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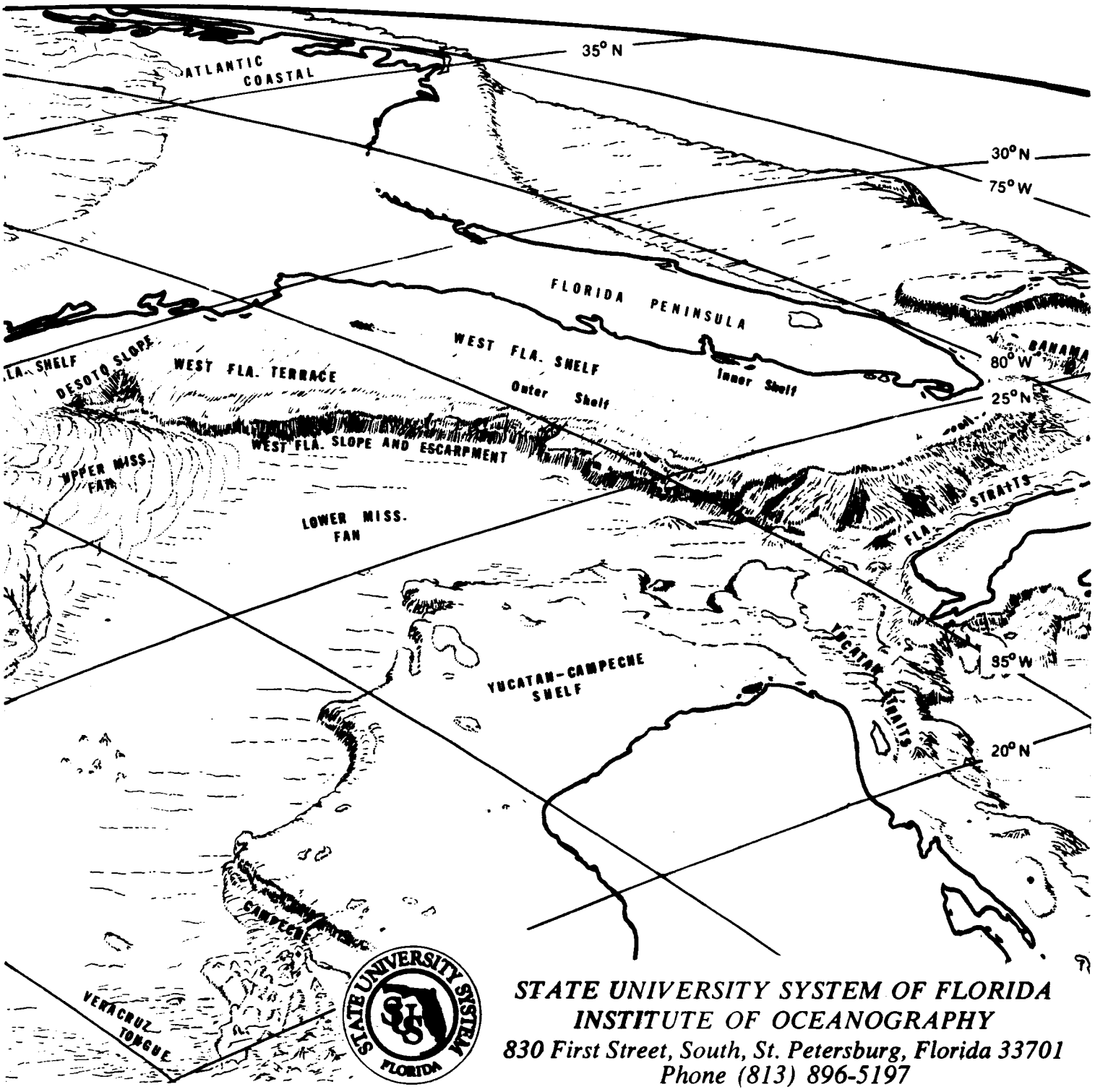

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STUDIES OF CLAY MINERALS (AND FINE-GRAINED NON-CLAYS) OF PARTICULATES OF WATER COLUMN FROM THE MAFLA OCS BASELINE MONITORING SITES

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INTRODUCTION

Although Manheim, et al. (1972) found montmorillonite and kaolinite in suspended matter in surface waters of the northern Gulf of Mexico, no systematic studies have been taken to determine if suspended mineralogy varies with seasons from the MAFLA OCS monitoring sites. This baseline information is essential to determine any adverse variation of suspended matter caused by drilling operations. In this paper are reported two significant changes of suspended minerals with seasons.

PROCEDURES

Field Sampling

In collaboration with the sampling program for a study of trace metals in water columns, suspended particulates in the remaining 21 ℓ solution were separated through 0.45 μ millipore filters using an inline-47 closed filtration system. The detailed procedure for collecting samples is described by Betzer (1976). A total of 46 samples from 15 stations at three sampling periods - July, 1975; September-October, 1975; and January, 1976 - were collected and stored at 4°C until they were analyzed in the lab.

Laboratory Analysis

Filter papers which contained particulates were first rinsed thoroughly with deionized water to remove residual salts. The particulates were then resuspended and filtered through Selas Flotronic silver membranes (0.45 μ size and 25 mm diameter) for X-ray analysis. In order to obtain a complete analysis of both clay and non-clay minerals in particulates, the samples were first X-rayed without treatment, and then X-rayed following various treatments with ethylene glycol vapor for 12 hr, with drying at 25°C, and heating at 110°C, 300°C, and 550°C. The X-ray analysis was carried out on a Norelco diffractometer using CuK_{α}, nickel filtered radiation generated with 35 Kv and 20 ma. A 1° beam slit and 762 μm receiving slit were used throughout scanning (2° to 33° 2θ) except for lower 2θ peaks (3° to 9° 2θ) where a 1/4° beam slit was used. The scanning speed was set at 1/2° 2θ/min with chart paper on 76 cm/hr. Relative percentages of clay and non-clay minerals were also estimated following the method described by Huang, et al. (1974).

RESULTS AND DISCUSSION

A total of 450 data points were obtained from the analysis of suspended matter in the water columns of the MAFLA monitoring sites, as shown in Tables 1-6. They are described as follows:

A. First (July) and Second (September-October) Sampling Period

Clay minerals are predominant, and exceed more than 46% of the total suspended minerals. In July samples, clay mineral content of suspended particulates generally decreased seaward in all transects

(except #IV), whereas in September samples the clay content increased seaward. This suggests that suspended mineralogy in the sites is strongly dependent on the season.

Furthermore, the distribution of clay minerals in suspended matter is different from that in surface sediments. The most striking is the presence of talc in virtually all sampling stations, which was not found in surface sediments. Specifically, the distribution patterns are as follows:

(1) Talc decreased seaward in most transects except those on the West Florida Shelf where talc increased seaward.

(2) Kaolinite generally decreased seaward, and has higher concentrations in Transects #III and IV than on the West Florida Shelf.

(3) Chlorite did not show any significant trend although it slightly decreased seaward on the West Florida Shelf (Transect #II).

(4) Illite virtually shows no significant trends.

B. Third (January) Sampling Period

As shown in Tables 5 and 6, the overall distribution patterns of suspended minerals are significantly different from those from the July and September samples. The major differences are as follows:

(1) In January samples, the percent of clay minerals in suspended particulates increased seaward.

(2) Relative abundances of individual clay minerals in suspended matters are similar to those found in bottom sediments.

On the West Florida Shelf, kaolinite is a predominant clay in particulates, whereas on the Mississippi Shelf, smectite is the most abundant clay mineral in the suspended matter. Carbonate minerals (including aragonite, low-Mg calcite and high-Mg calcite, and dolomite) are also present in appreciable amounts, up to 70% of total suspended minerals in the Transect # I of the West Florida Shelf. These data strongly suggest that some disturbance of bottom sediments may have occurred during the January sampling period, which, in turn, affects the overall distribution of suspended minerals.

(4) In contrast to the first and second sampling periods, talc in the January samples was only found on the West Florida Shelf, and was virtually absent on the Mississippi Shelf. This is quite a contrast to those found in the July and September samples from the Mississippi Shelf in which talc was almost 30-40% of the total suspended materials. This comparison rules out a possibility of contamination of talc from the sampling ship. It is conceivable that talc may have originated in the beach sands, where talc was reported to be present in significant amounts.

In conclusion, results of suspended mineralogy in the MAFLA monitoring sites are significantly different from those found by Manheim, et al. (1972). Suspended minerals in the sites are strongly dependent on the seasons, and further studies are needed to verify these seasonal variations.

TABLE 1

PERCENT (%) COMPOSITION OF CLAY AND NON-CLAY MINERALS IN SUSPENDED PARTICULATE MATTER FROM 10 M DEPTH ON THE WEST FLORIDA SHELF - THE MAFLA SITES

(JULY 14, 1975 & July 21, 1975)

ation #	Smectite	Chlorite	Illite	Kaolinite	Talc	Quartz	Feldspars	Aragonite	L.M. Calcite	Dolomite
1101	--	10	11	23	13	23	8	--	6	6
1102	T	5	19	22	32	11	11	--	--	--
1103	--	6	9	18	18	14	20	8	6	--
1204	--	8	18	16	18	25	15	--	--	--
1205	--	10	9	13	33	14	21	--	--	--
1206	--	9	8	16	15	26	26	--	--	--
1207	--	T	18	28	T	18	36	--	--	--
1308	--	16	14	23	38	--	9	--	--	--
1309	--	5	21	21	40	13	T	--	--	--
1310	T	--	8	20	38	11	23	--	--	--
1311	--	16	14	12	30	7	21	--	--	--
1412	7	11	11	25	6	25	15	T	--	--
1413	--	T	22	25	--	41	12	--	T	--
1414	--	T	12	15	26	19	18	10	T	--
1415	--	8	9	13	49	15	6	--	--	--

L.M. Calcite- low magnesium calcite
T- trace amount

TABLE 2

PERCENT (%) COMPOSITION OF CLAY AND NON-CLAY MINERALS IN SUSPENDED PARTICULATE MATTER FROM 10 M DEPTH ON THE WEST FLORIDA SHELF - THE MAFLA SITES

(SEPTEMBER 16, 1975 & OCTOBER 3, 1975)

ation #	Smectite	Chlorite	Illite	Kaolinite	Talc	Quartz	Feldspars	Aragonite	L.M. Calcite	Dolomite
1101	--	7	12	30	29	11	11	T	--	--
1102	--	5	8	19	49	5	14	T	--	--
1103	--	--	12	29	43	--	16	--	--	--
1204	--	7	T	16	41	8	7	--	T	21
1205	--	6	6	50	1	18	T	5	14	--
1205a	--	17	17	22	T	20	24	T	--	--
1206	--	T	20	32	48	--	T	--	--	--
1207	--	7	7	39	18	14	15	--	--	--
1308	--	T	9	17	25	11	38	--	--	--
1309	--	T	10	20	10	16	44	--	--	--
1310	--	15	T	29	14	11	31	--	--	--
1311	--	--	26	38	--	--	36	--	--	--
1412	--	18	18	18	21	15	5	--	--	5
1413	--	--	T	29	38	14	19	--	--	--
1414	--	--	25	33	--	11	31	--	--	--
1415	16	23	--	22	T	--	39	--	--	--

1205a before hurricane
1205 after hurricane

L.M. Calcite - low magnesium calcite
T - trace amount

TABLE 3

THE CONTENT (%) OF CLAY MINERALS IN SUSPENDED PARTICULATE MATTER FROM 10 M DEPTH ON THE WEST FLORIDA SHELF

(JULY 14, 1975 & JULY 21, 1975)

Station #	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

TABLE 4

THE CONTENT (%) OF CLAY MINERALS IN SUSPENDED PARTICULATE MATTER FROM 10 M DEPTH ON THE WEST FLORIDA SHELF

(SEPTEMBER 16, 1975 & OCTOBER 3, 1975)

Station #	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

TABLE 5

PERCENT (%) COMPOSITION OF CLAY AND NON-CLAY MINERALS IN SUSPENDED PARTICULATE MATTER FROM 10 M DEPTH ON THE WEST FLORIDA SHELF - THE MAFLA SITES

(JANUARY, 1976)

. #	Smectite	Chlorite	Illite	Kaolinite	Talc	Quartz	Feldspars	Aragonite	L.M. Calcite	H.M. Calcite	Dolomite
101	--	3	1	5	2	6	--	12	47	17	7
102	--	3	2	12	5	5	--	7	57	9	--
103	--	15	13	12	38	15	7	7	--	--	--
204	--	14	6	37	12	23	8	--	--	--	--
205	--	8	9	13	11	32	18	--	--	--	9
206	--	19	4	57	0	20	--	--	--	--	--
207	3	4	3	23	2	12	6	4	36	7	--
308	T	10	9	52	8	17	4	--	T	T	T
309	--	6	11	13	11	28	17	--	--	--	14
310	--	T	6	36	9	20	15	--	--	--	14
311	*	*	*	*	*	*	*	*	*	*	*
412	45	1	6	18	0	28	2	--	--	--	--
413	45	1	8	12	0	32	2	--	--	--	--
414	66	T	6	8	T	18	2	--	--	--	--
415	57	T	7	10	4	21	T	--	--	--	--

.M. Calcite - Low magnesium calcite
.M. Calcite - High magnesium calcite
- Trace Amount
- Not enough sample

TABLE 6

THE CONTENT (%) OF CLAY MINERALS IN SUSPENDED PARTICULATE MATTER FROM 10 M DEPTH ON THE WEST FLORIDA SHELF

(JANUARY, 1976)

Station #	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

* - Not enough sample
T - Trace Amount

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CLAY MINERAL STUDIES OF SURFACE SEDIMENTS FROM THE MAFLA OCS BASELINE MONITORING SITES

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ABSTRACT

Forty-two box cores (up to 30 cm in length) were sampled along six transects from the MAFLA OCS baseline monitoring sites. Clay mineral analyses from the upper 10 cm of the cores show that on the West Florida Shelf, kaolinite is the most abundant, followed by chlorite-vermiculite mixed layer which is unique in this shelf area and peaks at the Fort Myers transect. Chlorite-vermiculite mixed layer generally decreased seaward. This distribution pattern of clay minerals is quite different from that on the Mississippi-Alabama Shelf where smectite predominates the clay mineral assemblages and virtually no vermiculite-chlorite mixed layer occurs. These two distinctly different patterns suggest that clay minerals originate from two distinct sources and mechanisms. Moreover, smectite is relatively concentrated in the outer shelf from all transects, and shows a decreasing trend toward the West Florida Shelf which suggests the influence of the bottom currents on the distribution pattern of smectite in the area.

INTRODUCTION

In the first MAFLA baseline study, Huang, et al. (1975) found distinctly different patterns of clay mineral assemblages within the MAFLA monitoring sites. In order to provide a long-term baseline reference for the determination of any variation of bottom sediments caused by drilling operation, a total of 84, paired subcores were collected from 42 stations in the sites for clay analysis. In this paper are reported two facies of clay minerals in surface sediments from the MAFLA sites. Their possible origins also are discussed.

PROCEDURES

Cores which were collected in the fall of 1975, were kept at 4°C until laboratory analyses were performed.

In the laboratory, the upper 10 cm sediments of the subcores were taken and digested in deionized water overnight to insure complete dispersion. The clay fractions (<2 μ) were completely separated from the bulk sample by treating with one milliliter of 2.5 M NH_4OH (dispersing agent), prior to centrifuging for two minutes at 1000 RPM. Two oriented clay slides were prepared for each sample by treatment with Mg-glycerated saturation and K-saturation. To minimize any experimental variation for an estimate of relative percentages of individual clays, a 35 μ clay film was prepared on ceramic tiles for X-ray analysis. X-ray diffractograms were obtained for each sample from (1) the Mg-glycerated saturated clays which were X-rayed after consecutively drying in air at 25°C, and heating at 110°C for 12 hr; and (2) from the K-saturated clays, which were

X-rayed after consecutively drying in air at 25°C, and heating at 110°C for 12 hr, at 300°C for four hours and finally at 550°C for one hour.

Since clay fractions of surface sediments, particularly from the West Florida Shelf, contain noticeable amounts of carbonate, about 1-2 ml of dilute HCl (3%) was added directly to the clay film to enhance peaks of clay minerals in samples. Results of the acid treatment showed no adverse effects, as also discussed by Huang, et al. (1975).

Identification of the 14 Å chlorite-vermiculite mixed layers follow the criteria as pointed out by Huang, et al. (1975).

Relative percentages of individual clay minerals were also estimated following the procedure described by Huang, et al. (1975).

RESULTS AND DISCUSSION

A total of 420 data from the clay analysis of bottom sediments in the MAFLA monitoring sites were obtained, and shown in Tables 1 and 2. Average content of clay minerals in both subcores A and B are shown in Table 3, and their areal distribution patterns are shown in Figures 1 to 5. Two distinctly different facies of clay minerals are characteristic for the bottom sediments in the MAFLA sites. They are as follows:

A. West Florida Shelf

Generally, kaolinite is the most abundant, followed by chlorite-vermiculite mixed layer which is unique only in this shelf, and peaks at the Fort Myers transect. Smectite in this area is present in small amounts along the outer shelf and shows a decreasing trend southeastward. The distribution patterns of individual clay minerals are further docu-

mented as follows:

(1) Kaolinite shows a general increase southeastward to Tampa Bay, but a decrease seaward, ranging from 69% on the inner shelf to as low as 30% at the shelf-slope interface. This suggests that kaolinite is primarily controlled by transportation from West Florida.

(2) Chlorite-vermiculite which is unique in this region, increases from trace amounts off Pensacola to a maximum of 45% on the Fort Myers shelf, and decreases seaward. The occurrence of the mixed layers can be due to reworking of older shelf deposits, or transformation from smectite transported by rivers of West Florida, as described by Huang, et al. (1975).

(3) Smectite which occurs mostly at the outer shelf decreases considerably from the Alabama Shelf to the West Florida Shelf, as shown in Figure 1. This distribution pattern appears to be influenced by the clockwise currents of the Gulf as described by Shepard (1973) along the margins of the slope. Whether this mechanism is significant in controlling the clay distribution in the MAFLA sites remains to be verified by analyzing more samples in the future MAFLA programs.

B. Mississippi-Alabama Shelf

The distribution pattern of clay mineral assemblages on the Mississippi-Alabama Shelf is significantly different from that on the West Florida Shelf. Generally, smectite in this region is the most abundant clay mineral in bottom sediments, and chlorite-vermiculite is virtually absent.

(1) Smectite, up to 80%, generally decreases seaward. Results of this study are consistent with those found by Milne and Earley (1958), Griffin (1962) and Huang, et al. (1975). Major factors for the clay distribution pattern in this region are primarily transportation of sediments from the Mississippi and Mobile Rivers.

(2) Kaolinite which is considerably less abundant than on the West Florida Shelf, increases southeastward along the shelf transect. This suggests that the outer segment of the transect is partially affected by the West Florida provenance.

In both shelves, illite is practically distributed uniformly across the shelf environments.

In conclusion, three findings are significant:

A. Two distinct facies of clay minerals in surface sediments from the MAFLA sites - one on the West Florida Shelf and the other on the Mississippi-Alabama shelf.

B. Smectite which shows a decreasing trend from the outer shelf of the Alabama to that of West Florida is apparently influenced by the "Loop" Current.

C. Key clay minerals to be used for monitoring in the future are different in different parts of the MAFLA sites. Smectite (or chlorite-vermiculite) can be used for the Mississippi-Alabama Shelf, whereas kaolinite and chlorite-vermiculite can be used for the West Florida Shelf.

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Table 1. The content (%) of clay minerals in surface sediments from the MAFLA OCS baseline monitoring sites (A set), 1975.

Station Number	Smectite	Chlorite	Chlorite-Vermiculite Mixed Layer	Illite	Kaolinite
2101A	9	13	45	13	20
2102A	16	11	32	8	33
2103A	-	14	40	8	38
2104A	T	20	43	6	31
2105A	T	11	30	18	41
2106A	24	9	20	12	35
2207A	-	35	18	11	36
2208A	7	23	12	9	49
2209A	6	30	15	5	44
2210A	*	*	*	*	*
2211A	4	33	17	6	40
2212A	27	12	9	13	29
2313A	45	6	5	9	35
2314A	*	*	*	*	*
2315A	*	*	*	*	*
2316A	T	21	23	4	52
2317A	5	18	19	9	49
2318A	11	18	20	4	47
2419A	6	16	20	5	53
2420A	3	9	31	3	55
2421A	4	6	21	6	63
2422A	13	4	15	5	63
2423A	8	4	14	4	70
2424A	12	4	16	11	57
2425A	5	8	30	8	49
2426A	14	6	24	7	49
2427A	45	2	6	9	38
2528A	17	10	11	6	56
2529A	8	25	9	8	50
2530A	18	24	9	10	39
2531A	15	15	7	11	52
2532A	22	18	8	12	40
2533A	27	18	4	7	44
2534A	25	14	3	8	50
2535A	40	18	-	6	36
2536A	54	5	-	6	35

Table 1 - continued.

Station Number	Smectite	Chlorite	Chlorite-Vermiculite Mixed Layer	Illite	Kaolinite
2637A	73	2	-	4	21
2638A	81	4	-	4	11
2639A	73	2	-	10	15
2640A	54	6	-	18	22
2641A	50	T	-	17	33
2642A	43	9	-	17	31
2644A	53	5	-	10	32
2645A	57	5	-	13	25

T - Trace amount
* - No sample taken

Table 2. The content (%) of clay minerals in surface sediments from the MAFLA OCS baseline monitoring sites (B set), 1975

Station Number	Smectite	Chlorite	Chlorite-Vermiculite Mixed Layer	Illite	Kaolinite
2101K	7	15	45	13	20
2102K	4	16	44	10	26
2103K	2	14	43	5	36
2104K	T	16	40	4	40
2105K	T	11	32	16	41
2106K	25	8	19	12	36
2207K	--	36	17	6	41
2208K	3	26	16	5	50
2209K	3	30	15	5	46
2210K	*	*	*	*	*
2211K	5	30	14	5	46
2212K	42	8	7	11	32
2313K	43	7	7	12	31
2314K	*	*	*	*	*
2315K	*	*	*	*	*
2316K	T	20	23	7	50
2317K	5	16	19	8	52
2318K	11	17	21	5	46
2419K	9	15	22	6	48
2420K	6	9	30	6	49
2421K	3	6	22	6	63
2422K	4	6	20	6	64
2423K	8	5	16	4	67
2424K	9	4	18	9	60
2425K	6	9	29	12	44
2426K	13	7	22	11	47
2427K	47	3	6	10	34
2528K	17	10	10	6	57
2529K	5	19	8	8	60
2530K	10	17	6	9	58
2531K	8	19	9	11	53
2532K	22	17	6	8	47
2533K	21	18	4	7	50
2534K	27	17	4	9	43
2535K	38	15	--	11	36
2536K	58	6	--	6	30

Table 2 - continued.

Station Number	Smectite	Chlorite	Chlorite-Vermiculite Mixed Layer	Illite	Kaolinite
2637K	67	4	--	12	17
2638K	78	7	--	7	8
2639K	70	3	--	13	14
2640K	52	3	--	20	25
2641K	54	T	--	18	29
2642K	39	9	--	18	34
2643K	65	5	--	11	19
2644K	54	6	--	11	29
2645K	53	7	--	16	24

T - Trace amount
* - No sample taken

Table 3. The average content (%) of clay minerals in surface sediments from the MAFLA OCS baseline monitoring sites (A & B set), 1975.

Station Number	Smectite	Chlorite	Chlorite-Vermiculite Mixed Layer	Illite	Kaolinite
2101	8	14	45	13	20
2102	10	13	38	9	30
2103	2	14	42	6	37
2104	T	18	42	5	35
2105	T	11	31	17	41
2106	25	8	19	12	36
2207	--	36	17	8	39
2208	5	24	14	7	50
2209	5	30	15	5	45
2210	*	*	*	*	*
2211	4	32	16	5	43
2212	40	10	8	12	30
2313	44	6	6	11	33
2314	*	*	*	*	*
2315	*	*	*	*	*
2316	T	21	23	5	51
2317	5	17	19	8	51
2318	11	17	21	4	47
2419	7	16	21	5	51
2420	4	9	31	4	52
2421	3	6	22	6	63
2422	8	5	18	5	64
2423	8	4	15	4	69
2424	10	4	17	10	59
2425	5	8	30	10	47
2426	14	6	23	9	48
2427	46	2	6	10	36
2528	17	10	10	6	57
2529	6	22	9	8	55
2530	14	21	7	9	49
2531	11	17	8	11	53
2532	22	17	7	10	44
2533	24	18	4	7	47
2534	26	16	2	8	47
2535	39	17	--	8	36
2536	56	5	--	6	33

Table 3 - continued

Station Number	Smectite	Chlorite	Chlorite-Vermiculite Mixed Layer	Illite	Kaolinite
2637	70	3	--	8	19
2638	80	5	--	5	10
2639	72	2	--	11	15
2640	53	4	--	19	24
2641	52	T	--	17	31
2642	41	9	--	17	33
2643	67	4	--	9	20
2644	54	5	--	10	31
2645	55	6	--	14	25

T - Trace amount
* - No sample taken

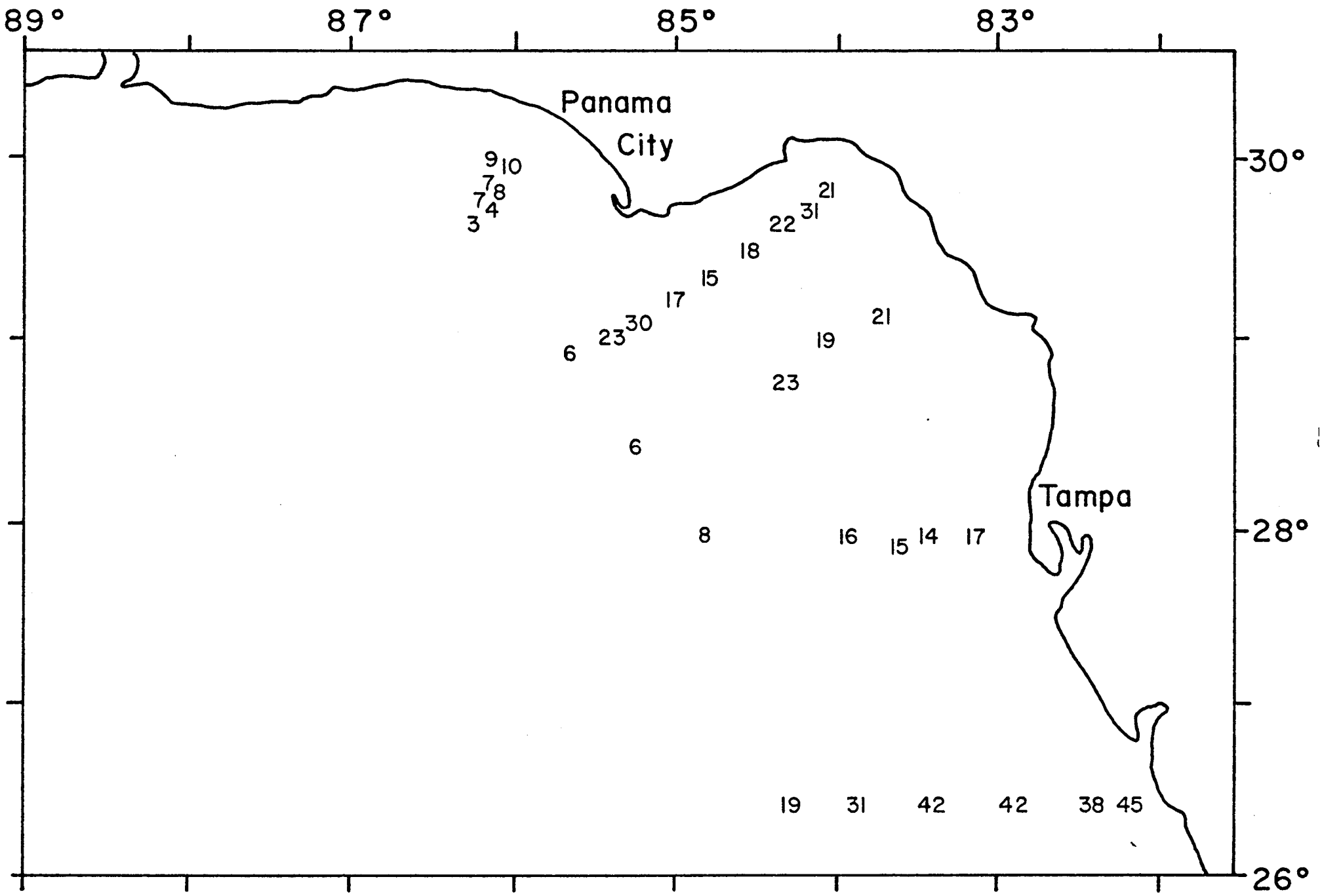

Figure 1. Percent Chlorite-Vermiculite in the less than 2 u fraction of sediments, average of 2.

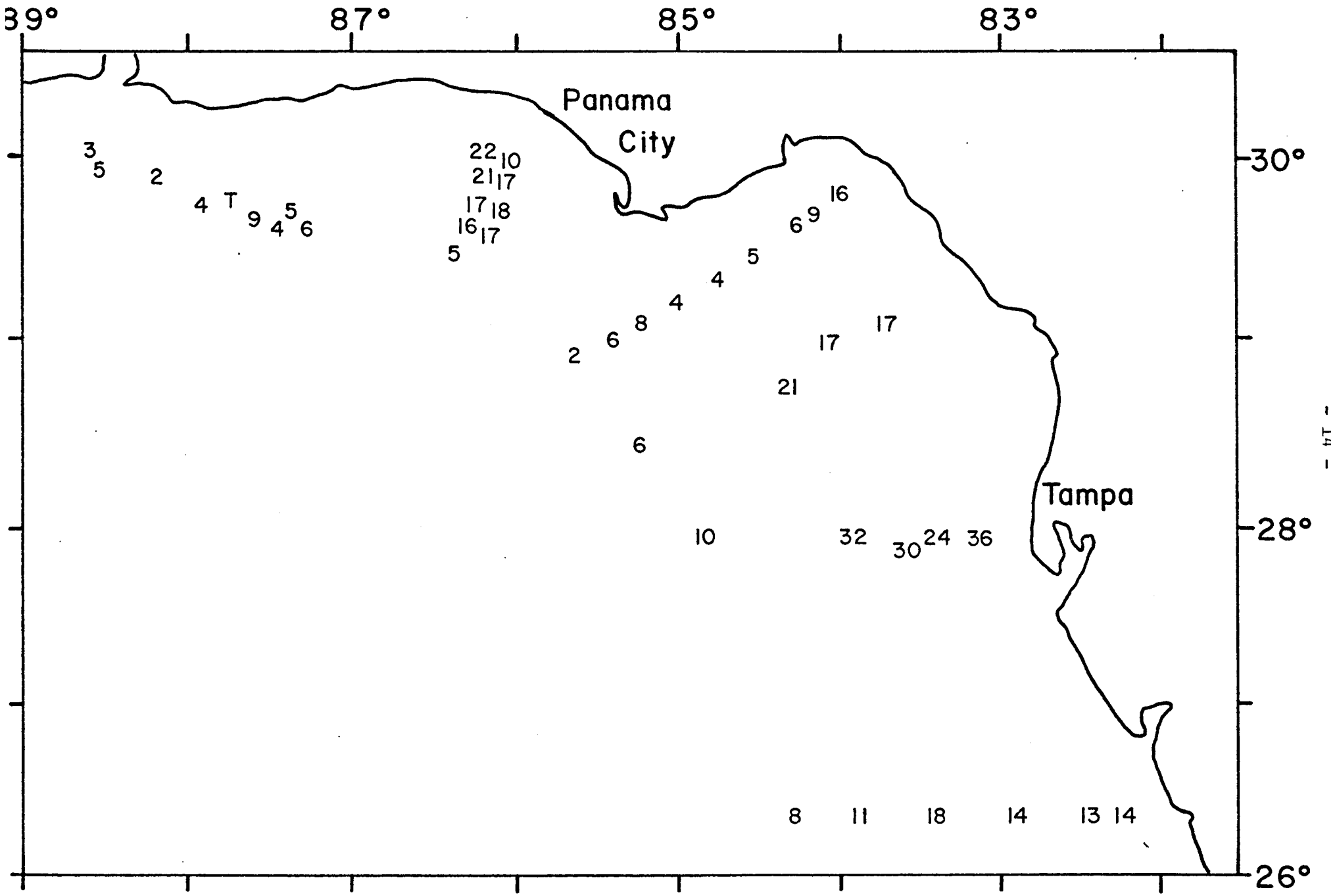

Figure 2. Percent Chlorite in the less than 2 u fraction of sediments, average of 2.

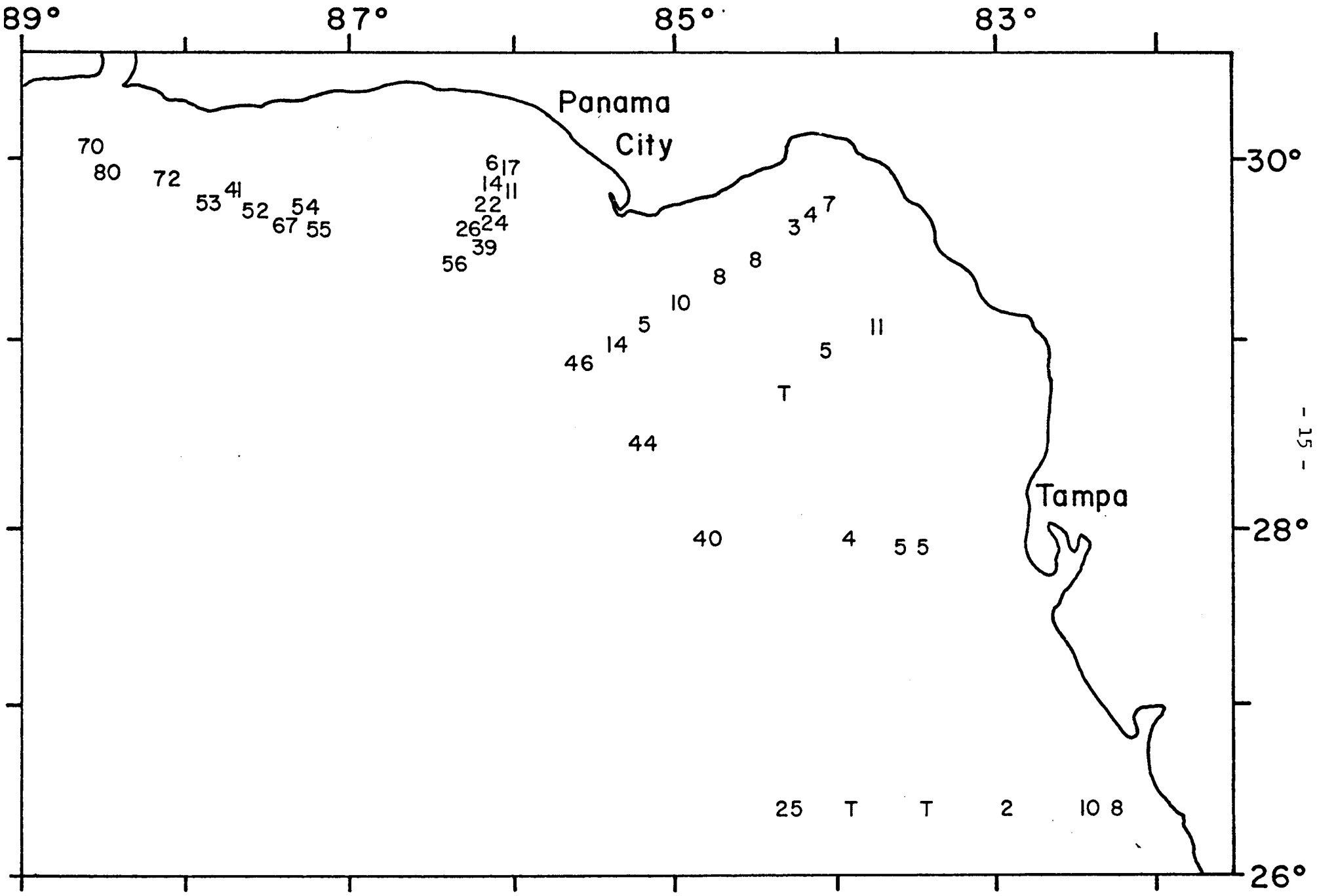

Figure 3. Percent Smectite in the less than 2 u fraction of sediments, average of 2.

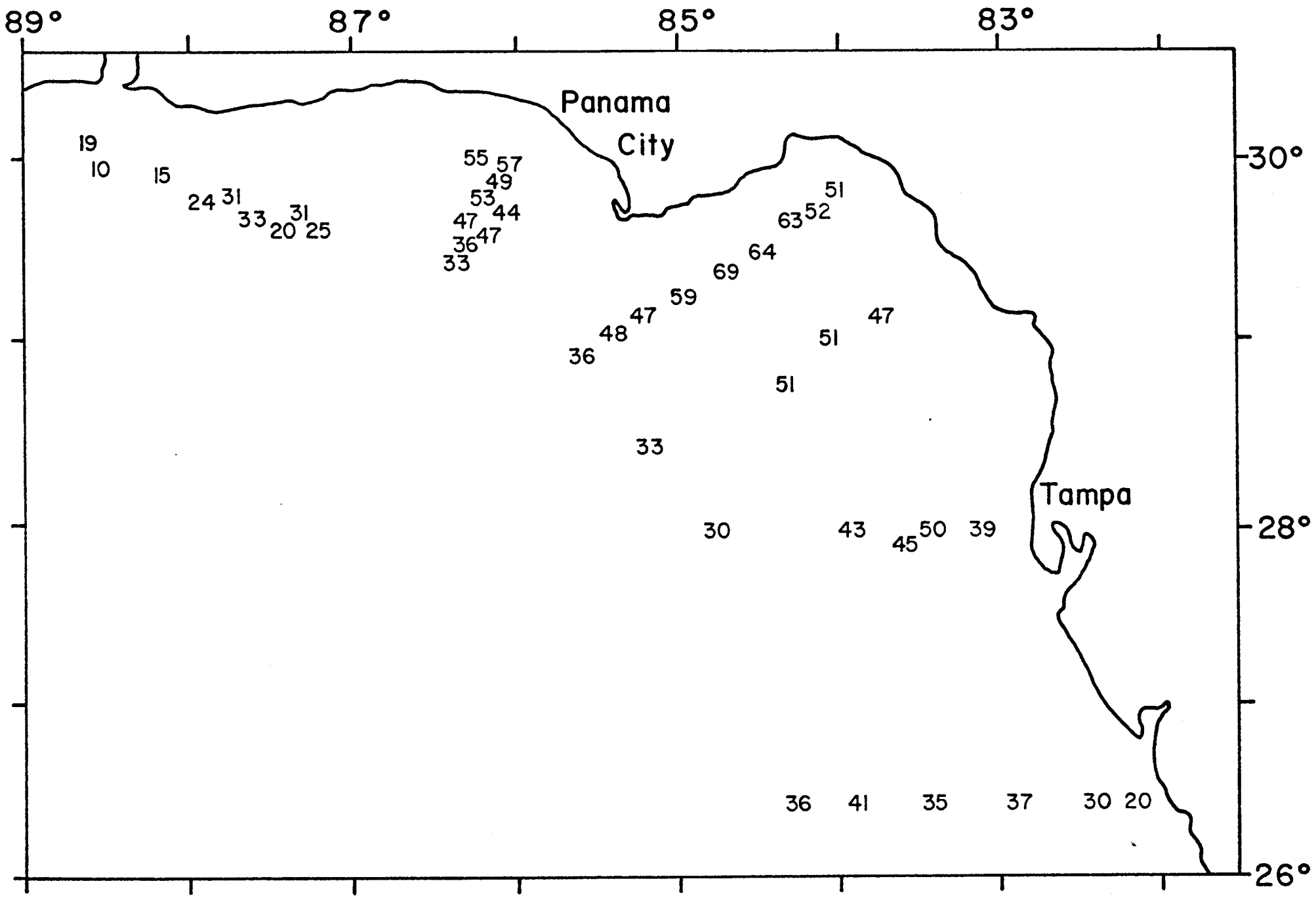

Figure 4. Percent Kaolinite in the less than 2 u fraction of sediments, average of 2.

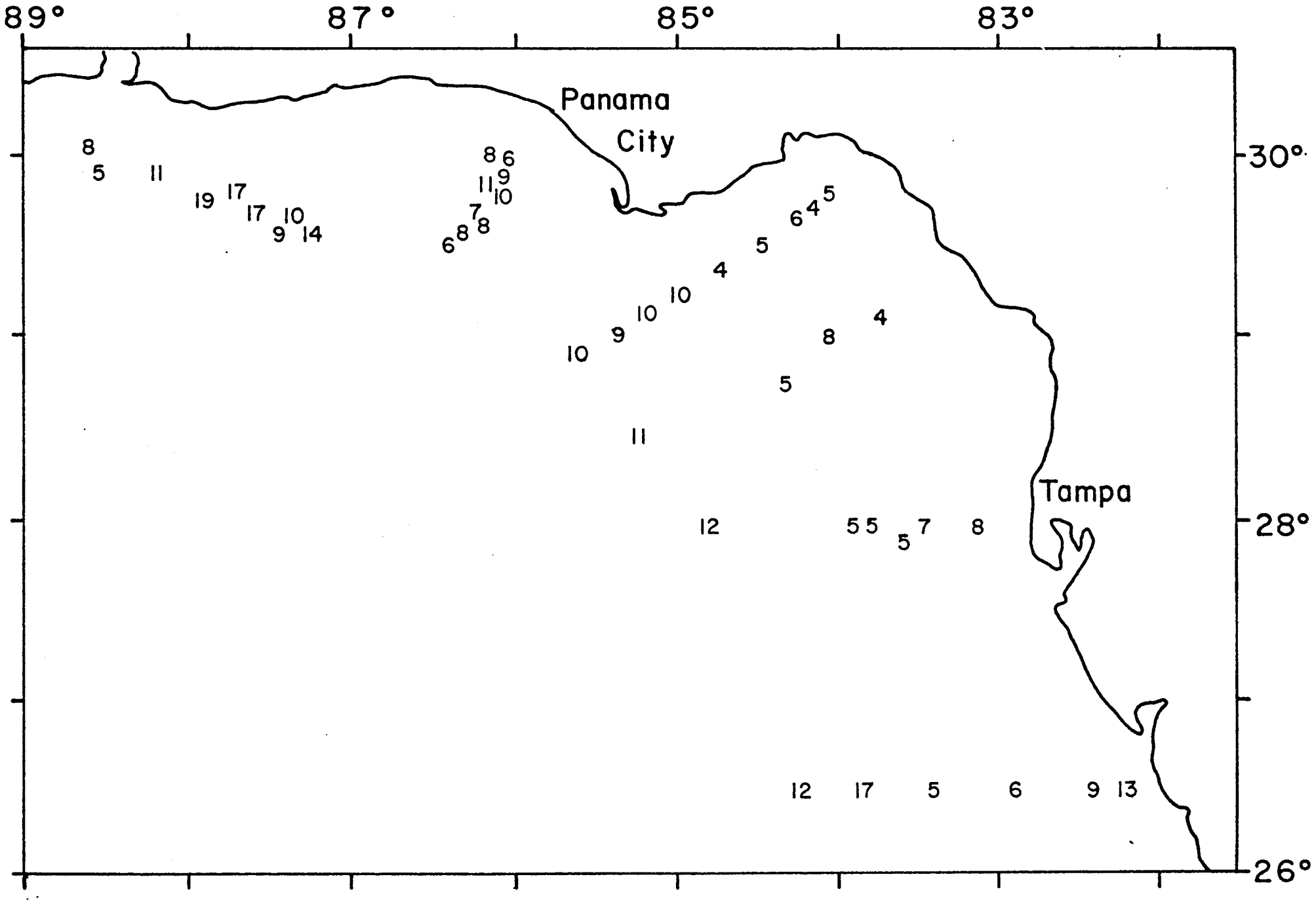

Figure 5. Percent Illite in the less than 2 u fraction of sediments, average of 2.

CLAY MINERAL STUDIES OF SURFACE SEDIMENTS FROM THE MAFLA OCS RIG MONITORING SITES (TEXAS)

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Principal Investigator:
Wen H. Huang

INTRODUCTION

To characterize the fine-grained mineralogy of bottom sediments at the rig sites prior to drilling, a total of 74 cores were collected from 25 stations for three sampling periods. In this paper is reported clay analysis of bottom sediments from the rig monitoring sites, which will serve as baseline data for the determination of any adverse variation of the bottom sediments caused by the drilling operation itself.

PROCEDURES

After cores were cut, sediments from the topmost layers, 10 cm, were taken and digested in water overnight. Clay fractions (<2 μ size) were completely separated from sediments by a superspeed centrifuge and analyzed for clay mineral constituents in the sediments by X-ray diffraction. Two oriented clay slides were prepared for each sample by treatment with Mg-glycerated saturation and K-saturation, and were X-rayed following the procedure as described by Huang, et al. (1975), and Huang (1976). Relative percentages of clay minerals in the sediments were also estimated.

RESULTS AND DISCUSSION

A total of 300 data from the clay analysis of 74 samples, Tables 1-3, lead to the significant features in the following:

A. As shown in Tables 1-3, the seasonal variation of clay minerals in bottom sediments from the rig site is relatively insignificant within experimental error. This fairly constant content of clay minerals in the site can provide a good solid foundation for the characterization of any variation of bottom sediments caused by drill operation.

B. Smectite is the most abundant clay mineral in the area, followed by illite and kaolinite. Chlorite is only present in trace amount. This distribution pattern of clay mineral assemblages in the site is similar to that on the Mississippi-Alabama Shelf. Therefore, key clay mineral for monitoring any variation of sediment by drilling operation is either smectite or chlorite. Any significant changes of concentrations of smectite and chlorite can be assumed by the course of drilling operation, and therefore these two minerals can serve as key minerals for the monitoring purpose.

C. Furthermore, there appears a decrease of smectite from the inner to outer ring of the east half of the monitoring site, whereas from the west half of the monitoring sites, a decrease of smectite was found from the inner to outer ring.

Table 1. The content (%) of clay minerals in surface sediments from the MAFLA OCS rig monitoring sites (Texas). (Pre-drilling operations.)

Station Number	Smectite	Illite	Kaolinite	Chlorite
500101	81	10	9	T
510201	86	7	7	T
510301	77	12	11	T
510401	82	10	8	T
510501	76	14	10	T
510601	73	14	13	T
510701	72	19	9	T
510801	78	12	10	T
550901	76	13	11	T
551001	81	7	12	T
551101	81	11	8	T
551201	78	11	11	T
551301	80	10	10	T
551401	83	9	8	T
551501	80	12	8	T
551601	76	10	14	T
551701	78	12	10	T
591801	76	14	10	T
591901	78	11	11	T
592001	65	23	12	T
592101	75	14	11	T
592201	81	11	8	T
592301	79	11	10	T
592401	82	9	9	T
592501	76	12	12	T

T - Trace amount

Table 2. The content (%) of clay minerals in surface sediments from the MAFLA OCS rig monitoring sites (Texas) - Second Sampling Period. (During-drilling operations.)

Station Number	Smectite	Illite	Kaolinite	Chlorite
500102 M2	*	*	*	*
510201 M2	72	20	8	T
510301	82	14	4	T
510401	71	17	12	T
510501	75	18	7	T
510601	79	15	6	T
510701	84	11	4	T
510801	80	15	5	T
550901	80	14	6	T
551001	82	13	5	T
551101	77	18	5	T
551201	77	18	5	T
551301	75	18	7	T
551401	74	21	5	T
551501	80	15	5	T
551601	80	15	5	T
551701	78	16	6	T
591801	74	19	7	T
591901	77	16	7	T
592001	76	18	6	T
592101	76	18	6	T
592201	76	19	5	T
592301	75	18	7	T
592401	74	20	6	T
592501	77	17	6	T

T - Trace amount
* - Missing sample

Table 3. The content (%) of clay minerals in surface sediments from the MAFLA OCS rig monitoring sites (Texas) - Third Sampling Period. (Post-drilling operations.)

Station Number	Smectite	Illite	Kaolinite	Chlorite
510101 M2	81	14	5	T
510201 M3	78	17	5	T
510301 M3	75	18	7	T
510401 M3	78	17	5	T
510501 M3	80	15	5	T
510601 M3	75	18	7	T
510701 M3	80	14	5	T
510801 M3	73	20	7	T
510901 M3	78	17	5	T
551001 M3	80	14	6	T
551101 M3	76	16	8	T
551201 M3	74	20	6	T
551301 M3	71	21	8	T
551401 M3	73	20	7	T
551501 M3	79	16	5	T
551601 M3	79	16	5	T
551701 M3	80	14	6	T
551801 M3	78	18	4	T
551901 M3	79	15	6	T
592001 M3	79	16	5	T
592101 M3	77	20	3	T
592201 M3	80	13	7	T
592301 M3	75	20	5	T
592401 M3	76	17	7	T
592501 M3	78	17	5	T

T - Trace amount

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PHYTOPLANKTON CHLOROPHYLL AND PRIMARY PRODUCTIVITY FOR THE MAFLA SURVEY

1975 - 1976

Florida State University, Department of Oceanography

Principal Investigator:
Richard L. Iverson

PHYTOPLANKTON CHLOROPHYLL AND PRIMARY PRODUCTIVITY FOR THE MAFLA SURVEY 1975 - 1976

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INTRODUCTION

The phytoplankton ecology of the northeastern Gulf of Mexico is not well known. Phytoplankton species composition has been reported for various areas of the northeastern Gulf of Mexico (reviewed by Steidinger, 1973). Very little data is available concerning phytoplankton primary productivity and chlorophyll distribution in the open northeastern Gulf of Mexico which is considered highly oligotrophic based on a few productivity estimates (El Sayd, et al., 1972).

Phytoplankton species composition and chlorophyll data were collected during the first MAFLA survey (1974 - 1975). During the 1975 - 1976 MAFLA survey, chlrophyll and primary productivity data were collected and combined with estimates of photosynthetically active radiation to yield assimilation rates. It was postulated that since assimilation rates are normalized to phytoplankton biomass (estimated by chlorophyll) and to available light, assimilation rate values would provide a better reference data set for use in evaluating effects of hydrocarbon extraction operations than would raw productivity estimates.

