Bathygadus macrops
4. Chaunax pictus
5. Neoscopelus macrolepidotus
6. Diplacanthopoma sp.
7. Pseudophichthys laterodorsalis
8. Laemonema barbatulum
9. Coryphaenoides colon
10. Etmopterus schultzi

11. Barathronus bicolor
12. Bathygadus melanobranchus
13. Cruriraja rugosa
14. Decapterus punctatus
15. Dicrolene sp.
16. Halosaurus guentheri
17. Hoplunnis sp.
18. Nettastoma melanura
19. Nezumia sp.
20. Macrouridae sp.
21. Synaphobranchus sp.
22. Yarella blackfordi

Other Species that Live in the Zone

23. Bembrops gobioides
24. Coelorinchus caribbaeus

25. Epigonus pandionis
26. Lophiodes monae
27. Merluccius albidus
28. Parasudis truculenta
29. Peristedion greyae
30. Poecilopsetta beani

Asteroidea

Species with Maximum Population in Zone
(Species in Rank Order)

1. Pectinaster gracilis
2. Persephonaster echinulatus
3. Plinthaster dentatus
4. Hymenaster sp.
5. Hymenasteridae

Other Asteroid Species that Live in the Zone

6. Nymphaster arenatus

Holothuroidea

(no holothurians were found that attain maximum population in the zone. However, Mesothuria lactea was collected in the zone)

Echinoidea

(no echinoids were found that attain maximum population in the zone. However, Plesiodiadema antillarum was collected in the zone)

Crinoidea

(Atelecrinus balanoides attains maximum populations in the zone; Democrinus brevis was collected there but is more abundant at a deeper depth)

Penaeidae

Maximum Population in Zone

1. Hymenopenaeus debilis

Other Species that Live in the Zone

2. Plesiopenaeus ediwardsianus

Caridea

Species with Maximum Population in Zone
(Species in Rank Order)

1. Plesionika holthuisi
2. Glyphocrangon alispina
3. Glyphocrangon longlevi
4. Prionocrangon pectinata
5. Psalidopus barbouri

Other Species that Live in the Zone

6. Acanthephyra armata
7. Nematocarcinus rotundus
8. Glyphocrangon nobilis
9. Pontophilus gracilis

Anomura-Galatheidae

Species with Maximum Population in Zone
(Species in Rank Order)

1. Munida valida
2. Munidopsis erinaceus
3. Munidopsis alaminos

Anomura-Paguridae

Maximum Population in Zone

1. Parapagurus pilosimanus

Archibenthal Zone-Horizon A (475-750 m)--continued

Chirostylidae and Lithodidae

Maximum Population in Zone

1. Uroptychus nitidus

Brachyura

Species with Maximum Population in Zone

(Species in Rank Order)

1. Bathyplax typhla
2. Rochinia crassa
3. Trichopeltarion nobile

Other Species that Live in the Zone

4. Ethusa microphthalma
5. Benthochascon schmitti
6. Geryon quinquedens

Archibenthal Zone-Horizon B (775-950 m)--The species of the faunal assemblage characterizing this zone are as follows:

Demersal Fishes

Species with Maximum Population in Zone

(First 10 Species in Rank Order)

1. Synaphobranchus brevidorsalis
2. Synaphobranchus oregoni
3. Monomitopus sp.
4. Coryphaenoides mexicanus
5. Bathygadus melanobranchus
6. Nezumia suilla
7. Halosaurus guentheri
8. Lepophidium brevibarbe
9. Epigonus macrops
10. Gadomus arcuatus
11. Apistrurus parvipinnis
12. Bathyuroconger vicinus
13. Bathypterois viridescens
14. Epigonus occidentalis
15. Hydrolagus sp.
16. Leptoderma macrops

Other Species that Live in the Zone

17. Barathromus bicolor
18. Bathygadus macrops
19. Bembrops gobioides
20. Chaunax pictus
21. Dibranchus atlanticus
22. Diplacanthopoma sp.
23. Epigonus pandionis
24. Neoscopelus macrolepidotus
25. Nezumia aequalis
26. Nezumia sp.
27. Parasudis truculenta
28. Peristedion greyae
29. Poecilopsetta beani
30. Yarella blackfordi

Asteroidea

Species with Maximum Population in Zone
(Species in Rank Order)

1. Goniopecten demonstrans
2. Gonioasteridae

Other Species that Live in the Zone

1. Pectinaster gracilis
2. Plinthaster dentatus
3. Hymenaster sp.
4. Plutonaster intermedius
5. Nymphaster arenatus
6. Dipsacaster sp.

Holothuroidea

(Only Mesothuria lactea attains maximum populations in the zone, and Molpadia blakei is the only other species collected here)

Echinoidea

(No echinoid species attains maximum populations in the zone, but Plesiodiadema antillarum was collected here)

Crinoidea

(Although *Democrinus brevis* was collected here, it is more abundant at deeper depths)

Penaeidae

Species with Maximum Population in Zone

1. *Plesiopenaeus edwardsianus*

Other Species that Live in the zone

2. *Benthesicymus bartletti*
3. *Hymenopenaeus debilis*

Caridea

Species with Maximum Population in Zone

1. *Acanthephyra armata*

Other Species that Live in the Zone

2. *Plesionika holthuisi*
3. *Glyphocrangon alispina*
4. *Nematocarcinus rotundus*
5. *Glyphocrangon aculeata*
6. *Glyphocrangon nobilis*
7. *Pontophilus gracilis*

Anomura-Galatheidae

Species with Maximum Population in Zone

1. *Munidopsis spinosa*

Other Species that Live in the Zone

2. *Munidopsis polita*
3. *Munida valida*
4. *Munida microphthalma*
5. *Munidopsis longimanus*

Archibenthal Zone-Horizon A (475-750 m)--continued

6. Munidopsis sigsbei

Anomura-Paguridae

Species with Maximum Populations in Zone

(Species in Rank Order)

1. Parapagurus bicristatus
2. Parapagurus n.sp.

Other Species that Live in the Zone

3. Parapagurus pictus
4. Parapagurus pilosimanus
5. Catapaguroides microps

Chirostylidae and Lithodidae

Species with Maximum Population in Zone

1. Lithodes agassizii

Other Species Living in the Zone

2. Uroptychus nitidus

Brachyura

Species with Maximum Population in Zone

1. Geryon quinquedens
2. Brachyura sp.
3. Rochinia umbonata

Other Species that Live in the Zone

4. Benthochascon schmitti
5. Rochinia crassa
6. Bathyplax typhla

Upper Abyssal Zone (975-2250 m)--The species of the faunal assemblage characterizing this zone are as follows:

Demersal Fishes

Species with Maximum Population in Zone

(First 10 species in Rank Order)

1. Gadomus longifilis
2. Stephanoberyx monae
3. Dicrolene sp.
4. Nezumia cyrano
5. Ilyophis brunneus
6. Bathygadus favosus
7. Venefica procera
8. Bathypterois quadrifilis
9. Aldrovandia affinis
10. Conocara sp.

11. Acromycter perturbata
12. Aldrovandia gracilis
13. Apistrurus laurissonii
14. Bathophilus sp.
15. Bathypterois phenax
16. Bembrops anatirostris
17. Cataetyx sp.
18. Coelorinchus sp.
19. Ipnops murrayi
20. Malacoraja purpuriventralis
21. Squalogadus modificatus
22. Trachonurus vellosus
23. Xyelacyla myersi

Other Species that Live in the Zone

24. Bathygadus macrops
25. Bathypterois viridescens
26. Bembrops gobioides
27. Coryphenoides mexicanus
28. Gadomus arcuatus
29. Halosaurus guentheri
30. Monomitopus sp.
31. Nezumia aequalis
32. Nezumia suilla
33. Poecilopsetta beani
34. Parasudis truculenta
35. Peristedion greyae
36. Synaphobranchus brevidorsalis
37. Synaphobranchus oregoni

Asteroidea

Species with Maximum Population in Zone

(Species in Rank Order)

1. Plutonaster intermedius
2. Dipsacaster sp.

Upper Abyssal Zone (975-2250 m)--continued

3. Zoraster fulgens
4. Nymphaster arenatus
5. Ceramaster grenadensis
6. Henricia antillarum

Other Species that Live in the Zone

7. Hymenaster sp.

Holothuroidea

Species with Maximum Population in Zone
(Species in Rank Order)

1. Molpadia musculus
2. Molpadia barbouri
3. Echinocucumis hispida
4. Molpadia blakei

Other Species that Live in the Zone

5. Mesothuria lactea
6. Pseudostichopus sp.A

Echinoidea

Species with Maximum Population in Zone
(Species in Rank Order)

1. Plesiodiadema antillarum
2. Phormosoma placenta

Crinoidea

(Only Democrinus brevis attains maximum populations here;
no other species was found in the zone)

Penaeidae

Species with Maximum Population in Zone
(Species in Rank Order)

1. Benthesicymus bartletti
2. Hymenopenaeus aphoticus

Other Species that Live in the Zone

3. Hymenopenaeus debilis

Caridea

Species with Maximum Population in Zone
(Species in Rank Order)

1. Nematocarcinus rotundus
2. Glyphocrangon aculeata
3. Glyphocrangon nobilis
4. Pontophilus gracilis
5. Acanthephyra eximia
6. Heterocarpus oryx
7. Bathypalaemonella serratipalma
8. Bathypalaemonella texana

Anomura-Galatheidae

Species with Maximum Population in Zone
(Species in Rank Order)

1. Munidopsis longimanus
2. Munidopsis simplex
3. Munida micropthalma
4. Munidopsis sigsbei
5. Munidopsis abbreviata

Other Species that Live in the Zone

6. Munidopsis polita
7. Munida valida

Anomura-Paguridae

Species with Maximum Population in Zone

1. Catapaguroides microps

Other Species that Live in the Zone

2. Parapagurus pictus
3. Parapagurus pilosimanus
4. Pagurus n. sp.

Upper Abyssal Zone (975-2250 m)--continued

Chirostylidae

Species with Maximum Population in Zone

1. Uroptychus sp.

Brachyura

(No brachyuran species attain maximum populations in this zone, but the following species do occur there:)

1. Bathyplax typhla
2. Geryon quinquedens
3. Rochinia crassa

Macrura

Polychelidae

Species with Maximum Population in Zone

1. Stereomastis sculpta

Nephropidae

(No nephropids attain maximum populations in the zone, but the following species occur there:)

1. Nephropsis rosea
2. Nephropsis agassizii

Mesoabyssal Zone-Horizon C (2275-2700 m)--As was noted in the Tereco Report (1983), we observe that a very sharp break occurs here between the Upper Abyssal Zone and Horizon C of the Mesoabyssal Zone.

Mesoabyssal Zone-Horizon C (2275-2700 m)--continued

Groups	Upper Abyssal	Mesoabyssal
1. Fish species	37	2
2. Asteroids	7	2
3. Holothuroids	6	2
4. Echinoids	2	0
5. Penaeids	3	0
6. Carideans	8	4
7. Galatheids	7	1

Demersal Fishes

Thus far only two species of demersal fishes have been collected in the Mesoabyssal Zone, Venefica procera and Cataetyx sp., neither of which attain maximum populations here.

Asteroidea

Species with Maximum Populations in the Zone

1. Pseudarchaster sp.

Other Species Living in the Zone

2. Dipsacaster sp.

Holothuroidea

Species with Maximum Populations in the Zone

1. Pseudostichopus sp.A
2. Pseudostichopus sp.B

Penaeidae

(No species of penaeid decapods were collected here)

Mesoabyssal Zone-Horizon C (2275-2700 m)--continued

Caridea

Species with Maximum Population in the Zone

1. Nematocarcinus ensifer

Other Species that Live in the Zone

2. Glyphocrangon aculeata
3. Glyphocrangon nobilis
4. Pontophilus gracilis

Anomura-Galatheidae

Only one galatheid species was collected in this zone, Munida micropthalma; it attains maximum populations in the Upper Abyssal Zone.

Anomura-Paguridae

Only one pagurid species was collected in this zone, Parapagurus pictus; it attains maximum populations in the Shelf/Slope Transition Zone.

Chirostylidae

Gastroptychus spinifer attains maximum populations in this zone.

Brachyura

No brachyuran crabs were collected in this zone.

Nodal Constancy in Invertebrate Groups

Nodal constancy relates to a morphological and functional prototype and notes how closely the species of the group approach or vary from the characteristics of the prototype. It is of course these structural and functional traits that determine how the species respond positively or

negatively to the habitat. In this study, the species groups have been determined phylogenetically. That is, the species collected have been grouped by families or higher taxa, rather than by similarity clustering. It is assumed that the taxa used correspond to structure and functional traits.

Perhaps the Galatheidae illustrate these concepts reasonably well for offshelf waters. Ordinarily one considers the species of the genus Munida to prefer shallow parts of the continental slope, but there are some species that move away from the Munida modality. Typically, too, species of the genus have well developed eyes that are heavily pigmented, but one species, Munida microphthalma, is atypical in that it not only lives at depths in excess of 1000 m but also its eyes have regressed to a state of near blindness. These characteristics are typical of galatheid species in the genus Munidopsis, all of which are blind and many of which live below 1000 m depth. These tendencies are graphically depicted in Figure 4-6 where increasing constancy is indicated by denser shading in the cells. Near the bottom of the figure one sees that whereas the highest proportion of species conform to the shallow habitats, there are some outliers, viz., Munida valida and Munida microphthalma, that account for the distribution of species sets in the figure. By the same token, sets of Munidopsis species exhibit constancy toward the deeper stations except for two outliers, viz., Munidopsis robusta and M. polita, that usually exist in small numbers. There is, however, a fundamental difference in potential fate of the two genera. It seems to be a fair assumption that Munida and Munidopsis evolved from a common ancestor that had "normal" eyes. In time, Munidopsis species lost this trait and probably cannot regain sight even as they may move up the slope. Munida microphthalma on the other hand has undergone convergent evolution in regard to eye structure, as it approaches a Munidopsis modality in habitat and eye structure. This is probably not reversible. It is possible that Munida valida is in process of following the path of M. microphthalma.

The Brachyura are a very coherent group in that a high proportion of the species thus far collected adhere to occupation of habitats on the upper slope and outer shelf. The carideans on the other hand have a tendency to assume roles in deeper habitats. The Asteroidea and Holothuroides form another contrasting pair of groups.

