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FINAL REPORT ON THE

BASELINE ENVIRONMENTAL SURVEY OF THE MAFLA LEASE AREAS CY 1974

BLM CONTRACT NO. 08550-CT4-11

FINAL REPORT #2
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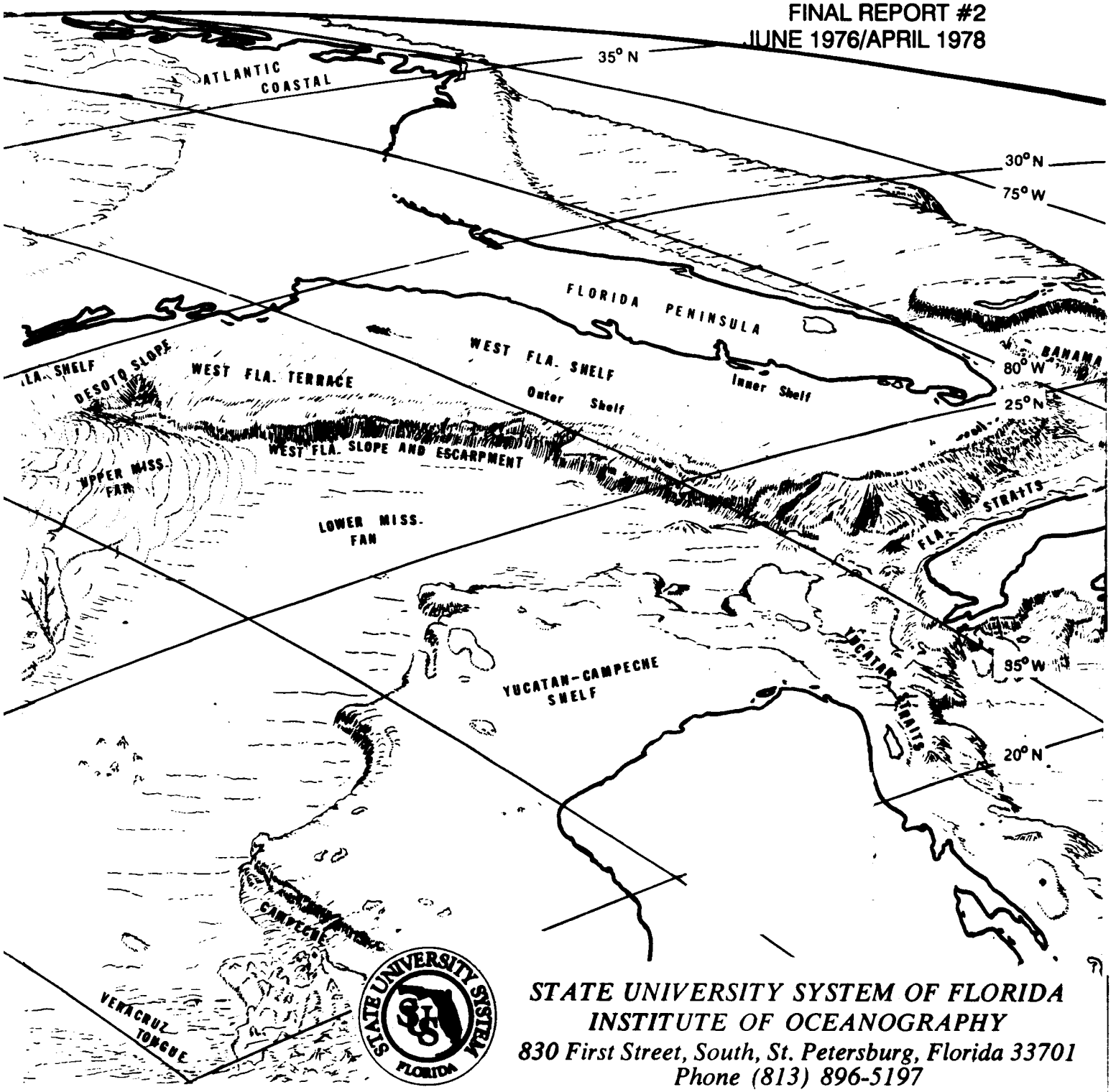

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FINAL REPORT

on the

BASELINE ENVIRONMENTAL SURVEY OF THE MAFLA LEASE AREAS

Contract No. 08550-CT4-11

Submitted To

Bureau of Land Management
U. S. Department of the Interior

Washington, D.C.

Submitted By

Florida Board of Regents Office

On Behalf Of

State University System of Florida
Institute of Oceanography Consortium

Edited By

James E. Alexander

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

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INTRODUCTION

Impending Outer Continental Shelf (OCS) oil exploration and production activities in the eastern Gulf of Mexico have catalyzed the interest and concern of a significant cross-section of individuals. Early in 1974 a Conference/Workshop was held in St. Petersburg, Florida to define the critical research and information needs in the subject area to discuss the development of a scientifically sound and relevant interdisciplinary program and to identify the persons to implement this program.

Stewart (1974) in his summary of the conclusions and recommendations emanating from the Conference/Workshop indicated the objectives of the studies to be initiated by the Bureau of Land Management (BLM) in the Mississippi-Alabama-Florida (MAFLA) area of the eastern Gulf of Mexico as explained to the Conference/Workshop participants to be:

(1) an initial or short-term baseline study in the vicinity of the present lease tracts and

(2) a continuing or long term study in the eastern Gulf of Mexico, including the areas specified above.

Subsequent to this the BLM contracted with the State University System of Florida, Institute of Oceanography (SUSIO) to obtain benchmark data in the lease tracts of the eastern Gulf of Mexico prior to oil and gas explorations.

The resultant work statement for these studies focused on an interdisciplinary study, including chemical (especially trace metals and hydrocarbons), biological, geological and limited physical oceanography of the above regions in May-July, 1974.

In this baseline study, the SUSIO Consortium's survey was directed and largely restricted to five discrete lease areas on the MAFLA shelf of the eastern Gulf of Mexico, extending from approximately 89° W, south of Pascagoula, Mississippi, to a tract west of Clearwater, off Tampa Bay, Florida (Fig. 1). Although it is not possible to deal with these areas as a consortium, they are representative of the habitats of the MAFLA OCS. Near the Mississippi Delta, the silt-clays bottoms are masked by a turbid layer (nepheloid layer) and have generally low benthic productivity. Drowned algal reefs have been reported at the edge of the continental shelf south of Mobile Bay. Eastward toward peninsular Florida, a transition to a carbonate substrate, more transparent waters, and significant benthic productivity is recognized. The major high relief area, the Florida Middle Ground, on the outer shelf roughly midway between St. Petersburg and Apalachicola, Florida, represents a unique hermatypic coral reef environment whose associated flora and fauna are far north of their usual geographic limits. It is also a major fishing resource for the northwestern Gulf. Although topographic and lithologic data are sketchy, other areas of relief and living coral occur on the limestone shelf south of 29° N and provide shelter and habitat for significant bottom populations. The significance of these areas for fish populations, including some tropical species not found in the northwestern Gulf of Mexico, is still poorly understood.

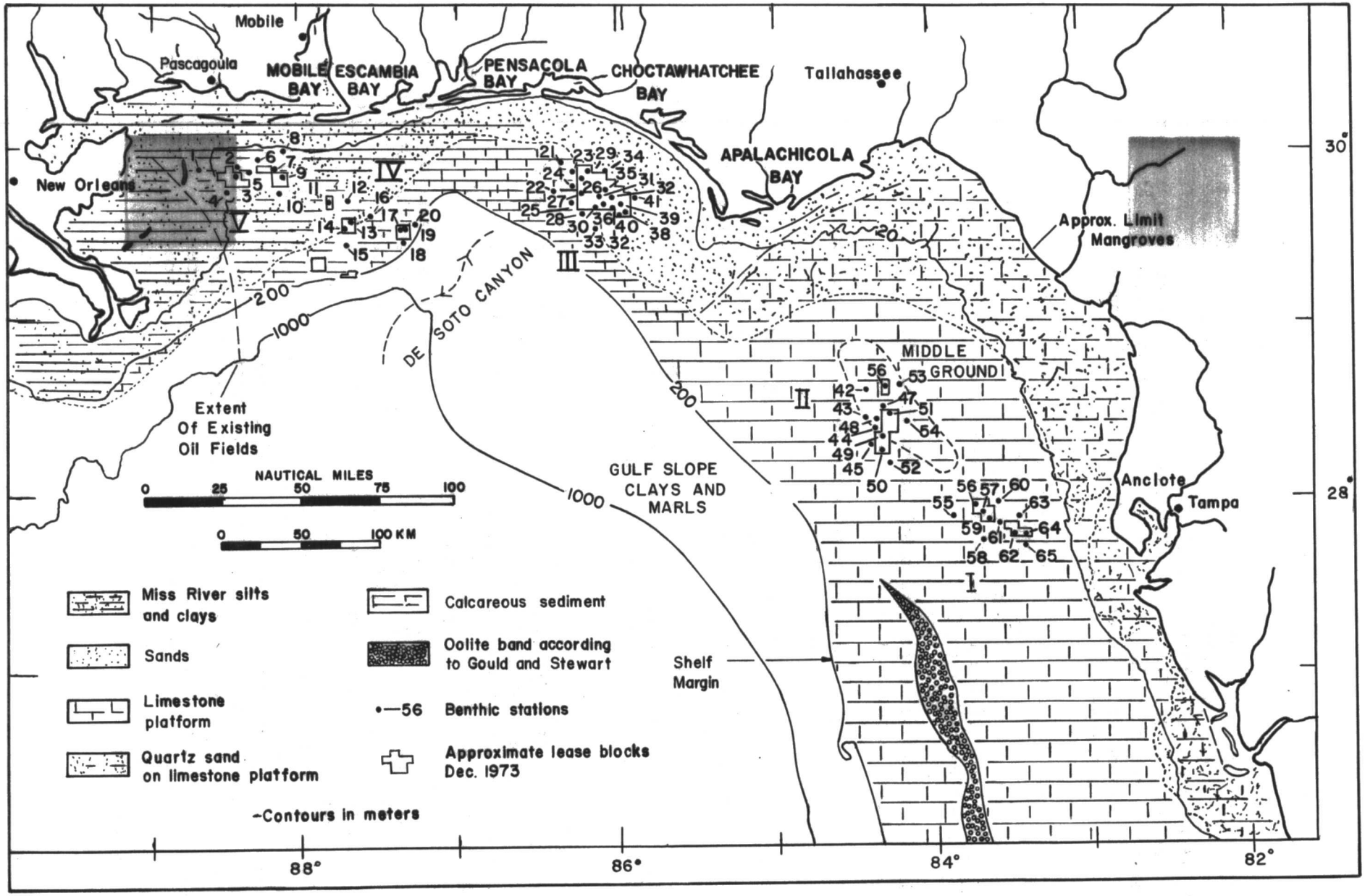


Figure 1. General Location Map of Bottom Stations.
Sources: Ludwick, 1964
Brooks in Jones et al., 1973
Emery and Uchupi, 1972
Gould and Stewart, 1955

Facing the lease tracts IV, V, and to some extent III (Fig. 1), are a series of offshore barrier bars and islands with sandy beaches on their seaward sides, and silt-mud and tidal marshes on their shoreward sides. Off tracts I and II are beds of seagrasses and algae that form a productive element approaching or exceeding the phytoplankton productivity in the region. At the shore zone itself fine quartz sand beaches alternate with mangrove begetation that serves to protect shorelines from storm erosion, and provides shelter and organic matter for marine vertebrates and their food chain elements.

The west Florida shelf as whole is one of the least investigated shelf areas of the U.S. continental margin. Nevertheless, it is known to contain many unusual features and display unusual phenomena. One such feature is the Tortugas banks, which forms perhaps the most prolific shrimping grounds in the Gulf of Mexico. A band of the inner-central shelf is both the site of recurring outbreaks of red tide (blooms of the toxic dinoflageellate, Gymnodinium breve) and a well-developed drowned karst zone. Submarine discharge is known in this area, the best-known of the occurrences being "Mudhole Spring" 18 km (10 NM.) off Sanibel Island, near Charlotte Harbor and Fort Myers, Florida. The warm (36° C) character of its discharge indicates that the water is issuing from considerable depth, and provides an indication that the frequently cavernous and possibly fault-related hydrologic pathways that characterize the upper 1000 m and sometimes deeper strata in southwest-central Florida extend offshore.

One of the keys to the clarity of the Florida shelf waters south of about 29° N, which plays a role in benthic productivity, is the relative paucity of clay minerals in bottom sediments. The carbonate-rich bottoms that extend beyond an inner sand belt to the shelf edge have relatively coarse sediments that are not easily transported long distances under normal conditions. Owing to the generally favorable climate, the attractiveness of the coastline and the fisheries, the eastern Gulf shore south of Tarpon Springs has an exceptionally strong tourist industry. Sports fishing follows closely behind the construction industry as an economic base of the region, leading commercial fishing by a factor of about 15 to one in terms of dollar value. Although no breakdown is currently available for the west coast of Florida nd eastern Gulf States, the total value of the sports fisheries for Florida has recently been estimated by the Florida Coastal Coordinating Coucil (M. Stursa, personal communication) to be about $480 million per year.

Existing pollutants in the offshore submerged land area are an important consideration, for in order to make meaningful use of baseline surveys on the shelves one must quantify contaminant levels, as well as be able to determine their origin. Significant inputs of pollutants of hydrocarbons, trace metals and pesticides were noted from a number of estuaries, bays and other areas in the Escarosa study (1973) (notably at Mobile, Escambia and Choctawhatchee Bays). Phosphate wastes, other industrial effluents and sewage waste inputs still occur in Tampa Bay, although at reduced levels. Hydrocarbons in selected barrier-bar sediments have been investigated (Palacas, 1975). In the investigated cases, the traceable pollutants (chiefly in sediments) do not extend far offshore. However, the enormous sediment load transported by the Mississippi River, contains a significant smount of pollutants (specific documentation is sparse) swept far to the east under atypical conditions.

A fact that affects both faunal and floral character in the eastern Gulf of Mexico is the exceptionally irregular nature of current patterns. The major influence is the Loop Current, which surges into the Gulf from late summer through the winter period. Warm Caribbean surface waters in some years extend as far northward as the Mississippi Delta before losing coherence. Loop Current waters have been observed to impinge on the shelf as far landward as the Anclote (Tarpon Springs) estuary (Fig. 1). When the Loop Current meets flood conditions in the Mississippi River, entrainment and water movement patterns have caused transport of freshened waters eastward, then southward along the shelf. These waters have salinities as low as 22 °/oo compared to normal Gulf waters having 35 °/oo - 36.5 °/oo (or higher for Loop Current incursions). Such freshened-water masses may contain river-related turbidity and have been observed during 1973 to round the Florida straits and travel northward along the east coast of Florida to Georgia and South Carolina offshore (Wallace, 1975; Atkinson and Wallace, 1975).

Although a substantial amount of literature is available in scattered sources on the area in question, many facets are known only in a sketchy or fragmentary way. The existing data are summarized in two useful compendia. Jones et al. (1973) present an encyclopedic summary of information on the eastern Gulf of Mexico. McNulty et al. (1972) provide an overall survey of the coasts and estuaries along the western margin of Florida, as the first in a proposed four-volume series.

The chief objective of this study, as mandated by the Bureau of Land Management, was to sample water, sediments and organisms on the leased tracts before arrival of drilling rigs in mid-summer of 1974. Scientific data were to be collected from two major sources:

1. The water column, to include the phytoplankton, zooplankton neuston, basic water properties, nutrients, trace metals and hydrocarbons in various forms along an extended traverse with sample stations concentrated in the lease sites, and

2. A bottom survey consisting of a relatively limited number of Master Stations (65) with sufficient subsamples (10 at each Master Station) to obtain a statistically significant evaluation of the existing benthic community. All box core samples utilized for this work were to be sieved and sorted for higher level taxonomic groups, whereas only a few taxa (polychaete worms, micromolluscs, and doraminidera) were to be determined to species. Selected invertebrates were to be sectioned, stained and analyzed histopathologically. Such analyses are more sensitive that determinations of population changes to impact of pollutants, since influences on specific organs (tumors, necrosis, etc.) may be detected before pollutant levels affecting survival are reached. The remainder of the materials were to be archived as benchmark materials, thereby permitting comparison with future seasonal surveys, and in particular, with surveys conducted subsequent to possible petroleum discovery and production on the shelf. Where box coring was not possible owing to hard substrates, investigation and documentation of surficial flora and fauna and sediment type were to be performed by divers, dredging and bottom photography (diver-conducted and remote camera). All locations for benthis surveys were to be fixed by state-of-the-art, precision navigator systems.

Especial attention was te be given to the Florida Middle Ground and Clearwater areas, where bottom flora and fauna are highly developed, and bottom visibility is good.

In addition, the description and analysis of basic properties of sediments (carbonate content, grain size, clay mineralogy, petrographic description), carbonate skeletal and organism remains from Areas I, II, and III were to be described and categorized by statistical and graphic methods as providing longer-term clues to bottom habitats. All of these measurements were to be performed on one box core from the 10 taken at each Master Station.

Intensive studies of certain chemical constituents found in the sediments, waters and biota of the area were to be performed. Cadmium, copper and lead were to be analyzed as a base for evaluationg potentially toxic pollutants. Barium, used as a weighting material (as barium sulfate) in drilling muds, was included to provide a tracer for drilling mud. Nickel and vanadium concentrations are high in crude oils and hence serve as inorganic (trace) indicators of petroleum residues where the organic fraction has been partially or wholly dissipated by leaching or microbial attack. Chromium and iron may be included in drilling mud activities and also serve as control elements for evaluating levels of other constituents. These metals were to be studied in bottom sediments (Master Stations), selected bottom organisms and waters, suspended matter, and zooplankton.

High molecular weight (extractable) hydrocarbons were to be analyzed by gas chromatography in waters, sediments, benthic organisms, zooplankton, and particulate matter in the water column. All of these measurements were to be performed to establish baseline levels of hydrocarbons in the pertinent phases. It was recognized that sediments, benthic organisms, zooplankton, and finally water and particulate matter in the water column have successively shorter residence times in the environment in question. However, to the extent that the short range phenomena can be related to typical water mass structures, productivity, physico-chemical interrelations, or influence on more permanent phases, their chemical properties were held to have significance worth evaluating. Light hydrocarbons (C_1 - C_5) were determined on bottom, intermediate and surface waters to attempt to detect natrual hydrocarbon seeps or other emanations from the sea floor, or evidence of pre-existing pollutants.

Measurements of ATP (adenosine triphosphate) were to be performed on the water column and sediments. Such measurements serve as a measure of living microbial activity, and protoplasmic biomass (including foraminifera and other microfauna) which may have implications for general metabolic activity, including the rate at which hydrocarbons may be degraded by natural processes.

Carful attention was to be paid to intercalibration and other checks on analytical validity, especially in the case of chemical parameters that require state-of-rhe-art technique or are otherwise critical, such as hydrocarbons. Baseline values of key parameters are useful only insofar as their accuracy and freedom from excessive error occasioned by sampling and handling procedures can be assured. The level of analytical and manipulative variability must be determined to separate it from natural variability. Checks were to be performed both by the chief investigators, and outside laboratories selected by the Bureau of Land Management.

Finally, it was recognized that single occupations of stations do not, for many parameters (especially faunal and floral) constitute adequate baseline information. Though not included in the current program, it was understood that reoccupation of stations and resurvey of parameters would form an element of future continuation studies.

The individual investigators and their areas of investigation are shown in Table 1.

Table 1

Principal Investigators

Program management was under the guidance of Dr. Robert Smith. Study elements and the respective Principal Investigators are listed below. The abbreviated Contract Number (CT4-11) is used in lieu of year when citing these investigations for work performed in this study.

I. Sea Floor.

A. Geology.

Standard Sediment Parameters	L. J. Doyle W. Huang T. Mayou
Carbonate Sediment Analysis	H. R. Wanless

B. Biology.

Characterization of Epifaunal and Epifloral Benthic Communities	T. S. Hopkins
Remote Bottom Photography	T. E. Pyle J. C. McCarthy
Distribution and Significance of Foraminifera	W. D. Bock
The Micromollusca	D. R. Moore
Polychaetous Annelids in Areas IV and V	B. A. Vittor
Macro-infauna	H. Kritzler
Histological Archiving	N. J. Blake

C. Chemistry.

Trace Metal Concentrations	B. J. Presley
Trace Metals in Benthic Organisms	S. Betzer
Hydrocarbons in Benthic Macrofauna	P. A. Meyers
High Molecular Weight Hydrocarbons in Sediments and Benthic Algae	T. & J. Lytle
Sediment Adenosine Triphosphate	P. A. LaRock

Table 1 (continued)

II. Water Column.	
A. Biology.	
Phytoplankton: Cell Concentrations, Species Composition and Chlorophyll	R. L. Iverson R. A. Woodmansee
Analysis of Baseline STudies of Zooplankton from Offshore Oil Lease Sites in the Eastern Gulf of Mexico	F. J. Maturo R. A. Woodmansee
Statistical Considerations	Maturo et al.
Model for Lease Tracts I, II, and III	Maturo et al.
Zooplankton Analysis for Lease Tracts IV and V	Woodmansee et al.
Model for Lease Tracts IV and V	Maturo et al.
Community Structure and Present Hydrocarbon Content of Drifting Sargassum	H. J. Humm
B. Chemistry.	
Water Column Adenosine Triphosphate	P. A. LaRock
Particulate and Dissolved Organic Carbon Concentrations	G. A. Knauer
Suspended Matter and Trace Metal Determinations	P. R. Betzer
Zooplankton Trace Metals	G. A. Knauer P. R. Betzer
Trace Metal Analysis of Sea Water Samples Collected in the MAFLA Baseline Survey	D. A. Segar
Nutrient Analyses	K. A. Fanning
Dissolved Low Molecular Weight Hydrocarbons	W. M. Sackett D. R. Schink
Dissolved High Molecular Weight Hydrocarbons from Zooplankton	J. A. Calder
Particulate Hydrocarbons	R. H. Pierce

FIELD METHODS

Four research vessels were involved in the collection of these data during May - July, 1974 in the MAFLA region. The vessels, their assignments and their navigational requirements are shown in Table 2.

Table 2

Vessels, their assignments and navigational equipment used in MAFLA.

Vessel	Assignment	Navigation
M/V MISS FREEPORT	Box coring, dredging and benthic photography	LORAC
R/V BELLOWS	Diving, water column, and dredging	LORAC (diving)
R/V TURSIOPS	Water column	LORAN A
R/V GULF RESEARCHER	Water column	LORAN A

Individual station locations and vessel navigation for the box coring and diving operations were provided by LORAC Services Corporation, Houston, Texas. The LORAC radio location network consisted of semi-permanent land transmitting stations and one or more receiving units (located aboard ship) designed and operated to ascertain vessel position.

LORAN A was used in all of the water column work conducted off the M/V GULF RESEARCHER and R/V TURSIOPS.

I. Sea Floor.

A. Sampling Design.

1. Box Core Stations. Samples for sediment and infauna were collected by use of a box corer, which removed a sediment plug measureing 21.5 cm x 30.5 cm. Depth of the core plug varied (maximum 43.2 cm) depending upon the sediment thichness. The box core was designed to obtain an undisputed quantitative sample in almost any sediment type.

Box coring was attempted at each of the 65 benthic stations. Wherever possible 11 separate box cores were collected at each station. If substrate condition did not allow for adequate box core sampling, a Capetown dredge was employed.

2. Dive/Dredge Stations. Stations for dive/dredge were established within the 5 lease areas with 43 stations being sampled. Although the sample sites varied in depth from 20 to 140 m the diver surveys were limited to depths

shallower than 45 m. Divers used standard SCUBA equipment and a dive team consisted of no less than 2 individuals per dive. Two to three dives were necessary at each station with the exception of a few stations in Areas IV and V where a single dive was sufficient to document a "zero visibility" condition. Benthic photographs were taken with standard NIKONOS II cameras equipped with 35 and 28 mm lenses and coupled with SUBSEA MK150 strobes. Movies were taken with a Super 8 movie camera in a GIDDINGS housing equipped with a 100 w GIDDINGS light. Quantitative measurements were recorded by using a portable 5 m^2 frame.

Capetown dredging was executed at all dive/dredge stations using 10 min tows. Mesh size of the dredge lines was established for each station by the Chief Scientist. Capetown dredging was executed using 10 min tows. Upon arrival on deck the dredge was emptied onto a 1.22 m x 2.44 m (4 ft. x 8 ft.) sorting board which was systematically prescrubbed with detergent and rinsed with sea water before each haul. All dredge hauls were carefully sorted for differing species.

B. Geology. At each station bottom photographs were taken with an EG&G Model 200-210A camera - 100 w·s strobe combination. Exposures were accomplished with the camera oriented normal to and approximately 2 m above the bottom (resultant coverage was approximately 2.5 m^2.). Most photography for the effort was accomplished using monochromatic film.

Box coring was attempted at each benthic station. Prior to the removal of any samples from an individual core, the core top was photographed (color) with a Honeywell Pentax SLR camera equipped with flash and attached to a frame. A Vane shear measurement was taken using a hand held unit. A side view color photograph was then taken. Each photograph included an identification tag, a color code scale, a linear scale, and a designation of the top of the core. Finally, a 5 cm deep sub-core was taken from 9 of the 11 cores collected at each station for archiving for future standard sedimentary analyses.

One box core at each station was also subsampled with a 10 cm deep sub-core for sediment archiving. In addition to photography and visual description, a 2 cm x 6.5 cm x 20 cm slab was taken from this core which was then x-radiographed for sedimentary structures. An epoxy relief peel was also taken for detailed substrate characterization.

C. Chemistry.

1. Sediment.

a. Trace Metals. A subsample was removed from a single box core at each station by pushing a pre-cleaned, 10 cm long, 2 cm diameter plastic tube through the sediment. The subsample was taken from the center of the box to insure an undisturbed and uncontaminated sample. The plastic tubes containing the samples were tightly capped and stored at 5°C until the analytical work was begun.

b. Hydrocarbons and Total Organic Carbon. From the same core from which the trace metal sample had been removed, one 10 cm^2 subsample, taken with a metal cylinder, was placed in a glass cylinder and frozen for total organic carbon analysis.

Two subcores were removed using an appropriate metal cylinder from a separate core. Both of these were placed in pre-cleaned (chloroform) jars and frozen. One of these was analyzed for hydrocarbons, the other was archived.

2. Biota.

a. ATP. A 1 cm^3 plug of sediment was removed from the box core and extracted at 5°C with 5 mℓ 0.6 N H_2SO_4 in a tube. Each sample was mixed intermittently at 10 s intervals for a total of 60 s (longer vortex mixing does not enhance recovery) and the tubes were allowed to settle for 10 min. An internal standard of 1 mℓ of 100 mg/mℓ ATP was added to one of the triplicate samples, and 1 mℓ of TRIS buffer to the remaining two samples. The samples were vortex mixed for an additional 10 s and then centrifuged for 5 min at 1800 g. Four mℓ of the supernatant were transferred to a 10 mℓ beaker, followed by addition of 1 mℓ of 0.048 M (18 g/ℓ) solution of Na-EDTA made up in TRIS. The pH of the acid extract was adjusted to 7.8 with NaOH. The samples were then quantitatively transferred to a calibrated test tube, the volume adjusted to 10 mℓ with TRIS and frozen for subsequent analysis.

b. Trace Metals. Samples for trace metal analysis were collected by diver, Capetown dredge, and box core. Key dominant macrofauna were placed in individual plastic bags and frozen.

c. Hydrocarbons. Samples for hydrocarbon analysis were collected similar to trace metals. Key dominant macrofauna were placed in glass jars, previously cleaned with chloroform, and frozen.

d. Histopathology. Samples for histopathology were collected by diver and Capetown dredge. Key dominant macrofauna were fixed in Dietrich's fluid.

D. Biology.

1. Infauna. Box cores from each benthic station were sieved for the analysis of infauna community structure. A foraminifera sub-core (2 cm dia.) was removed from two cores at each station. Two sub-cores for micromolluscs were also taken from the cores sampled for foraminifera.

2. Epifauna. Samples for epifauna were collected on dive/dredge stations. Each dive team set a frame in the bottom and documented species diversity and abundance through photography, organism counts and specimen collection. The dive groups were coordinated in such a was as to prevent the succeeding dive teams from resampling an area already described.

Quantitative measurements were not recorded in the Florida Middle Ground reefs in Area II due to the limited dive times coupled with large species diversity and individual abundance. Emphasis was placed on photography and specimen collections with special attention given to coelenterates, sponges, molluscs and algae.

Specimens collected during the Capetown dredge phase that were not used for chemical analyses were preserved according to specimen type. Fish were preserved

in 10% formalin buffered with calcium carbonate. Invertebrates were preserved in either 70% ethanol or 50% isopropanol. Benthic algae were preserved in 5% formalin and labeled for future identification.

II. Water Column.

A. Physical.

1. Expendable Bathythermograph (XBT). XBT probes were launched at each station and at the discretion of the Chief Scientist. Surface temperatures were taken with bucket thermometers for calibration.

2. STD Cast. STD lowering were made to within a few metres ofthe bottom with a battery powered Model 9060 STD unit. Each cast was calibrated by on the two methods. The first method utilized two 1.7 ℓ Niskin bottles equipped with protected reversing thermometers. For each cast one bottle was set a one metre depth and other set immediately above the STD unit. The second calibration method placed no bottles on the STD cast. Immediately prior to the particular STD cast a three bottle hydrocast (30 ℓ Niskin bottles equipped with protected reversing thermometers) was made and samples drawn from one metre, middle and bottom depths. Both of these methods relied on the reversing thermometer readings and the salinity samples taken out of each bottle.

B. Chemistry. On each station a three bottle cast was made using 30 ℓ Niskin bottles. Samples were obtained from one metre, mid-depth and several metres from the bottom. If a thermocline existed, the mid-depth bottle was placed at the thermocline depth.

1. Dissolved Oxygen. Two 300 mℓ water samples were taken from the Niskin bottles at each depth and treated with 2.0 mℓ each of manganous sulphate and alkaline potassium iodide. The bottles were sealed with tape and returned to the shore laboratory.

2. Dissolved Micronutrients. One hundred millilitres of sea water were filtered through pre-washed 0.4 μm Nuclepore filters using plastic and stainless steel apparatus. The filtrate was stored in polypropylene bottles and frozen.

3. Particulate and Dissolved Organic Carbon. To avoid contamination from internal rubber closures all Niskin bottles were fitted with metal springs. Samples (200 mℓ) were filtered through pre-combusted glass fiber filters. The filters were then placed in pre-combusted glass ampoules, covered with aluminum foil and frozen.

Aliquots of the above filtrate were placed in acid-washed, 120 mℓ (4 oz.) screw cap glass bottles fitted with Teflon cap liners. The filtrate was poisoned with $HgCl_2$ and refrigerated.

4. C_1 to C_5 Dissolved Hydrocarbons. A hydrocarbon Sniffer unit measuring C_1 to C_5 dissolved hydrocarbons was towed behind the ship. The sensor readouts were recorded every five minutes.

5. Dissolved Low Molecular Weight Hydrocarbons. Sample bottles which had been pre-cleaned and fitted with ground glass stoppers were over filled with 1000 mℓ of sea water and poisoned with sodium azide. The ground glass stoppers were inserted with tape.

Each sample bottle had previously been cleaned by washing successively with tap water, hydrochloric acid, tap water, distilled water and acetone.

6. Particulate and Dissolved High Molecular Weight Hydrocarbons. Samples were drawn into stainless steel containers cleaned with acid and chloroform ($CHCl_3$). Forty to 60 ℓ (for each sample) were filtered through pre-combusted flass fiber filters housed in a stainless steel millipore filter holder. The filters were folded into pre-combusted aluminum foil and frozen.

Forty litres of filtrate from the above was drawn into acid-$CHCl_3$ cleaned stainless steel containers and poisoned with 20 mℓ of $CHCl_3$.

7. Particulate and Dissolved Tract Metals. The 30 ℓ Niskin bottles were attached to polyethylene sheathes wire rope. As the wire was paid out it was wiped with chloroform. The Niskin bottles were allowed to flush for 5 min before tripping. The entrapped seawater was transferred to acid washed 20 ℓ Nalgene carboys via Teflon tubing (each carboy was rinsed with the seawater sample before being filled). Samples were immediately transferred to the ship's laboratory where filtration procedures were performed.

Water from each 20 ℓ carboy was gravity fed through silicone rubber tubing to all-plastic inline Millipore filter holders, each of which was equipped with a 47 mm dia., 0.4 μm pore size Nuclepore membrane. After filtration was completed, the Nuclepore membranes were rinsed with 25 mℓ of deionized water. The inline filters were transferred immediately to polyethylene bags, sealed and stored at 5°C.

Two litres of the filtrate (less than 2 ℓ were obtained in most cases) from each sample were placed in scrupulously clean, one-litre high density, polyethylene bottles and acidified with 10 mℓ of concentrated nitric acid.

C. Biology.

1. ATP. Two 1000 mℓ water samples were taken from Niskin bottles at each depth and filtered through 0.45 μm Millipore filters. The filter was quickly plunged into screw cap tubes containing 10 ml of 0.025 M TRIS buffer (pH 7.5) maintained at 100°C for 10 min in a 115°C oil bath. After ATP extraction, the samples were cooled in an ice bath, brought to 10.0 mℓ volume. Following this the TRIS containing ATP and the filter were transferred to Whirl-paks and frozen.

2. Phytoplankton. A 20 ℓ aliquot was filtered through 20 μm mesh screen (Nitex) to separate "net" plankton from nannoplankton. The "net" plankton were washed into glass bottles and preserved with a buffered formalin. For the nannonplankton, a pre-determined portion of the above filtrate was passed through a 0.45 μm millipore filter which was then desiccated until analyzed. Approximately 4 ℓ of sea water were also fixed with 45% buffered formalin for the identification of plankton.

3. Chlorophyll. Three one-litre samples were filtered through GF/A glass fiber filters and frozen.

4. Zooplankton. At each station, three to five 15-min and one 1-h oblique tow(s), within specific depth ranges (surface, mid-depth and bottom waters) were taken using 0.5 m dia. Nitex nets of 202 µm mesh size equipped with double-trip mechanisms and flow meters. All tows were taken, while drifting, from the leeward side of the vessel. Upon retrieval, the flow meter readings were recorded and the nets thoroughly washed down.

The contents of the cod end from the 15-min tows were drained through 20 µm Nitex netting, transferred to glass jars and preserved in a 5% buffered formalin solution for later identification and statistical analysis.

For the 1-h plankton tows, acid-washed glass jars were used for cod-ends and the wire was wiped clean with chloroform. Upon retrieval the sample was split using a Folsom plankton splitter.

Approximately 25% of the sample was drained on a 20 µm Nitex netting, blotted as dry as possible, and a displacement volume determined. This portion of the sample was then preserved in 5% buffered formalin for later identification and statistical analysis.

The remaining sample was then split in half. One of these was drained on acid washed 20 µm Nitex netting, placed in acid washed, pre-weighted glass jars and frozen. This sample was used for biomass and trace metal determinations. The remaining aliquot was immediately placed in previously cleaned glass vials equipped with Teflon caps and frozen for later hydrocarbon analysis.

LABORATORY PROCEDURES

I. Sea Floor.

A. Geology, Standard Sediment Parameters. Subsamples 10 cm deep were taken fromeach of two 5-cm diameter cores from separate box cores from each coring station. Splits were analyzed for grain size, percent carbonate, and clay mineralogy. A split of the >62 μm fraction of the sediment was sieved at full phi intervals and another run through a rapid sediment analyzer (settling tube). In samples where the <63 μm sediment exceeded 10% by weight of the total samples, pipette analyses were performed to determine the amount of silt and clay present. One subsample was analyzed for percent carbonates using acid leaching with hydrochloric acid.

Sieved sediment samples from Area I, II and III, were separated into the following size fractions: >2000 μm, 2000-1000 μm, 1000-500 μm, 500-250 μm, 250-125 μm, and 125-62 μm. For each size fraction the following descriptions and analyses were made by examination under binocular microscope.

1. General color and characterization of sediment type (dominant constituents).

2. Description of the major carbonate grain types including:

   a. Surface texture
   b. Degree of fragmentation
   c. Presence of sediment infilling of grains
   d. Color of grains if at variance with general color of sediment
   e. Consistency of unidentified and non-skeletal grains
   f. Probable grain type classification of majority of unidentifiable grains
   g. General description of non-carbonate portions

3. Grain count of constituent types in each size fraction. Where sufficient number of grains were present, at least 300 carbonate grains were present, at least 300 carbonate grains were identified. Where less than 300 carbonate grains were present, the total number of grains were identified. Concurrent counts of non-carbonate grain was made.

The following skeletal grain types were differentiated:

   a. Mollusk
   b. Benthic foraminifera
   c. Pelagic foraminifera
   d. Halimeda
   e. Echinoderm
   f. Ostracod
   g. Sponge spicule (including opaline silica)
   h. Alcyonarian
   i. Bryozoan

j. Coralline algae
k. Coral
l. Tubes

4. The following non-skeletal and other grain types were differentiated:

a. Pellets
b. Intraclasts
c. Carbonate rock fragments
d. Blackened carbonate grains

Classified under the heading "unidentified carbonate" grains were those skeletal and non-skeletal grains that could not be given certain classification as to origin. From the grain counts within each size fraction, two basic types of calculations were made:

Computation of percent carbonate and percent non-carbonate

$$\% \text{ carbonate} = \frac{\text{\# counts of carbonate grains} \times 100}{\text{total \# grain counts}}$$

$$\% \text{ non-carbonate} = \frac{\text{\# counts non-carbonate grains} \times 100}{\text{total \# grain counts}}$$

Computation of percent that a particular carbonate constituent is of the total carbonate. For example:

$$\% \text{ mollusk} = \frac{\text{\# counts mollusk grains} \times 100}{\text{total \# carbonate grain counts}}$$

Clay mineralogy was done on the fine fraction of the samples using x-ray diffraction. Analyses were conducted by using Mg saturated mounts which were x-rayed at 25° and 100°C, and K saturated mounts which were X-rayed at 25°, 100°, 300° and at 550°C. Clay minerals were identified and their relative abundance determined on a semi-quantitative basis by calculating peak areas.

