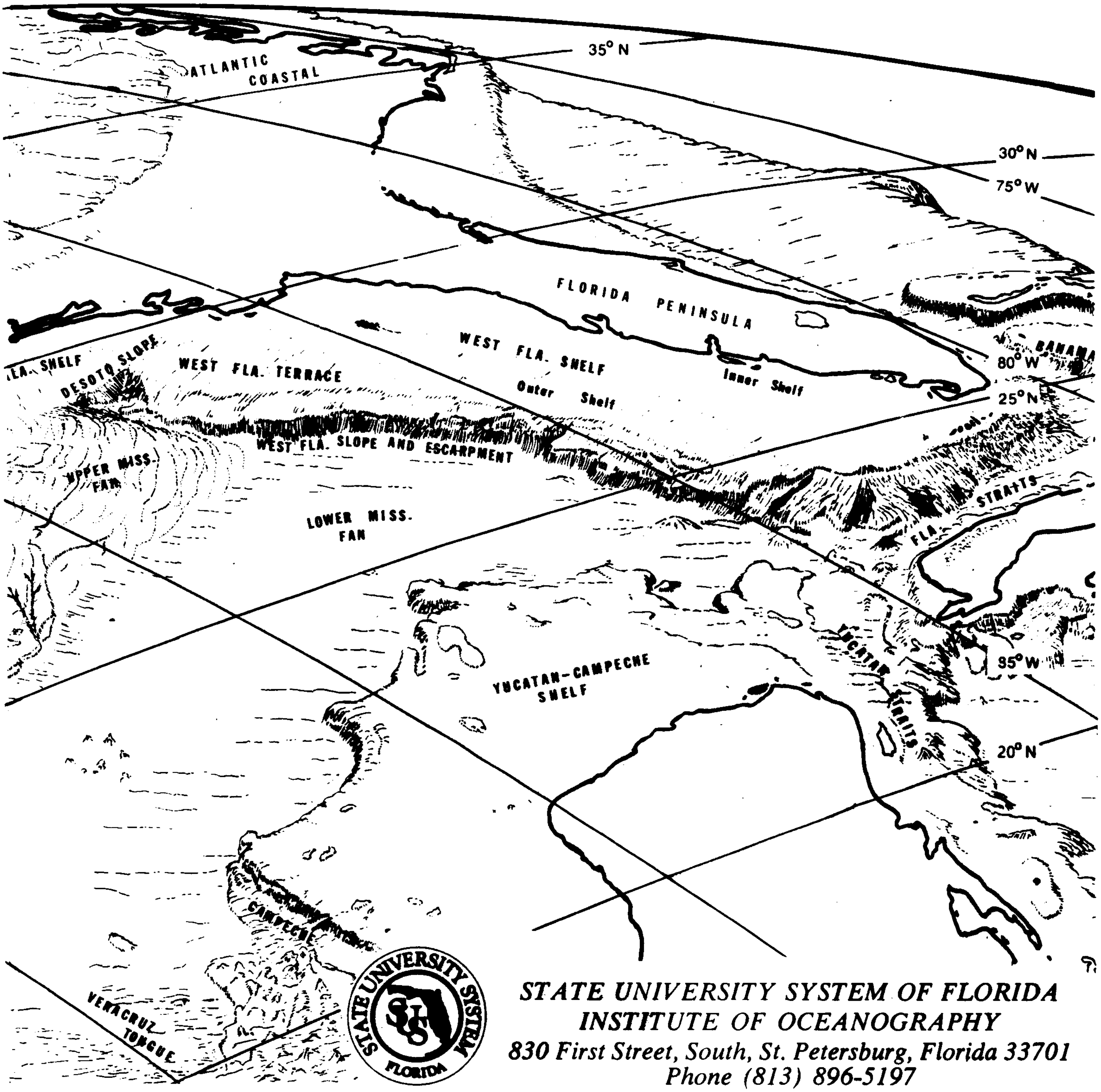
1977 - 21

PRINCIPAL INVESTIGATORS FINAL REPORTS

BLM CONTRACT NO. 08550-CT5-30

VOLUME I (VII)



STATE UNIVERSITY SYSTEM OF FLORIDA
INSTITUTE OF OCEANOGRAPHY
830 First Street, South, St. Petersburg, Florida 33701
Phone (813) 896-5197

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PRINCIPAL INVESTIGATORS FINAL REPORTS

A Report to the Bureau of Land Management

in fulfillment of

Contract No. 08550-CT5-30

Submitted by

- State University System of Florida

Institute of Oceanography

Program Manager
James E. Alexander, SUSIO

Technical Coordinators:
Theodore T. White, SUSIO
Kenneth W. Turgeon, SUSIO

GEOPHYSICAL INVESTIGATIONS OF THE MAFLA LEASE AREA

Mahlon M. Ball

See Thomas E. Pyle

ZOOPLANKTON, SUSPENDED MATTER AND NEUSTON FOR THE BLM SURVEYS TO THE EASTERN GULF OF MEXICO

University of South Florida, Department of Marine Science

Principal Investigator:
Peter R. Betzer

Associate Investigator:
Martin A. Peacock

INTRODUCTION

Interest in the impact of oil exploration and subsequent exploitation has provided the need to further explore and understand certain reactive constituents and their cycles within the oceans. These trace constituents of seawater can be excellent indicators of certain types of pollution provided baseline levels have been established.

Trace constituents are concentrated and transported by suspended matter, zooplankton and neuston in a variety of ways. Zooplankton have been shown to transport trace elements through: vertical migrations across mixing barriers (Pearcy and Osterberg, 1967), moulting of exoskeletons (Fowler and Small, 1967), the sinking of skeletal structures after death (Arrhenius, 1963), the incorporation of elements into fast-sinking fecal pellets (Osterberg, et al., 1963), and the passage of elements to a higher trophic level (Osterberg, Pearcy and Curl, 1964). Suspended matter, both biogenic and terrigenous, may have elevated trace metal concentrations from chemical processes such as chelation, adsorbtion, precipitation and flocculation. This material is often adsorbed to or ingested by small marine zooplankton who concentrate the metal ions and transport them either to the benthos or higher up the food chain.

The concentration levels of different zooplankton populations may vary due to: the amount of the element available (Goldberg, 1957); the temperature and salinity of surrounding waters (Duke, et al., 1969); the population turnover rates (Martin, 1970), and the physiological state of the organisms (Haywood, 1970). Zooplankton populations will show further differences in elemental composition since each population can consist of up to twelve phyla of very different morphologies and trophic levels. Moreover, each species may exhibit vastly different chemical contents (Nicholls, Curl and Bowen, 1959).

Heavy metal pollution has already caused severe losses of shellfish and other commercial fisheries, as well as affecting human health in isolated cases (Merlini, 1971). Heavy metals, unlike the major constituents of seawater, are highly reactive, and much needs to be known about their transport in the marine environment. Suspended matter, neuston, and zooplankton which are able to remove, concentrate and transport trace metals, are thus important in the fluxes of these heavy metals throughout the oceanic environment.

Sample Collection

Suspended matter, zooplankton and neuston samples were collected aboard the R/V TURSIOPS on four transects across the western and southern continental shelves of Florida, Alabama and Mississippi (Figure 1). The samples were collected during June and September of 1975, and January of 1976 as part of the MAFLA project. Neuston were collected for analysis during the last two sampling periods. One suspended matter and zooplankton sample was collected at each of the fifteen stations situated on the transects; two neuston samples (day and night) were collected at these same locations. During the September, 1975, sampling period, one additional sample was collected following Hurricane ELOISE at Station 1205 on the Florida Middle Grounds.

Water samples were collected at 10 meters depth on plastic sheathed hydrowire using one 30 ℓ polyvinyl chloride (PVC) Niskin bottle, with an internal rubber closure.

Suspended materials were separated from the water in the 30 ℓ Niskin bottle onto 47 mm diameter, 0.4 μm pore size, Nucleopore^R membranes. The filtering system, which was closed to atmospheric contamination consisted of 9.5 mm I.D. silicon rubber (leached with 4 N HCl prior to sampling) which carried the water from the Niskin bottle to a high density, linear polyethylene Millipore filter head. To minimize contamination during the sampling period, the disconnected tubing was covered with polyethylene bags. Prior to filtering a new sample the tube was flushed with approximately one liter of that sample. To prevent exposure to shipboard contamination, the filters were loaded prior to sampling and removed after sampling with Teflon^R tweezers in a clean bench. Filtration was carried out by pressurizing the Niskin bottles with 0.35 kg/cm^2 of filtered nitrogen. In an attempt to prevent any atmospheric contamination

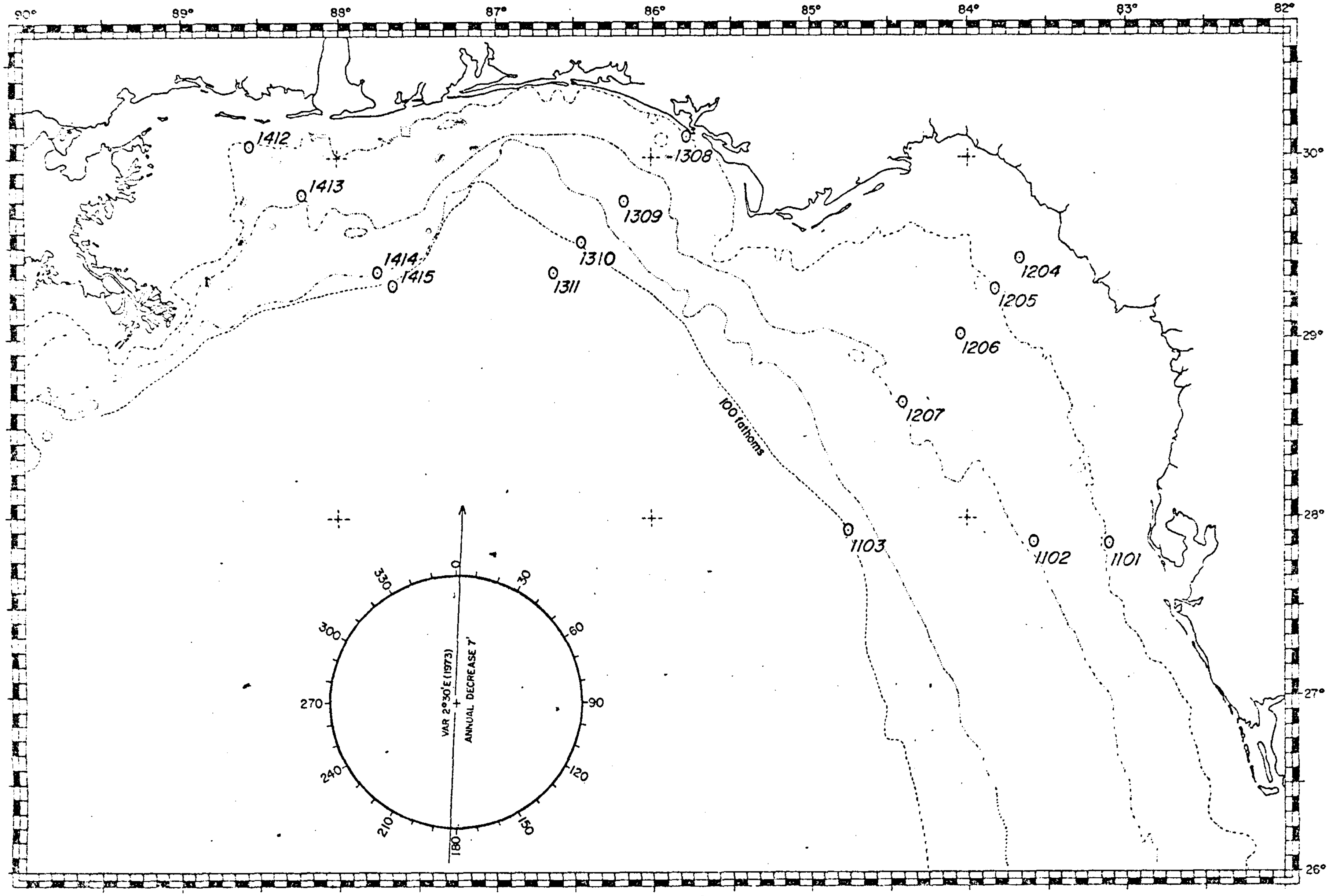

Figure I. MAFLA Water Column Stations, 1975-1976.

the system was completely sealed to the atmosphere and was constructed of high density linear polyethylene. To prevent contamination by material in the nitrogen pressure cylinder, two high density polyethylene Millipore filter heads containing 47 mm, 0.1 μm pore size, Nuclepore^R membranes were placed between the nitrogen source and the Niskin bottles. The water obtained after filtering was retained in a polyethylene reservoir for a volume measurement.

Zooplankton samples were collected on stepped oblique trawls with a 0.5 m zooplankton net with a mesh size of 202 μm. The bridle, net frame and net grommets were all constructed of brass so that there is a possibility of some contamination. All tows were done on plastic hydrowire with the hydroweight enclosed in a large plastic bag. In an attempt to minimize ship rust and paint contamination, the net was sent down closed until it was beneath the boat's keel at which time it was opened and was closed at the same location when being brought aboard. The net was washed down with surface water collected in plastic buckets rather than using the ship's seawater system which would increase the potential for sample contamination via the introduction of metal particles. After removal of the plastic cod end containing the sample the net itself was cleaned with the seawater system, rinsed overboard, and stored in large plastic bags until the next sampling.

The zooplankton in the cod end were divided in a plastic splitter that had been rinsed with 4 N HCl and deionized water - one part for hydrocarbon and the other for trace metal analysis. Excess water was removed on a ring of No. 20 netting, and the concentrated zooplankton were stored in jars - acid rinsed glass jars - for the first two cruises and acid leached polyethylene bottles for the last cruise. These samples were frozen until they were returned to the laboratory.

At each station neuston samples were collected once during the day and once at night. Samples were exposed to many possible forms of contamination from either the portion of the water column being sampled or from the sampling gear and technique. The neuston sled's structural members were constructed from various forms of metal - many of them rusty. Immediately in front of the net opening was a flowmeter with rusty attachment hooks although on the winter cruise of 1976 this was exchanged for a more suitable stainless steel flowmeter attached with shock cords. The nets were continually exposed to airborne contaminants between stations since the net remained uncovered. The greatest source of contamination was felt to be the tar balls and other miscellaneous objects often collected (cigarette filters, plastic bags, etc.) during tows. Although these objects comprise only a part of the neuston samples they mask any changes occurring in the living biota.

Samples after collection were concentrated on a ring of No. 20 netting, at which time large tar balls and other objects (Sargassum, sea grass, etc.) were removed with solid Teflon^R tweezers. During the second sampling period samples were frozen in acid-washed glass jars while acid leached polyethylene bottles were used for the last sampling period.

Preparation of Samples

Prefiltration preparation of the Nuclepore^R membranes consisted of a 48 hr desiccation using silica-gel after which they were weighed to the nearest microgram using a Perkin Elmer AD2 microbalance. Variability in weighing techniques was ±3 micrograms as determined by replicate weighings of membranes on consecutive days. Static electricity associated with the membranes was removed prior to each weighing by passing the membrane over a polonium source. The filters were then loaded into the Millipore filter heads which had just been acid leached two hours and washed. These filter heads were then placed in plastic bags for use at sea.

After the filtration was completed, it was necessary to remove residual sea water so the filter heads had ∿15 ml of deionized water sucked through with a Nalgene hand held plastic pump. The heads were then placed in plastic bags, sealed and refrigerated until return to the laboratory. Here the membranes were removed and placed in linear polyethylene funnels mounted in a laminar-flow clean bench, where they were further rinsed with about 12 ml of deionized water to remove any residual salt trapped on the filter. After a 48 hr desiccation period over silica gel, the pads were again weighed on the Perkin Elmer balance. The total suspended load was determined by dividing the difference between the tare and final weight by the liters of water which had been filtered.

To separate the particulate trace metals into a weak-acid soluble and refractory fractions, the dissolution process was carried out in two steps. The initial process whose purpose was to dissolve the carbonate materials and to remove the easily reduced metal hydroxyoxides from the suspended matter, consisted of a two hour leach of the filter with a solution of acetic acid (25% v/v). The procedure was carried out by placing the folded filter in the same funnel assembly which was used to rinse the membrane and then filling them with approximately four ml of the acetic acid solution. After two hours the acid, retained in the funnel by a Teflon^R stopcock, was drained into an acid cleaned, one ounce linear polyethylene bottle. The filters were then triply washed with deionized water which was drained into the bottle with the filtrate. To prevent the loss of metal species to the walls of the polyethylene bottles (Robertson, 1968), the pH was lowered to >1 by adding 0.5 ml of concentrated Ultrex^R(J. T. Baker) hydrochloric acid. The process was completed by transferring this solution to an acid washed, 25 ml volumetric flask, brought to volume and returned to the one ounce bottle.

This solution, referred to as the weak acid soluble fraction, contains the material collected on the filter that is susceptible to dissolution by a weak acid. This assumption is based upon the findings of Chester and Hughes (1966, 1967) that "an acetic acid (25% v/v) attack on a pelagic clay will liberate into solution those trace elements present in the carbonate minerals, those adsorbed onto mineral surfaces, and those precipitated in acid-soluble iron oxide minerals, but will only slightly affect those present in the ferro-manganese minerals." It was estimated by these authors that only 0.85% of the Fe_2O_3 contained in the pelagic clay tested was removed by the acetic acid.

After the weak-acid dissolution process the filters were returned to their respective vials for the second dissolution technique.

The second technique is designed to bring into solution the clay minerals and refractory metal oxides unaffected by the weak-acid leach. This is carried out using an all-Teflon^R decomposition vessel and is patterned after the techniques of Buckley and Cranston (1971). However, due to the limited amount of oceanic suspended materials which is normally available for analysis (<2000 μg) the procedure has been modified to reduce contamination and to optimize the analyses of such small amounts of material (Eggimann and Betzer, 1976). The modified procedure consists of placing the previously leached Nuclepore^R filter with the remaining suspended material into an all-Teflon^R bomb and adding 0.75 ml of concentrated Ultrex^R hydrochloric acid with an Eppendorf^R pipette. The vessel is closed and sealed with a lucite collar to prevent any loss of volatile constituents and placed in a 95°C hot water bath for 30 min. After removal, the vessel is cooled in a freezer which allows the bomb to be opened without the loss of volatile constituents.

This is followed by the injection of 0.25 ml of concentrated Ultrex^R nitric acid, using an Eppendorf^R pipette, at which point the vessel is closed and re-immersed in the controlled-temperature bath for a period of 30 min. After this heating and a subsequent cool-down, the vessel is opened and 0.050 ml of concentrated Ultrex^R hydrofluoric acid (0.05% of the final volume) is added, again using an Eppendorf^R pipette. After the vessel is heated for a one-hour period in the water bath, it is again cooled and opened. The filter is removed from the vessel using Teflon^R tweezers and placed in a linear polyethylene funnel which drains into a 100 ml, acid-washed, LPE volumetric flask. The filter is unfolded, rinsed several times with deionized water, removed from the funnel and discarded.

The acid remaining in the decomposition vessel is poured into the funnel and the vessel is thoroughly rinsed with deionized water. After the funnel has been rinsed, the flask is brought to volume.

The digestion procedure is a reliable means of dissolving clay and refractory materials (Eggimann and Betzer, 1976). Treatment of between 100 and 2000 µg of the U.S.G.S. W-1 standard and the National Bureau of Standards Plastic Clay (98a) show that the recovery of the certified elements (Al, Cr, Fe, Mg and Si) was within one standard deviation of 100%, indicating that there was complete dissolution of these materials (Eggimann and Betzer, 1976). The amount of reference material used in testing the digestion procedure was chosen to encompass the normal range of open-ocean suspended matter samples. However, in this sample range, the low levels of the remaining certified elements (Fleischer, 1969) determined in this study (Cd, Cu, Pb and Ni) resulted in concentrations below the detection limit for flameless atomic absorption (Table 1). It was therefore not possible to ascertain whether these elements were completely recovered, although the complete recovery of the other certified elements suggests that there was total destruction of the clay lattice and, therefore, complete recovery of the trace elements also.

Zooplankton and neuston samples upon return to the laboratory were dried in an oven at 65°C and then ground with an agate mortar and pestle for the first two sampling periods and with a porcelain lined spex mixer mill for the last sampling period. Previous experimentation had shown 0.5 g of dried zooplankton contained sufficient quantities of trace metals for analysis. Half gram amounts of homogenized dried

Table 1. Comparison of Quality Control Organism Samples*
(concentrations in ppm dry weight)

Species Name	Sta. No.	Lab of Analysis+	Cd	Cr	Cu	Fe	Pb	Ni	V[a]
Zooplankton	1206	USF	5.32	0.39	12.5	118	0.37	1.3	2.9
		TAMU	4.50	1.70	9.8	123	0.34	0.9	-
Zooplankton	1309	USF	4.66	0.98	19.4	224	0.94	3.2	1.8
		TAMU	4.10	1.20	29.0	257	0.62	3.7	-
Stenorhynchus seticornis	146	USF	0.40	0.16	25.6	56.4	0.22	<0.2	<0.4
		TAMU	0.53	0.98	35.6	50.0	2.7	<0.5	-
Cinachyra sp.	251	USF	0.36	0.80	6.5	157	0.55	10.5	3.9
		TAMU	0.30	<0.10	7.0	170	2.0	15.0	-
Clypeaster raveneli	II - B	USF	0.28	0.77	6.8	148	0.56	0.6	1.0
		TAMU	0.30	0.40	4.6	148	2.0	<0.5	-

* All samples collected from third sampling period

\+ USF = University of South Florida (Betzer)
TAMU = Texas A&M University (Presley)

a Vanadium values not yet available from TAMU zooplankton were weighed onto acid cleaned pyrex watch glasses with a four place Mettler balance. These watch glasses were then transferred to an International Plasma low temperature asher where the organic material was oxidized leaving the trace components. The ash on the watch glasses was then transferred into Teflon^R decomposition vessels with solid Teflon^R tweezers and three milliliters of Ultrex^R nitric acid. Bombs were sealed, enclosed with a lucite collar and placed in a hot (95°C) water bath for six hours. After this time, they were cooled in a freezer, to allow opening and prevent the loss of any volatile components. This solution was then transferred to 50 ml acid-washed, LPE, volumetric flask, and brought to volume.

Sample Analysis

Elemental analysis of all samples of both the suspended matter and organisms was carried out using atomic absorption spectroscopy. Perkin Elmer atomic adsorption spectrometers (Models 403 and 503) were used for the analysis of all elements except silica. Silica was determined on a Technicon Autoanalyzer II; the analyses for aluminum, cadmium, chromium, copper, iron, lead, nickel, and vanadium were made using a heated graphite atomizer (Perkin Elmer HGA2000 and HGA2100). Analysis of calcium was carried out with an air-acetylene flame. The standard conditions and instrument settings used in the flame and the flameless mode were the same as those recommended by Perkin Elmer (1971). All measurements were made in the adsorbance mode, the peak heights being recorded on a Perkin Elmer Model 56 recorder. The injection of samples into the heated graphite atomizer was made using 25 or 50 μℓ Eppendorf^R pipettes.

The weak-acid soluble fraction of the samples was analyzed for calcium, cadmium, chromium, copper, iron, lead, nickel and vanadium. The elements analyzed with refractory fraction included aluminum, cadmium, chromium, copper, iron, lead, nickel, silica and vanadium. The zooplankton and neuston were analyzed for cadmium, chromium, copper, iron, lead, nickel and vanadium. The samples of each group were analyzed with a minimum of three combined standards whose concentrations bracketed those of the samples. New standards were prepared weekly from stock, 1000 ppm solutions (Fisher Certified Atomic Adsorption Standards) and were made up in the same acid matrix as the samples. Acid matrix blanks were also run with standards to correct standards for any absorbance by blanks. Nuclepore membrane blanks were run for the suspended matter samples to correct for any contributions by the filter samples.

The absorbance of each sample was determined by averaging three peak readings. This average absorbance was converted to concentration by comparison with a working curve computed by first order regression analysis based upon three standards. To insure linearity of the standard curves only curves with correlation coefficients of 0.95 or greater were used to calculate sample concentration. In an effort to reduce operator bias, computation of the working curve and sample concentration was done by an IBM 360/65 computer.

Analytical Accuracy

Analysis of bovine liver and orchard leaves for their certified constituents with the procedure outlined for the zooplankton and neuston, produced recoveries within the range of the reported values (see Table 2). Intercalibration comparisons for the digestion and analysis of zooplankton

Table 2. Accuracy and Precision of Tissue Samples
(concentrations in ppm dry weight)

Element	Bovine liver (NBS)	Bovine liver (determined)*
Cd	0.27 ± 0.04	0.32 ± 0.03
Cu	193 ± 10	187 ± 8
Fe	270 ± 20	252 ± 12
Pb	0.34 ± 0.08	0.35 ± 0.1

* Mean values obtained from 20 separate analyses.

and benthic macrofauna were performed between our laboratory and Texas A&M University (Presley). The results are presented in Table 1 and show a good correlation.

Standard clay (W-1) in amounts bracketing our suspended loads were analyzed for the certified constituents with the procedure outlined for refractory suspended material. Recoveries were within the range of reported values (see Table 3).

RESULTS AND DISCUSSION

Suspended matter, zooplankton and neuston samples were collected for the 1975-76 MAFLA program on four transects across the continental shelf of the northeastern Gulf of Mexico (see Figure 1). The transects will be referred to as the 1100, 1200, 1300 and 1400 transects, as shown in Figure 1. Four stations were collected on each transect, except the 1100 transect on which only three stations were sampled.

Sampling for the MAFLA program occurred during three seasons, but suspended loads and their composition indicated a bi-seasonality of water column conditions for the northeastern Gulf of Mexico. Mean suspended loads for the summer and fall were 109±69 $\mu g/\ell$, and 117±53 $\mu g/\ell$ respectively (one standard deviation). A two-sample t-test of unpaired samples with equal variances found these values not to be significantly different at the 99% confidence level. However, the mean suspended load for the winter was 278±210 $\mu g/\ell$, and a two sample t-test of unpaired samples found the winter values to be significantly different from the summer and fall at the 99% confidence level. When equality of variances were tested between the winter and summer and fall, it was found that

Table 3. Elemental recovery of USGS-W1 standard clay. Values presented as average precentage composition.*

Element	Standard Clay (W1)	Standard Clay (Determined)
SiO_2	52.6	52.4±1.4
Al_2O_3	16.9	14.7±0.7
Fe_2O_3	11.2	11.0±0.4
CaO	10.96	10.89±0.21

* Mean values obtained from 2 x 3 group analyses during fall and winter sampling periods.

the variances about the means were significantly different. This is accounted for by the greater variability of the suspended loads for the winter season.

Physical processes appear to be the primary cause of the seasonal differences in suspended load. Pierce (1976) has noted that in the presence of a strong halocline or thermocline, it would be doubtful if the mass of suspended material is ever sufficient to overcome the density differences imposed by temperature and salinity changes between water masses. Furthermore, Brewer and others (1976) have concluded that advection along isopycnals is an important process in controlling the distribution of suspended matter. Physical data, collected concurrently with our suspended material, disclosed stable water conditions (established thermocline and halocline) during the summer and fall in the northeastern Gulf of Mexico. As might be expected, the suspended material which was collected at or above (10 m) the thermocline and/or halocline was dominated by biogenic (siliceous and calcareous) particles. The winter however, displayed unstable water conditions (no thermocline or halocline) and intense mixing due to winter storms, resulting in an alteration in both the quantity and composition of the suspended material.

An interesting corollary to the effect of physical processes on the suspended loads occurred during the second sampling period. Station 1205 was sampled immediately prior to Hurricane ELOISE and again after the hurricane. Suspended loads at the same station were doubled (128 μg/ℓ to 210 μg/ℓ) by the physical mixing due to the hurricane forces. Similar observations were made off the North Carolina coast where suspended loads were more than doubled over pre-storm values by the passage of a hurricane, and within a week the concentration values had returned to pre-hurricane values (Rodolfo, et al., 1971).

The weak-acid soluble composition of Station 1205 after the hurricane showed a five-fold increase in calcium, a four-fold increase in iron, a doubling of lead and an increase in nickel. Calcium carbonate content of the suspended load increased from 5.3% to 23% after the hurricane. The refractory fraction of Station 1205 showed an increase in silica, iron, aluminum, and vanadium. Silica to aluminum ratios decreased after the hurricane (12 to 4.1) possibly due to an increased clay content of the suspended matter. Mineralogical analysis of the suspended material, although unable to determine an increase in suspended clay content, did find a shift in mineral composition following the hurricane. The percentage of chlorite, illite, and feldspar increased at the same time kaolinite decreased. Hurricanes generate physical mixing forces which alter the suspended loads and their composition. Similar physical processes (no thermocline, water of low stability, intense mixing) occur during the winter with the same results.

The composition of the weak-acid soluble fraction of the suspended matter at the fifteen stations for the three sampling sessions is presented in Tables 4-6. This data also shows a bi-seasonality in the composition of the suspended matter. Weak-acid soluble calcium comprised a consistent percentage (1.76±1.55) of the suspended material for all stations during the summer and fall. It has been previously noted (BLM 2nd Quarterly Report) that calcium values for the fall were elevated in comparison to the

TABLE 4

BLM SUSPENDED MATTER

WEAK ACID SOLUBLE FRACTION

CRUISE NUMBER 1

WEIGHT PERCENT ELEMENT OF THE SUSPENDED LOAD

STATION NUMBER	DEPTH IN M	SUSPENDED LOAD IN UG/LITER	% AL	% CA	% CD	% CR	% CU	% FE	% NI	% PB	% SI	% V
			1X	1X	100X	100X	100X	10X	100X	100X	1X	1X
1101	10.	145.	NA	0.57	0.11	*****	0.49	1.19	*****	1.38	*****	NA
1102	10.	73.	NA	0.45	0.09	*****	1.25	0.27	*****	0.46	*****	NA
1103	10.	17.	NA	1.23	0.15	*****	2.82	1.07	*****	*****	*****	NA
1204	10.	58.	NA	0.71	0.16	*****	1.30	1.64	*****	1.72	*****	NA
1205	10.	169.	NA	0.39	0.06	*****	0.97	0.30	*****	0.72	*****	NA
1206	10.	73.	NA	0.54	0.24	*****	4.21	0.38	*****	2.06	*****	NA
1207	10.	102.	NA	1.20	0.10	*****	1.22	0.41	*****	0.57	*****	NA
1308	10.	106.	NA	0.80	1.59	*****	3.18	1.77	*****	1.12	*****	NA
1309	10.	95.	NA	0.73	0.53	*****	1.83	0.51	*****	0.72	*****	NA
1310	10.	55.	NA	1.17	1.22	*****	4.43	1.13	*****	2.90	*****	NA
1311	10.	56.	NA	0.52	0.53	*****	2.81	0.56	*****	2.74	*****	NA
1412	10.	298.	NA	0.27	0.16	*****	0.77	1.39	*****	3.25	*****	NA
1413	10.	76.	NA	0.46	1.28	*****	2.26	1.20	*****	0.86	*****	NA
1414	10.	178.	NA	0.43	0.36	*****	1.10	0.37	*****	3.26	*****	NA
1415	10.	129.	NA	0.98	1.61	*****	3.42	1.05	*****	3.48	*****	NA

***** = NOT DETECTABLE

TABLE 5

BLM SUSPENDED MATTER

WEAK ACID SOLUBLE FRACTION

CRUISE NUMBER 2

WEIGHT PERCENT ELEMENT OF THE SUSPENDED LOAD

STATION NUMBER	DEPTH IN M	SUSPENDED LOAD IN UG/LITER	% AL	% CA	% CD	% CR	% CU	% FE	% NI	% PB	% SI	% V
			1X	1X	100X	100X	100X	10X	100X	100X	1X	1X
1101	10.	197.	NA	2.09	0.34	*****	0.15	0.05	*****	0.24	*****	NA
1102	10.	53.	NA	2.34	0.29	*****	0.15	*****	*****	0.53	*****	NA
1103	10.	63.	NA	3.07	0.47	*****	0.20	0.46	*****	0.83	*****	NA
1204	10.	184.	NA	1.06	0.14	*****	*****	0.16	*****	0.32	*****	NA
1205	10.	128.	NA	2.12	0.14	*****	*****	0.07	*****	0.42	*****	NA
1215 *	10.	210.	NA	9.29	0.11	*****	0.05	0.27	6.12	0.90	*****	NA
1206	10.	104.	NA	2.31	0.26	*****	0.44	0.02	1.41	0.42	*****	NA
1207	10.	134.	NA	4.40	0.23	*****	0.94	0.15	*****	0.45	*****	NA
1308	10.	111.	NA	1.82	0.19	*****	0.21	0.54	4.85	0.69	*****	NA
1309	10.	54.	NA	1.38	0.17	*****	0.46	*****	*****	0.58	*****	NA
1310	10.	93.	NA	3.58	0.26	*****	0.52	*****	2.19	0.22	*****	NA
1311	10.	144.	NA	2.19	0.24	*****	*****	0.01	*****	0.35	*****	NA
1412	10.	158.	NA	0.65	0.69	*****	*****	0.17	*****	1.38	*****	NA
1413	10.	122.	NA	2.74	0.39	*****	0.75	*****	11.49	0.64	*****	NA
1414	10.	37.	NA	1.40	0.28	*****	0.14	0.18	*****	1.11	*****	NA
1415	10.	75.	NA	2.96	0.38	*****	0.27	0.27	*****	1.17	*****	NA

***** = NOT DETECTABLE

* After Hurricane ELOISE

TABLE 6

BLM SUSPENDED MATTER

WEAK ACID SOLUBLE FRACTION

CRUISE NUMBER 3

WEIGHT PERCENT ELEMENT OF THE SUSPENDED LOAD

STATION NUMBER	DEPTH IN M	SUSPENDED LOAD IN JG/LITER	% AL	% CA	% CD	% CR	% CU	% FE	% NI	% PB	% SI	% V
			1X	1X	100X	100X	100X	10X	100X	100X	1X	1X
1101	10.	547.	NA	25.27	0.04	0.04	0.02	0.64	*****	0.73	*****	NA
1102	10.	437.	NA	13.28	0.02	0.05	*****	0.30	*****	0.29	*****	NA
1103	10.	70.	NA	6.37	0.12	*****	*****	0.11	*****	0.38	*****	NA
1204	10.	194.	NA	9.47	0.05	*****	*****	1.08	*****	0.31	*****	NA
1205	10.	57.	NA	4.14	0.28	*****	0.28	0.67	*****	0.25	*****	NA
1206	10.	758.	NA	10.18	0.04	0.05	*****	0.43	*****	0.31	*****	NA
1207	10.	399.	NA	16.54	0.03	0.06	*****	0.31	*****	0.44	*****	NA
1308	10.	231.	NA	0.18	0.07	0.01	*****	3.02	*****	0.30	*****	NA
1309	10.	143.	NA	0.36	0.11	*****	*****	0.83	*****	0.35	*****	NA
1310	10.	164.	NA	0.12	0.19	*****	*****	0.79	*****	*****	*****	NA
1311	10.	25.	NA	0.37	0.54	*****	0.47	0.74	*****	0.51	*****	NA
1412	10.	281.	NA	0.05	0.11	0.17	*****	21.77	*****	0.36	*****	NA
1413	10.	483.	NA	0.07	0.04	0.01	*****	6.31	*****	0.27	*****	NA
1414	10.	91.	NA	0.37	0.15	*****	*****	3.24	*****	0.78	*****	NA
1415	10.	294.	NA	0.28	0.09	0.02	*****	6.02	*****	0.52	*****	NA

***** = NOT DETECTABLE

first sampling period. The winter's weak-acid soluble calcium values are skewed with extremely high calcium values reported for the I and II Transects ($\bar{X} = 12.2\%$) and values of one to two orders of magnitude lower for the III and IV Transects ($\bar{X} = 0.23\%$). Using the mean calcium composition and mean suspended loads of the I and II Transects, one finds that $CaCO_3$ comprises 1.8% and 6.2%, respectively, of the SPM for the summer and fall versus 30.5% of the SPM for the winter.

Weak-acid soluble cadmium remained consistent throughout the sampling periods. Chromium, which was non-detectable during the first two sampling sessions, was detected at certain stations during the winter where suspended loads were relatively large (>200 μg/ℓ). Copper and lead values were highest for the first sampling session and somewhat lower in both subsequent sampling sessions. Weak-acid soluble iron was lowest during the fall sampling period and comparable for summer and winter on all transects except the IV Transect of the winter. The iron concentration on the IV Transect was 8-36 times greater during the winter (i.e. $\bar{X} = 0.93\%$ for winter, $\bar{X} = 0.021\%$ for fall, $\bar{X} = 0.10\%$ for summer) than in the fall and summer. Simultaneously, high refractory aluminum, iron, and silicon values suggest that this weak-acid soluble iron results from a poorly structured hydroxyoxide form in association with clay material. This is further discussed in another section of this report.

The composition of the refractory suspended matter for the three sampling periods is presented in Tables 7-9. Interesting trends and differences were evident in this fraction. Aluminum, iron, and silica concentrations were greatest during the winter sampling. This could have resulted from river runoff, resuspension of bottom sediments, and increased

TABLE 7

BLM SUSPENDED MATTER

REFRACTORY FRACTION

CRUISE NUMBER 1

WEIGHT PERCENT ELEMENT OF THE SUSPENDED LOAD

STATION NUMBER	DEPTH IN M	SUSPENDED LOAD IN JG/LITER	% AL	% CA	% CD	% CR	% CU	% FE	% NI	% PB	% SI	% V
			1X	1X	100X	100X	100X	10X	1X	100X	1X	1X
1101	10.	145.	0.53	NA	0.02	0.31	0.09	4.56	*****	0.16	8.40	*****
1102	10.	73.	0.47	NA	*****	0.52	*****	4.34	*****	0.06	6.72	*****
1103	10.	17.	1.28	NA	0.08	0.99	0.69	10.96	*****	1.76	6.08	*****
1204	10.	58.	0.32	NA	0.05	0.62	0.31	3.91	*****	0.47	5.44	*****
1205	10.	169.	0.28	NA	0.03	0.40	0.25	2.62	*****	0.50	3.97	*****
1206	10.	73.	0.34	NA	*****	0.57	0.49	3.52	*****	0.16	6.04	*****
1207	10.	102.	0.30	NA	*****	0.57	0.47	3.18	*****	0.91	6.60	*****
1308	10.	106.	0.82	NA	0.06	0.59	4.53	4.96	*****	1.41	5.42	*****
1309	10.	95.	0.30	NA	0.10	0.53	5.00	4.18	*****	0.87	3.21	*****
1310	10.	55.	1.61	NA	0.15	0.92	3.36	3.25	*****	1.53	5.10	*****
1311	10.	56.	0.49	NA	0.11	0.53	4.26	2.60	*****	0.99	3.23	*****
1412	10.	298.	2.32	NA	0.05	0.35	0.79	10.29	*****	0.84	16.75	*****
1413	10.	76.	1.35	NA	0.04	0.34	2.78	8.86	*****	0.68	11.84	*****
1414	10.	178.	0.28	NA	0.02	1.25	0.81	2.15	*****	0.54	14.07	*****
1415	10.	129.	0.59	NA	0.97	0.77	4.32	3.47	*****	0.39	14.84	*****

***** = NOT DETECTABLE

TABLE 8

BLM SUSPENDED MATTER

REFRACTORY FRACTION

CRUISE NUMBER 2

WEIGHT PERCENT ELEMENT OF THE SUSPENDED LOAD

STATION NUMBER	DEPTH IN M	SUSPENDED LOAD IN UG/LITER	% AL	% CA	% CD	% CR	% CU	% FE	% NI	% PR	% SI	% V
			1X	1X	100X	100X	100X	10X	1X	100X	1X	1X
1101	10.	197.	0.17	NA	0.05	0.30	0.08	1.13	*****	0.98	5.06	*****
1102	10.	53.	0.09	NA	0.24	0.62	0.35	0.66	*****	1.30	4.74	*****
1103	10.	63.	0.15	NA	0.43	1.36	*****	4.71	*****	1.50	5.09	*****
1204	10.	184.	0.49	NA	0.03	0.53	*****	2.13	*****	0.53	4.95	*****
1205	10.	128.	0.45	NA	0.08	0.54	*****	1.90	*****	0.80	5.48	*****
1215 *	10.	210.	1.91	NA	0.05	0.69	0.12	7.12	*****	0.85	7.78	*****
1206	10.	104.	0.40	NA	0.07	0.47	0.20	1.71	*****	0.80	4.05	*****
1207	10.	134.	1.10	NA	0.14	0.34	0.24	4.34	*****	0.84	3.64	*****
1308	10.	111.	0.17	NA	0.34	0.93	*****	1.71	*****	1.01	4.61	*****
1309	10.	54.	0.23	NA	0.14	0.75	*****	1.22	*****	1.83	3.65	*****
1310	10.	93.	0.14	NA	0.08	5.63	*****	3.07	*****	0.76	2.79	*****
1311	10.	144.	0.68	NA	0.07	0.58	*****	2.55	*****	0.59	4.29	*****
1412	10.	158.	0.55	NA	0.75	1.61	2.41	3.56	*****	4.88	7.94	*****
1413	10.	122.	0.53	NA	0.04	1.71	*****	2.42	*****	2.14	6.35	*****
1414	10.	37.	0.53	NA	0.56	2.22	*****	5.25	*****	4.44	11.20	*****
1415	10.	75.	0.40	NA	0.03	1.24	*****	1.51	*****	1.68	5.71	*****

***** = NOT DETECTABLE

* After Hurricane ELOISE

TABLE 9

BLM SUSPENDED MATTER

REFRACTORY FRACTION

CRUISE NUMBER 3

WEIGHT PERCENT ELEMENT OF THE SUSPENDED LOAD

STATION NUMBER	DEPTH IN M	SUSPENDED LOAD IN UG/LITER	% AL	% CA	% CD	% CR	% CU	% FE	% NI	% PB	% SI	% V
			1X	1X	100X	100X	100X	10X	1X	100X	1X	1X
1101	10.	547.	1.12	NA	*****	0.32	*****	4.82	*****	0.23	9.34	*****
1102	10.	437.	1.75	NA	0.05	0.44	*****	7.65	*****	0.16	8.42	*****
1103	10.	70.	0.33	NA	*****	0.45	*****	2.07	*****	0.88	7.01	*****
1204	10.	194.	1.76	NA	*****	0.48	*****	8.02	*****	0.51	17.66	*****
1205	10.	57.	1.11	NA	1.10	0.83	*****	5.93	*****	1.69	19.55	*****
1206	10.	758.	1.71	NA	0.05	0.30	*****	6.03	*****	0.11	7.37	*****
1207	10.	399.	1.48	NA	*****	0.48	*****	7.39	*****	0.18	12.91	*****
1308	10.	231.	2.73	NA	*****	0.56	*****	10.56	*****	0.53	16.44	*****
1309	10.	143.	2.76	NA	*****	0.85	*****	12.72	*****	0.50	11.93	*****
1310	10.	164.	0.96	NA	0.42	0.57	4.17	8.46	*****	3.08	22.38	*****
1311	10.	25.	0.47	NA	*****	1.05	*****	3.58	*****	1.77	24.55	*****
1412	10.	281.	9.89	NA	*****	1.13	*****	28.83	*****	0.90	30.42	*****
1413	10.	483.	8.84	NA	*****	0.90	*****	38.28	*****	0.55	27.40	*****
1414	10.	91.	6.25	NA	*****	2.03	*****	32.35	*****	1.42	26.13	*****
1415	10.	294.	4.73	NA	*****	1.08	*****	24.74	*****	0.73	22.42	*****

***** = NOT DETECTABLE

primary productivity (diatoms). It is likely that all three mechanisms are operating to elevate certain elements depending upon the sample location. An excellent tool for evaluating the origin of the particles is the weight ratios of each element to refractory aluminum (see Tables 10-15). Refractory aluminum is used because it is not greatly concentrated by organisms and has a primary source in clay minerals.

Diatoms, which utilize silica in their frustules, would, upon analysis show a high silicon/aluminum ratio (>6) since they incorporate minor amounts of aluminum (see Bennekom and Gaast, 1976). However, clays, which are alumino-silicate minerals, would display low silicon/aluminum ratios (2 - 6:1). Examination of Tables 10-15 show low silicon/aluminum ratios on the IV Transect of the third sampling period when compared to the IV Transects of the other sampling periods. These alumino-silicate values result from an increased clay content of the winter suspended loads (∿60%). Whereas high calcium values occurred on the carbonate-rich West Florida shelf (Davies and Moore, 1970), the high alumino-silicate values occur on the Mississippi-Alabama shelf where clays are an important part of the bottom sediments (Griffin, 1962). This reflection of shelf sediment composition by the suspended matter implies that physical processes were sufficient to resuspend and transport bottom and river material during the winter in the northeastern Gulf of Mexico. The high silicon/aluminum ratios found on other transects and at other times of the year indicate increased silica concentrations resulting from biological sources or quartz sand which would essentially dilute the existing clay. Suspended mineralogy work by Dr. Huang found quartz to be present at 89% of the stations samples in amounts sufficient to contribute significant quantities of silica.

TABLE 10

BLM SUSPENDED MATTER

WEAK ACID SOLUBLE FRACTION

CRUISE NUMBER 1 WEIGHT RATIO OF EACH ELEMENT TO REFRACTORY ALUMINUM

STATION NUMBER	DEPTH IN M.	SUSPENDED LOAD IN UG/LITER	CA / AL 1X	CD / AL 100X	CR / AL 100X	CU / AL 100X	FE / AL 10X	NI / AL 1X	PB / AL 100X	SI / AL 1X	V / AL 1X
1101	10.	145.	1.08	0.21	*****	0.93	2.26	*****	2.62	NA	*****
1102	10.	73.	0.96	0.19	*****	2.65	0.58	*****	0.97	NA	*****
1103	10.	17.	0.96	0.12	*****	2.20	0.83	*****	*****	NA	*****
1204	10.	58.	2.20	0.49	*****	4.05	5.08	*****	5.34	NA	*****
1205	10.	169.	1.39	0.22	*****	3.48	1.07	*****	2.58	NA	*****
1206	10.	73.	1.59	0.72	*****	12.47	1.13	*****	6.12	NA	*****
1207	10.	102.	4.06	0.34	*****	4.10	1.39	*****	1.94	NA	*****
1308	10.	106.	0.97	1.93	*****	3.86	2.15	*****	1.36	NA	*****
1309	10.	95.	2.40	1.74	*****	5.99	1.67	*****	2.37	NA	*****
1310	10.	55.	0.73	0.76	*****	2.75	0.70	*****	1.80	NA	*****
1311	10.	56.	1.27	1.10	*****	5.79	1.15	*****	5.63	NA	*****
1412	10.	298.	0.12	0.07	*****	0.33	0.60	*****	1.40	NA	*****
1413	10.	76.	0.34	0.95	*****	1.67	0.89	*****	0.64	NA	*****
1414	10.	178.	1.55	1.28	*****	3.98	1.32	*****	11.74	NA	*****
1415	10.	129.	1.67	2.75	*****	5.84	1.78	*****	5.95	NA	*****

***** = NOT DETECTABLE

TABLE 11

BLM SUSPENDED MATTER

WEAK ACID SOLUBLE FRACTION

CRUISE NUMBER 2   WEIGHT RATIO OF EACH ELEMENT TO REFRACTORY ALUMINUM

STATION NUMBER	DEPTH IN M.	SUSPENDED LOAD IN UG/LITER	CA / AL	CD / AL	CR / AL	CU / AL	FE / AL	NI / AL	PB / AL	SI / AL	V / AL
			1X	100X	100X	100X	10X	1X	100X	1X	1X
1101	10.	197.	12.14	1.99	*****	0.89	0.32	*****	1.40	NA	*****
1102	10.	53.	26.91	3.39	*****	1.69	*****	*****	6.10	NA	*****
1103	10.	63.	20.29	3.08	*****	1.32	3.03	*****	5.49	NA	*****
1204	10.	184.	2.16	0.29	*****	*****	0.33	*****	0.65	NA	*****
1205	10.	128.	4.76	0.31	*****	*****	0.16	*****	0.94	NA	*****
1215	10.	210.	4.86	0.06	*****	0.03	0.14	0.03	0.47	NA	*****
1206	10.	104.	5.84	0.66	*****	1.11	0.05	0.04	1.07	NA	*****
1207	10.	134.	3.99	0.21	*****	0.85	0.14	*****	0.41	NA	*****
1308	10.	111.	10.61	1.08	*****	1.23	3.13	0.28	4.01	NA	*****
1309	10.	54.	6.06	0.77	*****	2.04	*****	*****	2.55	NA	*****
1310	10.	93.	26.46	1.91	*****	3.82	*****	0.16	1.62	NA	*****
1311	10.	144.	3.22	0.35	*****	*****	0.02	*****	0.52	NA	*****
1412	10.	158.	1.17	1.24	*****	*****	0.31	*****	2.48	NA	*****
1413	10.	122.	5.15	0.74	*****	1.40	*****	0.22	1.20	NA	*****
1414	10.	37.	2.63	0.52	*****	0.26	0.34	*****	2.09	NA	*****
1415	10.	75.	7.46	0.95	*****	0.69	0.68	*****	2.95	NA	*****

***** = NOT DETECTABLE

TABLE 12

BLM SUSPENDED MATTER

WEAK ACID SOLUBLE FRACTION

CRUISE NUMBER 3 WEIGHT RATIO OF EACH ELEMENT TO REFRACTORY ALUMINUM

STATION NUMBER	DEPTH IN M.	SUSPENDED LOAD IN UG/LITER	CA / AL 1X	CD / AL 100X	CR / AL 100X	CU / AL 100X	FE / AL 10X	NI / AL 1X	PB / AL 100X	SI / AL 1X	V / AL 1X
1101	10.	547.	22.53	0.04	0.03	0.02	0.57	*****	0.65	NA	*****
1102	10.	437.	7.58	0.01	0.03	*****	0.17	*****	0.17	NA	*****
1103	10.	70.	19.49	0.36	*****	*****	0.34	*****	1.17	NA	*****
1204	10.	194.	5.39	0.03	*****	*****	0.61	*****	0.18	NA	*****
1205	10.	57.	3.74	0.25	*****	0.25	0.61	*****	0.22	NA	*****
1206	10.	758.	5.97	0.02	0.03	*****	0.25	*****	0.18	NA	*****
1207	10.	399.	11.16	0.02	0.04	*****	0.21	*****	0.30	NA	*****
1308	10.	231.	0.06	0.03	0.01	*****	1.11	*****	0.11	NA	*****
1309	10.	143.	0.13	0.04	*****	*****	0.32	*****	0.13	NA	*****
1310	10.	164.	0.12	0.20	*****	*****	0.83	*****	*****	NA	*****
1311	10.	25.	0.79	1.16	*****	1.01	1.60	*****	1.09	NA	*****
1412	10.	281.	0.00	0.01	0.02	*****	2.20	*****	0.04	NA	*****
1413	10.	483.	0.01	0.01	0.00	*****	0.71	*****	0.03	NA	*****
1414	10.	91.	0.06	0.02	*****	*****	0.52	*****	0.13	NA	*****
1415	10.	294.	0.06	0.02	0.00	*****	1.27	*****	0.11	NA	*****

***** = NOT DETECTABLE

TABLE 13

BLM SUSPENDED MATTER

REFRACTORY FRACTION

CRUISE NUMBER 1 . WEIGHT RATIO OF EACH ELEMENT TO REFRACTORY ALUMINUM

STATION NUMBER	DEPTH IN M.	SUSPENDED LOAD IN UG/LITER	CA / AL	CD / AL	CR / AL	CU / AL	FE / AL	NI / AL	PB / AL	SI / AL	V / AL
			1X	100X	100X	100X	1X	1X	100X	1X	1X
1101	10.	145.	NA	0.03	0.59	0.17	0.87	*****	0.31	15.97	*****
1102	10.	73.	NA	*****	1.10	*****	0.92	*****	0.13	14.29	*****
1103	10.	17.	NA	0.06	0.77	0.54	0.85	*****	1.37	4.74	*****
1204	10.	58.	NA	0.16	1.94	0.97	1.21	*****	1.46	16.90	*****
1205	10.	169.	NA	0.11	1.46	0.90	0.94	*****	1.79	14.27	*****
1206	10.	73.	NA	*****	1.68	1.44	1.04	*****	0.48	17.89	*****
1207	10.	102.	NA	*****	1.94	1.59	1.07	*****	3.08	22.26	*****
1308	10.	106.	NA	0.07	0.71	5.50	0.60	*****	1.72	6.59	*****
1309	10.	95.	NA	0.32	1.74	16.40	1.37	*****	2.84	10.54	*****
1310	10.	55.	NA	0.09	0.57	2.08	0.20	*****	0.95	3.16	*****
1311	10.	56.	NA	0.23	1.10	8.76	0.54	*****	2.03	6.65	*****
1412	10.	298.	NA	0.02	0.15	0.34	0.44	*****	0.36	7.21	*****
1413	10.	76.	NA	0.03	0.25	2.06	0.66	*****	0.50	8.77	*****
1414	10.	178.	NA	0.07	4.52	2.90	0.77	*****	1.96	50.68	*****
1415	10.	129.	NA	1.65	1.32	7.38	0.59	*****	0.66	25.33	*****

***** = NOT DETECTABLE

TABLE 14

BLM SUSPENDED MATTER

REFRACTORY FRACTION

CRUISE NUMBER 2 WEIGHT RATIO OF EACH ELEMENT TO REFRACTORY ALUMINUM

STATION NUMBER	DEPTH IN M.	SUSPENDED LOAD IN UG/LITER	CA / AL	CD / AL	CR / AL	CU / AL	FE / AL	NI / AL	PB / AL	SI / AL	V / AL
			1X	100X	100X	100X	1X	1X	100X	1X	1X
1101	10.	197.	NA	0.30	1.77	0.44	0.66	*****	5.69	29.47	*****
1102	10.	53.	NA	2.71	7.12	4.07	0.76	*****	14.92	54.44	*****
1103	10.	63.	NA	2.86	9.01	*****	3.12	*****	9.89	33.67	*****
1204	10.	184.	NA	0.07	1.17	*****	0.43	*****	1.07	10.08	*****
1205	10.	128.	NA	0.18	1.21	*****	0.43	*****	1.80	12.28	*****
1215	10.	210.	NA	0.03	0.36	0.06	0.37	*****	0.44	4.07	*****
1206	10.	104.	NA	0.18	1.18	0.52	0.43	*****	2.03	10.24	*****
1207	10.	134.	NA	0.12	0.31	0.22	0.39	*****	0.76	3.30	*****
1308	10.	111.	NA	2.01	5.40	*****	0.99	*****	5.86	26.82	*****
1309	10.	54.	NA	0.64	3.32	*****	0.54	*****	6.04	16.06	*****
1310	10.	93.	NA	0.59	41.62	*****	2.27	*****	5.59	20.61	*****
1311	10.	144.	NA	0.11	0.85	*****	0.38	*****	0.87	6.32	*****
1412	10.	158.	NA	1.35	2.90	4.35	0.64	*****	8.80	14.32	*****
1413	10.	122.	NA	0.07	3.21	*****	0.45	*****	4.01	11.94	*****
1414	10.	37.	NA	1.05	4.19	*****	0.99	*****	8.38	21.10	*****
1415	10.	75.	NA	0.09	3.12	*****	0.38	*****	4.25	14.40	*****

***** = NOT DETECTABLE

TABLE 15

BLM SUSPENDED MATTER

REFRACTORY FRACTION

CRUISE NUMBER 3 WEIGHT RATIO OF EACH ELEMENT TO REFRACTORY ALUMINUM

STATION NUMBER	DEPTH IN M.	SUSPENDED LOAD IN UG/LITER	CA / AL 1X	CD / AL 100X	CR / AL 100X	CU / AL 100X	FE / AL 1X	NI / AL 1X	PB / AL 100X	SI / AL 1X	V / AL 1X
1101	10.	547.	NA	*****	0.28	*****	0.43	*****	0.21	8.32	*****
1102	10.	437.	NA	0.03	0.25	*****	0.44	*****	0.09	4.81	*****
1103	10.	70.	NA	*****	1.37	*****	0.63	*****	2.69	21.43	*****
1204	10.	194.	NA	*****	0.27	*****	0.46	*****	0.29	10.04	*****
1205	10.	57.	NA	1.00	0.75	*****	0.54	*****	1.53	17.68	*****
1206	10.	758.	NA	0.03	0.18	*****	0.35	*****	0.06	4.32	*****
1207	10.	399.	NA	*****	0.33	*****	0.50	*****	0.12	8.71	*****
1308	10.	231.	NA	*****	0.21	*****	0.39	*****	0.20	6.03	*****
1309	10.	143.	NA	*****	0.31	*****	0.46	*****	0.18	4.33	*****
1310	10.	164.	NA	0.43	0.59	4.35	0.88	*****	3.21	23.29	*****
1311	10.	25.	NA	*****	2.25	*****	0.77	*****	3.80	52.71	*****
1412	10.	281.	NA	*****	0.11	*****	0.29	*****	0.09	3.08	*****
1413	10.	483.	NA	*****	0.10	*****	0.43	*****	0.06	3.10	*****
1414	10.	91.	NA	*****	0.32	*****	0.52	*****	0.23	4.18	*****
1415	10.	294.	NA	*****	0.23	*****	0.52	*****	0.16	4.74	*****

***** = NOT DETECTABLE

The distribution of nearshore particulate iron has been found to be dominated by the presence of detrital silicates, although the concentration of marine organisms in surface waters can also be significant (Spencer, et at., 1972). It is therefore interesting to note the consistency of the Fe/Al ratios for the winter and fall sampling (see Figure 2), except at those stations during the fall where the Cr/Al ratios are very high and then the Fe/Al ratios are also high (Stations 1310, 1103). A correlation coefficient of 0.96 was calculated between Al and Fe for the fall and winter (excluding Stations 1310 and 1103 at the fall), whereas a correlation coefficient of 0.75 was calculated between Al and Fe for the summer. The lower correlation of the early summer is believed to have resulted from increased biological activity by amorphous silica secreting organisms, diatoms. The high silica concentrations and high Si/Al ratios on all the transects during the summer indicate that diatoms dominate the suspended composition and incorporating Fe, unsupported by aluminim during growth. However the fall and winter periods were dominated by carbonate organisms and resuspended sediments respectively, and here the particulate iron is associated with detrital silicates. Thus it would seem that particulate iron in surface water of the northeastern Gulf of Mexico is primarily controlled by detrital silicates although biological organisms are important seasonally, depending on the concentration and type of organisms present.