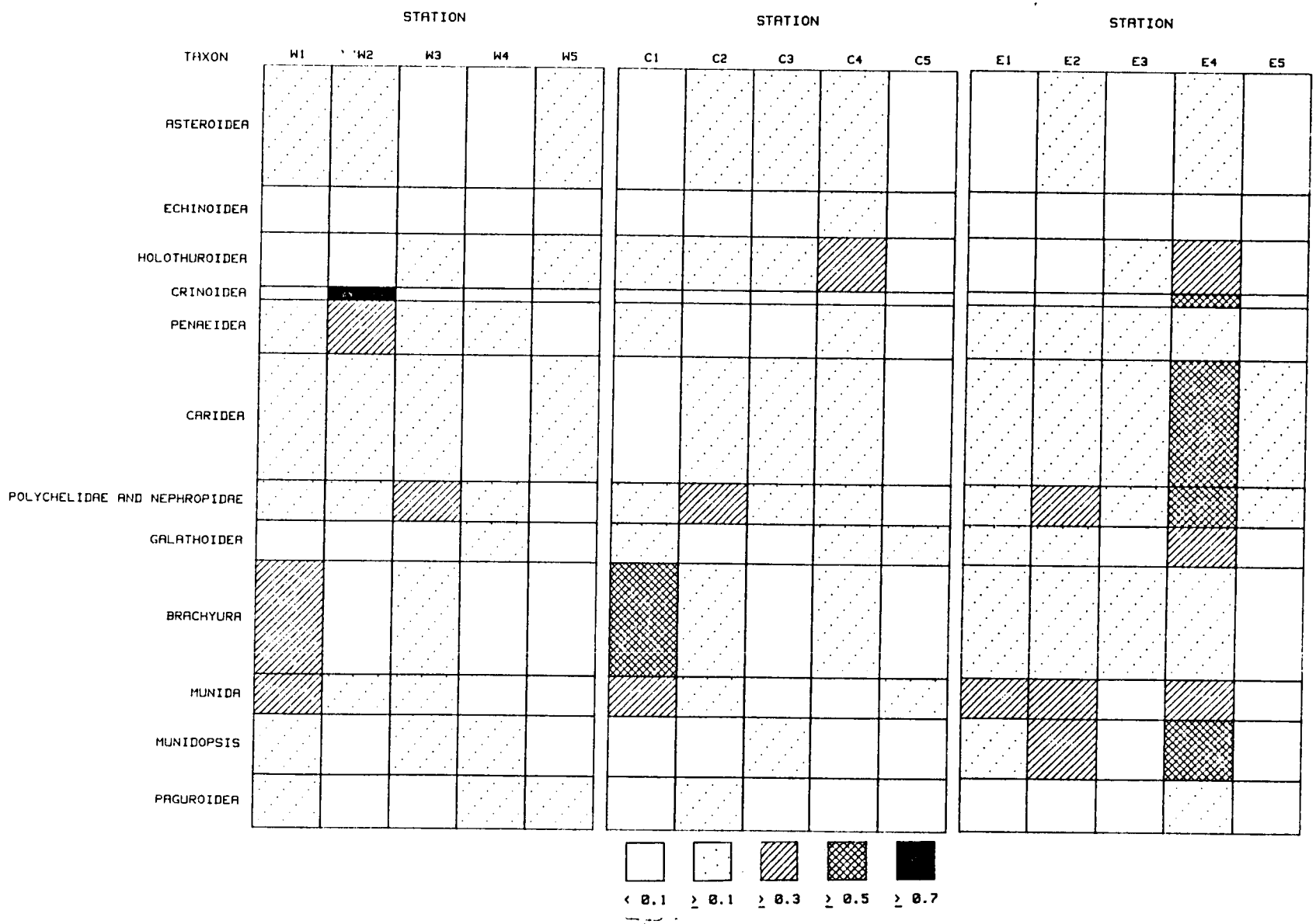


Figure 4-6. Nodal constancy of echinoderm and decapod groups of the macroepifauna.

Macroepifaunal Fidelity to Habitat Selection

Fidelity is related to constancy but emphasizes to what extent a set of related species adheres to their usual habitat selection. Habitat in the context of the present study is synonymous with transect station. When interpreting Figure 4-7, one must keep in mind that the LGL study samples only the bathymetric center of the continental slope, and also has thus far collected from a very limited depth series. Nevertheless, one can see in Figure 4-7 two things. First, most of the species sets are relatively constant in habitat selection and the selection is compatible with their constancy index. Second, there is a moderate trend among the majority of groups toward occupation of deeper habitats on the East Transect.

Two-way Nodal Analyses of Fish Data

Two-way nodal analyses of the LGL fish data measuring species constancy and fidelity are of considerable interest, even though with two cruises we have barely enough data to make such analyses feasible. Constancy, of course, is a proportionality within a species group that seeks to relate actual co-occurrences of species within the group to the total possible that could have occurred together. Obviously, the response of the species is to the habitat, but the measure of this latter selection process is better depicted in a two-way table of fidelity, as will be discussed after consideration has been given to constancy.

Constancy--The constancy analysis in Figure 4-8 displays several interesting points quite graphically. It must be remembered that the vertical extent of the family bars are proportional to the number of species within the family. The most significant families in this deep-water study are the Macrouridae (grenadiers), the Synaphobranchidae (eels), Ophidiidae (cusk-eels and brotulas), the Halosauridae (halosaurs), and the Bathypteroidae ("tripod" fishes). First, we note that the grenadiers occurred on all transects, but they were not only more abundant on the East Transect but also a larger proportion penetrated to greater depths there. This trend of west-to-east deepening has been noted in

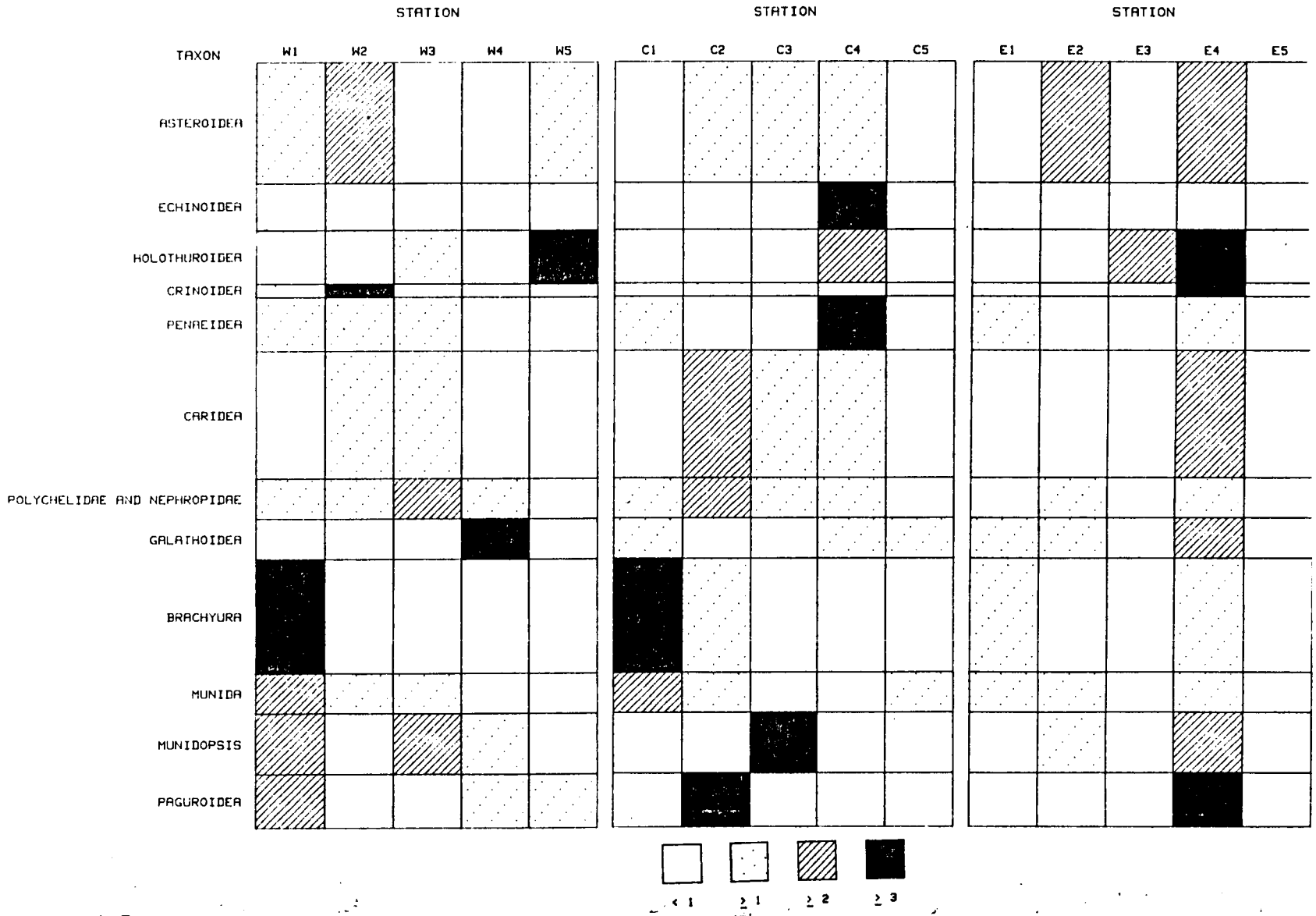


Figure 4-7. Nodal fidelity of echinoderm and decapod groups of the macroepifauna.

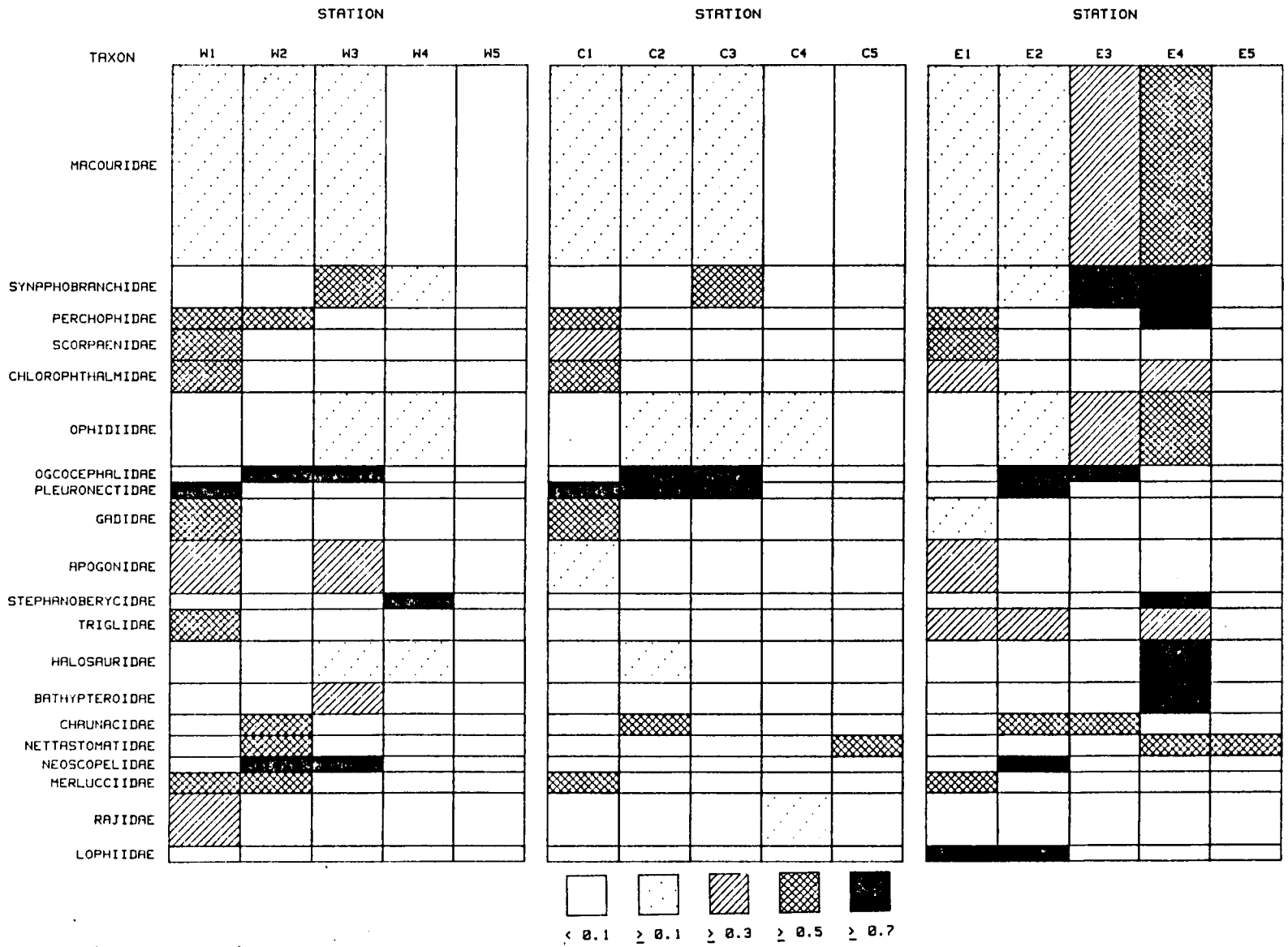


Figure 4-8. Nodal constancy of fish families (listed in order of numerical abundance). Vertical length of family columns is proportional to the number of species within the family.

earlier sections of the report. The same phenomenon is even more striking in the cases of the Synaphobranch eels, cusk-eels, halosaurs, and bathypteroids. The constancy with which, say, the grenadiers appear in similar proportions except for the interesting depth penetration to the east is remarkable.

Fidelity--In the present study the series of five stations per transect are the equivalents of habitats. The stations on a given transect differ in regard to depth and each has a geographically different pair of counterparts. Thus, fidelity in this context is a measure of the degree to which any one or all of the species grouped in a family select with relative constancy a given habitat or set. For instance, note in Figure 4-9 that the grenadiers (Macrouridae) occur at no more than three stations on any one of the transects. But here again, we see that they occur deeper on the East Transect. Essentially the same pattern is followed by synaphobranchid eels, chloropthalinids, cusk-eels (ophidiidae), halosaurs, bathypeteroids, chaunacids, etc. We eagerly await the results of Cruise III during which sampling at Station 5 on the Central Transect appears to have been more productive than Cruises I and II.

4.4 BENTHIC PHOTOGRAPHY

Five stations were photographed on the Central Transect during Cruise I, and five stations each were photographed from the Western, Central and Eastern Transects during Cruise II. Given that 800 photographs are taken at each station, the total photographic sample from Cruises I and II comprises 12,000 frames, from which a total subsample of 2000 frames are being analyzed.

Much of the first year of the program has been devoted to developing and perfecting equipment and analytical software for processing the photographs. To date, analysis has been completed for three shallow stations--W1, C1 and E1. Over 46,000 data records were generated by analysis of 300 photographs. These records were further processed into approximately 10,000 records to produce the findings presented below.

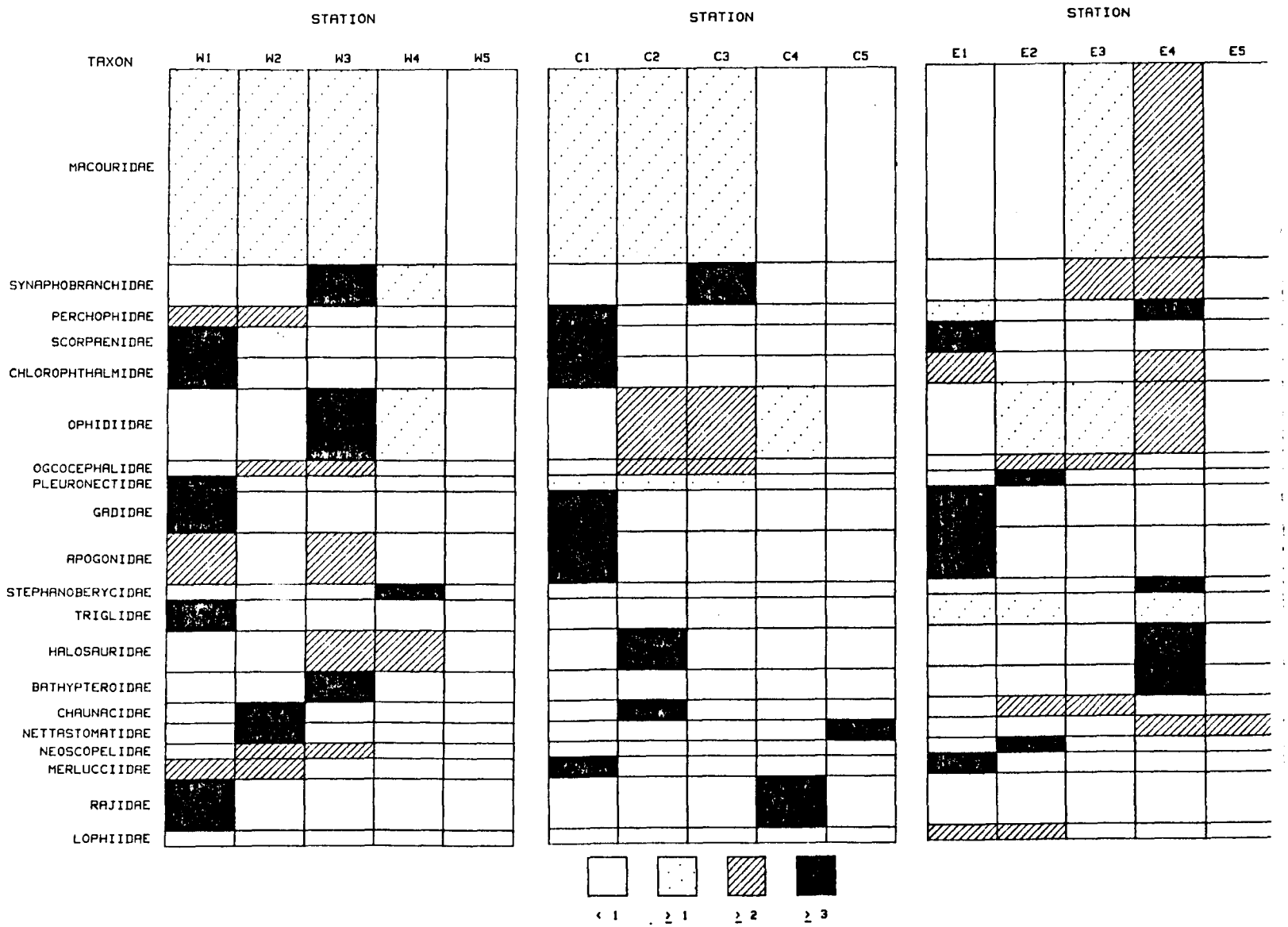


Figure 4-9. Nodal fidelity of fish families (listed in order of numerical abundance). Vertical length of family columns is proportional to the number of species within the family.