METHODS

Water samples were collected with PVC Niskin bottles from surface and from near-bottom or from the depth at which light energy was one percent of the surface value. Three 2-liter subsamples were filtered through Whatman GF/A glass fiber filters after which several ml of a saturated soultion of $MgCO_3$ were

passed through each filter. Filters were frozen and returned to shore where they were processed using methods given in Strickland and Parsons (1972).

For primary productivity estimates, three subsamples of about 200 ml were drawn into glass bottles after which each bottle was innoculated with 10 uCi of C-14 as $NaHCO_3$. Bottles were placed in a deck-board incubator constructed of plexiglass covered with blue plastic. Blue filters have been shown to result in higher carbon fixation than has the use of neutral density filters. Temperature was regulated in the deck incubator by pumping seawater from the ship sea chest through the incubator. Solar radiation was measured continuously during incubation of the productivity samples using a Lambda quanta sensor. After a 3-hour incubation period, samples were fixed with mercuric chloride then filtered through Whatman GF/C glass fiber scintillation pads. The pads were frozen and transported to shore where carbon-14 activity was measured with a liquid scintillation spectrometer using Aquasol as the scintillation cocktail. Stable carbon content of seawater samples was estimated with the titration alkalinity method given in Strickland and Parsons (1972). Assimilation ratios were calculated by dividing hourly productivity estimates by chlorophyll a values obtained from the same water samples from which water for productivity estimates was obtained. These values were then divided by quanta flux for the exposure period.

RESULTS AND DISCUSSION

Data obtained during the 1975 - 1976 MAFLA survey are contained in Appendix I.

The average and range of seasonal chlorophyll a values for each MAFLA transect are presented in Table 1 and 2. Figures 1 a,b,c and 2 a,b,c illustrate spatial chlorophyll a distribution patterns in surface and bottom water, respectively.

With the exception of transect 4, surface chlorophyll a values ranged between 0.1 and 0.5 mg/m^3 throughout the MAFLA region during the summer sampling period. Surface chlorophyll a values were greater in transects 3 and 4 than in transects 1 and 2 (Fig. 1a). Bottom chlorophyll a values were, in general, greater than surface values (Fig. 2b). There appeared to be an offshore decrease in chlorophyll a in transects 2, 3, and 4. The range of chlorophyll a values was greater in bottom than in surface water.

Chlorophyll a values were, in general, higher in the fall than in the summer in transects 1 and 2 and lower in transects 3 and 4 for both surface and bottom samples (Fig. 1b, 2b). Transects 1 and 2 were sampled after hurricane Eloise had passed through the study aread and the increased chlorophyll a may have been caused by advection of relatively nutrient-rich water into the study area or by nutrient input accompanying sediment resuspension. Fall surface offshore chlorophyll a values were among the lowest observed during the MAFLA survey.

With the exception of transect 4, winter chlorophyll a values generally ranged between 0.1 and 0.5 mg/m^3 in both surface and

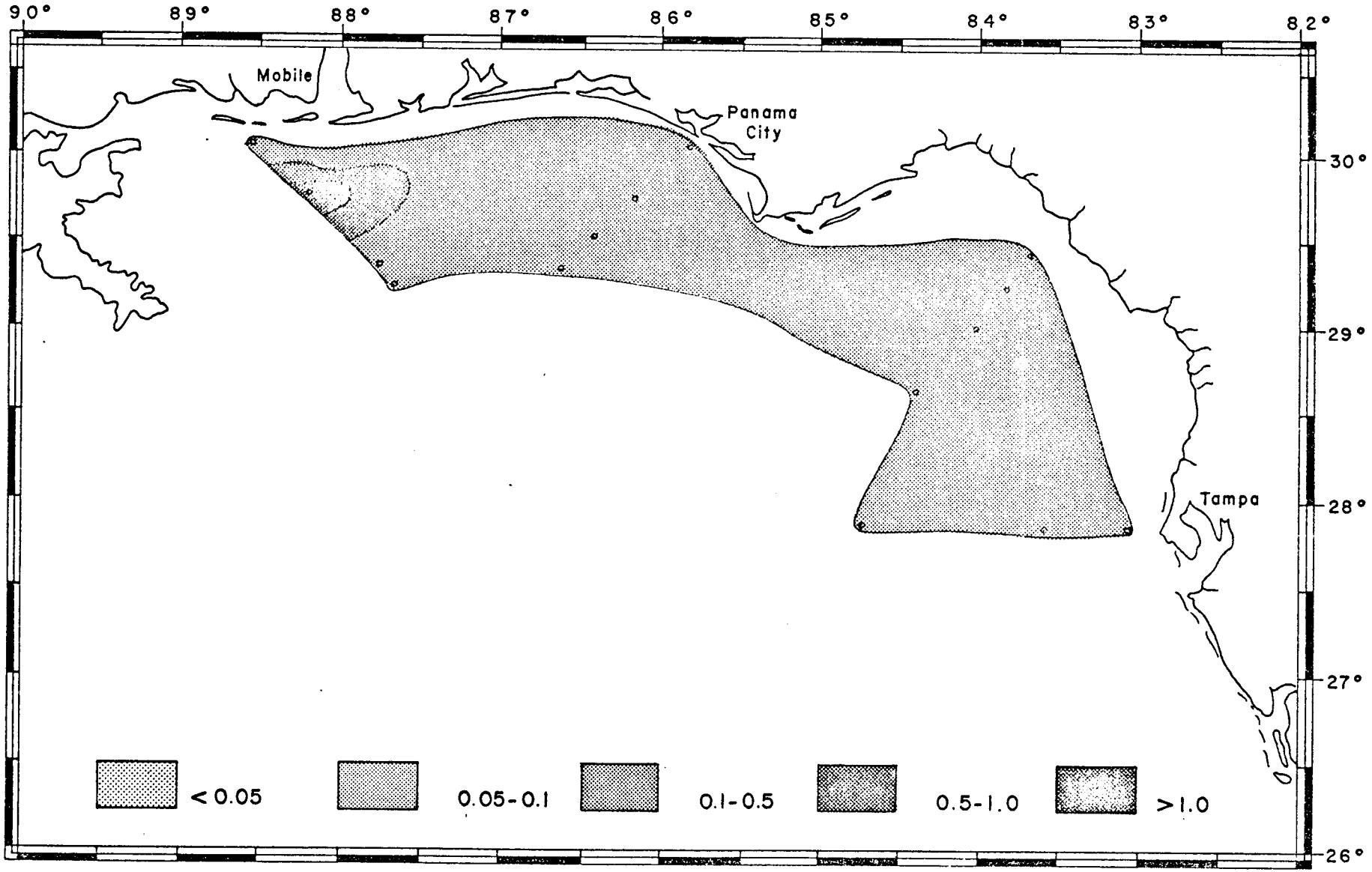

Figure 1a. The horizontal distribution of the surface chlorophyll a (mg/m^3), June-July, 1975.

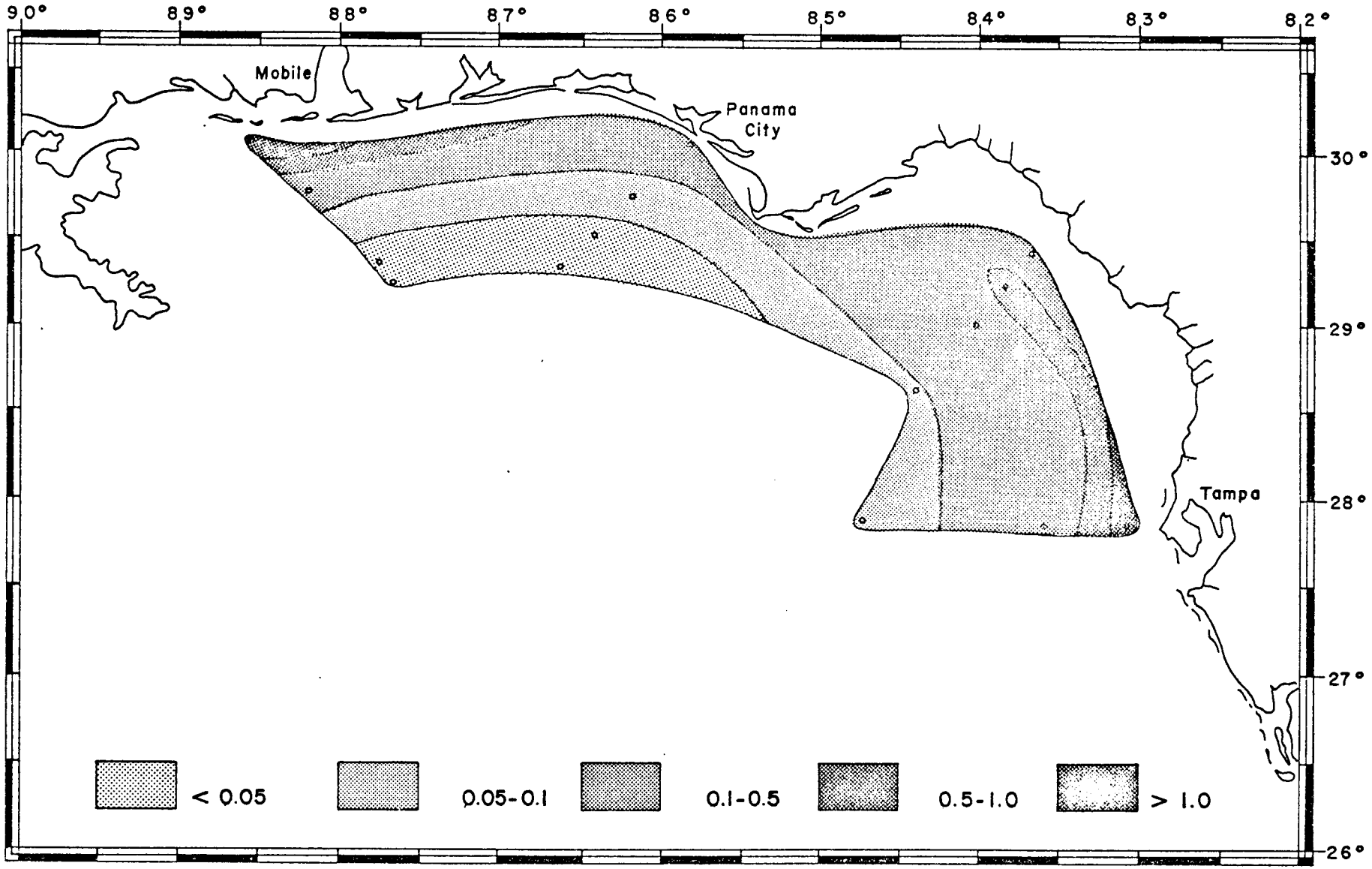

Figure 1b. The horizontal distribution of the surface chlorophyll a (mg/m^3), September-October, 1975.

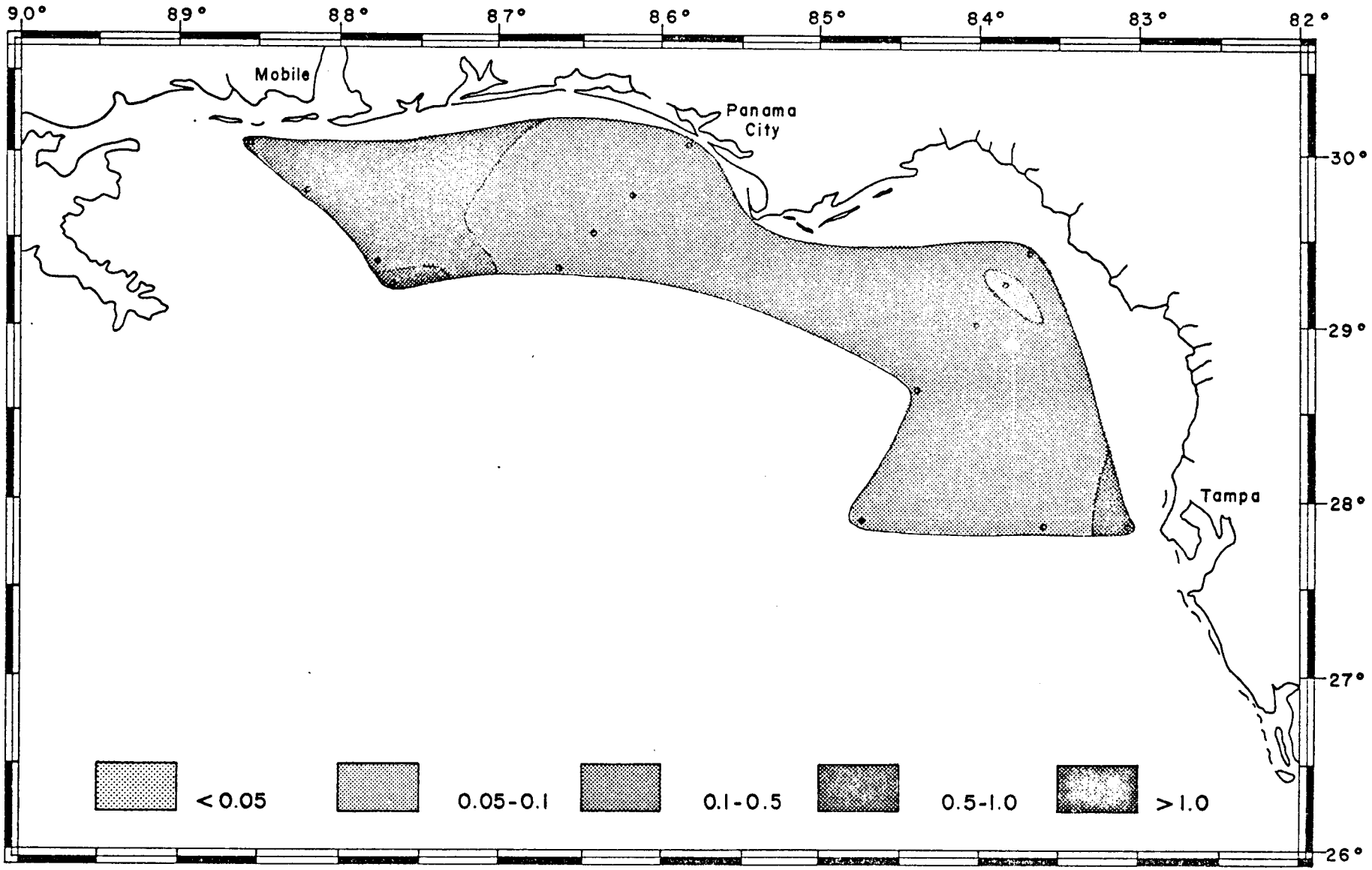

Figure 1c. The horizontal distribution of the surface chlorophyll a (mg/m^3), January-February, 1976.

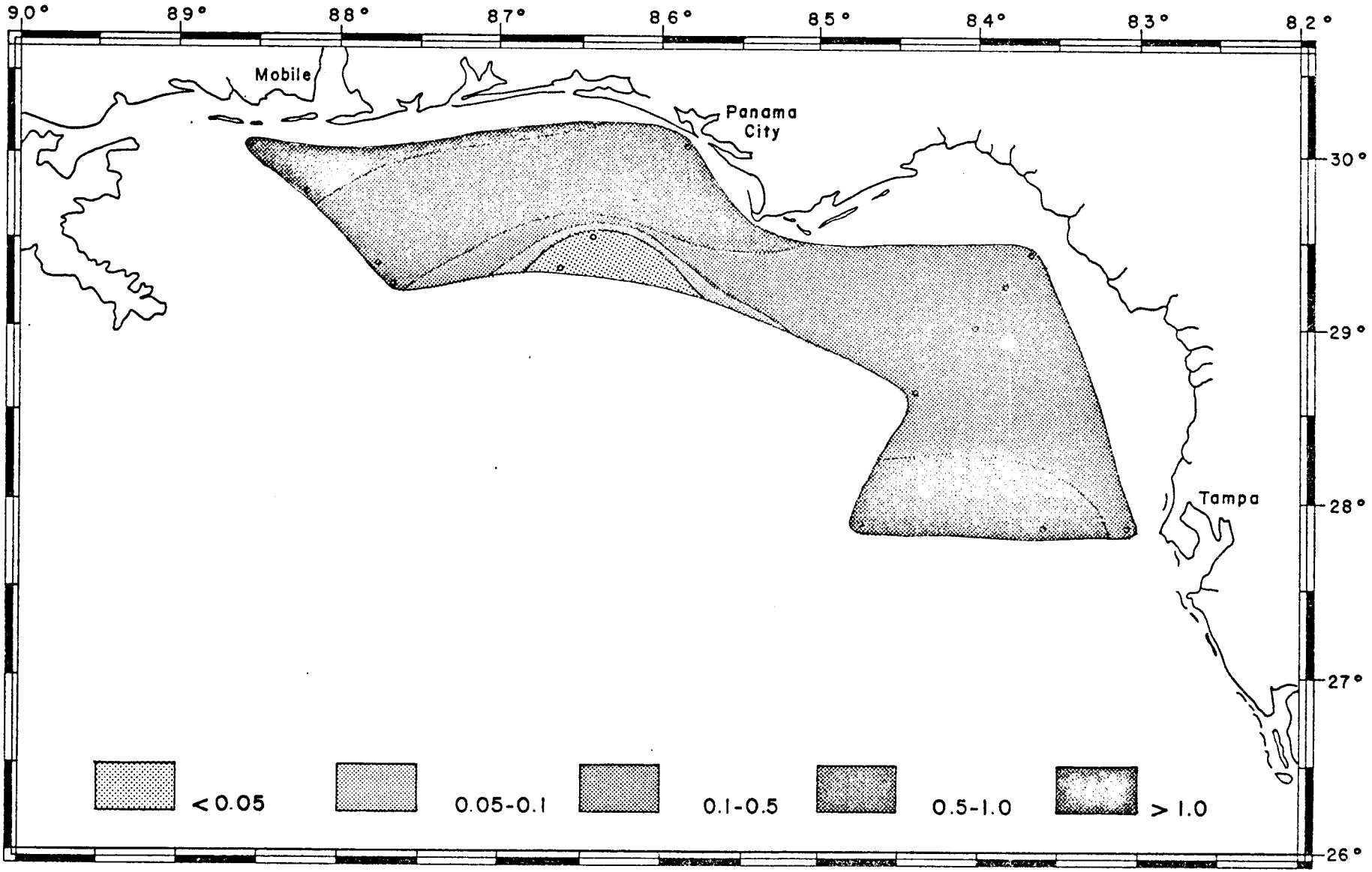

Figure 2a. The horizontal distribution of the bottom chlorophyll a (mg/m^3), June-July, 1975.

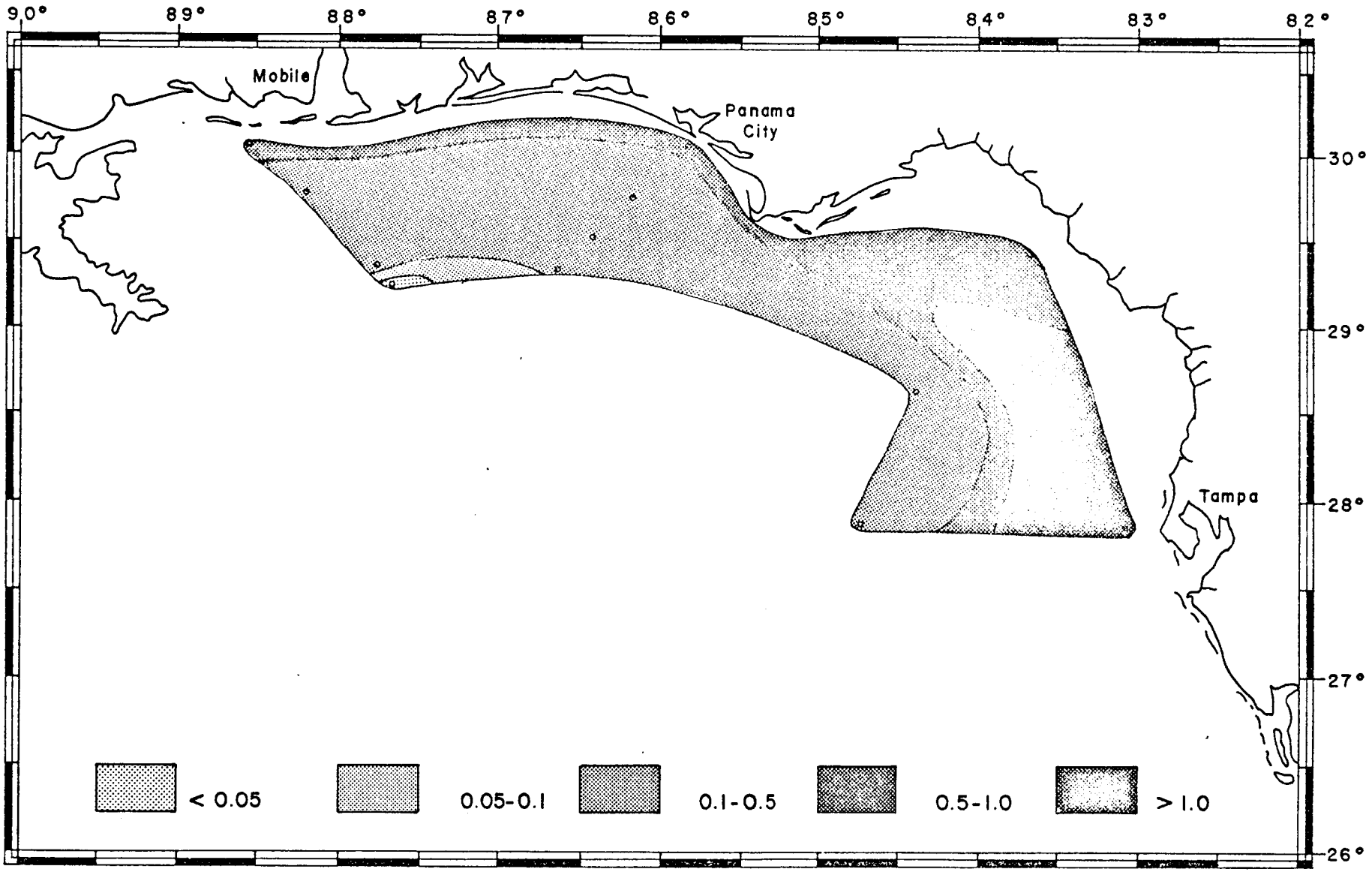

Figure 2 b. The horizontal distribution of the bottom chlorophyll a (mg/m^3) September-October, 1975.

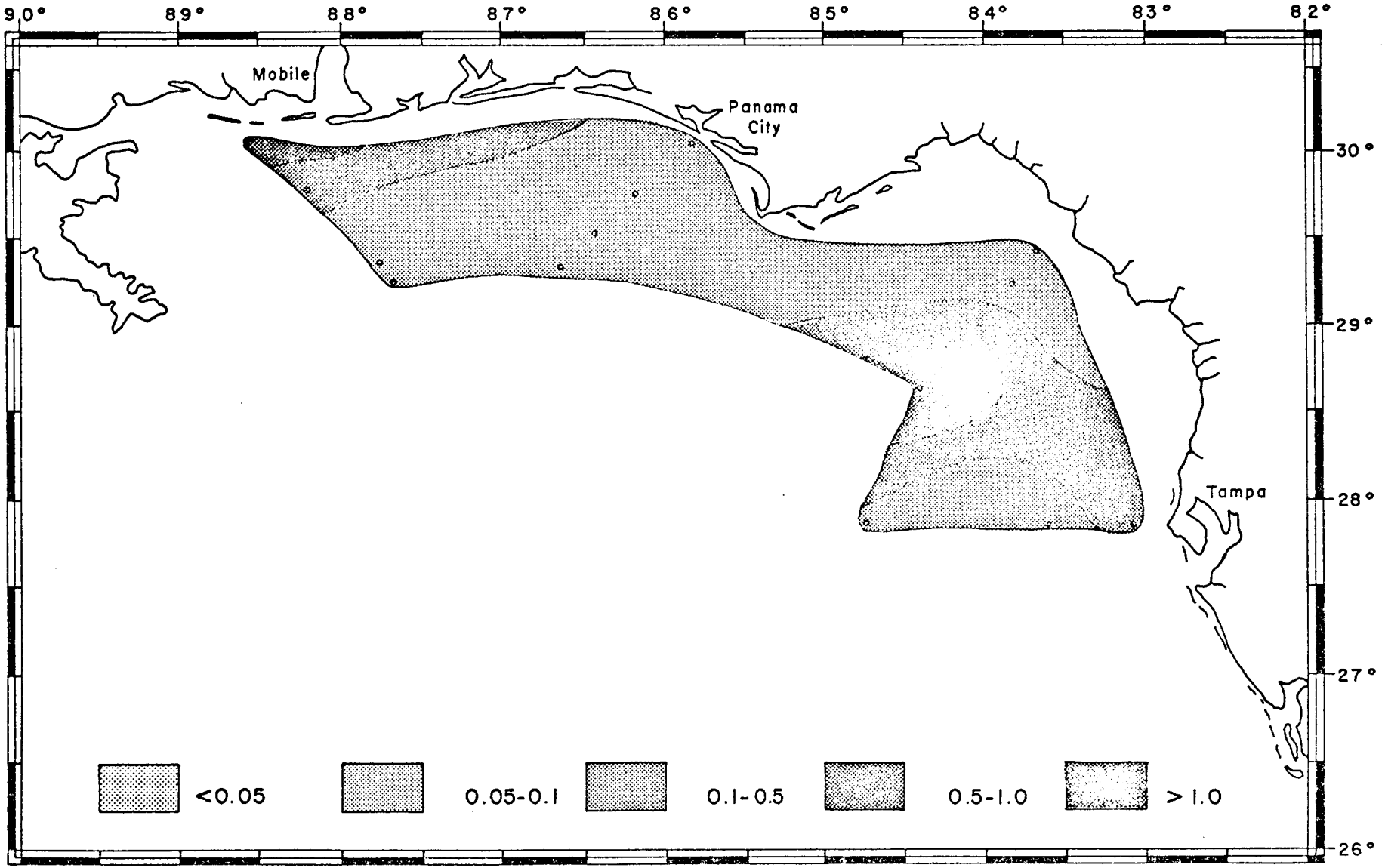

Figure 2c. The horizontal distribution of the bottom chlorophyll a (mg/m^3) January-February, 1976.

bottom water samples (Fig. 1c,2c). Higher chlorophyll a values which were evident along transect 4 may be the result of effects of nutrients discharged from the Mississippi River of from Mobile Bay.

The average and range of surface primary productivity values are presented in Table 3 while the spatial distribution of surface primary productivity is presented in Figures 3 a,b,c. Mean productivity walues were of similar magnitude for summer and fall along each transect except for transect 1 where fall values were highter. Winter productivity values were significantly lower than summer and fall vales along transects 1,2, and 3. Bottom productivity balues for summer and fall were incorrectly obtained due to placement of productivity bottles in the wrong deck incubator box. Attempts to correct the values based on ratios of productivity for the correct deck box were not successful due to nolinearities in the data. Bottom productivity values for the winter sampling period varied from 30 percent to less than 1 percent of surface productivity values (appendix I).

There was no apparent correlation between either chlorophyll a values or primary productivity values and temperature or salinity.

Average surface assimilation rates together with ranges of values are presented in table 4. Differences between largest and smallest mean values are reduced by about a factor of 4 for transect 1, 2, and 3 assimilation rates compared to productivity values. Average assimilation rates for transect 4 show more

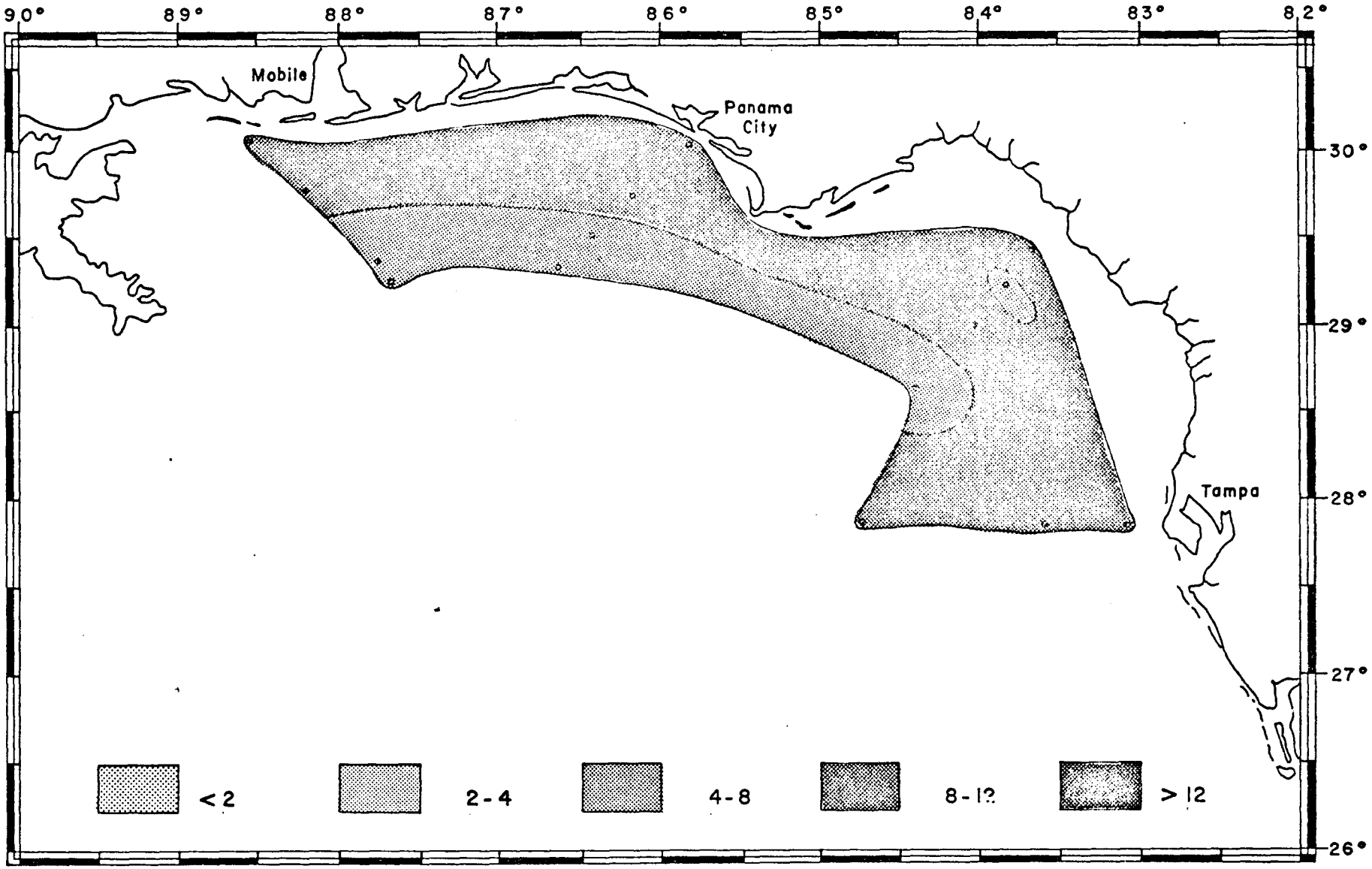

Figure 3a. The horizontal distribution of surface primary productivity (g C/m /hr) June - July, 1975.

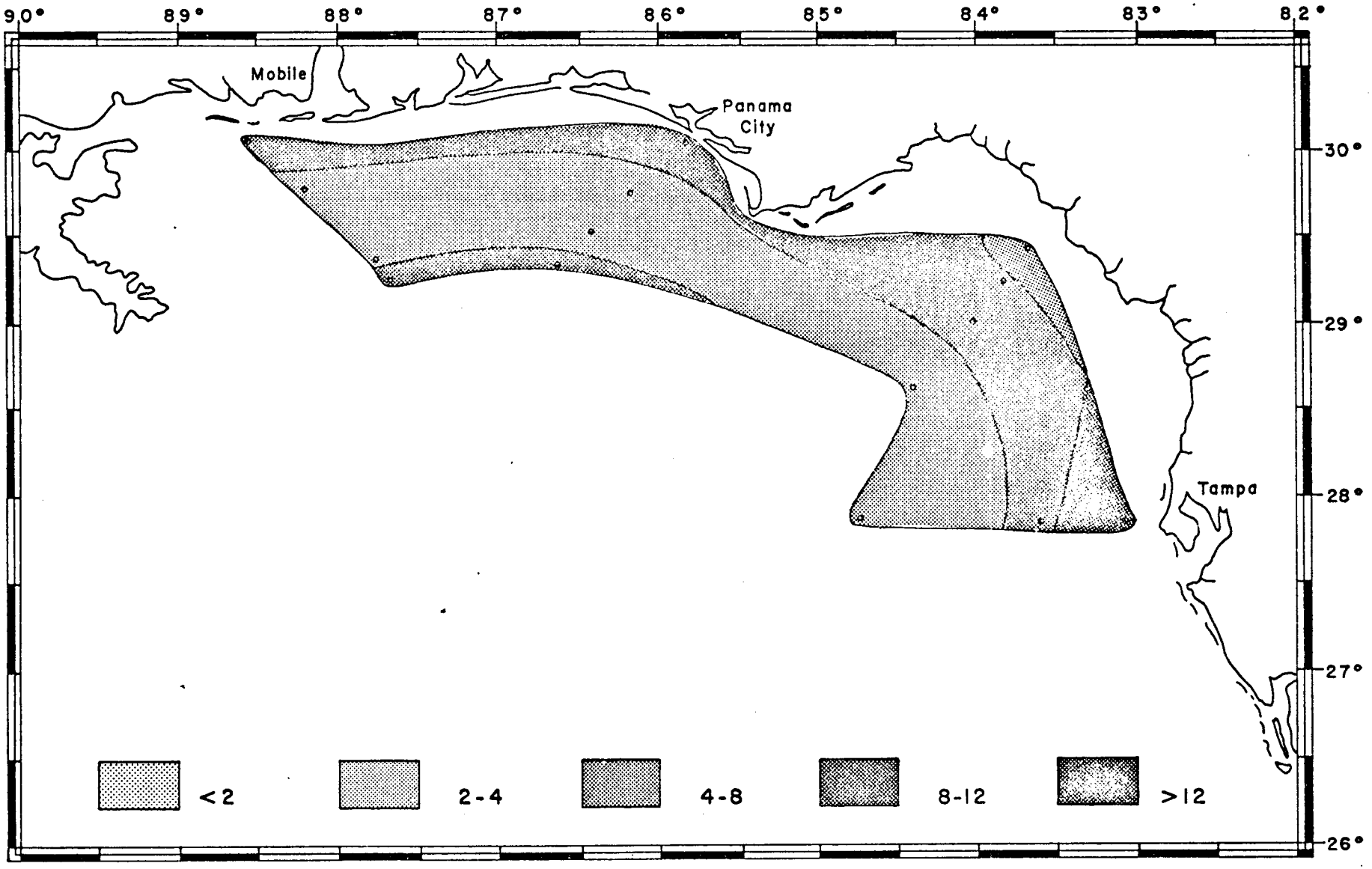

Figure 3b. The horizontal distribution of surface primary productivity (g C/m /hr) September-October, 1975.

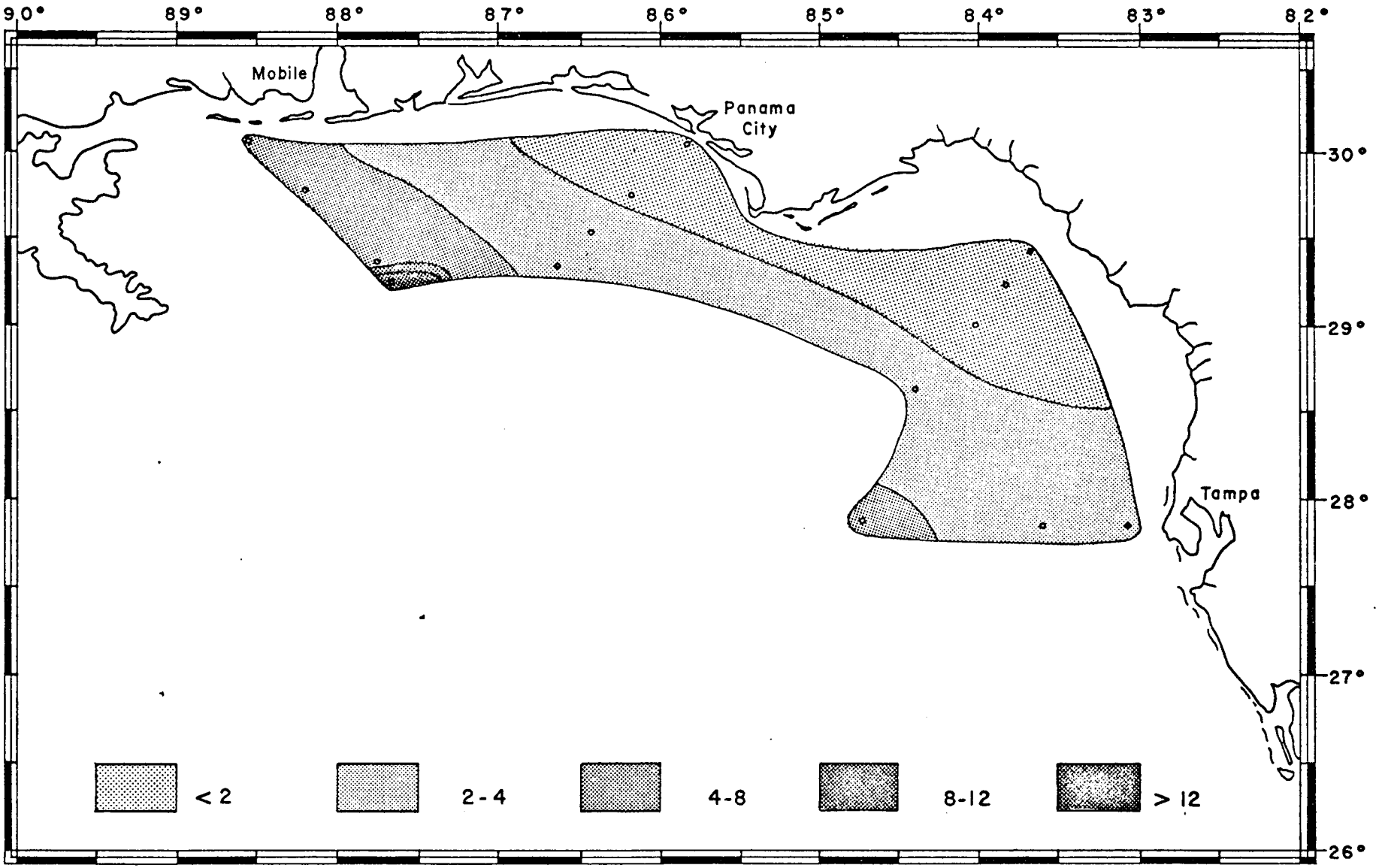

Figure 3c. The horizontal distribution of surface primary productivity (gC/m /hr) January-February, 1976.

variance than do productivity values. Apparently the use of assimilation rates reduces variability caused by differences in chlorophyll a concentration and light, both of which influence primary productivity values.

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Table 1 Average surface concentrations of chlorophyll *a* (mg/m^3) and the observed range of concentrations along each transect

Season	1	2	3	4
Summer	0.21	0.13	0.36	0.80
range	0.13-0.31	0.10-0.17	0.26-0.49	0.39-1.48
Fall	0.47	0.31	0.12	0.33
range	0.09-1.18	0.10-0.57	0.03-0.35	0.04-1.09
Winter	0.37	0.27	0.34	0.94
range	0.22-0.57	0.09-0.50	0.27-0.36	0.54-1.73

Table 2 Average bottom concentrations of shlorophyll *a* (mg/m^3) and the observed range of concentrations along each transect

Season	1	2	3	4
Summer	0.57	0.28	0.49	1.70
range	0.11-0.86	0.26-0.29	0.01-0.97	0.51-4.37
Fall	1.90	0.63	0.22	0.27
range	0.21-4.85	0.34-0.95	0.11-0.51	0.05-0.54
Winter	0.45	1.12	0.36	0.55
range	0.21-0.73	0.10-3.38	0.24-0.45	0.28-1.04

Table 3 Average seasonal surface primary productivity (mg C m^{-3} hr^{-1}) and the observed ranges along each transect

Season	1	2	3	4
Summer	9.4	7.9	8.8	7.6
range	8.1 - 11.8	4.3 - 10.9	7.7 - 9.3	6.3 - 9.1
Fall	12.0	7.3	8.3	8.7
range	6.9 - 18.8	6.0 - 8.8	4.2 - 10.9	7.6 - 10.4
Winter	3.4	1.5	2.0	8.0
range	2.1 - 4.5	1.1 - 2.4	1.8 - 2.1	6.7 - 13.6

Table 4 Average surface assimilation rate values and observed ranges along each transect. mg C/(mg chl)/E m^{-2}/hr

Season	1	2	3	4
Summer	2.8	2.1	2.1	1.1
range	0.1 - 8.2	0.4 - 3.6	0.7 - 3.9	0.3 - 1.4
Fall	2.0	4.4	2.8	2.5
range	1.2 - 2.9	1.3 - 18.3	0.9 - 4.6	1.8 - 3.3
Winter	2.6	0.9	1.9	1.4
range	0.6 - 4.6	0.5 - 1.6	0.2 - 7.9	0.6 - 2.1

APPENDIX I

June - July 1975

Station	Time (EDT)	Depth (m)	Chlorophyll a, mg m^{-3} 1	2	3	mean	Primary Productivity, mg C m^{-3} hr^{-1} 1	2	3	mean	Solar Radiation E m^{-2}	Assimilation Rate $\frac{mg\ C(mg\ chl\ a)^{-1}}{(E\ m^{-2})(hr)}$
1101	0745-1055	sfc	0.248	0.145	0.171	0.188	5.639	10.065	7.413	7.706	5.01	8.18
1101	0740-1050	15	0.099	0.088	0.113	0.100	0.759	0.684	0.629	0.691	.003	2303.3
1101	1235-1535	sfc	0.102	0.231	0.188	0.174	10.502	15.927	7.334	11.254	11.88	5.44
1101	1230-1530	15	0.125	0.115	0.118	0.119	0.974	0.867	0.943	0.928	.0078	999.78
1102	0805-1105	sfc	0.117	0.125	0.173	0.138	1.021	1.045	1.669	1.245	4.75	1.90
1102	0800-1100	30	0.850	0.766	0.933	0.850	1.031	0.640	0.644	0.772	.003	302.75
1102	1300-1605	sfc	0.107	0.142	0.135	0.128	1.160	1.360	1.398	1.306	11.34	0.899
1102	1255-1600	30	0.832	0.840	0.922	0.865	1.109	0.496	0.781	0.795	.007	131.29
1103	0840-1140	sfc	0.405	0.435	0.330	0.390	0.663	0.489	0.485	0.546	10.40	0.14
1103	0845-1145	102	0.735	0.758	0.743	0.745	0.606	0.569	1.673	0.949	.0068	187.33
1103	1300-1600	sfc	0.230	0.225	0.230	0.228	0.395	0.280	0.506	0.394	13.26	0.13
1103	1255-1555	102	0.690	0.710	0.740	0.713	0.445	0.541	0.631	0.539	.0087	86.89

Station	Time (EDT)	Depth (m)	Chlorophyll a				Primary Productivity mg C m^{-3} hr^{-1}				Solar Radiation E m^{-2}	Assimilation Rate $\frac{mg\ C(mg\ chl\ a)^{-1}}{(E\ m^{-2})(hr)}$
			1	2	3	mean	1	2	3	mean		
1204	0810-1115	sfc	0.180	0.163	0.232	0.192	5.090	4.265	4.318	4.558	8.16	2.91
1204	0805-1110	12	0.238	0.250	0.182	0.223	0.883	0.460	0.508	0.617	.0054	512.37
1204	1240-1545	sfc	0.108	0.139	0.190	0.142	0.619	1.088	-	0.854	13.63	0.44
1204	1235-1540	12	0.361	0.356	0.364	0.360	1.243	0.683	0.538	0.821	.0089	256.24
1205	0755-1055	sfc	0.186	0.117	0.130	0.144	2.510	1.360	3.744	2.538	4.98	3.54
1205	0750-1050	16	0.225	0.204	0.251	0.227	0.451	0.721	0.597	0.590	.0032	812.22
1205	1310-1610	sfc	0.121	0.159	0.092	0.124	0.791	1.095	0.887	0.924	3.57	2.09
1205	1305-1605	16	0.161	0.158	0.177	0.165	0.343	0.297	0.167	0.269	.0023	708.83
1206	0810-1110	sfc	0.122	0.106	0.182	0.137	1.890	2.362	0.919	1.857	7.67	1.77
1206	0805-1105	24	0.258	0.233	0.268	0.253	0.875	0.500	0.616	0.664	0.005	524.90
1206	1300-1615	sfc	0.124	0.121	0.076	0.107	1.793	0.947	0.795	1.178	10.47	1.05
1206	1300-1615	24	0.285	0.297	0.314	0.299	0.192	0.302	0.145	0.213	.0069	103.24

Station	Time (EDT)	Depth (m)	Chlorophyll a 1	2	3	mean	Primary Productivity mg C m^{-3} hr^{-1} 1	2	3	mean	Solar Radiation E m^{-2}	Assimilation Rate $\frac{mg\ C(mg\ chl\ a)^{-1}}{(E\ m^{-2})(hr)}$
1207	0825-1135	sfc	0.013	0.093	-	0.053	1.818	1.629	0.891	1.446	7.51	3.63
1207	0820-1130	32	0.228	0.119	0.227	0.191	0.145	0.117	0.126	0.129	.005	135.08
1207	1250-1555	sfc	0.160	0.179	0.122	0.154	1.478	1.319	0.959	1.252	6.72	1.21
1207	1245-1550	32	0.388	0.324	0.242	0.318	0.218	0.241	0.111	0.190	.0044	135.79
1308	0800-1100	sfc	0.366	0.308	0.331	0.335	6.914	9.987	7.569	8.157	6.65	3.66
1308	0755-1055	15	0.599	0.779	0.743	0.707	0.325	0.212	0.371	0.303	.0044	97.40
1308	1255-1555	sfc	0.364	0.472	0.379	0.405	11.100	11.292	5.525	9.306	11.92	1.93
1308	1250-1550	15	0.749	1.389	1.534	1.224	0.321	0.303	0.445	0.356	.0079	36.82
1309	0810-1110	sfc	0.438	0.618	0.519	0.525	3.730	2.717	3.131	3.193	7.10	0.86
1309	0810-1110	48	0.548	0.568	0.477	0.531	0.205	0.121	0.291	0.206	.0047	82.54
1309	1250-1550	sfc	0.501	0.414	0.472	0.462	0.934	0.707	1.634	1.092	11.88	0.20
1309	1245-1545	48	0.389	0.458	0.440	0.429	0.142	0.184	0.299	0.208	.0081	59.86

Station	Time (EDT)	Depth (m)	Chlorophyll a 1	2	3	mean	Primary Productivity mg C m^{-3} hr^{-1} 1	2	3	mean	Solar Radiation E m^{-2}	Assimilation Rate $\frac{mg\ C(mg\ chl\ a)^{-1}}{(E\ m^{-2})(hr)}$
1310	0825-1125	sfc	0.067	0.077	0.125	0.090	1.573	1.914	2.161	1.883	6.72	3.11
1310	0820-1120	59	0.051	0.075	-	0.063	0.131	0.070	0.083	0.095	.0044	342.71
1310	1225-1525	sfc	0.057	0.054	-	0.056	1.499	2.646	1.434	1.860	8.62	3.85
1310	1220-1520	59	0.102	0.093	-	0.098	0.132	0.077	0.047	0.085	.0052	166.80
1311	0820-1130	sfc	0.077	0.435	-	0.256	1.379	0.902	1.391	1.224	6.47	0.74
1311	0815-1125	86	0.365	0.253	-	0.309	0.548	0.503	0.631	0.561	.004	453.88
1311	1300-1600	sfc	-	-	-	-	0.513	1.149	0.372	0.678	10.88	-
1311	1300-1600	86	0.146	0.203	-	0.175	0.125	0.083	0.045	0.084	.007	68.57
1412	0755-1055	sfc	0.369	0.302	0.398	0.356	3.213	7.084	4.332	4.876	4.08	3.36
1412	0750-1050	12	3.268	3.568	3.611	3.482	0.441	0.355	0.203	0.333	.0026	36.78
1412	1300-1605	sfc	0.377	0.301	0.934	0.537	7.960	5.188	4.552	5.900	12.27	0.90
1412	1255-1600	12	5.633	4.805	5.329	5.258	0.294	0.550	0.333	0.392	.008	9.32

Station	Time (EDT)	Depth (m)	Chlorophyll a				Primary Productivity mg C m^{-3} hr^{-1}				Solar Radiation E m^{-2}	Assimilation Rate $\frac{mg\ C(mg\ chl\ a)^{-1}}{(E\ m^{-2})(hr)}$
			1	2	3	mean	1	2	3	mean		
1413	0830-1130	sfc	1.690	1.829	1.722	1.747	11.742	11.595	10.343	11.227	7.15	0.90
1413	0830-1130	31	1.118	1.264	0.963	1.115	0.106	0.110	0.122	0.113	.0047	21.56
1413	1330-1630	sfc	0.885	0.921	0.908	0.905	18.369	17.936	18.924	18.416	11.02	1.38
1413	1330-1630	31	1.240	1.187	1.214	1.214	0.317	0.315	0.385	0.339	.0072	52.03
1414	0840-1140	sfc	1.139	0.904	0.992	1.012	2.029	3.120	1.757	2.302	5.09	0.45
1414	0835-1135	61	0.649	0.727	0.849	0.757	0.560	0.657	0.542	0.586	.0033	234.58
1414	1300-1630	sfc	0.804	0.697	0.747	0.749	3.742	4.361	0.520	2.874	8.07	0.33
1414	1300-1630	61	0.728	0.981	1.150	1.073	0.362	0.189	0.202	0.251	.0053	63.23
1415	0845-1150	sfc	0.244	0.351	0.387	0.327	1.695	1.059	1.086	1.280	8.74	0.45
1415	0840-1145	71	0.425	0.449	0.482	0.452	0.324	0.300	0.472	0.365	.0057	141.67
1415	1410-1710	sfc	0.455	0.456	0.420	0.444	0.381	1.709	0.342	0.811	3.81	0.48
1415	1405-1705	71	0.521	0.562	0.596	0.560	0.211	0.320	0.393	0.308	.0025	220.0

