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WEST HACKBERRY STRATEGIC PETROLEUM RESERVE SITE BRINE DISPOSAL MONITORING, YEAR I REPORT

Final Report. Volume 3: Biological Oceanography

FOSSIL ENERGY

February 1983

Work Performed Under Contract No. AC96-80PO10288

McNeese State University
Lake Charles, Louisiana

and

Texas A&M University
College Station, Texas

U. S. DEPARTMENT OF ENERGY

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WEST HACKBERRY STRATEGIC PETROLEUM RESERVE SITE BRINE DISPOSAL MONITORING

YEAR I REPORT
FINAL REPORT

VOLUME III
BIOLOGICAL OCEANOGRAPHY

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through the
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February, 1983

TABLE OF CONTENTS

LIST OF TABLES

CHAPTER 6

BENTHOS

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6.1 Introduction

The Department of Energy's Strategic Petroleum Reserve Program began discharging brine into the Gulf of Mexico from its West Hackberry site near Cameron, Louisiana in May 1981. The brine originates from underground salt domes being leached with water from the Intracoastal Waterway, making available vast underground storage caverns for crude oil. The effects of brine discharge on macrobenthic communities in Calcasieu Lake and coastal habitats off Cameron are herein presented.

The term "benthos" in this project refers to invertebrate species which live on the sediment surface or burrow beneath it. Since "benthos" are usually divided into several size components, it should be indicated that the faunal component of the benthos treated in this investigation are the macrobenthos. By definition, macrobenthos are animals retained on a 0.5 mm screen sieve following rinsing. They include such organisms as crustacea, molluscs, annelids, and a number of other taxa. Benthic organisms which pass through a 0.5 mm sieve are termed meiobenthos, and are not included in this study. Benthos large enough to be collected by otter trawl, termed megabenthos, are included in Chapter 7.

The macrobenthos are generally considered to be good indicators of pollution. They are especially important in assessing impacts of high-density effluents such as brine which would be expected to remain over the seabed following discharge. A number of attributes of benthic communities make the benthos important for investigations of pollutants. These include: 1) their sedentary nature; 2) the nature of their habitat: basically two dimensional since most benthos concentrate at the sediment-water interface; 3) their relative longevity which makes the community reflective of long-term or "integral" environmental conditions; and 4) their susceptibility to pollutants concentrated in the sediments or at the sediment-water interface (Boesch, in press). Both of the first two points simplify quantitative sampling of benthic species, and together with the latter points, aid in interpretation of these data as they relate to impacts due to man's activities.

6.1.1 Objective

The primary objective of this study is to determine the effects of brine discharge on macrobenthic communities in the area of the West Hackberry brine diffuser. Macrobenthic communities of Calcasieu Lake are also characterized for use as baseline data should discharged brine enter the lake or intake operations result in salt water intrusion.

6.1.2 Background

The response of benthic communities to man-induced pollution is well documented in the literature (e.g. Pearson and Rosenberg, 1978).

There is little historical literature, however, concerning the macrobenthos of the inner continental shelf or estuaries of southwest Louisiana. Most of the data now available result from brine-related studies made by a variety of institutions within the past four years, despite the fact that the area has for years supported both an extensive petroleum industry and a rich commercial fishery. With these industries providing additional potential impacts on the benthic community, the problem of detection of brine-related impacts is compounded.

Most baseline studies of the northern Gulf continental shelf center around areas well east or west of the study site. Parker (1956, 1960, 1975) described macrobenthic communities surrounding the mouth of the Mississippi River. Extensive data were collected during the Bureau of Land Management baseline studies of 1974-1978, though these studies concentrated on proposed oil drilling sites off south Texas, the Mississippi-Alabama-Florida (MAFLA) area, and around platforms of central Louisiana. Benthic baseline data of the continental shelf are also available through numerous investigations off Texas (e.g. Defenbaugh, 1973; Flint, 1979; Flint and Holland, 1980), though none of these may be directly comparable to habitats off Cameron. Studies are currently underway off Terrebonne Bay, Louisiana, in conjunction with the Louisiana Offshore Oil Pipeline (LOOP) (Ragan, 1978; Thomas, 1978) and off Freeport, Texas (S.A.I., 1978; Hann and Randall, 1980; Hann and Randall, 1981a; Hann and Randall, 1981b).

With only limited success, a number of attempts have been made to assess the environmental impact of oil development on benthic communities off Louisiana (Farrell, 1974, 1979; Kritzler, 1979; Thompson, 1979; Bedinger, 1979) and Texas (Armstrong et al., 1979, Harper et al., 1981). Since the study site is also within an area of active oil platforms, data from certain of these areas has been used to provide insight into benthic community patterns off Cameron.

The West Hackberry study area was initially examined in preliminary investigations by Science Applications Incorporated (S.A.I.), from September 1977 through May 1978 (S.A.I., 1978). A second study of the West Hackberry area was conducted by Parker et al. (1980) from June 1978 through May 1979 employing quarterly sampling.

A multidisciplinary 3-month baseline study of the diffuser area, which included identical methodology and many of the same sampling sites as those of this investigation, was undertaken in January-April 1981 employing monthly sampling (Weston and Gaston, 1982). The following conclusions were reached by Weston and Gaston concerning macrobenthic communities in the West Hackberry study area:

1. Sediment type in the offshore study area range from silty clay to sandy mud, never with more than 48% sand. The percentage of sand is lowest at the diffuser and immediately to the north, and increases to the east, south and west.
2. Comparisons with previous studies in the vicinity of the West Hackberry diffuser site by Science Applications Incorporated

(1978) and the National Marine Fisheries Service (Parker et al., 1980) are useful in some instances but limited by differences in methodology and taxonomy.

3. The ampharetid polychaete, Sabellides sp. A, and the phoronid, Phoronis sp. A, are the numerically dominant species throughout the offshore study area during February - April 1981.

4. The fauna of the diffuser area is characterized by strong numerical dominance of relatively few species which show dramatic population fluctuations both spatially and temporally. In this regard the macrobenthos are more typical of an estuarine community than a true continental shelf fauna. Such a community is maintained by the high turbidity of near-shore bottom waters, seasonal variations in temperature, and general inconstancy of the area.

5. The dramatic, unpredictable population irruptions characteristic of many of the macrobenthos will lessen the potential for impact assessment following brine discharge.

6. Some habitat differences based on the percentage of sand in the sediments are revealed by the multivariate analyses between those stations near the diffuser and the perimeter stations (M1, M3, M11, and CS). These faunal differences are primarily in species abundance and not in composition of species at the sites.

7. Even considering substrate-related faunal differences, the fauna of the study area is remarkably homogeneous. This homogeneity should greatly enhance the capacity for environmental impact assessment following brine discharge.

Calcasieu Lake was not included in the preliminary studies of West Hackberry by S.A.I. (1978) or Parker et al. (1980). A comprehensive macrobenthic study of Calcasieu Lake benthos was conducted by Shirley (in prep.), but these data are not yet available. Weston and Gaston (1982) collected monthly samples at the same five Calcasieu Lake estuary sites occupied during the present investigation, and reached the following conclusions:

1. Sediments at the estuarine stations are generally clayey silts and sandy silts, though there is considerable spatial and temporal variation in and among sites.
2. Estuarine fauna is numerically dominated by polychaetes and molluscs, particularly *Paraprionospio pinnata*, *Mediomastus californiensis*, *Streblospio benedicti*, *Mulinia lateralis*, and *Macoma mitchelli*. Most species collected are eurytopic, and widely distributed throughout estuaries of the northern Gulf of Mexico and United States East Coast.
3. The estuarine stations, particularly stations E1 and E5, represent distinct habitat types separable from one another primarily on the basis of salinity.

4. Station E5, located at the mouth of the Calcasieu Lake estuary, is more comparable to the marine stations than to the other estuarine stations both in species composition and abundance.

6.2 Materials and Methods

6.2.1 Field Sampling

6.2.1.1 Marine

During the present study, May 1981 - April 1982, seven stations are sampled monthly and an additional four (M6, M15, DN, DS) are included in quarterly sampling (Figure 6-1). Marine sampling sites are located primarily on an east-west transect along the 10 meter depth contour to minimize the effects of bathymetric faunal variation.

Station M10A is located 100 m west of the center of the brine diffuser, 0.67 km northeast of M10. The D stations (DE, DN, DS, DW) are all located in the immediate vicinity of the diffuser, 0.9 km to the north, south, east and west of M10A. Stations M15 and M6 are 1.85 km east and west (respectively) of the diffuser. Similarly, M18 and M3 are 3.70 km to the east and west. Station M20 is 9.25 km east of the diffuser.

Marine stations are located by LORAN C, and if in the vicinity of the diffuser, verified by dead reckoning from the numerous buoys in the area. At each site observations are made of time, sea state, and weather conditions. A vertical profile at three meter intervals is made of conductivity, temperature, dissolved oxygen and pH with a Hydrolab Series 8000 meter. Turbidity samples are taken with a 3-liter Van Dorn sampler.

Six replicate grab samples are taken at all marine stations using a 0.1 m^2 stainless steel Smith-McIntyre grab (Figure 6-2). The

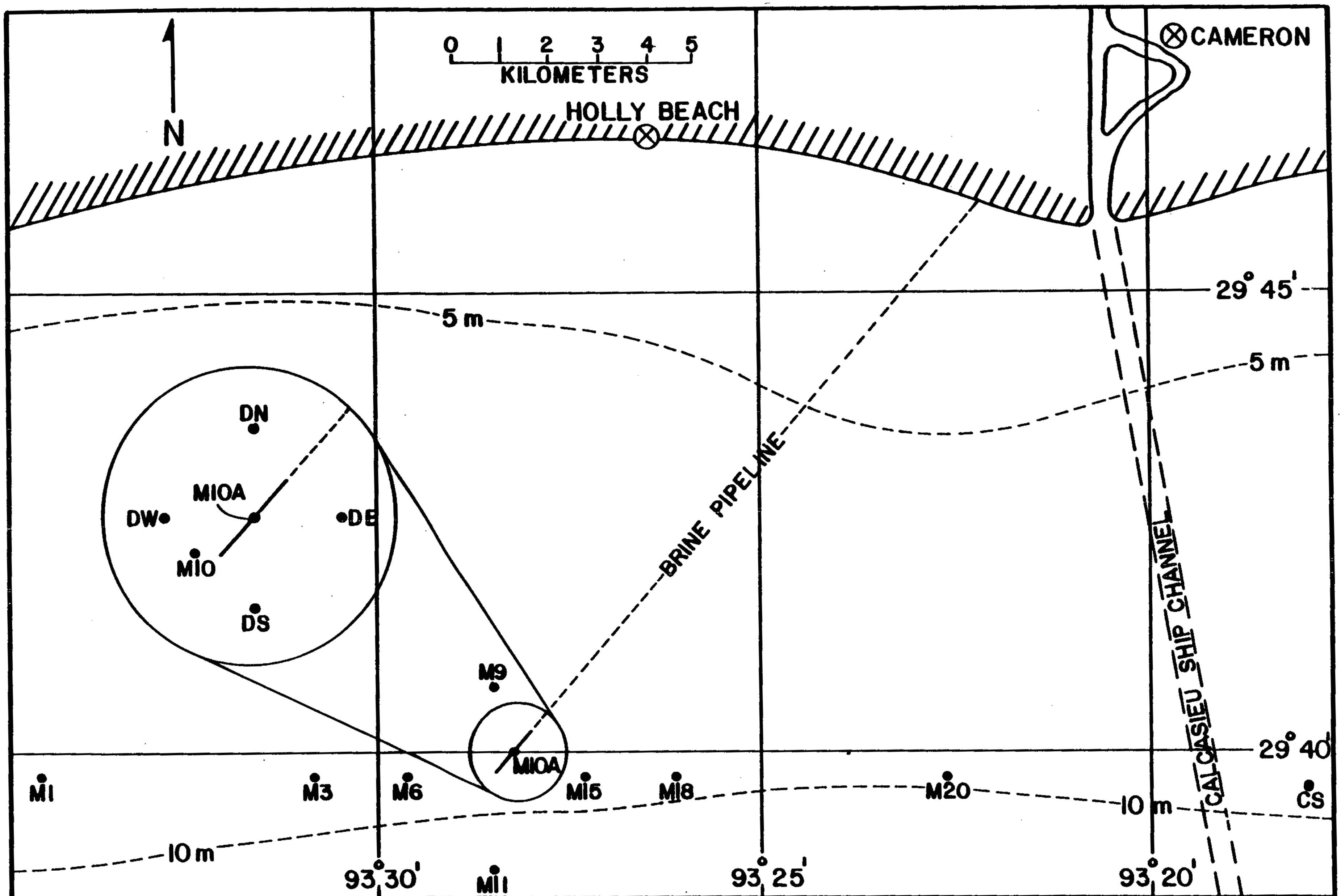


Figure 6-1. Macrobenthic marine sampling sites of the post-discharge investigation. Diffuser is indicated by dark line at end of pipeline.

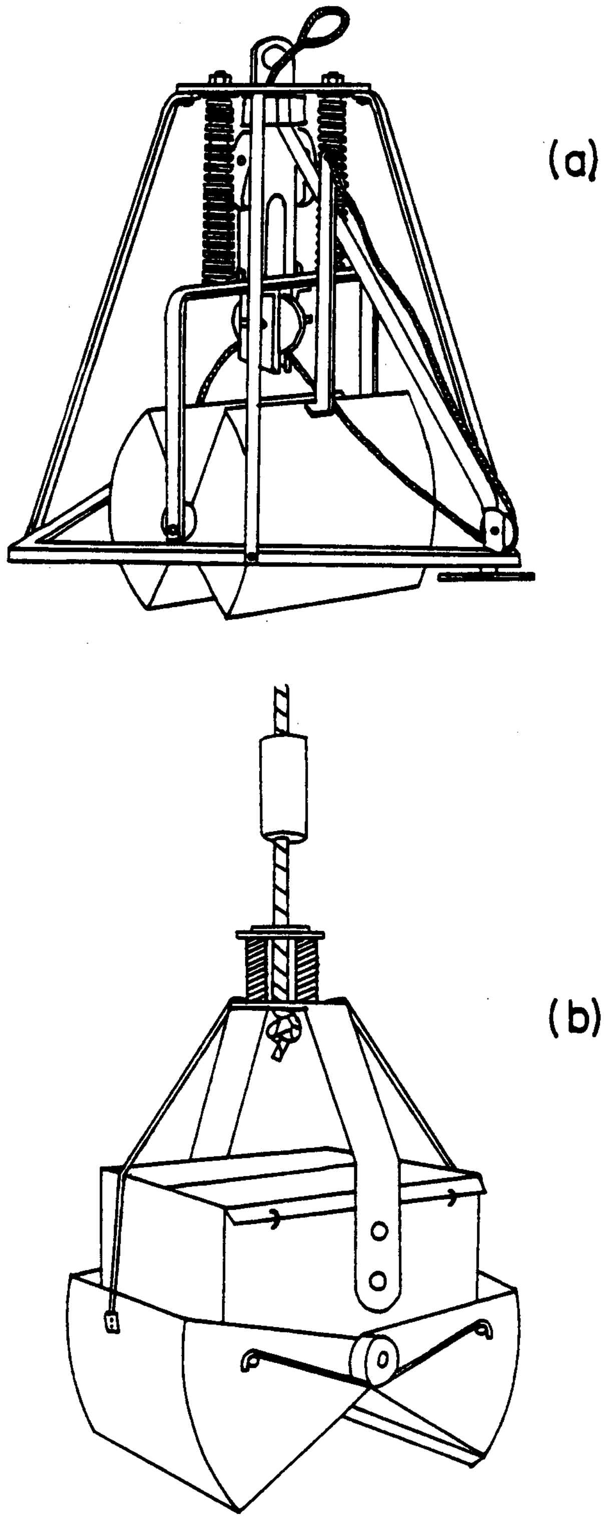


Figure 6-2. Grab samplers used in macrobenthic sampling.
(a) 0.1 m^2 Smith-McIntyre grab used at marine stations.
(b) 0.05 m^2 Ekman grab used at estuarine stations.
(after Standard Methods, 1976).

number of replicates necessary to adequately sample the community was determined during a special cruise in January 1981 (see Weston and Gaston, 1982).

After each sample is retrieved, the upper doors of the grab are opened and depth of penetration is measured. A 2.7 cm diameter x 12 cm length core is inserted into the sediment to obtain a sample for grain size analysis. The contents of the core are transferred to a Whirl-Pak bag and stored on ice. The contents of the grab are immediately washed through a 0.5 mm screen. The material retained on the sieve is preserved in 10% buffered formalin containing Rose Bengal as a vital stain, and stored in a container labelled with station, replicate, and cruise number.

6.2.1.2 Estuarine

Five estuarine stations (Figure 6-3) are sampled monthly from May 1981 - April 1982. The location of estuarine stations is determined by dead reckoning. At each site, observations are made of weather conditions and water quality as at the marine stations.

Five replicate grab samples are taken at all estuarine stations using a 0.05 m^2 Ekman grab (Figure 6-2), with the exception of E5, where a 0.1 m^2 Smith-McIntyre grab is used. The number of replicates required was determined during a special January 1981 cruise (see Weston and Gaston, 1982), during which 10 replicates were taken near station E4. Field processing of the estuarine samples is identical to that of the marine samples discussed above.

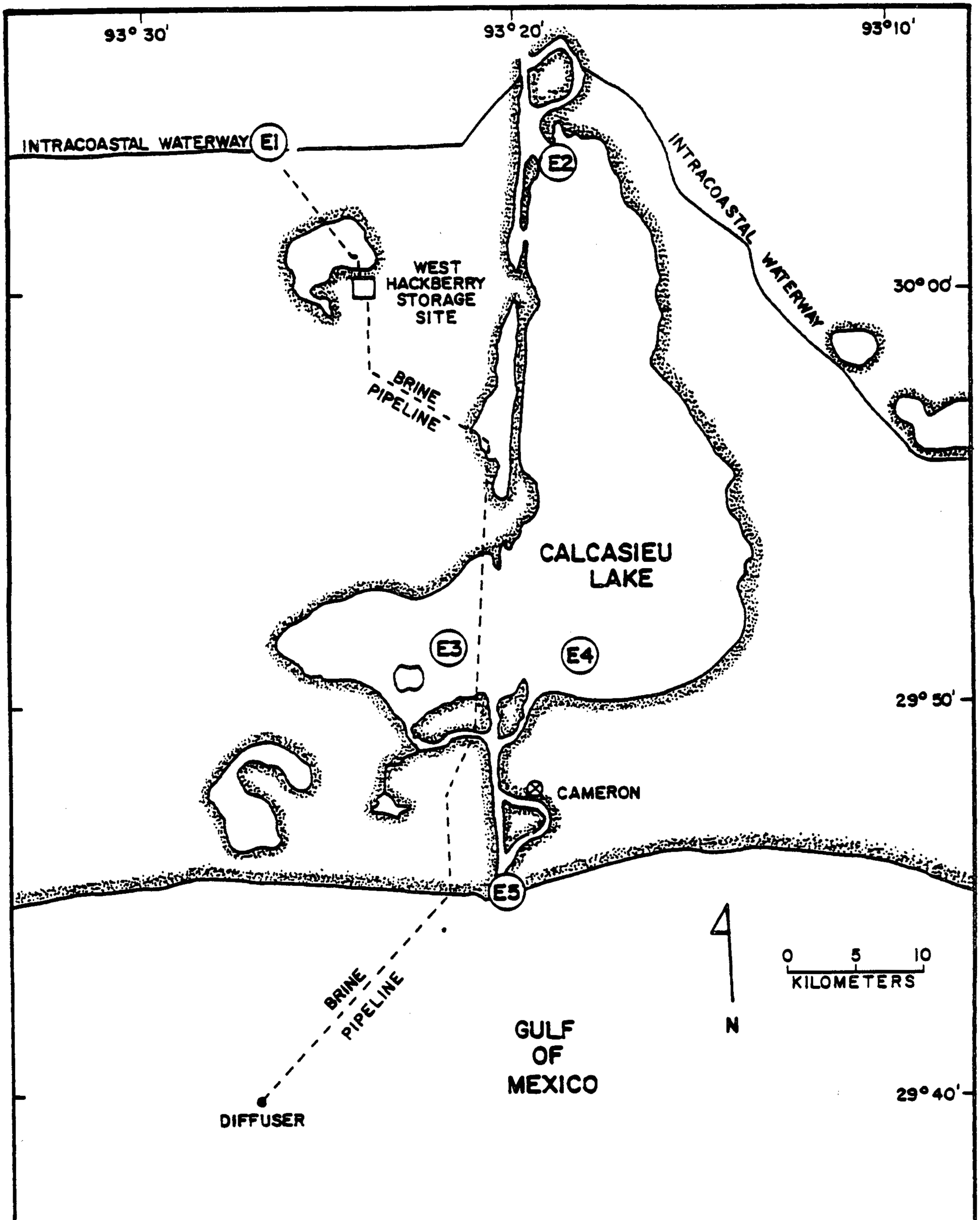


Figure 6-3. Macrobenthic estuarine sampling sites of the post-discharge investigation

6.2.2 Laboratory Analyses

Benthic samples preserved in formalin are stored in the laboratory until analyses begin. Analyses include rinsing, sorting to major taxa, and identification of macrofaunal species.

The rinsing procedure is accomplished by placing the sample in a large enamel tray, repeatedly washing the sample with water, and decanting the supernatant through a 0.5 mm screen. In this manner, the sample is washed free of the formalin preservative, and all light-bodied organisms are concentrated on the 0.5 mm screen. Heavy-bodied organisms, such as large molluscs, remain in the enamel tray and are later removed by sorting with the naked eye. Organisms retained on the 0.5 mm screen are examined under a dissecting microscope, and sorted to major taxa (e.g. Decapoda, Mollusca, etc.). Each major taxon is placed in an individual vial and stored in 70% ethanol pending species determination.

Identification and enumeration of macrofaunal organisms is performed under stereomicroscopy, and when necessary, compound microscopy. Each organism is identified to the lowest possible taxonomic level, generally species, and placed in 70% ethanol for long-term storage. Major taxonomic references used for identification of benthic species are listed in Table 6-1. Complete references of these citations are included in the bibliography. It should be noted that this represents only major references and not a complete list of all references used in benthic taxonomy. The number of individuals of each

Table 6-1. Major taxonomic references used for identification of benthic species.

Cnidaria
- Carlgren and Hedgpeth 1952

Annelida
- Blake 1971
- Day 1973
- Fauchald 1977
- Foster 1971
- Gardiner 1976
- Hartman 1951, 1965
- Pettibone 1963, 1966

Sipuncula
- Cutler 1973
- Stephen and Edmonds 1972

Mollusca
- Abbott 1974
- Andrews 1977
- Morris 1973

Crustacea
- Barnard 1969
- Bousfield 1973
- Chace 1972
- Felder 1973
- Manning 1969
- Menzies and Frankenberg 1966
- Pilsbry 1916
- Schultz 1969
- Stuck, Perry, and Heard 1979
- Tattersall 1951
- Williams 1965
- Zullo 1979

Echinodermata
- Pawson 1977
- Thomas 1965

species collected in each replicate is recorded on laboratory data sheets. Each species is then identified by a 10 digit taxonomic code, which is used in all computer manipulations.

A reference, or voucher, collection of each species collected is maintained to insure taxonomic standardization within this study. Specimens are preserved in glass jars containing 70% ethanol preservative, and labelled inside. All labels indicate, at a minimum, the date, location, depth of collection, and contract number. A reference collection will be maintained by McNeese State University until its deposition in the United States National Museum, Smithsonian Institution.

6.2.3 Grain Size Analysis

Grain size analysis is performed by the Hydrometer and Sieve Method (American Society for Testing and Materials, 1972). A 50 g sample of wet sediment is combined with 125 ml of sodium hexametaphosphate solution (40 g l^{-1}) and allowed to soak overnight. The slurry is transferred to a dispersion cup and mixed for one minute. The mixture is then transferred to a sedimentation cylinder and made to volume (1000 ml). The contents of the cylinder are mixed by inverting the cylinder equipped with a rubber stopper for one minute. The cylinder is placed on a level table top and hydrometer readings (Hydrometer 152H) are taken at 2, 5, 15, 30, 60, 250, and 1440 minutes. Temperature of the liquid to one tenth °C is recorded after each hydrometer reading. After the final hydrometer reading is taken, the contents of the cylinder are transferred to a set of sieves (phi size -2, -1, 0, 1, 2, 3, and 4) and wet sieved. The contents of each sieve were transferred to a preweighed vessel, dried overnight at 103-105°C and the vessel reweighed. The data generated by the procedure are used to calculate grain size ranging from a phi size of -2 to >10.

6.2.4 Statistical Analyses

Several indices of community structure are employed in data analysis of the benthic collections. Diversity is measured using Shannon's formula (Pielou, 1966):

$$H' = -\sum_{i=1}^{s} p_i \log_2 p_i$$

where p_i is the proportion of the i-th species and s equals the number of species in the sample. This index is dependent on both number of species in the sample as well as their relative dominance. To examine these two parameters independently, species richness (S) and evenness (J) are computed separately using the formulae:

$$S.R. = \frac{s-1}{\ln N} \qquad J = \frac{H'}{\log_2 s}$$

where N equals the total number of individuals. These indices, when calculated for a station, are based on the number of species and their mean abundances in all replicate grabs taken.

A variety of non-parametric tests are employed in analysis of the data, including Kendall's coefficient of concordance, Wilcoxon signed-ranks test and Mann-Whitney U test (Sokal and Rohlf, 1981). The spatial dispersion of marine organisms is usually contagious ("clumped"), and thus assumptions required for use of parametric tests (e.g. normal distribution and homogeneity of variance) often cannot be met. Even by transformation of the raw data, it may be impossible to meet these assumptions, particularly with few replicates. Non-parametric tests are chosen, as they are "distribution-free", requiring no assumptions to be made concerning the shape of the parent distribution.

In order to present the large data set in an interpretable form, as well as determine zones of rapid faunal change, multivariate analysis techniques are employed. In analyses of the marine stations rare species are eliminated. Rare species are identified as those which occur in a single replicate sample. In analyses of the estuarine stations no species are dropped, because of the smaller size of the data set, the low abundance of species, and the greater habitat heterogeneity between stations causing many species to be unique to one particular site.

Clustering is performed using the Virginia Institute of Marine Science program COMPAH (Combinatorial Polythetic Agglomerative Hierarchical Program). Log transformation (log X-1) and the Bray-Curtis similarity measure (Bray and Curtis, 1957) are employed in the clustering. This similarity measure can be expressed as:

$$S_{jk} = 1 - \frac{\sum_{i=1}^{n} | X_{ji} - X_{ki} |}{\sum_{i=1}^{n} (X_{ji} + X_{ki})}$$

where, in normal clustering, S_{jk} equals the similarity between stations j and k, and X_{ji} and X_{ki} equal the abundances of species i in station j and k respectively. In inverse (species) clustering, the roles of the stations and species are reversed and S_{jk} becomes the similarity between species j and k.

Two sorting strategies are used in the numerical classification analyses. A group average sorting strategy (Sneath and Sokal, 1973, as an "unweighted pair-group method using unweighted arithmetic averages") is employed which, having characteristics intermediate between the contracting and dilating strategies discussed above, induces a minimum of space distortion in the dendrogram. However, in some data sets, group average sorting causes undesirable chaining among the entities. Flexible sorting (Lance and Williams, 1967), with beta established at -0.25, is also employed. Though flexible sorting seldom induces chaining, it has the drawback of occasionally causing misclassifications. Both sorting strategies are used, and the more informative of the two presented in the text.

The statistical techniques discussed above are applied in order to assess the severity and extent of environmental impact resulting from brine discharge. Numerical classification is performed to delimit zones of faunal similarity and identify consistent temporal and spatial trends. As applied in the present context of impact assessment, should an impact occur, stations within the brine plume should be biologically dissimilar from unimpacted stations, and thereby form a discrete cluster. The significance of these patterns in cluster analyses, and implications of brine-induced impact, can be tested using matched site comparisons. Variations in community structure between sites can then be quantified by indices of diversity, species richness and evenness.

6.3 Results

6.3.1 Sediments

6.3.1.1 Marine

Surficial sediments of the offshore study area are generally silty-clays with approximately 10% sand, 35% silt and 55% clay (Figures 6-4 - 6-8). With only a few exceptions (most notably M3) there is a general homogeneity in sediment type among the stations. Of particular importance is the similarity in substrate composition among selected control (M18 and M20) and near-diffuser (M10A and DW) sites. This close similarity in sediment type, and the consequent similarity in faunal composition, enhances the capability for detection of brine discharge impact in matched site comparisons.

The differences in substrate composition that exist among the offshore stations can best be illustrated by changes in the percentage of sand (Figure 6-9). There is a general increase in percentage of sand to the south, east and west of the diffuser area with the gradient to the south and west being the strongest. This same gradient has been found in previous investigations of the study area including the February-April 1981 pre-discharge characterization (Weston and Gaston, 1982) and the 1978-1979 Texoma study (Hausknecht, 1980), indicating persistence of this gradient over at least the last four years.

As sediment samples are taken from each of the six replicate grab samples, an estimate can be made of the spatial variability or "patchiness" at each station. Two examples of this interreplicate variability

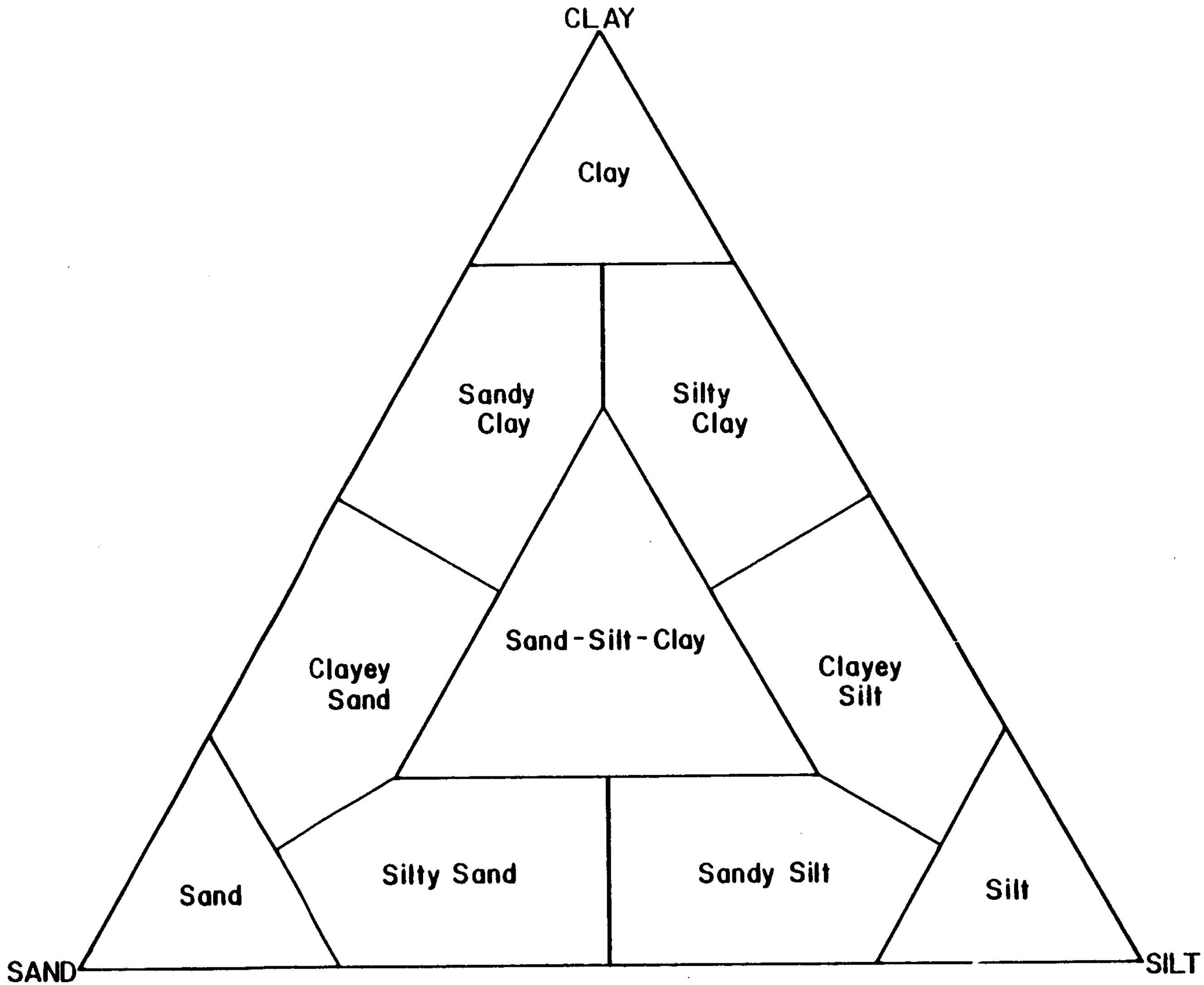


Figure 6-4. Ternary textural diagram (Shepard diagram) showing standard sediment classifications.