Refractory iron concentrations were greatly elevated on the IV Transect during the winter compared to other sampling seasons. This obviously resulted from increases in the contribution of clay

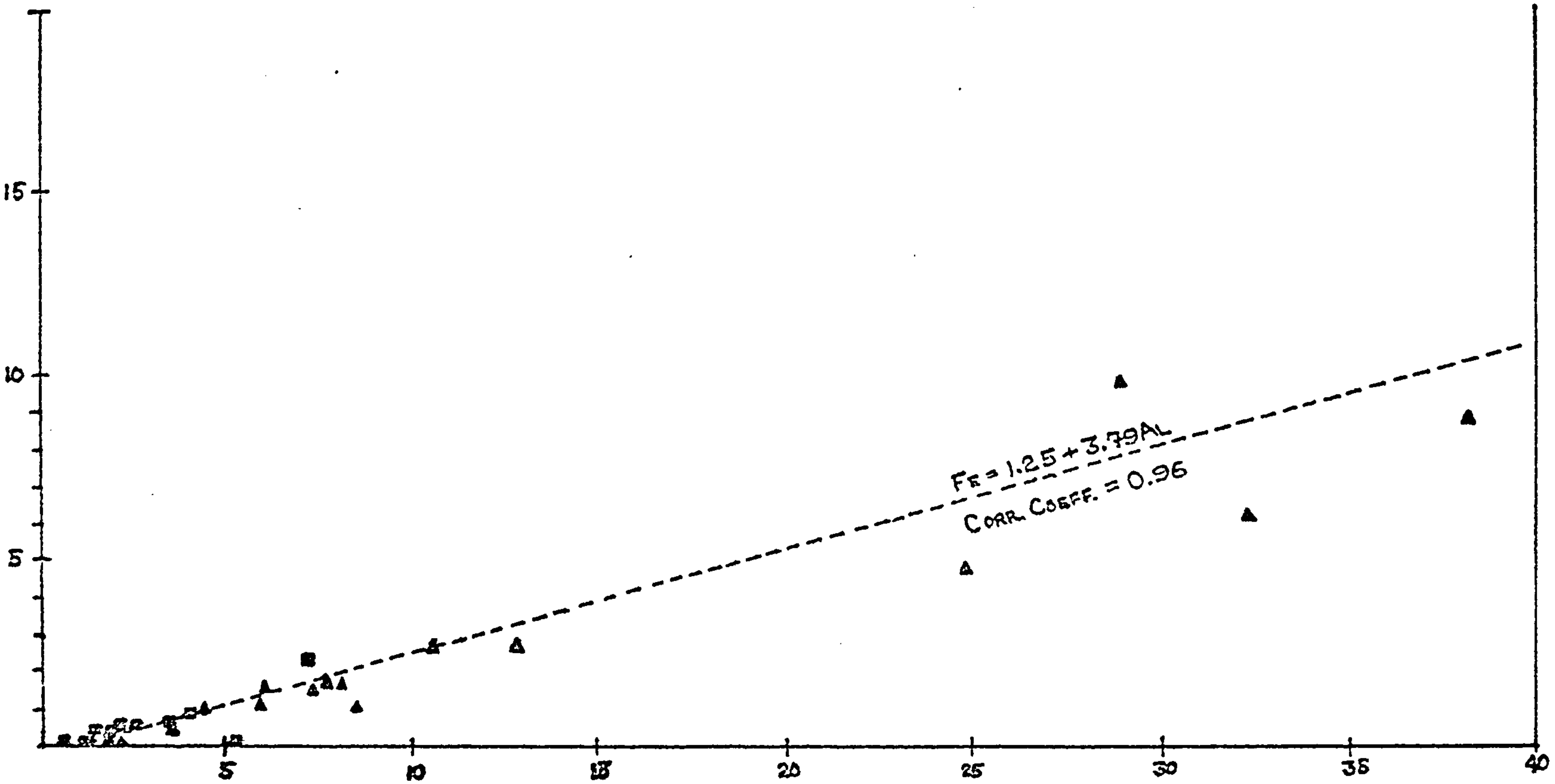

Figure 2. Refractory Al versus Refractory Fe
for second and third sampling sessions.

minerals made to the suspended matter.

Mineralogical analysis of the suspended fraction from the IV Transect showed that smectite and kaolinite were dominant during the winter. This assemblage of suspended clays should have a Fe/Al ratio of approximately 0.055 for smectite (Degens, 1965) and 0.051 for kaolinite (Weaver and Pollard, 1976). However, our data for the IV Transect shows Fe/AL ratios of 0.29 - 0.52. This discrepancy can be explained by the existence of free ferric oxide particles and/or the adsorbtion of iron to the clay particles. Tieh and Pyle (1972) described cores from the same region composed of composite clay particles stained with iron oxides and/or hydroxides. The concurrently high weak-acid soluble and refractory iron concentrations for the IV Transect indicate iron to be partitioned at different oxidation states possibly indicative of recently deposited sediments and/or river runoff.

Refractory chromium showed some interesting trends during the three sampling periods. During all seasons, chromium appears to increase as one goes from the I to the IV Transects. High Cr/Al ratios are generally found at those stations with high Si/Al ratios, and it is possible that biological mechanisms might, in part, be responsible for these increased chromium concentrations in suspended matter.

Refractory lead is another element that appears to be influenced by biological activity. High Pb/Al ratios are often matched with high Si/Al ratios and this is particularly evident during the fall sampling session. It is noted that high Pb/Al and high Cr/Al ratios appear to occur at those stations where there are low suspended loads, which could result in artificially high element-to-aluminum ratios because of the increased possibility of contamination. However, with elevated Cr/Al ratios one should expect elevated Fe/Al ratios if contamination occurred. This appears to be the case for Stations 1103 and 1310 during the fall but still does not explain many other stations of the summer, fall and winter which have elevated Cr/Al and Pb/Al ratios occurring with high Si/Al ratios.

It is difficult to discuss refractory copper, nickel and vanadium since they were often at the detection limits of our analytical procedure.

Comparison and interrelation of our data with the mineralogy of suspended matter and sediments (Dr. W. Huang) provides further insights into our results. The dominant clay mineral on the Mississippi-Alabama shelf is smectite with both chlorite and chlorite-vermiculite mixed layers present in trace amounts (Table 16). If the suspended mineraology data is examined for the IV Transect (Table 17) one finds smectite present at only one station for the summer and fall but present at all stations during the winter. Thus it would appear that physical processes are causing the suspended mineralogy to more closely reflect the sediments' mineral composition during the winter. This is consistent with our conclusion that clays dominate the suspended material during the winter, but not during the remainder of the year on the IV Transect.

Suspended mineralogy from the winter found carbonates (aragonite, low magnesium calcite, high magnesium calcite and dolomite) present in appreciable amounts on the I Transect, and to quote Dr. Huang, "These suggest that some stirring up from the bottom sediments may have occurred." This data corroborates our elevated carbonate values found on the I and II Transects during the winter. Similarly, we also attribute

Table 16. Clay Mineral Content (%) of Surface Sediments from the MAFLA Sites (Preliminary Results)

Station No.	Smectite	Chlorite of Chlorite-Vermiculite mixed layer	Illite	Kaolins
2101	8	64	11	17
2102	10	54	10	26
2103	T	48	8	43
2104	T	62	5	32
2105	0	39	14	47
2106	24*	28	15	33
2207	0	54	11	35
2208	7	44	8	41
2209	7	45	6	42
2211	4	45	5	46
2212	37	21	13	29
2313	46	13	10	31
2316	7	43	6	44
2317	3	39	9	49
2318	8	39	5	48
2419	3	39	4	54
2420	5	37	6	52
2421	4	29	2	65
2422	12	22	5	61
2423	15	16	4	65
2424	11	20	8	61
2425	5	39	8	48
2426	14	29	8	49
2427	45	9	8	38
2528	11	34	3	52
2529	9	36	4	51
2530	18	35	4	43
2531	16	23	7	54
2532	24	28	10	38
2533	27	21	10	42
2534	24	20	4	52
2535	37	15	7	41
2536	49	5	8	38
2637	74	2	3	21
2638	82	5	4	9
2639	75	3	7	15
2640	61	6	10	23
2641	55	T	12	32
2642	43	6	17	34
2643	76	T	6	17
2644	49	4	14	33
2645	61	4	9	26

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* Expanded mixed layers

Table 17. The Content (%) of Clay Minerals in Suspended Particulate Matter from 10 m Depth on the West Florida Shelf

July 14, 1975 and July 21, 1975

Station No.	Smectite	Chlorite	Illite	Kaolinite	Talc
1101	-	18	19	40	23
1102	T	7	25	27	41
1103	-	12	18	34	36
1204	-	15	29	27	29
1205	-	15	15	20	50
1206	-	19	17	33	31
1207	-	T	38	62	T
1308	-	17	16	26	41
1309	-	6	23	24	47
1310	T	11	13	30	57
1311	-	32	20	42	16
1412	11	18	18	43	10
1413	-	T	46	54	-
1414	-	T	23	28	49
1415	-	11	12	16	61

T Trace Amount

Table 17. continued The Content (%) of Clay Minerals in Suspended Particulate Matter from 10 m Depth on the West Florida Shelf

September 16, 1975 and October 3, 1975

Station No.	Smectite	Chlorite	Illite	Kaolinite	Talc
1101	-	9	16	38	37
1102	-	6	11	23	60
1103	-	-	14	35	51
1204	-	11	T	26	63
1205	-	9	10	79	2
1205a	-	31	31	38	T
1206	-	T	20	32	48
1207	-	10	10	56	24
1308	-	T	18	34	48
1309	-	T	25	50	25
1310	-	26	T	49	25
1311	-	-	40	60	-
1412	-	24	24	24	28
1413	-	-	T	43	57
1414	-	-	43	57	-
1415	26	38	-	36	T

1205a before hurricane
1205 after hurricane

T Trace Amount

Table 17. The Content (%) of Clay Minerals in
continued Suspended Particulate Matter from
10 m Depth on the West Florida
Shelf

January, 1976

Station No.	Smectite	Chlorite	Illite	Kaolinite	Talc
1101	-	31	9	44	16
1102	-	15	10	51	24
1103	-	19	17	15	49
1204	-	20	8	54	18
1205	-	18	23	31	28
1206	-	24	5	71	0
1207	9	12	9	65	5
1308	T	13	11	66	10
1309	-	16	27	30	27
1310	-	T	11	70	19
1311	*	*	*	*	*
1412	63	2	9	26	0
1413	68	2	12	18	0
1414	83	T	7	10	T
1415	74	T	9	13	5

T Trace Amount
* Not enough sample

resuspension of bottom sediments as the primary carbonate enrichment process.

The zooplankton collected displayed a remarkable consistency in their concentrations of various elements (see Table 18). However, iron levels were elevated on the IV Transect during the winter sampling period.

The mean iron concentration for the winter (1192 ppm) was 4-8 times that of the summer (253 ppm) or the fall (116 ppm). The concurrently high iron values for the weak-acid soluble and refractory fraction of the SPM indicate that suspended matter could be the cause of the zooplankton's elevated concentrations. In order to determine how much clay would have to be in our 0.5 gram zooplankton samples in order to elevate the iron values above their previous levels, a short calculation was made.

The difference between the mean iron concentration for the winter and that of the summer and fall for the IV Transect is 1008 μg Fe/g of zooplankton. Knowing the mean Fe/Al ratio (0.41) of the refractory SPM for the IV Transect of the winter, one would need ∿1,230 μg of Al/0.5 g of zooplankton to contain sufficient Fe. According to Huang the suspended mineralogy of the clay minerals was approximately 72% smectite and 17% kaolinite for the IV Transect. Aluminum constitutes 20% of kaolinite (Weaver and Pollard, 1967) and 11% of smectite (Degens, 1965). Using these assumptions one finds that 11.2 mg of clay (2.2% of sample mass) are required to elevate iron levels in zooplankton.

This calculation is based on the assumption that all the iron we found in the zooplankton is adsorbed on or contained in clay lattices. If a free ferric oxide form existed, then this amount of clay would

BLM ZOOPLANKTON

TOTAL ELEMENT ANALYSIS

CRUISE NUMBER 1

ELEMENT CONCENTRATION IN PARTS PER MILLION

STATION NUMBER	DEPTH IN M	SAMPLE MASS (MILLIGRAMS)	AL	CA	CD	CR	CU	FE	NI	PB	SI	V
			1X	1X	1X	1X	1X	1X	1X	1X	1X	1X
1101	0.	509.	NA	NA	4.36	0.21	8.07	61.	1.18	0.72	NA	8.95
1102	0.	512.	NA	NA	6.93	0.67	10.72	116.	1.50	2.17	NA	13.02
1103	0.	510.	NA	NA	13.66	0.91	28.98	106.	3.80	1.94	NA	5.65
1204	0.	480.	NA	NA	7.35	0.84	11.08	151.	1.48	1.75	NA	3.95
1205	0.	533.	NA	NA	7.52	0.52	26.34	126.	1.86	3.63	NA	12.22
1206	0.	524.	NA	NA	8.33	0.38	9.40	67.	1.40	1.29	NA	7.40
1207	0.	535.	NA	NA	6.95	0.25	9.67	51.	1.78	1.24	NA	5.97
1308	0.	995.	NA	NA	5.34	0.16	14.42	67.	1.93	0.86	NA	1.01
1309	0.	1047.	NA	NA	4.96	0.06	8.09	54.	0.88	0.40	NA	2.17
1310	0.	993.	NA	NA	5.57	0.69	11.59	83.	2.23	2.58	NA	1.07
1311	0.	909.	NA	NA	11.85	1.06	15.86	161.	3.59	3.28	NA	1.26
1412	0.	1003.	NA	NA	10.96	3.23	14.83	553.	2.29	3.03	NA	4.59
1413	0.	994.	NA	NA	4.20	0.42	15.78	178.	1.94	1.28	NA	11.92
1414	0.	997.	NA	NA	2.82	0.28	9.55	86.	1.57	0.98	NA	15.32
1415	0.	1008.	NA	NA	4.26	0.75	31.95	197.	3.79	2.91	NA	7.45

***** = NOT DETECTABLE

BLM ZOOPLANKTON

TOTAL ELEMENT ANALYSIS

CRUISE NUMBER 2

ELEMENT CONCENTRATION IN PARTS PER MILLION

STATION NUMBER	DEPTH IN M	SAMPLE MASS (MILLIGRAMS)	AL	CA	CD	CR	CU	FE	NI	PB	SI	V
			1X	1X	1X	1X	1X	1X	1X	1X	1X	1X
1101	0.	518.	NA	NA	2.09	0.17	9.78	55.	3.15	0.25	NA	1.69
1102	0.	567.	NA	NA	2.91	0.16	14.29	69.	3.46	0.86	NA	5.66
1103	0.	491.	NA	NA	17.95	0.37	21.66	60.	5.27	0.79	NA	0.80
1204	0.	590.	NA	NA	2.60	0.38	12.15	77.	0.91	1.26	NA	5.40
1205	0.	505.	NA	NA	10.70	0.30	17.05	97.	1.59	3.54	NA	*****
1215	0.	521.	NA	NA	2.80	1.05	21.88	192.	1.56	4.22	NA	0.37
1206	0.	543.	NA	NA	3.01	0.31	12.43	79.	2.14	2.01	NA	1.42
1207	0.	519.	NA	NA	3.19	0.17	12.19	62.	1.05	1.17	NA	0.47
1308	0.	476.	NA	NA	2.83	0.33	13.30	54.	0.98	0.69	NA	4.75
1309	0.	502.	NA	NA	10.65	0.17	12.44	60.	3.34	1.07	NA	0.19
1310	0.	526.	NA	NA	12.70	3.81	23.44	52.	9.74	1.18	NA	2.05
1311	0.	555.	NA	NA	12.17	0.70	19.77	144.	9.22	2.09	NA	0.28
1412	0.	486.	NA	NA	2.65	0.21	88.01	84.	1.23	0.66	NA	1.02
1413	0.	505.	NA	NA	3.07	0.71	16.71	49.	1.27	2.52	NA	34.32
1414	0.	506.	NA	NA	23.99	0.63	20.34	94.	5.52	3.37	NA	0.92
1415	0.	472.	NA	NA	22.19	5.46	42.40	237.	9.75	13.37	NA	1.04

***** = NOT DETECTABLE

B L M   Z O O P L A N K T O N

TOTAL ELEMENT ANALYSIS

CRUISE NUMBER 3

ELEMENT CONCENTRATION IN PARTS PER MILLION

STATION NUMBER	DEPTH IN M	SAMPLE MASS (MILLIGRAMS)	AL	CA	CD	CR	CU	FE	NI	PB	SI	V
			1X	1X	1X	1X	1X	1X	1X	1X	1X	1X
1101	0.	519.	NA	NA	9.57	1.59	14.54	381.	1.68	3.26	NA	1.60
1102	0.	537.	NA	NA	7.86	0.89	14.18	113.	2.07	3.44	NA	0.99
1103	0.	522.	NA	NA	6.78	0.19	10.54	53.	3.76	0.67	NA	2.35
1204	0.	486.	NA	NA	3.12	0.54	33.26	173.	1.26	1.78	NA	1.32
1205	0.	597.	NA	NA	4.61	0.18	12.55	82.	0.90	0.16	NA	1.21
1206	0.	526.	NA	NA	5.33	0.39	12.48	118.	1.32	0.37	NA	2.88
1207	0.	540.	NA	NA	6.16	*****	17.61	60.	1.25	0.34	NA	2.17
1308	0.	500.	NA	NA	8.51	2.79	12.47	1892.	2.10	7.89	NA	4.79
1309	0.	506.	NA	NA	4.66	0.98	19.43	224.	3.23	0.94	NA	1.77
1310	0.	513.	NA	NA	6.84	0.50	13.44	244.	3.41	12.49	NA	15.22
1311	0.	453.	NA	NA	8.21	0.33	18.16	100.	5.49	0.69	NA	2.05
1412	0.	558.	NA	NA	3.97	1.98	11.89	*****	2.45	1.17	NA	25.41
1413	0.	516.	NA	NA	2.69	1.00	24.09	1542.	3.54	0.97	NA	3.66
1414	0.	490.	NA	NA	2.85	0.32	17.12	280.	1.54	0.16	NA	3.04
1415	0.	505.	NA	NA	6.12	0.59	17.70	892.	2.12	0.80	NA	6.83

***** = NOT DETECTABLE

obviously be reduced. The high weak-acid soluble iron values for the IV Transect indicate that a reduced form of iron could be available. Assuming the dry weight of an organism to be 1/10 of its wet weight, then 11.2 mg of clay would be 0.2% of the zooplankton (wet wt.) or 2% of zooplankton (dry wt.). Jørgensen (1966) has indicated that copepods show little selectivity in assimilating particles from 1-50 µm in diameter and can efficiently sweep water volumes ranging from 72 to >2,000 ml· 24 hr^{-1} mg dry wt^{-1}. Since the dominant zooplankton of the offshore stations was Paracalanas, a calanoid copepod and of the inshore station (1411) was Paracalanas, Eucalanas, and fish eggs (data from Caldwell and Maturo) 11.2 mg of clay does not seem to be an unreasonable amount.

The concentration of the remaining elements (Cd, Cr, Cu, Fe, Ni, Pb, V) is in good agreement with those reported by other authors (see Table 19). Variations that did occur between stations and transects were felt to be due to taxonomic composition, population turnover rates and geographic location.

Neuston concentrations for the 2nd and 3rd sampling periods are presented in Tables 20-21. Due to the abundance of foreign objects and ease of possible contamination, the neuston data is difficult to evaluate. It is interesting that in every case tar balls were noted prior to ashing, there were high vanadium concentrations. No readily discernable trends could be found between time of day, geographical location or period of sampling. It will probably be necessary to improve our sampling procedures before any reasonable biologic interpretations can be made.

Suspended loads and chemical composition of the suspended matter indicate a bi-seasonal water structure for the Northeastern Gulf of Mexico.

Table 19. The average trace metal content (ppm) of zooplankton in the eastern Gulf of Mexico in the summer and fall, 1975 and winter, 1976.

	Fe	Cr	Ni	Cd	V	Pb	Cu
1st sampling session (June, 1975)	137.1 ±124.30	0.67 ± .75	2.08 ± .93	7.00 ±3.1	6.80 ±4.67	1.87 ±1.02	15.09 ± 7.76
2nd sampling session (Sept., 1975)	91.55 ± 54.14	0.94 ±1.5	3.76 ±3.22	8.47 ±7.53	4.02 ±8.58	2.44 ±3.14	22.37 ±19.14
3rd sampling session (Jan., 1976)	549.6 ±701.1	0.88 ± .76	2.41 ±1.25	5.82 ±2.17	5.02 ±6.68	2.34 ±3.45	15.30 ± 3.63
Martin and Knauer (1972) Monterey Bay	344		3.9	6.2		6.9	5.4
Sims (1975)	1,181		3.9	1.9		10.0	16.2
Windom (1972)				3.9		32.0	82.0
Martin (1970)	1,200		42.0			49.3	41.0
Topping (1972)				1.0		15.0	16.2
Martin and Knauer (1974) Pacific	348			2.4		7.2	15.44

TABLE 20

BLM NEUSTON

TOTAL ELEMENT ANALYSIS

CRUISE NUMBER 2

ELEMENT CONCENTRATION IN PARTS PER MILLION

STATION NUMBER	DEPTH IN M	SAMPLE MASS (MILLIGRAMS)	AL	CA	CD	CR	CU	FE	NI	PB	SI	V
			1X	1X	1X	1X	1X	1X	1X	1X	1X	1X
1101	0.	516.	NA	NA	1.81	0.02	8.60	47.6	0.77	0.16	NA	1.51
1101	0.	516.	NA	NA	3.75	4.61	16.40	75.5	1.80	12.27	NA	0.71
1102	0.	509.	NA	NA	2.49	0.68	15.37	415.0	2.70	0.79	NA	2.31
1102	0.	547.	NA	NA	2.08	0.11	18.17	162.0	2.14	0.65	NA	0.94
1102	0.	503.	NA	NA	3.58	0.09	49.74	58.3	3.86	1.20	NA	0.85
1103	0.	545.	NA	NA	3.39	0.33	21.04	137.0	9.47	0.40	NA	7.00
1103	0.	514.	NA	NA	10.40	1.39	24.47	98.6	5.73	10.14	NA	1.13
1204	0.	530.	NA	NA	1.98	1.91	13.64	388.0	1.93	7.47	NA	2.02
1204	0.	513.	NA	NA	2.66	0.46	17.80	236.0	2.42	2.13	NA	5.10
1205	0.	532.	NA	NA	1.19	0.63	19.78	123.0	2.32	2.58	NA	2.05
1205	0.	501.	NA	NA	0.48	0.48	6.89	146.0	1.77	1.33	NA	1.14
1205	0.	523.	NA	NA	1.34	1.63	28.75	228.0	2.74	2.64	NA	2.16
1206	0.	534.	NA	NA	2.75	0.35	12.19	127.0	3.54	1.14	NA	1.40
1206	0.	509.	NA	NA	4.17	0.42	51.13	358.0	5.59	1.92	NA	6.13
1207	0.	514.	NA	NA	3.21	0.28	13.92	161.0	4.50	0.94	NA	1.21
1207	0.	513.	NA	NA	4.52	0.88	18.43	1460.0	5.50	1.14	NA	3.08

***** = NOT DETECTABLE

TABLE 20 - continued

BLM NEUSTON

TOTAL ELEMENT ANALYSIS

CRUISE NUMBER 2

ELEMENT CONCENTRATION IN PARTS PER MILLION

STATION NUMBER	DEPTH IN M	SAMPLE MASS (MILLIGRAMS)	AL	CA	CD	CR	CU	FE	NI	PB	SI	V
			1X	1X	1X	1X	1X	1X	1X	1X	1X	1X
1308	0.	512.	NA	NA	2.25	0.49	23.86	94.0	1.34	2.91	NA	1.33
1308	0.	529.	NA	NA	2.93	2.13	17.11	293.0	2.19	12.13	NA	0.93
1309	0.	506.	NA	NA	6.00	0.66	17.37	538.0	6.08	1.75	NA	*****
1309	0.	488.	NA	NA	6.19	1.39	24.28	1796.0	3.66	5.59	NA	0.41
1310	0.	467.	NA	NA	26.85	1.27	20.60	3130.0	9.25	5.34	NA	11.40
1310	0.	489.	NA	NA	0.40	0.04	22.10	675.0	6.34	0.99	NA	2.57
1311	0.	498.	NA	NA	0.31	0.36	19.60	1500.0	8.66	1.45	NA	6.43
1311	0.	498.	NA	NA	3.95	0.08	57.90	186.0	2.33	0.45	NA	1.11
1412	0.	502.	NA	NA	1.00	0.83	11.80	467.0	2.07	1.11	NA	0.37
1412	0.	495.	NA	NA	0.66	0.56	14.90	360.0	2.22	0.99	NA	2.20
1413	0.	501.	NA	NA	1.19	0.45	13.50	673.0	2.31	0.86	NA	0.94
1413	0.	501.	NA	NA	0.35	0.49	26.40	464.0	6.59	1.64	NA	2.65
1414	0.	477.	NA	NA	3.52	0.30	23.20	1090.0	11.25	0.99	NA	1.98
1414	0.	493.	NA	NA	5.42	0.18	33.50	29.2	1.05	1.60	NA	1.27
1415	0.	492.	NA	NA	2.71	0.84	38.30	2920.0	8.53	0.94	NA	10.20
1415	0.	512.	NA	NA	1.66	0.11	28.40	74.4	1.97	2.92	NA	*****

***** = NOT DETECTABLE

TABLE 21

BLM NEUSTON

TOTAL ELEMENT ANALYSIS

CRUISE NUMBER 3

ELEMENT CONCENTRATION IN PARTS PER MILLION

STATION NUMBER	DEPTH IN M	SAMPLE MASS (MILLIGRAMS)	AL	CA	CD	CR	CU	FE	NI	PB	SI	V
			1X	1X	1X	1X	1X	1X	1X	1X	1X	1X
1101	0.	499.	NA	NA	2.59	2.34	7.45	487.6	1.74	3.55	NA	2.85
1101	0.	645.	NA	NA	1.66	2.38	12.80	906.2	2.62	1.74	NA	0.70
1102	0.	514.	NA	NA	6.61	3.11	20.77	1249.2	2.96	4.45	NA	0.91
1102	0.	679.	NA	NA	4.41	0.48	15.82	109.8	1.96	0.12	NA	*****
1103	0.	572.	NA	NA	3.11	0.24	8.26	140.9	8.23	0.50	NA	3.92
1103	0.	505.	NA	NA	6.04	0.18	7.16	42.6	14.90	0.17	NA	1.40
1204	0.	557.	NA	NA	2.86	6.08	6.41	195.8	2.64	14.46	NA	12.30
1204	0.	566.	NA	NA	2.56	1.62	11.81	602.3	2.17	4.40	NA	34.56
1205	0.	496.	NA	NA	4.45	0.20	7.78	102.7	1.03	0.17	NA	0.56
1205	0.	518.	NA	NA	2.71	0.26	13.44	65.6	1.02	0.10	NA	*****
1206	0.	530.	NA	NA	6.56	0.18	7.33	103.8	1.99	*****	NA	0.54
1206	0.	504.	NA	NA	3.10	0.22	11.31	62.7	1.04	0.88	NA	*****
1206	0.	493.	NA	NA	6.76	0.79	9.50	114.3	1.28	0.25	NA	0.97
1207	0.	498.	NA	NA	6.88	0.64	7.01	159.3	1.29	0.10	NA	1.43
1207	0.	506.	NA	NA	7.03	0.29	10.80	87.6	1.59	0.04	NA	0.73
1308	0.	505.	NA	NA	3.58	1.58	10.20	465.8	1.60	2.17	NA	1.54

***** = NOT DETECTABLE

TABLE 21 - continued

BLM NEUSTON

TOTAL ELEMENT ANALYSIS

CRUISE NUMBER 3

ELEMENT CONCENTRATION IN PARTS PER MILLION

STATION NUMBER	DEPTH IN M	SAMPLE MASS (MILLIGRAMS)	AL	CA	CD	CR	CU	FE	NI	PB	SI	V
			1X	1X	1X	1X	1X	1X	1X	1X	1X	1X
1308	0.	490.	NA	NA	1.85	0.78	6.51	300.2	0.92	1.44	NA	1.97
1309	0.	674.	NA	NA	4.37	3.44	12.55	387.6	3.85	11.61	NA	0.47
1309	0.	502.	NA	NA	5.71	0.45	16.02	139.1	6.76	0.38	NA	0.89
1310	0.	521.	NA	NA	5.53	2.50	8.60	124.1	2.34	0.30	NA	2.66
1310	0.	470.	NA	NA	5.63	2.61	15.76	234.6	2.91	36.41	NA	2.37
1311	0.	491.	NA	NA	6.77	0.31	8.68	76.1	3.84	2.47	NA	1.16
1311	0.	538.	NA	NA	5.43	0.15	16.28	50.7	2.25	0.56	NA	*****
1412	0.	542.	NA	NA	2.30	1.29	13.93	377.7	5.91	1.84	NA	5.85
1412	0.	581.	NA	NA	1.96	4.34	13.22	657.7	2.00	19.04	NA	4.31
1412	0.	511.	NA	NA	1.60	0.91	9.27	306.4	1.15	1.36	NA	5.32
1413	0.	557.	NA	NA	1.74	0.05	6.73	55.9	1.29	0.44	NA	0.80
1413	0.	579.	NA	NA	6.81	0.54	11.57	345.5	1.93	0.59	NA	2.18
1414	0.	459.	NA	NA	2.72	0.56	11.69	196.3	1.91	10.09	NA	1.47
1414	0.	564.	NA	NA	2.90	0.34	13.09	178.6	1.64	0.44	NA	0.46
1415	0.	505.	NA	NA	2.04	0.38	9.64	232.0	2.01	0.15	NA	10.81
1415	0.	661.	NA	NA	2.39	0.29	23.03	184.3	1.03	0.44	NA	0.99

***** = NOT DETECTABLE

The chemical composition also appears to reflect an environment of resuspended bottom sediments during the winter which is being transported to the 183 m contour on some stations (1103, 1415). During the remainder of the year the suspended loads appear to be dominated by biological particles both carbonate and siliceous.

Suspended matter composition is a reflection of the source of the particles whether biogenic or terrestrial and their relative abundance. Knowledge of the composition of the suspended matter at various geographic locations, time of year and depth could serve as an invaluable tool for detecting and tracing elevated metal pollutant levels.

Zooplankton which were collected on oblique trawls of the water column showed high iron concentrations at those stations having increased amounts of clay-rich suspended material. Zooplankton, reflecting this seasonal change in suspended matter, are likely to reflect similar significant alterations of the water column in the case of injected pollutants. Oil, known to contain elevated levels of nickel and vanadium (Smith, et al., 1975), is biodegraded by marine bacteria (ZoBell, 1962) which in turn are a portion of the food source for zooplankton. Since nickel and vanadium were detectable in all zooplankton samples, any significant increases in their concentrations could be detected and hopefully correlated with changes in their hydrocarbon content.

REFERENCES

Arrhenius, G.O.S. (1963). Pelagic sediments. In: The Sea (editor M. N. Hill), Vol. 3, p. 655-727. Interscience.

Brewer, P. G., D. W. Spencer, P. E. Biscaye, A. Hanley, P. L. Sachs, C. L. Smith, S. Kadar, and J. Fredericks (1976). The distribution of particulate matter in the Atlantic Ocean. Earth and Planetary Science Letters, 32, p. 393-402.

Buckley, D. E. and R. E. Cranston (1971). Chem. Geol., 7, 273.

Chester, R. and M. J. Hughes (1967). A chemical technique for the separation of ferro-manganese minerals, carbonate minerals and adsorbed trace elements from pelagic sediments. Chem. Geol., 2, p. 249-262.

Davies, D. K. and W. R. Moore (1970). Dispersal of Mississippi sediments in the Gulf of Mexico. J. SEdiment. Petrol. 40, p. 339-353.

Duke, T. et al. (1969). Influence of environmental factors on the concentration of 65 Zn by an experimental community. In Proc. 2nd Natl. Symp. on Radio-ecology, Ann ARbor, (editor D. J. Nelson, and F. C. Evans), p. 355-362.

Eggimann, D. W. and P. R. Betzer (1976). Decomposition and analysis of refractory oceanic suspended materials. Anal. Chem., 48, p. 866-890.

Fleischer, M. (1969). U. S. Geological Standards - I. Additional data on rocks G-1 and W-1, 1965-1967, Geochim. Cosmochim. Acta., 33, p. 65-79.

Fowler, S. W. and L. F. Small (1967). Moulting as a possible mechanism for vertical transport of zinc-65 in the sea. J. of Oceanol. Limnol., 1, p. 237-245.

Goldberg, E. D. (1957). Biogeochemistry of trace metals, In: J. W. Hedgpeth (ed.), Treatise on marine ecology and paleo-ecology, v. 1, Geol. Soc. Am. Mem. 67, p. 345-358.

Griffin, G. M. (1962). Regional clay-mineral facies-products of weathering intensity and current distribution in the northeastern Gulf of Mexico. Geol. Soc. Am. Bull. 73, p. 737-767.

Haywood, J. (1970). Studies on the growth of Phaeodactylum tricornutum. v. 1, The relationship to sodium, potassium, calcium, and magnesium. J. Mar. Biol. Assoc. U. K. 50, p. 293-299.

Huang, Wen H. 1976 Final Report to Bureau of Land Management

Jørgensen, C. B. (1966). Biology of suspension feeding. Pergamon. 357 p.

Martin, J. H. (1970). The possible transport of trace elements via moulted copepod exoskeletons. Limnol. Oceanogr., 15, p. 756-761.

Martin, J. H. and G. A. Knauer (1973). The elemental composition of plankton. Geochim. Cosmochim. Acta. 37, p. 1639-1653.

Merlini, Margaret. Heavy metal contamination, In: Impingement of Man on the Oceans, ed. D. W. Hood. Wiley-Interscience, New York, 1971, p. 461-486.

Nicholls, C. D., Curl, H. Jr., and Bowen, V. T. (1959). Spectrographic analysis of marine plankton. Limnol. Oceanogr. 4, p. 472-478.

Osterberg, C. L. Carey, A. G. Jr., and Curl, H. Jr., (1964). Acceleration of sinking rates of radionuclides in the ocean. Nature 200, p. 1276-1277.

Osterberg, C. L., Pearcy, W. G., and Curl, H. Jr., (1964). Radioactivity and its relationship to the oceanic food chains. J. Mar. Res. 22, p. 2-12.

Pearcy, W. G. and Osterberg, C. L. (1967). Depth, diel, seasonal, and geographic variations in zinc-65 of midwater animals of Oregon. Int. J. Oceanol. Limnol. 1, p. 103-116.

Pierce, J. W. (1976). Suspended sediment transport at the shelf break and over the outer margin, In: Marine Sediment Transport and Environmental Management, ed. D. J. STanley and D. J. P. Swift. John Wiley and Sons, Inc., New York, p. 437-458.

Robertson, D. E. (1968). Role of contamination in trace metal analyses of sea water. Anal. Chem., 40, p. 1067-1072.

Rodolfo, K. S., B. A. Buss, and O. H. Pilkey (1971). Suspended sediment increase due to Hurricane GERDA in continental shelf waters off Cape Lookout, North Carolina. J. SEdiment Petrol. 41, p. 1121-1125.

Sims, R. R. (1975). Selected chemistry of primary producers, primary consumers and suspended matter from Corpus Christi Bay and the northwest Gulf of Mexico. M. S. Thesis, Texas A&M University.

Smith, A. J., J. O. Rice, W. C. Shaner, Jr., and C. C. Cerato (1975). Trace analysis of iron, nickel, copper and vanadium in petroleum products, In: The Role of Trace Metals in Petroleum, ed. T. F. Yen, Ann Arbor Science, Ann Arbor, p. 149-160.

Spencer, D. W., P. G. Brewer, and P. L. Sachs (1972). Aspects of the distribution and trace element composition of suspended matter in the Black Sea. Geochim. Cosmochim. 36, p. 71-86.

Tieh, T. T. and T. E. Pyle (1972). Distribution of elements in Gulf of Mexico sediments, In: Contributions on the Geological and Geophysical Oceanography of the Gulf of Mexico (5), ed. R. Rezak and J. Henry. Gulf Publishing Co., Houston, Texas, p. 129-152.

Topping, G. (1972). Heavy metals in zooplankton from Scottish waters, North Sea and Atlantic Ocean, In: Baseline studies of pollutants in the marine environment. Nat. Sci. Found., Wash. D.C., p. 149-159.

van Bennekom, A. J. and S. J. van der Gaast (1976). Possible clay structures in frustules of living diatoms. Geochim. Cosmochim, 50, p. 1149-1152.

Weaver, C. E. and L. D. Pollard (1973). The chemistry of clay minerals. Elsevier Scientific Publishing, New York, p. 134.

Windom, H. L. (1972). Arsenic, cadmium, copper, lead, mercury and zinc in marine biota- North Atlantic Ocean, In: Baseline studies of pollutants in the marine environment. Nat. Sci. Found., Wash. D.D., p 121-148.

ZoBell, C. E. (1962). The occurrence effects and fate of oil polluting the sea. Intern. J. Air Water Pollution, 7, p. 173-193.

ENVIRONMENTAL MONITORING SURVEY OF THE MAFLA LEASE AREA

TRACE METALS IN BENTHIC MACROFAUNA (1975-1976)

University of South Florida, Department of Marine Science

Principal Investigator:
Susan B. Betzer

Associate Investigator:
Robert R. Sims, Jr.

ABSTRACT

Seasonal collections of dominant macroinvertebrates were made three times during the year. These included sponges, corals, molluscs, crustaceans, and echinoderms. A total of 226 samples were collected from 26 stations on the Florida shelf by diving, dredging, and trawling.

A combination of dry and wet oxidations was performed on all samples. Samples were ashed in a low-temperature asher, followed by a further oxidation using HNO_3 in a teflon bomb. The samples were then analyzed for their concentrations of the following elements: cadmium, chromium, copper, iron, lead, nickel, and vanadium. All elements were determined by atomic absorption spectrophotometry.

Sponges generally show the greatest variation in their trace metal content; also, the average concentrations of trace elements in sponges are higher than they are in most other groups. In contrast, corals are not only more uniform in their metal concentrations but also exhibit the lowest concentrations for all trace metals when compared to other phyla.

Trends are limited, due to the number of samples collected. However, sponges and echinoderms display some geographical trends. Most groups show at least some seasonal trends.

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INTRODUCTION

Concern over trace metal contamination in the marine environment is well-founded (Kobayashi, 1970; Roskam, 1965; Tatsumoto and Patterson, 1963). Increased industrial activity (both land and sea) has resulted in an accelerated mobilization of a number of trace metals such as: cadmium, chromium, copper, iron, lead, nickel, and vanadium. Some of these metals are known to be highly toxic to biological systems (Oehme, 1972), while others are necessary in trace amounts for normal growth and development (Bowen, 1966).

In the marine environment, these elements may enter the biosphere through a number of pathways. One such pathway that has come about, with the increased demand for energy, is the possible introduction of potentially toxic metals via offshore oil drilling and production. It has long been known, that it is the sediments which represent the reservoir of trace metals in the sea (Riley and Chester, 1971). Under reducing conditions in the sediment, the Eh and pH are lowered and the possibility of bringing normally insoluble metals into solution exists. Under normal conditions, the diffusion of these metals into the water column would be minimal. However, under conditions where the sediment is greatly disturbed, as in drilling, the possibility exists of significantly increasing the dissolved and/or particulate metal content of the water column. Trace elements may enter the marine environment, due to offshore drilling, in another manner. Yen (1975) has shown that certain crude oils contain significant concentrations of the metals previously mentioned. In fact, Yen (1975) has shown nickel and vanadium concentrations in some crude oil to be as great as 300 ppm.

Trace metal concentrations in benthic invertebrates can provide a sensitive measure to these changes in environmental conditions. Since benthic invertebrates are normally confined to the same general geographical locations during their entire lives, they have the potential of being seasonal as well as geographical indicators of environmental contamination.

The main purpose of this study was to provide background information on the levels of the seven metals studied in benthic macroinvertebrates from the MAFLA lease area. Secondary objectives arose from this. These included: (1) baseline metal concentrations in organisms from a relatively unpolluted environment, (2) trends, both geographical and seasonal in metal concentrations among the dominant groups sampled, and (3) variations and the degree of "scatter" of trace metal concentrations among species within a phyla and samples within a species.

METHODS

Sampling

Collections of dominant macrofauna were made seasonally a three times during the year. Collections were made during the summer 1975, fall 1975, and winter, 1976. During each sampling period, samples were collected by dredging and trawling (18 stations) and diving (eight stations), for a total of 78 stations sampled per year (see Figure 1). A total of 226 different samples including: sponges, corals, molluscs, crustaceans, and echinoderms were analyzed for their content of cadmium, copper, iron, lead, nickel, and vanadium. In addition 60 other samples were analyzed in replicate during the course of the year, making the total number of samples analyzed 286.

Analysis

After collection, all samples were immediately frozen in polyethylene bags. On returning to the laboratory, the samples were thawed, weighed, dried to a constant weight at 60°C and reweighed. The drying process normally took

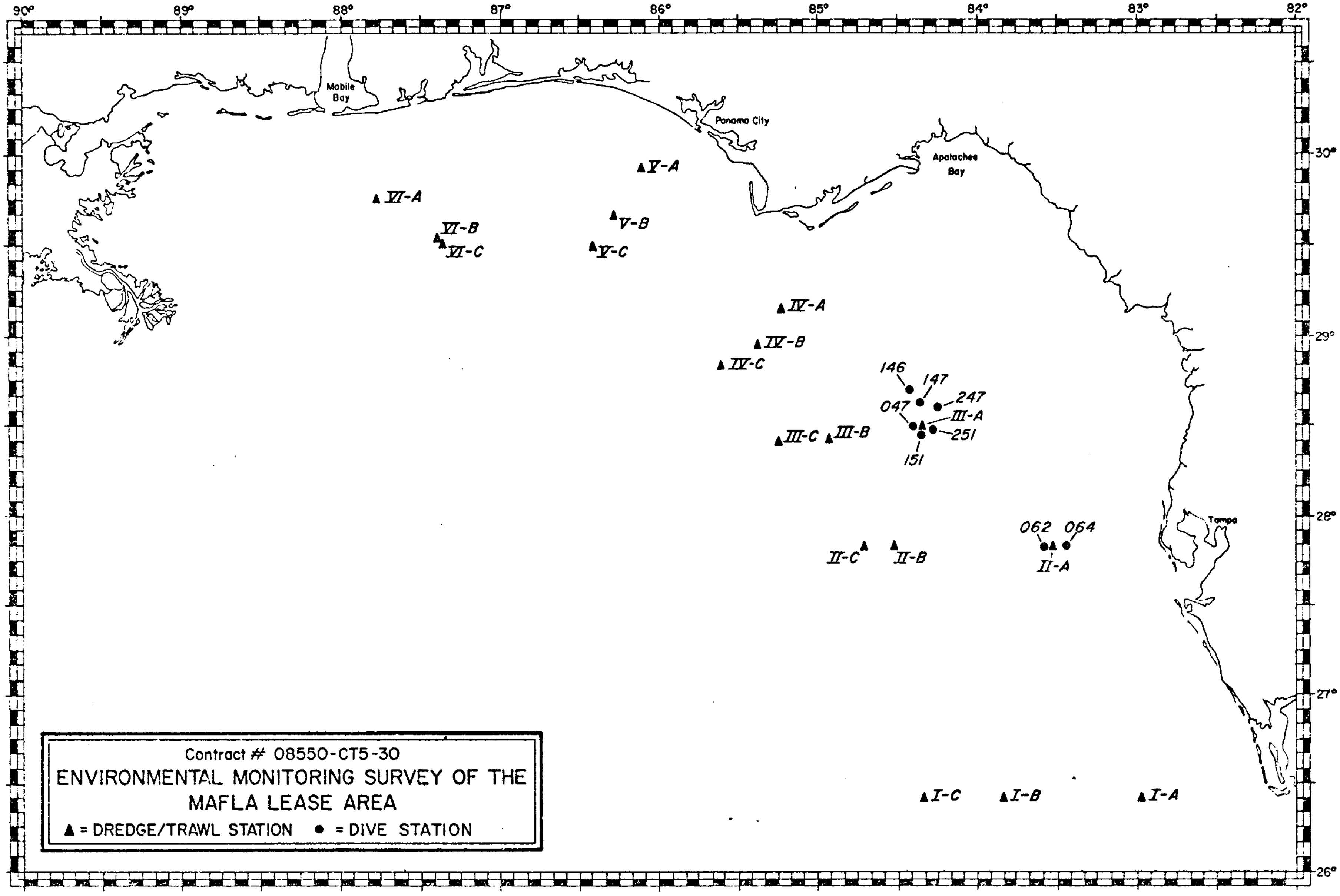


Figure 1. Location of sampling sites

four to five days. All samples, excluding corals, were then ground to a homogeneous powder using a porcelain-lined Spex mixer-mill. In some cases (especially for those samples analyzed in quintuplicate) several individuals from a sample were homogenized together. This was necessary in order to obtain enough material for analysis. Approximately 0.5-0.75 g of sample was then weighed onto a pyrex watch glass and placed in an International Plasma Corp. low temperature asher (LTA) for approximately five hours. In the case of corals, small pieces were used which had been "semi-ground" using a mortar and pestle. After ashing, the sample was oxidized further, using a modification of a technique developed by Eggimann and Betzer (1976). The ashed sample was placed in a TFE teflon bomb to which three milliliters of concentrated Ultrex nitric acid were subsequently added. The bomb was then placed in a hot water bath (≈85°C) for five hours.

After digestion, the sample was washed into a 50 ml polypropylene volumetric flask and brought to volume using deionized water.

Copper and iron were determined directly on a Perkin-Elmer model 503 atomic absorption spectrophotometer using an air/acetylene flame. When necessary, appropriate dilutions were made using 1 N HNO_3.

For the other metals (because of their lower concentrations) it was necessary to use an HGA-2100 graphite furnace (flameless atomizer). A deuterium arc background corrector was used to subtract interferences due to non-specific causes. Aqueous standards were prepared using Fisher standard reference solutions.

Precisions and accuracies for all elements determined are presented on Table 1. The organic standard used in this study was N.B.S. bovine liver. The results of our quality control samples are listed on Appendix A.

RESULTS

The cumulative raw data for all three sampling periods is summarized in

Appendix B. As one can see the metal concentrations are extremely variable, not only among the various groups but also among most of the species within a group.

Table 1

Accuracy and Precision of Tissue Samples
(concentrations in ppm dry weight)

Element	Bovine liver (NBS)	Bovine liver (determined)*
Cd	0.27±0.04	0.32±0.03
Cu	193±10	187±8
Fe	270±20	252±12
Pb	0.34±0.08	0.35±0.1

* Mean values obtained from 20 separate analyses.

Overall, sponges vary more than any other phyla. Most metal values vary at least ten times among species and at least five times within a species (Appendix B).

During the first sampling period Guitarra sp. appears to concentrate cadmium and chromium to higher levels than other sponges. This is also true of iron and vanadium, to a lesser degree. An unidentified Sponge "B" also is high in chromium. Copper is fairly consistent within the entire group. Iron and lead values show a high degree of "scatter" both within the group and also within a species. Nickel and vanadium concentrations vary less than most of the other metals.

A greater number of species and samples of sponges were analyzed during the second sampling period. However, some of the species collected in the first period were not collected during the second. As in the first period, Guitarra sp. concentrates cadmium to the greatest degree. The exception to this is Anthosigmella varians, which, due to the high cadmium, iron, and nickel values, is probably contaminated. Cliona celata, Ircinia campana, and Neofibularia nolitangere oxeata also contain elevated concentrations of chromium and iron. Copper and vanadium values are consistent with the first period. Nickel concentrations vary a great deal.

During the third sampling period Guitarra sp. again has relatively high values for cadmium and iron. Copper and lead are somewhat consistent among all sponges. Vanadium is non-detectable in many of the sponges during this period.

Corals tend to be quite consistent in their metal concentrations. In fact, the values for trace elements in corals are remarkably uniform for all species during the three sampling periods. The only exception to this are Millepora alcicornis and Phyllangia americana.

Only one species of mollusc of any dominance was analyzed. Cadmium appears to be the only element in which the concentrations are above normal.

Crustaceans are the most diverse group of benthic macrofauna that were collected. This is true not only because of the various feeding habits, but also because some species have a great deal more mobility than others (i.e. Sicyiona brevirostris).

During the first period five species were collected, all of which are somewhat dominant. Multi-samples were analyzed for each species. Cadmium, chromium, copper, lead, nickel, and vanadium values are similar in most samples. Stenorhynchus seticornis exhibits lower iron concentrations during the first period. Crustaceans collected in periods two and three show the same trends as those collected in period one.

The number of echinoderms analyzed during the first sampling period is too limited to show many trends. Copper concentrations do not vary much among samples. The other metal values appear to show a great deal of "scatter". The samples collected during period two represent mainly one genus. Metal values in the third period are similar to those of the first.

DISCUSSION

In order to fulfill the objectives listed in the introduction, this section will be presented by phyla (group) rather than by element.

Sponges

As was mentioned earlier, the variation among samples in this group of organisms is extremely high for all metals. As one can see (Table 2) iron concentrations range over two orders of magnitued. The reasons for such large variations are not known. It is possible that these large variations are due to a number of factors, including the number of different species and geological location. Out of 68 samples there were 26 species. This high percentage of different species certainly lends itself to variations in trace metal concentrations. Also, if the samples are collected in areas where the suspended load is high, and dominated by alumino-silicate material, the possibility exists of significantly increased values for certain trace metals. If one integrates all three sampling periods, the sponges exhibit greater variation in every metal than most other groups. This is surpassed only by the molluscs and crustaceans with reference to cadmium and copper.

In general, the sponges contained significantly higher concentrations of chromium, iron, and nickel (Table 2). Although Table 2 indicates a great deal of "scatter" in the concentration of these elements in sponges, it is somewhat misleading in the case of nickel. Looking at Appendix B, one can see that a majority (60%) of the sponge samples have nickel concentrations greater than 10 ppm. Thus nickel values are consistantly high in most of the sponges. While a few of the sponges may contain elevated nickel values as a result of sediment contamination (due to increased chromium and iron), it is not felt that this is true for other sponges (i.e. Cinachyra sp. and Pseudoceratina crassa). Bowen and Sutton (1951) attributed the high nickel values in many sponges to the microflora associated with them.

Table 2

Comparison of the Average Trace Metal Concentrations among the Various Phyla of Benthic Macrofauna from the MAFLA Lease Areas (concentrations in ppm dry weight)

Group Name	No. of samples* analyzed		Cd	Cr	Cu	Fe	Ni	Pb	V
Sponges	68	Range	0.058- 9.670	0.06- 29.80	3.0- 20.5	30.0- 4500	0.4- 372	<0.01- 8.82	<0.4- 8.8
		Mean	2.367	3.11	7.7	516	22.7	<1.17	<1.6
		Std. Dev.	2.540	5.75	3.9	835	52.0	1.50	1.7
Corals	55	Range	0.020- 1.610	<0.01- 0.59	3.7- 10.1	17.0- 123	<0.2- 9.6	0.07- 2.72	<0.4- 6.0
		Mean	0.214	<0.23	7.1	39.3	<1.0	0.29	<1.9
		Std. Dev.	0.317	0.43	1.2	19.0	2.2	0.41	1.4
Molluscs	14	Range	0.660- 35.0	0.32- 9.52	1.5- 44.2	19.3- 308	1.3- 70.3	0.15- 1.66	<0.4- 6.0
		Mean	13.65	4.38	7.9	89.4	22.1	0.94	<3.1
		Std. Dev.	11.33	3.14	10.8	67.8	17.6	0.43	2.0
Crustaceans	59	Range	0.050- 12.120	<0.01- 1.46	12.7- 110	11.0- 773	<0.2- 1.9	<0.01- 6.94	<0.4- 3.9
		Mean	1.807	<0.38	50.7	125	<0.7	<0.82	<1.5
		Std. Dev.	2.141	0.28	24.1	144	0.4	1.46	0.9
Echinoderms	30	Range	0.056- 1.190	<0.01- 1.53	5.1- 21.3	19.3- 1832	<0.2- 6.2	0.27 7.96	<0.4- 8.3
		Mean	0.320	<0.73	7.8	267	<0.9	1.26	<1.9
		Std. Dev.	0.274	0.52	3.2	355	1.2	1.75	1.9

* For some metals, the number of samples analyzed is one less than that given.

Appendix C shows the metal concentrations and variations within a species among the dominant macrofauna. Only two species of sponges display any dominance, Cinachyra sp. and P. crassa. The only consistency in metal concentrations within each of these species is in copper and nickel. This trend continues throughout all the sampling periods.

Geological trends in trace metal concentrations are not readily apparent among the sponges. This is probably due, in part, to the lack of sufficient numbers of samples, of the same species, at all stations. Therefore, only those stations where samples were collected during at least two of the three sampling periods will be considered in the geographical trends. Also, because of the lack of sufficient data, any geographical trends should be viewed only as possible indicators and not proven facts.

Sponges collected at Stations I-B, II-A, 062, and 064 are consistently lower in their nickel concentrations than those from other stations (Appendix B). A reason for this is not known. Those sponges from Stations VI-B and V-A are consistently higher in chromium and iron. They are also somewhat elevated in their concentrations of vanadium and nickel, respectively. However, these values may be biased somewhat in the case of Station VI-A, since Guitarra sp. is dominant (high chromium and iron values may be characteristic of this sponge). This situation does not exist at Station V-A. Becuase of the location of Station V-A (Figure 1) which is near areas where the suspended loads are sometimes greater than areas further to the south, the elevated chromium, iron, and nickel values may be due, in part, to sediment contamination. Brooks and Rumsby (1965) have demonstrated similar correlations between these elemental concentrations and sediment content of organisms. Within a sampling period, Cinachyra sp. is noticeably higher in cadmium, iron, lead, and vanadium at Stations II-A, 062, and 064 than it is at other stations. The reason for this is not known, except that these stations are close to the Tampa-St. Petersburg area, a region which is somewhat industrialized.

Seasonal trends in sponges are almost impossible to interpret within a time frame of one year. Because Cinachyra sp. and P. crassa were the only sponges collected in sufficient quantities at the same station locations during all three sampling periods, they are the only sponges used for seasonal trends. Both sponges show a steady decrease in every metal, excluding copper and nickel, as one proceeds from the first to the third sampling period (Appendix C).

Although the range of values for metals in sponges appears quite large, other studies indicate that our values certainly are within the ranges of those found by other investigators (Bowen, 1966; I.D.O.E., 1972; Vinogradov, 1953).

Corals

Corals exhibit the greatest consistency in their concentrations of trace metals (Table 2). The ranges in nickel and vanadium appear to contradict this statement; however, only seven samples out of 55 have values greater than the mean for nickel, and only 17 samples show values greater than the mean for vanadium values are below the detection limit (Appendix B). This lack of "scatter" in values may be due partly to the similar metabolism and feeding habits of the group as a whole; also, only seven species were collected and most of the stations are located quite near one another (Figure 1). Other authors have noted this same uniformity in trace element concentrations (Livingston and Thompson, 1971).

In addition to the consistency in their trace metal concentrations, corals also have the lowest values for the metals when compared to other phyla. They average from five to ten times lower in their values than most of the other groups (Table 2).

The lack of variation in trace element concentrations within species of corals is even more remarkable than the lack of variation within the group (Appendix C). Since all coral samples were collected in a localized area, it is impossible to conclude any geographical trends. However, one seasonal trend was observed. Both dominant corals, *Madracis decactis* and *Porites divaricata*, show decreasing values in their cadmium, chromium, and nickel values as one goes from the first sampling period to the third. It is possible, however, that this trend may not be completely due to environmental conditions. Our laboratory was working at or near the detection limit for the above-mentioned metals during the three sampling periods. Our analytical techniques were improved with time; thus, our ability to distinguish between slight variations in instrumental results was refined and our detection ability improved. Since our analytical ability improved slightly during the course of the year, the slight differences in the metal concentrations in corals may not be significant.

Data concerning trace metal concentrations in corals is very scarce. The few studies that have been done used neutron activation analysis (N.A.A.) to obtain their results (Livingston and Thompson, 1971; Forster *et al.*, 1972). One of the problems with N.A.A. is the poor detection limits for many of the elements of interest. Thus our values are significantly lower for many of the metals in corals than those reported in the literature.

Molluscs

The results on the data obtained on molluscs is so scanty (only 14 samples were collected and analyzed) that data interpretation is difficult, if not impossible. Essentially only one species was collected, *Spondylus americanus*.

Molluscs vary a great deal in their concentrations of cadmium, chromium, and copper. This is quite surprising, when one considers that *S. americanus* comprised 11 of the 14 samples and that most samples were collected from one area (Table 2). Cadmium, chromium, and nickel values are greater than those of most of the other groups.

S. americanus exhibits no trends in its trace metal concentrations with one exception: cadmium values decrease rapidly toward the third sampling period.

Comparative values of the molluscs analyzed in this study are almost non-existent in the literature, except for a few values (I.D.O.E., 1972).

Crustaceans

As a whole, crustaceans vary to a lesser degree in their trace metal concentrations than most other groups. This is somewhat surprising since crustaceans are the most diverse and mobile group of organisms sampled. They exhibit many types of feeding habits (filter feeders, detrital feeders, and carnivores). Also crustaceans were collected from stations covering the entire MAFLA lease area. Thus, if there were any differences in trace metal concentrations due to geography, the range in trace metal concentrations would be influenced accordingly. Other than cadmium and copper, metal values are not significantly higher in crustaceans. Nickel and vanadium are near the detection limit in many cases (Table 2).

Variations in trace element concentrations amont the dominant species are again shown in Appendix C. In all three sampling periods, Stenorhynchus seticornis shows the least variation for all elements. Since all S. seticornis samples were collected from one area (Appendix B, Figure 2), that may be a possible reason why the trace element concentrations are so uniform.

No geographical trends were encountered; at best, seasonal trends are very limited. S. seticornis was the only crustacean collected in sufficient quantities at the same location during the three sampling periods that can be used to show any seasonal trends. Cadmium, nickel, and vanadium decrease slightly in concentration as one proceeds from the first to the third sampling period. Iron values show a slight increase (Appendix C).