Data resulting from digitized slide analyses included the following:

(1) Numbers of Lebensspuren (tracks, burrows, etc.).
(2) Mean sizes or areas of each type of Lebensspuren.
(3) Percent cover and deisnty for each type of Lebensspuren.
(4) Percent cover for all Lebensspuren.
(5) Numbers of individuals of benthic invertebrates and fishes.
(6) Size or length of benthic invertebrates or fishes.

For the three stations presented here the total effort or area surveyed was as follows: Station W1 - 260.6 m^2, Station C1 - 190.1 m^2, and Station E1 - 303.7 m^2. Taxonomic names appearing in raw counts, densities or other data tables presented in the following station descriptions are exclusive. That is, even though one taxon might include another lower taxon appearing in the list, both names would represent individual observations.

4.4.1 Station Descriptions

Station W1

Station W1 camera transect photographs were obtained from a depth of 445 m to 477 m. Some unforeseen delays in camera deployment precluded reaching the target depth of 350 m at this first station of the cruise. The total area surveyed was 260.6 m^2. Table 4-42 provides raw counts and densities of the four major types of observations from Station W1 photographs. These were the following: (1) artifacts, (2) consolidated materials, (3) Lebensspuren, and (4) biota. Within the category of biota, a total of 18 fish, 19 decapod crustaceans, 1 sea grass blade, 6 unknown anemones, 16 glass sponges and 1 ophiuroid was observed.

A total of 4762 Lebensspuren structures was recorded. These observations were grouped into seven subcategories that combined similar types having very subtle differences. These Lebensspuren subcategories were the following: individual ridges, solitary lumps, individual grooves, sets of grooves, solitary depressions, groups of depressions, and

TABLE 4-42

Raw counts and density (no./ha) of artifacts, consolidated material, lebensspuren and biota observed in photographic samples taken at Stations W1, C1 and E1 on Cruise II. Total area surveyed (square meters): W1 - 260.6, C1 - 190.1, E1 - 303.7.

Classification	RAW COUNT			DENSITY PER HECTARE		
	W1	C1	E1	W1	C1	E1
Artifacts	0	2	0	0	107.4	0
Consolidated materials	2	1	2	76.8	53.7	65.9
Lebensspuren						
Individual ridges	0	1	0	0	53.7	0
Solitary lumps	93	129	94	3569.1	6928.4	3095.4
Individual grooves	91	4	56	3492.3	214.8	1844.1
Sets of grooves	27	0	0	1036.2	0	0
Solitary depressions	187	405	988	7176.5	21751.9	32534.3
Groups of depressions	4364	179	3918	167478.0	9613.8	129017.7
Sculptured strips	0	0	3	0	0	98.8
Biota						
Thalassia sp.	1	2	1	38.4	105.2	32.9
Hyalonema sp.	16	0	3	614.0	0	98.8
Zoantharia-Actiniaria	6	0	2	230.3	0	65.9
Hyalinoecia tubicola	0	1	0	0	52.6	0
Decapoda	0	3	0	0	157.8	0
Penaeidea	0	1	0	0	52.6	0
Penaeopsis	0	3	0	0	157.8	0
Penaeopsis serrata	4	20	0	153.5	1052.0	0
Hymenopenaeus robustus	8	0	0	307.0	0	0
Galatheidae	4	0	0	153.5	0	0
Munida sp.	0	1	0	0	52.6	0
Pyromaia arachna	0	0	1	0	0	32.9
Benthochascon schmitti	3	7	2	115.1	368.2	65.9
Asteroideb	0	1	0	0	52.6	0
Ophiuroidea	1	0	0	38.4	0	0
Scyliorhinus retifer	1	0	0	76.8	0	0
Chloroptnalmidae	0	2	0	0	105.2	0
Chloropthalmus agassizi	4	2	0	153.5	105.2	0
Dibranchus atlanticus	1	0	0	38.4	0	0
Urophycis sp.	0	2	0	0	105.2	0
Macrouridae	4	2	0	153.5	105.2	0
Coelorhynchus caribbaeus	0	3	0	0	157.8	0
Coelorhynchus coelorhynchus	1	1	0	38.4	52.6	0
Hymenocephalus italicus	6	0	0	230.3	0	0
Bembrops gobioides	1	1	3	38.4	52.6	98.8

sculptured strips. The categories of ridges and lumps should also have matching categories described as sets of ridges and groups of lumps (Hersey 1967), but these Lebensspuren features were not observed. Appendix D gives raw counts and densities of all specific Lebenssspuren types observed following the designations given by Hersey (ed. 1967).

In terms of areal coverage, consolidated material features were scarce (~0.36%) and were described as rough sediment blocks or slabs. The most prevalent Lebensspuren, both in abundance and areal coverage, was the category "groups of depressions." A total of 4364 individual depressions seen to occur in groups accounted for 1.02% of the 260.6 m^2 area sampled at Station W1. The mean area of each depression was 6.1 cm^2.

Station C1

Photographs analyzed from Station C1 extended from a bottom depth of 318 m to a maximum of 347 m. A total of 190.1 m^2 of bottom area was included. This smaller area resulted from a lower mean camera altitude and thereby smaller individual areas for each photograph.

Total raw counts and density per hectare for each category of observation are shown in Table 4-42 with detailed classifications provided in Appendix D. This station, with a total of all types of only 718, had far fewer observations of Lebensspuren than was observed at similar depths on the other two trransects. Although the area surveyed was considerably smaller, these numbers also represent much lower densities of Lebensspuren than were seen at other stations. For example, the density of depressions arranged in groups at Station C1 was 9613 per hectare as opposed to 167,478 per hectare at Station W1.

Depressions in groups exhibited a percent coverage of 0.07%, having a total of only 179 observations over an area 190.1 m^2. The mean size of these depressions was larger than those observed at Station W1; 7.6 cm^2 as opposed to 6.1 cm^2, respectively. The Lebensspuren category of solitary lumps had greater density and percent coverage at Station C1 than at the other two stations. These features covered a total of 0.28% of the bottom at C1, with the average lump having an area of 40.7 cm^2.

Observations of biota at this station included 13 fish, 35 decapod crustaceans, 1 polychaete worm tube (Hyalinoecia tubicola), 2 sea grass blades, and 1 asteroid.

Station E1

Photographs analyzed from Station E1 were taken at depths of from 348 m to 369 m. A total of 303.7 m^2 was surveyed. When compared with Stations W1 and C1, the raw counts and densities of biota presented in Table 4-42 show considerably fewer observations at Station E1. Only three fish were observed, all of these of a single species, Bembrops gobioides. Only three decapod crustaceans were observed. The remaining biota consisted of a single sea grass blade, two anemones and three observations that were either glass sponge stalks or sea pens.

Raw counts and densities of other categories of observations consisting of consolidated materials and Lebensspuren varieties are shown in Table 4-42 and detailed in Appendix D. The dominant category of Lebensspuren here, as at Station W1, was groups of depressions, totalling 3918 records or 129,018/hectare.

4.4.2 Comparisons of Four Bottom Features

The rigorous classification and enumeration of the digitized data permits quantitative comparisons between important bottom features and biota observed in the photographs. As an example of this approach, four broadly prevalent characters were selected for detailed analysis. These were the following: (1) fish, (2) decapods (biota); and (3) groups of depressions and (4) solitary lumps (Lebensspuren).

The first step in the analysis was to show variation of the densities of these characters with depth. Figures 4-10 through 4-15 show densities at frame time for these characters overlaid with depth at frame time. The most immediate result of these plots is that occurrence of all four characters appears to be highly variable on a spatial basis. The depth range covered was about 30 m for all three stations. Closer examination suggests that there may be trends with depth for some of the characters. Fish densities appear to decrease with depth at Stations C1 and E1. An

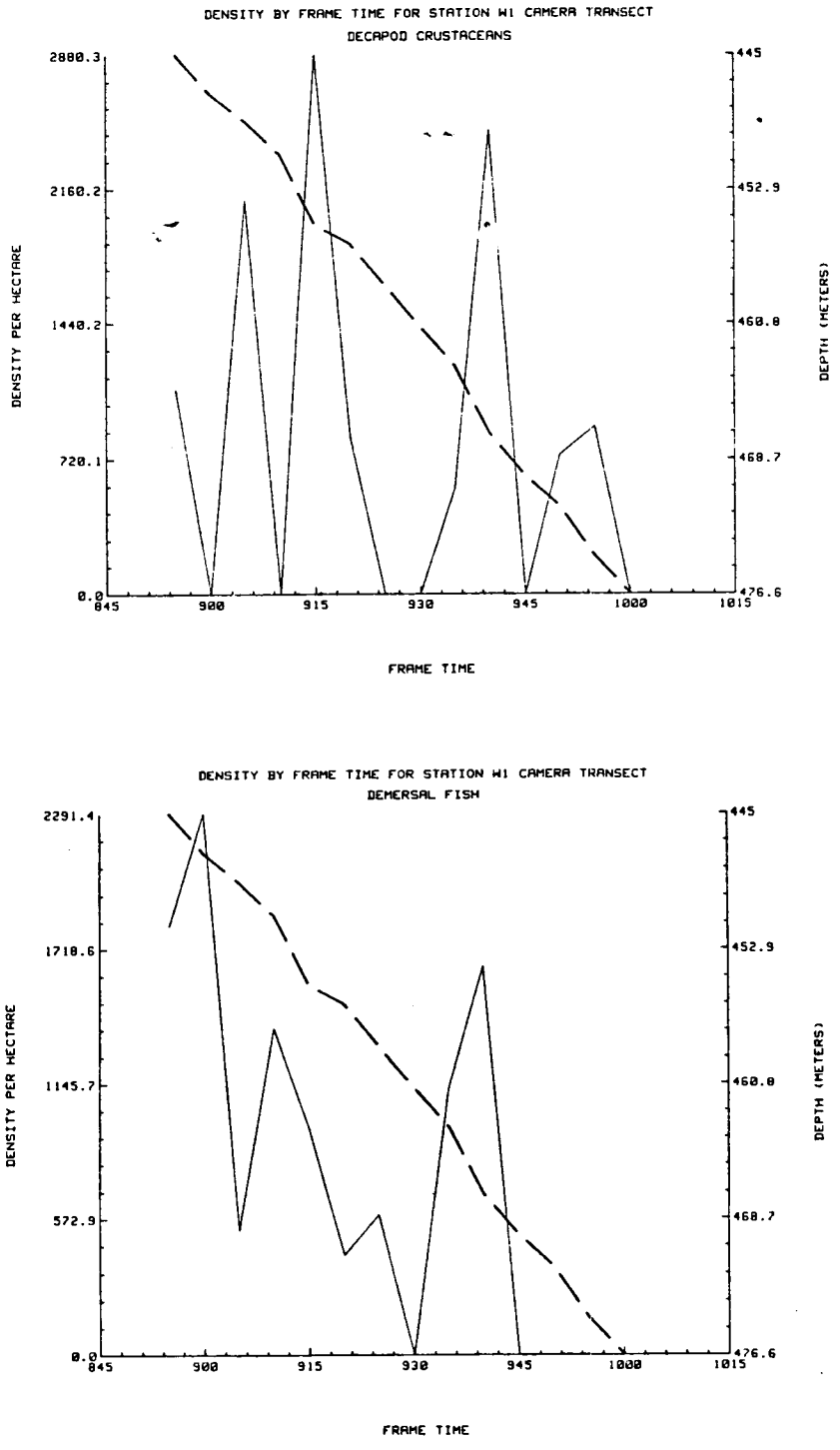
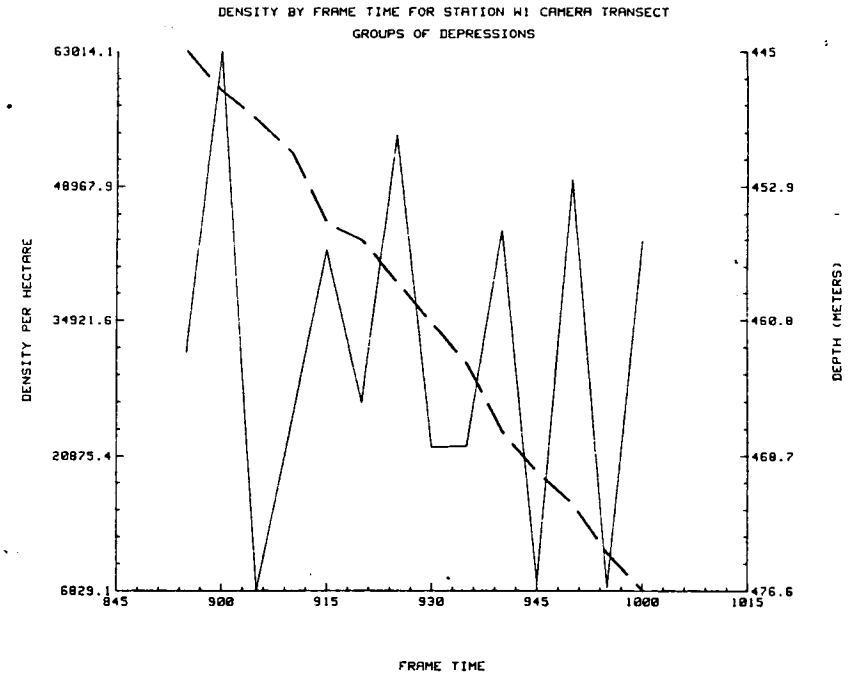


Figure 4-10. Density by frame time vs. depth at station W1 for decapod crustaceans and demersal fish. Dashed line represents depth.