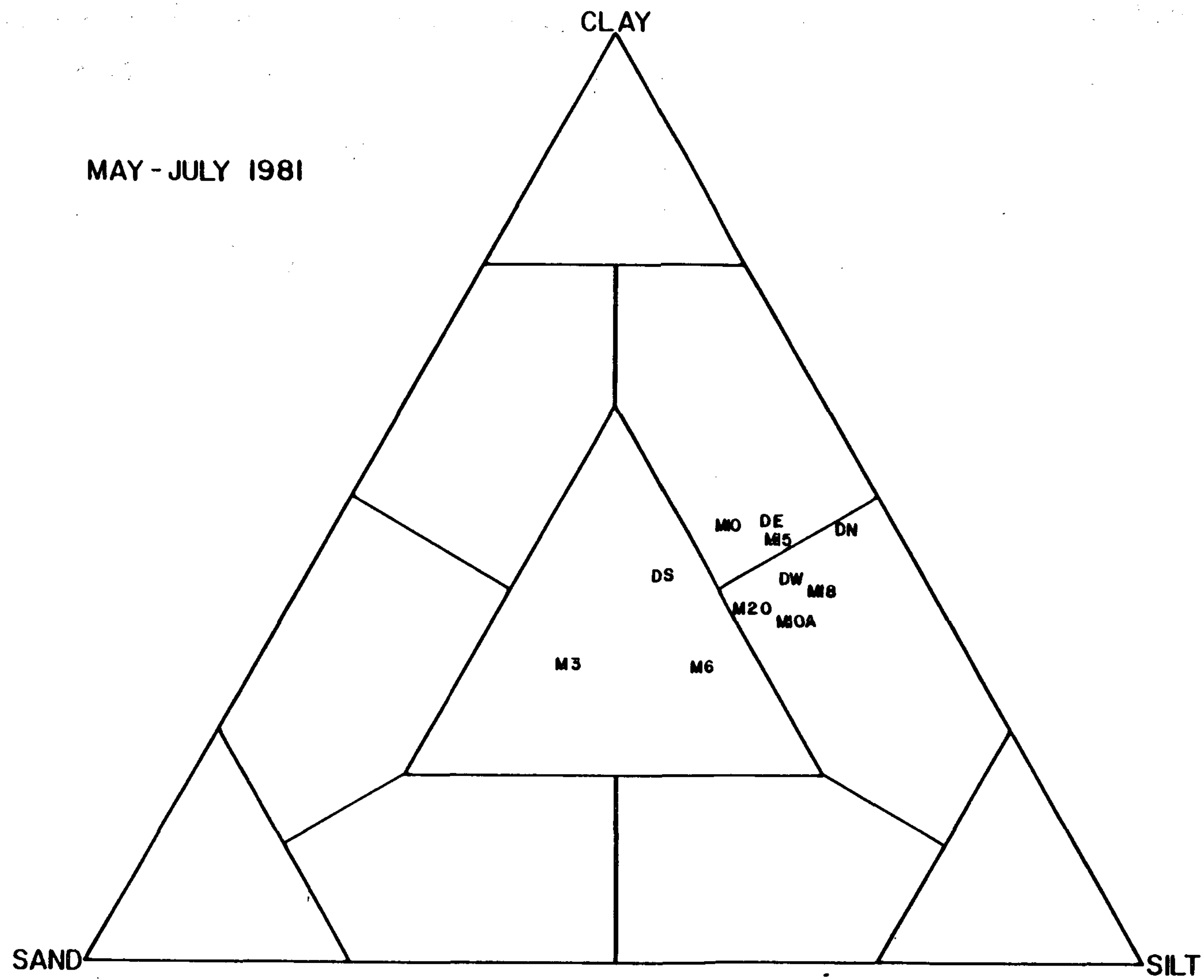


Figure 6-5. Ternary textural diagram of surficial sediments at the marine sampling stations, averaged over the three month period May - July 1981.

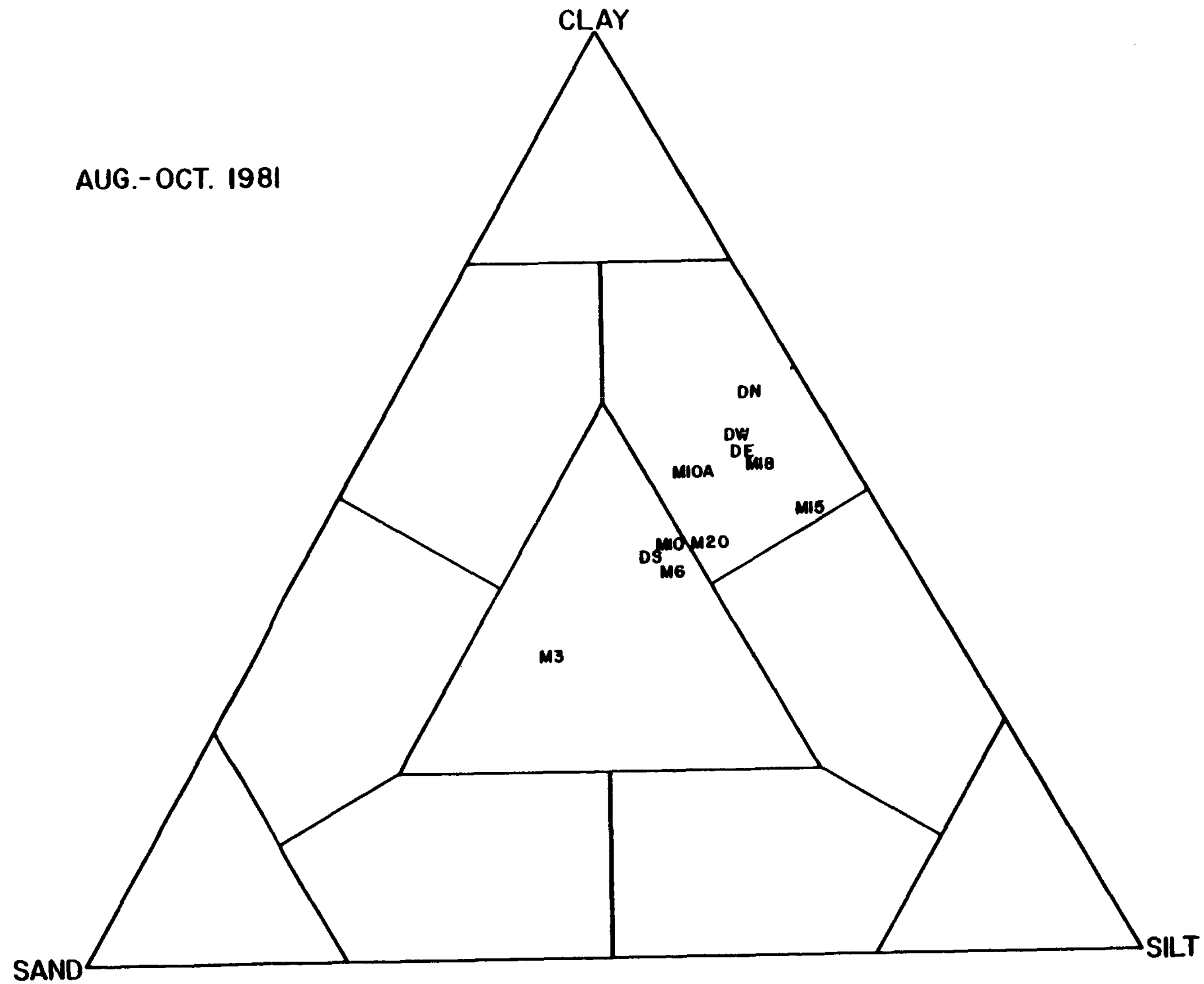


Figure 6-6. Ternary textural diagram of surficial sediments at the marine sampling stations, averaged over the three month period August - October 1981.

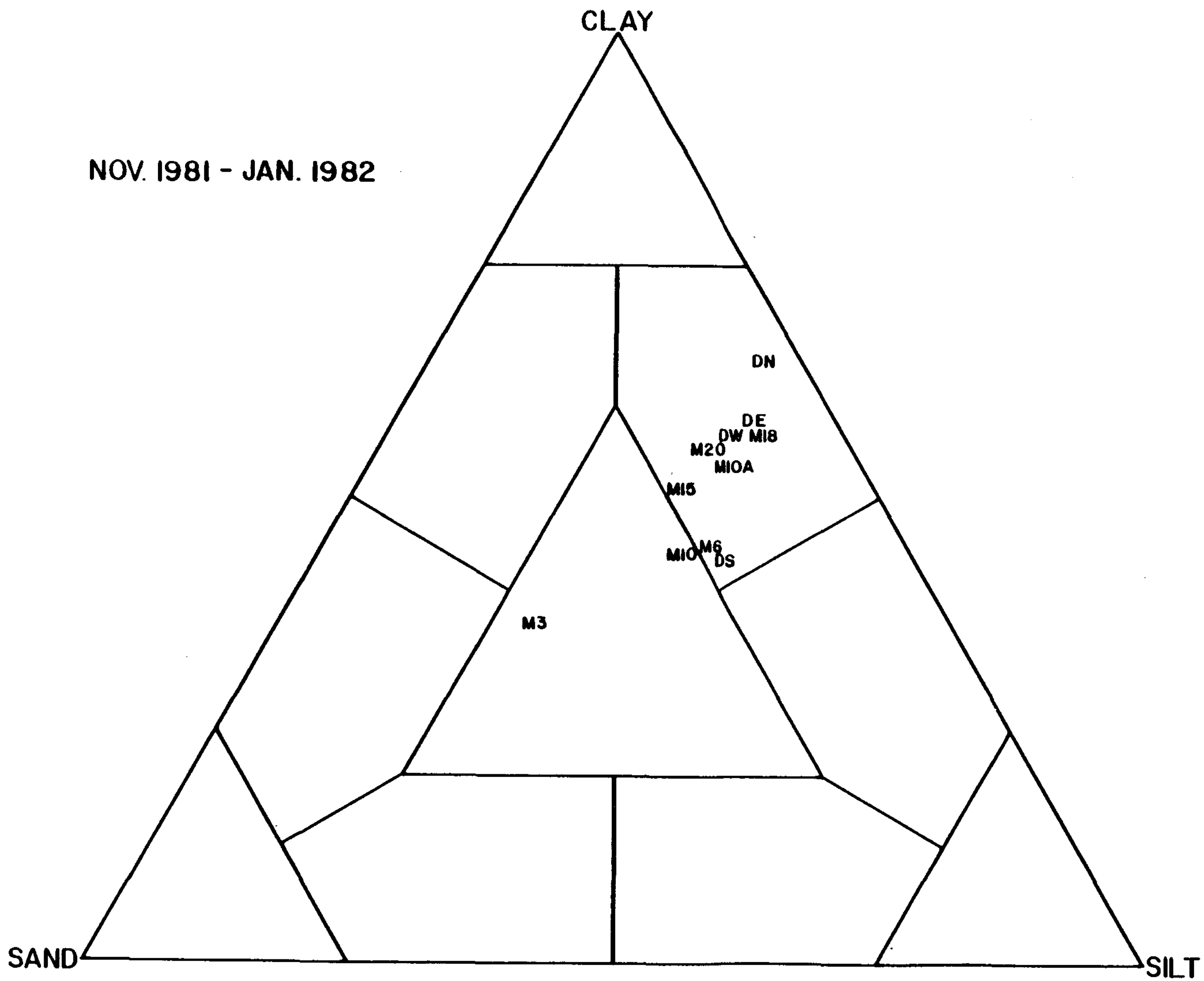


Figure 6-7. Ternary textural diagram of surficial sediments at the marine sampling stations, averaged over the three month period November 1981 - January 1982.

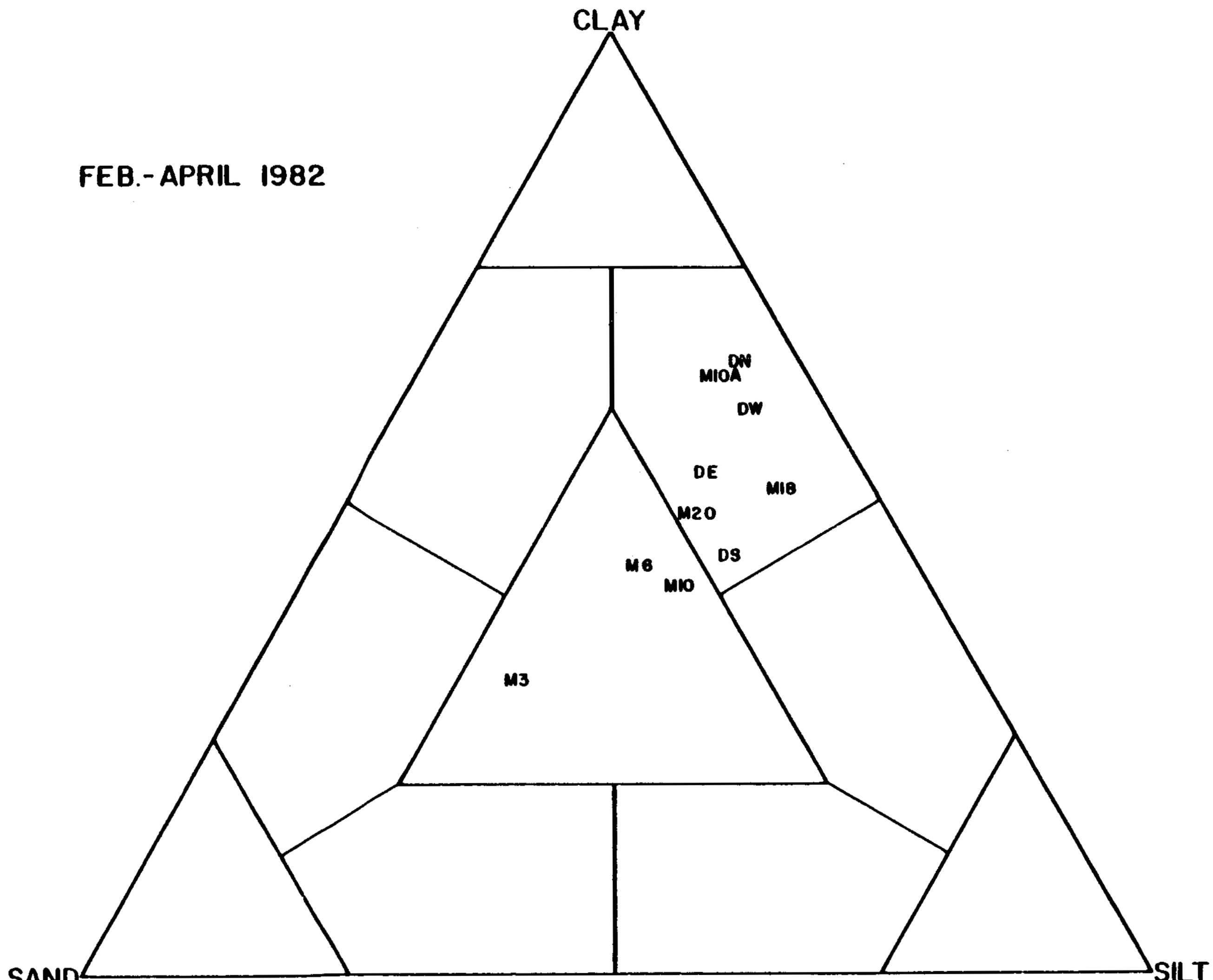


Figure 6-8. Ternary textural diagram of surficial sediments at the marine sampling stations, averaged over the three month period February - April 1982.

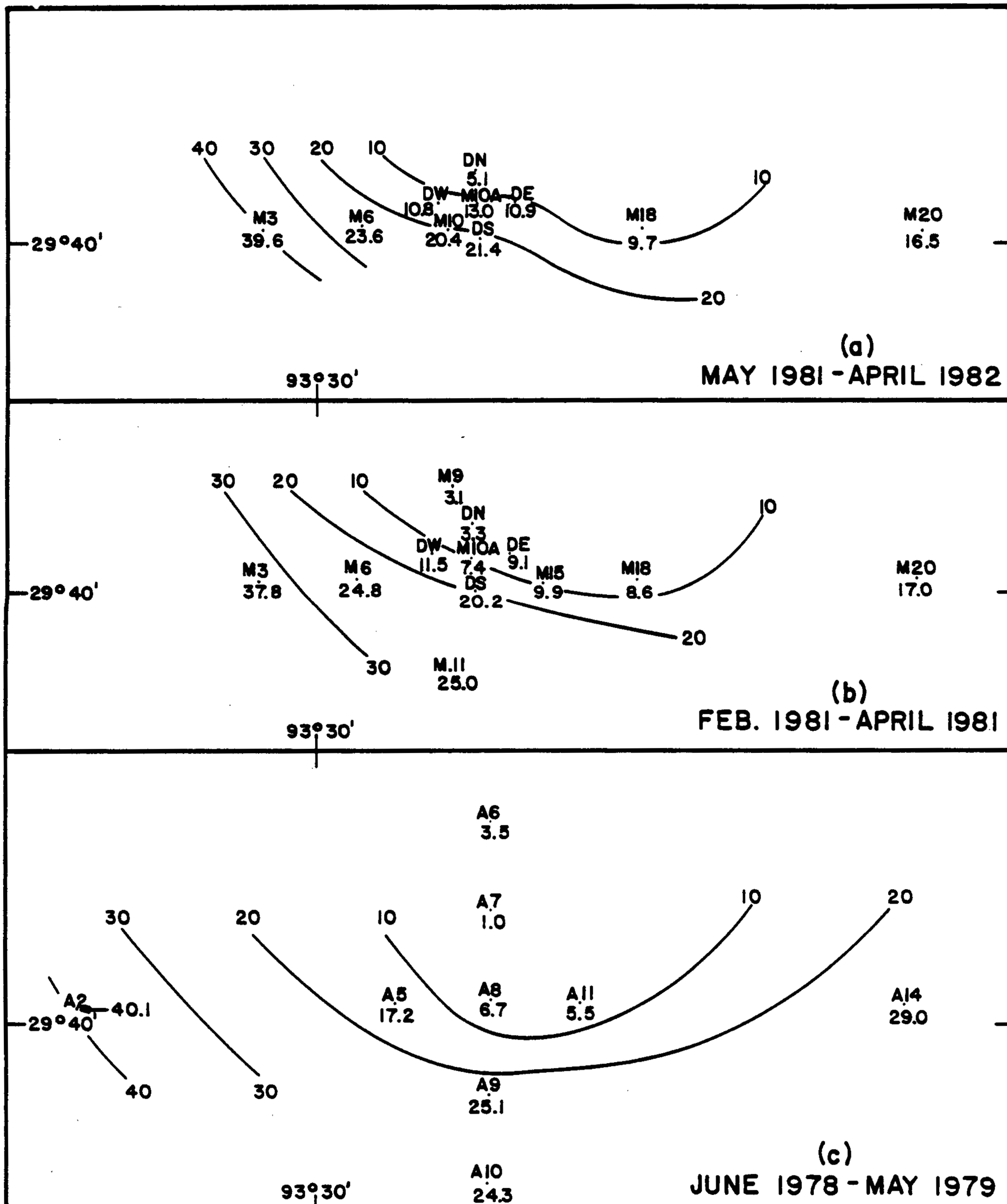


Figure 6-9. Percentage of sand in surficial sediments of the marine sampling stations as measured during three investigations. (a) present study-values are means taken over 12 sampling intervals; (b) pre-discharge study (after Weston and Gaston, 1982); (c) NOAA/NMFS Texoma investigations (after Hausknecht, 1980).

are illustrated in Figure 6-10 in which cumulative size-frequency curves are calculated for each of the six replicate grabs at two sites. Station M20 represents a "worst case" situation in which the curves are displaced along the abscissa with very little overlap among replicates. If only one grab sample is taken as representative, the median diameter could be calculated as ranging anywhere between 4.97 Ø (coarse silt) and 9.63 Ø (medium clay). At station M3 there is much less interreplicate variability, with a high degree of overlap among the replicates.

The fact that the degree of interreplicate variability at a given station is generally consistent month after month supports the contention that this variability is a true reflecton of habitat patchiness, rather than a result of analytical variability. Station M20 consistently has high interreplicate variability during each of the twelve sampling intervals, while the sediments at M3 consistently show a high degree of homogeneity among replicates. In Figure 6-11, all marine stations are ranked according to the degree of spatial variability at the site. The degree of spatial variability at a given station is calculated by determining the median grain size for each replicate during a given month and then averaging these values over the six replicates to obtain a mean median diameter and standard deviation of the median for that month. These standard deviations are then averaged over the 12 sampling intervals to obtain a mean standard

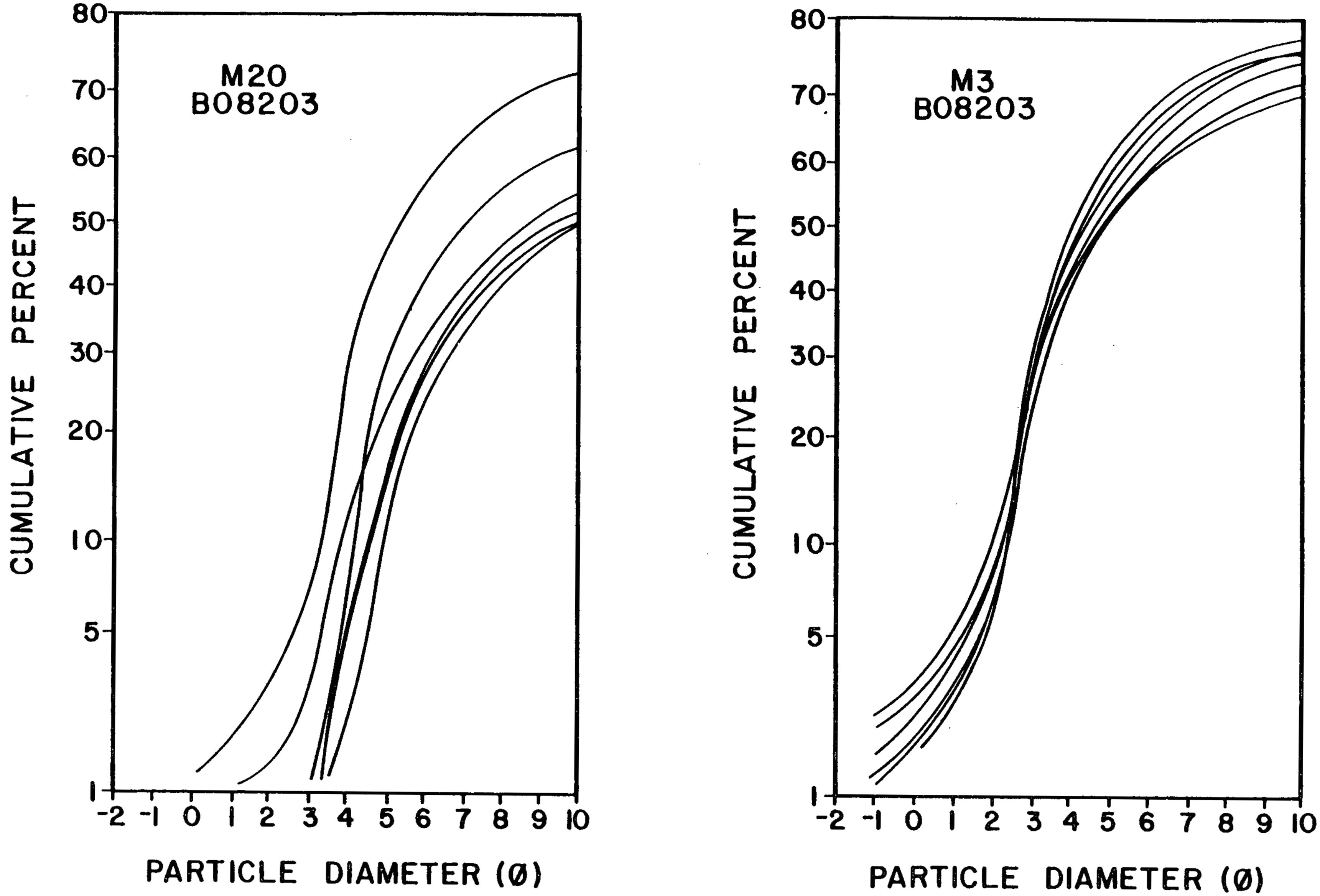


Figure 6-10. Interreplicate variability as shown by cumulative size-frequency curves for six replicate grab samples at stations M20 and M3 in March 1982.

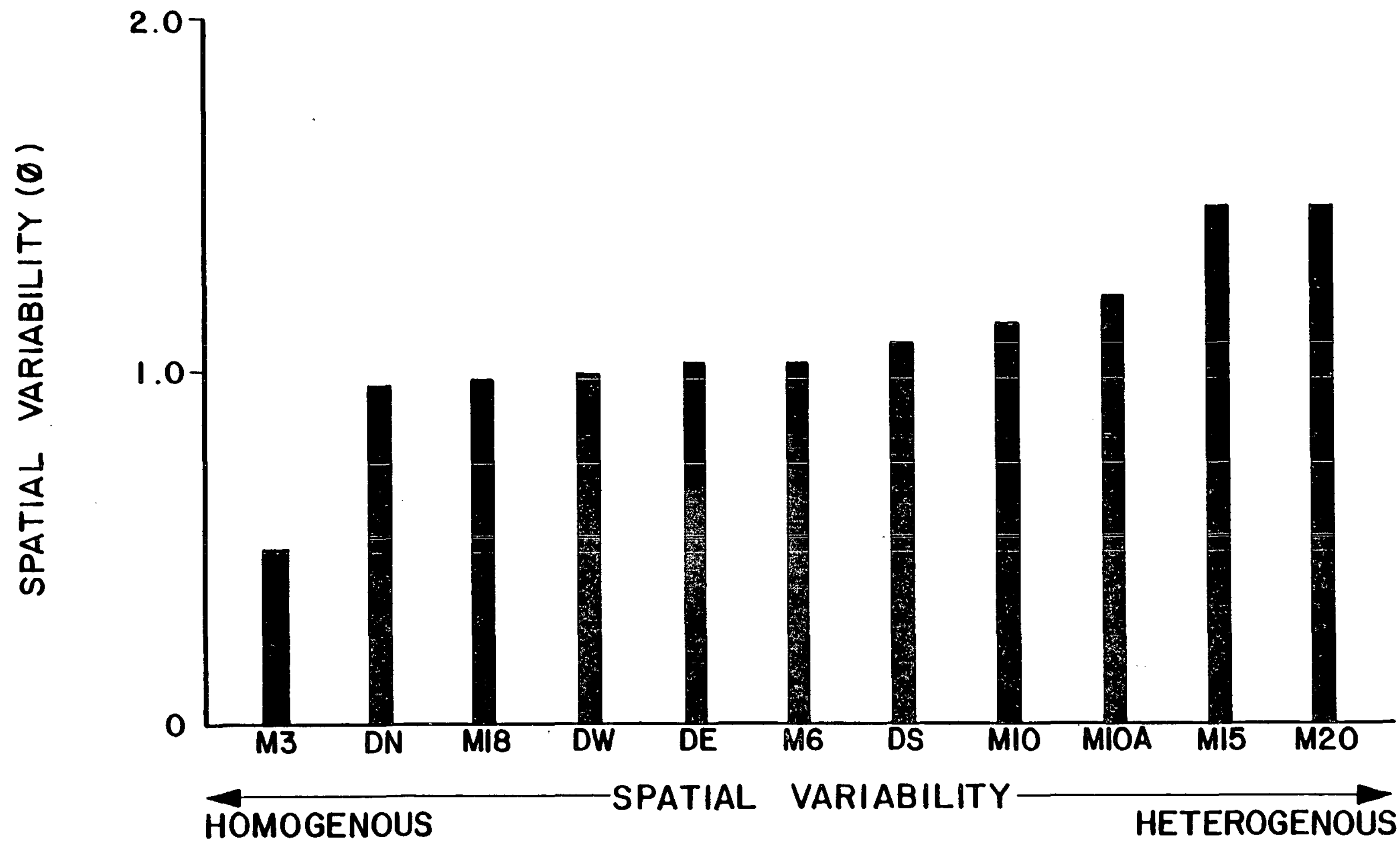


Figure 6-11. Marine sampling stations as ranked in order of spatial sediment variability among the six replicate samples taken during each sampling period.

deviation of the median diameter which is employed as an index of spatial variability.

Marine stations are also ranked in regards to temporal variation of sediment parameters among the twelve monthly sampling periods (Figure 6-12). This index is calculated as the standard deviation about the mean when the mean median diameters for each sampling period are averaged over the twelve sampling periods. Station M3, in addition to being the most spatially homogeneous, shows the least temporal variability. This is to be expected, since the median particle size at M3 is greater than any other station, it would be the least altered by any given current regime. Station M10A shows the greatest temporal variability, however this may be attributable to station relocation difficulties. This station is located within 100 meters of the diffuser trench. A strong gradient of sediment type may be expected in this area because of dredging operations, and slight differences in station location may result in significant differences in sediment characteristics. This variability, though clearly spatial in nature, would not be distinguishable from temporal changes by the study design.

The temporal fluctuations in median grain size are illustrated in Figures 6-13 and 6-14. At both stations, M18 and DW, an increase in median particle diameter (decreased Ø) is evident in the summer of 1981. By September, median particle diameter decreases to approximately 9 Ø at both stations and remained at about this level through April, 1982. Analysis of temporal changes at all offshore

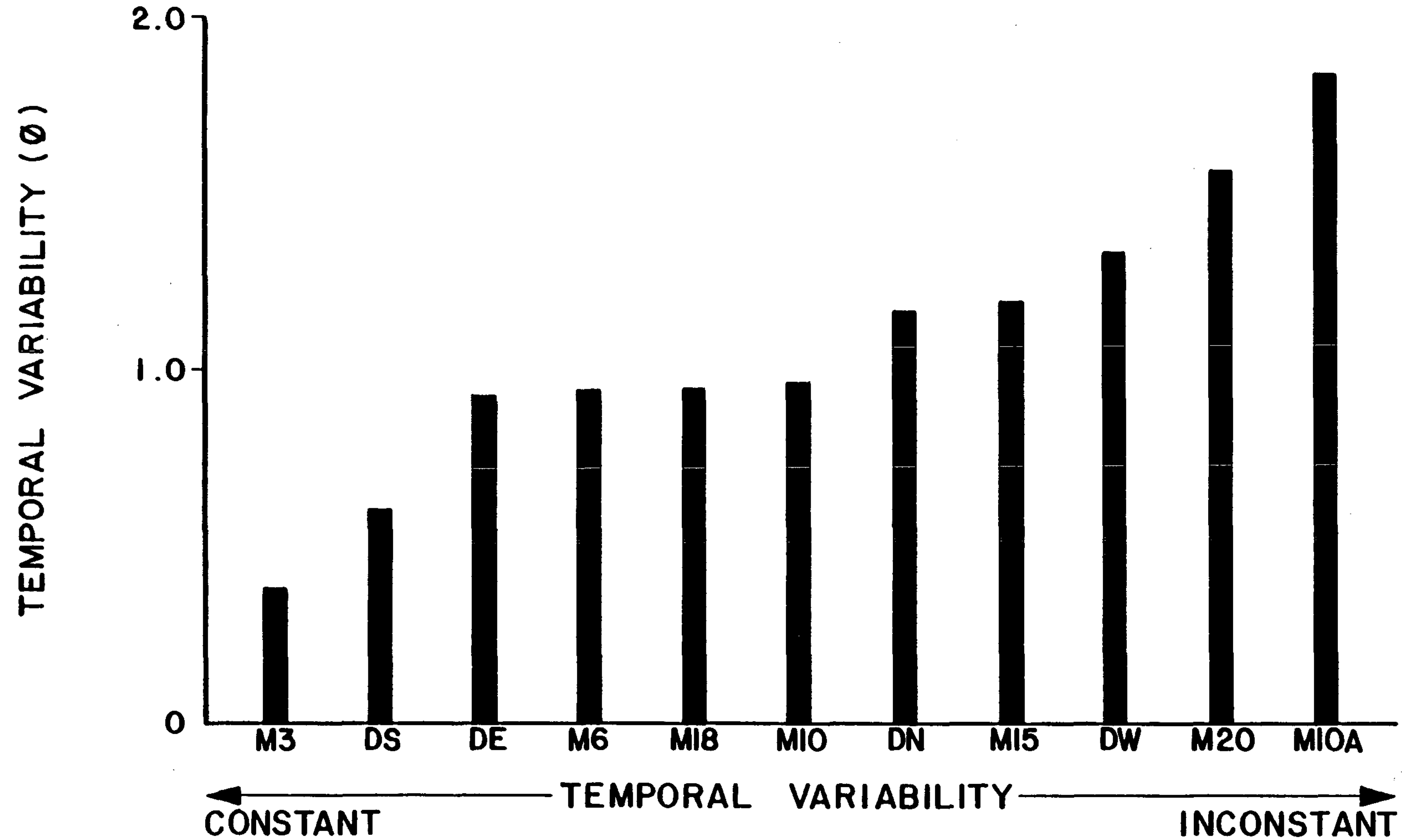


Figure 6-12. Marine sampling stations as ranked in order of temporal sediment variability over the twelve sampling periods at each station.