B. Chemistry.

1. Sediments.

a. Tract Metals. Initial sample preparation involved drying the entire aliquot (~50 g) of wet sediment at 105°C and then reducing it to a fine powder with a porcelain lined Spex mixer-mill. Cadmium, chromium, copper, iron, lead, and nickel were determined by atomic absorption spectrophotometry after dissolution of the sediment. Barium and vanadium were determined by instrumental neutron activation of the solid sample.

For total dissolution, approximately 1 g of finely powdered sediment was heated in a muffle furnace at 400-450°C for 8 h to ash the organic matter present. Observations conducted in these studies indicate that there is no loss of the pertinent metals on heating to 450°C (this confirms the findings of Gorsuch, 1970).

After heating, the samples were transferred to FEP Teflon beakers and 3 mℓ of 16 N HNO_3, 5 mℓ of HF (48%), and 2 mℓ of $HClO_4$ were added. The acid/sediment mixture was heated to near dryness. A second acid mixture (3 mℓ HF, 2 mℓ $HClO_4$) was then added and again heated to near dryness. The residue was redissolved in 5 mℓ of 5 N HCl and diluted with deionized water to 25 m .

i. Atomic Absorption Spectrophotometry. Copper, lead and nickel were determined by direct aspiration into a Jarrell-Ash model 810, two channel atomic absorption spectrophotometer. Iron was determined after appropriate dilution by the same technique. Background absorbance, due to molecular bank absorption and light scattering, was monitored, where necessary, by simultaneously measuring the absorbance of a non-specific line and the analytical line of the element of interest. A method of additions analysis was also used to check matrix effects.

Cadmium and chromium in all samples were determined by flameless atomic absorption techniques using a Perkin-Elmer Model 303 atomic absorption spectrophotometer equipped with a HGA-2000 graphite atomizer and a deuterium background corrector. In preparation for these analyses, 0.1 g samples were dry ashed at 450°C and transferred to screw-cap polyethylene centrifuge tubes. An acid mixture of 2 mℓ of 12 N HCl, 2 mℓ aqua regia, and 2 mℓ HF (48%) was added to the tubes which were then sealed and heated at 90-95°C for 2 h. After heating, the solutions were transferred to FEP Teflon beakers and heated to dryness. The residue was dissolved with 3 mℓ of 4 N HCl and diluted 50 mℓ with deionized water. Analysis was by flameless atomic absorption spectrophotometry after the appropriate dilution (usually a 500-3000 fold dilution) was made.

Copper, lead and nickel were also run by flameless atomic absorption as a check on flame methods. USGS standard rocks W-1 and AGV-1 were analyzed by both flame and flameless atomic absorption to check precision and accuracy.

ii. Neutron Activation Analysis. Neutron activation analysis was found to be more suitable than atomic absorption spectroscopy for barium and vanadium determination. Initial preparation for neutron activation involved accurately weighing about 0.5 g of sediment, which had been dried at 105°C, into a small 1 g capacity polyethylene vial. The vial was heat-sealed to prevent loss of sample during analysis. The marked, encapsulated samples were irradiated by the 1 MW Triga reactor at the Texas A&M University Nuclear Science Center.

For vanadium analysis, each sample was irradiated separately for 5 min (this process was facilitated by a pneumatic transport system which can rapidly transfer samples in and out of the reactor core). The sample vial was placed in a secondary poly vial, together with an aluminum flux monitor, and transported to the core for the 5 min time period.

After return of the sample and a 1 min delay, the aluminum flux monitor was counted by multichannel pulse height analyzer. After an appropriate delay period (usually 3-5 min so that the dead time was 30%) the irradiated sediment sample was palced on an Ortec Ge(Li) detector and counted using a separate GEOS Quanta 4096 channel multichannel pulse height analyzer. The analyzer was set for a gain of 1.0 keV per channel. The vanadium peak for the V-52 analyzed is at 1434 keV. After a 5 min counting period, the spectrum was stored on magnetic tape.

Data reduction was done using the program HEVESY (Schlueter, 1972). The program calculates peak intensities and converts these to concentration by comparison with appropriate USGS standard rocks (DTS-1 and AGV-1). Corrections were made for varying delay times, dead times, and neutron fluxes.

For barium analysis, the sediments were irradiated for a 14 h period. The samples were placed in aluminum Swagelok tubes along with standards and blanks and set in a rotisserie in the reactor core. After irradiation the samples were allowed to "cool" for 7 to 14 d.

The irradiated samples were counted for 2 h using an Ortec Ge (Li) detector and a Canberra Model 8700, 1024 channel multichannel pulse height analyzer. The peak of interest was that produced by barium x-rays at 29 keV; the gain was set so that the peak was recorded in channel 160. After the 2 h counting period, the spectrum was recorded on magnetic tape. Data reduction was performed by HEVESY using the USGS standard rock W-1 as a basis for sample concentration calculation.

As indicated above, USGS rocks were analyzed to determine the accuracy of the analyses. The results of these measurements are shown in Table 3.

Table 3. U.S.G.S. Standard Rock Determinations (ppm)

W-1	Ba	Cd	Cr	Cu	Fe%	Ni	Pb	V
U.S.G.S. reported value	160	0.15	114	110	7.78	76	7.8	264
Texas A&M	-	0.2	131±14	109±1	7.76±0.03	71±5	8.9 ±2	240 ±40
Battelle, N.W.	-	-	111	130	7.4	60	10	220

U.S.G.S. Standard Rock Determinations (ppm)

AGV-1	Ba	Cd	Cr	Cu	Fe%	Ni	Pb	V
U.S.G.S. reported value	1208	0.09	12.2	59.7	4.74	18.5	35.1	125
Texas A&M	1020±12	0.1	15±4	59±1	4.57±0.06	18±2	35±2	140 ±2

The overall agreement between these data is good. A further study on these data was made by investigators at Battelle N.W. Laboratories.

The precisions of the metal analyses were considerably lower for sediments with high metal content than for sediments with low metal content. Overall precision for Ba, Fe and V (given as ± one standard deviation divided by the mean) were

12%, 3% and 16% resp. These were determined by replicate processing of subsamples. For metal levels >10 ppm the precisions for the other metals are as follows: Cr, 15%; Cu, 3%; Ni, 9%; Pb, 10%. At lower levels (1-5 ppm) these four elements, along with cadmium, sometimes have precisions ≥25%.

b. Hydrocarbons.

i. Separation Procedure. The frozen sediment was thawed at room temperature after which an aliquot (approx. 100 g) was taken for percent carbonate and percent organic carbon analyses. A separate aliquot was filtered (Whatman #43-$CHCl_3$ washed) in a large Buchner funnel filter apparatus to remove excess water. Each sample was then covered with methanol (where necessary, e.g. silt-clay, the samples were blended for 1 min) for 24 h.

The methanol-water was filtered off, the sediment washed with fresh methanol and the methanol-water filtrates combined. The latter were extracted with three 50 ml portions of hexane. The aqueous solutions were discarded. The sediment was then extracted overnight (chloroform - one sample volume). An Artek Sonic Dismembrator was used (15 min - setting 60) with constant stirring to enhance this lipid extraction. After sonication the sample was warmed and filtered. The sediment cake was washed on the filter funnel with fresh, hot $CHCl_3$. The sample was then covered in fresh $CHCl_3$, sonicated, heated and filtered again. This process was repeated until the filtrate was colorless. The extracted sediment was dried at 100°C and weighed. These extracts were then combined with the hexane extracts, reduced in volume to 50 mℓ in a rotary evaporator, and washed with twice-distilled water made acidic (pH 4) with HCl. The water fraction was back extracted with fresh $CHCl_3$ and discarded.

Sulfur was removed from the lipid extract by treatment with activated copper. Copper wool (City Chemical Corp.) was boiled twice in concentrated HCl for 15 min, washed with distilled water, dried with acetone and placed in lipid extract. After heating under a hot water tap the mixture was stirred and allowed to stand overnight. The mixture was then filtered through pre-washed Whatman #43 paper and the copper wool rinsed again with fresh $CHCl_3$.

The sulfur-free extract was reduced to near dryness on a rotary evaporator and taken up in $CHCl_3$ to 25.00 mℓ. An aliquot (2 or 3 mℓ) was then taken for lipid dry weight determination, palced in a pre-washed and pre-tared glass vial and reduced to dryness under High Dry nitrogen. The remainder of the lipid extract was reduced to dryness in a rotary evaporator, treated with 20-20 mℓ of 0.5 N KOH in methanol and refluxed overnight to saponify. Distilled water and 50 mℓ benzene were then added and the mixture was refluxed for an additional 15 min to facilitate extraction of the non-saponifiable compounds (including hydrocarbons) into the benzene.

After transfer to a separatory funnel, the benzene fraction was removed and the methanol-water fraction re-extracted with 50 mℓ portions of benzene. This extracted methanol-water fraction was used later for the isolation and purification of saponified compounds (fatty acids and other acidic constituents). The combined benzene extracts were reduced to dryness, taken up in 1 mℓ of hexane, and the hexane charged to an adsorption column packed with neutral alumina over silica gel, 1:4 (v/v). The alumina-silica gel was never less than 50 times the weight

of lipid charged to the column. Both the silica gel and alumina (Woelm activity grade I) were heated overnight at 150°C prior to column packing. Columns were washed with at least two column volumes of hexane before charging.

Aliphatic hydrocarbons were eluted with three column volumes of hexane, followed by an equal volume of benzene to elute the aromatic hydrocarbons. Following collection each fraction was taken to dryness in a rotary evaporator under High Dry Nitrogen without heat. The fractions were stored in a desiccator over silica gel and weighed.

ii. Gas Chromatography. Two gas chromatographs were used in this study, a Perkin-Elmer 990 (equipped with a PEP-1 Data System, digital data printout and a 1 mV potentiometric-recorder), and a Perkin-Elmer 3920. Each chromotograph was equipped with dual flame ionization detectors, with helium as carrier gas. All gases used were trap dried before use.

Samples were run on three columns:

(a) 3% (by weight) SE-30 G.C. grade on Anakrom AS 90/100 mesh in 3.2 mm x 2 m stainless steel 304 columns. Program 100°-250°C at 4°C/min, isothermal at 250°C for 32 min, helium flow 8 cm/s. (Aliphatic hydrocarbons).

(b) 4% (by weight) FFAP on Anakrom AS 90/100 mesh in 3.2 mm x 2 m stainless steel 304 columns. Program 90°-225°C at 6°C/min, isothermal at 225°C for 32 min, helium flow 8 cm/s. (Aliphatic-Aromatic hydrocarbons).

(c) Support-coated open tubular columns, 1.6 mm (0.76 mm i.d.) x 15.25 m (1/16" x 50') stainless steel 316. FFAP coated on Chromosorb R6470-1. Program 65°-220°C at 6°C/min, isothermal at 220°C for 16 min, helium flow 30 cm/s. (Aliphatic hydrocarbons).

Columns were washed before packing with the following solvent series: water, Alconox solution, water, dil. nitric acid, water, methanol, chloroform and acetone. The anakrom AS, SE-30 G.C. grade and Chromosorb #6470-1 were supplied by Analabs, Inc., and the FFAP by Varian Aerograph. Columns were conditioned by being held at the initial temperature for 1 h, then programmed at 0.5°C/min to the final temperature. This was repeated and the column was finally conditioned by holding at the final temperature for 2 h.

Each day that aliphatic or aromatic hydrocarbon samples were gas chromotographed, both hexane blank and blanks consisting of representative solvent volumes were run through the entire hydracarbon work-up procedure and aliphatic weight standards were also run. The latter consisted of a hexane solution of weighed amounts of the following pure compounds:

C10:0, C12:0, C14:0, C16:0, C18:0, C20:0, C22:0, C24;0, C28:0, C32:0 (all from Applied Science Laboratories), Pristane (Aldrich Chemical Co) and Phytane (Analabs).

Identification of aliphatic hydrocarbons, and pristane and phytane was by comparison of retention times with the standard on two different stationary phases, augmented by Kovats Index assignments for each peak. Kovats Indices were calculated

by interpolation based on smooth curve fitting techniques of Hiroshi Akima (1972). For the calculation of resolved peak area: unresolved envelop area for each chromatogram, areas were measured by planimetry using a Lietz planimeter. Quantitative analysis was accomplished on FFAP columns. SE-30 gas chromatographs were used only for qualitative identifications to verify identifications on FFAP.

iii. Clean-up and Contamination Prevention.

(a) All glassware was washed according to the following procedures:

(i) Alconox
(ii) Acid cleaning bath solution
(iii) Distilled water
(iv) High temperature oven dry 3 h
(v) Rinse immediately before use with appropriate solvent
(vi) KOH-methanol cleaning solution was also used where appropriate

(b) All solvents, hexane, methanol, chloroform and water were glass distilled.

(c) All internal surfaces of rotary evaporator were rinsed with chloroform prior to each use. Automatic feed by Teflon tubing was used in evaporating large samples. All other laboratory ware being made of Teflon or stainless steel was treated as glass in the cleaning procedures except for the omission of the acid bath step in the cleaning of the stainless steel.

(d) Concentrated HCl, A.R. was extracted three times with chloroform before use.

(e) KOH, alumina and glasswool were Soxhlet extracted in benzene for 48 h.

(f) Teflon stopcocks, and glass or Teflon stoppers and filter adaptors were used throughout.

c. Percent Carbonate and Percent Organic Carbon. Each sediment aliquot was dried at 40°C to constant weight and then acidified with 6 N HCl to remove carbonate. The acidified sample was allowed to stand overnight and filtered using a Millipore apparatus with glass fiber filter pad. The sediment cake was washed on the filter with distilled water until the filtrate had neutral pH. After drying at 40°C to constant weight, each sample was ground to a powder with mortar and pestle and stored in a washed plastic vial. The percent organic carbon content of the sediment was determined using a LECO radiofrequency induction furnace with LECO Automatic Direct Reading Gordon Determinator. Primary grade oxalic acid samples were used to standardize and calibrate the LECO apparatus. The average variation in triplicate organic carbon determinations was less than ±0.10% organic carbon.

2. Biota.

a. ATP. In assaying the acid-extracted ATP samples a standard curve prepared in TRIS cannot be used to calculate final ATP concentrations. TRIS has been reported to interfere with the accuracy of some electrodes, but no effects were discernible at the molarity used. A series of ATP standards for acid-extracted samples was prepared at the same time the environmental samples were extracted. These were prepared by mixing 3 mℓ of 0.6 N H_2SO_4, 1 mℓ of 0.048 M EDTA solution and 1 mℓ of the desired ATP standard, neutralizing with NaOH and adding TRIS for a final volume of 10 mℓ. The standards covered the range 0.3-50 ng ATP/mℓ and were frozen along with the extracted samples to be assayed by the bioluminescent reaction. The luciferin-luciferase mixture used in these studies was prepared by reconstituting each vial of lyophilized firefly lantern extract (Sigma Chemical Company, FLE-50) with 12.5 mℓ distilled water, 7.5 mℓ of 0.1 M arsenate buffer (Sigma Chemical Company, FF-AS-100), and 5 mℓ of 0.05 M magnesium sulfate. The enzyme was allowed to stand for 6-7 h at 23-25°C in order to remove indigenous ATP. After aging, the preparation was filtered (Whatman #2) to remove residual debris. After clarification and during use, the enzyme was kept in an ice bath. One half millilitre of enzyme was used for each ATP assay.

For the analysis 1 mℓ of either the sample extract or the ATP standard was added to a chromic acid washed liquid scintillation counter (LSC) vial, followed by the addition of 0.5 mℓ of 0.025 M TRIS buffer (pH 7.75). The vial was then closed and 0.5 mℓ of the enzyme preparation (see below) was injected into the vial through a small hole drilled into the cap. Exactly 1 min after injection an 0.1 min count was taken (Manual Liquid Scintillation Counter, Nuclear Chicaga, Model 4534). The LSC counter was operated in a non-coincident mode using one photomultiplier tube (Schram, 1970), and with a maximum window opening of 0.5-10.0 V. The count taken represents an integral measurement of the area under the luminescent decay curve between 60 and 66 s after the start of the reaction. For each enzyme preparation a standard curve was made by plotting the logarithm of the integral count rate versus the logarithm of the appropriate ATP concentration. Standard solutions containing 1 mg/ℓ disodium crystalline ATP (Sigma Chemical Co., A3127) in 0.025 M TRIS buffer were prepared and stored frozen in 10 mℓ aliquots.

b. Trace Metals. Each sample was thawed, weighed, dried to constant weight at 60°C and reweighed. A subsample (∿1 g) was prepared for ashing, usually by homogenizing with an agate mortar and pestle. In some cases, e.g. leathery sponges and stony corals, whole segments were ashed without homogenizing. The sample was placed in a Teflon watch glass and ashed for 2-6 h in a low temperature asher.

The asher was then transferred to a Teflon bomb and digested 4-5 h at 95°C with concentrated ultra- pure nitric acid. After cooling the solution was transferred to a 50 mℓ volumetric flask and made up to volume with double-deionized water. The solution was then analyzed for Cd, Cr, Cu, Fe, Ni, Pb, and V, using a Perkin-Elmer 503 atomic absorption spectrophotometer equipped with heated graphite furnace and deuterium background corrector. Appropriate standards and blanks were run with each set of samples.

Recovery was checked by ashing, digesting and analyzing samples of Bovine Liver certified by the National Bureau of Standards. The results are shown in Table 4.

Table 4. Precision and Accuracy of Trace Metal Analysis of Bovine Liver. (Mean ± 1 standard deviation.)

Concentration in µg/g dry weight.

	Cd	Cu	Fe	Pb
National Bureau of Standards	0.27 ± 0.04	193 ± 10	270 ± 20	0.34 ± 0.08
This study	0.31 ± 0.02	175 ± 8	251 ± 2	0.32 ± 0.02

c. Hydrocarbons.

i. Fauna. The wet tissue of the organism was homogenized. A known weight of the homogenate was refluxed 1 h with 150 mℓ benzene/methanol, 2:1, to extract lipids. The extract was isolated from the tissue by filtration through a prerinsed Whatman 54 filter. After filtration, the filter and tissue were rinsed successively with 20 mℓ methanol, 20 mℓ benzene, and 100 mℓ petroleum ether. The extract and rinses were combined in a separatory funnel and washed with 100 mℓ water. After isolation of the organic phase, the aqueous wash was extracted twice with 20 mℓ petroleum ether. The organic phase and these two extracts were combined and evaporated to dryness on a rotary evaporator at 30°C. The residue, representing total lipid material of the organism, was weighed on a Cahn electrobalance.

The total lipid material was dissolved in 20 mℓ benzene/methanol, 1:1, and transferred to a 50 mℓ screw-cap centrifuge tube. The lipids were saponified in the sealed tube by adding 5 mℓ 0.5 N methanolic KOH and 3 mℓ water and heating at 100°C for 30 min. After the tube cooled, 10 mℓ petroleum ether was added and the contents mixed by shaking. The organic layer was removed, and the aqueous phase (pH 10) was extracted twice with 10 mℓ petroleum ether. The extracts were combined with the initial organic layer and evaporated to dryness. The residue, representing total nonsaponifiable lipids, was weighed on the Cahn balance.

The nonsaponifiable lipids were dissolved in a small volume of petroleum ether and transferred to an alumina/silica gel column containing 2 g of each adsorbant, both 5% deactivated. The column diameter was 9 mm. Saturated hydrocarbons were eluted with 20 mℓ petroleum ether; unsaturated hydrocarbons with 20 mℓ benzene. The solvent was evaporated from both fractions using a nitrogen stream, and the residues weighed on the Cahn balance.

Saturated and unsaturated hydrocarbons were further analyzed by gas/liquid chromatography using Varian Aerograph 1520-C and a Hewlett-Packard 5711-A gas chromatographs equipped with flame ionization detectors. The columns used were 2.1 mm i.d. x 6 m stainless steel, packed with 3% OV-101 on Chromosorb W-HP 80/100, or 5% GP60G Eutectic Mixture on Chromosorb G-AW 80/100. The analyses

were temperature-programmed from 90°C to 310°C at 8°/min, except when the SP-100 column was employed. The program was 100°C to 250°C for this column. The upper temperature was held for 16 min for all programs, and the nitrogen carrier flow rate was 20 mℓ/min.

ii. Flora. Samples of benthic algae collected by dredging and/or diving were stored frozen in glass containers that had been prewashed with $CHCl_3$. At the laboratory, samples were thawed, macerated in MeOH, filtered and extracted three times in $CHCl_3$, using sonification. The combined extracts were taken to a small volume in a rotary evaporator at room temperature and washed with acidified water (pH 4) to remove salts. (An aliquot was taken of the lipid extracts for weight of total extractables and carbon-13 determination. Immediately before saponification, the extracts were taken to dryness under prepurified N_2 at room temperature. The extracts were saponified overnight in 10 mℓ of 0.5 N KOH in methanol. An equal volume of H_2O was added after the saponification. The non-saponifiables were extracted three times with 10 mℓ benzene. The volume of the non-saponifiables extracted was reduced to dryness at 1 mℓ vol. (under N_2), taken up in hexane, and analyzed by column chromatography (1:5 v/v of microneutral alumina overlying silica gel, both activated or activity 1, after washing with 3 column volumes of hexane). The aliphatic hydrocarbons were eluted with three column volumes of hexane and the aromatic then was eluted with three column volumes of benzene. The eluted extracts were taken to dryness (under N_2) and weighed. Gas chromatographic analysis was performed using two columns, coated with SE-30 and FFAP. Flame ionization and temperature programming were employed. Retention indices based on known standards were computed.

d. Histopathology of Benthic Invertebrates. After fixing in Dietrich's fixative and embedding in Paraplast (utilizing a 15 h processing routing on a Technicon tissue processor) the tissues were sectioned at 6 μm and stained with hemotoxylin-eosin. Two slides each of 2-6 tissue blocks per animal were prepared and were archived for future comparison with organism resamplings from the lease tracts. Species included in the sampling area shown in Table 5.

C. Biology.

1. Infauna. Box core samples were stained with rose bengal stain and sorted into five major taxonomic groups: molluscs, arthropods, echinoderms, polychaetes, and miscellaneous. Biomass measurements were recorded for each group. Weights were on the basis of the preserved organisms (70% ethanol) corrected for shrinkage due to narcotization and preservation and converted to wet weight.

Polychaetes were identified to at least the level of family. Micromolluscs and foraminifera were identified to the species level.

2. Epifauna. Dive/dredge samples for epifauna were sorted into six major groups: corals, molluscs, crustaceans, algae, echinoderms, and sponges. Epifauna was identified to the species level, where possible.

Table 5 List of Species for Histopathological Archiving

Porifera
- Callyspongia sp.
- Ircinia fasciculata
- Ircinia campana
- unid. spp.

Cnidaria
- Dichocoenia stokesii
- Muricea sp.
- Oculina diffusa
- Plexaurella sp.
- Porites furcata
- Scolymia sp.

Annelida
- Polychaeta
- unid spp.

Mollusca
- Gastropoda
- Cassis madagascariensis
- unid. spp.

Pelecypoda
- Argopecten gibbus
- Argopecten mucosus
- Echinochama cornuta
- Lyropecten nodosus
- Spondylus americanus

Caphalopoda
- Octopus joubini

Arthropoda
- Crustacea
- Calappa angusta
- Calappa flammea
- Lysiosquilla excavatrix
- Mithrax spinossisimus
- Pachycheles rugimonus
- Paguristes sericeus
- Penalopsis goodi
- Portunus ordwayi
- Portunus anceps
- Scyllarus sp.
- Sicyione parri
- Synalpheus longicarpus

Echinodermata
- Asteroidea
- Astropecten duplicatus
- Astropecten sp.
- Echinaster sp.
- Goniaster tessellatus
- Luidia clathrata

Echinoidea
- Eucidaris tribuloides

Holothuroidea
- Holothuria sp.

Ophiuroidea
- Ophioderma brevispinum

Miscellaneous species
- Membranipora sp.
- Styella sp.
- unid. tunicate spp.
- Amphioxus

II. Water Column.

A. Chemistry.

1. Dissolved Oxygen. Analyses were conducted as described in Strickland and Parsons (1968).

2. Nutrient. The frozen samples were thawed and analyzed in triplicate for nitrate, nitrite, silica, and phosphate plus arsenate. All nutrients were analyzed by a Technicon Autoanalyzer II although silica and phosphate-arsenate were determined on some samples by manual methods (Strickland and Parsons, 1968 and Fanning and Pilson, 1973). Ascorbic acid was used as the reductant in the automated technique for silica.

3. Particulate and Dissolved Organic Carbon. Organic carbon determinations were made using a Total Carbon Analyzer (Oceanography International, Inc.) functioning on the principle described by Menzel and Vaccaro (1964) for determining organic carbon in seawater. The apparatus consisted of several subunits. The ampoule purging and sealing unit provided a carbon-free oxygen source for flushing carbonate derived atmospheric CO_2 from ampoules and an ampoule sealing apparatus designed to prevent the introduction of combustion gases into the sample. The analyzing unit consisted of a device for opening ampoules, a gas train for introducing organically derived CO_2 into a nitrogen stream, a magnesium perchlorate gas dryer, and non-dispersive infrared analyzer attuned for CO_2 detection. The signal from the infrared analyzer was displayed on a strip chart recorded equipped with a chart integrator for quantitative measurement of peak area.

a. Dissolved Organic Carbon. Five millilitres of the filtrate were placed in precombusted 10 mℓ ampoule containing 200 mg of potassium peroxydisulfate ($K_2S_2O_8$) and then acidified with 0.2 ml of 8.5% phosphoric acid. The ampoules were purged of inorganic CO_2 for 5 min, sealed and boiled at 100°C for 4 h to oxidize organic compounds, and analyzed for CO_2.

B. Particulate Organic Carbon. Particulate organic carbon was determined in a manner similar to DOC. Filters containing particulate matter from thoroughly shaken water samples were folded with clean Teflon forceps and placed in ampoules. Fove millilitres of distilled water were added to the ampoules containing the filter pads in addition to the reagents added to each ampoule for DOC determination. Ampoules containing POC were then purged, sealed, and boiled at 100°C for 4 h and analyzed in a manner identical to DOC-containing ampoules. A standard CO_2 conversion graph was constructed by plotting the integrated peak area versus CO_2 content resulting from the analysis of increasing amounts of potassium bithallate solution containing 3, 5, 10, 20, 30, 50 and 100 µgC/ampoule. Sample organic carbon concentrations were determined by comparing the integrated peak area of the ampoule to the standard graph. Appropriate reagent blank values were determined at least once for every set of samples of both DOC and POC. Particulate organic carbon reagents blanks were determined by placing unused precombusted filters in ampoules followed by identical treatment used for sample POC ampules.

4. Dissolved Low Molecular Weight Hydrocarbons. In the laboratory, dissolved light hydrocarbons were stripped from the sea water by applying a

vacuum and the gases were analyzed by flame ionization gas chromatography. These techniques were similar to those described in Swinnerton and Tinnen (1957) and McAuliffe (1971). The methods employed for the continuous ("sniffing") measurement of these hydrocarbons in sea water were similar to those described by Brooks and Sackett (1973).

5. Dissolved High Molecular Weight Hydrocarbons. The filtered sea water (40 ℓ) was acidified to pH 2 with concentrated HCl and extracted with $CHCl_3$ in a separatory funnel or liquid-liquid extractor. Extracts from each sample were combined and reduced to small volume for storage in a freezer. The extract was taken to dryness, under nitrogen, immediately before saponification. Saponification, column chromatography, and gas chromatographic analysis were conducted on the extracts in a manner similar to that described for zooplankton hydrocarbon analysis.

6. Particulate Hydrocarbons. The filters were thawed and extracted three times with $CHCl_3$/MeOH (1:1) under sonication. The combined extracts were taken to a small volume in a rotary evaporator, frozen for storage, saponified, separated on columns, and analyzed as described under zooplankton hydrocarbon analysis with the exception of using packed columns.

7. Hydrocarbons in Zooplankton. Samples were thawed and, under dissecting microscope, tar balls and other non-plankton materials were removed, and the tar balls saved for hydrocarbon analysis. The plankton samples were dried at 60°C in tared containers to obtain dry weights, and then homogenized in $CHCl_3$/MeOH-KOH (1:1) under ultrasonics and the extractions repeated until the extracts were colorless. The extracts were taken to small volumes by rotary evaporation under pre-purified nitrogen at room temperature and stored in a freezer.

Immediately before saponification, extracts were taken to dryness under purified nitrogen at room temperature. They were then saponified overnight in 10 mℓ of 0.5 N KOH in MeOH. Equal volumes of water were added to both the saponifiable and non-saponifiable fractions followed by extraction into hexane. These were then diluted to known volume and aliquots taken for weight determinations. The volume was then reduced to 1 mℓ under nitrogen for column chromatography. A column of 1:5 (v/v) microneutral alumina overlying silica gel was washed with 3 column volumes of hexane. The samples were charged into the column, allowed to percolate in, and then rinsed into the column with several small volume rinses of hexane, allowing each to percolate into the column. Alphatic hydrocarbons were eluted with three column-volumes of hexane, and aromatics eluted with three volumes of benzene. Extracts were reduced to small volume in preweighed containers and analyzed by gas chromatography.

All GC analysis was performed on a Hewlett Packard 5830A gas chromatograph. Analysis of the samples was done with a support coated open tubular (SCOT) capillary volume, using diethylene glycol succinate as a liquid phase. Nitrogen was used as a carrier gas. The splitter was adjusted for a 3:1 split ratio giving 5 mℓ/min through the column. The column oven was temperature programmed from 80°C to 190°C at 3°C/min of rise time with an isothermal hold at 190°C for 140 min. Injection temperature was 250°C and the flame ionization detector was operated at 350°C. Chart speed was 0.25 cm/min with an attenuation of 24.

Retention indices were computed based on known standards. Extracts were reduced to dryness under nitrogen and weighed.

8. Suspended Matter and Trace Metals. The samples of suspended particulate matter collected at each hydrographic station were processed and analyzed as follows:

The filter pads were removed in a clean bench from the inline filter holders and placed in polypropylene jars containing silica gel. After drying for 48 h, the filters were weighed for the calculation of the mass of suspended particulate matter.

After weighing, the filters were sealed in all-Teflon bombs and digested with aqua regia and HF using a modification of the methods specified in Bernas (1968) and Buckley and Granston (1972). So that signal to noise ratios could be maximized all acids used in the dissolution of the suspended material were of Ultrux grade or redistilled reagent grade acids from a sub-boiling silica still.

The digested materials were transferred from the all-Teflon bomb to a volumetric flask and diluted to volume with double deionized, redistilled water. This solution was then analyzed for cadmium, chromium, copper, iron, lead, nickel, and vanadium on a Perkin-Elmer 503 atomic absorption spectrophotometer equipped with a Model 2100 heated graphite furnace and deuterium background corrector.

9. Dissolved Trace Metals. The elements cadmium, copper, iron, lead, nickel and vanadium were extracted from the sea water samples by methyl ethyl isobutyl ketone extraction after complexation with ammonium pyrollidine dithiocarbonate. After extraction the trace metals were reverted back to aqueous solution by evaporating the ketone to dryness and ashing the residue with a few millilitres of silica redistilled nitric acid.

The resulting aqueous solution was made up to a volume of 5 mℓ and analysis was carried out by injections of this solution into the heated graphite atomizer (Segar, 1971, 1973, 1974) and subsequent flameless atomic absorption spectrophotometry. The analysis was carried out using a standard additions method similar to that used by Brewer et al. (1969). Water samples were also analyzed for some of these metals by direct injection analysis using the recently developed HGA 2100 heated graphite atomizer (Segar and Ediger, 1975).

Chromium was determined in the sea water samples by direct injection into the HGA 2100 and also by flameless atomic absorption spectorphotometry following concentration by extraction of its acetylacetonate into methyl isobutyl ketone (Chan et al., 1968).

The samples were analyzed for barium by direct injection of 50 mℓ volumes of sea water into the graphite atomizer and selective volatilization analysis using standard additions for calibrations. A number of the same samples were reanalyzed by ion exchange concentration of the barium (Bowen, 1956) and flameless atomic absorption.

10. Trace Metals in Zooplankton. The dried samples were ground in an acid-rinsed procelain mortar and pestle; aliquots of the homogenate were trans-

ferred in clean bench to an all-Teflon bomb. Ten millilitres of redistilled reagent grade 70% nitric acid were added and the bomb sealed. The bomb was transferred to a water bath and digested at 90°C for 58 h. The solution was trasferred to a polypropylene volumetric flask and diluted to volume using double deionized redistilled water. The solution was analyzed for cadmium, chromium, copper, iron, lead, nickel, and vanadium in a Perkin-Elmer Model 503 atomic absorption spectrophotometer equipped with a Model 2100 heated graphite furnace and deuterium background corrector.

B. Biology.

1. ATP. The ATP content of the samples was assayed by (1) extracting the ATP (as discussed previously) and (2) measuring the emission of light brought about by the reaction of ATP luciferin-luciferase according to the method of Strehler and Totter (1952). The assay procedure is summarized below:

Lyophilized extracts of firefly lanterns were kept frozen until used. As stated previously each vial was reconstituted 24 h before use and aged to reduce the background count rate of the preparation. Approximately forth assays could be performed per vial of FLE-50, and the enzyme preparation did not lose activity during the normal working day.

ATP standard curves were prepared for each enzyme batch. A standard solution, containing 2,000 mg/ℓ ATP, was divided into 10 mℓ vials, sealed, and frozen until needed. One vial of the concentrated standard was thawed and diluted with TRIS buffer (0.25 M, pH 7.75) to give final ATP concentrations of 0.3, 0.5, 0.7, 1, 2, 3, 5, 7, 10, 15, and 20 µg/ℓ to prepare a standard curve. Each of these dilutions was assayed by adding 1 mℓ of the solution, 0.5 mℓ TRIS and 0.5 mℓ enzyme preparation to a scintillation vial and measuring the light emission. A curve of best fit was drawn through the data points, and the count rate at 60 s plotted against ATP concentration on a log-log scale to obtain the standard curve.

The luminescent decay of the ATP-enzyme reaction mixture was measured using a Nuclear Chicago Model 4534 educational liquid scintillation counter interfaced with a Nuclear Data 110 multichannel analyzer. The scintillation counter was not equipped to run repetitive counts and the multichannel analyzer was used to provide this function. The N.D. 110 was operated so that each of the 128 channels was open for data acquisition sequentially for a predetermined counting period over the range 1 ms to 10 s/chn.

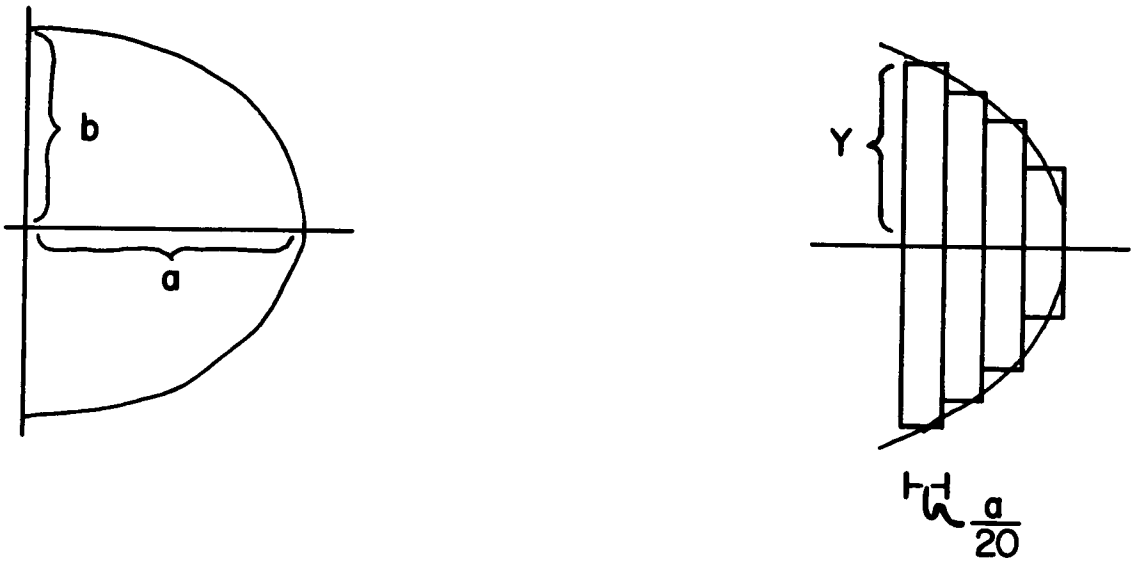
2. Phytoplankton. Phytoplankton identifications, cell counts and cell volume measurement, were made by allowing aliquots of the net fraction of the phytoplankton to settle in combination chambers for 48 h, then removing the cylinders and making counts on the plate chamber using a Zeiss Invertoscope D equipped with phase contract. The filter pads bearing the nannoplankton were cleared and mounted. Counts were made using a Zeiss Photomicroscope II equipped with phase contract and Nomarski Differential Interference Contrast. Identification was carried as far as possible; however, since the nannoplankton are not well described, only rarely was identification carried past the genus level.

The procedures used in calculating the volumes for the phytoplankton were those suggested by Mullin, Sloane and Eppley (1966). Cell volume was computed from

the linear dimensions of the cells, assuming the cells to be spherical, cylindrical, or ellipsoidal in shape. In the case of spherical cells the following calculation was used; Volume = $4/3\ r^3$ where r = radius. For those assumed to be cylindrical; Volume = $r^2h\pi$ where r = radius; h = height. For those assumed to be ellipsoidal; and integration of the ellipsoidal shape approximated by dividing one-half that shape into twenty cylinders and summing the volume of those cylinders and doubling for an approximation of the ellipsoidal volume. The size of the cylinders was determined for the following equation:

$$y = \left(b^2 - \frac{b^2x^2}{a^2}\right)^{\frac{1}{2}}$$

where x increases from 0 to a by a/20 units, a/20 = height of cylinder, and y = radius of cylinders.



Cell volumes were converted to cell carbon with the formula given by Mullin, Sloane and Eppley (1966).

3. Chlorophyll. Frozen filters were cut into small pieces and homogenized with 90% acetone in a Sorvall homogenizer (cup immersed in an ice bath) before being processed with the spectrophometric method given in Strickland and Parsons (1972) using the SCOR-UNESCO wave lengths.

4. Zooplankton Analysis. Each sample was split using a Folsom plankton splitter; one-half was archived and the other half split repeatedly until a subsample containing at least 200 adult copepods was obtained. A technique was used by which the analyst selected the split to be saved from each operation of the Folsom Splitter by means of a random number table. Counting was done in a channeled counting tray.