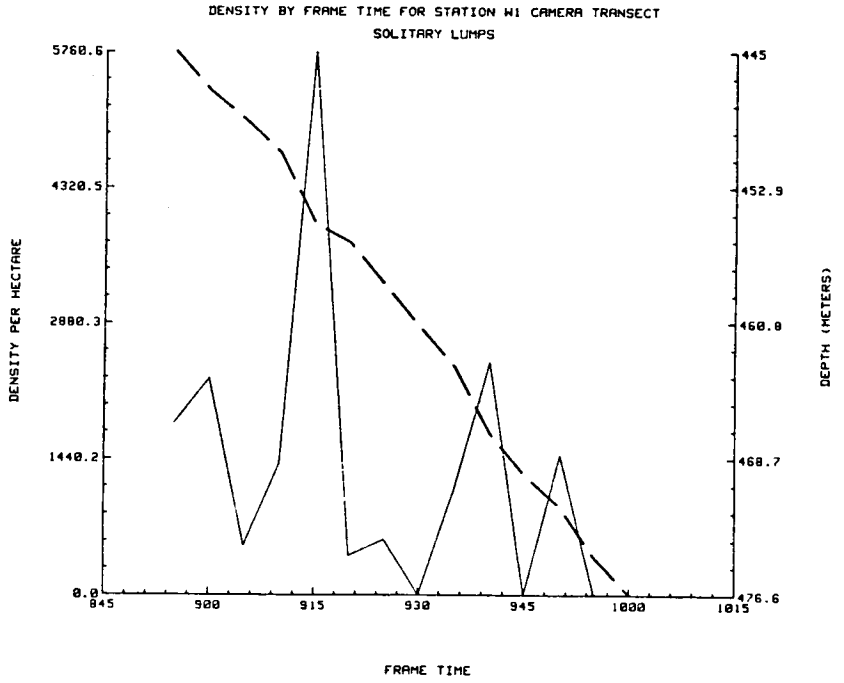
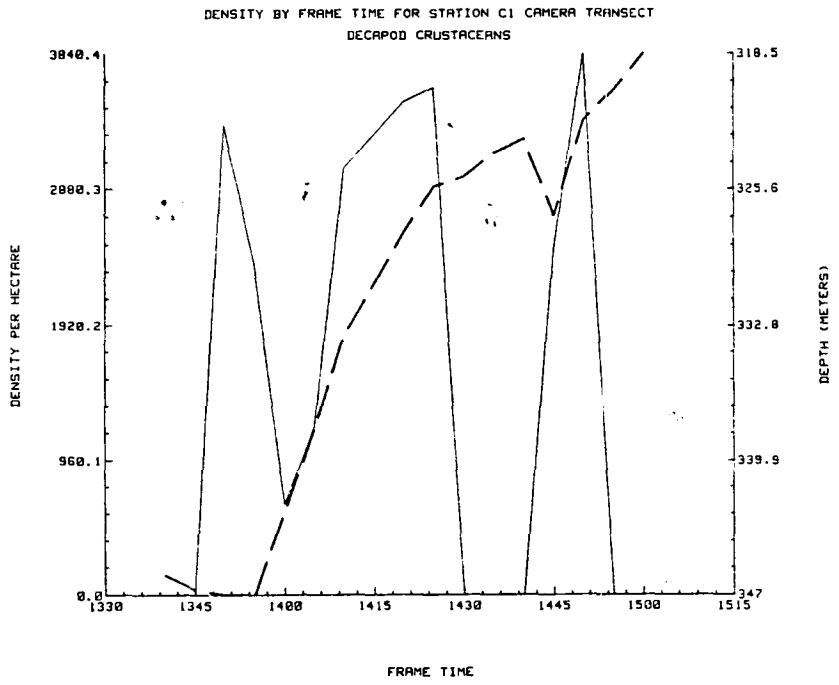


Figure 4-11. Density by frame time vs. depth at station W1 for lebensspuren categories of groups of depressions and solitary lumps. Dashed line represents depth.



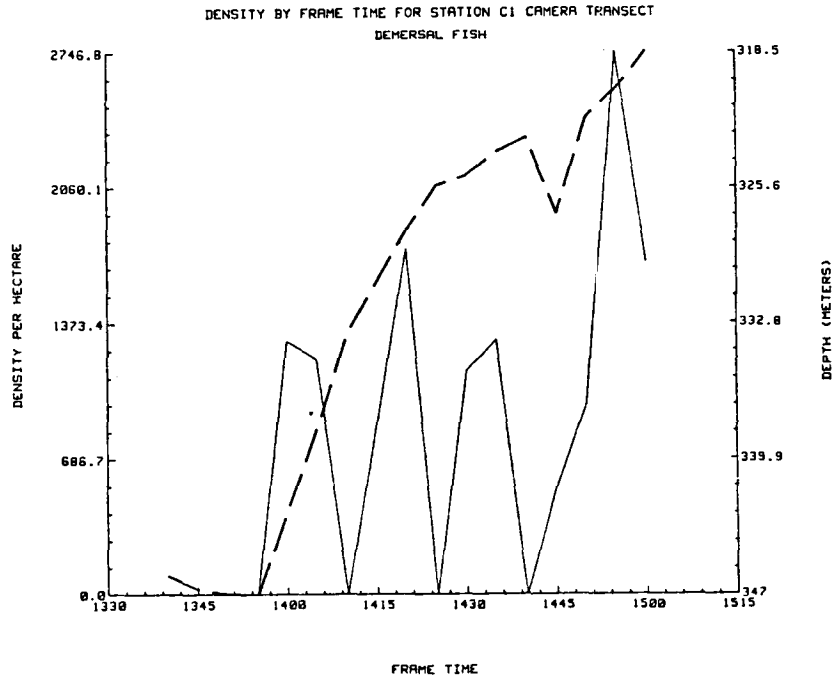


Figure 4-12. Density by frame time vs. depth at station C1 for decapod crustaceans and demersal fish. Dashed line represents depth.

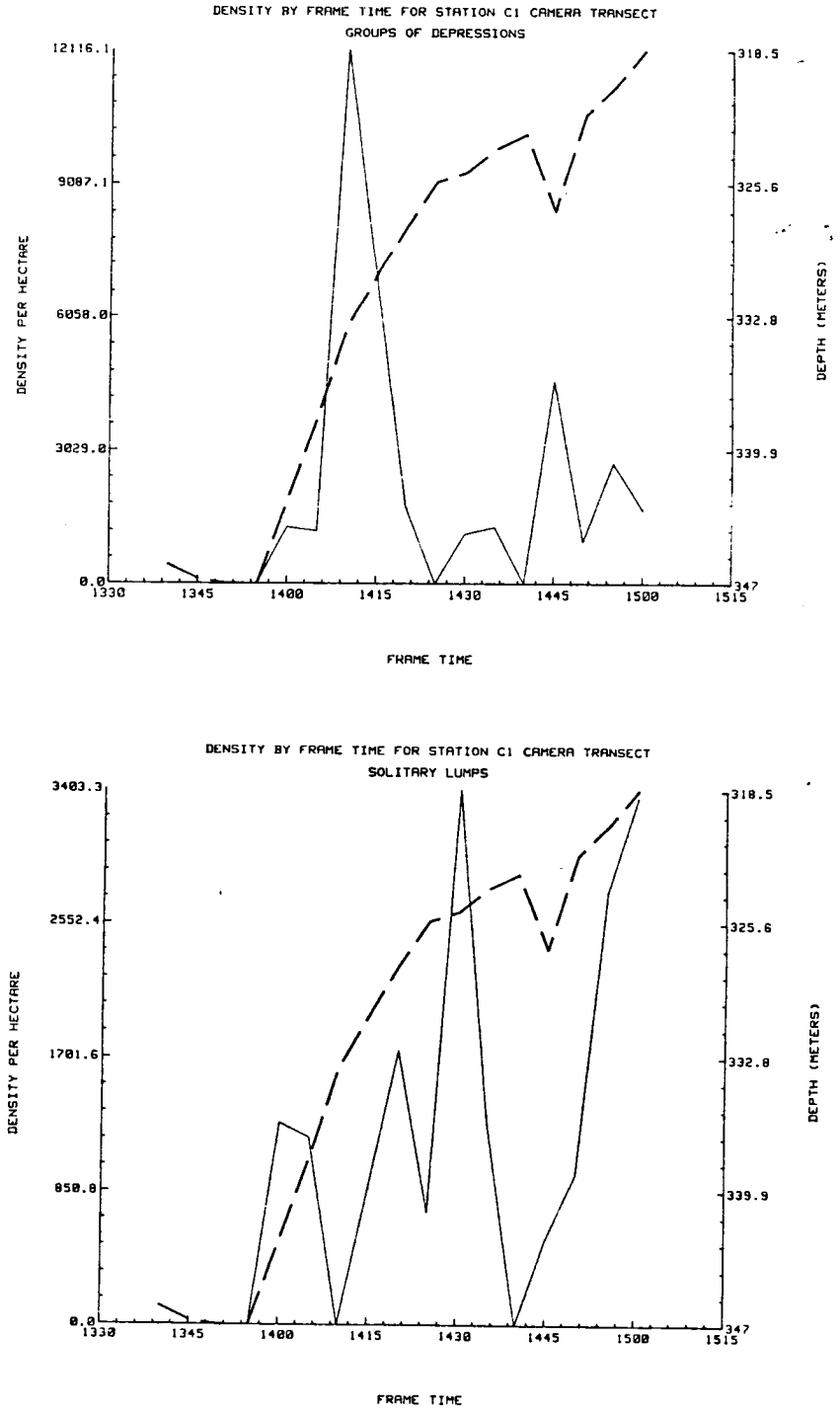
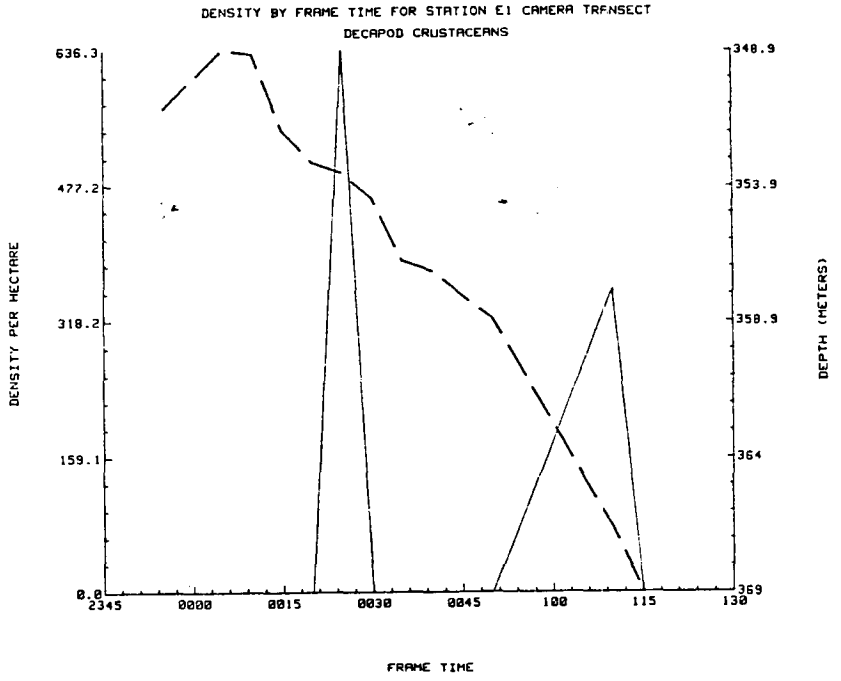


Figure 4-13. Density by frame time vs. depth at station C1 for lebensspuren categories of groups of depressions and solitary lumps. Dashed line represents depth.



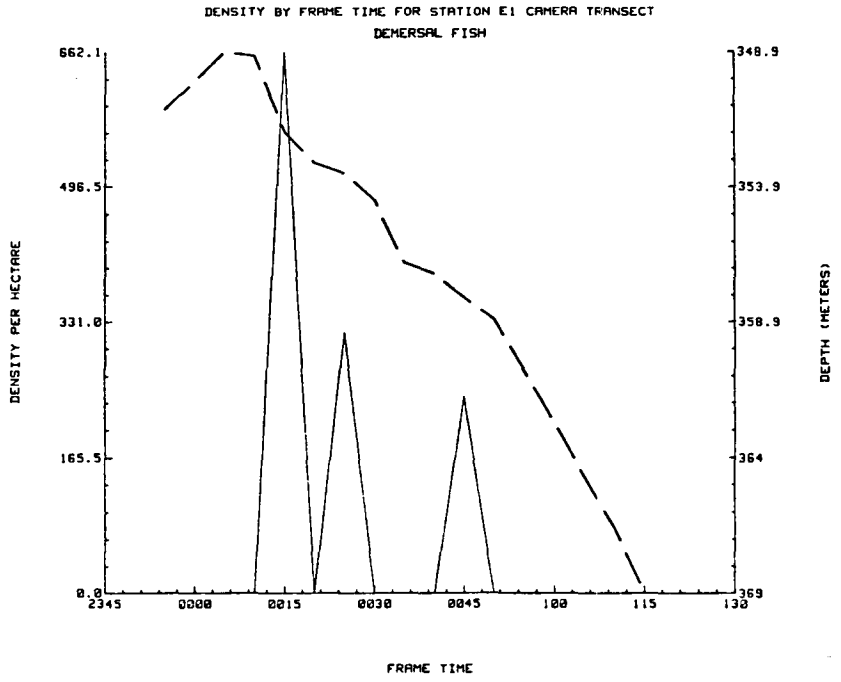
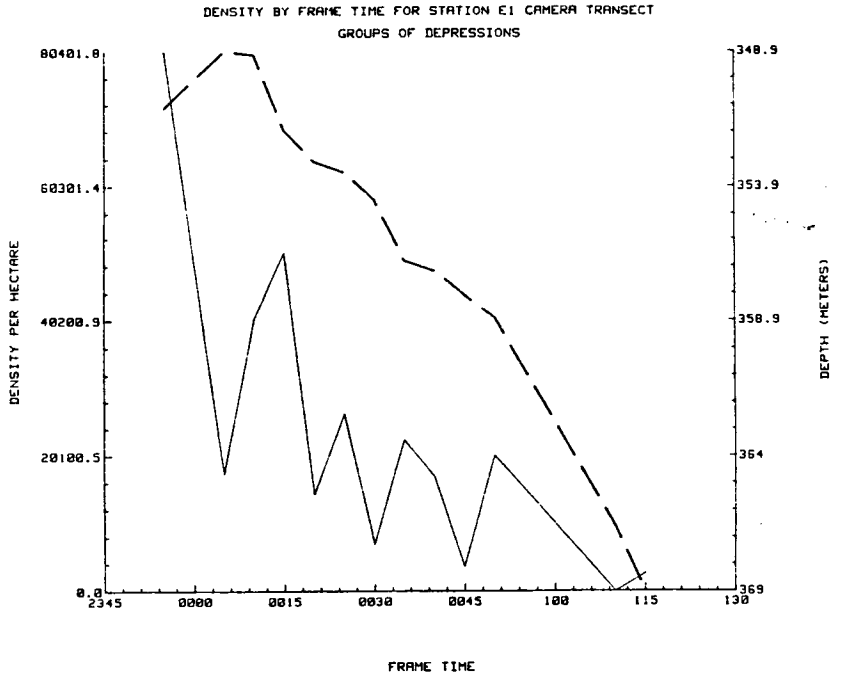


Figure 4-14. Density by frame time vs. depth at station E1 for decapod crustaceans and demersal fish. Dashed line represents depth.



