

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

Florida State University, Department of Oceanography

Principal Investigator:
George A. Knauer

Associate Investigator:
Charles C. Aller

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 discernible 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 century 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 inorganic 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 gibberillins (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 0.003μ (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 0.5μ (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 protozoans, 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 interconvertibility 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

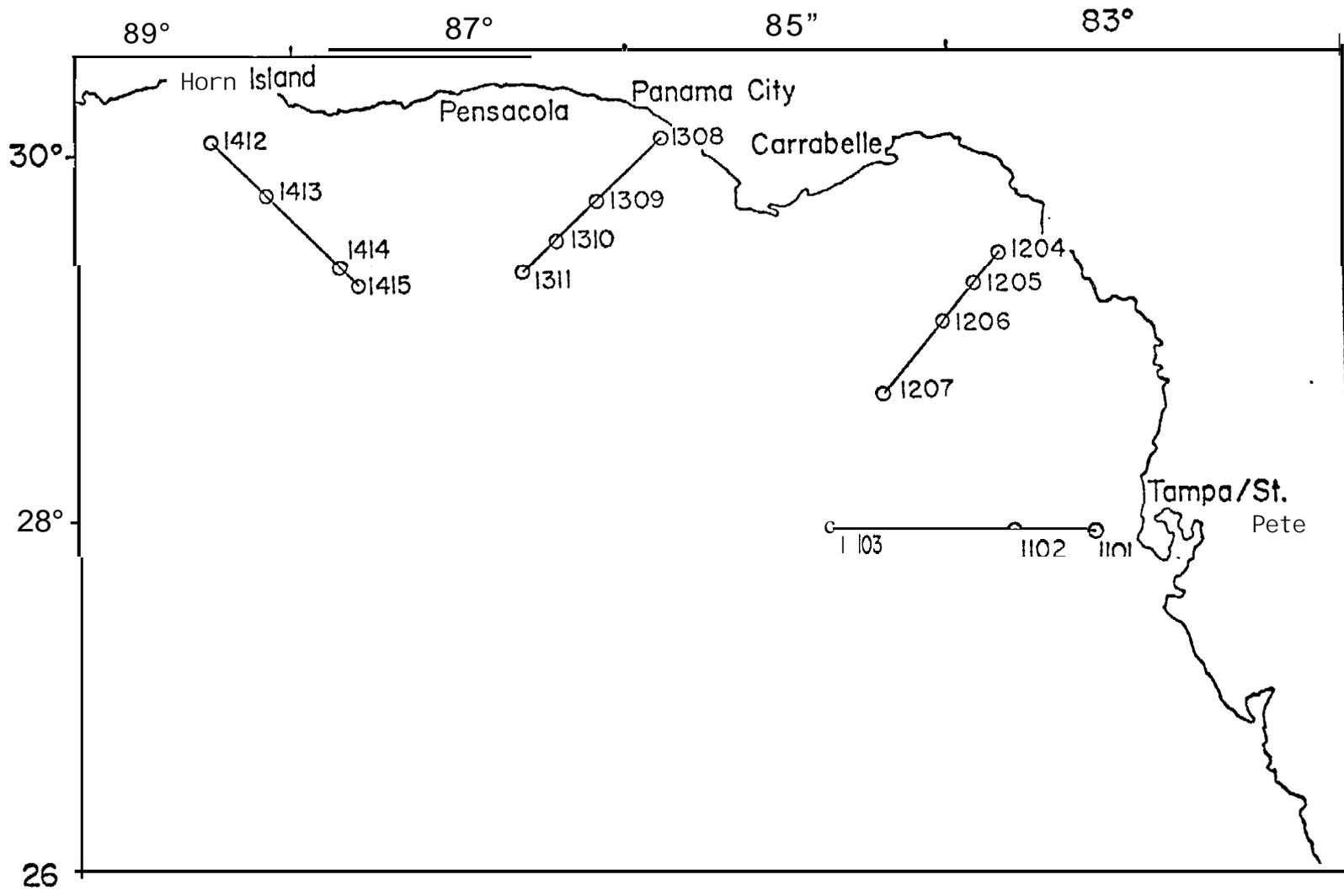


Figure 1. --Study Area

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

B 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.

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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 Bias 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 Bias 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 ($\text{K}_2\text{S}_2\text{O}_8$) 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 Poc	1975 DOC	Sep/Oct POC	1975 DOC	Jan/Feb Poc	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 mesa 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 130?. 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

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

The Relationship of Organic Carbon to Other Oceanographic Parameters

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On the same cruises which produced the organic carbon data other investigators examined additional oceanographic parameters. These included phytoplankton chlorophyll 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.

B
D
D 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. Figure's 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 reinforces 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 11 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 11 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 chlorophyll 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.

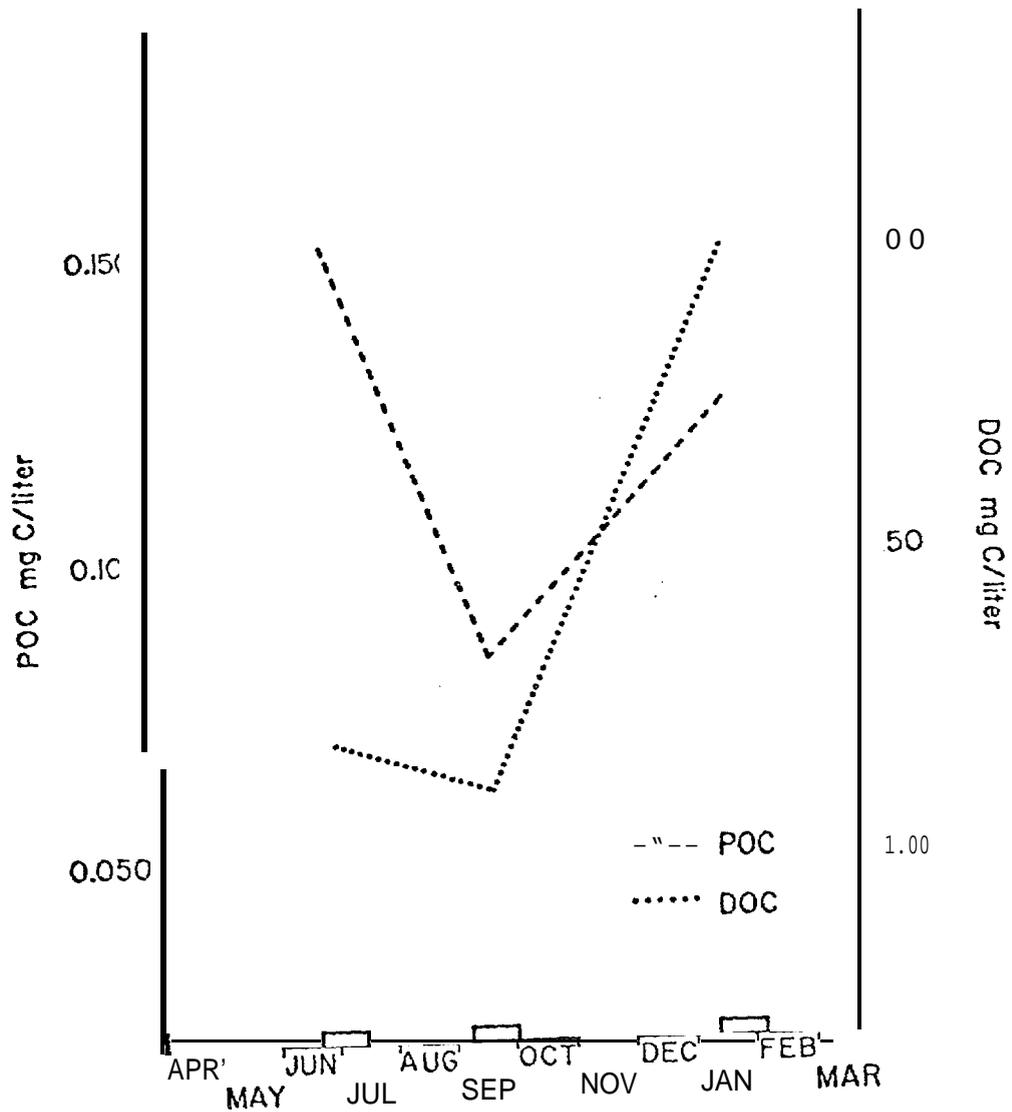


Figure 2. -- Temporal Variation of Organic Carbon in the Northeast Gulf of Mexico at ten meters depth