A number of the crustacean species analyzed in this study are not cited elsewhere in the literature. So in order to make any comparisons to the trace element concentrations of other studies, it was necessary to integrate the various crustacean species together. In general, the trace metal values in crustaceans from this study compare favorably with those of other investigators (Bryan, 1968; I.D.O.E., 1972; Martin, 1974; Sims and Presley, 1976).

Echinoderms

Except for iron and lead, the echinoderms are second only to corals in their degree of consistency concerning the various trace elements. Again, this is somewhat surprising, considering that out of the 29 samples analyzed there were 11 species. *Brissopsis elongata*, from the third sampling period, is not included in this group because the values are so much greater for chromium and iron. Furthermore, the samples were collected from stations encompassing most of the MAFLA lease area. As is the case with most other groups, nickel and vanadium values are quite low.

Because of the lack of sufficient data, any trends in this phylum are also limited. Samples at Transect VI (especially VI-C) contain significantly higher iron values than the rest of the samples (Appendix A, Figure 1). A possible explanation for this may be the input of terrigenous material in this area (see Sponge section). No seasonal trends were observed.

When comparing trace metal values in echinoderms from this study to others, the same problem was encountered as that with the crustaceans: the same species have not been analyzed by others. Therefore, it was again necessary to group all echinoderms together. Our data is quite similar to those of Riley and Segar (1970). I.D.O.E. (1972) data is quite scarce. Vinogradov's (1953) values are close to ours, except that his copper values are much greater (>100 ppm).

CONCLUSIONS

Because so many different species and phyla were collected with relatively few samples from each, it is somewhat difficult to draw any definite conclusions concerning all the various phyla together. However, some conclusions can be made concerning individual phyla and species within a phylum.

For the most part, the variation in the trace metal concentrations among the various groups is quite high. Variation in the metal concentrations among species within a phylum is also, in most cases, relatively great. This is especially true for the sponges, in which the variation, or "scatter", for trace element values is several orders of magnitude. Reasons for such variability among phyla, as well as among species within a phylum, might include: (1) changes in feeding habits, which affect the physiology and metabolism; (2) geographic location, since some organisms are quite mobile and travel into and out of areas where the trace metal concentrations vary in the environment; and (3) seasonal variation of elemental concentrations in organisms.

Corals, contrary to other groups, are very uniform in their trace metal concentrations. This is true not only among the various species but also among individuals within a species.

In spite of the large variation among most species within a phylum, some trends were noted. Sponges and echinoderms are the only groups which display any geographical trends. Although seen in most groups, seasonal trends are minimal. In all cases, these trends should be viewed only as possible indicators.

In general, sponges show the greatest concentrations of chromium, iron and nickel. The high nickel values may be explained partly by a symbiotic relationship. In contrast, corals are the lowest in every metal when compared to other groups. In fact, nickel and vanadium concentrations are non-detectable in many of the samples.

The trace metal concentrations in all groups from this study are well within the range of those reported by other investigators. Indeed, as far as trace metals are concerned, the results of the analyses in the organisms from the MAFLA lease area indicate that this area approaches a "pristine" environment.

LITERATURE CITED

Bowen, H.J.M.: Trace Elements in Biochemistry, 241 pp. New York: Academic 1966.

Bowen, V.T. and D. Sutton: Comparative studies of mineral constituents of marine sponges I. The genera Dysidae, Chondrilla Terpios. J. Mar Res. *10*, 153-167 (1951).

Brooks, R.R. and M.G. Rumsby: The biogeochemistry of trace element uptake by some New Zealand bivalves. Limnol. Oceanogr. *10*, 521-527 (1965).

Bryan, G.W.: Concentrations of zinc and copper in the tissues of decapod crustaceans. J. Mar. Biol. Ass. U.K. *48*, 303-321 (1968).

Eggimann, D.W. and P.R. Betzer: Decomposition and analysis of refractory oceanic suspended materials. Anal. Chem. *48*, 886-890 (1976).

Forster, W.O. , E.D. Wood and F. Padovani: A study program to identify problems related to oceanic environmental quality in the Caribbean. *In*: Baseline studies of pollutants in the marine environment. pp. 275-324. Wash. D.C.: Nat. Sci. Found. 1972.

International Decade of Oceanography Workshop on Baseline Studies: Baseline studies of pollutants in the marine environment. 799 pp. Wash., D.C.: Nat. Sci. Found. 1972.

Kobayashi, J: Relation between the "itai-itai" disease and the pollution of river water by cadmium from a mine. *In*: Adv. water poll. res. proc. int. cong., San Francisco, Hawaii, 5th pp. 1-8. Ed. by S. H. Jenkins. New York: Pergamon 1970.

Livingston, H.D. and G. Thompson: Trace element concentrations in some modern corals. Limnol. Oceanogr. *16*, 786-796 (1971).

Martin, J.L.M.: Metals in *Cancer irroratus* (Crustacea: Decapoda): concentrations, concentration factors, discrimination factors, correlations. Mar. Biol. *28*, 245-251 (1974).

Oehme, F.W.: Mechanisms of heavy metal toxicities. Clinical Tox. *5*, 151-167 (1972).

Riley, J.P. and R. Chester: Introduction to Marine Chemistry. 465 pp. New York: Academic 1971.

___________ and D.A. Segar: The distribution of the major and some minor elements in marine animals, I. echinoderms and coelenterates. J. Mar. Biol. Ass. U.K. *50*, 721-730 (1970).

Roskam, R.T.: A case of copper pollution along the Dutch shore. *In*: C.M. council meeting. Int. council for the exploration of the sea, sect. C., pp. 10-15. Amsterdam: Near Northern Seas Committee 1965.

Sims, R. R., Jr. and B. J. Presley: Heavy metal concentrations in organisms from an actively dredged Texas bay; Bull. Env. Contam. Tox. 16, (1976) (in press).

Tatsumoto, M. and C. C. Patterson: The concentration of common lead in sea water. In: Earth science and meteorites. pp. 74-89. Ed. by J. Geiss and E. D. Goldberg. Amsterdam: North Holland 1963 .

Vinogradov, A. P.: The elementary chemical composition of marine organisms. 647 pp. In: Sears Foundation for Mar. Res., Mem. II. New Haven: Yale University 1953.

Yen, T. F.: The role of trace metals in petroleum. 221 pp. Ann Arbor Mich.: Ann Arbor Science 1975.

APPENDICIES

Appendix A

Comparison of Quality Control Organisms Samples
(concentrations in ppm dry weight)

Species Name	Station Number	Lab. of Analysis+	Cd	Cr	Cu	Fe	Ni	Pb	V^a
Zooplankton	1206	USF	5.32	0.39	12.5	118	1.3	0.37	2.9
		TAMU	4.50	1.70	9.8	123	0.9	0.34	- -
Zooplankton	1309	USF	4.66	0.98	19.4	224	3.2	0.94	1.8
		TAMU	4.10	1.20	29.0	257	3.7	0.62	- -
Stenorhynchus seticornis	146	USF	0.40	0.16	25.6	56.4	<0.2	0.22	<0.4
		TAMU	0.53	0.98	35.6	50.0	<0.5	2.7	- -
Cinachyra sp.	251	USF	0.36	0.80	6.5	157	10.5	0.55	3.9
		TAMU	0.30	<0.10	7.0	170	15.0	2.0	- -
Clypeaster raveneli	II-B	USF	0.28	0.77	6.8	148	0.6	0.56	1.0
		TAMU	0.30	0.40	2.2	148	<0.5	2.0	- -

* All samples collected from third sampling period

\+ USF = University of South Florida (Betzer)
TAMU = Texas A&M University (Presley)

[a] Vanadium values not yet available from TAMU

Appendix B

Concentrations of Trace Elements in Benthic Macrofauna
(concentrations in ppm dry weight)

1st Sampling Period

Species Name	Station Number	Part Analyzed*	Cd	Cr	Cu	Fe	Ni	Pb	V
				SPONGES					
Sponge "B"	VI-B	A	1.080	29.80	7.1	217	2.3	3.45	5.8
Sponge "D"	I-B	A	2.450	0.94	14.5	116	19.5	8.82	1.2
Sponge "G"	III-A	A	0.112	0.51	6.9	561	0.4	1.38	0.6
Geodia gibberosa	V-A	A	1.090	2.70	3.6	1150	25.9	0.11	1.2
Guitarra sp.	VI-B	A	8.270	29.80	7.6	708	5.9	5.13	8.8
Placospongia sp	I-A	A	4.310	3.71	3.0	68.5	1.0	2.07	2.9
Cinachyra sp.	047	A	1.900	0.44	6.9	84.3	27.0	1.0	0.7
	062	A	5.760	5.39	6.2	935	1.5	1.96	2.4
	064	A	4.850	4.06	6.9	883	1.1	1.95	3.8
	146	A	2.160	0.61	4.5	84.2	15.8	0.32	1.5
	147	A	2.110	3.43	5.5	421	18.4	0.36	1.2
	151	A	2.840	1.41	6.3	163	12.5	0.76	1.4
	247	A	2.020	0.43	6.3	65.8	25.1	0.22	0.8
	* 251	A	3.020	0.61	5.0	80.2	16.7	0.48	1.5

Appendix B (cont'd)

1st Sampling Period

Species Name	Station Number	Part Analyzed*	Cd	Cr	Cu	Fe	Ni	Pb	V
Pseudoceratina crassa	047	A	1.220	1.46	7.6	143	23.6	0.72	1.1
	146	A	5.800	2.71	7.1	199	12.8	2.12	5.8
	147	A	0.934	3.15	20.5	312	16.6	3.92	1.0
	151	A	1.300	1.98	8.8	211	5.3	5.39	1.9
	247	A	2.490	0.84	6.4	91.4	16.6	1.03	1.2
	251	A	6.060	0.36	6.5	79.6	18.8	0.46	1.7
CORALS									
Solenastrea hyades	062	A	0.105	2.45	5.3	60.8	0.6	0.55	2.3
Cladocora arbuscula	064	A	0.083	0.40	5.4	321	<0.2	0.24	3.6
	064	A	1.610	1.95	9.3	32.6	0.5	1.74	2.9
Madracis decactis	047	A	0.113	0.40	7.0	24.8	0.3	0.31	1.9
	146	A	0.061	0.28	5.7	22.1	0.5	0.24	1.4
	147	A	0.771	0.17	5.2	17.3	6.5	0.11	1.2
	151	A	0.485	0.21	5.5	16.9	0.22	0.16	1.0
	247	A	0.116	0.38	4.6	22.3	1.5	0.24	2.8
	251	A	1.33	0.38	3.7	18.0	0.3	0.11	1.0

Appendix B (cont'd)

1st Sampling Period

Species Name	Station Number	Part Analyzed*	Cd	Cr	Cu	Fe	Ni	Pb	V
				CORALS					
Porites divaricata*	047	A	0.215	0.26	6.9	21.7	<0.2	0.16	1.9
	147	A	0.461	0.27	6.1	18.3	0.4	0.13	1.2
	151	A	1.110	0.59	6.5	19.1	0.3	2.72	4.9
	247	A	0.251	0.32	6.9	20.6	1.0	0.28	1.5
	251	A	0.438	0.43	5.1	20.8	0.3	0.16	0.4
				MOLLUSCS					
Spondylus americanus*	151	A	20.8	2.59	9.2	80.8	20.5	1.42	6.0
	247	A	20.4	1.89	6.9	71.9	5.4	1.04	5.6
Mercenaria campechiensis	V-B	C	2.670	1.88	10.0	308	21.3	1.31	1.5
				CRUSTACEANS					
Myropsis quinquespinosa	IV-C	A	2.690	0.50	82.7	132	1.8	0.24	3.9
	V-C	A	3.790	0.51	50.0	150	0.9	0.22	1.5
Sicyiona brevirostris	IV-A	E	0.149	0.44	12.7	11.2	<0.2	0.80	<0.4
	VI-A	B	0.571	0.44	31.0	106	1.2	0.73	1.7

Appendix B (cont'd)

1st Sampling Period

Species Name	Station Number	Part Analyzed*	Cd	Cr	Cu	Fe	Ni	Pb	V
Acanthocarpus alexandri	IV-C	A	1.250	0.65	38.7	276	1.9	0.24	1.2
	V-C	A	1.100	1.46	45.0	773	0.2	0.48	2.4
	*VI-C	A	0.500	0.71	53.7	245	0.8	5.88	1.3
Portunus gibbesi	VI-A	D	12.10	0.61	44.1	54.4	<0.2	1.62	0.8
Portunus spinicarpus	I-B	A	7.120	0.42	61.0	26.4	0.5	6.94	1.0
	II-B	A	4.640	0.42	50.5	50.2	0.4	4.88	0.4
	IV-B	A	2.580	0.42	57.0	76.2	0.7	6.40	0.4
	V-B	A	2.770	0.81	61.4	235	0.5	0.23	0.8
	VI-A	A	0.936	1.05	26.2	669	0.6	1.80	1.0
	VI-A	A	0.815	0.33	19.1	89.2	0.6	0.29	<0.4
Stenorhynchus seticornis	047	C	1.610	0.35	23.3	38.1	0.9	0.83	1.8
	146	C	1.160	0.31	19.3	35.2	0.8	0.61	2.4
	147	C	1.830	0.25	21.7	32.1	0.9	0.73	2.2
	151	C	1.890	0.37	24.6	39.2	1.7	0.17	2.5
	247	C	1.070	0.46	29.2	61.9	0.9	0.25	2.0
	251	C	1.720	0.40	34.3	41.9	1.0	0.31	1.4

Appendix B (cont'd)

1st Sampling Period

Species Name	Station Number	Part Analyzed*	Cd	Cr	Cu	Fe	Ni	Pb	V
ECHINODERMS									
Astroporpa annulata	VI-B	A	1.19	1.51	5.2	641	1.4	1.74	2.2
Comactina echinoptera	I-B	B	0.350	0.59	7.0	41.0	0.6	7.96	0.9
Echinaster sp.	V-A	A	0.569	0.49	21.3	108	6.2	0.38	2.0
Encope michelini	IV-A	A	0.079	1.23	6.5	235	<0.2	6.4	7.9
Brissopsis elongata *	IV-C	F	0.072	0.95	7.2	523	0.8	1.87	0.9
*	VI-C	F	0.089	2.44	7.2	1300	1.5	2.04	8.3
Stylocidaris affinis	V-A	A	0.842	0.28	5.1	19.3	0.8	0.27	2.2
	VI-B	A	0.924	0.64	6.7	196	0.8	0.82	1.9
Clypeaster raveneli	IV-B	A	0.162	0.79	7.6	81.4	0.6	0.35	1.9
Clypeaster durandi	VI-A	A	0.210	0.78	7.2	229	0.8	0.54	1.8

Appendix B (cont'd)

2nd Sampling Period

Species Name	Station Number	Part Analyzed*	Cd	Cr	Cu	Fe	Ni	Pb	V
SPONGES									
Sponge "B"	IV-A	A	6.580	2.45	3.1	492	141	1.01	0.7
Sponge "C"	III-B	A	0.475	0.06	3.4	30.0	12.9	0.05	<0.4
Anthosigmella varians	I-A	A	64.500	0.77	12.1	2260	2320	0.27	1.0
Axinella polycapella	II-A	A	5.480	1.37	4.2	85.2	1.2	0.15	0.6
Spongosorites sp.	III-B	A	0.226	2.23	4.7	1241	3.8	1.76	2.50
Mycale sp.	II-B	A	9.670	1.43	8.5	736	7.7	0.50	2.0
Epallax sp.	I-B	A	0.462	6.14	6.1	469	0.5	0.54	2.1
Tethya sp.	I-B	A	2.360	6.75	6.6	520	1.0	1.97	3.4
Cliona celata	064	A	0.158	17.87	6.8	3022	1.1	2.55	4.9
Ircinia campana	V-A	A	0.663	16.2	11.2	2992	13.9	3.78	3.3
Agelas	III-A	A	1.670	0.65	15.6	169	18.2	0.78	1.8
	146	A	2.170	0.91	18.2	64.1	21.6	0.13	0.5
	147	A	5.960	1.03	17.5	61.7	16.1	0.19	1.1
Neofibularia nolitangere oxeata	V-A	A	7.480	11.23	7.3	2685	183	1.86	2.6
Sponge "A"	064	A	2.400	2.79	4.9	256	2.2	0.28	1.0

Appendix B (con'td)

2nd Sampling Period

Species Name	Station Number	Part Analyzed*	Cd	Cr	Cu	Fe	Ni	Pb	V
Guitarra sp.	VI-B	A	8.580	10.45	7.6	4500	6.3	0.58	6.2
Cinachyra sp.	*II-A	A	5.120	0.88	3.9	200	0.7	0.45	1.2
	247	A	1.500	1.39	4.7	130	16.8	0.16	<0.4
Pseudoceratina crassa	I-A	A	1.550	1.66	19.2	268	33.1	0.07	1.7
	251	A	1.000	0.89	8.1	67.0	31.8	0.23	<0.4
				CORALS					
Solenastrea hyades	II-A	A	0.085	0.15	7.8	78.2	<0.2	0.40	<0.4
	062	A	0.091	0.03	7.5	35.1	<0.2	0.26	<0.4
	064	A	0.089	0.09	7.9	123	<0.2	0.40	1.3
Cladocora arbuscula	062	A	0.060	0.10	7.0	51.1	<0.2	0.24	6.0
	064	A	0.094	0.03	6.8	56.7	<0.2	0.21	2.9
Madracis decactis	III-A	A	0.243	<0.01	7.6	27.0	9.6	0.34	3.0
	047	A	0.045	<0.01	7.1	35.7	<0.2	0.35	1.9
	146	A	0.081	<0.01	6.9	37.4	<0.2	0.17	4.8
	147	A	0.045	<0.01	6.5	31.8	<0.2	0.13	2.5

Appendix B (cont'd)

2nd Sampling Period

Species Name	Station Number	Part Analyzed*	Cd	Cr	Cu	Fe	Ni	Pb	V
	151	A	0.047	<0.01	6.9	35.1	<0.2	0.17	3.5
	*247	A	0.070	<0.01	6.8	36.5	<0.2	0.16	6.0
	251	A	0.041	<0.01	7.0	35.9	<0.2	0.14	2.1
Porites divaricata	047	A	0.325	---	6.8	35.6	<0.2	0.27	3.8
	146	A	0.330	<0.01	6.8	36.2	<0.2	0.14	2.4
	147	A	0.193	<0.01	6.8	34.2	1.8	0.20	3.7
	151	A	0.108	<0.01	7.0	35.9	<0.2	0.07	2.2
	247	A	0.229	<0.01	6.3	31.6	<0.2	0.18	1.7
	*251	A	0.211	<0.01	6.8	36.1	<0.2	0.08	2.8
Phyllangia sp.	062	A	0.120	0.51	9.0	106	<0.2	0.48	0.5
				MOLLUSCS					
Spondylus americanus	III-A	C	19.4	8.73	5.1	121	31.5	0.63	5.0
	047	C	22.0	4.09	5.0	63.2	70.3	0.82	3.0
	147	C	21.7	9.52	3.2	77.3	27.8	1.66	5.1
	*151	C	11.5	0.44	2.3	69.5	25.8	0.51	3.2
	247	A	35.0	3.3	3.5	79.5	33.7	1.05	4.7
	251	C	26.6	7.72	8.1	70.2	30.6	1.49	3.4

Appendix B (cont'd)

2nd Sampling Period

Species Name	Station Number	Part Analyzed*	Cd	Cr	Cu	Fe	Ni	Pb	V
Mercenaria campechiensis	V-B	C	3.150	0.75	8.1	107	8.7	1.07	0.9
CRUSTACEANS									
Calappa angusta	I-C	C	0.895	0.48	27.2	53.6	<0.2	0.195	2.9
Parapenaeus longirostris	II-C	C	1.150	<0.01	106	55.3	0.7	0.16	1.6
Hymenopenaeus tropicalis	VI-B	C	0.809	0.06	67.3	135	1.7	0.49	1.2
	VI-C	B	2.930	0.49	96.1	474	0.46	1.4	1.7
Sicyiona brevirostris	I-A	A	0.424	1.07	29.9	104	0.5	0.15	0.6
	III-A	A	0.317	0.09	76.6	69.1	0.5	0.31	1.5
	IV-A	A	0.228	<0.01	93.4	91.9	0.5	0.67	2.1
	IV-B	A	0.474	<0.01	92.0	49.9	0.8	0.42	1.6
Acanthocarpus alexandri	IV-C	C	0.518	0.03	80.0	124	<0.2	0.28	3.0
	V-C	C	2.680	0.30	71.8	245	0.3	0.66	2.3
Portunus spinicarpus	1-A	C	1.010	0.75	44.2	85.8	0.6	0.13	1.1
	III-A	A	5.870	0.11	36.0	89.3	0.8	0.35	1.8
	III-B	A	2.660	<0.01	79.8	35.9	0.9	0.21	2.2
	III-C	A	3.740	<0.01	58.1	159	0.7	0.25	3.1

Appendix B (cont'd)

2nd Sampling Period

Species Name	Station Number	Part Analyzed*	Cd	Cr	Cu	Fe	Ni	Pb	V
	IV-B	C	2.180	0.35	66.2	78.2	<0.2	0.34	2.3
	VI-A	A	0.358	0.38	51.0	326	0.7	0.54	2.0
Stenorhynchus seticornis	047	C	0.771	0.72	28.5	43.5	1.4	0.34	1.5
	*146	C	0.849	0.41	36.7	47.8	1.2	0.46	1.4
	147	C	1.260	0.28	57.8	69.7	1.6	0.48	1.9
	151	C	0.635	0.44	59.4	39.4	0.5	0.43	1.7
	247	C	1.240	0.89	37.2	71.4	0.3	0.36	1.8
	251	C	1.000	0.47	40.0	69.9	<0.2	0.56	2.5
ECHINODERMS									
Astropecten sp.	VI-A	C	0.249	0.37	10.0	318	3.2	0.70	1.5
Clypeaster raveneli	III-B	A	0.326	1.01	7.2	291	1.0	0.81	1.4
	IV-B	A	0.207	0.28	7.2	140	0.3	0.43	2.4
Clypeaster durandi	I-A	A	0.221	1.53	7.4	230	0.4	0.47	0.6
	VI-A	A	0.107	0.74	7.4	704	0.5	1.58	<0.4

Appendix B (cont'd)

3rd Sampling Period

Species Name	Station Number	Part Analyzed*	Cd	Cr	Cu	Fe	Ni	Pb	V
SPONGES									
Sponge "C"	I-B	A	0.171	1.72	4.5	261	1.1	1.19	<0.4
	III-B	A	0.208	0.70	4.0	173	0.9	0.25	<0.4
Sponge "F"	I-B	A	4.445	3.16	6.1	422	1.9	1.96	<0.4
Yvesia or Gnayella	II-B	A	4.248	2.03	7.4	526	5.0	1.12	1.8
Xetospongia sp.	III-A	A	0.093	0.49	10.4	86.4	19.0	1.42	1.1
Asteopus sp.	III-B	A	0.126	0.30	4.8	70.7	21.8	<0.01	<0.4
Verongia longissma	I-A	A	3.458	0.50	16.9	166	75.9	0.91	<0.4
Tethya sp.	II-A	A	0.362	1.97	4.8	388	1.4	0.52	1.2
Haliclona rubens	I-A	A	0.334	2.84	6.3	476	2.4	0.35	1.7
	I-A	A	8.270	0.95	6.4	127	2.4	0.36	<0.4
Neofibularia nolitangere ixeata	V-A	A	1.633	1.35	7.9	820	372	0.74	1.3
Guitarra sp.	VI-B	A	6.733	2.73	8.7	2030	2.4	2.87	2.1
Placospongia sp.	I-A	A	0.058	0.14	3.2	43.0	0.4	0.08	<0.4
Cinachyra sp.	II-A	A	1.877	1.05	6.4	265	0.8	0.30	<0.4
	047	A	0.623	0.32	5.7	89.9	20.9	0.33	0.9

Appendix B (cont'd)

3rd Sampling Period

Species Name	Station Number	Part Analyzed*	Cd	Cr	Cu	Fe	Ni	Pb	V
Cinachyra sp.	062	A	1.740	0.64	5.7	222	0.8	0.65	<0.4
	064	A	0.644	3.76	7.1	863	0.8	0.95	2.6
	146	A	0.454	0.27	5.4	105	8.6	0.54	<0.4
	147	A	0.543	0.71	6.4	142	19.1	0.64	<0.4
	151	A	0.371	0.59	5.8	96.4	6.0	0.80	<0.4
	247	A	0.239	0.46	5.0	143	13.9	0.49	<0.4
	*251	A	0.365	0.80	6.5	157	10.5	0.55	3.9
Pseudoceratina crassa	047	A	0.352	0.33	8.6	87.7	39.6	0.33	<0.4
	146	A	0.790	0.18	8.9	79.3	27.0	0.33	<0.4
	147	A	0.284	0.50	10.7	106	22.7	0.77	<0.4
	151	A	0.247	1.25	11.4	126	20.7	1.20	<0.4
	247	A	0.216	0.40	10.0	117	20.5	0.83	<0.4
	251	A	0.371	0.39	8.3	91.4	20.0	0.40	<0.4

Appendix B (cont'd)

3rd Sampling Period

Species Name	Station Number	Part Analyzed*	Cd	Cr	Cu	Fe	Ni	Pb	V
				CORALS					
Solenastrea hyades	II-A	A	0.021	0.35	7.9	54.1	<0.2	0.22	1.4
	062	A	0.041	0.03	8.6	34.7	<0.2	0.25	0.8
	064	A	0.045	0.16	8.4	51.4	<0.2	0.25	<0.4
Cladocora arbuscula	064	A	0.025	0.14	8.4	63.2	<0.2	0.20	0.7
Madracis decactis	III-A	A	0.030	0.11	7.8	36.8	0.7	0.13	<0.4
	047	A	0.039	0.08	7.7	38.4	0.3	0.13	<0.4
	146	A	0.040	0.07	7.6	36.3	<0.2	0.11	1.4
	147	A	0.038	0.08	7.8	40.4	<0.2	0.12	<0.4
	151	A	0.072	0.05	7.7	41.1	<0.2	0.17	<0.4
	247	A	0.020	0.09	8.5	44.9	<0.2	0.22	1.9
	251	A	0.039	<0.01	7.6	38.2	<0.2	0.11	1.7
Porites divaricata	*047	A	0.068	0.06	7.6	41.9	<0.2	0.11	1.7
	146	A	0.269	0.18	7.5	46.1	<0.2	0.14	2.6
	147	A	0.127	0.15	7.7	36.0	<0.2	0.13	<0.4
	151	A	0.112	0.20	6.8	32.2	<0.2	0.31	1.5
	247	A	0.070	0.01	8.5	42.3	<0.2	0.17	<0.4

Appendix B (cont'd)

3rd Sampling Period

Species Name	Station Number	Part Analyzed*	Cd	Cr	Cu	Fe	Ni	Pb	V
	251	A	0.280	0.07	7.6	41.4	<0.2	0.15	1.3
Phyllangia americana	062	A	0.073	0.99	10.1	308	0.6	0.70	2.3
Siderastrea radians	064	A	0.020	0.06	8.1	35.7	<0.2	0.12	1.3
Millepora alcicornis	147	A	0.472	0.13	8.3	36.1	8.4	0.52	<0.4
	151	A	0.262	0.01	8.5	39.9	7.6	0.17	<0.4
	247	A	0.339	0.07	8.2	35.0	6.9	0.09	1.6
MOLLUSCS									
Spondylus americanus	147	A	2.038	6.31	1.7	33.0	9.2	0.65	<0.4
	*151	A	3.875	4.33	3.3	66.1	17.1	0.71	3.9
	247	A	1.525	1.76	1.5	19.3	5.9	0.15	1.4
Murex beauii	II-C	A	0.660	0.32	44.2	84.2	1.3	0.61	<0.4
CRUSTACEANS									
Calappa angusta	I-C	B	0.699	0.22	32.7	103	0.4	0.40	<0.4
Myropsis quinques-perforata	II-C	A	6.540	0.32	95.3	175	0.9	0.65	<0.4

Appendix B (cont'd)

3rd Sampling Period

Species Name	Station Number	Part Analyzed*	Cd	Cr	Cu	Fe	Ni	Pb	V
Hymenopenaeus tropicalis	I-A	C	0.692	0.35	69.1	69.2	1.1	<0.01	<0.4
Sicyiona brevirostris	I-A	A	0.179	0.51	37.5	84.2	0.8	0.26	<0.4
	III-A	A	0.050	0.32	45.7	51.4	0.4	0.28	<0.4
	IV-A	D	0.827	0.20	110	71.3	0.7	0.35	<0.4
	V-A	A	0.073	0.26	84.7	82.4	0.6	0.39	<0.4
Acanthocarpus alexandri	III-C	B	0.445	0.42	39.1	383	0.7	0.33	0.9
Portunus spinicarpus	I-B	A	5.466	0.19	60.4	51.5	0.3	0.25	<0.4
	III-A	A	3.201	0.22	39.4	57.3	0.7	0.45	<0.4
	IV-B	A	3.354	0.35	67.8	172	0.9	0.36	1.4
Stenorhynchus seticornis	047	C	0.661	0.09	29.5	69.9	0.7	0.30	3.0
	*146	C	0.397	0.16	25.6	56.4	<0.4	0.22	<0.4
	147	C	0.417	0.28	35.9	80.4	0.6	0.73	<0.4
	151	C	0.430	0.01	32.3	52.4	<0.2	0.47	<0.4
	247	C	0.430	0.23	39.1	86.3	<0.2	0.52	<0.4
	251	C	0.461	0.21	27.7	71.4	<0.2	0.47	<0.4

Appendix B (cont'd)

3rd Sampling Period

Species Name	Station Number	Part Analyzed*	Cd	Cr	Cu	Fe	Ni	Pb	V
					ECHINODERMS				
Coelopleurus floridanus	VI-C	A	0.119	1.45	8.0	1832	1.9	2.51	<0.4
Astrophyton muricatum	247	A	0.505	0.35	5.9	40.0	0.5	0.44	<0.4
Astropecten sp.	I-C	C	0.463	0.01	11.5	64.1	<0.2	0.35	<0.4
	IV-A	A	0.294	0.01	15.2	70.7	<0.2	0.44	1.7
Astroporpa annulata	III-B	A	0.293	0.39	6.1	54.3	0.8	0.56	0.9
	V-B	B	0.647	0.36	6.0	52.2	0.4	0.55	<0.4
	VI-B	A	0.207	0.25	7.0	151	0.6	0.56	1.9
Comactina echinoptera	I-B	A	0.268	0.65	6.8	110	0.6	0.74	<0.4
Brissopsis elongata	VI-C	A	0.117	9.41	11.8	9794	8.5	7.74	9.3
Stylocidaris affinis	V-A	A	0.239	0.80	6.8	369	0.4	0.55	2.1
	VI-B	A	0.100	0.36	7.6	580	0.6	1.51	0.8
Clypeaster raveneli	*II-B	A	0.278	0.77	6.8	148	0.6	0.56	1.0
	IV-B	A	0.234	0.91	6.6	278	0.3	0.47	4.6
Clypeaster durandi	VI-A	A	0.056	0.36	5.9	94.2	0.2	0.67	2.0

Appendix B (cont'd)

3rd Sampling Period

Species Name	Station Number	Part Analyzed*	Cd	Cr	Cu	Fe	Ni	Pb	V
	062	A	0.187	0.90	7.0	140	<0.2	0.39	1.0

* = Averaged from 5 replicated samples

+A = Representative sample from one whole organism

B = One whole organism

C = Several whole organisms

D = Head section (internal organs)

E = Tail section (mostly muscle tissue)

F = One whole organism which contained sediment

Appendix C

Intraspecies Variability of Trace Metals among the Dominant Macrofauna (concentrations in ppm dry weight)

Species Name	No. of samples* analyzed		Cd	Cr	Cu	Fe	Ni	Pb	V
				SPONGES					
				1st Sampling Period					
Cinachyra sp.	8	Range	1.900-5.850	0.43-5.39	4.5-6.9	65.8-935	1.1-26.9	0.10-1.96	0.8-3.8
		Mean	3.080	2.05	6.0	339	14.7	0.77	1.6
		Std. Dev.	1.450	2.00	0.9	370	9.6	0.76	1.0
Pseudoceratina crassa	6	Range	1.220-5.800	0.36-3.15	6.4-20.5	79.6-312	5.3-23.6	0.72-5.39	1.0-5.8
		Mean	2.967	1.75	9.4	172	15.6	2.27	2.1
		Std. Dev.	2.357	1.07	5.5	87.0	6.2	1.98	1.8
				2nd Sampling Period					
Cinachyra sp.	2	Range	1.500-5.100	0.58-1.39	3.9-4.7	130-200	0.8-16.8	0.16-0.45	<0.4-1.2
		Mean	3.310	0.98	4.3	165	8.8	0.30	<0.8
		Std. Dev.	2.600	0.57	0.6	49	11.3	0.20	0.6
Pseuodoceratina crassa	2	Range	1.000-1.550	0.89-1.66	8.1-19.2	67.0-268	31.8-33.1	0.07-0.23	<0.4-1.7
		Mean	1.275	1.27	13.6	137	32.4	0.15	<1.0
		Std. Dev.	0.389	0.54	7.8	185	0.9	0.11	<0.9
				3rd Sampling Period					
Cinachyra sp.	9	Range	0.239-1.877	0.32-1.05	5.0-7.1	86.9-863	0.8-20.9	0.30-0.95	<0.4-3.9
		Mean	0.785	0.96	5.9	231	9.0	0.58	<0.8
		Std. Dev.	0.570	1.02	0.7	230	7.3	0.20	1.4

Appendix C
cont'd

Species Name	No. of samples* analyzed		Cd	Cr	Cu	Fe	Ni	Pb	V
Pseudoceratina crassa	2	Range	1.000- 1.550	0.89- 1.66	8.1- 19.2	67.0- 268	31.8- 33.1	0.07- 0.23	<0.4- 1.7
		Mean	1.275	1.27	13.6	137	32.4	0.15	<1.0
		Std. Dev.	0.389	0.54	7.8	185	0.9	0.11	<0.9
3rd Sampling Period									
Cinachyra sp.	9	Range	0.239- 1.877	0.32- 1.05	5.0- 7.1	86.9- 863	0.8- 20.9	0.30- 0.95	<0.4- 3.9
		Mean	0.785	0.96	5.9	231	9.0	0.58	<0.8
		Std. Dev.	0.570	1.02	0.7	230	7.3	0.20	1.4
Pseudoceratina crassa	6	Range	0.216- 0.790	0.18- 1.25	8.3- 11.4	79.3- 126	20.0- 39.6	0.33- 1.20	--- ---
		Mean	0.377	0.51	9.6	101	25.1	0.64	<0.4
		Std. Dev.	0.200	0.32	1.2	18.1	7.5	0.35	---
CORALS									
1st Sampling Period									
Madracis decactis	6	Range	0.061- 1.330	0.17- 0.40	3.7- 7.0	17.3- 24.8	0.3- 1.5	0.11- 0.31	1.0- 2.8
		Mean	0.479	0.32	5.3	20.0	0.6	0.19	1.5
		Std. Dev.	0.500	0.12	1.1	3.0	0.5	0.08	0.7
Porites divaricata	5	Range	0.129- 1.110	0.26- 0.59	5.1- 6.9	18.3- 21.7	<0.2- 1.0	0.13- 0.28	0.4- 4.9
		Mean	0.478	0.37	6.3	20.0	<0.4	0.18	2.0
		Std. Dev.	0.379	0.14	0.7	2.0	0.3	0.07	1.7
2nd Sampling Period									
Madracis decactis	7	Range	0.041- 0.081	---- ----	6.5- 7.6	27.0- 41.8	---- ----	0.13- 0.35	1.9- 6.0
		Mean	0.055	<0.01	7.0	35.0	<0.2	0.21	3.4
		Std. Dev.	0.016	----	0.3	5.0	----	0.09	1.5

Appendix C
cont'd

Species Name	No. of samples* analyzed		Cd	Cr	Cu	Fe	Ni	Pb	V
Porites divaricata	6	Range	0.108- 0.325	---- ----	6.3- 7.0	31.6- 36.2	---- ----	0.07- 0.27	1.7- 3.8
		Mean	0.233	0.01	6.7	35.0	<0.2	0.16	2.7
		Std. Dev.	0.084	----	0.2	2.0	----	0.08	0.8
Madracis decactis	7	Range	0.020- 0.072	0.01- 0.11	7.6- 8.5	36.3- 44.9	---- ----	0.11- 0.17	<0.4- 1.9
		Mean	0.040	0.07	7.8	39.5	<0.2	0.14	<0.7
		Std. Dev.	0.010	0.03	0.3	2.8	----	0.04	0.8
Porites divaricata	6	Range	0.068- 0.280	0.01- 0.20	6.8- 8.5	32.2- 42.3	---- ----	0.11- 0.31	<0.4- 1.7
		Mean	0.154	0.10	7.6	40.0	<0.2	0.17	<1.2
		Std. Dev.	0.090	0.09	0.5	4.6	----	0.07	0.9
MOLLUSCS									
1st Sampling Period									
Spondylus americanus	2	Range	20.4- 20.8	1.89- 2.59	6.9- 9.2	71.9- 80.8	5.4- 20.5	1.04- 1.42	5.6- 6.0
		Mean	20.6	2.25	8.0	76.0	13.0	1.23	5.8
		Std. Dev.	0.3	0.49	1.6	6.4	10.6	0.27	0.3
2nd Sampling Period									
Spondylus americanus	6	Range	19.4- 35.0	3.31- 9.56	2.3- 6.1	63.2- 79.5	25.8- 33.7	0.51- 1.66	3.0- 5.1
		Mean	22.7	6.92	4.2	72.0	29.9	1.03	4.1
		Std. Dev.	7.8	2.58	1.4	6.0	3.1	0.46	1.0
3rd Sampling Period									
Spondylus americanus	3	Range	1.525- 3.875	1.76- 6.31	1.5- 3.3	19.3- 66.1	5.9- 17.1	0.15- 0.71	<0.4- 3.9
		Mean	2.479	4.14	2.2	39.5	10.7	0.51	<1.8
		Std. Dev.	1.010	1.86	0.8	19.6	4.5	0.25	1.6

Appendix C
cont'd

Species Name	No. of samples* analyzed		Cd	Cr	Cu	Fe	Ni	Pb	V
CRUSTACEANS									
1st Sampling Period									
Sicyiona brevirostris	2	Range	0.149-0.571	0.44-0.44	12.7-31.0	11.2-106	<0.2-1.2	0.73-0.80	<0.4-1.7
		Mean	0.360	0.44	21.8	58.6	<0.8	0.76	<1.1
		Std. Dev.	0.298	0.00	12.9	67.0	0.5	0.05	0.9
Acanthocarpus alexandri	3	Range	0.500-1.250	0.65-1.46	38.7-53.7	245-773	0.8-1.9	0.24-5.88	1.2-2.4
		Mean	0.950	0.94	45.8	431	0.9	2.20	1.6
		Std. Dev.	0.397	0.45	7.5	296	0.8	3.19	0.7
Portunus spinicarpus	6	Range	0.815-7.120	0.33-1.05	19.1-61.4	26.5-669	0.3-1.4	0.29-6.94	<0.4-1.4
		Mean	3.143	0.54	45.7	190	0.9	3.42	<0.9
		Std. Dev.	2.400	0.27	18.5	245	0.5	3.03	0.5
Stenorhynchus seticornis	6	Range	1.070-1.890	0.25-0.46	19.3-34.3	32.1-61.9	0.9-1.7	0.17-0.83	1.4-2.5
		Mean	1.547	0.36	25.4	41.0	1.0	0.48	2.0
		Std. Dev.	0.349	0.07	5.5	7.0	0.3	0.28	0.4
2nd Sampling Period									
Sicyiona brevirostris	4	Range	0.228-0.474	<0.01-1.07	29.9-92.0	49.9-104	0.5-0.8	0.15-0.67	0.6-2.1
		Mean	0.361	0.29	73.0	79.0	0.6	0.41	1.4
		Std. Dev.	0.110	0.52	29.7	24.0	0.1	0.26	0.6
Acanthocarpus alexandri	2	Range	0.518-2.68	<0.01-0.49	71.8-80.0	124-245	<0.2-0.6	0.28-0.66	2.3-3.0
		Mean	1.600	<0.19	75.9	184	<0.4	0.47	2.6
		Std. Dev.	1.529	0.26	5.8	85	0.3	0.26	0.5

Appendix C
cont'd

Species Name	No. of samples* analyzed		Cd	Cr	Cu	Fe	Ni	Pb	V
Portunus spinicarpus	6	Range	0.358-5.870	<0.01-0.75	36.0-79.8	35.9-326	<0.2-0.9	0.15-0.67	1.1-3.1
		Mean	2.636	0.21	55.9	129	<0.6	0.30	2.1
		Std. Dev.	1.986	0.30	15.7	104	0.2	0.14	0.6
Stenorhynchus secticornis	6	Range	0.635-1.250	0.28-0.89	28.5-57.8	39.4-71.4	<0.2-1.6	0.34-0.56	1.4-2.5
		Mean	0.959	0.53	39.9	56.9	<0.9	0.44	1.8
		Std. Dev.	0.254	0.22	9.7	14.9	0.6	0.08	0.4

3rd Sampling Period

Species Name	No. of samples* analyzed		Cd	Cr	Cu	Fe	Ni	Pb	V
Sicyiona brevirostris	4	Range	0.050-0.827	0.20-0.51	37.5-110	51.4-84.2	0.4-0.8	0.26-0.32	---- ----
		Mean	0.282	0.32	69.6	72.3	0.6	0.32	<0.4
		Std. Dev.	0.320	0.12	29.5	13.1	0.1	0.05	----
Acanthocarpus alexandri	1	Range	---- ----	---- ----	---- ----	---- ----	---- ----	---- ----	---- ----
		Mean	0.445	0.42	39.1	383	0.7	0.33	0.9
		Std. Dev.	----	----	----	----	----	----	----
Portunus spinicarpus	3	Range	3.201-5.466	0.19-0.35	39.4-67.8	51.5-172	0.3-0.9	0.25-0.45	<0.4-1.4
		Mean	4.007	0.25	55.9	93.6	0.6	0.35	<0.7
		Std. Dev.	1.030	0.07	12.0	55.4	0.2	0.08	0.6
Stenorhynchus seticornis	6	Range	0.397-0.661	0.09-0.28	25.6-39.1	52.4-86.3	<0.2-0.7	0.22-0.73	<0.4-3.0
		Mean	0.466	0.17	31.7	69.5	<0.2	0.45	<0.5
		Std. Dev.	0.090	0.09	4.7	12.0	0.3	0.16	1.1

Appendix C
cont'd

Species Name	No. of samples* analyzed		Cd	Cr	Cu	Fe	Ni	Pb	V
						ECHINODERMS			
						1st Sampling Period			
Stylocidaris affinis	2	Range	0.842-0.924	0.28-0.64	5.1-6.7	19.3-196	0.8-0.8	0.27-0.82	1.9-2.2
		Mean	0.883	0.46	5.9	107	0.8	0.54	2.0
		Std. Dev.	0.058	0.25	1.1	125	0.0	0.39	0.2
Clypeaster sp.	2	Range	0.162-0.210	0.78-0.79	7.2-7.6	81.4-229	0.6-0.8	0.35-0.54	1.8-1.9
		Mean	0.186	0.78	7.4	155	0.7	0.44	1.8
		Std. Dev.	0.040	0.01	0.3	105	0.1	0.13	0.0
						2nd Sampling Period			
Clypeaster sp.	4	Range	0.107-0.326	0.28-1.53	7.2-10.9	140-704	0.3-3.2	0.43-1.58	<0.4-2.4
		Mean	0.222	0.79	7.8	337	1.1	0.80	<1.3
		Std. Dev.	0.079	0.51	1.2	216	1.2	0.46	0.8
						3rd Sampling Period			
Stylocidaris affinis	2	Range	0.100-0.239	0.36-0.80	6.8-7.6	369-580	0.4-0.6	0.55-1.51	0.8-2.1
		Mean	0.167	0.58	7.2	474	0.5	1.03	1.5
		Std. Dev.	0.070	0.22	0.4	106	0.1	0.48	0.6
Clypeaster sp.	4	Range	0.056-0.278	0.36-0.91	5.9-7.0	94.2-278	<0.2-0.6	0.39-0.67	1.0-4.6
		Mean	0.191	0.73	6.6	165	<0.3	0.52	2.2
		Std. Dev.	0.090	0.22	0.4	68	0.2	0.10	1.5

*For some elements, the number of samples analyzed is one less than that given.

Appendix D

Recommendations for Future Study

1) In order to obtain reliable statistics concerning trace metal variations within a species, several samples of the same species from a station should be collected.

2) Geographical trends have more significance when many samples of the same species are collected from many geographical locations.

3) Better seasonal trends can be observed when several samples of the same species are collected from the same locations, throughout all seasons.

4) Perhaps more emphasis should be placed on corals in future studies. They are not only the lowest in their trace metal concentrations, but also show the least variation. This is especially significant in the case of nickel and vanadium, which are non detectable in many instances. Therefore, even slight elevations in the concentrations of these elements, in corals, may be indicative of imput by man (i.e. contamination from petroleum).

BLM MAFLA DEMERSAL FISH SURVEY 1975-1976

Co-Principal Investigators:

Stephen A. Bortone
University of West Florida, Department of Biology

Garry F. Mayer
University of South Florida, Department of Marine Science

Robert L. Shipp
University of South Alabama, Department of Biology

ABSTRACT

Trawl and dredge collections of fishes were taken from 18 stations, each sampled during July, October, 1975, and February/March 1976. The stations were located at approximately 37 m, 93 m and 183 m depths along each of six transects located in the north central to southeastern Gulf of Mexico.

A total of 8882 specimens representing 204 species were captured, identified, weighed, measured, and archived. These data were then analyzed for species diversity, seasonal variation of species composition and biomass, dominant species and possible migratory activity. In addition, tissue samples were removed from selected individuals for subsequent hydrocarbon/trace metal analysis.

Species diversity appeared most consistent at 183 m stations. However, differences in absolute diversity between depths were inconclusive. Numbers of species and biomass appeared only slightly higher at shallower depths. There appeared to be little geographical variation in any of these parameters.

Species dominance was the most consistent and valuable faunal characterization noted. Based on species dominance, faunal variation was more marked between depths than between geographically separate stations of the same depth.

INTRODUCTION

Demersal fishes are a major component of the benthic fauna of continental shelves. Many species of demersal fishes are the principal components of the top trophic levels of continental shelf ecosystems. Therefore, knowledge of these species is imperative in the understanding and characterization of such ecosystems, and tissue analysis of these species can be most revealing toward an assessment of pathways taken by various compounds in continental shelf food webs.

Analysis of demersal fish communities in the MAFLA lease area was initiated during 1975, the second year of the project by the Bureau of Land Management (BLM). The following represents data gathered during the 1975-1976 sampling period, and must be considered an interim report, awaiting the year to year comparisons of subsequent field work.

MATERIALS AND METHODS

Characterization of transects

Six transects were established within the MAFLA lease area (Figure 1), each consisting of stations at approximately 37 (A stations), 93 (B stations), and 183 (C stations) m depths. The northernmost two transects (VI), located south of Mobile Bay, and V located south of Pensacola Bay) lay partially over the steep slopes of the northern sector of the DeSoto Canyon, which resulted in close proximity of the stations within each transect, especially the 93 and 183 m stations. Transect III traversed the Florida Middle Ground area, which placed the A station amongst scattered coral reefs. Transect I, extending westward from the Fort Myers area, was bordering on tropical substrate, and the A station was characterized by considerable biogenic relief. Transects IV and II were located

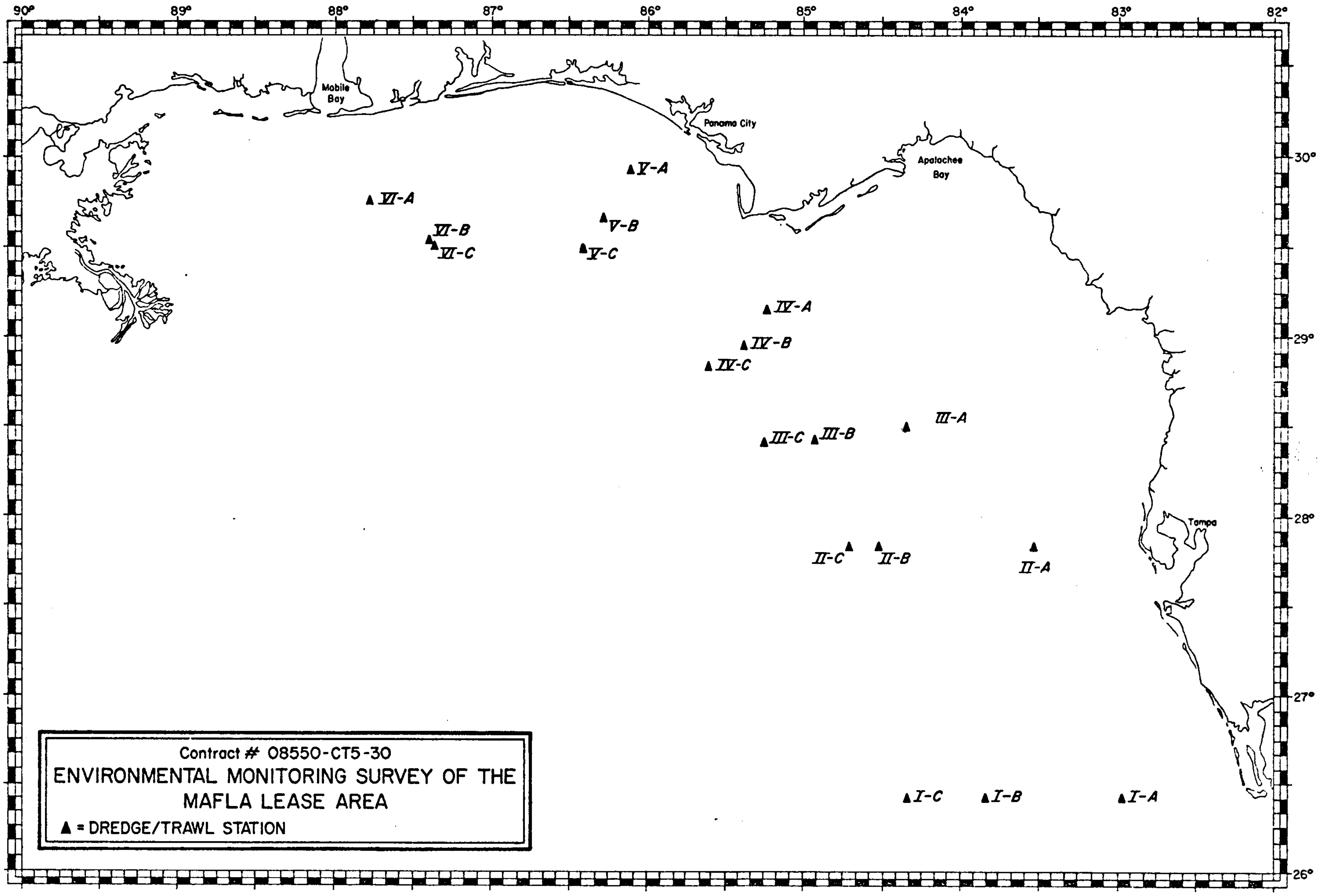


Figure 1. Location of sampling sites

on gently sloping shelf bottom, with no outstanding topographic features.

Sampling periods

The transects were sampled three times during the period from 1 June 1975 to 30 March 1976. During the first sampling period (June/July), dredge/trawl operations were conducted from the R/V GYRE and R/V BELLOWS; cruises for both vessels were during July, 1975. Dredge/trawl collections during the next sampling period (September/October) were conducted aboard the R/V GYRE during October 1975. The final dredge/trawl samples (January-March sampling period) were conducted aboard the R/V GYRE and R/V BELLOWS during February 1976, during which period all but dredge samples at 6B and 6A were taken. These latter were completed aboard the R/V TURSIOPS during March 1976. Specific information regarding each cruise activity is contained in cruise reports submitted to the Bureau of Land Management.

Sampling procedure and gear

Station locations (Table 1) were located by LORAN A navigational procedures.

One trawl sample was taken during each sampling period at each station. All trawling samples were taken with a 9.1 m semi-balloon trawl, with fine 9.5 m mesh cod-end liner. Bottom time for A and B stations was 15 min, for C stations 30 min. The trawl was pulled at approximately 1-4 knots. Trawls were taken in a direction generally paralleling that of the transect, but occasionally, topographic features or vessel operational procedures required variance from this pattern.

Two dredge samples were taken at each station. A standard Capetown dredge with fine mesh 12.7 m or less, depending on bottom composition) metal screen liner was used for obtaining samples. Dredge durations (bottom time)

TABLE 1. Numbers of species of fishes collected during 1975-1976 MAFLA program.

	Transect	VI	V	IV	III	II	I
	July, 1975	27	17	36	17	16	33
Station A	October, 1975	21	28	25	33	32	36
	February/March, 1976	8	24	14	24	35	31
	July, 1975	9	27	10	13	15	18
Station B	October, 1975	18	18	23	35	15	19
	February/March, 1976	13	18	11	13	15	19
	July, 1975	26	14	11	7	11	10
Station C	October, 1975	21	25	19	23	18	11
	February/March, 1976	4	8	15	10	19	20

were 15 min each for the A and B stations, 30 min for C stations. Towing procedure for dredge samples paralleled those for the trawl.

Both trawl and dredge samples were deposited directly on sterilized sorting platforms. Specimens for hydrocarbon/trace metal analysis were removed first, and weighed, measured and prepared for subsequent analysis. Then, all remaining fish specimens were removed and placed in 10% formalin (4% formaldehyde) solution. Small, delicate specimens were placed in vials. In those rare cases where a species was represented by extremely numerous (>100) individuals, some were removed for pesticide analysis. These were first counted, weighed, and entered into field notes. Separation of dredge and trawl samples was maintained until after laboratory analysis was completed.

Specimens were transferred from the research vessels to the appropriate laboratories, where all were individually identified, weighed, measured, catalogued and archived into collections at the Universities of South Alabama, South Florida, and West Florida. The material deposited in University of South Florida will ultimately be transferred to the permanent collection of the other institutions. Copies of catalog entries have been deposited with the BLM-MAFLA program director.

RESULTS

All data gathered from the demersal fish collections, including numbers, lengths, and weights of all specimens of all species taken from dredge and trawl collections (exceptions noted in materials and methods) have been submitted to the data management section of the BLM-MAFLA program. Computer analyses are not yet available, however, results as can be reasonably derived without computer aid are included herein.

A total of 8882 specimens, representing 204 species, and a total weight of 302,547 g were taken. A station by station and season by season breakdown is included in Tables 2-5, also included in this table are H (species diversity) values for each collection. Graphical representation of these data has been presented in appropriate quarterly reports and is included herein.

Species dominance both by numbers and weight is awaiting computer analysis.

DISCUSSION

October collections at all stations and transects usually yielded higher species numbers, numbers of individuals, biomass and species diversity (see Figure 2-7). There is no apparent reason to suspect gear bias during this period, as all collecting specifications remained essentially unchanged. Therefore, some seasonal variation, with an increased fauna during fall, is evidenced by these data. One possible hypothesis to explain this observation would be that during early fall (e.g. October) stock from spring and summer spawnings would be entering a size class large enough to be sampled by the gear. However, winter depletion of stocks would not yet be incurred. Effects of Hurricane ELOISE, which crossed Transects V and VI, should not have affected the deeper stations nor the transects to the south, and thus would not enter into a hypothesis concerning the seasonal increase in October.

Collections, though variable from season to season, are amazingly similar between stations at similar depths as well as between transects, when considered on a year long basis. Repeated sampling tends to damp atypical collections, and thus revealed a more realistic conclusion regarding faunal composition.

TABLE 2. Number of specimens of fishes collected during 1975-1976 MAFLA program.

	Transect	VI	V	IV	III	II	I
Station A	July, 1975	264	64	218	129	116	102
	October, 1975	119	157	122	435	138	215
	February/March, 1976	15	185	52	203	269	153
Station B	July, 1975	68	307	16	24	100	192
	October, 1975	315	156	477	357	99	256
	February/March, 1976	192	68	57	26	160	139
Station C	July, 1975	369	92	53	29	27	59
	October, 1975	347	552	290	350	210	72
	February/March, 1976	8	27	78	22	123	209

TABLE 3. Total biomass (grams) of specimens of fishes collected during 1975-1976 MAFLA program.

	Transect	VI	V	IV	III	II	I
	July, 1975	5699	1557	7163	2059	3744	3640
Station A	October, 1975	3809	7680	10646	14832	5497	22594
	February/March, 1976	543	8704	1372	6683	17579	7333
	July, 1975	1283	5234	410	879	3521	7618
Station B	October, 1975	3952	4611	13274	16137	5087	15165
	February/March, 1976	1408	2331	1694	658	4188	8094
	July, 1975	5686	2956	1496	279	560	767
Station C	October, 1975	7985	20407	5978	9827	7130	649
	February/March, 1976	64	1576	3820	1025	4128	1428

TABLE 4. Species diversity ($\overline{H}$) of demersal fishes collected during 1975-1976 MAFLA program.

	Transect	VI	V	IV	III	II	I
	July, 1975	1.83	2.36	2.91	1.21	2.14	2.74
Station A	October, 1975	2.26	2.58	2.62	2.29	3.01	2.79
	February/March, 1976	1.88	2.02	2.02	2.29	2.56	2.63
	July, 1975	1.53	1.67	2.36	2.38	2.06	2.30
Station B	October, 1975	1.36	2.31	1.93	2.87	1.85	1.86
	February/March, 1976	0.93	1.99	1.49	2.24	2.07	2.54
	July, 1975	2.11	2.07	2.00	1.56	2.11	1.77
Station C	October, 1975	2.23	2.24	1.94	2.26	2.10	1.79
	February/March, 1976	1.21	1.52	1.93	2.14	2.37	1.80

TABLE 5. Total catches (specimens, biomass in grams) of demersal fishes collected during 1975-1976 MAFLA program.