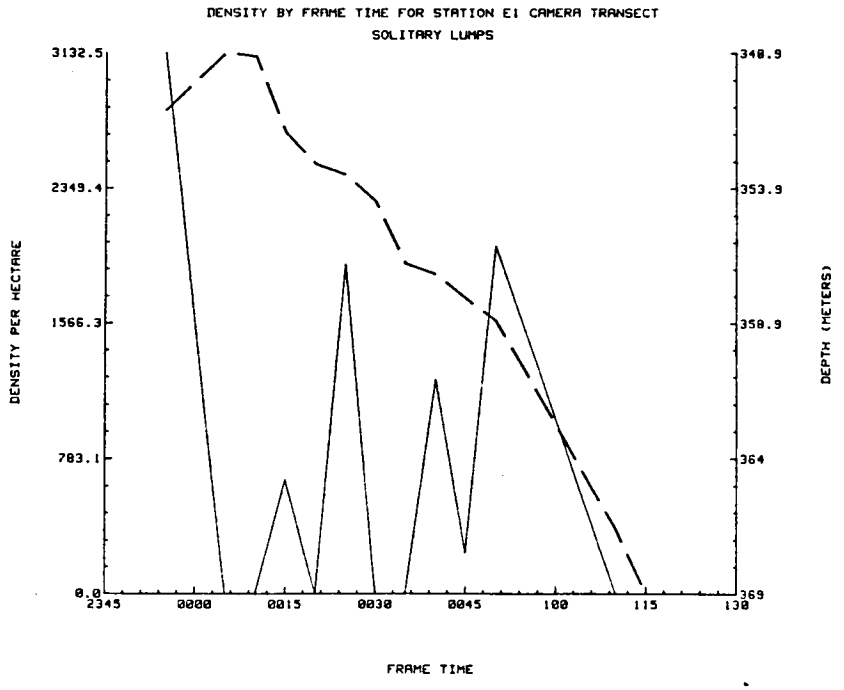


Figure 4-15. Density by frame time vs. depth at station E1 for lebensspuren categories of groups of depressions and solitary lumps. Dashed line represents depth.

intriguing artifact of the plots is the sharp variation in the density of groups of depressions at W1 and at C1--apparently in response to changes in depth.

The index of cluster size (ICS, see Douglas 1975) is a measure of spatial variability that can detect patterns of distribution ranging from patchy to regularly spaced. When applied to the four characters in question the ICS indicated that the Lebensspuren solitary lumps were randomly distributed, while groups of depressions were patchily distributed for all three stations. The biota, fish and crustaceans both tended toward a regular distribution, but the ICS values were not definitive.

Comparisons of the densities of these four characters among the three stations was carried out using a Kruskal-Wallis one-way analysis of ranks. The fish and decapods showed contradictory results. At a p value $\geq$ 0.05, the decapod densities are most similar at Stations E1 and W1, while the fish densities were most similar at Stations W1 and C1. Similarities of the Lebensspuren densities supports the results of the index of cluster size comparisons. For the groups of depressions, all three stations test out dissimilar, while for the solitary lumps, all stations appear similar (at p value = 0.064). These results give persuasive evidence that the two types of Lebensspuren studied result from different organisms or processes.

4.4.3 Length Measurements

Another valuable type of data obtained from digitized photographs has been the calculation of actual length or other dimensions of objects. Table 4-43 presents results of measured objects from Stations W1, C1 and E1. This technique was especially applicable to the measurement of fish lengths and the determination of length or width of the carapace for decapod crustaceans. All data presented here were obtained by digitized measurements of biota or other objects resting directly on the bottom. By using this qualification, the dimensions of the object can be determined directly from calculations using the altitude of the camera. Procedures have also been developed for determining the size of objects located a short distance off of the bottom substrate by the use of the object's

TABLE 4-43

Mean lengths and standard deviations (centimeters) of selected biota and lebensspuren observed in bottom photographs on Cruise II.

Biota	W1			C1			E1		
	N	mean	s.d.	N	mean	s.d.	N	mean	s.d.
Thalassia sp.	1	23.700	0	2	3.150	0.212	0	0	0
Hyalonema sp.	16	11.031	10.261	0	0	0	3	11.467	12.150
Zoantharia-Actiniaria	4	14.250	12.166	0	0	0	0	0	0
Hyalinoecia tubicola	0	0	0	1	13.200	0	0	0	0
Penaeopsis	0	0	0	3	2.200	3.811	0	0	0
Hymenopenaeus robustus	8	11.050	3.580	0	0	0	0	0	0
Galatheidae	4	1.825	0.299	0	0	0	0	0	0
Munida sp.	0	0	0	1	2.300	0	0	0	0
Pyromaia arachna	0	0	0	0	0	0	1	3.400	0
Benthochascon schmitti	3	6.400	1.114	7	6.386	1.165	2	6.200	0.566
Scyliorhinus retifer	1	24.300	0	0	0	0	0	0	0
Chloroptalmidae	0	0	0	2	5.650	0.354	0	0	0
Chloroptalmus agassizi	4	11.400	7.619	2	12.900	3.818	0	0	0
Dibranchus atlanticus	1	10.800	0	0	0	0	0	0	0
Urophycis sp.	0	0	0	2	39.050	9.970	0	0	0
Macrouridae	4	15.150	12.283	2	18.850	7.566	0	0	0
Coelorhynchus caribbaeus	0	0	0	3	19.233	16.673	0	0	0
Coelorhynchus coelorhynchus	1	17.400	0	1	6.600	0	0	0	0
Hymenocephalus italicus	6	34.450	47.196	0	0	0	0	0	0
Bembrops gobioides	1	8.200	0	1	3.600	0	3	28.767	5.350
Lebensspuren									
Individual ridges	0	0	0	1	36.400	0	0	0	0
Individual grooves	85	5.964	7.257	3	33.500	39.764	49	10.086	18.604
Sets of grooves	26	8.623	8.883	0	0	0	0	0	0

shadow in conjunction with measured separation of the camera and the source of light producing the shadow (strobe).

The majority of the remote measurement calculations appear to be reasonably realistic.

A total of 29 measurements of decapopd crustaceans was obtained. Carapace widths appear to be reliable and were very consistent.

Mean carapace widths for the crab Benthochascon schmitti Stations W1, C1 and E1 were 6.40, 6.38 and 6.20 cm, respectively. A number of actual specimens of B. schmitti were obtained from the otter trawl at Station C1 allowing comparisons between calculated dimensions obtained through photographs and actual specimens measured in the laboratory. From a total of 21 measurements of trawled specimens, the mean carapace width was 5.12 cm. A total of eight digitized measurements of carapace length was made for the shrimp Hymenopenaeus robustus at Station W1. The carapace length for these 8 individuals averaged 11.1 m. In comparison, only one specimen was obtained by otter trawl which measured 9.0 cm.

A total of 34 fish length measurements was derived from analyzed photographs. All but three of these were from Stations W1 and C1. It appears that some of the measurement calculations for fish lengths have used erroneous data or incorrect calculations. For example, the mean digitized length for six observations of the macrourid, Hymenocephalus italicus was 34.5 cm at Station W1 while all specimens captured at this station had a mean length of only 11.8 cm. There are also unresolved problems with the data obtained from digitized measurements of the five observations of Bembrops gobioides.

Other digitized fish lengths were more similar to actual samples. The greeneye, Chloropthalmus agassizi was measured by digitizer in four photographs at Station W1 and had a mean length of 11.4 cm. Two individuals were measured digitally at Station C1 and had a mean length of 12.9 cm (Table 4-43). Samples obtained from trawling included 35 specimens of C. agassizi from Station W1 with a mean length of 11.4 cm; exactly the same as those photographed. A single C. agassizi of 13.2 cm was trawled from Station C1. This compares well with the mean length of 12.9 cm for the two individuals photographed at this station.

Other taxa presented in Table 4-43 including Urophycis sp., Macrouridae, Coelorhynchus caribbaeus, C. coelorhynchus and Dibranchus

atlanticus all had measured lengths calculated from digitized data within limits of those obtained from trawl samples at the same stations during the same cruise. One taxa of special note was a cat shark, Scyliorhinus retifer photographed at Station W1. This species was not obtained from any trawl samples. The distinctive color patterns visible from above distinguish it from all other cat sharks found in North American waters. An average length reported for this species by Castro (1983) is 38 cm. A length of 24.3 cm was obtained for the photographed specimen.

The majority of measurements obtained from digitized photographic images are within reasonable ranges for the taxa in question. The comparisons of both areas or sizes of bottom features as well as the length or width of organisms between depths, stations and transects may provide additional important information not available from conventional sampling techniques.

5.0 SUMMARY

5.1 ENVIRONMENTAL FEATURES

The water column over each transect was characterized by the presence of distinctive water masses that showed little seasonal or geographic variation. From top to bottom, these water masses included a shallow mixed layer of Gulf Water (usually present from the surface to 250 m); Tropical Atlantic Central Water (~300 to 500 m); Antarctic Intermediate Water (~500 to 1000 m); and Gulf Deep Water, a mixture of North Atlantic Deep and Caribbean Mid-water. These zones roughly correspond in depth to the faunal zones listed by Pequegnat (1983) except that both the Upper Abyssal and Mesoabyssal occur in Gulf Deep Water. Gulf Deep Water is distinctly colder than the water masses above, and temperature is undoubtedly one of the important factors controlling depth distributions of organisms.

Bottom sediments at stations in the Central Transect in November 1983 were clay-sized at Stations C1, C2, and C3, with deeper stations containing higher proportions of either silt (C5) or silt- and sand-sized particles (C4). The same stations on the Central Transect during Cruise II (April 1984) typically had a higher proportion of silt-sized particles than had been observed in November of the previous fall. Sediment levels of organic carbon and calcium carbonate were also higher in samples taken on Cruise II than in samples taken on Cruise I. Results of the sediment hydrocarbon levels also suggested that an influx of terrigenous material (bulk organic matter and plant biowaxes) to the bottom occurred between the two samplings.

On a geographic basis, bottom sediments at stations on the Eastern Transect contained considerably more sand and silt than sediments on the other transects, even though all stations were predominantly clay. Calcium carbonate levels were highest in sediments from the Eastern Transect, and higher in Western Transect samples than in Central Transect samples. The pattern of organic carbon levels in the sediments indicated levels to have been highest on the Central Transect, and then generally higher for sediments from the Western Transect than for sediments from the Eastern Transect. An exception was noted for the deepest station; i.e.,

organic carbon levels at Station E5 were higher than levels at Station W5. Organic carbon levels exhibited a trend of decrease with depth. At the Central Transect, sediment organic carbon in November 1983 was characteristic of carbon provided by marine phytoplankton, based upon carbon isotopic analyses.

With one exception, results from carbon isotopic analyses for benthic organisms not collected in the vicinity of oil seeps in April 1983 suggested that the biota derive most of their energy from sinking photosynthetic carbon (marine phytoplankton). The exception (a crab, Geryon quinquedens) had a carbon isotopic value suggesting a food source other than marine phytoplankton alone. Animals collected from around seeps had carbon isotope levels suggesting chemosynthesis, as opposed to photosynthesis, provided the energy being utilized as a food source.

Sediments at all three transects had a mixture of thermogenic, terrigenous, and planktonic hydrocarbons. The two samplings at the Central Transect suggested an influx of low UCM terrigenous material occurred between Cruises I and II. This terrigenous material consisted primarily of bulk organic matter and plant biowaxes. The material being transported to this area appeared to be compositionally constant with time. The biowaxes were characterized by a low molecular weight UCM and by $n\text{-}C_{15}$ to $n\text{-}C_{19}$ compounds. The higher molecular weight UCM present appeared to accumulate in place and was much more highly degraded than the terrigenous material. Piston coring in the Gulf of Mexico intraslope has demonstrated that the Central Transect is in an area of active natural oil seepage. Piston cores sampled at these sites have generally showed an increase in hydrocarbons with depth. This suggests that the source of the high molecular weight UCM in the sediments is upward migration, though transport of anthropogenic hydrocarbons to the sediment by water column particulates cannot be ruled out.

The influence of riverborne material in the sediments decreased from the Central to the West to the East Transect. The reduced hydrocarbon levels in the East Transect were primarily due to smaller terrigenous and thermogenic inputs. Planktonic and algal inputs were difficult to discern in the West and Central Transects, but were readily apparent in the East Transect as shown by the numerous alkenes detected. This may be due to more rapid sedimentation rates at the Central and West Transects and/or

the large input of riverine material causing rapid dilution of oceanic detritus. Elevated microbial activity in the sediments and/or in the water column may also assist in removing the more labile marine debris.

In general, hydrocarbons were only present in low concentrations in the sediments, especially at the East Transect. Aliphatic hydrocarbon levels ranged from ~10 to 50 ppm. Aliphatic hydrocarbon levels recorded in the literature range from 1 to 3000 ppm. The low concentrations generally occur in very sandy areas, whereas the high concentrations occur in polluted, shallow waters. In areas of pervasive seepage on the Gulf of Mexico slope, aliphatic hydrocarbons have been measured in excess of 100,000 ppm.

With one exception, all organisms surveyed for hydrocarbon contamination appeared to be pristine. The exception was a pooled sample of shrimp (Nematocarcinus rotundus, five individuals) from Station E3. A complete suite of alkanes and the unresolved complex mixture present in this sample strongly suggested petroleum contamination. However, bottom tars were also collected in this trawl. The shrimp may have become contaminated in the trawl, but one would expect that contamination during sampling would have been confined to the exterior hard parts.

5.2 BIOLOGICAL FEATURES

Biological studies include investigations of the meiofauna (organisms passing through a 300 micron screen but retained on a 62 micron screen), the macroinfauna (organisms retained on a 300 micron screen) and the megafauna which were sampled by trawling. The meiofaunal collections from the Central Transect for Cruises I and II indicated a substantial increase in density occurred in April 1984 as compared to levels observed in November 1983, particularly at the shallowest station. There was also a marked change in the relative abundance of major taxa, namely the increased relative abundance of Foraminifera. The density data for the Central Transect suggested a trend of decreasing abundance of meiofauna with depth.

Comparisons of the three geographic regions in terms of meiofauna density and composition showed the Central Transect to have had the highest levels as well as a higher proportion of Foraminifera than was

present in collections from the other two transects. Whereas the collections from the Western Transect exhibited a moderate decline in abundance with depth, no such trend was observed for samples from the Eastern Transect.

The meiofaunal collections are yielding good numbers of a newly described phylum, the Loricifera, and the poorly-known kinorhynchs. Both groups contain at least genera and species new to science. It is now known that the Loricifera are not restricted to shallow, sandy substrates, given that collections have been taken as deep as 2530 m on clay bottoms.

Density levels of macroinfauna from the slope taken during this study are markedly higher (range was from 2435 to 8628 organisms/m^2) than levels previously reported from the Gulf of Mexico slope and abyss (25 to 1095 organisms/m^2). Our samples were screened with a seive having 0.3 mm mesh whereas the previous study used a 0.42 mm mesh. The typical macroinfauna we are seeing from the samples are minute, making weighing impractical without destroying the samples. The size feature probably also accounts, in large part, for the disparity between our and previous measurements of macroinfaunal density from deep-Gulf habitats.

The seasonal data for the macroinfauna from the Central Transect also suggested an increase in density in April 1984 as compared to November 1984, but the increase was not nearly as pronounced as the change observed for meiofauna. On the Central Transect, density of macroinfauna did not exhibit a pronounced decrease with depth but there was an obvious decline in abundance at 2530 m. Polychaetes were the numerical dominants at all depths on the Central Transect except at 2530 m where nematodes of a macroinfaunal size equalled or exceeded the relative numbers of polychaetes.

Macroinfaunal densities on the Eastern and Central Transects were higher than the density of organisms found on the Western Transect. The Western Transect also differed in that macroinfaunal density exhibited a decline with depth. On both Central and Eastern Transects, density levels were rather consistent from 348 to 1341 m, but abundance dropped sharply at 2530 m.

The macroinfaunal groups which have been sorted to the species level are exceedingly diverse and contain many new species and genera. The taxonomist for the tanaidacean collections has indicated that once all the

specimens from Cruise II are described, it will increase the number of known species, world-wide, by 20%.

Of the megafauna collected to date, the decapod crustaceans, echinoderms and demersal fish collections have been identified to the species level. There were 78 species of decapods (led in variety by the anomurans and galatheids), 33 species of echinoderms (not including the brittle stars) and 94 species of fish, representing 42 families. Bathymetric distributional patterns of the megafauna collected to date agree very closely with previous work, providing credence to historical faunal zonation and assemblage characterization schemes based upon the megafauna.