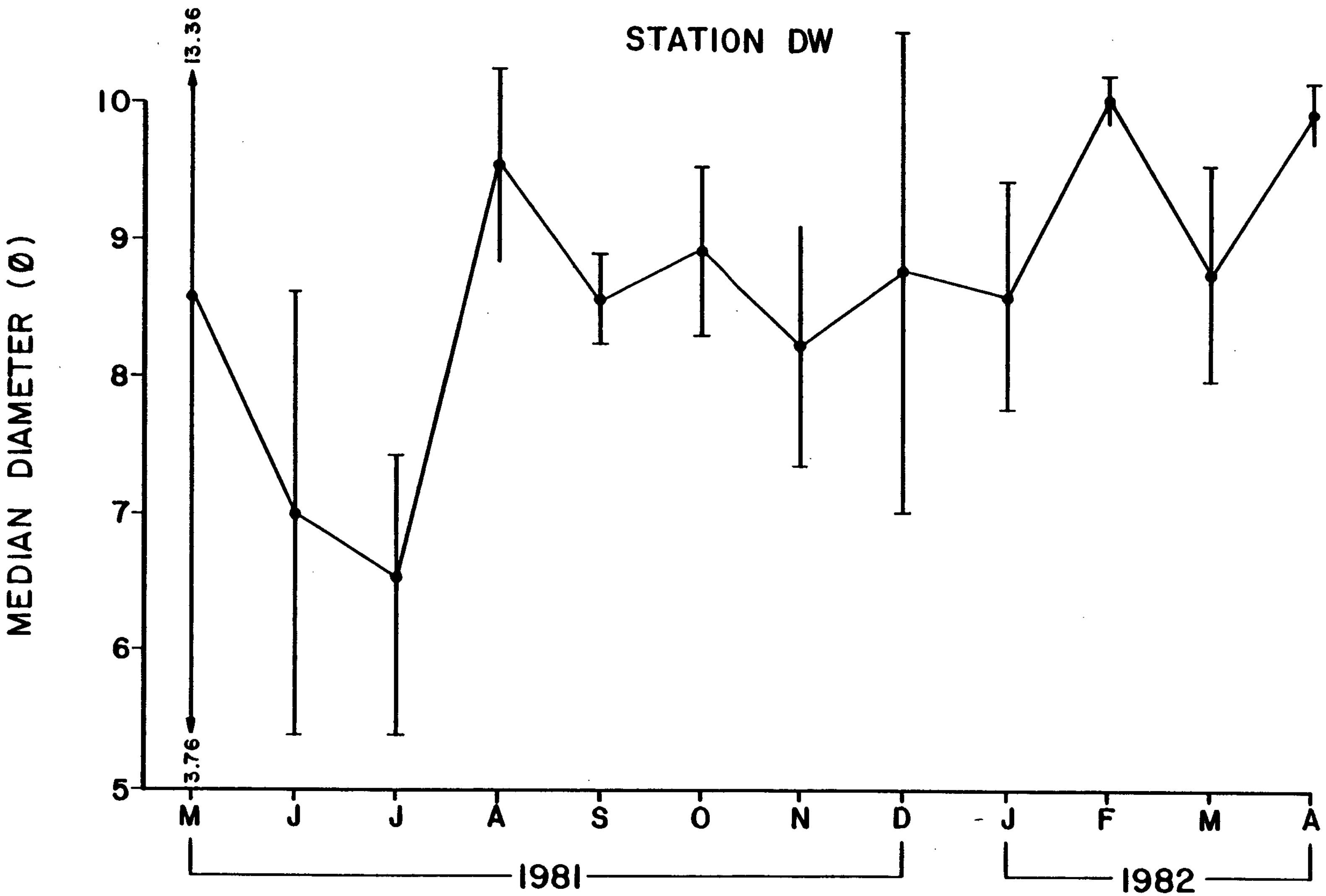


Figure 6-13. Temporal variation of median particle size during the twelve month post-discharge investigation at station DW. Error bars represent standard deviation around the mean for the six replicate samples.

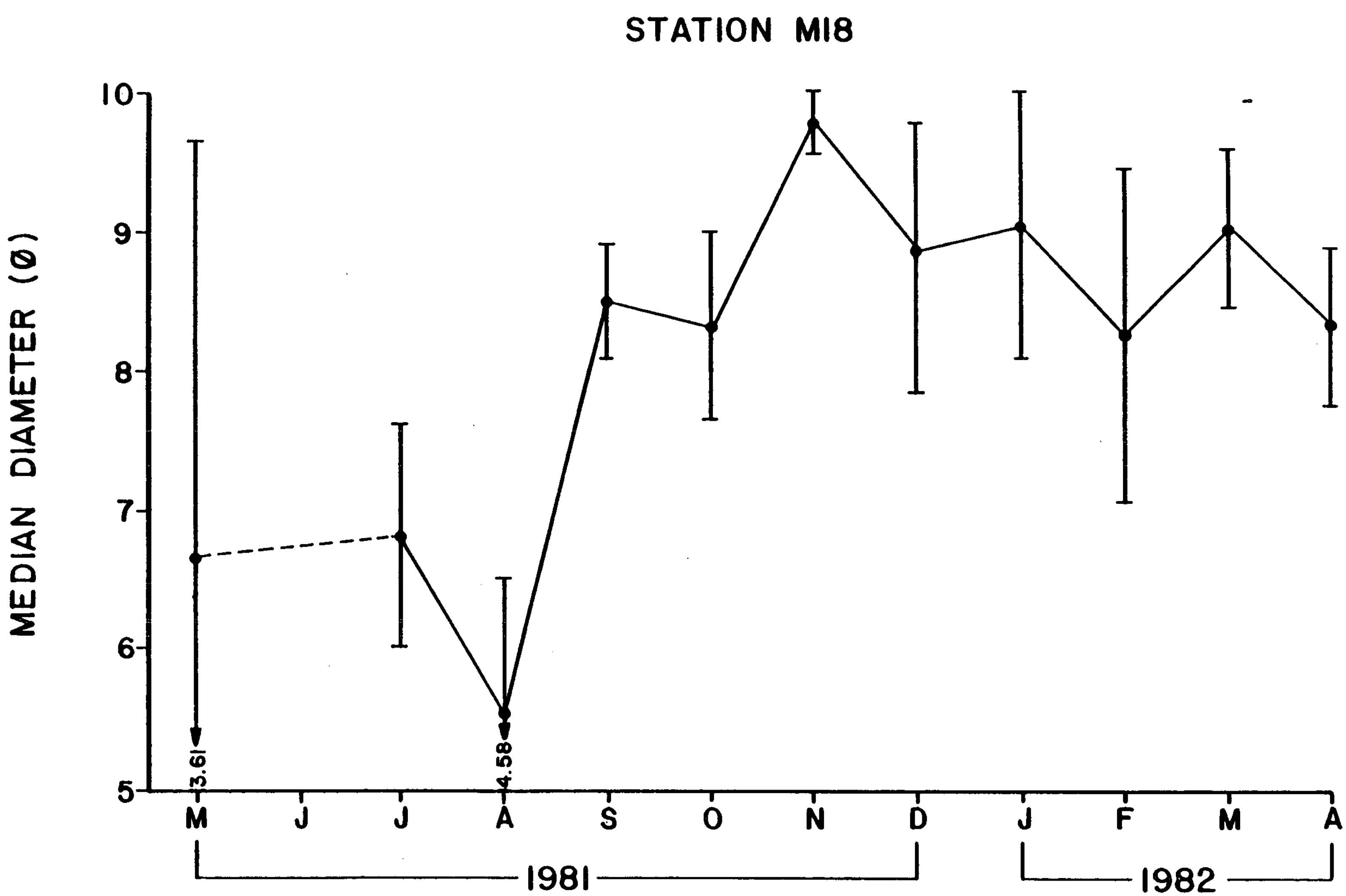


Figure 6-14. Temporal variation of median particle size during the twelve month post-discharge investigation at station M18. Error bars represent standard deviation around the mean for the six replicate samples.

stations illustrates the same basic trends (Kendall's coefficient of concordance, $\alpha < .01$) indicating that a broad-scale phenomenon rather than local conditions is responsible for the observed changes. Bottom current velocity is the phenomenon most likely responsible and some correlation of current velocity and median grain size is evident (Figure 6-15). Though the correlation is certainly imperfect, the increase in median grain size during the summer of 1981 does correspond to a period of unusually high current velocity during June.

6.3.1.2 Estuarine

Surficial sediments of the estuarine stations are predominantly sandy muds, though they show extreme variability among stations and over time (Figures 6-16 - 6-19). Estuarine stations generally have a higher percentage of sand than most marine stations, with this quantity being greatest at station E5 ($\overline{x}$ = 45.5% sand) and decreasing in the sequence E5 > E2 > E1 > E4 > E3. Interreplicate variability is generally lower at estuarine stations than marine stations, though at the estuarine sites this variability may periodically be significant (Figure 6-20). The relatively low variability among replicates can probably be accounted for by the fact that the water depth at the estuarine sites is commonly only about 1 meter, and anchoring, therefore, allows grab samples to be taken very close to one another.

Temporally, the estuarine stations show a high degree of change, with E2 being the most variable in this regard. Stations E3 and E4 are

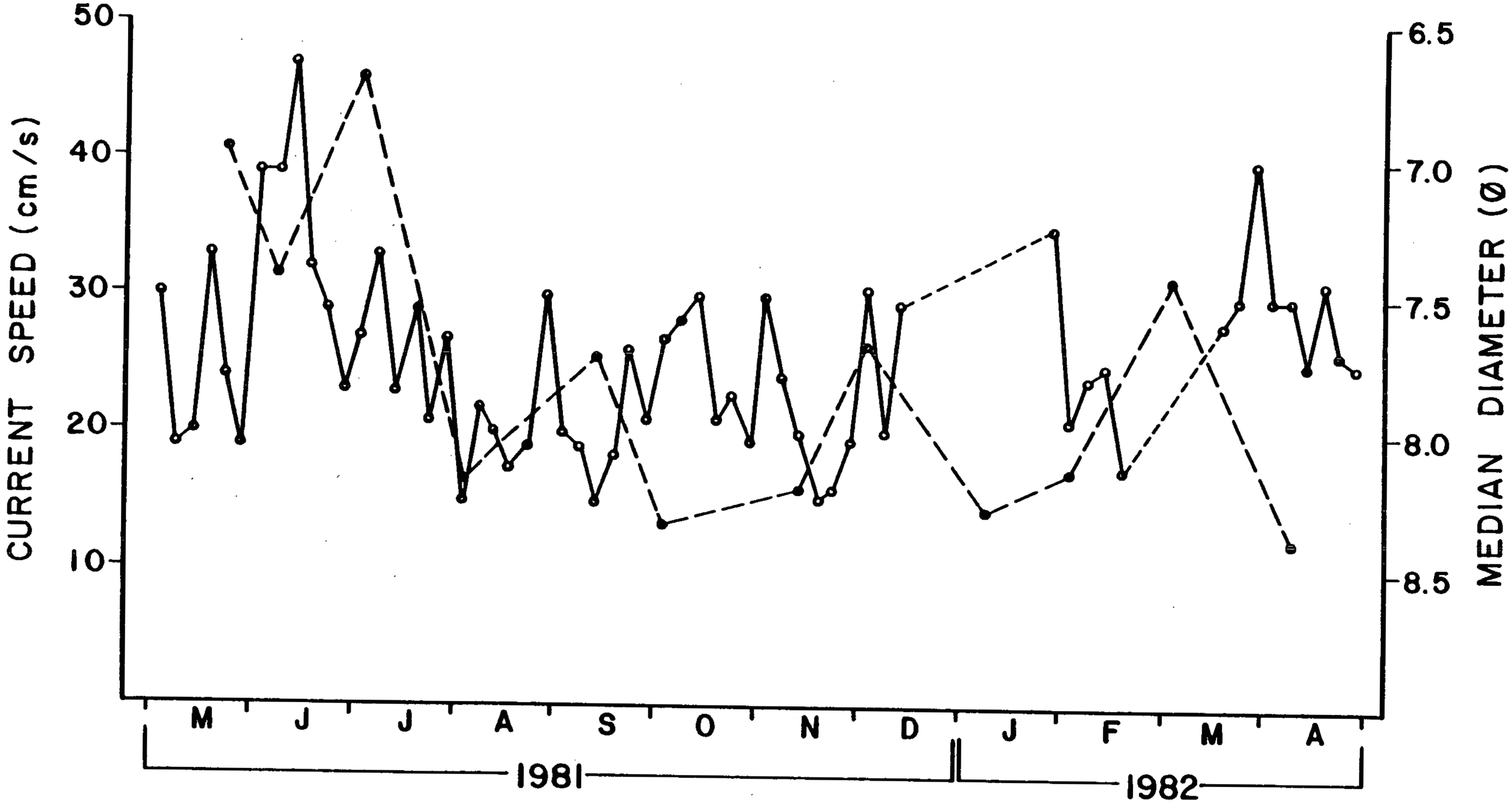


Figure 6-15. Average median grain size of the marine stations (dashed line) as compared against bottom current speed (solid line). Current speed is presented as the highest value recorded on the bottom current meter at the diffuser during each five day interval.

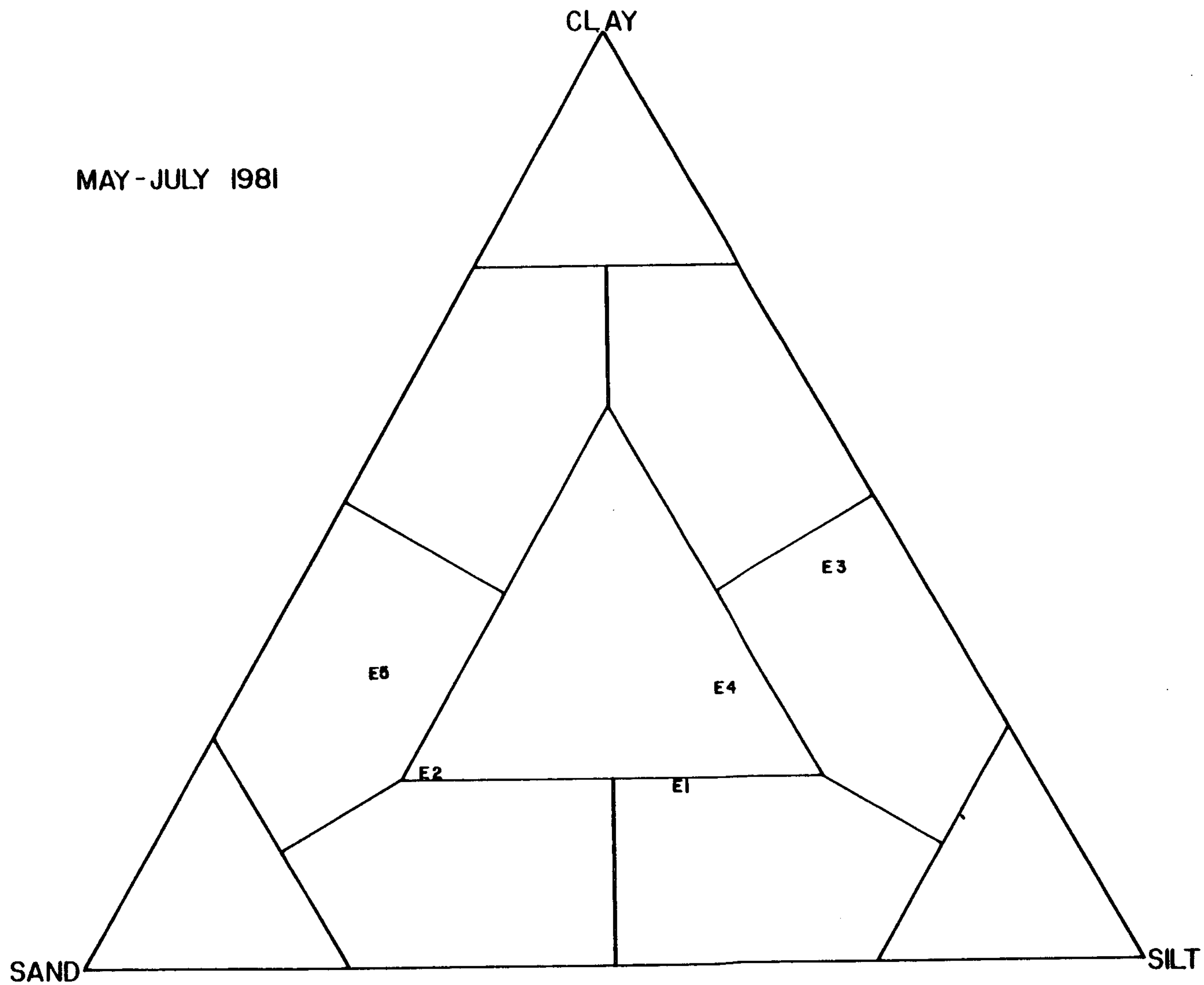


Figure 6-16. Ternary textural diagram of surficial sediments at the estuarine sampling stations, averaged over the three month period May - July 1981.

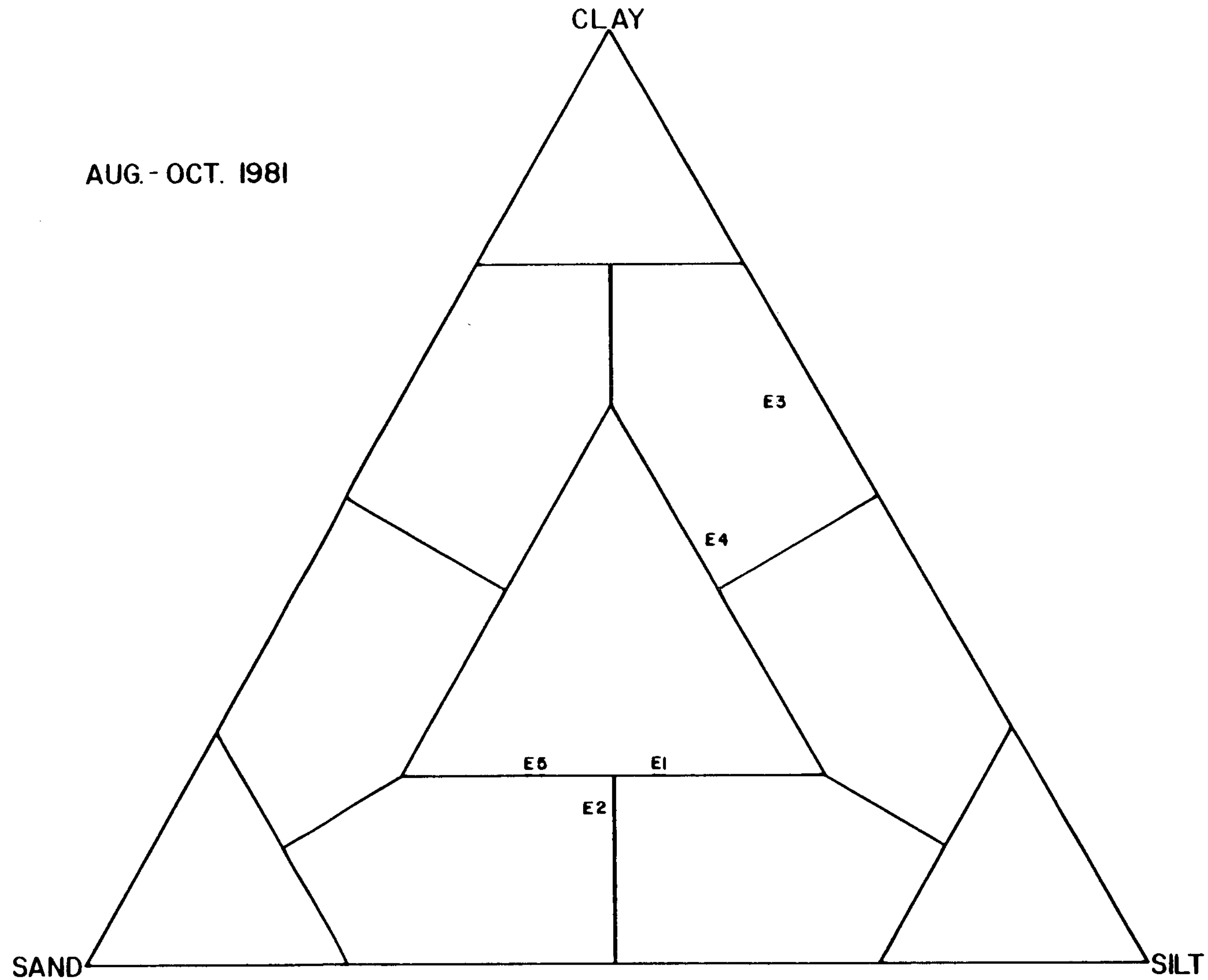


Figure 6-17. Ternary textural diagram of surficial sediments at the estuarine sampling stations, averaged over the three month period August - October 1981.

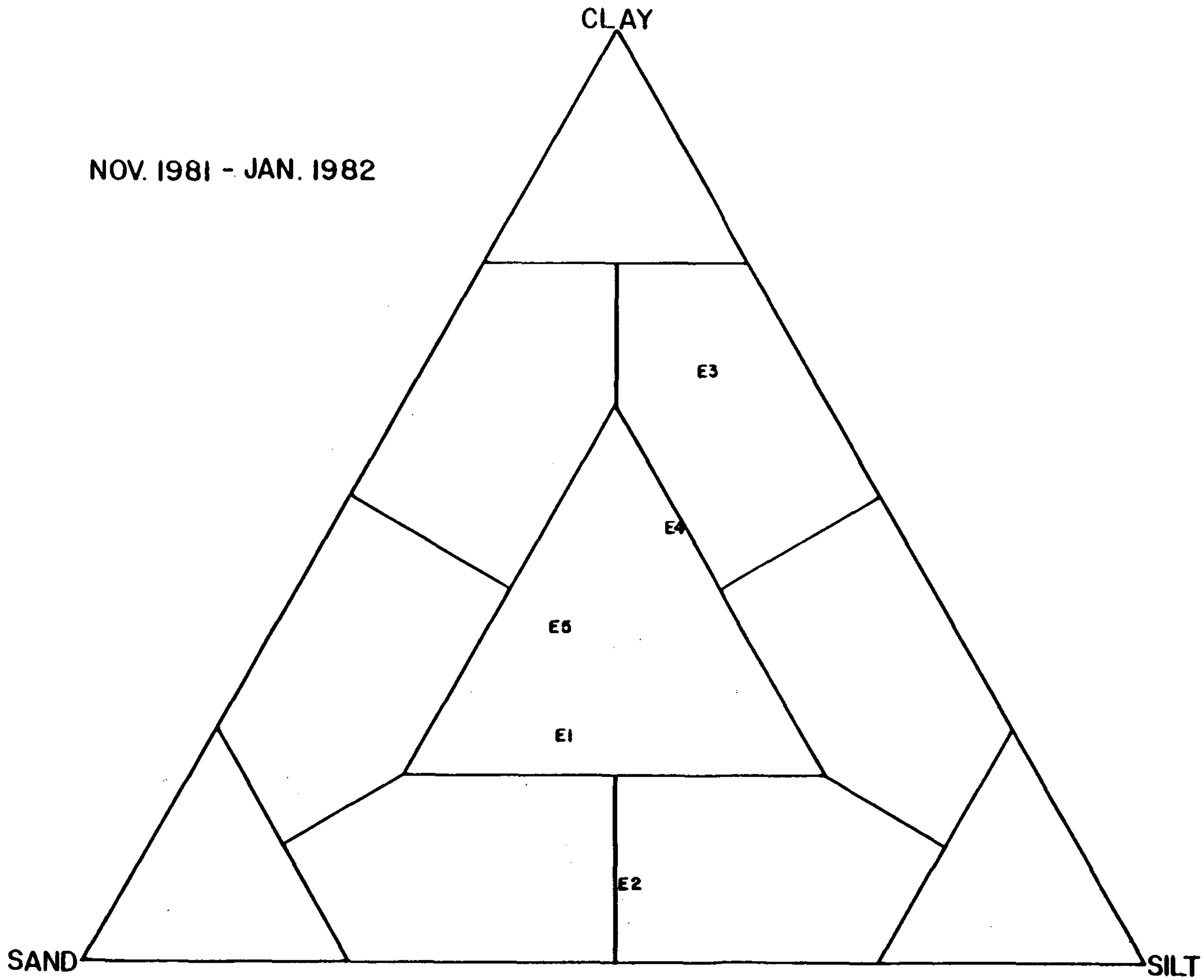


Figure 6-18. Ternary textural diagram of surficial sediments at the estuarine sampling stations, averaged over the three month period November - January 1982.

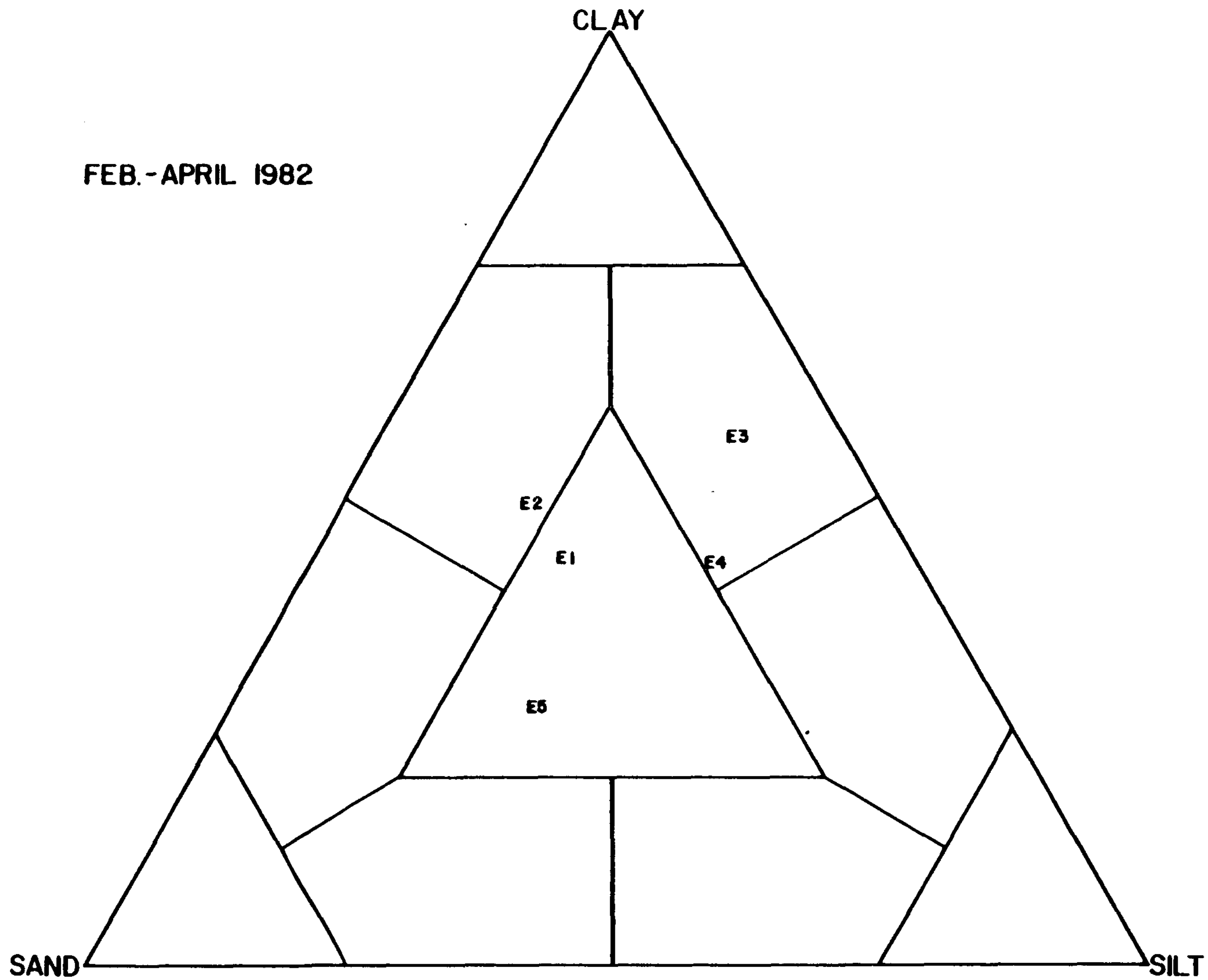


Figure 6-19. Ternary textural diagram of surficial sediments at the estuarine sampling stations, averaged over the three month period February - April 1982.

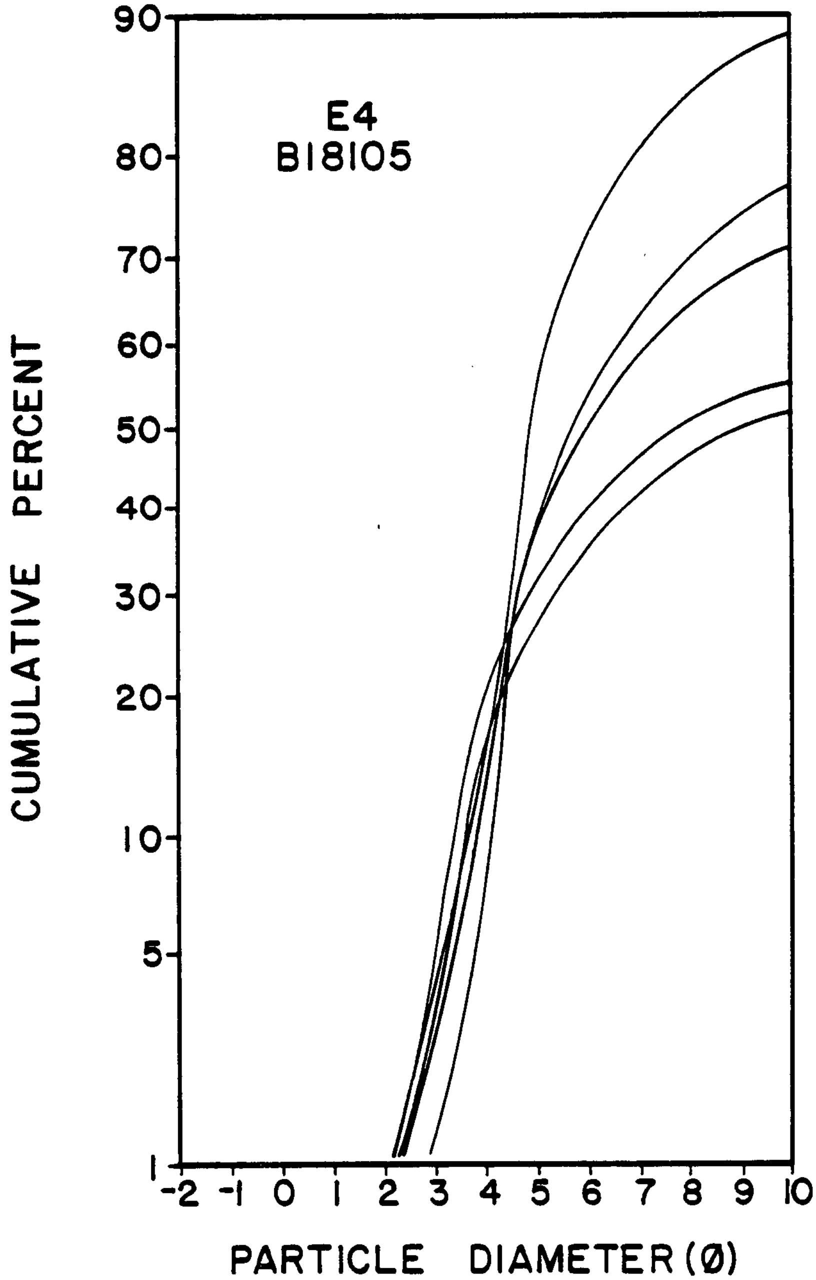


Figure 6-20. Interreplicate variability as shown by cumulative size-frequency curves for five replicate samples at station E4 in May 1981.

the only sites which show concordant changes throughout the 12 month period. Both of these stations show an increase in the percentage of clay in the summer of 1981 with a concomittant decrease in the percentage of silt, and relatively constant proportions of the sand, silt and clay fractions thereafter.

6.3.2 Hydrology

The hydrology of the marine and estuarine study areas is discussed at length in Chapters 2 and 3. The brief discussion below is intended to provide a general characterization of the study area. Only parameters which are pertinent to later discussions of benthic organisms have been included. Data presented are from CTD/DO measurements made during biological sampling cruises.

6.3.2.1 Marine

Variations in bottom water physical parameters between collection sites (spatial variation) and between cruises (temporal variation) are presented. Discussion of spatial variation concerns conditions in the study area during benthic cruises only. Data collected by all disciplines are presented in discussion of temporal variation. For brevity, only the temporal data of matched sites M18 and M10A are presented in this chapter. More complete data on changes in salinity are available in Chapter 2.

Considerable differences in bottom salinity occur between stations during most months (Figures 6-21 - 6-23). The most persistent trend observed is the increase in salinity around the diffuser due to

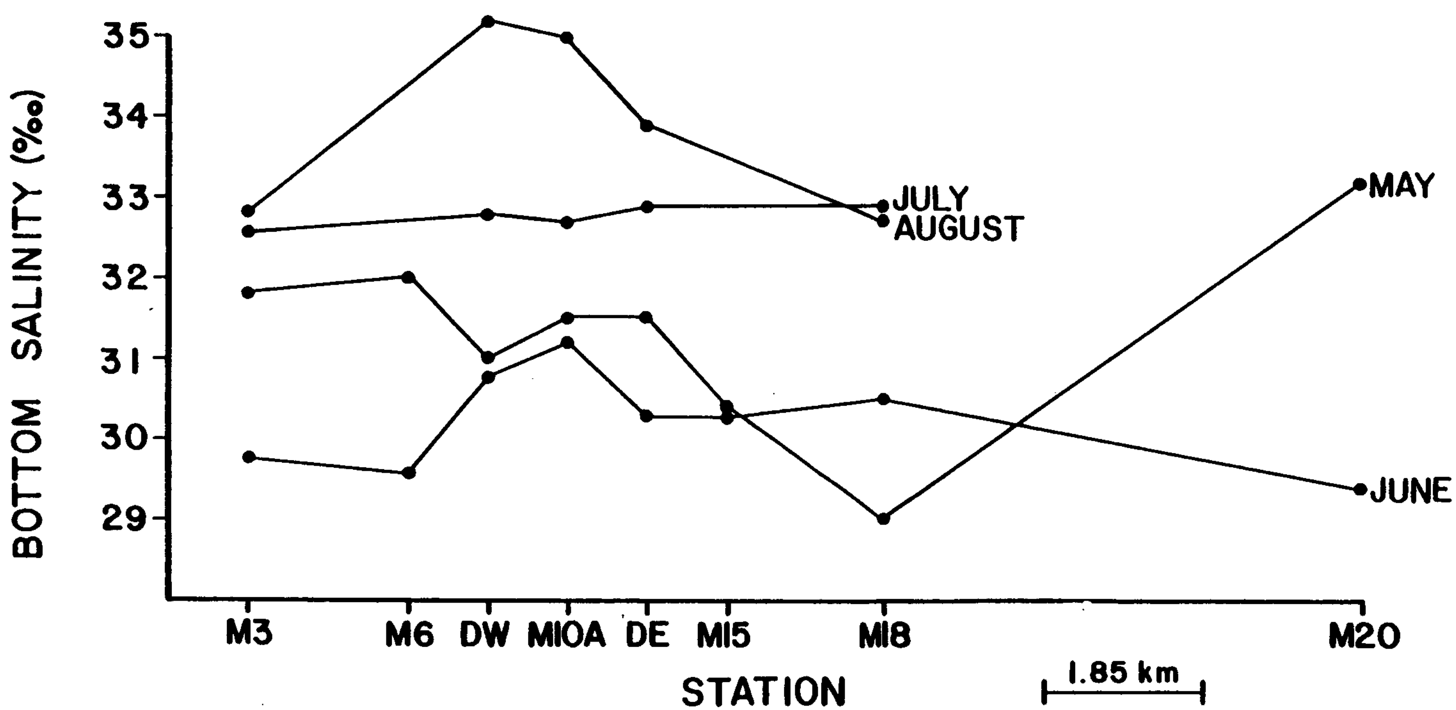


Figure 6-21. Bottom salinity at marine stations along the 10 m isobath May - August 1981.