September - October 1975

Station	Time (GMT)	Depth (m)	Chlorophyll a mg chl a m^{-3} 1	2	3	mean	Primary Productivity mg C m^{-3} hr^{-1} 1	2	3	mean	Solar Radiation E m^{-2}	Assimilation Rate $\frac{mg\ C(mg\ chl\ a)^{-1}}{(E\ m^{-2})\ (hr)}$
1101	1245-1547	sfc	0.488	0.420	0.498	0.469	8.885	7.623	6.458	7.655	9.09	1.796
		12m	4.389	4.304	4.247	4.313	1.188	1.742	3.405	2.112	.0059	83.0
1101	1652-1952	sfc	2.195	1.739	1.853	1.929	30.234	29.463	29.996	29.898	10.27	1.509
		12m	5.187	5.615	5.444	5.415	20.643	10.755	2.917	11.438	.0068	310.6
1102	1332-1632	sfc	0.124	0.228	0.156	0.169	1.865	2.115	2.488	2.156	10.43	1.223
		30m	0.748	0.754	0.782	0.761	0.422	0.657	0.880	0.653	.0069	124.4
1102	1744-2045	sfc	0.108	0.078	0.100	0.095	2.277	1.814	2.504	2.198	10.19	2.271
		30m	0.956	1.112	1.034	1.034	0.522	0.480	2.078	1.027	.0067	148.2
1103	1313-1614	sfc	0.182	0.086	0.062	0.110	2.075	1.083	2.579	1.912	4.63	2.34
		50m	0.208	0.182	0.180	0.190	0.573	0.354	0.213	0.380	.0031	645.2
1103	1740-2055	sfc	0.074	0.054	0.066	0.065	2.005	0.808	2.467	1.760	9.13	2.967
		50m	0.218	0.214	0.230	0.221	0.985	0.894	0.406	0.762	.0060	574.7
1204	1215-1516	sfc	0.294	0.242	0.276	0.271	2.003	2.444	2.012	2.153	6.05	1.313
		10m	0.369	0.387	0.417	0.391	0.493	0.447	0.609	0.516	.0040	329.9
1204	1732-2032	sfc	0.584	0.606	0.561	0.584	7.251	8.420	9.057	8.243	6.09	2.315
		10m	0.589	0.669	0.635	0.631	2.199	1.401	1.267	1.622	.0040	642.6

Station	Time (GMT)	Depth (m)	Chlorophyll a, mg chl a m^{-3} 1	2	3	mean	Primary Productivity, mg C m^{-3} hr^{-1} 1	2	3	mean	Solar Radiation E m^{-2}	Assimilation Rate $\frac{\text{mg C(mg chl a)}^{-1}}{(\text{E m}^{-2})\ (\text{hr})}$
1205	1230-1530	sfc	0.283	0.266	0.261	0.270	1.506	2.948	2.370	2.275	7.04	1.197
		15m	0.397	0.385	0.436	0.406	0.309	0.394	0.207	0.303	.0046	162.2
1205-A	1235-1535	sfc	0.476	0.470	0.476	0.474	4.698	4.814	4.272	4.595	6.37	1.522
		15m	0.550	0.618	0.601	0.590	0.287	0.440	0.219	0.315	.0042	127.1
1205-A	1702-2004	sfc	0.691	0.669	0.652	0.671	17.202	18.195	18.059	17.819	11.16	2.380
		15m	0.810	0.883	0.810	.818	2.008	1.077	3.968	2.351	.0074	388.4
1205			NO SAMPLES COLLECTED HURRICANE ELOISE									
1206	1255-1600	sfc	0.122	0.114	0.136	0.124	0.887	1.880	2.514	1.763	7.09	2.005
		23m	0.606	0.697	0.771	0.691	1.515	0.217	0.234	0.655	.0047	201.7
1206	1722-2022	sfc	0.116	0.108	0.120	0.115	4.313	3.162	3.598	3.691	9.58	3.350
		23m	1.397	1.97	1.97	1.264	0.585	0.823	1.013	0.807	.0063	101.3
1207	1250-1550	sfc	0.116	0.104	0.100	0.107	7.704	2.851	3.396	4.650	2.37	18.34
		25m	0.425	0.385	0.527	0.446	2.568	0.715	2.307	1.863	.0016	2610.7
1207	1716-2016	sfc	0.080	0.084	0.082	0.082	2.501	2.765	2.387	2.884	8.93	3.94
		25m	0.238	0.272	0.244	0.251	0.920	0.630	1.650	1.067	.0059	720.5
1308	1245-1620	sfc	0.329	0.312	0.340	0.327	5.156	3.909	4.197	4.421	9.29	1.455
		14m	0.623	0.640	0.657	0.640	0.322	0.474	0.665	0.487	.0061	124.7
1308	1714-2015	sfc	0.419	0.351	0.334	0.368	2.872	6.088	4.514	4.491	12.40	0.984
		14m	0.408	0.397	0.406	0.404	0.873	0.478	0.570	1.140	.0082	344.1

Station	Time (GMT)	Depth (m)	Chlorophyll a mg chl a m^{-3} 1	2	3	mean	Primary Productivity mg C m^{-3} hr^{-1} 1	2	3	mean	Solar Radiation E m^{-2}	Assimilation Rate $\frac{mg\ C(mg\ chl\ a)^{-1}}{(E\ m^{-2})\ (hr)}$
1309	1315-1620	sfc	0.052	0.071	0.069	0.064	0.559	0.715	0.418	0.564	3.75	2.350
		45m	0.402	0.374	0.419	0.398	0.135	0.118	0.188	0.147	.0025	147.7
1309	1820-2121	sfc	0.086	0.080	0.068	0.078	1.563	1.661	1.614	1.613	4.50	4.595
		45m	0.158	0.160	0.146	0.155	0.605	0.137	0.394	0.379	.0030	815.0
1310	1247-1550	sfc	0.037	0.039	0.042	0.039	0.280	0.953	0.519	0.584	6.25	2.396
		90m	0.164	0.148	0.170	0.161	0.280	0.438	0.256	0.325	.0041	492.3
1310	1815-2115	sfc	0.034	0.036	0.030	0.033	1.719	1.147	0.935	1.267	8.85	4.338
		90m	0.125	0.120	0.126	0.124	0.439	0.362	0.244	0.348	.0058	483.9
1311	1252-1553	sfc	0.034	0.035	0.035	0.035	0.502	0.962	1.574	1.013	7.89	3.668
		90m	0.096	0.083	0.081	0.087	0.515	0.954	0.790	0.753	.0052	1664.5
1311	1832-2133	sfc	0.024	0.032	0.028	0.028	1.619	0.864	0.463	0.982	12.68	2.766
		90m	0.056	0.060	0.071	0.062	0.650	0.538	0.492	0.560	.0084	1075.3
1412	1220-1520	sfc	1.063	0.961	0.893	0.972	14.061	15.934	14.343	14.779	6.01	2.530
		14m	0.570	0.604	0.527	0.567	0.175	0.124	0.126	0.142	.0040	62.61
1412	1725-2025	sfc	1.190	1.156	1.241	1.196	30.898	29.552	17.065	25.838	12.34	1.751
		14m	0.502	0.502	0.510	0.505	0.684	0.615	0.627	0.642	.0081	156.9
1413	1240-1540	sfc	0.165	0.144	0.180	0.163	2.761	2.487	1.541	2.263	5.48	2.533
		29m	0.255	0.216	0.246	0.239	0.072	0.158	0.100	0.110	.0036	127.8

Station	Time (GMT)	Depth (m)	Chlorophyll a mg chl a m^{-3} 1	2	3	mean	Primary Productivity mg C m^{-3} hr^{-1} 1	2	3	mean	Solar Radiation E m^{-2}	Assimilation Rate $\frac{mg\ C(mg\ chl\ a)^{-1}}{(E\ m^{-2})\ (hr)}$
1413	1826-2126	sfc	0.084	0.080	0.108	0.091	2.131	2.822	2.421	2.458	9.74	2.770
		29m	0.357	0.323	0.317	0.332	0.824	0.564	0.362	0.583	.0064	274.4
1414	1253-1553	sfc	0.041	0.038	0.043	0.041	0.986	0.779	0.555	0.773	7.69	2.452
		65m	0.156	0.160	0.170	0.162	0.581	0.646	0.715	0.647	.0051	783.1
1414	1843-2144	sfc	0.039	0.036	0.037	0.037	0.385	1.836	0.648	0.956	7.91	3.266
		65m	0.225	0.230	0.251	0.235	0.401	0.400	0.323	0.375	.0052	306.9
1415	1303-1605	sfc	0.040	0.044	0.056	0.047	1.650	0.476	0.588	0.905	9.54	2.018
		90m	0.054	0.058	0.059	0.057	0.058	0.089	0.066	0.071	.0063	197.7
1415	1840-2145	sfc	0.031	0.031	0.029	0.030	1.416	0.782	0.687	0.962	11.32	2.833
		90m	0.049	0.056	0.047	0.051	0.824	0.881	0.447	0.717	.0075	1874.5

BLM PHYTOPLANKTON, WINTER (JAN-FEB) 1976 — T-7601 or BLM #28

Station	Incubation Times (GMT)	Depth (m)	Chlorophyll-A mg chl-a m^{-3} 1	2	3	CHL-A Mean	Primary Productivity mgC m^{-3} hr^{-1} 1	2	3	Mean	Solar Radiation Σ m^{-2}	Assimilation Rate $\frac{mgC(mg\ chl\text{-}a)^{-1}}{(\Sigma m^{-2})(hr)}$
1101	1404-1706	sfc	0.655	0.646	0.731	0.677	3.175	2.712	3.190	3.026	7.93	0.564
		15	0.689	0.672	0.655	0.672	2.049	1.292	1.748	1.696	0.10	25.23
1101	1757-2100	sfc	0.485	0.427	0.479	0.464	3.773	4.960	3.205	3.979	9.76	0.879
		15	0.822	0.836	0.724	0.794	0.623	1.206	0.663	0.831	0.12	8.722
1102	1405-1705	sfc	0.237	0.246	0.213	0.232	1.661	2.188	--	1.925	1.80	4.610
		26	0.228	0.210	0.222	0.220	0.717	0.485	0.404	0.535	0.027	90.07
1102	1815-2115	sfc	0.210	0.204	0.216	0.210	2.529	2.208	2.100	2.279	2.41	4.503
		26	0.204	0.219	0.195	0.206	0.452	0.763	1.056	0.757	0.036	102.1
1103	1432-1732	sfc	0.459	0.425	0.391	0.425	5.721	6.220	6.136	6.026	8.79	1.613
		54	0.595	0.816	0.672	0.694	0.930	1.046	1.733	1.236	0.134	13.29
1103	1855-2155	sfc	0.218	0.258	0.224	0.233	2.516	2.956	3.591	3.021	3.71	3.495
		54	0.158	0.137	0.146	0.147	0.268	0.366	0.462	0.365	0.056	44.34
1204	1405-1708	sfc	0.306	0.315	0.354	0.325	1.428	1.501	1.502	1.477	8.32	0.546
		8	0.360	0.363	0.348	0.357	1.190	1.435	1.263	1.296	1.59	2.283
1204	1828-2130	sfc	0.300	0.270	0.243	0.271	1.200	1.140	1.027	1.122	8.48	0.488
		8	0.339	0.294	0.312	0.315	1.259	1.053	1.135	1.149	1.62	2.252
1205	1415-1715	sfc	0.095	0.100	0.086	0.096	1.169	1.383	1.052	1.201	8.01	1.562
		14	0.114	0.114	0.102	0.107	1.061	1.046	1.002	1.036	1.53	6.328

Station	Incubation Times (GMT)	Depth (m)	Chlorophyll-A mg chl-a m^{-3} 1	2	3	CHL-A Mean	Primary Productivity mgC m^{-3} hr^{-1} 1	2	3	Mean	Solar Radiation Σ m^{-2}	Assimilation Rate $\frac{mgC(mg\ chl\text{-}a)^{-1}}{(\Sigma m^{-2})\ (hr)}$
1205	1840-2140	sfc	0.087	0.084	0.082	0.084	1.095	0.679	1.009	0.928	6.74	1.639
		14	0.087	0.102	0.088	0.092	0.790	1.008	0.660	0.819	1.29	6.901
1206	1420-1720	sfc	0.198	0.213	0.213	0.208	1.209	1.220	1.371	1.267	8.54	0.713
		23	0.604	0.587	0.493	0.561	2.029	2.250	2.798	2.359	1.63	2.580
1206	1830-2131	sfc	0.171	0.169	0.168	0.169	1.347	1.304	1.472	1.374	8.77	0.927
		23	0.761	0.672	0.741	0.725	3.042	3.011	3.595	3.216	1.68	2.640
1207	1422-1725	sfc	0.714	0.757	0.825	0.765	3.508	3.753	4.060	3.774	8.03	0.614
		29	2.480	2.309	2.522	2.437	7.958	8.175	8.847	8.327	1.54	2.219
1207	1840-2142	sfc	0.228	0.198	0.249	0.225	1.992	2.035	1.927	1.985	8.64	1.021
		29	4.190	4.318	4.489	4.332	17.321	20.341	16.333	17.998	1.65	2.518
1308	1425-1725	sfc	0.417	0.378	0.366	0.387	0.984	0.538	0.916	0.813	8.48	0.248
		14	0.544	0.510	0.442	0.499	2.333	2.319	2.031	2.228	1.62	2.756
1308	1825-2125	sfc	0.318	0.357	0.321	0.332	2.141	1.930	1.674	1.915	7.79	0.740
		14	0.396	0.354	0.369	0.373	2.277	2.667	2.359	2.434	1.49	4.380
1309	1515-1815	sfc	0.351	0.321	0.327	0.333	1.576	2.147	1.507	1.743	7.00	0.748
		43	0.249	0.351	0.285	0.295	0.301	0.288	0.285	0.291	0.106	9.306
1309	1900-2200	sfc	0.312	0.324	0.300	0.312	2.177	2.403	2.049	2.210	0.890	7.959
		43	0.276	0.294	0.297	0.289	0.388	0.139	0.257	0.261	0.010	90.31

Station	Incubation Times (GMT)	Depth (m)	Chlorophyll-A mg chl-a m^{-3} 1	2	3	CHL-A Mean	Primary Productivity mg Cm^{-3} hr^{-1} 1	2	3	Mean	Solar Radiation Σ m^{-2}	Assimilation Rate $\frac{mgC(mg\ chl\text{-}a)^{-1}}{(\Sigma m^{-2})\ (hr)}$
1310	1455-1755	sfc	0.570	0.621	0.587	0.593	2.276	2.437	2.977	2.563	7.24	0.597
		67	0.629	0.663	0.655	0.649	1.182	0.680	0.869	0.910	0.11	12.75
1310	1900-2200	sfc	0.216	0.228	0.219	0.238	1.629	1.630	1.653	1.637	5.68	1.211
		67	0.255	0.252	0.255	0.254	0.694	0.581	0.896	0.724	0.086	33.14
1311	1430-1730	sfc	0.333	0.270	0.276	0.293	1.426	2.462	1.970	1.953	3.59	1.857
		53	0.234	0.213	0.237	0.228	0.352	0.920	0.323	0.532	0.05	46.67
1311	1855-2155	sfc	0.228	0.237	0.243	0.236	1.896	3.365	1.478	2.246	5.54	1.718
		53	0.261	0.228	0.252	0.247	0.462	0.903	0.993	0.786	0.08	39.78
1412	1429-1730	sfc	0.731	0.765	0.765	0.754	3.290	3.254	3.188	3.244	6.96	0.618
		12	0.935	0.986	0.998	0.966	1.793	1.562	1.354	1.570	0.106	15.33
1412	1825-2125	sfc	0.782	0.842	0.833	0.819	5.765	5.261	5.147	5.391	6.33	1.045
		12	1.224	0.995	1.139	1.119	6.227	1.798	1.235	3.087	0.096	28.74
1413	1435-1735	sfc	0.680	0.706	0.757	0.714	5.560	3.900	8.838	6.099	5.50	1.553
		26	0.536	0.510	0.544	0.530	0.925	1.080	4.744	2.160	0.084	48.52
1413	1832-2132	sfc	0.731	0.697	0.714	0.714	7.572	7.747	6.357	7.225	5.96	1.698
		26	0.536	0.544	0.553	0.544	6.499	2.305	1.767	3.524	0.09	71.98

Station	Incubation Times (GMT)	Depth (m)	Chlorophyll-A mg chl-a m^{-3} 1	2	3	CHL-A Mean	Primary Productivity Mg Cm^{-3} hr^{-1} 1	2	3	Mean	Solar Radiation Σ m^{-2}	Assimilation Rate $\frac{mgC(mg\ chl\text{-}a)^{-1}}{(\Sigma m^{-2})\ (hr)}$
1414	1425-1725	sfc	0.544	0.536	0.638	0.573	5.140	7.208	7.906	6.751	7.04	1.674
		41	0.318	0.345	0.312	0.325	0.742	0.562	1.022	0.775	0.11	21.68
1414	1825-2125	sfc	0.527	0.502	0.502	0.510	6.795	8.477	8.390	7.887	7.16	2.160
		41	0.324	0.303	0.318	0.315	0.422	0.505	0.549	0.492	0.11	14.20
1415	1430-1735	sfc	1.625	1.710	1.796	1.710	16.566	10.226	16.686	14.493	7.51	1.129
		34	0.323	0.332	0.332	0.329	0.542	1.005	0.700	0.749	0.11	20.70
1415	1905-2205	sfc	1.796	1.710	1.753	1.753	12.171	17.179	8.482	12.611	5.58	1.289
		34	0.198	0.243	0.228	0.223	0.726	1.273	0.567	0.855	0.085	45.11

A SURVEY OF PARTICULATE AND DISSOLVED ORGANIC CARBON ALONG THE CONTINENTAL SHELF OF THE NORTHEASTERN GULF OF MEXICO

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ABSTRACT

Both particulate and dissolved organic carbon (POC and DOC) were found to fluctuate seasonally over the shelf of the Northeastern Gulf of Mexico. POC reached the highest levels during the summer and winter and was at a minimum during the fall. DOC exhibited low levels during the summer and fall and was at a maximum during the winter. When different regions of the Gulf shelf were considered POC was found to be more variable, following localized seasonal patterns, while DOC was found to be remarkably uniform throughout the study area.

Within each season the apparent levels of particulate and dissolved organic carbon were not generally found to differ statistically when distance from shore or transects were considered. An exception to this was a decline in POC immediately offshore during the fall. Tabulation of POC and DOC quantities did suggest that trends related to the spatial distribution of organic carbon may have existed but were statistically undetectable. Individual stations were found to exhibit no consistent discernable patterns throughout the year, although the winter was a period of uniformity for both POC and DOC throughout the shelf.

Levels of particulate carbon were closely related to phytoplankton standing stocks, as estimated by chlorophyll a, along the entire Northeastern Gulf shelf although the relationship was strongest near shore. Measured quantities of dissolved organic carbon could not be related to any of the parameters considered in this study.

INTRODUCTION

Particulate (POC) and dissolved (DOC) organic carbon are commonly measured oceanographic parameters. Although the precise chemical composition and ecological significance of these sea water constituents remains poorly understood, their origin, quantity and distribution are important because they are known to influence chemical and biological processes occurring in the sea. Consisting of both living and detrital elements, the particulate material may influence the light distribution properties of sea water, serve as a substrate for bacteria, or provide food for a variety of other marine organisms (Johannes, 1965; Freidrich, 1969; Parsons, 1963; Riley and Chester, 1971; Yentsch, 1962). The dissolved organics may be utilized directly as food by some marine organisms, they may function as inhibitors or stimulants to growth, or provide needed trace elements bound to organic complexes (Guillard and Cassie, 1963; Johnston, 1963; Pomeroy, et. al., 1963; Riley and Chester, 1971; Zobell, 1946). Duursma (1965) has also indicated that DOC may sometimes be considered a conservative property of large water masses. Other studies suggest the possibility that interconvertability between POC and DOC may exist (Baylor and Sutcliffe, 1963; Riley, 1963).

The general in situ processes controlling the production and distribution of POC and DOC are reasonably well understood and function similarly throughout the world's oceans. However, in marine areas adjacent to land masses, such as over the continental shelf, these processes become more complex as both man made and natural terrestrial influences enter into consideration.

This investigation was designed to describe the temporal and spatial fluctuations in the levels of POC and DOC along the continental shelf of the Northeast Gulf of Mexico from Pascagoula, Mississippi to Tampa, Florida. Additionally, the relationship of these parameters to terrestrial influences,

in situ biological processes, and chemical and physical oceanographic parameters was examined. All data were collected concurrently during three sampling periods: June/July 1975, September/October 1975, and January/February 1976.

Previous Research

In the late nineteenth centery the chemical oceanographer Konrad Natterer was, apparently, the first to note the presence of dissolved organic matter in sea water (Anderson, 1969; Duursma, 1965). In the routine course of chemical analysis on sea water samples Natterer noted that the dry weights measured exceeded those which were expected based upon the known chemical composition of sea water. By precipitating inorganics and extracting the organics from an evaporated filtrate using ethyl alcohol, Natterer was able to demonstrate the possible presence of palmitic and stearic acids as well as glycerol. He attributed the existence of dissolved organic materials to the decomposition of marine organisms.

By the time data was first published (1892-94) on Natterer's work he had refined his technique such that he was able to report approximately two milligram/liter of dissolved organic carbon for open surface sea water, and as much as one order of magnitude higher in coastal waters. Although dissolved organics had been known to be present in fresh water aquatic systems for some time, his findings aroused great interest and controversy primarily because the amount of dissolved organic matter was high when compared to that in suspension (Anderson, 1969; Duursma, 1965).

In the years immediately following the publication of Natterer's work, great interest in this organic reservoir in sea water was evidenced by biologists

who speculated on the possible utilization of dissolved organics as a food source by marine organisms. A foremost proponent of the theory that marine animals obtained a major portion of their nutrient requirements from dissolved substances was Putter (1908). In subsequent years, marine research, which concentrated on the food potential of DOC, was able to substantially discard this preliminary theory (Duursma, 1965; Friedrich, 1969; Keys, et. al., 1935).

DOC originates from terrestrial sources, decay and subsequent dissolution of dead organisms, and the excretion products of phytoplankton, zooplankton, and larger marine organisms (Riley and Chester, 1971). While terrestrial sources may form a major input to neritic waters, the relative contribution of the latter two components depends upon location (Duursma, 1961; Duursma, 1965; Hellebust, 1965; Wangersky, 1965; Wood, 1963).

It is apparent that the presence of DOC, or some component of it, is required for marine life to exist. Few, if any, marine organisms are able to survive in saline solutions identical in all respects to sea water but lacking dissolved organics (Wagner, 1969). This knowledge suggests, and research has indicated, that DOC may provide food for marine bacteria (Keys, et. al., 1935; Zobell, 1946), basic nutrients and vitamins required to sustain phytoplankton growth (Guillard and Cassie, 1963; Pomeroy, et. al., 1963) and stimulants and inhibitors to growth such as marine giberillins (Johnston, 1963). Related to the final category are toxins and antibiotics excreted by some species which have pronounced effects on other species. Phytoplankton are notorious for this activity, a dramatic example of which is the lethal red tide (Riley and Chester, 1971).

The particulate fraction of the organic material present in sea water has never been universally defined and accepted with respect to size. Some

investigators have suggested that particulate material which is not truly dissolved may exist to 0.003 μ (Sharp, 1973). An average definition, considering the range found in the literature, would probably be that suspended organic material which is retained by a filter having a pore size of 0.5 μ (Riley and Chester, 1971).

POC is comprised of living organisms and non-living detritus. The living portion is composed predominantly of phytoplankton with lesser contributions from bacteria, yeasts, fungi, and zooplankton. The nekton are usually excluded from consideration because of their insignificant contribution to the total quantity of oceanic organic carbon (Friedrich, 1969; Parsons, 1963; Riley and Chester, 1971). The living segment is usually taken to be about 10 percent of the total particulate organic material, although ATP extraction has indicated that 25 percent may be a more accurate minimum figure (Parsons, 1963; Sheldon, et. al., 1973). The detrital portion of POC can consist of any organic refuse including dead phyto or zooplankton, fecal material, or organic aggregates adsorbed on inorganic substrates (Parsons, 1963).

Ecologically, the interrelationships of POC with other environmental parameters are somewhat better known than those of DOC. The amount of particulate material affects the distribution of light in the photic zone (Friedrich, 1969). POC is known to furnish substrates for bacteria and the suggestion has been made that, while energy budgets of pelagic microorganisms remain unknown, a substantial portion of nutrients may be regenerated wholly within the photic zone (Parsons, 1963; Wood, 1963). Johannes (1965) has further argued that marine portozoans, feeding upon bacteria-containing particulate organic aggregates complete the cycle of nutrient regeneration.

It is, of course, well known that the living elements of POC, such as

phytoplankton, furnish food for larger organisms. While the complete picture of utilization of the detrital POC is unclear, research has indicated it may be employed in several ways. Detritus may constitute a satisfactory food source for some zooplankton (Baylor and Sutcliffe, 1963; Parsons, 1963). Other zooplankton may rely on detritus for survival during periods of phytoplankton paucity (Parsons, 1963; Riley, 1963; Riley and Chester, 1971). Work by Poulet (1973) has indicated that certain copepods are size selective feeders regardless of whether the food source is living or dead.

Many observers have noted and worked with the dissolved organic aggregates occurring at the ocean surface which are classified as natural sea slicks. Evidence appears to support the contention that these slicks play important roles in the development of neustonic populations (Banse, 1964; Garrett, 1967; Hardy, 1973). It is also at the sea surface that the potential interconvertability of the organic material from the dissolved to the particulate phase may take place. Natural surface processes, such as wind and wave action, are apparently sufficient to produce particulate aggregates from the available dissolved material (Riley, 1963). This process has been replicated in the laboratory by bubbling filtered sea water and the particulate material so produced was sufficient to maintain a culture of the brine shrimp Artemia salina (Baylor and Sutcliffe, 1963).

How important or extensive this process may actually be is unknown since the rate at which it occurs under natural conditions remains undetermined. Riley (1963) has submitted that the dissolved organic fraction of sea water represents a huge pool of available nutrients rather than material in a refractory or transient state. At least some of the dissolved material is converted to particulate form and employed as food. The result may be a steady-state system which fully utilizes and provides a connecting link between the

dissolved and particulate reservoirs of organic material (Riley, 1963).

While a clear ecological picture of the overall importance of POC and DOC in the marine environment has yet to emerge, their quantity and distribution patterns in the open ocean are well known and generally agreed upon. Throughout the world the quantity of DOC ranges from about 0.05 to 2.0 mg/ℓ with values above 1.2 mg/ℓ occurring infrequently. The particulate fraction is typically about 10 percent of the dissolved fraction ranging from approximately 0.01 to 0.15 mg/ℓ. Both fractions exhibit their highest values at the surface, decrease with increasing depth, and reach low relatively constant values, both spatially and temporally, below 200-500 m (Duursma, 1961; Duursma, 1965; Gordon and Sutcliffe, 1973; Menzel, 1967; Menzel and Goering, 1966; Sharp, 1973; Wagner, 1969; Wangersky, 1965; Wangersky and Gordon, 1965). Owing to the complexity of shelf environments, these areas do not display such well defined distribution patterns and may exhibit POC and DOC values an order of magnitude higher than those reported for the open ocean (Dryer, 1973; Fredericks and Sackett, 1970; Maurer and Parker, 1972).

The very limited previous research concerning DOC and POC in the shelf and open Gulf environments of the Gulf of Mexico has shown Gulf distribution profiles to be essentially similar to those of POC and DOC reported elsewhere. However, while the quantity of DOC was also similar to other ocean areas, POC values in the open Gulf were five times higher. This difference was attributed to land runoff and a relatively large continental shelf area with high productivity (Fredericks and Sackett, 1970).

Working primarily in the western and north central U.S. Gulf, Fredericks and Sackett, (1970) also found a sharp gradient in DOC values from the coast to the edge of the shelf. A later, more detailed survey including some of

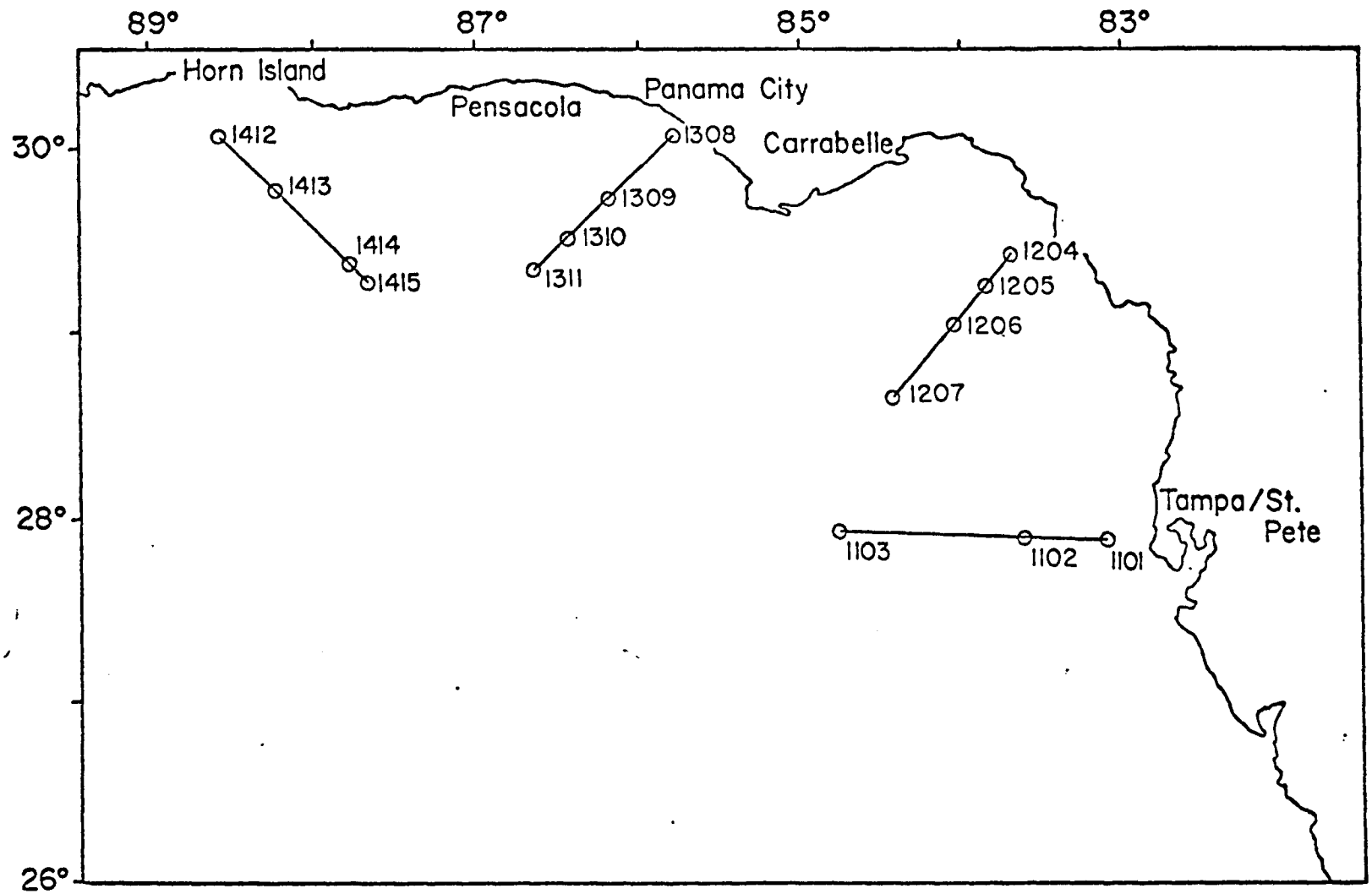

Figure 1. --Study Area

the same area studied by Fredericks and Sackett (1970) did not substantiate the existence of this gradient, but rather found bands of maximum and minimum DOC values which were attributed to water circulation patterns superimposed on the input of DOC from coastal regions (Maurer and Parker, 1972). Those areas of the Gulf which have been reported on were not studied seasonally. No published work is available on the distribution of organic carbon along the continental shelf of the Northeastern Gulf of Mexico.

Area of Investigation

Samples were collected three times during the year at each of 15 stations which were distributed along four offshore transects on the continental shelf of the Northeast Gulf of Mexico from Pascagoula, Mississippi to Tampa, Florida (Figure 1). The sampling periods were June/July 1975, September/October 1975, and January/February 1976. All samples were collected during the morning hours (0700-1000) and all stations were sampled at ten meters depth. Additional samples were taken at the one percent light level at most of the deeper stations.

The landward portion of the study area reflects great diversity in both human and natural development which might be expected to influence offshore processes related to organic carbon distribution. The most northern and western Transect IV lies off the coast of industrial areas of Mississippi and Alabama proximate to the Mississippi River and Mobile Bay systems. Transect II, to the south of Apalachee Bay, Florida is adjacent to humid, densely vegetated, relatively undeveloped land areas. Transect III, running southwestward from Panama City, Florida shares common characteristics with both of the previously mentioned transects. Transect I runs westerly off Tampa, Florida, an area of intense coastal development.

Similarly diverse are the offshore environments. The two most northerly and westerly transects lie above a relatively compressed shelf area and converge on either side of the northern boundary of the DeSoto Canyon. Transect II includes the coral formations of the biologically diverse and highly productive Florida Middle Ground, while the southerly transect cuts across the very broad gently sloping shelf area to the west of Tampa.

Little published data exists on the physical oceanography and current patterns for the entire study area. An examination of the available data does suggest that the study area embraces two distinct physical oceanographic regions. The first of these runs along the shelf from Tampa Bay to Cape San Blas and includes Transects I and II. This area is principally influenced by land run-off although the Loop Current may exert some influence on its extreme southern and outer boundaries at certain times during the year. Surface currents in this area move slowly alongshore in a Northwesterly direction throughout most of the year. The second region extends from Cape San Blas to Mobile Bay and includes Transect III and IV. This is an area of greater complexity than the first, being heavily influenced by the Mississippi River/ Mobile Bay systems. Currents in this area can be extremely complex eddy structures heavily affected by both of the extuarine areas noted and the Loop Current (Jones, 1973).

METHODS AND MATERIALS

Sampling

Sea water samples from the Gulf of Mexico used to measure POC and DOC were collected aboard R/V TURSIOPS using acid cleaned, well rinsed, 30 ℓ PVC Niskin sampling bottles equipped with teflon fittings. This type of sampler has been found not to contribute any measurable level of organic contamination (Gordon, 1969). A subsample of ten to twenty liters was removed, using teflon tubing, from the Niskin bottle to a carboy for transfer to the laboratory for the initial shipboard processing.

Initial sample processing took place in the laboratory aboard R/V TURSIOPS within one hour of sample collection. For POC, a well agitated 200 ml sea water sample was filtered under five cm vacuum through a precombusted 24 mm Whatman GF/F glass fiber filter (pore size 0.5 μ) using a Gelman filter funnel on a Millipore manifold. The filter was removed with acid washed teflon forceps, folded cylindrically, placed in a pre-combusted 10 ml ampoule, capped with aluminum foil and frozen until subsequent processing ashore. This operation was performed in triplicate for each sample. For DOC, approximately 100 ml of the filtrate from the above operation was placed in a four ounce acid washed teflon capped glass bottle, poisoned with mercuric chloride ($HgCl_2$) to prevent biological alteration of the carbon content, and refrigerated in the dark at 4°C until subsequent processing ashore.

Apparatus

Determination of both POC and DOC was made using a Total Carbon Analyzer (Oceanography International, Inc.) which refined the wet oxidation process detailed by Menzel and Vaccaro (1964) and extended the analytical technique

to include POC as well as DOC. The analyzer consisted of two subunits which allowed the stepwise processing of samples. The ampoule purging and sealing unit consisted of a pure oxygen source for sparging the samples to remove carbonate and ambient CO_2 and a burner designed to seal the ampoules while preventing the introduction of combustion derived CO_2 into the sample. The analyzer unit provided a breaker for opening the ampoules, a pure nitrogen carrier gas, and a non-dispersive infrared analyzer for measurement of the CO_2 evolved from each sample. Carbon level signals from the analyzer were graphically displayed on a strip chart recorder.

Analysis Procedure

Once ashore, processing of the POC filters began with the addition of a five ml aliquot of the preserved filtrate to a precombusted ten ml ampoule identical to those used for POC. This was done in triplicate for each water sample. Following these initial operations, all treatments of POC and DOC were identical.

To each ampoule was added 100 mg of potassium persulfate ($K_2S_2O_8$) followed immediately by 0.250 ml of 8.5% phosphoric acid. The samples were then purged of inorganic and atmospheric CO_2 by bubbling with purified O_2 for five minutes, sealed, and transferred to a 100°C water bath for four hours in order to oxidize the organic carbon to CO_2 (Williams, 1962).

Upon analysis the ampoules were opened and the total quantity of CO_2 present in each sample was displayed as an integrated peak area on the strip chart recorder. Actual carbon values for each sample were determined by comparison of the sample peak area with the peak area of a standard curve generated by

the analysis of ampoules containing known quantities of carbon derived from potassium acid phthalate (KHP). A separate standard curve was employed for each day's analytical work. Filter and reagent blanks were run for all samples as required, averaging approximately 1.2 µg of carbon each.

RESULTS AND DISCUSSION

Comparison with previous Research

A comparison of the range of organic carbon values found by this study with the studies of Fredericks and Sackett (1970) and Maurer and Parker (1972), who worked in the central and western areas of the Gulf of Mexico, is summarized in Table 1. Maurer and Parker did not publish carbon values for their individual stations off the Texas coast, so a precise estimate of the comparability of this study and their work is difficult. Maurer and Parker also did not report a mean DOC value and did not sample for POC. However, it does appear that while the range of values found in this study are similar to those found both by Maurer and Parker and Fredericks and Sackett, interesting regional variations may exist.

The difference between the mean levels of dissolved organic carbon found by the studies cannot be said to be significant. Further, the origin of this difference is difficult to assess since the studies did not employ identical seasonal sampling designs. It is also evident from Table 1 that both the ranges and mean values for particulate organic carbon reported by Fredericks and Sackett and by this study are dissimilar. The mean level reported by Fredericks and Sackett is higher than that found by this study by a factor of two. It should be noted that Fredericks and Sackett sampled primarily in the shelf area surrounding the Mississippi River, an area of heavy particulate loading. Thus this sampling design reflects the substantial regional influence of the Mississippi River on the particulate organic carbon levels in the Western Gulf of Mexico.

Temporal Variation of Organic Carbon in the Northeast Gulf of Mexico

All particulate and dissolved organic carbon data collected by this study are tabulated in Table 7 in Appendix B. In order to standardize the data for

TABLE 1

COMPARISON OF PARTICULATE AND DISSOLVED ORGANIC CARBON DATA FROM THE GULF OF MEXICO

Source	POC mg/ℓ		DOC mg/ℓ	
	Range	Mean	Range	Mean
Fredericks and Sackett	.022-1.911	.214	.58-2.35	1.08
Maurer and Parker	NP	NP	1.0-3.7	NP
This Study (s)	.016-.470	.106 (.063)	.48-2.58	1.41 (.37)

NP - Not Presented

TABLE 2

PARTICULATE AND DISSOLVED ORGANIC CARBON BY STATION
(at 10 m in mg/ℓ)

Station	Jun/Jul 1975 POC	Jun/Jul 1975 DOC	Sep/Oct 1975 POC	Sep/Oct 1975 DOC	Jan/Feb 1976 POC	Jan/Feb 1976 DOC
1101	0.130	2.58	0.221	1.61	0.208	2.38
1102	0.086	1.35	0.070	0.80	0.120	2.47
1103	0.030	0.71	0.056	0.48	0.094	1.68
1204	0.112	1.25	0.111	1.42	0.138	2.18
1205	0.122	1.21	0.151	1.09	0.086	1.93
1206	0.086	0.96	0.080	1.25	0.149	1.77
1207	0.119	0.56	0.067	0.89	0.163	1.67
1308	0.217	0.62	0.102	0.94	0.127	1.71
1309	0.162	1.11	0.039	0.94	0.071	1.87
1310	0.116	1.36	0.030	1.19	0.079	1.86
1311	0.145	1.09	0.026	0.93	0.063	1.89
1412	0.470	1.05	0.112	1.75	0.236	2.71
1413	0.151	0.93	0.112	1.35	0.089	1.68
1414	0.183	1.31	0.043	1.22	0.077	1.95
1415	0.171	1.89	0.036	0.89	0.190	2.33
$\bar{x}$	0.153	1.20	0.084	1.12	0.126	2.01
s	0.099	0.51	0.053	0.33	0.054	0.33

comparison of spatial and temporal variations only those samples taken at ten meters depth, which are common to all stations and all seasons, are usually considered in those sections dealing with organic carbon data only. The data for ten meters are presented in Table 2.

The most obvious feature of the data presented in Table 2 is the seasonal variation of both the particulate and dissolved fractions when the mean values of these components within each sampling period are considered. This cyclical pattern is graphically depicted in Figure 2. Trends in particulate organic carbon exhibit a maximum in the early summer, a minimum during the early fall, and an intermediate level during the winter. A statistical comparison using the entire data set for the sampling periods shows that at $p = 0.05$ the fall sampling period mean was lower than either of the values for the other seasons. The summer and winter periods were statistically equivalent.

Examining the group mean of each sampling period, the dissolved organic carbon also exhibits a trend in seasonal variability. DOC was lowest in the fall and highest during the winter. In fact, the high winter DOC values are an evident feature of the individual data in Table 2. Of the 15 stations 14 have their highest DOC levels during the winter sampling period. Statistically the summer and fall data sets were equivalent, with the winter level being significantly higher than either of the others.

An examination of the data of Table 2 shows that the seasonal observations which have been made are the result of working with the mean levels of each of the carbon components. The individual stations do not consistently display the previously noted variations. For POC, 11 of the 15 stations have their minimum level during the fall period while for DOC, 14 of the 15 stations

display their maximum level during the winter. Therefore, several grouped divisions of the data were made for a more precise seasonal comparison.

Table 3 presents the results of grouping by assigning the stations to depth zones in the following manner. The inshore group represents the mean levels of POC and DOC of Stations 1101, 1204, 1205, 1308 and 1412 within each sampling period. The depth range of these stations was approximately 0 to 15 m. Similar mean values are presented in the intermediate group which comprises Stations 1102, 1206, 1207, 1309, and 1413 with an approximate depth range to 43 m. In like fashion the offshore group represents Stations 1103, 1310, 1311, 1414, and 1415 with a depth range to 350 m. These depth zones are geographically depicted in Figure 3.

The averages in Table 3 indicate that, at all depth zones, the lowest POC values do indeed occur during the fall with the other seasons roughly equivalent as was the case when the total Northeast Gulf was considered. Statistically however, only the intermediate and offshore depth groups can be said to follow this pattern, as POC mean levels along the inshore division were equivalent throughout the year. This result suggests a greater year around uniformity of the distribution of the particulate fraction in near shore environments relative to the offshore in the Northeast Gulf.

With respect to the dissolved organic carbon, statistical analysis demonstrates that the highest levels for all depth zones exist during the winter period with roughly equivalent levels for the other two seasons sampled. The noted summer-fall equality and winter maximum for DOC also appears to hold when the distance from shore along the shelf is considered.

In addition to grouping by depth zones the stations were also considered

by individual transect. The relative locations of the transects are presented in Figure 3, and the sampling period means for particulate and dissolved organic carbon, by transect, are found in Table 4.

Statistically ($p = 0.05$) the seasonal POC means for individual transects do not follow the overall Northeastern Gulf distribution for any of the transects, although the two western Transects III and IV are closer to it than the two eastern transects. The mean level of particulate organic carbon was determined to be statistically equivalent between seasons along I and II Transects. Along Transect III, a relatively high level of POC was found in the summer with the remaining two sampling periods having similar, but lower, mean values. Along Transect IV the highest value occurred in the summer period and the lowest in the fall. Thus, while none of the transects match the seasonal variation of overall Gulf means exactly, Transect IV provides the closest approximation with a gradual change to an equality of means across the seasons as one moves towards the eastern transects. There is certainly the possibility, looking only at the absolute numerical values, that Transect I may actually represent an entirely different seasonal distribution pattern which has its minimum in the summer rather than in the fall. However, since only three stations are considered on Transect I, a more comprehensive sampling program would be required to support this observation.

The seasonal variation of dissolved organic carbon (Table 4) is much easier to interpret than it was with respect to POC. In most cases the transects had significantly higher mean DOC levels during the winter with the fall and summer sampling periods being lower and statistically equivalent. The sole exception to this was an intermediate summer level along Transect I which was

determined statistically not to differ from either the fall or winter mean levels. Thus it appears, with only slight variation, that the seasonal distribution of the mean values for dissolved organic carbon along each transect approximates the seasonal distribution for DOC over the entire Northeast Gulf.

From the preceding statistical manipulations some general observations may be made. First, while a distinct seasonal pattern of particulate organic carbon variability emerges when all stations in the Northeast Gulf of Mexico are considered in toto, the use of only such aggregate comparisons may obscure differences which may actually exist when either different depths of shelf waters representing different distances from shore or different transects are examined.

A second observation is that the seasonal variability of dissolved organic carbon was remarkably uniform throughout the study area. A consideration of three depth zones, of each transect individually, and of all stations together produced a virtually identical model of seasonal fluctuation.

Spatial Variation of Organic Carbon in the Northeast Gulf of Mexico

In order to assess the effect of location on the variability of organic carbon levels in the Northeast Gulf of Mexico the data was considered by depth zones (Table 3, Figure 3), by transect (Table 4, Figure 3), and by individual stations (Table 1, Figures 4, 5, and 6). These categories are identical to those of the previous section.

The depth zone data (Table 3) exhibits trends that, in all seasons, indicate that the particulate organic carbon declines in the transition from

inshore to offshore. However, only the POC mean levels for the fall sampling period displayed a statistically significant decline from the inshore to offshore zones. While this POC gradient is not unexpected in shelf areas proximate to terrestrial sources of organic carbon it was not noted by Fredericks and Sackett (1970) in their study of organic carbon in Western Gulf waters.

In contrast to particulate organic carbon the dissolved fraction does not appear to exhibit any pronounced pattern in any of the three sampling periods. A possible exception to this might be the slight inshore to offshore gradient for the fall period DOC. Statistically, however, the means were found to be equivalent within each of the three sampling periods across the three depth zones. This is in contrast to the work of Fredericks and Sackett (1970) who reported a consistent decline in the levels of DOC to the edge of the continental shelf.

When the particulate organic carbon data for the transects are compared, within each seasonal period, no significant statistical differences are found between any of the mean values of Table 4. This is in spite of the fact that it appears, numerically, that the eastern I and II and western III and IV sampling areas register different POC levels during both the summer and fall periods. Comparing these transects by eastern and western groups did show that combined Transects I and II had a significantly lower POC level than combined Transects III and IV during the summer season. The other two sampling periods displayed an equivalence of POC levels using this scheme. For particulate organic carbon, although no statistical differences could be shown with the limited existing data, the noted trends suggest that the possibility that the eastern and western regions of the study area might be displaying different

levels during the summer and fall and similar levels during the winter ought not to be excluded.

Statistical analysis of the DOC data by transect within each sampling period does not detect any apparent trends indicating that dissolved organic carbon does not vary significantly from transect to transect for any one season.

In order to examine more precisely the spatial variation of POC and DOC along each transect the individual stations for each sampling period were compared. The statistically significant results of this evaluation are depicted in Figures 4, 5, and 6.

Looking first at POC, the stations exhibit more variability in the summer (Figure 4) and fall (Figure 5) than in the winter (Figure 6). It is only during the winter that particulate organic carbon displays the same trend across every transect; there is a decrease moving from the most inshore to the next adjacent offshore station. No other adjacent stations on any of the winter transects display any differences. Neither the fall nor summer follow the same pattern as the winter. In both of these seasons POC does seem to show a somewhat general decline moving offshore, but each transect and each season has its own unique pattern. Across all sampling periods POC consistently declines from Stations 1101 to 1102 and from 1308 to 1309. During the summer and fall consistent declines are registered from Stations 1205 to 1206 and from 1308 to 1310.

Like the particulate component the dissolved organic carbon appears more variable in the summer and fall than in the winter when it is remarkably uniform over the whole of the sampled shelf area. By contrast, in the variable seasons

of summer and fall each transect develops its own unique DOC gradient. The entire Transect I has a consistent gradient from inshore during both summer and fall. Transect II shows a decline in both summer and fall from Station 1206 to Station 1207, but this appears to be coupled with bands of maximum and minimum DOC in the fall. Still another pattern is evident along Transect III which has a consistent summer/fall maximum at Station 1310. Unlike any of the others, Transect IV almost completely reverses its gradient between summer and fall.

Fredericks and Sackett (1970) observed a consistent decline in DOC as one moved offshore to the edge of the shelf in the Western Gulf. Maurer and Parker (1972) found persistent alternating bands of maximum and minimum DOC as they sampled towards deeper water off Texas. Clearly either of these findings is applicable to the Northeastern Gulf shelf at certain times along certain transects, but neither adequately describes any location in this study on a seasonal or annual basis. Each transect in each sampling period was found to be unique, although the winter was a period of remarkable uniformity.

No simple model seems evident to explain the spatial variation of organic carbon along the Northeastern Gulf shelf. Grouping the data by depth zones suggests that POC undergoes an overall decline towards offshore although this was supported statistically for only one sampling period. The transect groupings indicated that perhaps POC in the eastern and western areas behaved in different fashions, but this finding could not be substantiated statistically. In contrast to POC the DOC was remarkably uniform, within sampling periods, whether depth zones or transects were considered. Examining the relationships of adjacent stations to one another along each transect served to emphasize the

different trends, perhaps reflective of different processes, occurring in specific regions of the Northeast Gulf.