The benthic photography aspect of the program to date has been mainly devoted to the development of quantitative analytical procedures which have now been finalized. Preliminary results of photographic analysis for Stations W1, C1, and E1 from Cruise II indicate Station C1 was characterized by a greater density of both biota and Lebensspuren than the other two stations.

5.3 CONCLUSIONS

Few conclusions can, or should, be made at this early point in the program. However, it would appear that there are marked regional differences in the slope environment and biota, as well as seasonal changes. The latter may prove to be related, in large part, to the influence of river discharge.

From the standpoint of hydrocarbon contamination, the slope environment and biota have thus far appeared pristine, or nearly so. Natural seeps are prevalent in the vicinity of the Central Transect and may, in fact, provide an additional source of energy to deep-Gulf communities in this region. Such areas may also contain unusual biological assemblages. Data from Cruise III suggest this to be the case. The results of that cruise will be described in subsequent reports.

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APPENDIX A

DECAPOD CRUSTACEAN SPECIES LIST BY STATION

Appendix A

Counts of ANOMURA for Cruise I by numerical dominance.

	Station					
Taxon	C1	C2	C3	C4	C5	Total
MUNIDA LONGPES	23	0	0	0	0	23
MUNIDA VALIDA	0	2	3	0	0	5
PARAPAGURUS PILOSIMANUS	0	3	0	0	0	3
LITHODES AGASSIZII	0	0	2	0	0	2
PARAPAGURUS N. SP.	0	0	2	0	0	2
CATAPAGUROIDES MICROPS	0	0	1	1	0	2
PAGURISTES SP.	1	0	0	0	0	1
PARAPAGURUS BICRISTATUS	0	0	1	0	0	1
MUNIDA FORCEPS	1	0	0	0	0	1
PORCELLANA SIGSBEIANA	1	0	0	0	0	1
Total	26	5	9	1	0	41

Appendix A (Cont)

Counts of ANOMURA for Cruise II by numerical dominance.

Taxon	Station W1	W2	W3	W4	W5	Total
MUNIDA LONGPES	24	0	0	0	0	24
MUNIDOPSIS ROBUSTA	13	0	0	0	0	13
MUNIDOPSIS SPINOSA	0	0	8	0	0	8
MUNIDA VALIDA	0	4	2	0	0	6
MUNIDOPSIS SIGSBEI	0	0	3	0	0	3
PARAPAGURUS PICTUS	2	0	0	0	1	3
PAGURUS ROTUNDIMANUS	2	0	0	0	0	2
PARAPAGURUS N. SP.	0	0	0	1	0	1
MUNIDOPSIS SIMPLEX	0	0	0	1	0	1
MUNIDA IRRASA	1	0	0	0	0	1
UROPTYCHUS NITIDUS	0	0	0	1	0	1
MUNIDOPSIS POLITA	1	0	0	0	0	1
Total	43	4	13	3	1	64

Taxon	Station C1	C2	C3	C4	C5	Total
PARAPAGURUS SP.	0	20	0	0	0	20
MUNIDA VALIDA	0	9	0	0	0	9
PARAPAGURUS PILOSIMANUS	0	3	0	0	0	3
PORCELLANA SIGSBEIANA	2	0	0	0	0	2
MUNIDA FORCEPS	2	0	0	0	0	2
MUNIDOPSIS LONGIMANUS	0	0	1	0	0	1
LITHODES AGASSIZII	0	0	0	1	0	1
GASTROPTYCHUS SPINIFER	0	0	0	0	1	1
MUNIDA MICROPHTHALMA	0	0	0	0	1	1
MUNIDA LONGPES	1	0	0	0	0	1
Total	5	32	1	1	2	41

Taxon	Station E1	E2	E3	E4	E5	Total
MUNIDA VALIDA	0	99	0	4	0	103
UROPTYCHUS NITIDUS	0	22	0	3	0	25
MUNIDA LONGPES	17	0	0	0	0	17
MUNIDOPSIS ROBUSTA	9	4	0	0	0	13
MUNIDOPSIS ERINACEUS	0	9	0	0	0	9
MUNIDOPSIS LONGIMANUS	0	2	0	4	0	6
MUNIDOPSIS SIMPLEX	0	0	0	5	0	5
MUNIDOPSIS SIGSBEI	0	0	0	4	0	4
MUNIDA SP.	1	1	0	0	0	2
UROPTYCHUS SP.	0	0	0	2	0	2
MUNIDOPSIS ABBREVIATA	0	0	0	2	0	2
MUNIDOPSIS POLITA	1	0	0	1	0	2
PARAPAGURUS PILOSIMANUS	0	0	0	1	0	1
AXIIDAE SP.A	1	0	0	0	0	1
MUNIDOPSIS ALAMINOS	0	1	0	0	0	1
MUNIDA MICROPHTHALMA	0	0	0	1	0	1
Total	29	138	0	27	0	194

Appendix A (Cont)

Counts of BRACHYURA for Cruise I by numerical dominance.

	Station					
Taxon	C1	C2	C3	C4	C5	Total
LYREIDUS BAIRDII	20	0	0	0	0	20
BATHYPLAX TYPHLA	0	13	2	0	0	15
ETHUSA MICROPHTHALMA	6	1	0	0	0	7
PYROMAIA ARACHNA	7	0	0	0	0	7
ACANTHOCARPUS ALEXANDRI	6	0	0	0	0	6
GERYON QUINQUEDENS	0	0	2	0	0	2
BRACHYURA SP.	0	0	2	0	0	2
COLLODES LEPTOCHELES	1	0	0	0	0	1
CHACELLUS FILIFORMIS	1	0	0	0	0	1
BENTHOCHASCON SCHMITTI	1	0	0	0	0	1
PALICUS GRACILIS	1	0	0	0	0	1
ROCHINIA UMBONATA	0	0	1	0	0	1
TRICHOPELTARION NOBILE	0	1	0	0	0	1
Total	43	15	7	0	0	65

Appendix A (Cont)

Counts of BRACHYURA for Cruise II by numerical dominance.

	Station					
Taxon	W1	W2	W3	W4	W5	Total
LYREIDUS BAIRDII	25	0	0	0	0	25
BATHYPLAX TYPHLA	0	21	1	0	0	22
PYROMAIA ARACHNA	9	0	0	0	0	9
GERYON QUINQUEDENS	0	0	6	0	0	6
BATHYNECTES SUPERBA	2	0	0	0	0	2
PALICUS GRACILIS	2	0	0	0	0	2
ROCHINIA CRASSA	1	0	0	0	0	1
STENOCIONOPS SPINIMANA	1	0	0	0	0	1
ACANTHOCARPUS ALEXANDRI	1	0	0	0	0	1
BENTHOCHASCON SCHMITTI	1	0	0	0	0	1
Total	42	21	7	0	0	70

	Station					
Taxon	C1	C2	C3	C4	C5	Total
LYREIDUS BAIRDII	44	0	0	0	0	44
BATHYPLAX TYPHLA	0	38	0	6	0	44
BENTHOCHASCON SCHMITTI	30	0	0	0	0	30
PYROMAIA ARACHNA	20	0	0	0	0	20
ETHUSA MICROPHTHALMA	7	0	0	0	0	7
TRICHOPELTARION NOBILE	0	6	0	0	0	6
ROCHINIA CRASSA	4	1	0	0	0	5
THALASSOPLAX ANGUSTA	3	0	0	0	0	3
GERYON QUINQUEDENS	0	0	0	3	0	3
PALICUS GRACILIS	2	0	0	0	0	2
BATHYNECTES SUPERBA	2	0	0	0	0	2
ACANTHOCARPUS ALEXANDRI	1	0	0	0	0	1
Total	113	45	0	9	0	167

	Station					
Taxon	E1	E2	E3	E4	E5	Total
BATHYPLAX TYPHLA	1	90	0	5	0	96
BENTHOCHASCON SCHMITTI	62	0	2	0	0	64
GERYON QUINQUEDENS	2	0	3	3	0	8
ROCHINIA CRASSA	0	6	0	1	0	7
PYROMAIA ARACHNA	2	0	0	0	0	2
Total	67	96	5	9	0	177

Appendix A (Cont)

Counts of POLYCHELIDAE AND NEPHROPIDAE for Cruise I by numerical dominance.

	Station					
Taxon	C1	C2	C3	C4	C5	Total
STEREOMASTIS SCULPTA	0	1	13	2	0	16
NEPHROPSIS ROSEA	0	1	1	0	0	2
NEPHROPSIS ACULEATA	1	0	0	0	0	1
Total	1	2	14	2	0	19

Appendix A (Cont)

Counts of POLYCHELIDAE AND NEPHROPIDAE for Cruise II by numerical dominance.

	Station					
Taxon	W1	W2	W3	W4	W5	Total
STEREOMASTIS SCULPTA	0	0	18	4	0	22
NEPHROPSIS AGASSIZI	0	0	2	0	0	2
SCYLLARUS CHACEI	1	0	0	0	0	1
POLYCHELES TYPHLOPS	0	1	0	0	0	1
Total	1	1	20	4	0	26

	Station					
Taxon	C1	C2	C3	C4	C5	Total
STEREOMASTIS SCULPTA	0	2	16	4	0	22
NEPHROPSIS ROSEA	0	2	0	0	0	2
POLYCHELES TYPHLOPS	1	0	0	0	0	1
Total	1	4	16	4	0	25

	Station					
Taxon	E1	E2	E3	E4	E5	Total
STEREOMASTIS SCULPTA	0	3	6	44	1	54
NEPHROPSIS ACULEATA	6	1	0	0	0	7
NEPHROPSIS AGASSIZI	0	0	0	1	0	1
NEPHROPSIS ROSEA	0	0	0	1	0	1
Total	6	4	6	46	1	63

APPENDIX B

ECHINODERM SPECIES LIST BY STATIONS

Counts of ASTEROIDEA for Cruise I by numerical dominance.

	Station					
Taxon	C1	C2	C3	C4	C5	Total
ASTROPECTEN AMERICANUS	11	0	0	0	0	11
PECTINASTER GRACILIS	0	0	5	0	0	5
NYMPHASTER ARENATUS	0	0	0	2	0	2
PLUTONASTER INTERMEDIUS	0	0	2	0	0	2
GONIASTERIDAE	0	0	1	0	0	1
ASTROPECTEN COMPTUS	1	0	0	0	0	1
PLINTHASTER DENTATUS	0	0	1	0	0	1
Total	12	0	9	2	0	23

Appendix B (Cont)

Counts of ASTEROIDEA for Cruise II by numerical dominance.

	Station					
Taxon	W1	W2	W3	W4	W5	Total
PECTINASTER GRACILIS	0	19	0	0	0	19
PSEUDARCHASTER SP.	0	0	0	0	3	3
ODONTASTER HISPIDUS	2	0	0	0	0	2
HYMENASTER SP.	0	2	0	0	0	2
NYMPHASTER ARENATUS	0	1	0	0	0	1
ASTROPECTEN AMERICANUS	1	0	0	0	0	1
DIPSACASTER SP.	0	0	0	0	1	1
Total	3	22	0	0	4	29

	Station					
Taxon	C1	C2	C3	C4	C5	Total
PLUTONASTER INTERMEDIUS	0	0	0	9	0	9
PERSEPHONASTER ECHINULATUS	0	4	0	0	0	4
GONIOPECTEN DEMONSTRANS	0	0	4	0	0	4
PLINTHASTER DENTATUS	0	3	0	0	0	3
NYMPHASTER ARENATUS	0	0	1	2	0	3
DIPSACASTER SP.	0	0	1	0	0	1
CERAMASTER GRENADENSIS	0	0	0	1	0	1
ASTROPECTINIDAE	1	0	0	0	0	1
PECTINASTER GRACILIS	0	1	0	0	0	1
Total	1	8	6	12	0	27

	Station					
Taxon	E1	E2	E3	E4	E5	Total
PERSEPHONASTER ECHINULATUS	0	10	0	0	0	10
PECTINASTER GRACILIS	0	5	0	0	0	5
DIPSACASTER SP.	0	0	0	2	0	2
ZOROASTER FULGENS	0	0	0	2	0	2
PLINTHASTER DENTATUS	0	2	0	0	0	2
HYMENASTERIDAE	0	1	0	0	0	1
HYMENASTER SP.	0	0	0	1	0	1
HENRICIA ANTILLARUM	0	0	0	1	0	1
Total	0	18	0	6	0	24

Appendix B (Cont)

Counts of ECHINOIDEA for Cruise I by numerical dominance.

	Station					
Taxon	C1	C2	C3	C4	C5	Total
PLESIODIADEMA ANTILLARUM	0	2	0	16	0	18
BRISSOPSIS SP.	10	0	0	0	0	10
BRISSOPSIS ALTA	4	0	0	0	0	4
PHORMOSOMA PLACENTA	0	0	0	2	0	2
BRISSOPSIS ATLANTICA	1	0	0	0	0	1
Total	15	2	0	18	0	35

Appendix B (Cont)

Counts of ECHINOIDEA for Cruise II by numerical dominance.

	Station					
Taxon	W1	W2	W3	W4	W5	Total
Total	0	0	0	0	0	0

	Station					
Taxon	C1	C2	C3	C4	C5	Total
PHORMOSOMA PLACENTA	0	0	0	2	0	2
Total	0	0	0	2	0	2

	Station					
Taxon	E1	E2	E3	E4	E5	Total
Total	0	0	0	0	0	0

Appendix B (Cont)

Counts of HOLOTHUROIDEA for Cruise I by numerical dominance.

	Station					
Taxon	C1	C2	C3	C4	C5	Total
MESOTHURIA LACTEA	0	0	6	0	0	6
ECHINOCUCMIS HISPIDA	0	0	0	1	0	1
MOLPADIA BLAKEI	0	0	1	0	0	1
MOLPADIA BARBOURI	0	0	1	0	0	1
Total	0	0	8	1	0	9

Appendix B (Cont)

Counts of HOLOTHUROIDEA for Cruise II by numerical dominance.

	Station					
Taxon	W1	W2	W3	W4	W5	Total
PSEUDOSTICHOPUS SP. A	0	0	0	0	4	4
PSEUDOSTICHOPUS SP. B	0	0	0	0	3	3
MOLPADIA BARBOURI	0	0	2	0	0	2
Total	0	0	2	0	7	9

	Station					
Taxon	C1	C2	C3	C4	C5	Total
MESOTHURIA LACTEA	0	6	12	0	0	18
PSEUDOSTICHOPUS SP. A	0	0	0	2	0	2
ECHINOCUCMIS HISPIDA	0	0	0	2	0	2
MOLPADIA CUBANA	1	0	0	0	0	1
MOLPADIA BLAKEI	0	0	0	1	0	1
Total	1	6	12	5	0	24

	Station					
Taxon	E1	E2	E3	E4	E5	Total
MESOTHURIA LACTEA	0	0	8	5	0	13
MOLPADIA MUSCULUS	0	0	0	7	0	7
MOLPADIA BARBOURI	0	0	1	5	0	6
Total	0	0	9	17	0	26

Appendix B (Cont)

Counts of CRINOIDEA for Cruise I by numerical dominance.

	Station					
Taxon	C1	C2	C3	C4	C5	Total
DEMOCRINUS BREVIS	0	0	7	0	0	7
Total	0	0	7	0	0	7

Appendix B (Cont)

Counts of CRINOIDEA for Cruise II by numerical dominance.