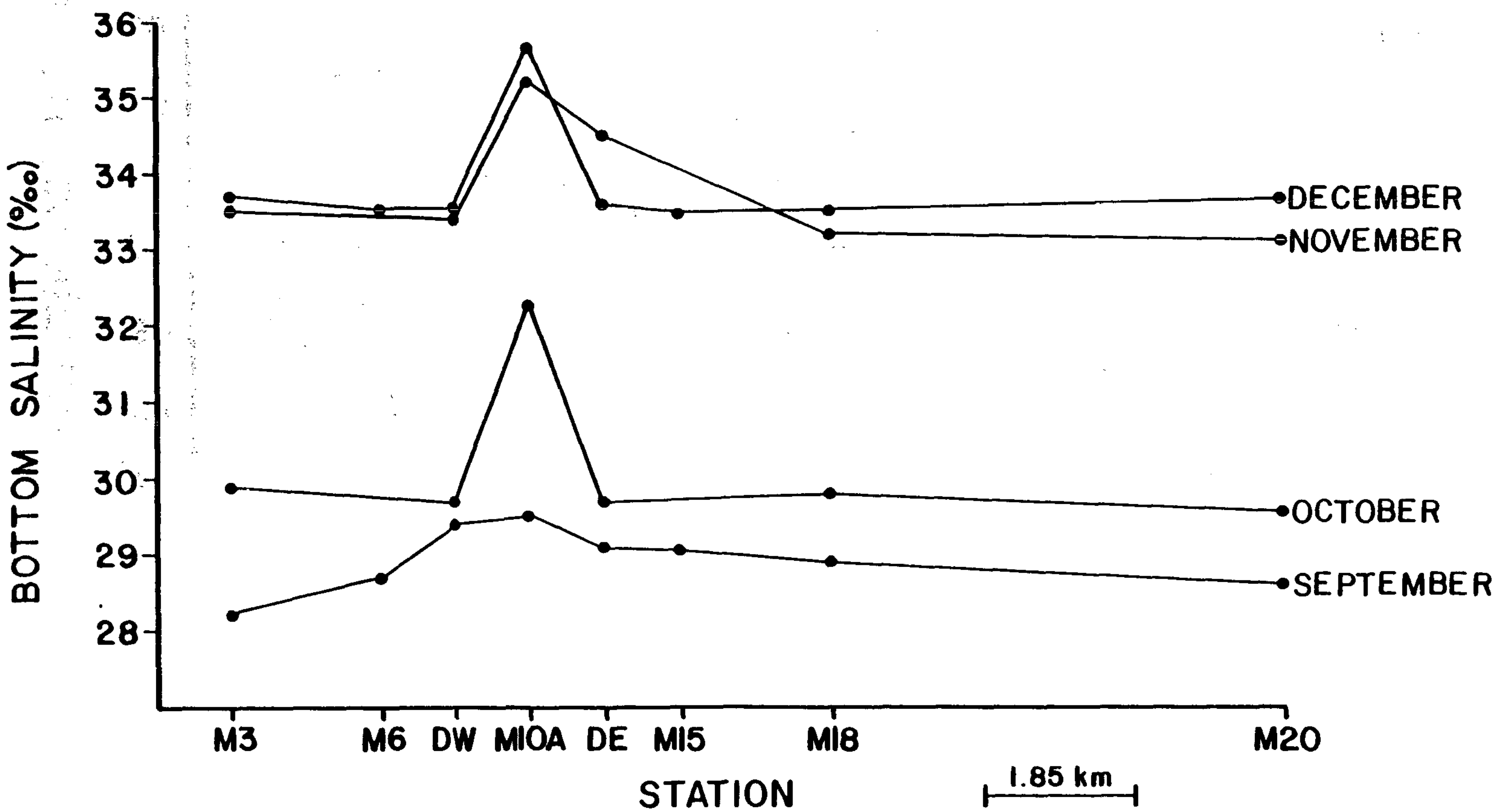


Figure 6-22. Bottom salinity at marine stations along the 10 m isobath September - December 1981.

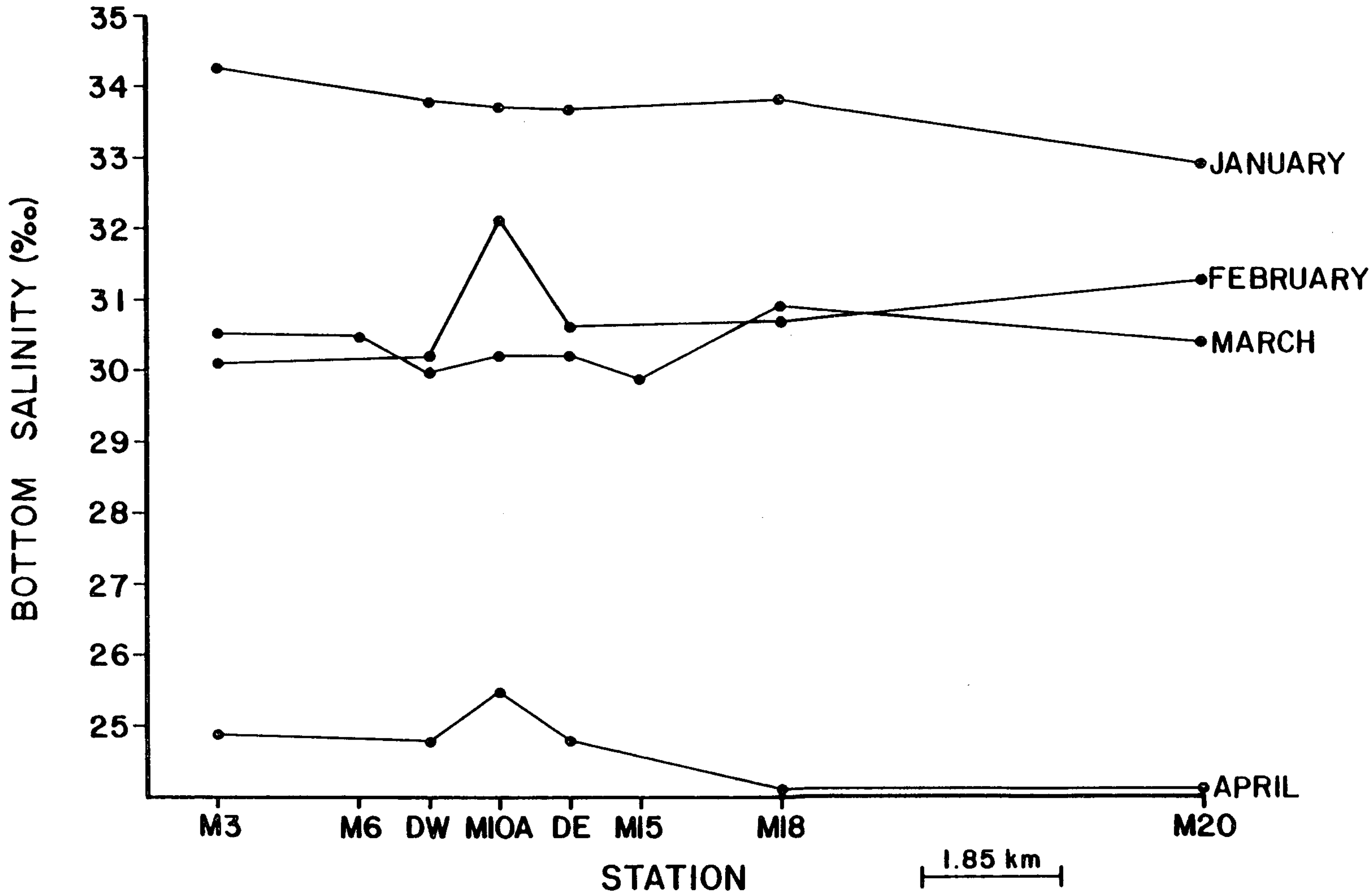


Figure 6-23. Bottom salinity at marine stations along the 10 m isobath January - April 1982.

discharge of brine. It should be noted that brine discharge was minimal when some of these data (e.g. September, January) were collected.

Temporal salinity variations in the study area are presented for station M18 (Figure 6-24) and M10A (Figure 6-25). Bottom salinity varies from 25-35^{o}/oo over the 15-month period. Such wide fluctuations in salinity are typical of inner shelf habitats in Louisiana due to the freshwater discharge of the Mississippi and Atchafalaya Rivers.

Spatial and temporal variations in interstitial (i.e. pore water) salinity, taken from Chapter 5, are presented in Figure 6-26. Though considerable temporal variation is evident, there is remarkable consistency within control and within potential impact sites during any given month, especially over the last nine months. Since August 1981, the interstitial salinity of sediments around the diffuser (sites M10A, M10, DW) has been consistently 1-3^{o}/oo higher than that of the control sites. Station DE is more similar to control sites than diffuser sites, though it is only 1 km east of the diffuser. This is consistent with results of plume tracking (Chapter 4), in which the highest salinity of the brine plume seldom included station DE.

The variations in temperature in the study area are shown for stations M18 and M10A (Figures 6-27 and 6-28). The annual bottom temperatures vary seasonally over 21°C, but vary little (usually less than 0.3°C) between stations during any sampling period.

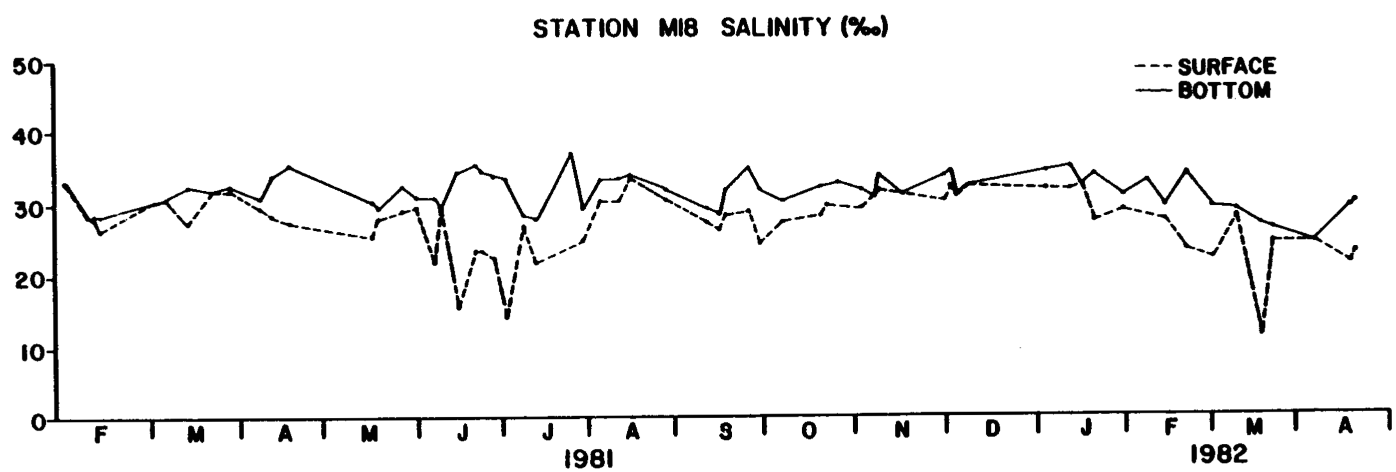


Figure 6-24. Surface and bottom salinities at station M18 during the pre-discharge study (February - April 1981) and present study (May 1981 - April 1982).

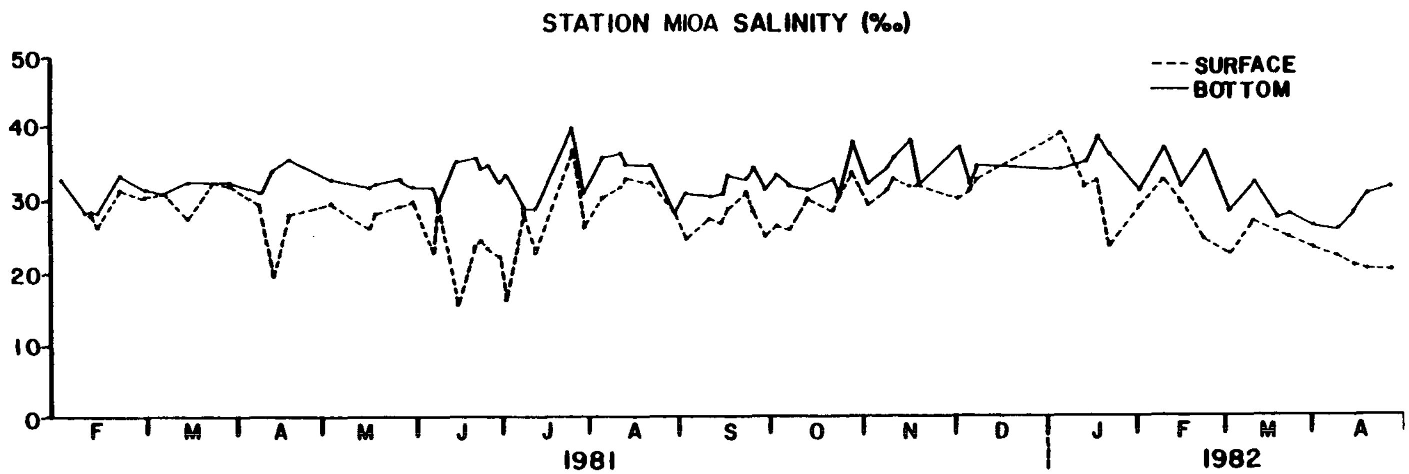


Figure 6-25. Surface and bottom salinities at station M10A during the pre-discharge study (February - April 1981) and present study (May 1981 - April 1982).

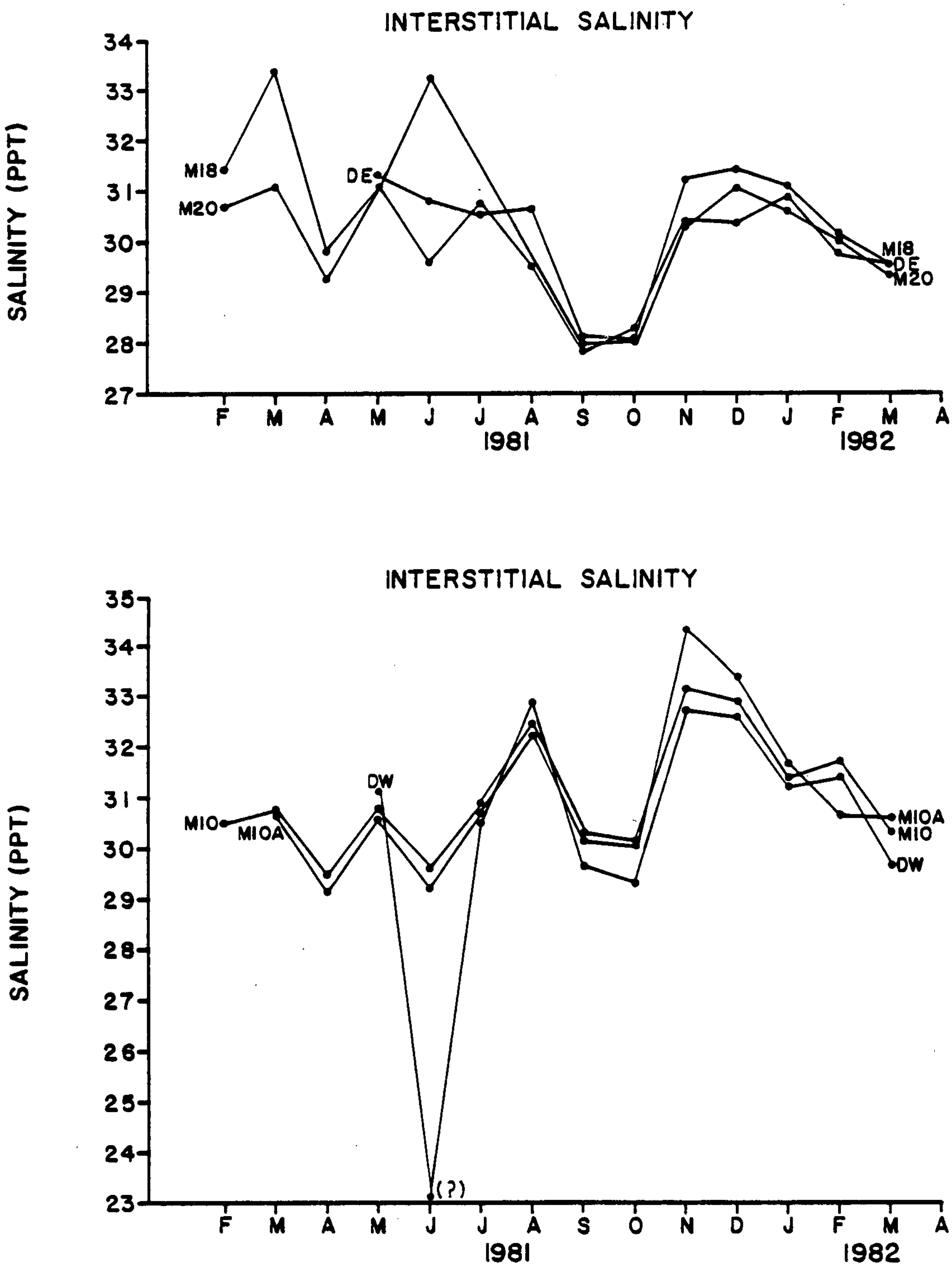


Figure 6-26. Interstitial salinity at control sites (stations M18, M20, DE) and potential impact sites (stations M10, M10A, DW) during the pre-discharge study (February - April 1981) and present study (May 1981 - April 1982).

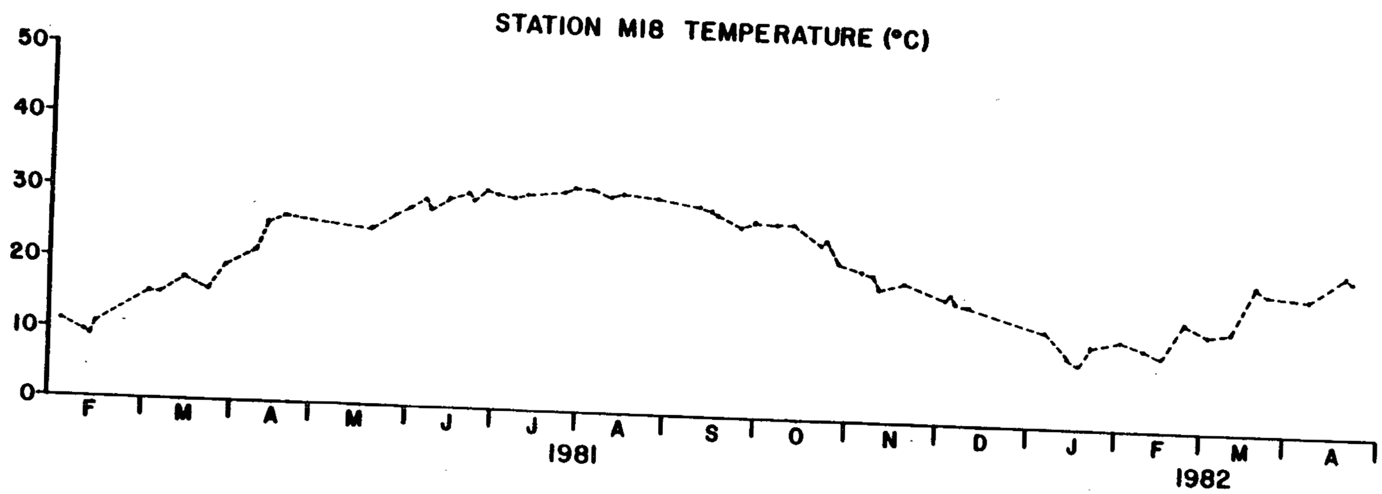


Figure 6-27. Bottom temperatures at station M18 during the pre-discharge study (February - April 1981) and present study (May 1981 - April 1982).

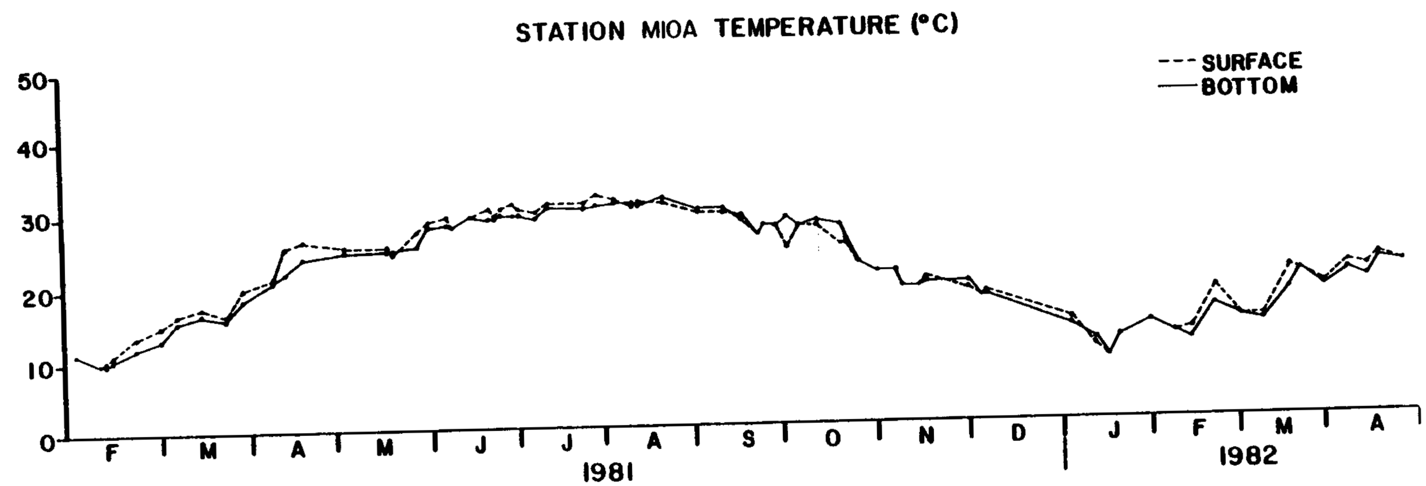


Figure 6-28. Bottom temperatures at station M10A during the pre-discharge study (February - April 1981) and present study (May 1981 - April 1982).

The dissolved oxygen concentration of bottom waters exhibits wide variation both spatially and temporally. The most notable temporal changes are the periods of low dissolved oxygen during the summer of 1981, during which bottom dissolved oxygen concentrations often dropped below 1 ml l^{-1} (Figures 6-29 and 6-30). These periods of hypoxia were noted intermittently from mid-June through mid-September and correspond to a period of pronounced salinity stratification. During the later half of July and early August bottom dissolved oxygen concentrations at the diffuser (2.5 - 3.5 ml l^{-1}) exceeds that of station M18 (0.5 - 2.0 ml l^{-1}). This elevation of dissolved oxygen in the vicinity of the diffuser results from either aeration of bottom water by mixing with the oxygenated brine effluent or, more probably, from turbulent mixing of the water column during brine discharge and the consequent breakdown of stratification. During late August and September, oxygen levels at the diffuser site dropped below those of control sites. This corresponds to periods during which brine discharge was suspended (August 24-31; September 3-14).

6.3.2.2 Estuarine

Physical measurements made at the estuarine stations confirm the obvious: there is considerable spatial and temporal variation in hydrology of the Calcasieu Lake estuary. The data presented herein are collected on board monthly benthic cruises. Because of the high variation in physical parameters depending on tidal and weather conditions, these data can only be considered approximations and not

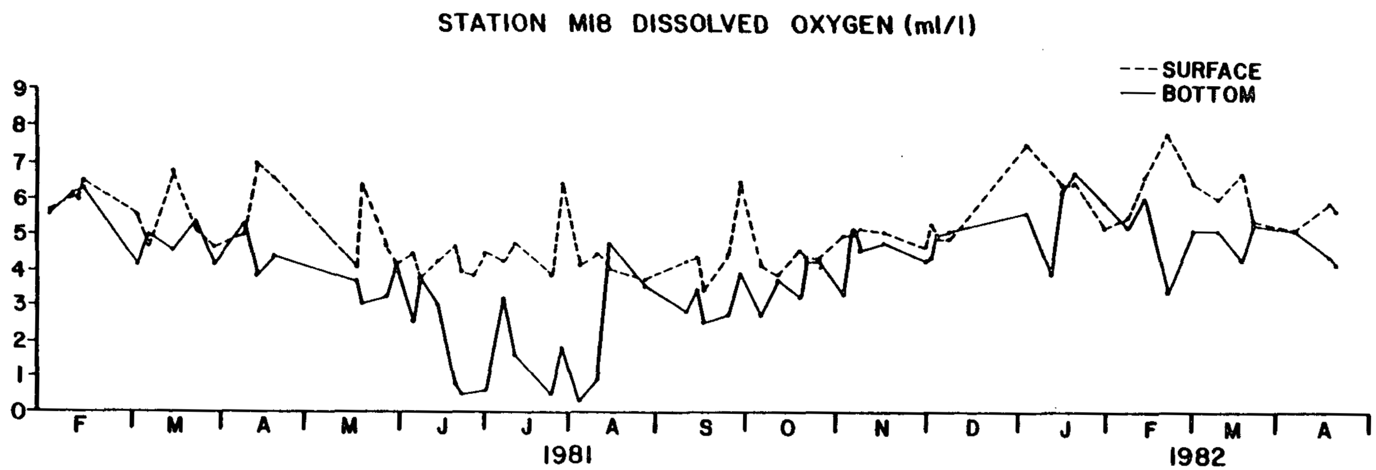


Figure 6-29. Surface and bottom dissolved oxygen values at station M18 during the pre-discharge study (February - April 1981) and present study (May 1981 - April 1982).

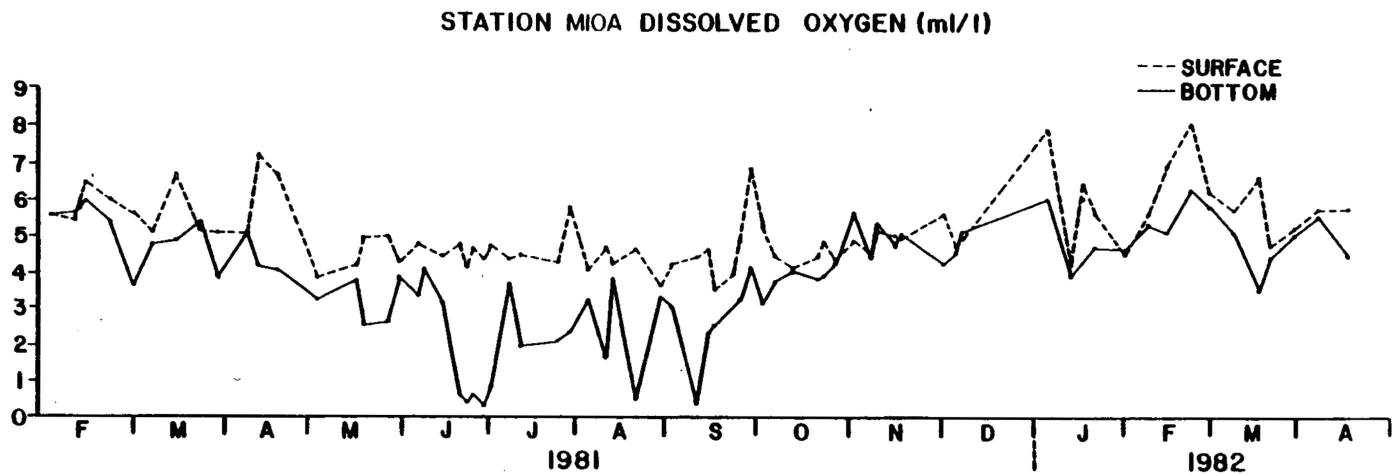


Figure 6-30. Surface and bottom dissolved oxygen values at station M10A during the pre-discharge study (February - April 1981) and present study (May 1981 - April 1982).

precise characterizations of the physical environment at these sites. More complete data on estuarine physical parameters are provided in Chapter 3.

Not unexpectedly, bottom salinity (Figure 6-31) increases from the Intracoastal Waterway (station E1) towards the mouth of the estuary (station E5). There is a pronounced freshwater influence on all stations, as indicated by the considerable temporal variation seen over the 15 month study period. Bottom salinity decreases markedly from May to June at all sites, then gradually increases until December. Salinity is higher at all sites during the spring of 1981 than during the same period in 1982, perhaps due to abnormally low rainfall in 1981.

Mean bottom temperature (Figure 6-32) ranges from a summer high of 30°C to a late winter low of 8°C. Bottom dissolved oxygen (Figure 6-32) also varies seasonally. Highest values (5.8 - 7.0 ml l^{-1}) occur during the coldest period of the year, and lowest values (2.3 - 3.9 ml l^{-1}) generally lag one to two months behind the warmest period. Dissolved oxygen concentrations never reach below 2 ml l^{-1} as occurs in the offshore study area during summer.

6.3.3 Population Statistics

A total of 247 macrobenthic species have been collected during the 12-month study period. This includes 85 species of polychaetes, 73 crustaceans, 60 molluscs, and 29 species representing numerous other

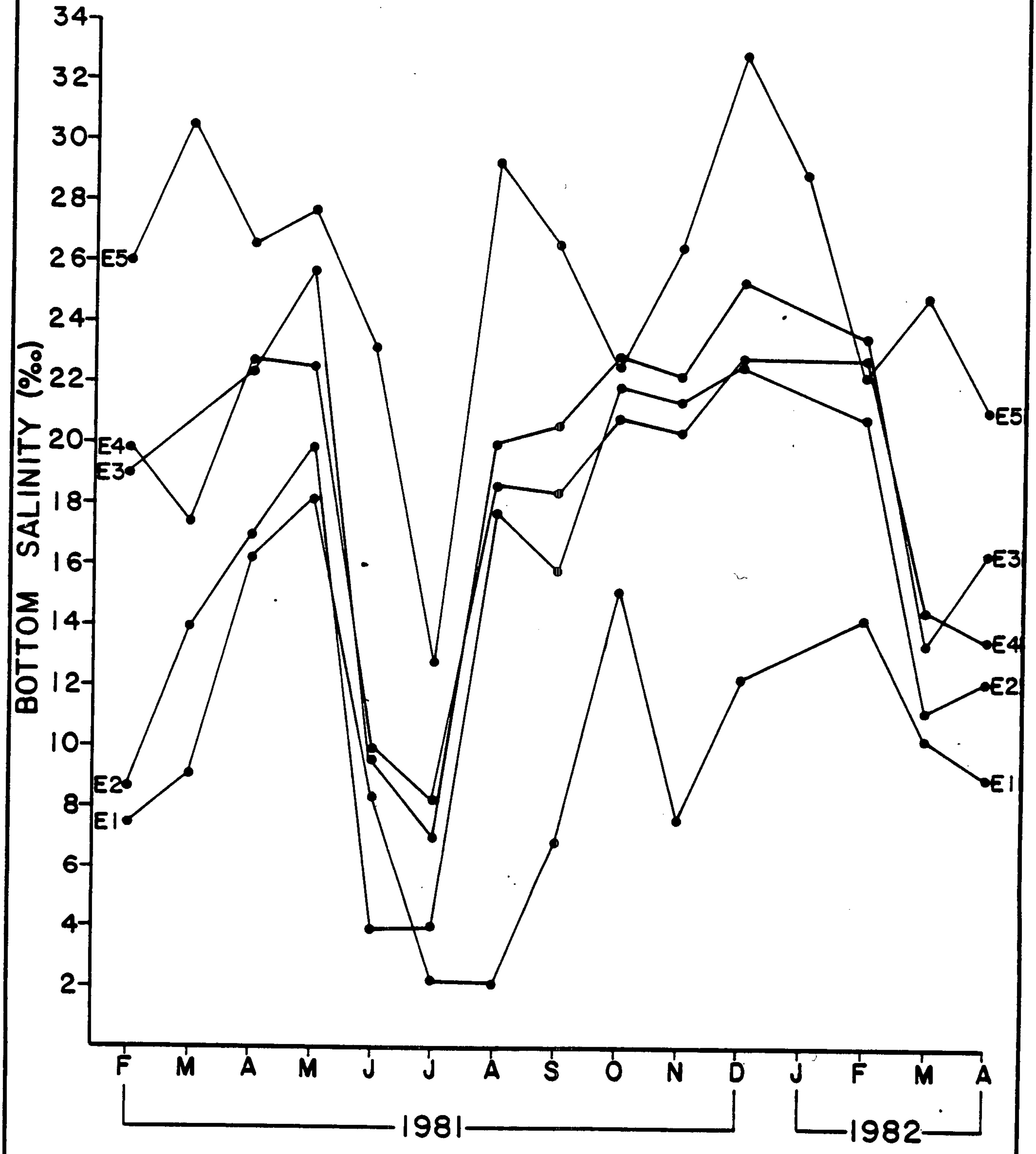


Figure 6-31. Bottom salinity at estuarine sites (stations E1, E2, E3, E4, E5) during the pre-discharge study (February - April 1981) and present study (May 1981 - April 1982).