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

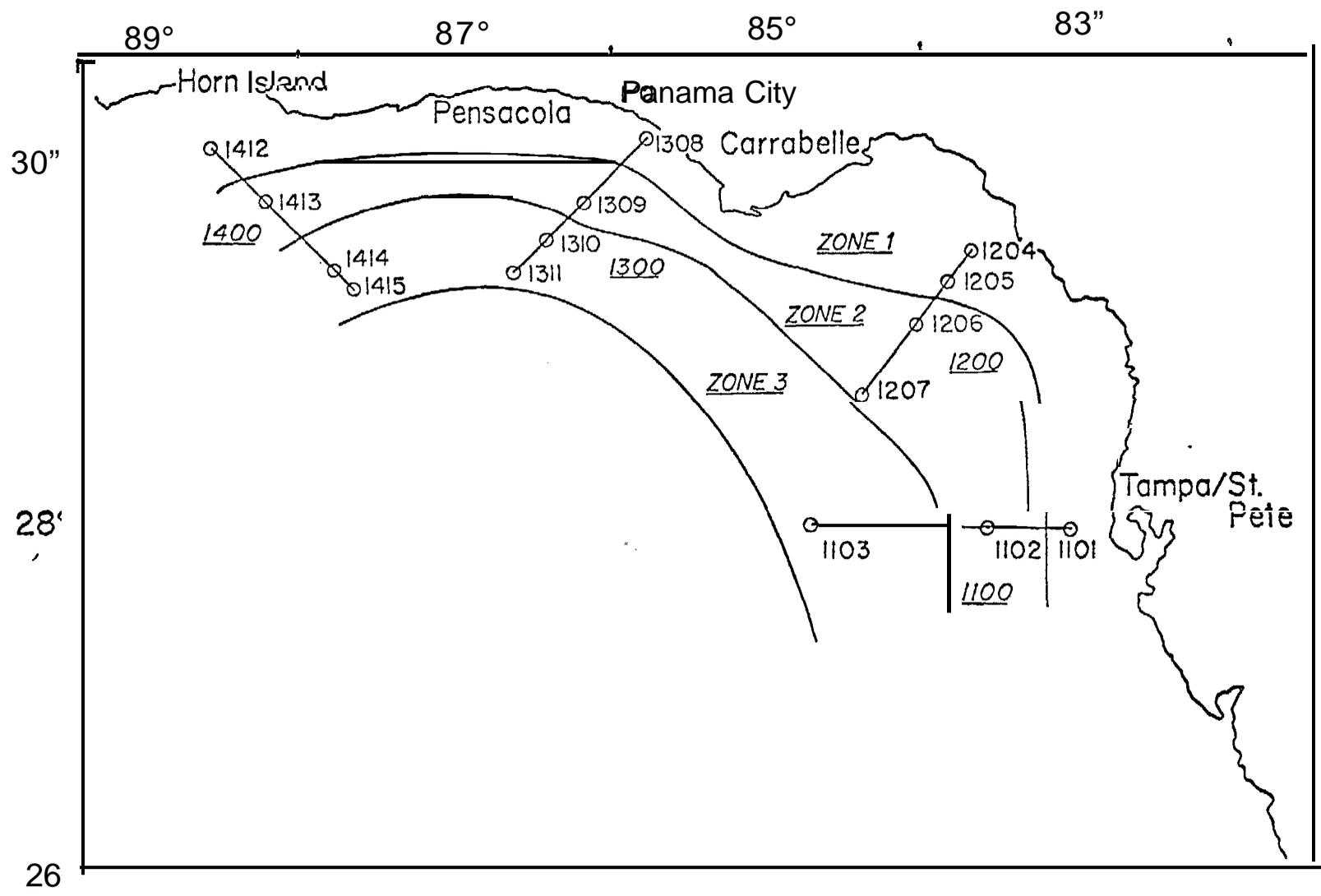


TABLE 4

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

Transect	Jun/Jul 1975		Sep/Oct 1975		Jan/Feb 1976	
	Poc	DOC	Poc	DOC	Poc	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)

C

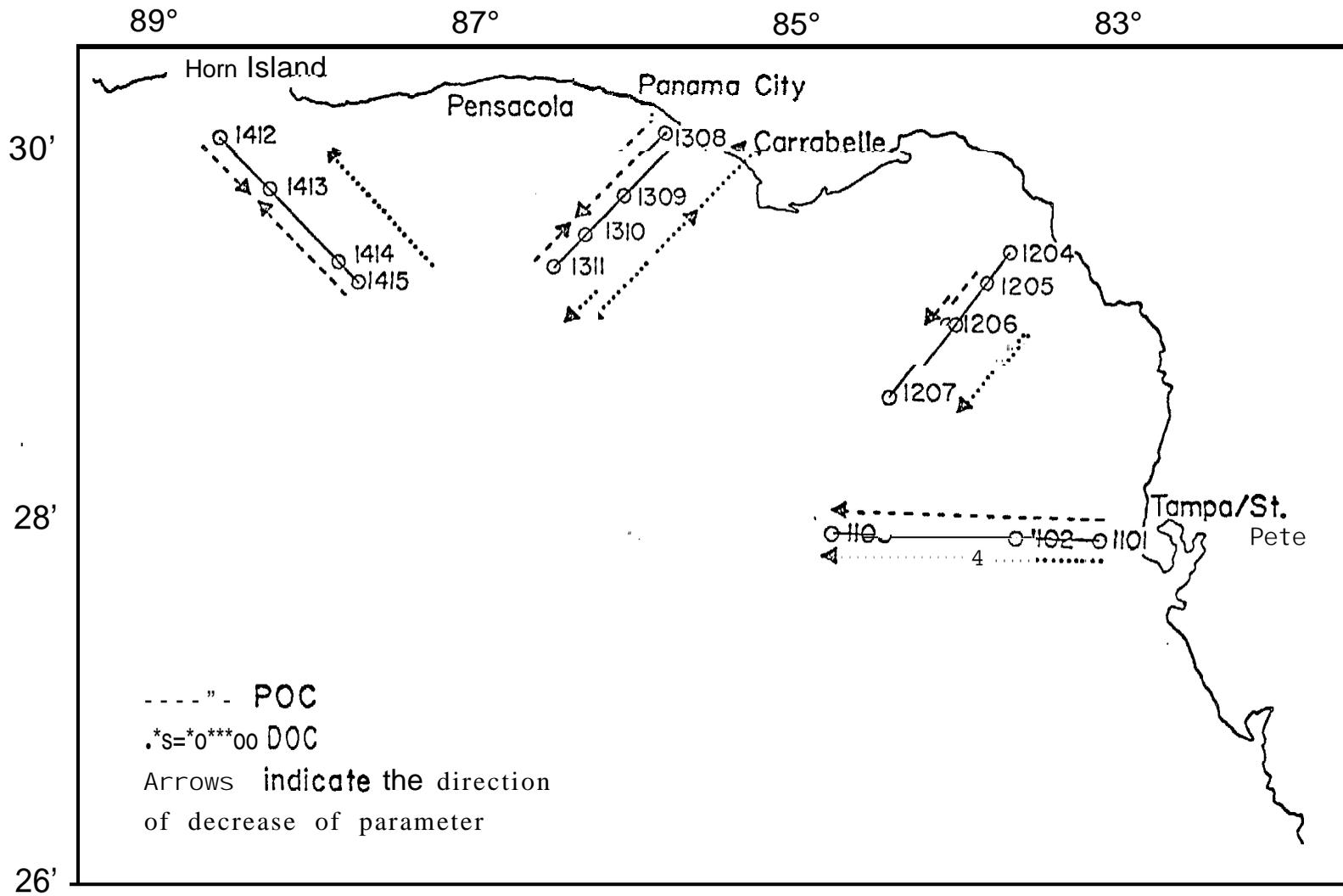
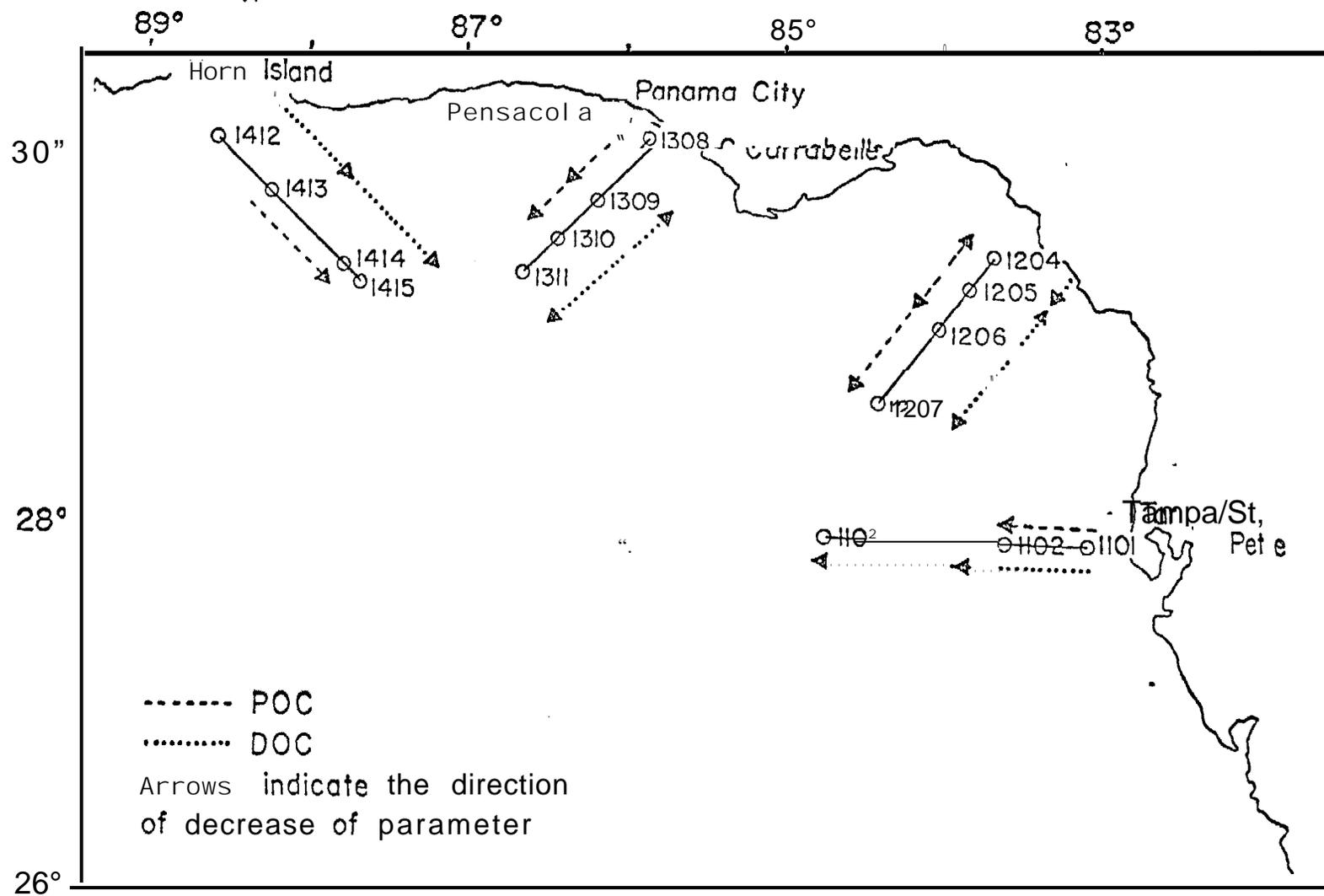