	Station					
Taxon	W1	W2	W3	W4	W5	Total
ATELECRINUS BALANOIDES	0	12	0	0	0	12
DEMOCRINUS BREVIS	0	1	0	0	0	1
Total	0	13	0	0	0	13

	Station					
Taxon	C1	C2	C3	C4	C5	Total
Total	0	0	0	0	0	0

	Station					
Taxon	E1	E2	E3	E4	E5	Total
DEMOCRINUS BREVIS	0	0	0	9	0	9
Total	0	0	0	9	0	9

APPENDIX C

FISH SPECIES LIST BY STATIONS

Counts of Fish from Cruise I by numerical dominance.

	Station					
Taxon	C1	C2	C3	C4	C5	Total
COELORINCHUS CARIBBAEUS	76	1	0	0	0	77
POECILOPSETTA BEANI	31	0	0	0	0	31
UROPHYCIS CIRRATA	29	0	0	0	0	29
PARASUDIS TRUCULENTA	15	0	0	0	0	15
SYNAPHOBRANCHUS BREVIDORSALIS	0	3	6	1	0	10
NEZUMIA AEQUALIS	0	6	1	0	0	7
GADOMUS LONGIFILIS	0	0	6	0	0	6
UROPHYCIS FLORIDANUS	6	0	0	0	0	6
DICROLENE SP.	0	5	0	0	0	5
MALACOCEPHALUS OCCIDENTALIS	5	0	0	0	0	5
MONOMITOPUS SP.	0	0	4	0	0	4
ARGENTINA STRIATA	4	0	0	0	0	4
PSEUDOPHICHTHYS LATERODORSALIS	0	4	0	0	0	4
HEMANTHIAS LEPTUS	4	0	0	0	0	4
CHLOROPHTHALMUS AGASSIZI	4	0	0	0	0	4
PONTINUS LONGISPINIS	4	0	0	0	0	4
COELORINCHUS COELORHYNCHUS	3	0	0	0	0	3
LEPOPHIDIDIUM BREVIBARBE	1	0	2	0	0	3
PERISTEDION MINIATUM	3	0	0	0	0	3
EPIGONUS PANDIONIS	3	0	0	0	0	3
CHAUNAX PICTUS	0	3	0	0	0	3
MERLUCCIUS ALBIDUS	2	0	0	0	0	2
DIPLACANTHOPOMA SP.	0	2	0	0	0	2
POLYMIXIA LOWEI	2	0	0	0	0	2
PERISTEDION GREYAE	2	0	0	0	0	2
BATHYGADUS MACROPS	0	2	0	0	0	2
STEINDACHNERIA ARGENTEA	2	0	0	0	0	2
SETARCHES GUENTHERI	1	0	0	0	0	1
GNATHAGNUS EREGIUS	1	0	0	0	0	1
HOPLOSTETHUS OCCIDENTALIS	1	0	0	0	0	1
PRIONOTUS STEARNSI	1	0	0	0	0	1
CORYPHAENOIDES COLON	0	1	0	0	0	1
NEOSCOPELUS MACROLEPIDOTUS	0	0	1	0	0	1
YARELLA BLACKFORDI	0	0	1	0	0	1
EPIGONUS OCCIDENTALIS	0	0	1	0	0	1
DECAPTERUS PUNCTATUS	0	1	0	0	0	1
CRURIRAJA RUGOSA	0	1	0	0	0	1
CATAETYX SP.	0	0	0	1	0	1
MACRORHAMPHOSUS SCOLOPAX	1	0	0	0	0	1
BATHOPHILUS SP.	0	0	0	1	0	1
APISTURUS PARVIPINNIS	0	0	1	0	0	1
SYNAPHOBRANCHUS OREGONI	0	0	1	0	0	1
RAJA GARMANI	1	0	0	0	0	1
BATHYUROCONGER VICINUS	0	0	1	0	0	1
Total	202	29	25	3	0	259

Counts of Fish from Cruise II by numerical dominance.

	Station					
Taxon	C1	C2	C3	C4	C5	Total
COELORINCHUS CARIBBAEUS	34	0	0	0	0	34
POECILOPSETTA BEANI	13	1	1	0	0	15
MALACOCEPHALUS OCCIDENTALIS	13	0	0	0	0	13
UROPHYCIS CIRRATA	10	0	0	0	0	10
NEZUMIA AEQUALIS	0	5	2	1	0	8
COELORINCHUS COELORHYNCHUS	7	0	0	0	0	7
DIBRANCHUS ATLANTICUS	0	1	5	0	0	6
EPIGONUS PANDIONIS	5	0	0	0	0	5
BEMBROPS GOBIOIDES	5	0	0	0	0	5
DICROLENE SP.	0	0	3	1	0	4
BATHYGADUS MELANOBRANCHUS	0	1	3	0	0	4
CHAUNAX PICTUS	0	3	0	0	0	3
MERLUCCIUS ALBIDUS	3	0	0	0	0	3
BATHYGADUS MACROPS	0	2	1	0	0	3
SYNAPHOBRANCHUS BREVIDORSALIS	0	0	2	0	0	2
CORYPHAENOIDES COLON	0	1	1	0	0	2
SYNAPHOBRANCHUS OREGONI	0	0	2	0	0	2
DIPLACANTHOPOMA SP.	0	2	0	0	0	2
ETMOPTERUS SCHULTZI	0	2	0	0	0	2
PARASUDIS TRUCULENTA	2	0	0	0	0	2
VENEFICA PROCERA	0	0	0	0	2	2
YARELLA BLACKFORDI	0	1	1	0	0	2
BARATHRONUS BICOLOR	0	1	1	0	0	2
HEMANTHIAS LEPTUS	1	0	0	0	0	1
POLYMETME CORYTHAEOLA	1	0	0	0	0	1
MALACORAJA PURPURIVENTRALIS	0	0	0	1	0	1
ARGENTINA STRIATA	1	0	0	0	0	1
HALOSAURUS OVENII	0	1	0	0	0	1
PONTINUS LONGISPINIS	1	0	0	0	0	1
PSEUDOPHICHTHYS LATERODORSALIS	0	1	0	0	0	1
UROPHYCIS FLORIDANUS	1	0	0	0	0	1
CHLOROPHTHALMUS AGASSIZI	1	0	0	0	0	1
Total	98	22	22	3	2	147

Counts of Fish from Cruise II by numerical dominance.

	Station					
Taxon	W1	W2	W3	W4	W5	Total
SETARCHES GUENTHERI	59	0	0	0	0	59
BEMBROPS GOBIOIDES	46	1	0	0	0	47
CHLOROPHTHALMUS AGASSIZI	35	0	0	0	0	35
POECILOPSETTA BEANI	24	0	0	0	0	24
EPIGONUS PANDIONIS	15	0	3	0	0	18
DIBRANCHUS ATLANTICUS	0	15	2	0	0	17
SYNAPHOBRANCHUS BREVIDORSALIS	0	0	15	1	0	16
SYNAPHOBRANCHUS OREGONI	0	0	12	0	0	12
MONOMITOPUS SP.	0	0	9	0	0	9
UROPHYCIS CIRRATA	8	0	0	0	0	8
DICROLENE SP.	0	0	6	1	0	7
HALOSAURUS GUENTHERI	0	0	7	0	0	7
NEOSCOPELUS MACROLEPIDOTUS	0	4	1	0	0	5
NEZUMIA AEQUALIS	0	5	0	0	0	5
CORYPHAENOIDES MEXICANUS	0	0	5	0	0	5
BROSMICULUS IMBERBIS	5	0	0	0	0	5
COELORINCHUS COELORHYNCHUS	4	0	0	0	0	4
MALACOCEPHALUS OCCIDENTALIS	4	0	0	0	0	4
MERLUCCIUS ALBIDUS	3	1	0	0	0	4
NEZUMIA SUILLA	0	0	4	0	0	4
BATHYGADUS MACROPS	0	3	0	0	0	3
GNATHAGNUS EREGIUS	3	0	0	0	0	3
COELORINCHUS CARIBBAEUS	3	0	0	0	0	3
GURGESIELLA SINUSMEXICANUS	3	0	0	0	0	3
HYMENOCEPHALUS ITALICUS	3	0	0	0	0	3
NEZUMIA SP.	0	1	1	0	0	2
NEZUMIA CYRANO	0	0	2	0	0	2
HEMANTHIAS LEPTUS	2	0	0	0	0	2
ALDROVANDIA AFFINIS	0	0	0	2	0	2
LAEMONEMA BARBATULUM	0	2	0	0	0	2
EPIGONUS MACROPS	0	0	2	0	0	2
PERISTEDION GREYAE	2	0	0	0	0	2
POLYMETME CORYTHAEOLA	2	0	0	0	0	2
BATHYGADUS MELANOBRANCHUS	0	0	2	0	0	2
CHAUNAX PICTUS	0	2	0	0	0	2
HYDROLAGUS SP.	0	0	1	0	0	1
IPNOPS MURRAYI	0	0	0	1	0	1
MACROURIDAE	0	1	0	0	0	1
NETTASTOMA MELANURUM	0	1	0	0	0	1
BATHYPTEROIS VIRIDESCENS	0	0	1	0	0	1
CORYPHAENOIDES COLON	0	1	0	0	0	1
PARASUDIS TRUCULENTA	1	0	0	0	0	1
PERISTEDION MINIATUM	1	0	0	0	0	1
OPHICHTHUS CRUENTIFER	0	1	0	0	0	1
PONTINUS LONGISPINIS	1	0	0	0	0	1
RAJA LENTIGINOSA	1	0	0	0	0	1
STEPHANOBERYX MONAE	0	0	0	1	0	1
SYNAGROPS SPINOSA	1	0	0	0	0	1
YARELLA BLACKFORDI	0	1	0	0	0	1
HOPLUNNIS SP.	0	1	0	0	0	1
HOPLOSTETHUS OCCIDENTALIS	1	0	0	0	0	1
Total	227	40	73	6	0	346

Counts of Fish from Cruise II by numerical dominance.

	Station					
Taxon	E1	E2	E3	E4	E5	Total
STEPHANOBERYX MONAE	0	0	0	33	0	33
GADOMUS LONGIFILIS	0	0	0	31	0	31
SYNAPHOBRANCHUS BREVIDORSALIS	0	0	15	14	0	29
HYMENOCEPHALUS ITALICUS	27	0	0	0	0	27
BEMBROPS GOBIOIDES	5	0	0	17	0	22
DIBRANCHUS ATLANTICUS	0	13	9	0	0	22
PERISTEDION GREYAE	14	1	0	1	0	16
SYNAPHOBRANCHUS OREGONI	0	0	9	4	0	13
UROPHYCIS CIRRATA	13	0	0	0	0	13
ILOPHIS BRUNNEUS	0	0	2	11	0	13
CHLOROPHTHALMUS AGASSIZI	11	0	0	0	0	11
NEZUMIA CYRANO	0	0	1	10	0	11
DICROLENE SP.	0	0	2	8	0	10
MONOMITOPUS SP.	0	0	3	7	0	10
BATHYGADUS FAVOSUS	0	0	0	10	0	10
NEZUMIA AEQUALIS	0	7	2	0	0	9
BATHYGADUS MACROPS	0	7	0	2	0	9
BATHYPTEROIS QUADRIFILIS	0	0	0	9	0	9
CHAUNAX PICTUS	0	7	1	0	0	8
VENEFICA PROCERA	0	0	0	6	1	7
EPIGONUS PANDIONIS	6	0	0	0	0	6
CONOCARA SP.	0	0	0	6	0	6
NEZUMIA SUILLA	0	0	1	4	0	5
LOPHIODES MONODI	4	1	0	0	0	5
DIPLACANTHOPOMA SP.	0	3	2	0	0	5
SETARCHES GUENTHERI	5	0	0	0	0	5
ALDROVANDIA AFFINIS	0	0	0	4	0	4
PARASUDIS TRUCULENTA	0	0	0	4	0	4
NEOSCOPELUS MACROLEPIDOTUS	0	4	0	0	0	4
BATHYGADUS MELANOBRANCHUS	0	0	4	0	0	4
BATHYPTEROIS PHENAX	0	0	0	4	0	4
LAEMONEMA BARBATULUM	0	3	0	0	0	3
CORYPHAENOIDES MEXICANUS	0	0	2	1	0	3
COELORINCHUS COELORHYNCHUS	3	0	0	0	0	3
PSEUDOPHICHTHYS LATERODORSALIS	0	2	0	0	0	2
MERLUCCIUS ALBIDUS	2	0	0	0	0	2
SYNAGROPS BELLA	2	0	0	0	0	2
GADOMUS ARCUATUS	0	0	1	1	0	2
ETMOPTERUS SCHULTZI	0	2	0	0	0	2
POECILOPSETTA BEANI	0	2	0	0	0	2
BARATHRONUS BICOLOR	0	1	0	0	0	1
TRACHONURUS VILLOSUS	0	0	0	1	0	1
LEPTODERMA MACROPS	0	0	1	0	0	1
SYNAPHOBRANCHUS SP.	0	1	0	0	0	1
MALACOCEPHALUS OCCIDENTALIS	1	0	0	0	0	1

Appendix C (Cont)

Counts of Fish from Cruise II by numerical dominance.

Taxon	Station E1	E2	E3	E4	E5	Total
APISTRURUS LAURUSSONII	0	0	0	1	0	1
BATHYPTEROIS VIRIDESCENS	0	0	0	1	0	1
BEMBROPS ANATIROSTRIS	0	0	0	1	0	1
SYMPHURUS MARGINATUS	1	0	0	0	0	1
SQUALOGADUS MODIFICATUS	0	0	0	1	0	1
CATAETYX SP.	0	0	0	1	0	1
CORYPHAENOIDES COLON	0	1	0	0	0	1
ALDROVANDIA GRACILIS	0	0	0	1	0	1
ACROMYCTER PURTURBATOR	0	0	0	1	0	1
HOPLOSTETHUS OCCIDENTALIS	1	0	0	0	0	1
XYELACYBA MYERSI	0	0	0	1	0	1
HELICOLENUS DACTYLOPTERUS	1	0	0	0	0	1
COELORINCHUS SP.	0	0	0	1	0	1
HALOSAURUS GUENTHERI	0	0	0	1	0	1
Total	96	55	55	198	1	405

APPENDIX D

BENTHIC PHOTOGRAPHY - DETAILS OF DIGITIZED PHOTOGRAPH STATISTICS

APPENDIX D. Benthic photography - details of digitized photograph statistics.

Appendix D1- Raw counts and densities for all categories of observation in benthic photographs.