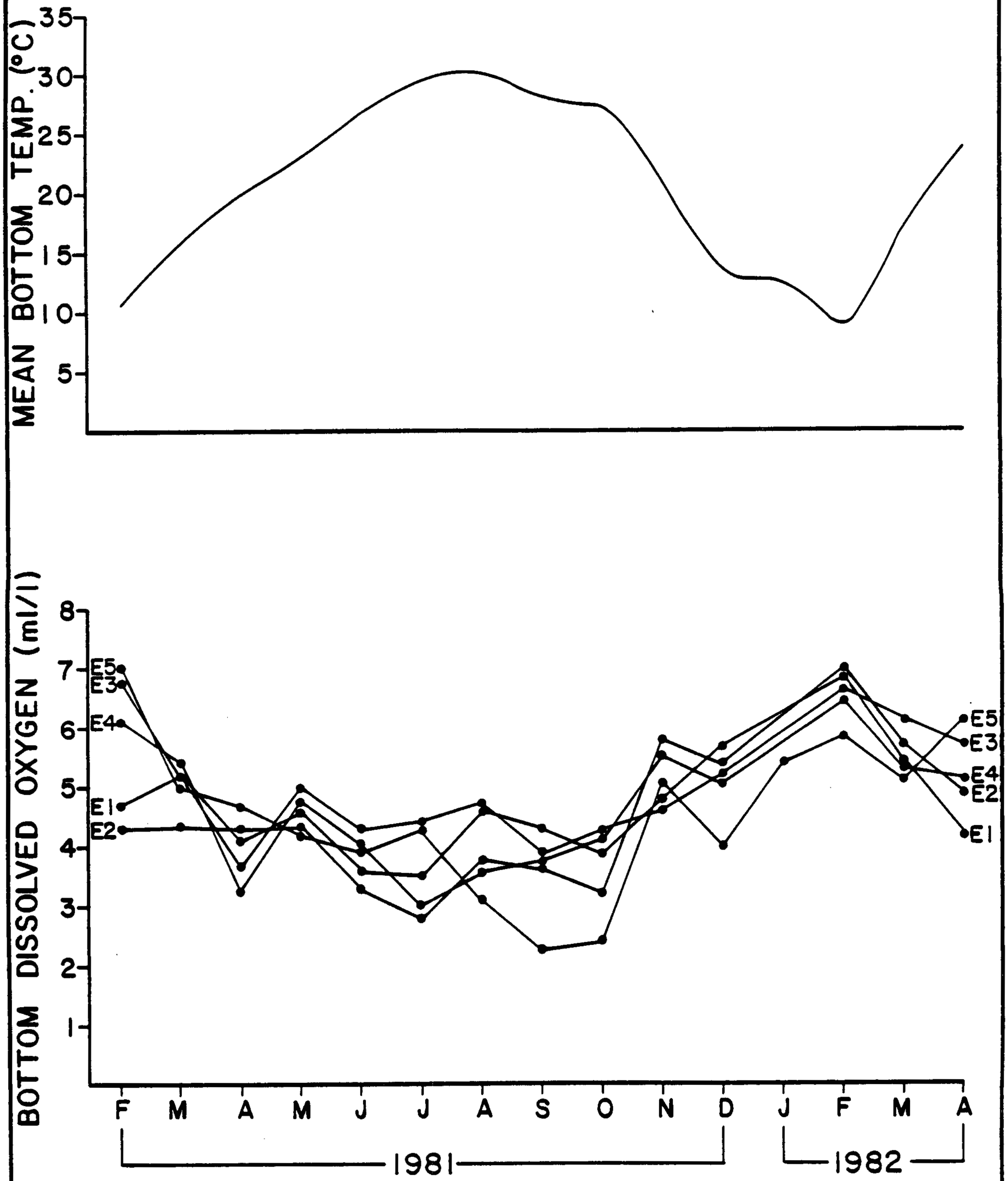


Figure 6-32. Mean bottom temperature and bottom dissolved oxygen values at estuarine sites (stations E1, E2, E3, E4, E5) during the pre-discharge study (February - April 1981) and present study (May 1981 - April 1982).

taxa (Table 6-2). In all, over 225,000 individual specimens have been identified.

6.3.3.1 Marine

The total number of individuals (Table 6-3) varies considerably, both spatially, due to habitat differences, and temporally, due to mortality and larval recruitment. The greatest abundances of macrobenthos (14,620-21,790 individuals m^{-2}) occurs at station M3 in May and June (Table 6-3). The lowest abundance (670 individuals m^{-2}) occurs at station M18 during August, a time of hypoxic conditions on the shelf. Spatial and temporal variations in abundance of individuals are evident in Figure 6-33 in which data from both control and near-diffuser sites are presented. In general, at these sites greatest abundances occur during late winter and spring, and lowest abundances occur during summer.

The total numbers of species (Figure 6-34) varies considerably with time. During summer, fewer species are present at both control and near-diffuser sites. The greatest numbers of species generally occur in late spring (May-June).

Shannon diversity has been used for a number of years by investigators to measure environmental stress on macrobenthic community structure. The use of such diversity indices has decreased somewhat in recent years, however, as investigators have begun to realize the theoretical limitations in interpreting these values. Semantic problems have plagued the concept since its inception, to the point

Table 6-2. Macrobenthic species collected at marine and estuarine stations.

CNIDARIA
- Anthozoa
  - Anthozoa sp.A
  - Anthozoa sp.B
  - Anthozoa sp.C
  - Actiniidae
    - *Bunodactis texaensis*
  - Actinostolidae
    - *Paranthus rapiformis*
  - Aiptasiidae
    - *Aiptasia pallida*

PLATYHELMINTHES
- Turbellaria
  - Polycladia sp.A
  - Polycladia sp.B
  - Polycladia sp.C
  - Polycladia sp.D
  - Polycladia sp.E

NEMERTINEA
- *Cerebratulus lacteus*
- Nemertea sp.B
- Nemertea sp.D
- Nemertea sp.G
- Nemertea sp.K

ANNELIDA
- Oligochaeta
- Polychaeta
  - Ampharetidae
    - *Ampharete* cf. *acutifrons*
    - *Hobsonia florida*
    - *Sabellides* sp.A
  - Amphictenidae
    - *Cistena regalis*
  - Amphinomidae
    - *Pseudeurythoe paucibranchiata*
  - Capitellidae
    - *Capitella capitata*
    - *Heteromastus filiformis*
    - *Mediomastus californiensis*
    - *Notomastus hemipodus*
    - *Notomastus latericeus*

Table 6-2. continued

Chaetopteridae
Spiochaetopterus oculatus
Chrysopetalidae
Paleanotus heteroseta
Cirratulidae
Chaetozone sp.
Cirratulus cf. *filiformis*
Tharyx sp.
Cossuridae
Cossura delta
Cossura soyeri
Dorvilleidae
Schistomeringos rudolphi
Eunicidae
Marphysa sanguinea
Flabelligeridae
Piromis roberti
Glyceridae
Glycera americana
Goniadidae
Glycinde solitaria
Hesionidae
Gyptis brevipalpa
Gyptis vittata
Podarke obscura
Lumbrineridae
Lumbrinerides sp.A
Lumbrineris aberrans
Lumbrineris ernesti
Lumbrineris sp.A
Ninoe sp.A
Magelonidae
Magelona cf. *cincta*
Magelona cf. *phyllisae*
Maldanidae
Asychis elongata
Axiothella sp.A
Clymenella torquata
Nephtyidae
Aglaophamus circinata
Aglaophamus verrilli
Nephtys incisa
Nephtys simoni
Nephtys sp.A
Nereidae
Laeonereis culveri
Nereis lamellosa
Nereis micromma

Table 6-2. continued

- *Nereis succinea*
- *Nereis* sp.A

Onuphidae
- *Diopatra cuprea*

Opheliidae
- *Armandia maculata*

Orbiniidae
- *Scoloplos texana*

Oweniidae
- *Myriochele oculata*
- *Myriowenia* sp.A
- *Owenia fusiformis*

Paraonidae
- *Aricidea catherinae*
- *Aricidea* cf. *alisdairi*
- *Aricidea lopezi*
- *Aricidea pseudoarticulata*
- *Aricidea suecica*
- *Cirrophorus americanus*

Phyllodocidae
- *Eteone heteropoda*
- *Eumida sanguinea*
- *Phyllodoce arenae*

Pilargidae
- *Ancistrosyllis jonesi*
- *Parandalia fauveli*
- *Sigambra bassi*
- *Sigambra tentaculata*
- *Sigambra wassi*

Polynoidae
- *Lepidasthenia* sp.A
- *Lepidonotus sublevis*
- Polynoidae sp.A
- Polynoidae sp.B
- Polynoidae sp.D

Sabellidae
- *Megalomma bioculatum*

Serpulidae
- *Hydroides protulicola*

Sigalionidae
- *Pholoe* sp.A
- *Sthenelais boa*
- *Sthenolepis* sp. A

Spionidae
- *Malacoceros* sp.A
- *Paraprionospio pinnata*
- *Polydora ligni*
- *Polydora socialis*

Table 6-2. continued

Prionospio cirrifera
Spiophanes bombyx
Spiophanes missionensis
Streblospio benedicti
Terebellidae
Loimia medusa
Syllidae
Autolytus dentalius

MOLLUSCA
Gastropoda
Acteocinidae
Acteocina canaliculata
Aeolidiidae
Cerberilla tanna
Arminidae
Armina sp. A
Buccinidae
Cantharus cancellarius
Columbellidae
Anachis catenata
Anachis obesa
Corabidae
Doridella obscura
Crepidulidae
Crepidula fornicata
Epitoniidae
Epitonium angulatum
Epitonium apiculatum
Epitonium multistriatum
Epitonium rupicola
Eulimidae
Strombiformis bilineatus
Haminoeidae
Haminoea succinea
Hydrobiidae
Texadina sphinctostoma
Muricidae
Thais haemastoma floridana
Nassariidae
Nassarius acutus
Naticidae
Natica canrena
Natica pusilla
Polinices duplicatus
Sinum perspectivum
Pyramidellidae
Odostomia cf. *weberi*
Odostomia cf. *gibbosa*
Turbonilla sp.A
Turbonilla sp.B

Table 6-2. continued

Turbonilla sp.C
Retusidae
Volvulella texasiana
Terebridae
Terebra sp.
Vitrinellidae
Cyclostremiscus pentagonus
Solariorbis blakei
Vitrinella floridana
Unidentified
Nudibranchia sp.A

Bivalvia
Arcidae
Anadara ovalis
Anadara transversa
Neotia ponderosa
Corbulidae
Corbula barrattiana
Corbula cf. _swiftiana_
Cuspidariidae
Cardiomya sp.A
Mactridae
Mulinia lateralis
Mytilidae
Amygdalum papyrium
Brachiodontes exustus
Nuculanidae
Nuculana sp.A
Pandoridae
Pandora trilineata
Petricolidae
Petricola pholadiformis
Pholadidae
Cyrtopleura costata
Pinnidae
Atrina serrata
Semelidae
Abra aequalis

Table 6-2. continued

Solecurtidae
- *Tagelus plebius*

Solenidae
- *Solen viridis*

Tellinidae
- *Macoma constricta*
- *Macoma mitchelli*
- *Macoma tageliformis*
- *Macoma tenta*
- *Tellina alternata*
- *Tellina tampaensis*
- *Tellina versicolor*
- *Tellina* sp.A

Veneridae
- *Agriopoma texasiana*
- *Chione cancellata*
- *Chione clenchi*

ARTHROPODA

Pycnogonida
- Phoxichiliidae
  - *Anoplodactylus petiolatus*

Cirripedia
- Balanidae
  - *Balanus eburneus*
  - *Balanus improvisus*

Stomatopoda
- Squillidae
  - *Squilla empusa*

Mysidacea
- Mysidae
  - *Brasilomysis castroi*
  - *Mysidopsis almyra*
  - *Mysidopsis bahia*
  - *Mysidopsis bigelow*

Cumacea
- Bodotriidae
  - *Cyclaspis varians*
- Diastylidae
  - *Oxyurostylis* sp.A

Tanaidacea
- Paratanaidae
  - *Hargeria rapax*

Isopoda
- Idoteidae
  - *Edotea triloba*
- Munnidae

Table 6-2. continued

- *Munna* sp.A
- Sphaeromidae
  - *Cassidinidea ovalis*
- Amphipoda
  - Ampeliscidae
    - *Ampelisca abdita*
  - Agrissidae
    - *Argissa hamatipes*
  - Amphilochidae
    - *Gitanopsis* sp.A
  - Aoridae
    - *Grandidierella bonnieroides*
    - *Lembos* sp.
  - Bateidae
    - *Batea catharinensis*
  - Caprellidae
    - *Caprella equilibra*
    - *Paracaprella pusilla*
  - Corophiidae
    - *Cerapus benthophilus*
    - *Corophium* sp.A
    - *Corophium* sp.B
    - *Corophium louisianum*
    - *Erichthonius brasiliensis*
  - Gammaridae
    - *Gammarus mucronatus*
    - *Melita nitida*
  - Ischyroceridae
    - *Jassa falcata*
  - Isaeidae
    - *Microprotopus shoemakeri*
    - *Microprotopus* sp.A
    - *Photis* sp.
  - Lilgeborgiidae
    - *Listriella barnardi*
  - Oedicerotidae
    - *Monoculodes* sp.A
    - *Synchelidium americanum*
  - Stenothoidae
    - *Parametopella* sp.A
  - Synopiidae
    - *Tiron tropakis*
- Decapoda
  - Calappidae
    - *Hepatus epheliticus*
  - Callianassidae
    - *Callianassa (Gourretia) jamaicense*
    - *Callianassa (Gourretia) latispina*

Table 6-2. continued

Upogebia affinis
Hippolytidae
Latreutes fucorum
Latreutes parvulus
Leucosiidae
Persephona crinata
Persephone mediterranea
Majidae
Libinia sp.
Ogryididae
Ogryides alphaerostris
Paguridae
Clibanarius vittatus
Pagurus longicarpus
Pagurus pollicaris
Pagurus sp.B
Palaemonidae
Leander tenuicornis
Pasiphaeidae
Leptochela serratorbita
Penaeidae
Penaeus aztecus
Sicyonia dorsalis
Trachypenaeus constrictus
Trachypenaeus similis
Pinnotheridae
Pinnixa chaetopterana
Pinnixa pearsei
Pinnixa sp.B
Pinnixa sp.C
Porcellanidae
Petrolisthes armatus
Portunidae
Callinectes sapidus
Callinectes similis
Ovalipes floridanus
Portunus gibbesii
Sergestidae
Acetes americanus
Lucifer faxoni
Xanthidae
Eurypanopeus depressus
Hexapanopeus angustifrons
Neopanope texana
Panopeus herbstii
Rithropanopeus harrisii

Table 6-2. continued

SIPUNCULA
- *Aspidosiphon albus*
- *Golfingia* cf. *trichocephala*
- *Phascolion strombi*

ECHIURA
- Thalassemidae
  - *Thalassema* sp.A

PHORONIDA
- *Phoronis* sp.A

BRACHIOPODA
- *Glottidea pyramidata*

ECHINODERMATA
- Ophiuroidea
  - Amphiuridae
    - *Hemipholis elongata*
    - *Micropholis atra*
- Holothuroidea
  - Phyllophoridae
    - *Pentamera* sp.A
  - Synaptidae
    - Synaptidae sp.A

HEMICHORDATA
- *Balanoglossus aurantiacus*

Table 6-3. Total individuals (m^{-2}) collected at each site per month. Values are based on means of 6 replicate samples.

STATION	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	JAN	FEB	MAR	APR
M3	14620	21790	6220	4780	2830	2360	2130	1540	1890	3320	2740	5610
M6	1320	2310	*	*	2020	*	*	1630	*	*	*	*
M10	4510	3760	2640	4480	1550	2250	3300	2670	2380	3420	3210	4090
M10A	4980	13050	1020	1350	2050	2040	2520	3260	1960	2940	4740	3910
M15	3900	3100	*	*	1930	*	*	2170	*	*	5950	*
M18	3140	4190	2150	670	1680	1380	1940	2080	2740	5410	3210	5880
M20	1410	2740	*	*	2010	1720	1770	1830	2910	6780	8840	6230
DE	3570	1830	980	1520	1730	2390	1610	2220	3070	4730	4730	5920
DN	7200	2930	*	*	1520	*	*	2170	*	*	4130	*
DS	3030	3120	*	*	1220	*	*	2580	*	*	6200	*
DW	4520	3300	2780	2040	1710	1830	1510	1760	1980	2890	3940	4890

* no data collected

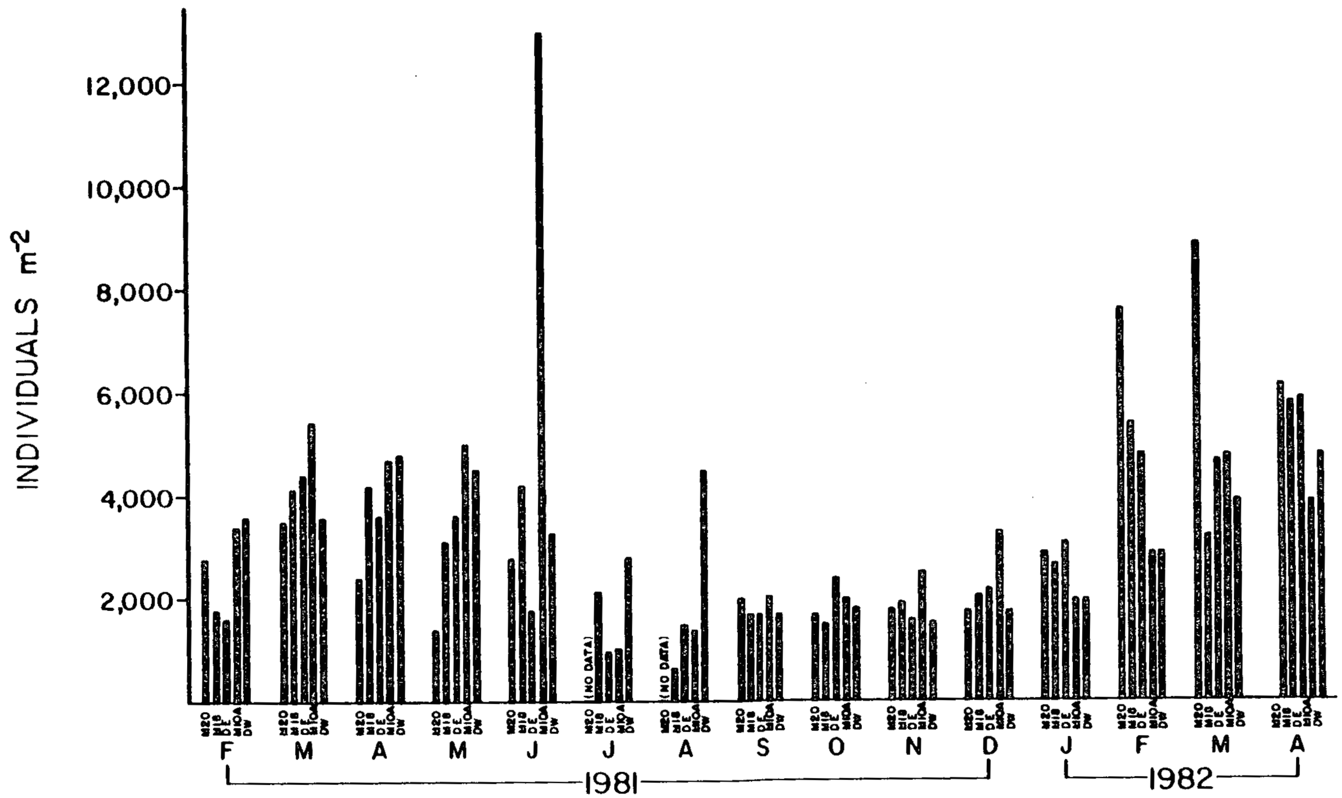


Figure 6-33. Total macrofaunal density throughout the pre- and post-discharge investigations at five selected marine stations.

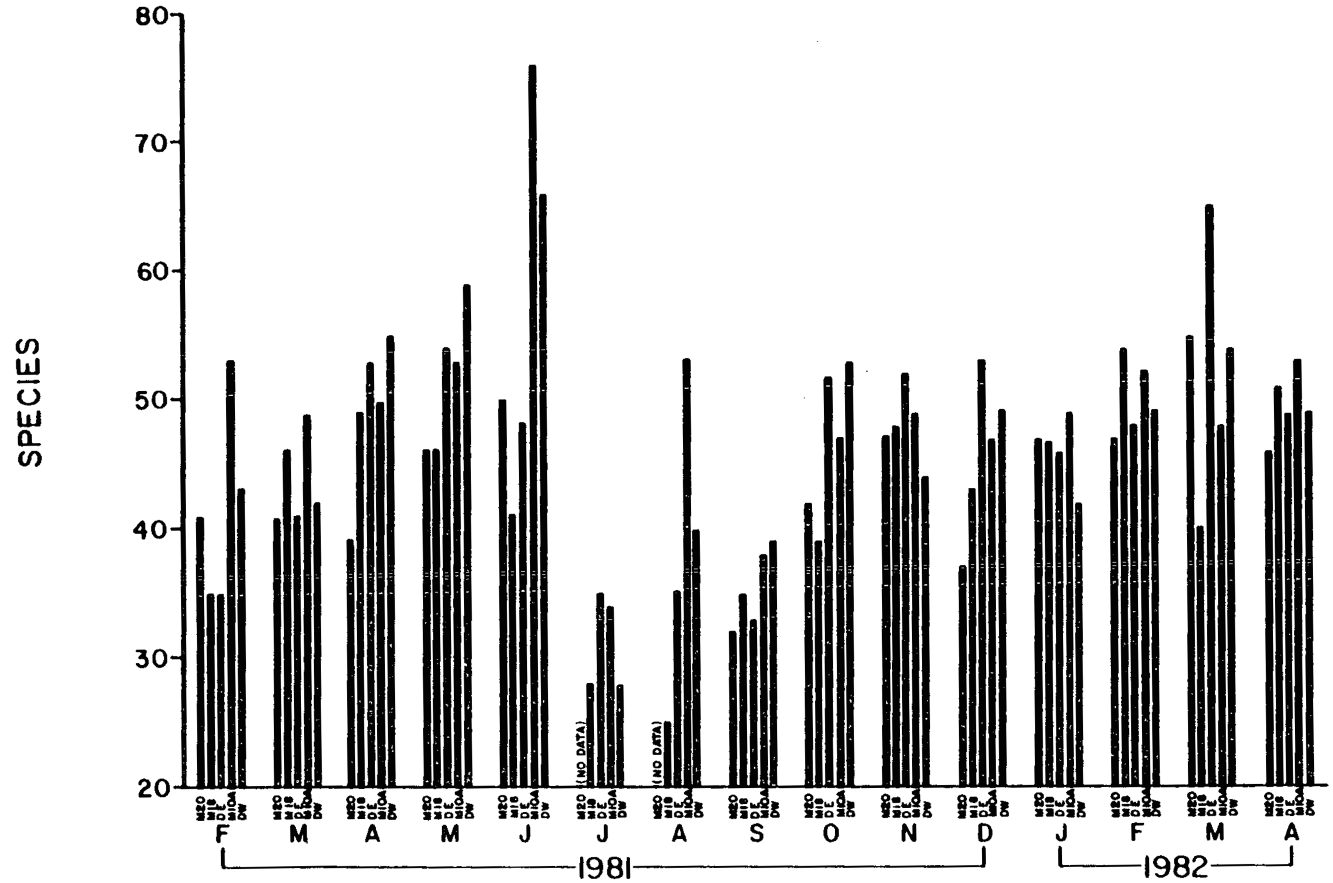


Figure 6-34. Number of species collected in six replicate grabs throughout pre- and post-discharge investigations at five selected marine stations.

that some investigators have proposed dropping the term entirely (Hurlbert, 1971). Furthermore, one of the applications of diversity indices has been the comparison of separate studies. Variations in community composition, sampling methodology, and taxonomic expertise between studies severely limits the usefulness of this application of diversity indices. Shannon's index is best interpreted in light of the individual components of species diversity: species richness and species evenness. Values for species richness (Table 6-4) and species evenness (Table 6-5), as well as Shannon diversity (Table 6-6) are discussed in this investigation.

A number of stations (e.g. M10, M6) are relatively speciose as evidenced in the species richness values (Table 6-4). Sampling sites to the east of the diffuser (e.g. stations M15, M18, M20) are generally less species rich than those to the west (e.g. stations M3, M6). Species evenness values, a measure of how evenly the individuals are distributed among the species, are presented in Table 6-5. Values at station M3 are consistently lower than other sites from May to August, and are higher than all other sites from October to March.

More evident than spatial differences are the temporal variations in Shannon diversity, species richness, and species evenness which occur during the year (Figure 6-35). Three representative sites (stations M3, M10A, M18) are presented for this discussion. There is clearly a radical change in values of all three indices during summer hypoxia. Additionally, throughout the year values for evenness and

Table 6-4. Species richness values for marine stations.

STATION	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	JAN	FEB	MAR	APR
M3	6.31	8.46	5.75	7.62	8.50	10.25	11.00	9.73	9.92	11.37	9.08	10.30
M6	8.60	11.21	*	*	7.91	*	*	8.25	*	*	*	*
M10	9.33	11.47	7.35	9.83	8.53	10.89	11.20	12.71	11.15	11.14	9.70	8.98
M10A	8.37	10.45	7.14	10.59	6.95	8.65	8.68	7.95	9.10	8.80	7.47	8.71
M15	7.88	6.45	*	*	5.89	*	*	6.69	*	*	7.83	*
M18	7.83	6.62	5.03	5.70	6.64	7.71	8.92	7.87	8.20	8.42	6.58	7.84
M20	9.10	8.73	*	*	5.85	7.96	8.89	6.91	8.10	7.21	7.96	6.99
DE	9.02	9.02	7.41	6.77	6.21	9.31	10.04	9.62	7.86	7.63	10.23	7.52
DN	6.99	7.22	*	*	5.17	*	*	7.43	*	*	7.80	*
DS	8.75	9.93	*	*	8.53	*	*	8.83	*	*	8.71	*
DW	9.49	11.21	4.80	7.33	7.39	9.99	8.57	9.28	7.76	8.30	8.70	7.75

* no data collected

Table 6-5. Species eveness values for marine stations.

STATION	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	JAN	FEB	MAR	APR
M3	0.13	0.16	0.27	0.36	0.63	0.70	0.69	0.71	0.71	0.70	0.70	0.56
M6	0.66	0.70	*	*	0.51	*	*	0.65	*	*	*	*
M10	0.40	0.50	0.45	0.56	0.65	0.68	0.55	0.56	0.60	0.60	0.70	0.59
M10A	0.43	0.23	0.75	0.75	0.68	0.58	0.62	0.60	0.69	0.62	0.58	0.58
M15	0.41	0.59	*	*	0.51	*	*	0.65	*	*	0.44	*
M18	0.47	0.47	0.49	0.74	0.49	0.67	0.69	0.63	0.50	0.52	0.48	0.34
M20	0.63	0.54	*	*	0.40	0.53	0.72	0.62	0.44	0.37	0.32	0.30
DE	0.54	0.67	0.75	0.46	0.53	0.67	0.69	0.65	0.54	0.52	0.55	0.41
DN	0.28	0.46	*	*	0.51	*	*	0.70	*	*	0.65	*
DS	0.38	0.47	*	*	0.65	*	*	0.58	*	*	0.44	*
DW	0.35	0.51	0.36	0.61	0.64	0.67	0.72	0.69	0.67	0.49	0.51	0.43

* no data collected

Table 6-6. Shannon diversity values for marine stations.

STATION	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	JAN	FEB	MAR	APR
M3	0.71	0.98	1.43	2.01	3.56	4.08	4.08	4.02	4.06	4.26	3.98	3.39
M6	3.58	4.19	*	*	2.77	*	*	3.50	*	*	*	*
M10	2.31	3.06	2.43	3.34	3.57	4.02	3.31	3.46	3.59	3.65	4.11	3.41
M10A	2.47	1.41	3.82	4.30	3.55	3.20	3.45	3.34	3.90	3.51	3.23	3.31
M15	2.29	3.11	*	*	2.56	*	*	3.39	*	*	2.48	*
M18	2.61	2.54	2.36	3.46	2.49	3.53	3.84	3.39	2.79	2.99	2.56	1.93
M20	3.48	3.06	*	*	2.01	2.86	3.97	3.22	2.43	2.06	1.88	1.68
DE	3.14	3.72	3.86	2.35	2.68	3.82	3.94	3.71	2.97	2.90	3.30	2.30
DN	1.54	2.47	*	*	2.43	*	*	3.76	*	*	3.61	*
DS	2.14	2.75	*	*	3.52	*	*	3.25	*	*	2.57	*
DW	2.08	3.05	1.72	3.23	3.37	3.82	3.91	3.88	3.61	2.74	2.95	2.40

* no data collected

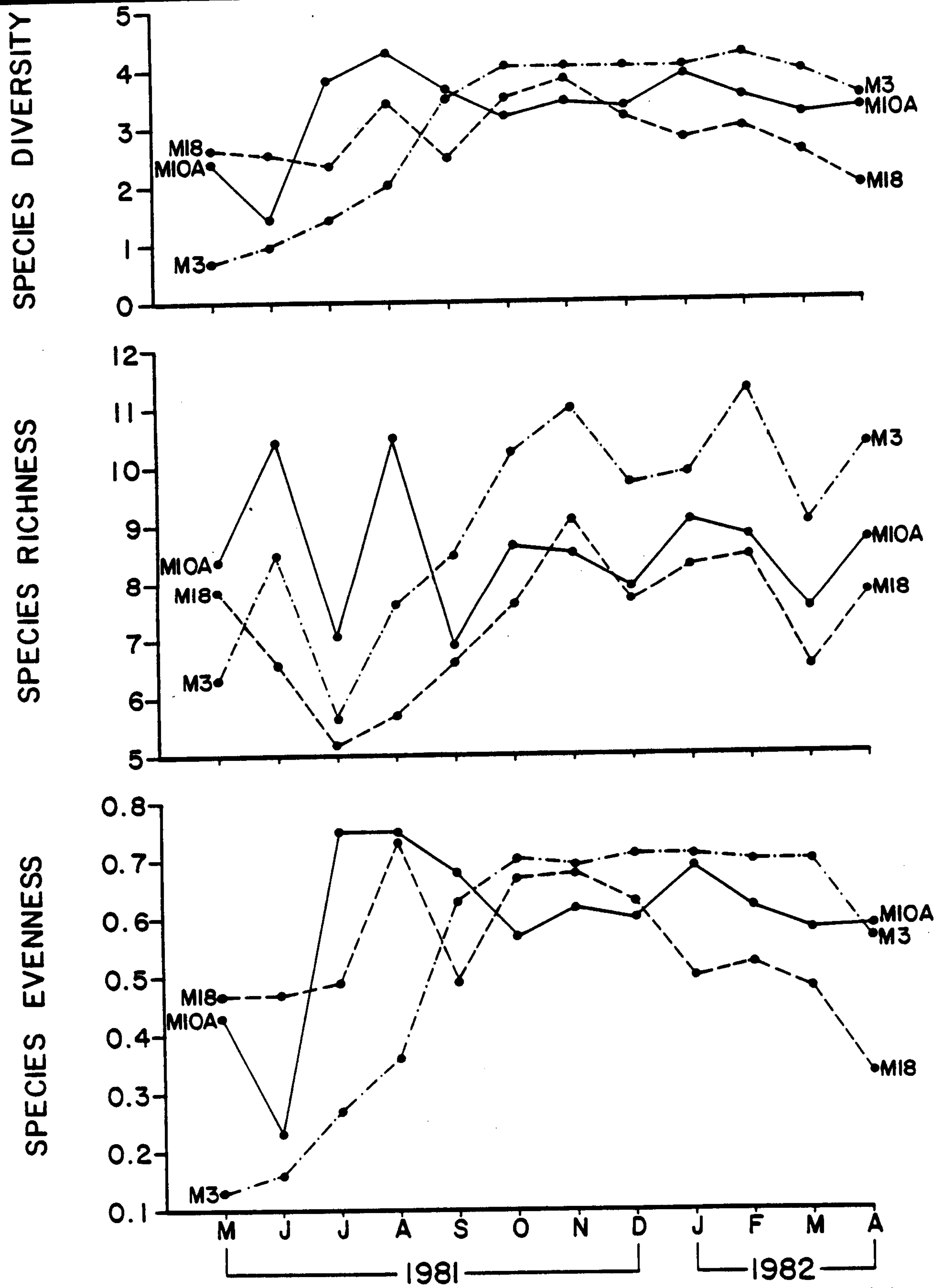


Figure 6-35. Temporal variation in species diversity, species richness and species evenness at three selected marine stations.