The results of each sample count were recorded on a sheet which doubled as a coding sheet for computer card punching. Individual analysts were tested for accuracy in identifying organisms during the sample processing.

The counted portion of each sample was gently washed with distilled water and placed in a labeled, pre-weighed aluminum weighing boat with a small amount of distilled water. These were then dried at 60°C until repetitive weighings remained constant. The sample and boat were then weighed to determine biomass. All samples were processed simultaneously in drying ovens. Series weighings were made to adjust for hygroscopic differences.

Table 6 Chief geological parameters of bottom (box core) sediments (from Doyle et al.) Clays are defined as <.004 mm; silt is 0.004 - .63 mm; sand is 0.65 - 2 mm; coarse fraction is >2 mm. Size data based on sieve and pipette analysis.

Sta.	Depth (m)	Coarse Frac. (%)	Sand (%)	Silt (%)	Clay (%)	CO_2(%) as $CaCO_3$	Lithologic description
			Area I				
55A	44	1.0	38	55	6.1	86	Coarse calcareous sand, shell hash, coral; calcareous silt, inhomogen. substations.
56A	37	.1	62	31	6.5	83	Calcareous silt and sand with shell fragments
57A	38	.7	69	28	2.3	87	Fine calcareous sand, shell fragments, grass and reddish branchlets mud burrow
58A	43	-	-	-	-	high	Very coarse carbonate rubble; sponge
59A	35	-	-	-	-	high	Carbonate bedrock; no sample
60A	31	.3	62	34	3.7	82	Calcareous sand and silt; sparse shell grass; black particles
61A	33	.8	62	33	3.8	73	Calcareous sand and mud, grass tubes
62A	34	1.5	92	2.5	3.4	89	Very coarse calcareous sand and rubble, pink coral and black particles
63A	30	1.0	46	45	9.3	75	Calcareous sandy silt; shell and black particles
64A	30	.3	50	45	4.6	84	Well sorted fine calcareous sand and silt; shell and black particles, mud tubes
65A	42	.1	57	40	2.1	80	Fine-medium calcareous sand
			Area II				
42A	37	9.7	67	18.6	4.4	82	Calcareous sand and fine silt, small shell debris-filled burrows
43A	45	-	-	-	-	high	Coarse shell and carbonate rock rubble
44A	53	4.3	92	3.3		82	Very coarse calc.and shell rubble, black material and grass tubes
45A	44	1.4	85	8.1	5.3	73	Calcareous sand with high percent black material
46A	37	1.9	86	10	2.3	52	Fine-medium calcareous sand
47A	36	12	85	2.9		93	Shell hash with worm holes, sponges and seaweed, algae
48A	40	1.7	63	34	2.0	82	Calcareous sand with shell and black particles
49A	42	-	-	-	-	high	Top surface clay; fine to coarse sand of carbonate material with black particles
50A	48	1.4	91	7.3		77.4	Coarse calcareous sand and rubble, grass fragments; layered
51A	27	-	-	-	-	high	
52A	54	3.4	49	40.9	6.2	87	Fine calcareous mud with shell and black particles
53A	37	1.8	62	13.2	1.4	88	Medium-coarse calcareous sand with 2 cm fine carbonate on top with shell hash, worm burrows
54A	34	-	-	-	-	-	

Table 6 contd.

Sta.	Depth (m)	Coarse Frac. (%)	Sand (%)	Silt (%)	Clay (%)	CO_2 (%) as $CaCO_3$	Lithologic description
			Area III				
21A	51	9.1	58	31	1.7	76	Calcareous sand, coarse
22A	82	7.6	74	16	3.1	83	Calcareous sand, v. coarse, shell debris
23A	64	.2	36	59	5.1	63	Sandy, calcareous mud, tubes on surface
24A	64	.2	27	67	5.7	68	Fine carbonate mud, burrowed
25A	80	.3	40	51	9.1	73	Sandy carbonate mud
26A	57	2.0	73	18	7.0	56	Medium calcareous sand with appreciable quartz silt
27C	68	.2	34	45	21	67	Sandy carbonate mud with quartz
28A	66	7.1	89	3.2		82	Silt and clay, coarse calcareous sand
29A	46	1.7	80	12	6.1	65	Calcareous sand, fine-medium with some quartz admixture
30A	48	2.4	93	4.1		76	Well-sorted calcareous sand -shell hash with quartz
31A	41	5.9	89	4.5		85	Coarse calcareous sand-shell hash
32C	42	-	-	-	-	-	Coarse calcareous sand-shell hash
33A	69	15	80	5.2		80	Layered coarse calcareous sand-shell hash
34A	35	39	59	1.9		80	Coarse shell hash and calcareous algae
35A	36	3.0	94	2.6		70	Coarse calcareous sand-shell hash with quartz sand-clay admixture of calcareous red algae
36A	40	4.3	93	2.5		57	Shell hash in cone-shaped holes; calc. algae
37A	40	9.4	87	3.8		65	Coarse calcareous sand with shell hash
38A	38	6.1	83	5.9	4.7	62	Graded (inverse) calcareous sand, shell fragments, polychaete tubes
39A	36	3.1	93	3.3		24	Coarse calcareous sand with larger fragments
40A	36	14.9	83	1.7		34	Coarse quartz sand with carbonate fragments
41A	31	.4	94	4.5	1.0	14.2	Medium quartz sand with shell hash, some calcareous algae

Table 6 contd.

Sta.	Depth (m)	Coarse Frac. (%)	Sand (%)	Silt (%)	Clay (%)	CO_2(%) as $CaCO_3$	Lithologic description
			Area IV				
11A	35	4.1	96	2		13	Brown medium-coarse sand, lower layers include shell hash
12A	36	17	78	3.6		34	Coarse sand and abundant shell frags
13A	35	.5	97	1.9		3.2	Fine-medium, well-sorted sand
14A	35	.9	97	2.1		4.9	" " " " "
15A	45	.1	96	3.4		6.9	Medium sand, sparse shell debris
16A	36	.3	97	1.9		3.5	Fine sand, well sorted, sparse shell darker bioturbated (?) zones
17A	66	11	85	3.7		84	V. coarse, calc. sand, some quartz sand.
18A	82	8.0	85	7.2		84	V. coarse,quartz*calc. sand, mud-filled burrows; sds. well-rounded
19A	82	9.2	72	5.8	3.3	45	V. coarse quartz sand and calc. sand occ. muddy inclusions.
20A	85	2.9	91	5.7		83	V. coarse calc. sand, worm tubes on surface only.
			Area V				
1A	13	.2	12	53	35	7.4	Soft clayey silt (quartz), minor shell, burrowed
2A	24	2	14	47	33	18	Soft clayey silt (quartz) with shell, burrowed near top
3A	29	.1	20	51	28	16	Soft brnsh. gray clayey silt, streaked with black material and sand, burrowed
4A	29	<.1	12	73	15	16	Clayey shelly silt with black organic matter and sand streaks, burrowed
5A	31	.1	25	58	17	19	Brownish silty clay, black streaks and burrows
6A	29	1.4	61	25	12	19	Brownish silty sand with appreciable clay; burrows and shells
7A	32	.6	31	20.2	9.0	17	Fine silty sand, clayey, shelly surface burrow only
8A	24	.6	89	5.0	5.1	8.0	Fine gray sand, trails and tubes on top.
9A	31	2.1	74	6.6	5.6	14	Med-fine gray sand, shelly
10A	35	2.2	43	11	2.7	21	Varicolored sand, shelly, some burrows

*quartz. = quartzose

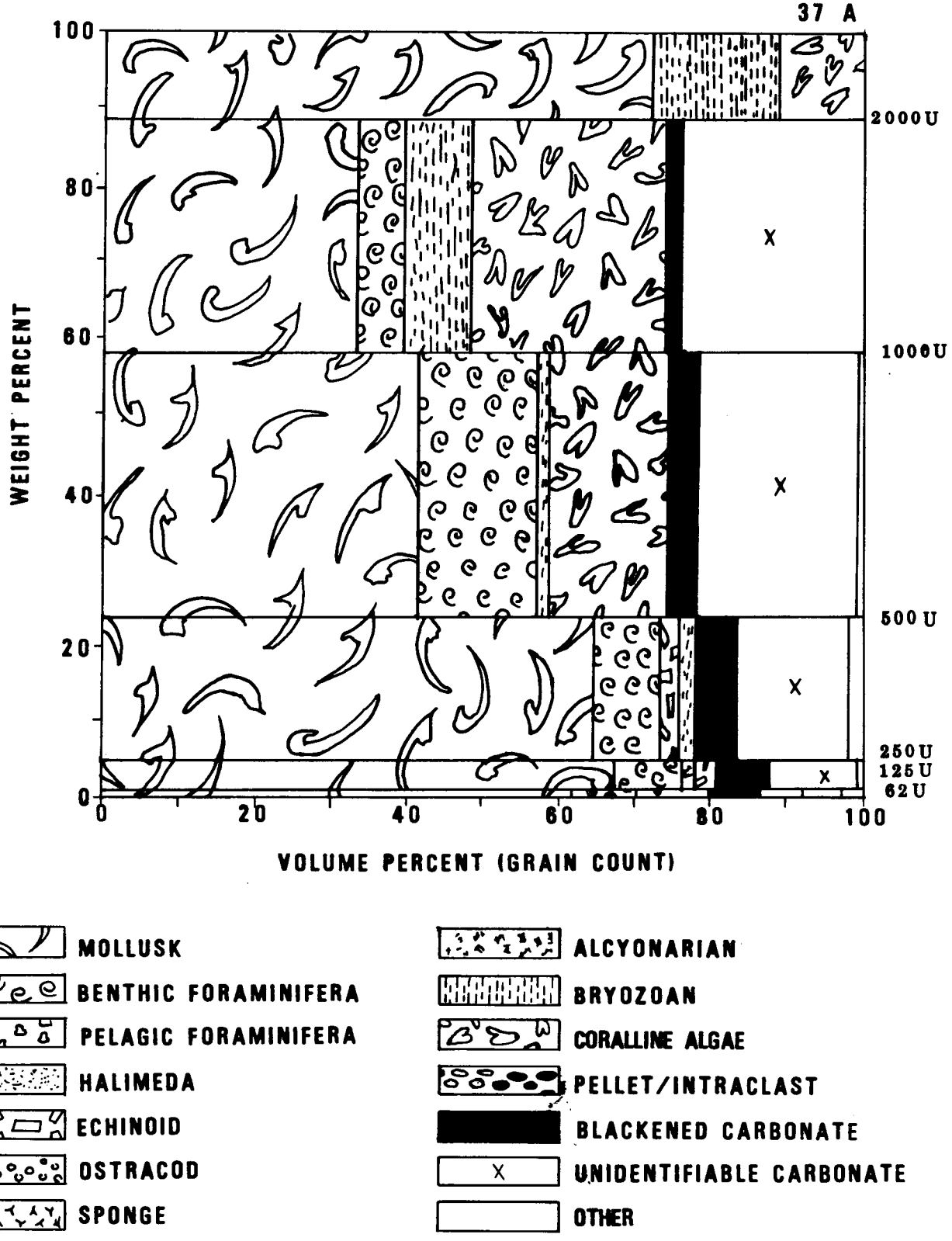
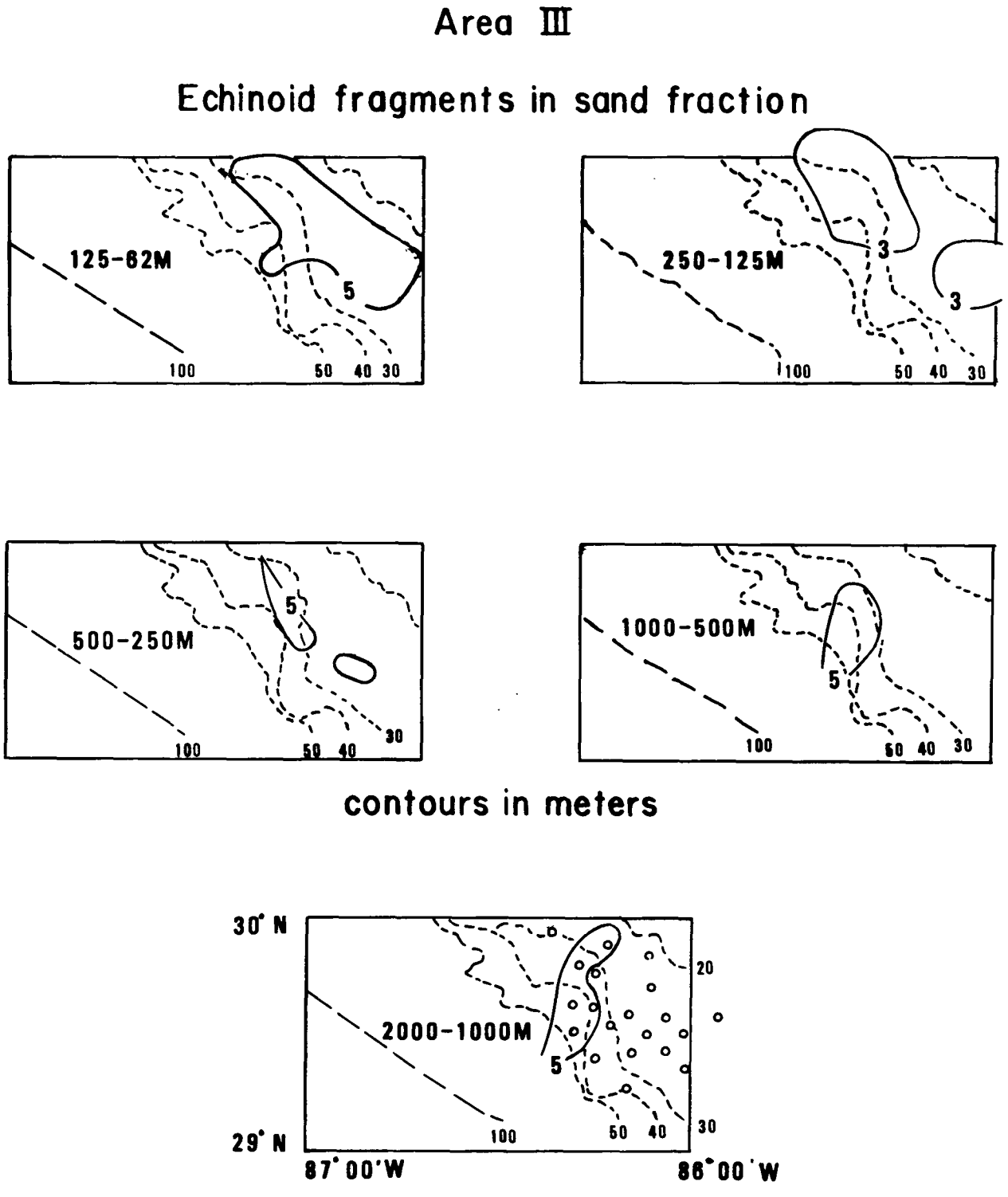


Figure 2. Graphic display of skeletal particle distribution, Area III, Station 37 (Wanless and Dravies).

Figure 3. Distribution of echinoid fragments in sand fractions (Wanless & Dravies)



RESULTS AND DISCUSSION

I. Sea Floor.

A. Geology.

1. Lithology. Major geological parameters are shown in Table 6. These data indicate the following features. Areas I and II are dominated by carbonates, the greater part being present in sand and silt-size skeletal debris. Clay-size matter (<0.04 mm) is less than 10% and often below 4%. This paucity of clay-sized materials accounts in part for the clarity of the water, since particulate matter, once stirred by currents, will normally settly quickly.

These sites include a great variety of carbonate skeletal matter (Wanless and Davies, CT4-11). The dominant carbonate-depositing organisms, with the exception of the high relief areas of the Florida Middle Ground, contributing to skeletal debris over these areas, as well as Area III are molluscan shells, followed by foraminifera, bryozoa and echinoids, and worm encrustations and remains. The Florida Middle Ground contains large accumulations of coral-algal debris, derived from breaddown of reef products. Calcareous algae typically encrust ridge prominences. Carbonate studies were not performed in Areas IV and V.

A sample of the skeletal description is shown in Fig. 2 for Station 37, in Area III (Wanless and Davies, CT4-11). The diagram shows that in the greater than 2000 μm fraction more than 70% of the fragments are of molluscan origin, the remaining material being about 15% bryozoans and 10% coralline algae. Benthic foraminifera reach their greatest extent in the 500 - 1000 μm fraction. In general, sizes greater than 250 μm were almost exclusively carbonate.

An interesting petrographic observation relates to the findings that weathering and bio-corrosion of skeletal particles signifies appreciable reworking and exposure of materials and attack of particles on exposed surfaces. This was most evident in the Florida Middle Ground area. In contrast, rippled bottoms off Clearwater were frequently characterized by clear, uncorroded grains.

In Area III carbonate is still predominant, but large quantities of quartz silt and sand occur, especially in the northeastern part of the area. The petrographic studies in some cases also shed light on the degree of dispersal of organism remains by currents after death. For example, Fig. 3 (redrawn from Wanless and Davies, CT4-11) reveals that the coarser echinoid fragments were deposited in a pattern transverse to depth contours in Area III. As finer (and more transportable) sizes are reached, the pattern shifts to a longshore or contour-parallel pattern. Such patterns are useful since they place in perspective integrated accumulations of organisms over a longer period of time, in contrast to the variable occurrence that may be present for an samplings of live materials. However, such studies are complicated by the fact that it is not always possible to ascertain the time period over which the accumulations have occurred.

Area IV shows a marked change in lithologic type. The area is divided into a southeastern carbonate facies similar to that of Area III, and a northwestern quartz sand facies with limited caly and silt. This area is clearly affected

by detrital material from the Mississippi River, and begins to show significant increases in bottom turbidity (see photograph, Fig. 4 g, following section), and suspended matter (Betzer, CT4-11). Some of the coarser carbonate deposits show evidences of worm borings in the upper portions of the sediment, whereas the quartz sand sediments tend to be bored to greater depth.

Area V is dominated by silts and sands, with appreciable clays. Black streaks, presumably of organic matter, are common, as is extensive worm burrowing. In spite of this, the organic carbon content is surprisingly low, as given in Table 7.

Table 7. Carbonate and organic carbon content in dry sediments, by area. From Lytle and Lytle (CT 4-11) except as noted.

Lease area	C_{org}(%)1	CO_3 = as $CaCO_3$(%)
I	3.60	86.4
II	2.08	85.9
III	1.42	71.0
IV	0.77	56.4
V	0.58	15.52

1. On carbonate-free basis.
2. From Doyle, et al. (CT4-11).

Clay minerals are shown in Table 8 (Huang, CT4-11). These data are in agreement with clay mineral assemblages reported from bottom sediments and suspended matter in the northeastern Gulf of Mexico (Griffin, 1962; Manheim et al., 1972). A montmorillonite-kaolinite suite is being contributed by the Mississippi River. Toward the Apalachicola River Kaolinite dominance increases, whereas southward (Areas I and II) montmorillonite virtually disappears in favor of kaolinite, with subsidiary concentrations of chlorite and illite.

One should bear in mind that in the latter areas these minerals do not make up a significant proportion of the bulk sediment, since the silicate clay fraction is very small. However, these data are useful both to identify sources of mineral detritus and establish baseline concentrations for the sediment. For example discharged drilling muds in quantities of a few to 30 tonnes per deep hole, should these not be retained at the drill site and dumped elsewhere, will probably have little significance for clay-rich areas such as V, and might be very difficult to detect. In Areas I and II, on the other hand, the montmorillonite-rich drilling muds would contract sharply with local bottoms and might be readily detected. It was earlier feared that drilling mud might be an ecological hazard in the delicate Middle Ground reef sites. Although no documentation on this question is apparently available as yet, on site observations during drilling on Area II have as yet not noted significant accumulations of mud or deleterious effects on local organisms (D. Beaumariage, personal communication).

Table 8. Clay minerals as a percent of total clay mineral fraction. Range shown excludes a few fringe or aberrant values. (Huang, CT4-11).

Study Area	Chlorite	Illite	Kaolinite	Montmorillonite
I	21-33	3-10	56-72	Trace-6
II	13-30	6-16	60-75	Trace-10
III	10-19	5-12	50-76	15-28
IV	Trace	10-20	16-45	50-81
V	Trace-3	5-7	50-76	66-87

Strength of sediments (vane-shear measurements) as determined on the box-cored samples by shipboard geologist (students of W. R. Bryant contributing to studies of Doyle, CT4-11). These data vary greatly from minimal strength to over 8800 kg/m^2 (1800 lb/ft^2). The highest rigidities were observed in shell rubble, which also presented difficulties in penetrating core with the vane. The lowest strengths were reported in Area I (a few hundred to a few thousand kg/m^2 (a few tens to a few 100's lb/ft^2)) with remaining areas fluctuating widely in the thousands of kg/m^2 (hundreds of lb/ft^2). It is evident that poor sorting, especially box-like frameworks of coarse skeletal debris, mixed with finer sediment, contributes to sediment rigidity, whereas relatively homogenous, finer silts and carbonate muds are minimally rigid.

2. Remote Bottom Photography. Sixty-five remote bottom photography stations were occupied, at each of the master stations between May 16 and June 20, in conjunction with box coring. And EG&G Model 200 camera and Model 210A 100 w·s strobe were triggered by a lead weight connected to a tilt switch. The distance from bottom was about 2 m, giving bottom coverage of about 2.5 m^2. A total of 648 exposures (615 black and white and 33 color) are available in 35 mm format, and have been rated in terms of photographic visual quality. Nearly all C (poor) negatives (92%) came from Area V, and appear to be due to nepheloid layers or turbidity near bottom, and zero visibility after diver perturbation. According to suspended matter-Secchi disk plots in Manheim et al. (1972), such conditions imply particulate concentrations upwards of 100 mg/ℓ. In the remainder of the areas, photographic quality is generally good.

Fig. 4. Bottom Photographs (Pyle). See text for explanations. All photographs, except 4f, depict approximately 2.5 m^2 of bottom.

a. Area I, Station 56
b. Area I, Station 57
c. Area II, Station 51
d. Area III, Station 32
e. Area III, Station 27
f. Area IV, Station 12B
g. Area V, Station 10

Fig. 4a. Area I. Station 56.

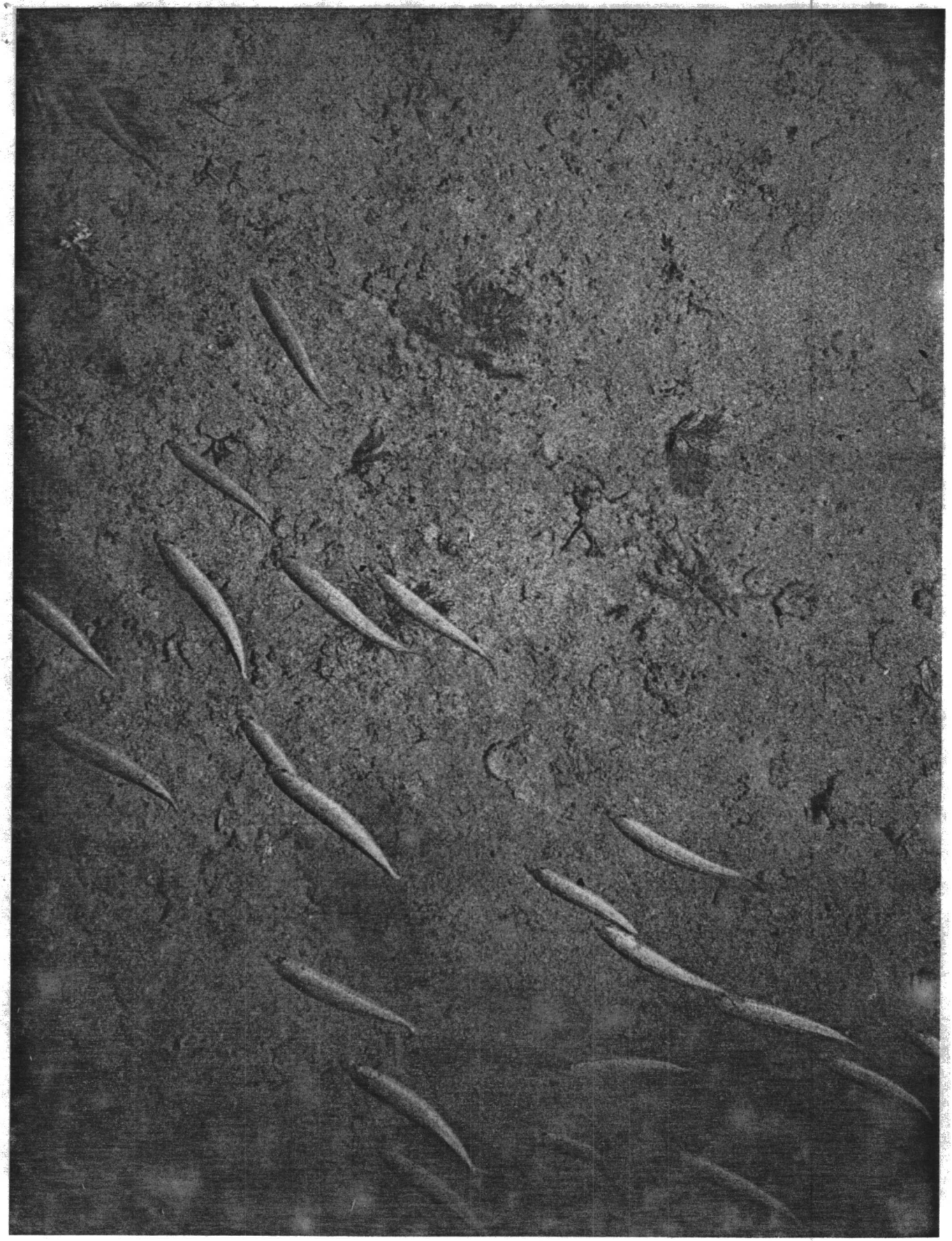


Fig. 4b. Area I. Station 57.

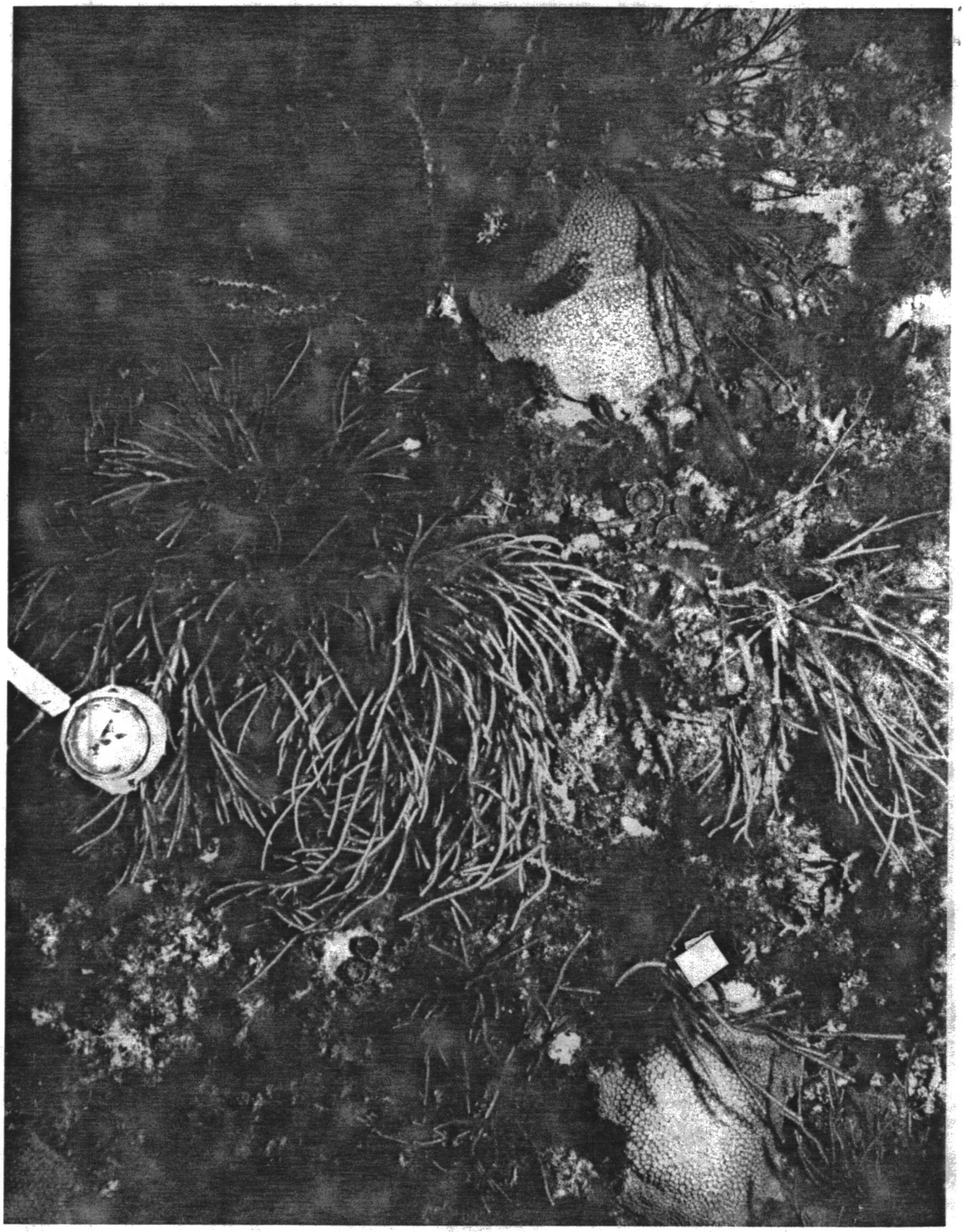


Fig. 4c. Area II. Station 51.

Fig. 4d. Area III. Station 32.

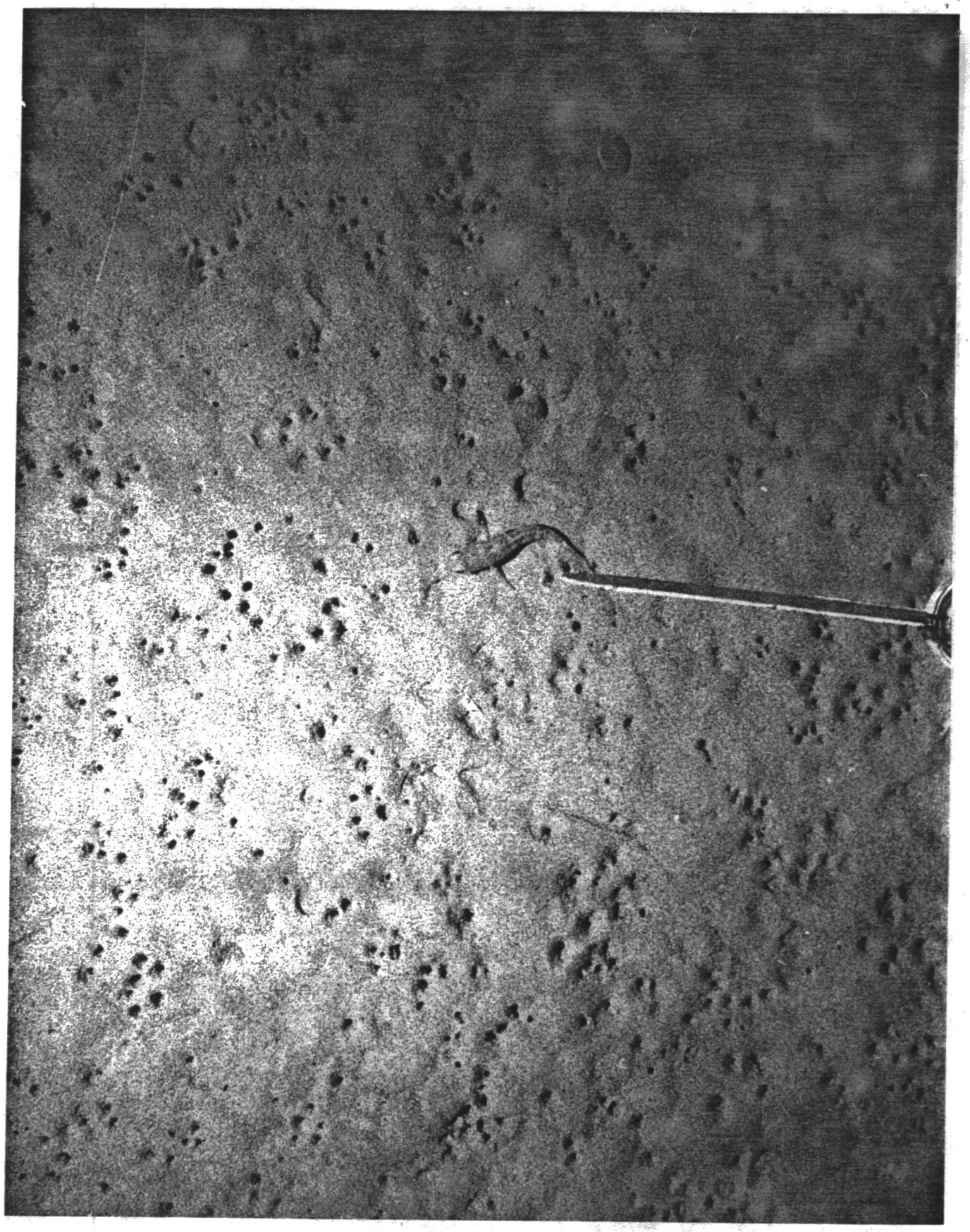
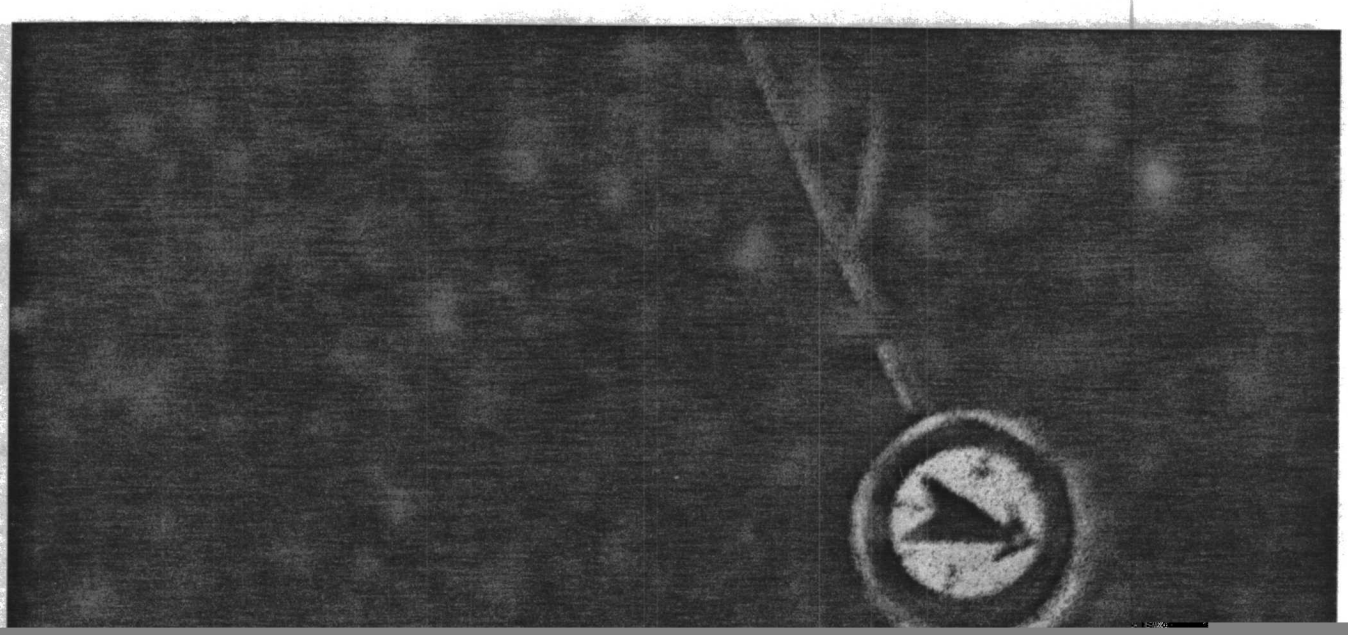


Fig. 4e. Area III. Station 27.



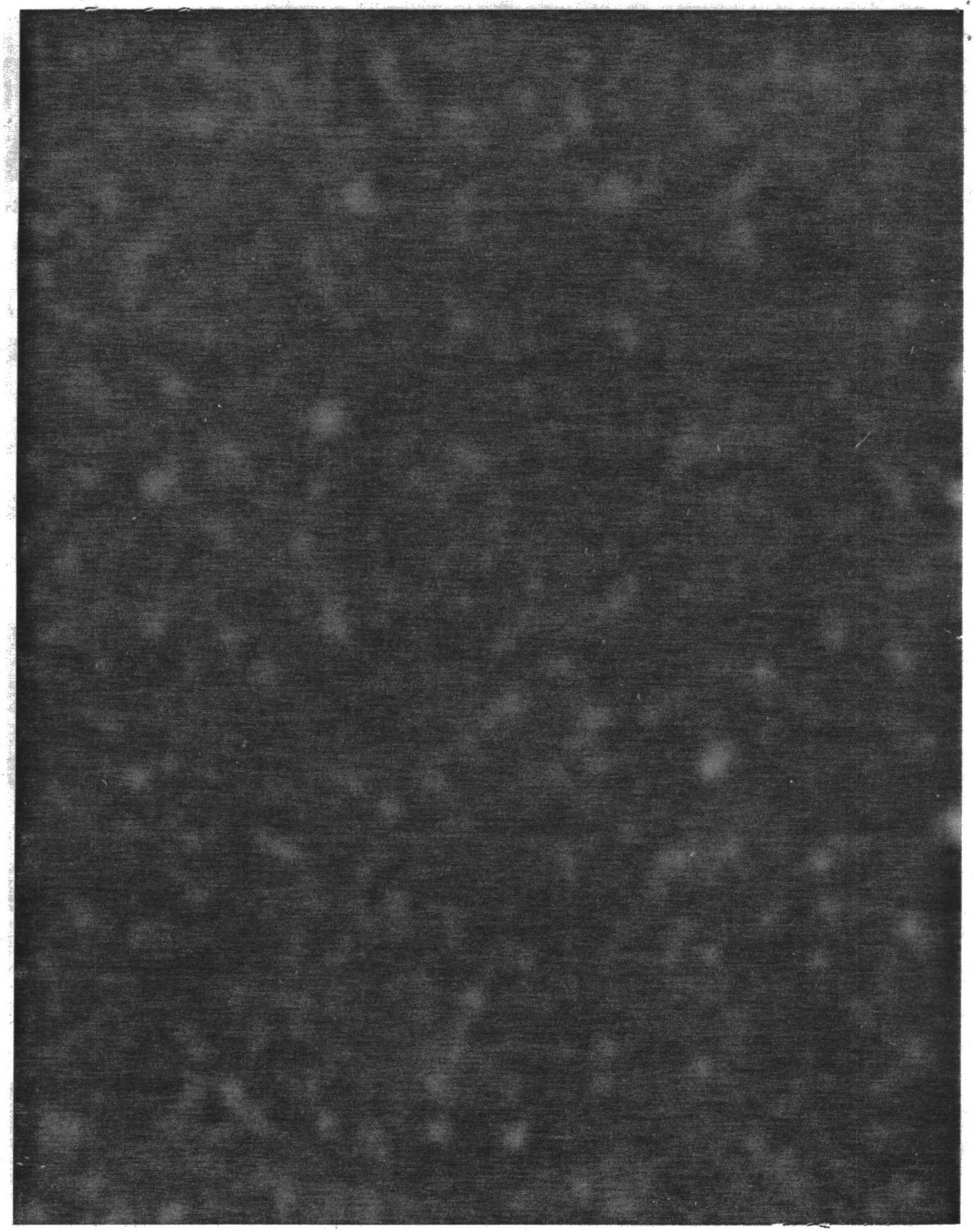


Fig. 4g. Area V. Station 10.