	Transect	VI	V	IV	III	II	I	Total
Station A	Specimens (#)	398	406	392	767	523	470	2956
	Biomass (grams)	10051	17941	19180	23572	26831	33567	131142
Station B	Specimens	575	531	550	407	359	587	3009
	Biomass	6643	12176	15378	17674	12796	30877	95544
Station C	Specimens	724	671	421	401	360	340	2917
	Biomass	13735	24939	11294	11131	11818	2844	75761
Grand Totals	Specimens	1697	1608	1363	1575	1242	1397	8882
	Biomass	30429	55056	45852	52377	51445	67388	302547

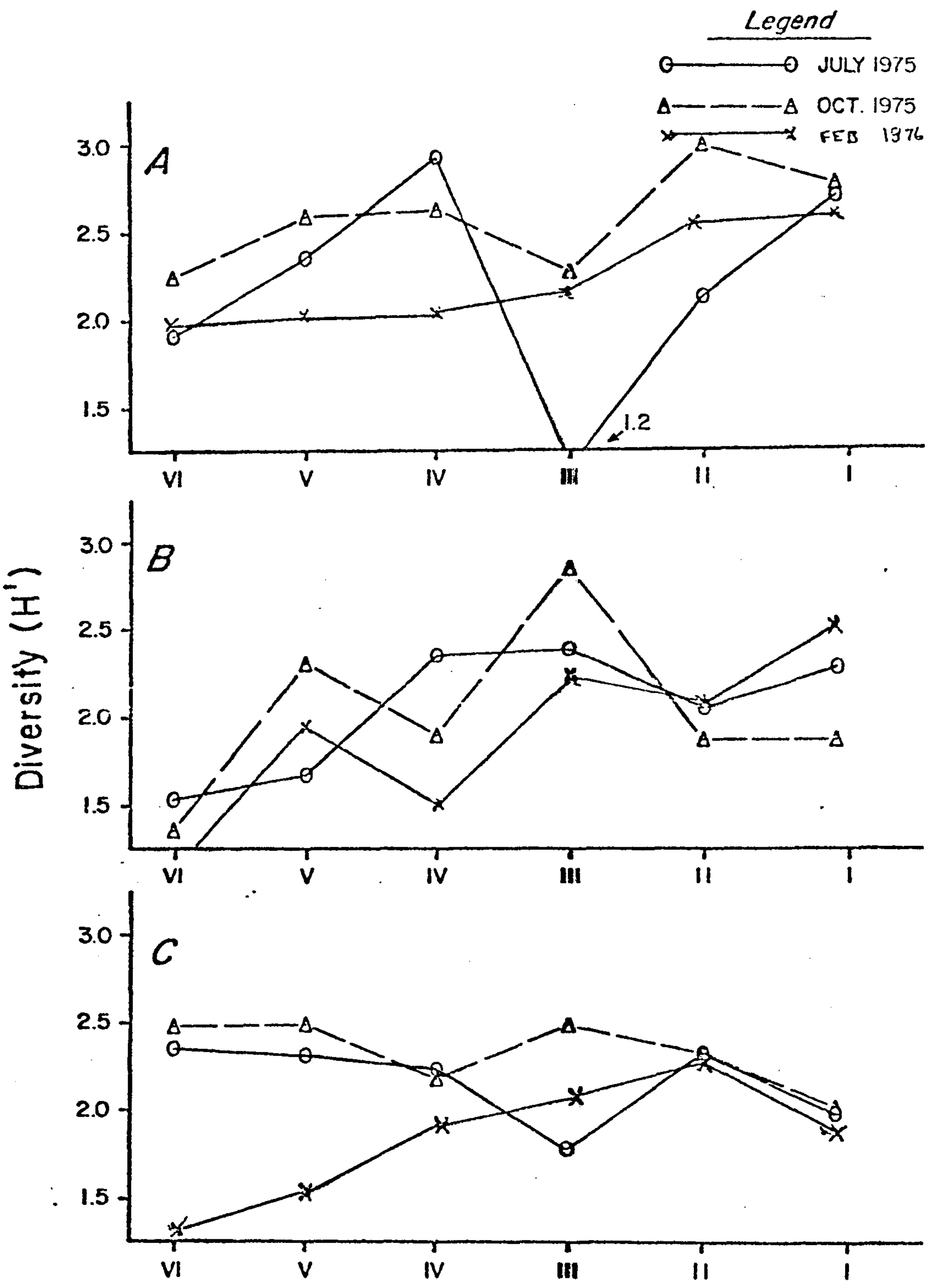

Legend
JULY 1975
OCT. 1975
FEB 1976
Diversity (H')
A
B
C
3.0
2.5
2.0
1.5
1.2
VI
V
IV
III
II
I

Figure 2.

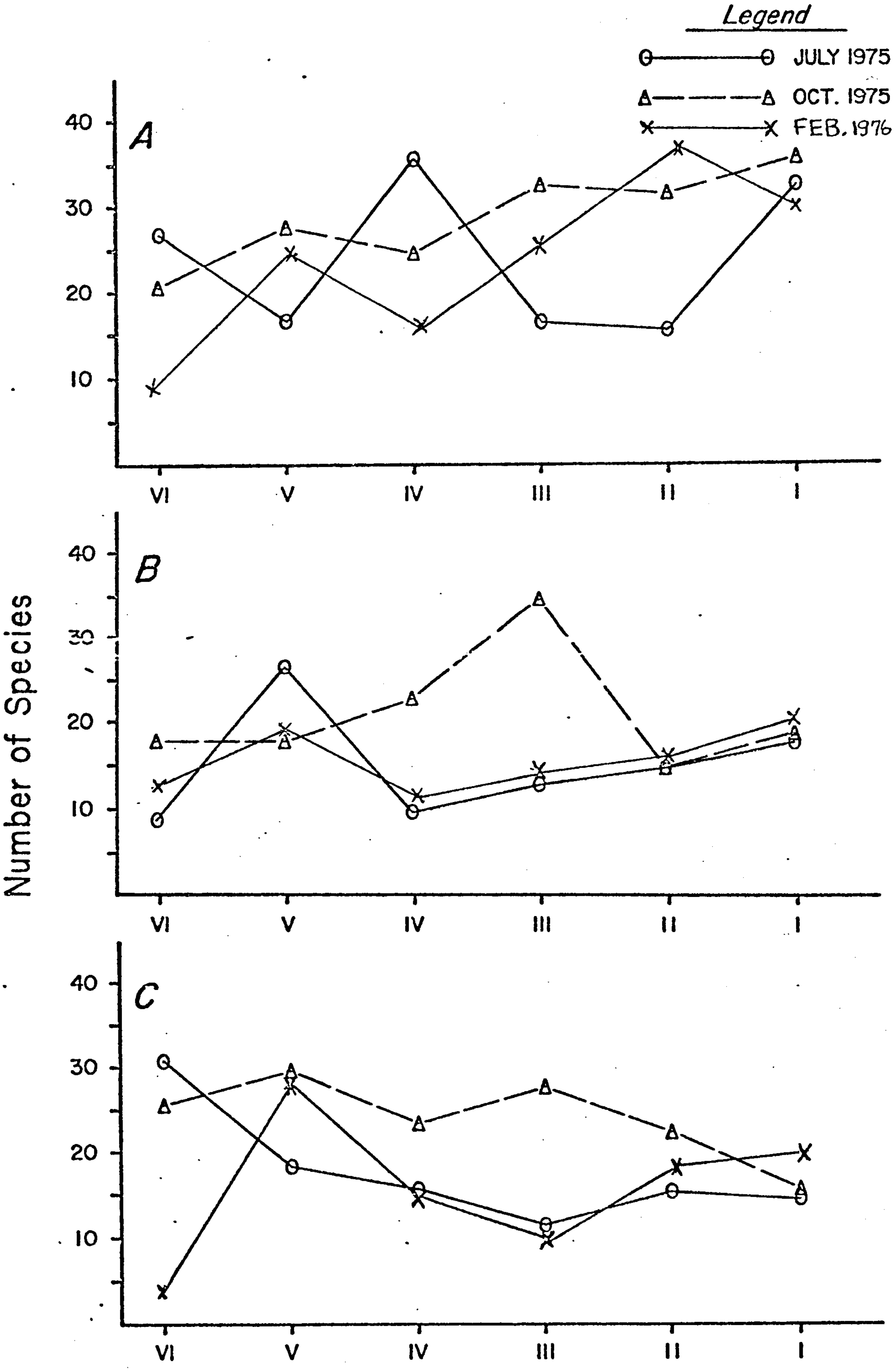

Legend
JULY 1975
OCT. 1975
FEB. 1976
Number of Species
A
B
C
40
30
20
10
VI
V
IV
III
II
I

Figure 3.

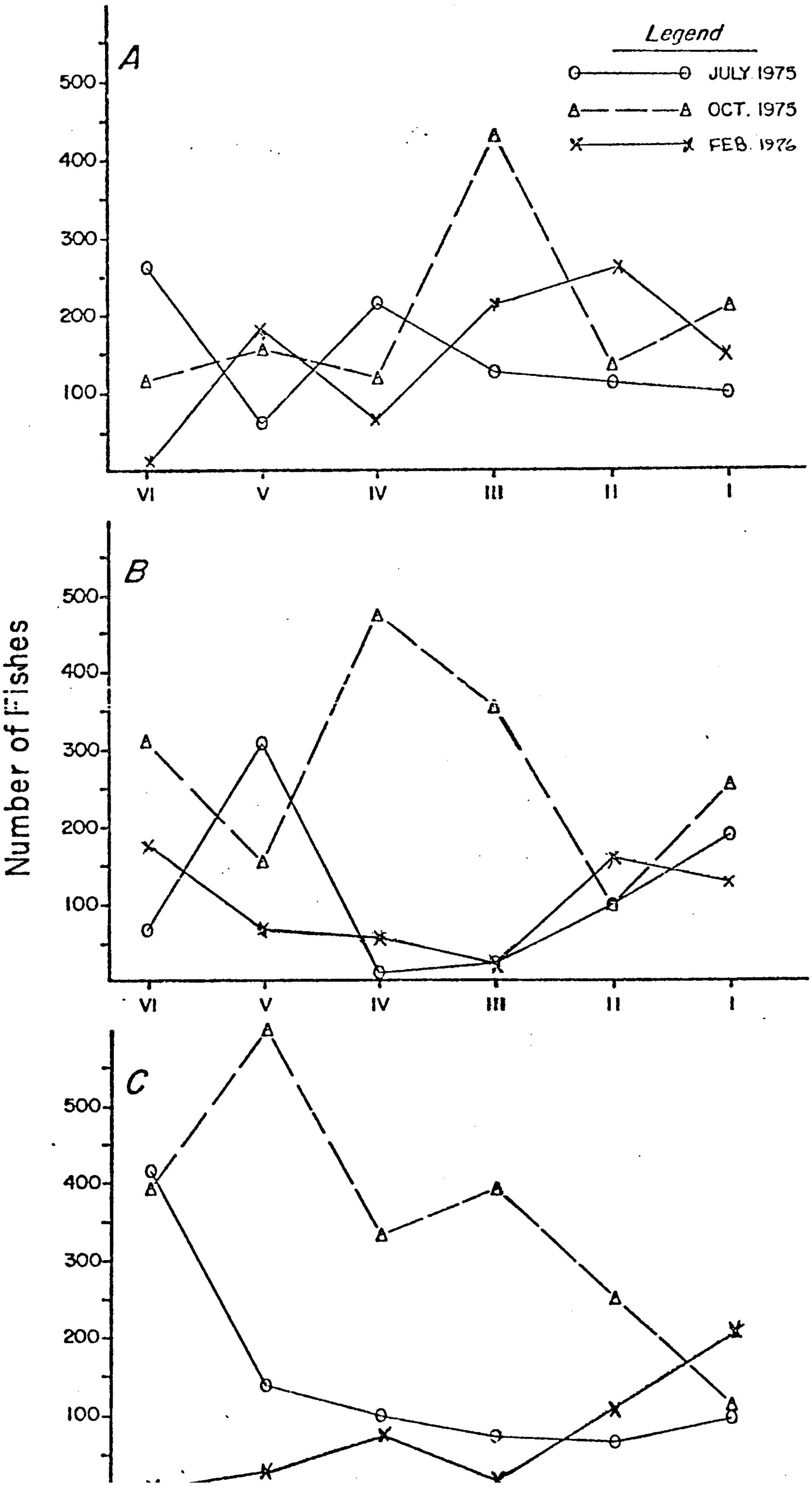

Legend
JULY 1975
OCT. 1975
FEB. 1976
A
B
C
Number of Fishes
500
400
300
200
100
VI
V
IV
III
II
I

Figure 4.

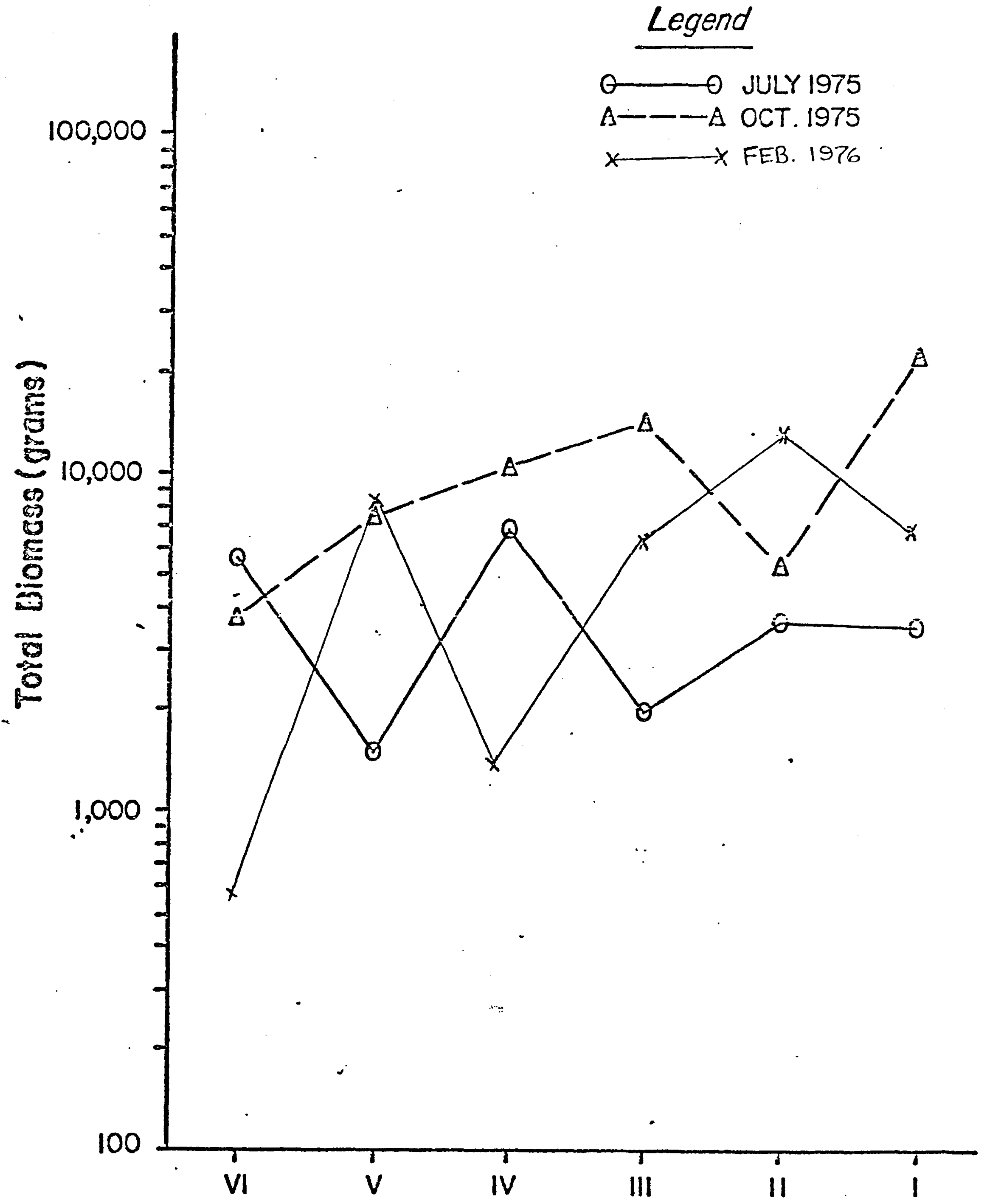


Figure 5. A Stations (20-30 fms)

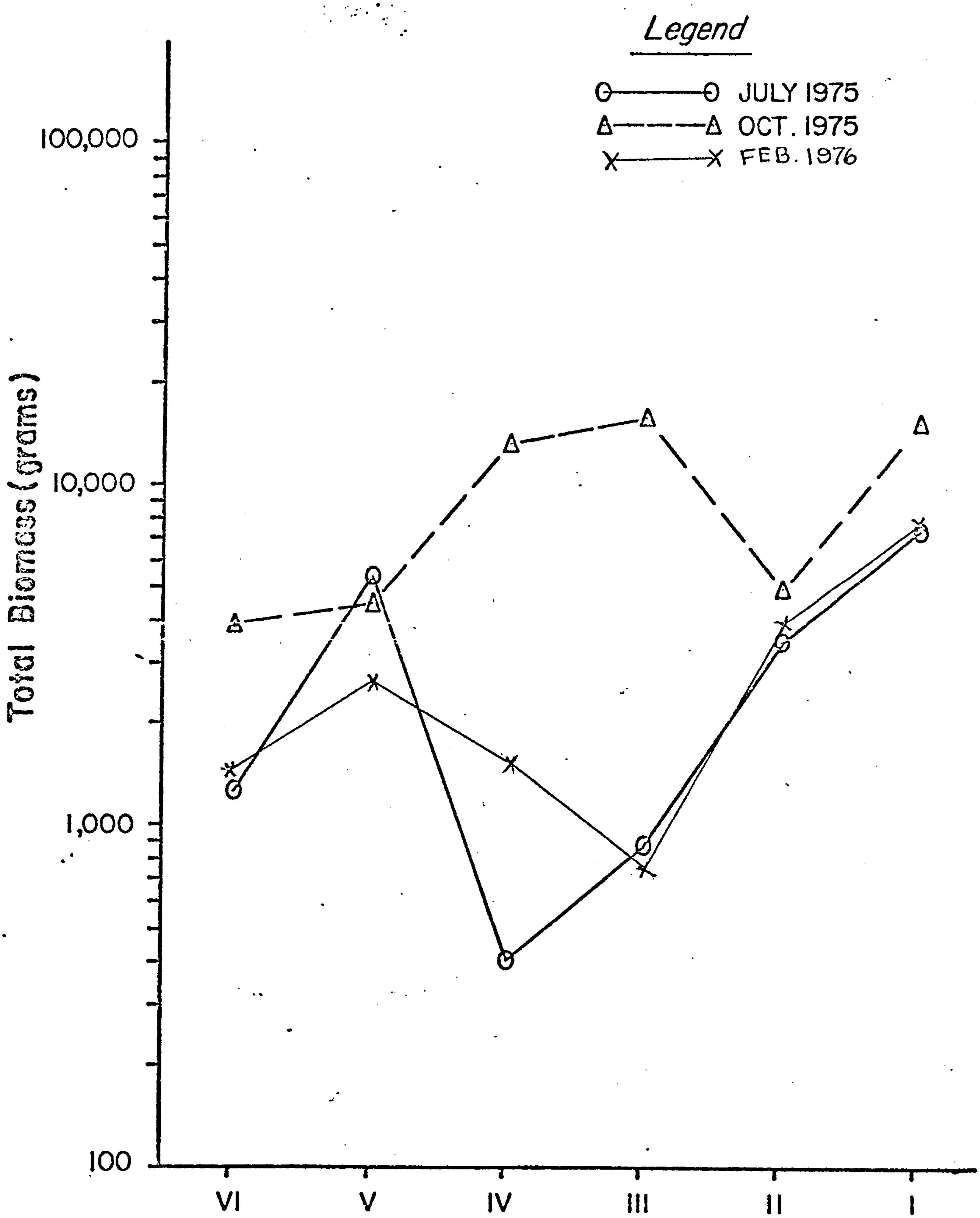


Figure 6. B Stations (50-60 fms)

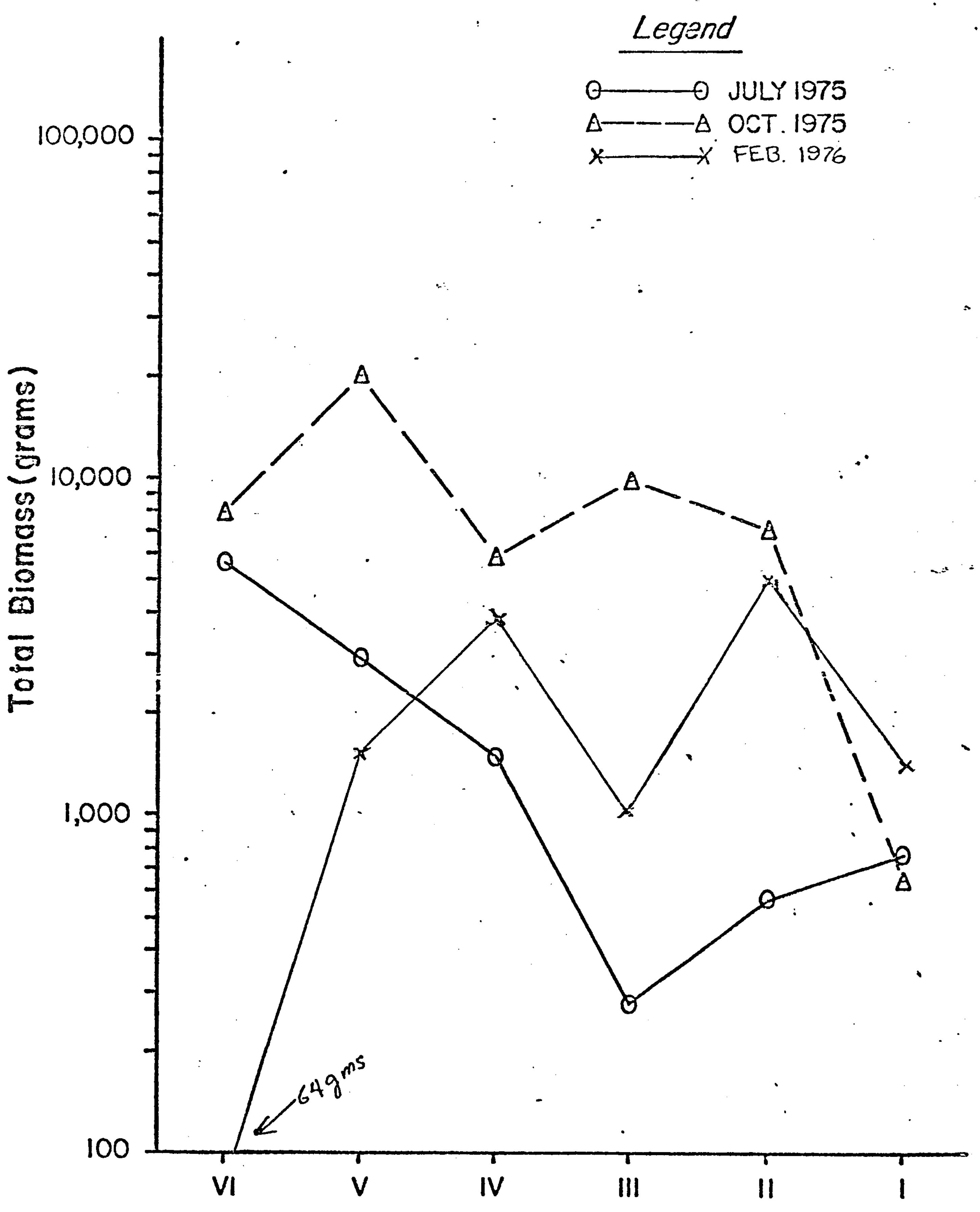


Figure 7. C Stations (80-100 fms)

Species dominance data, though still preliminary and in need of computer analysis, indicated a relatively uniform species assemblage between stations at similar depths. Exceptions were stations (especially shallow water) where relief or biogenic substrate harbored fauna differing from adjoining bottoms.

Further discussion of findings is premature and must await computer analysis of data. Species lists for each station and sampling season are presented in Appendix I. Length frequency data are presented in Appendix II.

APPENDIX I

Species Lists

Station I-A, Sample Period 1

Species	Number of Specimens	Wet Weight (gm)
Blennius marmoreus	1	2
Apogon quadrisquamatus	1	2
Coryphopterus punctipectophorus	1	0.3
Haliohoeres caudalis	1	0.9
Raja eglanteria	1	91
Synodus foetens	3	317
Synodus intermedius	2	56
Trachinocephalus myops	1	89
Opsanus pardus	1	12
Antennarius ocellatus	1	68
Ogcocephalus radiosus	2	941
Hippocampus erectus	1	12
Centropristis ocyurur	1	0.3
Diplectrum formosum	2	238
Hypoplectrus puella	4	160
Monocanthus ciliatus	3	32
Chromis enchrysurus	2	29
Sphoeroides spengleri	1	14
Halichoeres caudalis	1	84
Eupomacentrus variabilis	1	8
Emblemaria atlantica	1	2
Monacanthus hispidus	9	261
Blennius marmoreus	1	0.5
Syacium papillosum	31	1,302
Evermannichthys spongicola	1	0.1
Gobicsoma xanthiprora	1	0.1
Lythrypnus sp.	1	0.1
Prionotus ophryas	1	11
Prionotus roseus	6	205
Scorpaena sp.	1	26
Bothus ocellatus	1	34
Bothus robinsi	11	438
Citharichthys macrops	1	63
Etropus rimosus	5	42

Replicate Totals

Species	34
Animals	102
Sample weight (gm)	4,541

Shannon-Weaver Statistics

H Prime	2.7712
H Max	3.5264
J Prime	0.7858

Station II-A, Sample Period 1

Species	Number of Specimens	Wet Weight (gm)
Branchiostoma floridae	1	0.1
Prionotus martis	1	45
Prionotus roseus	1	1.2
Scorpaena calcarata	2	70
Syacium papillosum	1	15
Sphoeroides dorsalis	3	19
Raja texana	1	425
Synodus foetens	7	824
Centropristis ocyurus	1	1
Diplectrum formosum	2	282
Bellator militaris	42	149
Prionotus martis	1	68
Monacanthus hispidus	10	195
Prionotus ophryas	5	136
Syacium papillosum	23	571
Prionotus roseus	5	138
Cyclopsetta fimbriata	1	82
Scorpaena calcarata	4	145
Bothus robinsi	14	453
Citharichthys macrops	2	136

Replicate Totals

Species	20
Animals	127
Sample weight (gm)	3,755

Shannon-Weaver Statistics

H Prime	2.2317
H Max	2.9957
J Prime	0.7450

Station III-A, Sample Period 1

Species	Number of Specimens	Wet Weight (gm)
Emblemaria piratula	1	0.1
Opsanus parcus	1	2
Scorpaena calcarata	1	9
Lythrypnus nesiotes	2	0.1
Monacanthus sp.	1	15
Gymnothorax moringa	1	543
Lythrypnus sp.	1	0.1
Holocentrus bullisi	1	36
Hypoplectrus puella	1	19
Pristigenys alta	1	58
Chaetodon sedentarius	2	77
Holacanthus bermudensis	1	100
Chromis enchrysurus	7	57
Chromis scotti	92	544
Emblemaria atlantica	1	0.5
Lythrypnus nesiotes	2	0.1
Emblemaria piratula	1	0.1
Evermannichthys spongicola	10	0.9

Replicate Totals

Species	18
Animals	127
Sample weight (gm)	1,462

Shannon-Weaver Statistics

H Prime	1.2473
H Max	2.8904
J Prime	0.4315

Station IV-A, Sample Period 1

Species	Number of Specimens	Wet Weight (gm)
Branchiostoma floridae	37	0.7
Carapus bermudensis	1	0.6
Gillelus sp. A	1	0.5
Symphurus minor	1	2
Ioglossus sp.	2	0.1
Gymnothorax nigromarginatus	1	0.5
Scorpaena calcarata	1	27
Bothus robinsi	1	42
Emblemaria piratula	13	1
Syacium papillosum	22	1,204
Raja eglanteria	3	476
Gymnothorax nigromarginatus	1	131
Synodus intermedius	1	81
Trachinocephalus myops	2	218
Monacanthus ciliatus	11	243
Antennarius ocellatus	1	68
Halieutichthys aculeatus	14	231
Ogcocephalus parvus	1	16
Ogcocephalus sp.	3	182
Symphurus diomedianus	3	105
Ophidion holbrooki	7	566
Hippocampus erectus	1	22
Centropristis ocyurus	3	106
Diplectrum formosum	6	579
Rypticus bistrispinus	1	21
Monacanthus hispidus	22	681
Emblemaria piratula	24	2
Sphoeroides corsalis	3	108
Chilomycterus schoepfi	3	457
Bellator militaris	1	4
Prionotus martis	1	39
Prionotus ophryas	2	160
Prionotus roseus	3	155
Scorpaena erasiliensis	5	392
Scorpaena calcarata	8	213
Balistes capriscus	2	87
Acanthostracion quadricornis	1	158
Cyclopsetta fimbriata	3	224
Gastropsetta frontalis	1	47
Gymnachirus melas	2	112

Replicate Totals

Species	40
Animals	219
Sample weight (gm)	7,162

Station IV-A, Sample Period 1 - continued

Shannon-Weaver Statistics

H Prime	2.9922
H Max	3.6889
J Prime	0.8111

Station V-A, Sample Period 1

Species	Number of Specimens	Wet Weight (gm)
Branchiostoma floridae	17	1
Serranus notospilus	1	0.4
Emblemaria piratula	1	0.1
Emblemaria sp.	2	0.2
Palatagobius paradoxus	2	0.3
Symphurus minor	1	0.5
Risor ruber	1	0.1
Raja eglanteria	1	229
Gymnothorax nigromarginatus	2	125
Synodus intermedius	9	311
Trachinocephalus myops	1	143
Hemipteronotus novacula	5	178
Emblemaria piratula	9	0.3
Sphoeroides dorsalis	1	78
Syacium papillosum	5	351
Gymnachirus melas	1	68
Monacanthus ciliatus	1	19
Monacanthus hispidus	2	53
Chaenopsis sp.	1	0.1

Replicate Totals

Species	19
Animals	63
Sample weight (gm)	1,558

Shannon-Weaver Statistics

H Prime	2.4073
H Max	2.9444
J Prime	0.8176

Station VI-A, Sample Period 1

Species	Number of Specimens	Wet Weight (gm)
Etropus rimosus	2	1.8
Ophichthus gomesi	1	121
Sardinella anchovia	5	122
Saurida brasiliensis	2	4
Synodus foetens	1	48
Trachinocephalus myops	11	631
Porichthys porosissimus	3	88
Bregmaceros atlanticus	1	0.7
Lepophidium jeannae	1	7
Ophidion sp.	2	77
Ophidion holbrooki	1	89
Otophidium omostigmum	2	15
Diplectrum bivittatum	3	8
Trachurus lathami	1	9
Vomer setapinnis	1	0.8
Stenotomus caprinus	2	115
Equetus sp.	1	2
Bellator militaris	11	14
Prionotus roseus	22	232
Prionotus rubio	2	39
Prionotus salmonicolor	12	631
Peprilus burti	1	2
Citharichthys macrops	1	36
Cyclopsetta chittendeni	1	155
Cyclopsetta fimbriata	1	8
Etropus rimosus	126	439
Syacium papillosum	102	2,740
Gymnachirus melas	2	65

Replicate Totals

Species	28
Animals	321
Sample weight	5,704

Shannon-Weaver Statistics

H Prime	1.8585
H Max	3.3322
J Prime	0.5578

Station I-B, Sample Period 1

Species	Number of Specimens	Wet Weight (gm)
Ogcocephalus sp. (corniger)	1	12
Scorpaena agassizi	1	26
Halieutichthys aculeatus	4	48
Bellator militaris	1	33
Serranus notospilus	1	0.2
Monacanthus ciliatus	1	28
Hippocampus erectus	2	12
Syacium papillosum	3	221
Syacium papillosum	29	1,271
Bellator militaris	33	855
Scorpaena sp.	1	0.1
Scorpaena agassizi	45	1,506
Serranus notospilus	1	1
Monacanthus ciliatus	3	69
Halieutichthys aculeatus	10	122
Hippocampus erectus	2	15
Synodus intermedius	14	472
Saurida normani	8	620
Trachinocephalus myops	8	542
Symphurus diomedianus	1	36
Ophidion holbrooki	1	21
Monacanthus hispidus	3	109
Ogcocephalus parvus	1	5
Sphoeroides dorsalis	10	667
Prionotus alatus	9	427

Replicate Totals

Species	25
Animals	193
Sample weight (gm)	7,618

Shannon-Weaver Statistics

H Prime	2.4721
H Max	3.2189
J Prime	0.7680

Station II-B, Sample Period 1

Species	Number of Specimens	Wet Weight (gm)
Syacium papillosum	16	199
Prionotus alatus	5	203
Saurida normani	4	571
Pagrus pagrus	1	223
Pristipomoides aquilonaris	2	226
Synodus intermedius	1	49
Ogcocephalus parvus	3	38
Gymnothorax nigromarginatus	1	36
Lophiomus sp.	2	80
Serranus notospilus	1	0.6
Kathetostoma albigutta	7	342
Halieutichthys aculeatus	15	99
Citharichthys cornutus	2	6
Prionotus sp.	4	0.8
Scorpaena agassizi	36	949

Replicate Totals

Species	15
Animals	100
Sample weight (gm)	3,022

Shannon-Weaver Statistics

H Prime	2.0631
H Max	2.7080
J Prime	0.7619

Station III-B, Sample Period 1

Species	Number of Specimens	Wet Weight (gm)
Chriolepis sp.	1	0.1
Lythrypnus nesiotes	1	0.1
Muraena retifera	1	96
Kathetostoma albigutta	1	23
Neomerinthe hemingwayi	1	38
Saurica normani	1	140
Synodus intermedius	3	141
Syacium papillosum	4	142
Chromis enchrysurus	1	5
Prionotus alatus	4	99
Bellator militaris	3	81
Centropristis ocyurus	2	66
Sphoeroides ocrsalis	1	36

Replicate Totals

Species	13
Animals	24
Sample weight (gm)	867

Shannon-Weaver Statistics

H Prime	2.3835
H Max	2.5649
J Prime	0.9293

Station IV-B, Sample Period 1

Species	Number of Specimens	Wet Weight (gm)
Citharichthys cornutus	2	5
Peristedion gracile	3	82
Raja texana	1	12
Halieutichthys aculeatus	1	10
Prionotus stearnsi	1	14
Centropristis ocyurus	1	27
Lepophidium jeannae	1	44
Monacanthus hispidus	1	42
Symphurus diomedianus	3	87
Syacium papillosum	2	87

Replicate Totals

Species	10
Animals	16
Sample weight (gm)	410

Shannon-Weaver Statistics

H Prime	2.1873
H Max	2.3026
J Prime	0.9499

Station V-B, Sample Period 1

Species	Number of Specimens	Wet Weight (gm)
Decodon puellaris	1	41
Mullus auratus	1	58
Centropristis ocyurus	1	44
Serranus notospilus	1	1
Hemanthias leptus	1	2
Monclene antillarum	1	5
Trachurus lathami	1	30
Pontinus longispinis	9	305
Pristipomoides aquilonaris	14	386
Citharichthys cornutus	5	14
Bembrops anatirostris	4	207
Synodus poeyi	4	31
Urophycis floridanus	3	148
Callionymus agassizi	3	39
Peristedion gracile	13	193
Stenotomus caprinus	4	179
Serranus atrobranchus	4	88
Halieutichthys aculeatus	6	60
Pikea mexicana	13	126
Trichopsetta ventralis	8	98
Ogcocephalus sp.	4	51
Saurida erasiliensis	2	4
Bregmaceros atlanticus	2	0.5
Physiculls sulvus	2	7
Syacium papillosum	1	55
Ariomma bondi	1	10
Prionctus stearnsi	198	3,051

Replicate Totals

Species	27
Animals	307
Sample weight (gm)	5,234

Shannon-Weaver Statistics

H Prime	1.6734
H Max	3.2958
J Prime	0.5077

Station VI-B, Sample Period 1

Species	Number of Specimens	Wet Weight (gm)
Syacium papillosum	22	717
Citharichthys cornutus	20	66
Synodus poeyi	1	16
Ogcocephalus sp. (corniger)	1	27
Ogcocephalus sp. (declavirostris)	2	24
Cyclopsetts fimbriata	2	295
Bellator egretta	1	11
Serranus atrobranchus	1	4
Serranus notospilus	18	129

Replicate Totals

Species	9
Animals	68
Sample weight (gm)	1,289

Shannon-Weaver Statistics

H Prime	1.5325
H Max	2.1972
J Prime	0.6975

Station I-C, Sample Period 1

Species	Number of Specimens	Wet Weight (gm)
Antigonia capros	7	372
Synodus poeyi	1	5
Saurida normani	3	129
Callionymus agassizi	1	10
Serranus notospilus	13	124
Prionotus stearnsi	6	31
Parahollardia lineata	1	5
Lonchistium sp. A.	1	4
Zalieutes mcgintyi	3	6
Citharichthys cornutus	23	82

Replicate Totals

Species	10
Animals	59
Sample weight (gm)	768

Shannon-Weaver Statistics

H Prime	1.7653
H Max	2.3026
J Prime	0.7666

Station II-C, Sample Period 1

Species	Number of Specimens	Wet Weight (gm)
Antennarius radiosus	2	9
Parahollardia lineata	1	27
Urophycis floridanus	3	232
Scorpaena agassizi	5	205
Zalieutes mcgintyi	2	13
Serranus notospilus	2	15
Bellator egretta	1	21
Citharichthys cornutus	8	35
Syacium sp.	1	0.4
Lonchistium sp. A.	1	1.8
Chriolepis sp. A.	1	0.3

Replicate Totals

Species	11
Animals	27
Sample weight (gm)	560

Shannon-Weaver Statistics

H Prime	2.1056
H Max	2.3979
J Prime	0.8781

Station III-C, Sample Period 1

Species	Number of Specimens	Wet Weight (gm)
Saurida normani	1	73
Urophycis floridanus	1	65
Scorpaena agassizi	2	71
Citharichthys cornutus	11	45
Zalieutes mcgintyi	5	23
Bollmania sp. A.	1	0.5
Chriolepis sp. A.	8	2

Replicate Totals

Species	7
Animals	29
Sample weight (gm)	280

Shannon-Weaver Statistics

H Prime	1.5588
H Max	1.9459
J Prime	0.8011

Station IV-C, Sample Period 1

Species	Number of Specimens	Wet Weight (gm)
Urophycis floridanus	5	639
Prionotus alatus	2	90
Scorpaena agassizi	2	62
Zalieutes mcgintyi	18	72
Bembrops anatirostris	4	139
Monolene sessilicauda	2	29
Saurida normani	6	348
Citharichthys cornutus	9	43
Pristipomoides aquilonaris	1	2
Chriolepis sp. A.	2	0.8
Mullus auratus	1	65

Replicate Totals

Species	11
Animals	52
Sample weight (gm)	1,490

Shannon-Weaver Statistics

H Prime	1.9957
H Max	2.3979
J Prime	0.8323

Station V-C, Sample Period 1

Species	Number of Specimens	Wet Weight (gm)
Parahollardia lineata	1	55
Lophiomus sp.	1	109
Prionotus alatus	5	216
Saurida normani	2	172
Hemanthias leptus	1	45
Trichopsetta ventralis	3	136
Citharichthys cornutus	4	29
Neobythites gilli	1	8
Paralichthys squamilentis	1	244
Urophycis floridanus	3	378
Monolene sessilicauda	21	305
Pontinus longispinis	24	1,476
Bembrops anatirostris	16	730
Zalieutes mcgintyi	9	53

Replicate Totals

Species	14
Animals	92
Sample weight (gm)	3,956

Shannon-Weaver Statistics

H Prime	2.0662
H Max	2.6391
J Prime	0.7829

Station VI-C, Sample Period 1

Species	Number of Specimens	Wet Weight (gm)
Neomerinthe hemingwayi	1	478
Lopholatilus chamaeleonticeps	1	403
Argentina striata	3	85
Hemanthias leptus	12	234
Poecilopsetta beani	6	61
Callionymus agassizi	3	50
Brmbrops anatirostris	28	909
Decapterus punctatus	4	280
Urophycis floridanus	1	155
Neoepinnula orientalis	2	166
Lepophidium sp. A.	3	47
Neobythites gilli	1	11
Antigonia combatia	3	21
Zalieutes mcgintyi	2	12
Ogcocephalus nasutus	4	85
Ogcocephalus vespertilio	3	143
Pontinus longispinis	20	448
Monolene sessilicauda	4	16
Prionotus paralatus	3	121
Prionotus stearnsi	26	582
Synagrops spinosa	15	155
Diaphus dumerili	4	10
Macrorhamphosus scolopax	173	858
Polymixia lowei	30	295
Peristedion gracila	16	33
Pikea mexicanus	1	29

Replicate Totals

Species	26
Animals	369
Sample weight (gm)	5,687

Shannon-Weaver Statistics

H Prime	2.1120
H Max	3.2581
J Prime	0.6482

Station I-A, Sample Period 2

Species	Number of Specimens	Wet Weight (gm)
Etropus rimosus	1	17
Antennarius ocellatus	2	31
Symphurus diomedianus	1	27
Symphurus minor	1	0.1
Syacium papillosum	2	72
Monacanthus ciliatus	1	8
Centropristis ocyurus	1	6
Prionotus roseus	1	20
Scorpaena erasiliensis	1	29
Halieutichthys aculeatus	6	31
Synodus intermedius	2	162
Bothus robinsi	1	35
Sphoeroides spengleri	3	226
Hypoplectrus puella	3	96
Diplectrum formosum	3	274
Lutjanus synagris	4	809
Syacium papillosum	60	2,173
Trachinocephalus myops	1	75
Synodus foetens	1	245
Lactophrys quadricornis	5	1,286
Prionotus ophryas	4	418
Monacanthus hispidus	14	716
Chromis enchrysurus	1	14
Equetus lanceclatus	8	480
Equetus umbrosus	3	310
Monacanthus ciliatus	5	77
Centropristis ocyurus	2	26
Prionotus roseus	2	180
Pomacanthus arcuatus	1	423
Holacanthus bermudensis	5	1,579
Aluterus schoepfi	4	3,171
Priacanthus arenatus	2	898
Apogon aurolineatus	2	1
Scorpaena erasiliensis	4	498
Scorpaena calcarata	2	86
Ophidion sp.	9	1,038
Phaeoptyx pigmentaria	1	2
Apogon pseudomaculatus	2	17
Gobiesox strumosus	1	5
Canamus proridens	19	4,658
Haemulon aurolineatum	25	2,374

Replicate Totals

Species	41
Animals	216
Sample weight (gm)	22.593

Shannon-Weaver Statistics

H Prime	2.8837
H Max	3.7136
J Prime	0.7765

Station II-A, Sample Period 2

Species	Number of Specimens	Wet Weight (gm)
Halieutichthys aculeatus	1	18
Cyclopsetta fimbriata	1	100
Monacanthus ciliatus	3	41
Bothus robinsi	1	44
Scorpaena calcarata	3	33
Monacanthus hispidus	18	579
Prionotus salnomicolor	1	64
Aluterus schoepfi	2	58
Scorpaena erasiliensis	5	376
Haemulon aurolineatum	1	99
Hippocampus erectus	1	8
Bothus Robinsi	1	22
Equetus lanceclatus	2	127
Diplectrum formosum	1	110
Centropristis ocyurus	2	184
Prionotus ophryas	3	129
Chilomycterus schoepfi	1	266
Bellator militaris	1	14
Lactophrys quadricornis	1	318
Balistes capriscus	3	252
Synodus intermedius	5	296
Synodus foetens	9	913
Prionotus roseus	10	432
Sphoeroides spengleri	4	171
Sphoeroides dorsalis	7	249
Monacanthus ciliatus	12	216
Etropus rimosus	11	88
Svacium papillosum	15	183
Saurida erasiliensis	1	0.5
Synodus poeyi	2	5
Lythrypnus nesiotes	2	0.2
Emblemaria piratula	1	0.1
Blennius marmoreus	3	2
Pristigenys alta	4	100

Replicate Totals

Species	34
Animals	138
Sample weight (gm)	5,498

Shannon-Weaver Statistics

H Prime	3.0732
H Max	3.5264
J Prime	0.8715

Station III-A, Sample Period 2

Species	Number of Specimens	Wet Weight (gm)
Scorpaena calcarata	1	15
Bothus robinsi	1	36
Diplectrum formosum	1	108
Scorpaena calcarata	73	1,496
Bothus robinsi	31	960
Diplectrum formosum	2	119
Prionotus ophryas	1	43
Lythrypnus elasson	1	0.1
Gastropsetta frontalis	3	155
Trachinocephalus myops	4	207
Centropristis ocyurus	7	197
Gymnothorax nigromarginatus	2	225
Sphoeroides spengleri	3	158
Antennarius ocellatus	1	42
Rhomboplites aurorubens	2	23
Synodus poeyi	2	55
Sphoeroides dorsalis	1	35
Prionotus alatus	1	17
Monacanthus ciliatus	1	26
Sphoeroides sp.	1	0.4
Ioglossus sp.	1	0.1
Monacanthus hispidus	3	80
Chromis scotti	1	2
Apogon pseudomaculatus	2	7
Apogon aurolineatus	1	2
Decapterus punctatus	1	18
Halieutichthys aculeatus	2	32
Synodus intermedius	13	653
Serranus phoebe	14	825
Prionotus roseus	28	1,228
Bellator militaris	13	287
Hippocampus erectus	3	39
Cyclopsetta fimbriata	3	173
Astrapogon alutus	2	4
Haemulon aurolineatum	90	2,564
Syacium papillosum	119	5,000

Replicate Totals

Species	36
Animals	435
Sample weight (gm)	14,832

Shannon-Weaver Statistics

H Prime	2.3152
H Max	3.5835
J Prime	0.6461

Station IV-A, Sample Period 2

Species	Number of Specimens	Wet Weight (gm)
Ogcocephalus sp. (corniger)	1	63
Bothus robinsi	1	40
Chilomycterus schoepfi	1	33
Emblemaria piratula	2	0.2
Halieutichthys aculeatus	3	99
Aluterus schoepfi	9	4,253
Sardinella anchovia	1	52
Decapterus punctatus	1	39
Scorpaena calcarata	2	54
Ophidion sp.	1	50
Scorpaena erasiliensis	8	646
Echeneis neucratoides	2	588
Symphurus diomedianus	1	35
Balistes capriscus	1	18
Monacanthus ciliatus	2	45
Sphoeroides dorsalis	2	45
Gymnothorax nigromarginatus	3	218
Prionotus ophryas	4	211
Monacanthus hispidus	23	607
Synodus intermedius	12	651
Risor ruber	2	0.2
Raja eglanteria	1	161
Diplectrum formosum	20	1,635
Centropristis ocyurus	16	865
Syacium papillosum	3	190

Replicate Totals

Species	25
Animals	122
Sample weight (gm)	10,598

Shannon-Weaver Statistics

H Prime	2.6206
H Max	3.2189
J Prime	0.8141

Station V-A, Sample Period 2

Species	Number of Specimens	Wet Weight (gm)
Prionotus roseus	1	63
Antennarius ocellatus	2	25
Kathetostoma albigutta	1	100
Anarchias yoshiae	1	3
Syacium papillosum	5	95
Ogcocephalus parvus	2	28
Monacanthus hispicus	1	23
Ariosoma impressa	1	26
Ogcocephalus sp. (corniger)	1	22
Branchiostoma sp.	16	2
Ophidion sp.	3	183
Scorpaena calcarata	3	46
Hippocampus erectus	2	21
Monacanthus hispidus	2	71
Sphoeroides corsalis	2	93
Chilomycterus schoepfi	1	218
Hemipteronotus novacula	8	387
Synodus intermedius	5	284
Diplectrum formosum	3	279
Trachinocephalus mupos	6	748
Gymnothorax nigromarginatus	17	1,203
Prionotus roseus	13	758
Gobulus sp.	1	0.1
Synodus poeyi	3	4
Chaenopsis sp.	1	.1
Lythrypnus elasson	1	.1
Symphurus minor	1	.6
Pristigenys alta	1	13
Porichthys porosissimus	1	38
Centropristis ocyurus	12	708
Syacium papillosum	40	2,212

Replicate Totals

Species	31
Animals	157
Sample weight (gm)	7,654

Shannon-Weaver Statistics

H Prime	2.7197
H Max	3.4340
J Prime	0.7920

Station VI-A, Sample Period 2

Species	Number of Specimens	Wet Weight (gm)
Symphurus diomedianus	1	34
Syacium papillosum	1	36
Etropus rimosus	6	23
Prionotus roseus	2	39
Syacium gunteri	1	25
Syacium gunteri	14	194
Prionotus roseus	8	239
Synodus foetens	8	656
Diplectrum bivtitatum	4	27
Rhomboplites aurorubens	2	64
Pagrus pagrus	1	259
Prionotus rubio	1	26
Centropristis ocyurus	3	274
Syacium papillosum	34	1,381
Synodus poeyi	1	3
Saurida brasiliensis	1	0.5
Symphurus minor	1	0.1
Cyclopsetta chittendeni	1	113
Cyclopsetta fimbriata	1	152
Etropus rimosus	18	55
Prionotus salmonicolor	2	95
Prionotus ophryas	4	60
Engyophrys senta	1	2
Hemipteronotus novacula	1	39
Serranus atrobranchus	2	12

Replicate Totals

Species	25
Animals	119
Sample weight (gm)	3,809

Shannon-Weaver Statistics

H Prime	2.4865
H Max	3.2189
J Prime	0.7725

Station I-B, Sample Period 2

Species	Number of Specimens	Wet Weight (gm)
Halieutichthys aculeatus	1	9
Ogcocephalus sp.	1	71
Scorpaena agassizi	1	0.6
Citharichthys gymnorhinus	1	0.5
Gymnothorax nigromarginatus	4	222
Saurida sp.	1	40.1
Saurida normani	3	42.7
Synodus intermedius	25	1,612
Synodus poeyi	1	2
Trachinocephalus myops	22	1,343
Halieutichthys aculeatus	4	40
Citharichthys gymnorhinus	1	0.8
Monacanthus ciliatus	1	19
Hippocampus erectus	3	23
Bellator militaris	5	142
Prionotus alatus	23	1,131
Scorpaena agassizi	20	717
Monacanthus hispidus	2	66
Centropristis ocyurus	4	201
Kathetostoma albigutta	2	103
Syacium papillosum	127	8,436
Sphoeroides dorsalis	3	183

Replicate Totals

Species	22
Animals	255
Sample weight (gm)	14,749

Shannon-Weaver Statistics

H Prime	1.8822
H Max	3.0910
J Prime	0.6089

Station II-B, Sample Period 2

Species	Number of Specimens	Wet Weight (gm)
Lepophidium graellsi	1	6
Gymnothorax nigromarginatus	4	412
Synodus intermedius	7	314
Saurida normani	18	1,460
Halieutichthys aculeatus	1	9
Sphoeroides dorsalis	2	85
Bellator egretta	1	30
Prionotus alatus	7	299
Scorpaena agassizi	10	411
Serranus notospilus	2	6
Pristipomoides aquilunaris	1	92
Priacanthus arenatus	1	224
Lagodon rhomboides	2	133
Syacium papillosum	40	1,880

Replicate Totals

Species	14
Animals	97
Sample weight (gm)	5,361

Shannon-Weaver Statistics

H Prime	1.8989
H Max	2.6391
J Prime	0.7195

Station III-B, Sample Period 2

Species	Number of Specimens	Wet Weight (gm)
Lophiomus sp.	1	39
Gymnothorax nigromarginatus	1	95
Synodus intermedius	13	783
Trachinocephalus myops	6	313
Urophycis floridana	2	99
Urophycis regius	3	210
Halieutichthys aculeatus	5	58
Lephophidium jeannae	1	52
Sphoéroides dorsalis	5	245
Bellator militaris	36	866
Prionotus alatus	16	748
Scorpaena agassizi	3	114
Centropristis ocyurus	24	1,558
Scorpaena dispar	14	910
Scorpaena sp.	1	0.3
Holocentrus bullisi	2	89
Serranus notospilus	2	2
Rypticus bistrispinus	3	39
Serranus phoebe	28	1,346
Equetus sp.	5	243
Pristigenys alta	2	86
Chromis enchrysurus	3	82
Chaetodon aya	14	331
Chaetodon sedentarius	2	98
Lagodon rhomboides	42	3,289
Zalieutes mcgintyi	2	9
Stenotomus caprinus	1	84
Kathetostoma albigutta	4	191
Pagrus pagrus	2	150
Mullus auratus	12	752
Syacium papillosum	32	1,025
Symphurus diomedianus	3	79
Holacanthus bermudensis	1	448
Monacanthus ciliatus	56	1,142
Monacanthus hispidus	11	343
Acanthostracion quadricornis	1	79

Replicate Totals

Species	36
Animals	359
Sample weight (gm)	15,997

Shannon-Weaver Statistics

H Prime	2.9131
H Max	3.5835
J Prime	0.8129

Station IV-B, Sample Period 2

Species	Number of Specimens	Wet Weight
Prionotus alatus	3	23
Syacium papillosum	5	163
Gymnothorax nigromarginatus	6	696
Synodus intermedius	7	330
Synodus foetens	1	99
Saurida normani	3	196
Halieutichthys aculeatus	5	50
Urophycis regius	4	151
Lepophidium jeannae	2	52
Bellator militaris	182	2,554
Prionotus alatus	32	568
Symphurus diomedianus	6	143
Prionotus stearnsi	4	67
Prionotus roseus	2	65
Prionotus salmonicolor	7	442
Peristidion gracile	127	3,857
Centropristis ocyurus	23	919
Kathetostoma albigutta	1	29
Stenotomus caprinus	6	406
Lagodon rhomboides	2	152
Mullus auratus	5	280
Syacium papillosum	38	1,554
Sphoeroides dorsalis	1	38
Citharichthys gymnorhinus	1	2

Replicate Totals

Species	24
Animals	473
Sample weight (gm)	12,836

Shannon-Weaver Statistics

H Prime	1.9539
H Max	3.1781
J Prime	0.6148

Station V-B, Sample Period 2

Species	Number of Specimens	Wet Weight (gm)
Synodus intermedius	12	826
Synodus poeyi	3	44
Saurida normani	3	190
Trachinocephalus myops	12	733
Urophycis regius	29	1,247
Bellator militaris	3	42
Prionotus stearnsi	1	10
Prionotus roseus	4	170
Prionotus salmonicolor	1	80
Centropristis ocyurus	6	247
Trachurur lathami	8	261
Mullus auratus	6	326
Syacium papillosum	6	244
Citharichthys cornutus	1	3
Paralichthys squamilentis	1	101
Sphoeroides dorsalis	2	87
Stenotomus caprinus	16	633

Replicate Totals

Species	17
Animals	114
Sample weight (gm)	5,244

Shannon-Weaver Statistics

H Prime	2.3910
H Max	2.8332
J Prime	0.8439

Station VI-B, Sample Period 2

Species	Number of Specimens	Wet Weight (gm)
Opistognathidae	1	3
Gymnothorax nigromarginatus	1	87
Raja texana	1	340
Ophichthus ocellatus	1	82
Synodus poeyi	9	98
Halieutichthys aculeatus	5	5
Ogcocephalus vespertilio	1	3
Bellator egretta	5	86
Scorpaena agassizi	8	117
Serranus notospilus	212	1,185
Pristipomoides aquilonaris	33	227
Synagrops spinosa	7	193
Trachurus lathami	2	119
Mustelus canis	1	417
Opistognathidae	1	0.7
Kathetostoma albigutta	1	47
Syacium papillosum	24	1,350
Parahollardia lineata	1	11
Sphoeroides dorsalis	1	0.3

Replicate Totals

Species	19
Animals	315
Sample weight (gm)	4,371

Shannon-Weaver Statistics

H Prime	1.3247
H Max	2.9444
J Prime	0.4499

Station I-C, Sample Period 2

Species	Number of Specimens	Wet Weight (gm)
Hemanthias leptus	4	7
Saurida normani	1	344
Serranus notospilus	2	16
Pontinus rathbuni	2	29
Lonchistium sp. A.	1	3
Prionotus stearnsi	25	134
Antigonia capros	1	19
Saurida brasiliensis	7	12
Citharichthys cornutus	20	53
Zalieutes mcgintyi	8	32
Bellator brachychir	1	0.3

Replicate Totals

Species	11
Animals	72
Sample weight (gm)	649

Shannon-Weaver Statistics

H Prime	1.7911
H Max	2.3979
J Prime	0.7469

Station II-C, Sample Period 2

Species	Number of Specimens	Wet Weight (gm)
Ancylopsetta dilecta	5	206
Urophycis regius	1	83
Urophycis cirratus	2	98
Urophycis floridanus	11	1,919
Pristipomoides aquilonaris	1	108
Glossanodon pygmaeus	1	1
Halieutichthys aculeatus	1	0.7
Scorpaena agassizi	10	471
Lepophidium sp. B	30	419
Serranus notospilus	4	32
Lepophidium sp. C	13	854
Prionotus stearnsi	1	15
Citharichthys cornutus	80	312
Pikea mexicanus	1	4
Gymnothorax nigromarginatus	3	381
Saurida normani	21	1,516
Raja garmani	8	653
Zalieutes mcgintyi	17	58

Replicate Totals

Species	18
Animals	210
Sample weight (gm)	7,131

Shannon-Weaver Statistics

H Prime	2.0978
H Max	2.8904
J Prime	0.7258

Station III-C, Sample Period 2

Species	Number of Specimens	Wet Weight (gm)
Mullus auratus	1	88
Bembrops anatirostris	19	901
Bellator egretta	3	78
Prionotus alatus	12	640
Lophiomus sp.	7	592
Urophycis floridanus	12	1,304
Pristipomoides aquilonaris	10	1,362
Trichopsetta ventralis	1	34
Saurida normani	21	1,692
Scorpaena agassizi	34	1,492
Bellator brachychir	8	9
Synodus poeyi	17	30
Ancylopsetta dilecta	13	772
Antigonia capros	1	12
Zalieutes mcgintyi	18	64
Citharichthys cornutus	143	534
Serranus notospilus	3	7
Pikea mexicanus	1	1
Prionotus stearnsi	2	8
Pontinus rathbuni	1	3
Glossanodon pygmaeus	4	2
Saurida brasiliensis	12	14
Gymnothorax nigromarginatus	2	190

Replicate Totals

Species	23
Animals	345
Sample weight (gm)	9,829

Shannon-Weaver Statistics

H Prime	2.2475
H Max	3.1355
J Prime	0.7168

Station IV-C, Sample Period 2

Species	Number of Specimens	Wet Weight (gm)
Pontinus longispinis	1	63
Prionotus stearnsi	3	6
Parahollardia lineata	1	63
Urophycis floridanus	2	256
Saurida normani	12	953
Lophiomus sp.	2	239
Trichopsetta ventralis	1	47
Prionotus alatus	14	811
Scorpaena agassizi	20	795
Ancylopsetta dilecta	2	134
Saurida brasiliensis	10	12
Synodus poeyi	3	8
Citharichthys cornutus	112	299
Zalieutes mcgintyi	74	297
Bembrops anatirostris	18	880
Pristipomoides aquilonaris	6	1,052
Monolene sessilicauda	4	57
Glossanodon pygmaeus	3	2
Serranus notospilus	2	5