Figure 4--- Spatial Variation of Organic Carbon in the Northeast Gulf of Mexico, summer 1975



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

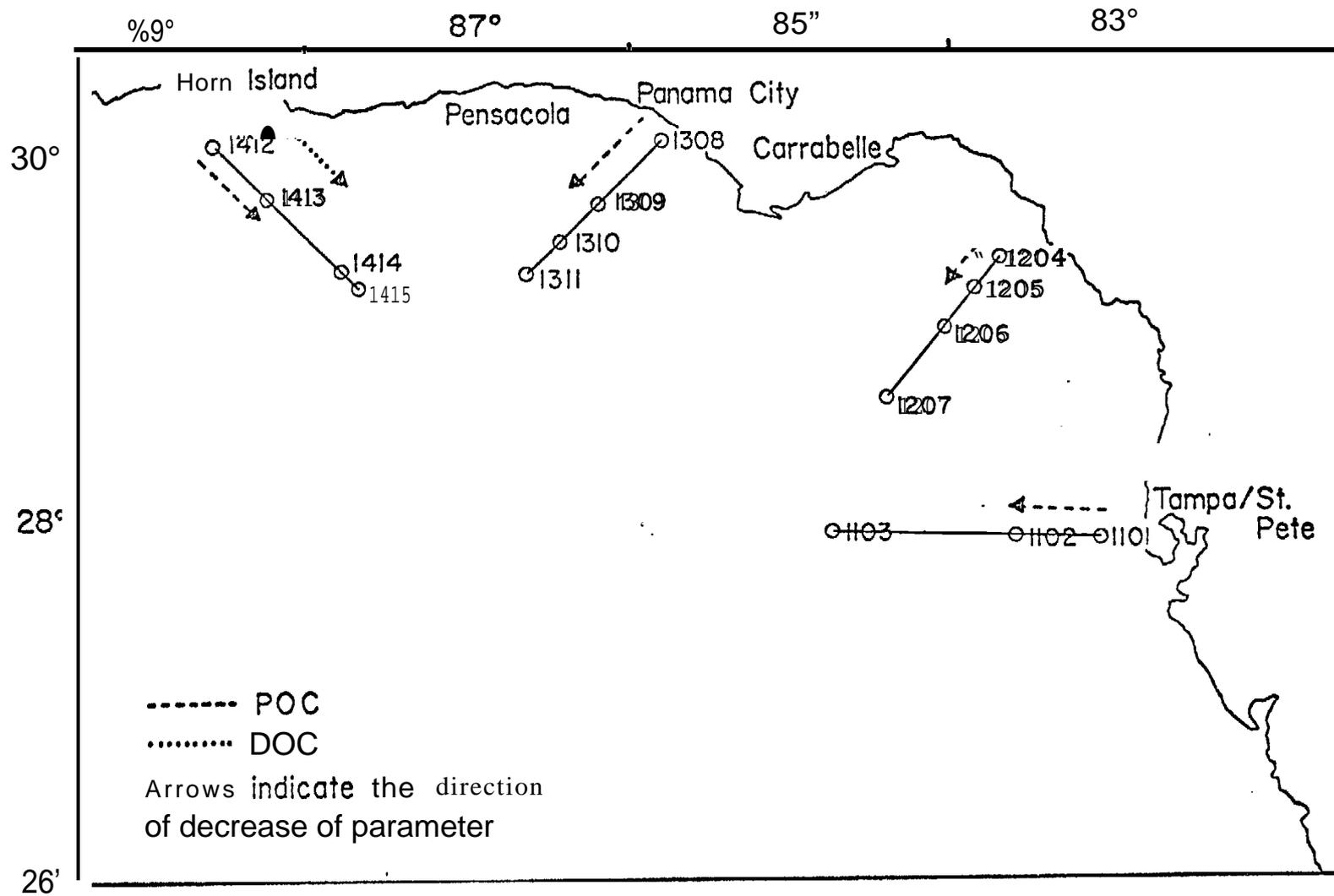


Figure 6--- Spatial Variation of Organic Carbon in the Northeast Gulf of Mexico, Winter 1976

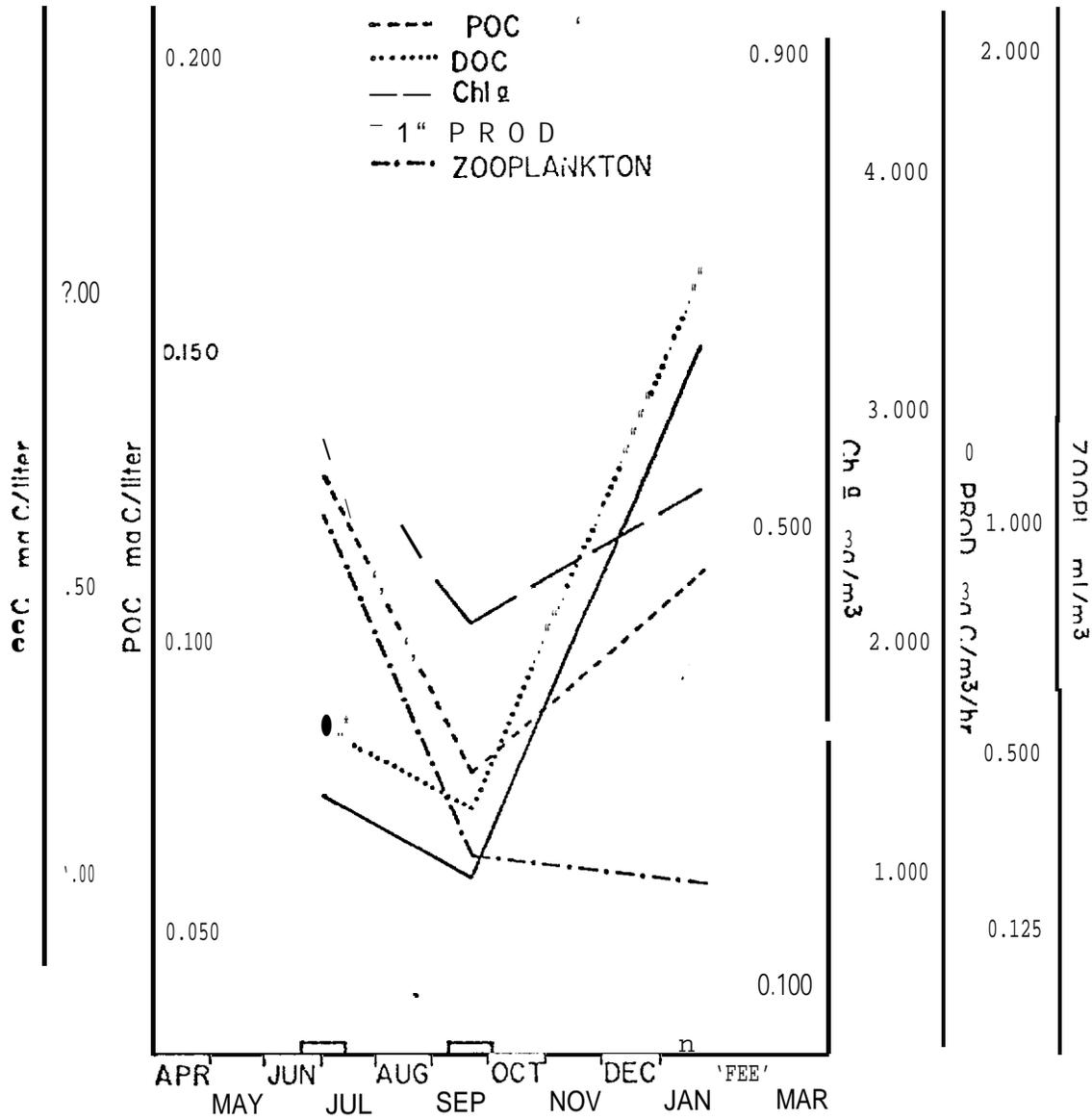


Figure 7.--Temporal Variation of Organic Carbon, Chlorophyll, Primary Productivity, and Zooplankton Over the Continental Shelf of the Northeast Gulf of Mexico