Shannon diversity are closely correlated, indicating that temporal variations in diversity among the marine stations are due almost entirely to changes in the relative abundance of the species rather than to differences in the number of species inhabiting the sites. This results from the numerical dominance of a few species at particular sites, a trend that may be related to either environmental stress or seasonal recruitment patterns of the species. The low value for evenness which occurs at station M10A in June (Figure 6-35) is atypical of the pattern seen at any other station, and represents a sudden irruption in population of a single species (*Phoronis* sp. A).

6.3.3.2 Estuarine

Values for Shannon diversity, species richness, and species evenness are presented in Table 6-7. Less species are present in the upper estuary (station E1) than at the estuary mouth (station E5), as evidenced in the values for species richness. Additionally, station E5 is numerically dominated by only a small percentage of the species in the community, (e.g. *Phoronis* sp. A, *Mulinia lateralis*, *Streblospio benedicti*), resulting in relatively low values for species evenness from May to September. Generally, however, there is little temporal variation in evenness at estuarine sites during the year. There are no temporal trends in species richness values common to all sites.

Table 6-7. Shannon diversity, species richness, and species evenness values for estuarine sites.

STATION	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	JAN	FEB	MAR	APR
					SHANNON DIVERSITY							
E1	2.41	2.23	1.66	2.21	3.03	2.31	2.42	2.22	*	2.15	2.81	2.00
E2	2.10	3.23	3.24	3.59	3.97	3.30	2.90	2.25	*	2.69	2.60	3.63
E3	2.83	2.65	*	2.47	2.82	2.84	2.45	2.54	*	2.65	3.12	3.17
E4	2.60	2.61	2.55	2.35	3.10	3.20	2.93	2.88	*	2.59	3.11	3.12
E5	1.08	0.85	1.91	1.27	3.11	3.62	2.37	3.21	*	3.76	3.52	3.49
					SPECIES RICHNESS							
E1	3.54	3.29	2.80	3.26	5.38	2.66	4.21	4.93	*	5.78	5.09	3.17
E2	3.41	6.04	6.76	5.65	6.25	5.74	6.11	4.41	*	4.77	4.79	6.70
E3	5.19	4.24	*	4.15	4.64	4.73	4.70	3.92	*	4.55	5.45	5.75
E4	4.54	3.40	4.21	3.79	4.93	3.74	4.86	5.12	*	4.94	5.47	4.93
E5	5.93	5.15	4.74	4.50	6.36	8.86	4.44	6.18	*	8.91	7.54	6.65
					SPECIES EVENNESS							
E1	0.62	0.62	0.52	0.70	0.78	0.73	0.62	0.54	*	0.46	0.85	0.51
E2	0.53	0.67	0.67	0.88	0.88	0.72	0.59	0.66	*	0.58	0.56	0.74
E3	0.64	0.66	*	0.69	0.74	0.73	0.63	0.81	*	0.62	0.71	0.72
E4	0.57	0.67	0.59	0.60	0.74	0.86	0.69	0.82	*	0.59	0.70	0.71
E5	0.21	0.17	0.39	0.27	0.63	0.74	0.56	0.85	*	0.68	0.66	0.68

* no data collected

6.3.4 Species Distributions

6.3.4.1 Marine

The ten most numerically dominant species collected each month are presented in Table 6-8. Spatial distribution patterns of selected species are analyzed by comparison of abundance variations between collection sites during particular cruises. Temporal trends are analyzed by comparion of species abundance variations between cruises (i.e. over time). General temporal trends are additionally discussed with reference to baseline data collected in the study area by Science Applications Incorporated (1978), Parker et al. (1980), and Weston and Gaston (1982).

During the three month period prior to brine discharge two species, Phoronis sp. A (Phoronida) and Sabellides sp. A (Polychaeta) numerically dominant the macrobenthic communities of the study area (Table 6-8). Though the high abundance of Sabellides sp. A does not continue following the discharge of brine, Phoronis sp. A population numbers continue to increase, totalling 72% of the total macrobenthos in May. This pattern of domination by Phoronis sp. A continues through July. Populations of Phoronis sp. A decrease in number through August and September. By October Phoronis sp. A is not among the 10 most numerically dominant species. The population irruption observed in the winter and spring of 1981 is not repeated in 1982.

Spatial distribution of Phoronis sp. A is shown for five stations in Figure 6-36. During pre-discharge sampling (February-April 1981) Phoronis is more common around the diffuser than at control sites M18 and M20 (Figure 6-37). During June, following the initial discharge of

Table 6-8. Numerically dominant marine species by mean abundance (individuals m^{-2}) and percentage of benthic community. (An = Anthozoan, B = Barnacle, C = Cumacean, M = Mollusk, N = Nemertean, P = Polychaete, Ph = Phoronid).

FEBRUARY 1981	$\bar{x}$	percentage of total individuals	Cumulative percent
Sabellides sp. A (P)	1102	43.2	43.2
Balanus improvisus (B)	308	12.1	55.3
Mulinia lateralis (M)	178	7.0	62.3
Magelona cf. phyllisae (P)	162	6.3	68.6
Paraprionospio pinnata (P)	110	4.3	72.9
Mediomastus californiensis (P)	106	4.1	77.0
Nemertea sp. B (N)	88	3.4	80.4
Phoronis sp. A (Ph)	72	2.8	83.2
Oxyurostylis sp. A (C)	72	2.8	86.0
Cossura soyeri (P)	38	1.5	87.5

MARCH 1981	$\bar{x}$	percentage of total individuals	Cumulative percent
Sabellides sp. A (P)	1517	35.5	35.5
Phoronis sp. A (Ph)	1402	32.8	68.4
Balanus improvisus (B)	356	8.3	76.7
Oxyurostylis sp. A (C)	137	3.2	79.9
Nemertea sp. B (N)	111	2.6	82.5
Magelona cf. phyllisae (P)	93	2.2	84.7
Mulina lateralis (M)	71	1.6	86.4
Mediomastus californiensis (P)	70	1.6	88.0
Paraprionospio pinnata (P)	65	1.5	89.5
Cerebratulus lacteus (N)	40	0.9	90.5

Table 6-8. continued

APRIL 1981	$\bar{x}$	percentage of total individuals	Cumulative percent
Phoronis sp. A (Ph)	2822	50.0	50.0
Sabellides sp. A (P)	1653	29.1	79.1
Magelona cf. phyllisae (P)	154	2.7	81.8
Balanus improvisus (B)	134	2.4	84.1
Nemertea sp. B (N)	129	2.3	86.4
Paraprionospio pinnata (P)	94	1.7	88.0
Mediomastus californiensis (P)	91	1.6	89.7
Diopatra cuprea (P)	76	1.4	91.0
Cossura soyeri (P)	49	0.9	91.9
Oxyurostylis sp. A (C)	46	0.8	92.7

MAY 1981	$\bar{x}$	percentage of total individuals	Cumulative percent
Phoronis sp. A (Ph)	3446	71.9	71.9
Nemertea sp. B (N)	183	3.8	75.7
Paraprionospio pinnata (P)	150	3.1	78.9
Diopatra cuprea (P)	122	2.5	81.4
Magelona cf. phyllisae (P)	103	2.1	83.6
Glycinde solitaria (P)	102	2.1	85.7
Mediomastus californiensis (P)	77	1.6	87.3
Spiochaetopterus oculatus (P)	70	1.5	88.8
Cirratulus cf. filiformis (P)	63	1.3	90.1
Sthenolepis sp. A (P)	52	1.1	91.1

Table 6-8. continued

JUNE 1981	$\bar{x}$	percentage of total individuals	Cumulative percent
Phoronis sp. A (Ph)	3980	70.1	70.1
Paraprionospio pinnata (P)	263	4.6	74.8
Mediomastus californiensis (P)	205	3.6	78.4
Magelona cf. phyllisae (P)	158	2.8	81.1
Glycinde solitaria (P)	148	2.6	83.7
Diopatra cuprea (P)	122	2.2	85.9
Nemertea sp. B (N)	113	2.0	87.9
Spiochaetopterus oculatus (P)	83	1.5	89.4
Nemertea sp. D (N)	81	1.4	90.8
Cossura soyeri (P)	72	1.3	92.0

JULY 1981	$\bar{x}$	percentage of total individuals	Cumulative percent
Phoronis sp. A (Ph)	1737	64.5	64.5
Magelona cf. phyllisae (P)	241	9.0	73.4
Cossura soyeri (P)	101	3.8	77.2
Nemertea sp. B (N)	100	3.7	80.9
Spiochaetopterus oculatus (P)	61	2.3	83.2
Paraprionospio pinnata (P)	52	1.9	85.1
Diopatra cuprea (P)	50	1.9	86.9
Cirratulus cf. filiformis (P)	41	1.5	88.4
Ancistrosyllis jonesi (P)	34	1.3	89.7
Sigambra tentaculata (P)	29	1.1	90.8

Table 6-8. continued

AUGUST 1981	$\bar{x}$	percentage of total individuals	Cumulative percent
Paraprionospio pinnata (P)	854	26.3	26.3
Phoronis sp. A (Ph)	798	24.6	51.0
Owenia fusiformis (P)	288	8.9	59.9
Anthozoa (An)	246	7.6	67.4
Magelona cf. phyllisae (P)	224	6.9	74.4
Diopatra cuprea (P)	103	3.2	77.6
Nassarius acutus (M)	85	2.6	80.2
Sigambra tentaculata (P)	76	2.3	82.5
Glycinde solitaria (P)	71	2.2	84.7
Cossura soyeri (P)	70	2.1	86.8

SEPTEMBER 1981	$\bar{x}$	percentage of total individuals	Cumulative percent
Paraprionospio pinnata (P)	973	47.8	47.8
Magelona cf. phyllisae (P)	199	9.7	57.5
Sigambra tentaculata (P)	107	5.3	62.8
Diopatra cuprea (P)	100	4.9	67.7
Glycinde solitaria (P)	94	4.6	72.3
Phoronis sp. A (Ph)	76	3.7	76.0
Owenia fusiformis (P)	64	3.1	79.2
Cossura soyeri (P)	61	3.0	82.1
Nereis micromma (P)	45	2.2	84.4
Nassarius acutus (M)	43	2.1	86.5

Table 6-8. continued

OCTOBER 1981	$\bar{x}$	percentage of total individuals	Cumulative percent
Paraprionospio pinnata (P)	825	35.3	35.3
Magelona cf. phyllisae (P)	226	9.7	44.9
Glycinde solitaria (P)	195	8.3	53.3
Sigambra tentaculata (P)	142	6.1	59.3
Owenia fusiformis (P)	121	5.2	64.5
Pseudeurythoe paucibranchiata (P)	84	3.6	68.1
Diopatra cuprea (P)	83	3.6	71.6
Mediomastus californiensis (P)	68	2.9	74.5
Mulina lateralis (M)	58	2.5	77.0
Cossura soyeri (P)	55	2.4	79.3

NOVEMBER 1981	$\bar{x}$	percentage of total individuals	Cumulative percent
Magelona cf. phyllisae (P)	370	17.4	17.4
Paraprionospio pinnata (P)	289	13.6	31.0
Owenia fusiformis (P)	251	11.8	42.8
Sigambra tentaculata (P)	158	7.4	50.2
Pseudeurythoe paucibranchiata (P)	152	7.1	57.3
Mediomastus californiensis (P)	134	6.3	63.6
Cirratulus cf. filiformis (P)	109	5.1	68.8
Cossura soyeri (P)	88	4.1	72.9
Nemertea sp. B (N)	77	3.6	76.5
Glycinde solitaria (P)	64	3.0	79.5

Table 6-8. continued

DECEMBER 1981	$\bar{x}$	percentage of total individuals	Cumulative percent
Magelona cf. phyllisae (P)	369	16.7	16.7
Cirratulus cf. filiformis (P)	358	16.3	33.0
Paraprionospio pinnata (P)	332	15.0	48.0
Pseudeurythoe paucibranchiata (P)	191	8.7	56.7
Sigambra tentaculata (P)	159	7.2	63.9
Mediomastus californiensis (P)	146	6.6	70.5
Owenia fusiformis (P)	121	5.5	76.0
Cossura soyeri (P)	77	3.5	79.5
Glycinde solitaria (P)	55	2.5	82.0
Nemertea sp. D (N)	37	1.7	83.7

JANUARY 1982	$\bar{x}$	percentage of total individuals	Cumulative percent
Cirratulus cf. filiformis (P)	844	34.7	34.7
Magelona cf. phyllisae (P)	331	13.6	48.3
Pseudeurythoe paucibranchiata (P)	202	8.3	56.6
Paraprionospio pinnata (P)	176	7.2	63.8
Mediomastus californiensis (P)	140	5.8	69.6
Sigambra tentaculata (P)	126	5.2	74.8
Owenia fusiformis (P)	114	4.7	79.5
Cossura soyeri (P)	90	3.7	83.1
Cerebratulus lacteus (N)	40	1.7	84.8
Nemertea sp. B (N)	33	1.4	86.2

Table 6-8. continued

FEBRUARY 1982	$\bar{x}$	percentage of total individuals	Cumulative percent
Cirratulus cf. filiformis (P)	1675	39.5	39.5
Mulina lateralis (M)	517	12.2	51.7
Magelona cf. phyllisae (P)	407	9.6	61.4
Paraprionospio pinnata (P)	254	6.0	67.3
Mediomastus californiensis (P)	252	5.9	73.3
Owenia fusiformis (P)	167	4.0	77.2
Sigambra tentaculata (P)	148	3.5	80.7
Pseudeurythoe paucibranchiata (P)	137	3.2	84.0
Cossura soyeri (P)	103	2.4	86.4
Cerebratulus lacteus (N)	50	1.2	87.6

MARCH 1982	$\bar{x}$	percentage of total individuals	Cumulative percent
Cirratulus cf. filiformis (P)	1769	48.0	48.0
Magelona cf. phyllisae (P)	308	8.4	56.4
Mediomastus californiensis (P)	305	8.3	64.7
Mulina lateralis (M)	262	7.1	71.8
Paraprionospio pinnata (P)	195	5.3	77.1
Pseudeurythoe paucibranchiata (P)	138	3.7	80.9
Sigambra tentaculata (P)	130	3.5	84.4
Cossura soyeri (P)	79	2.1	86.5
Cerebratulus lacteus (N)	36	1.0	87.5
Owenia fusiformis (P)	35	0.9	88.4

Table 6-8. continued

APRIL 1982	$\bar{x}$	percentage of total individuals	Cumulative percent
Cirratulus cf. *filiformis* (P)	2965	56.7	56.7
Mediomastus californiensis (P)	423	8.1	64.8
Magelona cf. *phyllisae* (P)	393	7.5	72.3
Owenia fusiformis (P)	205	3.9	76.2
Sigambra tentaculata (P)	164	3.1	79.4
Cossura soyeri (P)	141	2.7	82.1
Pseudeurythoe paucibranchiata (P)	133	2.5	84.6
Paraprionospio pinnata (P)	120	2.3	86.9
Cerebratulus lacteus (N)	73	1.4	88.3
Nemertea sp. D (N)	63	1.2	89.5

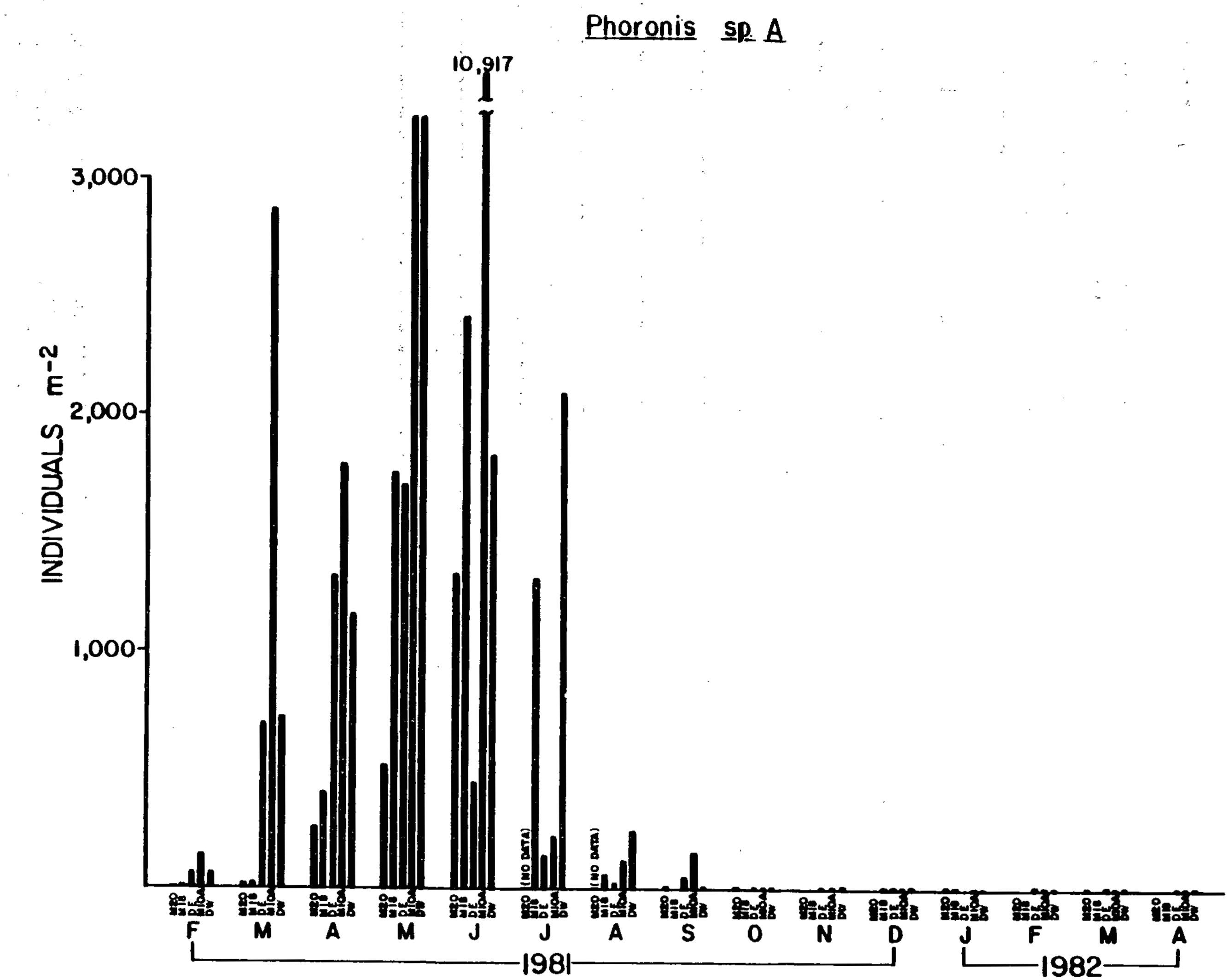
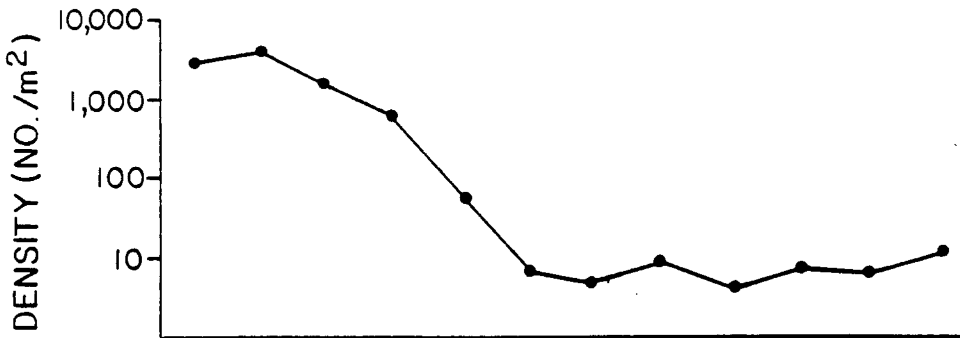


Figure 6-36. Density of Phoronis sp. A throughout the pre- and post-discharge investigations at five selected marine stations.



	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	JAN	FEB	MAR	APR
M10A	3250	10917	232	72	158	2	2	5	0	7	2	2
M10	3042	2042	1668	475	22	13	15	45	15	5	3	0
OS	2083	1792			15			5			12	
OW	3250	1833	2083	252	7	3	2	5	0	2	5	3
OE	1708	450	145	28	47	3	2	5	0	10	10	3
ON	5833	1792			22			0			2	
M6	383	542			77			12				
M15	2583	1250			3			2			8	
M3	13500	19417	5042	3100	397	25	18	7	5	30	13	80
M18	1750	2417	1308	65	0	0	0	2	3	0	0	0
M20	525	1333			12	2	0	0	3	0	0	0

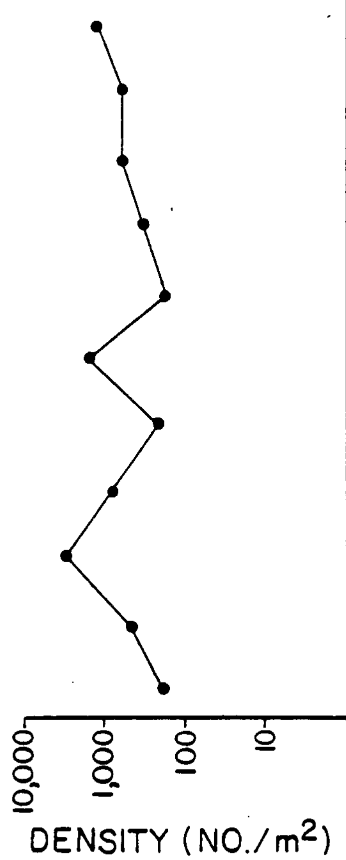


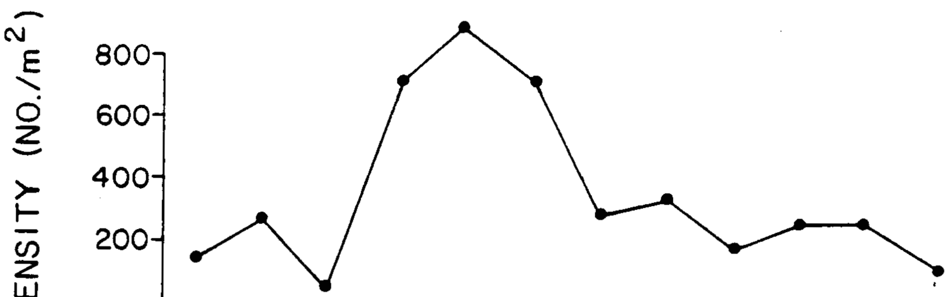
Figure 6-37. Density of Phoronis sp. A at marine stations sampled during the present study. Graph above indicates density for given months averaged over all stations. Graph to the left indicates density for given stations averaged over all months.

brine, populations of Phoronis irrupt in number at station M10A, the site nearest the diffuser. By July densities at station M10A and elsewhere decrease, presumably due to the effects of hypoxia.

The polychaete, Paraprionospio pinnata, increases from 52 individuals m^{-2} in July to a maximum of 973 individuals m^{-2} in September (Figure 6-38). Populations of this species gradually decrease in number, and stabilize at approximately 150 individuals m^{-2} throughout the remainder of the year.

Magelona cf. phyllisae, a burrowing polychaete, is the dominant macrobenthic species during November and December (Table 6-8) when population numbers reach 370 individuals m^{-2}. Though it is not the most abundant species in April 1982, its abundance reaches a maximum that month in the study area (423 individuals m^{-2}). It is among the ten most dominant species every month. The spatial distribution pattern of M. cf. phyllisae is shown in Figures 6-39 and 6-40. There is a general trend of larger populations around the diffuser than at control sites. This distribution pattern is statistically significant during certain months (see section 6.3.5 below).

The most numerically dominant species from January to April 1982 is Cirratulus cf. filiformis, a sedentary polychaete (Table 6-8). Its populations reach 6400 individuals m^{-2} at control site M20 during March 1982, though are only 25 individuals m^{-2} during the same period in 1981 (Figures 6-41 and 6-42). In the study area C. cf. filiformis increases dramatically from October 1981 to March



	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	JAN	FEB	MAR	APR
M10A	203	158	30	270	640	923	923	1175	253	340	337	167
M10	237	218	38	1212	522	483	150	103	85	105	142	50
DS	105	252			395			212			277	
DW	170	195	105	855	642	615	175	293	152	127	183	140
DE	245	207	25	892	1007	797	2188	335	228	347	318	192
DN	70	235			933			230			443	
M6	52	293			1158			412				
M15	155	435			1135			442			320	
M3	145	317	88	853	907	745	240	200	203	322	177	65
M18	178	358	65	187	998	483	185	153	190	370	188	120
M20	88	225			1388	902	128	93	117	165	163	107

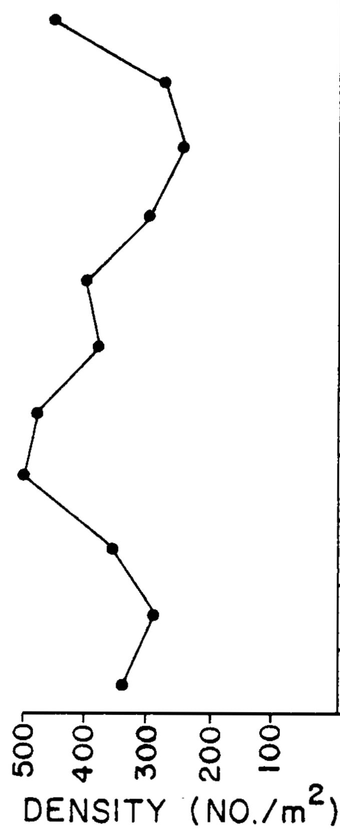


Figure 6-38. Density of Paraprionospio pinnata at marine stations sampled during the present study. Graph above indicates density for given months averaged over all stations. Graph to the left indicates density for given stations averaged over all months.

Magelona cf. *phyllisae*

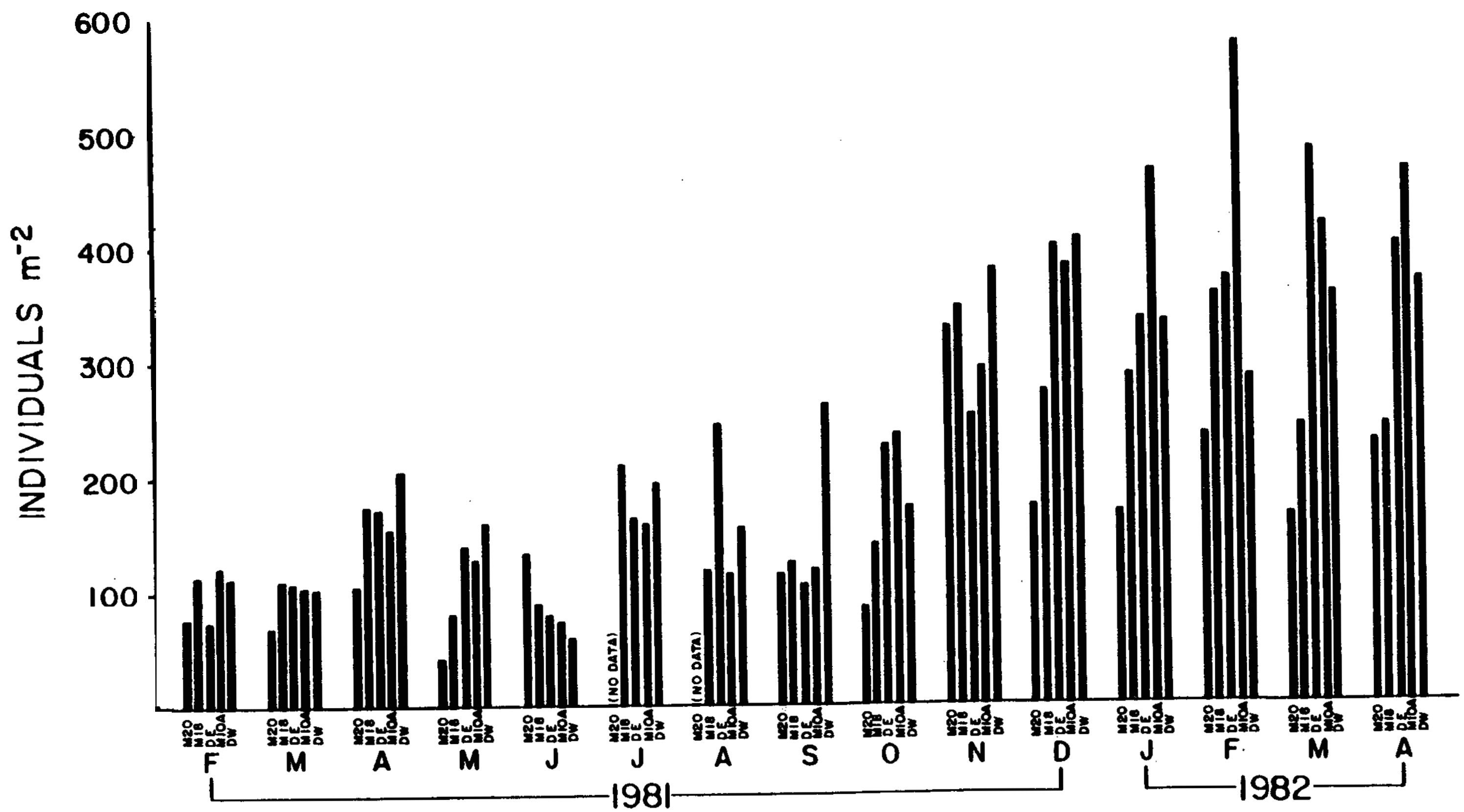
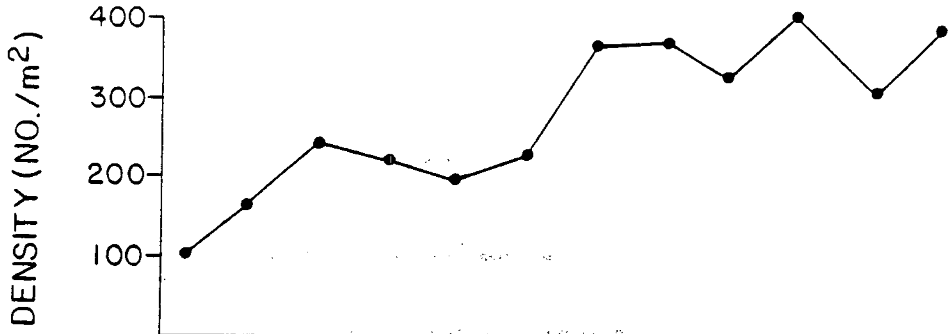


Figure 6-39 Density of *Magelona* cf *phyllisae* throughout the pre- and post-discharge investigations at five selected marine stations.



	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	JAN	FEB	MAR	APR
M10A	123	125	160	117	255	237	295	388	280	578	443	467
M10	162	150	250	282	165	283	435	417	428	357	365	302
DS	65	173			217			472			495	
DW	160	107	195	157	263	173	382	405	207	288	362	370
DE	140	140	163	247	103	225	253	400	337	372	485	400
DN	65	85			105			387			453	
M6	63	140			120			387				
M15	158	290			118			398			438	
M3	63	272	253	202	398	210	545	360	477	662	555	742
M18	83	152	210	118	125	142	348	272	282	358	242	240
M20	45	138			115	87	330	173	167	237	163	228

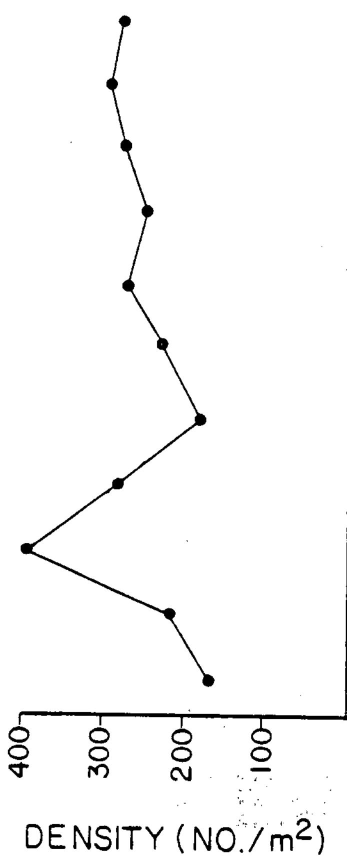


Figure 6-40. Density of Magelona cf. phyllisae at marine stations sampled during the present study. Graph above indicates density for given months averaged over all stations. Graph to the left indicates density for given stations averaged over all months.