The Relationship of Organic Carbon to Other Oceanographic Parameters

On the same cruises which produced the organic carbon data other investigators examined additional oceanographic parameters. These included phytoplankton cholorophyll a and primary productivity, zooplankton displacement volume, STD profiles for temperature and salinity, transmissometry, and dissolved nutrients (PO_4, NO_3, NO_2). Data on these parameters which were utilized for the purpose of comparison are presented in Tables 8 through 12 in Appendix B. Additionally, some POC and DOC samples were taken from the depth of one percent light at many of the stations in all seasons. All organic carbon data collected for this study are presented in Table 7 in Appendix B. In examining the relationship between parameters all available data points were considered.

Two different approaches were used to consider possible relationships between dissolved and particulate organic carbon and other oceanographic variables. The first technique was the graphical depiction of mean levels across the sampling year. The second was the determination of simple linear correlation coefficients for all variables with POC and DOC as the dependent variables. Both of these approaches included an examination with respect to both seasonal and spatial considerations. Analysis of the data included consideration by transect and depth zones as discussed in previous chapters.

Figures 7 through 10 graphically present the mean levels of DOC, POC chlorophyll a, primary productivity, and zooplankton displacement volume over the sampling year for the total Gulf of Mexico and for the subdivisions by

depth zones. Identical scales are employed for each of these figures. Any interpretation of the information presented in these figures must be performed cautiously because of the limited number of data points and the (typically) high variability exhibited by the biological variables which make an effective statistical examination of the data difficult.

Within these limitations some trends appear to be evident. In general, the data shown in Figures 7 through 10 appear to fluctuate together throughout the year. The high winter levels for some quantities, notably chlorophyll a and primary productivity, in many of the group categories appear to be at variance with conventional interpretations of seasonal succession patterns; normal expectation being a low winter level.

It is generally accepted that living organisms make variable and significant contributions to the particulate fraction by their presence and to the dissolved fraction by their metabolic products (Riley and Chester, 1971). Thus, in discussing possible interpretations of Figures 7 through 10, POC has been related to chlorophyll and zooplankton and DOC to primary productivity.

Considering first the total Gulf shelf area under study (Figure 7) it is apparent that the seasonal fluctuations of dissolved organic carbon and primary productivity are similar. Likewise the relative levels of particulate organic carbon and chlorophyll a follow one another closely. Zooplankton varies with POC in the summer-fall measurements, but not into the winter. In previous sections it has been shown that the DOC and POC curves do, in fact, indicate statistically significant seasonal differences. Unfortunately the high variability of the other parameters (see Tables 8 and 9, Appendix B) do not allow similar statistical distinctions to be drawn for these variables.

Figure 7 does suggest that, over the Northeastern Gulf shelf, in situ biological processes may be exerting an influence on the observed levels of POC and DOC.

Aggregating data for the entire shelf may obscure different processes occurring in other shelf areas. Figures 8, 9, and 10, which present the seasonal fluctuations for all parameters by depth zone groupings, suggest that this is the case. Inshore (Figure 9), as with the total shelf (Figure 7), trends for primary productivity and dissolved organic carbon vary in a similar manner. Unlike the total shelf, the chlorophyll trend parallels the zooplankton measurements from the fall to the winter sampling period suggesting that, inshore, other factors may strongly influence the levels of particulate organic carbon during this time period. These processes may include exchange or mixing with sediments or effects from land runoff. The intermediate and offshore zones (Figures 9 and 10) follow the general pattern of trends for the total shelf (Figure 7).

Considering the seasonal mean levels of all the parameters under consideration by transects reenforces the concept that each area of the Gulf represents different combinations of processes and interactions between the parameters. Data from along Transect III suggests that this region is quite similar to the entire Gulf shelf study area as depicted in Figure 7 and previously discussed. Transect IV follows the general trend pattern established for the total shelf (Figure 7), but is an area of extreme seasonal fluctuation undoubtedly heavily influenced by the Mobile Bay and Mississippi River systems. The lack of clearly identifiable patterns along Transects I and II indicates that processes other than those in situ biological ones examined may be largely

responsible for the seasonal fluctuations of POC and DOC. Along Transect I the influence of human activity from heavily populated coastal areas is probably evident while the relatively shallow Transect II reflects the fluctuating inputs from the extensive coastal marsh and seagrass systems in this region.

Although limited by its high variability, one method of assessing the contribution of phytoplankton to particulate carbon levels has been the determination of carbon to chlorophyll ratios (Steele and Baird, 1961; Steele and Baird, 1962). For this study, over the total Northeastern Gulf shelf, the carbon to chorophyll ratios varied throughout the year from 95:1 in the summer, 44:1 in the fall, to 69:1 during the winter. This suggests that the phytoplankton make the most significant percentage contribution to particulate organic carbon during the fall.

A means of examining the temporal relationships of these parameters more closely is to focus on each of the sampling periods rather than across the entire year. This has been done through a series of linear regression analyses which employed the following procedures. The ten meter organic carbon determinations were compared with either the surface or the closest to ten meter phytoplankton/nutrient hydrocast. The one percent light level organic carbon determinations compare exactly with the phytoplankton/nutrient hydrocasts. Exact individual station depths may be found in Tables 7 and 8 of Appendix B. Separate analyses by depth (10 m vs one percent light level) supported the validity of this technique; the significance of regressions was not affected by employing this approximation. Salinity and temperature regressions with organic carbon were precise depth matches in almost all instances. Since zooplankton tows fished the entire water column, upper and lower organic

carbon determinations were averaged for purposes of regression analysis. Transmissometry and organic carbon matched exactly in depth at ten meters.

Regression analysis was performed using all variables with particulate and dissolved organic carbon as the independent variable. Table 5 summarizes the significant ($p = 0.05$) correlations. Regressions for depth zones are based on few points and should be considered with caution. Figures 11 through 19 of Appendix C present scattergrams for chlorophyll a, primary productivity, and zooplankton against POC and DOC respectively.

The data of Table 5 permits a closer examination of the relationships suggested by Figures 7 through 10. Immediately evident is the fact that, over the Northeastern Gulf shelf, particulate organic carbon correlates well with chlorophyll a during the summer and fall sampling periods. Further, the supportive correlation coefficients for the depth zones for chlorophyll in these two time categories suggest that it is the areas closest to shore which exhibit the strongest relationship between phytoplankton and particulate carbon. These associations have been noted by other investigators (Menzel and Goering, 1965; Parsons and Strickland, 1959).

During summer and fall, the zooplankton also show good correlations with POC. The significant inshore correlation coefficients in support of those for the total shelf, probably indicate that the zooplankton are related to the particulate organic material primarily through the necessity to feed on phytoplankton. In fact, since zooplankton will usually contribute only a few percent to the actual POC present, the correlations between POC and zooplankton may be taken as a further indication of a more direct relationship between the particulate fraction and phytoplankton. The scattered, inconclusive correlations between POC and primary productivity may be related to zooplankton

grazing pressure. The limited winter relationships between POC, chlorophyll and primary productivity in the absence of any zooplankton correlation appear to sustain this contention.

Particulate organic carbon relates weakly to salinity in the fall but this relationship is more pronounced during winter. The salinity data of Table 10 show the inshore to offshore salinity increase is most pronounced during the winter months. This would have the effect of making any consistent decline in POC as the result of dilution offshore appear more evident. Recalling Figure 6, which noted the immediate offshore winter decline in the levels of particulate organic material, and observing that chlorophyll correlates well with POC during the winter inshore, it would appear that the processes affecting POC are fairly similar throughout the year along the Northeast Gulf shelf. Thus the data suggests that the current-salinity structure rather than some change in the source of POC is responsible for the salinity correlations during the fall and winter sampling periods.

Unlike POC, the results of this study cannot link the dissolved fraction to in situ biological processes. Correlations for DOC recorded in Table 5 are absent or weak. The apparently strong correlation with primary productivity during the winter is based upon only five data points. The weak salinity correlations during the fall and winter, reflecting simple dilution in the open Gulf, are, as with POC, the result of a more organized inshore to offshore salinity gradient during these seasons. No significant correlations between particulate or dissolved organic carbon and any of the other parameters were found.

The strong and consistent correlations found throughout the year between particulate organic carbon and chlorophyll and the concurrent fluctuations of

these two quantities over the entire shelf study area (Figure 7) indicate that the phytoplankton comprise a significant portion of the POC in this region. Considering the entire Gulf of Mexico, Dryer (1973) estimated that phytoplankton contributed 38 times the amount of terrestrially derived POC. When dealing with the shelf this estimate would undoubtedly have to be revised downward because of the proximity to terrestrial inputs. Knauer (1976), working during the summer of 1974 in the same Northeastern Gulf shelf area as this study, found by ATP extraction that an average of 50% of the particulate organic carbon was living. Thus the present finding that phytoplankton strongly influence the levels of particulate organic carbon along the Northeast Gulf coast shelf appears to find support in several separate studies.

Dryer (1973) found that terrestrial DOC inputs were the major controlling influence on near shore Gulf of Mexico DOC concentrations. The decline of this influence was marked by a pronounced dissolved organic carbon gradient related to salinity in estuarine areas. Further, Dryer calculated that the total contributions to the DOC of the entire Gulf of Mexico from primary production and river inputs were approximately equal.

If the measure of chlorophyll does in fact provide an indirect measure of approximately 50% of the particulate organic material as Knauer has suggested with ATP extraction, then the relationships established are between quantities on the same order of magnitude. In attempting to link dissolved organic carbon with primary productivity, however, additional considerations are involved. The reservoir of DOC represents a pool of material while the primary productivity is a rate quantity three orders of magnitude smaller (see Tables 7 and 8). A reliable estimate is that only about 10% of the photoassimilated carbon is added to the dissolved pool directly as excretion (Hellebust, 1965). This

suggests that the annual relationships depicted in Figures 7 through 10 may exist but be undetectable by the comparisons of Table 5. Certainly the unique station to station variations of Figures 4 through 6 and the absence of the inshore to offshore gradient noted by Fredericks and Sackett (1970) are indications that in situ processes are important to the observed levels of DOC.

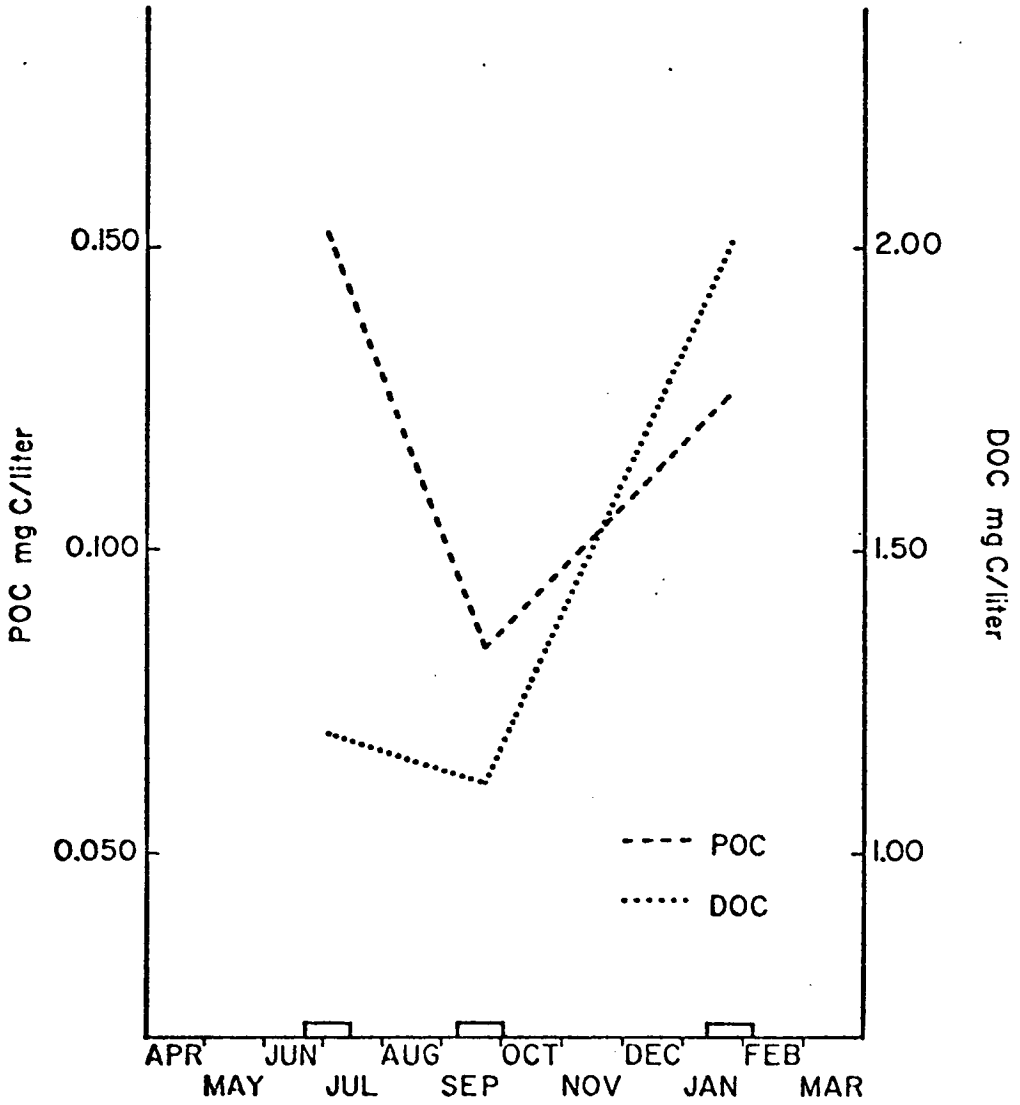

Figure 2. -- Temporal Variation of Organic Carbon in the Northeast Gulf of Mexico at ten meters depth

TABLE 3

PARTICULATE AND DISSOLVED ORGANIC CARBON BY DEPTH ZONES FOR THE NORTHEASTERN GULF OF MEXICO (at 10 m in mg/ℓ)

Zone	Jun/Jul 1975 POC	Jun/Jul 1975 DOC	Sep/Oct 1975 POC	Sep/Oct 1975 DOC	Jan/Feb 1976 POC	Jan/Feb 1976 DOC
1	.210	1.34	.139	1.36	.159	2.18
(s)	(.151)	(0.74)	(.049)	(0.34)	(.061)	(0.39)
2	.121	0.98	.074	1.05	.118	1.89
(s)	(.036)	(0.29)	(.026)	(0.24)	(.039)	(0.33)
3	.129	1.27	.038	0.94	.101	1.94
(s)	(.061)	(0.43)	(.012)	(0.29)	(.051)	(0.24)

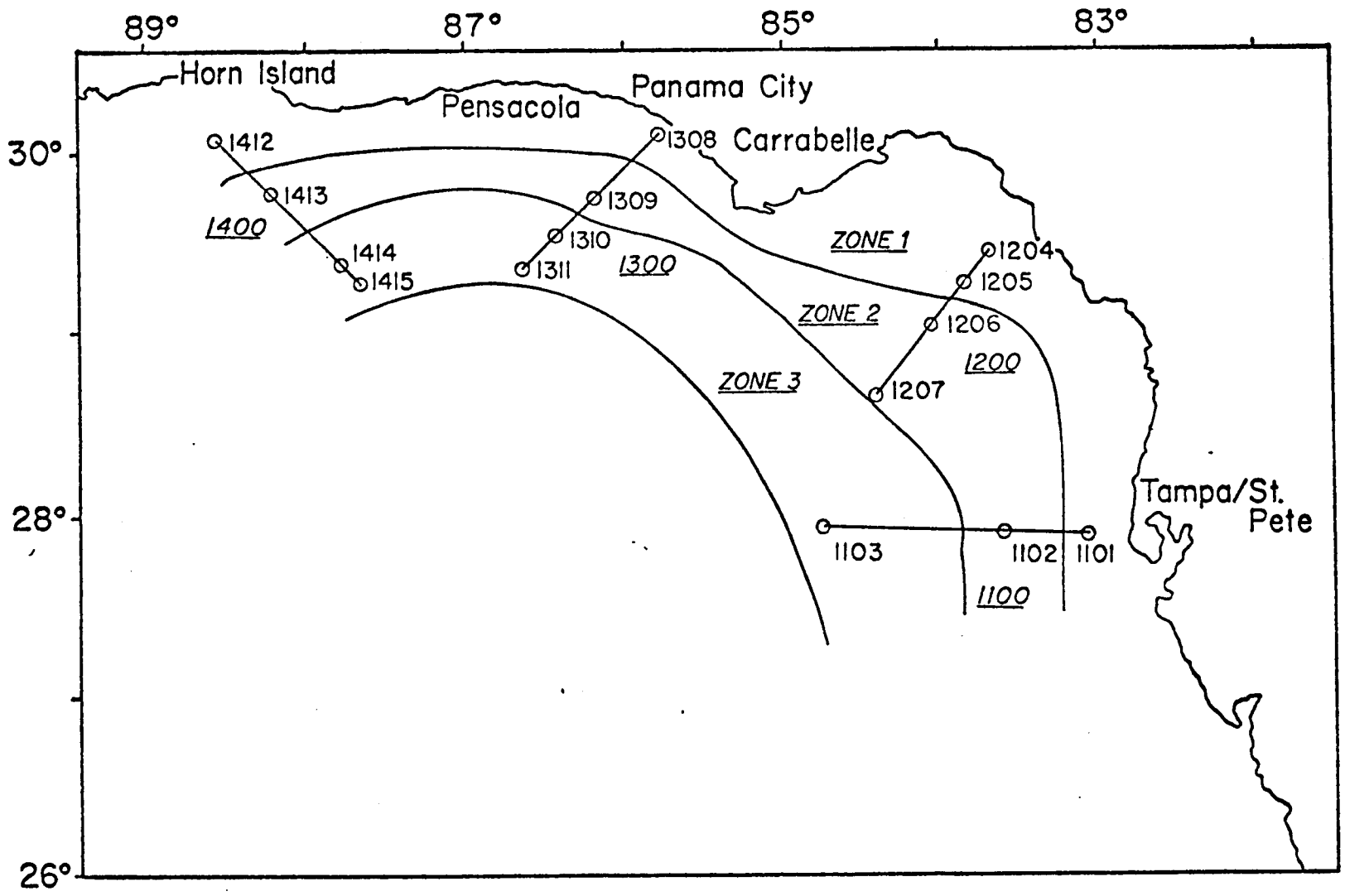
89°
87°
85°
83°
30°
28°
26°
Horn Island
Pensacola
Panama City
Carrabelle
1412
1413
1414
1415
1308
1309
1310
1311
1400
1300
ZONE 1
ZONE 2
ZONE 3
1204
1205
1206
1207
1200
1100
1103
1102
1101
Tampa/St.
Pete

TABLE 4

PARTICULATE AND DISSOLVED ORGANIC CARBON BY TRANSECT AND SEASON (at 10 m in mg/ℓ)

Transect	Jun/Jul 1975 POC	Jun/Jul 1975 DOC	Sep/Oct 1975 POC	Sep/Oct 1975 DOC	Jan/Feb 1976 POC	Jan/Feb 1976 DOC
1100	.082	1.55	.116	0.96	.141	2.18
(s)	(.050)	(0.95)	(.091)	(0.58)	(.060)	(0.43)
1200	.110	1.00	.102	1.16	.134	1.89
(s)	(.016)	(0.32)	(.037)	(0.23)	(.034)	(0.22)
1300	.160	1.05	.049	1.00	.085	1.84
(s)	(.042)	(0.31)	(.036)	(0.13)	(.029)	(0.08)
1400	.244	1.30	.076	1.30	.148	2.17
(s)	(.151)	(0.43)	(.042)	(0.36)	(.078)	(0.45)

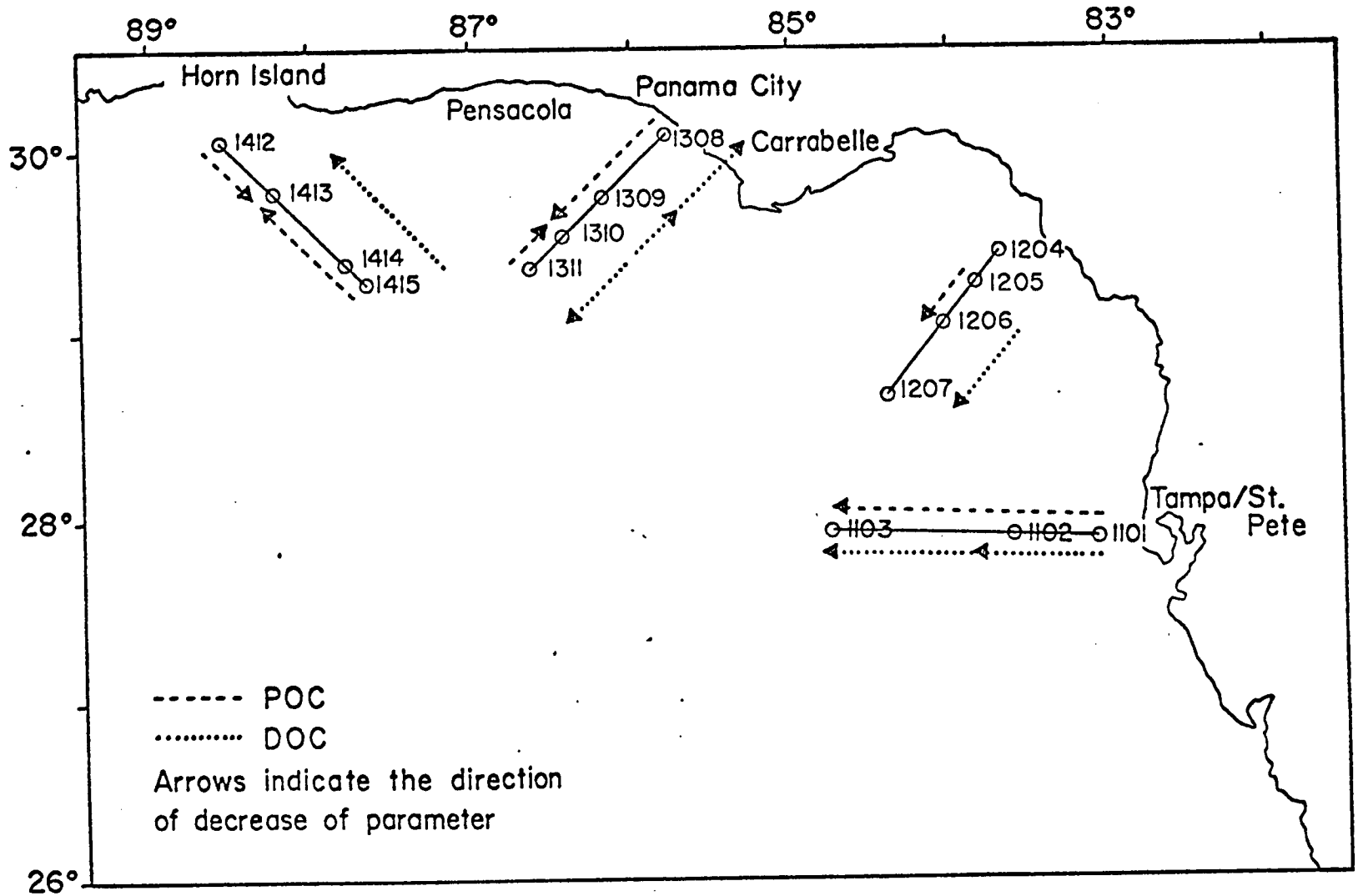

Figure 4.-- Spatial Variation of Organic Carbon in the Northeast Gulf of Mexico, Summer 1975

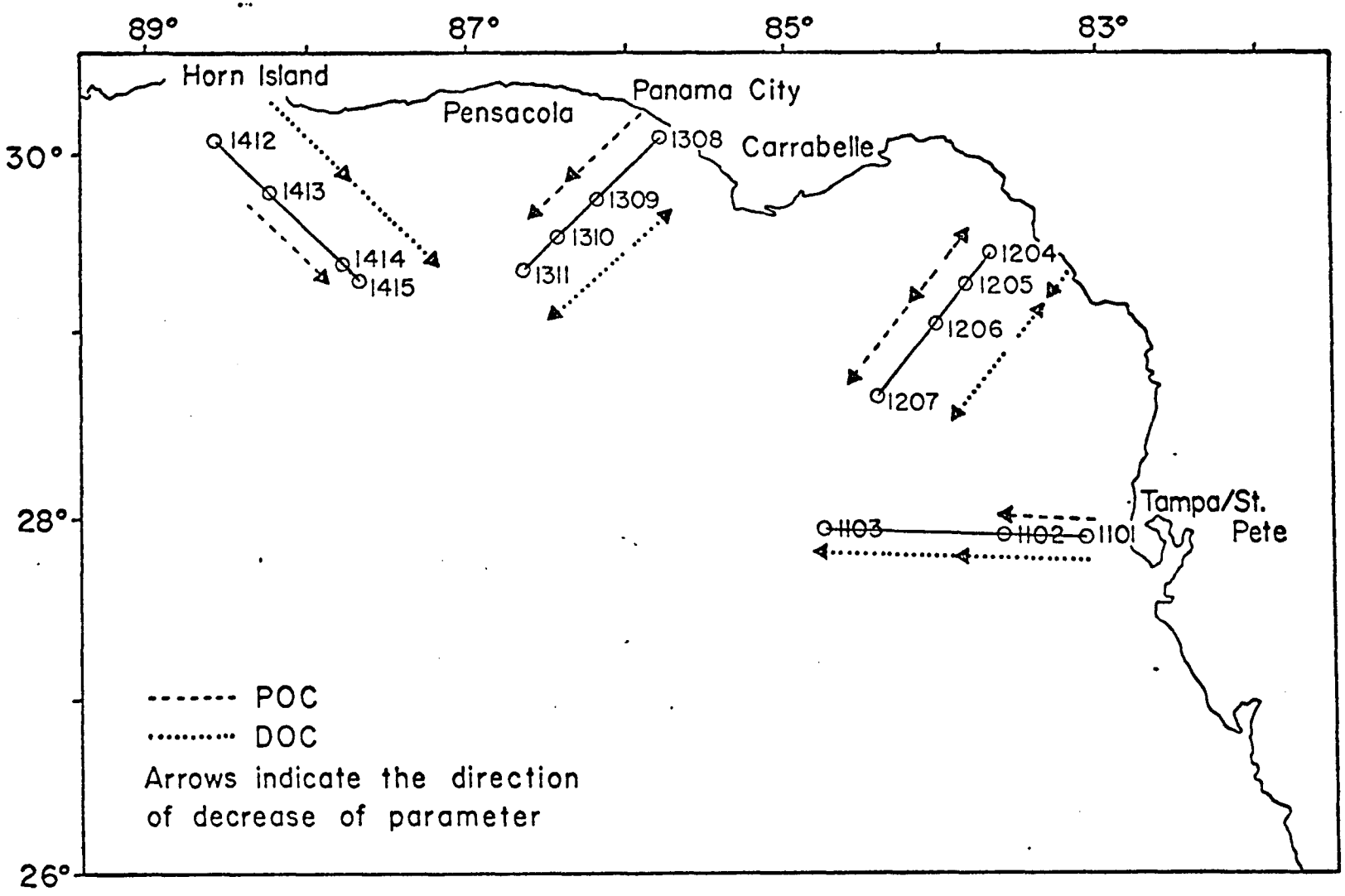

Figure 5.-- Spatial Variation of Organic Carbon in the Northeast Gulf of Mexico, Fall 1975

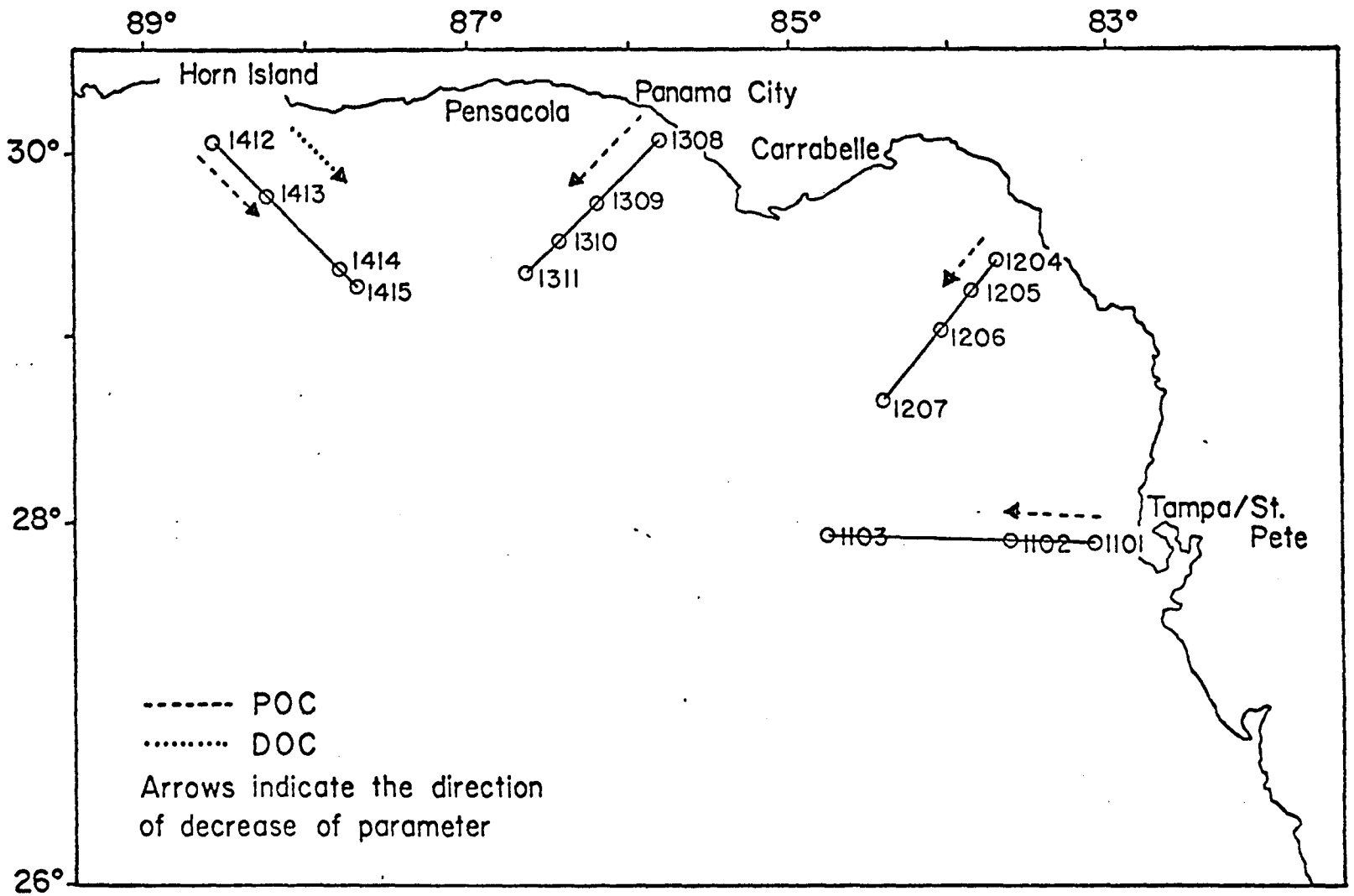

Figure 6.-- Spatial Variation of Organic Carbon in the Northeast Gulf of Mexico, Winter 1976

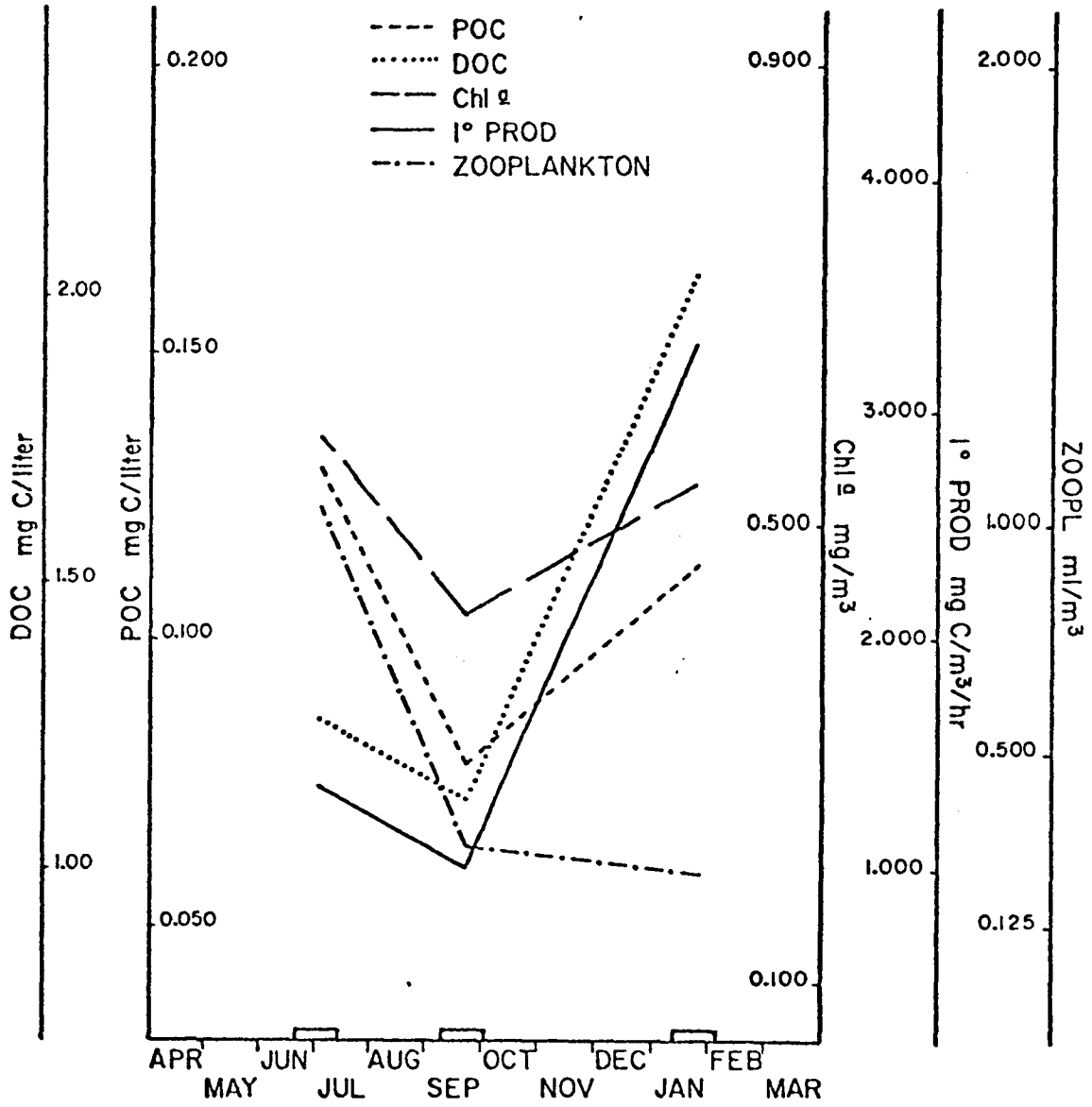

Figure 7.--Temporal Variation of Organic Carbon, Chlorophyll, Primary Productivity, and Zooplankton Over the Continental Shelf of the Northeast Gulf of Mexico

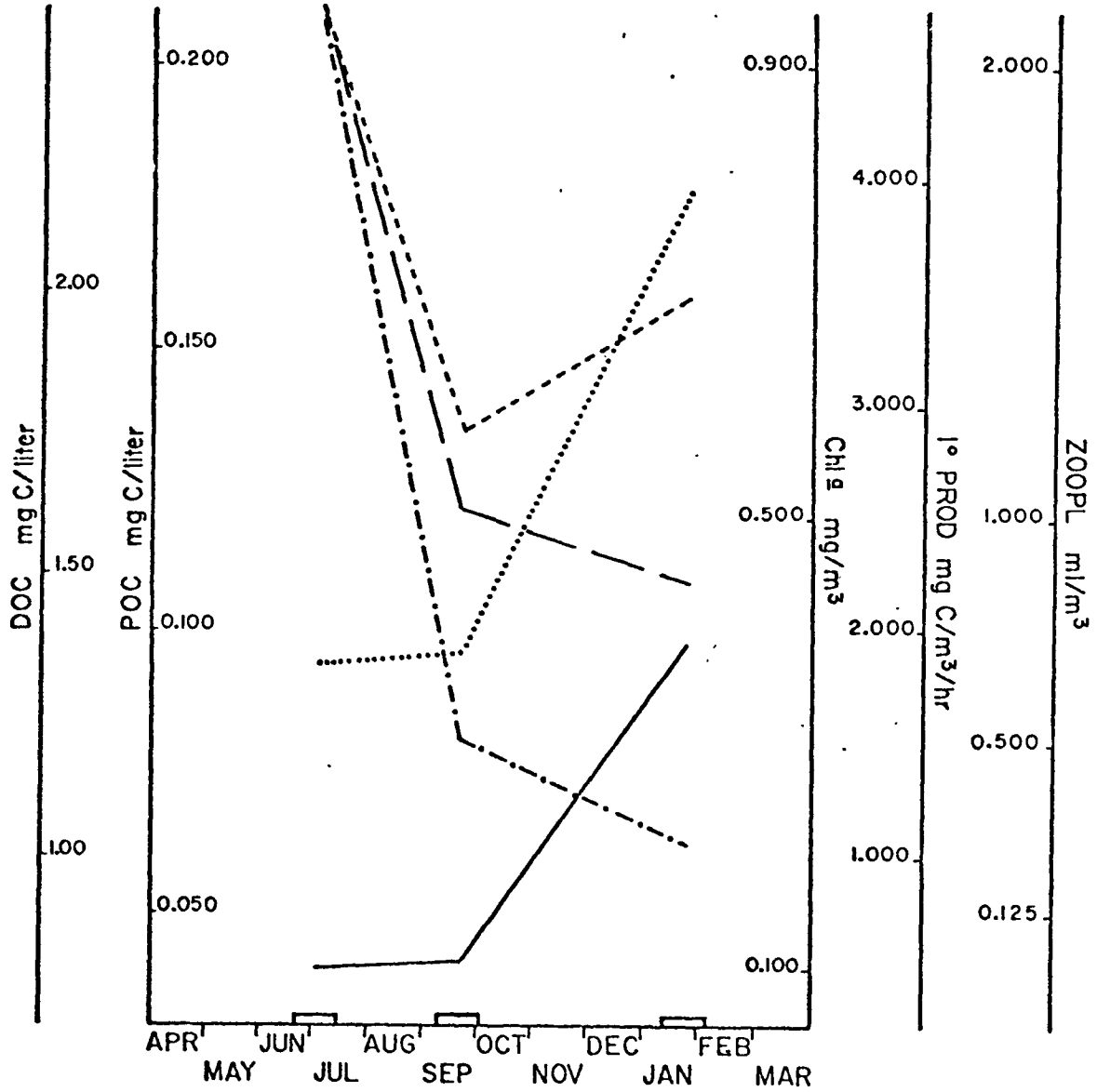

Figure 8.--Temporal Variation of Organic Carbon, Chlorophyll, Primary Productivity, and Zooplankton - Depth Zone 1

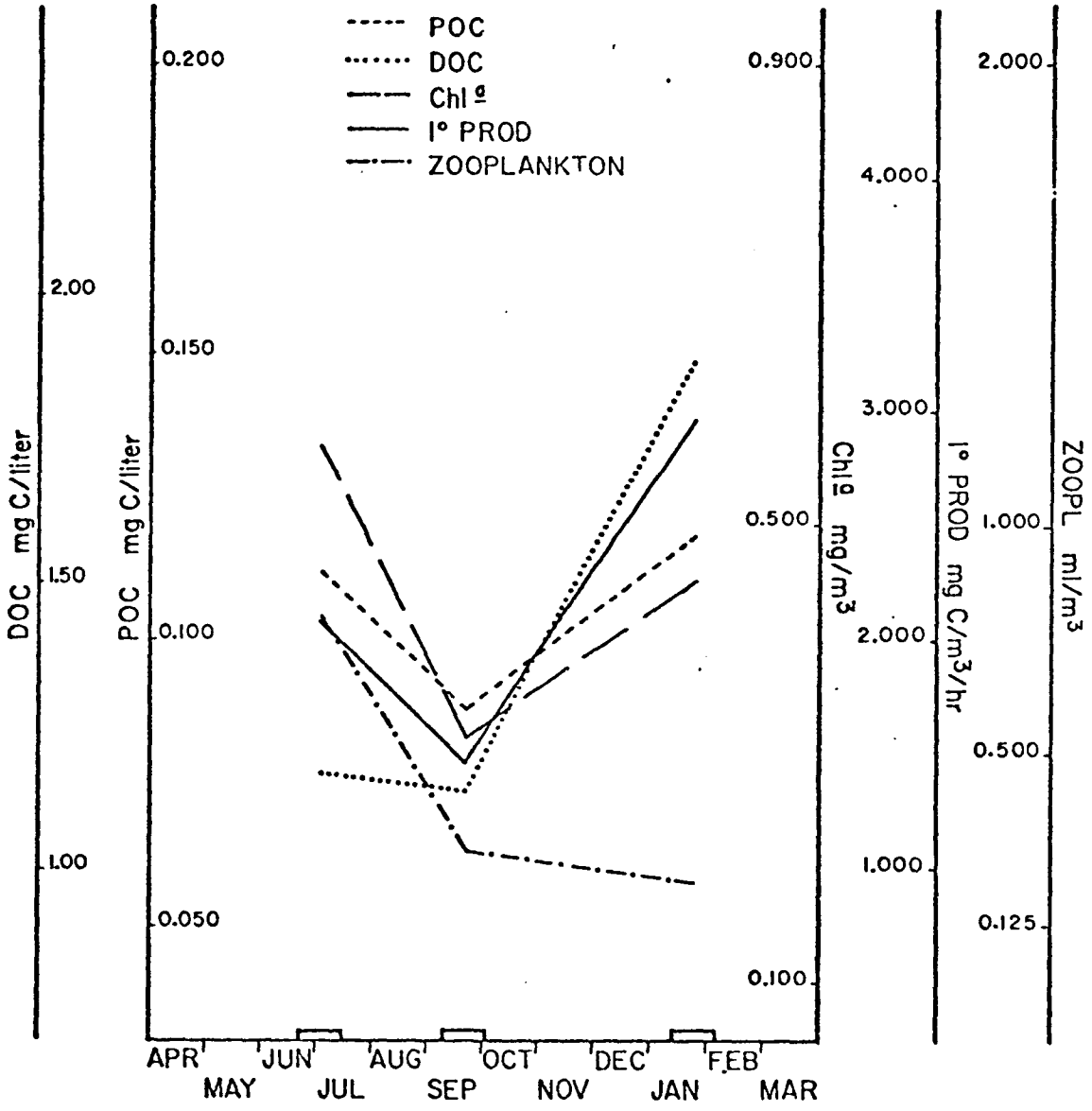

Figure 9.-- Temporal Variation of Organic Carbon, Chlorophyll, Primary Productivity, and Zooplankton - Depth Zone 2

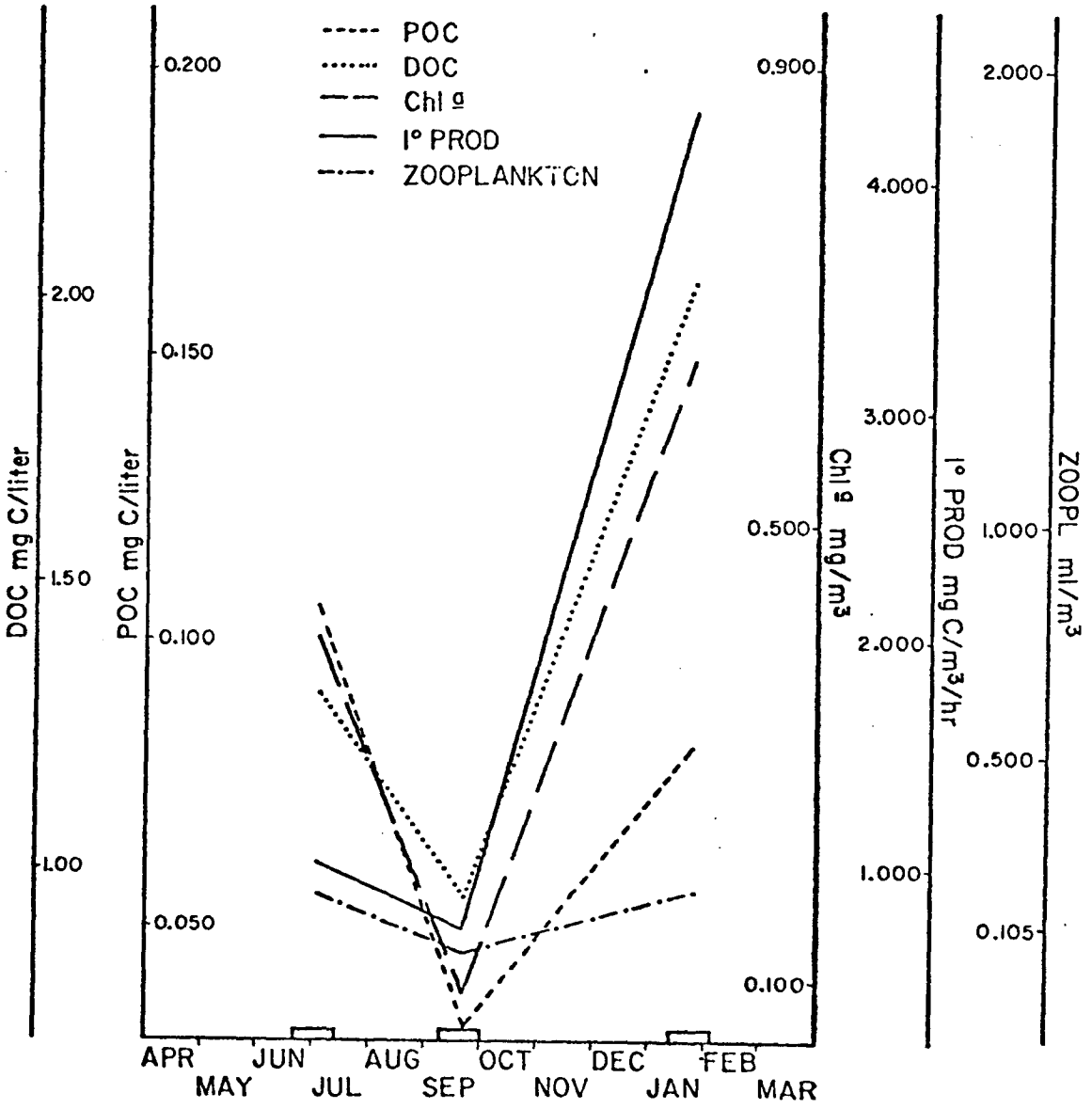

Figure 10.-- Temporal Variation of Organic Carbon, Chlorophyll, Primary Productivity, and Zooplankton - Depth Zone 3

TABLE 5

SIGNIFICANT r^2 VALUES OF LINEAR REGRESSION ANALYSIS

Variable	Region	Jun/Jul 1975 POC	Jun/Jul 1975 DOC	Sep/Oct 1975 POC	Sep/Oct 1975 DOC	Jan/Feb 1976 POC	Jan/Feb 1976 DOC
Chl *a*	Shelf	0.70		0.57	0.18		
	Zone 1	0.98		0.86		0.97	
	Zone 2	0.44		0.46			
	Zone 3					0.72	
1° Prod	Shelf						
	Zone 1			0.79		0.86	0.89
	Zone 2						
	Zone 3	0.63		0.49		0.85	
Zoopl	Shelf	0.87		0.77	0.42		
	Zone 1	0.97		0.77			
	Zone 2						
	Zone 3			0.79			
Temp	Shelf					0.39	
Sal	Shelf			0.25	0.25	0.52	0.32
Trans	Shelf						
PO_4	Shelf						
NO_3	Shelf						
NO_2	Shelf						

Note: p = 0.05. All correlations are positive except temperature and salinity. Blank cells indicate no significant correlation with the exception of nutrients (winter) and transmissometry (summer) for which data was absent.

CONCLUSIONS

1. Both particulate and dissolved organic carbon were found to fluctuate seasonally over the shelf of the Northeastern Gulf of Mexico. POC reached the highest levels during the summer and winter and was at a minimum during the fall. DOC exhibited low levels during the summer and fall and was at a maximum during the winter. When different regions of the Gulf shelf were considered, POC was found to be more variable, following localized seasonal patterns, while DOC was found to be remarkably uniform throughout the study area.

2. Within each season the apparent levels of particulate and dissolved organic carbon were not generally found to differ statistically when distances from shore or transects were considered. An exception to this was a decline in POC immediately offshore during the fall. Tabulation of POC and DOC quantities did suggest that trends related to the spatial distribution of organic carbon may have existed but were statistically undetectable. Individual stations were found to exhibit no consistent discernable patterns throughout the year, although the winter was a period of uniformity for both POC and DOC throughout the shelf.

3. Levels of particulate carbon were closely related to phytoplankton standing stocks, as estimated by chlorophyll a, along the entire Northeastern Gulf shelf although the relationship is strongest near shore. Measured quantities of dissolved organic carbon could not be related to any of the parameters considered in this study.

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APPENDIX A

PRECISION AND STATISTICAL TREATMENT OF DATA

The precision of the analytical technique for the organic carbon determinations was based upon triplicate determinations for all samples. Table 6 provides the average standard deviations and precision at the 95% confidence limit for each of the seasonal sampling periods by category of determination.

Statistical analysis of data was performed using the Vogelback Computing Center, Northwestern University, Statistical Package for the Social Sciences (SPSS), version 6.00 of April 1, 1975.