Replicate Totals

Species	19
Animals	290
Sample weight (gm)	5,979

Shannon-Weaver Statistics

H Prime	1.9442
H Max	2.9444
J Prime	0.6603

Station V-C, Sample Period 2

Species	Number of Specimens	Wet Weight (gm)
Bembrops anatirostris	134	4,054
Saurida normani	16	2,563
Antigonia capros	2	116
Zenopsis ocellata	1	59
Paralichthys squamilentis	1	203
Trichopsetta ventralis	10	496
Pikea mexicanus	23	454
Decodon puellaris	4	145
Ancylopsetta dilecta	1	75
Ogcocephalus vespertilio	1	59
Saurida brasiliensis	8	20
Pontinus longispinis	148	6,421
Prionotus stearnsi	1	12
Serranus notospilus	7	50
Prionotus alatus	29	1,537
Zalieutes mcgintyi	38	197
Synagrops bella	3	3
Monolene sessilicauda	55	644
Citharichthys cornutus	46	136
Lophiomus sp.	3	359
Urophycis floridanus	10	1,632
Pristipomcides aquilonaris	8	1,152
Bellator egretta	1	19
Ophidiidae sp. A	1	0.3
Argentina striata	1	0

Replicate Totals

Species	25
Animals	552
Sample weight (gm)	20,406

Shannon-Weaver Statistics

H Prime	2.2352
H Max	3.2189
J Prime	0.6944

Station VI-C, Sample Period 2

Species	Number of Specimens	Wet Weight (gm)
Zalieutes mcgintyi	1	6
Steindachneria argentea	101	2,552
Monolene sessilicauda	1	20
Paralichthys squamilentis	1	413
Congrina macrosoma	3	107
Zalieutes mcgintyi	51	220
Citharichthys cornutus	5	10
Macrorhamphosus scolopax	1	5
Pontinus rathbuni	1	13
Pontinus longispinis	1	5
Urophycis regius	3	240
Ogcocephalus vespertilio	1	99
Poecilopsetta beani	35	317
Urophycis floridanus	3	674
Lepophidium cervinum	3	102
Congrina flava	13	462
Lepophidium sp. A.	11	195
Raja lentigenosa	18	290
Bembrops anatirostris	10	542
Polymixia lowei	55	906
Argentina striata	6	162
Synagrops spinosa	23	367

Replicate Totals

Species	22
Animals	347
Sample weight (gm)	7,707

Shannon-Weaver Statistics

H Prime	2.2460
H Max	3.0910
J Prime	0.7266

Station I-A, Sample Period 3

Species	Number of Specimens	Wet Weight (gm)
Hippocampus erectus	1	12
Emblemaria atlantica	1	2
Emblemaria piratula	4	0.4
Corvphopterus punctipectophorus	1	0.7
Lythrypnus nesiotes	1	0.1
Risor ruber	1	0.1
Sphoeroides spengleri	1	0.3
Synodus foetens	3	354
Ophidion holbrooki	1	53
Halieutichthys aculeatus	5	52
Lepophidium jeannae	8	164
Centropristis ocyurus	2	401
Diplectrum formosum	2	181
Lutjanus synagris	1	277
Haemulon aurolineatum	17	742
Calamus leucosteus	1	178
Holacanthus ciliaris	1	328
Pomacanthus arcuatus	1	336
Evermannichthys spongicola	3	0.3
Scorpaena calcarata	14	363
Scorpaena brasiliensis	1	87
Bellator militaris	2	27
Prionotus ophyras	1	119
Prionotus salmonicolor	1	87
Bothus robinsi	8	264
Etropus rimosus	26	796
Syacium papillosum	36	1,327
Symphurus diomedianus	1	11
Acanthostracion quadricornis	4	994
Sphoeroides spengleri	2	100
Hippocampus erectus	1	5
Synodus intermedius	1	68

Replicate Totals

Species	32
Animals	153
Sample weight (gm)	7,335

Shannon-Weaver Statistics

H Prime	2.6554
H Max	3.4657
J Prime	0.7662

Station II-A, Sample Period 3

Species	Number of Specimens	Wet Weight (gm)
Ogcocephalus sp.	1	0.7
Zalieutes mcgintyi	1	0.5
Ophidiidae juv.	1	0.1
Scorpaena calcarata	1	63
Prionotus roseus	1	61
Hippocampus erectus	1	11
Synodus foetens	1	105
Sardinella anchovia	1	37
Synodus foetens	11	1,900
Synodus intermedius	4	702
Porichthys porosissimus	2	59
Ophidion holbrooki	5	397
Ophidion sp.	3	155
Hippocampus erectus	1	16
Centropristis ocyurur	7	367
Diplectrum formosum	20	2,746
Pristigenys alta	1	38
Rhomboplites aurorubens	2	248
Haemulon aurolineatum	27	2,413
Orthopristis chrysoptera	8	775
Equetus acuminatus	3	88
Equetus lanceolatus	3	130
Lagodon rhomboides	8	620
Pagrus pagrus	3	314
Scorpaena brasiliensis	1	35
Scorpaena calcarata	26	701
Prionotus martis	10	472
Prionotus ophryas	1	47
Prionotus roseus	1	69
Prionotus tribulus	1	113
Bothus robinsi	4	107
Syacium papillosum	3	167
Gymnachirus melas	1	31
Acanthostracion quadricornis	1	194
Balistes capriscus	5	243
Monacanthus ciliatus	2	41
Monacanthus hispidus	94	3,765
Aluterus schoepfi	1	158
Sphoeroides nephelus	1	138
Sphoeroides spengleri	1	51

Replicate Totals

Species	40
Animals	269
Sample weight (gm)	17,578

Station II-A, Sample Period 3 - page 2

Shannon-Weaver Statistics

H Prime	2.6029
H Max	3.6889
J Prime	0.7056

Station III-A, Sample Period 3

Species	Number of Specimens	Wet Weight (gm)
Halieutichthys aculeatus	1	9
Scorpaena calcarata	1	38
Bothus robinsi	2	54
Etropus rimosus	4	41
Synodus intermedius	3	284
Porichthys porosissimus	4	63
Halieutichthys aculeatus	3	17
Ogcocephalus sp. No. 1	2	33
Ogcocephalus sp. No. 2	1	0.9
Lephophidium jeannae	1	20
Ophidion holbrooki	2	196
Centropristis ocyurus	1	20
Diplectrum formosum	1	121
Serranus phoebe	5	94
Apogon aurolineatus	5	45
Apogon pseudomaculatus	1	6
Haemulon aurolineatum	35	2,351
Chromis scotti	3	23
Hemipteronotus novacula	1	32
Scorpaena brasiliensis	2	301
Scorpaena calcarata	40	575
Bothus robinsi	2	26
Etropus rimosus	38	340
Syacium papillosum	39	1,359
Acanthostracion quadricornis	1	431
Monacanthus hispidus	1	54
Sphoeroides dorsalis	1	5
Sphoeroides spengleri	3	146

Replicate Totals

Species	28
Animals	203
Sample weight (gm)	6,685

Shannon-Weaver Statistics

H Prime	2.3556
H Max	3.3322
J Prime	0.7069

Station IV-A, Sample Period 3

Species	Number of Specimens	Wet Weight (gm)
Ariosoma impressa	1	23
Rypticus bistrispinus	1	15
Emblemaria piratula	3	0.2
Ogcocephalus parvus	1	23
Raja eglanteria	1	310
Gymnothorax nigromarginatus	1	132
Trachinocephalus muops	1	56
Synodus intermedius	7	262
Ogcocephalus parvus	1	4
Halieutichthys aculeatus	4	46
Etrumeus teres	22	13
Diplectrum formosum	1	87
Prionotus roseus	3	141
Syacium papillosum	3	159
Bothus robinsi	3	99

Replicate Totals

Species	15
Animals	53
Sample weight (gm)	1,370

Shannon-Weaver Statistics

H Prime	2.0768
H Max	2.7080
J Prime	0.7669

Station V-A, Sample Period 3

Species	Number of Specimens	Wet Weight (gm)
Gymnothorax nigromarginatus	1	39
Ariosoma impressa	2	54
Ogcocephalus sp.	1	2
Gobulus myersi	2	0.1
Scorpaena brasiliensis	3	276
Scorpaena calcarata	5	133
Prionotus roseus	1	27
Syacium papillosum	13	96
Monacanthus hispidus	1	33
Trachinocephalus myops	4	328
Halieutichthys aculeatus	2	31
Otophidium omostigmum	2	18
Diplectrum formosum	2	193
Centropristis ocyurus	14	843
Rypticus bistrispinus	1	13
Kathetostoma albigutta	1	34
Scorpaena brasiliensis	9	1,126
Scorpaena calcarata	6	44
Prionotus ophyras	2	75
Prionotus martis	3	67
Prionotus roseus	4	192
Prionotus salmonicolor	1	43
Bothus robinsi	1	30
Cyclopsetta fimbriata	1	202
Syacium papillosum	87	3,536
Gymnachirus melas	5	192
Monacanthus ciliatus	1	24
Monacanthus hispidus	9	268
Sphoeroides dorsalis	1	84

Replicate Totals

Species	29
Animals	185
Sample weight	8,003

Shannon-Weaver Statistics

H Prime	2.2408
H Max	3.3673
J Prime	0.6655

Station VI-A, Sample Period 3

Species	Number of Specimens	Wet Weight (gm)
Pontinus rathbuni	1	3
Symphurus papillosum	1	87
Symphurus diomedianus	2	26
Symphurus minor	1	7
Synodus foetens	1	193
Stenotomus caprinus	1	66
Bellator militaris	1	12
Etropus rimosus	4	15
Syacium papillosum	3	133

Replicate Totals

Species	9
Animals	15
Sample weight (gm)	542

Shannon-Weaver Statistics

H Prime	2.0262
H Max	2.1972
J Prime	0.9222

Station I-B, Sample Period 3

Species	Number of Specimens	Wet Weight (gm)
Scorpaena agassizi	1	34
Trachinocephalus mypos	13	770
Syacium papillosum	57	3,915
Synodus intermedius	7	452
Prionotus alatus	11	537
Bellator militaris	7	215
Gymnothorax nigromarginatus	2	181
Mullus auratus	6	401
Halieutichthys aculeatus	6	80
Ogcocephalus parvus	1	13
Sphoeroides dorsalis	10	615
HIppocampus erectus	1	5
Citharichthys gymnorhinus	1	1
Scorpaena brasil iensis	1	153
Raja texana	1	182
Caulolatilus sp.	1	0.9
Carangidae	1	0.o
Saurida erasiliensis	1	0.2
Argentina silus	1	0.1
Scorpaena agassizi	8	479

Replicate Totals

Species	20
Animals	137
Sample weight (gm)	8,034

Shannon-Weaver Statistics

H Prime	2.1465
H Max	2.9957
J Prime	0.7165

Station II-B, Sample Period 3

Species	Number of Specimens	Wet Weight (gm)
Prionotus stearnsi	1	1
Syacium papillosum	5	159
Halieutichthys aculeatus	3	37
Ogcocephalus parvus	1	13
Peristedion gracile	4	97
Mullus auratus	50	2,454
Prionotus stearnsi	5	7
Synodus foetens	1	122
Saurica normani	11	745
Syacium papillosum	35	1,488
Saurida brasiliensis	5	9
Prionotus alatus	7	221
Gymnothorax nigromarginatus	2	172
Kathetostoma albigutta	1	44
Halieutichthys aculeatus	4	39
Ogcocephalus parvus	2	26
Peristedion gracile	10	244
Citharichthys cornutus	1	3
Leptocephalus sp.	2	2
Scorpaena agassizi	10	305

Replicate Totals

Species	20
Animals	160
Sample weight (gm)	6,188

Shannon-Weaver Statistics

H Prime	2.2703
H Max	2.9957
J Prime	0.7579

Station III-B, Sample Period 3

Species	Number of Specimens	Wet Weight (gm)
Scorpaena agassizi	1	0
Gymnothorax nigromarginatus	1	33
Chromis enchrysurus	1	16
Muraenesocidae	1	3
Scorpaena agassizi	1	0
Synodus intermedius	1	46
Syacium papillosum	3	146
Bellator militaris	7	124
Moacanthus hispidus	1	54
Centropristis ocyurus	5	170
Rypticus bistrispinus	1	13
Lepophidium jeannae	1	17
Hippocampus erectus	1	3
Citharichthys cornutus	1	3

Replicate Totals

Species	14
Animals	26
Sample Weight (gm)	628

Shannon-Weaver Statistics

H Prime	2.2979
H Max	2.6391
J Prime	0.8707

Station IV-B, Sample Period 3

Species	Number of Specimens	Wet Weight (gm)
Syacium papillosum	1	30
Halieutichthys aculeatus	1	13
Lepophidium sp.	1	24
Trachinocephalus myops	1	75
Prionotus alatus	1	26
Prionotus stearnsi	4	71
Bellator militaris	33	530
Syacium papillosum	9	470
Saurida brasiliensis	3	10
Centropristis ocyurus	2	92
Raja Texana	1	353

Replicate Totals

Species	11
Animals	57
Sample weight (gm)	1,694

Shannon-Weaver Statistics

H Prime	1.4924
H Max	2.3979
J Prime	0.6224

Station V-B, Sample Period 3

Species	Number of Specimens	Wet Weight (gm)
Verma kendalli	1	11
Halieutichthys aculeatus	2	27
Ophidion sp.	1	1
Saurida brasiliensis	1	4
Prionotus stearnsi	1	7
Dactylopterus volitans	1	51
Porichthys porosissimus	1	20
Bellator militaris	1	10
Syacium papillosum	2	85
Mullus auratus	1	47
Halieutichthys aculeatus	2	25
Raja olseni	1	37
Centropristis ocyurus	1	47
Leiostomus xanthurus	3	337
Pristipomoides aquilonaris	2	49
Decapterus punctatus	1	26
Scorpaena erasiliensis	1	75
Scorpaena agassizi	23	433
Stenotomus caprinus	22	57

Replicate Totals

Species	19
Animals	68
Sample weight (gm)	1,349

Shannon-Weaver Statistics

H Prime	2.0289
H Max	2.9444
J Prime	0.6891

Station VI-B, Sample Period 3

Species	Number of Specimens	Wet Weight (gm)
Halieutichthys aculeatus	2	22
Parahollardia lineata	1	2
Antennarius radiosus	1	2
Synodus poeyi	9	84
Prionotus alatus	1	15
Bregmaceros atlanticus	1	0.3
Bellator egretta	11	152
Saurida brasiliensis	1	77
Sphoeroides sp.	1	3
Syacium papillosum	2	180
Kathetostoma albigutta	1	88
Halieutichthys aculeatus	4	25
Ogcocephalus parvus	5	51
Serranus notospilus	152	707

Replicate Totals

Species	14
Animals	192
Sample weight (gm)	1,408

Shannon-Weaver Statistics

H Prime	0.9546
H Max	2.6391
J Prime	0.3617

Station I-C, Sample Period 3

Species	Number of Specimens	Wet Weight (gm)
Citharichthys cornutus	1	2
Bellator Egretta	1	6
Antigonia combatia	2	5
Lophiomus sp.	1	5
Prionotus stearnsi	18	93
Serranus notospilus	35	338
Antigonia capros	2	7
Saurida normani	15	289
Hemanthias leptus	10	36
Hemanthias vivanus	3	46
Citharichthys cornutus	103	359
Bellator egretta	3	15
Synagrops bella	1	5
Decodon puellaris	2	31
Pontinus rathbuni	1	21
Ancylopsetta dilecta	3	134
Synodus poeyi	1	5
Antennarius radiosus	1	1
Peristedion sp.	2	3
Lonchistium sp.	1	3
Bellator brachychir	1	2
Zalieutus mcgintyi	7	25

Replicate Totals

Species	22
Animals	214
Sample weight (gm)	1,431

Shannon-Weaver Statistics

H Prime	1.8775
H Max	3.0910
J Prime	0.6074

Station II-C, Sample Period 3

Species	Number of Specimens	Wet Weight (gm)
Bembrops anatirostris	1	47
Lophiomus sp.	1	4
Zalieutes mcgintyi	3	5
Peristedion miniatum	1	119
Callionymus agassizi	2	48
Bembrops anatirostris	5	258
Prionotus alatus	5	255
Bellator egretta	5	160
Ancylopsetta dilecta	1	30
Synodus intermedius	1	38
Ophichthus ocellatus	2	252
Saurida normani	34	2,624
Serranus notospilus	19	145
Citharichthys cornutus	20	62
Synagrops bella	2	5
Saurida brasiliensis	7	19
Peristedion gracile	1	9
Antigonia combatia	4	16
Glossanodon pygmaeus	2	3
Macrorhamphosus scolopax	1	12
Zalieutes mcgintyi	6	32

Replicate Totals

Species	21
Animals	123
Sample weight (gm)	4,139

Shannon-Weaver Statistics

H Prime	2.3841
H Max	3.0445
J Prime	0.7831

Station III-C, Sample Period 3

Species	Number of Specimens	Wet Weight (gm)
Peprilus burti	1	120
Prionotus alatus	1	59
Mullus auratus	1	66
Peristedion miniatum	4	582
Scorpaena agassizi	3	144
Bembrops anatirostris	1	11
Zalieutes mcgintyi	3	14
Citharichthys cornutus	4	16
Pikea mexicanus	3	8
Hippocampus erectus	1	5

Replicate Totals

Species	10
Animals	22
Sample weight (gm)	1,025

Shannon-Weaver Statistics

H Prime	2.1375
H Max	2.3026
J Prime	0.9283

Station IV-C, Sample Period 3

Species	Number of Specimens	Wet Weight (gm)
Urophycis cirratus	1	0.6
Saurida normani	36	2,740
Mullus auratus	3	180
Prionotus alatus	3	184
Lophiomus sp.	1	92
Gnathagnis egregius	1	29
Peristedion miniatum	2	326
Decodon puellaris	1	41
Bembrops anatirostris	6	125
Prionotus stearnsi	8	41
Pontinus rathbuni	1	5
Citharichthys cornutus	5	22
Zalieutes mcgintyi	8	31
Monelene sessilicauda	1	2
Pikea mexicanus	1	2

Replicate Totals

Species	15
Animals	78
Sample weight (gm)	3,821

Shannon-Weaver Statistics

H Prime	1.9329
H Max	2.7080
J Prime	0.7138

Station V-C, Sample Period 3

Species	Number of Specimens	Wet Weight (gm)
Paralichthys squamilentis	1	417
Poeciliopsetta beani	1	25
Monolene sessilicauda	1	10
Synagrops spinosa	2	15
Neobythites gilli	1	4
Zalieutus mcgintyi	1	2
Pontinus longispinis	8	432
Scorpaena agassizi	12	612

Replicate Totals

Species	8
Animals	27
Sample weight (gm)	1,517

Shannon-Weaver Statistics

H Prime	1.5240
H Max	2.0794
J Prime	0.7329

Station VI-C, Sample Period 3

Species	Number of Specimens	Wet Weight (gm)
Zalieutes mcgintyi	1	0.8
Bembrops anatirostris	1	34
Lophiomus sp.	1	16
Citharichthys cornutus	2	3
Zalieutes mcgintyi	3	10

Replicate Totals

Species	5
Animals	8
Sample weight (gm)	64

Shannon-Weaver Statistics

H Prime	1.4942
H Max	1.6094
J Prime	0.9284

APPENDIX II

Length Frequency Data

Size Class (cm)

Species	0-5	5-10	10-15	15-20	20-25	25-30	30-35	35-40	40-45	45-50	50-100	100 →
Syacium papillosum	21	128	534	329	23	2						
Citharichthys cornutus	88	485										
Synodus poeyi	2	40	15									
Ogcocephalus sp. (corniger)		3	1									
Ogcocephalus sp. (declavirostris)		2										
Cyclopsetta fimbriata		2	1	6	4							
Bellator egretta	1	24	7									
Serranus atrobranchus	1	6										
Serranus notospilus	22	335										
Decodon puellaris		3	5									
Mullus auratus			79	5	1							2
Centropristis ocyurus	2	26	100	14	2							
Hemanthias leptus	5	20	2	1								
Monolene antillarum		1										
Trachurus lathami		1	9	2								
Pontius longispinis	12	53	80	36								
Pristipomoides aquilonaris	4	40	8	24	2							
Bembrops anatirostris	1	10	64	129	13							
Urophycis floridanus				12	29	11	2					
Callionymus agassizi		4	5									
Peristedion gracile		17	29	1								
Stenotomus caprinus		16	36									
Halieutichthys aculeatus	15	100										
Pikea mexicana	3	9	1									
Trichopsetta ventralis		5	14	4								
Ogcocephalus sp.	2	4	3	1								
Saurida brasiliensis	14	51										
Bregmaceros atlanticus	4											
Physiculus fulvus		2										
Ariomma bondi		1										
Prionotus stearnsi	14	243	48									
Raja texana		1		2					2			
Lepophidium jeannae			5	3	5	1						
Monacanthus hispidus	1	137	85									

	Size Class (cm)											
Species	0-5	5-10	10-15	15-20	20-25	25-30	30-35	35-40	40-45	45-50	50-100	100 →
Symphurus diomedianus			13	9								
Chriolepis sp.	1											
Lythrypnus nesiotes	8											
Muraena retifera								1				
Kathetostoma albigutta		10	8									
Neomerinthe hemingwayi			1			1						
Saurida normani	2	13	22	94	62	14	9				1	
Synodus intermedius	1		27	109	15	1	1					
Chromis enchrysurus	2	13										
Prionotus alatus	1	36	151	3								
Bellator militaris	42	254	7									
Sphoeroides dorsalis	2	7	47									
Pagrus pagrus			4	2	1							
Ogcocephalus parvus	1	14										
Gymnothorax nigromarginatus		2					18	15	15	3	1	
Lophiomus sp.	2	7	9	2								
Prionotus sp.	4											
Scorpaena agassizi	13	101	136								4	
Monacanthus ciliatus	1	105										
Hippocampus erectus			13	7	1							
Scorpaena sp.	2	1										
Trachinocephalus myops			13	70	9							
Ophidion holbrooki			1	3	7	6						
Lopholatilus chamaeleonticeps							1					
Argentina striata			8									
Poecilopsetta beani		30	11									
Decapterus punctatus			3	4								
Neopinnula orientalis				1	1							
Lepophidium sp. A.			4	9	1							
Neobythites gilli		1	2									
Antigonia combatia	8	1										
Zalieutes mcgintyi	128	143										
Ogcocephalus nasutus		4										
Ogcocephalus vespertilio		2	4									

Size Class (cm)

Species	0-5	5-10	10-15	15-20	20-25	25-30	30-35	35-40	40-45	45-50	50-100	100 →
Monolene sessilicauda		9	79									
Prionotus paralatus			3									
Synagrops spinosa		34	13									
Diaphus dumerili		4										
Macrorhamphosus scolopax		100	2									
Polymixia lowei		83	2									
Pikea mexicanus	3	20	7									
Parahollardia lineata	2	3	1									
Paralichthys squamilentis				1	2	2						
Chriolepis sp. A.	11											
Bollmania sp. A.	1											
Antennarius radiosus	4											
Syacium sp.	1											
Lonchistium sp. A.	1	2										
Antigonia capros	2	7	4									
Etropus rimosus	28	167	4									
Ophichthus gomesi											1	
Sardinella anchovia			6	1								
Synodus foetens		1		8	22	16	1					
Porichthys porosissimus		3	8									
Ophidion sp.	3	2		1	10	5						
Otophidium omostigmum		1	3									
Diplectrum bivittatum	3	3	1									
Vomer setapinnis	1											
Equetus sp.	1		5									
Prionotus roseus	4	24	82	9								
Prionotus rubio		2	1									
Prionotus salmonicolor			16	9								
Peprilus burti	1			1								
Citharichthys macrops			2	2								
Cyclopsetta chittendeni				1	1							
Gymnachirus melas		4	7									
Branchiostoma floridae	55											
Emblemaria piratula	59											

Size Class (cm)

Species	0-5	5-10	10-15	15-20	20-25	25-30	30-35	35-40	40-45	45-50	50-100	100 →
Emblemaria sp.	2											
Palatagobius paradoxus	2											
Symphurus minor	3	2										
Risor ruber	5											
Raja eglanteria				1	1	2		2				
Hemipteronotus novacula	1		12	2								
Prionotus martis			14	2								
Scorpaena calcarata	13	160	23									
Diplectrum formosum	1		3	54	2							
Prionotus ophryas	2	8	8	7								
Bothus robinsi		9	73									
Opsanus pardus	1	1										
Monacanthus sp.		1										
Gymnothorax moringa											1	
Lythrypnus sp.	2											
Holocentrus bullisi			3									
Hypoplectrus puella	1	3	5									
Pristigenys alta		9										
Chaetodon sedentarius		2	2									
Holacanthus bermudensis			2	3	1	1						
Chromis scotti	44	49										
Emblemaria atlantica	1	2										
Evermannichthys spongicola	14											
Carapus bermudensis			1									
Gillelus sp. A	1											
Ioglossus sp.	2											
Antennarius ocellatus	1	4										
Rypticus bistrispinus		7										
Chilomycterus schoepfi		2		4								
Scorpaena brasiliensis	2	3	20	17								1
Balistes capriscus		4	6	1								
Acanthostracion quadricornis			2	3	3							
Gastropsetta frontalis			4									
Blennius marmoreus	5											

Species	Size Class (cm) 0-5	5-10	10-15	15-20	20-25	25-30	30-35	35-40	40-45	45-50	50-100	100 →
Leiostomus xanthurus				2								1
Lepophidium sp.												
Muraenesocidae						1						
Leptocephalus sp.												
Caulolatilus sp.	1											
Carangidae	1											
Argentina silus	1											
Poeciliopsetta beani			1									
Zalieutus mcgintyi	7	1										
Gnathagnis egregius		1										
Peristedion miniatum				1	6							
Monelene sessilicauda		1										
Hemanthias vivanus		3										
Peristedion sp.	2											
Lonchistium sp.		1										
Gobulus myersi	2											
Prionotus ophyras			2									
Symphurus papillosum				1								
Ogcocephalus sp. No. 1		2										
Ogcocephalus sp. No. 2	1											
Lephophidium jeannae				1								
Gymnothorax nigomarginatus										1		
Etrumeus teres	22											
Ophidiidae juv.	1											
Hippocamphus erectus					1							
Orthopristis chrysoptera			1	7								
Equetus acuminatus			3									
Prionotus tribulus				1								
Sphoeroides nephelus				1								
Corvphopterus punctipectophorus	1											
Calamus leucosteus				1								
Holacanthus ciliaris				1								
Hippocampus eroctus			1									

	Size Class (cm)											
Species	0-5	5-10	10-15	15-20	20-25	25-30	30-35	35-40	40-45	45-50	50-100	100 →
Gobiesox strumosus		1										
Calamus proridens				14	5							
Steindachneria argentea			3	40	55	1						
Congrina macrosoma						1	2					
Pontinus rathbuni	2	5										
Urophycis regius			22	16	2							
Lepophidium cervinum					3							
Congrina flava						1	2	9	1			
Raja lentigenosa	1	15	2									
Zenopsis ocellata			1									
Ancylopsetta dilecta		2	8	15								
Synagrops bella	2	4										
Ophididae sp. A		1										
Glossanodon pygmaeus	7	3										
Bellator brachychir	10											
Urophycis cirratus	1			2								
Lepophidium sp. B			12	18								
Lepophidium sp. C				1	6	6						
Raja garmani			6	2								
Opistognathidae	1	1										
Ophichthus ocellatus									1		2	
Mustelus canis										1		
Peristidion gracile			28	69								
Lagodon rhomboides		2	45	9								
Citharichthys gymnorhinus	3	1										
Urophycis floridana			1	1								
Scorpaena dispar		1	12	1								
Chaetodon aya		14										
Lepophidium graellsi			1									
Halieutichyhys aculeatus		1										
Saurida sp.	1											
Verma kendalli									1			
Dactylopterus volitans			1									
Raja olseni		1										

Size Class (cm)

Species	0-5	5-10	10-15	15-20	20-25	25-30	30-35	35-40	40-45	45-50	50-100	100 →
Apogon quadrisquamatus	1											
Coryphopterus punctipectophorus	1											
Halichoeres caudalis	1			1								
Ogcocephalus radiosus					1	1						
Sphoeroides spengleri	1	4	12	1								
Eupomacentrus variabilis		1										
Gobiosoma xanthiprora	1											
Bothus ocellatus			1									
Syacium gunteri		9	5	1								
Rhomboplites aurorubens		2	2	2								
Engyophrys senta		1										
Antenarrius ocellatus		2										
Anarchias yoshiae			1									
Ariosoma impressa					2	1						
Branchiostoma sp.	11	1										
Gobulus sp.	1											
Chaenopsis sp.	1											
Lythrypnus elasson	3											
Aluterus schoepfi			3		1	2	5	5				
Echenesis neucratoides							1	1				
Sphoeroides sp.	2											
Ioglossus sp. ?	1											
Apogon pseudomaculatus	1	4										
Apogon aurolineatus	3	5										
Serranus phoebe		6	41									
Astrapogon alutus	2											
Haemulon aurolineatum		65	86	44								
Equetus lanceolatus			10	3								
Lactophrys quadricornis				2	4							
Lutjanus synagris				3	2							
Equetus umbrosus			1	2								
Pomacanthus arcuatus				1	1							
Priacanthus arenatus			1		1		1					
Phaeoptyx pigmentaria	1											

RIG MONITORING OF THE MAFLA AREA

University of Miami, Rosenstiel School of Marine and Atmospheric Science

Principal Investigator:
Wayne D. Bock

RESULTS & DISCUSSION

The rig monitoring samples were collected from the Mustang Island area, eight samples each from 100 m range, 500 m range and 1000 m range, and one from the rig site during November 1975 and March 1976 (no rig sample from January 1976). All the sediments from the rig monitoring samples are extremely fine. Of the approximately 15 ml samples collected for foraminiferal analyses less than one milliliter was retained on 63 μm sieves from each sample. All the foraminifera present in the samples were less than 125 μm in their smallest dimension with only rare exceptions; in most cases much less. The sediment greater than 63 μm was composed of either fine quartz grains or polychaete fecal pellets. The greatest abundances of foraminifera were always associated with the pellet-rich samples. Abundances vary seasonally, but species composition remained constant. Only four species occur consistently in abundances over one percent (three over five percent), and the stress indicator species, Ammonia beccarii, completely dominated every sample composing 55%-88% of the living fauna and somewhat less of the total fauna. The other three major dominate species, in order of abundance, Elphidium galvestonense, Buliminella cf. B. bassendorfensis and Nonionella atlantica, are also stress indicators. Only rarely do other species become more abundant than one percent, and then it was also species able to survive in stressed environments such as Buliminella elegantissima and Nonionella opima.

In normal marine shelf environments in a 24 m water depth (the sampling depth) a rather diverse benthonic foraminiferal fauna usually exists, generally supporting a population of 25-60 species with abundance dependent to some extent on grain size of sediment, the coarser the sediment the lower the diversity and abundance and vice versa. Adult individuals usually attain close to maximum size for the major dominant species (here defined as those species comprising five percent or more of the foraminiferal population). At the sample sites for rig monitoring over ninety percent of the sediment was less than 63 µm, but species diversity was still very low, 8-18, with only the four species noted above consistently occurring in abundances over one percent. Of these four, Buliminella cf. B. bassendorfensis attained abundances of five percent or greater at only about one third of the stations, and Nonionella atlantica at about one fourth. Elphidium galvestonense usually comprised 6-20% of the population, rarely reaching thirty percent. Ammonia beccarii var. parkinsoniana and Ammonia beccarii var, tepida completely dominated the foraminiferal fauna, both varieties taken together comprised up to 88% of the population. This latter species is a world-wide indicator of stress conditions. In normal marine shelf environments with depths of 24 m it is unusual for it to comprise as much as one percent of the population. All the foraminiferal species were depauperate, only rare specimens attaining a size greater than 125 µm. Depauperate faunas have long been associated with stress conditions. Size alone, however, does not necessarily indicate a stressed environment, but associated with low species diversity and dominance of a stress indicator species, the evidence is conclusive.

Foraminiferal abundance was also unusually low for fine-grained sediments, generally much less than 100 specimens/ml of sediment. It is possible that these figures are considerably biased due to the small size of individuals. Almost all specimens encountered appeared to be adult despite their small size. Certainly most of the juveniles were not retained on the 63 µm sieve. Abundances vary considerably from station to station, but considerably less so seasonally; stations with greatest abundances remained constant from sampling season to sampling season. Greatest abundances were always associated with pellet-rich sediment. The pellets were identified as polychaete fecal pellets; numerous polychaetes were observed with fecal pellets contained within their body cavities. One must conclude that conditions which favor polychaete growth and reproduction (at least for the species encountered at these stations) are also favorable to the *Ammonia*-dominant foraminiferal fauna. Polychaetes are well-known pollution indicators.

Almost all foraminifera observed, despite their small size, appeared to be normally developed. No aberrant growths, malformed or thin-walled specimens were observed. Apertural development and pore size and distribution appeared normal for the size of the specimens encountered. Apparently the degree of stress had not reached the point where these abnormalities occur.

Variation in foraminiferal abundances occurs from pre-drilling to drilling to post-drilling conditions. The number of living foraminiferal specimens per sample decreased from F1 to F2 and then increased from F2 to F3 at every station except two, 510601 and 592501. And with the exception of these two stations the foraminiferal abundances never quite recovered to the pre-drilling (F1) levels. Stations 510201, 510301, 551001, 551701 and 551901 had the greatest degree of change, (see Table 1), and all are located northeast of the rig suggesting bottom currents carrying rig-associated pollutants to the northeast. The least change in degree of foraminiferal abundance is at the stations on the 1000 m range, and the most at the 500 m range; the former would be expected if drilling operations were a source of deleterious pollution, but the latter is unexpected since the 100 m range "being closer" should theoretically be the most adversely affected. If the anomalous effects of station 510601, however, were disregarded, then there would be an aureole of greatest change from the rig decreasing outward.

On the species level, the species most tolerant of stress conditions, Ammonia beccarii, would be expected to increase in percentage of the total living population from pre-drilling to drilling time, if drilling operations were deleterious to the environment. It does at all but three stations. Then again, after removal of the rig, A. beccarii should decrease in percentage. It does at all but five stations (Table 2).

CONCLUSION

The depauperate benthonic foraminiferal fauna, the low species diversity, the low foraminiferal abundance, the dominance of Ammonia beccarii and the association of high foraminiferal abundance with polychaete fecal pellets indicate a highly stressed marine environment in the area of the monitored drilling rig. The cause of stress is almost certainly due to the phenomenon related to the creation of the nepheloid layer above the bottom sediments. Drilling operations appear to have further increased stress in the area, and after removal of the drilling rig the area appears to be on the way to restoring itself to pre-drilling foraminiferal abundance levels.

Table 1. Foraminiferal abundance and per cent living - Mustang Island Rig Monitoring area.

SAMPLE #	TOTAL/SAMPLE F1	TOTAL/SAMPLE F2	TOTAL/SAMPLE F3	LIVE/SAMPLE F1	LIVE/SAMPLE F2	LIVE/SAMPLE F3	% LIVE F1	% LIVE F2	% LIVE F3
500102	11248	----	8438	658	----	532	5.8	----	6.3
510201	3485	1029	2267	2259	379	815	64.8	36.8	36.0
510301	3308	267	1721	2833	195	1142	85.6	76.0	66.4
510401	800	353	578	360	236	303	45.0	66.9	52.4
510501	1034	655	806	591	348	452	57.2	53.1	37.6
510601	827	2057	2535	488	1263	1518	59.0	61.4	59.9
510701	1051	306	527	348	109	163	33.1	35.6	30.9
510801	1205	415	601	466	155	245	38.7	37.3	40.8
510901	10000	497	742	2008	294	393	20.1	59.2	53.0
551001	3000	878	1898	1200	189	689	40.0	21.5	36.3
551101	1800	497	1136	274	185	215	15.2	37.3	18.9
551201	2400	800	1648	848	493	693	35.3	61.6	42.1
551301	1149	339	724	234	60	182	20.4	25.6	25.1
551401	1974	870	1376	726	299	549	36.3	41.2	39.9
551501	1200	796	973	600	411	508	50.0	51.6	52.2
551601	2764	810	1775	1032	326	626	37.3	40.3	35.3
551701	725	200	525	231	74	153	31.9	36.9	29.1
591801	600	380	490	193	134	162	32.2	35.2	33.1
591901	1200	354	774	701	213	453	58.4	60.3	58.5
592001	1054	465	765	432	205	317	41.0	44.1	41.4
592101	1187	751	951	514	342	430	43.3	45.6	45.2
592201	1406	1054	1262	450	351	401	32.0	33.3	31.8
592301	4800	4080	4440	2480	2158	2348	51.9	52.9	52.9
592401	527	295	397	145	92	122	27.5	31.2	30.7
592501	616	761	596	225	288	255	36.5	37.8	42.8

F1 = November 1975
F2 = January 1976
F3 = March 1976

Table 2. Per cent distribution of the three major living dominant foraminiferal species - Mustang Island Rig Monitoring area.

Ammonia beccarii

Sta. No.	001	102	103	104	105	106	107	108	109	510	511	512	513	514	515	516	517	918	919	920	921	922	923	924	925
F1	55.3	69.0	60.0	61.0	73.0	73.7	73.3	62.3	75.0	70.7	87.6	64.7	66.7	67.0	83.6	68.0	78.8	80.8	74.3	83.0	72.0	84.7	75.0	73.1	73.3
F2		68.0	83.1	86.0	83.0	79.0	74.3	80.0	84.7	64.0	86.5	83.0	71.7	75.6	84.0	71.0	81.1	82.1	75.1	84.9	73.7	88.0	77.0	73.9	74.7
F3	58.3	68.0	65.3	64.3	78.3	76.3	71.8	76.3	79.3	75.0	87.0	75.0	64.8	71.3	84.0	69.7	83.0	82.1	77.3	85.7	76.3	86.7	76.3	72.1	74.5

Elphidium galvestonense

Sta. No.	001	102	103	104	105	106	107	108	109	510	511	512	513	514	515	516	517	918	919	920	921	922	923	924	925
F1	15.3	14.0	30.3	11.0	16.7	12.0	10.7	9.3	12.0	8.0	5.8	11.0	17.5	15.0	10.3	16.7	10.0	10.3	12.0	9.3	10.3	7.0	13.7	4.8	12.4
F2		15.7	8.2	7.6	8.7	13.0	15.6	14.8	11.2	16.9	4.9	5.0	15.0	14.0	9.0	14.7	9.5	7.5	11.7	9.8	9.7	6.3	12.3	6.5	10.4
F3	15.0	15.0	20.7	10.3	12.7	12.7	12.8	14.3	11.3	9.3	4.7	8.0	11.5	14.7	9.7	15.7	9.8	9.3	10.0	8.0	10.0	6.7	13.0	4.1	11.4

F1 = November 1975
F2 = January 1976
F3 = March 1976

Table 2 - continued

<u>Buliminella</u> <u>c.f.</u> <u>B.</u> <u>bassendorfensis</u>

Sta. No.	001	102	103	104	105	106	107	108	109	510	511	512	513	514	515	516	517	918	919	920	921	922	923	924	925
F1	9.0	5.0	1.3	7.7	3.7	4.0	6.0	7.0	3.7	2.3	0.7	5.0	5.0	3.3	1.3	6.0	2.6	6.2	4.0	4.0	11.7	3.3	2.0	7.6	4.9
F2		2.0	4.1	2.5	4.0	0.0	9.2	3.2	4.1	9.5	5.4	8.7	5.0	4.3	0.7	5.0	4.1	3.7	7.0	3.9	11.0	2.7	2.7	9.8	5.2
F3	8.3	3.3	2.0	7.0	5.0	2.0	9.2	4.1	4.0	4.0	4.2	6.7	6.6	3.7	1.0	5.7	2.6	5.6	4.3	3.3	11.3	3.0	2.3	8.2	5.1

F1 = November 1975
F2 = January 1976
F3 = March 1976

FORAMINIFERA OF THE MAFLA AREA

University of Miami, Rosenstiel School of Marine and Atmospheric Science

Principal Investigator:
Wayne D. Bock

ABSTRACT

The environmental monitoring program for 1975-1976 (BLM Contract No. 08550-CT5-30) was conducted along six transects running from shallow water to as deep as the 183 m contour at the edge of the Continental Shelf along the Mississippi-Alabama-Florida Shelf. Foraminiferal trends, in general, remained constant over the seasonal sampling periods. The major dominant species essentially remained the same from season to season at virtually every station with some shifts in abundance in the five or six most dominant species. The major changes in the foraminiferal faunas were in species abundance. There were minor changes in abundance from the May - June to September sampling periods. Twenty stations showed an increase in foraminiferal abundance, twenty showed a decrease and three remained essentially unchanged. There was no data for comparison at two stations due to non-collection at stations 14 and 15 during the May - June sampling period. From September to January nine stations showed an increase in foraminiferal abundance, thirty-five showed a decrease and three showed essentially no change. Seven of the nine stations showing an increase were located in Transects V and VI which were sampled immediately after Hurricane ELOISE, most of the rest showed considerable decreases in abundances of the living fauna, over 80% at some stations. The increases are probably due to increased productivity after stirring up of the bottom by the hurricane. The decreases are probably associated with adverse winter conditions.

Only three species were common to all five areas of the first year's sites; *Cibicides* aff. *C. floridanus*, *Hanzawaia strattoni* and *Rosalina columbiensis*. The second year's transects were also dominated by the same species along with an additional three species; *Cassidulina curvata*, *Cassidulina subglobosa* and *Quinqueloculina lamarckiana*. The additional dominant species reflect the change in the sampling program from clusters among oil lease sites to transects which run from shallower to deeper water than the depths at the first year's sampling stations.

Several trends exist among the foraminifera of the MAFLA area, some of which were noticeable in the first year's program, but became more apparent with the transect method of sampling. Diversity increases seaward in almost every transect. Living percentages increase northward and to the west. Living percentages are high for areas with low sedimentation rates. The numbers of specimens increase with decreasing sediment size. The upper limit of the depth habitat for *Cassidulina curvata* and *C. subglobosa* becomes shallower to the north. The shallowest stations of Transects I, II, III and IV contain faunas with large numbers of specimens of several species attached to individual quartz grains. Some of these species, especially *Asterigerina carinata* and *Rosalina concinna*, have always been described as free-living.

In the total populations there is a relict reef fauna running in an arcuate band from offshore of Fort Myers, Florida to offshore of

Mobile, Alabama. The relict fauna is found in different depths along this band, and there is evidence that the Late Pleistocene or Early Holocene reef existed in shallower, warmer waters than are present in the same area today.

ACKNOWLEDGEMENTS

The author wishes to thank the Bureau of Land Management for providing research funds under Contracts 08550-CT4-11 and 08550-CT5-30 and the State University System of Florida Institute of Oceanography for subcontracting the foraminiferal programs to the Rosenstiel School of Marine and Atmospheric Science, University of Miami, and making this research possible.

PREVIOUS WORK

The foraminiferal faunas from the northern part of the MAFLA area are well known with several excellent papers describing ecological habitats. In 1949, S. W. Lowman reported on foraminiferal faunas from surface samples along three profiles in the northern Gulf. He also found abundant specimens of Amphistegina in an elongate band, subparallel to the shoreline, off the coast of the Florida panhandle in about 70 m of water.

The stations in MAFLA Area 5 contain faunas similar to those described by Phleger (1954) from Mississippi Sound, (1955) from the eastern Mississippi Delta area, and (1960) from the northern Gulf of Mexico, and by Lankford (1959) from the east Mississippi Delta margin. Both authors established species characteristic of ecological facies.

Parker (1954) reported on the distribution of the foraminifera in the northeastern Gulf of Mexico and found five faunal depth boundaries which she suggested were controlled by salinity and temperature. About 15 of the samples were located in the area covered by the MAFLA investigations, mostly in the northern and western part of the area, but with a few samples from the southern part of the area.

Ludwick and Walton (1957) reported on 150 benthonic foraminiferal species contained in 41 sediment samples from an area in the northeastern Gulf of Mexico roughly covering an area from shore to the 183 m line, from the Mississippi Delta to Cape San Blas. They described both living and dead populations and found a nonindigenous West Indian assemblage that was abundant among the dead forms. Included were reef-type species most prominent among pinnacles on the shelf edge in 80-110 m of water.

Walton (1964), using several thousand sediment samples collected by Gulf Research and Development Company from the northeastern Gulf, east of the Mississippi Delta, made faunal analyses of the benthonic foraminiferal assemblages contained in the sediments. From this and existing data he outlined 14 biofacies based on generic dominance, and also compiled frequency distribution charts for most of the dominant species.

Research on the southern part of the MAFLA area is scarce. In addition to the few samples reported on by Parker (1954), Bandy (1956), supplementing Parker's work, reported on the foraminifera in several West Florida bays and in sediment samples from transects across the West Florida shelf. He described the ecological habitats of foraminifera the shelf. Many of the benthonic species reported by Bandy are present in the southern part of the MAFLA area.

METHODS

Duplicate sediment samples were collected from 45 stations over three sampling periods with the exception of the May-June collections from which no material was collected from stations 14 and 15 due to loss of marker buoys and insufficient time to relocate the stations.

Subsamples for foraminiferal analysis were collected in 2.5 cm diameter, 15 cm long glass tubes. The upper three cm of each subsample was extruded and preserved in glutaraldehyde to allow for identification of living specimens by protoplasm content.

After transport to the laboratory the samples were wet sieved through a 63 μm sieve to remove the finer sediment and retained wet for analysis. The retention of a wet sample allows for identification of protoplasm content without the use of questionable staining techniques. After sieving, the amount of sediment greater than 63 μm was measured, 300 specimen total populations were picked and identified, the planktonic/benthonic ratios were determined, the percentage of living specimens was determined for each sample, and the number of total and living specimens was calculated per ml of sediment and per sample. In addition, after the 300 specimen total population was picked, counts and species identifications of additional living specimens were made from each sample until a 300 specimen living population was obtained. Percentages were then determined for each species in the living populations.

Results of the analyses

The frequency distributions of all extant species were determined for the three sampling periods of the 1975-1976 environmental monitoring program. The six transects can be characterized by the following major dominant benthonic foraminiferal species:

Transect I

Ammonia beccarii
Asterigerina carinata
Cibicides aff. C. floridanus
Cibicides deprimus
Hanzawaia strattoni
Neoconorbina orbicularis
Quinqueloculina lamarckiana
Remaneica sp.
Rosalina concinna
Rosalina columbiensis
Rosalina foridana

Amphistegina gibbosa
Cassidulina curvata
Cassidulina subglobosa
Planulina ariminensis

Transect II

Asterigerina carinata
Cibicides aff. C. floridanus
Hanzawaia strattoni
Neoconorbina orbicularis
Quinqueloculina lamarckiana
Reussella atlantica
Rosalina columbiensis
Rosalina concinna
Textularia mayori

Cassidulina curvata
Cassidulina subglobosa
Cibicides concentricus
Planulina ariminensis
Siphonina pulchra
Trochammina advena

Transect III

Asterigerina carinata
Cibicides aff. C. floridanus
Cibicides deprimus
Hanzawaia strattoni
Planulina exorna
Quinqueloculina lamarckiana
Rosalina columbiensis
Rosalina concinna

Brizalina lowmani
Cassidulina curvata
Cassidulina subglobosa
Planulina ariminensis
Siphonina pulchra
Uvigerina flintii

Transect IV

Ammonia beccarii
Cibicides aff. C. floridanus
Elphidium discoidale
Hanzawaia strattoni
Planulina exorna
Quinqueloculina lamarckiana
Remaneica sp.
Rosalina columbiensis
Rosalina concinna

Amphistegina gibbosa
Cassidulina curvata
Cassidulina subglobosa
Cibicides concentricus
Lenticulina orbicularis
Siphonina pulchra
Uvigerina flintii

Transect V

Amphistegina gibbosa
Brizalina lowmani
Cassidulina curvata
Cassidulina subglobosa
Cibicides aff. C. floridanus
Hanzawaia strattoni
Lenticulina orbicularis
Nonionella atlantica
Planulina exorna
Quinqueloculina lamarckiana
Reussella atlantica
Rosalins columbiensis
Trochammina advena

Brizalina subaenariensis mexicana
Cibicides concentricus
Hoeglundina elegans
Lenticulina calcar
Uvigerina flintii

Transect VI

Ammonia beccarii
Amphistegina gibbosa
Buliminella cf. B. bassendorfensis
Buliminella elegantissima
Cassidulina curvata
Cassidulina subglobosa
Cibicides aff. C. floridanus
Elphidium galvestonense
Fursenkoina pontoni
Hanzawaia strattoni
Nonionella atlantica
Planulina exorna
Quinqueloculina lamarckiana
Rosalina columbiensis
Rosalina concinna

Brizalina lowmani
Lenticulina orbicularis

In general the major dominant species at almost every station remained relatively uniform throughout the three sampling seasons with only some changes in order of abundance. The species usually occurring in approximately 91 m to 183 m of water are listed below the dashed lines.

There are several general trends which are noticeable in the MAFLA area:

1) Diversity increases seaward in every transect. In general the more restricted waters of the shallow, near-shore areas support a less diverse fauna than the deeper stations near the edge of the Continental Shelf. This pattern can be disrupted, however, by coarse sediment, hard substrate areas such as the Florida Middle Ground located in Transect III where diversity may be less than on either the shoreward or seaward side.

2) Living percentages increase to the north and west, with the highest percentages being recorded in the areas immediately influenced by Mississippi runoff off the coast of Mississippi and Alabama. The

percentages were higher in the first year than the second in this area, and this may be due to the greater amount of runoff in 1974 than in 1975. There were also much higher percentages of stress indicator species such as Ammonia beccarii in 1974.

3) Living percentages are high for areas of low sedimentation rates, especially the areas off the Florida coast. Initially it was thought that this reflected a seasonal bloom since many juvenile forms were observed. This may be part of the answer, but since the 1975-76 samples produced equally high living percentages off Florida, and more adult specimens of these same species were present, other causes for the high percentages must be sought. In most bays on the west coast of Florida the sediment is composed mainly of quartz sand, an environment which is somehow creating conditions which result in the dissolution of the $CaCO_3$ tests of the dead foraminifera leaving apparent assemblages with 60-80% live specimens. Although offshore conditions may not be so extreme, the sediment is also primarily composed of quartz sand and, at least some dissolution may be occurring.

4) The numbers of specimens increase with decreasing sediment size. This may simply be a result of physically more specimens in the smaller size fractions, but it may also be that there is a greater source of nutrients and food supply available in the finer sediments, which would support a larger population.

5) The upper limit of the depth habitat for Cassidulina curvata and C. subglobosa decreases northward. In the southern transects these two species are found in abundance only at the deeper stations, but in

Transect V they occur in abundance at all stations in the transect including the shallowest ones. In Transect VI they also occur at stations shallower than to the south. This may be a result of latitude where the shallower depths of Transects V and VI may have temperatures similar to the deeper stations of Transects I-IV. This is unlikely.

The Loop Current may also be affecting bottom currents which carry bottom water from greater to shallower depths bringing with it conditions which permit survival of species indigenous to the greater depths. There are several other deeper water species which occur at the same stations, although not in abundance. The Loop Current is apparently carrying a planktonic fauna with it into water shallower than normal for their survival. The planktonic/benthonic ratios are much too high for the depths encountered. Further seasonal sampling should indicate whether or not species abundances of *C. curvata* and *C. subglobosa* coincide with the presence of the Loop Current.

6) The shallowest stations of Transects I-IV contain foraminiferal faunas with large numbers of specimens of several species attached to individual quartz grains. Some of these species, especially *Asterigerina carinata* and *Rosalina concinna*, have always been described as free-living. This is the first attached occurrences of these two species known to this author. The stations with large percentages of the attached forms are all in approximately 10-33 m of water where current action shifts the sand bottom. The foraminifera are obviously using the quartz grains to which they are attached as anchors to allow them to exist in an environment which otherwise might prove hostile. The two species mentioned above are free-living at the other stations where they occur.

There is also a noticeable orientation in mode of attachment in the attached species. Hanzawaia strattoni, Rosalina concinna, Cibicides cf. C. floridanus, Remaneica sp., a few Rosalina columbiensis all attach with their apertural sides down. Globulina caribaea attaches to the quartz grains by some other part of the test than the aperture. Asterigerina carinata attaches by its aperture, but in every observable instance it orients its test in an upright position perpendicular to the plane of its width.

Another aspect which is invaluable in environmental monitoring is the presence of stress indicator species. Ammonia beccarii is represented in abundance by two varieties at only the shallower stations of Transect VI (Area 5) and at station 2101, Transect I. It is considered here for its potential for indicating stress placed on the environment by activities associated with petroleum exploration and production. It is a well-known indicator, occurs over vast areas of the world ocean, and is well studied. The fact that it occurs in every transect, although usually in very low frequencies, provides an indicator species for monitoring. With increasing stress placed on the environment, from whatever source, this species will increase in abundance as the normal fauna finds it more difficult to survive. It also provides a method for measuring recovery time from environmental contamination by recording the time necessary for an area to change from a fauna dominated by A. beccarii to that of its normal species composition. Other stress indicator species which are present in the MAFLA area are Nonion depressulum matagordanum and the various species of Elphidium.

If the stress conditions become so great that only a monospecific fauna remains, the degree of stress can also be determined by measurements of deformed chambers and changes in wall thickness of A. beccarii.

Although this report deals principally with the living fauna, it is worth examining the total fauna with regard to Amphistegina gibbosa. This species occurs live in abundance at different depths in different transects, always in association with coarse sediment. The genus is a worldwide reef indicator and most species belonging to it are always associated with reefs or high energy, hard substrates. The percentages of A. gibbosa in the total fauna are far greater than in the living fauna, and the majority of them show signs of reworking, indicating a relict fauna. Other reef species, at times abundant in the relict fauna, but rare in the living fauna, are Archaias angulatus and Peneroplis proteus. The presence of A. angulatus in the relict fauna, but its absence, or at least only a rare occurrence, in the living fauna indicates a Late Pleistocene or Early Holocene reef, thriving at a time when the water temperatures were warmer than those of today. In the Gulf of Mexico-Caribbean region at present, A. angulatus is not able to survive in cool water temperatures (Seiglie, 1968). Parker and Curray (1956) and Ludwick and Walton (1957) arrived at similar conclusions, the former based on the faunal evidence of mollusks and corals with abundant lithothamnoid algae and bryozoans, and the latter on skeletal remains of foraminifera, calcareous algae, mollusks, stony corals and bryozoans. Both papers stated that the water was much shallower and warmer than at present.

A comparison of the living benthonic foraminiferal faunas in the MAFLA area over the three sampling periods indicates changes in species composition are minor for the major dominant species, but changes in species distribution and especially abundance do occur naturally. At most stations these changes are relatively unimportant while at a few they are extreme. The causes for extreme change at a station while one immediately adjacent has little change are not completely understood at present. Additional seasonal sampling should clarify these changes. In general most stations showed minor changes in species abundance from the May-June to September sampling periods. Twenty stations showed an increase, twenty showed a decrease and three remained essentially unchanged. In most cases the changes were minor. From September to January nine stations showed an increase in foraminiferal abundance, thirty-five showed a decrease and three showed essentially no change. Seven of the nine stations showing an increase were located in Transects V and VI, which were sampled immediately after Hurricane ELOISE, most of the rest showed considerable decreases in abundances of the living fauna, over 80% at some stations. The increases could be due to increased productivity produced by disturbance of bottom sediments by the hurricane. The decreases are probably associated with adverse winter conditions. Much more numerous and smaller specimens were noticed during the May-June and September sampling periods, probably reflecting times of maximum reproduction occurring during the warm summer months.

A comparison of the 12-15 cm and surface three cm of the total faunas indicates some minor changes occurring in the foraminiferal faunas, but for the most part the major dominant species remained the same.

STATISTICAL ANALYSIS

The following statistical parameters were calculated using living foraminiferal data: correlation between mean grain size and foraminiferal abundance, Shannon-Weaver diversity and evenness indices, Sander's affinities and Montford cluster analysis.

Correlation coefficients for mean grain size and live foraminiferal abundance were calculated for each of the A and K replicates using:

$$\frac{\Sigma\ (Xi-\bar{X})\ (Yi-\bar{Y})}{[\Sigma\ (Xi-\bar{X})^2\quad \Sigma\ (Yi-\bar{Y}\ ^2)]^{\frac{1}{2}}}$$

where Xi is the foraminiferal abundance of the i-th sample and Yi is the mean grain size of the i-th sample. For the living population as a whole the only significant correlation noted was for the greater than 500 μm size range which had 0.86097 and 0.91551 correlation coefficients for the A and K replicates respectively. Although correlations were low for living populations there are strong indications that grain size of sediment does control distribution of certain individual species.

Diversity and evenness for all stations are listed in Table 1. Diversity plotted by Transect (Figs. 1-2) shows the normal expected increase seaward for Transects I-III. Transect IV shows the same general trend with the exception of station 24 for the second and third seasonal samplings. This is undoubtedly due to the very coarse sediment encountered at these times where diversity is affected by grain size. Transect V and VI show no appreciable seaward increase in diversity.