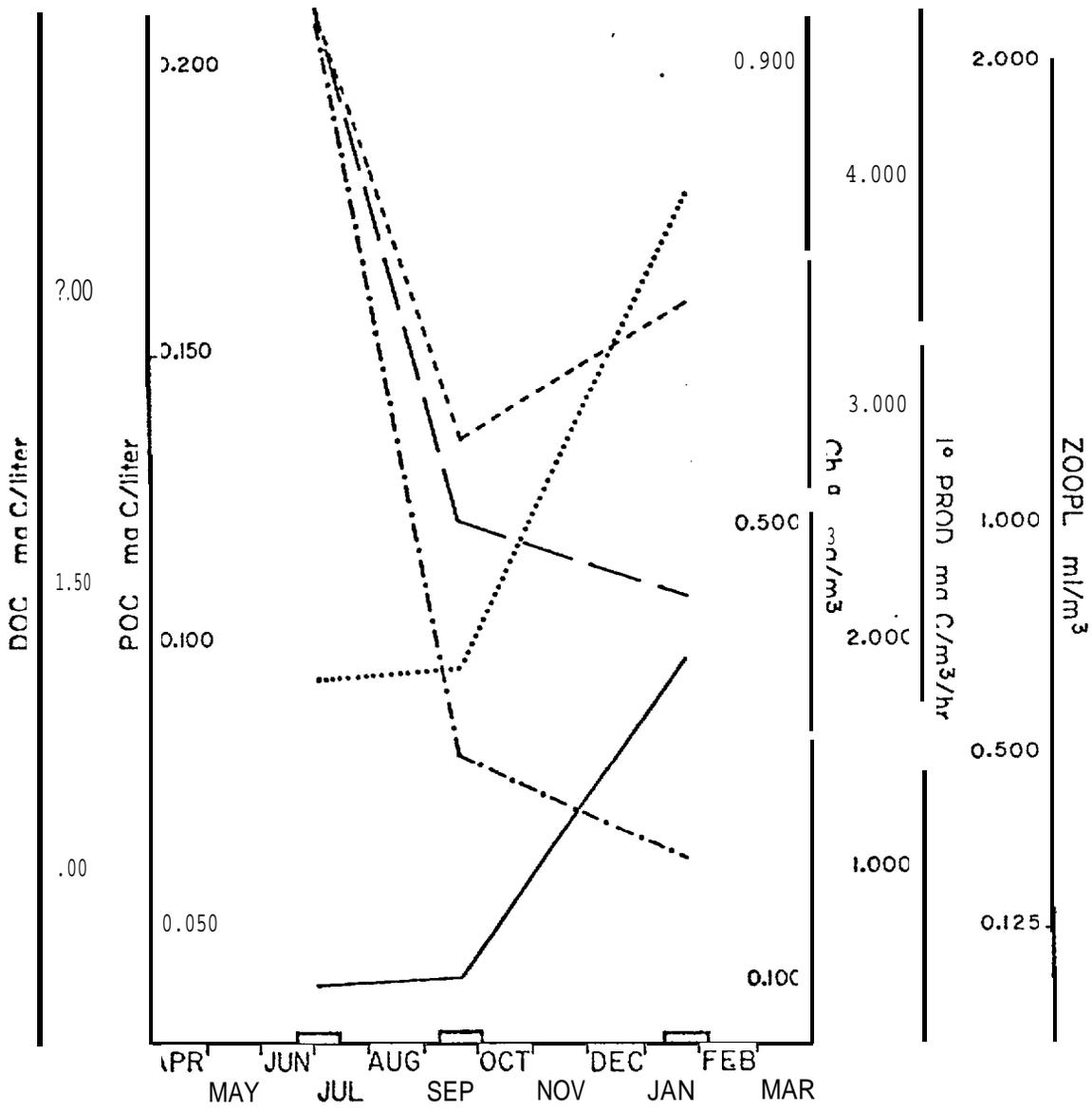


Figure 8. --Temporal Variation of Organic Carbon, Chlorophyll, Primary Productivity, and Zooplankton - Depth Zone 1

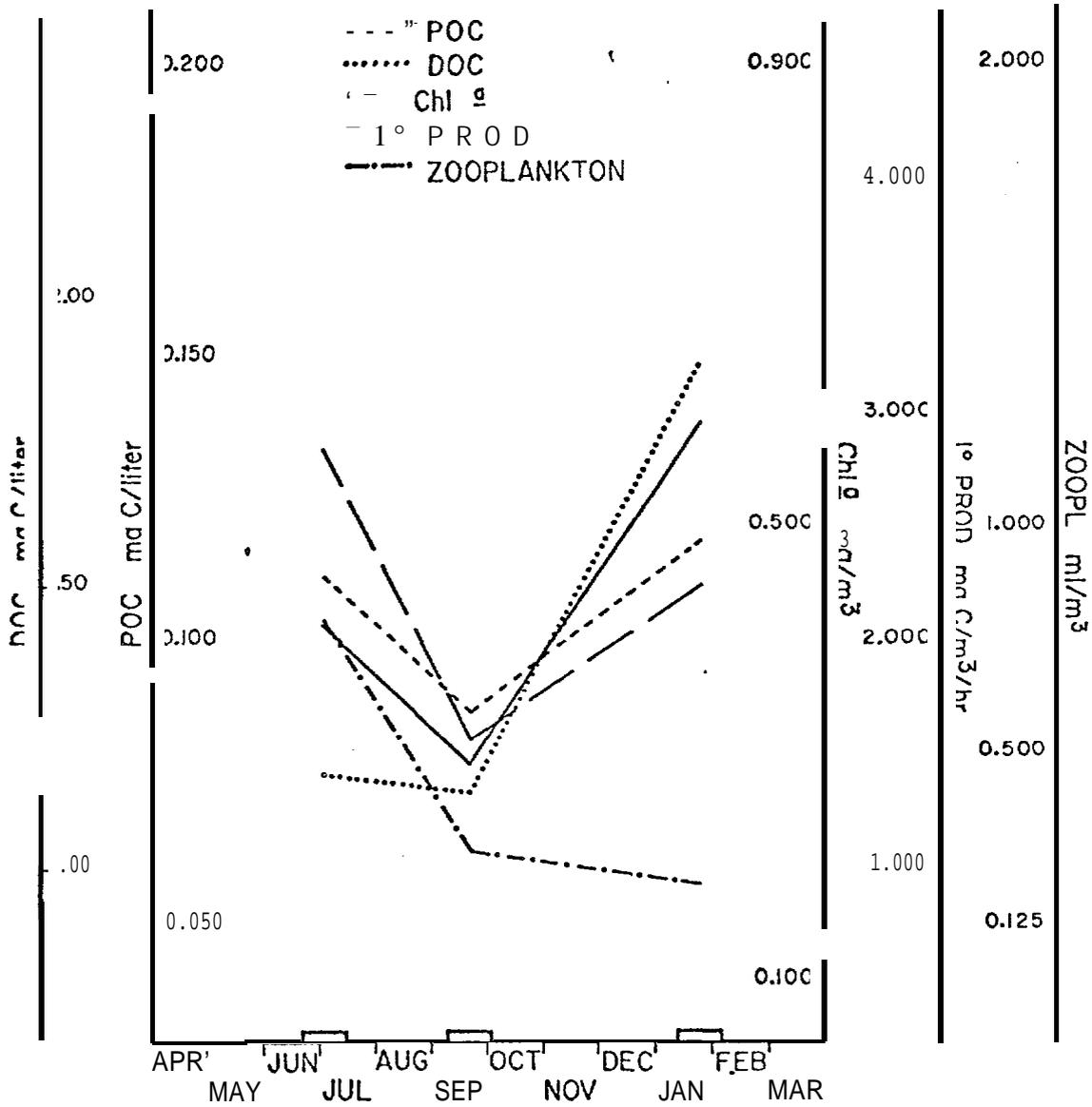


Figure 9--- Temporal Variation of Organic Carbon, Chlorophyll, Primary Productivity, and Zooplankton - Depth Zone 2

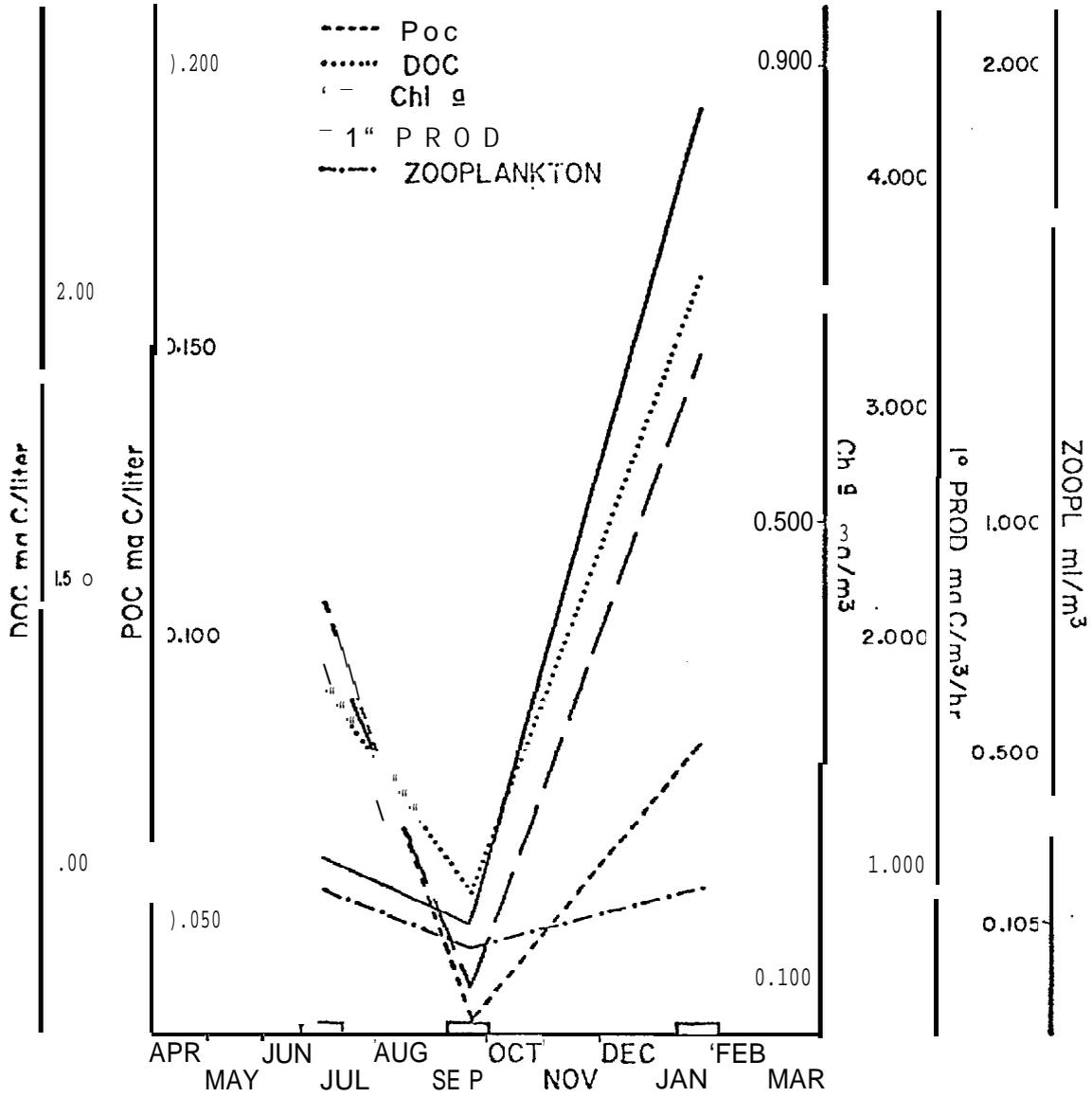


Figure 10--- Temporal Variation of Organic Carbon, Chlorophyll, Primary Productivity, and Zooplankton - Depth Zone 3

TABLE 5

SIGNIFICANT r^2 VALUES OF LINEAR REGRESSION ANALYSIS

Variable	Region	Jun/Jul 1975		Sep/Oct 1975		Jan/Feb 1976	
		POC	DOC	POC	DOC	POC	DOC
Chl \bar{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 discernible 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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TABLE 6

PRECISION OF ORGANIC CARBON DATA

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

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.