TABLE 6

PRECISION OF ORGANIC CARBON DATA

	Jun/Jul 1975		Sep/Oct 1975		Jan/Feb 1976	
	POC	DOC	POC.	DOC	POC	DOC
Avg Standard Deviation	0.011	0.125	0.007	0.057	0.016	0.238
Avg 95% Conf Interval (±)	0.027	0.31	0.017	0.14	0.040	0.59

APPENDIX B

TABULATED DATA

TABLE 7

NORTHEASTERN GULF SHELF PARTICULATE AND DISSOLVED ORGANIC CARBON (mg/ℓ)

Station	z (m)	Jun/Jul 1975 POC	DOC	z (m)	Sep/Oct 1975 POC	DOC	z (m)	Jan/Feb 1976 POC	DOC
1101	10	.130	2.58	10	.221	1.61	10	.208	2.38
1102	10	.086	1.35	10	.070	0.80	10	.120	2.47
	30	.103	1.72	30	.106	1.94			
1103	10	.030	0.71	10	.056	0.48	10	.094	1.68
	102	.088	1.39	50	.032	0.87	54	.028	2.46
1204	10	.112	1.25	10	.111	1.42	10	.138	2.18
1205	10	.122	1.21	10	.151	1.09	10	.086	1.93
1206	10	.086	0.96	10	.080	1.25	10	.149	1.77
	24	.086	1.39	23	.107	0.97			
1207	10	.119	0.56	10	.067	0.89	10	.163	1.67
	32	.073	0.97	25	.104	1.10			
1308	10	.217	0.62	10	.102	0.94	10	.127	1.71
1309	10	.162	1.11	10	.039	0.94	10	.071	1.87
	50	.109	1.07	45	.104	1.31			
1310	10	.116	1.36	10	.030	1.19	10	.079	1.86
	59	.069	1.33	90	.032	0.97	67	.078	2.58
1311	10	.145	1.09	10	.026	0.93	10	.063	1.89
	86	.072	1.18	90	.016	0.71	53	.037	1.51
1412	10	.470	1.05	10	.112	1.75	10	.236	2.71
1413	10	.151	0.93	10	.112	1.35	10	.089	1.68
	31	.147	1.67	30	.088	0.88			
1414	10	.183	1.31	10	.043	1.22	10	.077	1.95
				65	.034	1.15			
1415	10	.171	1.89	10	.036	0.89	10	.190	2.33
	71	.081	1.49	90	.019	1.10			
$\bar{x}$		.130	1.26		.078	1.12		.113	2.04
s		.084	0.43		.048	0.32		.058	0.37

TABLE 8

PHYTOPLANKTON CHLOROPHYLL a (mg/m^3) AND PRIMARY PRODUCTIVITY ($mgC/m^3/hr$)

Station	z (m)	Jun/Jul 1975 CHL a	PROD	z (m)	Sep/Oct 1975 CHL a	PROD	z (m)	Jan/Feb 1976 CHL a	PROD
1101	15	0.100	0.691	12	4.313	2.112	12	0.677	3.026
1102	0	0.138	1.245	0	0.169	2.156	0	0.232	1.925
	30	0.850	0.772	30	0.761	0.653			
1103	0	0.390	0.546	0	0.110	1.912	0	0.425	6.026
	102	0.745	0.949	50	0.190	0.380	54	0.694	1.236
1204	12	0.223	0.617	10	0.391	0.516	10	0.325	1.477
1205	16	0.227	0.590	15	0.590	0.315	16	0.096	1.201
1206	0	0.137	1.857	0	0.124	1.763	0	0.208	1.267
	24	0.253	0.664	23	0.691	0.665			
1207	0	0.053	1.446	0	0.107	4.650	0	0.765	3.774
	32	0.191	0.129	25	0.446	1.863			
1308	15	0.707	0.303	14	0.640	0.487	14	0.387	0.813
1309	0	0.525	3.193	0	0.064	0.564	0	0.333	1.743
	48	0.531	0.206	45	0.398	0.147			
1310	0	0.090	1.883	0	0.039	0.584	0	0.593	2.563
	59	0.063	0.095	90	0.161	0.325	67	0.649	0.910
1311	0	0.256	1.224	0	0.035	1.013	0	0.293	1.953
	86	0.309	0.561	90	0.087	0.753	53	0.228	0.532
1412	12	3.482	0.333	14	0.567	0.142	12	0.754	3.244
1413	0	1.747	11.227	0	0.163	2.263	0	0.714	6.099
	31	1.115	0.113	29	0.239	0.110			
1414	0	1.012	2.302	0	0.041	0.773	0	0.573	6.751
				65	0.162	0.647			
1415	0	0.327	1.280	0	0.047	0.905	0	1.710	14.493
	71	0.452	0.365	90	0.057	0.071			
$\bar{x}$		0.580	1.358		0.423	1.002		0.536	3.280
s		0.740	2.238		0.825	1.018		0.363	3.388

TABLE 9

ZOOPLANKTON DISPLACEMENT VOLUME (ml/m^3)

Station	Jun/Jul 1975	Sep/Oct 1975	Jan/Feb 1976
1101	0.439	1.08	0.391
1102	0.573	0.188	
1103	0.063	0.094	0.277
1204	0.833	0.365	0.294
1205	1.04	0.261	0.115
1206	0.579	0.239	
1207	0.574	0.181	
1308	1.626	0.335	0.494
1309	0.171	0.169	0.277
1310	0.259	0.062	0.233
1311	0.115	0.044	0.094
1412	6.54	0.567	0.124
1413	2.13	0.687	0.171
1414	0.47	0.093	0.308
1415	0.08	0.031	0.0854
$\bar{x}$	1.033	0.293	0.239
s	1.631	0.288	0.127

Note: Fishing depth was the entire water column at each station.

TABLE 10

SALINITY (°/oo) AND TEMPERATURE (°C)

Station	z (m)	Jun/Jul 1975 T	S	z (m)	Sep/Oct 1975 T	S	z (m)	Jan/Feb 1976 T	S
1101	10	28.39	35.01	10	26.82	34.00	10	14.06	34.33
1102	10	28.13	35.50	10	27.06	35.40	10	15.89	36.18
	30	20.50	36.18	30	22.90	36.23			
1103	10	28.62	35.28	10	27.40	35.92	10	19.38	36.28
	102	20.00	35.60	50	24.79	36.32	50	19.34	36.28
1204	10	28.38	33.01	10	28.52	32.40	10	11.97	34.30
1205	10	28.41	32.07	10	26.91	32.98	10	14.30	35.80
1206	10	28.39	32.36	10	26.58	33.47	10	15.72	36.15
	24	21.44	35.84	23	25.00	35.80			
1207	10	28.20	31.54	10	26.06	34.78	10	17.59	36.23
	32	21.82	36.23	25	27.00	35.80			
1308	10	23.00	35.94	10	28.00	34.80	10	13.45	34.95
1309	10	28.62	32.20	10	29.54	35.00	10	19.50	36.23
	50	20.00	36.29	45	24.00	36.18			
1310	10	27.80	32.20	10	29.42	35.72	10	19.29	
	60	20.20	36.23	90	22.00	36.42	75	18.55	
1311	10	28.14	32.57	10	29.55	35.40	10	19.84	36.27
	86	19.23	36.40	90	21.62	36.36	50	19.82	36.27
1412	10	22.19	36.17	10	29.25	29.00	10	14.17	32.50
1413	10	27.45	35.63	10	28.86	30.20	10	17.50	35.45
	30	28.00	36.18	30	22.16	36.20			
1414	10	28.00	34.00	10	29.24	35.15	10	18.90	35.69
				65	22.18	36.39			
1415	10	27.90	35.00	10	29.25	35.31	10	18.19	34.60
	75	21.00	36.21	90	21.59	36.33			
$\bar{x}$		24.93	34.82		26.31	34.78		17.08	35.49
s		3.72	1.77		2.80	1.94		2.56	1.04

TABLE 11

TRANSMISSOMETRY
(%T over 1 m at 10 m depth)

Station	Jun/Jul 1975	Sep/Oct 1975	Jan/Feb 1976
1101		82.0	57.0
1102		91.0	49.5
1103		90.0	81.0
1204		59.5	84.0
1205		75.0	87.5
1206		88.0	74.5
1207		87.0	60.0
1308			65.0
1309			88.0
1310			90.0
1311			94.0
1412			56.0
1413			61.5
1414			79.0
1415			95.0
$\bar{x}$		83.1	74.8
s		11.0	15.3

APPENDIX C

SCATTERGRAMS

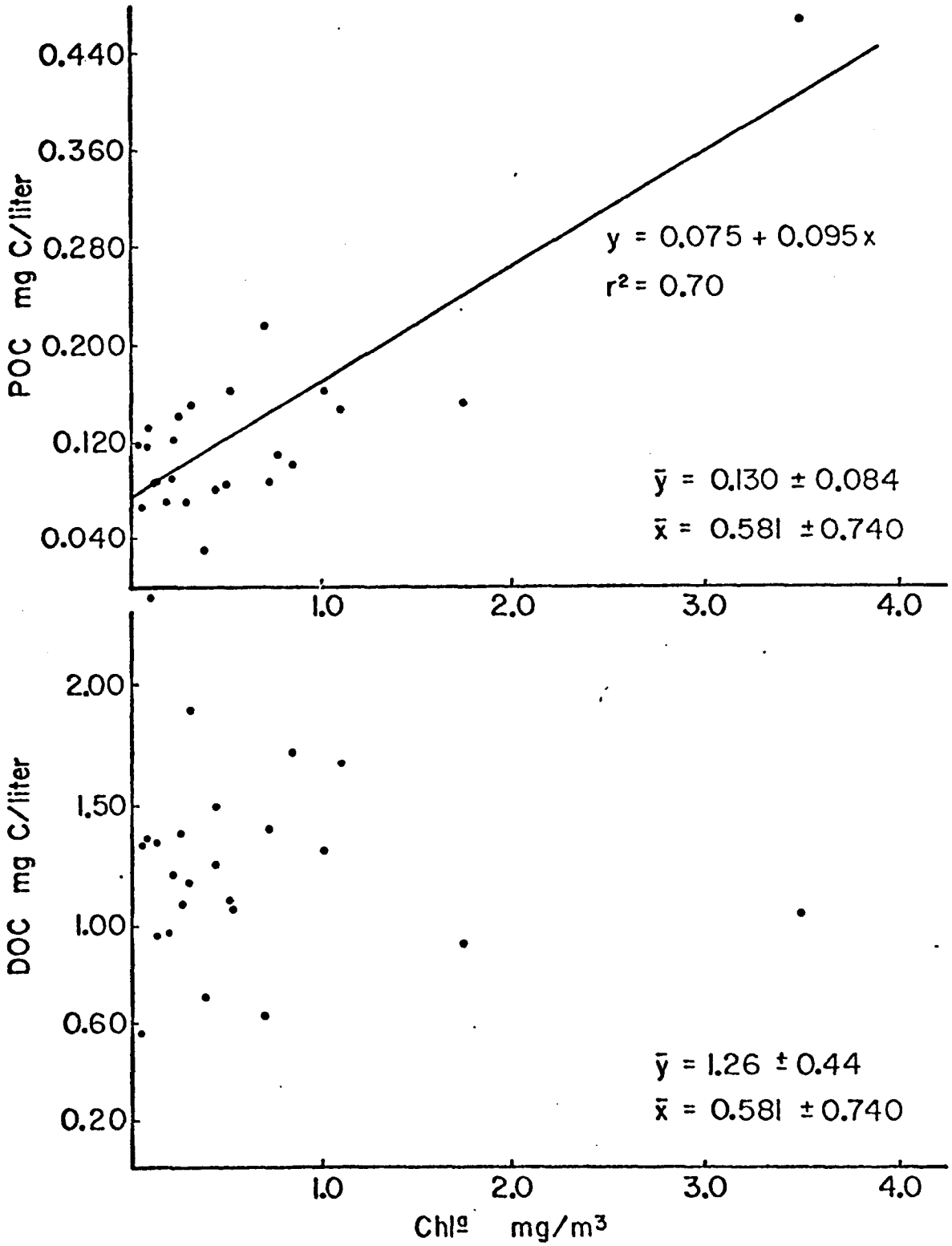


Figure 11.--Organic Carbon vs. Chlorophyll a
Summer 1975

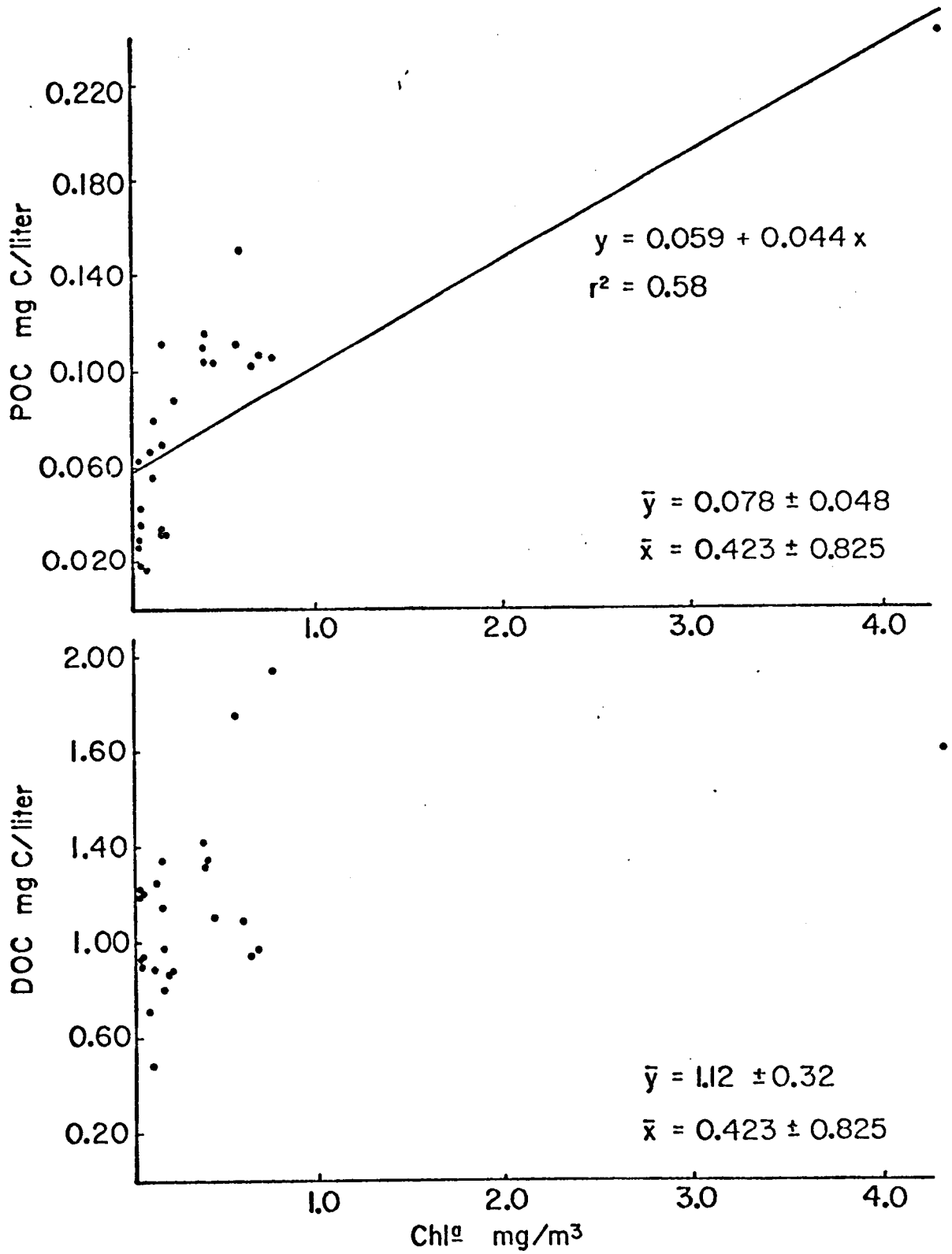


Figure 12.-- Organic Carbon vs. Chlorophyll a
Fall 1975

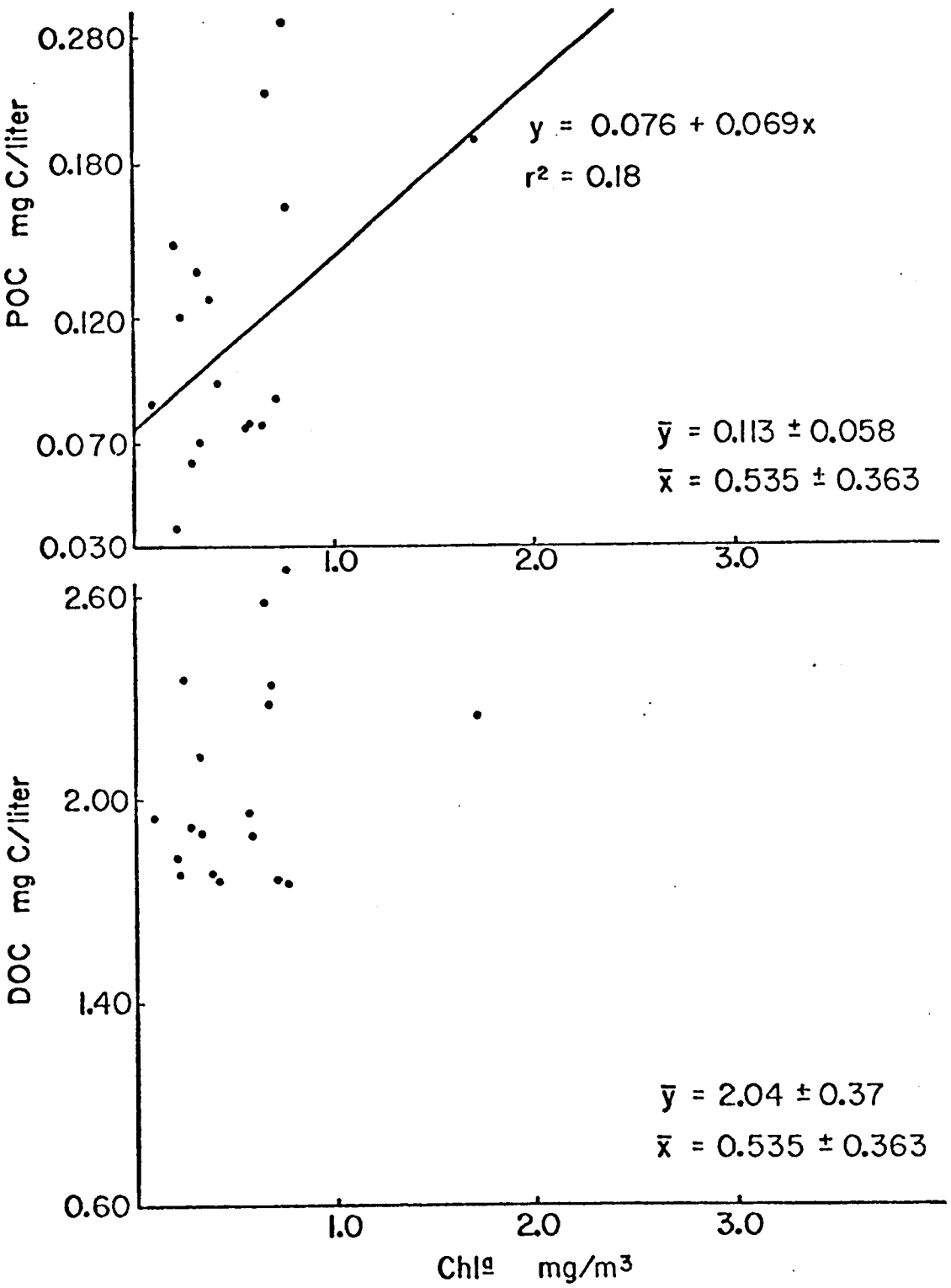


Figure 13.-- Organic Carbon vs. Chlorophyll a
Winter 1976

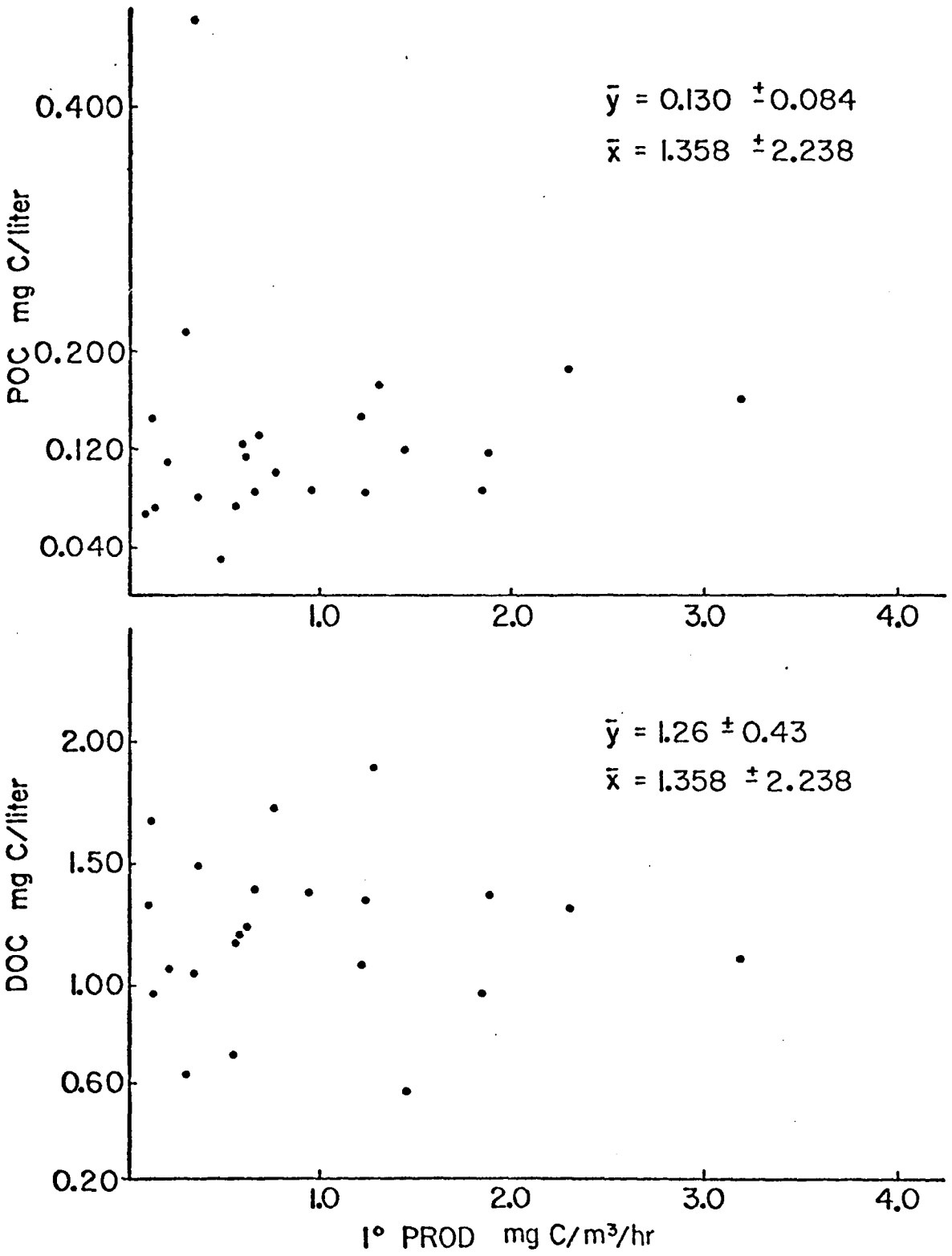


Figure 14.-- Organic Carbon vs. Primary Productivity
Summer 1975

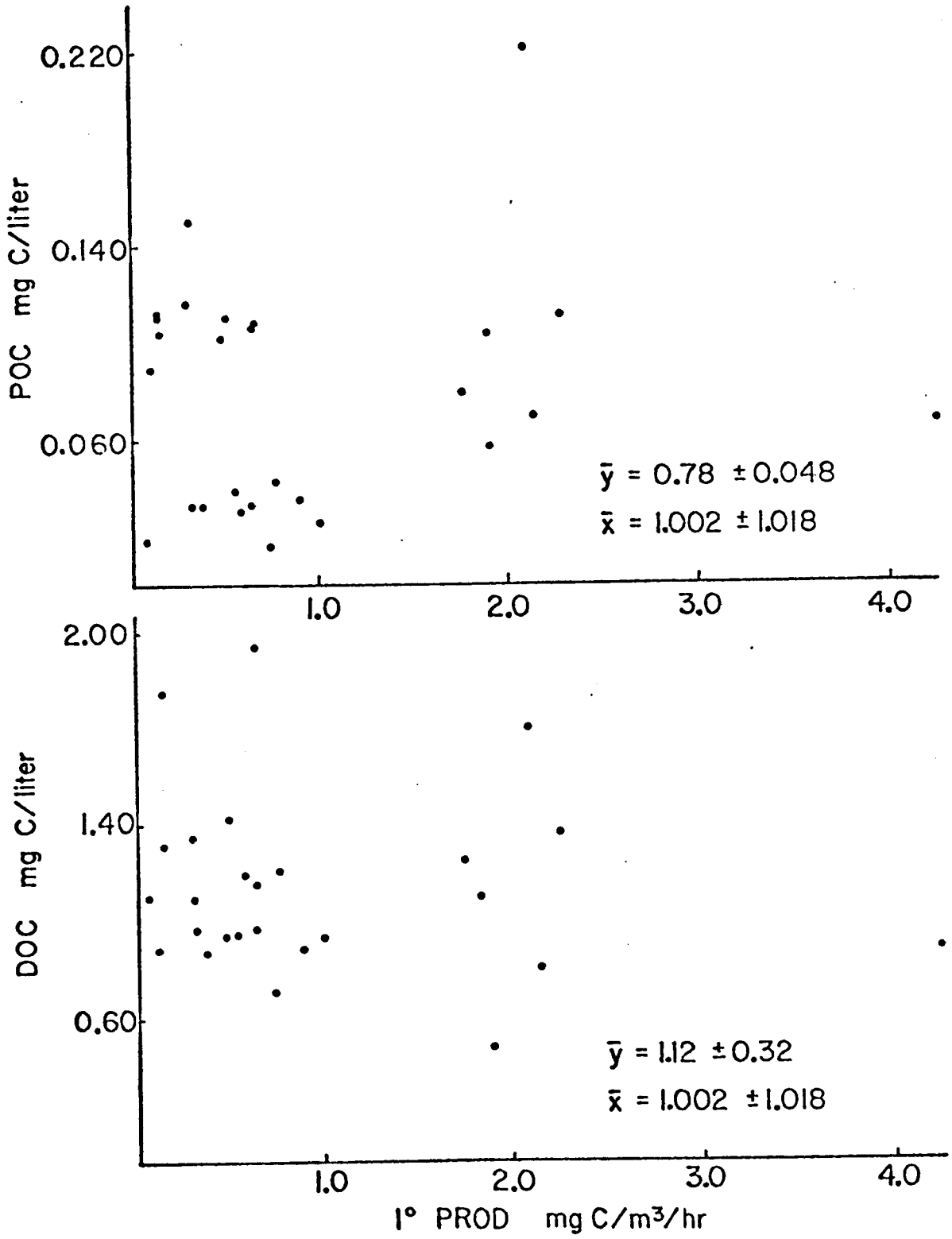


Figure 15.--Organic Carbon vs. Primary Productivity
Fall 1975

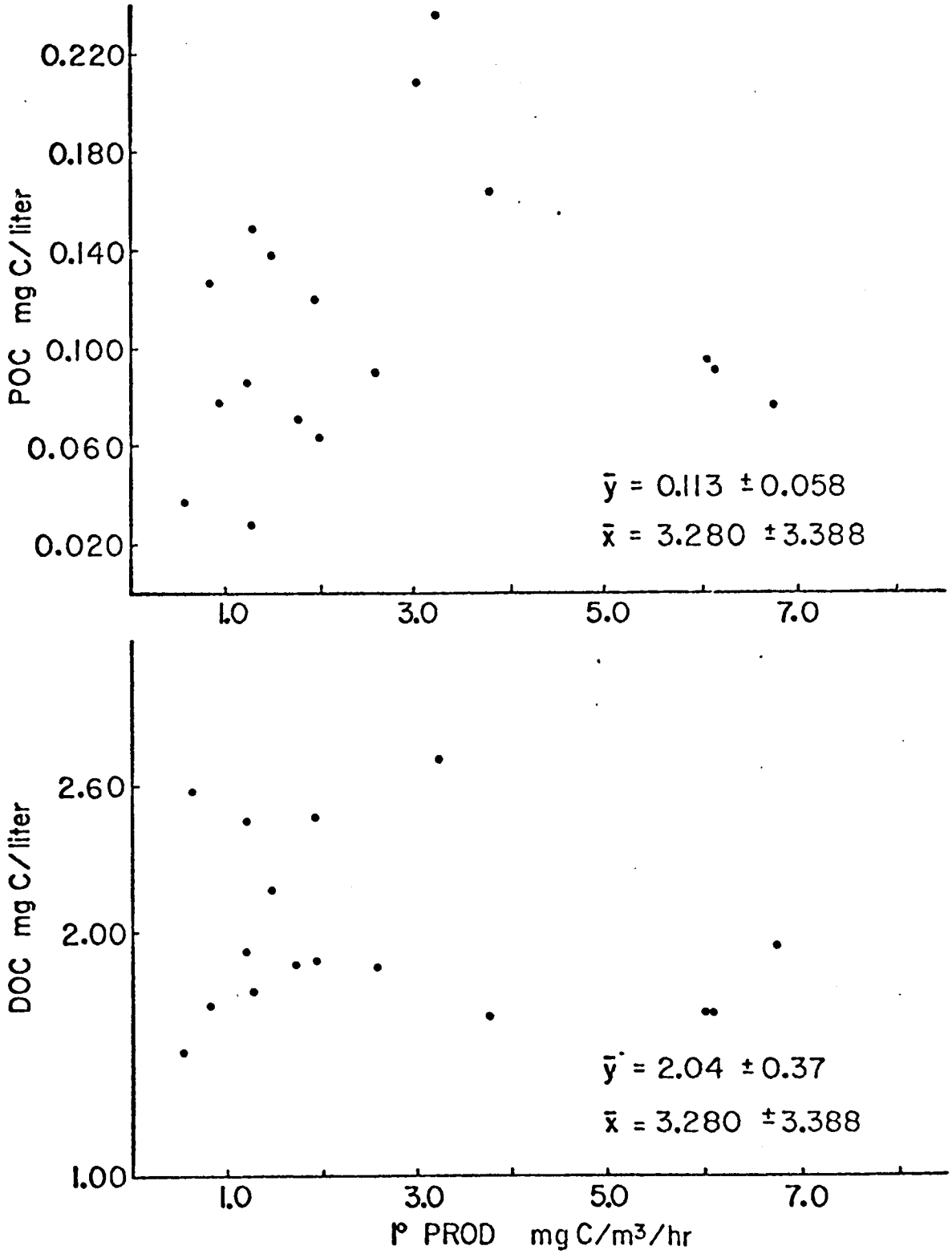


Figure 16.-- Organic Carbon vs. Primary Productivity
Winter 1976

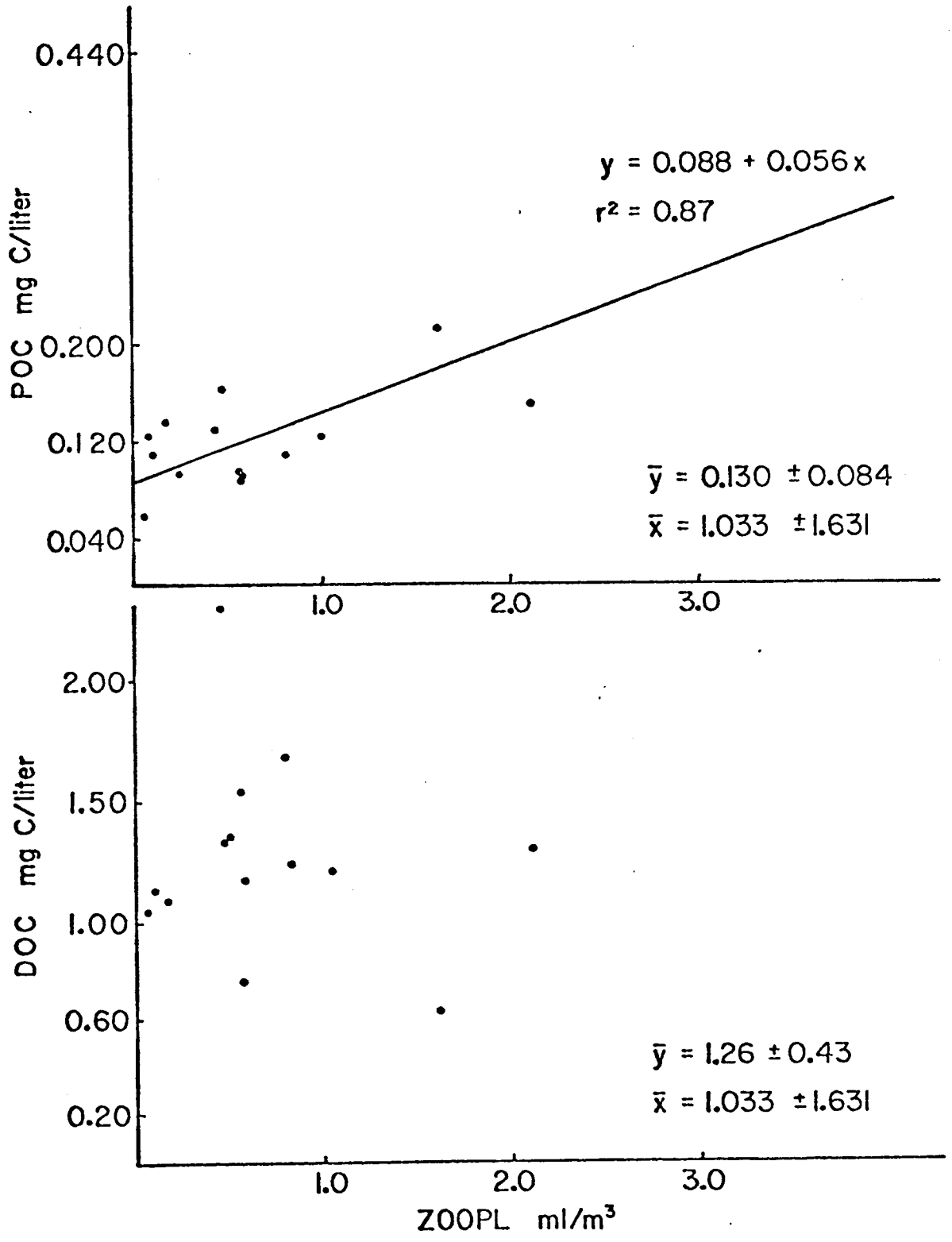


Figure 17.-- Organic Carbon vs. Zooplankton
Summer 1975

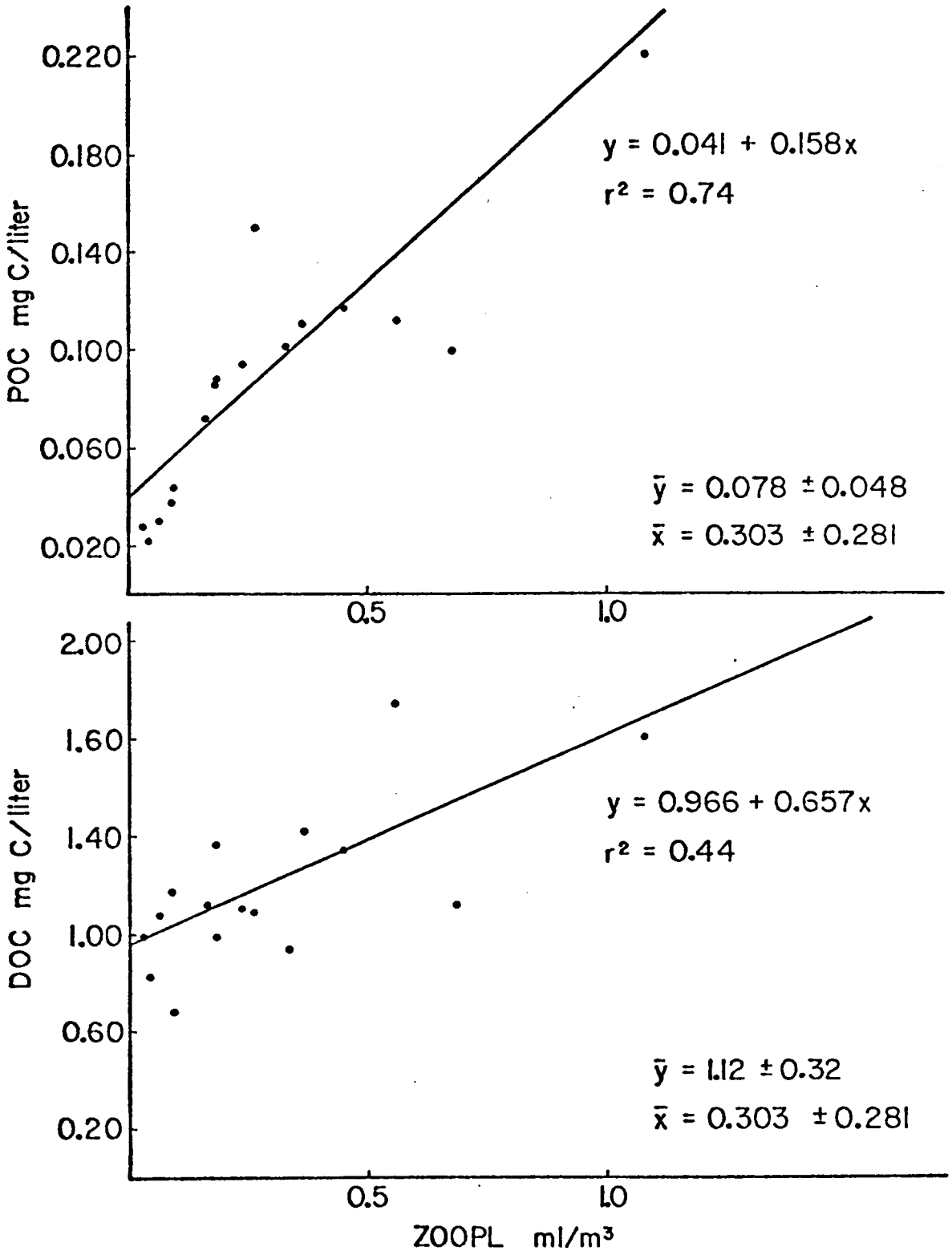


Figure 18.-- Organic Carbon vs. Zooplankton
Fall 1975

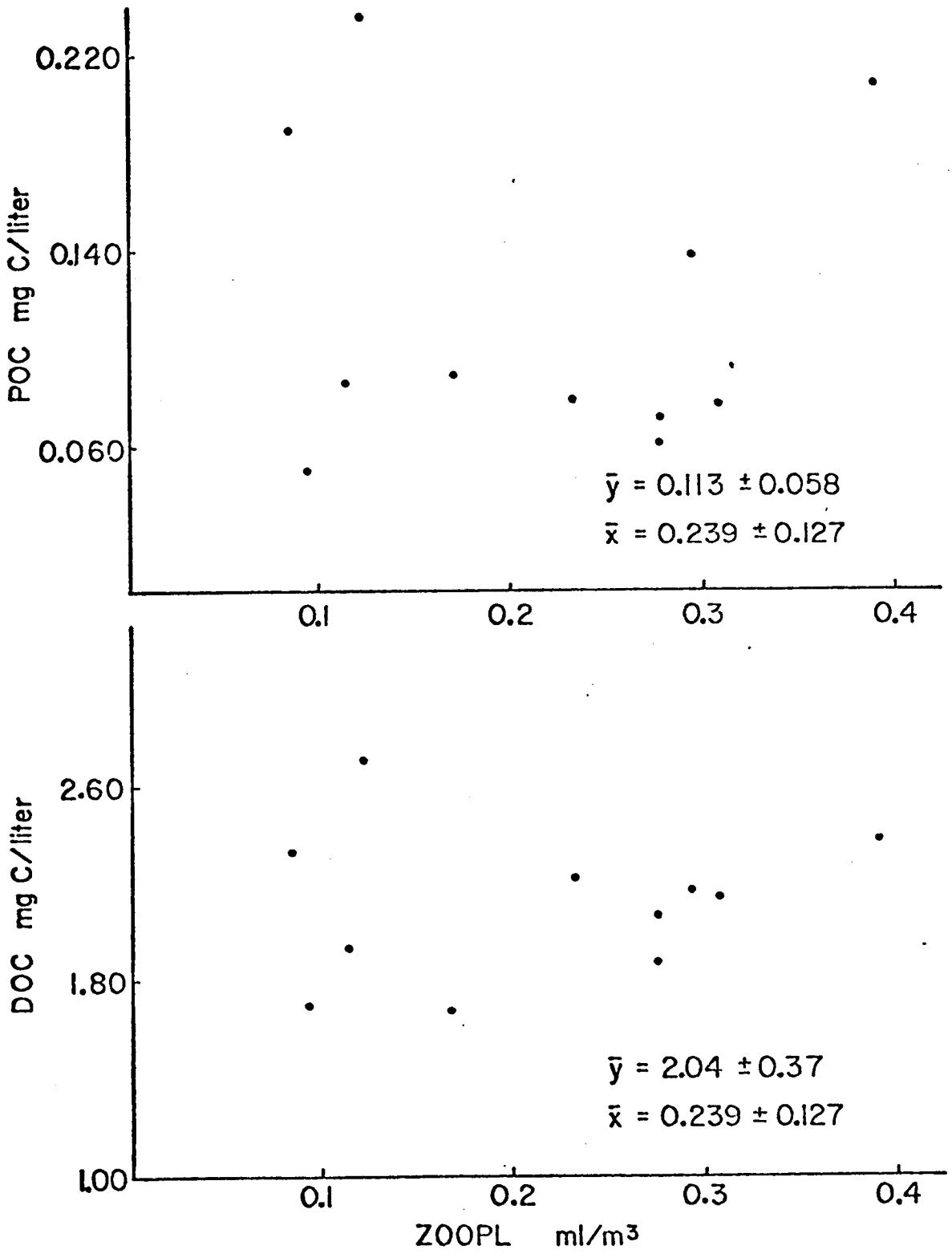


Figure 19.--Organic Carbon vs. Zooplankton
Winter 1976

ESTIMATION OF BIOMASS OF BENTHIC INVERTEBRATE MACROFAUNA AND IDENTIFICATION OF POLYCHAETOUS ANNELIDS FOR THE BLM MAFLA EXTENDED BASELINE AND MONITORING STUDY

Florida State University, Department of Oceanography

Principal Investigator:
Henry Kritzler

TABLE OF CONTENTS

ABSTRACT

The work accomplished in a subcontract to furnish data and the results of statistical analysis of the data concerning spatial and temporal distributions of benthic macroinfauna biomass and of polychaetous annelid species on four transects across the offshore continental shelf between Apalachee Bay and Fort Myers, Florida is reported. Homogeneity of sampled polychaete assemblages appeared consistent with evaluation of representativeness (as number of replicates per sample) which was considered inadequate for 17 of 27 samples collected in July, 1975. A negative correlation between biomass and depth was observed. No consistent correlation between biomass and depth was seen. At most stations high polychaete diversity could be correlated with widespread distribution of fine sediment, in itself an indicator of environmental stability. Five types of significantly associated polychaete species groups were detected, affording a basis for classifying the stations. The existence of more than one distinct polychaete assemblage, correlated with the general character of the sediments was demonstrated at some stations.

INTRODUCTION

A. Contractual Obligations

As indicated in the title, the primary obligation of this subcontractor has been to furnish the Prime Contractor with data concerning the distributions of benthic invertebrate macrofauna biomass and to identify to family level at least, but in most cases to species, the polychaetous annelids found in samples taken in the summer and fall of 1975 and in the winter of 1976 on four transects across the MAFLA offshore continental shelf.

An additional obligation of this subcontractor has been to collaborate with the Data Management and Statistical Analysis Group (another subcontractor, hereinafter referred to as DMSAG) in subjecting these data to numerical analyses in order to

1. Evaluate the representativeness of samples of the sampled polychaete assemblages.

2. Evaluate the homogeneity of the sampled polychaete assemblages.

3. Identify significantly associated groups of polychaete species characteristic of the sites at which the samples were taken.

4. Evaluate polychaete diversity at each of these stations.

5. Look for correlations between polychaete distributions and those of other variables.

In addition, this subcontract has called for collaborating with other subcontractors in describing the biotic community charactistic of each sampling site and in developing broad area characterizations of benthic infaunal environments based on a lithologic map.

Preliminary or consequent to the discharge of these obligations has been

1. Assisting in the collection of samples and data at sea.

2. Segregating all biotic material from the samples.

3. Sorting these segregates into five major categories - molluscs, crustaceans, echinoderms, polychaetes and miscellaneous.

4. The establishment of an archive for the storage of these materials in whatever stage of work-up.

B. Literature Survey

Biomass

For a survey of the literature on biomass of benthic invertebrate macrofauna in the northeast Gulf of Mexico (or anywhere else) the attention of the Prime Contractor is directed to whomever it was that decided that biomass measurements are relevant to this study.

Polychaetes

For a survey of the literature on the polychaetous annelids of the northeast Gulf of Mexico, the Prime Contractor's attention is directed to the following publication:

> Perkins, T. H. and T. Savage. 1975. A bibliography and check list of Polychaetous Annelids of Florida, the Gulf of Mexico, and the Caribbean Region. Florida Marine Research Publications, 14, 62 pp.

Of the titles listed therein, numbers 27, 33, 35, 44 a and b, 51, 53a, 54, 54a, 61, 80, 81, 81a, 82, 83, 84a, 85, 86, 87, 88, 89, 90, 92, 93, 94, 95, 97, 98, 99, 100, 101, 102, 103, 104, 105, 105a, 109, 110, 115, 116b and c, 118, 119, 120, 135, 143, 162, 163, 164, 165, 166, 190, 192, 195, 196, 198, 204, 205, 206, 210, 227, 229, 238a, 239, 240, 241, 242, 245, 250, 252, 256, 257, 258, 259, 260, 264 are in the personal library of this subcontractor.

Other works to which the writer frequently refers are:

Fauvel, P. 1923. Polychétes Errantes.
Faune de France, 5, 448 pp.

_____. 1927. Polychétes Sedentaires.
Ibid. 16, 494 pp.

_____. 1953. Annelida polychaeta
The Fauna of India. The Indian Press, Ltd.
Allahabad. 507 pp.

Hartmann-Schroeder, G. 1971. Annelida, Borstenwürmer,
Polychaeta. Die Tierwelt Deutschlands.
Gustav Fischer Verlag, Jena, 594 pp.

Ushakov, P. V. 1955. Polychaeta of the Far Eastern Seas of the
U.S.S.R. Isdatel'stvo Akademii Nauk SSSR, Moskva,
Leningrad, 419 pp.

The final authority on polychaete taxonomy for this study has been, with some exceptions,

Hartman, O. Catalogue of the Polychaetous Annelids of the
World, Parts I and II, Supplement and Index.

(Items 102 and 103 in Perkins and Savage.)

MATERIALS AND METHODS

A. Materials

The materials upon which this study was based consisted of box core and anchor dredge samples taken on two Transects (Nos. III and IV) and polychaetes segregated from box core and anchor dredge samples taken on two other Transects (Nos. I and II) on three seasonal cruises - July and September, 1975 and January, 1976. Box core samples consisted of nine replicates each. Anchor dredge samples consisted of two replicates each. The planned and actual positions of the sampling stations may be found in the Prime Contractor's reports and elsewhere.

B. Methods

In Figure 1 a flow diagram of the steps involved in the discharge of this subcontractor's individual obligations is presented.

1. Processing on shipboard

The first four steps, relating to the processing of samples at sea, have been performed exactly as prescribed in the Prime Contractor's work statement with the exception that the samples were stored in cotton bags immersed in the buffered formalin preservative. This was not an innovation in the 75/76 effort. Cotton bags, rather than glass or plastic containers, were used in the 1974 samplings also.

2. Rough sorting

In the laboratory each sample replicate, consisting of one or two cotton bags of sediment containing the preserved remains of organisms, was washed free of formaldehyde and stained with rose bengal - a red dye which has a great affinity for protoplasm. The stained biotic material was then sorted out of the inorganic sediment, first by flotation on saturated NaCl and then by hand sorting from enamel trays. All the isolates were preserved in 70% ethanol which leaches out the red stain.

3. Fine sorting

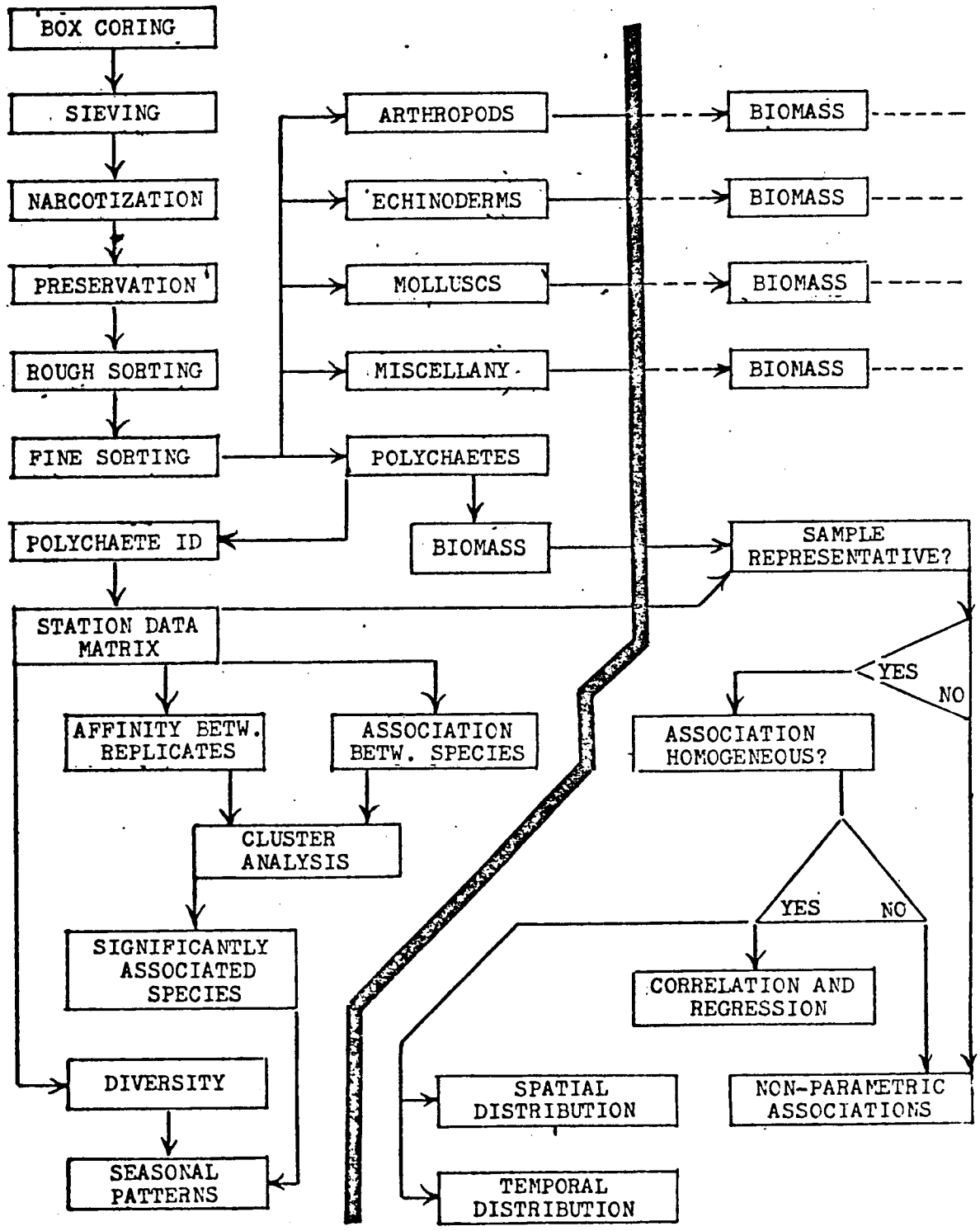
The rough sorted material was then fine sorted into the five categories prescribed by the work statement - molluscs, crustaceans, echinoderms, polychaetes and miscellaneous. Each such fraction was preserved in 70% ethanol and labelled to identify it with the station, the year, the season, and the sample replicate.