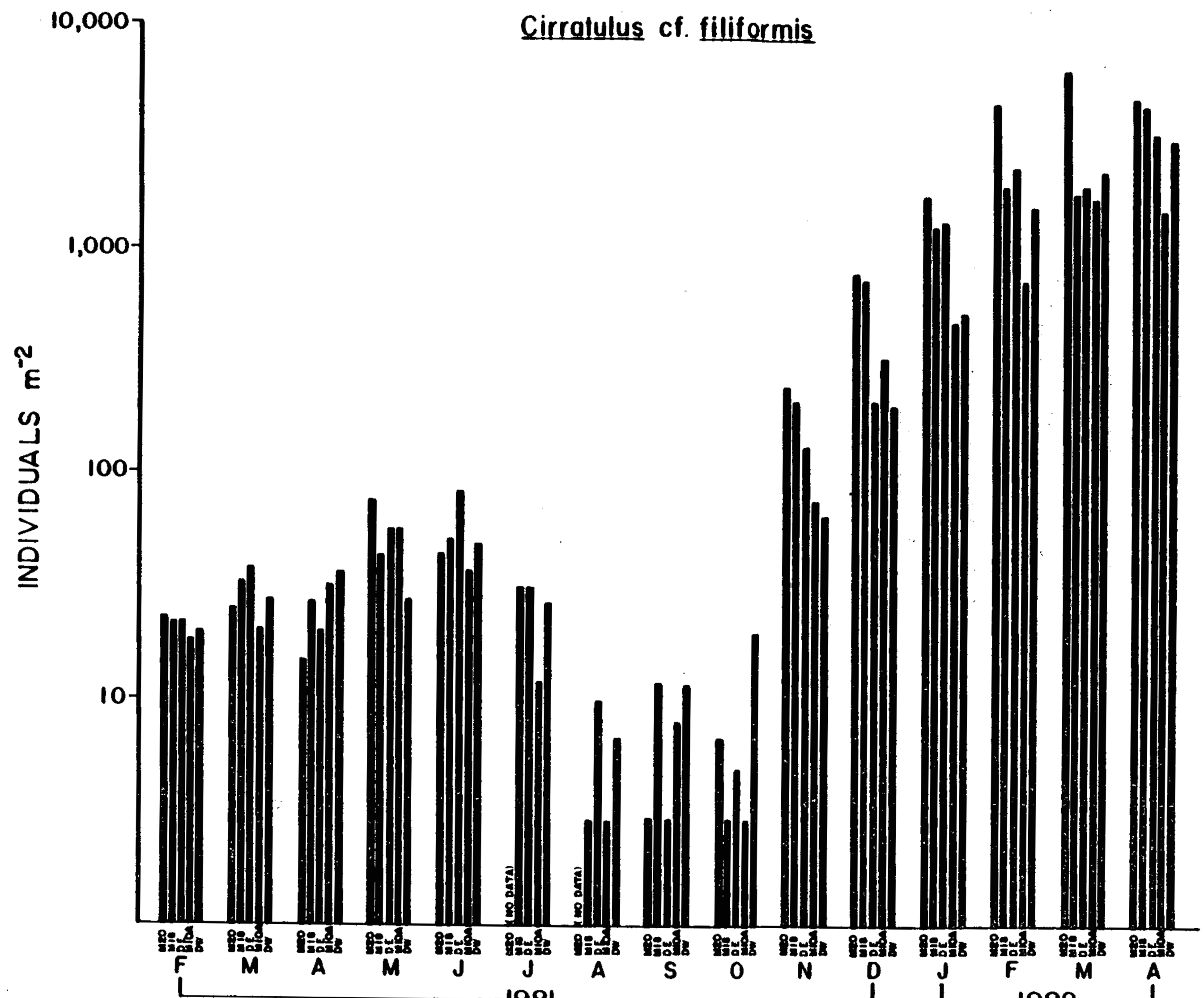
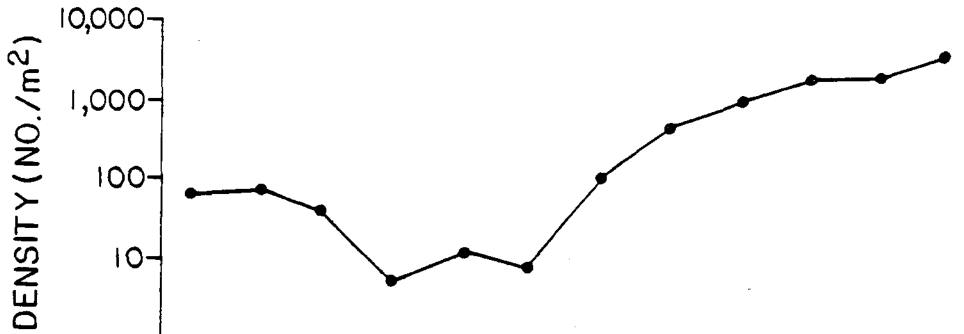


Figure 6-41. Density of Cirratulus cf. filiformis throughout the pre- and post-discharge investigations at five selected marine stations.



	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	JAN	FEB	MAR	APR
M10A	57	38	12	3	8	3	77	303	468	718	1700	1527
M10	72	27	28	3	15	7	15	47	357	182	213	1180
DS	63	68			3			927			3690	
DW	28	48	27	7	12	20	67	203	533	1590	2003	3032
DE	57	85	32	10	3	5	135	213	1352	2345	1955	3632
DN	42	28			15			338			1220	
M6	57	108			7			62				
M15	65	48			10			307			3632	
M3	130	78	150	2	7	2	15	17	177	500	353	2300
M18	43	52	32	3	12	3	208	743	1278	1902	1832	4268
M20	77	45			3	7	247	780	1742	4490	6398	4768

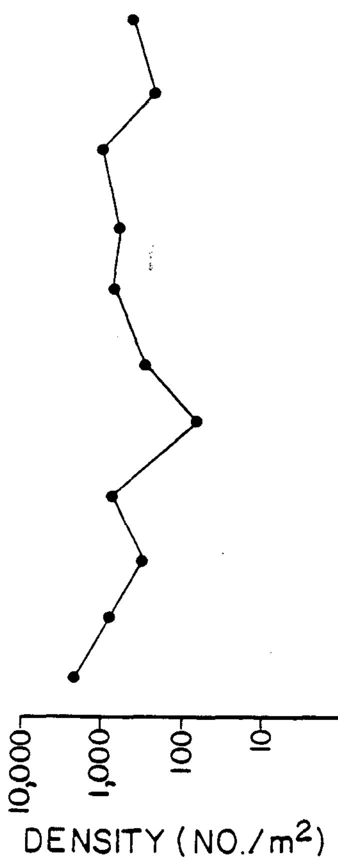


Figure 6-42. Density of Cirratulus cf. filiformis at marine stations sampled during the present study. Graph above indicates density for given months averaged over all stations. Graph to the left indicates density for given stations averaged over all months.

1982 at control sites, and is significantly more abundant there than in near-diffuser sites (see section 6.3.5 below).

Many of the species in the study area are opportunistic species whose life history is adapted to rapid colonization of a habitat. Included among these are the polychaetes, Mediomastus californiensis, Owenia fusiformis, and the phoronid, Phoronis sp. A mentioned above. Spatial and temporal variations in abundance of M. californiensis are shown in Figures 6-43 and 6-44. It is most abundant around the diffuser (station M10A) in June 1981 and February - April 1982, and least abundant during hypoxic conditions of the summer 1981. O. fusiformis is similarly most abundant around the diffuser (Figure 6-45). It is not present in the study area in the three month period before discharge begins, but unlike most species it increases in population numbers during hypoxia. It is among the ten numerical dominants every month after August 1981.

Another of the polychaetes among the dominant species is Pseudeurythoe paucibranchiata. During pre-discharge studies it is more abundant at stations M10A and DW than elsewhere (Figure 6-46, Table 6-8). It is nearly absent from the study area from May to August 1981, then populations increase throughout the fall and winter. The greatest abundances are in January 1982 at station M18, though no consistent distribution patterns persists from month to month.

Nassarius acutus is a gastropod mollusk. It is among the ten most numerically dominant species for only two months, August and September

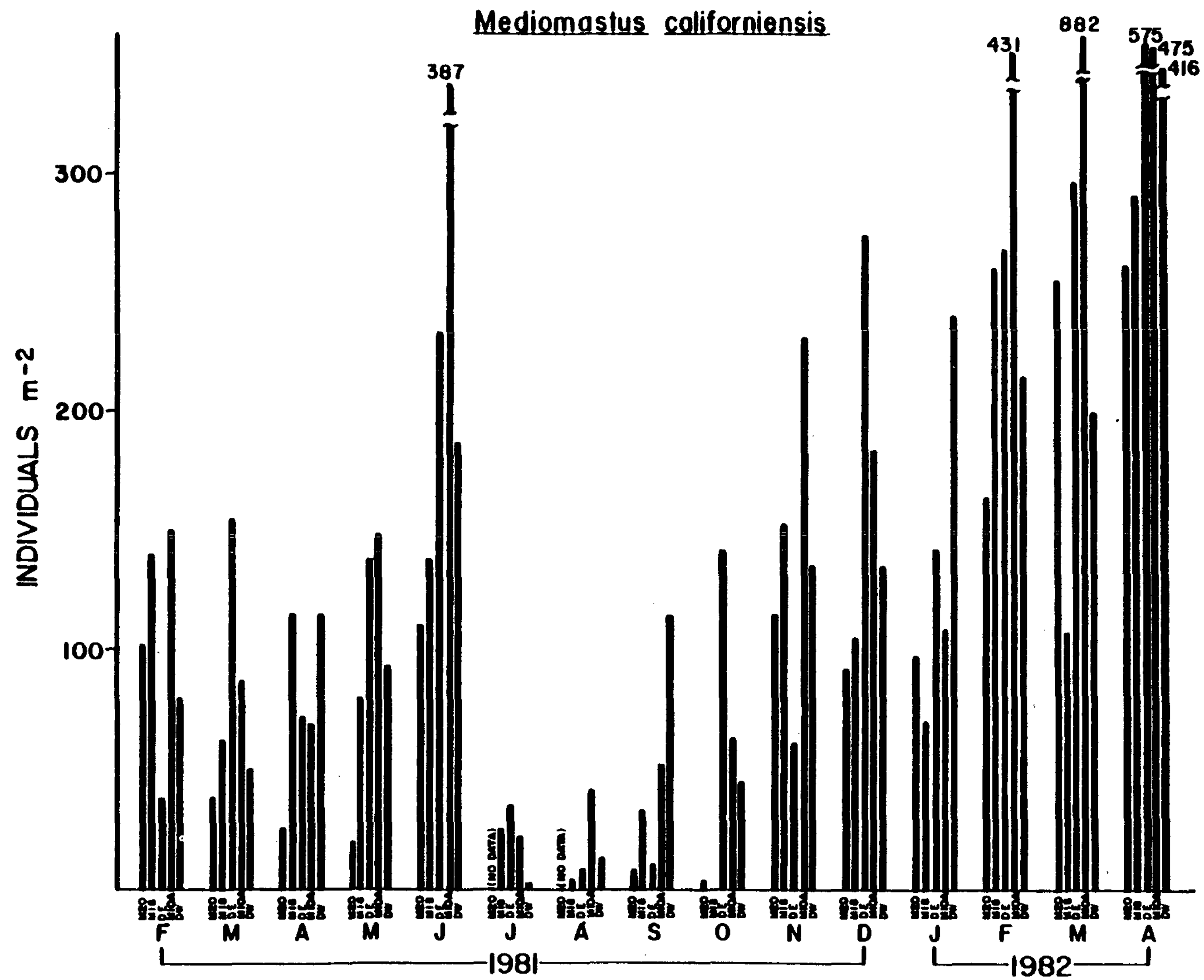
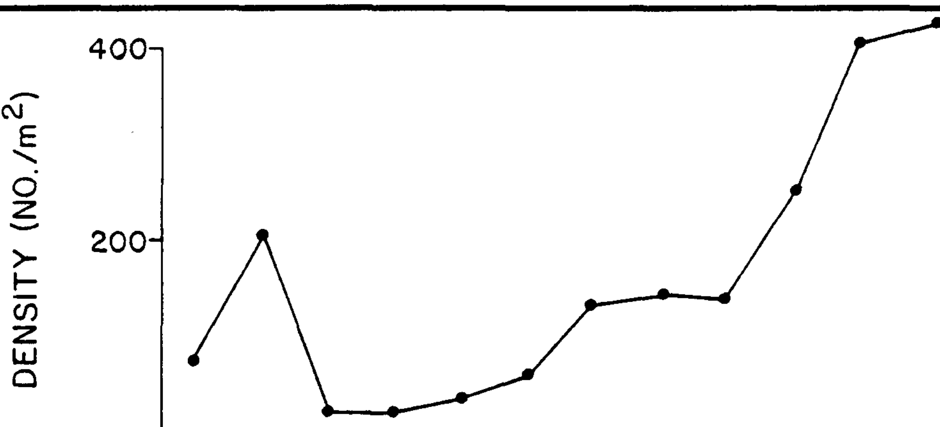


Figure 6-43. Density of Mediomatus californiensis throughout the pre- and post-discharge investigations at five selected marine stations.



	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	JAN	FEB	MAR	APR
M10A	148	387	22	42	52	63	230	183	108	430	882	477
M10	88	260	12	47	48	65	163	140	187	183	568	367
DS	30	65			8			207			400	
DW	93	187	2	13	114	45	135	135	240	215	337	422
DE	138	233	35	8	10	142	62	273	142	268	297	595
DN	42	183			0			168			418	
M6	42	132			10			85				
M15	83	273			10			107			323	
M3	78	310	10	0	62	87	82	105	137	217	383	555
M18	80	140	25	3	33	0	153	105	70	280	107	292
M20	18	110			8	3	115	92	97	168	255	263

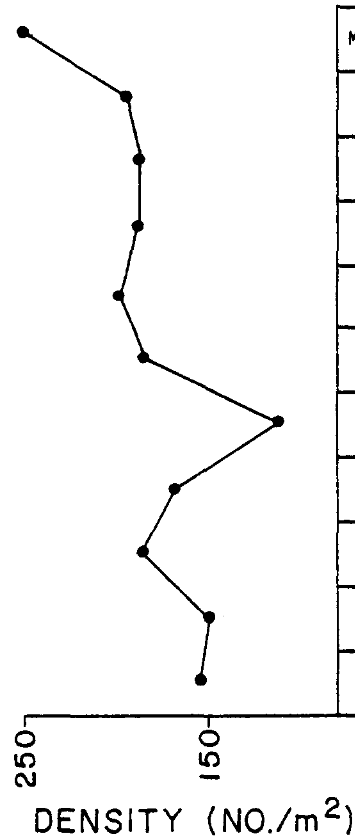


Figure 6-44. Density of Mediomastus californiensis at marine stations sampled during the present study. Graph above indicates density for given months averaged over all stations. Graph to the left indicates density for given stations averaged over all months.

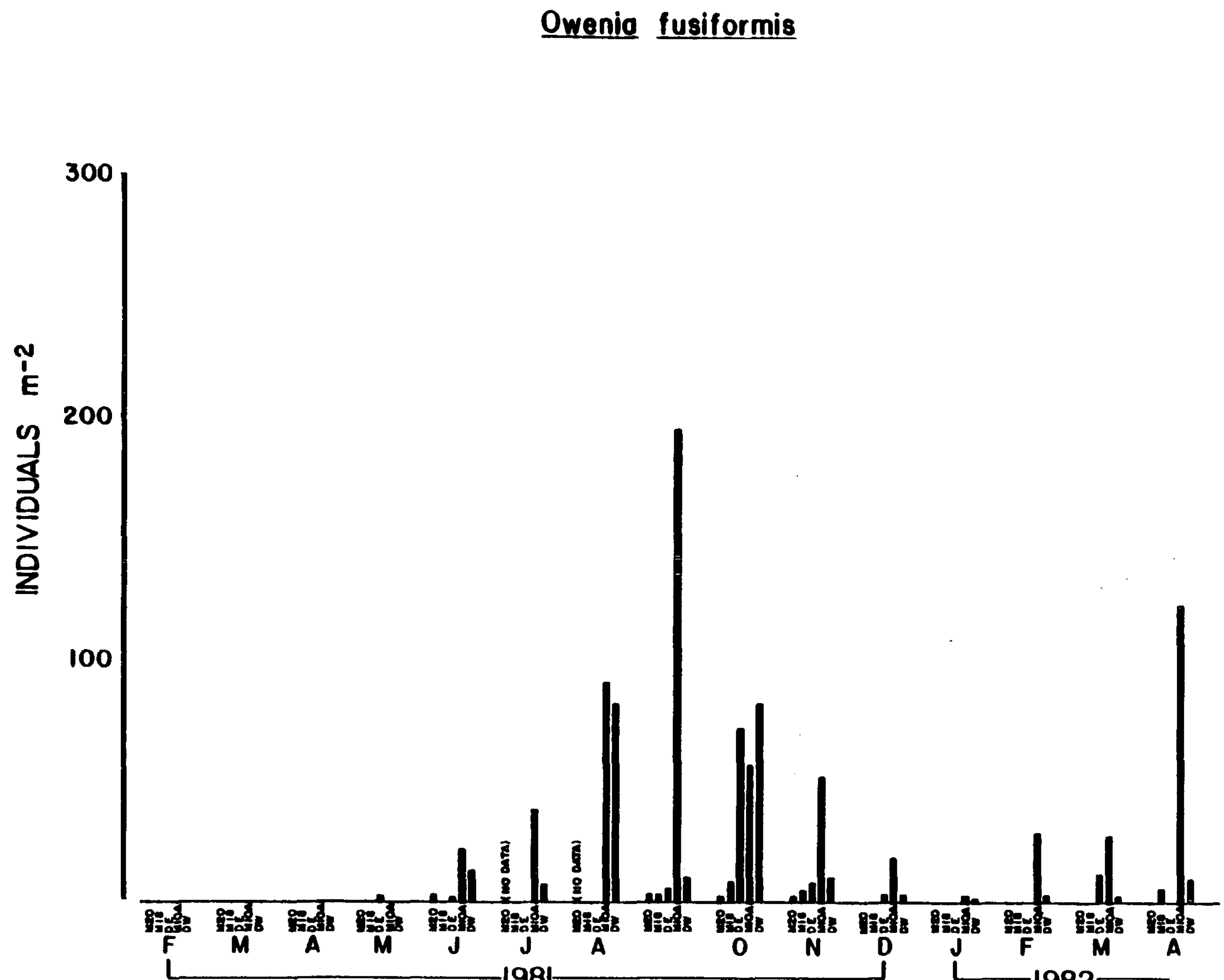


Figure 6-45. Density of Owenia fusiformis throughout the pre- and post-discharge investigations at five selected marine stations.

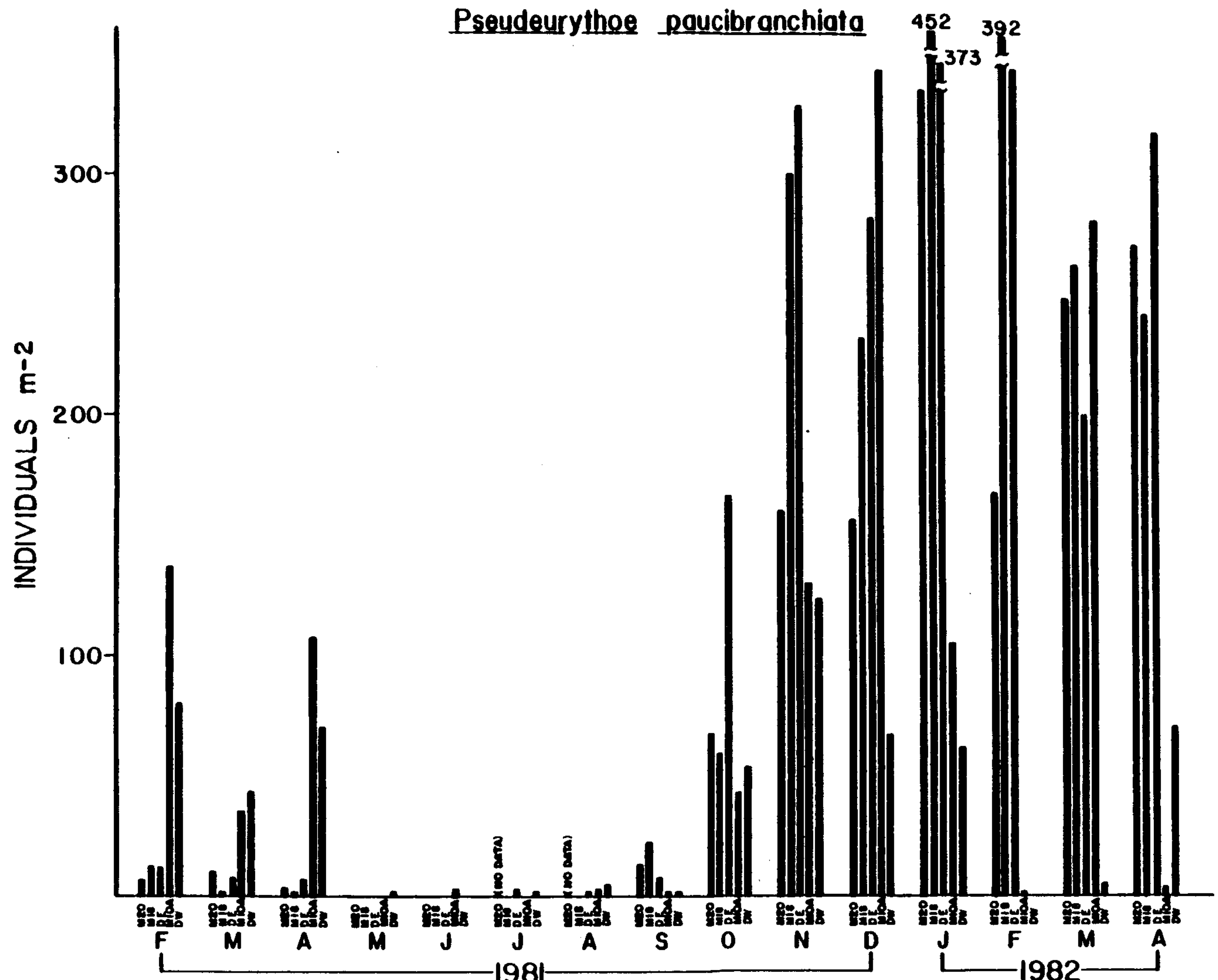


Figure 6-46. Density of Pseudeurythoe paucibranchiata throughout the pre- and post-discharge investigations at five selected marine stations.

(Table 6-8); however, its spatial distribution is noteworthy. *N. acutus* is generally more abundant at the diffuser site (station M10A) than elsewhere (Figure 6-47). This trend is especially pronounced during December when over 300 individuals m^{-2} occur at that site, while populations at other near-diffuser and control sites are below 30 individuals m^2.

The susceptibility of amphipod crustaceans to physiological stress has been demonstrated in recent East Coast investigations (Sanders 1978, Boesch in press). Amphipods are generally poorly represented in the study area (Figure 6-48), however, due in part to the fine texture of the sediments. Nevertheless, they are generally more abundant at the diffuser site (station M10A) than elsewhere during the two months following brine discharge (i.e. May - June 1981). Since the onset of hypoxia in July, very few amphipods have been collected. Population abudances of amphipods in spring 1982 are below those of the same period in 1981.

There are numerous macrobenthic species more commonly collected in the vicinity of the diffuser than elsewhere, but whose abundances are so low or occurrence so sporadic as to preclude rigorous statistical analyses. These species are presented in Figures 6-49 and 6-50. The total number of individuals collected throughout the study area is given (n), and the percentage of this total collected at only stations M10 and M10A is indicated by the shaded areas. The dotted line indicates the percentage of the total individuals expected based on the

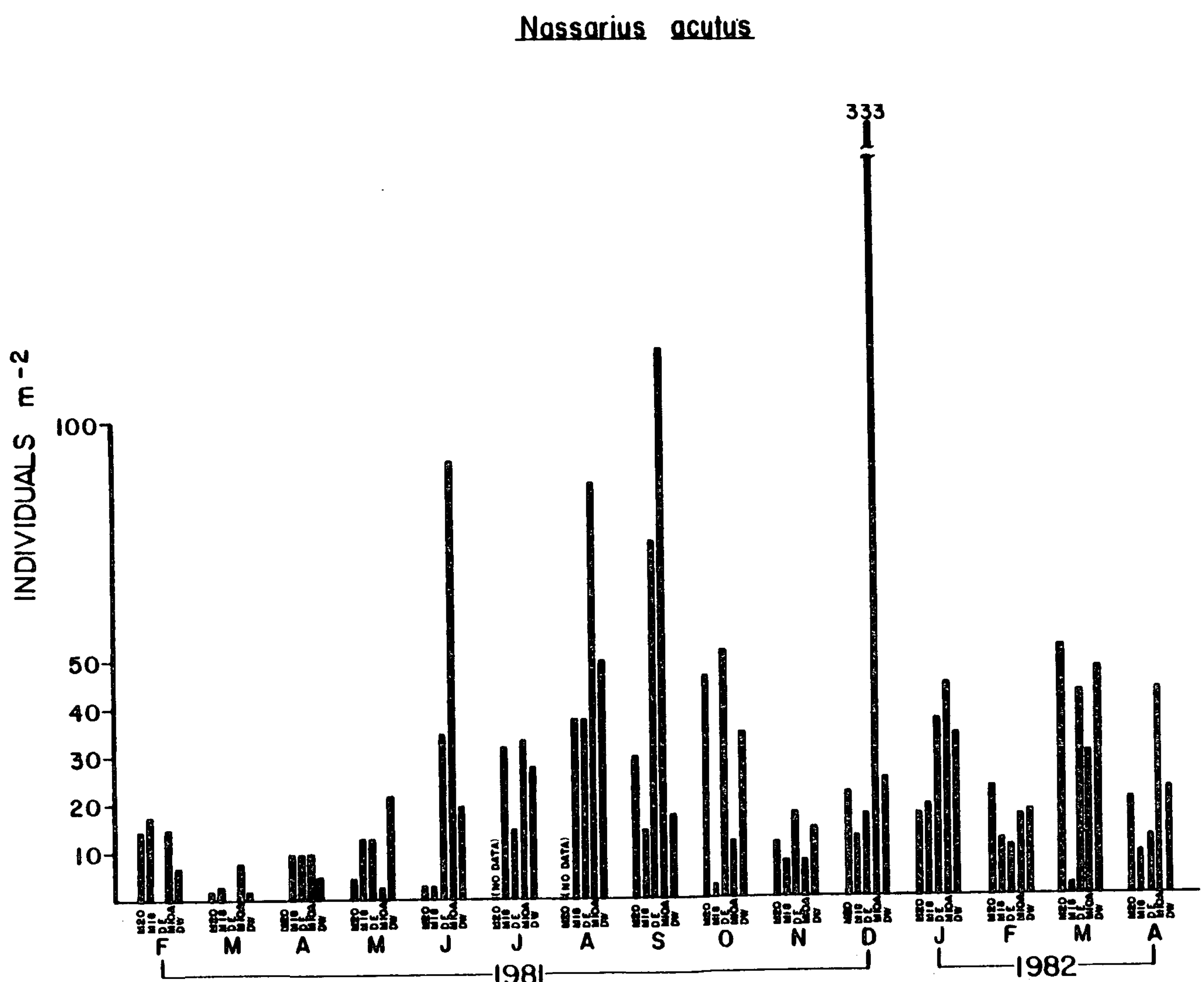


Figure 6-47. Density of Nassarius acutus throughout the pre- and post-discharge investigations at five selected marine stations.

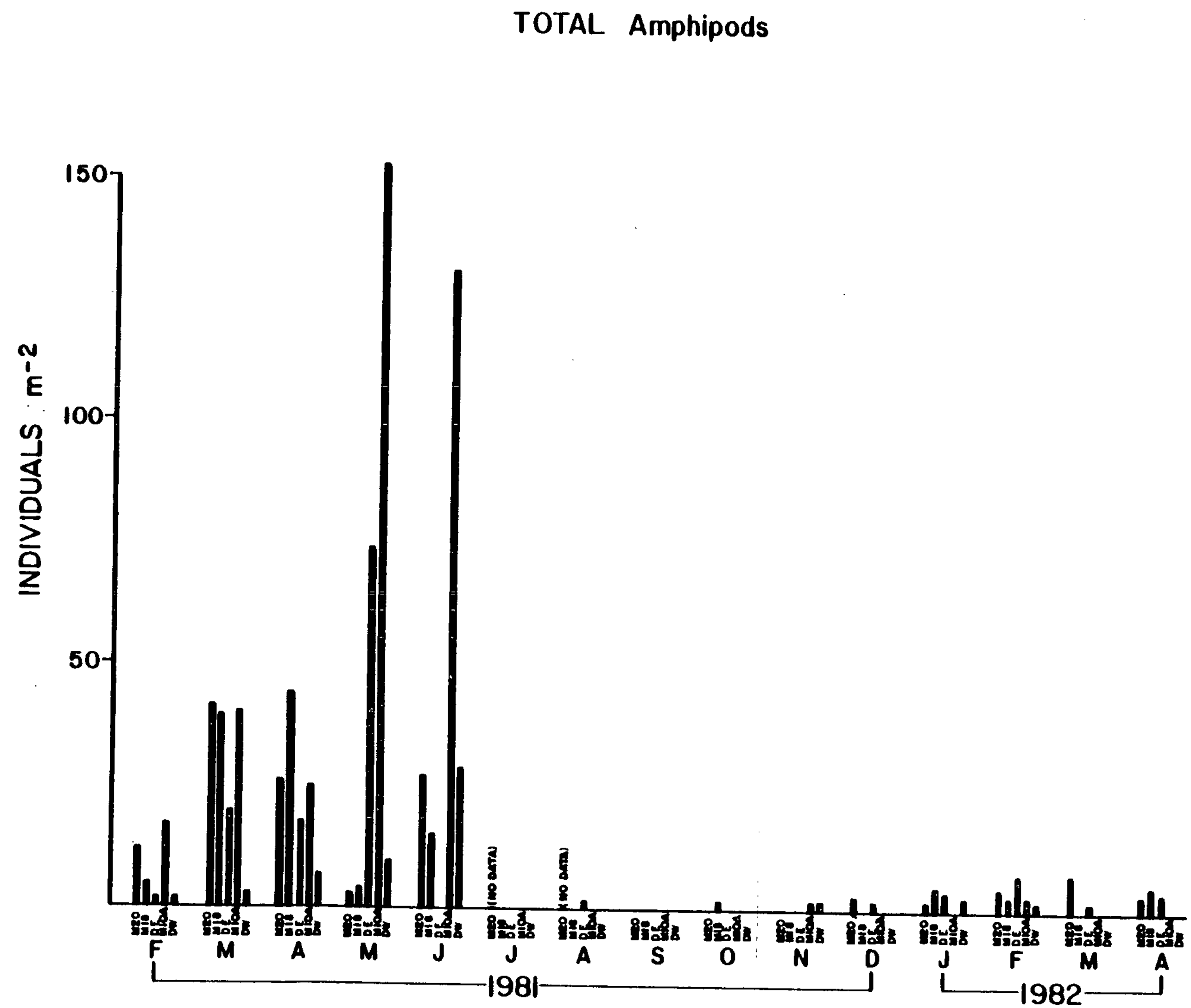


Figure 6-48. Density of amphipod crustaceans throughout the pre- and post-discharge investigations at five selected marine stations.

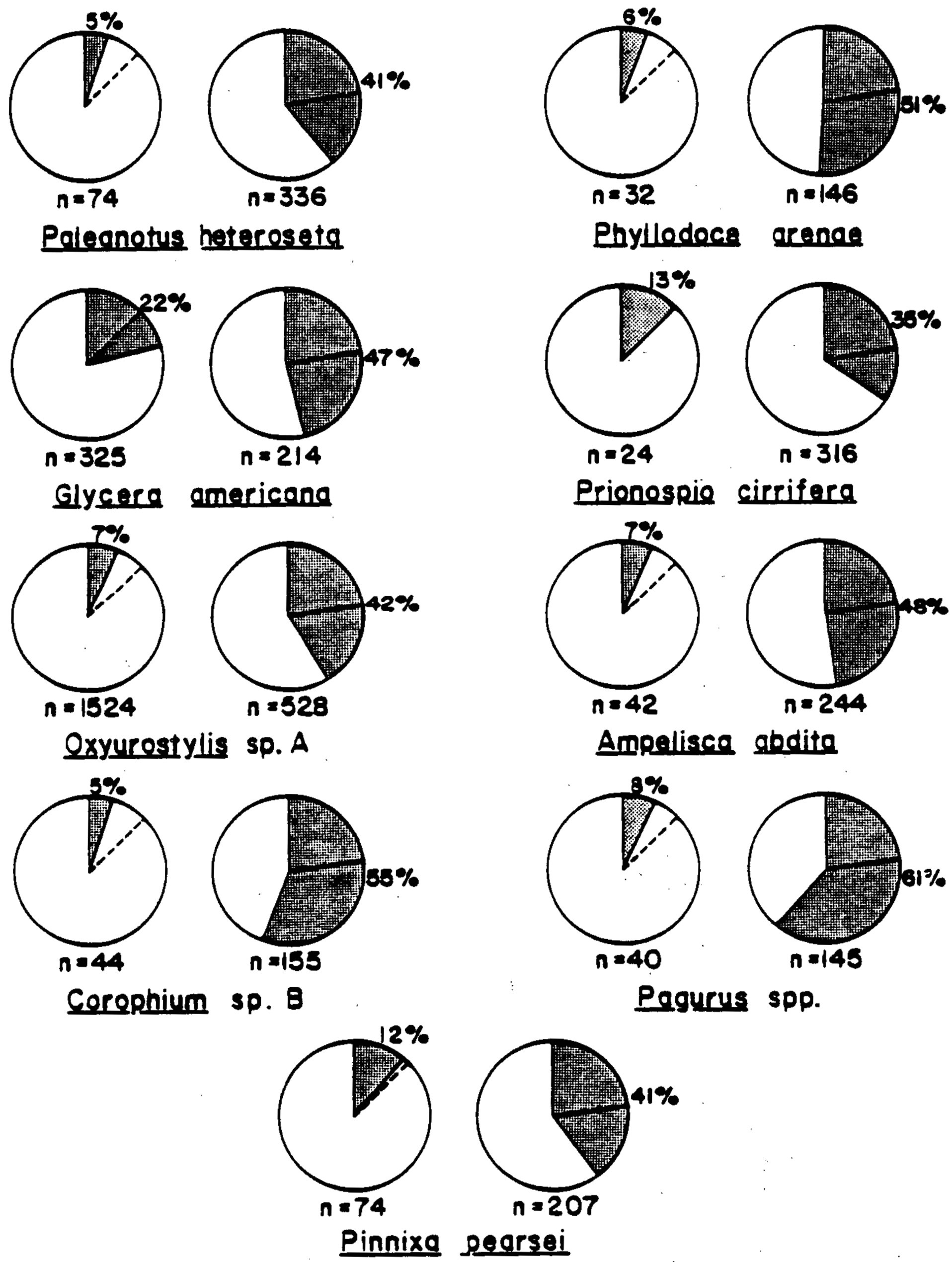


Figure 6-49. Pie diagrams of pre-discharge (left) and post-discharge (right) abundances of selected species. Number of individuals at stations M10 and M10A are expressed as a percentage (shaded area) of the total number of individuals collected in the study area (n). Dashed line indicates the expected percentage of total individuals at M10 and M10A based on the percentage of total samples taken (13% pre-discharge, 24% post-discharge).