APPENDICES

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	0.34	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	.476	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	.068	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 CHL a	1975 PROD	z (m)	Sep/Oct CHL a	1975 PROD	z (m)	Jan/Feb CHL a	1976 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			
141s	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			
x s		0.580	1.358		0.423	1.002		0.536	3.280
		0.740	2.238		0.825	1.018		0.363	3.388

TABLE 9
ZOOPLANKTON DISPLACEMENT VOLUME (ml/m³)

B

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 . 1 7 1	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

P

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

TABLE 10
SALINITY (‰) AND TEMPERATURE (°C)

Station	z Jun/Jul 1975			z Sep/Oct 1975			z Jan/Feb 1976		
	(m)	T	s	(m)	T	s	(m)	T	s
1101	10	28.39	35.01	10	26.82	34.00	10	14.06	34.23
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	19.32	36.28
	102	20.00	35.60	50	24.79	36.32	50	19.34	36.23
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	35.20
1206	10	28.39	32.36	10	26.58	33.47	10	15.72	36.25
	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
	so	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	35.27
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/Ott 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

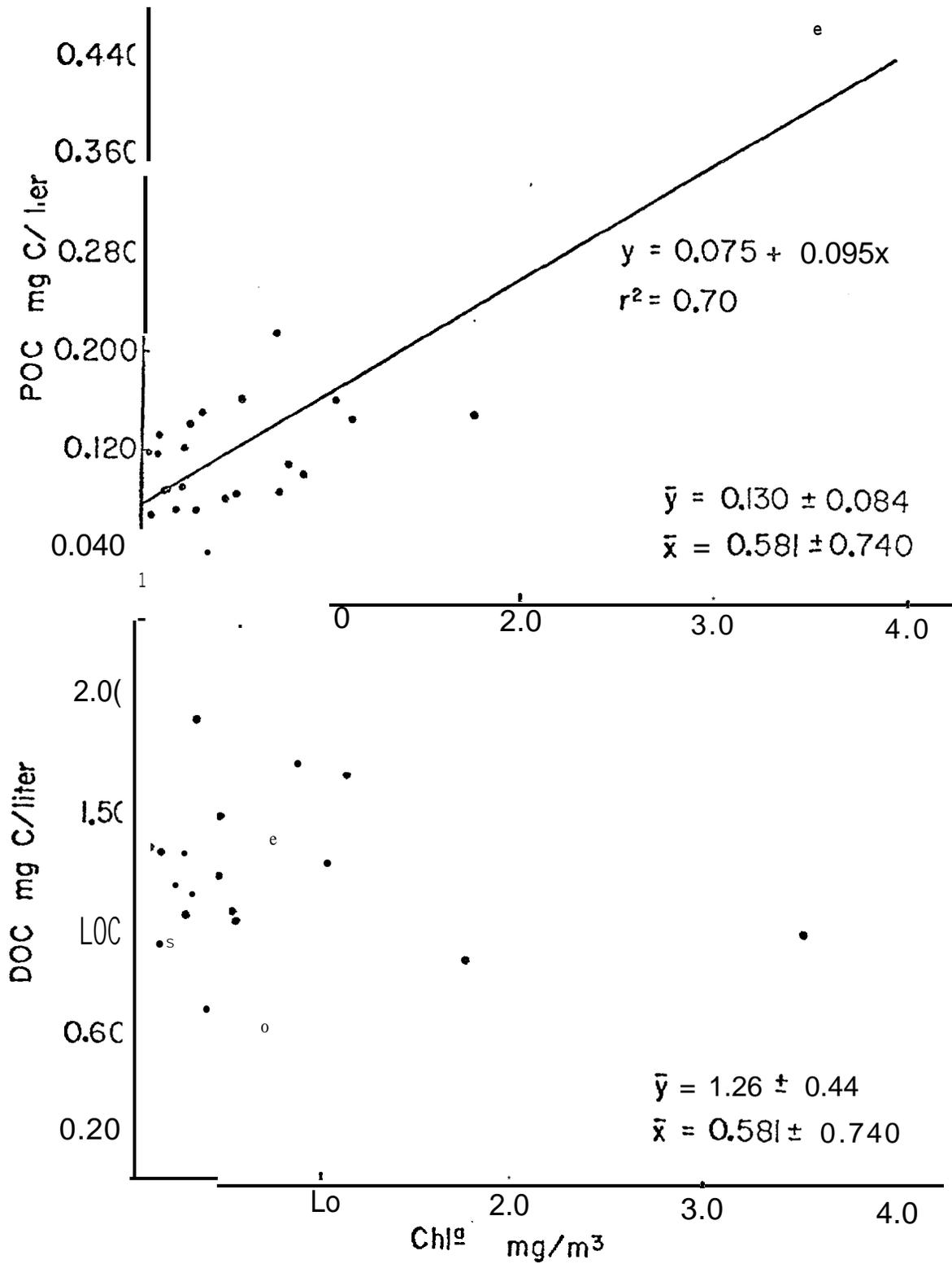


Figure 11.--Organic Carbon vs. Chlorophyll a
Summer 1975

B
P

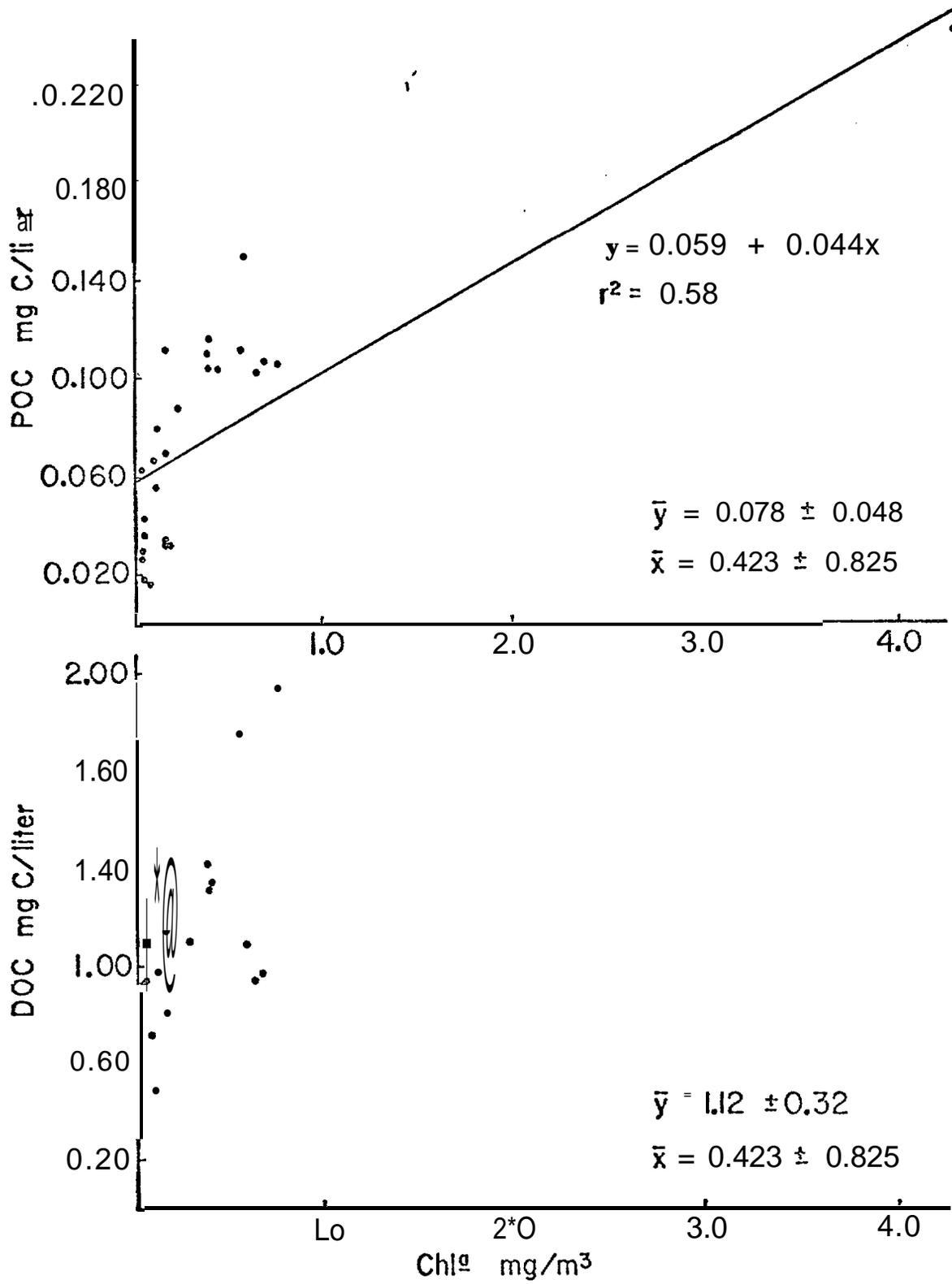


Figure 12--- Organic Carbon vs. Chlorophyll a
Fall 1975

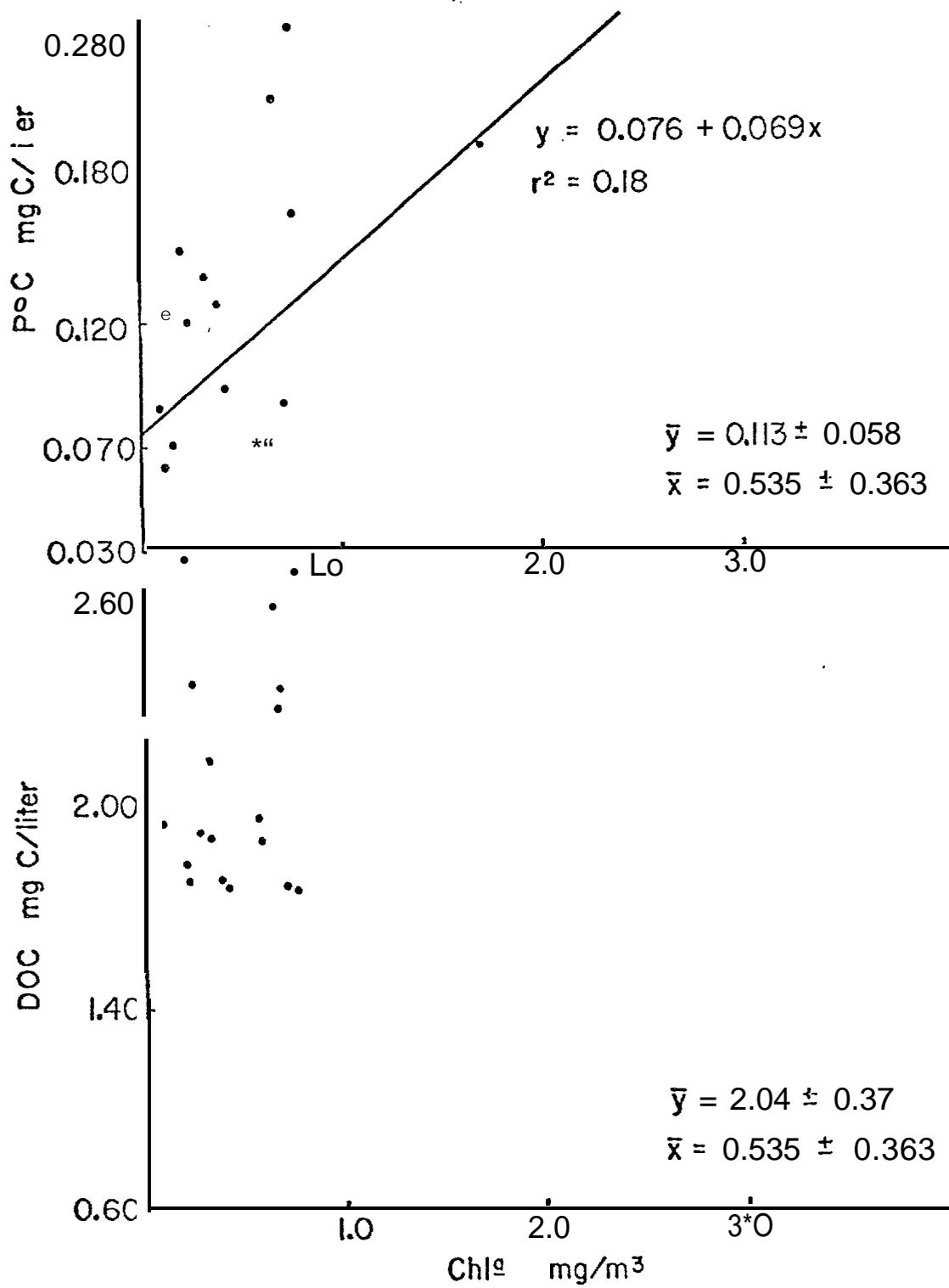


Figure 13--- Organic Carbon vs. Chlorophyll a
 Winter 19.76

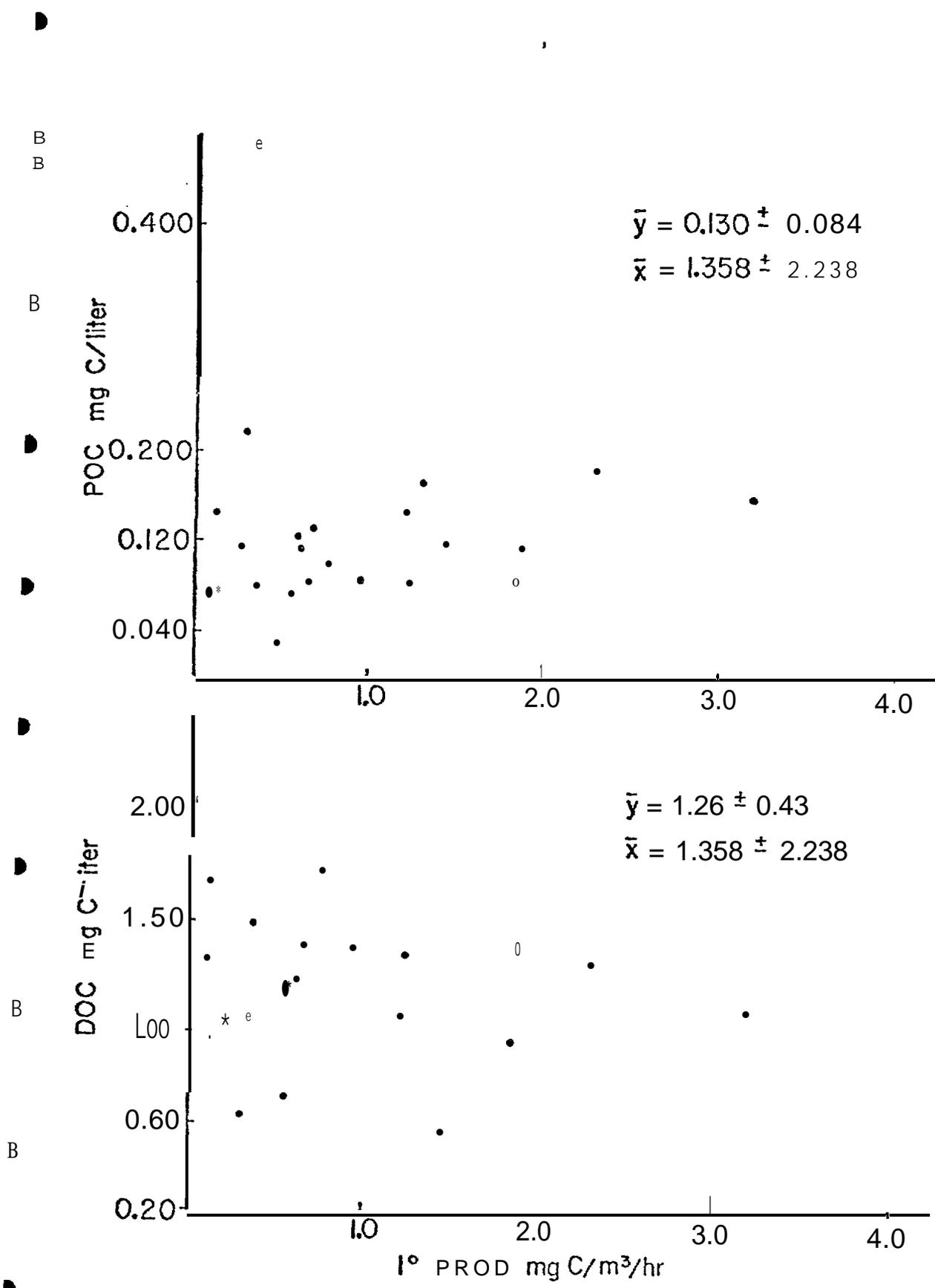


Figure 14.-- Organic Carbon vs. Primary Productivity
Summer 1975

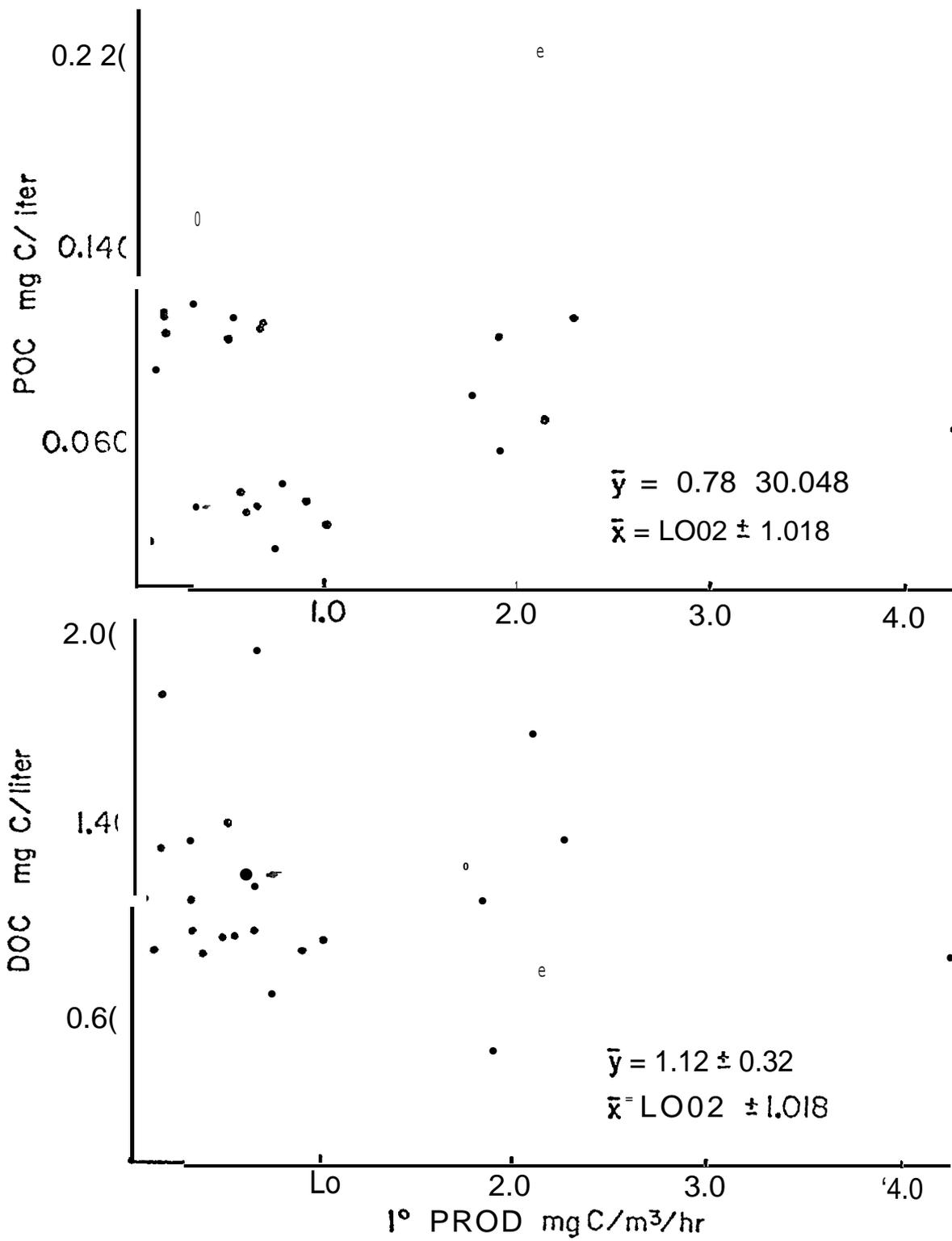


Figure 15.--Organic Carbon vs. Primary Productivity
Fall 1975

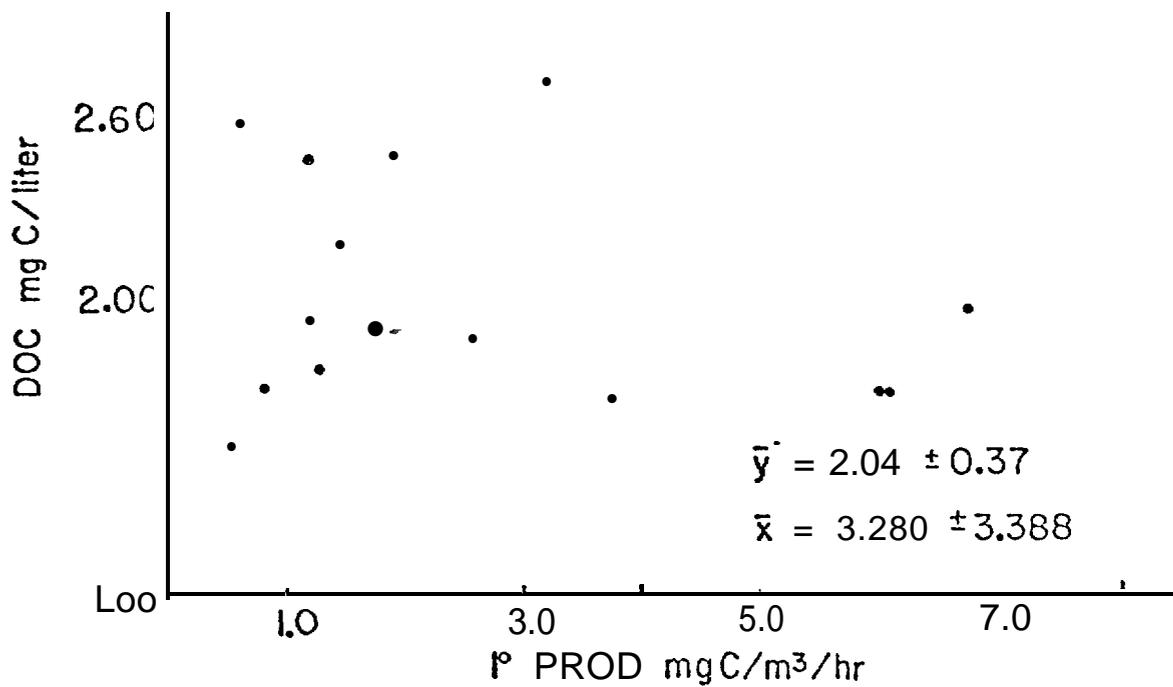
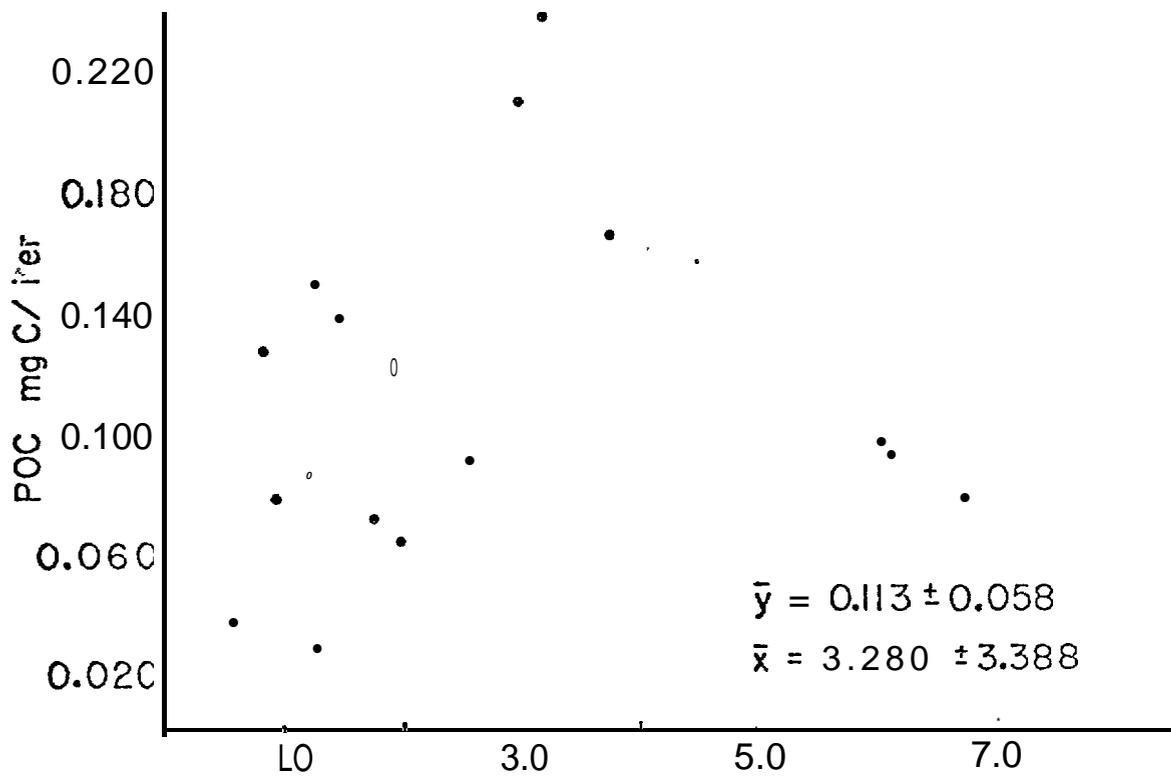