Though the contract called only for archiving of negative materials, a few samples of bottom photo coverage for the lease tracts are offered here to reveal some of the significant features in the areas (Fig. 4 a-g).

The marked change in visibility conditions on moving from Area V to IV and III are observable in Figs. 4 e-g. Borings of the kind depicted in many of the photographs were found filled with shell hash in some box cores. Evidences of fish and tracks and trails were abundant.

Although a dramatic increase in benthic fauna and flora is depicted in Site 51, on the Middle Ground, it must be remembered that this area was also subject to rapid changes in substrate, with bottom types more resembling those of Areas I and III occurring in patches of lower relief. Except in the poor visibility areas, evidences of boring and reworking were ubiquitous in the photographs, corresponding with observations on the cores, and the findings of the polychaete and other specialists.

B. Biology.

1. Total Living Biomass - ATP. The ATP technique provides a measure of total living biomass, since ATP is present in living protoplasm but is quickly dissipated on tissue death. That high-energy organophosphate compounds play a prime role in energy transfer in all metabolic processes, was already observed systematically by Harden and Young in 1905. However, analytical studies of these compounds to characterize marine biosystems have been employed only very recently, and the present studies are among the first to be linked with broad surveys of marine parameters.

In practice, the bulk of living biomass may frequently lie in bacteria and allied micro-organisms with a sibsidiary quantity contributed by zooplankton, phytoplankton, micro-infauna, such as foraminifera and the like. Unlike virtually all other organisms, bacteria are not only present in aerobic systems (respiration requirement) but can occur in appreciable quantities in anaerobic (anoxic) conditions, owing to the activities of sulfate-reducing and fermenting bacteria. Strictly anoxic conditions in near-surface surficial sediments are likely to be present in the present investigated areas chiefly in the high-organic, high-sedimentation rate areas east of the Mississippi Delta (Areas V and in part, IV). Nevertheless, one must recognize that whereas other organisms may be concentrated in the uppermost portions of box cores, or on sediment and rock surfaces, bacteria, and hence ATP, may not only decrease, but actually increase with depth. This effect must be taken into account when relating ATP measurements to surface and near-surface productivity.

The values in Table 9 show regional means for both the water column and sediment measurements. La Rock (CT4-11) notes that ATP surface values for Areas I, II, and III were equivalent to twice concentrations found elsewhere in the Gulf of Mexico, the Florida Straits, and the Caribbean. The normal range of ATP concentrations for surface samples in the open ocean range between 80 and 120 ng/ℓ (.08 - .12 µg/ℓ). Variations with depth for all tracts appeared to be irregular, with no consistent change with depth. The fluctuations in concentrations for Areas IV and V in the water column were extremely great, and the very marked enrichments are interpreted as being due to high nutrient and organic content of

water, coupled with concentrations of micro-organisms on the suspended particulate material. In contrast, the relatively low sediment ATP in Areas IV and V reflected the generally impoverished benthic fauna.

Table 9. Adenosine triphosphate concentrations (ATP). Compiled from data of La Rock (CT4-11). Variations of the means for stations are given as standard deviations.

Area	Sediment Values		Water Columns	Stations
	Wet Weight	Dry Weight		
	ppb	ppb	g/ℓ	
I	285 ± 39	339 ± 32	.16 ± .08	1, 2, 3
II	601 ± 117	764 ± 143	.22 ± .09	4, 5, 6
III	537 ± 71	699 ± 79	.15 ± .04	7, 8, 9
IV	314 ± 27	359 ± 46	1.4 ± .9	10, 11, 12
V	206 ± 46	343 ± 70	4.6 ± 4.6	13, 14, 15
Control Station (Outside V-IV)	-	-	1.2 ± 1.1	C-4

2. Polychaetous annelids. Polychaete worms were found in all areas of the survey, including Areas IV and V. Here some 190 species were identified, comprising 41 families, and 10,020 individuals were catalogued. Two families, Scalibregmidae and Sphaerodiriidae, have not been previously reported from the Gulf of Mexico. Since some closely related species and more obscure forms require time-consuming analysis for exact identification, some further new forms may be turned up at a later date.

The major species (defined as making up 5% or more of the sample) are given in Table 10. Although some ubiquitous forms (e.g., Lumbrineris parvipedata and Paraprionospio pinnata) are present, differences in assemblages can be discerned. Stations 1-5 are populated by species typical of fine sediments rich in organic matter, particularly the maldanid species Asychis carolinae and Clymenella torquata, and the nereid Ceratonereis tridentata. In general, this group of stations exhibits low species diversity and abundance.

A highly diverse and abundant assemblage is present in Stations 6-16, typical for sand-silt-shell substrates, whereas a third association occurs in the shell-hash sediments at Stations 17-20 (Area IV).

The relationship of sampling strategy to community identification is shown in Figs. 5 and 6, depicting a plot of sample area against species total. The figure of 0.48 m^2 approximates the total area of 8 box cores less subsidiary samples. In Fig. 5, Station 1, samples from only one box core would have yielded only a third of the total species recovered. Yet further box cores would not have added significantly to the total. In Fig. 6, an extremely diverse assemblage (Station 11) is still increasing at the tenth core, whereas at Station 17 the characteristic change in slope toward the asymptote is already marked.

Table 10 . "Dominant Taxa" (Polychaetes) defined as those species representing at least five percent of total individuals in MAFLA Areas I and II.

Dominant Taxon	Stations																						
	42	43	44	45	46	47	48	49	50	51	52	53	54	55	56	57	58	59	60	61	62	63	64	65
Aglaophamus verrilli	X			X	X						X	X			X									
Aedicira belgicu	X			X							X				X	X			X	X		X	X	X
Pareulepis sp.																							X	
Prionospio cirrifera				X															X				X	X
Cossura delta														X	X									
Lumbrineris parvapedata																			X	X		X		X
Notomastus latericeus	X			X							X			X		X				X				X
Magelona n. calitornica																X			X					
Glycera tenuis									X															
Goniada teres			X		X				X				X								X			
Haplosyllis spongicola		X				X		X		X							X	X						
Eunice vittata			X		X	X			X				X					X			X			
Eunice rubra		X						X									X	X						
Kinberginereis inermis	X						X					X		X										
Jasmineira elegans			X		X				X			X				X				X	X			
Paraonis gracilis	X																							
Spiophanes bombyx	X																				X			
Anaitides madeirensis		X						X									X							
Exogone sp.			X																					
Prionospio paucibranchiata				X																				
Harmothoe bobo								X										X						
Typosyllis alternata								X		X								X						
Streblosoma hartmanae								X										X						
Prionospio pinnata											X													
Longosoma prionota											X													
Lysidice ninetta													X											
Sigambra tentaculata														X	X	X				X			X	
Maldane sarsi															X									
Cirratulus filiformis																X								
Ceratonereis costae																		X						
Armandia polyophthalma																			X	X				
Pygospio elegans																				X		X		X

Table 10. "Dominant Taxa" (Polychaetes) defined as those species representing at least five percent of total individuals in MAFLA Area III.

Dominant Taxon	Stations																			
	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41
Langerhansia cornuta	X	X									X		X				X	X			
Aglaophamus verrilli	X		X	X	X	X	X		X												
Onuphis eremita oculata	X	X						X					X								
Aedicira belgicu	X					X			X												X
Chrysaspio bielemi	X																				
Lumbrineris branchiata		X	X																		
Pareulepis sp.			X			X	X														
Haploscoloplos fragilis			X	X	X		X														
Prionospio cirrifera			X		X		X														
Cossura delta			X	X	X		X														
Chaulophorus babirusa				X																	
Paralacydonia paradoxa				X																	
Lumbrineris parvapedata					X		X								X	X					
Prionospio cirrobranchiata						X		X		X			X								
Lumbrineris mucronata							X														
Spiophanes soederstromi								X													
Magelona longicornis									X												
Notomastus latericeus									X												
Magelona n. calitornica										X											
Typosyllis vittata											X			X	X						
Glycera tenuis											X										X
Goniada teres											X		X		X	X	X	X	X	X	
Haplosyllis spongicola												X									
Eunice vittata												X		X			X				
Harmothoe lunulata												X									
Syllis gracilis												X									
Eunice rubra												X									
Kinberginereis inermis																					

Table 10 contd.

Dominant Taxon	Stations																				
	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41
Poecilochaetus johnsoni													X								
Nerinides agilis															X						
Hipponoa multibranchiata																	X				
Typosyllis variegata																	X				
Jasmineira elegans																	X		X	X	
Nephtys bucera																					X
Goniada littorea																					X
Lumbrineris inflata																					X

Table 10. "Dominant taxa" (polychaetes) defined as those species representing at least five percent of total individuals in MAFLA Areas IV and V.

Dominant Taxon	Stations																		
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
Paraprionospiopinnata	X	X	X	X	X	X	X	X	X				X			X				
Asychis carolinae	X	X																		
Aglaophasmus verrilli	X														X					
Clumenella torguata	X																			
Ceratonereis tridentata		X	X	X	X	X	X													
Lumbrineris parvipedata		X	X	X	X	X	X	X	X	X	X	X	X	X	X	X		X	X	
Ceratoneries irritabilis		X																		
Ninoe nigripes			X	X																
Diopatra caprea			X	X																
Nephtys picta				X																
Cirrophorus lyriformis				X																
Notomastus latericeus				X																
Cossura sp. A					X		X													
Aedicira belgicae						X	X	X			X	X	X	X	X			X	X	X
Mediomastus californiensis						X	X	X		X				X	X	X				
Magelona pettiboneae		X						X								X				
Cirratulid Species								X	X	X					X	X				
Poecilochaetus johnsoni									X	X						X				
Paraonid Species									X	X	X		X	X	X	X				
Samythella eliasoni												X							X	
Eunice antennata												X								
Syllis spongicola												X								
Glycinde nordmanni																X				
Glycera oxycephala																	X			
Dorvillea sociabilis																	X			
Onuphis eremita																	X		X	X

Table 10 contd.

Dominant Taxon	Stations																		
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
Exogene dispar																	X	X	X	X
Melinna maculata																		X	X	
Syllis cornuta																		X	X	X
Synelmis albini																		X	X	
Chone duneri																			X	
Amage auricula																				X
Myriochele bioculata																				X
Onuphis microcephala								X												

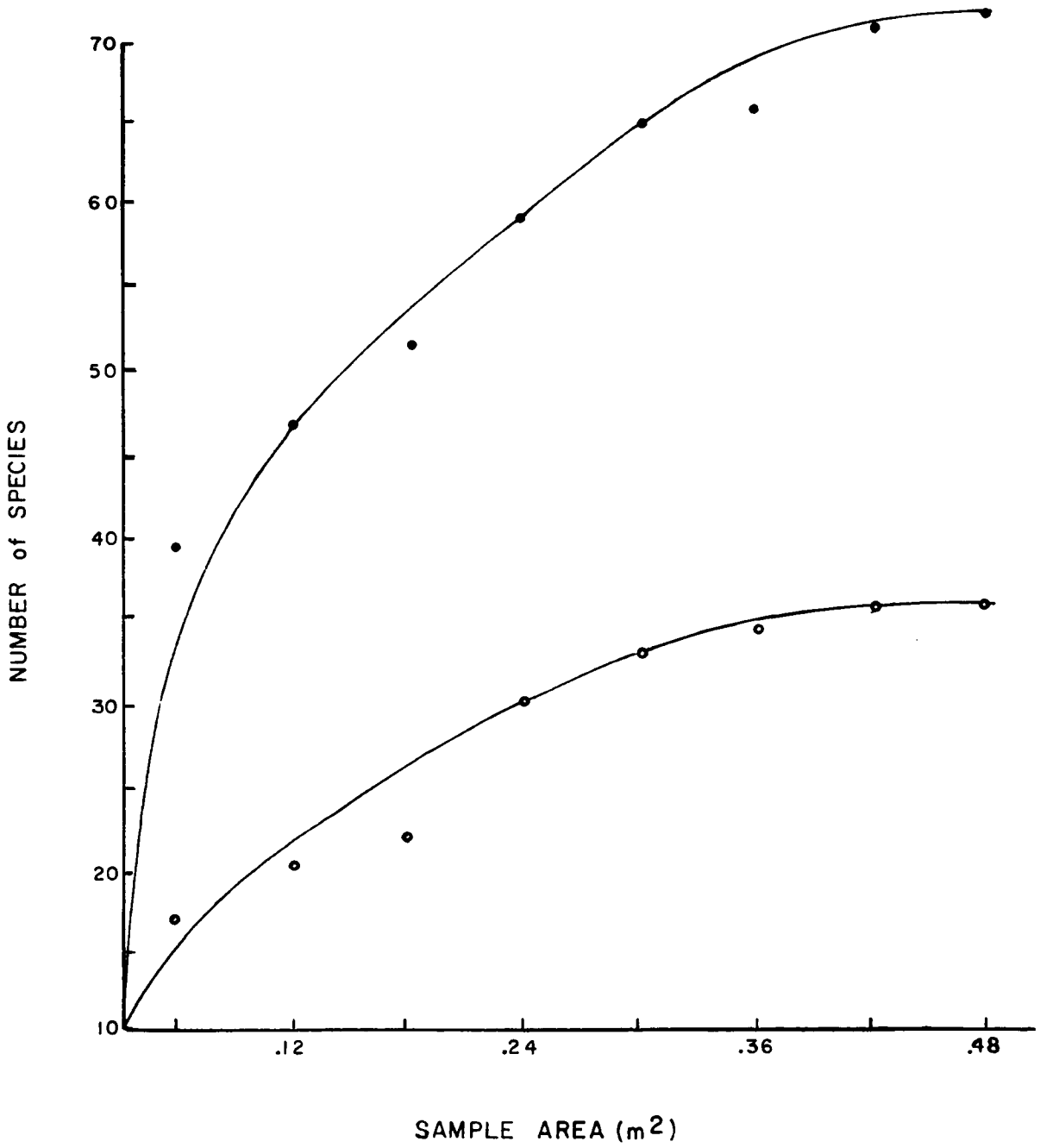


Figure 5 Relationship between sample area and abundance of species at two stations in MAFLA Area V. (Vittor, CT4-11)

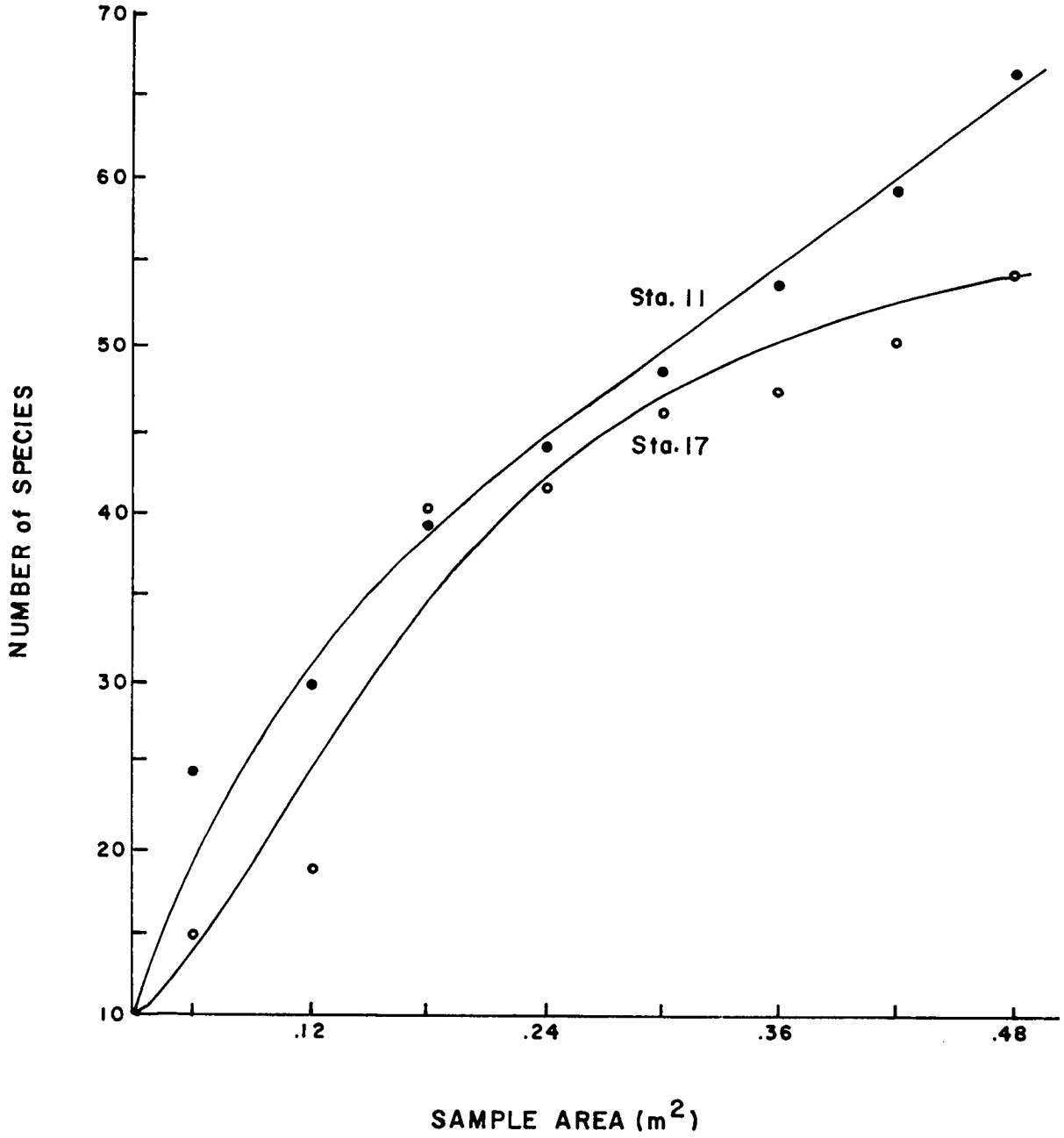


Figure 6 Relationship between sample area and abundance of species at two stations in MAFLA Area IV. (Vittor, CT4-11)

3. Micromollusca. Micromolluscs are small species of molluscs that reach a maximum size of 7 mm, some never reaching 1 mm in maximum length. There generally are no taxonomic divisions separating them from macromolluscs. Micromolluscs in the northeastern Gulf belong to three classes - Bivalvia, Gastropoda, and Scaphopoda. Most Bivalvia are filter feeders, although a few forms feed on small animals (e.g., Cuspidariidae) or are deposti feeders. Gastropods are browsers, predators, or parasites. Since the abundance of micromollusca is largely determined by their method of feeding and the abundance of the appropriate food, filter feeders and browsers are much more numerous than carnivores and parasites.

In the sampled areas micromolluscs ranked third in abundance among invertebrate microinfauna according to the following sequence: formainifera, micromolluscs, bryozoans, ostracods, echinoid spines and remains, barnacles, microcorals (Guynia), and rare brachipods. A total of 4,241 bivalves, 3,084 gastropods, and 90 scaphopods were identified and counted, and some species remain to be identified fully. The main data are provided in Table 11.

Bottom type and its related physical parameters appeared to be the most important factor in determining abundance and distribution of the species, but in a few cases, depth seemed to be the controlling factor. Signs of heavy predation were everywhere (crabs, shrimp, and fish). For this reason, live adult micromolluscs were quite rare, whereas live larval or yound postlarval molluscs were fairly common in the fine fractions of the sediment. Thus, these animals appear to be an important part of the food chain for larger predatory animals.

4. Foraminifera. Percentage distribution of living benthonic foraminifera is given in Table 12. A total of 193 living species was reported. The percentage of living species is very high in Area V (to 66.7%) and decreases to the east and south with lowest percentage in Area I (6%). However, all percentages were higher than expected; many abundant species were represented by high percentages of juvenile specimens. Vock (CT4-11) attributes these facts to possible seasonal blooms of foraminifera, and in Areas IV and V, high sediment loads with large amounts of nutrients. One may also note that other investigators pointed out heavy grazing pressures, and this may in part account for the preponderance of juveniles. If so, benthonic foraminifera would appear to form key food elements for fish and crustacea.

Overall, fauna are relatively uniform, but Areas II and V contain species found abundantly only in their respective areas. Area II contains Peneroplis carinatus, Textularia agglutinans and T. conica, along with Amphistegina gibbosa which indicate reef-like conditions, or at least, high energy, hard substrate environments. In contrast, Area V contains Ammonia becarii, varieties parkinsoniana and tepida, Elphidium galvestonense, and other species capable of withstanding high degrees of stress. These species also contain symbiotic zooxanthellae and dinoflagellate zoochlorellae (green algae) that assist the organisms to survive if turbidity becomes too great for other species. Three species occur in abundance in all five areas and at almost all stations: Cibicides floridanus, Hanzawaea strattoni and Rosalina columbiensis.

A significant observation relates to the fact that specimens at 0-3 and 12-15 cm showed relatively minor differences in their planktonic/benthonic ratios. These

Table 11. Micromolluscs. Chart of occurrence and abundance.
Figures are for actual number of specimens.

Station Number	1	2	3	4	5	6	7	8	9	10	11	12	13
Depth in feet	42	78	96	90	102	96	105	78	102	114	114	120	114
Ml. per sample after sieving	6	8	5	3	18	19	29	36	8	7	23	36	29
Total number identified specimens per sample	5	17	5	4	62	101	196	65	122	123	51	29	11
Total number of ml. sediment	0.8	2	1	1.3	3.4	5.3	6.8	1.8	15.2	17.5	2.4	0.8	0.4
BIVALVES													
Nucula proxima		1			5	5	32	4	10	13	1	1	
Nuculana acuta		6	4	4	47	83	87	13	42	21	5	1	
Cyclopecten nanus									4	9	6		
Crassinella lunulata					3		3		4	11	3	2	
Pythinella cuneata					1	5	30	3	18	20			
Vesicomya pilula							2		2	4			
Linga amiantus		5	1		3	3	5	3		2			
Parvilucina multilineata										2			
Thyasira trisinuata													3
Tellina aequistriata													1
Tellina versicolor					3	4	13	11	8		11	6	3
Abra lioica								1					
Abra sequalis									1				
Gouldia cerina	2	2					2	6	12	17	11	7	
Chione grus									1				
Corbula swiftiana	2	1					7	5	11	4	1		
Verticordia ornata						1	3		2	1			

Table 11. contd.

Station Number		1	2	3	4	5	6	7	8	9	10	11	12	13
Alvania suberiana	GASTROPODS												1	
Caecum pulchellum											5	4	2	
Caecum imbricatum								2			4	1		1
Caecum cubitatum											1		1	
Finella dubia									2	2		4		
Natica pusilla			1					2	3	3	7	2	6	1
Anachis obesa		1							1	1		1	1	
Nannodiella melantica								3	1					1
Acteocina candei									3	1				
Retusa sulcata												1		
Volvulella texasiana								1						
Volvulella persimilis			1					2			2		1	1

Table 11. contd.

Station Number	14	15	16	17	18	19	20	21	22	23	24	25	26
Depth in feet	114	174	120	216	270	270	280	168	270	210	210	269	186
Ml. per sample after sieving	21	30	15	31	35	37	32	22	33	3	3	6	19
Total number identified specimens per sample	67	51	16	75	31	88	25	230	112	144	50	137	193
Total number of ml. sediment	3.2	1.7	1.1	2.5	0.9	2.4	0.8	10.4	3.4	48	16.7	23	10
BIVALVES													
Nucula proxima	1							8		14	10	14	7
Nuculana concentrica		16		1				69		28		5	42
Limopsis antillensis				6	9	5	1		1				
Limopsis sulcata						5	1		16				2
Arcopsis adamsi				8		2			2				
Crenella divaricata	1											1	
Dacrydium vitreum		3			2	5							
Cyclopecten nanus	4	6			1	1	1	2		3		5	2
Limea bronniana					2	4	1						
Crassinella lunulata		1		9	4	9	6	15	17	9	2	18	23
Glans dominguensis				12					2				1
Cuna dalli	2												
Astarte nana					2	1		1	4	3		1	
Pteromeris perplana				1						1			
Vesicomya pilula		3			4	9	8	42	31	43	8	44	6
Montacuta triquetra		6		2	1	7	1		2			3	19
Lucina nassula								3					
Linga amiantus	1												

Table 11. contd.

Station Number	14	15	16	17	18	19	20	21	22	23	24	25	26
Parvilucina multilineata	3	1						4		2			5
Thyasira trisinuata		1	2					5	1	5	11	22	3
Tellina sequistriata	2												
Tellina versicolor	13	5	7					5		4			15
Abra lioica				1									
Gouldia cerina	3	5	1	5		5	1	8	7			4	18
Pitar simpsoni ?	4												
Chione grus				4		1		1					
Corbula swiftiana										4	8		
Varicorbula operculata	4	1	3								2	1	
Verticordia ornata						1		6		2			5
Cardiomya ornatissima										1			
Arene tricarinata GASTROPODS				1				1					
Alvania suberiana			1	1					3				
Alvania cf. auberiana				3	1	9	1	1	4				
Alvania precipitata					2	5	1		7		1	5	
Parviturboides interruptus				1									
Cyclostremiscus cubanus				3									
Aorotrema pontogenes								1					
Caecum pulchellum				13	2	6	2	3	7	2		7	5
Caecum ryssotitum				2									
Caecum imbricatum	1												
Caecum floridanum									1				
Caecum cubitatum	8			1		1		4	1	3			10
Finella dubia	2	2				1		1				1	2
Seila adamsi				1									
Calytraea centralis	1												1
Natica pueilla	4	1						6		4	3		3
Anachis obesa	1							1					

Table 11.contd.

Station Number	14	15	16	17	18	19	20	21	22	23	24	25	26
Mitrella lunata	1												
Marginella sp.	4												
Granulina ovuliformis					1	1		2					
Olivella sp.	3												
Nannodiella melanitica	2												
Odostomia didyma				2									
Acteocina candei										1			
Pyrunculus caelatus						7		2	1		1	1	2
Retusa sulcata								1					
Volvulella persimilis	2							9	1		1	3	9
SCAPHOPODS													
Cadulus iota						2	1	25	4	9		1	12
Cadulus mayori								1		1	3	1	1

Table 11. contd.

Station Number	27	28	29	30	31	32	33	34	35	36	37	38	39
Depth in feet	222	219	150	156	135	138	228	114	120	132	132	126	120
Ml. per sample after sieving	5	18	10	22	45	34	43	30	33	53	42	40	35
Total number identified specimens per sample	81	95	145	165	115	107	87	57	42	65	131	83	139
Total number of ml. sediment	16.2	5.3	14.5	7.5	2.5	3.1	2	1.9	1.3	1.2	3.1	2.1	4
Nucula proxima BIVALVES	9		1				1				1		1
Nuculana concentrica	4	1	15	2			3				1		
Limopsis sulcata		2					2	1			2		
Arcopsis adamsi		10		4		2			1	1	1		1
Crenella divaricata	1			2	2	4					1		2
Musculus lateralis													1
Cyclopecten nanus	6	1	7	4	9	6	3	2	1	3	9	1	20
Limea bronniana							1						
Crassinella lunulata	22	19	22	40	29	15	13	4	11	12	25	24	25
Glans dominguensis		3		3	2	2				1	1		1
Astarte nana			1	5	5	2	5						3
Vesicomya pilula	4	2	3				10						
Montacuta triquetra	3	4	6	7	2		4			1			
Parvilucina multilineata	2		10	3	1					1		2	4
Thyasira trisinuata	9		2	1									1
Tellina versicolor			15		2		1		1	1			4
Gouldia cerina		5			5	2	4	4	3	9	21	11	13
Chione Grus						1	1		1		1	3	4
Corbula swiftiana			1										

Table 11. contd.

Station Number	27	28	29	30	31	32	33	34	35	36	37	38	39
Varicorbula operculata								8	3	1	10		6
Verticordia ornata			1	1		2	2						
Cardiomya ornatissima			2										
Cardiomya perrostrata				1									
Arene tricarinata GASTROPODS								1					2
Alvania auberiana		8		10	3			3	2	1	4		2
Alvania cf. auberiana							3						
Alvania precipitata		2					1						
Cyclostremiscus cubanus				3	2	3		2			5		
Cyclostremiscus jeannae													1
Teinostoma incertum					1								6
Aorotrema pontogenes				1			1						
Caecum pulchellum	7	31	2	32	36	55	10	17	11	19	30	21	12
Caecum bipartitum			2				1						
Caecum imbricatum			3	3								5	2
Caecum floridanum					3	1		2	1		1	1	2
Caecum plicatum						2							
Caecum cubitatum	7	6	22	25	6	6	2	6	3	5	6	7	3
Finella dubia			13	8	1	1	5	1	3		5	5	9
Seila adamsi						1	1						1
Calytraea centralis							1						
Natica pusilla	1		6		3			4	1	3			5
Marginella sp.											1		
Granulina ovuliformis								2					
Nannodiella melanitica										1			
Acteon punctostriatus													1
Acteocina candei							1				1		1
Pyrunculus caelatus		1		4	1	1	3			2	1		1
Retusa sulcata					1	1	1				1		1
Volvulella persimilis	1		6	2			1			4	3	1	4

Table 11.contd.

Station Number		27	28	29	30	31	32	33	34	35	36	37	38	39
Cadulus iota	SCAPHOPODS	3		5	5	1		6					2	
Cadulus mayori		2												

Table 11. contd.

Station Number	40	41	42	43	44	45	46	47	48	49	50	51	52
Depth in feet	120	102	120	147	144	175	120	117	132	138	156		177
Ml. per sample after sieving	44	43	12	32	37	15	18	38	16	35	33		5
Total number identified specimens per sample	50	62	166	64	177	137	272	250	272	142	123		82
Total number of ml. sediment	1.1	1.4	13.8	2	4.8	9.1	15.1	6.6	17	4	3.7		16.4
Nucula proxima BIVALVES		2					1						
Nuculana concentrica			2			9			3				15
Limopsis sulcata		2									1		
Arcopsis adamsi				1		1				3			
Crenella divaricata							6	2	3	1	2		
Musculus lateralis	1		1				1	2	1	2			
Cyclopecten nanus	2	1	3			7	9	2	3		5		1
Crassinella lunulata	4	2	13	9	42	16	30	6	25	27	22		
Glans dominguensis				1	1					4	2		
Carditopsis smithi					2			14	4				
Astarte nana					1	1							
Pteromeris perplana											1		
Vesicomya pilula						2							3
Montacuta triquetra					1	3				3	2		
Lucina nassula			5				2		3				
Linga amiantus					2				1				
Parvilucina multilineata	1		62			9	46	1	39	2	4		12
Parvilucina blanda													4
Thyasira trisinuata		2											
Tellina versicolor	1	3	4		1	3	4		3				

Table 11. contd.

Station Number	40	41	42	43	44	45	46	47	48	49	50	51	52
Abra lioica											1		
Gouldia cerina	8	10	5	1	5	11	7	9	23	4	8		3
Chione grus	1	1	1	1	2		2	10	1	5			
Ervilia concentrica									1	1	1		
Parastarte triquetra			1										
Hiatella artica					1		1	2	1	5			
Varicorbula operculata	1	6	7			10	29		2		1		16
Verticordia ornata						1	2						2
Cardiomya ornatissima						1							
Cardiomya perrostrata						1							
Arene tricarinata GASTROPODS					1			1					
Tricolia thalassicola				1	2			1		1			
Alvania auberiana	3		1	2	16	1	10	34	7	17	11		
Rissoina striatocostata								2					
Rissoina sp.								6					
Parviturboides interruptus			1										
Cyclostremiscus cubanus	2		1	2	8	1	2	14	1	1	2		
Cyclostremiscus beaui		1											
Teinostoma incertum					2		1	4		3	1		
Teinostoma biscaynense				1									
Aorotrema pontogenes					1		1						
Caecum pulchellum	16	4	10	40	66	4	22	117	47	54	18		
Caecum bipartitum			1				7		1		3		
Caecum imbricatum		4			2		3		4				
Caecum floridanum				3	1		2	5					
Caecum clava								1					
Caecum plicatum								3	1				
Caecum torquetum			1					7		1			
Caecum cubitatum	5	6	15	1	17	25			55	6	24		7
Caecum nitidum	1		1					1					

Table 11. contd.

Station Number	40	41	42	43	44	45	46	47	48	49	50	51	52
Finella dubia	1	6	17			17	35		37	1	6		13
Seila adamsi	1			1									
Calytraea centralis			1				1						
Natica pusilla	1	11	5			4	3		1				2
Marginella sp.			1		2				1		1		
Granulina ovuliformis											2		
Odostomia didyma								6		2			1
Acteocina candei			1			2	1						1
Pyrunculus caelatus						2					1		
Retusa sulcata		1	3		1	3				1			
Volvulella persimilis	1		3			2	5		2		1		2
Cadulus iota SCAPHOPODS						2					3		

Table 11. contd.

Station Number	53	54	55	56	57	58	59	60	61	62	63	64	65
Depth in feet	120	111	144	126	123	141		102	108	111	99	99	138
Ml. per sample after sieving	45	39	8	7	10	37		31	5	30	4	6	8
Total number identified specimens per sample	238	199	205	121	335	64		183	323	64	211	193	318
Total number of ml. sediment	5.5	5.1	25.6	17.3	33.5	1.7		5.9	64.6	2.2	52.8	32.2	39.8
Nucula proxima BIVALVES	1	1			2			1			4	1	3
Crenella divaricata	2		4	1	2			3	2			1	3
Dacrydium vitreum					1						1		
Musculus lateralis			2		1	1		2	1				3
Cyclopecten nanus	5		4			2						1	
Crassinella lunulata	16	18	49	3	8	11		5	6	9	1		5
Glans dominguensis			1										
Carditopsis smithi		7	1			2							
Astarte nana								1	1				
Pteromeris perplana		1											
Lucina nassula	1												
Linga amiantus											1		1
Parvilucina multilineata	10	1	18	56	128	2		85	133	1	90	64	118
Parvilucina blanda			1		1				1	1	8	2	1
Thyasira trisinuata			1										
Tellina versicolor			1		3				2		1	1	3
Abra lioica				5	2								
Abra sequalis								4					
Gouldia cerina	12	12	21	4	13	7		6	20	9	19	16	18
Chione grus	2	8	5						2	2	3		1
Histella arctica			3								1		1

Table 11. contd.

Station Number	53	54	55	56	57	58	59	60	61	62	63	64	65
Varicorbula operculata	3		7	5	33	3		9	31		16	17	19
Verticordia ornata	3												
Cardiomya ornatissima								1	1				
Cardiomya perrostrata			1					1					
Arene tricarinata GASTROPODS	2		3			1			1	2		1	
Tricolia thalassicola		3											
Alvania auberiana	15	9	15	1		4					2	1	
Rissoina sp.		3											
Parviturboides interruptus			1										
Cyclostremiscus cubanus	13	6	4		2				1	1	1	2	
Cyclostremiscus jeannae		1											
Teinostoma incertum	1					1							
Aorotrema pontogenes		1											
Caecum pulchellum	51	104	44	7	2	10				21	5		2
Caecum bipartitum	2			12	27			30	60	2	48	58	92
Caecum imbricatum		3				2				4		2	2
Caecum clava										1			
Caecum cubitatum	72	5	14	16	74	6		20	37	2	4	14	36
Caecum nitidum		1											
Finella dubia	17	4	4	8	26	8		7	16	5	4	8	13
Bittium varium		1											
Seila adamsi										1			
Natica pusilla	3	2			3			2	2	2		2	4
Marginella lavallecana		1											
Nannodiella melanitica				1		1					1		
Odostomia didyma		4								1			

Table 11. contd.

Station Number	53	54	55	56	57	58	59	60	61	62	63	64	65
Acteocina candei	1	1		1	3	1			3				1
Pyrunculus caelatus		1											
Retusa sulcata	2	1			2	2		5	1	1	1	1	
Volvulella persimilis	4	1		1	2			1	2			1	2

Table 12. Percentage distribution of living benthonic foraminifer

Station Number	1	2	3	4	5	6	7
Depth (feet)	42	78	96	90	102	96	105
Ml. sediment after sieving	4.9	3.7	3.65	1.5	10.0	5.9	12.2
Planktonic/benthonic ratio	0:100	0:100	7:100	4:100	1:100	3:100	8:100
% living benthonics	58.0	66.7	62.2	64.8	41.3	59.6	62.3
No. total specimens per sample	294,000	37,000	32,000	15,000	200,000	59,000	122,000
No. living specimens per sample	170,520	24,690	19,900	9,720	82,600	25,160	75,950
No. total specimens per ml. sediment	60,000	10,000	8,767	10,000	20,000	10,000	10,000
No. living specimens per ml. sediment	34,800	6,670	5,453	6,480	8,260	5,960	6,230

Table 12.contd.