	June 1975		September 1975		January 1976	
Station #	H'	J'	H'	J'	H'	J'
2101	2.6124	0.7348	2.4084	0.6774	2.1983	0.6597
2102	2.7515	0.7678	2.0311	0.6032	2.1261	0.6451
2103	3.1515	0.7938	3.6032	0.8111	3.1896	0.7822
2104	3.2224	0.8155	3.1016	0.7376	2.5837	0.6787
2105	3.1823	0.7542	3.1241	0.7540	2.8276	0.6825
2106	3.4256	0.8176	3.4986	0.8007	3.1624	0.7965
2207	2.0032	0.5949	1.9830	0.6036	2.1282	0.6457
2208	3.1015	0.7928	3.0470	0.7871	2.6237	0.7020
2209	3.1630	0.7929	3.1560	0.7876	3.0503	0.7335
2210	3.4707	0.8283	3.4238	0.7980	3.0147	0.7558
2211	3.3934	0.8255	3.2940	0.7834	3.1022	0.7577
2212	3.4987	0.8235	3.2631	0.8003	3.1243	0.8256
2313	3.2276	0.7949	3.2082	0.7603	2.9507	0.7468
2314			3.5515	0.8037	3.4002	0.8271
2315			3.1869	0.7752	3.0862	0.7701
2316	3.2477	0.8104	3.0106	0.7583	2.7830	0.7544
2317	3.1927	0.7897	2.9532	0.7304	2.8643	0.7258
2318	2.1349	0.6217	1.7397	0.5628	1.6385	0.5226
2419	1.8653	0.5382	1.9673	0.5784	2.2240	0.6206
2420	1.6640	0.5170	2.1153	0.5950	0.9974	0.5126
2421	2.6260	0.6783	2.4841	0.6350	2.6451	0.6727
2422	3.3331	0.8045	2.6023	0.6962	2.1766	0.6532
2423	3.0563	0.7559	2.7746	0.7207	2.7726	0.7466
2424	3.0844	0.7697	0.4631	0.1303	0.7206	0.4022
2425	3.0684	0.7804	2.6259	0.6981	2.7820	0.7325
2426	3.0381	0.7689	3.2087	0.7775	2.9844	0.7751
2427	3.5234	0.8571	3.0060	0.8095	3.2053	0.7894
2528	3.1285	0.7880	3.0600	0.7744	2.8247	0.8010
2529	3.1378	0.8063	2.9685	0.7798	3.4578	0.8346
2530	3.3671	0.8127	2.9768	0.7395	2.5593	0.7951
2531	3.2074	0.7968	3.3221	0.8114	3.2116	0.8089
2532	3.2291	0.8172	3.2875	0.8131	3.2262	0.7880
2533	3.1368	0.7828	3.2408	0.7707	3.0876	0.7267
2534	2.7559	0.7119	2.6460	0.6911	2.8150	0.7272
2535	3.1602	0.7687	3.2447	0.7862	3.1992	0.7582
2536	3.3382	0.8187	3.1528	0.7798	2.9927	0.7957
2637	2.5060	0.7231	2.4301	0.7217	2.5394	0.7541
2638	2.7007	0.7659	2.6474	0.7446	2.4372	0.7773
2639	2.4155	0.6548	2.6538	0.6855	2.5916	0.7074
2640	2.6491	0.7088	2.2706	0.6114	1.9495	0.5625
2641	2.5104	0.6634	2.3835	0.6941	2.6534	0.6818
2642	2.3028	0.6839	2.3354	0.6289	0.8001	0.4465
2643	3.0219	0.7411	3.0363	0.7446	2.6320	0.7135
2644	2.5762	0.7082	2.9084	0.6993	2.9797	0.7308
2645	3.3182	0.7734	2.9495	0.7502	2.9942	0.7343

Table 1. H' (diversity) and J' (eveness) measurements for the second year of the MAFLA program.

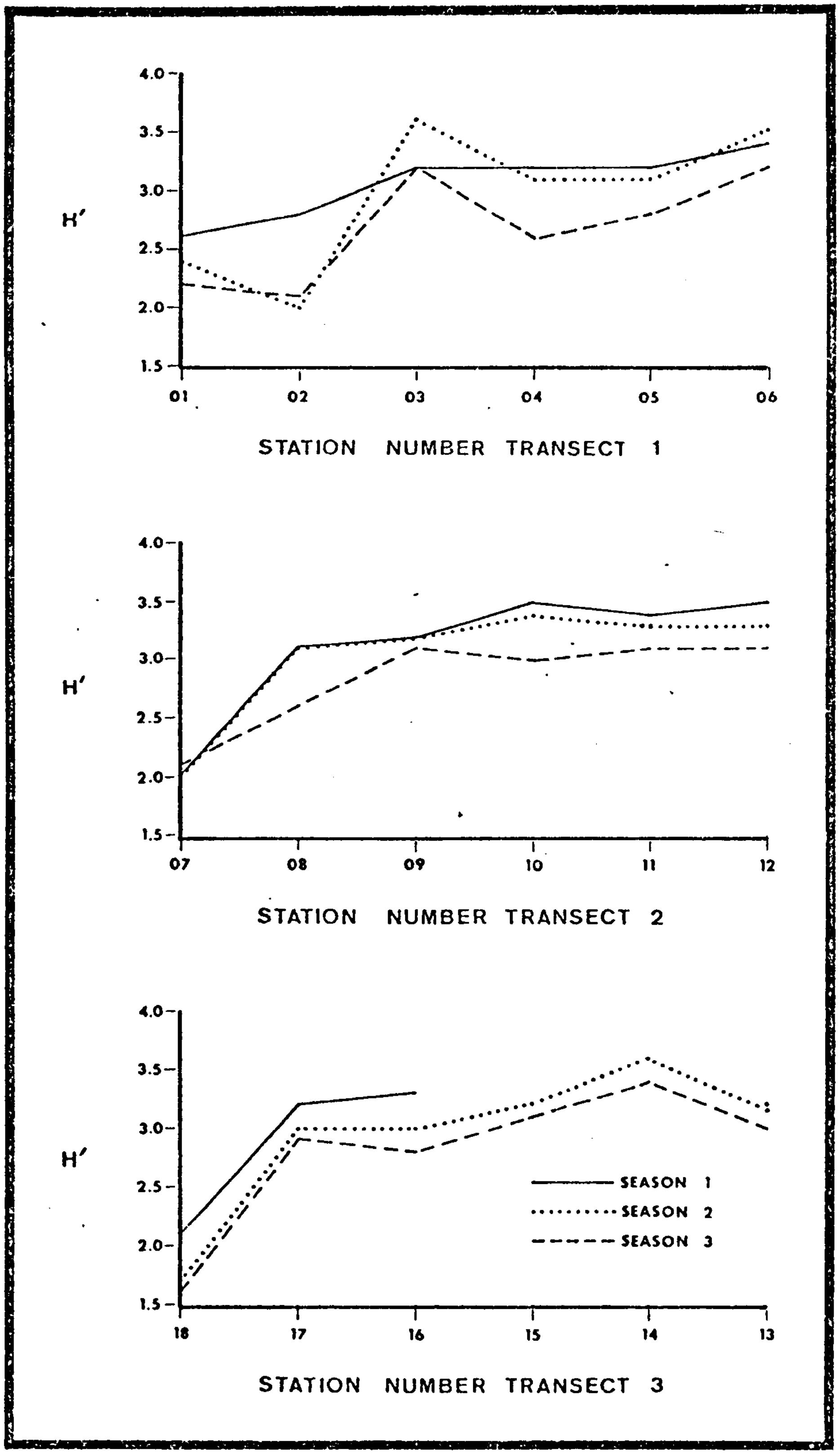


Figure 1. Shannon-Weaver diversity indices plotted by transect.

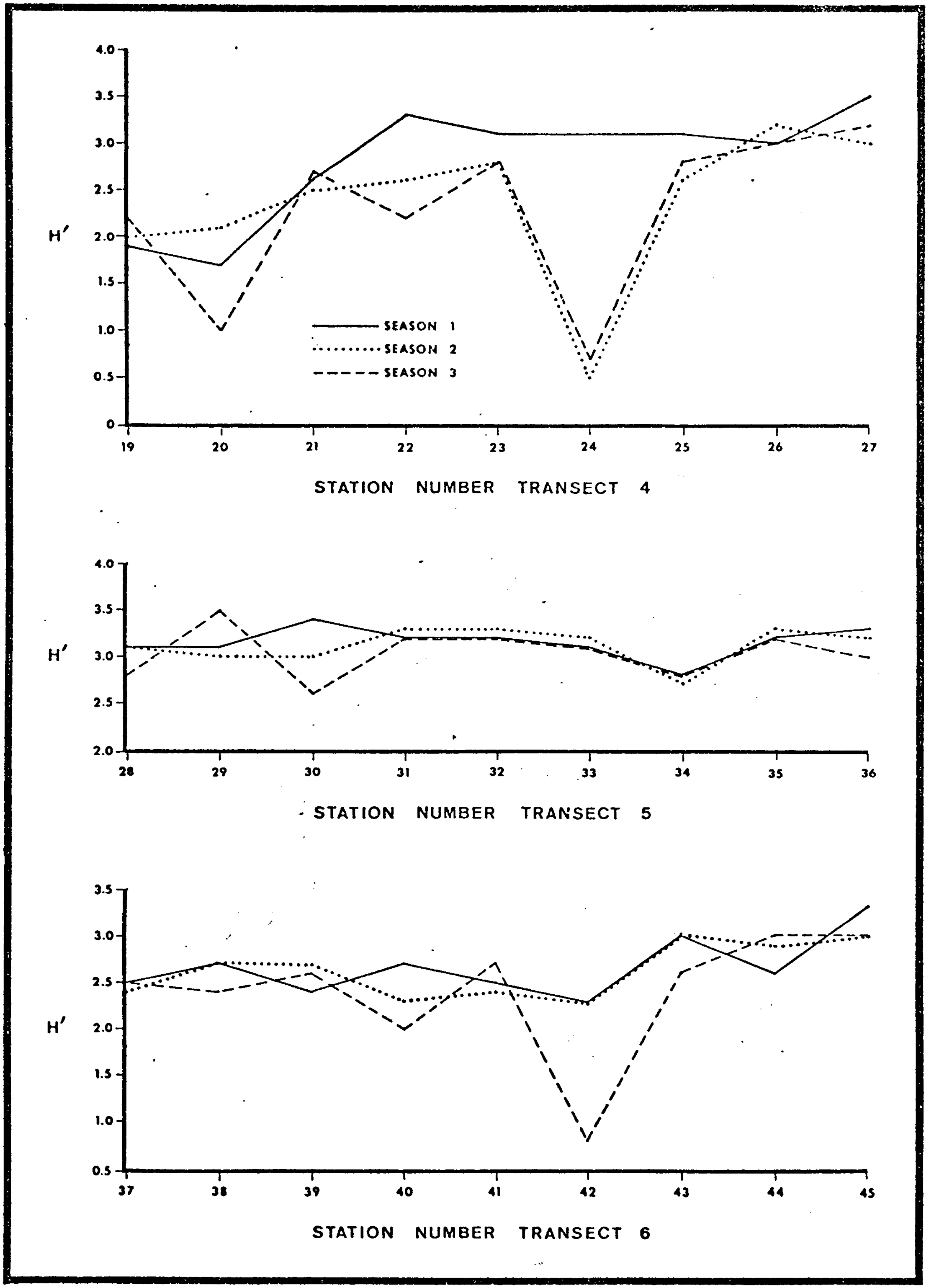


Figure 2. Shannon-Weaver diversity indices plotted by transect.

In Transect V this is due to the number of deeper-water species living farther up the shelf along with the normal species for the depths encountered. Upwelling along the DeSoto Canyon is undoubtedly creating conditions favorable for the deeper-water species, while the fauna normal for those depths are probably more dependent on other parameters such as light penetration, the two factors together providing favorable conditions for the two faunas to coexist and hence causing higher diversity in shallow water. Transect VI does show a slight increase in diversity at the seawardmost stations, but much less so than the clearly defined trends of Transects I-IV. The smoothing out of the curve is probably due to sediment grain size, with the shallowest stations nearest shore being much finer-grained than the deeper offshore stations, a reversal of the trend in the other five transects. The finer-grained sediments support a more diverse fauna inshore even though the habitat may be stressed due to low salinity, highly turbid river runoff water, while the offshore stations are considerably more coarse-grained, and thus support a less diverse fauna even though the habitat is normal marine.

Evenness plotted by transect (Figs. 3-5) shows the same general trends as diversity for Transects I-V for the same reasons stated above. Transect VI, however, again diverges from the general trend by having a U-shaped general curve. The nearshore stations show a high degree of evenness, even though the fauna is stressed, the major dominant species are evenly distributed in abundance. Proceeding offshore (stations 40-42) the dominant species of the coarser sediments are less evenly distributed. The farthest offshore stations again exhibit a high degree of evenness due to to the mixing of a fauna similar to that of stations 40-42 along

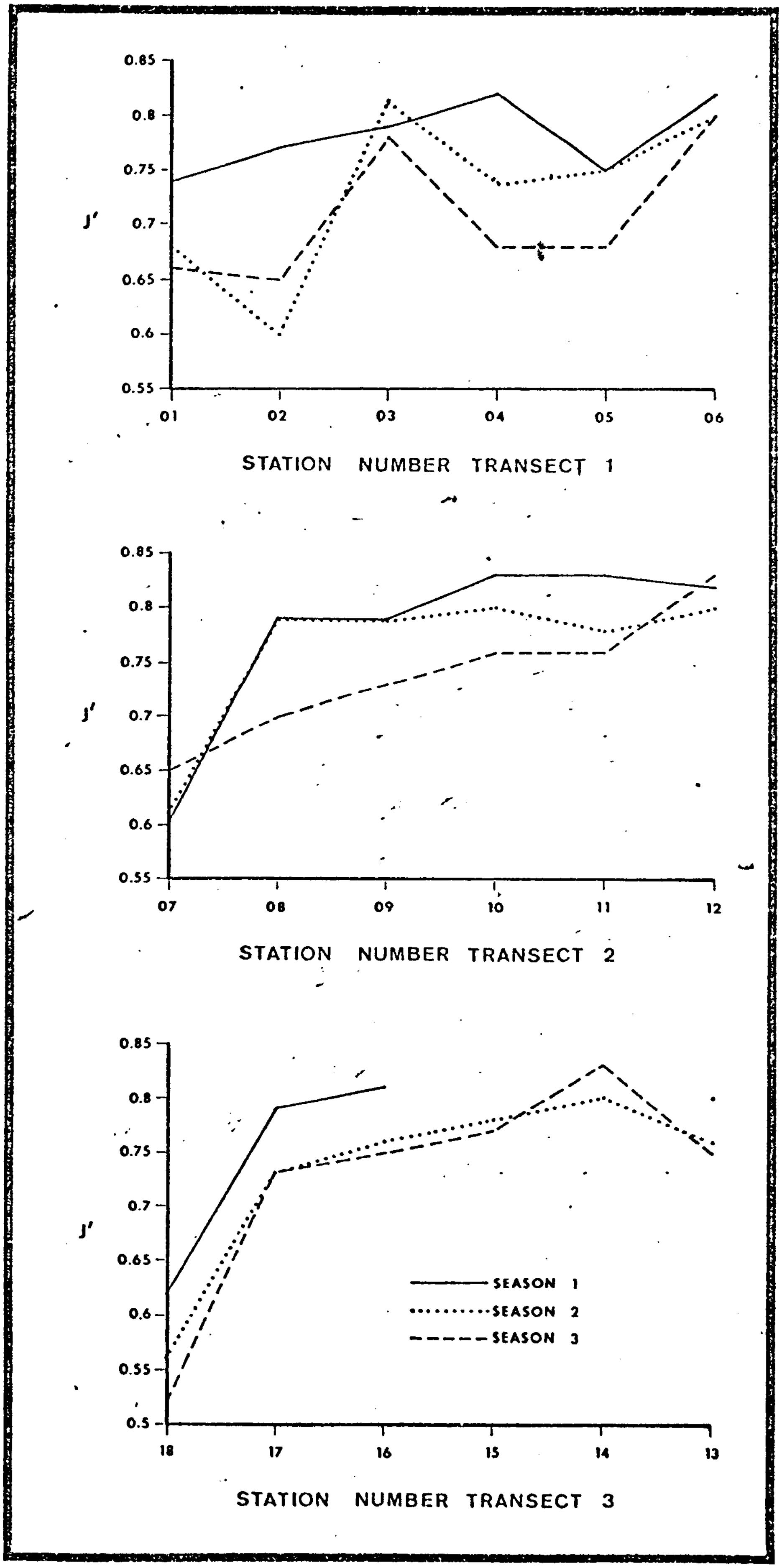


Figure 3. Evenness plotted by transect.

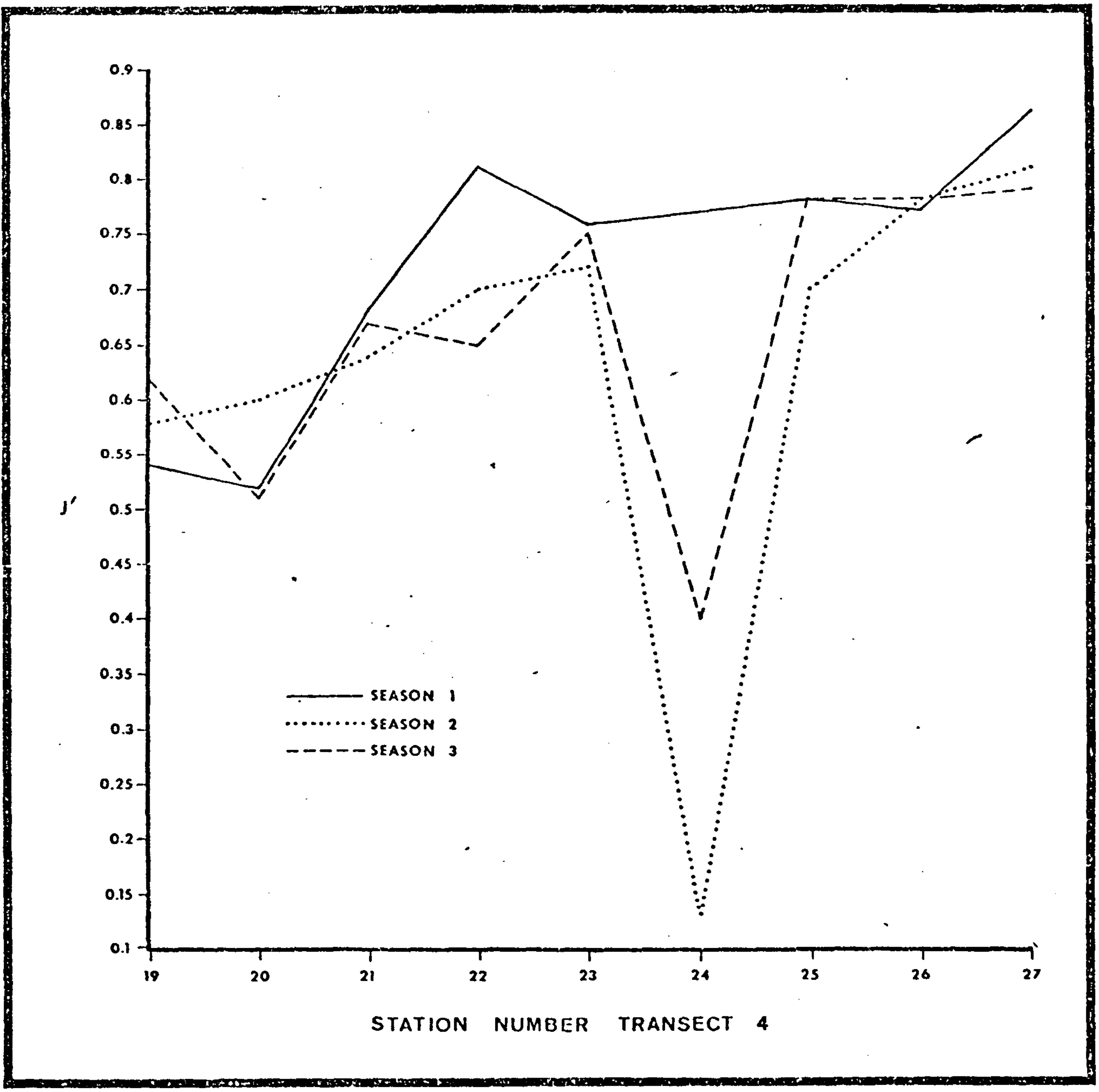


Figure 4. Evenness plotted by transect.

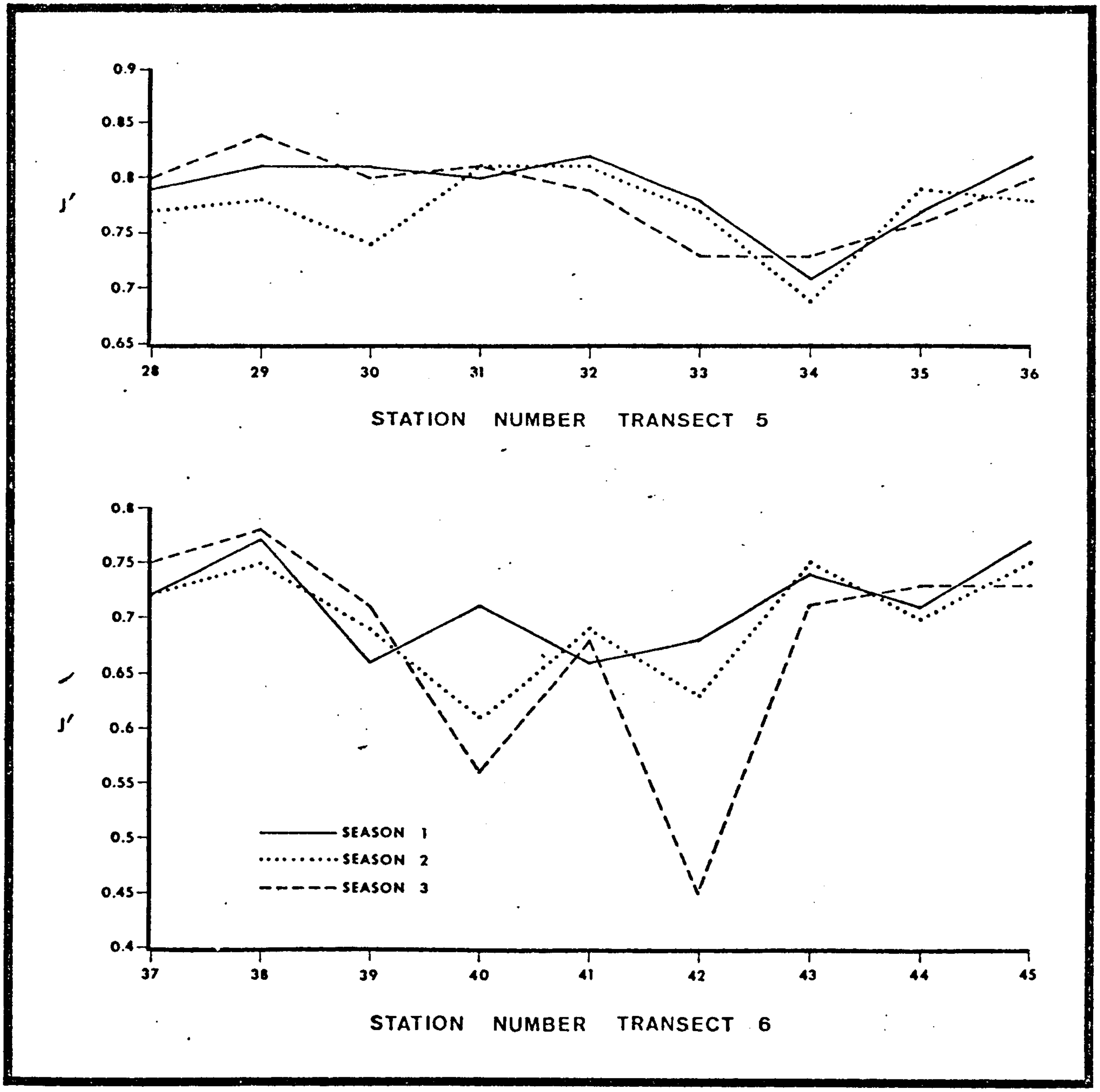


Figure 5. Evenness plotted by transect.

with a reef fauna.

Figure 6 shows diversity and evenness averaged over transects. In general these graphs show a remarkable uniformity of diversity and evenness over the entire MAFLA area. The low points on both graphs reflect the coarseness of sediment over most of Transect IV, and the influence of river runoff in Transect VI.

Sander's affinities indicate the midpoints of each transect are most similar to all other stations in the transects, with the exception of Transect VI where the trend is skewed shoreward by one station. In a north-south trend at the deepest stations (183 m) station 2313, again the midpoint, has the greatest affinity to all other stations in the trend. The near-shore stations of Transects I-IV also shows the highest affinities to all other stations along the north-south trend at the midpoint, station 2318.

Montford cluster analysis shows the greatest affinities between seasonal samplings at the same stations. This reflects a high degree of uniformity of the species composition of the faunas seasonally. The second highest affinities are between adjacent stations, both along transects and north-south trends. The least affinities, as one would expect, are between the shallowest and deepest stations and between distal ends of the overall area. In general, cluster analysis indicates a high degree of affinity over the entire MAFLA area over all seasons, only four group memberships falling lower than 26.1774.

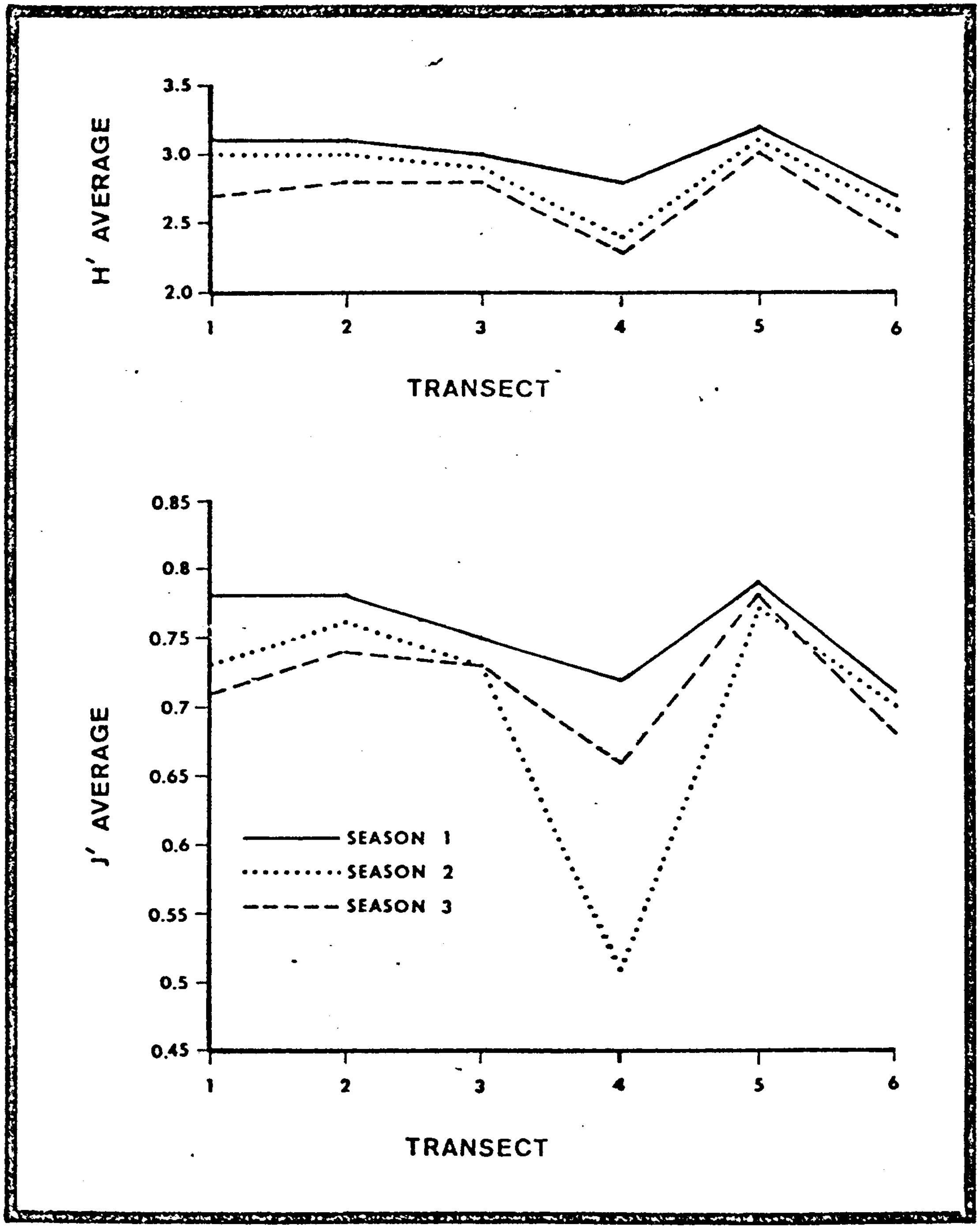


Figure 6. Diversity and evenness averaged by transect.

CONCLUSIONS

A comparison of the living benthonic foraminiferal faunas of the MAFLA area from 1974 and 1975 indicates changes in species distribution and abundance occur naturally. At some stations these changes are relatively unimportant while others are extreme. The causes for extreme change at one station while a station immediately adjacent has relatively little change are not completely understood at present. Seasonal sampling should clarify the causes for these changes.

Several foraminiferal trends have become apparent in the MAFLA area. Many of these are at least partially understood, but, again, seasonal sampling should clarify the reasons for the trends.

Stress indicator species occur in the MAFLA area and further monitoring should enable us to achieve a better understanding of their reactions to natural changes in the environment in addition to providing a means for determining introduction of man-made pollutants and their potential danger to the environment.

REFERENCES

Bandy, O. L., 1956. Ecology of foraminifera in northeastern Gulf of Mexico. U.S. Geol. Survey, Prof. Paper 274-6; 125-204.

Lankford, R.R., 1959. Distribution and ecology of foraminifera from east Mississippi Delta margin. Bull. Amer. Assoc. Petroleum Geologists 43(9):2068-2099.

Lowman. S.W., 1949. Sedimentary facies in Gulf Coast. Bull. Amer. Assoc. Petroleum Geologists. 33(12;:1939-1997.

Ludwick, J.C. and W.R. Walton, 1957. Shelf-edge calcareous prominances in northeastern Gulf of Mexico. Bull. Amer. Assoc. Petroleum Geologists 41(9):2054-2101.

Parker, F.L., 1954. Distribution of the foraminifera in the northeastern Gulf of Mexico. Bull. Harvard Mus. Comp. Zool. 111(10):453-588.

Parker, R.H. and J.R. Curray, 1956. Fauna and bathymetry on banks on continental shelf northwest Gulf of Mexico. Bull. Amer. Assoc. Petroleum Geologists 40(10):2428-2439.

Phleger, F.B., 1954. Ecology of foraminifera and associated microorganisms from Mississippi Sound and environs. Bull. Amer. Assoc. Petroleum Geologists 38(4):584-647.

______, 1955. Ecology of foraminifera in southeastern Mississippi Delta area. Bull. Amer. Assoc. Petroleum Geologists 39(5):712-752.

______, 1960. Sedimentary patterns of microfaunas in northern Gulf of Mexico. In Recent Sediment, Northwest Gulf of Mexico. Amer. Assoc. Petroleum Geologists: 267-381.

Seiglie, G.A., 1968. Relationships between the distribution of Amphistegina and the submerged Pleistocene reefs off western Puerto Rico. Tulane Stud. Geol. 6(4):139-147.

Walton, W.R., 1964. Recent foraminiferal ecology and paleoecology. In Approaches to paleoecology, John Imbrie and Normal Newell, eds. New York: John Wiley and Sons: 151-237.

INFAUNAL MACROMOLLUSCAN ASSEMBLAGES OF THE EASTERN GULF OF MEXICO

University of South Florida, Department of Marine Science

Principal Investigator:
Norman J. Blake

Associate Investigators:
David Bishof
John Studt

INTRODUCTION

Molluscs and polychaetes usually comprise the largest part of subtidal macroinfaunal (>500 μm) communities. This study was part of an attempt to characterize the benthic macrofaunal communities of the shelf and shelf break of the eastern Gulf of Mexico based upon quantitative sampling at 45 selected stations.

The infaunal macromolluscs of the shelf and slope of the eastern Gulf of Mexico mostly have been studied qualitatively. Techniques such as trawls and dredges have yielded much valuable information concerning the taxonomy and zoogeographic distributions of macromolluscs (Pulley, 1952; William Lyons, unpublished). In order to undertake a more ecological approach in which the assemblages are analyzed based upon their "structure" (diversity, species richness, evenness) or in which they are "classified" based upon the temporal and spatial distribution of individuals and species, replicate samples should be taken by a qualitative technique, preferably over multiple seasons.

METHODS

Figure 1 shows the station locations for the study along each of the six transects. Depths for each station are shown in Table 1. Each station was sampled during June 1975, September 1975, and January 1976. Station locations were determined by either Raydist or DECCA Hi Fix to a reported accuracy of ±30 m.

At each of the 45 stations an attempt was made to collect nine replicate box cores (21.3 cm x 30.5 cm) for macroinfaunal analysis. If after three successive attempts with the box core an adequate sample was

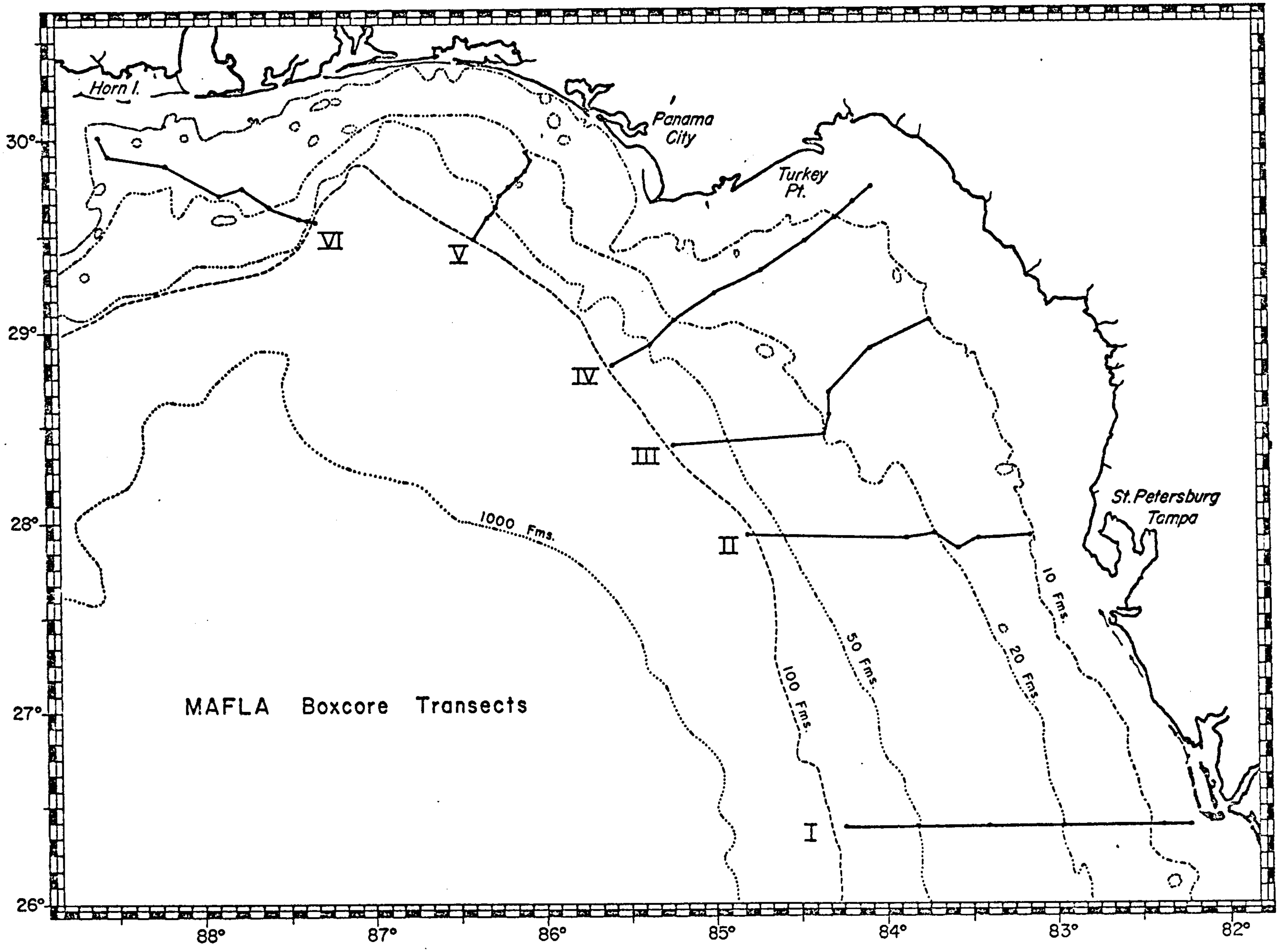


Figure 1. Location of the 45 box core stations on the six transects of the MAFLA study area during the 1975- 1976 seasonal sampling.

TABLE 1.
BOX CORE STATION LOCATIONS AND DEPTHS

BOX CORE STATION NOS.	DEPTH (M)	C.M. = 87° CLARKE (1866)	
		LATITUDE (N)	LONGITUDE (W)
2637	21	30° 01' 57.6"	88° 36' 58.58"
2638	24	29° 55' 29.633"	88° 33' 28.422"
2639	32	29° 53' 28.163"	88° 12' 28.021"
2640	35	29° 43' 28.612"	87° 54' 29.103"
2641	37	29° 45' 29.999"	87° 46' 29.072"
2642	36	29° 40' 29.965"	87° 37' 00.777"
2643	69	29° 36' 30.901"	87° 26' 57.646"
2644	75	29° 36' 12.660"	87° 23' 31.656"
2645	106	29° 35' 01.370"	87° 20' 06.365"
2101	11	26° 25' 00.233"	82° 14' 55.228"
2102	18	26° 24' 59.642"	82° 25' 00.200"
2103	37	26° 25' 01.273"	82° 58' 00.301"
2104	53	26° 25' 01.144"	83° 23' 00.754"
2105	90	26° 25' 00.918"	83° 49' 58.987"
2106	168	26° 24' 57.174"	84° 14' 59.247"
2207	19	27° 57' 00.142"	83° 08' 58.259"
2208	31	27° 56' 00.097"	83° 27' 30.782"
2209	34	27° 52' 30.523"	83° 33' 59.552"
2210	37	27° 57' 29.742"	83° 42' 29.381"
2211	43	27° 56' 29.170"	83° 52' 59.621"
2212	189	27° 56' 59.551"	84° 48' 00.607"
2313	176	28° 24' 02.916"	85° 15' 06.974"
2314	29	28° 28' 59.934"	84° 20' 59.902"
2315	29	28° 34' 01.342"	84° 20' 06.082"
2316	35	28° 42' 00.862"	84° 19' 59.566"
2317	29	28° 55' 59.313"	84° 05' 59.980"
2318	20	29° 05' 00.568"	83° 44' 59.371"
2419	10	29° 47' 00.918"	84° 05' 00.431"
2420	14	29° 41' 59.856"	84° 11' 00.192"
2421	19	29° 37' 00.294"	84° 17' 00.750"

TABLE 1.
BOX CORE STATION LOCATIONS AND DEPTHS (continued)

BOX CORE STATION NOS.	DEPTH (M)	C.M. = 87° CLARKE (1866) LATITUDE (N)	LONGITUDE (W)
2422	24	29° 29' 59.623"	84° 26' 59.811"
2423	30	29° 19' 58.932"	84° 44' 00.409"
2424	28	29° 12' 59.423"	85° 00' 01.004"
2425	36	29° 04' 59.526"	85° 14' 59.290"
2426	82	28° 57' 59.052"	85° 22' 58.260"
2427	171	28° 49' 59.244"	85° 37' 06.583"
2528	37	29° 54' 54.111"	86° 05' 00.407"
2529	38	29° 55' 59.797"	86° 06' 30.632"
2530	41	29° 50' 53.231"	86° 06' 24.405"
2531	45	29° 47' 59.987"	86° 09' 29.830"
2532	52	29° 45' 53.139"	86° 12' 18.162"
2533	67	29° 42' 53.424"	86° 15' 30.062"
2534	73	29° 39' 59.332"	86° 16' 59.158"
2535	117	29° 36' 59.163"	86° 19' 59.782"
2536	189	30° 18' 20.883"	86° 11' 59.148"

not obtained, a modified Sanders anchor dredge was used to collect two samples. The dredge was required at only six of the 135 station samplings.

A sample (five centimeters in diameter x depth of core) was taken from two of the nine box core replicates for sediment analysis leaving a total of approximately 0.54 m^2 for macroinfauna analysis. The top 15 cm of each of the nine replicates after sediment plug removal was sieved through a 500 μm mesh Nitex screen. The material remaining on the screen was placed in a cloth bag and narcotized for 30 min in 15% $MgSO_4$ after which it was preserved in 10% buffered formalin. The relatively less dense fauna (small polychaetes, crustaceans) were removed from the samples by flotation in a saturated NaCl solution. The remaining fauna were stained with one per cent rose bengal and sorted from the sediment. Fauna were divided into five groups (polychaetes, molluscs, crustaceans, echinoderms, and other) and stored in 70% EtOH. Wet weight biomass determinations were made for each group to the nearest 0.1 mg.

Only polychaetes (Vittor and Kritzler) and molluscs (Blake) were identified to the lowest practical taxonomic level.

All molluscs were identified to at least the family level, but only those individuals identified to at least the genus level were included in analyses. Key references for molluscan identification were Heath (1918), Henderson (1920), Clench (1941-1972), Hughes and Thomas (1971), Keen (1971), Kaas (1972), and Abbott (1974).

A standard analysis package was developed in collaboration with the DMSAG group. This package included the following:

1. Tabulation of numerical species dominance based upon an accumulated sum of the nine replicates (0.54 m^2).

2. Calculation of measurements of community structure.

The sum of the species collected in the nine replicates were used for these calculations. The Shannon-Wiener index of H' (Pielon, 1966) was used to measure species diversity as follows:

$$H' = -\Sigma \, p_i \log_2 p_i$$

where p_i is the proportion of individuals which belong to the species.

Species diversity has both a "species richness" component and an "evenness" component (Floyd and Ghelardi, 1964). Species richness (Margelef, 1958) was measured as follows:

$$SR = (S-1)/\ln N$$

where S is the number of species and N is the total number of individuals. Evenness (Pielon, 1966) was measured by the following formula:

$$J' = H'/\log_2 S.$$

3. Calculation of similarity. Affinity between stations and seasons was calculated using Sander's (1960) minimal faunal abundance (MFA) and the Morisita (1959) coefficient ($C\lambda$). These affinities were calculated as follows:

For two S species assemblages A and B with proportionate abundances of the i^{th} species a_i and b_i respectively,

$$MFA = \sum_{i=1} c_i, \text{ where } c_i = \begin{cases} a_i, & a_i \leq b_i \\ b_i, & b_i \leq b_i \end{cases}, \quad 0 \leq a, b, c \leq 1.$$

The value may be presented as a percentage by multiplying by 100.

$$C_\lambda = Z \sum_{i=1}^{\infty} \frac{n1i \; n2i}{(\lambda 1 + \lambda Z) \; N1N2}$$

N1i and N2i are the number of specimens of conjoint species and N1 and N2 are the total number of individuals in the two samples. The coefficients are determined for the two samples by

$$\lambda = \sum_{i=1}^{\infty} \frac{n_i(n_i-1)}{N(N-1)}$$

The 145 x 144 half matrices resulting MFA and C_λ were clustered by the Mountford (1962) weighted pair group method and the results presented as a dendrogram.

RESULTS

Sediments

The surficial sediment characteristics (Doyle, 1976) at the 45 box core stations are shown in Table 2. Sediments can be classified based upon particle size as well as mineral composition into five substrate types ranging from lime mud to coarse sand (quartz). On Transects I - VI, coarse to fine sand high in calcium carbonate content was present at most of the nearshore stations; the sediment at stations 2101, 2207, 2318, and 2419 contained quartz sand as well as some carbonates. At the deeper stations, the sediments were classified as lime muds even though particle size ranged from clay to sand.

Sample replication

In the 1974 MAFLA program, seven box cores were taken at each station for macrofaunal analysis. Indications were that this number was inadequate to describe the benthic assemblages at the majority of the stations. Figure 2 shows the cumulative number of molluscan species in the nine replicates at four different stations during the summer 1975 sampling effort. At the shallow mud stations of Transects V and VI, species saturation is reached within three to four replicates; and at the shallow sand stations of these two transects, species saturation is reached at five to six replicates. Seven replicates at the shallow sand stations of Transects I, II, III, and IV (represented in the figure by 2103) yield 70-85% of the species collected with nine replicates; and even with nine replicates, species saturation is not reached at some of these stations because of the continued addition of rare species.

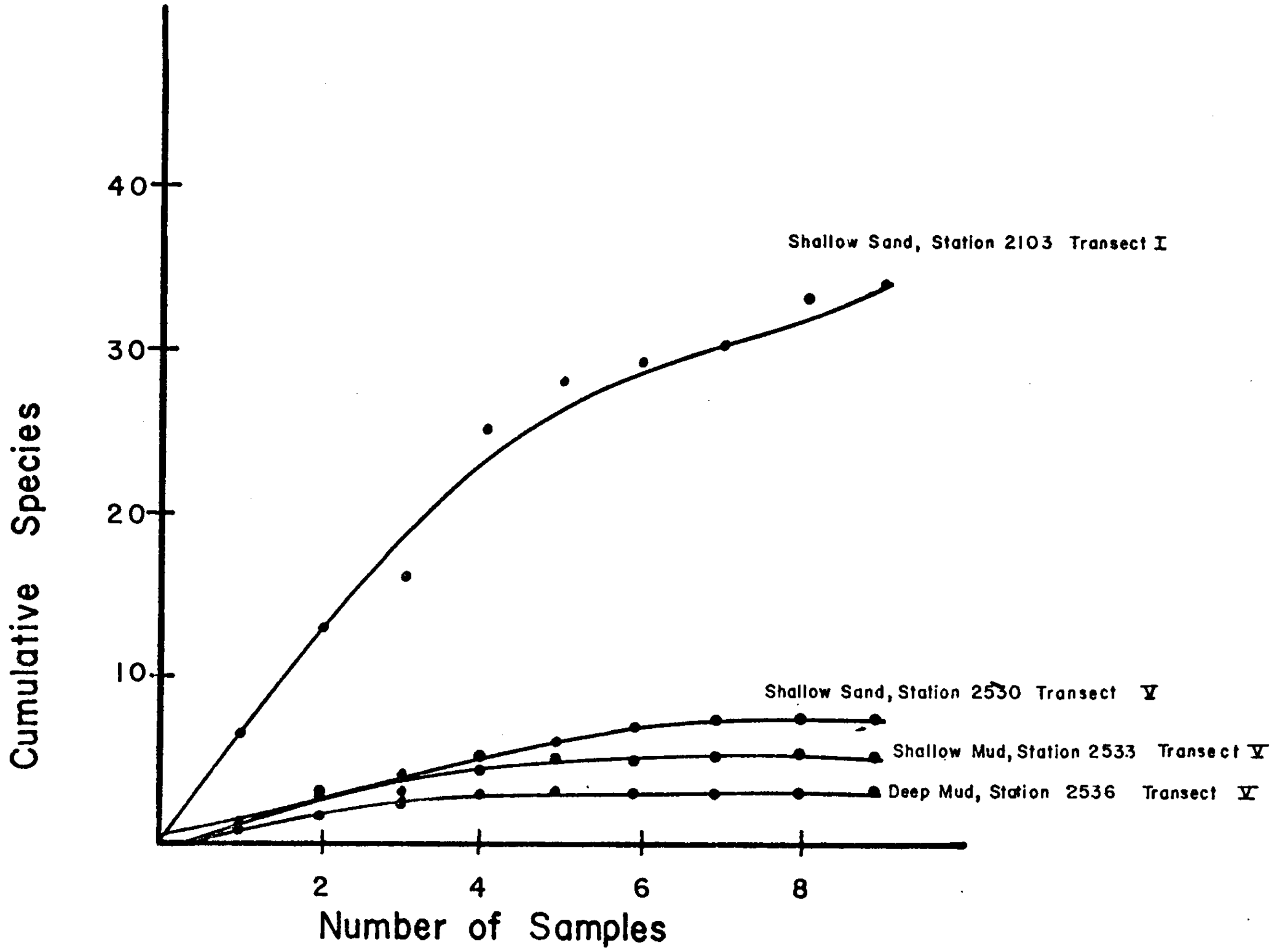


Figure 2. The cumulative number of species of macromolluscs collected with nine box cores in four different habitat types.

TABLE 2.
Surficial Sediment Characteristics for the
45 Box Core Stations (from Doyle, 1976)

Station	Mean Sediment Diameter (mm)	Calcium Carbonate (%)	Classifications
2101	.010	47.72	Carbonate clay
2102	.260	27.65	Carbonate sand
2103	.390	61.26	Carbonate sand
2104	.440	90.47	Carbonate sand
2105	.410	91.96	Carbonate sand
2106	.260	82.93	Carbonate sand
2207	.140	43.43	Carbonate sand
2208	.004	83.34	Carbonate clay
2209	.210	83.51	Carbonate sand
2210	not available	86.67	Carbonate sand
2211	.620	93.18	Coarse carbonate sand
2212	.260	88.00	Carbonate sand
2313	.009	85.04	Carbonate clay (Lime mud)
2314	not available	63.63	Coarse carbonate sand
2315	not available	64.35	Carbonate sand
2316	.180	53.55	Carbonate sand
2317	.052	79.48	Fine sand
2318	.480	10.77	Carbonate sand
2419	.210	19.19	Carbonate sand
2420	.250	66.87	Carbonate sand
2421	.125	51.53	Carbonate sand
2422	.440	43.81	Carbonate sand
2423	.430	72.46	Carbonate sand
2424	.270	9.27	Carbonate sand
2425	.490	8.27	Carbonate sand
2426	.280	34.27	Carbonate clay (Lime mud)
2427	.035	78.38	Carbonate clay (Lime mud)
2428	.740	58.62	Coarse carbonate sand
2529	1.100	71.82	Coarse carbonate sand
2530	.940	74.73	Coarse carbonate sand
2531	.880	84.71	Coarse carbonate sand
2532	.410	75.79	Carbonate sand
2533	.790	86.85	Coarse carbonate sand
2534	1.000	91.00	Coarse carbonate sand
2535	.020	69.31	Carbonate clay (Lime mud)
2536	.019	74.17	Carbonate clay (Lime mud)
2637	.026	13.29	Silty clay
2638	.020	17.54	Silty clay
2639	.130	20.78	Carbonate sand
2640	.420	19.67	Carbonate sand
2641	.150	5.31	Sand
2642	.250	6.51	Sand
2643	.570	83.97	Coarse carbonate sand
2644	.650	88.54	Coarse carbonate sand
2645	.710	84.29	Coarse carbonate sand

Species composition

Samples collected from the 45 stations during the three seasons of 1975 - 1976 yielded 282 identifiable macromolluscan (>500 μm) taxa (Table 3). The species included 141 gastropods, 120 bivalves, 13 scaphapods, 7 polyplacophorans, 1 aplacophoran. The list contains some species which are basically temperate in geographical distribution as well as others which are basically subtropical to tropical in geographical distribution. Although little is known about the ecology of the vast majority of species identified, both filter feeders and deposit feeders are represented in the list. Since all individuals collected by the box core and anchor dredge were identified to the lowest practical taxonomic level, the species list contains a limited number of epifaunal molluscs as well as infaunal molluscs.

Species abundances

Table 4 shows all molluscan species which were collected at the 45 stations during the three seasons and which represented at least five per cent of the total number of individuals. At the shallow water (20-90 m) stations of Transects I, II, III, and IV (Figure I), relatively more species were present in at least five per cent abundance than were present at the deeper water stations of these transects or the stations located on the Transects V and VI.

The abundances of the 282 species taken quantitatively by box core ranged from very rare (1 individual/0.54 m^2) to common (605 individuals/ 0.54 m^2). The most abundant species collected in the study were *Tellina versicolor*, *Parvilucina multilineata*, *Abra lioica*, and *Varicorbula operculata* respectively. *Tellina versicolor* occurred over broad areas of the MAFLA shelf (28 out of 45 stations) especially at the sand station in less than 90 m of water. The deeper water mud stations had generally lower

TABLE 3
INFAUNAL MOLLUSCS COLLECTED FROM MAFLA TRANSECTS I-VI DURING 1975-76

GASTROPODA

Scissurellidae
Scissurella crispata

Fissurellidae
Emarginula phrixodes
Emarginula pumila
Rimula frenulata
Hemitoma sp.
Diodora dysoni
Diodora jaumei
Lucapinella limatula

Trochidae
Solariella lucunella
Calliostoma roseolum
Calliostoma fascinans

Cyclostrematidae
Arene tricarinata

Turbinidae
Turbo castanea

Phasiaellidae
Tricolia thalassicola

Rissoidae
Alvania auberiana

Rissoinidae
Rissoina bryerea
Rissoina multicostata
Zebina browniana

Vitrinellidae
Cyclostremiscus sp.
Episcynia inornata
Teinostoma biscaynens

Tornidae
Macromphalina palmalitoris
Macromphalina floridana
Cochliolepis striata

Caedidae
Caecum pulchellum
Caecum bipartitum

Caecidae - continued
Caecum floridanum
Caecum imbricatum
Caecum cubitatum
Caecum stigosum
Caecum cornucopiae

Turritellidae
Turritella acropora

Architectonicidae
Pseudomalaxis centrifuga

Modulidae
Modulus modulus

Cerithiidae
Cerithium atratum
Cerithium litteratum
Finella dubia
Cerithiopsis crystallinum
Cerithiopsis taeniolata
Seila adamsi

Triphoridae
Triphora sp.

Epitoniidae
Opalia sp.
Epitonium krebsii
Epitonium novangliae

Mellanellidae
Melanella arcuata
Vitreolina bermudezi
Eulima bifasciatus
Eulimostrica hemphilli
Niso aeglees
Ocenida scalaris

Aclididae
Henrya sp.

Atlantidae
Atlanta peronii

Crepidulidae
Calyptraea centralis
Crucibulum auricula

GASTROPODA continued

Strombidae
Strombus alatus

Eratoidae
Triva maltbiana

Naticidae
Polinices lacteus
Polinices duplicatus
Sigatica carolinensis
Sigatica semisulcata
Sinum perspectivum
Natica livida
Natica marochiensis
Natica canrena
Natica pusilla

Cassidae
Phalium granulatum

Cymatiidae
Distorsio constricta macgintyi

Muricidae
Murex cabritii
Murex macgintyi
Murex leviculus
Murex pomum
Ocenebra minirosea
Poirieria stimpsonii
Calotrophon ostrearum

Columbellidae
Anachis hotessieriana
Anachis obesa
Anachis iontha
Mitrella lunata
Psarostola glypta
Psarostola minor
Psarostola sp.

Buccinidae
Cantharus cancellarius

Nassariidae
Nassarius albus

Fasciolariidae
Fasciolaria lilium hunteria

Olividae
Oliva sayana
Olivella sp.

Vexillinae
Costellaria laterculatum

Cancellariidae
Cancellaria reticulata
Trigonostoma tenerum

Marginellidae
Marginella hartleyanum
Marginella eburneola
Hyalina avena
Hyalina veliei

Conidae
Conus jaspideus

Terebridae
Terebra dislocata
Terebra glossema
Terebra nassula
Terebra concava

Turridae
Cochlespria radiata
Microdrillia comatoropis
Mitrolumna biplicata
Cerodrillia simpsoni
Glyphoturris sp.
Brachycythara biconica
Brachycythara barbarae
Cryoturris fargoi
Cryoturris filifera
Cryoturris citronella
Cryoturris quadrilineata
Kurtziella atrostyla
Rubellatoma rubella
Ithycythara lanceolata
Nannodiella melanitica
Glyphostoma hendersoni
Pyrocythara sp.
Daphnella
Platycythara elata
Rimosodaphnelle morra
Thelecythara floridana

Pyramidellidae
Odostomia seminuda
Turbonilla sp.

GASTROPODA continued

Acteonidae
Acteon punctostriatus
Acteon candens

Acteocinidae
Acteocina candei

Cylichnidae
Cylichna sp.
Scaphander sp.

Philinidae
Philine sagra

Bullidae
Bulla striata

Haminoeidae
Atys riiseana
Haminoea succinea

Retusidae
Retusa sulcata
Pyrunculus caelatus
Volvulella persimilis
Volvulella recta
Volvulella texasiana
Volvulella paupercula

Volvatellidae
Cylindrobulla beauii

Cuvieridae
Diacria trispinosa
Cavolinia uncinata

Siphonariidae
Williamia krebsii

SCAPHOPODA

Dentaliidae
Dentalium laqueatum
Dentalium texasianum
Dentalium ceratum
Dentalium bartletti
Dentalium semistriolatum
Dentalium ensiculus
Dentalium sowerbyi
Dentalium callipeplum
Dentalium eboreum

Siphonodentaliidae
Cadulus carolinensis
Cadulus quadridentatus
Cadulus tetrodon
Cadulus parvus

POLYPLACOPHORA

Ischnochitonidae
Ischnochiton boogii
Ischnochiton floridanus
Ischnochiton papillosus
Ischnochiton hartmeyeri

Chaetopleuridae
Chaetopleura apiculata

Chitonidae
Chiton squamosus

Acanthochitonidae
Acanthochitona pygmaea

APLACOPHORA

Chaetodermatidae
Chaetoderma sp.

BIVALVIA

Nuculidae
Nucula proxima
Nucula aegeensis

Nuculanidae
Nuculana carpentri
Nuculana acuta
Nuculana concentrica
Yoldia solenoides

Solemyacidae
Solemya velum

Arcidae
Arca zebra
Barbatia domingensis
Anadara baughmani
Bathyarca sp.
Arcopsis adamsi

BIVALVIA continued

Limopsidae
Limopsis cristata
Limopsis minuta
Limopsis sulcata

Glycymerididae
Glycymenis pectinata

Manzanellidae
Nucinella adamsi

Mytilidae
Crenella divaricata
Gregariella coralliophaga
Musculus lateralis
Lithophaga aristata
Modiolus americanus
Amygdalum papyrium
Amygdalum sagittatum
Botula fusca
Dacrydium vitreum

Pinnidae
Atrina sp.

Pteriidae
Pteria colymbus

Malleidae
Malleus candeanus

Pectinidae
Pecten raveneli
Chlamys benedicti
Aequipectin muscosus
Cyclopecten nanus
Argopecten gibbus

Plicatulidae
Plicatula gibbosa

Anomiidae
Anomia simplex

Limidae
Lima pellucida
Limatula setifera
Limea bronniana

Ostreidae
Ostrea equestris

Lucinidae
Linga pensylvanica
Linga sombrerensis
Linga excavata
Linga amiantus
Linga leacocyma
Parvilucina multilineata
Parvilucina blanda
Lucina nassula
Lucina muricata
Lucina radians
Anodontia philippiana
Anodontia albu
Divaricella dentata

Thyasiridae
Thyasira trisinuata
Thyasira flexuosa

Ungulinidae
Diplodonta punctata

Chamidae
Chama macerophylla
Chama congregata
Arcinella cornuta

Lasaeidae
Erycina emmonsi

Leptonidae
Montacuta limpida
Mysella sp.
Pythinella cuneata

Carditidae
Glans dominguensis
Pleuromersis tridentata
Pteromeris perplana

Astartidae
Astatre nana

Crassatellidae
Eucrassatella speciosa
Crassinella lunulata

Cardidiidae
Trachycardium egmontianum
Americardia media
Nemocardium peramabile
Nemocardium tinctum
Laevicardium laevigatum
Laevicardium pictum

BIVALVIA continued

Mactridae
Ervilia concentrica

Tellinidae
Tellina magna
Tellina listeri
Tellina squamifera
Tellina aequistriata
Tellina gouldii
Tellina alternata
Tellina versicolor
Tellidora cristata
Macoma tageliformis
Cymatoica orientalis

Semelidae
Semele purpurascens
Semele bellastriata
Semele nuculoides
Abra aequalis
Abra lioica

Solecurtidae
Solecurtus cumingianus
Solecurtus sanctaemarthae

Vesicomyidae
Vesicoma sp.