Figure 16--- Organic Carbon vs. Primary Productivity
 Winter 1976

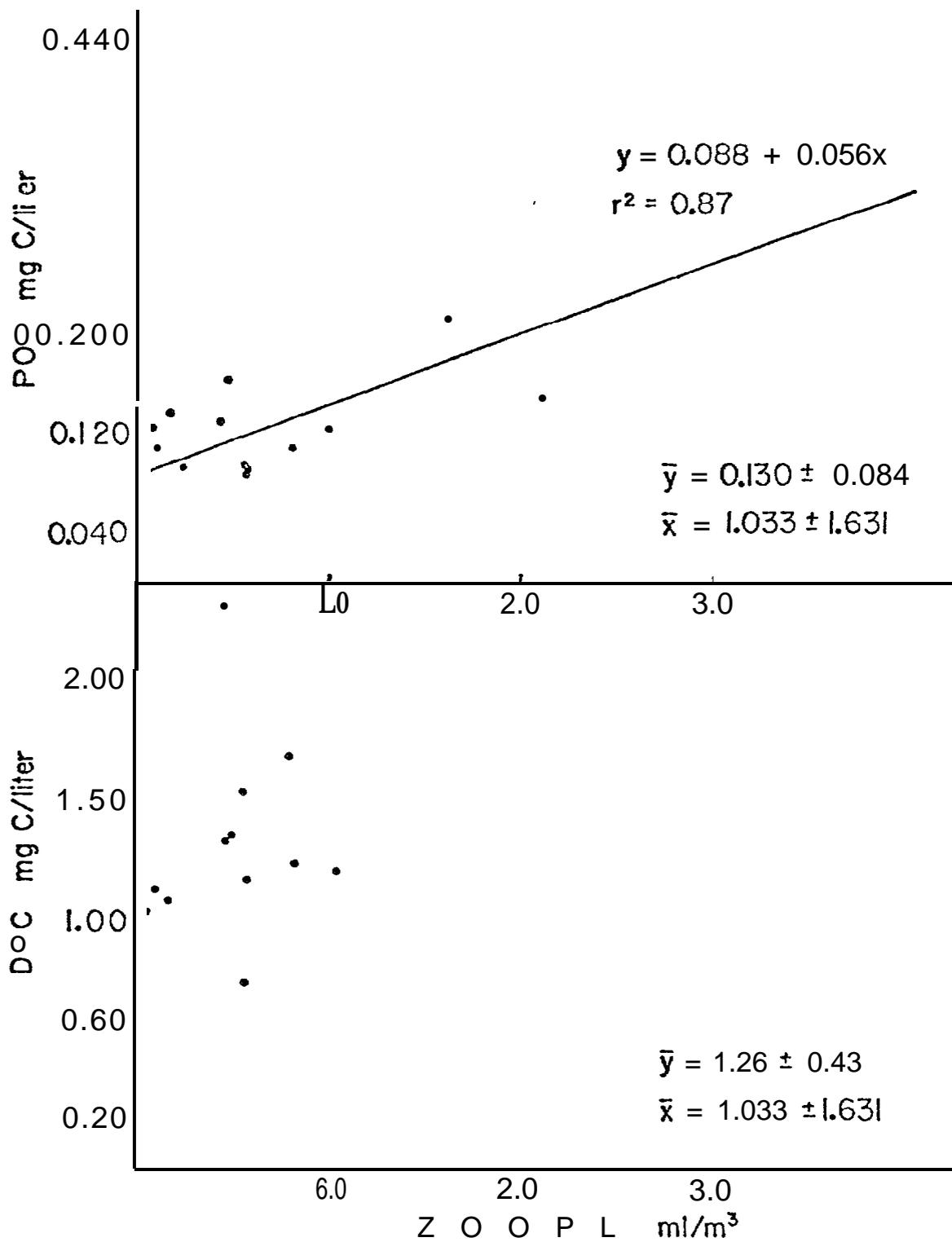


Figure 17.-- Organic Carbon vs. Zooplankton
 Summer 1975

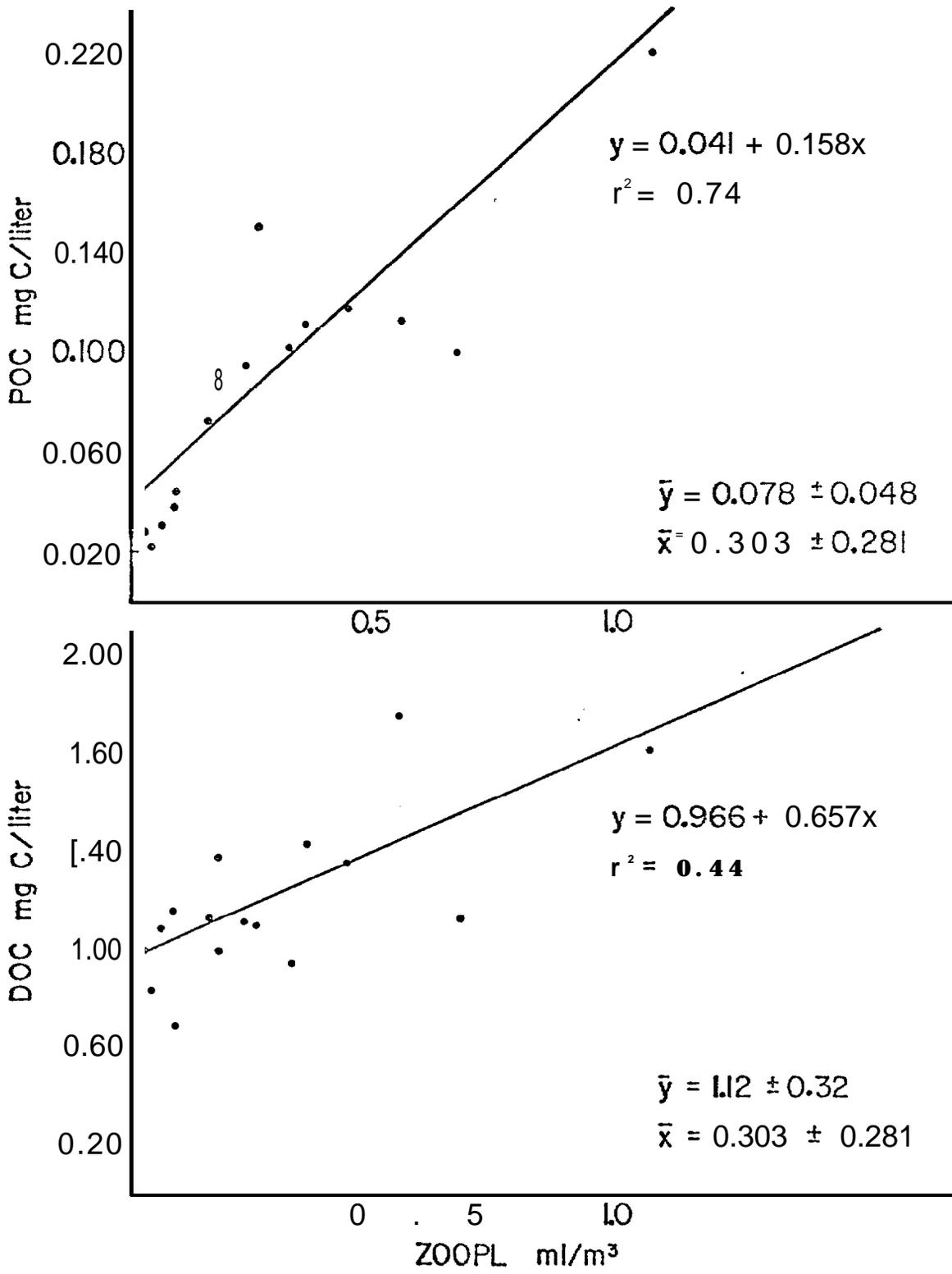


Figure 18 --- Organic Carbon vs. Zooplankton
Fall 1975

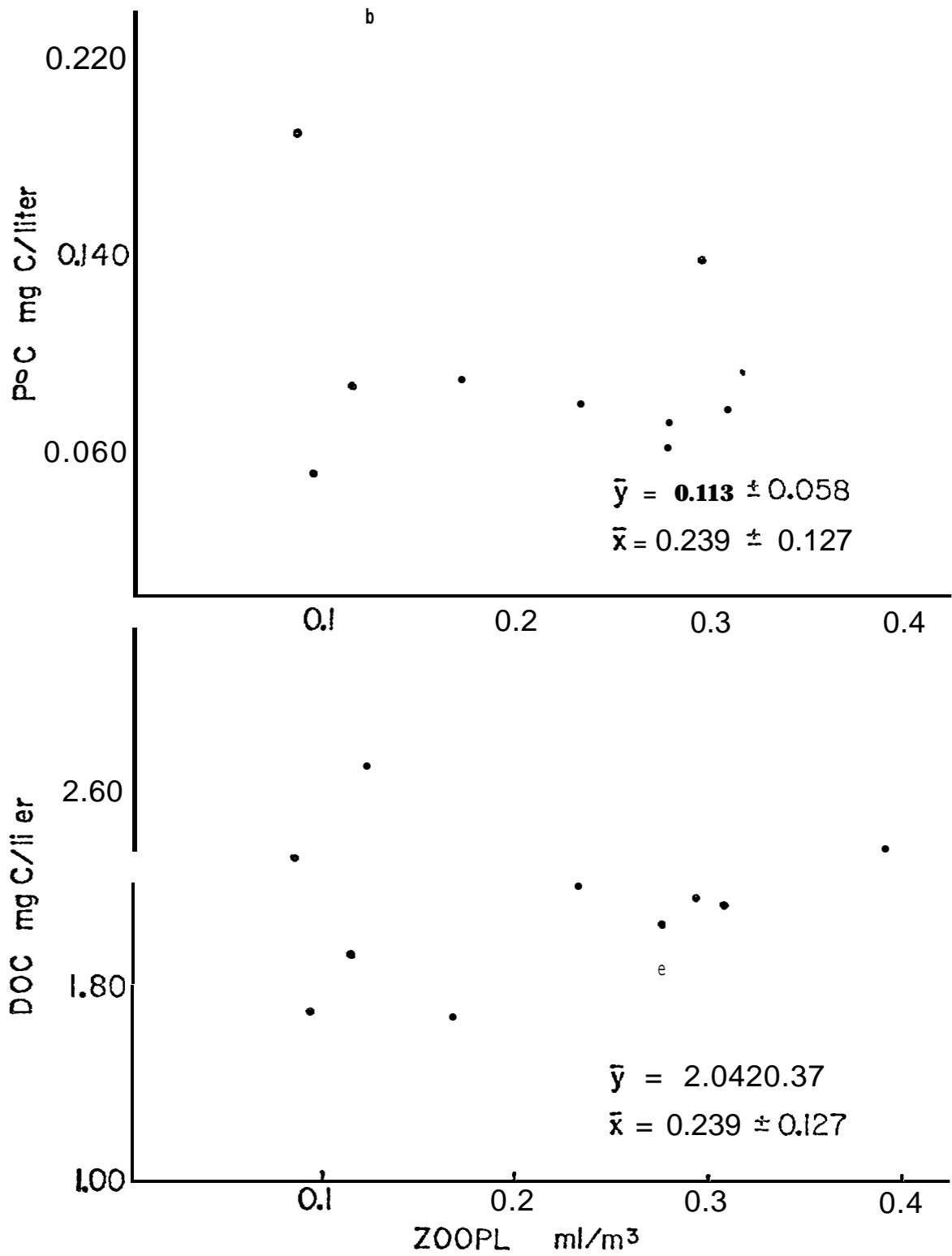


Figure 19 --Organic Carbon vs. Zooplankton
Winter 1976