Station Number	8	9	10	11	12	13	14
Depth (feet)	78	102	114	114	120	114	114
Ml. sediment after sieving	11.8	10.5	10.0	13.8	14.6	14.6	14.9
Planktonic/benthonic ratio	5:100	10:100	6:100	4:100	8:100	3:100	5:100
% living benthonics	56.8	56.9	42.3	51.5	43.6	40.6	45.6
No. total specimens per sample	13,829	80,700	20,000	2,621	1,759	1,664	7,408
No. living specimens per sample	7,855	95,909	8,060	1,349	767	675	3,375
No. total specimens per ml. sediment	1,172	7,686	2,000	190	120	113	479
No. living specimens per ml. sediment	666	4,373	846	98	53	46	227

Table 12.contd.

Station Number	1	2	3	4	5	6	7	8	9	10	11	12	13	14
Ammonia beccarii parkinsoniana	19.0	0.3	0.3	0.3	2.7		1.7		0.7	1.3	1.7	0.4	0.7	0.3
Ammonia beccarii tepida	22.3	10.0	8.7	7.3	4.0	5.3	2.0	2.7	1.3	2.3	1.3	0.4	1.1	
Ammonia translucens			0.3	0.7		0.7					0.3	0.4		0.3
Ammontium salsum	3.0			0.3	0.7		0.7			0.7				
Amphicoryne scalaris									0.3					
Amphistegina gibbosa										1.0	0.7	0.4		
Articulina mexicana					0.3									
Asterigerina carinata				0.3		0.3		1.0	0.3	1.7	0.7	0.4		2.7
Bigenerina irregularis	1.0	0.7	2.0	1.0	0.7	2.7	3.0	4.3	2.0	1.0	5.7	3.3	0.7	0.7
Bolivinita rhomboidalis	0.3													
Brizalina fragilis			0.3				0.3				0.3			
Brizalina lowmani		1.3	0.7	0.3		1.0	0.3	1.0		0.3		0.7	0.4	1.3
Brizalina striatula			0.3											
Buccella hanai					0.3	1.0		0.3						
Bulimina spicata	0.3													
Buliminella cf. B. bassendorfensis	3.0		0.3		2.3				0.3					
Buliminella elegantissima	0.7			0.3			0.3							
Cancris oblonga		0.3	0.7	0.3		0.7	0.3					1.1	1.1	
Cancris sagra		0.3								0.7	0.3	1.5	0.4	
Cassidulina crassa				0.3		1.3								
Cassidulina curvata													0.4	0.7
Cassidulina subglobosa			0.7	1.3			1.7	0.7	2.0		3.0	5.2	1.8	3.7
Chrysalidinella dimorpha	0.3													

Table 12.contd.

Station Number	1	2	3	4	5	6	7	8	9	10	11	12	13	14
Cibicides floridanus		1.7	0.7	0.3	3.3		3.0	5.0	3.0	11.3	5.3	8.1	15.1	15.0
Cibicides io		0.3												
Cibicides mollis												0.7		0.3
Cibicides sp.					1.7									
Cribroelphidium poeyanum		0.3												
Cyclogyra involvens												0.7		0.3
Cymbaloporetta squammosa											0.3			
Discorbis sp.					0.3					1.3				
Elphidium advenum		0.3												
Elphidium delicatulum	1.0		0.7							1.0				
Elphidium discoidale	3.3	7.3	7.7	5.0	0.7	3.3	1.7	1.7	2.3	1.0	1.7	0.7	1.4	2.0
Elphidium galvestonense	16.7	14.0	6.7	6.0	8.0	2.0	0.3		0.3	1.0	0.3	0.4		
Elphidium gunteri	3.0	0.3												0.3
Elphidium incertum mexicanum	2.3													
Elphidium sp.					0.3									
Eponides antillarum		1.0	2.7	2.0		2.3	5.0	0.3	2.3	1.3	6.0	3.0	2.9	3.3
Epistominella vitrea					2.3									
Fissurina spp.		0.3										0.4		
Fursenkoina compressa	2.3													
Fursenkoina mexicana						0.3	1.0	0.3			0.3	1.8		0.3
Fursenkoina pontoni	0.7	14.0	7.7	7.3	1.7	2.0	0.7		0.7	0.7	1.7	1.8	1.1	1.0
Guttulina australis				0.7	0.7		0.7	0.7					1.4	0.3
Guttulina hirsuta							0.3							
Guttulina laevis							0.3	0.3		0.7	1.0	0.7		0.3
Hanzawaia strattoni	4.3	17.7	26.7	27.7	25.7	20.7	27.0	38.0	40.7	39.0	40.7	22.9	42.3	33.7
Haplophragmoides sp.					0.3									

Table 12.contd.

Station Number	1	2	3	4	5	6	7	8	9	10	11	12	13	14
Lagena striata														0.3
Lenticulina calcar		0.7	1.0	2.7										
Lenticulina gibba	0.3	0.3	1.0	1.7			0.3						0.4	
Lenticulina orbicularis		0.7		1.0			0.3					0.4		
Lenticulina sp.			1.3											
Marginulina planata										0.3				
Marginulina sp.			0.3	1.7										
Miliolinella circularis					1.7	0.3				0.3		0.7		
Milolinella fichteliana								0.3						
Neoconorbina orbicularis		0.7		1.0		3.7	2.3	2.3	6.7		1.0	5.2	1.1	1.3
Nodobaculariella cassis		0.7				0.7				0.3				
Nonion depressulum matagordanum	3.3	1.3	0.3	1.0	1.7	1.3		0.7		0.3	0.3			
Nonionella atlantica	6.3	9.3	7.3	4.7	5.0	3.7	7.0	0.7	0.3	1.0	1.7	1.8	2.5	2.0
Nonionella opima	3.0	2.3	2.0	2.0	3.7	2.0	0.7		0.3	0.7	0.3	0.4		0.3
Nouria polymorphinoides		0.3		0.7		1.0	3.7	5.7	1.0		0.7	0.4	0.4	
Palmerinella gardenislandensis			0.3											
Peneroplis carinatus								1.7	0.3	1.3	0.7		2.2	3.3
Peneroplis proteus					0.3									
Planorbulina mediterranensis							1.3		2.3	1.0	1.0	0.8		0.3
Planulina exorna							1.7	0.3			1.3	0.4	1.4	0.7
Pseudonodosaria mayori							0.3							
Pyrgo nasutus						1.3	0.3					0.7		
Quinqueloculina bicostata				0.3		1.3	0.7	0.3	0.7	0.3	1.0	1.5	0.4	0.7
Quinqueloculina bicarinata										2.0				

Table 12. contd.

Station Number	1	2	3	4	5	6	7	8	9	10	11	12	13	14
Quinqueloculina bosciana						0.3						0.7		
Quinqueloculina compta						0.3								
Quinqueloculina horrida			0.3			1.3	1.0	0.3	1.3	0.3	0.3	0.4	0.4	
Quinqueloculina lamarckiana		3.3	3.7	5.0	4.0	7.7	6.7	2.7	4.7	2.3	5.3	3.3	1.8	4.0
Quinqueloculina laevigata		0.3	0.3			1.0		0.3	0.3					0.7
Quinqueloculina poeyana			0.3	0.7		0.3		1.3						
Quinqueloculina polygona							0.3		0.3	1.3	0.7	0.7	0.4	1.0
Quinqueloculina sabulosa							0.3	0.3		0.3				
Quinqueloculina seminulum			1.0			4.0	1.3	0.7	0.7	0.3	1.0	0.7	0.4	
Quinqueloculina spp.					2.0					1.3				
Rectobolivina advena			1.0	0.3	0.7	1.0								
Reophax irregularis								0.3	0.3					
Reussella atlantica	1.7	1.0	1.0	0.7	2.0	0.7	0.3	0.3	0.3	1.7	2.3	0.4	1.8	2.0
Rosalina bulbosa													0.4	
Rosalina columbiensis	0.7	0.7	7.0	10.0	17.7	17.3	16.0	21.3	14.0	8.3	3.3	11.9	10.8	7.7
Rosalina concinna		1.0				0.3						0.7	0.4	
Rosalina floridana						0.3			1.0	0.3	0.3	0.7		
Rosalina sp.							0.3							
Sagrina pulchella primitiva			0.7				0.3	0.3	0.3	0.3				
Siphonina pulchra									0.3					0.3
Sorites hofkeri						1.0	0.7		3.0	5.0			0.7	1.7
Spiroloculina soldanii						0.3								
Textularia agglutinans	1.0		0.3						1.3		1.3	0.7		
Textularia candeiana		0.3												
Textularia conica										0.3		0.4		0.3
Textularia earlandi														0.7

Table 12. contd.

Station Number	1	2	3	4	5	6	7	8	9	10	11	12	13	14
Textularia foliacea occidentalis												0.4		0.7
Textularia mayori		2.3	2.3	3.3	1.7	3.3	3.3	3.7	2.7	3.0	3.3	3.3	1.8	2.0
Textularia sp.													0.4	2.0
Tretomphalus planus												0.4		
Trifarina bella		0.3	0.3	1.3	2.7	0.7	0.3				1.3	1.5	1.1	
Triloculina bermudezi												0.4		
Triloculina brevidentata											0.3	0.7		
Triloculina insignis						0.7								
Triloculina linneiana comis														0.3
Triloculina rotunda										0.3				
Triloculina tricarinata						0.3			0.3			0.4		
Triloculina trigonula									0.3	0.7		1.1		
Triloculina sp.									0.7					
Trochammina ? sp.			0.3								1.0	0.7	0.4	0.3
Uvigerina flintii			0.3	0.3								0.4		
Uvigerina sp.			0.3		0.3									
Wiesnerella auriculata												1.1		0.3
Miscellaneous					0.7									
Trochammina inflata												2.2	0.7	0.3
No. of species	24	34	40	36	32	41	42	32	37	42	39	55	35	42

Table 12. contd.

Station Number	15	16	17	18	19	20	21
Depth (feet)	174	120	216	270	270	280	168
Ml. sediment after sieving	10.75	14.0	11.1	10.95	9.9	11.3	13.3
Planktonic/benthonic ratio	23:100	6:100	33:100	55:100	58:100	59:100	33:100
% living benthonics	51.4	44.5	26.0	30.3	42.7	16.3	48.2
No. total specimens per sample	11,190	10,990	7,250	8,967	9,948	18,300	70,900
No. living specimens per sample	5,721	4,644	1,882	2,715	4,252	2,976	34,156
No. total specimens per ml. sediment	1,036	746	653	819	1,005	1,619	5,331
No. living specimens per ml. sediment	532	332	170	248	429	263	2,569

Table 12.contd.

Station Number	22	23	24	25	26	27	28
Depth (feet)	270	210	210	264	186	222	219
Ml. sediment after sieving	14.8	9.6	6.0	6.25	11.2	7.9	12.0
Planktonic/benthonic ratio	35:100	35:100	37:100	54:100	16:100	27:100	17:100
% living benthonics	36.9	44.5	38.2	39.2	43.9	39.5	23.3
No. total specimens per sample	14,350	76,800	53,700	29,633	73,600	63,700	8,853
No. living specimens per sample	5,298	34,185	20,537	11,621	32,322	25,165	2,065
No. total specimens per ml. sediment	970	8,000	8,950	4,741	6,571	8,063	738
No. living specimens per ml. sediment	358	3,560	3,419	1,859	2,885	3,185	172

Table 12. contd.

Station Number	15	16	17	18	19	20	21	22	23	24	25	26	27	28
Ammodiscus anguillae					0.3									
Ammonia beccarii parkinsoniana	0.3	0.7					0.7		0.3	0.3	0.3	0.3	1.0	
Ammonia beccarii tepida		0.3					0.7					1.3		
Ammonia translucens			0.3	0.7	0.7	0.3		0.3	0.7	0.7				
Ammontium salsum	0.3													
Amphicoryne scalaris							0.3			0.3				
Amphistegina gibbosa			19.0	15.7	10.0	6.7		8.7	0.3		1.0			10.3
Archaias angulatus						0.3								
Articulina mexicana										0.7				
Articulina pacifica													0.3	
Articulina sagra								0.3						
Astacolus crepidulus						0.3		0.3	0.3	0.3				
Astacolus sp.				0.3	0.7									
Asterigerina carinata	0.7	1.0	0.3	0.7	1.0	1.3		0.7	0.3	0.3	1.7	1.3		6.7
Bigenerina irregularis	2.3	1.0		0.3		0.3	1.3	0.3	0.7		0.3	2.0		4.0
Brizalina barbata											0.3			
Brizalina fragilis	0.7	0.3	2.7		1.7	1.3	0.7	0.3	0.3	2.0		1.0	0.3	0.3
Brizalina lanceolata				0.3	1.0			0.3		0.3	0.3			
Brizalina lowmani	2.3	0.7	2.3	2.7	3.7	2.3	1.7	3.0	3.0	2.3	3.0	1.7	2.7	3.3
Brizalina paula				0.3					0.3				0.3	
Brizalina striatula			0.3				0.3							
Brizalina subspinescens						0.3							0.3	
Brizalina sp.	0.3													
Bulimina spicata						0.3	0.3							
Buliminella elegantissima		0.3									0.7			
Cancris oblonga	1.0	0.3	1.3		0.7	0.7	1.3	1.0	2.7	3.7	0.3	2.7	2.0	1.7
Cancris sagra			1.7		1.0		1.7	0.3	1.0	4.0	1.0	2.0	1.0	0.7

Table 12. contd.

Station Number	15	16	17	18	19	20	21	22	23	24	25	26	27	28
Cassidulina crassa			0.3			3.7								
Cassidulina curvata	0.3	0.7	9.7	7.6	8.0	7.0	1.0	8.0	0.7	0.7	1.7	0.7	0.7	5.7
Cassidulina subglobosa	8.7	5.8	18.0	25.0	23.0	13.3	9.0	18.0	11.7	10.0	15.7	8.0	8.3	12.7
Cibicides floridanus	9.3	12.3	16.7	19.7	17.7	19.0	12.7	15.3	8.3	4.3	16.7	10.7	7.3	10.0
Cibicides io							1.7	1.0	1.0	2.7		1.0	0.7	
Cibicides mollis		0.3												
Cibicides sp.							0.3				0.7			
Cyclogyra involvens												0.3		
Cyclogyra planorbis								0.3	0.3	0.3		0.7		0.3
Dentalina filiformis													0.3	
Discorbis sp.											1.7			
Elphidium advenum			0.3		0.7									
Elphidium delicatulum	0.3								0.3		0.3	0.3	0.7	
Elphidium discoidale	0.3	0.7		0.3		0.7	1.7	0.3	1.3		0.3	2.0	3.3	
Elphidium galvestonense										0.3				
Elphidium incertum mexicanum											0.7			
Eponides antillarum	4.7	3.3		0.3	0.3	0.3	1.0	0.3	2.7	2.0	2.0	2.7		1.0
Eponides regularis	0.3													
Eponides tumidulus				0.3	0.7	0.7								
Epistominella vitrea	0.3										0.3			
Fissurina spp.				0.3					0.3	0.3		0.3	0.3	
Fursenkoina complanata	0.3				0.3						0.3			
Fursenkoina mexicana	0.3	0.7			0.3		1.0		1.7	1.0	1.0	1.7	0.7	1.0
Fursenkoina pontoni	1.0	1.0		0.3	0.3		1.0	1.3	5.0	2.7	1.3	3.3	1.3	2.0
Guadryina aequa						0.7							0.3	
Guttulina australis							0.3		0.3	0.3		0.7		
Guttulina hirsuta		0.7					0.3							
Guttulina laevis	0.3						0.7			1.0	0.7	0.7		
Hanzawaia strattoni	33.3	31.0	2.0	0.3	0.7	2.7	19.3	6.0	16.7	11.7	13.7	17.0	14.7	6.7
Haplophragmoides sp.			0.3						0.3					

Table 12. contd.

Station Number	15	16	17	18	19	20	21	22	23	24	25	26	27	28
Lagena striata							0.3			0.3				
Lagena spp.	0.3						0.3							
Lenticulina calcar						0.3	1.3	1.0	1.0	1.3	1.0			
Lenticulina gibba					0.3	0.7	0.3	0.3	0.3	0.3	0.3			
Lenticulina orbicularis			5.0	5.0	6.0	5.3	1.3	6.7				1.7		3.3
Lenticulina peregrina										0.3				
Lenticulina iota ?	0.3													
Lenticulina rotulata											0.3			
Lenticulina sp.						0.3								
Marginulina planata					0.3	0.3		0.7						0.3
Marginulina sp.							0.3							
Miliolinella circularis	0.3		1.0	0.3		0.3	0.3	0.7	3.3	2.7	3.7	1.0	1.7	1.7
Milolinella fichteliana													0.3	
Miliolinella sp.									0.3		0.3			
Neoconorbina orbicularis	0.3	5.0	0.3	1.0			1.3	0.7	2.0	3.7		2.3	4.3	0.7
Nodobacullariella cassis								0.3		1.7			0.3	
Nodosaria pyrula											0.7			
Nodosaria sp.			0.3	0.3										
Nonion depressulum matagordanum	0.3	0.7	1.0	0.7			3.7	0.7	0.3		0.7			
Nonionella atlantica	2.0	3.0	1.3	0.3	0.7		3.3	2.3	4.7	4.3	2.3	3.3	4.3	
Nonionella opima	1.7						1.3			1.0				
Nouria polymorphinoides									0.3	0.7				
Oolina melo							0.3							
Osangularia cultur						0.3								
Peneroplis carinatus		3.0			0.3		0.3							
Peneroplis proteus		0.3												
Planorbulina mediterranensis	1.3	1.0	0.3		1.7		1.0		2.7	3.3	3.0	2.0	3.0	

Table 12. contd.

Station Number	15	16	17	18	19	20	21	22	23	24	25	26	27	28
Planulina exorna				0.3		3.0	1.0	1.3	2.0	3.7		3.7	10.3	5.7
Poroeponides lateralis			0.3	1.0	0.3	0.7		1.0						
Polymorphina fistulose form							0.3							
Pseudonodasaria mayori			0.3				0.3		0.3					
Pullenia quinqueloba					0.3									
Pyrgo denticulata												0.3		
Pyrgo depressa				1.3	0.7									
Pyrgo elongata				0.3	0.3									
Pyrgo fornasinii				0.3										
Pyrgo nasutus	1.0		1.7	0.3	0.3	0.7	1.3	0.7	0.7	4.0	1.3	0.7	1.3	0.3
Pyrgo subsphaerica		0.3											0.3	
Pyrgo ? sp.						0.3							0.3	
Quinqueloculina bicarinata	0.3													
Quinqueloculina bosciana			0.7		0.3		0.3		0.3		0.3			
Quinqueloculina compta		0.3												
Quinqueloculina cultrata	0.3													
Quinqueloculina horrida	0.7		0.3	2.0	3.0	8.0	0.7	2.0	1.0			1.0		1.0
Quinqueloculina lamarckiana	1.7	3.0	1.0	0.7		0.3	4.7	4.0	2.7	2.3	1.0	1.0	6.0	5.3
Quinqueloculina laevigata		0.3					0.3		0.3		1.3		0.7	
Quinqueloculina poeyana				0.3								0.3		
Quinqueloculina polygona	1.3		0.3	0.3			0.3				1.0	0.7		0.3
Quinqueloculina sabulosa	0.3													

Table 12, contd.

Station Number	15	16	17	18	19	20	21	22	23	24	25	26	27	28
Quinqueloculina seminulum	0.3		0.7					0.7			0.3			
Quinqueloculina subpoeyana											0.3			
Quinqueloculina spp.				0.3			0.3	0.3			0.3			
Rectobolivina advena	0.7											1.0		
Reophax irregularis			0.7				3.0	0.3	3.3	4.3	1.7	2.3	2.7	
Reophax nodulosus											0.3			
Reophax scorpiurus	0.3					0.3								
Reussella atlantica	1.7	1.3	0.3		0.3	0.7	1.0	1.0	0.7	0.7	0.3	2.0	2.3	0.7
Rosalina bulbosa		0.7											0.3	
Rosalina columbiensis	1.7	11.0	2.3	1.3	5.0	0.3	3.3	2.7	8.7	8.0	5.0	7.0	5.0	5.3
Rosalina concinna							0.7					0.3	0.7	
Rosalina floridana	0.3	0.3					0.3	0.3	0.3					
Rosalina floridensis				0.3		1.3			0.3				1.0	
Rosalina sp.							0.3							
Sagrina pulchella primitiva						0.7	0.7				0.3	0.7		
Sigmoilina distorta				0.3	1.3									
Siphonina bradyana				0.7	0.3			0.7			0.3			
Siphonina pulchra	0.3		1.0			0.7								
Siphotextularia sp.											0.7			
Sorites hofkeri	0.3	0.3									0.7		1.3	
Spirillina vivipara			0.3					0.7		0.3				
Spiroloculina grata				0.3								0.3	0.3	0.3
Spiroloculina soldanii			0.3		0.3	0.7			0.3	1.3		0.3		
Spiroloculina sp.						0.3								
Spiroplectammina floridana			0.3	1.7	1.0	3.3		1.3				1.0		4.0

Table 12. contd.

Station Number	15	16	17	18	19	20	21	22	23	24	25	26	27	28
Textularia agglutinans	2.0			0.3	0.3									
Textularia candeiana	1.3										0.3			
Textularia conica	0.3		0.3		0.3	3.7	0.3			0.3	2.7			
Textularia earlandi		0.3		0.3		0.3			0.7	0.7		0.3	2.0	
Textularia foliacea occidentalis		0.3				0.7	0.3	0.3	0.3	1.0		0.3		
Textularia mayori	6.3	3.0		0.3		1.0	3.0		1.0				1.7	
Textularia sp.		0.3	0.7										0.7	0.3
Textulariella barrettii			0.7	1.7	1.7			1.0						
Trifarina bella	2.0	2.0	1.0			1.7	1.3	0.3		0.7	2.3	1.0		
Trifarina bradyi	0.3				0.3			0.3	0.3					
Triloculina brevidentata			0.3	0.3				0.3	0.3	0.3		1.0	0.7	0.3
Triloculina insignis		0.3												
Triloculina tricarinata		0.3												
Triloculina trigonula							0.7				0.7		0.3	
Triloculina sp.			0.3											
Trochammina advena			0.3	0.7	1.0									3.0
Trochammina ? sp.		1.3		0.3		0.7	0.7			0.3		0.3		
Uvigerina flintii								0.3			0.3			
Uvigerina sp.			0.3								0.3			
Vaginulina ? sp.													0.3	
Wiesnerella auriculata		0.7							0.7	0.3		1.3	1.3	1.0
Miscellaneous	1.3			1.0	0.7	0.7							0.3	0.3
Saracenaria italica								0.3						
Saracenaria latifrons								0.3						
Trochammina inflata			0.7											
No. of species	51	42	46	48	45	50	60	51	53	50	55	51	48	33

Table 12. contd.

Station Number	29	30	31	32	33	34	35
Depth (feet)	150	156	135	138	228	114	120
Ml. sediment after sieving	12.8	10.0	10.4	9.75	9.15	12.75	10.3
Planktonic/benthonic ratio	13:100	13:100	7:100	12:100	19:100	7:100	11:100
% living benthonics	29.4	23.5	18.1	18.7	29.0	24.0	32.1
No. total specimens per sample	86,999	5,334	4,525	3,900	3,250	2,337	2,900
No. living specimens per sample	25,600	1,252	818	724	943	560	931
No. total specimens per ml. sediment	6,797	533	435	700	355	183	292
No. living specimens per ml. sediment	1,998	125	79	75	103	44	90

Table 12. contd.

Station Number	36	37	38	39	40	41	42
Depth (feet)	132	132	126	120	120	102	120
Ml. sediment after sieving	12.4	13.2	12.85	11.7	9.0	10.9	10.6
Planktonic/benthonic ratio	3:100	12:100	8:100	9:100	5:100	5:100	6:100
% living benthonics	26.4	28.7	31.4	36.7	23.3	33.3	9.2
No. total specimens per sample	6,840	7,100	16,660	7,660	1,809	4,396	49,600
No. living specimens per sample	1,804	2,036	5,227	2,786	422	1,447	4,580
No. total specimens per ml. sediment	552	538	1,296	650	201	399	4,679
No. living specimens per ml. sediment	146	154	407	238	47	133	430

Table 12. contd.

Station Number	29	30	31	32	33	34	35	36	37	38	39	40	41	42
Ammoddiscus sp.												0.3		
Ammonia beccarii parkinsoniana										1.0				
Ammonia beccarii tepida	1.0					1.7	0.3		1.0	1.7	1.7	0.3	3.0	
Ammonia translucens	0.3				1.0	0.7		0.7		0.7		0.3		
Ammontium salsum		0.3												
Amphistegina gibbosa		9.3	18.0	18.3	7.3	11.0	18.3	14.3	4.0	7.3	1.3	9.7		
Articulina pacifica				1.0										
Articulina sagra						0.3								
Asterigerina carinata		5.3			4.3	2.0	0.3	2.0	1.3		1.0	2.7	2.0	
Bigenerina irregularis	2.3	2.7	3.0		9.0	4.7	2.7	2.3	5.3	5.7	3.0	4.7	4.3	4.7
Brizalina fragilis		0.3			0.7		0.3							
Brizalina minima ?						0.3								
Brizalina lowmani	1.3	1.0	3.0	2.7		1.3	1.3	1.7	2.0		1.7	1.7	2.0	
Brizalina paula								0.3		0.3			0.3	
Buccella hanai												0.3		
Buliminella elegantissima							1.0							
Cancris oblonga		0.3	1.7	1.0	1.3		0.7	1.0		2.0	1.3	0.3	1.7	
Cancris sagra	0.7				1.3					1.3		0.7		
Cassidulina crassa		0.7										0.3		
Cassidulina curvata	1.3	1.3	1.7	3.0	3.0			1.0		1.3	1.3	0.3		
Cassidulina subglobosa	6.0	6.3	7.7	13.0	15.7	5.3	9.3	9.0	3.3	6.0	3.3	1.0	6.0	10.7
Cibicides floridanus	25.3	8.7	9.0	6.0	10.3	4.7	5.0	4.0	4.7	9.7	9.3	8.0	7.3	4.3
Cibicides io				1.0	0.7			1.0			1.0			
Cibicides sp.		0.3			0.3		0.7	0.7						
Cyclogyra planorbis				0.3		0.3	0.3		0.3			0.3	0.3	
Discorbis sp.							0.7							
Elphidium advenum					0.3		0.3							
Elphidium discoidale	4.3	0.7			1.7	4.0	0.7	1.3		4.3	4.3	1.0		2.0

Table 12. contd.

Station Number	29	30	31	32	33	34	35	36	37	38	39	40	41	42
Elphidium galvestonense							0.3		0.3					
Elphidium sp.										0.1		0.3		
Eponides antillarum	0.3	1.7				1.0	0.7				3.3	0.7	2.3	
Fissurina spp.					0.3		1.0					0.3		
Fursenkoina mexicana		0.7		1.3	1.0	1.0		2.3	2.0		1.0	1.0	1.7	
Fursenkoina pontoni	2.0	0.7		0.7		0.7	1.3		0.3			1.0		
Guadryina aequa		0.3												
Guttulina australis	0.7									0.3		0.3		
Guttulina hirsuta		0.3											0.3	
Guttulina laevis									1.3					
Hanzawaia strattoni	14.7	16.0	13.0	7.7	7.7	9.7	9.3	11.0	10.0	9.7	15.3	19.7	16.7	10.3
Lagena spp.												0.3		
Lenticulina gibba								1.3		3.0				
Lenticulina orbicularis		2.3			3.3		1.0	3.0	2.7			0.3		
Loxostomum truncatum										0.3	0.3			
Marginulina planata	0.3	0.3												
Miliolinella circularis	0.3		2.0		0.7		1.0		2.3	3.3		0.7	0.3	1.7
Miliolinella labiosa							0.3							
Neoconorbina orbicularis	5.3	4.7	1.0	6.0	2.0	8.3	2.0	3.0	3.0	7.0	4.3	3.7	3.0	
Nodobacullariella cassis	0.7		0.3				0.3							
Nodosaria sp.									0.3					
Nonion depressulum matagordanum			0.3				0.3		0.3	0.3	0.3	0.3	1.0	
Nonionella atlantica	1.0	0.7	2.0	1.0	2.3	4.0	3.0	3.7	1.3	3.7	3.3	2.0	2.0	0.3
Nonionella opima		0.3		1.0		2.0	0.3							
Nouria polymorphinoides	0.3		0.3		0.3									
Peneroplis carinatus		0.3		0.3			0.3		1.3			3.0	1.0	1.0
Planorbulina mediterranensis	3.0	0.7	2.3	6.7			1.3	2.3	4.0	1.3	3.0	0.3		4.7
Planulina exorna	8.7	6.3	6.7	5.0	2.3	4.0	5.7	7.7	6.0	7.3	8.3	6.0	5.3	2.7

Table 12, contd.

Station Number	29	30	31	32	33	34	35	36	37	38	39	40	41	42
Poroeponides lateralis	2.0	2.7				0.3	2.7		4.0	1.3	0.7	2.0	1.0	
Pyrgo elongata					0.3									
Pyrgo nasutus							0.3		1.0		1.0			
Pyrgo subsphaerica														0.3
Quinqueloculina bicostata		0.3							1.3				1.3	1.7
Quinqueloculina bosciana		0.3			0.3									
Quinqueloculina horrida	1.3	0.3			3.0				1.3			0.7		
Quinqueloculina lamarckiana	3.3	1.3	2.0	0.7	2.0	11.7	1.7	3.0	9.3	5.0	6.7	1.0	7.7	38.7
Quinqueloculina laevigata							0.7							
Quinqueloculina poeyana							0.7							
Quinqueloculina polygona				0.3										
Quinqueloculina seminulum							0.7	0.3	0.2					
Quinqueloculina subpoeyana					0.3		0.7							
Quinqueloculina spp.		0.3		0.3			0.3	0.3						
Rectobolivina advena	0.3					0.7			0.3	0.3				
Reophax irregularis	0.3				1.0									
Reussella atlantica	1.0	6.0	2.0	3.7	3.0	4.0	2.7	3.0	8.0		2.3	2.0	4.3	1.7
Rosalina bahamaensis		0.3					0.3							
Rosalina bulbosa								0.3						
Rosalina columbiensis	10.3	0.3	13.7	1.3	5.7	7.0	4.0	8.0	6.0	7.0	11.0	6.0	13.0	10.0

Table 12. contd.

Station Number	29	30	31	32	33	34	35	36	37	38	39	40	41	42
Rosalina concinna				1.0				0.7	2.0			1.3		
Rosalina floridana		0.3				1.0	1.3					0.7	0.3	
Rosalina floridensis		1.0	0.3	0.3	1.0	0.7	0.3	0.3	0.7			1.0		
Rosalina sp.		0.7			0.3							1.3		
Sagrina pulchella primitiva		1.7							1.0		0.3	0.7		
Siphonina bradyana		0.3												
Siphotextularia sp.							1.0							
Sorites hofkeri		0.3			1.0		0.3				0.3	1.0	1.0	
Spirillina decorata				0.3										
Spirillina vivipara								0.3						
Spiroloculina grata	0.3													
Spiroloculina soldanii							0.3							
Spiroplectammina floridana		0.3		3.0										
Textularia agglutinans		0.3				5.0	0.7	2.0			1.3	1.7	3.0	
Textularia candeiana											1.0			
Textularia conica		2.7	5.0			0.3	0.7	3.0			3.0	0.3	1.0	
Textularia earlandi			0.3		1.0					0.7	1.0			
Textularia foliacea occidentalis		1.0		0.3	0.3									
Textularia mayori		1.0		1.3	1.7		0.7	2.7	1.0	4.3	1.7	1.3		2.3
Textularia sp.		1.3										0.3		
Trifarina bella		2.0	1.3	1.3		1.3	1.0	1.7			1.0	0.7	1.0	
Trifarina Jamaicensis													0.3	
Triloculina brevidentata	1.0				0.3					0.3				
Triloculina rotunda							0.3							
Triloculina trigonula		0.3								0.3		0.3		

Table 12.contd.

Station Number	29	30	31	32	33	34	35	36	37	38	39	40	41	42
Trochammina advena			2.0	9.7	1.0			0.7	2.7	2.7			2.7	
Trochammina ? sp.		1.0	1.3				6.7		3.0		0.3	1.0		
Uvigerina flintii		0.3			0.3									
Wiesnerella auriculata						0.7	0.3						2.7	3.0
Miscellaneous		0.7		0.3		0.3	1.3		0.3			1.3		
Trochammina inflata												2.0		
No. of species	30	54	25	32	40	32	59	35	38	32	34	52	32	17

Table 12, contd.

Station Number	43	44	45	46	47	48	49
Depth (feet)	147	144	175	120	117	132	138
Ml. sediment after sieving	12.6	9.55	10.8	9.6	11.6	13.0	11.45
Planktonic/benthonic ratio	9:100	9:100	14:100	3:100	4:100	5:100	6:100
% living benthonics	15.0	13.6	36.1	12.5	18.7	12.9	13.2
No. total specimens per sample	8,933	6,140	6,783	9,900	3,068	26,900	10,250
No. living specimens per sample	1,337	835	2,951	1,242	573	3,475	1,358
No. total specimens per ml. sediment	709	643	628	1,031	269	2,069	895
No. living specimens per ml. sediment	106	87	227	129	49	267	118

Table 12. contd.

Station Number	50	51	52	53	54	55	56
Depth (feet)	156	84	177	120	111	144	126
Ml. sediment after sieving	13.45		9.0	14.2	10.5	7.4	7.7
Planktonic/benthonic ratio	5:100		10:100	2:100	5:100	12:100	3:100
% living benthonics	12.2		13.9	15.2	10.1	16.3	11.5
No. total specimens per sample	11,814		63,000	16,627	4,667	42,230	37,875
No. living specimens per sample	1,442		8,760	1,525	473	6,882	4,355
No. total specimens per ml. sediment	949		7,000	706	444	5,719	4,918
No. living specimens per ml. sediment	116		973	107	45	932	566

Table 12. contd.

Station Number	43	44	45	46	47	48	49	50	51	52	53	54	55	56
Ammonia beccarii parkinsoniana			0.3					0.3	0.3					
Ammonia beccarii tepida														2.0
Ammonia translucens	0.3													
Ammontium salsum													0.3	
Amphicoryne scalaris														0.3
Amphistegina gibbosa	9.0	6.0	0.3	2.7	4.7	2.7	4.0	14.0	8.3		2.7	4.3	1.0	
Archaias angulatus			1.0	0.3										
Articulina mucronata					0.3									
Articulina pacifica	0.3											0.3		
Articulina sagra			0.3											
Asterigerina carinata	2.0	1.3	6.3					6.0			7.7		0.3	
Bigenerina irregularis		3.7	2.7	3.3	9.0	6.7	11.7	11.7		6.0	2.7		1.3	5.7
Brizalina fragilis			0.3										0.3	
Brizalina goessii													0.3	
Brizalina lowmani		4.3	1.3		2.3			1.3		2.3	2.3		0.3	
Buliminella elegantissima													0.3	
Cancris oblonga	2.3	4.3	0.3										1.7	
Cancris sagra	1.7		0.7			1.0		0.7					0.7	
Carterina spiculotesta		0.3												
Cassidulina crassa								1.0						
Cassidulina curvata			1.3				0.7	0.3						
Cassidulina subglobosa	8.7	3.3	4.0	3.3	4.3	8.3	3.7	2.0		4.3	6.7		1.7	6.7
Cibicides floridanus	10.7	14.3	13.3	5.3	1.7	5.7	12.3	13.3	4.3	8.0	7.7	6.7	7.3	2.7
Cibicides io	1.0							0.7						
Cibicides mollis			0.7										2.0	
Cibicides sp.		0.3												
Discorbis sp.			1.3										2.3	

Table 12. contd.

Station Number	43	44	45	46	47	48	49	50	51	52	53	54	55	56
Elphidium advenum			0.3											0.3
Elphidium delicatulum		1.7							1.7				2.3	
Elphidium discoidale		0.7	2.3					1.3	1.3	3.3			1.0	3.3
Elphidium galvestonense													0.7	
Eponides antillarum			2.0	1.7				1.0		2.3			2.3	
Fissurina spp.			0.3										1.0	
Fursenkoina complanata													0.3	0.3
Fursenkoina mexicana	2.0			2.3				0.7		1.7			0.7	0.7
Fursenkoina pontoni	1.0	2.0	1.7	2.7		3.0	2.7	0.7				2.7	8.7	1.3
Fursenkoina spinicostata													1.0	
Glabratella ? sp.								0.3						
Guadryina aequa	0.3								0.7					
Guttulina australis				1.0									0.7	
Guttulina laevis			0.7					1.0					0.7	
Hanzawaia strattoni	4.3	2.3	17.0	14.7	3.0	11.3	5.3	6.7		23.0	19.7	10.0	10.7	27.0
Haplophragmoides bradyi								0.3						
Lagena spp.													0.3	
Lenticulina orbicularis								0.7						
Loxostomum truncatum						0.3								
Marginulina planata								0.3						
Miliolinella circularis	0.7	2.0	1.7	2.7	5.3	2.7	4.0	0.7	1.7	1.0		0.7	0.3	4.7
Miliolinella sp.									0.3					
Neoconorbina orbicularis	10.0	10.0	3.7	8.7	12.0	15.7	5.3	4.3	12.3	19.7	14.0	18.3	7.7	
Nodobacullariella cassis			1.0	0.3				0.3					0.3	
Nonion depressulum matagordanum	0.3	1.3	0.3	1.0		0.3							0.7	
Nonionella atlantica		0.3	0.3	5.0	4.0	0.3	2.3	0.3	2.3	2.3			2.7	1.7
Oolina melo		0.3												
Pavonia atlantica													0.3	

Table 12. contd.