Artifacts	RAW COUNT W1	RAW COUNT C1	RAW COUNT E1	DENSITY PER HECTARE W1	DENSITY PER HECTARE C1	DENSITY PER HECTARE E1
Unidentified metal can	0	1	0	0	52.6	0
Metallic canister - one flat end, one convex end	0	1	0	0	52.6	0

Consolidated Material	RAW COUNT W1	RAW COUNT C1	RAW COUNT E1	DENSITY PER HECTARE W1	DENSITY PER HECTARE C1	DENSITY PER HECTARE E1
Apparent rock or nodule	0	0	1	0	0	32.9
Consolidated sediment object with same characteristics as surrounding bottom	0	1	1	0	52.6	32.9
Rough sediment block or slab	2	0	0	76.8	0	0

Lebensspuren	RAW COUNT W1	RAW COUNT C1	RAW COUNT E1	DENSITY PER HECTARE W1	DENSITY PER HECTARE C1	DENSITY PER HECTARE E1
Random path without paralleling grooves	0	1	0	0	52.6	0
Unfeatured solitary lump - possibly not of biogenic origin	0	0	3	0	0	98.8
Solitary conical lump without apical hole	86	97	83	3300.4	5102.0	2733.1
Excavated sediment lump adjacent to deep burrow	3	11	6	115.1	578.6	197.6
Excavated sediment lump with probable organism responsible in view	0	1	0	0	52.6	0
Excavated sediment mound adjacent to very shallow eroded burrow	2	4	0	76.8	210.4	0
Excavated sediment lump adjacent to deep burrow	2	13	2	76.8	683.8	65.9
Distinctive area of reworked sediment, rough texture but no significant relief	0	3	0	0	157.8	0
Random pattern, broad, smooth without paralleling ridges	1	0	2	38.4	0	65.9
Random narrow, smooth may have paralleling ridges	16	2	13	614.0	105.2	428.1

Appendix D1- continued

Lebensspuren (continued)	RAW COUNT W1	RAW COUNT C1	RAW COUNT E1	DENSITY PER HECTARE W1	DENSITY PER HECTARE C1	DENSITY PER HECTARE E1
Sculptured groove, broad with paralleling ridges	0	1	0	0	52.6	0
Sculptured groove, numerous tranverse partitions within groove	1	0	0	38.4	0	0
Rough broad groove, gouge like as from a dragged object	1	0	1	38.4	0	32.9
Broad groove forming ring	2	0	0	76.8	0	0
Unsculptured groove - short, narrow, straight and very deep	1	0	0	38.4	0	0
Unsculptured groove - short, narrow, straight and narrow	69	1	40	2648.0	52.6	1317.2
Radiating set of individual broad grooves around central point with no structure	6	0	0	230.3	0	0
Set of two parallel grooves about two cm. apart	2	0	0	76.8	0	0
Radiating set of individual short narrow grooves from one side of central point with no structure	9	0	0	345.4	0	0
Radiating set of individual short narrow grooves from around a central point with no structure	10	0	0	383.8	0	0
Deep hole of no pariticular size or shape	77	199	832	2955.0	10466.9	27397.3
Shallow depression of no particular size or shape	104	197	152	3991.2	10361.7	5005.3
Large shallow depression with steep sides	0	1	1	0	52.6	32.9
Very rough shallow depression with irregular shape	4	0	0	153.5	0	0
Large deep excavated depression with surrounding mound built up on edges	1	1	0	38.4	52.6	0
Deep excavated depression with removed material accumulated to on side	1	5	2	38.4	263.0	65.9
Shallow excavated depression with removed material around it	0	2	0	0	105.2	0
Depression in a single row arranged in a complete circle	16	5	14	614.0	263.0	461.0

APPENDIX D (cont'd)

Appendix D1- continued

Lebensspuren (continued)	RAW COUNT W1	RAW COUNT C1	RAW COUNT E1	DENSITY PER HECTARE W1	DENSITY PER HECTARE C1	DENSITY PER HECTARE E1
Depression in a single row arranged in a partial circle	4310	160	3892	165405.6	8415.6	128161.6
Numerous small depressions arranged in a cluster	38	14	0	1458.3	736.4	0
Depressions arranged in an irregular circle around a large lump	0	0	12	0	0	395.2
Strip of adjacent depressions, paral - leled on each side by a row of deeper depressions without median grooves	0	0	3	0	0	98.8

Unknown - to be classified	RAW COUNT W1	RAW COUNT C1	RAW COUNT E1	DENSITY PER HECTARE W1	DENSITY PER HECTARE C1	DENSITY PER HECTARE E1
Ophiomusium like brittle star	3	1	0	115.1	52.6	0
Urchin like white sphere	2	0	0	76.8	0	0
Short translucent cylindrical structure	0	0	1	0	0	32.9

Unknown - to be classified (continued)	RAW COUNT W1	RAW COUNT C1	RAW COUNT E1	DENSITY PER HECTARE W1	DENSITY PER HECTARE C1	DENSITY PER HECTARE E1
Clump of material with tentacular like projections	0	1	0	0	52.6	0
Short tubular structure, white bulbous near ends, thin middle	0	0	1	0	0	32.9
Short tubular structure - transparent bulbous structures near ends, thin middle	0	1	0	0	52.6	0
Filamentious cluster	0	0	1	0	0	32.9
Unidentified pink and blue shrimp	1	2	0	38.4	105.2	0
Transparent stalks; V shaped	1	0	0	38.4	0	0

Appendix D2 - Mean areas and standard deviations (square centimeters) for all categories of observation in benthic photographs.

Biota	W1 N	W1 mean	W1 s.d.	C1 N	C1 mean	C1 s.d.	E1 N	E1 mean	E1 s.d.
Thalassia sp.	0	0	0	0	0	0	1	4.0	0
Zoantharia-Actiniaria	2	15.5	17.8	0	0	0	2	4.3	3.3
Ophiuroidea	1	2.4	0	0	0	0	0	0	0

Artifacts	W1 N	W1 mean	W1 s.d.	C1 N	C1 mean	C1 s.d.	E1 N	E1 mean	E1 s.d.
Unidentified metal can	0	0	0	1	4.4	0	0	0	0
Metallic canister - one flat end, one convex end	0	0	0	1	11.8	0	0	0	0

Consolidated material	W1 N	W1 mean	W1 s.d.	C1 N	C1 mean	C1 s.d.	E1 N	E1 mean	E1 s.d.
Apparent rock or nodule	0	0	0	0	0	0	1	169.6	0
Consolidated sediment object with same characteristics as surrounding bottom	0	0	0	1	2.3	0	1	154.0	0
Rough sediment block or slab	2	47.7	37.1	0	0	0	0	0	0

Lebensspuren	W1 N	W1 mean	W1 s.d.	C1 N	C1 mean	C1 s.d.	E1 N	E1 mean	E1 s.d.
Unfeatured solitary lump - possibly not of biogenic origin	0	0	0	0	0	0	3	28.3	36.8
Solitary conical lump without apical hole	86	25.7	33.8	97	17.6	49.1	83	20.5	16.9
Excavated sediment lump adjacent to deep burrow	3	27.5	27.3	11	113.3	245.1	46	123.9	148.3
Excavated sediment lump with probable organism responsible in view	0	0	0	1	1085.8	0	0	0	0
Excavated sediment mound adjacent to very shallow eroded burrow	2	3.8	0.3	4	4.1	1.4	0	0	0
Excavated sediment lump adjacent to deep burrow	2	34.5	31.0	13	14.9	24.5	2	176.5	170.1
Distinctive area of reworked sediment, rough texture but no significant relief	0	0	0	3	331.7	525.6	0	0	0
Random pattern, broad, smooth without paralleling ridges	1	6.6	0	0	0	0	2	27.2	34.3
Random narrow, smooth may have paralleling ridges	0	0	0	0	0	0	4	75.2	137.2
Sculptured groove, broad with paralleling ridges	0	0	0	1	668.4	0	0	0	0
Sculptured groove, numerous tranverse partitions within groove	1	7.1	0	0	0	0	0	0	0
Rough broad groove, gouge like as from a dragged object	1	6.6	0	0	0	0	1	1060.2	0
Broad groove forming ring	2	4.5	1.6	0	0	0	0	0	0
Unsculptured groove - short, narrow, straight and very deep	1	17.7	0	0	0	0	0	0	0
Radiating set of individual broad grooves around central point with no structure	1	61.8	0	0	0	0	0	0	0
Deep hole of no pariticular size or shape	77	8.4	10.7	199	4.7	6.1	832	6.6	4.2
Shallow depression of no particular size or shape	104	32.2	44.7	197	33.9	71.6	152	24.4	40.5
Large shallow depression with steep sides	0	0	0	1	103.1	0	1	116.3	0
Very rough shallow depression with irregular shape	4	132.1	106.9	0	0	0	0	0	0

APPENDIX D (cont'd)

Appendix D2 - continued

Lebensspuren (continued)	W1 N	W1 mean	W1 s.d.	C1 N	C1 mean	C1 s.d.	E1 N	E1 mean	E1 s.d.
Large deep excavated depression with surrounding mound built up on edges	1	483.4	0 @	1	3.6	0	0	0	0
Deep excavated depression with removed material accumulated to on side	1	41.6	0	5	75.2	120.4	2	50.4	65.6
Shallow excavated depression with removed material around it	0	0	0	2	66.4	6.6	0	0	0
Depression in a single row arranged in a complete circle (1)	16	6.2	0.4	5	3.0	0	14	4.2	3.2
Depression in a single row arranged in a partial circle	4310	6.1	5.8	160	7.9	12.2	3892	6.1	2.7
Numerous small depressions arranged in a cluster (1)	38	4.4	0.1	14	6.2	0	0	0	0
Depressions arranged in an irregular circle around a large lump	0	0	0	0	0	0	12	12.5	0.0
Strip or adjacent depressions, paral - leled on each side by a row of deeper depressions without median grooves	0	0	0	0	0	0	3	367.0	619.8

Unknown - to be classified	W1 N	W1 mean	W1 s.d.	C1 N	C1 mean	C1 s.d.	E1 N	E1 mean	E1 s.d.
Urchin like white sphere	2	6.6	1.4	0	0	0	0	0	0
Short translucent cylindrical structure	0	0	0	0	0	0	1	35.2	0
Clump of material with tentacular like projections	0	0	0	1	85.7	0	0	0	0
Short tubular structure, white bulbous near ends, thin middle	0	0	0	0	0	0	1	19.8	0
Filamentious cluster	0	0	0	0	0	0	1	162.6	0

Summary of major categories

Classification	W1 N	W1 mean	W1 s.d.	C1 N	C1 mean	C1 s.d.	E1 N	E1 mean	E1 s.d.
Artifacts	0	0	0	2	8.1	5.3	0	0	0
Consolidated materials	2	47.7	37.1	1	2.3	0	2	161.8	11.0
Lebensspuren									
Solitary lumps	93	25.5	33.1	129	40.7	149.5	94	30.7	53.7
Individual grooves	6	7.8	5.0	1	668.4	0	7	202.2	391.5
Sets or grooves	1	61.8	0	0	0	0	0	0	0
Solitary depressions	187	27.0	53.4	405	22.8	54.8	988	9.5	18.1
Groups of depressions	4364	6.1	5.7	179	7.6	11.5	3918	6.1	2.7
Sculptured strips	0	0	0	0	0	0	3	367.0	619.8

APPENDIX D (cont'd)

Appendix D3 - Percent coverage times one hundred and mean areas (square centimeters) for all categories of observation in benthic photographs.

Biota	percent coverage * 100			mean area		
	W1	C1	E1	W1	C1	E1
Thalassia sp.	0	0	0.01317	0	0	4.0
Zoantharia-Actiniaria	0.11897	0	0.02832	15.5	0	4.3
Ophiuroidea	0.00921	0	0	2.4	0	0

Artifacts	percent coverage * 100			mean area		
	W1	C1	E1	W1	C1	E1
Unidentified metal can	0	0.02314	0	0	4.4	0
Metallic canister - one flat end, one convex end	0	0.06207	0	0	11.8	0

Consolidated material	percent coverage * 100			mean area		
	W1	C1	E1	W1	C1	E1
Apparent rock or nodule	0	0	0.55848	0	0	169.6
Consolidated sediment object with same characteristics as surrounding bottom	0	0.01210	0.50711	0	2.3	154.0
Rough sediment block or slab	0.36650	0	0	47.7	0	0

Lebensspuren	percent coverage * 100			mean area		
	W1	C1	E1	W1	C1	E1
Unfeatured solitary lump - possibly not of biogenic origin	0	0	0.27990	0	0	28.3
Solitary conical lump without apical hole	8.49210	9.00157	5.59768	25.7	17.6	20.5
Excavated sediment lump adjacent to deep burrow	0.31661	6.55525	2.44864	27.5	113.3	123.9
Excavated sediment lump with probable organism responsible in view	0	5.71106	0	0	1085.8	0
Excavated sediment mound adjacent to very shallow eroded burrow	0.02917	0.08679	0	3.8	4.1	0
Excavated sediment lump adjacent to deep burrow	0.26442	1.01619	1.16241	34.5	14.9	176.5
Distinctive area of reworked sediment, rough texture but no significant relief	0	5.23399	0	0	331.7	0
Random pattern, broad, smooth without paralleling ridges	0.02533	0	0.17947	6.6	0	27.2
Random narrow, smooth may have paralleling ridges	0	0	0.99019	0	0	75.2
Sculptured groove, broad with paralleling ridges	0	3.51563	0	0	668.4	0
Sculptured groove, numerous tranverse partitions within groove	0.02725	0	0	7.1	0	0
Rough broad groove, gouge like as from a dragged object	0.02533	0	3.49118	6.6	0	1060.2
Broad groove forming ring	0.03454	0	0	4.5	0	0
Unsculptured groove - short, narrow, straight and very deep	0.06793	0	0	17.7	0	0
Radiating set of individual broad grooves around central point with no structure	0.23717	0	0	61.8	0	0
Deep hole of no paritícular size or shape	2.48914	4.90053	18.05886	8.4	4.7	6.6
Shallow depression of no particular size or shape	12.84138	40.33873	12.20005	32.2	38.9	24.4
Large shallow depression with steep sides	0	0.54228	0.38297	0	103.1	116.3
Very rough shallow depression with irregular shape	2.02708	0	0	132.1	0	0
Large deep excavated depression with surrounding mound built up on edges	1.85515	0.01894	0	483.4	3.6	0

Appendix D3 - continued.

Lebensspuren (continued)	percent coverage * 100			mean area		
	W1	C1	E1	W1	C1	E1
Deep excavated depression with removed material accumulated to on side	0.15965	1.97767	0.33193	41.6	75.2	50.4
Shallow excavated depression with removed material around it	0	0.69850	0	0	66.4	0
Depression in a single row arranged in a complete circle	0.37763	0.07890	0.19231	6.2	3.0	4.2
Depression in a single row arranged in a partial circle	100.77997	6.63099	77.74751	6.1	7.9	6.1
Numerous small depressions arranged in a cluster	0.64167	0.45655	0	4.4	4.2	0
Depressions arranged in an irregular circle around a large lump	0	0	0.49394	0	0	12.5
Strip of adjacent depressions, paral - leled on each side by a row of deeper depressions without median grooves	0	0	3.62521	0	0	367.0

Unknown - to be classified	percent coverage * 100			mean area		
	W1	C1	E1	W1	C1	E1
Urchin like white sphere	0.05066	0	0	6.6	0	0
Short translucent cylindrical structure	0	0	0.11591	0	0	35.2
Clump of material with tentacular like projections	0	0.45076	0	0	85.7	0
Short tubular structure, white bulbous near ends, thin middle	0	0	0.06520	0	0	19.8
Filamentious cluster	0	0	0.53543	0	0	162.6

The Department of the Interior Mission

As the Nation's principal conservation agency, the Department of the Interior has responsibility for most of our nationally owned public lands and natural resources. This includes fostering sound use of our land and water resources; protecting our fish, wildlife, and biological diversity; preserving the environmental and cultural values of our national parks and historical places; and providing for the enjoyment of life through outdoor recreation. The Department assesses our energy and mineral resources and works to ensure that their development is in the best interests of all our people by encouraging stewardship and citizen participation in their care. The Department also has a major responsibility for American Indian reservation communities and for people who live in island territories under U.S. administration.

The Minerals Management Service Mission

As a bureau of the Department of the Interior, the Minerals Management Service's (MMS) primary responsibilities are to manage the mineral resources located on the Nation's Outer Continental Shelf (OCS), collect revenue from the Federal OCS and onshore Federal and Indian lands, and distribute those revenues.

Moreover, in working to meet its responsibilities, the **Offshore Minerals Management Program** administers the OCS competitive leasing program and oversees the safe and environmentally sound exploration and production of our Nation's offshore natural gas, oil and other mineral resources. The MMS **Minerals Revenue Management** meets its responsibilities by ensuring the efficient, timely and accurate collection and disbursement of revenue from mineral leasing and production due to Indian tribes and allottees, States and the U.S. Treasury.

The MMS strives to fulfill its responsibilities through the general guiding principles of: (1) being responsive to the public's concerns and interests by maintaining a dialogue with all potentially affected parties and (2) carrying out its programs with an emphasis on working to enhance the quality of life for all Americans by lending MMS assistance and expertise to economic development and environmental protection.