Veneridae
Periglypta listeri
Ventricolaria rugatina
Circomphalus strigillinus
Chione cancellata
Chione latilirata
Chione grus
Gouldia cerina
Pitar simpsoni
Pitar cordatus
Callista eucymata
Macrocallista maculata
Dosinia discus

Cooperellidae
Cooperella atlantica

Corbulidae
Varicorbula operculata
Corbula contracta
Corbula cymella

Gastrochaenidae
Gastrochaena hians

Hiatellidae
Hiatella arctica

Lyonsiidae
Lyonsia hyalina floridana

Pandoridae
Pandora inflata

Periplomatidae
Periploma cf. compressa

Poromyidae
Poromya granulata

Verticordiidae
Verticordia ornata

Cuspidariidae
Cuspidaria jeffreysi
Cardiomya costellata
Cardiomya perrostrata

TABLE 4.
Species Dominance At The 45 Box Core Stations During 1975 - 1976

Species	Summer % by number	number	Fall % by number	number	Winter % by number	number
Station 2101						
Parvilucina multilineata	15.82	25	9.69	22	-----	--
Tellina versicolor	12.03	19	-----	--	-----	--
Solemya velum	9.49	15	16.30	37	11.97	28
Crepidula fornicata	7.59	12	-----	--	-----	--
Calyptraea centralis	6.96	11	-----	--	-----	--
Diplodonta punctata	5.06	8	5.29	12	-----	--
Ischnochiton papillosus	-----	--	32.16	73	26.07	61
Cerithium atratum	-----	--	5.73	13	-----	--
Plicatula gibbosa	-----	--	-----	--	5.56	13
Station 2102						
Tellina versicolor	25.97	20	54.12	92	33.16	64
Atys riiseana	11.69	9	-----	--	-----	--
Caecum bipartitum	10.39	8	-----	--	7.77	15
Eulimostrica hemphilli	10.39	8	-----	--	13.47	26
Laevicardium pictum	7.79	6	-----	--	-----	--
Varicorbula operculata	-----	--	-----	--	9.33	18
Station 2103						
Crenella divaricata	8.00	8	-----	--	-----	--
Varicorbula operculata	7.00	7	-----	--	-----	--
Tellina versicolor	6.00	6	14.62	19	6.96	16
Laevicardium pictum	6.00	6	-----	--	-----	--
Atys riiseana	5.00	5	-----	--	-----	--
Parvilucina multilineata	5.00	5	14.62	19	6.52	15
Abra lioica	5.00	5	-----	--	-----	--
Diplodonta punctata	-----	--	6.15	8	-----	--
Caecum pulchellum	-----	--	8.46	11	-----	--
Lyonsia hyalina floridana	-----	--	-----	--	6.96	16
Finella dubia	-----	--	-----	--	5.65	13

TABLE 4. (continued)
Species Dominance At The 45 Box Core Stations During 1975 - 1976

Species	Summer		Fall		Winter	
	% by number	number	% by number	number	% by number	number
Station 2104						
Tellina versicolor	11.67	7	-----	--	9.09	8
Olivella sp.	6.67	4	-----	--	-----	--
Amygdalum papyrium	6.67	4	-----	--	-----	--
Abra lioica	5.00	3	6.86	7	-----	--
Eulima bifasciatus	5.00	3	-----	--	-----	--
Brachycythara barbarae	5.00	3	-----	--	-----	--
Ischnochiton papillosus	-----	--	13.73	14	-----	--
Crassinella lunata	-----	--	6.86	7	6.82	6
Cadulus parvus	-----	--	5.88	6	-----	--
Semele nuculoides	-----	--	-----	--	9.09	8
Varicorbula operculata	-----	--	-----	--	5.68	5
Station 2105						
Abra lioica	31.58	12	51.72	15	8.77	5
Nucinella adamsi	10.53	4	-----	--	-----	--
Eucrassatella speciosa	7.89	3	-----	--	-----	--
Nuculana acuta	5.26	2	-----	--	-----	--
Cadulus parvus	-----	--	6.90	2	-----	--
Ischnochiton papillosus	-----	--	6.90	2	15.79	9
Parvilucina multilineata	-----	--	-----	--	8.77	5
Semele nuculoides	-----	--	-----	--	7.02	4
Limopsis sulcata	-----	--	-----	--	5.26	3
Barbatia dominguensis	-----	--	-----	--	5.26	3
Station 2106						
Abra lioica	14.63	6	14.29	6	10.71	1
Linga sombrerensis	14.63	6	-----	--	-----	--
Cardiomya sp.	7.32	3	-----	--	-----	--
Thyasira trisinuata	-----	--	19.05	8	-----	--

TABLE 4. (continued)

Species Dominance At The 45 Box Core Stations During 1975 - 1976

Species	Summer		Fall		Winter	
	% by number	number	% by number	number	% by number	number
Station 2106 continued						
Cyclopecten nanus	-----	--	14.29	6	-----	--
Limopsis cristata	-----	--	7.14	3	17.86	5
Parvilucina multilineata	-----	--	-----	--	25.00	7
Chaetoderma sp.	-----	--	-----	--	14.29	4
Dentalium texasianum	-----	--	-----	--	7.14	2
Station 2207						
Tellina versicolor	29.76	50	23.16	41	-----	--
Solemya velum	9.52	16	38.98	69	-----	--
Varicorbula operculata	-----	--	7.91	14	24.44	33
Station 2208						
Parvilucina multilineata	36.09	61	29.41	65	8.33	14
Caecum bipartitum	18.34	31	-----	--	14.88	25
Caecum cubitatum	11.83	20	13.12	29	5.95	10
Acteocina candei	8.28	14	-----	--	-----	--
Tellina versicolor	7.69	13	-----	--	5.36	9
Caecum pulchellum	-----	--	37.10	82	-----	--
Abra lioica	-----	--	-----	--	16.07	27
Station 2209						
Parvilucina multilineata	26.60	50	29.71	71	31.40	38
Caecum bipartitum	24.47	46	-----	--	9.92	12
Finella dubia	11.17	21	-----	--	-----	--
Acteocina candei	10.11	19	15.90	38	-----	--
Caecum pulchellum	-----	--	22.59	54	-----	--
Abra licica	-----	--	-----	--	17.36	21

TABLE 4. (continued)
Species Dominance At The 45 Box Core Stations During 1975 - 1976

Species	Summer % by number	number	Fall % by number	number	Winter % by number	number
Station 2210						
Parvilucina multilineata	50.74	241 *	33.21	87	5.45	43
Caecum bipartitum	9.68	46	-----	--	-----	--
Caecum cubitatum	7.79	37	26.72	70	-----	--
Caecum pulchellum	-----	--	10.69	28	-----	--
Varicorbula operculata	-----	--	-----	--	34.22	270
Station 2211						
Crassinella lunulata	18.75	15	12.31	8	5.48	4
Gouldia cerina	6.25	5	-----	--	-----	--
Pitar simpsoni	6.25	5	-----	--	-----	--
Parvilucina multilineata	5.00	4	-----	--	6.85	5
Corbula cymella	-----	--	6.15	4	-----	--
Frycina emmonsi	-----	--	6.15	4	-----	--
Gastrochaena hians	-----	--	-----	--	5.48	4
Varicorbula operculata	-----	--	-----	--	5.48	4
Station 2212						
Abra lioica	20.51	8	24.14	7	23.26	10
Cerithiopsis crystallinum	10.26	4	17.24	5	9.30	4
Verticordia ornata	7.69	3	6.90	2	-----	--
Cyclopecten nanus	7.69	3	-----	--	-----	--
Bathyarca glomerula	5.13	2	6.90	2	-----	--
Dentalium sp.	5.13	2	-----	--	-----	--
Nuculana acuta	5.13	2	-----	--	-----	--
Thyasira trisinuata	5.13	2	-----	--	-----	--
Chaetoderma sp.	-----	--	-----	--	25.58	11
Parvilucina multilineata	-----	--	-----	--	11.63	5

TABLE 4. (continued)
Species Dominance At The 45 Box Core Stations During 1975 - 1976

Species	Summer		Fall		Winter	
	% by number	number	% by number	number	% by number	number
Station 2313						
Abra lioica	47.62	10	92.86	13	40.00	6
Nuculana carpenteri	9.52	2	-----	--	-----	--
Nemocardium peramabile	-----	--	7.14	1	-----	--
Amygdalum papyrium	-----	--	-----	--	6.67	1
Cardiomya perrostrata	-----	--	-----	--	6.67	1
Lyonsia hyalina floridana	-----	--	-----	--	20.00	3
Cerithiopsis crystallinum	-----	--	-----	--	6.67	1
Dentalium sp.	-----	--	-----	--	6.67	1
Station 2314						
Parvilucina multilineata	37.23	51 *	-----	-- *	-----	--
Tellina versicolor	13.14	18	-----	--	15.79	6
Gastrochaena hians	-----	--	51.08	118	-----	--
Barbatia dominguensis	-----	--	5.19	12	-----	--
Botula fasca	-----	--	7.79	18	-----	--
Atys riiseana	-----	--	-----	--	5.26	2
Philine sagra	-----	--	-----	--	7.89	3
Varicorbula operculata	-----	--	-----	--	5.26	2
Tellina aequistriata	-----	--	-----	--	5.26	2
Pitar simpsoni	-----	--	-----	--	5.26	2
Cardiomya perrostrata	-----	--	-----	--	21.05	8
Station 2315						
Parvilucina multilineata	39.59	116 *	17.02	16	-----	--
Tellina versicolor	7.51	22	43.62	41	-----	--
Philine sagra	-----	--	6.38	6	-----	--
Varicorbula operculata	-----	--	5.32	5	-----	--

TABLE 4. (continued)
Species Dominance At The 45 Box Core Stations During 1975 - 1976

Species	Summer % by number	number	Fall % by number	number	Winter % by number	number
Station 2315 continued						
Gastrochaena hians	-----	--	-----	--	32.67	33
Corbula cymella	-----	--	-----	--	8.91	9
Station 2116						
Tellina versicolor	43.84	32	-----	--	7.38	9
Acanthochitona pygmaea	-----	--	15.85	13	-----	--
Abra lioica	-----	--	8.54	7	-----	--
Crassinella lunulata	-----	--	8.54	7	-----	--
Varicorbula operculata	-----	--	-----	--	14.75	18
Ischnochiton papillosus	-----	--	-----	--	7.38	9
Corbula cymella	-----	--	-----	--	5.74	7
Dentalium bartletti	-----	--	-----	--	5.74	7
Station 2317						
Cymatoica orientalis	15.63	10	-----	--	-----	--
Tellina versicolor	10.94	7	55.56	45	-----	--
Parvilucina multilineata	6.25	4	-----	--	-----	--
Lucina radians	6.25	4	-----	--	-----	--
Varicorbula operculata	6.25	4	-----	--	73.78	605
Station 2318						
Diplodonta punctata	16.67	4	5.26	6	-----	--
Abra lioica	8.33	2	19.30	2	-----	--
Tellina versicolor	8.33	2	10.53	12	18.52	5
Semele nuculoides	-----	--	5.26	6	-----	--
Thyasira trisinuata	-----	--	6.14	7	-----	--

TABLE 4. (continued)
Species Dominance At The 45 Box Core Stations During 1975 - 1976

Species	Summer % by number	number	Fall % by number	number	Winter % by number	number
Station 2318 continued						
Cadulus quadridentatus	-----	--	-----	--	51.85	14
Acteocina candei	-----	--	-----	--	7.41	2
Station 2419						
Tellina versicolor	48.53	33	27.27	18	64.00	16
Abra lioica	7.35	5	-----	--	-----	--
Ervilia concentrica	-----	--	10.61	7	-----	--
Solemya velum	-----	--	27.27	18	-----	--
Diplodonta punctata	-----	--	12.12	8	8.00	2
Station 2420						
Cadulus sp.	17.07	14	-----	--	-----	--
Diplodonta punctata	12.20	10	-----	--	-----	--
Abra lioica	8.54	7	-----	--	-----	--
Tellina versicolor	6.10	5	-----	--	-----	--
Acanthochitona pygmaea	-----	--	30.49	25	-----	--
Rissoinea multicostata	-----	--	7.32	6	-----	--
Eulima bifasciatus	-----	--	-----	--	14.29	1
Lyonsia hyalina floridana	-----	--	-----	--	14.29	1
Turbonilla sp.	-----	--	-----	--	28.57	2
Crassinella lunulata	-----	--	-----	--	28.57	2
Gastrochaena hians	-----	--	-----	--	14.29	1
Station 2421						
Varicorbula operculata	17.50	7	-----	--	88.29	407 *
Caecum pulchellum	15.00	6	-----	--	-----	--
Caecum bipartitum	15.00	6	-----	--	-----	--

TABLE 4. (continued)
Species Dominance At The 45 Box Core Stations During 1975 - 1976

Species	Summer % by number	number	Fall % by number	number	Winter % by number	number
Station 2421 continued						
Tellina versicolor	7.50	3	7.59	6	-----	-- *
Volvulella persimilis	5.00	2	-----	--	-----	--
Solemya velum	-----	--	53.16	42	-----	--
Parvilucina multilineata	-----	--	6.33	5	-----	--
Station 2422						
Semele bellastriata	10.87	5	-----	--	-----	-- *
Cymatoica orientalis	8.70	4	-----	--	-----	--
Corbula cymella	8.70	4	6.67	3	-----	--
Acanthochitona pygmaea	6.52	3	-----	--	-----	--
Varicorbula operculata	6.52	3	-----	--	-----	--
Laevicardium laevigatum	6.52	3	-----	--	-----	--
Macrocallista maculata	6.52	3	-----	--	11.54	6
Semele nuculoides	-----	--	6.67	3	-----	--
Parvilucina multilineata	-----	--	20.00	9	-----	--
Tellina versicolor	-----	--	11.11	5	-----	--
Cylindrobulla beauii	-----	--	6.67	3	-----	--
Diplodonta punctata	-----	--	-----	--	9.62	5
Pitar cordatus	-----	--	-----	--	23.08	12
Dosinia discus	-----	--	-----	--	7.69	4
Station 2423						
Laevicardium laevigatum	11.76	4	-----	--	-----	--
Macrocallista maculata	8.82	3	-----	--	-----	--
Tellina versicolor	5.88	2	-----	--	-----	--
Pitar simpsoni	5.88	2	-----	--	-----	--
Lyonsia hyalina floridana	5.88	2	-----	--	-----	--
Corbula cymella	5.88	2	-----	--	33.33	3

TABLE 4.(continued)
Species Dominance At The 45 Box Core Stations During 1975 - 1976

Species	Summer		Fall		Winter	
	% by number	number	% by number	number	% by number	number
Station 2423 continued						
Caecum stigosum	-----	--	23.53	12	-----	--
Macromphalina floridana	-----	--	11.76	6	-----	--
Gouldia cerina	-----	--	9.80	5	-----	--
Parvilucina multilineata	-----	--	5.88	3	-----	--
Amygdalum papyrium	-----	--	-----	--	11.11	1
Diplodonta punctata	-----	--	-----	--	11.11	1
Amygdalum sagittatum	-----	--	-----	--	11.11	1
Chione cancellata	-----	--	-----	--	11.11	1
Varicorbula operculata	-----	--	-----	--	11.11	1
Station 2424						
Tellina versicolor	6.25	2	19.51	16	23.08	6
Chione cancellata	6.25	2	-----	--	-----	--
Crenella divaricata	6.25	2	-----	--	-----	--
Diplodonta punctata	6.25	2	-----	--	-----	--
Cadulus quadridentatus	6.25	2	-----	--	-----	--
Caecum cubitatum	-----	--	6.10	5	-----	--
Crassinella lunulata	-----	--	7.32	6	-----	--
Corbula cymella	-----	--	6.10	5	-----	--
Varicorbula operculata	-----	--	6.10	5	-----	--
Semele nuculoides	-----	--	-----	--	15.38	4
Corbula contracta	-----	--	-----	--	11.54	3
Station 2425						
Tellina versicolor	13.33	2	5.88	2	55.38	72
Crucibulum auricula	13.33	2	-----	--	-----	--
Solemya velum	13.33	2	-----	--	-----	--
Pecten raveneli	13.33	2	-----	--	-----	--

TABLE 4. (continued)
Species Dominance At The 45 Box Core Stations During 1975 - 1976

Species	Summer		Fall		Winter	
	% by number	number	% by number	number	% by number	number
Station 2425 continued						
Semele bellastriata	13.33	2	-----	--	-----	--
Pteromeris perplana	13.33	2	-----	--	-----	--
Marginella hartleyanum	6.67	1	8.82	3	-----	--
Crassinella lunulata	-----	--	14.71	5	-----	--
Gastrochaena hians	-----	--	8.82	3	-----	--
Lima pellucida	-----	--	5.88	2	-----	--
Chlamys benedicti	-----	--	5.88	2	-----	--
Ischnochiton sp.	-----	--	-----	--	8.46	11
Station 2426						
Tellina versicolor	21.05	4	20.00	2	15.79	3
Abra lioica	5.26	1	-----	--	10.53	2
Poromya granulata	5.26	1	-----	--	-----	--
Nucinella adamsi	5.26	1	-----	--	-----	--
Dentalium sp.	-----	--	10.00	1	-----	--
Parvilucina multilineata	-----	--	10.00	1	-----	--
Cadulus sp.	-----	--	20.00	2	-----	--
Nuculana acuta	-----	--	10.00	1	15.79	3
Pandora inflata	-----	--	-----	--	5.26	1
Limopsis cristata	-----	--	-----	--	5.26	1
Olivella sp.	-----	--	-----	--	5.26	1
Solariella lacunella	-----	--	-----	--	5.26	1
Cardiomya perrostrata	-----	--	-----	--	5.26	1
Philine sagra	-----	--	-----	--	10.53	2
Station 2427						
Abra lioica	50.00	4	55.56	5	68.75	11
Cuspidaria sp.	12.50	1	-----	--	-----	--
Dentalium sp.	-----	--	-----	--	6.25	1

TABLE 4. (continued)
Species Dominance At The 45 Box Core Stations During 1975 - 1976

Species	Summer % by number	number	Fall % by number	number	Winter % by number	number
Station 2427 continued						
Cardiomya perrostrata	-----	--	-----	--	6.25	1
Dentalium ensiculus	-----	--	-----	--	6.25	1
Nemocardium peramabile	-----	--	-----	--	6.25	1
Station 2528						
Ischnochiton boogii	26.09	6	7.69	1	-----	--
Chlamys benedicti	13.04	3	-----	--	-----	--
Gastrochaena hians	8.70	2	7.69	1	-----	--
Gouldia cerina	-----	--	7.69	1	5.26	1
Tellina versicolor	-----	--	7.69	1	10.53	2
Varicorbula operculata	-----	--	7.69	1	5.26	1
Diplodonta punctata	-----	--	15.38	2	-----	--
Pteromeris perplana	-----	--	7.69	1	-----	--
Volvulella persimilis	-----	--	7.69	1	-----	--
Tellina listeri	-----	--	7.69	1	-----	--
Natica marochiensis	-----	--	7.69	1	-----	--
Semele bellastriata	-----	--	-----	--	5.26	1
Polinices duplicatus	-----	--	-----	--	5.26	1
Chione cancellata	-----	--	-----	--	5.26	1
Cyclopecten nanus	-----	--	-----	--	26.32	5
Semele purpurascens	-----	--	-----	--	5.26	1
Crassinella lunulata	-----	--	-----	--	5.26	1
Corbula contracta	-----	--	-----	--	5.26	1
Abra lioica	-----	--	-----	--	5.26	1
Station 2529						
Diplodonta punctata	5.88	1	7.14	1	-----	--
Semele purpurascens	5.88	1	-----	--	-----	--
Dentalium ceratum	5.88	1	-----	--	-----	--

TABLE 4. (continued)
Species Dominance At The 45 Box Core Stations During 1975 - 1976

Species	Summer		Fall		Winter	
	% by number	number	% by number	number	% by number	number
Station 2529 continued						
Crenella divaricata	-----	--	14.29	2	-----	--
Lima pellucida	-----	--	7.14	1	-----	--
Pleuromeris tridentata	-----	--	14.29	2	-----	--
Crassinella lunulata	-----	--	7.14	1	-----	--
Gouldia cerina	-----	--	7.14	1	-----	--
Gastrochaena hians	-----	--	7.14	1	-----	--
Solecurtus sanctaemarthae	-----	--	-----	--	8.33	1
Tellina versicolor	-----	--	-----	--	8.33	1
Cyclopecten nanus	-----	--	-----	--	16.67	2
Philine sagra	-----	--	-----	--	8.33	1
Ischnochiton papillosus	-----	--	-----	--	8.33	1
Varicorbula operculata	-----	--	-----	--	16.67	2
Amygdalum papyrium	-----	--	-----	--	8.33	1
Station 2530						
Crenella divaricata	18.18	2	14.29	3	-----	--
Astarte nana	18.18	2	-----	--	-----	--
Pleuromeris tridentata	9.09	1	-----	--	-----	--
Chione cancellata	9.09	1	-----	--	-----	--
Nassarius	9.09	1	-----	--	-----	--
Cuspidaria jeffreysi	9.09	1	-----	--	-----	--
Crassinella lunulata	-----	--	14.29	3	-----	--
Ischnochiton boogii	-----	--	14.29	3	-----	--
Tellina versicolor	-----	--	-----	--	30.00	3
Diplodonta punctata	-----	--	-----	--	20.00	2
Semele bellastriata	-----	--	-----	--	20.00	2
Pecten raveneli	-----	--	-----	--	10.00	1
Chione latilirata	-----	--	-----	--	10.00	1

TABLE 4. (continued)

Species Dominance At The 45 Box Core Stations During 1975 - 1976

Species	Summer % by number	number	Fall % by number	number	Winter % by number	number
Station 2531						
Gastrochaena hians	12.50	2	-----	--	-----	--
Amygdalum papyrium	6.25	1	-----	--	-----	--
Diplodonta punctata	6.25	1	-----	--	-----	--
Semele bellastriata	6.25	1	-----	--	8.33	1
Crenella divaricata	6.25	1	5.00	1	-----	--
Dentalium sp.	6.25	1	-----	--	-----	--
Semele purpurascens	6.25	1	10.00	2	-----	--
Crassinella lunulata	-----	--	20.00	4	8.33	1
Ischnochiton papillosus	-----	--	20.00	4	-----	--
Pitar simpsoni	-----	--	5.00	1	8.33	1
Laevicardium larvigatum	-----	--	5.00	1	-----	--
Polinices duplicatus	-----	--	5.00	1	-----	--
Marginella hartleyanum	-----	--	5.00	1	-----	--
Ischnochiton boogii	-----	--	10.00	2	-----	--
Varicorbula operculata	-----	--	-----	--	8.33	1
Macoma sp.	-----	--	-----	--	16.67	2
Tellina versicolor	-----	--	-----	--	33.33	4
Station 2532						
Tellina versicolor	17.65	3	-----	--	30.77	4
Amygdalum papyrium	5.88	1	-----	--	-----	--
Dentalium sowerbyi	5.88	1	-----	--	-----	--
Acanthochitona pygmaea	5.88	1	-----	--	-----	--
Macoma sp.	5.88	1	-----	--	-----	--
Corbula sp.	5.88	1	-----	--	-----	--
Pitar simpsoni	-----	--	28.57	2	-----	--
Astarte nana	-----	--	14.29	1	-----	--
Solemya velum	-----	--	14.29	1	-----	--
Diplodonta punctata	-----	--	-----	--	15.38	2

TABLE 4. (continued)
Species Dominance At The 45 Box Core Stations During 1975 - 1976

Species	Summer % by number	number	Fall % by number	number	Winter % by number	number
Station 2533						
Limopsis sulcata	30.77	4	50.00	2	16.67	1
Pitar simpsoni	15.38	2	-----	--	-----	--
Limopsis cristata	7.69	1	-----	--	-----	--
Limopsis minuta	7.69	1	-----	--	-----	--
Solariella lacunella	7.69	1	-----	--	-----	--
Abra lioica	-----	--	25.00	1	-----	--
Astarte nana	-----	--	25.00	1	-----	--
Cuspidaria jeffreysi	-----	--	-----	--	16.67	1
Station 2534						
Pitar simpsoni	44.44	4	100.00	3	12.50	1
Limopsis sulcata	22.22	2	-----	--	-----	--
Abra lioica	22.22	2	-----	--	12.50	1
Gouldia cerina	-----	--	-----	--	25.00	2
Varicorbula operculata	-----	--	-----	--	12.50	1
Cyclopecten nanus	-----	--	-----	--	25.00	2
Nassarius vibex	-----	--	-----	--	12.50	1
Station 2535						
Abra lioica	40.00	2	No living molluscs		40.00	2
Tellina versicolor	20.00	1			-----	--
Nuculana acuta	20.00	1			-----	--
Nassarius vibex	-----	--			20.00	1
Anadara baughmani	-----	--			20.00	1

TABLE 4. (continued)
Species Dominance At The 45 Box Core Stations During 1975 - 1976

Species	Summer % by number	number	Fall % by number	number	Winter % by number	number
Station 2536						
Yoldia solenoides	20.00	1	-----	--	14.29	1
Nuculana acuta	20.00	1	100.00	1	-----	--
Cerithiopsis crystallinum	20.00	1	-----	--	-----	--
Abra lioica	-----	--	-----	--	14.29	1
Amygdalum sagittatum	-----	--	-----	--	14.29	1
Chaetoderma sp.	-----	--	-----	--	28.57	2
Station 2637						
Abra lioica	33.33	1	-----	--	-----	--
Varicorbula operculata	33.33	1	-----	--	-----	--
Nuculana concentrica	33.33	1	100.00	1	-----	--
Tellina versicolor	-----	--	-----	--	42.86	3
Urosalpinx sp.	-----	--	-----	--	14.29	1
Cardiomya perrostrata	-----	--	-----	--	14.29	1
Nuculana sp.	-----	--	-----	--	14.29	1
Station 2638						
Nuculana concentrica	66.67	24	-----	--	57.14	8
Tellina versicolor	13.89	5	33.33	1	14.29	2
Anachis obesa	5.56	2	-----	--	-----	--
Nucula proxima	-----	--	66.67	2	7.14	1
Chione latilirata	-----	--	-----	--	7.14	1
Station 2639						
Nuculana concentrica	32.93	27	14.29	1	-----	--
Pythinella cuneata	12.20	10	-----	--	-----	--
Tellina versicolor	10.98	9	-----	--	-----	--

TABLE 4. (continued)
Species Dominance At The 45 Box Core Stations During 1975 - 1976

Species	Summer		Fall		Winter	
	% by number	number	% by number	number	% by number	number
Station 2639 continued						
Solecurtus cumingianus	-----	--	14.29	1	-----	--
Nuculana proxima	-----	--	14.29	1	8.33	3
Tellina squamifera	-----	--	14.29	1	11.11	4
Tellina alternata	-----	--	28.57	2	-----	--
Gouldia cerina	-----	--	14.29	1	-----	--
Amygdalum papyrium	-----	--	-----	--	5.56	2
Psarostola glypta	-----	--	-----	--	5.56	2
Chione latilirata	-----	--	-----	--	5.56	2
Diplodonta punctata	-----	--	-----	--	8.33	3
Sinum perspectivum	-----	--	-----	--	8.33	3
Lyonsia hyalina floridana	-----	--	-----	--	5.56	2
Station 2640						
Tellina versicolor	40.79	31	46.43	13	25.00	5
Macoma sp.	5.26	4	-----	--	-----	--
Lyonsia hyalina floridana	-----	--	7.14	2	-----	--
Varicorulb operculata	-----	--	10.71	3	-----	--
Crassinella lunulata	-----	--	-----	--	5.00	1
Chione latilirata	-----	--	-----	--	10.00	2
Nuculana concentrica	-----	--	-----	--	5.00	1
Amygdalum papyrium	-----	--	-----	--	10.00	2
Arcopsis adamsi	-----	--	-----	--	5.00	1
Gouldia cerina	-----	--	-----	--	5.00	1
Philine sagra	-----	--	7.14	--	-----	--
Station 2641						
Tellina versicolor	26.19	11	67.57	25	29.85	20
Cadulus quadridentatus	14.29	6	-----	--	-----	--
Cardiomya costellata	7.14	3	-----	--	-----	--

TABLE 4. (continued)
Species Dominance At The 45 Box Core Stations During 1975 - 1976

Species	Summer % by number	number	Fall % by number	number	Winter % by number	number
Station 2641 continued						
Tellina aequistriata	7.14	3	-----	--	-----	--
Abra lioica	-----	--	5.41	2	-----	--
Carciomya ornatissima	-----	--	5.41	2	-----	--
Solemya velum	-----	--	-----	--	8.96	6
Diplodonta punctata	-----	--	-----	--	7.46	5
Station 2642						
Tellina versicolor	43.18	19	56.00	14	56.25	18
Macoma sp.	6.82	3	-----	--	-----	--
Lyonsia hyalina floridana	-----	--	8.00	2	-----	--
Cadulus quadridentatus	-----	--	8.00	2	-----	--
Tellina aequistriata	-----	--	-----	--	6.25	2
Station 2643						
Tellina versicolor	41.18	7	30.77	4	29.41	5
Abra lioica	23.53	4	-----	--	-----	--
Macoma sp.	5.88	1	7.69	1	5.88	1
Nuculana acuta	5.88	1	-----	--	23.53	4
Scaphander sp.	5.88	1	-----	--	-----	--
Amygdalum papyrium	-----	--	7.69	1	-----	--
Tellina squamifera	-----	--	15.38	2	-----	--
Massarius albus	-----	--	7.69	1	-----	--
Tellina alternata	-----	--	7.69	1	-----	--
Gouldia cerina	-----	--	-----	--	5.88	1
Cyclopecten nanus	-----	--	-----	--	5.88	1
Verticordia ornata	-----	--	-----	--	5.88	1
Cardiomya perrostrata	-----	--	-----	--	5.88	1
Octopus sp.	-----	--	-----	--	5.88	1

TABLE 4. (continued)
Species Dominance At The 45 Box Core Stations During 1975 - 1976

Species	Summer		Fall		Winter	
	% by number	number	% by number	number	% by number	number
Station 2644						
Abra lioica	50.00	3	-----	--	-----	--
Linga sombrerensis	16.67	1	-----	--	-----	--
Macoma sp.	16.67	1	-----	--	-----	--
Pitar simpsoni	-----	--	50.00	1	50.00	2
Pleuromeris tridentata	-----	--	-----	--	25.00	1
Station 2645						
Abra lioica	20.00	3	No living molluscs		No living molluscs	
Limopsis minuta	6.67	1				
Astarte nana	6.67	1				
Limopsis cristata	6.67	1				
Olivella sp.	6.67	1				

abundances of all species. *Abra lioica* was the dominant species at most of the deep water (greater than 90 m) stations, although it occurred in abundances of only 1-15 individuals/0.54 m^2. Seasonality of species abundances is also suggested in Table 4. Some species which were completely absent from any of the nine replicates of one sampling were present in four to six of the nine replicates of another sampling and at times became the dominant species. The most abundant species listed above showed a definite trend toward maximum abundances during the winter sample suggesting a fall or winter recruitment. For example, *Varicorbula operculata* increased from seven individuals/0.54 m^2 in the summer to 605 in the winter, the latter number being mostly juveniles.

Community structure

Indices of community structure are shown in Table 5. The Shannon-Wiener index (H') and evenness (J') for the three seasons at the stations which were box cored are graphically presented in Figure 3. In general, H' which ranged from 0.26 to 3.36 declined from nearshore to offshore. and also from south (Transect I) to north (Transect VI). This index was therefore higher for the assemblages inhabiting the coarser sand sediment than for those inhabitating the finer mud sediments. Evenness (J') showed no consistent trend with either latitude or depth and ranged from 0.20 to 1.00.

Diversity also varied between seasons. At the nearshore stations at the southern transects (I, II, III, IV), H' was usually lowest during the fall sampling as a result of both the decline in the number of species and changes in dominance. Because of generally low species richness and abundances and even the non-occurrence of species, conclusions based upon values of these indices should be regarded as tentative at best.

Table 5. Species diversity (H'), eveness (J'), species richness (SR) at the 45 Box Core stations during the 1975 - 1976 seasonal sampling.

	Summer 1975				Fall 1975				Winter 1975			
Sta.#	H'	J'	SR	N	H'	J'	SR	N	H'	J'	SR	N
2101	3.08	.83	7.9	158	2.14	.67	4.24	227	2.85	.76	7.5	234
2102	2.35	.81	3.9	77	1.89	.58	4.9	170	2.47	.71	6.1	193
2103	3.37	.92	8.2	100	2.92	.84	6.6	130	3.36	.87	8.5	230
2104	3.23	.94	7.3	60	3.13	.88	7.4	102	3.12	.91	6.7	88
2105	1.99	.80	3.0	38	1.25	.64	1.8	29	1.8	.91	4.2	57
2106	2.09	.87	2.7	41	2.43	.86	4.3	42	2.03	.33	2.7	28
2207	3.05	.78	9.4	168	2.08	.62	5.4	177	2.45	.77	4.7	135
2208	2.07	.67	4.1	169	1.70	.57	3.5	221	2.52	.83	3.9	168
2209	2.27	.69	5.0	188	2.15	.66	4.6	239	2.27	.76	4.0	121
2210	*2.26	.55	9.7	475	2.04	.60	5.2	262	1.45	.44	3.9	789
2211	2.74	.85	5.4	80	2.86	.93	5.0	65	3.08	.94	5.8	73
2212	2.02	.92	2.2	39	1.88	.86	3.4	29	1.76	.80	2.1	43
2313	.90	.65	1.0	21	.26	.37	2.6	14	1.48	.83	1.8	15
2314	*2.55	.74	6.3	137	*1.84	.60	3.9	231	2.40	.89	3.8	38
2315	*2.67	.68	8.8	293	1.85	.65	3.5	94	2.33	.77	4.3	101
2316	2.11	.68	5.09	62	2.57	.84	4.5	82	3.24	.91	7.56	90
2317	3.01	.89	6.7	64	1.92	.62	4.8	81	.99	.35	2.48	640
2318	1.93	.93	2.2	24	2.81	.84	5.7	114	1.36	.70	1.8	27
2419	1.46	.59	2.6	68	2.07	.74	3.6	66	1.01	.56	1.6	25
2420	2.47	.85	3.9	82	2.34	.78	4.3	82	2.95	.93	6.01	46
2421	2.15	.87	3.0	40	1.76	.61	3.9	79	*.59	.20	3.3	461
2422	2.87	.94	5.2	46	2.59	.90	4.5	45	*2.62	.87	4.8	52
2423	2.70	.95	4.5	34	2.47	.84	4.6	51	1.67	.93	2.3	9
2424	2.78	.98	4.6	32	2.76	.87	5.2	82	2.02	.88	2.8	26
2425	1.93	.99	2.2	15	2.47	.93	3.7	34	1.72	.56	4.3	130
2426	1.15	.83	1.0	19	1.55	.96	1.7	10	2.08	.95	2.7	19
2427	.50	.72	2.1	8	----	---	---	9	.95	.59	1.4	16
2528	1.54	.86	1.6	23	2.27	.99	3.5	13	2.18	.91	2.6	19
2529	1.10	1.00	.7	17	2.04	.98	2.6	14	1.89	.97	2.4	12
2530	1.73	.97	2.1	11	1.93	.93	2.3	21	1.52	.95	1.7	10
2531	1.91	.98	2.2	16	2.02	.92	2.7	20	1.61	.90	2.0	12
2532	1.67	.93	1.8	17	1.04	.95	1.0	7	.64	.92	.39	13
2533	1.43	.89	2.6	13	1.04	.95	1.4	4	.69	1.00	.56	6
2534	1.04	.95	.9	9	----	---	---	3	1.73	.97	2.4	8
2535	1.04	.95	1.2	5	----	---	---	---	1,04	.95	1.2	5
2536	1.10	1.00	1.2	5	----	---	---	1	1.33	.96	1.5	7
2637	1.10	1.00	1.8	3	----	---	---	1	1.25	.90	1.5	7
2638	1.11	.57	1.7	36	.64	.92	.9	3	1.36	.84	1.5	14
2639	2.04	.74	3.4	82	1.75	.98	2.6	7	2.76	.95	4.7	36
2640	1.45	.63	2.1	76	1.84	.77	3.0	28	1.73	.89	2.0	20
2641	1.90	.82	2.4	42	1.08	.52	1.9	37	2.2	.78	3.6	67
2642	1.43	.62	2.4	44	1.41	.68	2.2	25	1.53	.64	2.9	32
2643	1.27	.79	1.4	17	1.61	.90	2.0	13	1.80	.87	2.5	17
2644	.95	.86	1.1	6	----	---	---	2	.64	.92	.72	4
2645	1.48	.92	1.5	15	----	---	---	---	----	---	---	---

* based on two anchor dredges rather than nine box cores

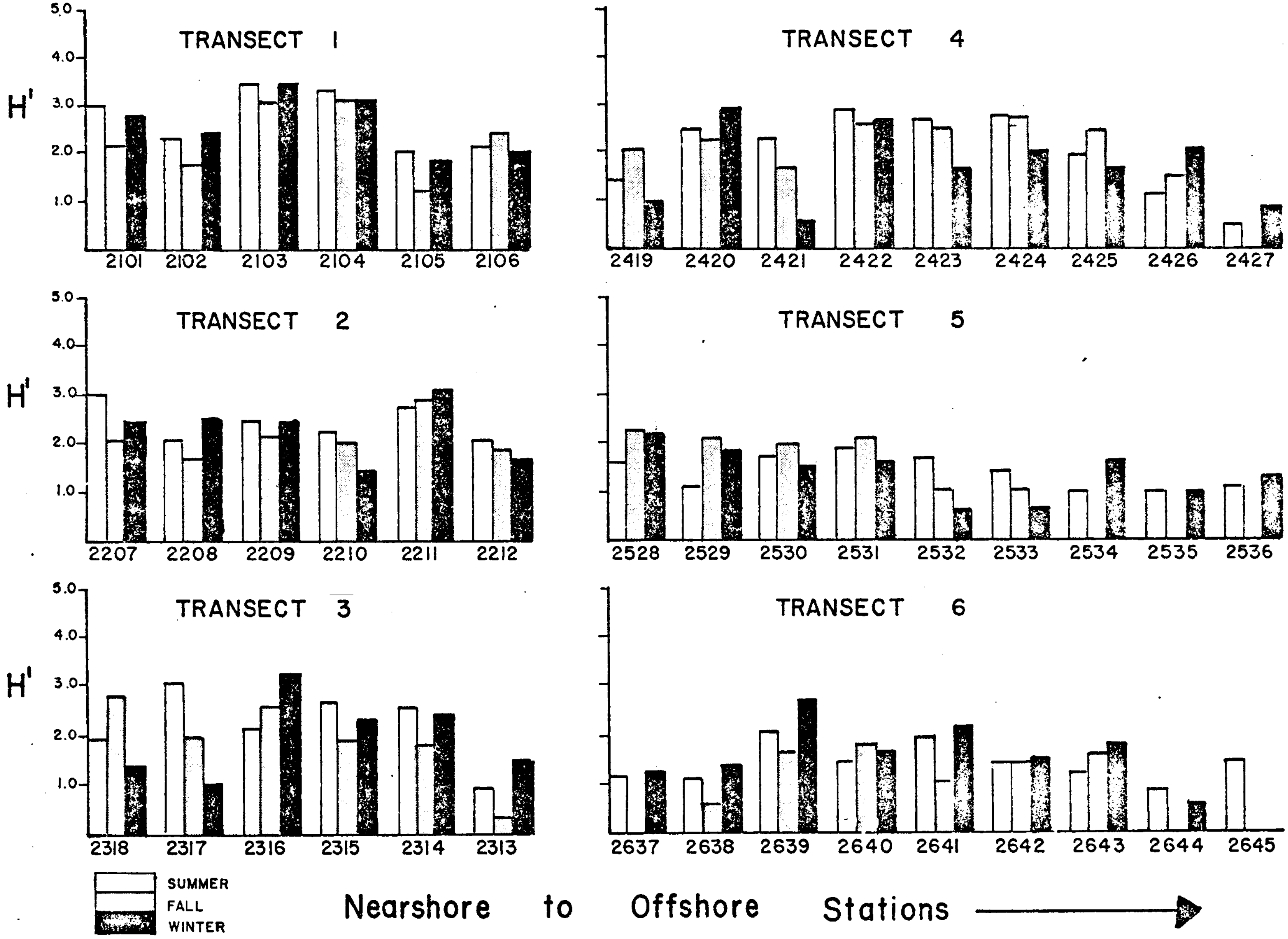


Figure 3. The Shannon-Wiener index for the 45 box core stations during the 1975-1976 seasonal sampling.

CLASSIFICATION

Similarity relationships at all stations between seasons are depicted after Mountford clustering in a dendrogram (Figure 4). Visual examination of the dendrogram reveals the following general tendencies about the molluscan assemblages:

1. Species composition at most stations is highly seasonally dependent throughout the MAFLA area. Affinities between any two seasons for any station vary as little as 20% (deep water or northern stations) to as much as 60% (nearshore, southern stations). There is, therefore, little within station seasonal continuity especially at the nearshore southern stations.

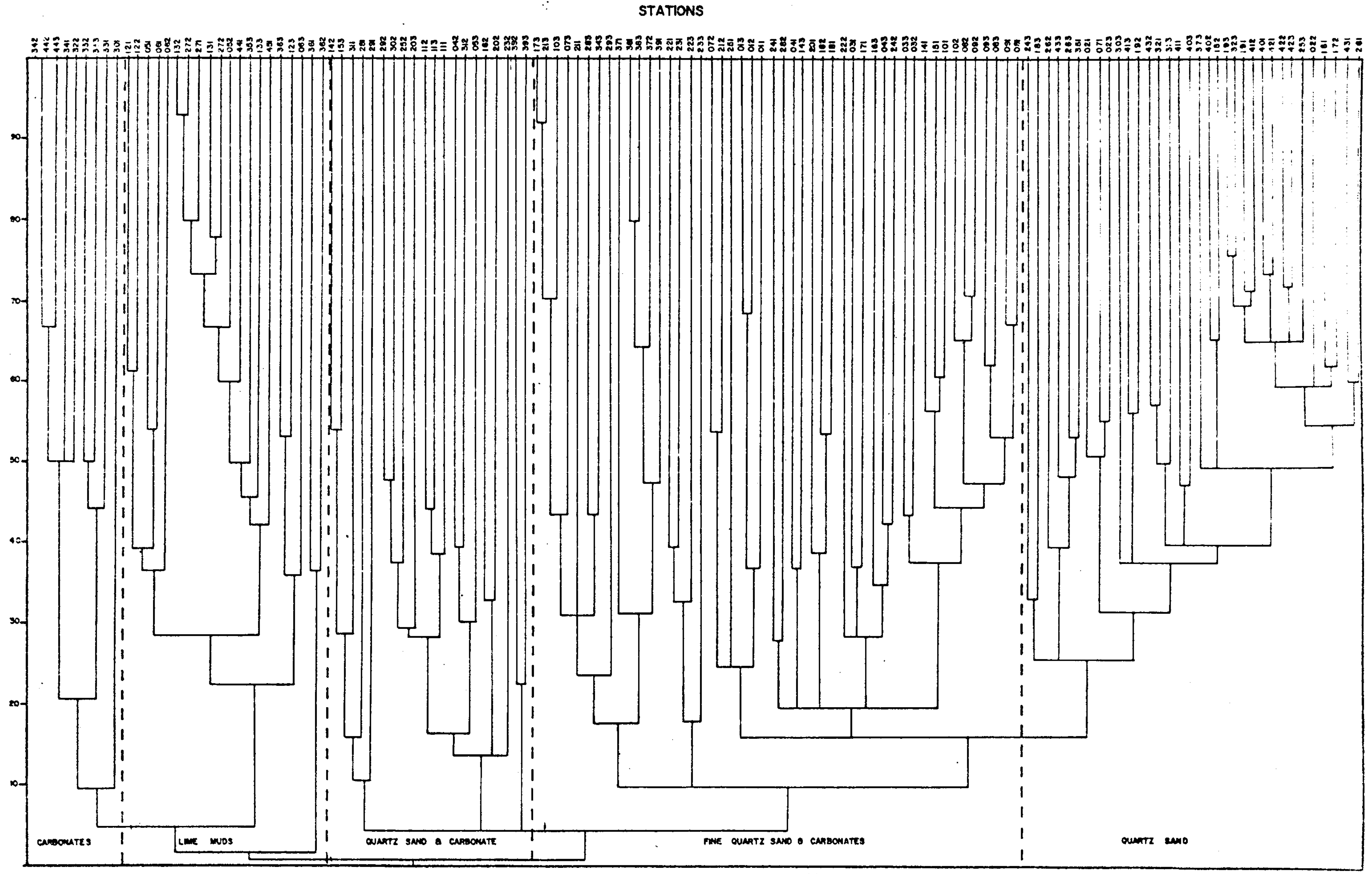
2. Stations exhibiting low diversities (Table 4) show greater affinity. This tendency is for the northern and deep water stations. For example, 1534 and 2644 during the fall sampling were 100% similar and 2313 and 2327 were 92.9% similar for the fall sampling.

3. Approximately one third of the stations show similarities exceeding 50% indicating that approximately two thirds of the assemblages exhibit taxonomic heterogeneity of 50% or greater. The mean affinity for the stations considered as a whole is approximately 30%.

Five major clusters are created at very low similarity levels (4.2% to 15.6%). These faunal breaks appear to be only partially related to sediment classification. Other factors which appear to be of importance, are season, latitude, depth, or even sampling problems.

Because of the variability in species composition indicated by low between season affinities, anomalies to the classification based upon the truncation are apparent within the dendrogram. For example 2424, whose sediment classification is carbonate sand, appears within one cluster for the summer and fall samplings and a different cluster for the winter sampling.

Figure 4. Dendrogram resulting from the Mountford clustering of the 45 box core stations over three seasons. Station number is indicated by the first two digits and season by the last digit (1=summer, 2=fall, and 3=winter). Dashed vertical lines separate major groups. The major sediment classifications within these groups are shown.


STATIONS
342 442 443 341 322 332 313 331 301 121 122 051 061 062 132 272 271 131 272 052 441 353 133 451 363 123 063 361 362 142 153 311 281 291 292 302 252 203 112 113 111 042 312 053 162 202 232 392 393 173 213 103 073 211 283 343 293 371 381 383 372 391 221 231 223 233 072 212 251 013 012 011 241 282 041 143 201 182 181 222 031 171 163 043 242 033 032 141 151 101 102 082 092 093 083 091 071 243 183 262 433 263 351 021 071 023 303 413 192 432 321 313 411 403 373 402 152 193 323 191 412 401 121 422 423 253 022 161 172 431 261
90
80
70
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50
40
30
20
10
CARBONATES
LIME MUDS
QUARTZ SAND & CARBONATE
FINE QUARTZ SAND & CARBONATES
QUARTZ SAND

DISCUSSION

The MAFLA box core sampling program has enabled the collection of a vast amount of data on benthic communities which far exceeds the precision and accuracy of collections made thus far on almost any other continental shelf. Such large amounts of data necessitate that this final report be only an initial attempt to understand and explain the molluscan assemblages based upon the limited employment of structural and classification techniques.

Variations in species composition and abundance by habitat and season contribute to assemblages appearing to be unique entities in time and space. Populations within the MAFLA area obviously are affected by seasonal phenomena such as recruitment based upon innate reproductive cycles or larval settlement induced through larval transport by seasonal currents such as the Loop Current. Loss within the populations may result either because of natural physiological factors such as age or because of adverse environmental conditions such as a hurricane, a phenomenon which may have affected some populations in Transects V and VI during the Fall 1976.

The stations which generally showed the lowest diversity (<2.00) were found on the shelf break or on the northern two transects (V and VI). On the northern transects especially, the assemblages are obviously influenced by the Mississippi River. Large amounts of fine sediments are contributed to these stations and turbidity remains high throughout the year (Manheim, 1976, MAFLA final report). This environment, and to a lesser extent the slope environment, must be inhabited by species tolerant of such conditions. These assemblages must be composed of essentially deposit feeders. Relatively few species in small abundances occur at these stations and any environmental perturbation is likely to eliminate the assemblage. Such assemblages are extremely difficult to adequately sample since the number of individuals per unit area is small. Measures of diversity and affinity at these stations based upon molluscs are tentative at best. Polychaetes and molluscs should be considered together especially at the northern and deeper stations.

On the southern transects, the assemblages are still typified by relatively low numbers of individuals compared to other assemblages in more temperate areas (Popham and Ellis, 1971; Boesch, 1972). The near-shore stations of Transects I, II, III and IV are characterized by species with few individuals although considerably more than appear on the northern Transects V and VI.

Clear definition of these molluscan assemblages is difficult based upon the techniques employed. The Mountford Clustering technique yielded very low similarity values between stations as well as between seasons. The partial definition of a community based upon a dominant mollusc in the Petersen-Thorson fashion (Thorson, 1957) is not readily apparent for the majority of the stations although in the construction of biolithologic map the Peterson-Thorson concept was applied based upon the summer sampling.

A more appropriate definition of the majority of the MAFLA benthic communities was given by Mills (1969) who viewed a community as a continuum in time and space and as "a group of organisms occurring in a particular environment, presumably interacting with each other, and separable by means of ecological survey from other groups." A start has been made but because of the variability, a low predictive capability exists for describing the benthic macromolluscan assemblages over the majority of the MAFLA area.

REFERENCES

Abbott, R. T. 1974. American Seashells, Van Nostrand Reinhold Co., New York, 663 pp.

Boesch, D. F. 1973. Classification and community structure of macrobenthos in the Hampton Roads area, Virginia, Mar. Biol. 21: 226-244.

Clench, W. J. (Editor). 1941-1972. Monographs of the marine mollusks of the western Atlantic. Johnsonia Vols. I-IV Dep. Mollusks Mus. Comp. Zool., Harvard University, Cambridge, Mass.

Cole, L. D. 1949. The measurement of interspecific association. Ecology, 30: 411-424.

Heath, H. 1918. Solenogastres from the eastern coast of North America. Memoirs of the Museum of Comparative Zoology at Harvard College. Vol. 45 (2) p. 186-261. pls. 1-14.

Henderson, J. B. 1920. A monograph of the east american scaphopod mollusks. Bull. 111 U.S. Nat. Mus. p. 1-177 pls. 1-20.

Hughes, R. N. and M. L. H. Thomas. 1971. The classification and ordination of shallow-water benthic samples from Prince Edward Island, Canada. J. Exp. Mar. Biol. Ecol., 7:1-39.

Kaas, P. 1972. Polyplacophora of the Carribbean region, Studies on the Fauna of Curacao and other Caribbean Islands, 141:1-162.

Keen, A. M. 1971. Sea Shells of Tropical West America, 2 ed. Stanford University Press, Stanford, California. 1064 pp.

Mountford, M. D. 1962. An index of similarity and its application to classificatory problems. Progress in Soil Zoology, London, Butterworth; 43-50.

Popham, J. D. and D. V. Ellis. 1971. A comparison of traditional, cluster and Zurich-Montpellier analyses of infaunal pelecypod associations from two adjacent sediment beds. Mar. Biol., 8:260-266.

Pulley, T. E. 1952. A zoogeographical study based on the bivalves of the Gulf of Mexico. Ph.D. diss., Harvard University. 215 pp.

Sanders, H. L. 1960. Benthic studies in Buzzards Bay, III. The structure of the soft bottom community, Limnol. Oceanogr., 5:138-153.

HISTOPATHOLOGY OF MACROINVERTEBRATES FROM AN OIL RIG SITE

University of South Florida, Department of Marine Science

Principal Investigator:
Norman J. Blake

INTRODUCTION

Histopathological samples were collected before, during, and after an exploratory rig operation to determine the effects of drilling upon benthic populations. The rig was located at 27°37'14"N, 96°57'55"W near Mustang Island off the Texas coast.

Figure 1 shows the station locations at which samples were collected. All individuals were fixed in Dietrich's fixative and returned to the laboratory for processing. All exoskeleton-bearing organisms were placed in "D-Cal" for varying periods of time depending upon size. They were then cut into pieces not greater than 0.5 cm thick and washed in flowing tap water for 24 hr. All tissues were processed on an Autotechicon using the 15.5 hr UC670-S29-Paraplast technique. Sections were cut at 6 µm and stained with Harris hematoxylin-eosin.

RESULTS AND CONCLUSIONS

Initially histopathological samples from a rig monitoring effort were to come from the Eastern Gulf of Mexico, preferably from the Florida Middle Ground. Lack of drilling in this area prevented this sampling and an area off the Texas coast had to be chosen. The benthic environment in the area of the rig is composed of very soft sediments (see Doyle) and foraminifera samples (see Bock) indicate stressed conditions. As a consequence, sessile macroinvertebrates are absent from the area and only two species of mobile Penaeid shrimp were collected in sufficient quantities for analysis (Table I). A total of 185 *Trachypenaeus similis*

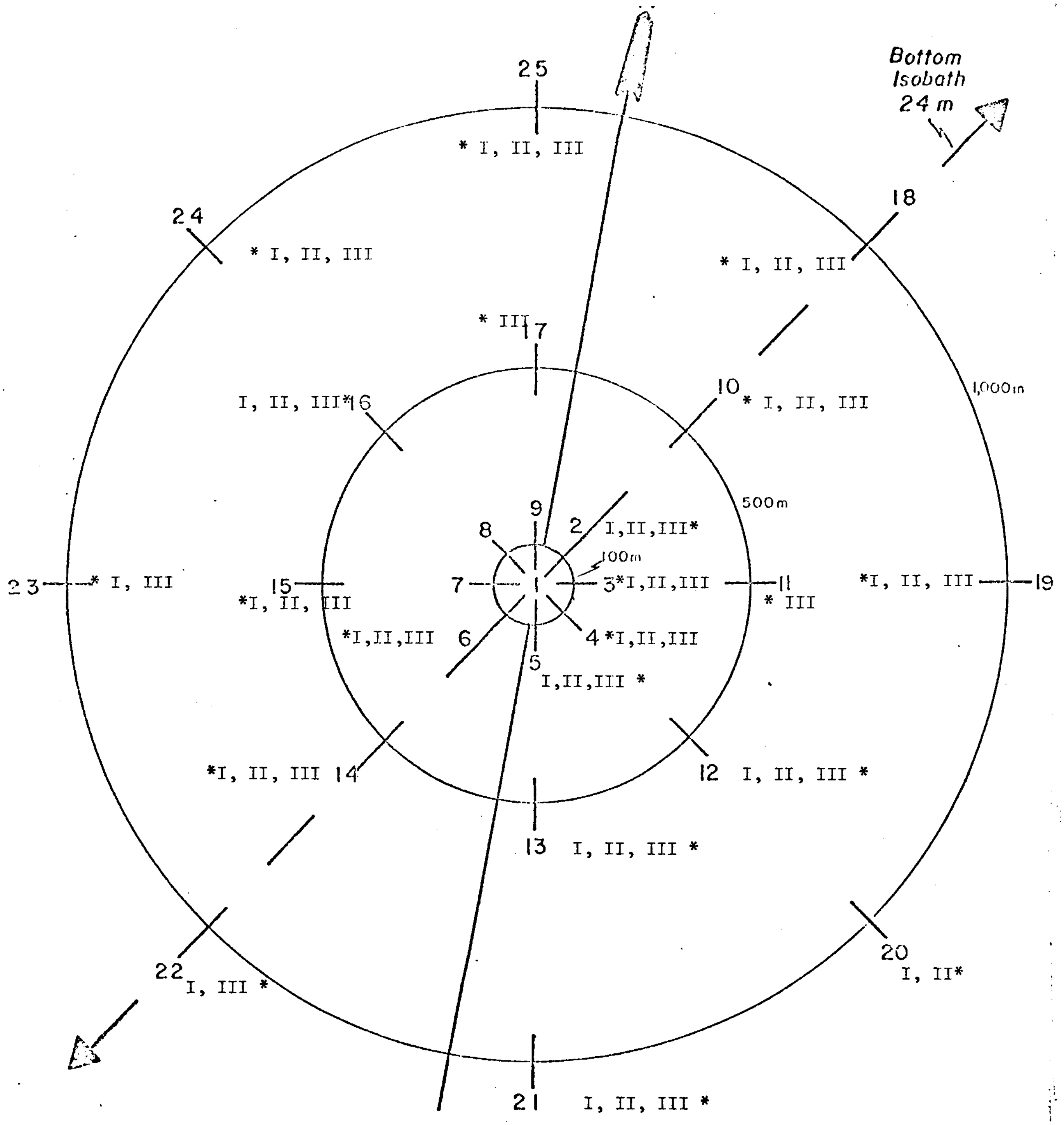

Figure 1.

Arrangement of stations for rig monitoring.

Drilling occurs at Station 1.

Stations with an asterisk are those from which histopathology samples were obtained and Roman numerals designate before, during, and after.

TABLE I.

Histopathology Samples Collected from the Rig Monitoring Effort (I, before; II, during; III, after)

Species	Station #	(12-3-75) I	(1-9&10-76) II	(3-26-76) III	Total
Trachypenaeus similis	02			5	5
	04	4		5	9
	06			5	5
	08			5	5
	10			5	5
	11			5	5
	12	6		5	11
	13		7	5	12
	14		7	5	12
	15			5	5
	16	6		5	11
	17			5	5
	18			5	5
	19			5	5
	20		7	5	12
	21		4	5	9
	22			5	5
	23			5	5
	24	3		5	8
	25	6		5	11
Subtotal		25	25	100	150

TABLE I. Continued

Species	Station #	(12-3-75) I	(1-9&10-76) II	(3-26-76) III	Total
Penaeus setiferus	02	3	5		8
	04		7		7
	06	1	5		6
	08	3	6		9
	10	2			2
	11		6		6
	13	6			6
	14	4			4
	15	1	2		3
	16		7		7
	17		7		7
	18	4			4
	19	5	4		9
	20	5			5
	21	4			4
	22	1			1
	23	7			7
	24		1		1
	25		2		2
2nd Subtotal		46	52	0	98
1st Subtotal		25	25	100	150
FINAL TOTAL		71	77	100	248

slides and 529 Penaeus setiferus slides were made and analyzed. Tissue sections include cornea, carapace, muscle, hepatopancreas, kidney, and gonad. Pathology, excluding parasites which were observed in a few of the individuals, was not detected in any of the before, during or after samples. This observation is not surprising since the shrimp probably moved in and out of the area and the same population was not repeatedly sampled. During sample period III, P. setiferus was not even present in the area.