Station Number	43	44	45	46	47	48	49	50	51	52	53	54	55	56
Peneroplis carinatus	7.3	1.0	3.7	3.0	3.3		0.7	0.3			7.3	8.3	0.3	2.0
Peneroplis proteus	0.3													
Planorbulina mediterranensis			1.0	2.7	5.0	3.7	12.3	0.7					3.3	
Planulina exorna	3.7	6.3	5.3	7.7	4.3	4.3	6.0	4.7	4.7	1.3		3.0	6.7	
Poroeponides lateralis			0.3	1.3	3.0			1.7	2.3				0.7	
Pseudonodosaria mayori					0.3									0.3
Pyrgo nasutus			2.3		1.0								1.3	
Pyrgo subsphaerica					0.3									
Quinqueloculina bicarinata			0.3											
Quinqueloculina bosciana			0.3	0.7	0.7									
Quinqueloculina cultrata			0.7										0.3	
Quinqueloculina horrida								0.3						
Quinqueloculina lamarckiana	5.7	7.7	2.3	8.0	3.7	7.3	2.7	0.7	9.7	10.3	9.7	9.3	1.7	31.0
Quinqueloculina laevigata						0.7			1.3					0.3
Quinqueloculina polygona			0.3											
Quinqueloculina seminulum										0.3	0.3			
Quinqueloculina subpoeyana			0.7										0.7	
Quinqueloculina spp.	1.0		1.3	0.3	1.0	0.3		0.3	5.0	0.3			0.7	
Reophax irregularis			0.7										0.7	

Table 12. contd.

Station Number	43	44	45	46	47	48	49	50	51	52	53	54	55	56
Reussella atlantica	3.0	3.7	1.7			2.7	2.0	2.7	2.7			1.7	3.7	
Rosalina columbienses	8.0	2.7	2.0	5.0	11.7	11.0	11.3	7.0	8.0	6.7	7.3	11.7		6.3
Rosalina concinna								0.3						
Rosalina floridana	0.3		2.0		1.0				3.0				3.0	
Rosalina floridensis	0.3							0.7						0.3
Rosalina suezensis			0.3										0.7	
Rosalina sp.		0.3						0.3						
Sagrina pulchella primitiva		0.3						0.3					1.0	
Sigmoilina distorta									1.3					
Siphonina pulchra								0.3						
Siphotextularia rolshauseni								0.3						
Siphotextularia sp.			1.3										1.7	
Sorites hofkeri			2.0	4.3									0.7	3.0
Spirillina vivipara					0.3									
Spiroloculina grata							0.3			0.3				
Spiroloculina soldanii	0.3		0.3											
Spiroloculina sp.						0.3								
Spiroplectammina floridana			0.3											
Textularia agglutinans	7.0	9.7	0.7	3.0	2.0	3.0	8.0	0.3	3.7	3.7	11.3	15.7		
Textularia candeiana			0.7						1.3					
Textularia conica	2.3	5.0	1.0	3.0	5.7		1.7	0.7	7.0	0.7		4.0	1.7	
Textularia earlandi	1.7	2.0		0.7	1.7			2.3	1.3				0.3	
Textularia foliacea occidentalis								0.3						
Textularia mayori			1.0		2.0	7.3	0.3	1.0					4.3	
Textularia sp.											0.3			

Table 12. contd.

Station Number	43	44	45	46	47	48	49	50	51	52	53	54	55	56
Tretomphalus planus									0.3					
Trifarina bella			0.3					0.3					0.3	
Trifarina bradyi								0.3						
Trifarina Jamaicensis					0.3									
Triloculina brevidentata						0.3								
Triloculina rotunda			0.3											
Triloculina tricarinata									0.3					
Triloculina trigonula		0.7	0.3								0.3			
Triloculina sp.										0.3				
Trochammina advena	0.7	2.0		1.3	1.3	0.3	1.0		6.0	2.0				
Trochammina ? sp.	2.0		0.3	1.3	3.7		0.7	2.0	4.7				1.3	
Valvulineria mexicana													0.7	
Wiesnerella auriculata	1.7			2.7	1.0	0.7	1.0		1.7			3.0	1.0	
Miscellaneous			0.3					0.7	2.3			0.3	1.0	
Trochammina inflata								1.3						
No. of species	32	30	57	30	31	25	23	50	30	21	15	16	57	20

Table 12. contd.

Station Number	57	58	59	60	61	62	63
Depth (feet)	123	141	114	102	108	111	99
Ml. sediment after sieving	9.7	10.65		9.2	10.9	15.3	8.0
Planktonic/benthonic ratio	4:100	4:100		2:100	1:100	1:100	2:100
% living benthonics	6.2	12.0		15.1	6.2	13.3	8.3
No. total specimens per sample	57,333	5,167		62,667	39,200	6,980	55,200
No. living specimens per sample	3,573	622		8,463	5,492	928	4,560
No. total specimens per ml. sediment	5,910	485		6,812	8,183	456	6,900
No. living specimens per ml. sediment	366	58		1,029	507	61	573

Table 12. contd.

Station Number	64	65
Depth (feet)	99	138
Ml. sediment after sieving	8.8	9.7
Planktonic/benthonic ratio	0:100	1:100
% living benthonics	7.1	9.7
No. total specimens per sample	49,233	54,511
No. living specimens per sample	3,476	6,916
No. total specimens per ml. sediment	5,595	5,626
No. living specimens per ml. sediment	397	714

Table 12. contd.

Station Number	57	58	59	60	61	62	63	64	65
Ammonia beccarii tepida		0.7		0.3		0.3			0.7
Amphistegina gibbosa								3.0	
Archaias angulatus									1.0
Asterigerina carinata	0.7	1.0		2.3		18.7			7.0
Bigenerina irregularis	5.3	7.0		6.3	3.0	4.3	14.0		5.7
Brizalina lowmani				0.3					0.3
Brizalina sp.									0.3
Cancris sagra				0.3					0.3
Cassidulina subglobosa						5.0			
Cibicides floridanus	8.7	12.3		9.3	6.7				11.0
Cibicides io				0.7				0.3	
Cibicides mollis									0.7
Cibicides sp.									0.3
Clavulina mexicana									0.7
Cribroelphidium poeyanum				1.0					1.3
Elphidium advenum									0.3
Elphidium delicatulum						0.3			
Elphidium discoidale	2.3	7.3		3.0	3.3				6.7
Elphidium galvestonense									0.3
Eponides antillarum	1.0			1.7			2.3	2.7	2.0
Fursenkoina complanata									0.3
Fursenkoina mexicana									0.3
Fursenkoina pontoni				1.7					1.7
Guttulina australis				1.0					1.0
Guttulina hirsuta				0.3					
Guttulina laevis				1.0			0.3		1.0
Gypsina vesicularis				0.3					

Table 12. contd.

Station Number	57	58	59	60	61	62	63	64	65
Hanzawaia strattoni	24.3	10.0		15.7	32.3	13.0	33.3	23.0	18.7
Miliolinella circularis	4.7	2.7		0.3		0.3			0.3
Neoconorbina orbicularis	7.0	15.0		10.3	3.3	14.0	4.3	7.0	5.7
Nodobacculariella cassis				0.7					0.3
Nonion depressulum matagordanum							0.3		
Nonionella atlantica		1.7		3.0	3.0	4.3	2.7		1.3
Nouria polymorphinoides		0.3		0.7					
Peneroplis carinatus				1.3			2.0		1.7
Peneroplis proteus									0.3
Planorbulina mediterranensis	6.7			1.3				4.3	
Planulina exorna	3.3			2.3	3.0				0.3
Pyrgo denticulata									0.3
Pyrgo depressa								0.3	
Pyrgo nasutus		1.0		0.3	0.3		1.0		1.0
Quinqueloculina bicostata				0.7				0.3	0.3
Quinqueloculina bicarinata				0.3					
Quinqueloculina bosciana								0.3	
Quinqueloculina dutemplei									0.3
Quinqueloculina lamarckiana	22.0	15.3		0.7	22.7	14.0	13.0	25.0	4.3
Quinqueloculina laevigata		0.3		0.3		0.3		0.3	

Table 12. contd.

Station Number	57	58	59	60	61	62	63	64	65
Quinqueloculina polygona		0.3			0.3		0.7		
Quinqueloculina seminulum				0.3					0.3
Quinqueloculina subpoeyana					0.3				
Quinqueloculina spp.							0.3		
Reophax irregularis					3.0				0.3
Reophax nana				0.3					
Reussella atlantica		0.7		4.0		2.7			1.0
Rosalina bulbosa		0.3				0.3	0.3	0.3	
Rosalina columbiensis	0.3	15.0		9.3	9.7	19.7	21.3	22.3	8.0
Rosalina concinna				5.0			1.7		
Rosalina floridana				1.3					1.3
Rosalina floridensis						0.3			
Rosalina sp.				0.7					
Sagrina pulchella primitiva		0.7		1.0		0.3	0.3		0.7
Sorites hofkeri	0.7			2.7			1.7	3.7	2.3
Spiroloculina sp.				0.3					
Textularia agglutinans		2.3		0.7					0.3
Textularia conica	1.7	4.7							
Textularia mayori				5.7	9.0			7.0	5.0
Trifarina bella		1.3				0.3			
Triloculina brevidentata						0.3	0.3		
Triloculina trigonula				0.3					
Triloculina sp.									0.3
Trochammina advena						0.3			0.3
Trochammina ? sp.									0.7

Table 12. contd.

Station Number	57	58	59	60	61	62	63	64	65
Wiesnerella auriculata	1.3					1.0			
Miscellaneous				0.3					1.0
Trochammina inflata				0.3					
No. of species	15	21		44	14	20	18	15	47

ranged from 54:100 to 1:100 (the latter at Stations 5 and 65). These data imply that incursions of pelagic fauna (via the Loop current) have been relatively stable in their patterns for the period of time involved between the depths in the sediment.

5. Epifauna and Epiflora. Examination of samples recovered by diving and dredging in the current investigations has revealed new and unusual species in every major epifaunal and epifloral group. The epifaunal groups referred to in this account are decapod crustaceans, sponges, molluscs, echinoderms, and hard and soft corals. Epifloral groups are Chlorophyta, Phaeophyta, and Rhodophyta (green, brown, and red algae).

Quantitative measurements were recorded by use of a portable 5 m^2 frame. Because of species diversity and abundance, quantitative measurements were not made on the reefs in Area II. (Diversity is used to represent the number of different species within a genus. Abundance refers to the total number of species within a given faunal or floral group.) Here emphasis was placed on photography and collections with emphasis on coelenterates, sponges, molluscs and algae. Capetown dredging was executed using 10 min tows. Numbers of species and suspected species are as follows:

Soft corals	19
Hard corals	24
Molluscs	107
Crustaceans	107
Algae	154
Echniderms	50
Sponges	260

Species diversity as well as abundance varied markedly from station to station within an area, as well as between areas, largely controlled by substrate. In Area II the swinging of the vessel on its anchor chain directed divers to different subenvironments.

Table 13 provides a summary of biotopes (sediment substrates harboring a given faunal-floral assemblage), indicator organisms, and relative abundance. The numbers following epifaunal-floral groups are coded according to the percentage which has been identified and archived among the total MAFLA species.

The linkages that Hopkins (CT4-11) provides between faunal-floral groups and substrate types are particularly valuable because these show coherent patterns for given regions. Thus, Area I, soft carbonate mud areas tended to be depauperate, whereas firm substrates such as hard compacted calcareous sand and shell rubble showed increasing abundance depending on the degree of firmness and occurrence of crevices and other shelters. The highest diversity and abundance for corals, sponges and algae are found in high relief rock ridge areas of Area II. Area III biotopes offer wide areas of shell hash and rubble over an apparently hard substrate. Molluscan and crustacean diversity is high, including a large food web. An example of this type of environment is found in Fig. 4e. In contrast, fine sand-mud bottoms revealed little by dradge. Area IV resembles Area II in point of cintrasting biotopes over short distances. However, whereas shell rubble produced abundant populations in Areas II and III, both species

Table 13

Summary of Biotopes and Community Indicators
in the MAFLA Lease Tract by Area

Area I

	BIOTOPE	STATION NOS.	INDICATOR ORGANISMS BY GENERA IN GROUP	RELATIVE SPECIES ABUNDANCE IN EACH EPIFAUNAL-EPIFLORAL GROUP
1)	Hard Compacted Sand w/Silt	65	a) SPONGES Ircinia Haliclona Spheciospongia b) ECHINODERMS Astropecten Encope c) HARD CORALS Cladocora d) ALGAE Caulerpa Dictyota Gracilaria e) DECAPOD CRUST. Synalpheus Pylopagurus Raninoides	SPONGES - Moderately Low 17/66 ECHINODERMS - Low 5/36 HARD CORALS - Low 5/22 MOLLUSCS - Very Low 2/86 CRUSTACEANS - Low 20/96 ALGAE - Moderately Low
2)	Shell Rubble, Sand w/Silt	62,64	a) SPONGES As @ #65 b) ECHINODERMS Astropecten Echinaster c) ALGAE As @ #65 d) HARD CORALS Cladocora e) MOLLUSCS Fasciolaria f) DECAPOD CRUST. Synalpheus Pylopagurus Ranilia	SPONGES - Moderately Low 24/66 ECHINODERMS - Low 8/36 HARD CORALS - Low 4/22 MOLLUSCS - Very Low 7/86 CRUSTACEANS - Moderately Low 25/96 ALGAE - Moderately Low
3)	Soft and Silty	60,61	No definitive organisms established. All Groups Low to absent.	

Table 13 contd.
Area II

BIOTOPE	STATION NOS.	INDICATOR ORGANISMS BY GENERA IN GROUP	RELATIVE SPECIES ABUNDANCE IN EACH EPIFAUNAL-EPIFLORAL GROUP
1) High Profile Rock	47, 146, 147 151, 247, 251, 452	a) SPONGES: Ircinia, Spheciospongia, Callyspongia b) ECHINODERMS: Ophiothrix, Diadema, Astrophyton c) DECAPOD CRUST.: Mithrax, Macrocoeloma, Stenorynchus d) HARD CORALS: Diochocoenla, Scolymia, Millepora e) SOFT CORALS: Muricea, Plexaura, Eunicea f) MOLLUSCS: Chlamys, Spondylus, Vermicularia g) ALGAE: Kallymenia, Sporochnus, Microdictyon	SPONGES - Moderate 30/66 ECHINODERMS - Low DECAPOD CRUSTACEA - Very Low 13/96 HARD CORALS - Moderately High 15/22 SOFT CORALS - Moderate 9/19 MOLLUSCS - Very Low 8/86 ALGAE
2) Low Profile Rock Patches with Intermittent Sand	42	a) SPONGES: Ircinia, Placospongia, Haliclona b) ECHINODERMS: Eucidaris, Diadema c) DECAPOD CRUST.: Pylopagurus, Stenorynchus, Alpheus d) HARD CORALS: Cladocora, Scolymia, Millepora e) SOFT CORALS: Eunicea f) MOLLUSCS: Laevicardium, Pecten, Vernicularia g) ALGAE: Microdictyon, Udotea	SPONGES - Moderately Low 20/66 ECHINODERMS - Moderately Low 14/36 DECAPOD CRUSTACEA - Very Low 13/96 HARD CORALS - Very Low 1/22 SOFT CORALS - Very Low 1/19 MOLLUSCS - Very Low 9/86 ALGAE - High

Table 13 contd.

Area II

BIOTOPE	STATION NOS.	INDICATOR ORGANISMS BY GENERA IN GROUP	RELATIVE SPECIES ABUNDANCE IN EACH EPIFAUNAL-EPIFLORAL GROUP
3) Coarse Sand	45, 46, 52 351	a) SPONGES Fibulia b) ECHINODERMS Encope Echinaster Goniaster c) DECAPOD CRUST. Munida Parthenope Scyllarus d) HARD CORALS Oculina e) SOFT CORALS Muricea f) MOLLUSCS Chlamys Tellina g) ALGAE Gigartina	SPONGES - Very Low 5/66 ECHINODERMS - Moderate 18/36 DECAPOD CRUSTACEANS - Moderate 42/96 HARD CORALS - Very Low 3/22 SOFT CORALS - Moderately Low 6/19 MOLLUSCS - Moderately Low 15/86 ALGAE - Very Low
4) Coarse Sand, Broken Rock & Shell	43, 44, 48, 49, 50	a) SPONGES Ircinia Geodia Tethya b) ECHINODERMS Eucidaris Echinaster Lytechinus c) DECAPOD CRUST. Munida Parthenope Pilumnus d) HARD CORALS Oculina e) SOFT CORALS Lophogorgia f) MOLLUSCS Vermicularia Chlamys Laevocardium g) ALGAE Caulerpa Microdictyon Dictyota	SPONGES - Moderate 33/66 ECHINODERMS - Moderate 19/36 DECAPOD CRUSTACEANS - Moderate 40/96 HARD CORALS - Very Low 1/22 SOFT CORALS - Very Low 1/22 MOLLUSCS - Moderately Low 20/86 ALGAE - Moderate
5) Hard Packed Sand	246	a) ECHINODERMS Lytechinus Luidia b) DECAPOD CRUST. Symethis Calappa Macrocoeloma c) ALGAE Caulerpa	SPONGES - Absent ECHINODERMS - Very Low 3/36 DECAPOD CRUSTACEANS - Moderately Low 34/96 HARD CORALS - Very Low 34/96 SOFT CORALS - Absent MOLLUSCS - Very Low 1/86

Table 13 contd.

Area III

BIOTOPE	STATION NOS.	INDICATOR ORGANISMS BY GENERA IN GROUP		RELATIVE SPECIES ABUNDANCE IN EACH EPIFAUNAL-EPIFLORAL GROUP
1) Shell Rubble	34, 35, 37, 39, 41	a) SPONGES Placospongia Ircinia Haliclona	e) DECAPOD CRUST. Pylopagurus Stenorhynchus Munida	SPONGES - Moderately Low 20/66 ECHINODERMS - Moderate 16/36 HARD CORALS - Very Low 3/22 SOFT CORALS - Low 4/19 MOLLUSCS - Moderate 51/86
		b) ECHINODERMS Echinaster Arbacia Eucidaris	f) MOLLUSCS Vermicularia Chlamys Aequipecten	DECAPOD CRUSTACEANS - Moderately High 59/96 ALGAE - Low
		c) HARD CORALS Oculina	g) ALGAE Botryocladia Struvea Rhodymenia	
		d) SOFT CORALS Leptogorgia		
2) Fine Sand - Mud	22	No definite organisms established		All groups virtually absent
3) Coarse Sand	134	a) SPONGES Cliona	d) MOLLUSCS Vermicularia Chlamys Octopus	SPONGES - Absent ECHINODERMS - Moderately Low 11/36 DECAPOD CRUSTACEANS - Moderately High 59/96 MOLLUSCS - Moderately Low 14/86 ALGAE - Low
		b) ECHINODERMS Astropecten Echinaster Goniaster	e) ALGAE As in 1) above	
		c) DECAPOD CRUSTACEANS As in 1) above		

Table 13 contd.

Area IV

BIOTOPE	STATION NOS.	INDICATOR ORGANISMS BY GENERA IN GROUP	RELATIVE SPECIES ABUNDANCE IN EACH EPIFAUNAL-EPIFLORAL GROUP
1) Shell Rubble	12	a) SPONGES Haliclona b) ECHINODERMS Echinaster Goniaster Astropecten c) DECAPOD CRUST. Dromida Munida d) MOLLUSCS Discorsio	All groups low to absent.
2) Fine Sand	13	a) ECHINODERMS Clypeaster Encope Astropecten b) DECAPOD CRUST. Ananimus c) MOLLUSCS Argopecten Laevicardium	All groups low to absent.
3) Hard Sand w/occasional Shell	14, 16, 17	a) ECHINODERMS Astropecten Luidia Echinaster b) DECAPOD CRUST. Calappa Petrochirus c) MOLLUSCS Discorsio Murox	All groups low to absent.
4) Mud, Shell-Gravel	18	a) ECHINODERMS Stylocidaris Astroporpa annulata Luidia b) SPONGES Halichondria	All groups low to absent.

Table 13 contd.

Area V

BIOTOPE	STATION NOS.	INDICATOR ORGANISMS BY GENERA IN GROUP	RELATIVE SPECIES ABUNDANCE IN EACH EPIFAUNAL-EPIFLORAL GROUP
1) Very Soft Black Mud	2-6	None established	All groups virtually absent.
2) Mud, Sand, Shell	1	a) ECHINODERMS Hemipholis b) SOFT CORALS Leptogorgia c) DECAPOD CRUST. Callinectes Penaeus	All groups very low to absent.

diversity and abundance for all fauna were low in Station 12. A distince departure in fauna was noted in Station 18, containing mud, shell and gravel; this included a deep water ophiuroid not collected elsewhere. Area V was the most depauperate area in the group. Only Station 1 revealed indicator species (Ophiuroid, Hemipholis, and the sea whip, Leptogorgia).

Inter-area comparison reveals that crabs and shrimps were most abundant in Areas II and III, well correlated with shell and rubble. Area III had the greatest number of species of molluscs, followed by II and IV, each with 50. Echinoderms were most abundant in Area II. Sponges and soft corals, requiring hard substrates, reach greatest species abundance in Area II.

In summary, substrate remains the key abiotic factor influencing the structure of benthic communities. Beyond this, Collard and D'Asaro (1973) point out that in depths from about 30 to 200 m the benthic fauna of the Gulf is generally West Indian in composition, whereas the deep Gulf fauna has Atlantic affinities. These relationships may partly be related to egg and larval transport via surficial Loop current waters to the shelf areas of the Eastern Gulf.

6. Histopathology of benthic invertebrates. The scope of the study did not include analysis of the sectioned samples, however, some qualitative and preliminary observations may be pertinent. Histopathological study of marine organisms is a relatively new field, hence many of the organic structures observed in the collected organisms are unknown or previously undescribed. This applies, for example, to alcyonarian corals and other epifauna from Area II (Florida Middle Ground). Table 5 indicates those species archived for Histopathology. From the limited observations made during control of tissue preparation, most organisms and organ development appeared to be normal in character. The chief pathologies noted were reactions to parasites - a normal feature in undisturbed bottoms.

Scallops recovered from Areas I - III showed males with spermatozoan development and females ready to spawn. Such developments are significant because the reproductive cycle is one of the organism functions most sensitive to influence of pollutants or other stress conditions. Since reproduction is frequently related to or triggered by variations in temperature, further observations may also reveal useful information about timing and reproductive strategy in valuable marine species.

C. Chemistry.

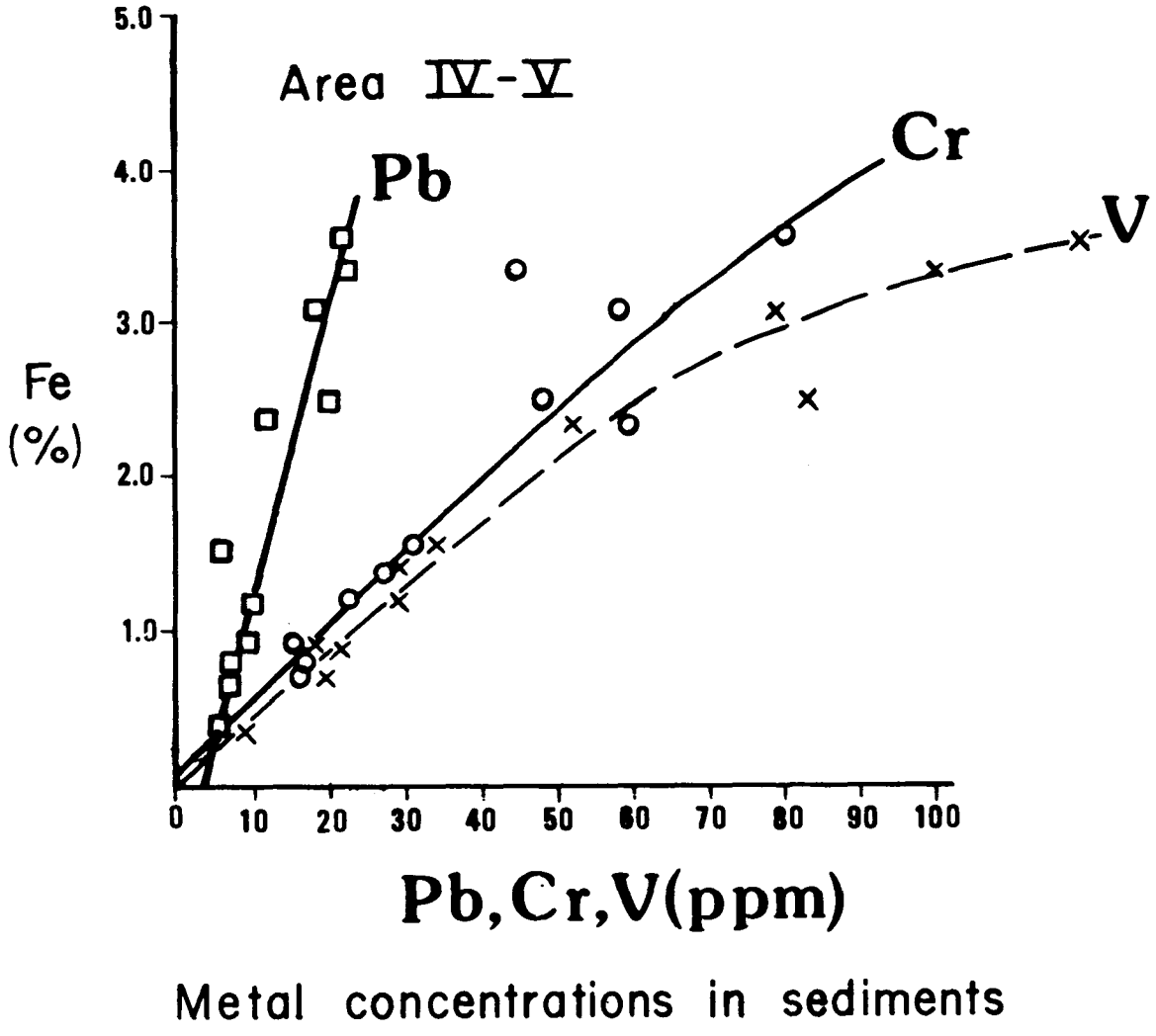
1. Sediment.

a. Trace Metals. Samples of each of the 65 master stations were selected for analysis of the 8 trace elements, as shown in Table 14. These data show that trace metals are generally well below the average concentration for nearshore sediments, due particularly to the large admixture of metal-poor carbonate. As in Fig. 7 many of the trace elements correlate with iron, not necessarily as a direct correlation, but merely because increase in iron signifies an increase in detrital clay components known to contain most of the metal concentrations. As pointed out by Presley (CT4-11), a map of trace constituents prepared by Holmes (1973) agrees with the low concentrations found here on much

Table 14. Sediment trace metal concentrations (from Presley, et al., CT4-11). N = number of samples. Standard deviation in parentheses.

Area	N	Ba(ppm)	Cd(ppm)	Cr(ppm)	Cu(ppm)	Fe(o/o)	Ni(ppm)	Pb(ppm)	V(ppm)
I	9	49(15)	.05(0)	18(5.4)	4 (.6)	.16(.04)	2 (1)	6 (1.3)	5(1.5)
II	8	46(12)	.07(.02)	13(6.8)	4.4(1.3)	.16(.08)	3 (1.5)	3.5(1.8)	6(4.5)
III	20	68(31)	.09(.05)	19(7.5)	4.9(2.7)	.52(.19)	4.5(1.9)	6 (1.6)	10(4)
IV	10	76(39)	.08(.03)	16(20)	4.5(3.8)	.66(.51)	4 (2.7)	7 (2.7)	13(7)
V	10	339(213)	.2 (.08)	39(23)	10.5(7.1)	2.01(1.11)	17 (13)	13 (6.5)	56(37)
Carbonate rocks		150	0.0X	11	14	.4	12	8	15
Nearshore sediments		750	0.X	100	48	3.5	55	20	130

Figure 7. Concentrations of trace metals and iron in MAFLA sediments (Presley)



of the west Florida shelf. However, some discrepancies may be noted. Holmes' map predicts between 100 and 150 ppm vanadium in much of Area V whereas a mean of only 56 was found in this report. Moreover, Holmes' map indicates more than 300 ppm V, some in an arc of sediments to the south, and between 70 and 100 ppm lead at a depth of about 600 m, south of Mobile Bay. However, the analyses on which the maps are based are semiquantitative, and the differences may be more apparent than real.

b. Hydrocarbons. There appear to be relatively little aliphatic/aromatic variations in Area I, suggesting a uniform source for hydrocarbons in the area. (Tables 15 and 16). Table 17 indicates that aromatic hydrocarbns are more abundant in peripheral stations than in the center of the area. The isoprenoid parameters of the lipids (Table 18) suggest that in Areas I - III organic sources of hydrocarbons such as algae or plankton are more likely than petroleum hydrocarbons. On the other hand, all of Area V and a part of Area IV (Stations 15-20) contain an envelope of aliphatics containing appreciable quantities of C_{14}-C_{20} n-alkanes with a fairly smooth distribution (compare Figs. 8 and 9). The alkane distribution and the isoprenoid ratios are those typical of sediments that have been exposed to crude oil. The petroleum-like hydrocarbons have been weathered only slightly. More severe weathering would cause relatively lower C_{14}-C_{20} concentrations and the C_{17}/pristane and phytane ratios would be correspondingly lower. The pristane/phytane ratio average is in agreement with oils produced in the Gulf. The dual maxima at C_{17} and C_{29} in the chromatograms may be seen in Fig. 9, whereas it is not present in Fig. 10, a chromatogram from the carbonate-rich Area I (Station 53).

In addition to sediments, a suite of algal samples (Tables 19 and 20) were also analyzed for hydrocarbons. The algal chromatograms show that the aliphatic hydrocarbons have a rather simple structure with prominent C_{15} and C_{17}. The aliphatic hydrocarbon spectra of the algae may contain some non-algal types due to inclusion of tissue from encrusting forms such as bryozoans. However, one sample (red alga Goniolithon) from Station 13 contains a series of normal aliphatics from C_{20} to C_{30} in large quantities and with no odd-even preference. The sample also has a low ratio of resolved peak/unresolved envelope which is indicative of petroleum pollution, and points to hydrocarbon of petroleum origin in this case.

2. Benthic Biota.

a. Trace Metals. Copper is, as expected, highest in crustaceans, which utilize the element in their respiratory pigment, hemocyanin (Table 21). Echinoderms and molluscs showed copper concentration on the same order as the sediments, whereas sponges and corals had an order of magnitude of lower concentration. Instead of copper, tunicates use vanadium in their respiratory pigments, and, not surprisingly, showed by far the highest concentration of this element (7 ppm). Nickel is extraordinarily enriched in sponges; their average concentration was more than 100-fold higher than average sediments. It was a matter of regret that lease Area V yielded so few macro-organisms, since it would have been expected to show marked differences from the other areas. Though at low levels, lead did increase markedly in crustaceans from this area (1.5 ppm).

Table 15

Lease Site I

Station #	Dry Weight Sediment (g)	Percent Carbonate	Percent Organic Carbon*	Weight Lipids (g)	Weight Aliphatic Hydrocarbons (g)	Weight Aromatic Hydrocarbons (g)
55	177.2	91.8	6.68	0.4805	0.00727	0.00875
56	196.4	89.9	3.91	0.2734	0.00293	0.00413
57	238.9	89.3	3.96	0.677	0.00433	0.00573
58	47.43	97.2	5.92	0.098	0.00128	0.00114
59	Dredge Sample					
60	752.9	62.5	1982	0.315	0.00304	0.00427
61	240.9	88.3	2.54	0.41125	0.00402	0.00572
62	40.35	96.27	4.28	0.03375		0.00128
63	328.97	84.2	1.63	0.337	0.00473	0.00338
64	368.7	83.5	4.34	0.33925	0.00391	0.00511
65	434.0	81.2	0.90	0.35625	0.00431	0.00407

* on a carbonate-free basis

Table 15 contd.

Lease Site II

Station #	Dry Weight Sediment (g)	Percent Carbonate	Percent Organic Carbon*	Weight Lipids (g)	Weight Aliphatic Hydrocarbons (g)	Weight Aromatic Hydrocarbons (g)
42	471.7	77.6	1.06	0.09388	0.00111	0.00136
43	No Sample					
44	148.5	92.6	2.33	0.10275	0.00171	0.00318
45	496.0	77.5	1.24	0.18075	0.00215	0.00420
46	801.5	63.8	0.52	0.28175	0.00377	0.00359
47	42.18	97.7		0.0925	0.00132	0.00154
48	371.0	83.7	1.91	0.1686	0.00221	0.00376
49	73.0	93.4	2.77	0.06125	0.00098	0.001696
50	200.8	90.3	2.59	0.2005	0.00161	0.00217
51	No Sample					
52	158.27	91.5	3.54	0.24363	0.00189	0.00407
53	213.6	91.1	2.82	0.2055	0.00192	0.00342
54	No Sample					

* on a carbonate-free basis

Table 15 contd.

Lease Site III

Station #	Dry Weight Sediment (g)	Percent Carbonate	Percent Organic Carbon*	Weight Lipids (g)	Weight Aliphatic Hydrocarbons (g)	Weight Aromatic Hydrocarbons (g)
21	467.8	80.8	1.95	0.19175	0.00296	0.00498
22	193.6	92.5	4.15	0.3112	0.00407	0.00283
23	641.83		1.66	0.837	0.00301	0.00353
24	503.46		2.27	0.47875	0.00043	0.00089
25	571.6	76.6	2.17	0.1931	0.00265	0.00364
26	665.33		0.59	0.2385	0.00250	0.00261
27	473.2	76.2	2.32	0.32775	0.00217	0.00251
28	210.96	90.3	2.12	0.1016	0.00155	0.00250
29	464.5	67.8	1.78	0.2000	0.00209	0.00291
30	395.4	78.0	1.43	0.13925	0.00233	0.00137
31	239.2	89.7	2.21	0.0955	0.00225	0.00203
32	No Sample					
33	152.06	93.0	2.74	0.1485	0.00149	0.00342
34	364.6	78.0	0.62	0.08725	0.0008	0.00102
35	597.9	74.3	0.43	0.10500	0.00218	0.00206

* on a carbonate-free basis

Table 15 contd.

Lease Site III contd.

Station #	Dry Weight Sediment (g)	Percent Carbonate	Percent Organic Carbon*	Weight Lipids (g)	Weight Aliphatic Hydrocarbons (g)	Weight Aromatic Hydrocarbons (g)
36	730.3	70.3	0.59	0.1490	0.00206	0.00243
37	589.5	72.2	0.49	0.09925	0.00193	0.00243
38	572.89	71.4	0.41	0.0921	0.00154	0.00168
39	1126.6	30.1	0.14	0.0631	0.00133	0.00177
40	1296.6	48.3	0.21	0.15325	0.00232	0.00386
41	1473.9	17.5	0.14	0.07838	0.00230	0.00316

* on a carbonate-free basis

Table 15 contd.

Lease Site IV

Station #	Dry Weight Sediment (g)	Percent Carbonate	Percent Organic Carbon*	Weight Lipids (g)	Weight Aliphatic Hydrocarbons (g)	Weight Aromatic Hydrocarbons (g)
11	1427.24		0.10	0.03162	0.00059	0.00088
12	1664.2	39.8	0.13	0.0386	0.00155	0.00170
13	2271.27		0.03	0.13375**	0.00014	0.00021
14	2355.1	10.6	0.06	0.04188	0.00020	0.00025
15	2457.2	13.2	0.12	0.254	0.00190	0.00120
16	2572.7		0.05	0.125	0.00016	0.00039
17	312.74		1.33	0.2445	0.00626	0.00311
18	201.0	93.1	2.29	0.0755	0.00315	0.00183
19	244.9	92.4	2.13	0.0283	0.00111	0.00134
20	344.9	89.1	1.41	0.10983	0.00414	0.00216

* on a carbonate-free basis

** Approximately 4/5 of the lipid spilled in work up.

Table 15 contd.

Lease Site V

Station #	Dry Weight Sediment (g)	Percent Carbonate	Percent Organic Carbon*	Weight Lipids (g)	Weight Aliphatic Hydrocarbons (g)	Weight Aromatic Hydrocarbons (g)
1	456.65		0.63	0.1512	0.003625	0.00435
2	722.7		0.75	0.2377	0.00421	0.00462
3	409.0		0.80	0.138	0.00574	0.00472
4	271.92		0.74	0.07375	0.00478	0.00328
5	1311.7		0.79	0.73144	0.01025	0.00717
6	1507.3		0.43		0.00916	0.00474
7	2023.7		0.54	0.5906	0.01288	0.01436
8	2043.0		0.23	0.4706	0.01037	0.00549
9	1991.0		0.30	0.06812	0.00240	0.00220
10	988.43		0.61	0.1016	0.00489	0.00257

* on a carbonate-free basis

Table 16

HYDROCARBONS IN BENTHIC MACROFAUNA

Lease Area	Individuals	% (aliphatics/lipids)	% (aromatic/lipids)
I	7	0.04 to 0.66	0.29 to 0.97
II	7	0.05 to 0.38	0.05 to 3.70
III	3	0.15 to 0.28	0.33 to 2.30
IV	10	0.05 to 0.70	0.27 to 2.33
V	2	0.32 to 0.69	1.02 to 1.34

Table 17 Comparison of Gravimetric Data Among Lease Areas

Lease Area	% Lipid/ Sed	% Aliph/ Lipid	ppm Aliph/ Sed	% Arom/ Lipid	ppm Arom/ Sed	% Org. C	% $CO_3^=$
I	0.147	1.14	17.41	1.55	21.31	3.60	86.42
II	0.086	1.22	10.25	1.92	15.96	2.08	85.92
III	0.473	1.43	5.09	1.78	6.20	1.42	71.0
IV	0.019	2.18	5.45	1.91	3.33	0.77	56.36
V	0.028	3.21	7.69	2.56	6.16	0.58	-

Table 18. Isoprenoid ratios* in sediment aliphatic hydrocarbons.