4. Biomass measurement

As prescribed in the work statement, the material contained in

Figure 1

S.O.P. for Macroinfauna Sampling, Processing, and Data Analysis



each of the five fractions was blotted free of excess preservative and weighed, wet, on a Mettler balance. The data were reported to the Prime Contractor on forms devised by DMSAG. The material was represerved, each category in its own separate container containing also a label identifying the category, the station, the replicate, the year and the season. All of the mollusc fractions were sent to Dr. N. J. Blake, University of South Florida. The remaining four subdivisions of each sample replicate were placed in archive in separate jars appropriately labelled. The polychaete fractions from the stations on Transects I and II were sent by Dr. Blake to the writer.

5. Polychaete Identification

All of the polychaetes in each sample replicate from Transects I, II, III, and IV were then identified - in most instances with known species. Some of these will no doubt be revised in the future. Some had to be identified as provisional new species, confirmation or revision of which will have to await the availability of time and resources.

There were more than 22,000 specimens in the material from the summer sampling. At this writing the number found in the fall and winter sampling is not known - because of the unavailability of computer print out. At any rate the overwhelming majority of them were very small - varying between one and five millimeters in length. Nevertheless, many could be identified at a glance with no greater magnification than that provided by a stereoscopic dissecting microscope. On rate occasions, larger specimens could be identified with the naked eye. When lower powers of magnification proved inadequate, the small speciments had to be set up as wet mounts between cover slips to be examined with the low or high dry

objectives of the compound microscope.

Occasionally, hours of hunting through the available literature led to the identification of strange, rare species. The few characterized as provisional new species represent kinds for which definitive identification was shelved in the interest of getting the data in on time.

The polychaetes found in the summer samples and in those from the fall sampling on Transects III and IV were packaged and labelled, each species in a separate vial. This, the most time consuming element of the process, was eliminated in working up the polychaetes from the winter samples and the Transect I and II fall samples. Otherwise, the identification and counts would not yet, as of this date, be finished.

The ploychaete data, consisting of the species and numbers of individuals found in each sample replicate were reported to the Prime Contractor on forms devised by DMSAG.

6. Data Analysis

All the other steps in the flow diagram represent stages in the necessarily computerized numerical analysis of the polychaete data. While the identification of polychaetes was in progress, exchanges between the writer and DMSAG led to the development of software for some of them, such as

a. A test for sample representativeness (with respect to sample size).

b. Numerical processes for the detection of significantly associated groups of polychaete species characteristic of the sampling sites.

c. A process for the evaluation of affinity between sample

replicates.

d. Cluster analysis (ordination) to be applied to the results of (c) in order to test the hypothesis that only one homogeneous community of organisms inhabits each sampling site.

e. A program for evaluating environmental stability at the sampling sites on the basis of the Shannon-Weaver indices of diversity (H') and of equitability (J').

After submission of the fourth quarterly report which was based largely on piecemeal computer analysis by DMSAG of the summer sampling polychaete data (Transects I, II, III, and IV) along the lines set forth above, the writer submitted to DMSAG a critique of the software coupled with suggestions for their consolidation into a sequence of subroutines governed by a calling program. This they did - producing a standard operating procedure for the analysis of all future batches of data elicited from samples based on the same level of quantitation.

No objective, statistical test for the evaluation of homogeneity of the sampled polychaete associations has been developed. Most such are based on estimates of the significance of the differences between means of two or more samples taken at the same place at the same time. It is possible that this technique could be used to evaluate seasonal change, which is to say - to compare samples taken at the same place and different times, but this has not yet been done.

Details of the methods referred to in 6 a, b, c, and d may be seen in the writer's fourth quarterly report. As a matter of fact, this final report is, in a sense, only an extension of the fourth quarterly report because no computer printout based on the standard operation procedure

applied to the fall and winter data has been received.

RESULTS

A. Identification of polychaetes

1. Numbers

Three hundred thirty-nine species of polychaetes were represented by more than 22,000 individuals in the summer sampling. The distributions by station and transect of numbers of species, numbers of individuals and density are shown in Table II. When reading this and other tables and figures, one must bear in mind that the station numbers run from lower to higher as one proceeds from shallow water inshore to deeper water offshore on Transects I, II, and IV, but that on Transect III the reverse is true.

2. Accuracy of identification

The individuals of all but 20 of the 339 were identified with species described in the literature available to the writer. The 20 others had to be listed as provisional new species. One of these could not be identified with a genus known to the writer and so had to be listed by family only, as a provisional new genus and new species. A list of the species found in each of the seasonal samplings may be obtained by interested parties by applying the appropriate DMSAG program to the data files.

3. Spatial distribution of polychaete species

The spatial distribution of the species themselves may be seen in the station data matrices. These matrices are the first step in the computer printout resulting from application of the standard operating procedure to the data files. They also show the numbers of individuals found in each replicate, as well as the individual population densities, and the

TABLE II

Numbers of Polychaete Species and Individuals and Polychaete Density -- Transects I, II, III and IV -- Summer Sampling

Transect	Station	Species	Individuals	Density*
I	2101	80	1558	2686
	2102	57	646	1113
	2103	125	878	1513
	2104	95	781	1346
	2105	82	325	560
	2106	70	222	382
II	2207	94	2195	3784
	2208	49	749	1291
	2209	60	2136	3682
	2210	67	662	1393
	2211	94	641	1105
	2212	44	251	432
III	2313	40	90	155
	2314	61	1712	4240
	2315	94	1296	2872
	2316	146	998	1720
	2317	117	744	1282
	2318	53	261	450
IV	2419	61	330	568
	2420	105	544	937
	2421	86	672	1158
	2422	142	1209	2084
	2423	115	900	1551
	2424	86	347	598
	2425	103	377	650
	2426	63	215	370
	2427	29	69	118

* Density = Individuals/m^2

total polychaete density at the stations.

4. Temporal distribution of polychaete species

Because of the lack of computer printout on the fall and winter samplings, nothing can be said about temporal distributions of polychaetes.

B. Biomass

Seasonal variation in polychaete biomass, as wet weight preserved in grams per square meter is given by stations in Table 1 and in Figures 2, 3, 4, and 5, which include graphs of the polychaete biomass distributions in the fall and winter samplings.

C. Data Analysis

For reasons not revealed to the writer, the statistical analysis of data was called "synthesis" in the RSP and in the Prime Contractor's work statement. Be that as it may, the following results were obtained:

1. Representativeness of samples

Of the 27 samples taken on the four transects in the summer sampling, five seemed unequivocally representative (with respect to sample size) of the sampled polychaete associations. Six more were rated "good" by the cumulative means test. For another six, sample size seemed equivocal, or, at best, only fair. Of the remaining ten, seven were clearly inadequate with respect to sample size. For the last three which were dredge station samples of n = 2 replicates each, this statistical analysis was inappropriate and therefore irrelevant. These results may be seen in Table III of this report and in the fourth quarterly report station summaries are given under "cumulative means of cumulative means."

2. Homogeneity of sampled polychaete associations

The bases for the assessment of homogeneity of sampled polychaete

TABLE I

Seasonal Variation in Polychaete Biomass
Transects I, II, III and IV

Transect	Station	Polychaete Biomass (g/m^2) Summer	Fall	Winter
I	2101	19.78	10.76	17.55
	2102	3.47	8.06	5.75
	2103	14.73	9.73	5.39
	2104	3.74	2.94	3.52
	2105	1.40	0.57	0.44
	2106	1.32	0.27	0.19
II	2207	13.75	8.55	13.51
	2208	4.02	1.23	2.85
	2209	4.25	2.77	4.87
	2210	10.67	2.87	4.38
	2211	4.09	6.28	7.92
	2212	0.55	0.86	1.55
III	2313	0.64	0.76	0.26
	2314	11.70	130.41	3.75
	2315	20.79	10.57	14.08
	2316	11.39	6.69	9.43
	2317	7.66	9.84	11.40
	2318	1.41	5.62	3.76
IV	2419	2.59	4.88	4.48
	2420	6.74	5.84	8.25
	2421	8.76	13.39	7.11
	2422	21.79	12.60	8.59
	2423	12.48	20.72	33.14
	2424	5.63	11.76	12.00
	2425	7.55	11.47	12.79
	2426	1.20	9.46	3.94
	2427	2.59	2.33	4.69

Transects I and II data courtesy of Dr. N. J. Blake

Figure 2

Correlation between polychaete and sediment parameters

Transect I

Upper graph

BIO = Biomass; SPE = Species; IND = Individuals; EQU = Equitability or J prime. The solid bar graph under each of these headings is for the summer sampling. The shaded bar graph under BIO is for the fall sampling, and the open graph is for the winter sampling.

Lower graph

The solid bar graph is for grain size; the shaded for calcium carbonate.

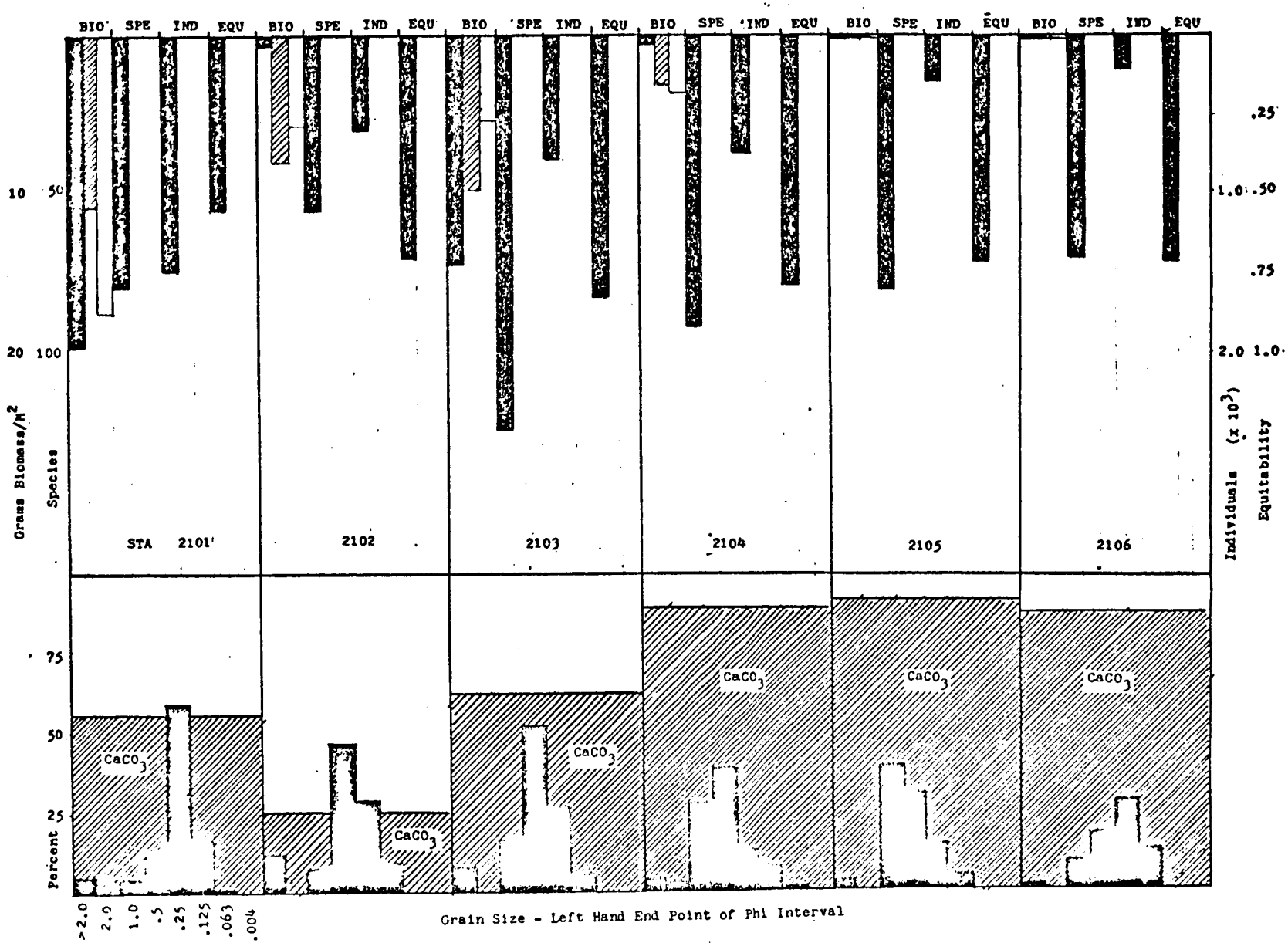

BIO SPE IND EQU
STA 2101
2102
2103
2104
2105
2106
Grams Biomass/M2
Species
Individuals (x 10³)
Equitability
Percent
CaCO3
Grain Size - Left Hand End Point of Phi Interval
>2.0
2.0
1.0
.5
.25
.125
.063
.004

Figure 2

Figure 3

Correlation between polychaete and sediment parameters

Transect II

Upper graph

BIO = Biomass; SPE = Species; IND = Individuals; EQU = Equitability or J prime. The solid bar graph under each of these headings is for the summer sampling. The shaded bar graph under BIO is for the fall sampling, and the open graph is for the winter sampling.

Lower graph

The solid bar graph is for grain size; the shaded for calcium carbonate.

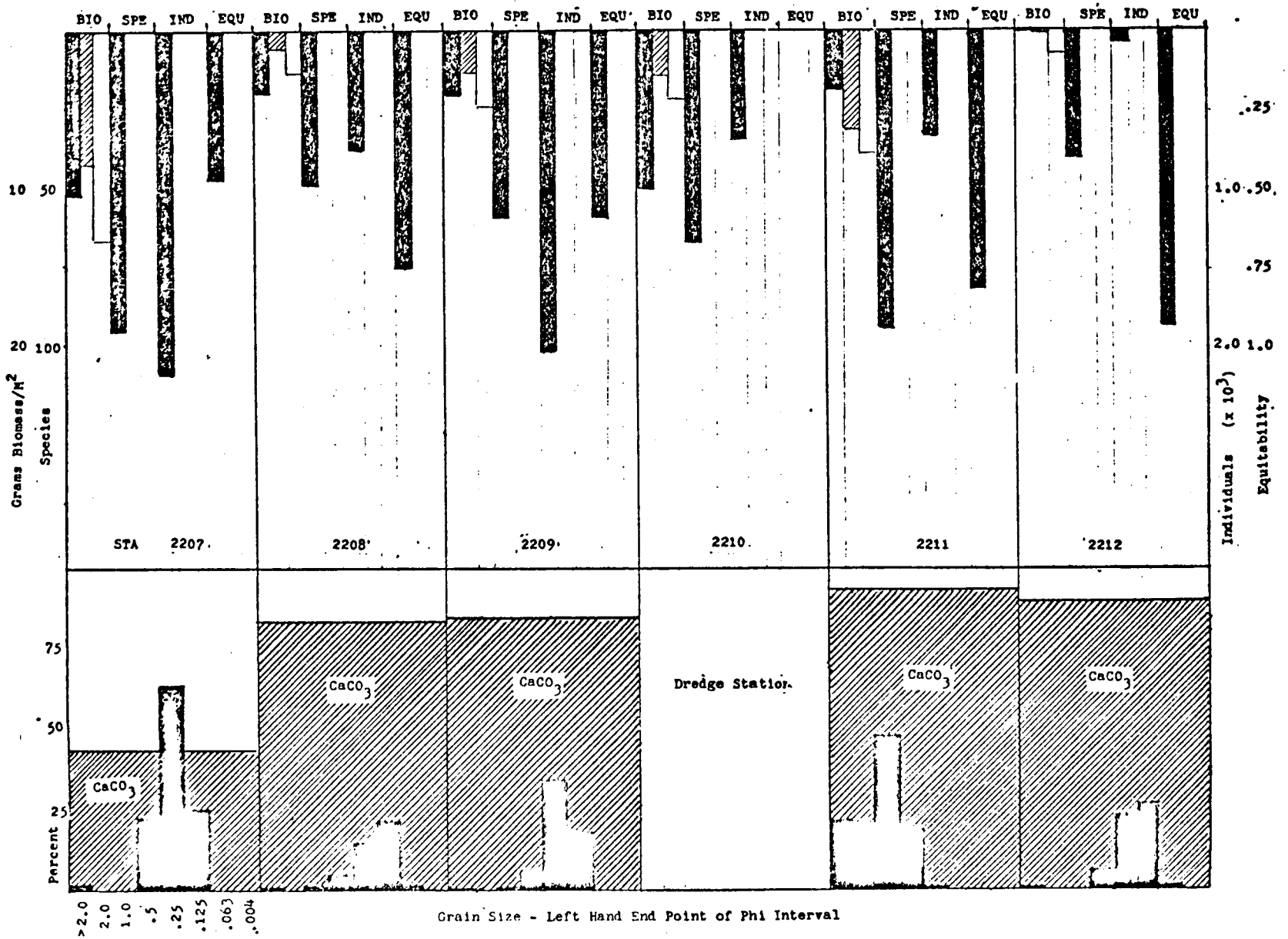

BIO SPE IND EQU BIO SPE IND EQU BIO SPE IND EQU BIO SPE IND EQU BIO SPE IND EQU BIO SPE IND EQU
10 50
20 100
Grams Biomass/M2
Species
STA 2207
2208
2209
2210
2211
2212
.25
1.0 .50
.75
2.0 1.0
Individuals (x 10³)
Equitability
75
50
25
Percent
CaCO3
Dredge Station
>2.0 2.0 1.0 .5 .25 .125 .063 .004
Grain Size - Left Hand End Point of Phi Interval

Figure 3

Figure 4

Correlation between polychaete and sediment parameters

Transect III

Upper graph

BIO = Biomass; SPE = Species; IND = Individuals; EQU = Equitability or J prime. The solid bar graph under each of these headings is for the summer sampling. The shaded bar graph under BIO is for the fall sampling, and the open graph is for the winter sampling.

lower graph

The solid bar graph is for grain size; the shaded for calcium carbonate.

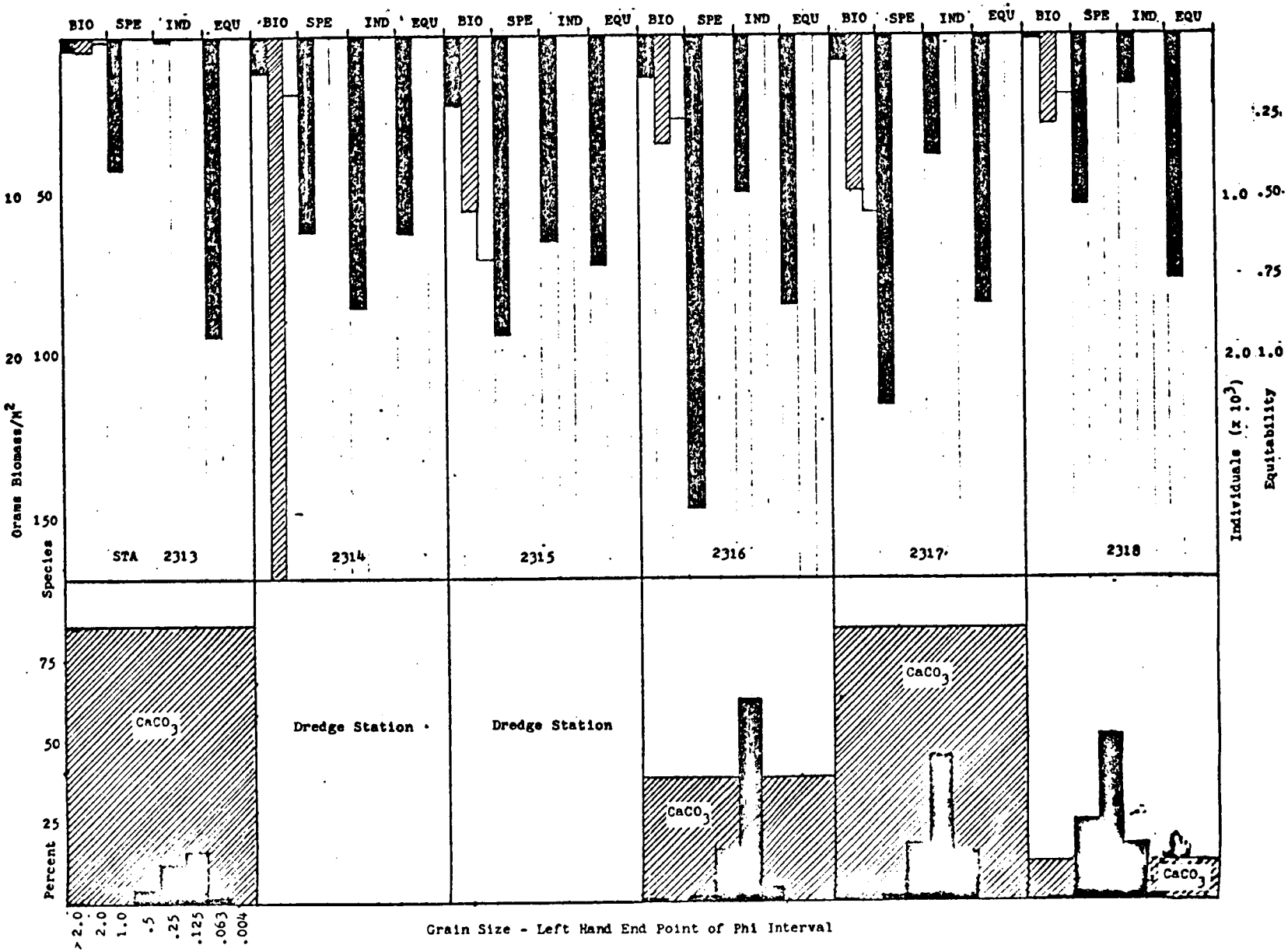

BIO SPE IND EQU
Grams Biomass/M²
Species
Individuals (x 10³)
Equitability
STA 2313
2314
2315
2316
2317
2318
Dredge Station
Dredge Station
CaCO3
Percent
Grain Size - Left Hand End Point of Phi Interval

Figure 4

Figure 5

Correlation between polychaete and sediment parameters

Transect IV

Upper graph

BIO = Biomass; SPE = Species; IND = Individuals; EQU - Equitability or J prime. The solid bar graph under each of these headings is for the summer sampling. The shaded bar graph under BIO is for the fall sampling, and the open graph is for the winter sampling.

Lower graph

The solid bar graph is for grain size; the shaded for calcium carbonate.

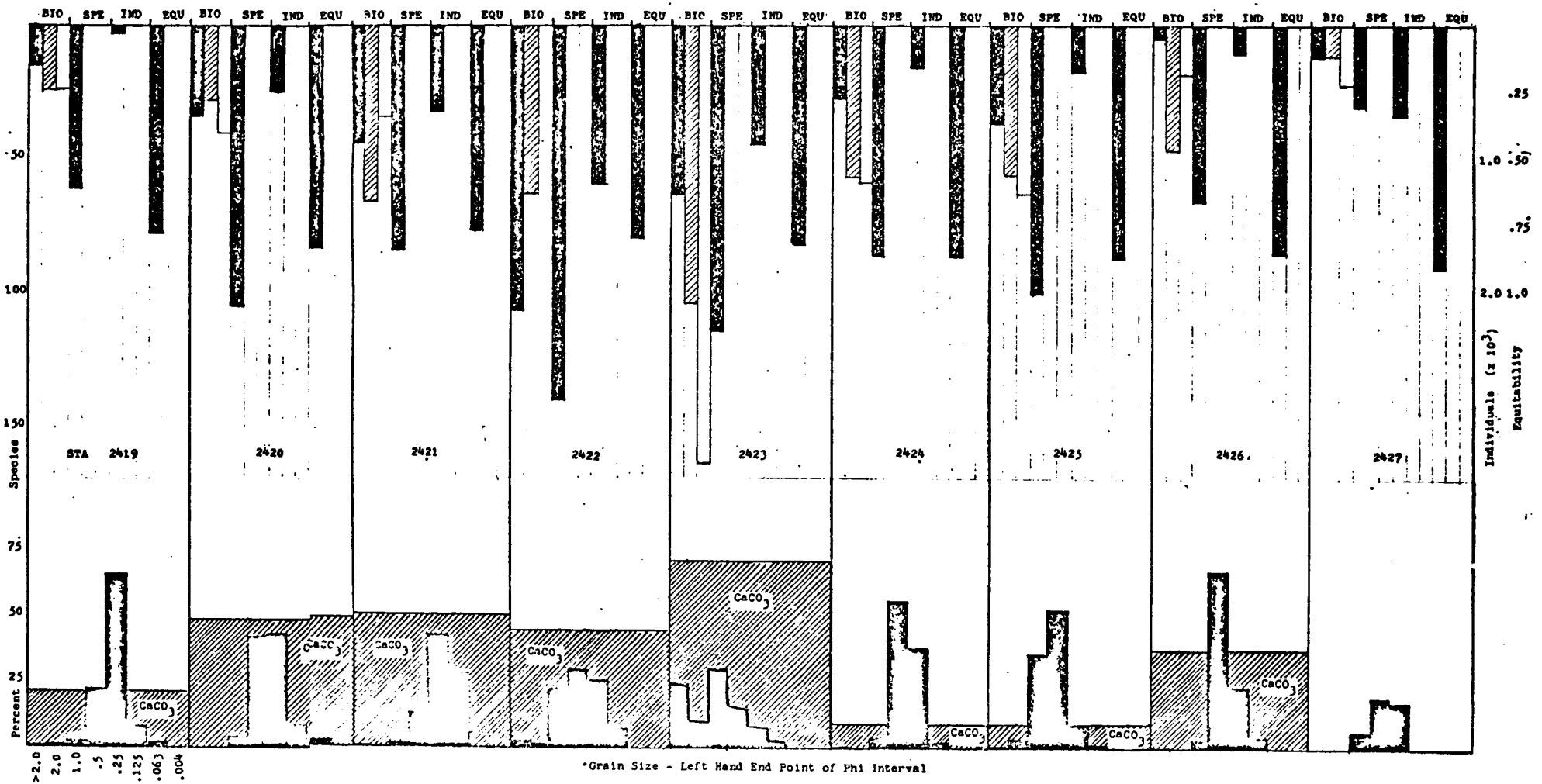

BIO SPE IND EQU
STA 2419
2420
2421
2422
2423
2424
2425
2426
2427
Species
Individuals (x 10³)
Equitability
Percent
CaCO3
>2.0 2.0 1.0 .5 .25 .125 .063 .004
*Grain Size - Left Hand End Point of Phi Interval

Figure 5

TABLE III

Classification of Stations on MAFLA Benthic Transects I, II, III and IV - Summer, 1975 Sampling - Based on Characteristic Polychaete Species Groups

Station	Primary	Secondary	Representation	Homogeneity	J'
2101	I	mixed	fair	good	.56
2102	I	mixed	fair	fair	.71
2103	Transitional	mixed	?	?	?
2104	Transitional	mixed	poor	fair	.80
2105	II	?	good	good	.72
2106	II	none	excellent	fair	.83
2207A	I	mixed	poor	poor	.47
2207B	mixed	?	?	?	.47
2208	I	mixed	poor	fair	.75
2209	I	I	good	good	.59
2210	mixed	none	?	?	?
2211A	mixed	mixed	excellent	excellent	.82
2211B	I	?	excellent	excellent	.82
2212	Transitional	Transitional	poor	poor	.79
2213	Transitional	none	good	fair	.94
2314	Transitional	none	?	?	?
2315	III	none	?	?	?
2316A	mixed	mixed	good	fair	.85
2316B	mixed	II	good	fair	.85
2317	I	none	poor	poor	.84
2318	mixed	none	fair	poor	.77
2419	II	none	fair	fair	.78
2420A	II	Transitional	fair	fair	.84
2420B	ransitional	none	fair	fair	.84
2421	I	none	good	good	.77
2422	III	none	excellent	good	.80
2423	III	mixed	good	good	.83
2424	I	none	good	fair	.87
2425	Transitional	none	poor	poor	.88
2426	mixed	none	poor	poor	.86
2427	mixed	none	poor	poor	.92

associations shown in Table III are two-fold and may be seen in the summer sampling station summaries in the fourth quarterly report. They are, respectively, "Range of MFP affinity; C lambda affinity" and under Mountford clustering "MFP/C lambda agreement." The rationale for these two-non-parametric assessments of homogeneity is given in the fourth quarterly report.

3. Identification of significantly associated species groups

Identification of significantly associated groups of polychaete species characteristic of each station was grounded on two bases.

First, those species which were represented in the sample by more than a certain percentage of the total number of individuals were listed as numerical dominants. For samples with high diversity ($J'>0.80$) the cut off point might might be as low as one percent. For stations with lower indices of diversity or equitability ($J'\leq 0.80$) the cut off was generally higher - around four percent. The rationale for this apparent inconsistency is discussed below.

The second basis was the search for significant affinity between species by applying to each sample data matrix Cole's coefficient of association. The definition of the coefficient as used here may be found in the fourth quarterly report, but it must be mentioned that it was applied to all possible pairs of species which occurred in at least five of the nine sample replicates. Within the limitations imposed by the definition, the coefficients varied between 0.3 and 1.5. Only those pairs with Cole affinity of 1.0 or greater were considered to be significantly associated. In almost all instances it was found that the numerical dominants were those species with Cole affinity for each other at the 1.0 level. The exceptions

were those few species which occurred in less than five replicates in numbers of individuals large enough to constitute greater than the cut off percentage of the total.

These processes resulted in a list of 48 species each of which was a numerical dominant in at least one of the 27 samples. The species and the order of their dominance in the 27 samples are shown in Table IV.

The list of these numerical dominants found in each sample is taken to be the primary group of significantly associated species groups characteristic of the sampling site. Five types of groups are recognizable. They are:

Type I - Spionid/paraonid association

Type II - Synelmis group

Type III - Eunicid/paraonid association

Transitional - Similar to Type I but with strong representation by nereids, ampharetids or the chrysopetalid, Bhawania goodei

Mixed - No dominant family or genus

The distribution of these Types, both as primary or secondary groups is shown in Table III.

Secondary groups of significantly associated polychaete species have been detected in some of the summer samples by listing the species with Cole affinity for each other at levels greater than 1.0 and counting the number of Cole affinities between any of the species in each of these groups with any of the species in the numerically dominant group. These relationships are shown graphically in the third page of each box core station summary in the fourth quarterly report.

4. Cluster Analysis

a. Microhabitats

As noted in the foregoing, the principal purpose of cluster analysis has been to test the hypothesis that only one biotic community exists at each sampling site. Evidence to the contrary is considered to indicate the existence within the area covered by the scatter of replicates of two or more microhabitats occupied by different biotic communities. These subdivisions of the material found in the samples may or may not coincide with the erection of primary and secondary groups characteristic of the sampling site.

Four such stations were identified in the summer sample. They were 2207, 2211, 2316 and 2420.

The dendrograms derived from cluster analysis applied to the summer samples may be seen in the fourth quarterly report. The species make-up of the presumptively distinct primary groups found in the above four station samples is shown in Table IV and V.

5. Diversity

The distributions of diversity (as J') are shown in Table II and in Figures 2, 3, 4, and 5.

6. Correlations

Correlations between the distributions of polychaete parameters (biomass, numbers of species, numbers of individuals and equitability) and sediment grain size frequency and carbonate distributions are shown in Figures 2, 3, 4, and 5.

Thanks to Dr. N. J. Blake, seasonal variation in biomass is shown in these figures. Thanks to DMSAG, who failed to deliver computer printout

Table IV

Numerically Dominant Polychaete Species Groups
Summer Sampling

	2101	2102	2103	2104	2105	2106	2207A	2207B	2208	2209	2210	2211A	2211B	2212	2313	2314	2315	2316A	2316B	2317	2318	2419	2420A	2420B	2421	2422	2423	2424	2425	2426	2427
Aedicira belgicae							2	6	3	3	4			2	4		3	1	1	1	4		3		4		4	1	2		
Aglaophamus verrilli	4	4		2									6			5					1		1	1	3			3			
Ampharete acutifrons				5																											
Ampharete americana																3															
Apoprionospio dayi		1	2						5											2					7						
Aricidea fauveli									1	1					5																
Bhawania goodei				1								5														3	1				
Capitita ambiseta																									5						
Ceratonereis sp nov																		6													
Chone ecaudata																													3		
Chone filicaudata																			6										1		
Cirratulus cirratus															7															3	
Cirrophorus furcata																														5	
Cossura delta											2			6																	
Eunice vittata												1					4	4								1	3				
Goniada teres																															3
Hemipodus roseus														5	2			7			6	4	4	3				4	5		
Hesionid ngen nsp																								2							
Kinbergineris inermis											6					1															
Lumbrineris (acuta)																															2
Lumbrineris parvapedata									6						6	4		3	3	5	3	5			6						
Lysidice ninetta																	2														
Magelona californica				3					4																						
Magelona longicornis															3																
Megalomma bioculatum																										4					
Minuspio cirrifera						2				2	1	4	3	1																1	
Neanthes acuminata			1																												
Nephtys bucera								4													2		6								
Nephtys picta																						1		4							
Nothria pallidula											3				1				4	3			5								
Nothria sp nov U														4																	
Onuphis microcephala											5																				
Paralacydonia paradoxa																															4
Paraonis gracilis										5			2	3																	
Paraonides lyra		3																			5										
Paraprionospio pinnata	3		3										4			2			2	6					2			5			
Pholoe minuta														7																	
Poecilochaetus johnsoni																															
Polydora tetrabranchiata	2																														
Prionospio ehlersi	1																														
Prionospio steenstrupi		2		4			1	5	2	4																2					
Progoniada regularis								1				2						8									2				
Protodorvillea Kefersteini								2																							
Pseudoeurythoe hirsuta																													6		
Rhamphobrachium sp nov B															8																
Scolelepis texana																													4		
Sigambra tentaculata													1																		
Spionid H															9															4	1
Spiophanes bombyx													5						5	4		3			1			2			
Syllis spongicola												2					1									5					
Synelmis albini					1	1												5				2	2								
Tachytrypane jeffreysii																														2	
Typosyllis regulata					2			3										2													

TABLE V

Polychaete Species Composition of Primary Groups
Microhabitat Stations - Summer 1975 Sampling

	2207		2211		2316		2420	
	A	B	A	B	A	B	A	B
Chrysopetalidae								
Bhawania goodei			5					
Dorvilleidae								
Protodorvillea kefersteini		2						
Eunicidae								
Eunice vittata			1		4			
Glyceridae								
Hemipodus roseus					7		4	3
Goniadidae								
Progoniada regularis		1	2		8			
Hesionidae								
Hesionid ngen nsp								2
Lumbrineridae								
Lumbrineris parvapedata					3	3		
Nereidae								
Ceratonereis sp nov					6			
Nephtyidae								
Aglaophamus verrilli							1	1
Nephtys bucera		4					6	
Nephtys picta								4
Onuphidae								
Nothria pallidula						4	5	
Paraonidae								
Aedicira belgicae	2	6			1	1	3	
Aricidea fauveli								
Paraonis gracilis				2				
Pilargidae								
Sigambra tentaculata				1				
Synelmis albini					5		2	
Sabellidae								
Chone filicaudata						6		
Spionidae								
Prionspio steenstrupi	1	5						
Minuspio cirrifera			4	3				
Paraprionospio pinnata				4		2		
Spiophanes bombyx				5		5		
Syllidae								
Syllis spongicola			3					
Typosyllis regulata		3			2			

in time, no seasonal comparison of the polychaete parameters was possible.

DISCUSSION

A. Polychaete Biomass

Biomass is a parameter, which is to say a numerical property, of a population or the assemblage of populations which consitute the biotic portion of an ecosystem. Estimates of biomass may be expressed, as they have been in this study, as the observed weight of the population found in the sample extrapolated to what it would have been had the sample covered the unit of area or volume selected for comparative purposes.

A more statistically acceptable estimate of biomass may be found by extrapolating the average or mean weight of organisms found in the sample to what it would have been had the number of replicates been large enough to cover the unit of area selected for comparative purposes.

The confidence with which estimates of any parameter may be accepted is dependent upon the sample's representativeness of the sampled population. Evaluations of sample representativeness are generally based on the dimensions of the replicate or sampling unit, or, if this is fixed, as in the case of the box corer used in this study, on the number of sampling units composing the sample.

Of the two forms of expressing biomass described in the foregoing, the former is less sensitive to sample representativeness. On the other hand, it is less reliable for comparative purposes.

Be that as it may, Table III and the summary sheets attached to the fourth quarterly report show that the summer samples taken at Stations 2101, 2104, 2207, 2208, 2212, 2317, 2318, 2419, 2420, 2425, 2426, and 2427 were

either unrepresentative or, at best only fairly representative of the sampled polychaete assemblages. No estimates of any sort based on computer analysis of the Station 2103 data are worth anything because of key punching errors in the input and of undue weight contributed by one replicate containing more than 1400 individuals of a very small colonial serpulid found in no other replicate in that sample.

Evaluations of representativeness of dredge samples of n = 2 replicates (Stations 2210, 2314, 2315 summer; 2314 fall; and 2422 winter) are without much meaning. Yet the anchor dredge samples are semiquantitative because the area sampled can be calculated from the sample volume.

Assessments of homogeneity can be seen in Table III, and in the summary sheets in the fourth quarterly report to parallel those of representativeness. Some samples seemed reasonably representative (e.g., the summer sample from Station 2316) but were not very likely to have been drawn from a homogeneous biota. In the case of the example, evidence to be discussed later suggested that the sample had been drawn from <u>two</u> communites, a case where an unfavorable evaluation of representativeness and/or homogeneity based on the <u>whole</u> sample might be expected. But in no case did a sample deemed unrepresentative appear to have been taken from a homogeneous community.

Because of the lack of computer printout, no assessment of representativeness of the fall or winter samples was available in time for this report. However, if we ássume that the fall and winter samples taken at Stations 2105, 2106, 2209, 2211, 2313, 2316, 2421, 2422, 2423, and 2424 were no less representative of the sampled polychaete associations, we may turn our attention to Table I and graphs in Figures 2, 3, 4, and 5.

It is probable that the very low polychaete biomasses found at

Stations 2105, 2106 and 2313 are related to depth and to the predominance of fine carbonate sediment. In passing, it may be mentioned that failure of the sediment grain size graphs to add up to the expected 100% may be attributed to the presence of a substantial percentage of fines which either pass through the finest sieve or never settle in the settling tube. Yet the numbers of species found at Stations 2105 and 2106 are not out of line with what may be looked for in fine grain, high carbonate sediments in shallow water. It is well known that polychaetes dominate the shallow water benthos when the sediment is fine - carbonate or not. At these lesser depths, biomass may be expected to be greater and it was, as, for example, in Stations 2209 and 2211, both of which were characterized by fine grain, high carbonate sediment in at least one replicate. The depths at these two stations were 30.5 and 43 m, respectively, whereas at 2105 it was 91 and at 2106 it was 164 m.

Station 2316 yielded a summer sample with more polychaete species than any other, which, however, added up to a biomass of approximately the same order of magnitude as those found at Stations 2209 and 2211. The high species count is most likely a consequence of the nine replicates of the Station 2316 summer sample having been drawn from two separate micro-habitats, a matter which will be discussed later. But the biomass is once again neatly correlated with depth, which at this station was about 35 m.

This correlation is again evident at Stations 2421, 2422, 2424 which occupy depths of 19, 24, and 33 m, respectively. The very high fall and winter polychaete biomasses found at Station 2423 consitute an anomaly for which there is not now a ready explanation.

The fall polychaete biomass at Station 2314 was too large for the

scale in Figure 4 to accommodate it (but see Table I). This was a two replicate anchor dredge sample which covered a bottom surface area of about 4050 cm^2, which is approximately two-thirds that covered by the nine replicates taken at the box core stations. This, too, remains as an unexplained anomaly.

No discussion of biomass would be complete without some reflections on the value of biomass measurements generally. Whatever component of the ecosystem one is concerned with, the validity of biomass measurements must be scrutinized very carefully. The larger and more complex the component, the less reliable are the biomass measurements. If one is measuring plankton biomass one must allow for the nannoplankton which slip through the net or the macroplankton which are too big for it. In the benthos there are many soft bodied organisms with little if any skeletal material. For such groups the biomass measurements may be realistic, but when dealing with the echinoderms the molluscs and the larger crustacea, unacceptable errors due to massive, non-living (non-biomass) skeletal materials enter the picture.

Another pitfall in the estimate of biomass stems from changes in mass which result from processing specimens after they are caught - narcotizing, preserving, washing, and represerving. Estimates of living biomass based on measurements of preserved material must take this into account.

What is needed is a set of constants and coefficients for each major taxon so wet or dry weights of preserved material may be converted to wet or dry weight of "fresh" material -- skeletal remains excluded. These are presently available for the polychaetes, but because they are not for any other group there has been no point to making the conversions in this study.

B. Polychaete Species and Individual Distributions

1. Density

Like biomass, density (the number of individuals per unit area or volume) is a population parameter. It can also be expressed in either of the two forms prescribed for biomass in the foregoing. The more empirical form, less dependent than the other one but by no means completely independent of sample representativeness, has, as in the case of biomass, been used in this study.

On all four transects there has been a fairly close relationship between polychaete population density and the depth. Transect III graphs in Figure 4 seem to contradict this, but it must be borne in mind that on this transect depths increase as one proceeds seaward from shore, then decrease as the transect crosses the Florida Middle Ground, then increase again seaward.

2. Diversity

The Shannon-Weaver indices of diversity used in this study are non-parametric. They are derived from the observed ratios of numbers of species to numbers of individuals. However, it goes without saying that one would be more comfortable with indices of any sort based on representative samples taken from homogeneous populations, than otherwise.

Three indices have been caluclated for each summer sample. They are H max, the index which would be obtained if the individuals found in the sample were evenly divided among the species; H', which is the index based on the actual, observed distribution of individuals among the species; and J' which is the ratio of H' to H max. Clearly J' is more informative than H'. Comparisons between stations may be made at a glance with J', which

has been used to represent diversity in Table III and in Figures 2, 3, 4, and 5. As a measure of the extent of approach of H' to H max, it contitutes a measure of evenness or equitability.

In the ensuing evaluation, J' values of less than 0.67 are taken to represent low diversity. Values between 0.68 and 0.77, inclusive, are considered equivocal, whereas values of 0.78 to 0.87 are rated high, and those exceeding 0.87 are very high.

Allowing for variation in the representativeness of the summer samples, there seem to be at most only three examples of low diversity. Two of them (Stations 2101 and 2207) are situated where one would expect to find more environmental stress - closest to shore. No explanation is forthcoming for the low diversity found at Station 2209, which seem to conform to expectations for an intermediate depth station with regard to biomass and the number of species.

Diversity at Stations 2102, 2105, 2208, 2318 and 2421 seem to be without particular significance, whereas at the rest of the stations it is high or very high suggesting widespread environmental stability. The bar graphs for equitability for Stations 2314 and 2315 in Figure 4 should be ignored. These, like Station 2210, were in the summer sampling dredge stations. Shannon-Weaver indices of diversity are certainly sample size dependent and are without meaning when based on samples of $n = 2$ replicates.

3. Significantly associated species groups

Table IV is a matrix showing the distribution of numerically dominant polychaete species among the 27 station samples. The numbers in the elements represent the species rank in descending order of dominance.

As pointed out in Section C, three of the foregoing, characterizing

a species as a numerical dominant was based on the percentage of the total number of individuals represented in the whole sample by the species in question. Justification for permitting the percentage above which the species were considered dominant to vary was based on the principle that numerical dominance is less significant in communities characterized by high diversity. The very fact of low diversity is a consequence of disproportionately high numerical dominance of a small fraction of the total number of species.

The primary group of significantly associated polychaete species identified as numerical dominants was also found to be those for which Cole's coefficient of interspecific association was equal to one. The exceptions to this were:

a. The numerical dominant groups found in dredge samples of n = 2 replicates each;

b. Those species in box core samples which were numerically dominant but whose frequency was less than five-ninths.

The one species which occurred in greatest numbers was Filograna implexa, a very small serpulid which lives in compact colonies. At the summer sampling at Station 2103, one box coring picked up a colony of this species containing 1410 individuals. The species was absent from the other eight replicates of the sample. Two other species were excluded from consideration for the same reason - Chone filicaudata, a small sabellid which lives in compact, isolated colonies, and Syllis spongicola, which is a commensal, or perhaps parasitic, inhabitant of sponges.

No pattern of distribution of the types of significantly associated polychaete species groups seems to have arisen out of the summer

sampling.

4. Microhabitats

The kind of sampling that has been done in this study is, in the opinion of the writer, inadequate for the broad area characterization of the northeast Gulf of Mexico OCS with respect to benthic communities. This assertion is substantiated by the fact that the summer samples taken at Stations 2207, 2211, 2316, and 2420 yielded evidence of the existence in the areas covered by the scatter of box corings of more than one habitat occupied by distinct polychaete assemblages. It is for this reason that two primary groups of numerical dominants are listed for each of these stations in Table IV and in Table V. The dendrograms resulting from cluster analysis of the MFP and C lambda affinity matrices show in each of these four cases a distinct dichotomy among the nine replicates.

A stronger case for this can be made for Stations 2211 and 2316 owing to the character of the sediments. Referring back to paragraph A, 1 in the section on Methods, it will be recalled that the material from each replicate retained by the 0.5 mm screen prescribed by the work statement was packaged on shipboard in a cotton cloth bag. In all but eight of the 27 samples, all nine replicates fitted into a single bag each. At the dredge stations (that is, stations with sediment so coarse that the box corer would not penetrate) many bags were required to package the two replicates. At Station 2423, two bags were needed for all nine of the box core replicates. At Stations 2105, 2211, 2316 and 2317 some replicates were accommodated by only one bag and others needed two.

Of the nine replicates in the Station 2211 sample only one - replicate "D" - fitted into a single bag. This was the one replicate in

this sample shown by the dendrogram to be representative of a distinct polychaete assemblage. At Station 2316, the summer sample was divisible into one group of replicates (A, B, C, and E) which required only one bag each (fine sediment) and another (D, F, G, H, and I) which was characterized by coarser sediment requiring two bags per replicate. This dichotomy was exactly matched by the dendrogram, which, incidentally surpassed all the rest in closeness of agreement between MFP and C lambda clustering. It is interesting to note that the sediment analysis depicted for this station in Figure 4 was done on a small aliquot taken from the "A" replicate. Station 2316 is situated on the Florida Middle Ground, a region of high relief which must have many microhabitats.

The assessment of homogeneity as being only "fair" at Station 2316 may be a straightforward manifestation of the almost even distribution of the replicates between two presumptive communities. The fact that only <u>one</u> of the nine replicates taken at Station 2211 seemed to have come from a habitat different from the other eight may be entirely consistent with the homogeneity rating at this station of "excellent." It should be borne in mind that in the affinity-ordination (clustering) analysis, the computer deals with the station data matrix as a whole and has not been programmed to do anything about dichotomies the existence of which it may reveal.

In the cases of the other two stations with one and two bag replicates, the correlation with the dendrograms was less convincing. At Station 2317 two replicates (H and I) required two bags; these two plus the single bag replicate E could be said to be representative of a polychaete assemblage different from the others, but agreement between the dendrograms was not too good.

At the fourth "mixed" (one bag, two bag) station, 2105, neither the distribution of the replicates among the bags nor the dendrograms led to a suggestion of separate microhabitats. Stations 2207 and 2420, both of whose summer samples yielded dendrograms suggesting microhabitats were one bag station - all the replicates fitting into single bags.

This situation points up to the desirability of having sediment analyses performed on aliquots taken out of all sample replicates used to characterize the benthic communities. As it happened, one sediment sample was taken out of only one of the nine benthic macrofauna replicates and the other out of a tenth. If both had been taken each out of one of the nine, there might have been instances of correlation between the sediment properties and the distribution of replicates among the presumptive microhabitats.

Although the navigators recorded the positions of the eleven box cores relative to the point at which each station buoy was placed, these were never plotted. Such plots might also have revealed spatial clustering of replicates similar to those produced in the dendrograms.

It is entirely reasonable to assume that the apparent unrepresentativeness of some of the samples may have been a consequence of similar discontinuities, which might have been better defined had more replicates been taken.

Another possibility is that apparent failure of polychaete species composition to support other evidence of these dichotomies might be rectified if the whole biotic community rather than a single taxon were considered.

CONCLUSIONS

The validity of results of the statistical analysis of polychaete data from the summer samples taken at 17 of the 27 stations on Transects I, II, III, and IV is in doubt. Three of these were essentially qualitative dredge samples of $n = 2$ replicates each. In one case the statistical analytical results were questioned because of keypunching errors and undue weighting caused by a single very abundant species found in only one of the nine replicates. The samples taken at the 13 others were considered inadequate with respect to sample size; more than nine replicates each would have been required to obtain representative samples.