HISTOPATHOLOGY ATLAS

Submitted as Volume VII

HYDROCARBON SNIFFER PROGRAM FOR MAFLA OCS RIG MONITORING

JUNE, 1975 TO JUNE, 1976

University of South Florida, Department of Chemistry

Principal Investigator:
Robert S. Braman

Associate Investigators:
Richard Gilbert
William Guerin

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A, Redesign

The AMOCO sniffer and auxillary equipment and an extensive parts box were received in good condition. The AMOCO sniffer was incapable of water analyses for specific hydrocarbons and it was therefore redesigned to permit gas chromatographic-like analyses for trace amounts of specific light hydrocarbons. The redesigned unit is shown in Figure 1.

The system is designed to permit the scrubbing collection of hydrocarbons from 10 to 50 ℓ of sea water or more, if necessary. Provision has also been made for batch analysis of up to 250 mℓ of sea water using the system shown in Figure 2. This modification can be used if very high concentrations of hydrocarbons are encountered.

The water scrubbing section of the unit was retained from the old AMOCO equipment. Helium gas was used as part of the scrubbing gas and also as a carrier for the hydrocarbons removed from the water samples. The sample gas stream is passed through a drying tube and into a liquid nitrogen-cooled U-trap which collects all of the hydrocarbons. The trapped gases are then analyzed by a flame ionization detector (FID) (Perkin-Elmer) as they evolve from the heated U-trap. The analysis obtained is similar to a programmed temperature gas chromatographic analysis and a typical standard analysis pattern is shown in Figure 3.

B. Construction

The light hydrocarbon analyzer (LHA) was constructed using the frame and much of the original equipment from the old AMOCO unit. The AMOCO unit was shock mounted and then designed for more rugged field use. Since the filter chambers had been leaking, a new gasket sealing compound had to be

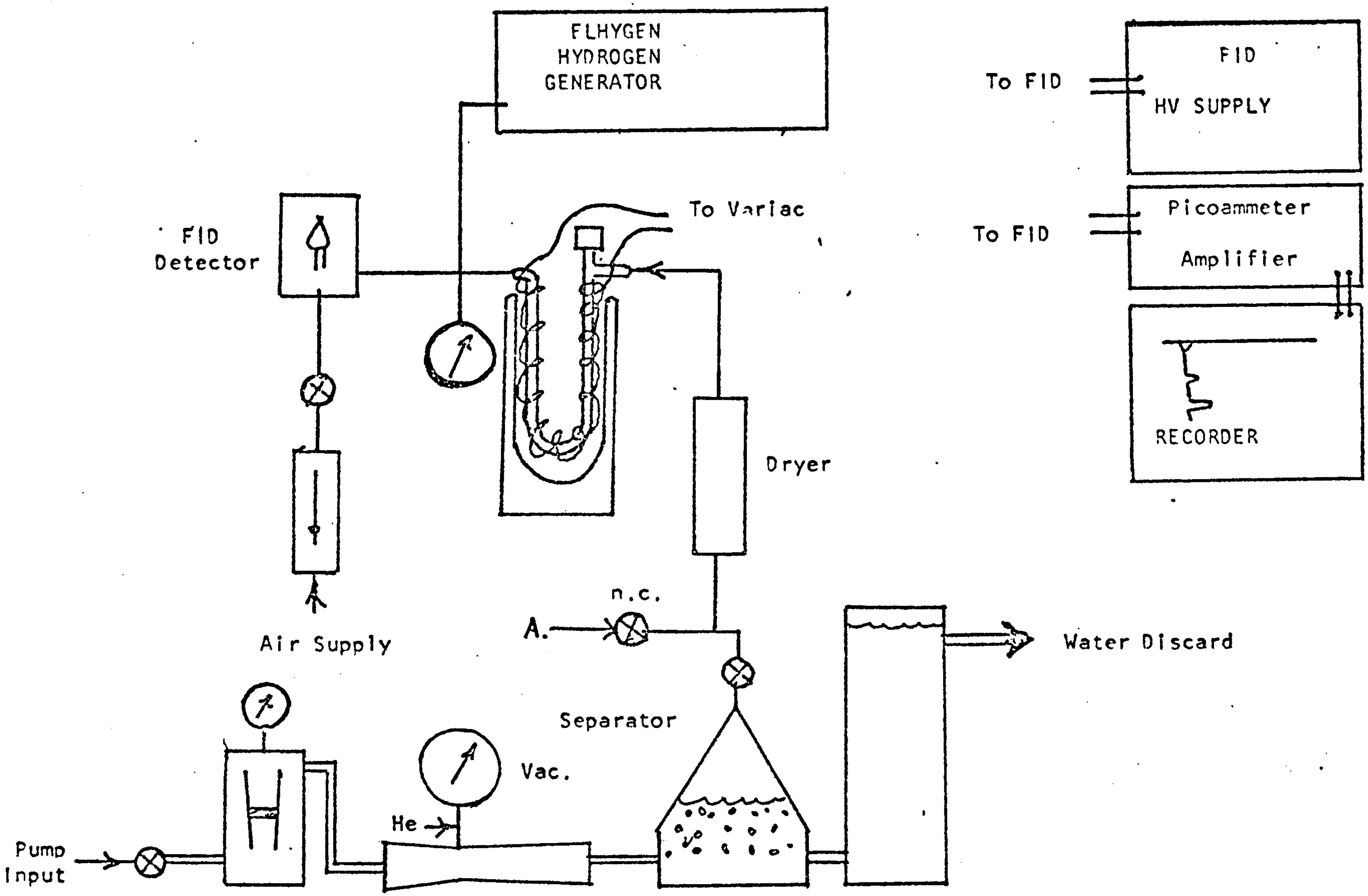


FIGURE I   Apparatus Arrangement for LHA Unit

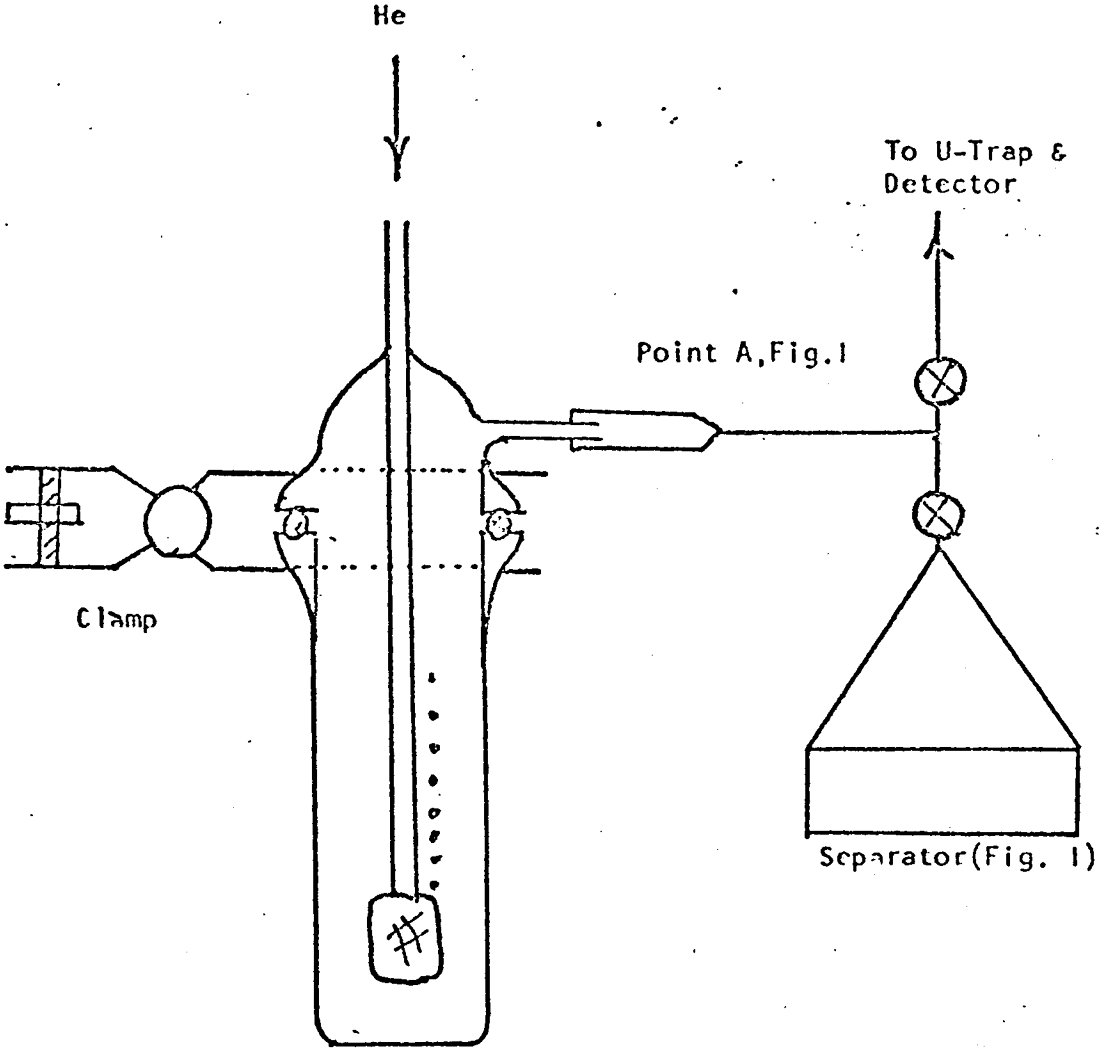


FIGURE 2 Batchwise Water Scrubbing System-Connection to LHA Unit

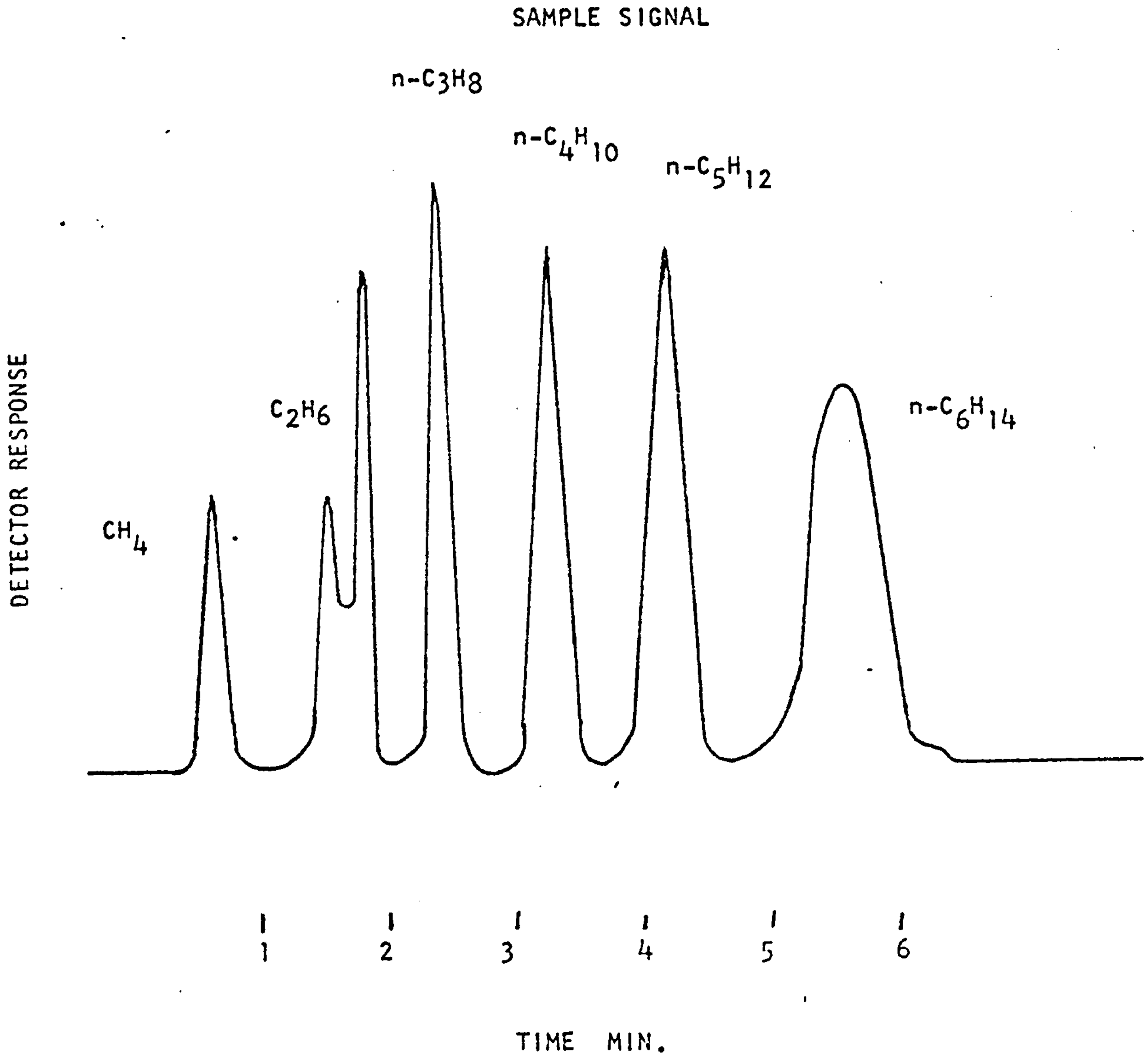


Figure 3 Standard sample detector response

used to replace the unsatisfactory silicon material previously used by AMOCO. Other problems encountered included elimination of leaks and plugged lines, simplifying the carrier gas system and mounting the U-trap in the instrument. The most serious problem was an amplifier failure during a sea trial but this amplifier was replaced with a new solid state FET transistor input stage amplifier (Kiethley Model 414S) and after the Rust Rack recorder was replaced by a new integrating strip chart recorder (Linear Instruments Corp.) no other data collection problems were encountered.

C. Laboratory Testing

Laboratory testing, redesign and construction were an interrelated part of this project. The experimental parameters of carrier gas flow rate, hydrogen gas and air feed rates to the detector, and sample gas flow rate had to be adjusted to obtain maximum sensitivity, maximum separation of components and minimum separation time. This was done along the way as modifications were made in the equipment. Analysis time was reduced to less than five minutes per sample.

Standarization of the detector response was found to be easily accomplished using a standard 1000 ppm mix of C_1 to C_6 normal alkanes in nitrogen gas (Micricyl calibration gas, MG technical products, Kearny, N. J.). Samples of 20 to 500 $\mu\ell$ were injected directly onto the liquid nitrogen cooled U-trap through an injection port. The limit of detection for hydrocarbons was found to be less than 0.1 $n\ell$/sample. This was well below the needed limit of detection for sea water analysis even when working at open ocean ambient concentrations (about 50 $n\ell/\ell$).

The efficiency of the water scrubbing system was tested using a

100 ℓ hold tank, as shown in Figure 4. The efficiency had to be known to relate the standardized detector response to light hydrocarbon concentrations in water. The scrubbing factor was found to be an exponential expression and is discussed later in this report. In the scrubbing efficiency experiments amounts of hydrocarbons were placed in 100 ℓ of water. The LHA continuously scrubbed these hydrocarbons from the tank as a function of time and returned the partially degassed water to the holding tank. Periodically two minute collections were acquired and analysed. To assure that the scrubbing process was monitored as a continuous function of time, the pump was temporarily halted during the analysis cycle. Figure 5 summarizes the results of a typical scrubbing experiment.

The scrubbing versus flow rate experiments were accomplished in an analogous manner. The instrument's flow gauge was calibrated in liters per minute of water flow and the scrubbing experiments were repeated at various flow rates. The results of these experiments are represented in Figure 6.

Data in Figure 6 indicates that control must be maintained over sample flow rate. Calibrations of the system for scrubbing factor upon which quantitative results depend must be made at the actual sampling flow rate. The k factor is not a highly sensitive function of flow rate, a 10% change in sample flow rate will cause a 10% change in results. Sample flow rate control was found to require careful observation of the flow meter during operation and occasional changing of filters in the sample pump system. During operations flow control was maintained to within ±5% relative of the calibration flow rate. Since flow rate is

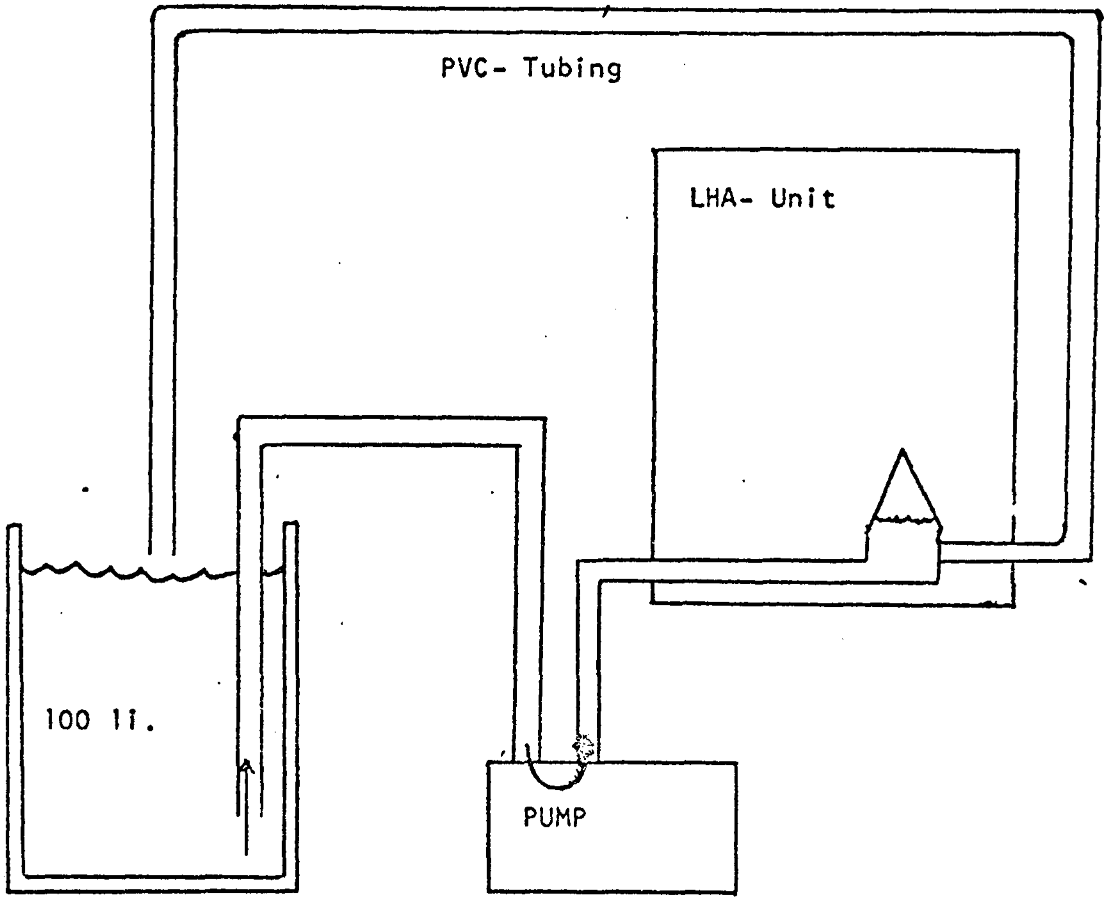
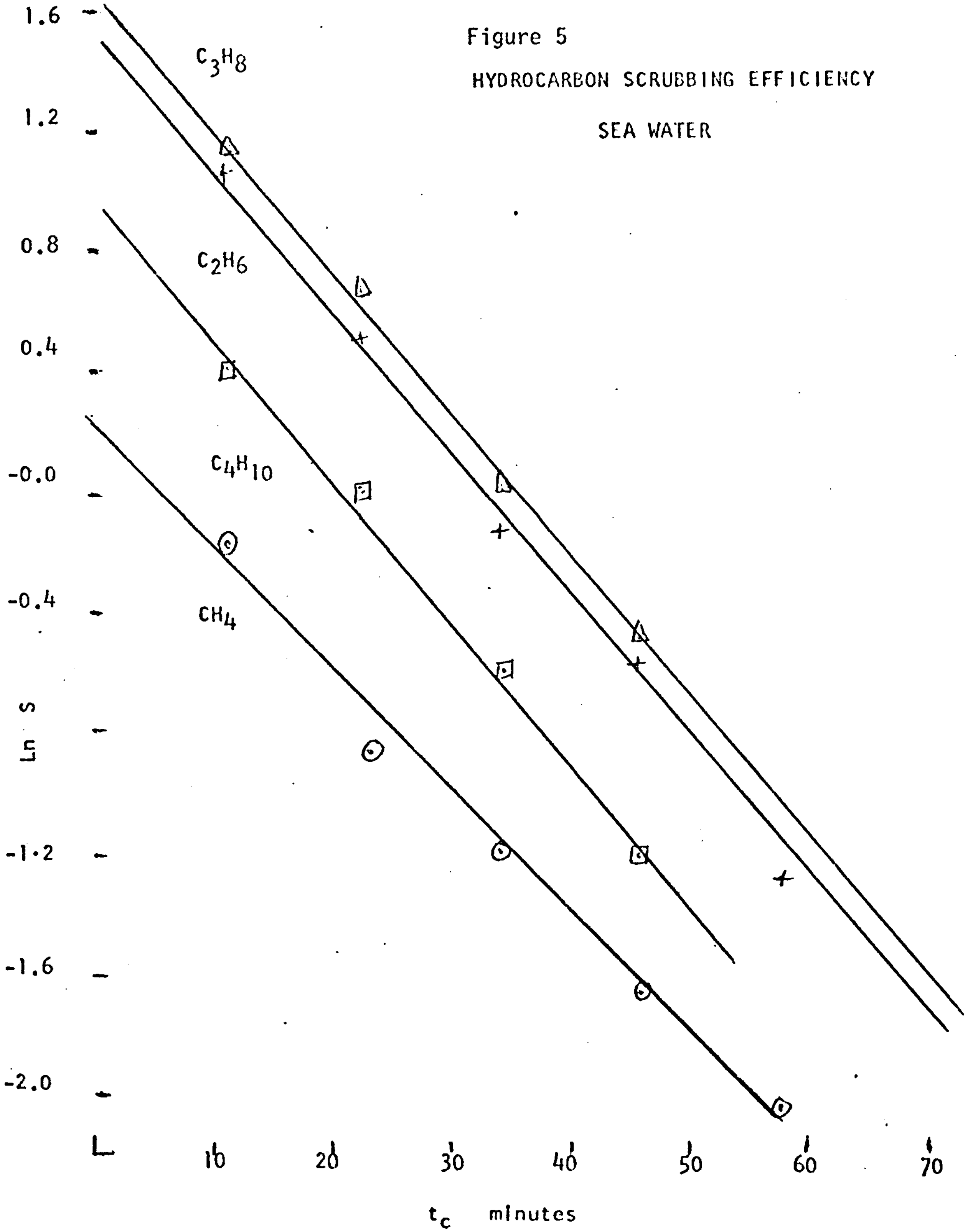


Figure 4 Apparatus Arrangement for Scrubbing Efficiency Experiments

Figure 5

HYDROCARBON SCRUBBING EFFICIENCY

SEA WATER



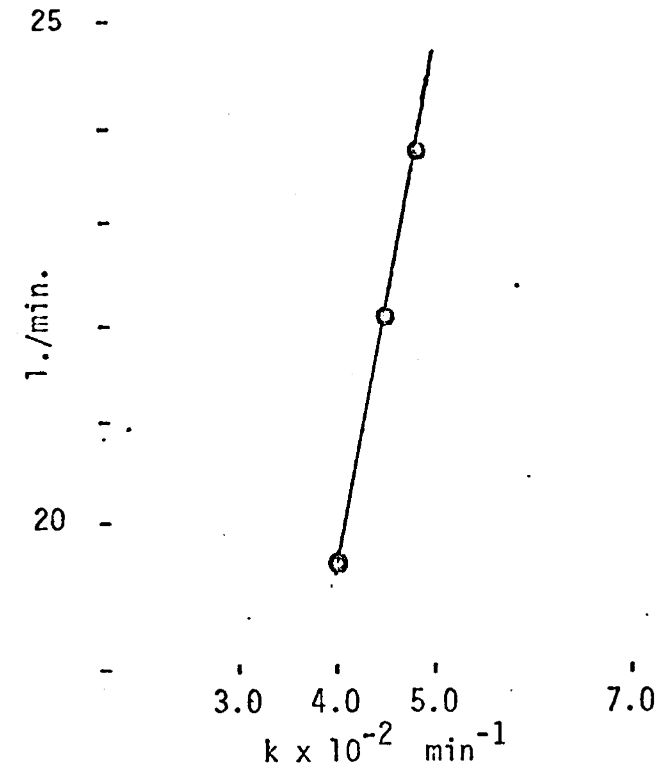


Figure 6 Flow vs. k (CH_4)

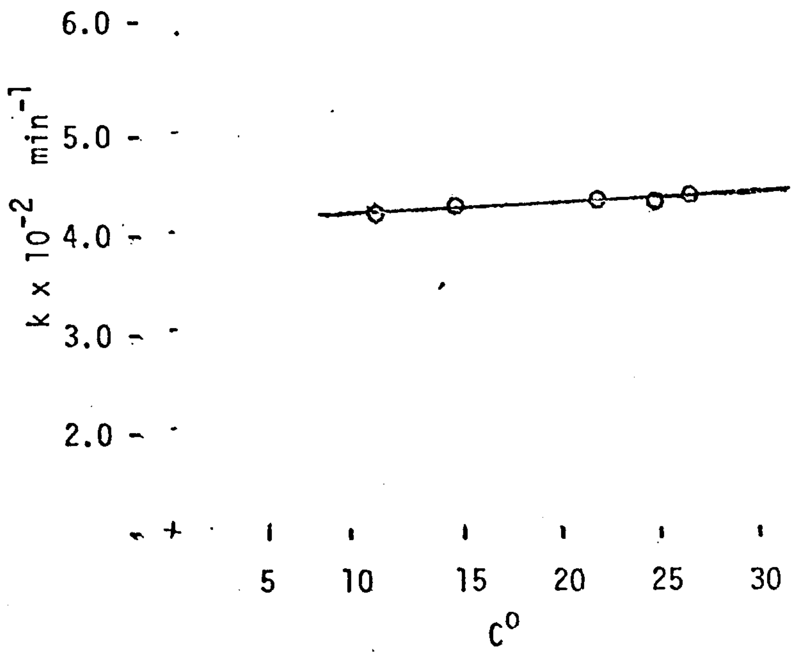


Figure 7 k vs. Temp. (CH_4)

the major source of error compared to others (temperature, calibrations, etc.), ±5% is a good estimate of the data precision of the system.

Scrubbing as a function of temperature experiments were done in the 100 ℓ Dewar tank. The temperature was adjusted before the analysis began and maintained by the addition of small amounts of ice. Low temperature experiments were terminated before any appreciable dilution error occurred. The results of these experiments are shown in Figure 7.

Temperature has little effect on the k factor for methane over a wide range. Failure to calibrate at each operating temperature should result in errors on the order of 2% relative.

D. Scrubbing Theory

The theory of exponential dilution has been investigated by Ritter and Adams*. The rate ($-dC_L/dt$) at which the hydrocarbons are eluted from the LHA is proportional to the concentration of hydrocarbons in the sample. Thus;

(1) $dC_L/dt = kC_L$

where k is a constant characteristic for the LHA and C_L is the concentration, nℓ/ℓ, of hydrocarbon in the aqueous sample. If X_t is the amount, nℓ, of hydrocarbons that has been scrubbed out after time t, $[W_o]$ the concentration, nℓ/ℓ, of the hydrocarbon in the water sample before scrubbing and V the volume, ℓ, of water scrubbed then equation (1) becomes;

(2) $dC_L/dt = -k((V[W_o] - X_t)/V)$.

Since $C_L = (V[W_o] - X_t)/V$ it follows that $dC_L/dt = -dX_t/Vdt$ and equation (2) can be expressed as;

(3) $-1/V(dx_t/dt) = -k((V[W_o] - X_t)/V)$

which can be simplified to

(4) $dX_t/dt = k(V[W_o] - X_t)$.

Rearranging equation (4) gives a familiar differential equation;

(5) $dX_t/(V[W_o] - X_t) = kdt$

and integration of (5) gives;

(6) $-\ln(V[W_o] - X_t) = kt + C_1$.

At t= 0, X_t becomes zero and the integration constant can be evaluated and equation (6) becomes;

---

* Ritter, Adams, Anal. Chem 612 (1976).

(7) $\ln (V[W_o]/ (V[W_o] - X_t)) = kt.$

Equation (7) can be expressed as;

(8) $V[W_o]/(V[W_o] - X_t) = \exp(kt)$

and then rearranged to give;

(9) $X_t = V[W_o] (1 - \exp(-kt)).$

Differentiation of (9) gives;

(10) $dX_t/dt = V[W_o]k \exp(-kt).$

Taking the ln of equation (10) gives;

(11) $\ln dX_t/dt = \ln(V[W_o]k) - kt$

and a plot of t vs $\ln dX_t/dt$ will give a line with slope k, the scrubbing factor for the analyzer. Once k has been obtained equation (9) can be used to evaluate the $[W_o]$ for environmental samples taken.

Since the scrubbed hydrocarbons are collected over a constant time interval, Δt, the signal that is actually recorded by the LHA is not the differential of X_t with respect to time but is in fact the increment in X_t with respect to delta time. It is necessary, therefore, to show that a plot of the increment in X_t vs time will also result in the evaluation of k.

The amount of hydrocarbon released after scrubbing for time, t, is expressed by equation (9). Thus the amount released after scrubbing, $t + \Delta t$, is given by;

(12) $X_{t + \Delta t} = V[W_o] (1 - \exp(-k(t + \Delta t)).$

The amount, $(X_{t + \Delta t} - X_t)$ collected over the time interval Δt is the difference between equation (9) and equation (12) and can be represented as;

(13) $\Delta X = (V[W_o] \exp(-kt)) (1 - \exp(-k\Delta t)).$

Expressing $\exp(-k\Delta t)$ as a series and neglecting the second order terms gives;

(14) $\exp(-k\Delta t) = 1 - k\Delta t$

and the substitution of equation (14) into (13) gives;

(15) $\Delta X = (V[W_o] \exp(-kt)) (k\Delta t)$

which can easily be represented as;

(16) $\Delta X/\Delta t = V[W_o]k \exp(-kt)$.

The error involved in expanding $\exp(-k\Delta t)$ to the first order term is five parts in 1000 when $k\Delta t$ has a value of 0.1 and decreases as the value of $k\Delta t$ decreases. Since k is equal to $(\ln 2)/\tau_{\frac{1}{2}}$, where $\tau_{\frac{1}{2}}$ is the half life of the scrubbing experiment, the expansion of $\exp(-k\Delta t)$ introduces an error of less than five parts in 1000 when the collection time, Δt, is less than 0.144 of $\tau_{\frac{1}{2}}$. Therefore equation (16) is an excellent approximation of equation (10) when Δt is less than 14.4% of $\tau_{\frac{1}{2}}$ and equation (16) can be utilized to evaluate the scrubbing factor, k.

E. Preliminary Field Testing

Field tests were made on two fresh water lakes. These were not overly successful because the high organic content of the lake water overloaded the detection system. The pumping and filtering systems were also overtaxed and no modifications for fresh water work were attempted. However, the batch analysis method, (see Figure 2), could be used in situations like this. A successful at-sea field test of the LHA unit was made in October 1975. The two sampling methods, as well as alternative water collection methods, were investigated and only minor correctable problems were encountered. In general, the sea trial showed that the equipment would operate on the R/V Bellows and provided a much needed training exercise for all project personnel.

F. Rig Monitoring

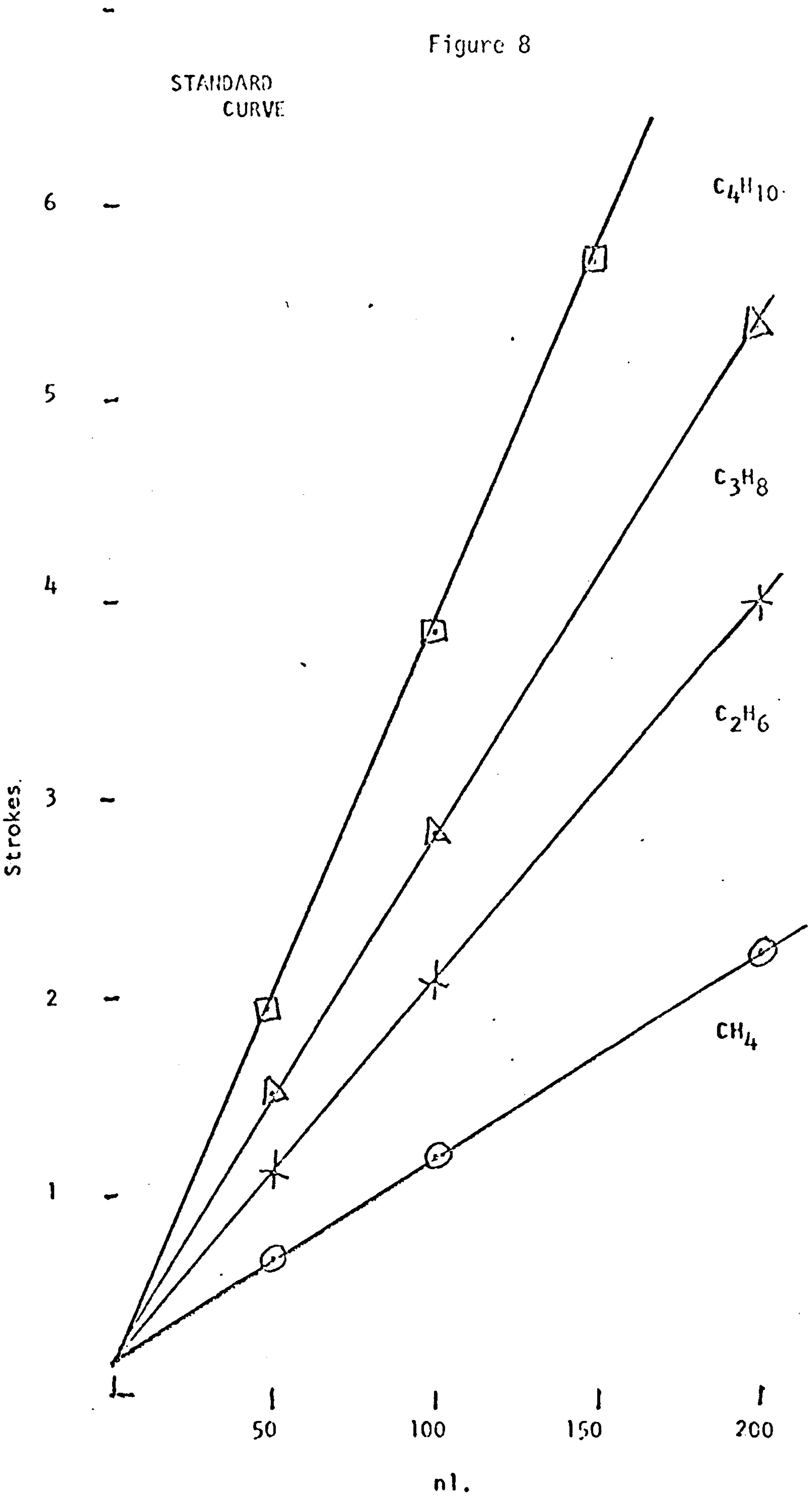
1. Calibration of Detector

Selected amounts of methane, ethane, propane and butane were drawn into a microliter syringe (Unimetrics) and then injected onto the cold trap. Corresponding detector response areas were plotted against injected gas volumes (Figure 8) and this data is also summarized in Appendix A. Periodic laboratory calibration checks were conducted and a calibration check was performed at each rig monitoring site.

2. On Site Sampling

The light hydrocarbon analyzer as described was employed in all operations. Water sampling was done through the ship's sampling pump systems during the first cruise period and by means of a towed tube

Figure 8


STANDARD
CURVE
Strokes
6
5
4
3
2
1
50
100
150
200
nl.
C_4H_{10}
C_3H_8
C_2H_6
CH_4

and pump system during all subsequent operations. During all field operations the flow rate was kept constant. The analysis procedure consisted of cold trapping for two minutes of scrubbing time while underway. Trapped, scrubbed gases were then analyzed for a period of approximately three to five minutes and the analysis cycle repeated. The analysis system therefore analyzed a composite sample of water obtained while the ship was underway and presented the average water quality for the distance traveled in the two minute period.

Scrubbing experiments, as described in section C, were conducted at sea to determine the value of the scrubbing factor. Linear regression analysis was employed to determine the slopes of lines obtained from the experimental data. These values of the scrubbing factor, k, are presented in Appendix A. Excellent correlation between experimental data and scrubbing theory was obtained and in all experiments conducted the collection time, two minutes, was less than 0.144 $\tau_{\frac{1}{2}}$.

3. Data Discussion

The drilling rig site near Port Aransas, Texas was surveyed prior to drilling on December 1-2, 1975. Data presented in Appendix A indicated that there is a detectable amount of methane present. The methane values are in accord with the findings of others. An interesting feature of the data is that the methane values decreased as the sampling point became further removed from the ship channel outlet to the Gulf. No particular pattern of hydrocarbons was noted in the test area.

Because of the termination of drilling operations prior to being able to survey the site near Port Aransas, Texas a second time, it was decided to survey a drilling operation at latitude 27°37'13.87"N, longitude 96°57'55.17"W, near Port O'Conner, Texas. The survey was done on January 23, 1976, and no general light hydrocarbon contamination was observed in the area. One of the samples obtained showed a substantial amount of light hydrocarbons, nevertheless, we believe it was caused by a single bubble of natural gas seepage and must be a solitary event since any substantial continual seepage or leakage from drilling would contaminate the entire area surveyed.

During the January 2-6 cruise period the towed sampling system was tested in the Corpus Christi ship channel. Results demonstrated the ability of the analyzer to detect light hydrocarbons in polluted waters. Nearby refineries were likely the source of C_2 to C_6 hydrocarbons found in the turning basin in the urban area of Corpus Christi. Waters decreased in hydrocarbon concentration as the more open areas of Corpus Christi bay were crossed and further yet as the ship channel approached the open Gulf. Data shown in Appendix A includes some results of air analyses of the port area.

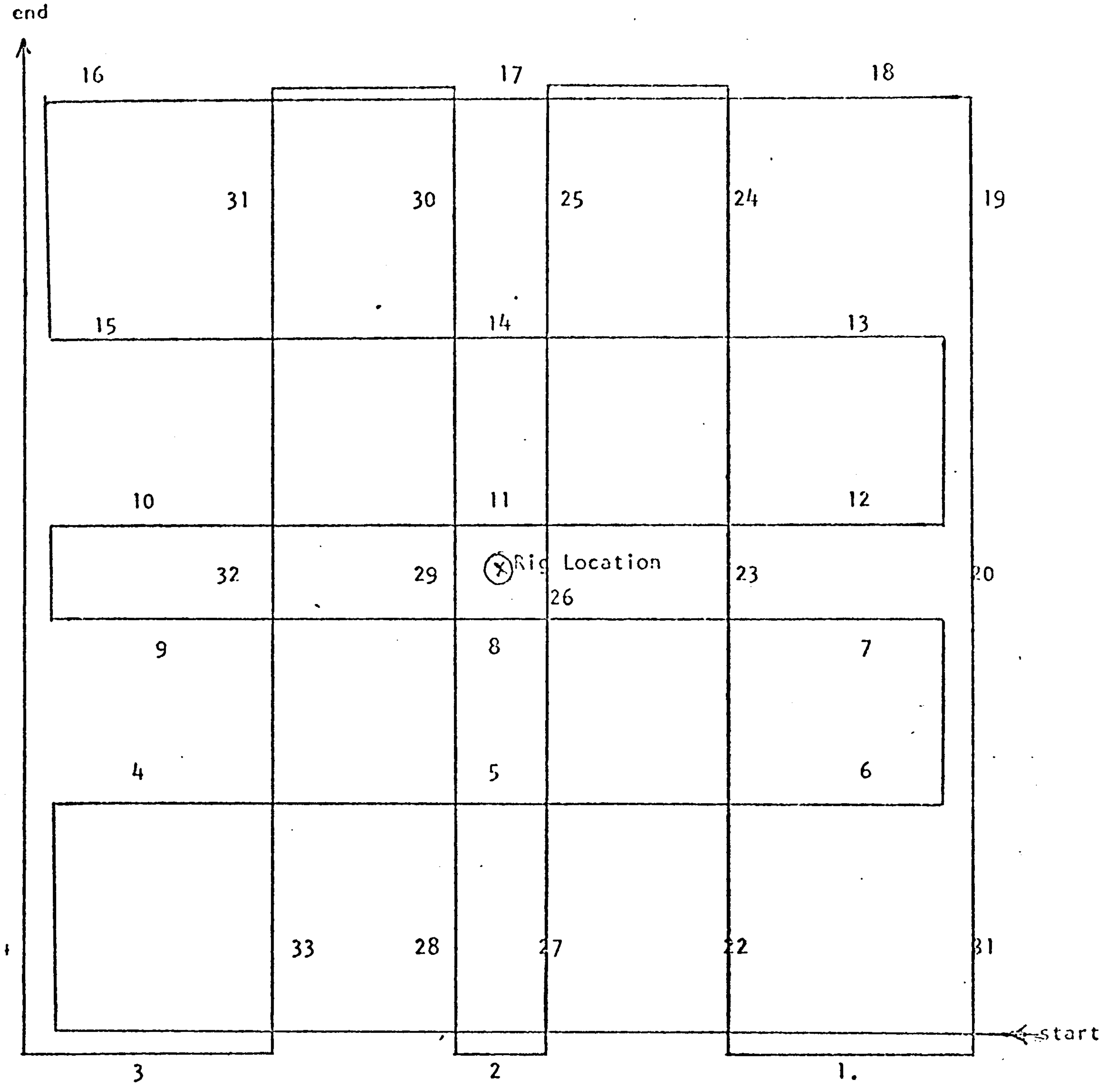
APPENDIX A

TABLE I

LHA SURVEY PRIOR TO DRILLING

nℓ/ℓ

sample No.	CH_4	C_3H_8	C_4H_{10}
0-1	390	8.6	14
0-2	290	3.8	9.5
0-3	250	4.2	10
1	170	6.7	13
2	110	6.3	6.7
3	64	3.8	9.2
4	54	6.9	9.2
5	31	4.2	9.0
6	9	6.1	9.5
7	56	7.1	12
8	35	4.4	9.5
9	30	-	9.2
10	85	5.9	10
11	38	5.5	11
12	36	7.1	14
13	103	7.1	16
14	31	8.4	14
15	39	4.8	11
16	16	5.0	8.6
17	34	5.3	9.9
18	38	1.0	6.7
19	40	5.5	13
20	36	6.7	10
21	28	5.5	8.2
22	39	4.6	9.8
23	35	2.7	7.4
24	31	9.0	16
25	57	-	-
26	48	3.6	3.8
27	28	4.0	4.8
28	36	8.0	13
29	25	5.3	11
30	26	6.1	-
31	34	2.9	6.7
32	25	3.2	7.8
33	28	2.5	2.7
34	43	7.8	12
35	48	11	16
36	47	8.6	14



RIG MONITORING SAMPLING GRID-SHIP TRACK
(location of samples-approx.)

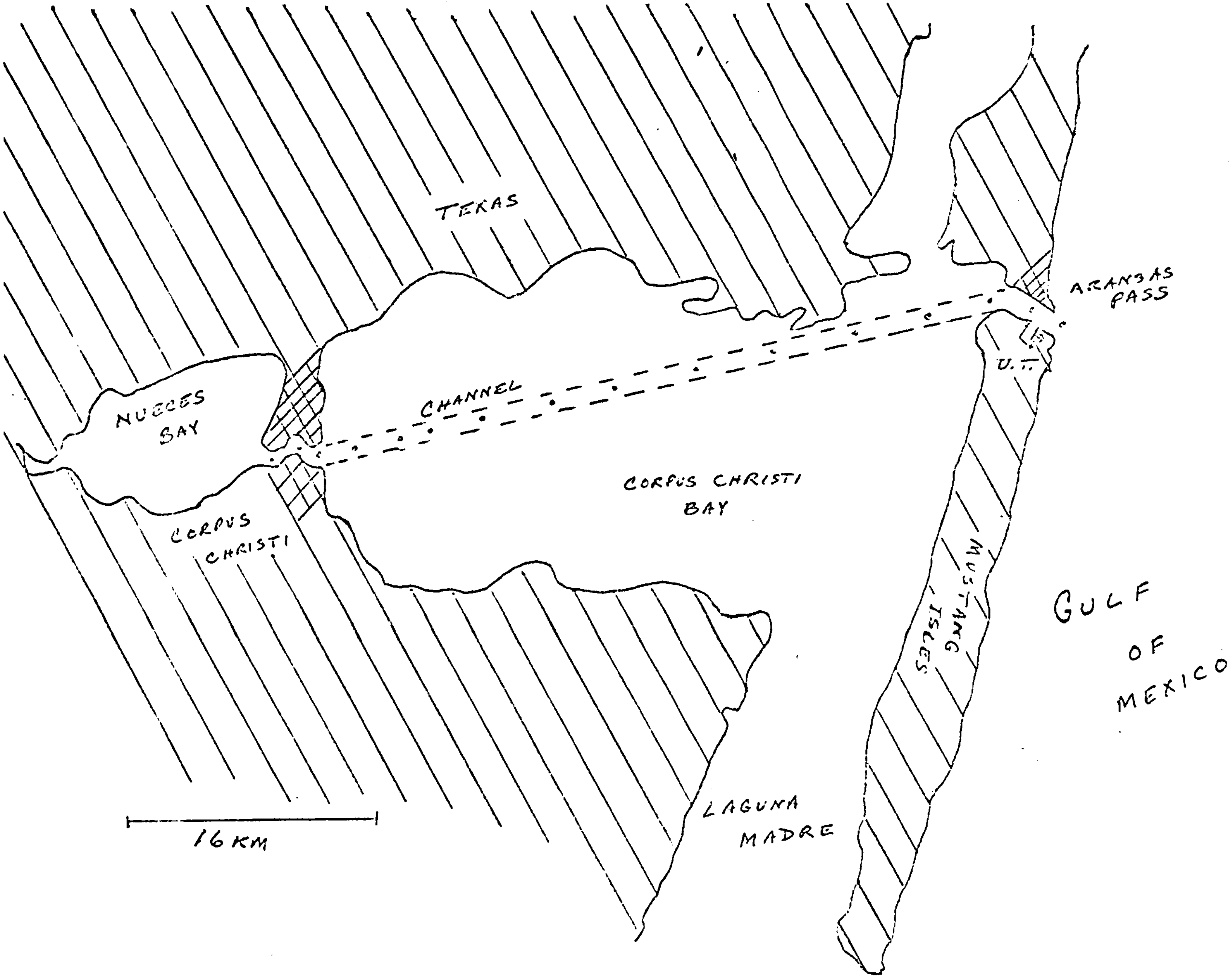

TEXAS
ARANSAS PASS
CHANNEL
NUECES BAY
U.T.
CORPUS CHRISTI BAY
CORPUS CHRISTI
MUSTANG ISLES
GULF OF MEXICO
LAGUNA MADRE
16 KM

TABLE 2

SURVEY OF CORPUS CHRISTI SHIP CHANNEL

nℓ/ℓ

sample No.	CH_4	C_3H_8	C_4H_{10}	C_5H_{12}	C_6H_{14}
W-1	940	16	340	230	97
W-2	lost	-	200	120	65
W-3	940	36	200	140	67
W-4	840	10	180	170	65
W-5	660	2.3	23	13	11
W-6	470	2.3	6.2	13	-
W-7	450	2.3	11	16	10
W-8	lost	2.7	6.5	8.2	-
W-9	380	3.4	5.7	6.9	1.9
W-14	270	6.1	-	-	-
W-15	220	1.3	-	-	-
W-16	80	-	-	-	-

Locations:		
	W-1 to W-3	interior port of C. Christi
	W-4 to W-9	Nueces bay towards Gulf
	W-14 - W-15	Outer ship channel
	W-16	At jetty near open gulf

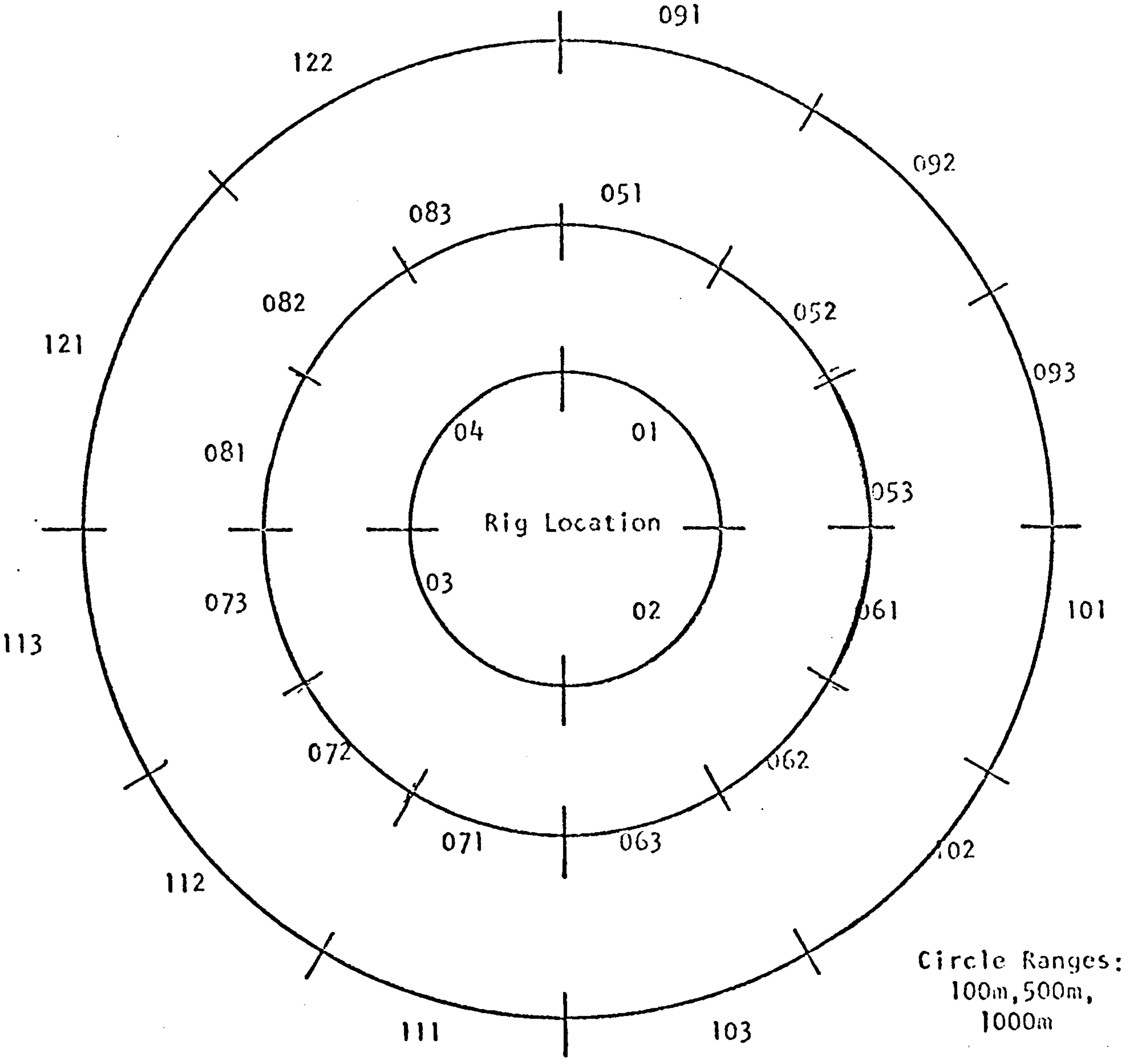
TABLE 3 . LHA- Unit Air Analysis Of Corpus Christi Ship Channel

$\mu\ell/\ell$

Sample No.	C_1H_4	C_3H_8	C_4H_{10}
A-7	0.11	17	0.3
A-6	0.02	6.7	0.4
A-5	0.02	4.9	-
A-4	0.03	5.7	-
A-3	0.03	6.4	0.9
A-2	0.03	7.3	0.4
A-1	0.03	9.5	-

Note locations:

A-7 to A-5	interior port of Corpus Christi
A-4 to A-1	Nueces bay towards Gulf



RIG MONITORING SAMPLING GRID- SHIP TRACK
(drilling operation underway)

TABLE 4

RIG MONITORING, DRILLING UNDERWAY

nℓ/ℓ

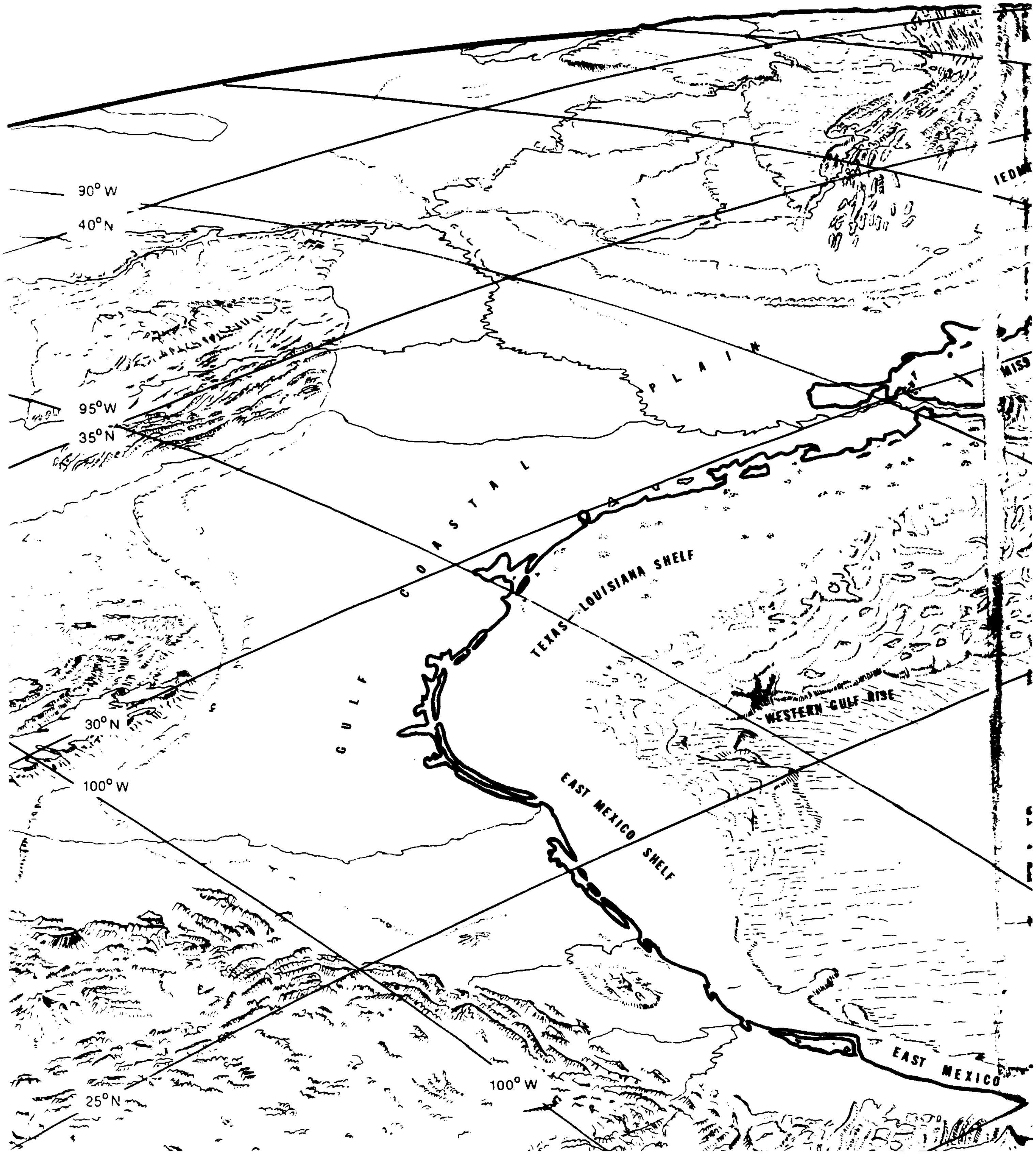
Sample No.	CH_4	Remarks
R-1	300	4025 m from rig
R-2	170	2816 m from rig
R-3	200	1770 m from rig
R-4	200	965 m from rig
	100 m Circle	
0-1	260	
0-2	220	
0-3	220	
0-4	220	
	500 m Circle	
051	230	
052	200	
053	190	
061	210	
062	105	
063	200	
071	200	
072	320	
073	180	
081	150	
082	100	
083	240	
	1000 m Circle	
091	880	C_2 180 C_3 40 C_4 100
092	330	
093	260	
101	140	
102	280	
103	250	
111	290	
112	250	
113	200	
121	220	
122	180	

Table 5

Regression Analysis for Scrubbing Factor

flow 17ℓ/min

T C^{o}	k x 10^{-2}	s.d. x 10^{-2}	corr.	alkane
11.5	4.07	0.48	0.997	CH_4
14.0	4.68	0.36	0.982	CH_4
22.0	3.58	1.2	0.978	CH_4
25.2	4.25	0.56	0.985	CH_4
25.2	3.96	0.27	0.985	C_2H_6
25.2	2.95	0.24	0.977	C_3H_8
22.0	4.05	0.74	0.992	C_2H_6
22.0	4.25	0.62	0.980	C_3H_6



90° W
40° N
95° W
35° N
30° N
100° W
25° N
100° W
G U L F   C O A S T A L   P L A I N
TEXAS—LOUISIANA SHELF
WESTERN GULF RISE
EAST MEXICO SHELF
EAST MEXICO
IEDM
MISS