Station Number	C_{17}/ Pristane	C_{18}/ Phytane	Pristane/ Phytane	Station Number	C_{17}/ Pristane	C_{18}/ Phytane	Pristane/ Phytane	Station Number	C_{17}/ Pristane	C_{18}/ Phytane	Pristane/ Phytane
1	2.25	3	2	23	5.25	5	2	45	3.5	6.8	3.2
2	2.5	2.75	1.5	24	4	8	3	46	4.38	3.22	0.89
3	2.25	4	2	25	2.71	14	7	47	5.6	8.39	2.42
4	2.3	3.6	2	26	4	6.5	1.87	48	6	16.43	3.57
5	2.14	3.3	2.33	27	2.88	10.67	2.67	49	6.96	4.5	2.33
6	2.17	2	1.5	28	2.88	7.33	5.33	50	3.08	6.5	3.25
7	1.5	2	1.6	29	4.1	4.67	1.66	52	3	7.5	3.5
8	1.56	2.6	1.8	30	2.33	2.8	1.2	53	5.0	8.57	0.57
9	1.6	3	2.5	31	4.4	9.14	2.86	55	22	9	0.67
10	2.33	3	1.5	33	2.12	5.6	3.2	56	70	5.62	0.5
11	2.86	2.17	1.17	34	2.38	3.17	1.3	57	100	12	0.5
12	2.73	3.57	2.14	35	3.14	10	4.67	58	6.14	3.67	1.83
13	1.36	1.5	1.4	36	2.14	4	2.33	60	16.67	1.2	0.36
14	Too small			37	3.08	6.75	3.25	61	17	2	0.5
15	2.86	3	1.4	38	3.75	18	8	63	3.5	4	2
16	2.2	2	1.67	39	4	6	2	64	14.29	1.67	1.17
17	4.75	3	1.6	40	4.29	5	2.33	65	10.67	1.0	0.75
18	2.4	2.57	1.43	41	5.5	5	3				
19	2.5	2.83	1.67	42	3.2	3.6	2				
20	2.8	5.5	2.5	44	3.6	4	2				
21	3.0	6.5	2.5								
22	3.29	8	3.5								

* Ratios were computed from planimetric calculation of component concentration using the peak and upper boundary of the unresolved envelope on FFAP chromatograms as the area.

Figure 8. Chromatogram of hydrocarbon extract from sediment, station 12, area IV (Lytle and Lytle)

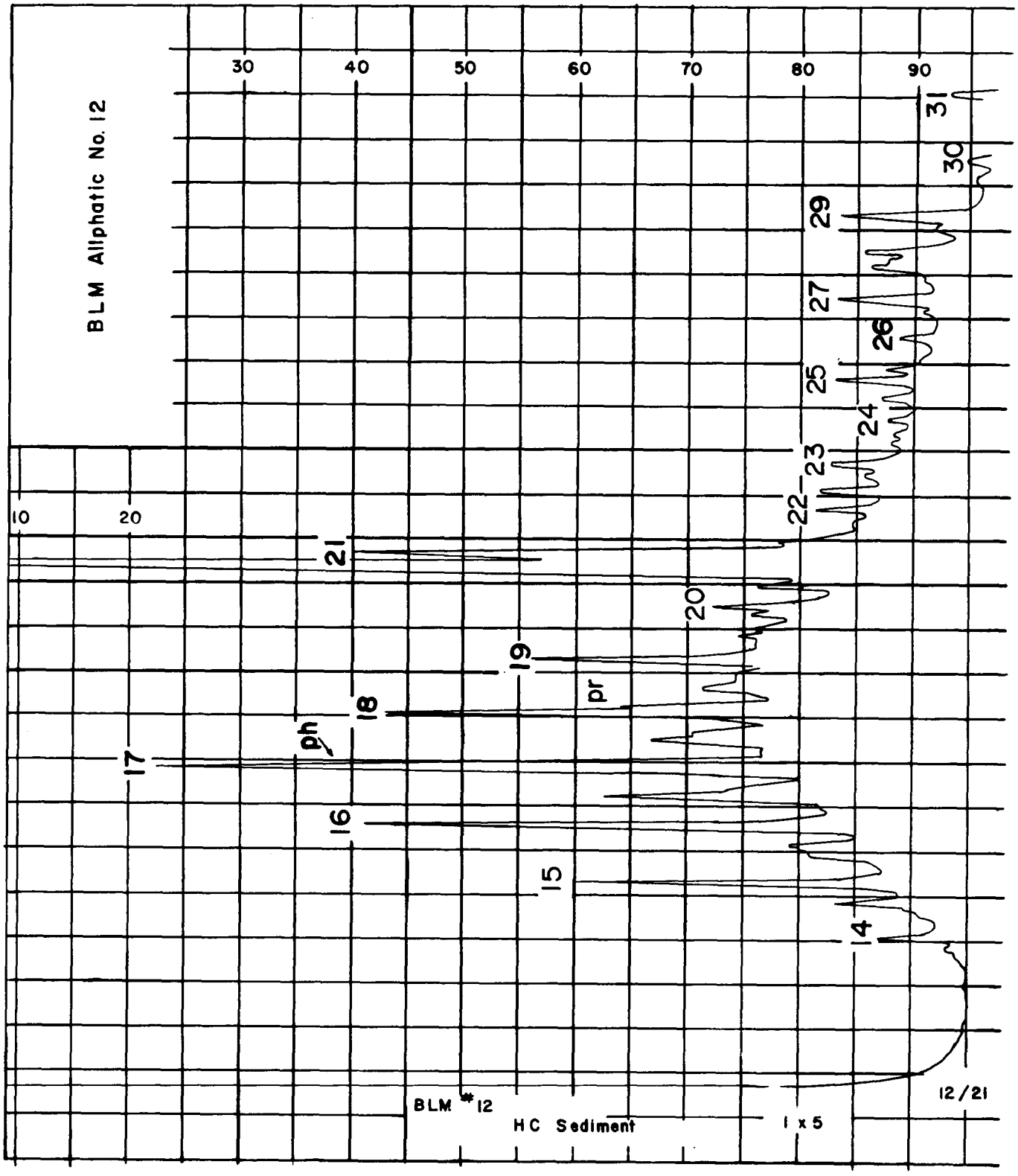


Figure 9. Chromatogram of hydrocarbon extract from sediment, station 55, area I

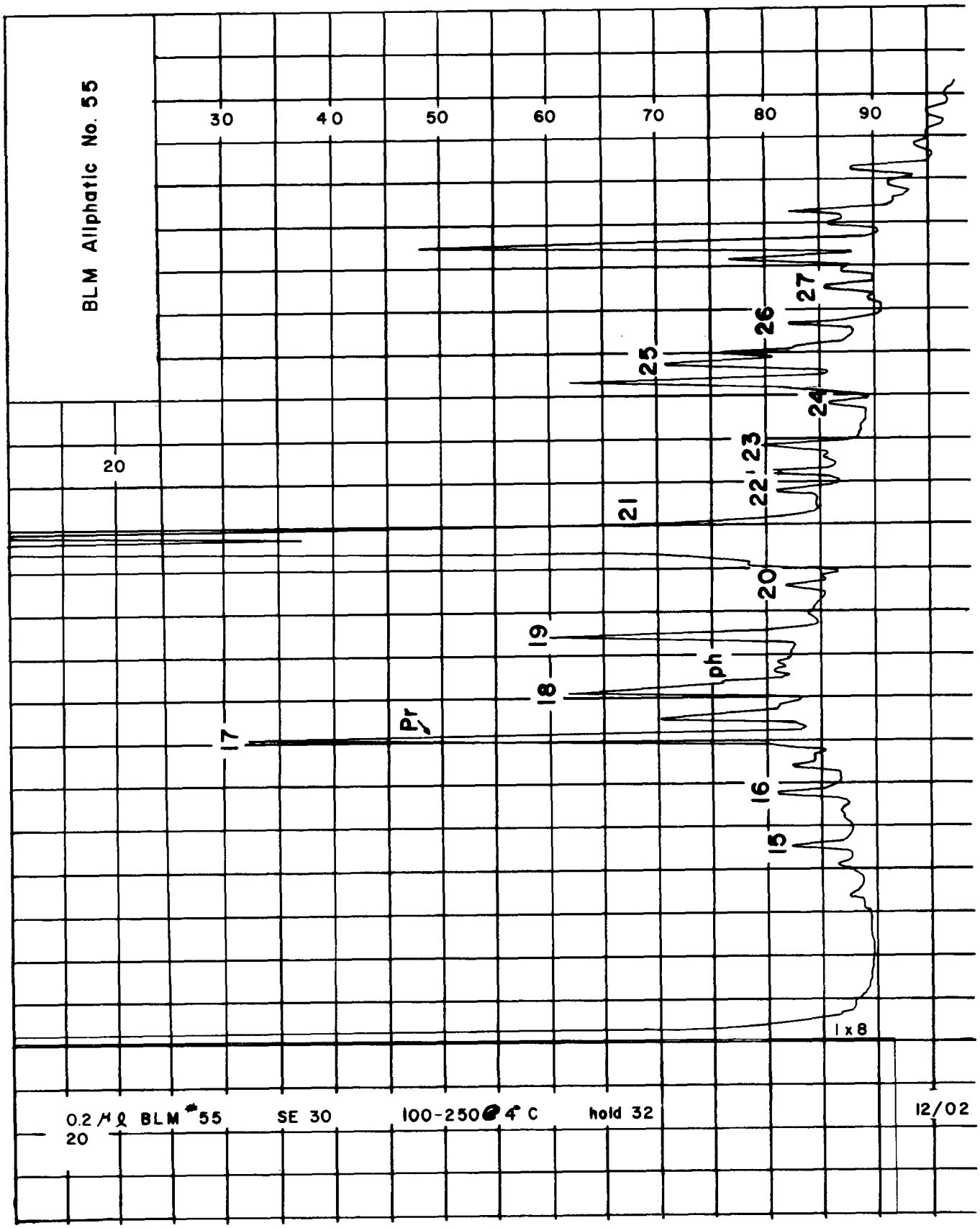


Figure 10. Chromatogram of hydrocarbon extract from sediment, station 53, area I

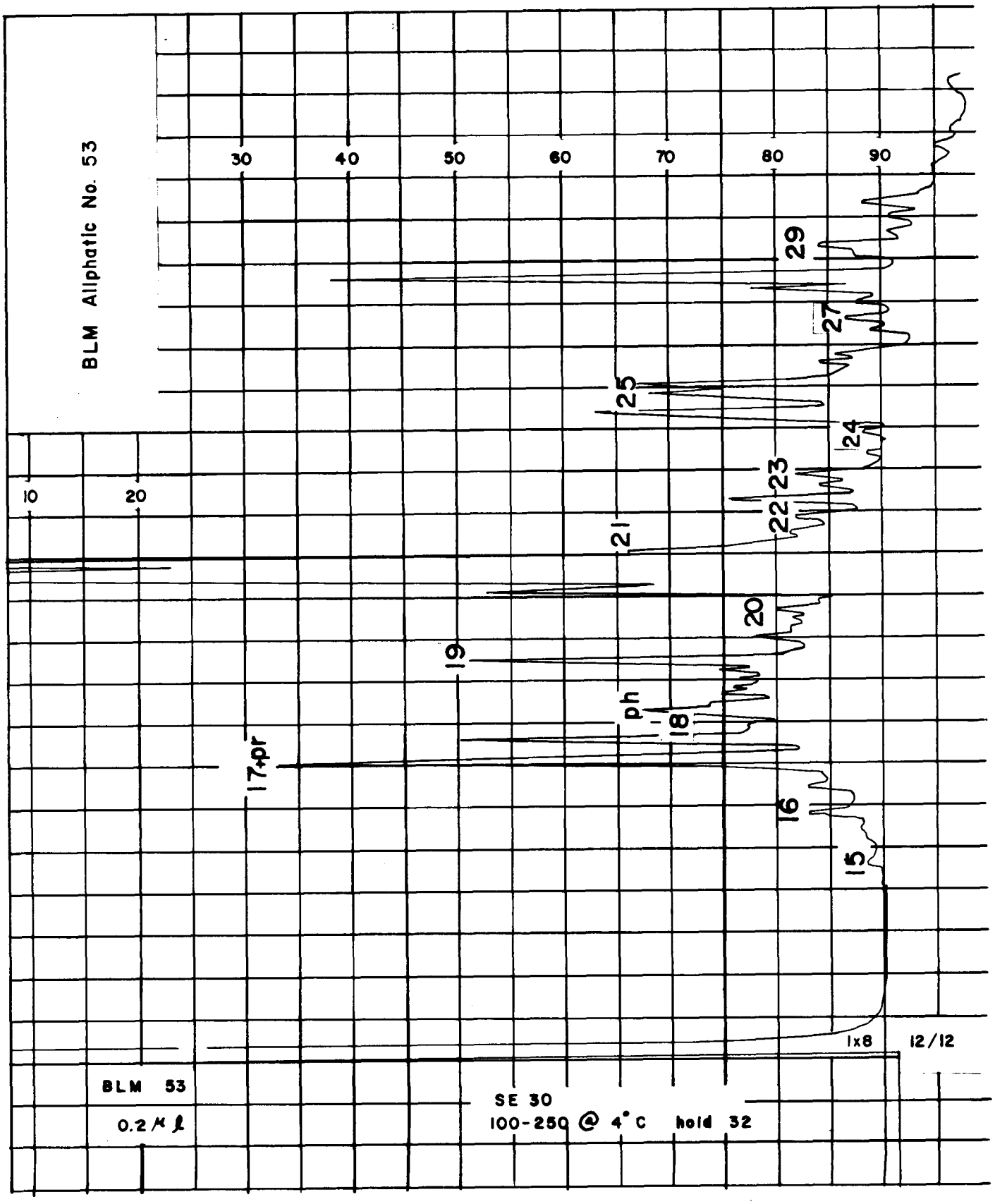


Table 19 Identification of dredge samples for Chemistry Section by Dr. Lionel N. Eleuterius, 14 January 1975.

Division Phaeophyta (brown algae)
Division Rhodophyta (red algae)
Division Chlorophyta (green algae)

Lease Site	Plant	Animal
I	#59 Sargassum filipendula (brown alga)	
	#59 Gracilaria sp. (probably domingensis) (red alga)	
II	#45 Rhodymenia sp. (red alga) (probably pseudopalmata)	Bugula sp. (Bryozoan)
	#46 Padina vickersiae (brown alga) Halimeda favulosa (green alga) Pterocladia bartletii (red alga)	Class Ectoprocta
	#49 Sargassum sp. (brown alga) Thalassia testudinum (rhizome) (flowering plant) Halymenia sp. (red alga)	Membranipora sp.
	#351 Halimeda favulosa (green alga) Dictyota sp. (brown alga) Spyridia sp. (red alga)	
III	#34 Padina vickersiae (brown alga)	Bugula sp. (Bryozoan) Serptularella sp. Halecuim sp.
	#39 Leptofauches rhodymenioides (red alga) Gracilaria sp. (red alga)	Bubula sp. (Bryozoan)
	#41 Gymnogongrus sp. (red alga) Halimeda sp. (green alga)	Class Ectoprocta Serpula sp. (worm tubes
IV	#13 Goniolithon sp. (red alga)	Class Ectoprocta

Table 20 Ratios Resolved Peaks/Unresolved Envelope

Algal Samples

Sample Number	Ratio in Aliphatic HC	Ratio in Aromatic HC
II-46	0.49	1.15
II-45	0.22	0.74
II-351	0.67	1.83
IV-13	0.09	0.56
III-34	0.23	0.66
III-39	0.19	0.71
II-49	0.36	1.06
Red-59	0.35	0.58
59-Sargassum	0.29	2.02
III-41	0.26	1.23
Average	0.32	1.05

TABLE 21

SUMMARY OF TRACE METAL CONCENTRATIONS IN EACH TAXONOMIC GROUP IN EACH LEASE AREA

Average μg/g dry wt. ± 1 S.E.M.

	NUMBER ANALYZED	Cd	Cr	Cu	Fe	Ni	Pb	V
LEASE Area I								
Sponges	16	5.8±2.3	2.6±0.7	4.96±0.70	625±146	380±143	0.48±0.12	1.5±.3
Soft Corals	1	0.50	0.62	0.76	137	0.79	0.30	0.9
Hard Corals	4	0.49±0.03	0.67±.14	0.48±0.19	173±35	0.38±0.1	0.28±0.08	1.2±0.1
Crustaceans	6	1.7±1.0	0.43±0.1	32.3±12.4	64±20	10±9.6	0.17±0.06	1.0±0.3
Echinoderms	7	0.70±0.21	0.16±.07	5.9±3.7	187±145	8.8±6	0.34±0.08	1.9±0.7
LEASE AREA II								
Sponges	24	3.12±1.22	1.25±0.41	5.63±1.06	208±53	121±80	1.17±0.4	1.13±0.18
Soft Corals	6	1.54±0.33	0.13±0.04	0.85±0.22	59±22	1.1±0.6	0.17±0.04	1.7±0.4
Hard Corals	9	0.43±0.06	0.32±0.14	0.65±0.18	100±31	3.1±1.5	0.21±0.04	1.6±0.2
Molluscs	7	7.48±3.22	5.0±2.5	3.84±1.55	170±30	18.2±5.1	0.70±0.21	4.1±1.2
Polychaete	1	5.06	1.25	5.65	552	111	1.25	1.9±0.6
Crustaceans	1	0.55	0.07	20	91	0.42	0.35	1.3±0.3

TABLE 21 (cont'd)

SUMMARY OF TRACE METAL CONCENTRATIONS IN EACH TAXONOMIC GROUP IN EACH LEASE AREA

Average μg/g dry wt. + 1 S.E.M.

	NUMBER ANALYZED	Cd	Cr	Cu	Fe	Ni	Pb	V
LEASE AREA II (cont'd)								
Echinoderms	5	2.96±2.4	0.27	4.63±2.70	49±12	0.51±.07	0.24±0.08	1.9±0.4
Tunicates	4	0.34±0.14	7.9±0.8	2.84±1.10	718±458	3.7±0.9	0.60±0.19	7.4±1.4
LEASE AREA III								
Sponges	6	11.5±7.5	5.1±1.6	3.20±1.16	901±436	154±104	1.38±0.38	3.1±0.8
Echinoderms	3	1.2±0.4	0.14±0.08	2.30±1.60	68±26	0.32±0.16	0.23±0.09	0.31±0.18
Tunicates	1	0.60	4.38	3.50±1.10	1.58	5.6±0.9	0.98±0.19	6.8
Amphioxus	1	3.4	0.38	1.4	92	3.9	0.29	2.5
LEASE AREA IV								
Molluscs	1	11.4	0.85	9.7	357	N.D.*	0.29	4.97
Crustaceans	1	1.05	0.085	12.4	7.7	N.D.*	0.068	N.D.*
Echinoderms	3	0.66±0.33	0.24±0.09	1.59±0.64	45±19	8.2±7.6	0.22±0.06	0.84±0.59

*Not Deductible

TABLE 21 (cont'd)

SUMMARY OF TRACE METAL CONCENTRATIONS IN EACH TAXONOMIC GROUP IN EACH LEASE AREA

Average μg/g dry wt. ± 1 S.E.M.

	NUMBER ANALYZED	Cd	Cr	Cu	Fe	Ni	Pb	V
LEASE AREA V								
Molluscs	2	2.38±0.05	0.66±0.11	4.95±0.39	412±118	3.70±1.79	0.24±0.04	2.05±0.63
Crustaceans	2	0.57±0.18	2.65±0.25	40±10	1700±77	0.57±0.49	1.47±0.72	4.91±0.32

b. Hydrocarbons in Benthic Organisms. The data on benthic organisms (Tables 16 and 22) show that most organisms contained considerably larger amounts of unsaturated hydrocarbons than saturated hydrocarbons, and the same group of the former appeared in essentially all organisms. Biogenic hydrocarbons such as pristane and squalene were important components. No series of homologous n-alkanes resembling Gulf crudes were evident. Thus a variety of organisms including shell fish, echinoderms and sponges indicated no evidence of chronic or severe petroleum pollution. Note, however, the algal data from Area IV.

II. Water Column.

Certain of the water properties such as expendable bathythermograph (XBT) and salinity-temperature-depth (STD), and dissolved oxygen measurements were not intended for physical oceanographic studies as such, but rather to line the water column measurements to physical oceanographic compilations and modeling studies being reported separately.

The location of water column stations is shown in Fig. 11.

A. Biology.

1. Nutrients. Replicate samplings and analyses of nitrate and nitrite nitrogen, silica, and phosphate plus arsenate showed standard deviations of 0.01 µg-at/ℓ. Some nitrate samplea showed loss in the last replicates presumably due to growth of algae after thawing.

The results, shown in Table 23, reveal generally low surface and intermediate values but a pronounced tendency for nutrient enrichment in the bottommost water samples, especially in Stations 10-15. Fanning discusses several possible sources of this effect. Upwelling at the shelf edge is rejected because all nutrients should be approximately equally enriched, yet silica is much more concentrated in the western than in the eastern group, without corresponding increase in nitrate. A potential mechanism is the release of nutrients for interstitial waters of underlying sediments through diffusion or seepage. However, an alternative explanation for the lower nitrate enrichments may be uptake by benthic algae, including zoochlorellae that exist symbiotically on benthic foraminifera.

2. Chlorophyll a. Chlorophyll a concentrations were low throughout the MAFLA area and the average concentration in the water column at any station was always less than 0.5 mg chlorophyll a/m^3. A persistent increase in concentration with depth was generally present at each station (Table 24).

3. Particulate and Dissolved Organic Carbon. The mean concentrations of particulate and dissolved organic carbon are shown in Table 25.

Table 22

Gravimetric Summary-Benthic Hydrocarbons

		RANGES (PERCENT OF TOTAL LIPIDS)		
LEASE AREA	SAMPLES	NON-SAPONFIABLES	ALIPHATICS	AROMATICS
I	20	13.54-76.76	0.05-5.54	0.25-1.84
II	17	11.84-74.82	0.05-9.44	0.14-4.05
III	7	10.62-47.07	0.04-5.18	0.33-1.56
IV	10	11.24-80.39	0.05-0.53	0.27-1.79
V	2	20.63-40.83	0.32-0.69	1.02-1.34

Table 23 Final Nutrient Concentrations from the MAFLA.
(All concentrations in µg-at/l)

Iverson's Set

Sample		PO_4-P*	NO_3-N	AutoAnal. SiO_2-Si	Manual SiO_2-Si	NO_2-N
1	T	0.71	1.26	1.22	0.9	0.01
	M	0.50	0.28	1.11	7.6	0.03
	B	0.61	0.19	1.75	2.0	0.03
2	T	0.08	0.30	0.71	0.8	0.03
	M	<0.01	0.19	0.47	2.0	0.02
	B	0.06	0.16	1.46	0.5	0.01
3	T	0.01	0.19	0.96	5.9	0.04
	M	0.01	0.20	0.98	1.1	0.05
	B	0.19	0.25	2.19	2.5	0.02
4	T	0.04	0.18	0.61	0.8	0.03
	M	0.01	0.18	0.57		0.02
	B	0.10	1.98	2.45		0.51
5	T	<0.01	0.20	0.80		0.04
	M	0.02	0.14	0.54		0.03
	B	<0.01	0.18	0.83		0.03
6	T	0.03	0.09	0.78		0.08
	M	0.05	0.22	0.98		0.02
	B	0.03	0.15	1.66		0.02
7	T	<0.01	0.20	1.34		0.01
	M	<0.01	0.20	2.33		<0.01
	B	0.16	0.44	3.43		0.17
8	T	0.03	0.20	0.96		0.02
	M	0.04	0.30	2.76		0.13
	B	0.44	6.63	5.34		0.57
9	T	0.08	0.22	1.12		0.02
	M	<0.01	0.18	0.82		0.03
	B	0.41	5.71	7.83		0.25
C1	T	0.02	0.19	0.55		0.04
	M	0.02	0.13	0.42		0.08
	B	0.20	0.30	1.30		0.04
C2	T	0.03	0.18	1.16		0.03
	M	<0.01	0.19	1.17		0.02
	B	0.05	0.27	2.66		0.40

* includes AsO_4-As

Table 23 contd.

Woodmansee's Set

Sample	AutoAnal. PO_4-P*	Manual PO_4-P*	NO_3-N	AutoAnal. SiO_2-Si	Manual SiO_2-Si	NO_2-N
10 T	0	0.02	0.20	1.91	1.76	0.04
M	0.13	0.11	0.06	2.00	2.26	0.02
B	0.46	0.56	3.38	9.96	10.42	0.07
11 T	0.02	0	0.24	1.06	1.01	0
M	0	0	0.26	1.48	1.49	0
B	0.22	0.27	1.20	13.00	13.31	0.47
12 T	0.01	0	0.24	2.82	2.47	0
M	0.01	0.05	0.35	4.07	4.22	0.05
B	0.12	0.17	0.76	9.30	9.22	0.46
13 T	0	0.05	0.19	0.43	0.24	0.04
M	0.28	0.28	1.21	9.25	9.92	0.26
B	0.47	0.44	0.43	15.53	15.98	0.20
14 T	0.02	0.05	0.08	0.04	0.17	0
M	0.02	0	0.23	0	0	0.02
B	0.29	0.22	4.96	8.39	8.42	0.23
15 T	0.09	0.11	0.39	2.44	2.75	0.02
M	0.06	0.06	0.09	0.16	0.47	0.03
B	0.44	0.42	7.25	14.88	15.17	0.21
A4 T	0.05	0.05	0.06	0.89	1.06	0.02
M	0	0.04	0.07	1.47	1.26	0.02
B	0.88	0.81	17.42	8.21	8.32	0
A5 T	0	0.04	0.14	0.58	0.48	0
M	0	0.04	0.11	0.95	1.07	0.01
B	0.38	0.39	7.17	8.61	8.96	0.13
A6 T	0.01	0	0.22	0.64	0.52	0.02
M	0.05	0.11	0.08	2.32	2.55	0.24
B	0.26	0.33	1.34	9.72	10.12	1.18
C3 T	0	0.04	0.06	0.58	0.48	0.01
M	0	0	0.30	1.64	1.79	0.09
B	0.25	0.26	6.65	7.92	8.07	0.48
C4 T	0.02	0	0.23	0	0	0
M	0	0.05	0.31	1.78	1.56	0.05
B	0.26	0.28	5.64	10.85	11.14	0.26

* includes AsO_4-As

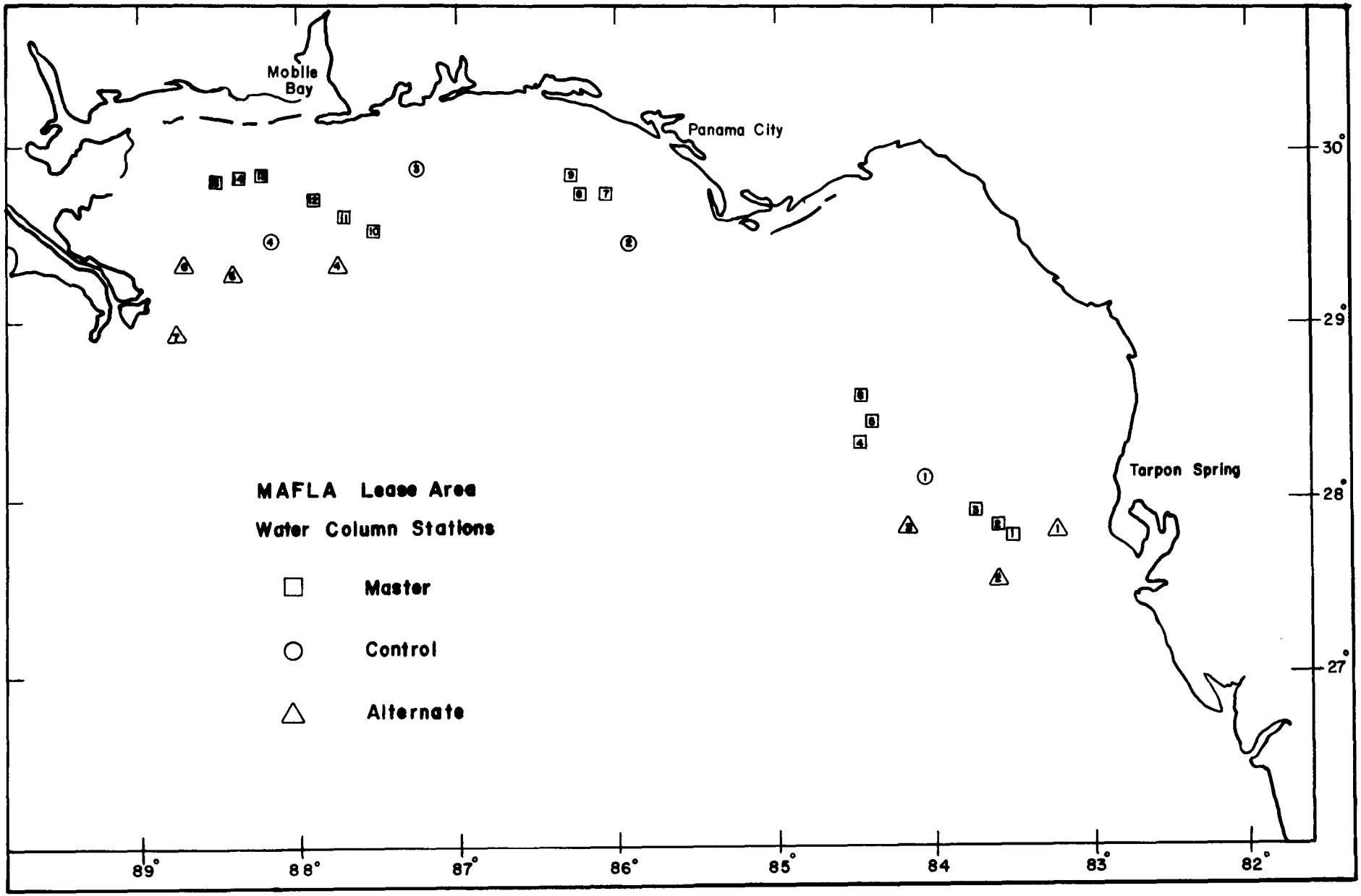


Fig. 11 Water Column Station Locations

Table 24

AREA CHLOROPHYLL SUMMARY

(Grand Mean over all depths, all stations, mg chlorophyll a/m^3)

	I	C1	II	C2	III	C3	IV	V	C4
Surface	0.08	0.11	0.10	0.07	0.05	0.05	0.09	0.19	0.02
Mid-level	0.08	0.12	0.17	0.12	0.33	0.23	0.18	0.23	0.22
Bottom	0.35	0.29	0.56	0.62	0.55	0.21	0.43	0.62	0.86
Mean	0.17	0.18	0.28	0.27	0.31	0.16	0.23	0.35	0.37

CHLOROPHYLL a PER CELL

I	C1	II	C2	III	C3	IV	V	C4
1.72×10^{-5}	1.38×10^{-5}	5.40×10^{-5}	1.03×10^{-4}	2.59×10^{-5}	2.36×10^{-5}	1.93×10^{-5}	2.20×10^{-5}	6.40×10^{-6}

Table 25. Dissolved organic carbon (DOC), particulate organic carbon (POC) and total suspended particulate matter (SPM) for the 5 lease areas. Values in mg/ℓ.

Area	Water Stations	DOC	POC	SPM
I	1,2,3,A1	1.81	.200	.129
II	4,5,6	1.00	.181	.217
III	C-2,7,8,9	1.88	.151	.091
IV	10,11,12	2.19	.147	.125
V	13,14,15	4.00	.215	.368

These data show some puzzling inconsistencies, in that POC values are higher in several cases than total suspended matter. This anomaly is not due to different sampling dates, for the water samples were drawn simultaneously on cruises of the TURSIOPS and GULF RESEARCHER. In neither case were significant systematic differences with depth noted, though Betzer (CT4-11) reported a sharp increase in total particulate matter from Station 13 to 1.8 mg/ℓ.

Also the particulate determinations did not register greater total particulate content toward the Mississippi Delta in view of known turbidities there, and strikingly confirmed by bottom photography (Fig. 4g). As was pointed out earlier, at least bottom waters must have in excess of 100 mg/ℓ in several of the benthic stations (1-10) in Area V. Moreover, ATP levels were as much as 20-fold greater than those found elsewhere.

The total living carbon values were calculated from ATP measurements and are presented in Table 26. These computations indicate that living carbon comprised an appreciable part of the particulate organic carbon. However, these data do not correlate well with the mean ATP levels reported in Table 9, and with the individual ATP levels on which the averages are based.

Table 26. Comparison of total living carbon calculated from C/ATP ratios and POC concentrations at selected MAFLA stations (mg C/m^3).

Station No.	Depth (M)	Living Carbon (ATP)	POC
MS 1	SFC	48	216
	15	51	161
	28	106	298
MS 3		41	178
	15	65	194
	36	91	218

Table 26 (continued).

Station No.	Depth (M)	Living Carbon (ATP)	POC
C-1	SFC	50	176
	20	80	172
	36	57	191
MS 4	SFC	141	176
	27	78	151
	48	116	174
MS 6	SFC	34	165
	20	85	144
	30	387	279

4. Phytoplankton; Sargassum. Net phytoplankton and filtered nannoplankton are tabulated in Tables 27, 28 and 29. The highest concentration of cells in net phytoplankton fraction (55,000 cells/ℓ) was located at Station C-4, where the pennate diatom, Nitzschia delicatissima made up 75% of the population. Subsidiary highs were recorded in nearby Area V, where the mean of 14,600 cells was also dominated by Nitzschia delicatissima. The third ranked station was C-1, whre a mean of about 11,000 cells was made up primarily of a centric diatom, Chaetoceros compressum, (49%) and Oscillatoria erythrae (30%), a blue-green filamentous alga. Total concentrations of nannoplankton showed marked uniformity throughout the MAFLA lease areas, and they were generally lower than net phytoplankton means. Maximum concentration was encountered in Area IV (4,900 cells/ℓ). In brief, diatoms greatly dominated shelf plankton in the MAFLA area, reaching maximum values in the coastal areas.

Sargassum weed, another type of macrophyte, has properties and a life history that fit it particularly well to serve as a monitor for pollutants in sea water. Eighty-one (81) samples of these algae, as well as benthic algae have been collected and archived for analysis or potential analysis of hydrocarbons or other constituents. These pelagic forms fall into two species: Sargassum fluitans, and Sargassum natans, which are closely related and tend to overlap. These large forms remain at the surface of the sea by flotation of their air sacs, and harbor an extraordinary community of organisms: bryozoa, mollusca, coelenterata, and fishes. Thus, "benthic" organisms are exposed to concentrated films of oil at the sea surface for long periods of time.

5. Zooplankton. The chief zooplankton species encountered in Areas IV and V are shown in Table 30. Examination of the extensive tabulated data of Maturo and Woodmansee (CT4-11) indicates that in Areas I and II, much lower biomasses ranging from 5 to 60 mg/m^3 are typical. Although calanoid copepods remain prominent, other zooplankters, such as gastropod veligers, shrimp bivalve larvae, ostracodes, tunicates (oikipleura), Globigerina, fish larvae, and pteropods are becoming significant. Area III falls in an intermediate position between I and II on the one hand, and IV and V on the other, yielding decreasing bivalve larvae, shrimp and other tunicates. In a very gross way, these relationships correlate also with macrofauna on the respective shelf area, insofar as

Table 27

AREA PHYTOPLANKTON SUMMARY

(Grand mean over all depths and all stations in cells per liter)

	AREA I	STATION C-1	AREA II	STATION C-2	AREA III	STATION C-3	AREA IV	AREA V	STATION C-4
NET PHYTOPLANKTON	6,298	10,998	3,310	994	7,757	5,300	6,966	14,665	55,305
NANNOPHYTOPLANKTON	3,527	1,981	1,854	1,611	4,196	1,472	4,933	1,212	2,296
NET/NANNO	1.79	5.55	1.79	0.62	1.85	3.60	1.41	12.10	24.09

Table 28. Concentrations of the dominant elements of the phytoplankton communities in Areas V and IV and at Stations C-4 and C-3, expressed in number of cells per litre.

Phytoplankter	V #/	IV #/	C-4 #/	C-3 #/
Chaetoceros spp.	850	4290(2)	11,170(3)	7900(1)
Leptocylindicus danicus	1160(3)	820	24,600(2)	830
Nitzschia closterium	380	1530(4)	0	80
Nitzschia delicatissima	31,400(1)	6390(1)	120,900(1)	1890(2)
Rhizosolenia alata f. gracillima	720	1500	3430	990(4)
Rhizosolenia fragilissima	940(2)	490	1680	70
Thalassionema nitzschioides	1980(2)	1890(3)	3600	1420(3)
Thalassiothrix mediterranea	700	490	4300(4)	310

Table 29

NET PHYTOPLANKTON SUMMARY

(Grand Mean over all depths, all stations, cells per liter)

Species	I	C1	II	C2	III	
Cyclotella sp.	-	-	-	362	926	Inc.
Coscinodiscus eccentricus	10	-	20	13	111	
Hemiaulus Haukii	165	378	40	5	22	Dec.
Hemiaulus Membranaceus	65	110	18	-	3	Dec.
Chaetoceros atlanticum	18	49	15	11	100	
Chaetoceros decipiens	101	200	67	35	297	
Chaetoceros compressum	1405	5377	335	4	2947	
Chaetoceros didymum	9	-	30	22	120	
Bacteriastrum delicatulum	38	217	-	11	-	
Bacteriastrum hyalinum	259	189	71	5	483	
Leptocylindricus danicus	13	16	5	4	347	Inc.
Rhizosolenio alata	42	70	38	12	685	
Rhizosolenio fragilissima	23	23	5	15	40	
Rhizosolenio stolterfothii	27	82	3	3	26	
Thalassionema nitzchioides	2	-	-	8	98	Inc.
Thalassiothrix frauenfoldi	3	1	3	12	38	Inc.
Thalassiothrix mediterronea	2	-	1	-	93	Inc.

Table 29 contd.

	I	C1	II	C2	III	
Nitzschia closterium	28	18	76	53	112	Inc.
Oscillatoria erythrae	4509	3306	2137	88	962	Dec.

NANNO PHYTOPLANKTON SUMMARY

(Grand Mean over all depths, all stations, cells per liter)

Species	I	C1	II	C2	III	
Navicula spp.	>	>	>	>	>	
Syracosphaeva sp.	446	221	93	101	43	
Gephyrocapsa oceania	1041	445	858	332	2964	Dec.
Oscillatoria erythrae	698	408	219	100	69	Dec.

Table 30 Mean zooplankton examples for Areas IV and V. Numbers/m^3. (Maturo and Woodmansee)

Category	V	IV	Category	V	IV
Total Copepods	9277	6527	Euchaeta	57	71
Paracalanus	3036	1586	Siphonophores	56	126
Acartia	2170	585	Calanus	20	53
Corycaeus	1699	353	Pyrocystis	19	48
Centropages	1320	483	Amphipods	15	29
Appendicularius	742	-	Hydromedusae	15	10
Eucalanus	701	106	Salps	14	252
Cladocera	497	19	Decapod larvae	11	26
Oithona	388	395	Ostracods	11	10
Oncaea	367	496	Ceratium	7	51
Sagitta	341	138	Lucifer (decapod)	4	12
Crab zoea	115	49	Megalops	4	5
Gastropod veligers	112	136	Fish larvae	2	23
Polychaetes	110	45	Foraminifera	1	2
Pelecypod veligers	92	27	Copilia	1	4
Nauplii	72	39	Tintinnids	1	2
Other calanoids	70	81	Egg cases	0	1
Fish eggs	62	57	Echinoderm larvae	0	1
Euterpina	61	20	Oikopleura (tunicate)	0	0
			Dry wt. mg/m^3	189	101

Table 31 Hydrocarbon properties for water column stations 7 and 9 (MS refers to master stations), Destin Dome area. Data of Calder.