Evaluations of homogeneity of the sampled polychaete association were consistent with those of adequacy of sample size.

Within the group of ten stations from which samples considered representative had been taken, a fairly consistent negative correlation between polychaete biomass and depth was noted. This was true for polychaete density also but not for the numbers of species which seemed to be more closely related to the properties of the sediments.

Diversity was considered low at only three box core stations. Two of them were situated on the shoreward ends of their respective transects where instability, the antithesis of diversity would be expected to be greater. Diversity increased with depth - the highest values being found in the data from the deepest stations. In general, polychaete diversity is high, a manifestation of the widespread distribution of fine sediment, in itself an indicator of environmental stability.

Significantly associated groups of polychaete species erected on the

basis of numerical abundance and between species affinity distributed themselves among five general group types in the summer sampling.

The probable existence of more than one biotic community, represented by polychaetes in the sample, in the area covered by the scatter of box corings was detected at four stations. At two of these, this conclusion was fortified by the general character of the sediments. This points to the desirability of more flexible sampling with respect to replicate number and scatter. Also recommended is the statistical analysis of data as soon as they are reported in order to tailor projected samplings to the realistics thereby revealed.

RECOMMENDATIONS

A distinction between "interdisciplinary" and "multidisciplinary" research has crept, somewhat belatedly, into recent correspondence. The former concept is considered by the writer to be closely related to that of the "synthesis" requirements which were written into the work statement and contract. Little thought was given to this by those who conceived of and committed the consortium to the experimental design. The kind of amalgamations of data and their interpretation which the writer believes was desired when the work statement dealt with "synthesis" can be achieved at only a very elementary level when:

a. A great disparity in quantitation exists between the various facets of the program;

b. The individuals whose inputs are supposed to form the basis for the "synthesis" are permitted to develop these inputs in isolation.

Recommendations for greater exchange between participants working in closely related areas should not be overridden by those whose chief concern is saving money.

Evaluation of data already at hand should be prerequisite to "designing the experiment" for another year's work - if there is to be any. Individuals to whom subordination to the collective is anathema should be weeded out of the program.

The data management group should be elevated from the status of a computerized file clerk appended to management to that of an integral part of the central scientific planning committee with the essential responsibility of advising the committee how best to plan for the ultimate synthesis, as well as of recommending to all concerned how their data may best be analyzed to produce the desired results.

Appendix I

Benthic Invertebrate Macroinfauna

FSU Marine Laboratory Archive - 1974 Collections

Explanation

Blake = transferred to N. J. Blake, University of South Florida
x = in archive, with other components of this replicate
- = none present in this replicate
Vittor = transferred to B. A. Vittor, Dauphin Island Sea Lab
M = amphipods and mysids removed by L. McKinney, Texas A&M; returned to archive
l = lost - accident in processing

Station	Replicate	Molluscs	Crustacea	Echinoderms	Polychaetes	Misc.
1	C	Blake	x	x	Vittor	x
	D	"	M	x	"	-
	E	"	-	x	"	x
	F	"	x	x	"	x
	G	"	x	x	"	x
	H	"	x	x	"	x
	I	"	x	x	"	x
	J	"	x	x	"	x
2	C	"	x	-	"	x
	D	"	-	-	"	x
	E	"	x	x	"	x
	F	"	M	x	"	x
	G	"	x	-	"	x
	H	"	-	x	"	x
	I	Blake	x	-	"	x
	J	"	x	-	"	x
3	C	-	x	-	"	x
	D	Blake	x	-	"	x

Station	Replicate	Molluscs	Crustacea	Echinodermata	Polychaetes	Misc.
	E	Blake	-	x	Vittor	x
	F	-	x	x	"	-
	G	-	x	x	"	x
	H	-	-	x	"	x
	I	Blake	x	-	"	x
	J	"	M	-	"	x
4	C	"	x	x	"	x
	D	-	x	x	"	-
	E	-	x	x	"	x
	F	Blake	x	x	"	x
	G	-	M	x	"	-
	H	-	-	-	"	x
	I	-	x	x	"	-
	J	-	x	x	"	x
5	C	Blake	x	x	"	x
	D	"	x	-	"	x
	E	"	x	x	"	x
	F	"	x	x	"	x
	G	"	M	x	"	x
	H	-	x	x	"	x
	I	Blake	x	x	"	x
	J	-	-	x	"	-
6	C	x	x	x	"	x
	D	Blake	x	-	"	x

Station	Replicate	Molluscs	Crustacea	Echinoderms	Polychaetes	Misc.
6	E	Blake	x	x	Vittor	x
	F	"	x	x	"	x
	G	"	M	x	"	x
	H	"	x	-	"	x
	I	"	x	x	"	x
	J	"	-	x	"	x
7	C	"	x	x	"	x
	D	"	x	x	"	x
	E	"	x	x	"	x
	F	"	x	x	"	x
	G	"	x	x	"	x
	H	"	x	-	"	x
	I	"	x	x	"	x
	J	"	M	x	"	x
8	C	"	x	x	"	x
	D	"	x	-	"	x
	E	"	x	-	"	x
	F	"	x	x	"	x
	G	"	x	-	"	x
	H	"	x	x	"	x
	I	"	x	x	"	x
	J	"	M	x	"	x
9	C	Blake	M	x	Vittor	x
	D	"	x	x	"	x

Station	Replicate	Molluscs	Crustacea	Echinoderms	Polychaetes	Misc.
9	E	Blake	x	x	Vittor	x
	F	"	x	x	"	x
	G	"	x	x	"	x
	H	"	x	x	"	x
	I	"	x	x	"	x
	J	"	x	x	"	x
10	C	"	x	x	"	x
	D	"	x	x	"	x
	E	"	x	x	"	x
	F	"	x	x	"	x
	G	"	x	x	"	x
	H	"	x	x	"	x
	I	"	x	x	"	x
	J	"	M	x	"	x
11	C	"	x	x	"	x
	D	"	M	x	"	x
	E	"	x	-	"	x
	F	"	x	-	"	x
	G	"	x	-	"	x
	H	"	x	x	"	x
	I	"	x	-	"	x
	J	"	x	x	"	x
12	C	"	x	x	"	x
	D	"	x	x	"	x

Station	Replicate	Molluscs	Crustacea	Echinoderms	Polychaetes	Misc.
12	E	Blake	M	x	Vittor	x
	F	"	x	x	"	x
	G	"	x	x	"	x
	H	"	x	x	"	x
	I	"	x	x	"	x
	J	-	x	-	"	x
13	C	Blake	M	x	"	x
	D	"	x	x	"	x
	E	-	x	x	"	x
	F	Blake	x	-	"	x
	G	lost----------	----------	----------	----------	-----
	H	Blake	x	-	"	x
	I	"	x	x	"	x
	J	"	x	-	"	x
14	C	"	x	x	"	x
	D	"	x	x	"	x
	E	"	x	x	"	x
	F	"	x	x	"	x
	G	"	x	x	"	x
	H	"	x	x	"	x
	I	"	M	x	"	x
	J	"	x	x	"	x
15	C	"	x	x	"	x
	D	"	x	x	"	x

Station	Replicate	Molluscs	Crustacea	Echinoderms	Polychaetes	Misc.
15	E	"	x	x	Vittor	x
	F	"	M	x	"	x
	G	"	x	x	"	x
	H	"	x	x	"	x
	I	"	x	x	"	x
	J	"	x	x	"	x
16	C	"	x	-	"	x
	D	"	x	x	"	x
	E	"	x	x	"	x
	F	"	x	x	"	x
	G	"	x	-	"	x
	H	"	x	x	"	x
	I	"	M	-	"	x
	J	"	x	-	"	x
17	C	"	x	x	"	x
	D	"	M	x	"	x
	E	-	x	x	"	x
	F	Blake	x	x	"	x
	G	"	x	x	"	x
	H	"	x	x	"	x
	I	"	x	x	"	x
	J	"	x	x	"	x
18	C	Blake	x	x	Vittor	x
	D	"	x	-	"	x

Station	Replicate	Molluscs	Crustacea	Echinoderms	Polychaetes	Misc.
18	E	"	x	x	Vittor	x
	F	"	x	-	"	x
	G	-	x	x	"	x
	H	Blake	M	-	"	x
	I	-	x	x	"	x
	J	Blake	x	-	"	x
19	C	"	x	x	"	x
	D	"	x	-	"	x
	E	"	x	x	"	x
	F	-	x	x	"	x
	G	Blake	x	x	"	x
	H	-	x	x	"	x
	I	Blake	x	x	"	x
	J	"	M	x	"	x
20	C	"	x	-	"	x
	D	"	x	-	"	x
	E	"	M	-	"	x
	F	"	x	-	"	-
	G	"	x	-	"	-
	H	"	x	x	"	x
	I	-	x	x	"	x
	J	Blake	x	x	"	x
21	C	"	x	x	x	x
	D	"	x	-	x	x

Station	Replicate	Molluscs	Crustacea	Echinoderms	Polychaetes	Misc.
21	E	Blake	M	x	Vittor	x
	F	"	x	-	x	x
	G	"	x	x	x	x
	H	"	x	x	x	x
	I	"	x	-	x	x
	J	"	x	-	x	x
22	C	"	x	-	x	x
	D	"	x	x	x	x
	E	-	x	-	x	x
	F	Blake	x	-	x	x
	G	"	x	-	x	-
	H	"	x	-	x	x
	I	-	x	-	x	x
	J	Blake	M	-	x	x
23	C	"	x	-	x	x
	D	"	x	-	x	x
	E	"	x	-	x	-
	F	-	x	-	x	-
	G	-	x	-	x	x
	H	Blake	x	-	x	x
	I	"	x	-	x	-
	J	"	M	x	x	-
24	C	lost				
	D	-	x	x	x	x

Station	Replicate	Molluscs	Crustacea	Echinoderms	Polychaetes	Misc.
24	E	Blake	x	-	x	x
	F	-	x	x	x	x
	G	Blake	x	x	x	x
	H	-	x	x	x	-
	I	Blake	x	-	x	x
	J	"	M	x	x	-
25	C	-	x	-	x	x
	D	-	x	-	x	x
	E	-	x	-	x	-
	F	Blake	x	-	x	x
	G	"	x	-	x	x
	H	"	x	-	x	x
	I	"	x	-	x	-
	J	-	M	x	x	x
26	C	Blake	x	-	x	-
	D	"	x	-	x	x
	E	"	x	-	x	x
	F	"	x	-	x	x
	G	_	M	-	x	-
	H	Blake	x	x	x	-
	I	"	x	x	x	-
	J	"	-	x	x	x
27	C	Blake	M	-	x	x
	D	"	-	-	x	-

Station	Replicate	Molluscs	Crustacea	Echinoderms	Polychaetes	Misc.
27	E	Blake	x	x	x	x
	F	"	x	x	x	x
	G	-	x	-	x	x
	H	-	x	-	x	-
	I	Blake	x	-	x	-
	J	"	-	-	x	-
28	C	"	x	x	x	x
	D	"	x	x	x	x
	E	"	M	x	x	x
	F	"	x	x	x	x
	G	"	x	-	x	x
	H	"	x	-	x	x
	I	"	x	-	x	x
	J	"	x	-	x	x
29	C	"	x	x	x	x
	D	"	x	x	x	x
	E	"	x	x	x	x
	F	"	x	x	x	-
	G	-	x	x	x	x
	H	Blake	x	x	x	x
	I	"	M	x	x	x
	J	-	x	x	x	x
30	C	Blake	x	x	x	x
	D	-	x	x	x	x

Station	Replicate	Molluscs	Crustacea	Echinoderms	Polychaetes	Misc.
30	E	Blake	M	-	x	x
	F	"	x	-	x	x
	G	"	x	x	x	x
	H	-	x	-	x	x
	I	-	x	-	x	-
	J	Blake	x	-	x	x
31	C	"	x	-	x	x
	D	"	M	-	x	x
	E	"	x	x	x	x
	F	"	x	-	x	x
	G	Blake	x	x	x	x
	H	"	x	-	x	x
	I	"	x	x	x	x
	J	"	x	-	x	x
32	C	"	M	x	x	x
	D	-	x	-	x	x
	Dr I	Blake	M	x	x	x
	Dr II	"	x	x	x	x
33	C	"	x	x	x	x
	D	"	x	x	x	x
	E	-	x	x	x	x
	F	Blake	x	-	x	x
	G	"	x	-	x	x
	H	"	x	x	x	x

Station	Replicate	Molluscs	Crustacea	Echinoderms	Polychaetes	Misc.
33	I	Blake	x	-	x	x
	J	"	M	x	x	x
34	C	"	M	x	x	x
	D	"	x	x	x	x
	E	"	x	-	x	x
	F	"	x	-	x	x
	G	"	-	-	x	x
	H	"	x	x	x	x
	I	"	x	-	x	x
	J	"	x	-	x	x
35	C	"	M	x	x	x
	D	"	x	-	x	x
	E	"	x	x	x	x
	F	"	x	x	x	x
	G	"	x	x	x	x
	H	"	x	x	x	x
	I	"	x	x	x	x
	J	"	x	-	x	x
36	C	"	x	x	x	x
	D	-	x	x	x	x
	E	-	x	x	x	x
	F	Blake	x	-	x	x
	G	"	x	x	x	x
	H	"	M	x	x	-

Station	Replicate	Molluscs	Crustacea	Echinoderms	Polychaetes	Misc.
36	I	Blake	x	-	x	x
	J	"	x	x	x	x
37	C	"	x	-	x	x
	D	"	x	-	x	x
	E	"	x	-	x	x
	F	"	x	-	x	x
	G	"	x	-	x	x
	H	"	x	-	x	x
	I	"	x	-	x	x
	J	"	M	-	x	x
38	C	"	x	-	x	x
	D	"	x	x	x	x
	E	"	M	x	x	x
	F	"	x	x	x	x
	G	"	x	x	x	x
	H	"	x	x	x	x
	I	"	x	x	x	x
	J	"	x	x	x	x
39	C	-	x	x	x	x
	D	Blake	M	-	x	x
	E	"	x	x	x	x
	F	"	x	-	x	x
	G	"	x	-	x	x
	H	"	x	-	x	x

Station	Replicate	Molluscs	Crustacea	Echinoderms	Polychaetes	Misc.
39	I	Blake	x	-	x	x
	J	"	x	-	x	x
40	C	"	x	-	x	x
	D	"	-	-	x	x
	E	"	x	-	x	x
	F	"	M	-	x	x
	G	"	x	-	x	x
	H	"	x	-	x	x
	I	-	x	x	x	x
	J	Blake	x	x	x	x
41	C	"	x	-	x	-
	D	"	x	-	x	x
	E	"	M	-	x	x
	F	"	x	-	x	x
	G	"	x	-	x	x
	H	-	x	-	x	x
	I	Blake	x	-	x	x
	J	"	x	-	x	x
42	C	"	x	x	x	x
	D	"	x	-	x	x
	E	"	x	x	x	x
	F	"	x	x	x	x
	G	"	x	x	x	x
	H	"	x	x	x	x

Station	Replicate	Molluscs	Crustacea	Echinoderms	Polychaetes	Misc.
42	I	Blake	x	x	x	x
	J	"	M	x	x	x
43	Dr I	"	M	x	x	x
	Dr II	"	x	x	x	x
44	C	"	x	x	x	x
	D	"	x	x	x	x
	E	"	x	-	x	x
	F	"	x	x	x	x
	G	"	x	x	x	x
	H	-	x	x	x	x
	I	Blake	x	-	x	x
	J	"	M	x	x	x
45	C	"	x	x	x	x
	D	"	M	x	x	x
	E	"	x	x	x	x
	F	-	x	x	x	x
	G	-	x	x	x	x
	H	Blake	x	x	x	x
	I	"	x	x	x	x
	J	"	x	x	x	x
46	C	"	M	-	x	x
	D	"	x	-	x	x
	E	"	x	-	x	x
	F	"	x	-	x	x

Station	Replicate	Molluscs	Crustacea	Echinoderms	Polychaetes	Misc.
46	G	Blake	x	x	x	x
	H	"	x	x	x	x
	I	"	x	x	x	x
	J	"	x	x	x	x
47	C	"	M	x	x	x
	D	"	x	x	x	x
	E	"	x	x	x	x
	F	"	x	x	x	x
	G	"	x	x	x	x
	H	"	x	x	x	x
	I	"	x	x	x	x
	J	"	x	x	x	x
48	C	"	x	x	x	x
	D	-	x	x	x	x
	E	Blake	x	x	x	x
	F	"	x	x	x	x
	G	"	x	x	x	x
	H	-	x	x	x	x
	I	Blake	x	x	x	x
	J	-	x	-	x	x
49	Dr I	Blake	M	x	x	x
	Dr II	"	x	x	x	x
50	C	"	x	-	x	x
	D	"	x	-	x	-

Station	Replicate	Molluscs	Crustacea	Echinoderms	Polychaetes	Misc.
50	E	-	x	x	x	x
	F	Blake	x	-	x	x
	G	-	x	x	x	x
	H	Blake	x	-	x	x
	I	"	M	-	x	x
	J	"	x	-	x	x
51	Dr I	"	M	x	x	x
	Dr II	"	x	x	x	x
52	C	"	x	-	x	-
	D	-	M	x	x	x
	E	"	x	x	x	x
	F	"	x	x	x	x
	G	"	x	x	x	x
	H	"	x	x	x	x
	I	"	x	x	x	-
	J	"	x	x	x	x
53	C	"	x	-	x	x
	D	"	x	-	x	x
	E	"	M	x	x	x
	F	"	x	x	x	x
	G	"	x	-	x	x
	H	"	x	x	x	x
	I	"	x	x	x	x
	J	"	x	x	x	x

Station	Replicate	Mollusca	Crustacea	Echinoderma	Polychaetes	Misc.
54	C	Blake	x	x	x	x
	D	"	M	x	x	x
	E	-	x	x	x	x
	F	Blake	x	-	x	x
54	Dr I	"	M	x	x	x
55	C	"	x	x	x	x
	D	"	x	x	x	x
	E	-	x	x	x	x
	F	Blake	M	x	x	x
	G	-	x	-	x	x
	H	Blake	x	-	x	x
	I	-	x	x	x	x
	J	Blake	x	-	x	x
56	C	"	x	x	x	x
	D	"	x	x	x	x
	E	"	x	-	x	x
	F	"	x	-	x	x
	G	"	M	x	x	x
	H	-	x	x	x	x
	I	"	x	x	x	x
	J	"	x	x	x	x
57	C	Blake	x	-	x	x
	D	"	x	-	x	x
	E	"	x	x	x	x

Station	Replicate	Molluscs	Crustacea	Echinoderms	Polychaetes	Misc.
57	F	Blake	x	x	x	x
	G	"	x	-	x	x
	H	"	x	-	x	x
	I	"	x	-	x	x
	J	"	M	-	x	x
58	Dr I	"	M	x	x	x
	Dr II	"	x	x	x	x
59	Dr I	"	M	x	x	x
	Dr II	"	x	x	x	x
60	C	"	x	-	x	-
	D	"	x	x	x	-
	E	"	x	-	x	x
	F	"	x	-	x	x
	G	"	x	-	x	x
	H	"	x	-	x	x
	I	"	M	-	x	x
	J	_	x	-	x	x
61	C	Blake	x	-	x	x
	D	"	x	-	x	x
	E	"	x	-	x	x
	F	-	x	-	x	x
	G	Blake	x	-	x	x
	H	-	x	-	x	x
	I	-	M	-	x	x

Station	Replicate	Molluscs	Crustacea	Echinoderms	Polychaetes	Misc.
61	J	Blake	x	x	x	x
62	C	-	x	-	x	x
	D	-	x	-	x	x
	E	Blake	x	x	x	x
	F	-	x	-	x	x
	G	Blake	x	-	x	x
	H	"	x	-	x	x
	I	"	x	-	x	x
	J	"	M	-	x	x
63	C	Blake	x	-	x	x
	D	"	x	-	x	x
	E	-	x	-	x	x
	F	Blake	x	-	x	x
	G	"	x	-	x	x
	H	"	x	-	x	x
	I	"	M	-	x	x
	J	"	x	-	x	x
64	C	"	x	-	x	x
	D	"	x	-	x	-
	E	-	x	-	x	x
	F	Blake	x	-	x	x
	G	"	x	-	x	-
	H	"	x	-	x	x
	I	-	x	-	x	x

Station	Replicate	Molluscs	Crustacea	Echinoderms	Polychaetes	Misc.
64	J	Blake	M	x	x	x
65	C	"	x	-	x	x
	D	"	x	x	x	x
	E	"	x	-	x	x
	F	"	x	-	x	x
	G	"	x	-	x	x
	H	"	M	-	x	x
	I	"	x	x	x	x
	J	-	x	-	x	x

Appendix II
Benthic Invertebrate Macroinfauna
FSU Marine Laboratory Archive - 75/76 Collections

Explanation
Blake = transferred to N. J. Blake, University of South Florida
x = in archive, with other components of this replicate
- = none present in this replicate
l = lost - processing accident

SUMMER, 1975 SAMPLING

Station	Replicate	Molluscs	Crustacea	Echinoderms	Polychaetes	Misc.
2313	A	Blake	-	x	x	x
	B	"	-	x	x	x
	C	"	-	-	x	x
	D	"	x	-	x	x
	E	"	x	-	x	-
	F	"	x	-	x	x
	G	"	x	-	x	x
	H	"	x	-	x	-
	I	"	x	x	x	x
2314	Dr I	"	x	x	x	x
	Dr II	"	x	x	x	x
2315	Dr I	"	x	x	x	x
	Dr II	"	x	x	x	x
2316	A	"	x	x	x	x
	B	"	x	x	x	x
	C	"	x	x	x	x
	D	"	x	x	x	x
	E	"	x	x	x	x

Station	Replicate	Molluscs	Crustacea	Echinoderms	Polychaetes	Misc.
2316	E	Blake	x	x	x	x
	F	"	x	x	x	x
	G	"	x	x	x	x
	H	"	x	-	x	x
	I	"	x	x	x	x
2317	A	"	x	-	x	x
	B	"	x	x	x	x
	C	"	x	-	x	x
	D	"	x	x	x	x
	E	"	x	-	x	x
	F	"	x	x	x	x
	G	"	x	x	x	x
	H	"	x	x	x	x
	I	"	x	-	x	x
2318	A	"	x	-	x	x
	B	"	x	x	x	x
	C	"	x	-	x	x
	D	"	x	x	x	x
	E	"	x	-	x	x
	F	"	x	-	x	x
	G	-	-	-	x	-
	H	-	x	-	x	x
	I	Blake	x	x	x	x

Station	Replicate	Molluscs	Crustacea	Echinoderms	Polychaetes	Misc.
2419	A	Blake	x	-	x	x
	B	"	x	-	x	x
	C	"	x	x	x	x
	D	"	x	-	x	x
	E	"	x	x	x	x
	F	"	x	-	x	x
	G	"	x	x	x	x
	H	"	x	x	x	x
	I	"	x	-	x	x
2420	A	"	x	x	x	x
	B	"	x	x	x	x
	C	"	x	x	x	x
	D	"	x	-	x	x
	E	"	x	-	x	x
	F	"	x	x	x	x
	G	"	x	x	x	x
	H	"	x	x	x	x
	I	"	x	-	x	x
2421	A	"	x	x	x	x
	B	"	x	x	x	x
	C	-	x	-	x	x
	D	Blake	x	-	x	x
	E	"	x	x	x	x

Station	Replicate	Molluscs	Crustacea	Echinoderms	Polychaetes	Misc.
2421	F	Blake	x	x	x	x
	G	"	x	x	x	x
	H	-	x	-	x	x
	I	Blake	x	x	x	x
2422	A	"	x	x	x	x
	B	"	x	x	x	x
	C	"	x	x	x	x
	D	"	x	x	x	x
	E	"	x	x	x	x
	F	"	x	x	x	x
	G	-	x	x	x	x
	H	Blake	x	x	x	x
	I	"	x	x	x	x
2423	A	"	x	x	x	x
	B	"	x	x	x	x
	C	"	x	x	x	x
	D	"	x	x	x	x
	E	"	x	x	x	x
	F	-	x	x	x	x
	G	Blake	x	x	x	x
	H	"	x	x	x	x
	I	"	x	x	x	x
2424	A	"	x	x	x	x

Station	Replicate	Molluscs	Crustacea	Echinoderms	Polychaetes	Misc.
2424	B	"	x	x	x	x
	C	"	x	-	x	x
	D	"	x	x	x	x
	E	"	x	-	x	x
	F	"	x	-	x	x
	G	"	x	x	x	x
	H	"	x	x	x	x
	I	"	x	-	x	x
2425	A	"	x	-	x	x
	B	"	x	-	x	x
	C	"	x	x	x	x
	D	"	x	-	x	x
	E	"	x	-	x	x
	F	-	x	-	x	x
	G	-	x	x	x	x
	H	Blake	x	x	x	x
	I	-	x	-	x	x
2426	A	Blake	x	-	x	x
	B	"	x	x	x	x
	C	"	x	-	x	x
	D	-	x	x	x	x
	E	Blake	x	-	x	x
	F	"	x	-	x	x

Station	Replicate	Molluscs	Crustacea	Echinoderms	Polychaetes	Misc.
2426	G	-	x	-	x	x
	H	Blake	x	x	x	x
	I	-	x	-	x	x
2427	A	-	x	-	x	x
	B	Blake	x	-	x	x
	C	-	x	x	x	x
	D	Blake	-	x	x	x
	E	"	x	-	x	x
	F	"	x	x	x	x
	G	-	x	-	x	x
	H	"	x	-	x	x
	I	"	-	-	x	
2101	A				x	
	B				x	
	C				x	
	D				x	
	E				x	
	F				x	
	G				x	
	H				x	
	I				x	
2102	A				x	
	B				x	

Station	Replicate	Molluscs	Crustacea	Echinoderms	Polychaetes	Misc.
2102	C				x	
	D				x	
	E				x	
	F				x	
	G				x	
	H				x	
	I				x	
2103	A				x	
	B				x	
	C				x	
	D				x	
	E				x	
	F				x	
	G				x	
	H				x	
	I				x	
2104	A				x	
	B				x	
	C				x	
	D				x	
	E				x	
	F				x	
	G				x	

Station	Replicate	Molluscs	Crustacea	Echinoderms	Polychaetes	Misc.
2104	H				x	
	I				x	
2105	A				x	
	B				x	
	C				x	
	D				x	
	E				x	
	F				x	
	G				x	
	H				x	
	I				x	
2106	A				x	
	B				x	
	C				x	
	D				x	
	E				x	
	F				x	
	G				x	
	H				x	
	I				x	
2207	A				x	
	B				x	
	C				x	

Station	Replicate	Molluscs	Crustacea	Echinoderms	Polychaetes	Misc.
2207	D				x	
	E				x	
	F				x	
	G				x	
	H				x	
	I				x	
2208	A				x	
	B				x	
	C				x	
	D				x	
	E				x	
	F				x	
	G				x	
	H				x	
	I				x	
2209	A				x	
	B				x	
	C				x	
	D				x	
	E				x	
	F				x	
	G				x	
	H				x	

Station	Replicate	Molluscs	Crustacea	Echinoderms	Polychaetes	Misc.
2209	I				x	
2210	Dr I				x	
	Dr II				x	
2211	A				x	
	B				x	
	C				x	
	D				x	
	E				x	
	F				x	
	G				x	
	H				x	
	I				x	
2212	A				x	
	B				x	
	C				x	
	D				x	
	E				x	
	F				x	
	G				x	
	H				x	
	I				x	

FALL, 1975 SAMPLING

Station	Replicate	Molluscs	Crustacea	Echinoderms	Polychaetes	Misc.
2313	A	-	x	-	x	x
	B	Blake	-	-	x	x
	C	"	x	-	x	x
	D	"	x	-	x	x
	E	-	-	-	x	x
	F	Blake	x	-	x	x
	G	"	-	-	x	-
	H	-	-	-	x	x
	I	-	-	-	x	x
2314	Dr I	Blake	x	x	x	x
	Dr II	"	x	x	x	x
2315	A	"	x	-	x	x
	B	"	x	x	x	x
	C	"	x	x	x	x
	D	"	x	x	x	x
	E	"	x	x	x	x
	F	"	x	-	x	x
	G	"	x	-	x	x
	H	"	x	x	x	x
	I	"	x	x	x	x
2316	A	Blake	x	x	x	x
	B	"	x	x	x	x
	C	"	x	x	x	x

Station	Replicate	Molluscs	Crustacea	Echinoderms	Polychaetes	Misc.
2316	D	Blake	x	x	x	x
	E	"	x	x	x	x
	F	"	x	x	x	x
	G	"	x	x	x	x
	H	"	x	x	x	x
	I	"	x	-	x	x
2317	A	"	x	x	x	x
	B	"	x	x	x	x
	C	"	x	x	x	x
	D	"	x	x	x	x
	E	"	x	-	x	x
	F	-	x	x	x	x
	G	Blake	x	x	x	x
	H	"	x	x	x	x
	I	"	x	x	x	x
2318	A	"	x	x	x	x
	B	"	x	x	x	x
	C	"	x	x	x	x
	D	"	x	x	x	x
	E	"	x	x	x	x
	F	"	x	x	x	x
	G	"	x	x	x	x
	H	"	x	x	x	x

Station	Replicate	Molluscs	Crustacea	Echinoderms	Polychaetes	Misc.
2318	I	Blake	x	x	x	x
2419	A	"	x	-	x	x
	B	"	x	x	x	x
	C	"	x	x	x	x
	D	"	x	x	x	x
	E	"	x	x	x	x
	F	"	x	x	x	x
	G	"	x	-	x	x
	H	"	x	x	x	x
	I	"	x	x	x	x
2420	A	"	x	x	x	x
	B	"	x	x	x	x
	C	"	x	x	x	x
	D	"	x	x	x	x
	E	"	x	x	x	x
	F	"	x	x	x	x
	G	"	x	x	x	x
	H	"	x	x	x	x
	I	"	x	x	x	x
2421	A	"	x	-	x	x
	B	"	x	x	x	x
	C	"	x	x	x	x
	D	"	x	x	x	x

Station	Replicate	Molluscs	Crustacea	Echinoderms	Polychaetes	Misc.
2421	E	Blake	x	x	x	x
	F	"	x	x	x	x
	G	"	x	x	x	x
	H	"	x	-	x	x
	I	"	x	x	x	x
2422	A	"	x	x	x	x
	B	"	x	x	x	x
	C	"	x	x	x	x
	D	-	x	x	x	x
	E	Blake	x	x	x	x
	F	"	x	x	x	x
	G	"	x	x	x	x
	H	"	x	x	x	x
	I	"	x	x	x	x
2423	A	"	x	x	x	x
	B	"	x	x	x	x
	C	"	x	x	x	x
	D	"	x	x	x	x
	E	"	x	x	x	x
	F	"	x	x	x	x
	G	"	x	x	x	x
	H	"	x	x	x	x
	I	"	x	x	x	x

Station	Replicate	Molluscs	Crustacea	Echinoderms	Polychaetes	Misc.
2424	A	Blake	x	-	x	x
	B	-	x	-	x	x
	C	Blake	x	x	x	x
	D	"	x	x	x	x
	E	"	x	x	x	x
	F	"	x	x	x	x
	G	"	x	x	x	x
	H	"	x	-	x	x
	I	"	x	x	x	x
2425	A	"	x	x	x	x
	B	"	x	-	x	x
	C	"	x	x	x	x
	D	"	x	x	x	x
	E	"	x	x	x	x
	F	"	x	x	x	x
	G	"	x	x	x	x
	H	"	x	x	x	x
	I	"	x	-	x	x
2426	A	-	x	x	x	x
	B	-	x	-	x	x
	C	-	x	-	x	x
	D	Blake	x	-	x	x
	E	"	x	x	x	x

Station	Replicate	Molluscs	Crustacea	Echinoderms	Polychaetes	Misc.
2426	F	Blake	x	-	x	x
	G	"	x	x	x	x
	H	"	x	-	x	x
	I	"	x	-	x	x
2427	A	"	x	-	x	x
	B	-	-	-	x	x
	C	Blake	x	-	x	-
	D	"	x	x	x	x
	E	"	-	-	x	x
	F	"	x	x	x	x
	G	"	-	-	x	x
	H	"	x	x	x	x
	I	-	x	-	x	x
2101	A				x	
	B				x	
	V				x	
	D				x	
	E				x	
	F				x	
	G				x	
	H				x	
	I				x	
2102	A				x	

Station	Replicate	Molluscs	Crustacea	Echinoderms	Polychaetes	Misc.
2102	B				x	
	C				x	
	D				x	
	E				x	
	F				x	
	G				x	
	H				x	
	I				x	
2103	A				x	
	B				x	
	C				x	
	D				x	
	E				x	
	F				x	
	G				x	
	H				x	
	I				x	
2104	A				x	
	B				x	
	C				x	
	D				x	
	E				x	
	F				x	

Station	Replicate	Molluscs	Crustacea	Echinoderms	Polychaetes	Misc.
2104	G				x	
	H				x	
	I				x	
2105	A				x	
	B				x	
	C				x	
	D				x	
	E				x	
	F				x	
	G				x	
	H				x	
	I				x	
2106	A				x	
	B				x	
	C				x	
	D				x	
	E				x	
	F				x	
	G				x	
	H				x	
	I				x	
2207	A				x	
	B				x	

Station	Replicate	Molluscs	Crustacea	Echinoderms	Polychaetes	Misc.
2207	C				x	
	D				x	
	E				x	
	F				x	
	G				x	
	H				x	
	I				x	
2209	A				x	
	B				x	
	C				x	
	D				x	
	E				x	
	F				x	
	G				x	
	H				x	
	I				x	
2210	A				x	
	B				x	
	C				x	
	D				x	
	E				x	
	F				x	
	G				x	

Station	Replicate	Molluscs	Crustacea	Echinoderms	Polychaetes	Misc.
2210	H				x	
	I				x	
2211	A				x	
	B				x	
	C				x	
	D				x	
	E				x	
	F				x	
	G				x	
	H				x	
	I				x	
2212	A				x	
	B				x	
	C				x	
	D				x	
	E				x	
	F				x	
	G				x	
	H				x	
	I				x	
2101	A				x	
	B				x	
	C				x	

Station	Replicate	Molluscs	Crustacea	Echinoderms	Polychaetes	Misc.
2101	E				x	
	F				x	
	G				x	
	H				x	
	I				x	
2102	A				x	
	B				x	
	C				x	
	D				x	
	E				x	
	F				x	
	G				x	
	H				x	
	I				x	
2103	A				x	
	B				x	
	C				x	
	D				x	
	E				x	
	F				x	
	G				x	
	H				x	
	I				x	

Station	Replicate	Molluscs	Crustacea	Echinoderms	Polychaetes	Misc.
2104	A				x	
	B				x	
	C				x	
	D				x	
	E				x	
	F				x	
	G				x	
	H				x	
	I				x	
2105	A				x	
	B				x	
	C				x	
	D				x	
	E				x	
	F				x	
	G				x	
	H				x	
	I				x	
2106	A				x	
	B				x	
	C				x	
	D				x	
	E				x	

Station	Replicate	Molluscs	Crustacea	Echinoderms	Polychaetes	Misc.
2106	F				x	
	G				x	
	H				x	
	I				x	
2208	A				x	
	B				x	
	C				x	
	D				x	
	E				x	
	F				x	
	G				x	
	H				x	
	I				x	
2209	A				x	
	B				x	
	C				x	
	D				x	
	E				x	
	F				x	
	G				x	
	H				x	
	I				x	
2210	A				x	

Station	Replicate	Molluscs	Crustacea	Echinoderms	Polychaetes	Misc.
2210	B				x	
	C				x	
	D				x	
	E				x	
	F				x	
	G				x	
	H				x	
	I				x	
2211	A				x	
	B				x	
	C				x	
	D				x	
	E				x	
	F				x	
	G				x	
	H				x	
	I				x	
2212	A				x	
	B				x	
	C				x	
	D				x	
	E				x	
	F				x	

Station	Replicate	Molluscs	Crustacea	Echinoderms	Polychaetes	Misc.
2315	C	Blake	x	x	x	x
	D	"	x	x	x	x
	E	"	x	x	x	x
	F	"	x	x	x	x
	G	"	x	x	x	x
	H	"	x	x	x	x
	I	"	x	x	x	x
2316	A	"	x	-	x	x
	B	"	x	x	x	x
	C	"	x	x	x	x
	D	"	x	-	x	x
	E	"	x	x	x	x
	F	"	x	x	x	x
	G	"	x	-	x	x
	H	"	x	x	x	x
	I	"	x	x	x	x
2317	A	"	x	-	x	x
	B	"	x	-	x	x
	C	"	x	-	x	x
	D	"	x	-	x	x
	E	"	x	-	x	x
	F	"	x	x	x	x
	G	"	x	x	x	x

Station	Replicate	Molluscs	Crustacea	Echinoderms	Polychaetes	Misc.
2317	H	Blake	x	-	x	x
	I	"	x	x	x	x
2318	A	"	x	-	x	x
	B	-	x	-	x	x
	C	Blake	x	x	x	x
	D	"	x	x	x	x
	E	"	x	x	x	x
	F	"	x	x	x	x
	G	"	x	-	x	x
	H	"	x	x	x	x
	I	"	x	x	x	x
2419	A	"	x	-	x	x
	B	-	x	x	x	x
	C	Blake	x	x	x	x
	D	"	x	x	x	x
	E	-	x	-	x	x
	F	Blake	x	x	x	x
	G	"	x	x	x	x
	H	"	x	-	x	x
	I	"	x	-	x	x
2420	A	"	x	x	x	x
	B	"	x	x	x	x
	C	"	x	x	x	x

Station	Replicate	Molluscs	Crustacea	Echinoderms	Polychaetes	Misc.
2420	D	Blake	x	x	x	x
	E	"	x	x	x	x
	F	"	x	x	x	x
	G	"	x	x	x	x
	H	"	x	x	x	x
	I	"	x	x	x	x
2421	A	"	x	x	x	x
	B	"	x	x	x	x
	C	"	x	x	x	x
	D	"	x	x	x	x
	E	"	x	x	x	x
	F	"	x	x	x	-
	G	"	x	x	x	x
	H	"	x	x	x	x
	I	"	x	x	x	x
2422	Dr I	"	x	x	x	x
	Dr II	"	x	x	x	x
2423	A	"	x	x	x	x
	B	-	x	x	x	x
	C	Blake	-	x	x	x
	D	-	x	x	x	x
	E	Blake	x	x	x	x
	F	"	x	x	x	x
					x	

Station	Replicate	Molluscs	Crustacea	Echinoderms	Polychaetes	Misc.
2423	G	-	x	-	x	x
	H	Blake	x	x	x	x
	I	"	-	x	x	x
2424	A	-	x	x	x	x
	B	Blake	x	x	x	x
	C	-	x	x	x	x
	D	Blake	x	x	x	x
	E	"	x	x	x	x
	F	"	x	x	x	x
	G	"	x	x	x	x
	H	"	x	x	x	x
	I	"	x	x	x	x
2425	A	"	x	-	x	x
	B	"	x	x	x	x
	C	"	x	x	x	x
	D	"	x	x	x	x
	E	"	x	-	x	x
	F	"	x	-	x	x
	G	"	x	x	x	x
	H	"	x	x	x	x
	I	"	x	x	x	x
2426	A	"	x	x	x	x
	B	-	-	-	x	x

Station	Replicate	Molluscs	Crustacea	Echinoderms	Polychaetes	Misc.
2426	C	-	x	x	x	x
	D	-	-	-	x	x
	E	Blake	x	x	x	-
	F	"	x	-	x	x
	G	"	x	-	x	-
	H	"	x	-	x	-
	I	"	x	x	x	-
2427	A	"	x	-	x	x
	B	"	x	-	x	x
	C	"	x	-	x	x
	D	"	-	-	x	x
	E	"	x	x	x	x
	F	"	x	-	x	x
	G	-	x	-	x	x
	H	Blake	x	-	x	x
	I	"	x	-	x	x

ADENOSINE TRIPHOSPHATE IN THE MAFLA TRACT AREA

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ABSTRACT

Measurements of adenosine triphosphate (ATP) in the MAFLA area indicated that seasonal changes were evident in all of the transects, except Transect V. Maximum ATP values were obtained in the second sampling period (September 1975) with the lowest concentrations found in the first sampling effort (June 1975). ATP was found to correlate with sediment grain size distribution with ATP increasing in concentration as the mean grain size increased. This relationship held for Transects II, III and IV and for some of the locations along Transect I. Transect V had little relationship between ATP and grain size with the exception of the second sampling period. In general, the ATP of Transect V showed the least seasonal variation, no relationship with sediment grain size, and no relationship to the organic carbon in the sediments. Transect VI had the single highest ATP concentrations encountered in the study but the transect was the most inconsistent in the study. Organic carbon, when plotted against ATP, indicated that as the organic carbon concentration increased the ATP decreased. The correlation coefficient of the plot (exclusive of Transects V and VI was 0.56. As was found for the grain size-ATP data, Transect V showed no relationship and indeed the ATP-carbon plot yielded a vertical line indicating complete independence of the ATP. Transect VI followed the trend of decreasing ATP with increasing carbon, except that for a given carbon concentration the ATP value was higher than for all of the other stations in the tract area. Transect V appears to be governed by either the overlying water, or terrestrial input. In either event Transect V is in no way comparable to the other stations in

the tract area. Transect VI reflects the apparent input of Mobile bay at the most landward locations (stations 37 and 38) and the effects of water mass movement at the most seaward stations (stations 43, 44, and 45).

INTRODUCTION

The measurement of adenosine triphosphate (ATP) is the only existing method to accurately measure living microbial biomass. The determination of ATP in marine sediments is difficult and the methodology has only recently been resolved by Karl and LaRock (1975) for sediment.

Thermal extraction procedures are ineffective and a cold sulfuric acid extraction method is currently the method of choice. Sulfuric acid effectively extracts the ATP, and after neutralization and complex formation of the interfering ionic species, the extract can be assayed by the luciferin-luciferase-ATP reaction.

The ATP assay does have a number of potential errors inherent in the procedure due to (1) the adsorption of the extracted ATP on sediment or detrital material, (2) competitive interference by both cations and anions in the enzyme assay. These potential errors can be compensated for by using internal ATP standards. Adsorption becomes critical when the sediment grain size distribution exceeds 25% fines (<0.063 mm) and when large quantities of colloidal or detrital materials are present in water samples. Ionic interference does not affect the ATP concentration in the extract, but rather inhibits enzyme activity. Activity can be restored by complexing the various ionic species (Ca^{++} in the case of the BLM sediments) using EDTA. Furthermore, ^{14}C labeled ATP has been found to be an excellent indicator of extraction efficiency and permits the actual adsorption to be determined for each individual sample. This has been found to significantly reduce the within sample variation for better statistical results.

METHODS

ATP

Six to ten 2 cc volumes of sediment were collected at each sampling station by inserting a sterile glass tube into one of the box cores. The sediment samples were transferred to culture tubes and stored on ice until extraction.

The ATP was extracted by mixing 2 cc of sediment with five milliliters of 0.6 N H_2SO_4 maintained by 5°C in a vortex mixer for a period of one minute. Internal standards of ATP were added to three of the sediment samples before addition of H_2SO_4. All samples were then treated similarly.

After the sediment had settled, the supernatant was withdrawn from the test tube quantitatively and transferred to a ten milliliter beaker. One milliliter of EDTA solution (18 mg EDTA/ml was added along with one milliliter of TRIS buffer solution; for carbonate sediments, two milliliters of EDTA were added. The solution was brought to pH 7.8 by adding NaOH. Then the entire extract was brought to a final volume of 10.0 ml with TRIS buffer solution, placed in Whirl-paks and frozen until assayed.

The Bioluminescent Reaction and Its Measurement

Once extracted, ATP can readily be assayed by means of the firefly bioluminescent reaction (Strehler, 1968). Firefly luciferin and luciferase react with ATP in the presence of Mg++ and molecular oxygen to yield a photon of light for each ATP molecule consumed at neutral or alkaline pH (McElroy, et al. 1969). When the reactants are mixed, an initial burst of light occurs followed by a long decay period (Schram, 1970). The addition

of arsenate buffer to the reaction mixture retards the decay of luminescence after the initial light burst (Strehler and Totter, 1954). Light emission in the luciferin-luciferase reaction is inhibited by the presence of both cations and anions (Aledort, et al., 1966; Strehler, 1968). Dilution of the enzyme mixture reduces the magnitude of the initial burst of light but does not affect the exponential relationship of the decay which lasts over a long period of time (Beutler and Baluda 1964; Rasmussen and Nielsen 1968; Schram 1970).

The luciferin-luciferase mixture used in our work was prepared by reconstituting each vial of lyophilized firefly lantern extract (Sigma Chemical Company, FLE-50) with 12.5 ml distilled water, 7.5 ml of 0.1 M arsenate buffer (Sigma Chemical Company, FF-AS-100), and 5 ml of 0.05 M magnesium sulfate. The enzyme was allowed to stand for between six to seven hours at 23-25°C in order to remove endogenous ATP. After aging, the preparation was filtered (Whatman #2) to remove residual debris. After clarification and during use, the enzyme was kept in an ice bath. One-half milliliter of enzyme was used for each ATP assay permitting about 45 assays at an approximate cost of 3-4 cents per assay.

A number of different light detecting instruments have been used for measuring the bioluminescent reaction. These generally can be divided into two types: those that measure the initial burst or peak intensity of the light emitted (Chappelle and Levin 1968; Rasmussen and Nielsen 1968; Allen 1973; Anderson and Davies 1973) and those that integrate the area under a portion of the decay curve that follows. A commercial instrument using peak intensity measurements has been developed but requires the use of specially prepared reagents (Allen, 1973; E. I. DuPont Corp.). St. John (1970) has

suggested that the peak intensity measurement might not be the most reliable means of determining ATP concentration.

The integral mode of counting has been used with a number of different light detecting instruments which include specially constructed photomultiplier assemblies (Holm-Hansen and Booth 1966), fluorometers (Beutler and Baluda 1964), a commercially available photometer (JRB Co., San Diego, Calif.), and the liquid scintillation counter (Strange, et al., 1963; Lin and Cohen, 1968; Schram, 1970; Schram and Roosens, 1972; Rudd and Hamilton, 1973).

In our work the emitted light from the firefly reaction was measured on a manual liquid scintillation counter (LSC) (Nuclear Chicago model 4534). For ATP analysis, the scintillation counter was operated in a noncoincident mode using one photomultiplier tube (Schram, 1970), and with a maximum window opening of 0.5-10.0 V. For analysis one milliliter of either the sample extract or the ATP standard was added to a chromic acid washed LSC vial, followed by addition of 0.5 ml of 0.025 M TRIS buffer (pH 7.75). Next, the vial was closed and 0.5 ml of the enzyme preparation injected into the vial through a small hole drilled in the cap. The vial was immediately inserted into the LSC and exactly one minute after enzyme injection, a 0.1 min count was taken. This count is an integral measurement of the area under the luminescent decay curve between 60 and 66 s after the start of the reaction. For each enzyme preparation, a standard curve was made by plotting the logarithm of the integral count rate versus the logarithm of the appropriate ATP concentration. Standard solutions containing one mg/milliliter disodium crystalling ATP (Sigma Chemical Company, A 3127) in 0.025 M TRIS buffer, were prepared and stored frozen in ten milliliter aliquots. When needed, the concentrated solution was diluted in TRIS or the acid extracting menstruum to cover a range of 0.3-50 ng/ml ATP.

RESULTS

A map of the sampling locations, station numbers and transect designations is given in Figure 1. The ATP data for each of the transects is given in Figures 2 to 7 with each figure containing three curves. Each curve in a given figure represents the data collected on a particular cruise as designated by the number on the curve. Seasonal differences are most evident on Transects I, II, III and IV. Portions of Transect VI showed seasonal effects (stations 42, 43, 44 and 45). Transect V, however, was most consistent over the entire sampling period with only occasional peaks (station 30 on Cruise No. 1, station 32 on Cruise No. 2 and station 34 on Cruise No. 3) departing from otherwise identical curves. In other words, Transect V did not show any of the seasonal differences found in the other areas.

In general, the ATP concentration was the greatest on the second cruise for Transects I, II, III, and portions of IV. The lowest concentrations in ATP were found on the first sampling period for these same locations. These data can be handled in a more quantitative manner, as will be discussed in a subsequent section, and yet we find that the second cruise did yield the greatest biomass followed by the data from the third and first cruises.

For a given transect, the lowest ATP concentration is usually the terminal or most distant station from land. These stations were at the edge of or off the shelf and were thus subjected to the influence of deep water movements. In particular, Dr. Georges Weatherly of the Department of Oceanography has reported the existence of a bottom boundary current that occurs at a depth of about 100 m. This current has a thickness of only four or five meters and is transient in nature; i.e. it is a temporary situation that damps itself out after a modest period of time, say thirty to forty days. In its presence,

materials may be pumped up from or down to the deep waters in the Gulf. While more detailed measurements are needed to clearly define the bottom boundary current, its existence will affect the bottom sediments on the edge of the shelf.

Three of the transects showed decreasing ATP concentrations with increasing distance from land. Transects I, III and V, and the remaining three had peaks or increases in ATP as one moved away from land. These transects with peaks along their length Transects II, IV and VI can be compared with one another as will be discussed later, from which it is possible to conclude that Transect VI bears no resemblance to any of the other regions in the study area, but Transects II, III and IV are essentially identical in the relationships between biomass and sediment conditions. ATP was found to increase in concentration as the sediment grain size increased. The peaks that were observed along Transects II, IV and VI occur where the sediment has the largest grain size. For example, the sediments along Transect II range in size from 0.004 to 0.026 mm except for station 11 which has a mean grain size of 0.62 mm. No sample was taken at station 10. The ATP peak on Transect II occurs at stations 10 and 11. In a similar fashion, the grain size distribution along Transect IV increases from 0.21 mm near land to 0.44 mm at station 22, with a maximum of 0.49 mm at station 25. At station 26 the grain size decreases to 0.28 with a grain size of 0.035 at station 27. The ATP peak occurs between stations 22 and 26 along this transect.

The presence of these regions of high ATP and coarse sediments implies the existance of bottom currents that scour the fines and transport materials, both organic and inorganic, into the area.

DISCUSSION

The most significant factor relating to ATP concentration is the sediment grain size distribution. Plots of sediment mean grain size versus ATP for each of the sampling periods indicates that as the grain size increases in diameter, the ATP concentration increases. In preparing such a plot, however, Transects V and VI must be treated separately. Transect V generally does not obey the ATP-grain size relationship, and Transect VI is apparently influenced by too many variables along its length to show any consistency.

Plots of mean grain size and ATP for the three sampling periods are shown in Figures 8, 9 and 10. The data obtained for the second sampling period (Figure 8) had the least variability and will be used to illustrate the ATP-grain size relationship. A regression line was passed through the points in the large encircled area and had a correlation coefficient of 0.88 ($r^2 = 0.88$). The trend clearly indicates that ATP is present in higher concentrations in the coarser sediments. In the same figure there is a plot for Transect V which shows a similar relationship, but the regression line has a much greater slope. Three distinct clusters of data were found for Transect VI, but here the trend appears to be a line with a negative slope, and hence ATP decreases as the grain size increases. The sediment-ATP principals that operate elsewhere in the Gulf are not operative at Transect VI.

Figures 9 and 10 are similar plots for the first and third sampling periods respectively, and show the same general trends. The slopes of the regression lines for Transects I, II, III and IV in each of the figures

differ and more scatter is found. Transect V shows a complete independence of ATP from grain size (the slopes of the regression lines are one for both figures, with a correlation coefficient of 0.01). Transect VI shows no trend at all other than that stations 37 and 38, and 39 and 41 appear "paired" and relatively consistent year round. Stations 40, 42, 43, 44 and 45 show extreme variability over the year, and have the highest ATP concentrations encountered.

The slopes of the regression lines can be used to demonstrate seasonal effects on ATP concentrations. The slopes of the regression lines for the first, second and third sampling periods are 81, 128 and 120 respectively.

The Relationship Between Sedimentary Organic Carbon and ATP

A comparison was made between ATP and the organic carbon content of the sediments (Figure 11). Carbon determinations were made on all stations for the first sampling period and at selected stations, the third sampling period. Consequently our discussion will be confined to the first sampling period only. A plot of organic carbon versus ATP is shown in Figure 11. As with the sediment data, Transects V and VI are not included in the regression analysis. The results for Transects I, II, III and IV show a decrease in ATP as the carbon concentration in the sediments increases. At first this seems backwards, but in fact it indicates that where a greater ATP biomass is present, more of the available carbon substrate is utilized and converted into cell mass or respiration. At higher carbon concentrations, and lower ATP value, it is suggested that the carbon measured is of a resistent or refractory nature and is not easily degraded.

Transect V again showed no consistent trend and the data were clustered in three groups. The largest data cluster did fall within the data set for

Transects I through IV, but the remaining data points represented extreme values for either ATP or carbon.

Transect VI did show a decreasing trend for ATP as the carbon concentration increased, and a regression line generated from the data of Transect VI had a slope essentially the same as for the other transects (-270 compared to -222 for Transects I to IV except that the regression line was displaced vertically. This implies that for a given quantity of carbon, the microbes at Transect VI would be more effective at converting it to biomass. An alternative possibility is that the carbon in the sediments at Transect VI is qualitatively different from that in the sediments at Transects I to IV and more easily decomposed. The data do not permit differentiation of these two speculations.

SUMMARY

This work indicates that the ATP method can be used to effectively characterize the sediment microbes and quantify seasonal and environmental variables. Some of the more pertinent findings of the ATP, carbon and sediment work are:

1. Sediment ATP concentrations exhibit seasonal variations with the greatest concentrations encountered in the early fall (September) with decreasing amounts found in the winter (January) and the least present in the early summer (June).
2. ATP content of sediments is directly proportional to the mean grain size distribution. ATP was found to increase as the grain size increased.
3. In the MAFLA tract area, Transects I, II, III and IV are similar in their ATP-grain size relationship.
4. Transect V showed no relationship to grain size, and organic

carbon. In fact, these stations appear to be independent of all of the parameters measured and might possibly be governed by the overlying water column. It is known that a gyre does split off from the eastward flow from the Mississippi and move northward over Transect V.

5. Transect VI is highly variable, and has a region of greatly elevated ATP concentrations. Stations 40, 42, 43, 44 and 45 had the greatest ATP concentrations encountered in the study, and showed marked variation over the year. It is suggested that Mobile Bay exerts significant influence over this portion of the transect.

6. Organic carbon was found to exhibit an inverse relationship to ATP. As the organic carbon concentration increased, the ATP concentration decreased. This situation suggests that the quality as well as the quantity of the organic substrate is important in determining the magnitude of the microbial population that will develop. A large population as evidenced by high ATP concentrations, will consume most of the organic carbon present if possible. Where a high carbon content exists in the sediments, one finds a low ATP. This suggests that carbon compounds are microbially refractory.

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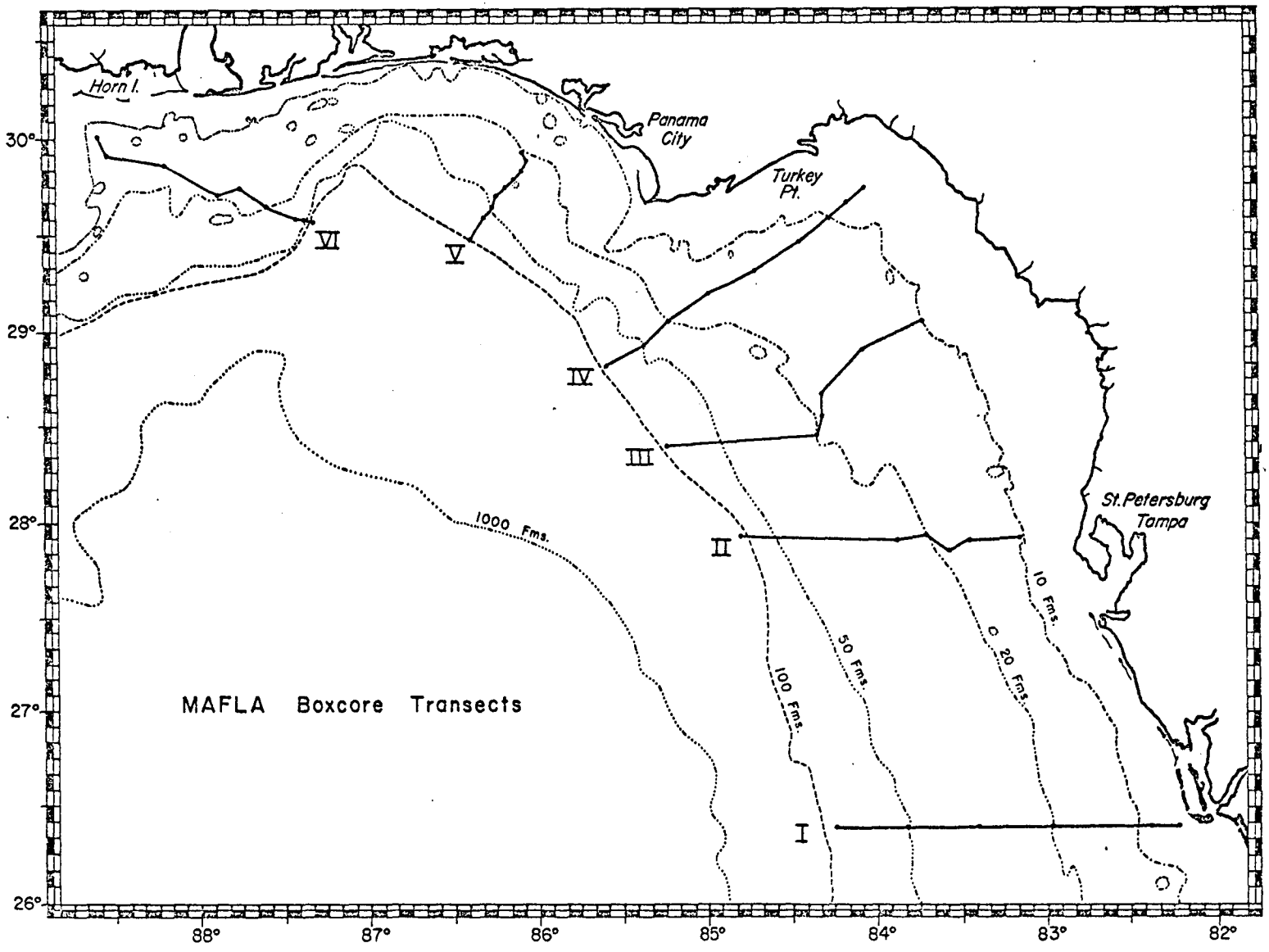


Figure 1. Location of the 45 box core stations on the six transects of the MAFLA study area during the 1975-1976 seasonal sampling.

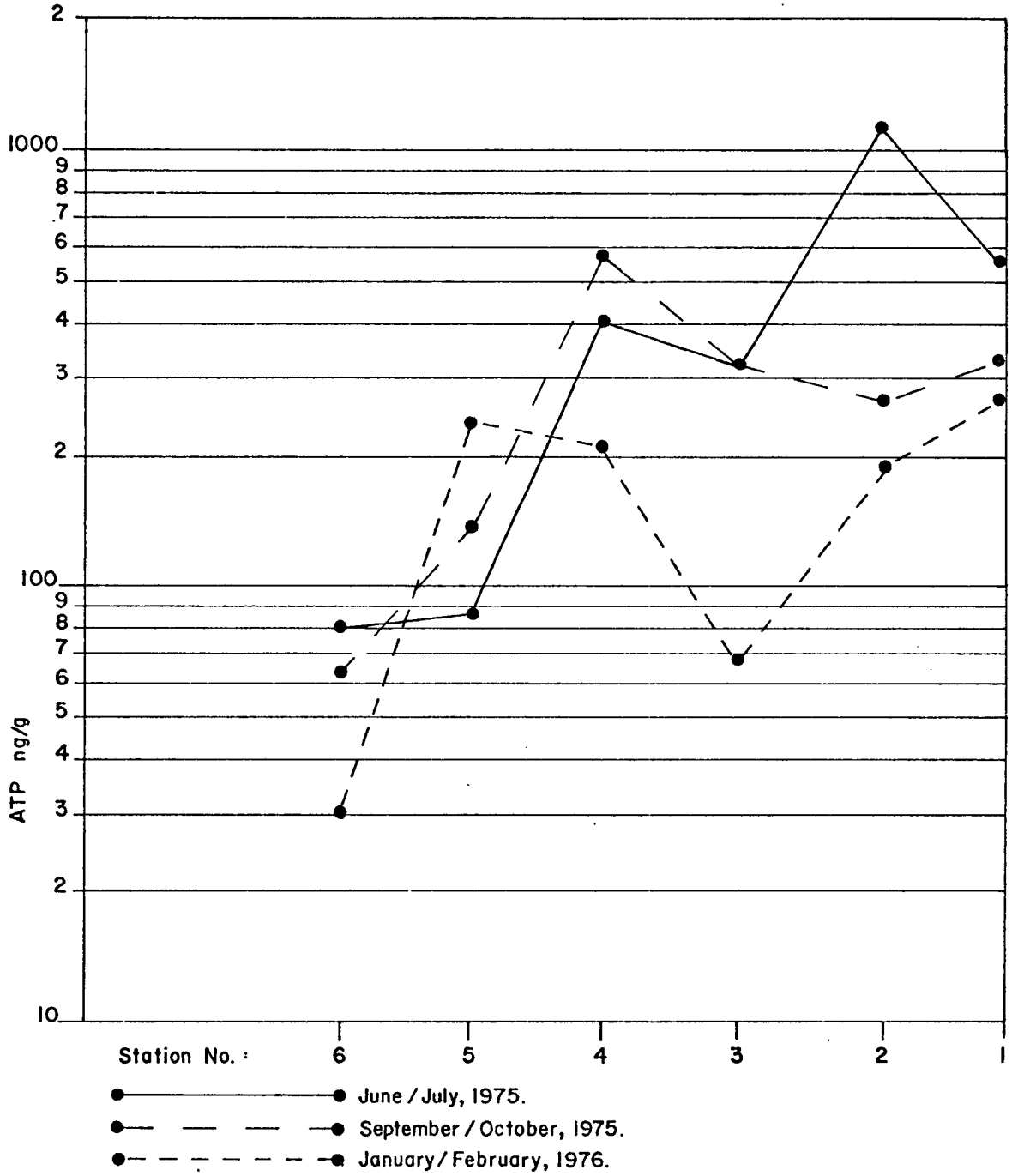


Figure 2. Seasonal ATP data along transect I .

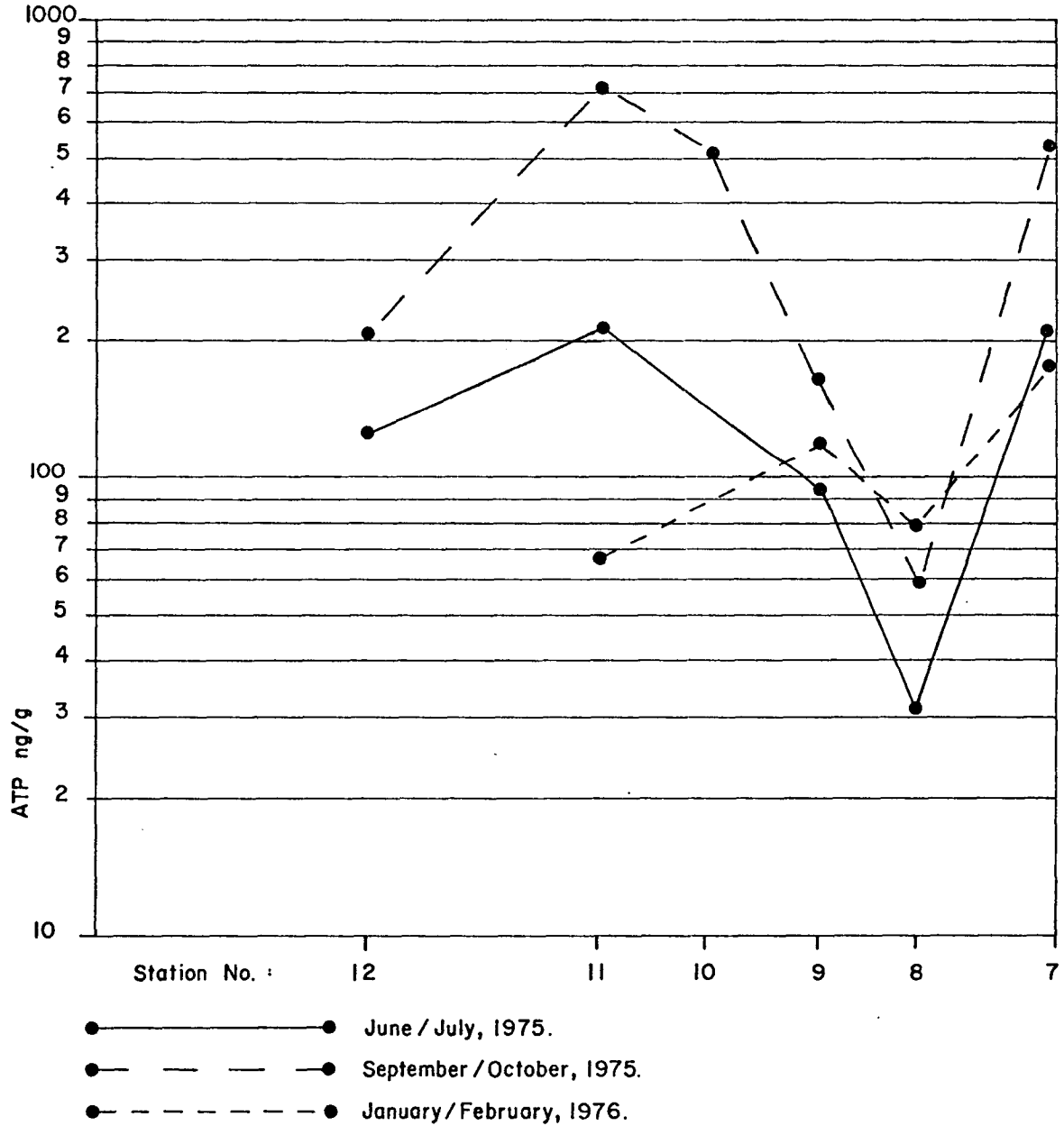


Figure 3. Seasonal ATP data along transect II.

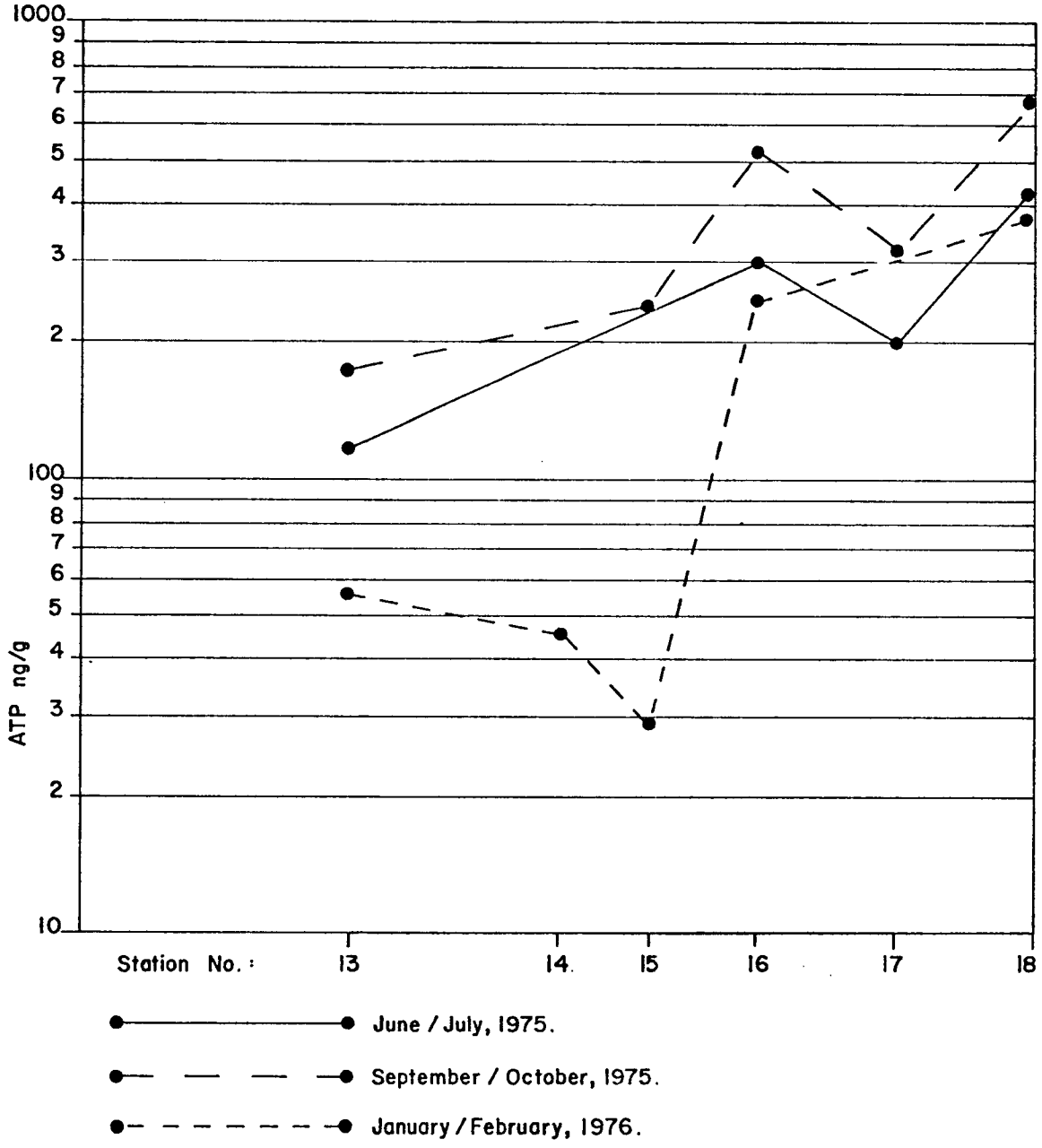


Figure 4. Seasonal ATP data along transect III.

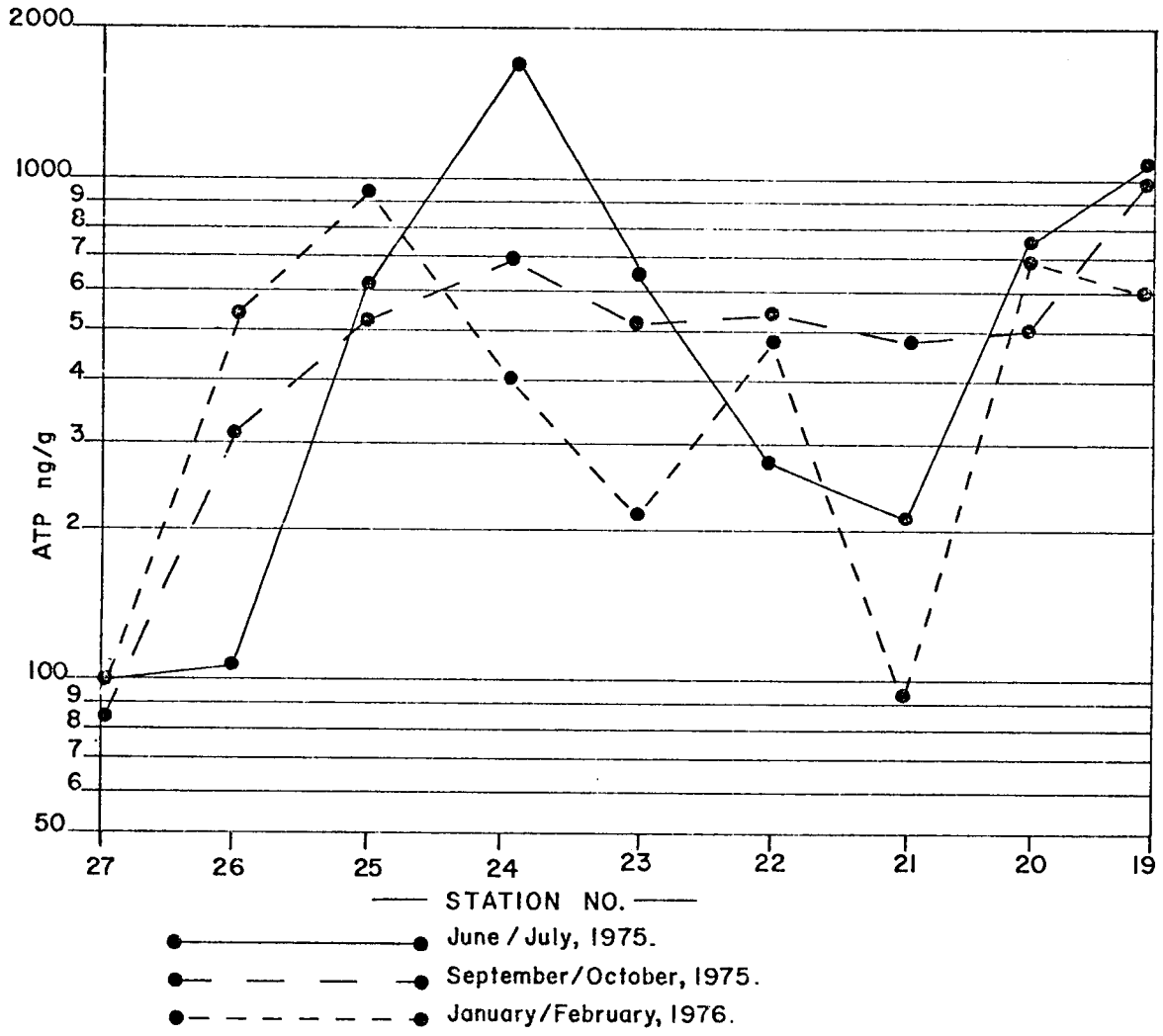


Figure 5. Seasonal ATP data along transect IV.

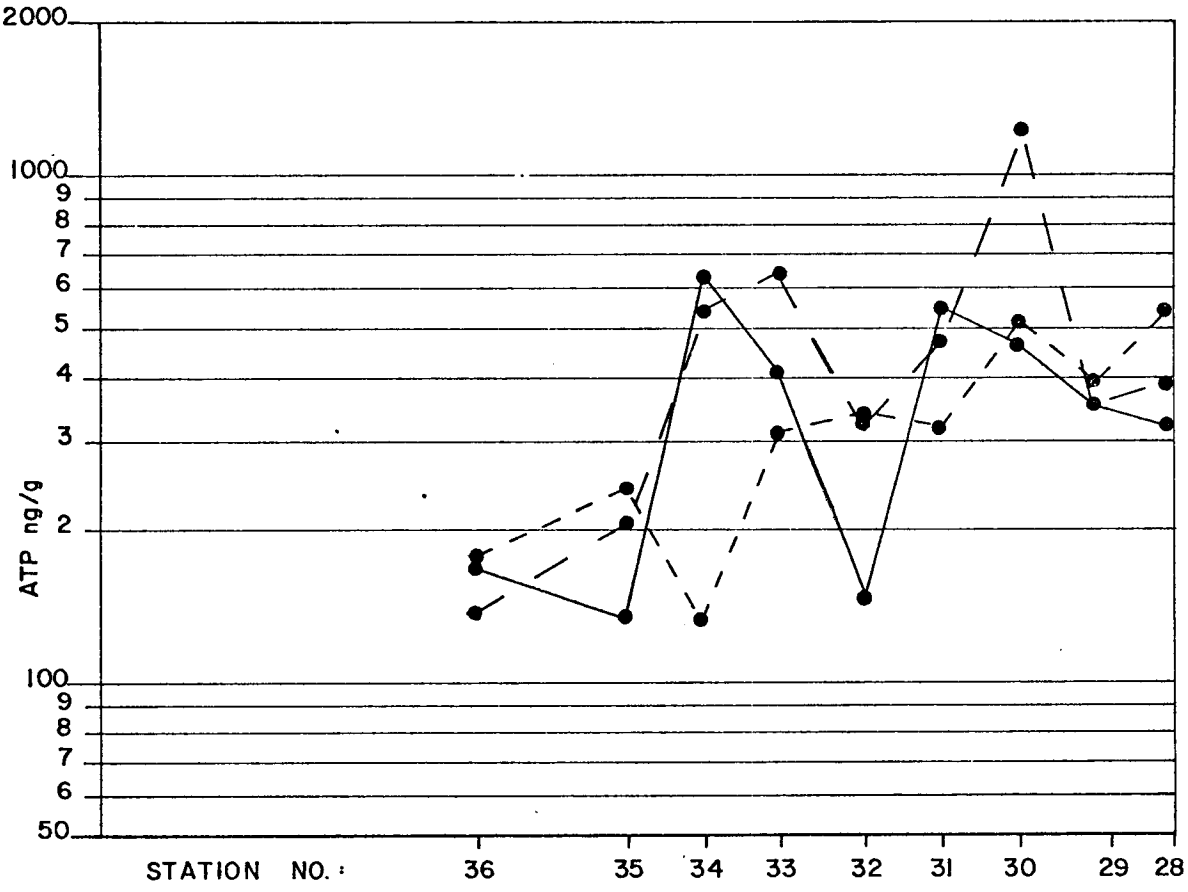


Figure 6. Seasonal ATP data along transect V.

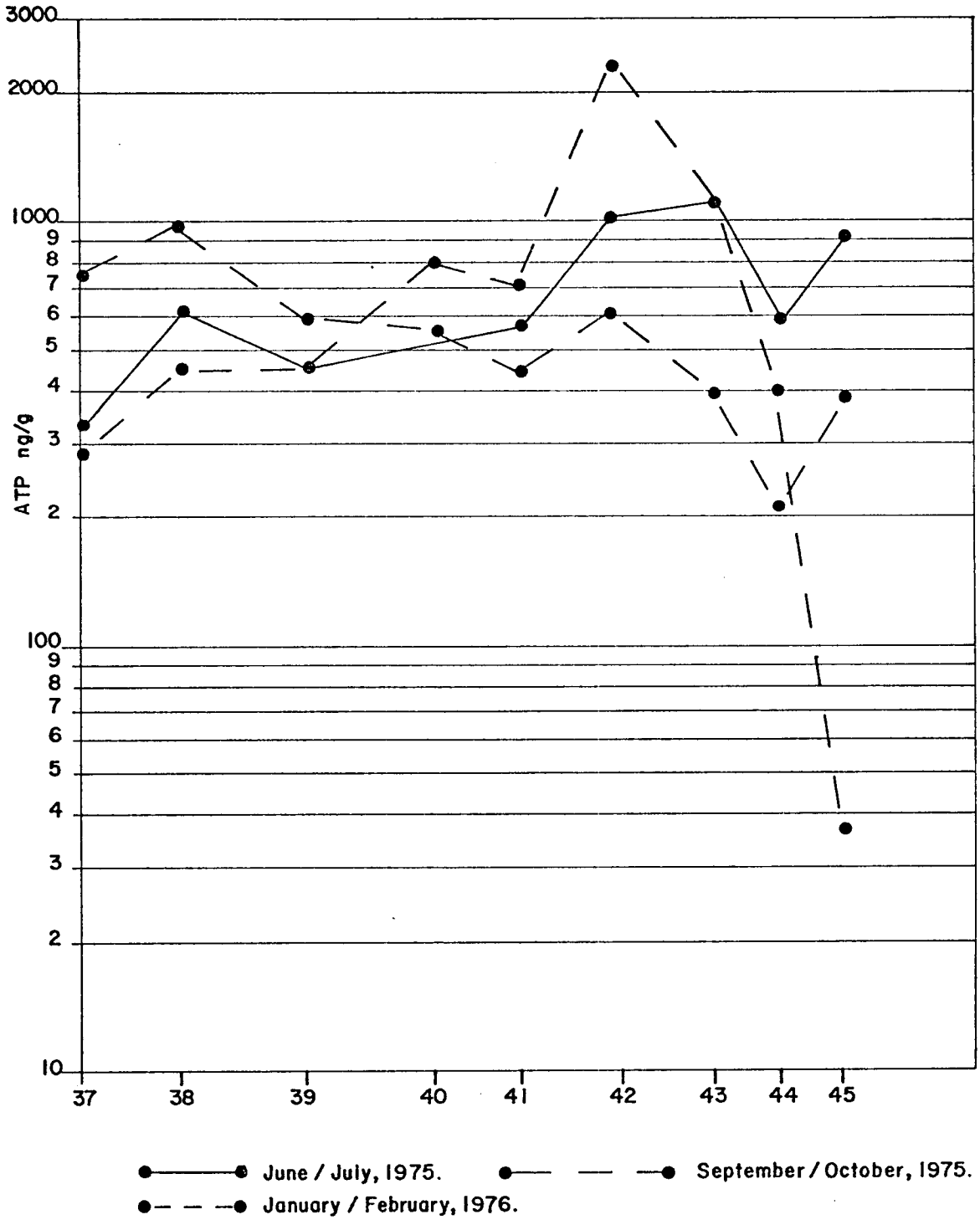


Figure 7. Seasonal ATP data along transect VI.

Figure 8.
Relationship between ATP and
Sediment grain size

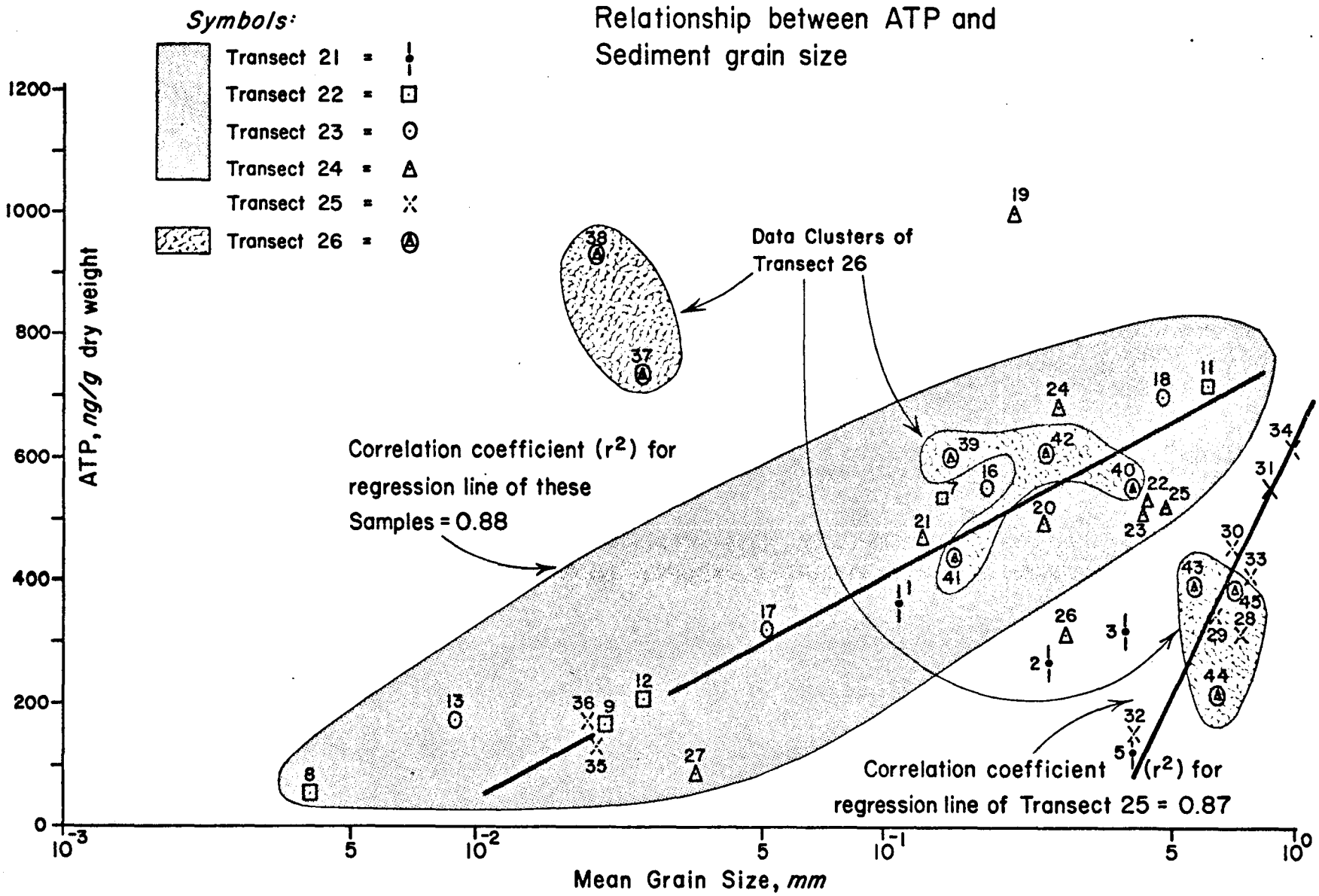


Figure 9. ATP/Sediment relationship (June/July, 1975).

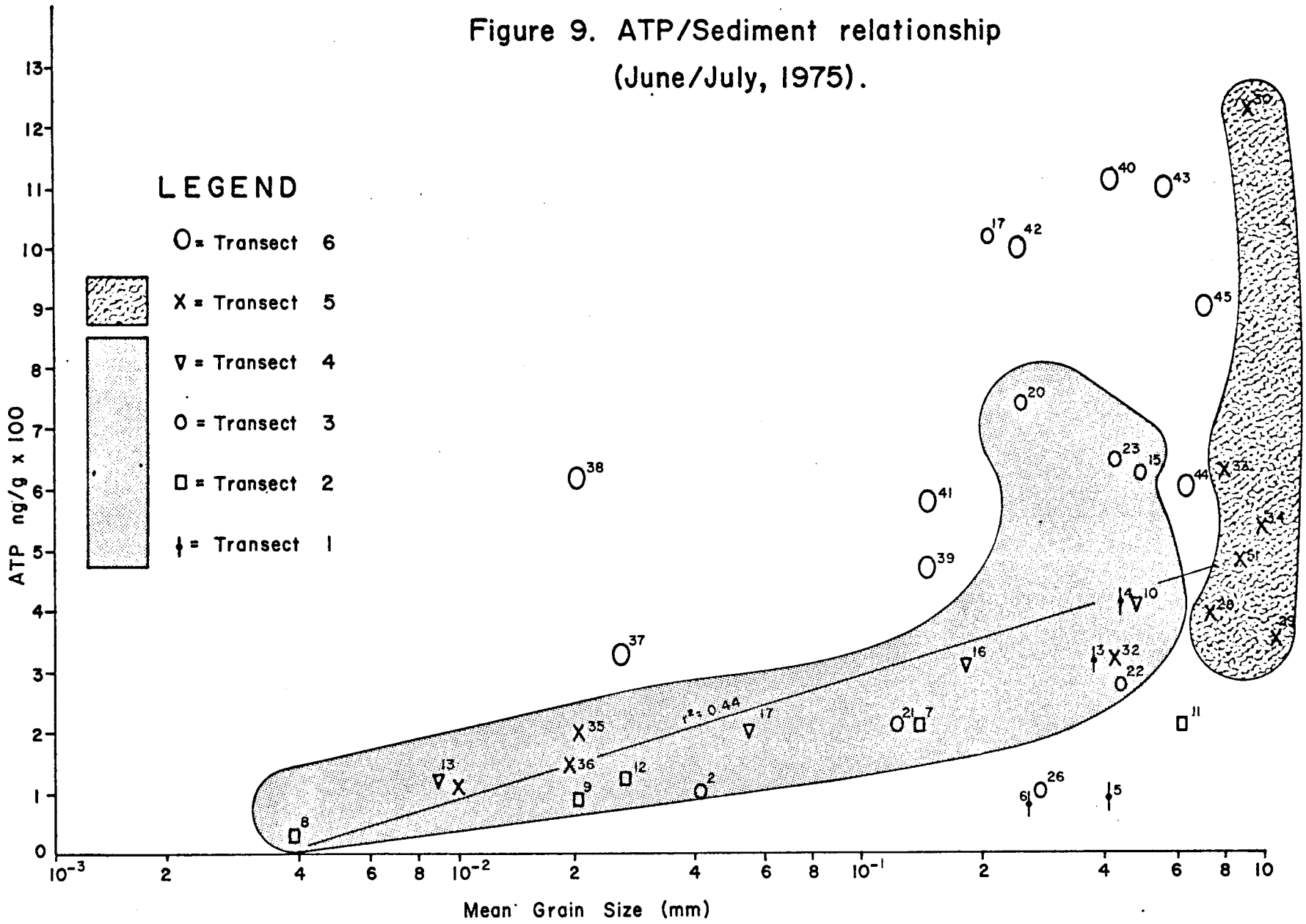


Figure 10. ATP/Sediment relationship (January/February, 1976).

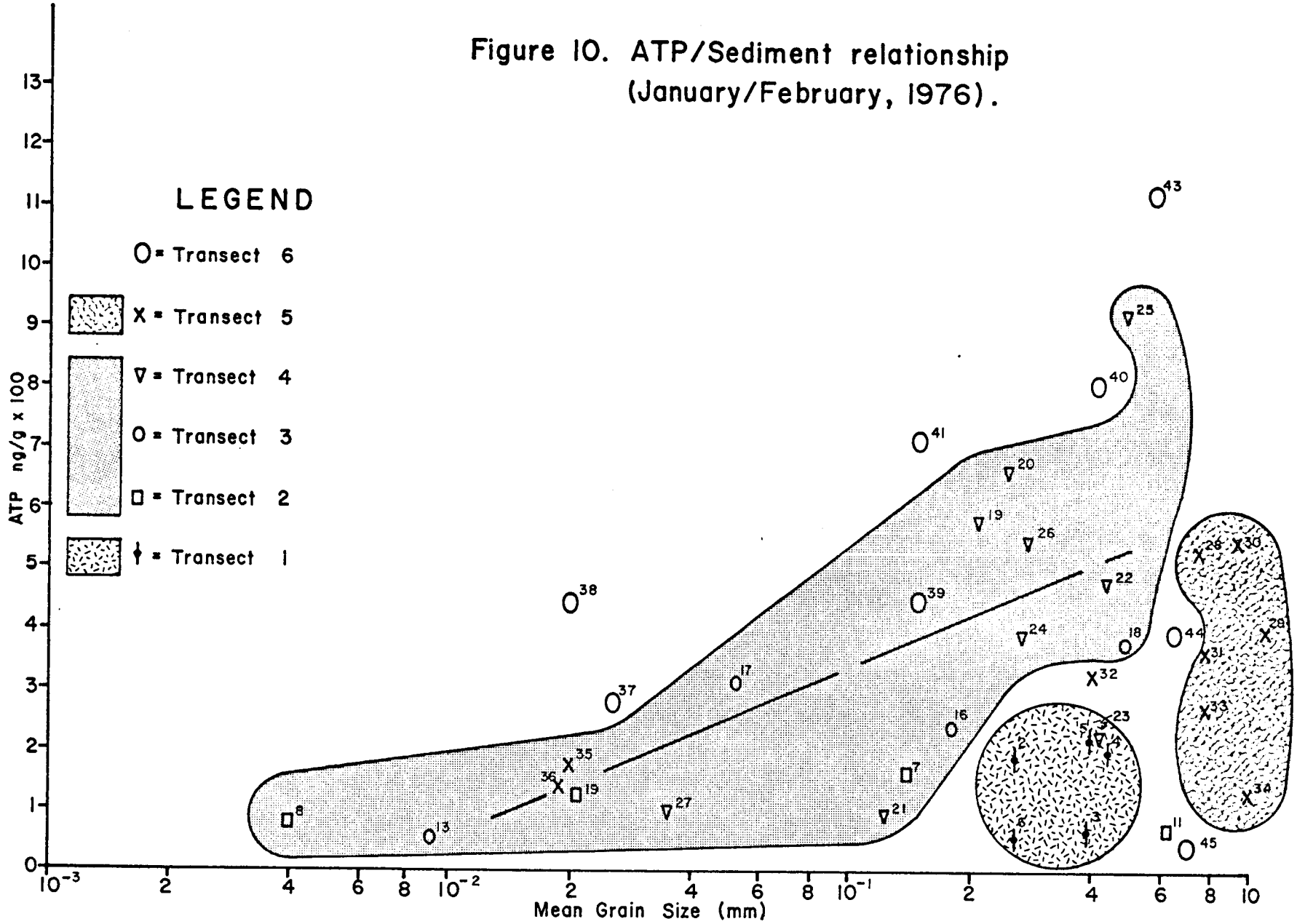
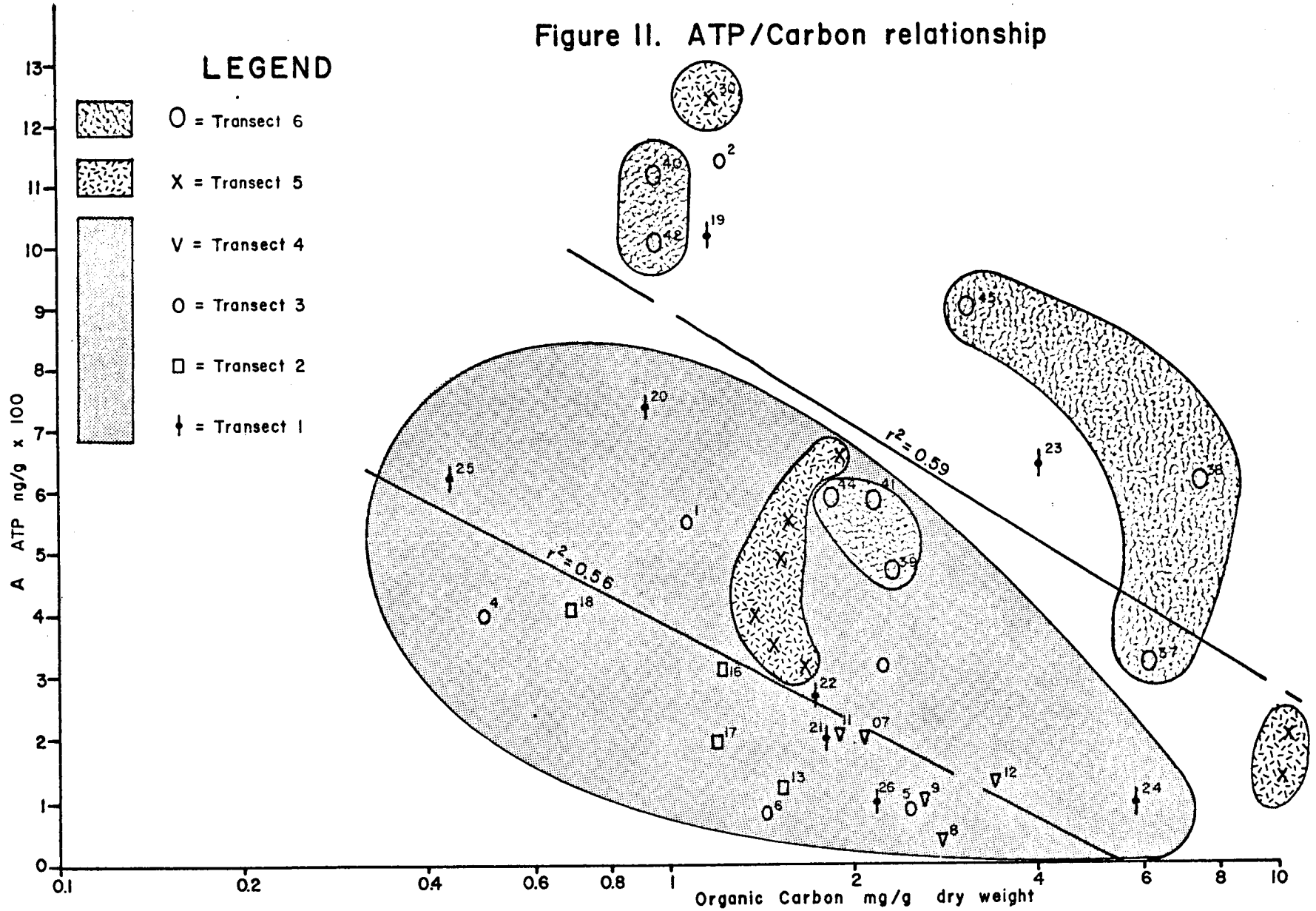
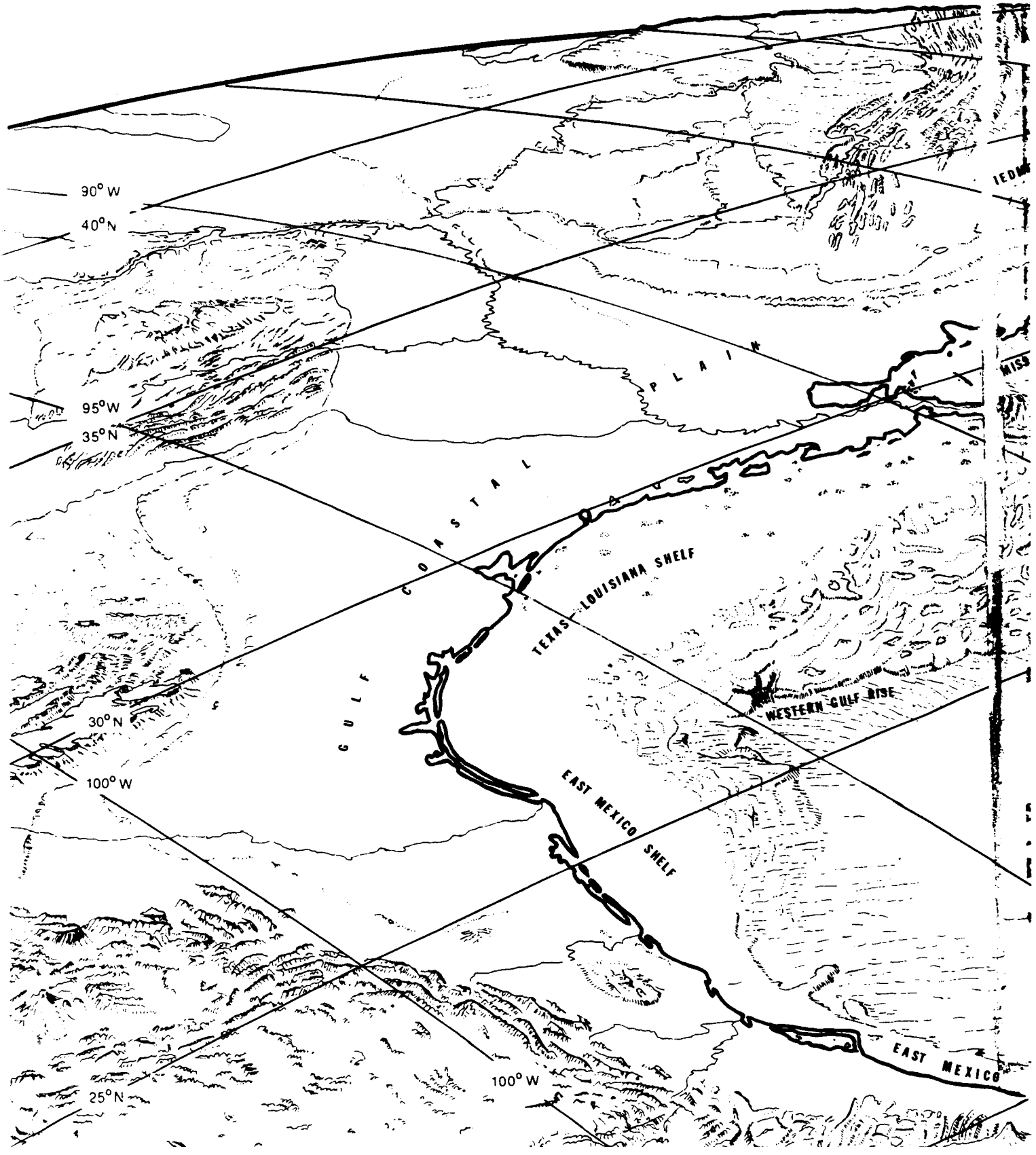


Figure II. ATP/Carbon relationship




90° W
40°N
95°W
35°N
30°N
100° W
25°N
100° W
GULF COASTAL PLAIN
TEXAS-LOUISIANA SHELF
WESTERN GULF RISE
EAST MEXICO SHELF
EAST MEXICO