		C17/PRIS		C18/PHY		PRIS/PHY		Odd/Even n-Paraffin		n-Paraffin/ Phytane		n-Paraffin/ C16	
		MS7	MS9	MS7	MS9	MS7	MS9	MS7	MS9	MS7	MS9	MS7	MS9
Surface:	Water	1.22	0.98	1.44	1.34	0.73	1.13	1.14	0.82	53.3	73.5	197	60.4
	Zoopl	0.06	0.10	1.54	2.06	73.9	184	1.43	1.40	49.7	244	28.1	105
Mid:	Water	NA	NA	2.35	1.69	NA	NA	0.97	1.11	150	56.8	NA	NA
	Zoopl	0.18	0.15	3.60	2.58	55.3	99.5	0.94	1.11	1950	355	149	89.4
Bottom:	Water	NA	1.02	NA	2.42	NA	1.17	NA	1.02	NA	39.5	NA	NA
	Zoopl	0.24	0.49	1.50	2.83	9.07	33.9	1.14	1.06	44.5	1020	54.9	248

		n-Paraffin range		Max n-Paraffin		Aromatic range		Max Aromatic	
		MS7	MS9	MS7	MS9	MS7	MS9	MS7	MS9
Surface:	Water	16-31	15-30	23,24	24	21.5-29.6	16.6-31.0	29.6	21.6
	Zoopl	15-25	13-31	21	25	15.9-25.4	14.1-29.7	21.1	27.0
Mid:	Water	18-28	18-28	25	25	21.8-29.6	26.0(only)	29.6	26.0
	Zoopl	13-30	13-30	25,26	25	13.4-29.1	12.3-29.1	14.0	22.6
Bottom:	Water	NA	17-29	NA	25,26	NA	16.5-29.5	NA	29.5
	Zoopl	15-30	12-31	25	26	16.1-29.7	12.0-27.6	27.5	22.6

impinging larvae and eggs are precursors of adult bivalves, ostracods, foraminifera, gastropods and fish.

To grapple with the complex variations in zooplankton within lease tracts, Maturo, Hearne, Ingram, Caldwell and Antoielli (CT4-11) developed an elaborate multivariate statistical program. This was used to study interactions with canonical variables such as hydrocarbons gases, C_3H_8, C_2H_4, CH_4, sunlight, hour, depth, intra-lease area, and inter-lease area variables. Whereas hour and hydrocarbon gases did not show correlations. Significant relationships were obtained with lease tract, station, and, to a lesser extent, depth variables.

B. Chemistry.

1. Hydrocarbons. The composition and components of sea water are recognized as transient properties which may change markedly depending on current movements and systems, input of materials from the shore or the sea floor, the atmosphere or, in the case of man's entry, from the surface of the sea. As a part of the baseline survey it was regarded as desirable to evaluate the hydrocarbon composition of the water column as reflecting a state of semi-equilibrium or exchange with a "normal", or pre-drilling state environment in the eastern Gulf.

a. Sea Water and Zooplankton. Hydrocarbons in water samples over the MAFLA tract showed no consistent trends with depth for either the aliphatic or aromatic fractions of any particular station. Nor were unique hydrocarbon concentrations found in different geographic lease areas; concentrations were extremely low and not far from the limit of analytical detectability. Some typical data, in this case from Area III (Destin Dome) are shown in Tables 31 and 32. Similar results were obtained for zooplankton. Whereas aliphatic hydrocarbons tend to have rather similar concentrations at different depths, the aromatics vary widely. The lack of consistent relationships between concentrations of aliphatics or aromatics in water and plankton may be either introduced by dietary hydrocarbons or zooplankton systhesis of endogenous hydrocarbon.

Table 32. Gravimetric data for hydrocarbons in water and zooplankton, water Stations 7 and 9, Destin Dome (Calder, CT4-11). Concentrations in original sample.

		Aliphatics		Aromatics	
		MS7	MS9	MS7	MS9
Surface:	Water	2.25	0.38 g/ℓ	3.23	0.70 g/ℓ
	Zoopl	0.10	0.31 mg/ℓ	0.10	3.77 mg/ℓ
Mid:	Water	3.1	3.75	0.13	3.00
	Zoopl	1.63	0.40	4.47	0.75
Bottom:	Water	N.A.*	4.63	N.A.*	1.63
	Zoopl	0.34	0.42	0.72	0.57

*N.A. = Not available (sample lost).

b. Low Molecular Weight Hydrocarbons. Two separate investigations were carried out. The first, conducted in May, 1974, in conjunction with retrieval of water samples for other purposes, recovered 111 water samples from surface, middle, and bottom layers of the water column. These samples were extracted and subsequently analyzed in the laboratory at Texas A&M University, Department of Oceanography. Results showed that virtually all samples yielded levels of hydrocarbon that could be expected for equilibrium with the atmosphere (Table 33).

In June, 1974, the Texas A&M "Sniffer" system, incorporating underway recovery of surface water by means of a hose and pump, was put aboard the MISS FREEPORT for the cruise from St. Petersburg back to Galveston via Panama City (June). On this occasion hydrocarbon levels from two to 20 times equilibrium were obtained in Areas III, IV, and V. Areas I and II had near equilibrium values. Additional rechecks were performed for Stations A 4, A 5, and A 6, south of Area V in late June confirmed the enhanced concentrations.

One explanation of these results might be that the hydrocarbons reported in June represent pollutants carried by the Mississippi River and dispersed in the Gulf. However, in view of the relatively rapid loss of light hydrocarbons to the atmosphere in the upper water column (scrubbed by air in the wave zone), this is not regarded as likely. Sudden sea floor emanations over the large area in question also seem unlikely. More probably, the light hydrocarbons emanate from water masses in the vicinity of the oil production platforms around the Mississippi Delta (see dashed line, Fig. 1). This explanation is supported by anomalously low salinities recorded around Panama City in early June (D. Wallace, personal communication), indicating that a mass of river-freshened water had moved eastward, carrying with it regional waters containing anomalous concentrations of hydrocarbons.

These observations suggest several conclusions.

1) Measurements of hydrocarbons in water at given locations may be less meaningful than identifying hydrocarbons in water masses.

2) No significant amount of hydrocarbon seepage or other emanations were observed over the lease tracts, including the Destin Dome, at a time when there was no communication with oilfield-influenced waters to the west.

3) Routine monitoring of low-molecular weight hydrocarbons in the MAFLA lease areas should be done only if and when oil and natural gas are discovered.

c. High Molecular Weight Hydrocarbons. Further data on high molecular weight hydrocarbons in zooplankton and water have been obtained by Meyers. He noted that concentrations of hydrocarbon in net plankton greater than 202 μm averaged 0.31 mg/g for the aliphatic fraction and 1.79 mg/g for the aromatic fraction (Table 34). Mass spectrometer and hydrogenation data indicate that these are probably polyolefins. The principal aliphatic hydrocarbon was always pristane, which is probably derived from the phytol portion of phytoplankton chlorophyll. Hence the low C_{17}/pristane ratios in zooplankton, averaging 0.13 ± 0.10. Pristane/ was high, averaging 167 ± 156. Areas IV and V have much higher pristane/phytane averages than do Areas I and II.

in the water column
(Sackett, Schink and Brooks)

Sample and Depth		Method	Concentrations in Nannoliters/Liter								Coordinates
			CH_4	C_2H_4	C_2H_6	C_3H_6	C_3H_8	$i\text{-}C_4H_{10}$	C_4H_8	$n\text{-}C_4H_{10}$	
MS 1, 5/74,	0 m	SM	35	27	t	t	6.4	---	---	---	27°45N 83°28W
			--	37	a	---	7.5	---	---	---	
	15 m	SM	36	23	a	---	5.4	---	---	---	
			--	26	a	---	7.5	---	---	---	
	28 m	SM	36	13	a	---	8.8	---	---	---	
			--	7.4	a	---	12	---	---	---	
MS 2, 5/74,	0 m	SM	49	25	5.4	---	8.0	---	---	---	27°52N 83°34W
			--	22	5.4	---	8.0	---	---	---	
	15 m	SM	50	18	a	---	6.4	---	---	---	
			57	13	a	---	5.6	---	---	---	
	30 m	SM	33	14	a	---	5.6	---	---	---	
MS 3, 5/74,	0 m	SM	52	22	a	---	8.0	---	---	---	27°56N 83°43W
	15 m	SM	35	19	a	---	8.0	---	---	---	
			--	24	a	---	11	---	---	---	
	36 m	SM	33	8.3	a	---	7.3	---	---	---	
MS 4, 6/74	0 m	SM	84	21	t	0.8	8.0	---	---	---	28°21N 84°24W
	27 m	SM	39	7.2	t	t	3.2	---	---	---	
	48 m	SM	29	3.6	a	---	2.4	---	---	---	
MS 5, 6/74,	0 m	SM	45	24	t	4.8	4.0	---	---	---	28°29N 84°21W
			--	15	t	t	7.0	---	---	---	
	25 m	SM	37	9.9	t	1.6	3.7	---	---	---	
			--	12	t	t	4.0	---	---	---	
	40 m	SM	42	5.4	t	t	2.4	---	---	---	
MS 6, 6.74	0 m	SM	41	35	a	6.4	3.8	---	---	---	28°43N 84°20W
			47	15	a	t	3.2	---	---	---	
	20 m	SM	34	14	3.6	t	3.9	---	---	---	
			33	9.4	t	t	3.4	---	---	---	
	30 m	SM	30	7.2	2.0	t	4.8	---	---	---	
			--	7.4	t	t	-	---	---	---	

Table 33 contd.

Sample and Depth		Method	Concentrations in Nannoliters/Liter								Coordinates
			CH_4	C_2H_4	C_2H_6	C_3H_6	C_3H_8	i-C_4H_{10}	C_4H_8	n-C_4H_{10}	
MS 7, 5/74,	0 m	SM	40	18	a	1.6	3.2	---	---	---	29°43N 86°01W
			42	7.2	a	1.0	3.4	---	---	---	
	18 m	SM	35	6.7	a	---	2.4	---	---	---	
			41	8.5	a	---	3.2	---	---	---	
	35 m	SM	34	11	a	---	4.0	---	---	---	
MS 8, 5/74,	0 m	SM	49	13	t	---	2.4	---	---	---	29°44N 86°14W
	22 m	SM	34	16	a	---	3.2	---	---	---	
			38	--	a	---	4.0	---	---	---	
	45 m	SM	34	2.7	a	---	2.4	---	---	---	
			38	4.1	a	---	2.4	---	---	---	
MS 9, 5/74,	0 m	SM	36	30	t	---	3.6	---	---	---	29°52N 86°16W
			38	9.0	t	---	3.6	---	---	---	
	26 m	SM	44	4.1	a	---	3.6	---	---	---	
			48	9.5	a	---	3.6	---	---	---	
	55 m	SM	30	2.7	---	---	1.8	---	---	---	
			44	3.2	---	---	1.8	---	---	---	
IA 4, 5/74,	1 m	SM	49	16	---	---	4.0	---	---	---	29°17N 87°40W
	28 m	SM	44	14	---	---	3.2	---	---	---	
	245 m	SM	53	2.7	---	---	2.4	---	---	---	
IA 5, 5/74,	1 m	SM	58	t	49	---	8.0	---	---	---	29°17N 88°26W
	46 m	SM	56	16[c]		---	4.8	---	---	---	
	60 m	SM	49	4.5	---	---	---	---	---	---	
IA 6, 5/74,	1 m	SM	53	14	7.2	t	4.0	---	---	---	29°20N 88°45W
	8 m	SM	95	t	63	---	8.0	---	---	---	
	47 m	SM	29	5.8	---	---	4.0	---	---	---	

Table 33 contd.

Sample and Depth		Method	Concentrations in Nannoliters/Liter								Coordinates
			CH_4	C_2H_4	C_2H_6	C_3H_6	C_3H_8	i-C_4H_{10}	C_4H_8	n-C_4H_{10}	
C 1, 6/74,	1 m	SM	45	18	---	---	6.4	---	---	---	28°13N 84°03W
			45	16	---	---	4.0	---	---	---	
	20 m	SM	50	14	---	---	4.0	---	---	---	
			53	14	---	---	4.0	---	---	---	
	36 m	SM	43	6.3	---	---	4.0	---	---	---	
			36	3.6	---	---	4.0	---	---	---	
C 2, 5/74	5 m	SM	--	14	7.2	---	2.4	---	---	---	29°28N 85°50W
	30 m	SM	65	9.4	---	---	3.6	---	---	---	
	38 m	SM	58	4.4	5.5	---	6.0	---	---	---	
C 3, 5/74,	1 m	SM	42	14	t	1.6	5.6	---	---	---	29°57N 87°10W
	23 m	SM	--	7.2	---	1.6	3.6	---	---	---	
	51 m	SM	33	14	---	1.6	2.4	---	---	---	
C 4, 5/74,	1 m	SM	40	t	99	---	10	---	---	---	29°33N 88°13W
	22 m	SM	42	13	---	t	4.0	---	---	---	
	38 m	SM	25	7.2	---	t	2.8	---	---	---	
I 10, 5/74,	1 m	SM	51	6.2	---	---	2.4	---	---	---	29°36N 87°25W
	18 m	SM	45	12	---	---	3.2	---	---	---	
	60 m	SM	37	5.4	---	---	1.2	---	---	---	
I 11, 5/74,	1 m	SM	56	8.0	---	---	3.2	---	---	---	29°41N 87°40W
	11 m	SM	45	3.0	---	---	2.4	---	---	---	
	30 m	SM	70	12	---	---	2.4	---	---	---	
I 12, 5/74	1 m	SM	54	10	---	---	3.2	---	---	---	29°46N 87°54W
	25 m	SM	39	8.0	---	---	4.0	---	---	---	
	34 m	SM	42	8.0	---	---	t	---	---	---	

Table 33 contd.

Sample and Depth		Method	Concentrations in Nannoliters/Liter								Coordinates
			CH_4	C_2H_4	C_2H_6	C_3H_6	C_3H_8	$i\text{-}C_4H_{10}$	C_4H_8	$n\text{-}C_4H_{10}$	
I 13, 5/74	1m	SM	40	14	80	---	3.2	---	---	---	29°57N 88°14W
	18 m	SM	50	11	---	t	2.0	---	---	---	
	26 m	SM	34	15	---	1.6	6.8	---	---	---	
I 14, 5/74,	1 m	SM	42	16	---	---	5.6	---	---	---	29°56N 88°24W
	12 m	SM	49	180[c]		---	24	---	---	---	
	26 m	SM	36	8.1	---	---	8.8	---	---	---	
I 15, 5/74,	1 m	SM	36	15	3.6	---	4.8	---	---	---	29°56N 88°33W
	10 m	SM	51	12	---	---	4.0	---	---	---	
	20 m	SM	59	4.5	---	---	4.0	---	---	---	
A 5, 6/74	1 m	SM	82	51	51	8.0	20	-	-	-	29°17N 88°26W
	8 m	SM	365	b	25	6.0	14	-	-	-	
	56 m	SM	465	b	660	t	175	-	-	-	
A 4, 6/74	1 m	SM	44	40	9.0	14	13	-	-	-	29°17N 87°40W
	169 m	SM	46	t	t	2.0	2.0	-	-	-	
	340 m	SM	41	t	t	3.0	16	-	-	-	
A 6, 6/74	1m	SM	61	50	55	13	27	-	-	-	29°20N 88°45 W
	19 m	SM	94	48	57	6.0	13	-	-	-	
	43 m	SM	55	11	7.0	2.0	6.0	-	-	-	
A 7, 6/74	1 m	SM	2200	51	37	8.0	17	-	-	-	28°55N 88°50W
	28 m	SM	249	40	41	8.0	12	-	-	-	
	320 m	SM	45	t	t	4.0	3.0	-	-	-	

[1]M=McAullife (1971) Method; S=Swinnerton and Linnenbom (1967) Method; SM=Methane analyzed by McAullife and C_2 and greater analyzed by Swinnerton and Linnenbom.

[2]Concentrations expressed in nannoliters (10^{-9}) of gas at STP per liter of sea water.

[3](-) indicates analysis of the component was not obtained; (---) indicates component was below detection limits of the method employed.

a = Ethene peak masked Ethane peak. b= Ethane peak masked Ethene peak. c= Insufficient separation of Ethane and Ethene to identify peak.

Table 34

SUMMARY OF DISSOLVED HIGH MOLECULAR WEIGHT HYDROCARBON DATA

	AREAS				
	I	II	III	IV	V
Water Hex. Frac. (Conc. ug/ℓ)	1.11± 0.73	3.01± 2.63	2.82± 1.62	1.27± 0.88	2.60± 0.86
Water Benz.Frac. (Conc. ug/ℓ)	3.44± 3.02	2.28± 2.26	1.74± 1.37	1.55± 0.52	2.00± 1.64
Water C_{17} Pris.	2.89± 2.20	2.17± 0.77	1.07± 0.13	1.29± 0.68	1.31± 0.43
Water C_{18} Phyt.	1.70± 0.21	2.18± 0.70	1.85± 0.51	1.77± 0.52	1.64± 0.27
Water Pris/Phyt	0.82± 0.41	1.34± 0.29	1.01± 0.24	1.37± 0.18	1.38± 0.43
Water n-par/phyt	30.63±18.23	19.24± 3.46	74.62±43.84	43.06±17.02	78.58±44.49
Water n-par/C_{16}	33.63±31.81	15.58± 9.78	128.55±96.38	41.80±32.39	75.14±36.54
Water O/E	0.95± 0.14	1.13± 0.38	1.01± 0.13	0.97± 0.11	0.93± 0.21
DOC mgC/ℓ (from Knauer, CT4-11)	1.81± 0.52	1.10± 0.30	1.95± 0.73	2.19± 0.86	4.00± 2.11
Hex.Frac/DOC g/mgC	0.61	2.74	1.45	0.58	0.65
Benz.Frac.ug/mgC	1.90	2.07	0.89	0.71	0.50

	TOTAL SAMPLES	ALL SURFACE	ALL MID	ALL BOTTOM
Water Hex. Frac. (Conc. ug/ℓ)	2.10± 1.55	1.73± 1.12	2.21± 1.88	2.21± 1.55
Water Benz.Frac. (Conc. ug/ℓ)	2.06± 1.85	2.86± 2.22	1.61± 1.51	1.48± 1.30
Water C_{17} Pris.	1.52± 1.13	1.66± 1.66	1.56± 0.91	1.33± 0.54
Water C_{18} Phyt.	1.71± 0.43	1.59± 0.25	1.93± 0.52	1.58± 0.39
Water Pris/Phyt	1.14± 0.37	1.12± 0.43	1.09± 0.37	1.22± 0.30
Water n-par/phyt	47.44±34.79	42.52±30.83	46.95±34.26	52.93±40.93
Water n-par/C_{16}	55.56±49.39	66.26±60.03	40.73±22.44	58.87±58.25
Water O/E	0.99± 0.19	1.06± 0.26	0.96± 0.14	0.94± 0.15
DOC mgC/ℓ (from Knauer, CT4-11	---	2.67± 1.55	2.07± 0.94	1.76± 1.09
Hex.Frac/DOC g/mgC	---	0.65	1.07	1.26
Benz.Frac.ug/mgC	---	1.07	0.78	0.84

No petroleum contamination, including tar balls, was noted on plankton or nets.

High molecular weight hydrocarbons in the water samples ranged from 0.08 to 7.23 µg/ℓ in the hexane fractions, with an average of 2.1 µg/ℓ. The benzene fraction (aromatic and polyolefinic hydrocarbons) ranged from 0.08 to 8.4 µg/ℓ. Normalized to total DOC, Area II had the highest average concentrations and Area IV the lowest. The chromatographic spectra were among the least complex observed, suggesting that the hydrocarbons may be of recent biosynthetic origin. None of the water samples showed evidence of petroleum-derived hydrocarbons.

d. Particulate Hydrocarbons. Total lipid concentrations present in the particulate hydrocarbon fraction ranged from 0.1 to 0.5 mg total sample (2-10 µg/ℓ) at control stations C-1 through 6. In Area III master Stations 7 and 9 has less than 0.1 mg/sample. Aliphatics were not detected below 0.05 mg/sample. Aromatic hydrocarbons were present in concentrations up to 0.15 mg/sample at Master Station MS9 and 0.13 mg/sample at Master Station 7. Petroleum hydrocarbons were not indicated from the chromatographic results.

Similar lipids were obtained from Stations C-3, C-4, and Master Station number 10, 12, 13 and 15 in Areas IV and V. However, all sites indicated concentrations of 0.01 mg to 0.05 mg aliphatic hydrocarbons/sample (0.2-1.0 µg/ℓ). Aromatic hydrocarbons gave the same 3-peak pattern as before. The unresolved aliphatic envelope from n - C_{18} to n - C_{30} suggests weathered petroleum hydrocarbons stemming from low-level, chronic influx.

2. Trace Metals.

a. Sea Water. A threefold system was used by Segar (CT4-11) to analyze trace metals in waters: waters were injected directly into the graphite furnace; acidified waters were injected, and organic extracts (APDC-MIBK) were injected. The following observations were made regarding reliability for these difficult (in terms of potential contamination or other systematic error) ultra-low trace metal analyses.

Vanadium showed consistent values on the order of 1.5 ppb which is not far from accepted oceanic values. Extractable Ni and Pb show significant variations, but both are in the accepted range for nearshore areas. They show values ranging from 0.25-2.5 ppm Ni, and 0.07 to 1.7 ppm Pb. Extractable Cu and Fe show some major discrepancies fro the listed values, or with each other; they are often well above the directly injected samples in concentration. Fifteen percent of the extractable analyses have concentrations higher than total injection. This and similar discrepancies for Cd, Cr, Cu and Fe were attributed to contamination in the laboratory or handling on ship.

The full analyses are shown in Table 35. Inspection of the data shows that certain values, especially Cu and Fe, appear high. Nonetheless these are among the lowest general values obtained in the literature for shelf waters, and we may regard them, at the least, as an upper maximum, and confirmation of absence of dissolved metalliferous pollutants.

b. Suspended Matter. Suspended particle mass and trace metal determinations were made on 42 samples from 14 stations. Mean value for total suspended matter was 184 µg/ℓ.

Table 35
Trace Metal Concentrations in Sea Water (Segar, CT4-11)
(μg/ℓ)

	Direct Injections of Extracted Sea Water Samples					Direct Injections of Sea Water			
Sample Number	Cu	Fe	Ni	Pb	V	Cd	Cr	Cu	Fe
361	3.0	4.5	1.1	0.07	1.3	0.3	1.9	1.1	4.2
365						<0.1	0.45	1.0	3.2
362	4.5	2.5	0.70	0.07	1.3	<0.1	2.1	3.6	6.7
366						<0.1	0.72	3.2	7.8
363	0.90	21	1.7	0.68	1.6	<0.1	1.6	1.5	7.2
364						<0.1	5.9	1.3	3.7
367	0.70	1.9	0.50	0.19	1.4	<0.1	3.1	1.8	45
371						5.8	0.72	31	5.2
368	2.7	0.8	0.35	0.36	1.3	<0.1	7.7	1.0	3.5
372						4.1	0.48		5.5
369	2.8	4.7	2.4	0.93	1.4	<0.1	0.68	1.2	7.0
370						<0.1	0.72	2.0	5.1
521	11	20	2.2	0.90	2.1	16	1.8	8.3	188
522						4.3	2.1	4.7	35
539	1.9	2.9	0.10	0.20	1.0	7.2	1.4	10	17
523	22	55	12	1.5	3.4	4.5	2.6	8.5	54
524						1.9	1.4	7.0	19
527	2.4	2.8	0.70	1.7	1.1	<0.1	0.94	4.0	25
525						2.6	5.8	3.5	22
530	6.2	3.5	0.70	0.32	1.2	11	4.7	13	22
526	4.1	4.4	1.1	0.65	1.0	0.10	4.2	2.0	11
876						2.7	1.2	1.6	8.6
528	1.4	1.3	0.15	0.09	1.4	1.4	2.1	10	65
878						2.2	1.7	3.7	32
529						<0.1	4.4	9.4	43
925	1.0	6.0	1.3	0.21	1.4	<0.1	1.2	2.0	20
531						0.48	1.2	2.2	37
540	1.7	3.9	0.60	0.58	1.6	<0.1	1.0	2.9	29

Table 35 (continued)

Sample Number	Cu	Fe	Ni	Pb	V	Cd	Cr	Cu	Fe
532						2.1	2.1	2.5	19
535	6.0	3.6	0.80	0.30	1.4	0.35	2.4	7.8	18
533	0.6	3.1	0.05	0.59	1.0	<0.1	1.8	2.2	30
537						<0.1	1.6	2.2	34
534	1.9	4.8	0.75	1.6	1.3	<0.1	1.6	5.2	11
538						<0.1	1.1	14	11
536	6.4	5.1	1.0	2.2	1.3	6.0	1.1	5.4	56
877	2.0	2.7	0.40	0.10	1.2	6.3	1.6	2.1	10
879	3.8	5.3	0.90	0.09	1.5	2.0	1.6	7.8	14
896						5.5	3.4	22	56
880	2.5	4.5	0.60	<0.07	1.4	14	2.3	2.1	9.7
883						1.3	2.0	3.2	28
881						1.2	1.6	3.5	18
891	2.7	32	3.1	0.25	1.1	2.3	3.0	1.9	55
882	2.2	5.3	0.45	1.0	1.1	5.6	1.4	3.7	28
885						18	2.5	29	7.7
884						<0.1	2.0	2.4	21
889	4.4	3.0	0.22	0.40	1.7	1.2	2.0	5.1	58
886	4.8	9.0	0.92	0.34	1.4	1.7	1.6	8.1	42
888						30	2.4	22	20
897	2.3	20	0.70	0.34	0.92	<40	2.2	8.4	63
901						0.4	3.0	1.9	8.1
905						<0.1	1.6	3.9	8.6
902						<0.1	2.3	1.6	10
906	0.90	<0.04	0.15	0.14	1.2	<0.1	1.8	2.2	11
903						<0.1	2.8	2.2	1.7
904						0.4	1.2	2.8	9.2
907						0.11	1.6	2.3	37
910	1.9	2.1	1.0	1.2	1.3	<0.1	1.7	2.1	8.9
908						<0.1	1.2	2.8	3.9
911	1.8	4.8	1.4	0.45	1.4	0.2	1.4	2.6	6.9

Table 35 (continued)

Sample Number	Cu	Fe	Ni	Pb	V	Cd	Cr	Cu	Fe
909						<0.1	3.4	2.2	44
912	1.3	0.4	0.65	0.25	0.5	<0.1	1.0	2.6	5.4
913	3.5	17	4.4	3.2	1.4	<0.1	1.6	2.1	18
916						<0.1	1.2	2.6	8.9
914						3.7	1.4	2.2	18
917	1.8	6.2	0.75	1.3	1.3	<0.1	2.9	2.2	6.9
915						<0.1	2.8	2.7	10
918	1.1	11	1.5	2.2	1.4	<0.1	6.9	1.5	5.4
919						5.3	5.0	13	35
922	1.4	21	1.9	1.2	1.4	<0.1	5.1	7.1	23
920	2.2	2.6	0.85	1.0	1.3	<0.1	3.1	2.1	8.8
923						<0.1	2.0	2.7	9.3
921	1.4	3.3	0.55	0.21	0.85	<0.1	4.4	1.5	17
924						<0.1	1.9	2.6	22
2001						<0.1	1.4	1.3	1.1
2007	0.8	<0.4	0.15	2.0		<0.1	1.0	1.5	0.80
2002						<0.1	1.8	1.3	2.2
2005	0.6	1.2	0.80	2.1	1.3	<0.1	1.2	1.5	1.3
2003						<0.1	1.4	2.7	0.48
2004	0.70	0.4	0.80		1.3	<0.1	1.1	1.4	0.80

Table 36

SUSPENDED MATTER TRACE METAL SUMMARY +

Area	No. of Samples		S.P.M.* (µg/l)	Cd	Cr	Cu	Fe	Ni	Pb	V
I	9	Average	129	59	160	199	.57	1486	200	N.D.
		Range	81-266	8-243	-	51-684	.24-.98	-	76-322	-
II	6	Average	217	15	N.D.	103	.22	3609	145	N.D.
		Range	74-200	3-25	-	31-187	.11-.47	-	44-316	-
III	9	Average	91	29	N.D.	481	1.26	N.D.	273	N.D.
		Range	49-161	8-73	-	133-898	.28-4.3	-	19-975	-
IV	9	Average	125	55	144	328	1.09	174	189	N.D.
		Range	50-334	14-100	64-276	162-563	.10-4.2	-	107-364	-
V	9	Average	368	45	120	254	1.19	52	109	57
		Range	61-1788	2-226	45-191	17-715	.25-4.8	-	14-209	-

+ Values for all elements are in µg/g dry weight except iron which is in percent.

* Suspended Particulate Matter in microgram per litre of water filtered.

Table 37

Average concentrations (μg/gram dry weight) trace metals in zooplankton from three MAFLA regions. Average concentration of these metals in the Pacific zooplankton is included for comparative purposes.*

I. West Florida Shelf / Middle Grounds

ELEMENT	Cd	Cr	Cu	Fe	Ni	Pb	V
$\bar{X}$	9.2	1.2	16.0	251	3.5	2.3	2.8

II. Destin Dome / Apalachicola

ELEMENT	Cd	Cr	Cu	Fe	Ni	Pb	V
$\bar{X}$	16.3	4.1	21.0	268	7.8	6.0	2.3

III. Mississippi River / Alabama

ELEMENT	Cd	Cr	Cu	Fe	Ni	Pb	V
$\bar{X}$	3.0	4.1	22.4	1345	3.4	4.6	6.2

IV. Pacific Zooplankton

ELEMENT	Cd	Cr	Cu	Fe	Ni	Pb	V
$\bar{X}$	4.3	<1.0	12.6	221	3.6	3.5	<3.1

* These values are integrated values of one hour tows taken from three depths at each station.

Previous work has shown that organic-rich suspended matter tends to be enriched in trace metals with respect to normal bottom sediments. The present trace metal composition of suspended matter is likewise characterized by such enrichment, particularly with respect to Cd and Ni in Areas I and II. If such enrichment is organic in nature, then the values toward the Mississippi River influence (clays) should be lower. This was observed for Cd, Cu, and Ni for Station 13, where values at 26 m depth dropped to 2 ppm Cd and 17 ppm Cu. These are values that might easily be found in river-bottom sediment. One must express surprise that more samples from Area V did not show much higher suspended matter values, in view of high turbidity there. The means are shown in Table 36.

c. Zooplankton. As might be expected of highly diverse organisms collected among zooplankton, their metal levels were extremely variable. Again, concentrations were higher than expected in comparison with Pacific zooplankton (Table 37). However, one may note that dissolved composition of sea water, as well as suspended matter tends to become relatively more enriched with trace constituents, the more free from particulate matter and the more impoverished in nutrients it is.

ENVIRONMENTAL APPLICATIONS AND CONCLUSIONS

I. Crude oil-like hydrocarbons have not been identified in sediments, bottom organisms, or organisms or phases in the water column in Areas I, II and III. Moreover, the abundance and diversity of organisms, as well as evidence of similar populations living in the same niches on the shelf in the recent past, suggest that these organisms are living in an essentially pristine and natural ecological state, and show no evidence of stress owing to influx of pollutants. The situation is more complex in Area IV. Proximity to the Mississippi Delta and its strong turbidity and periodic freshwater influences, creates a similar kind of stress for the westernmost stations as that encountered more strongly in Area V. Some sediments in the area contain aliphatic components of lipids which indicate petroleum-type hydrocarbons, whereas analyses of other sediments show only the odd-number predominance typical of biologically synthesized hydrocarbons. Organism analyses show similar divergent trends. Trace metals show background or subbackground levels. Area V sediments revealed universal indications of petroleum hydrocarbons in the sediments. Their weathered nature led the Lytles (CT4-11) to infer a Mississippi River origin for them. However, the areas in question are to a large extent poorly productive of epi- and infauna other than stress-tolerant species, and it is problematical what influence the added hydrocarbons have on the system.

II. Suspended matter and zooplankton productivity (via fecal pellet formation and sinking processes) are both known to be effective means of collection and sinking of oil pollutants. Therefore, the potential for removing oil from the sea surface and the water column is dependent upon the distribution of suspended matter. Hence, off Areas IV and V, spills and surficial slicks of oil will be brought down more effectively and rapidly (perhaps by one or more orders of magnitude) than in the clear water areas to the south. This means that, in the absence of human clean-up or recovery, a greater percentage of the oil will remain in surface water of the southern areas to be either moved on by currents or impinged on and sbsorbed at the coastal zone, except under unusual conditions such as storm-related turbidity.

III. Trace metals in sediments, waters, organisms or suspended matter have not shown concentrations beyond those expected for comparable unpolluted materials. In fact, sediments have unusuallly low background levels for tract constituents over much of the area. Trace metals in petroleum or petroleum-related brine seepages are not a major hazard, oweing to their low concentrations in oil and brine. Calculations show that some of the larger historical spills, if distributed over a typical bottom sediment area might have difficulty in building up ambient concentrations beyond background. Moreover, the chief elements in oils, nickel and vanadium, have relatively low toxicity. This does not preclude a buildup of detectable residues of nickel and vanadium in benthic and encrusting and fouling organisms and sediments as a result of chronic low level spills.

The excellent background of analytical information on organisms from a clean environment should invite complementary analyses of similar species from contaminated environments. if they can be found and vouched for, to establish comparative knowledge of metal influences on a wide spectrum of organisms.

Trace elements may be potentially more significant as pollution from land sources. The investigated sites were not close enough to shore and potential sources of pollutants to detect plumes and ranges of influence of land-derived wastes. Baseline maps of trace element and hydrocarbon constituents should, in the future extend to the shore to delineate land-derived influences from potential offshore pollutants.

IV. Over the short range, substrate largely controls bottom fauna. This is true to an extreme degree in the Florida Middle Ground. Over wider areas other factors come into play: temperature, recruitment of eggs and larvae via water movements are examples. The unusual fauna and flora of both the Flower Garden (Bright and Pequegnat, 1974) and the Florida Middle Ground reefs may require a combination of bottom substrate and impingement of Caribbean breeding stock, transported by the Loop Current.

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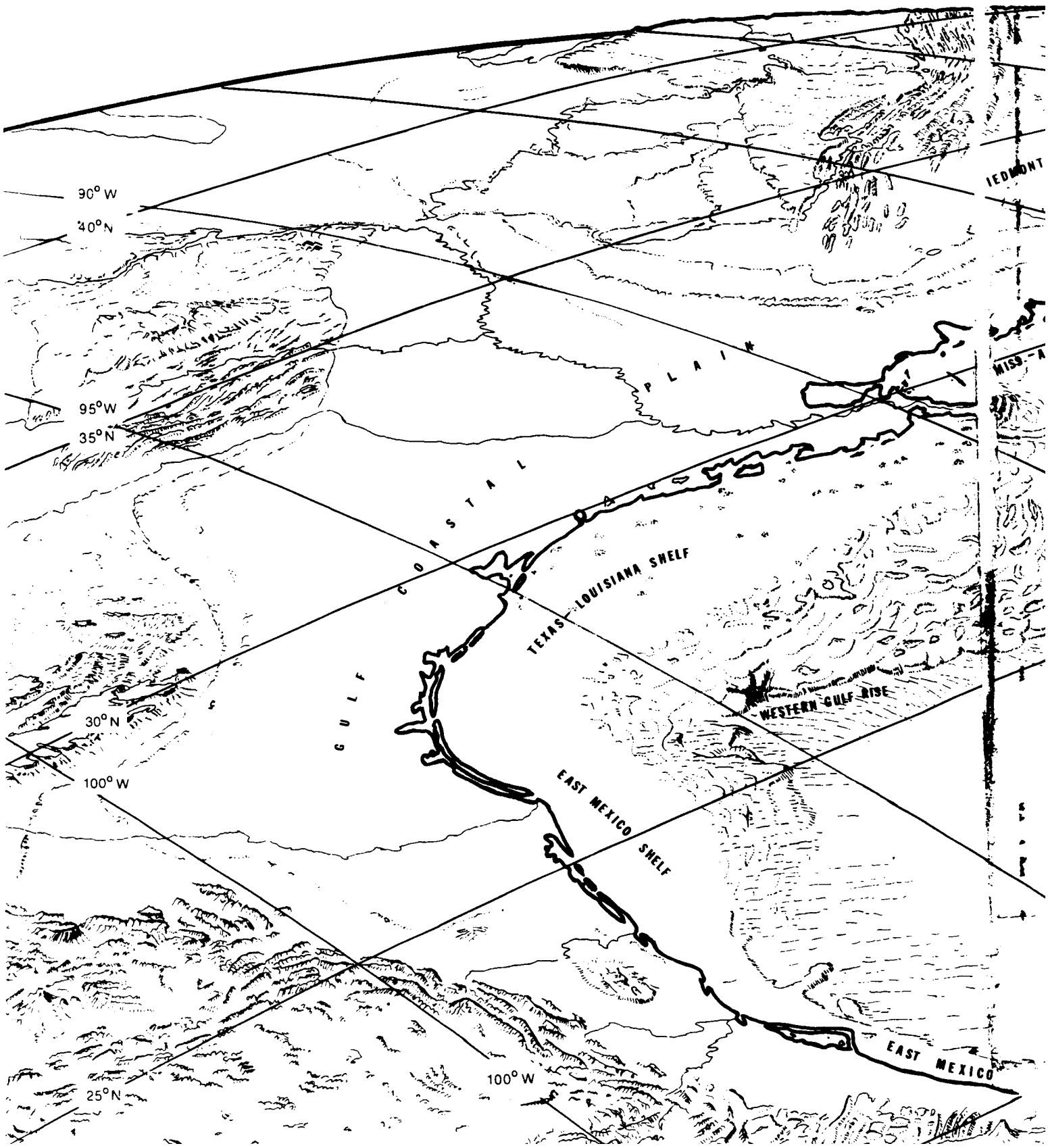
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