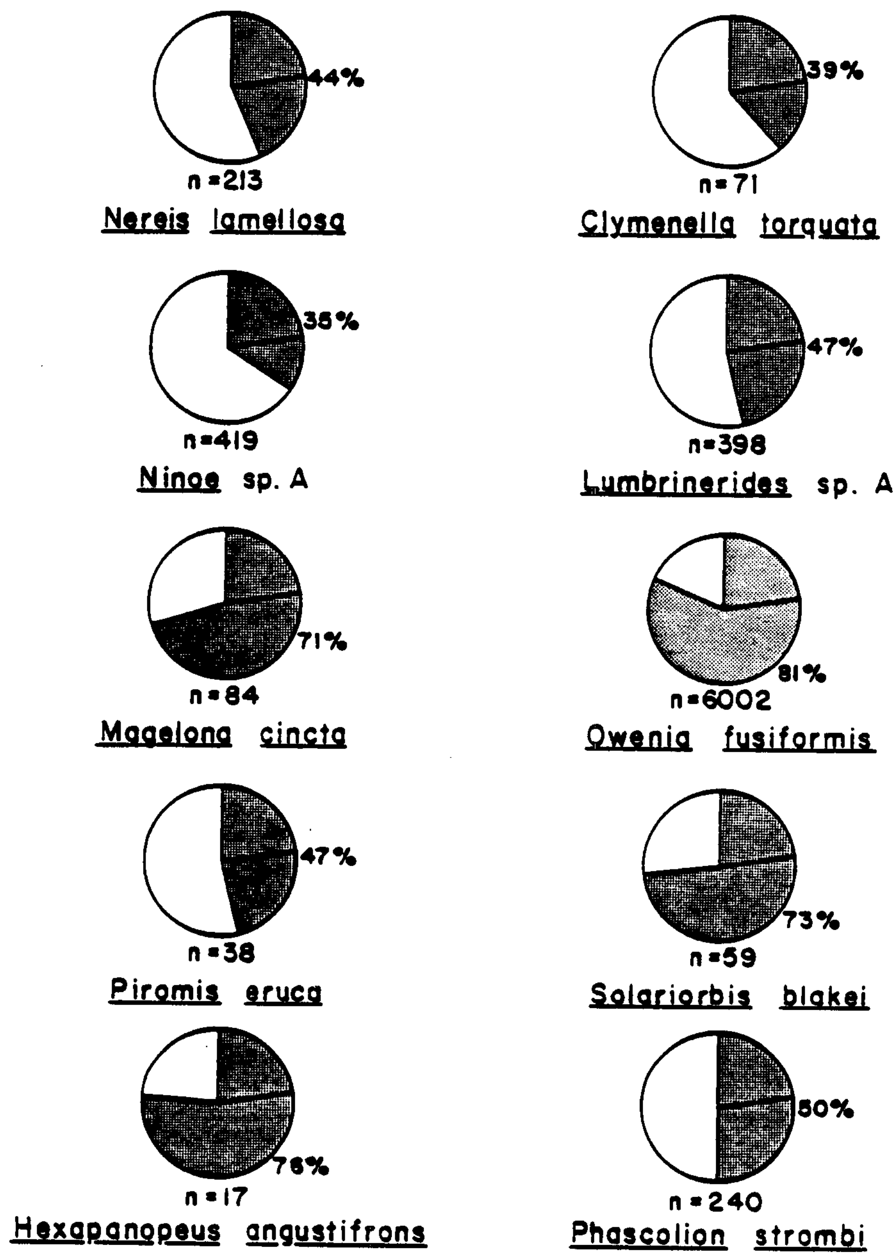


Figure 6-50. Pie diagrams of post-discharge abundances of selected species. Number of individuals at stations M10 and M10A are expressed as a percentage (shaded area) of the total number of individuals collected in the study area (n). Dashed line indicates the expected percentage of total individuals at M10 and M10A based on the percentage of total samples taken (24%).

percentage of the samples taken at only M10 and M10A in proportion to the total number of samples collected. For example, since 13% of the total samples collected during the pre-discharge period are collected at stations M10 and M10A, one would expect 13% of the total individuals to be collected at these sites. The same applies to the post-dicharge period during which 24% of the total samples are taken at M10 and M10A. Pre-discharge results are presented for comparison with post-discharge data in Figure 6-49. These data are based only on sampling sites in common between pre- and post-discharge, and thus M1, M9, M11 and CS are excluded from the pre-discharge calculation. Figure 6-50 includes only post-dicharge data as these species were absent or extremely rare during the pre-discharge period.

During the pre-discharge period, observed abundances of these species depart less than 9 percentage points from the expected densities. During post-discharge sampling, all these species show unexpectedly high densities in the immediate vicinity of the diffuser, in some cases exceeding three times the anticipated densities. Some of the species which show this most dramatically are virtually absent in the study area during pre-discharge sampling (e.g. Magelona cincta, Owenia fusiformis, Solariorbis blakei, and Hexapanopeus angustifrons).

6.3.4.2 Estuarine

Five estuarine sampling sites are occupied monthly during this study. These represent diverse habitat types from throughout the estuary, ranging from low salinity up-estuary sites (stations E1, E2) to a high salinity site at the mouth of Calcasieu Lake (station E5). Due to the uniqueness of each site (i.e. each community), the five sites are discussed independently. Spatial variations in distribution of estuarine species are not included in this analysis since the sampling sites do not represent complete gradient of habitats in the estuary. Temporal variations are discussed by site.

Station E1 is located at the water intake site in the Intracoastal Waterway. A single species, Mediomastus californiensis, comprises 38.8% of the macrobenthic organisms during the 12-month study period (Table 6-9). Streblospio benedicti, oligochaetes, and three nemerteans contribute an additional 43.5% of the total individuals. Paraprionospio pinnata is the only other species ever collected in abundance at station E1. The community is generally species depauperate, and has the lowest number of individuals of any estuarine site.

Most of the dominant species present at station E1 vary erratically in abundance (Table 6-10). Mediomastus californiensis is most abundant in February, but least abundant in March. Streblospio benedicti is most abundant in June and least abundant in July and March. Such variations in abundance may indicate station location or methodological errors, however, station E1 is located adjacent to a concrete bulkhead at the freshwater intake site, minimizing station relocation problems. Therefore, these dramatic population fluctuations are actual events, though it is not clear whether they are naturally

Table 6-9. Numerically dominant estuarine species and their percentage of the benthic community over 12 months. (A = Amphipod, An = Anthozoan, B = Barnacle, I = Isopod, M = Mollusk, My = Mysidacean, N = Nemertean, P = Polychaete, Ph = Phoronid)

	percentage of total individuals	cumulative percent
STATION E1		
Mediomastus californiensis (P)	38.8	38.8
Streblospio benedicti (P)	15.8	54.6
Oligochaeta	8.8	63.4
Nemertea sp. B (N)	8.1	71.5
Nemertea sp. D (N)	7.8	79.3
Nemertea sp. G (N)	3.1	82.3
Paraprionospio pinnata (P)	2.2	84.6
Parandalia fauveli (P)	2.1	86.7
Edotea triloba (I)	1.7	88.3
Rhynchocoela	1.4	89.8
STATION E2		
Mediomastus californiensis (P)	34.2	34.2
Mulinia lateralis (M)	12.1	46.3
Cerapus benthophilus (A)	7.3	53.6
Parandalia fauveli (P)	7.0	60.6
Streblospio benedicti (P)	6.1	66.7
Glycinde solitaria (P)	4.4	71.1
Nereis succinea (P)	4.2	75.3
Paraprionospio pinnata (P)	4.1	79.4
Balanus improvisus (B)	3.7	83.0
Macoma mitchelli (M)	2.0	85.0
STATION E3		
Mediomastus californiensis (P)	34.9	34.9
Paraprionospio pinnata (P)	18.1	53.0
Glycinde solitaria (P)	9.0	61.9
Mulinia lateralis (M)	9.0	70.9
Macoma mitchelli (M)	4.3	75.3
Streblospio benedicti (P)	4.2	79.4
Cossura delta (P)	3.7	83.1
Parandalia fauveli (P)	2.5	85.6
Mysidopsis almyra (My)	2.1	87.7
Nemertea sp. B (N)	2.0	89.7

Table 6-9. continued

	percentage of total individuals	cumulative percent
STATION E4		
Mediomastus californiensis (P)	27.2	27.2
Mulinia lateralis (M)	18.8	45.9
Paraprionospio pinnata (P)	15.6	61.5
Balanus improvisus (B)	5.8	67.3
Streblospio benedicti (P)	5.6	72.9
Glycinde solitaria (P)	5.3	78.2
Macoma mitchelli (M)	3.2	81.4
Parandalia fauveli (P)	3.1	84.5
Nemertea sp. G (N)	2.9	87.4
Pseudeurythoe paucibranchiata (P)	2.3	89.7
STATION E5		
Phoronis sp. A (Ph)	51.1	51.1
Mediomastus californiensis (P)	7.7	58.8
Mulinia lateralis (M)	6.2	65.0
Parandalia fauveli (P)	4.6	69.5
Paraprionospio pinnata (P)	4.3	73.8
Anthozoan sp. B (An)	4.2	78.0
Nemertea sp. D (N)	4.0	82.0
Streblospio benedicti (P)	3.0	85.0
Cossura delta (P)	1.8	86.9
Spiochaetopterus oculatus (P)	1.6	88.4

Table 6-10. Monthly abundance values (individuals m^{-2}) of numerically dominant species collected at station E1.

	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	JAN	FEB	MAR	APR
Mediomastus californiensis	342	152	208	104	20	132	292	388	NO DATA COLLECTED	1188	4	940
Streblospio benedicti	436	344	4	16	64	136	80	56		216	4	176
Oligochaeta	172	24	52	48	28	216	140	76		60	36	0
Nemertea sp. B	4	0	0	0	0	0	0	20		56	40	664
Nemertea sp. D	204	92	8	0	32	144	180	0		80	0	8
Nemertea sp. G	0	28	164	100	4	0	0	0		0	0	0
Paraprionospio pinnata	184	0	0	0	8	0	0	0		4	0	20
Parandalia fauveli	4	8	8	32	20	32	16	40		16	0	28
Edotea triloba	12	28	0	8	24	12	16	20		28	12	0

occurring or due to some aspect of freshwater withdrawal operations such as sediment scouring.

Station E2 is located in the upper part of Calcasieu Lake. It is numerically dominated by the capitellid polychaete, Mediomastus californiensis and the bivalve, Mulinia lateralis which contribute 46.3% of the total individuals collected at E2 (Table 6-11). The amphipod, Cerapus benthophilus, is not in abundance at E2 most of the year, but irrupted in abundance in November. No other species are abundant during the year. The dominant species are generally in least abundance during summer months and greatest abundance during the fall and winter.

Station E3, located in the West Cove area of lower Calcasieu Lake is also numerically dominated by Mediomastus californiensis. Three polychaetes, M. californiensis, Paraprionospio pinnata, and Glycinde solitaria, and the bivalve, Mulinia lateralis, contribute 71% of the macrobenthos (Table 6-12). All are most abundant from February to June, and least abundant during August or September (Table 6-12).

Station E4 is located near oyster reefs in lower Calcasieu Lake. Relative abundances are more evenly distributed among the species at E4 than at other estuarine stations (see section 6.3.3.2 above) as evidenced by the percentage composition of dominant species in Table 6-13. Mediomastus californiensis, Mulinia lateralis, and Paraprionospio pinnata are the most numerically abundant species. Like station E3, all are generally most abundant from February to June, though

Table 6-11. Monthly abundance values (individuals m^{-2}) of numerically dominant species collected at station E2.

	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	JAN	FEB	MAR	APR
Mediomastus californiensis	484	184	504	60	92	360	268	1564	NO DATA COLLECTED	1844	1872	112
Mulinia lateralis	964	12	32	8	76	8	24	32		432	568	432
Cerapus benthophilus	12	0	12	48	24	84	1228	24		112	12	4
Parandalia fauveli	16	36	104	28	28	132	140	316		216	276	208
Streblospio benedicti	92	224	64	20	28	44	372	372		396	56	0
Glycinde solitaria	8	0	0	8	64	224	88	220		132	164	32
Nereis succinea	8	84	20	20	100	28	468	12		0	8	144
Paraprionospio pinnata	92	16	212	0	24	216	148	132		28	12	0
Balanus improvisus	224	24	32	0	48	40	44	0		36	72	264

Table 6-12. Monthly abundance values (individual m^{-2}) of numerically dominant species collected at station E3.

	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	JAN	FEB	MAR	APR
Mediomastus californiensis	416	264	208	168	84	152	96	160	NO DATA COLLECTED	616	320	204
Paraprionospio pinnata	92	280	212	60	96	140	236	76		108	100	100
Glycinde solitaria	188	36	16	8	28	32	36	44		116	76	76
Mulinia lateralis	116	40	16	16	4	0	4	316		216	276	208
Macoma mitchelli	176	72	0	4	0	4	0	0		8	32	12
Streblospio benedicti	16	52	8	32	8	28	4	4		132	20	0
Cossura delta	4	4	0	0	16	16	8	48		52	72	40
Parandalia fauveli	36	8	4	0	4	4	28	36		4	36	20
Mysidopsis almyra	0	0	16	12	112	12	8	4		0	0	4
Nemertea sp. B	0	8	12	0	0	12	4	4		40	48	24

Table 6-13. Monthly abundance values (individuals m^{-2}) of numerically dominant species collected at station E4.

	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	JAN	FEB	MAR	APR
Mediomastus californiensis	856	400	992	492	192	76	384	84	NO DATA COLLECTED	740	84	140
Mulinia lateralis	500	96	40	4	12	0	100	20		1388	400	508
Paraprionospio pinnata	400	232	308	132	168	172	200	260		228	148	140
Balanus improvisus	944	0	0	0	0	0	0	0		0	0	0
Streblospio benedicti	20	300	280	40	132	20	28	12		64	4	16
Glycinde solitaria	144	64	12	4	56	84	44	60		132	92	180
Macoma mitchelli	0	4	72	8	12	0	0	8		144	140	136
Parandalia fauveli	16	232	36	20	48	44	24	12		36	8	28
Nemertea sp. G	4	0	312	148	12	0	0	0		0	0	0
Pseudeurythoe paucibranchiata	36	0	4	20	48	442	8	112		28	28	48

populations of *M. californiensis* reach a maximum in July (Table 6-13). Several species (*Mulinia lateralis*, *Balanus improvisus* and *Parandalia fauveli*) are periodically collected in abundance. For *B. improvisus* this results from sporadic collection of hard substrate (i.e. oysters), but the abundance of the other species most likely reflects population increases (*M. lateralis*) and patchy distribution (*Parandalia fauveli*).

Station E5, located at the mouth of Calcasieu Lake, is numerically dominated by the phoronid *Phoronis* sp. A (Table 6-14). The overwhelming abundance of *Phoronis* from May to August (x = 3188 individuals m^{-2}) is nearly a degree of magnitude greater than the abundance of any other species collected at station E5. The next most numerically dominant species are *Mediomastus californiensis* and *Mulinia lateralis*, both among the dominant species at other estuarine sites.

6.3.5 Matched site comparisons

The optimal study design for detection of impact from an operation such as brine discharge requires controls over both space and time (Green, 1979). While pre-discharge studies were conducted, their application as a temporal control is limited by their brief duration (three months) and the extreme temporal variability of the study area. In this instance, the spatial control provided by comparison of impacted vs non-impacted sites during a given time frame is of much greater value in impact detection. Given control and potentially impacted sites that are similar with respect to all relevant biological and environmental variables (matched sites), any biological change

Table 6-14. Monthly abundance values (individuals m^{-2}) of numerically dominant species collected at station E5.

	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	JAN	FEB	MAR	APR
Phoronis sp. A	2300	3650	3600	3200	480	54	0	6	22	14	56	172
Mediomastus californiensis	42	74	118	62	16	12	10	202	80	376	646	396
Mulinia lateralis	2	34	494	174	40	14	0	4	48	568	248	18
Parandalia fauveli	16	14	84	56	116	96	12	206	156	236	116	106
Paraprionospio pinnata	14	38	12	16	20	2	412	308	62	82	84	90
Anthozoan sp. B	0	0	20	14	26	6	0	0	6	176	322	518
Nemertea sp. D	42	38	62	114	172	2	82	82	46	100	136	194
Streblospio benedicti	0	10	674	0	12	6	4	0	0	10	32	50
Cossura delta	0	16	118	36	0	0	64	106	8	2	0	128
Spiochaetopterus oculatus	38	72	64	36	24	10	4	44	48	40	18	40

beyond the level of natural environmental variation, which occurs only at the potentially-impacted site and not at the control site, can be inferred to be an impact-related change.

In this analysis, stations M10A, located at the mid-point of the diffuser, and DW, located 0.9 km to the west of M10A in the direction of predominant current flow, are chosen as those sites most likely to show an impact from diffuser operations. Stations M18 and M20, located 3.7 and 9.3 km to the east of the diffuser, the direction of least frequent current flow, are chosen as the control sites. The use of duplicate control and potentially- impact sites is advantageous in that it minimizes the potential for natural variability being attributed to impact effects. A biological change must be observable at both of the impact sites and absent at both control sites in order to establish, with a high degree of certainty, the change as impact-induced.

During the three month pre-discharge sampling period, the comparability of these sites with respect to all relevant biological and physical variables was well established. During pre-discharge studies, temperature differences between these sites never exceeded 0.3°C, salinity differences were never greater than $0.4^{0}/oo$, and dissolved oxygen measurements were always within 0.3 ml l^{-1} (Weston and Gaston, 1982). Greater differences in physical parameters were observed between these stations during post-discharge studies but as discussed in Section 6.3.2.1, these differences are largely attributable to the brine effluent. Sediment type also is generally comparable between these sites as previously illustrated in Figure 6-9. There is 6% more sand at station M20 than at either M18, DW or M10A but this difference does not appear to be biologically significant. Further evidence of the comparability in sediment type is presented in Figure 6-51. The cumulative frequency curves of stations M10A, DW, and M18 (averaged over all sampling periods and replicates) are virtually identical. The slightly coarser sediments at M20 are evident but this difference is smaller than often found among replicates (refer to Figure 6-10).

With respect to biological similarity, the suitability of these stations for matched site comparisons was established during pre-discharge studies. During this period, no consistent difference among these stations was noted in the distribution of any dominant species. Some differences in the number of species and individuals was noted with station M20 commonly the lowest in both parameters and station M10A frequently among the highest.

Matched site comparisons are performed on post-discharge data in the following three categories: 1) number of species, 2) total macrofaunal density, and 3) selected dominant species. In all cases comparisons are first made within control sites and within impact sites before performing any control/impact comparisons.

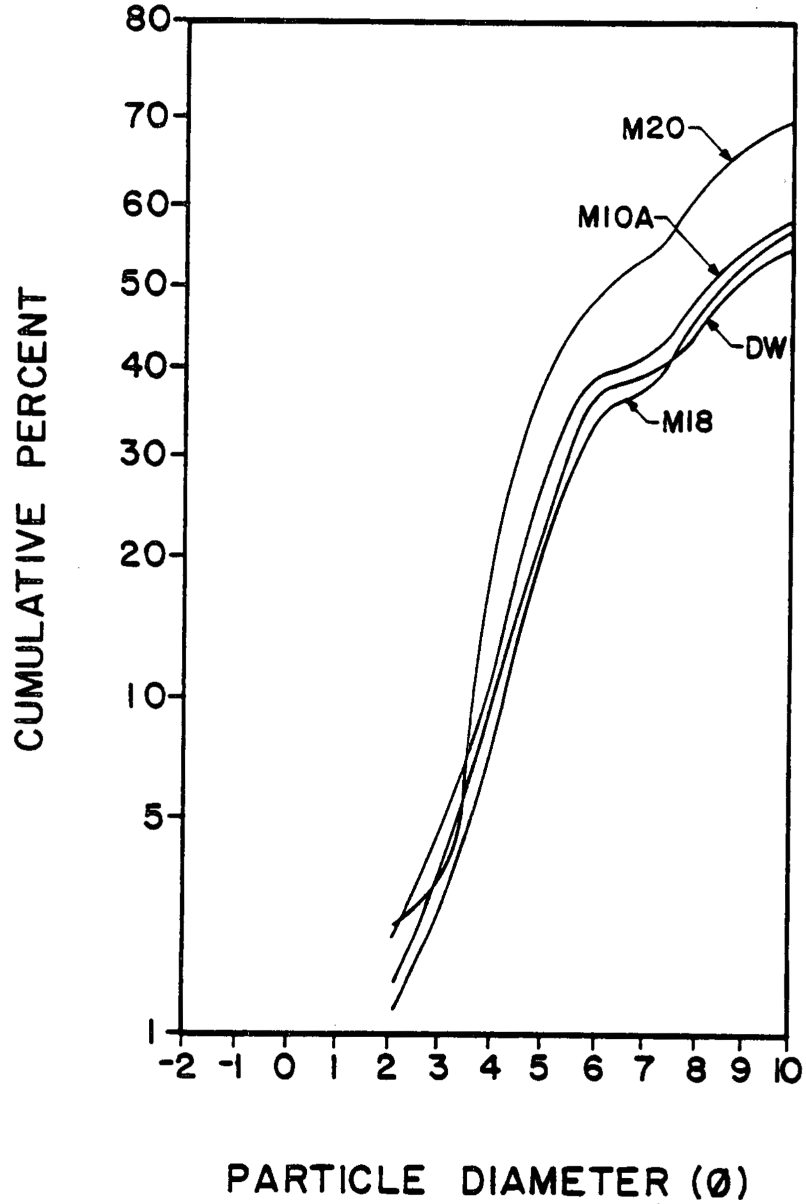


Figure 6-51. Cumulative size-frequency curves of sediment grain size for stations used in the matched site comparisons (M20, M18, DW, M10A). Data presented represent grand means over all replicates and sampling periods.

6.3.5.1 Number of species

The number of species at control sites M18 and M20 is compared to that at impact sites DW and M10A using Wilcoxon's signed-ranks test. This test considers both the magnitude and direction of the differences within pairs. Consequently, any difference in the number of species between control and impact sites must be consistent in direction throughout the study period to be considered significant.

The results of this analysis are presented in Table 6-15. Comparisons between the two impact sites and between the two control sites show no significant differences in number of species. However, the number of species at the impact sites are significantly greater ($\alpha < .01$) than the number of species at the control sites. This difference is consistent throughout the post-discharge period but may not result from discharge as it is evident in pre-discharge data as well.

6.3.5.2 Total macrofaunal density

Using the same statistical procedures as for number of species, the total macrofaunal density at control sites is compared against that of the impact sites (Table 6-16). No statistically significant differences are evident either among the impact sites, among the control sites, or between the impact and control sites.

6.3.5.3 Selected dominant species

Species chosen for analysis are selected from the dominant species during each monthly collection (Table 6-8). A score of 10 points is awarded to the dominant species in each month, and less numerous

Table 6-15. Number of species collected in six replicate grabs at selected matched sites, and results of Wilcoxon's signed-ranks test performed on 5/81 - 4/82 data.

	IMPACT SITES			CONTROL SITES		
	DW	M10A	$\bar{x}$	M18	M20	$\bar{x}$
2/81	43	53	48	35	41	38
3/81	42	49	45.5	46	41	43.5
4/81	55	50	52.5	49	39	44
5/81	59	58	58.5	46	46	46
6/81	66	76	71	41	50	45.5
7/81	28	34	31	28	--	28
8/81	40	53	46.5	25	--	25
9/81	39	38	38.5	35	32	33.5
10/81	53	47	50	39	42	40.5
11/81	44	49	46.5	48	47	47.5
12/81	49	47	48	43	37	40
1/82	42	49	45.5	47	47	47
2/82	49	52	50.5	54	47	50.5
3/82	53	47	50	39	55	47
4/82	49	53	51	52	48	50

Wilcoxon's signed-ranks test:
Impact (DW) vs. Impact (M10A): non-significant
Control (M18) vs. Control (M20): non-significant
Impact ($\bar{x}$ - DW, M10A) vs. Control ($\bar{x}$ - M18, M20): significant, $\alpha < .01$

Table 6-16. Total macrofaunal density (individuals m^{-2}) at selected matched sites, and results of Wilcoxon's signed-ranks test performed on 5/81 - 4/82 data.

	IMPACT SITES			CONTROL SITES		
	DW	M10A	$\overline{x}$	M18	M20	$\overline{x}$
2/81	3600	3450	3525	1840	2810	2325
3/81	3490	5460	4475	4150	3530	3840
4/81	4800	4690	4745	4220	2440	3330
5/81	4520	4980	4750	3140	1410	2275
6/81	3300	1300	2300	4190	2740	3465
7/81	2780	1020	1900	2150	--	2150
8/81	2040	1350	1695	670	--	670
9/81	1710	2050	1880	1680	2010	1845
10/81	1830	2040	1935	1380	1720	1550
11/81	1510	2520	2015	1940	1770	1855
12/81	1760	3260	2510	2080	1830	1955
1/82	1980	1960	1970	2740	2910	2825
2/82	2900	2850	2875	5400	7600	6500
3/82	3940	4740	4340	3210	8840	6025
4/82	2910	2350	2630	3530	3860	3695

Wilcoxon's signed-ranks test:
Impact (DW) vs. Impact (M10A): non-significant
Control (M18) vs. Control (M20): non-significant
Impact ($\overline{x}$ - DW, M10A) vs. Control ($\overline{x}$ - M18, M20): nonsignificant

species are given successively lower scores. The overall dominance ranking is then determined by summing the twelve monthly scores. The resultant ranking is presented in Table 6-17 and the top five species chosen for subsequent analysis.

The abundance of selected dominant species at control and impact sites is analyzed using the Mann-Whitney U test. This nonparametric test is used to test whether two independent groups have been drawn from the same parent population. Though it does not require the same assumptions to be met as its parametric equivalent, the t test, its power to reject the null hypothesis is nearly as great (Siegel, 1956). Comparisons are first made between the two control stations, treating each set of six replicates as an independent group. Only if this comparison reveals no significant difference (α established at .05) among the control sites is the test pursued further. The two control sites are then considered as one treatment and the 12 replicates are compared against the 12 replicates of the impact sites. This same procedure is followed for the two impact stations with the exception that significant differences between the impact sites does not preclude further analysis, providing differences from the controls are unidirectional (i.e. both impact sites have either higher or lower densities than the control sites). This assumption is necessary to account for the possibility of a gradient of impact. Since one of the two impact stations (M10A) is much closer to the diffuser, differences in density from the control stations could be more pronounced. This

Table 6-17. Dominant macrobenthic species of the marine study area during the post-discharge period. Score is based on both dominance during a given month and persistance throughout the study period (see text for discussion).

Rank		Score (max = 120)
1	*Magelona* cf. *phyllisae*	107
2	*Paraprionospio pinnata*	97
3	*Mediomastus californiensis*	58
4	*Cirratulus* cf. *filiformis*	58
5	*Phoronis* sp. A	54
6	*Sigambra tentaculata*	51
7	*Owenia fusiformis*	47
8	*Pseudeurythoe paucibranchiata*	38
9	*Diopatra cuprea*	35
10	*Cossura soyeri*	35
11	*Glycinde solitaria*	30
12	*Nemertea* sp. B	29
13	*Mulinia lateralis*	18
14	*Spiochaetopterus oculatus*	12
15	*Sabellides* sp. A	9
16	*Balanus improvisus*	7
17	*Cerebratulus lacteus*	7
18	*Nassarius acutus*	5
19	*Nemertea* sp. D	4
20	*Nereis micromma*	2
21	*Oxyurostylis* sp. A	1

analysis is repeated for all months in which the particular species is among the dominants. Pre-discharge data is included when appropriate.

On an annual basis, Magelona cf. phyllisae is the most numerically dominant species in the study area, consistently appearing in high numbers during every month. During the pre-discharge period, no significant differences are found in the density of M. cf. phyllisae between the control and impact sites (Figure 6-52). Beginning in May 1981, significant differences in population densities are apparent, with densities at the impact stations higher than at the control sites. The increased density of M. cf. phyllisae at the impact sites is noted in six of the twelve months of post-discharge study.

The density of Paraprionospio pinnata at the four matched sites is shown in Figure 6-53. During several months, the differences in density among the two control sites are so great as to preclude further impact vs control comparisons. This was the case in three of the twelve months during the post-discharge period. In only five of the remaining nine months is there a significant difference in abundance between the control and impact sites. This is considered coincidental, and no effect of the brine discharge on P. pinnata densities is apparent.

Mediomastus californiensis also shows no consistent statistically significant difference in densities between the impact and control stations (Figure 6-54). Though densities at the impact sites are generally higher, this trend is statistically significant in only three

		IMPACT		CONTROL				
Period	Date	DW	M10A	M18	M20	DW vs M10A	M10A vs M18	M18 vs M20
PRE-DISCHARGE	February, 1981	DW (118)	M10A (123)	M18 (115)	M20 (77)	n.s.	n.s.	n.s.
PRE-DISCHARGE	March, 1981	DW (98)	M10A (103)	M18 (108)	M20 (70)	n.s.	n.s.	n.s.
PRE-DISCHARGE	April, 1981	DW (203)	M10A (150)	M18 (183)	M20 (105)	n.s.		* *
POST-DISCHARGE	May, 1981	DW (160)	M10A (123)	M18 (83)	M20 (45)	n.s.	* *	n.s.
POST-DISCHARGE	June, 1981	DW (107)	M10A (125)	M18 (152)	M20 (138)	n.s.	n.s.	n.s.
POST-DISCHARGE	July, 1981	DW (195)	M10A (160)	M18 (210)	--	n.s.	n.s.	
POST-DISCHARGE	August, 1981	DW (157)	M10A (117)	M18 (118)	--	n.s.	n.s.	
POST-DISCHARGE	September, 1981	DW (263)	M10A (253)	M18 (125)	M20 (115)	n.s.	* *	n.s.
POST-DISCHARGE	October, 1981	DW (173)	M10A (237)	M18 (142)	M20 (87)	n.s.	* *	n.s.
POST-DISCHARGE	November, 1981	DW (382)	M10A (295)	M18 (348)	M20 (330)	n.s.	n.s.	n.s.
POST-DISCHARGE	December, 1981	DW (405)	M10A (388)	M18 (272)	M20 (173)	n.s.	* *	n.s.
POST-DISCHARGE	January, 1982	DW (345)	M10A (280)	M18 (282)	M20 (167)	n.s.	n.s.	n.s.
POST-DISCHARGE	February, 1982	DW (288)	M10A (578)	M18 (358)	M20 (237)	* *		* *
POST-DISCHARGE	March, 1982	DW (362)	M10A (443)	M18 (242)	M20 (163)	n.s.	* *	n.s.
POST-DISCHARGE	April, 1982	DW (370)	M10A (467)	M18 (240)	M20 (228)	n.s.	* *	n.s.

Figure 6-52. Population density of _Magelona_ cf _phyllisae_ (average number per m^2) at selected matched sites as analyzed by Mann-Whitney U test ($\alpha < .05$)

Period	Month	IMPACT: DW	IMPACT: M10A	CONTROL: M18	CONTROL: M20	DW vs. M10A	M10A vs. M18	M18 vs. M20
PRE-DISCHARGE	February, 1981	DW (63)	M10A (188)	M18 (53)	M20 (68)	* *	n.s.	n.s.
PRE-DISCHARGE	March, 1981	DW (25)	M10A (82)	M18 (38)	M20 (40)	n.s.	n.s.	n.s.
PRE-DISCHARGE	April, 1981	DW (112)	M10A (125)	M18 (90)	M20 (42)	n.s.	n.s.	n.s.
POST-DISCHARGE	May, 1981	DW (170)	M10A (203)	M18 (178)	M20 (88)	n.s.		* *
POST-DISCHARGE	June, 1981	DW (195)	M10A (158)	M18 (358)	M20 (225)	n.s.	* *	n.s.
POST-DISCHARGE	July, 1981	DW (105)	M10A (30)	M18 (65)	--	* *	n.s.	
POST-DISCHARGE	August, 1981	DW (855)	M10A (270)	M18 (187)	--	* *	* *	
POST-DISCHARGE	September, 1981	DW (642)	M10A (640)	M18 (998)	M20 (1388)	n.s.	* *	n.s.
POST-DISCHARGE	October, 1981	DW (615)	M10A (923)	M18 (483)	M20 (902)	* *		* *
POST-DISCHARGE	November, 1981	DW (175)	M10A (923)	M18 (185)	M20 (128)	* *	* *	n.s.
POST-DISCHARGE	December, 1981	DW (293)	M10A (1175)	M18 (153)	M20 (93)	* *	* *	n.s.
POST-DISCHARGE	January, 1982	DW (152)	M10A (253)	M18 (190)	M20 (117)	n.s.	n.s.	n.s.
POST-DISCHARGE	February, 1982	DW (127)	M10A (340)	M18 (370)	M20 (165)	* *		* *
POST-DISCHARGE	March, 1982	DW (183)	M10A (337)	M18 (188)	M20 (163)	n.s.	n.s.	n.s.
POST-DISCHARGE	April, 1982	DW (140)	M10A (167)	M18 (120)	M20 (107)	n.s.	n.s.	n.s.

Figure 6-53. Population density of _Paraprionospio pinnata_ (average number per m^2) at selected matched sites as analyzed by Mann-Whitney U test ($\alpha < .05$).

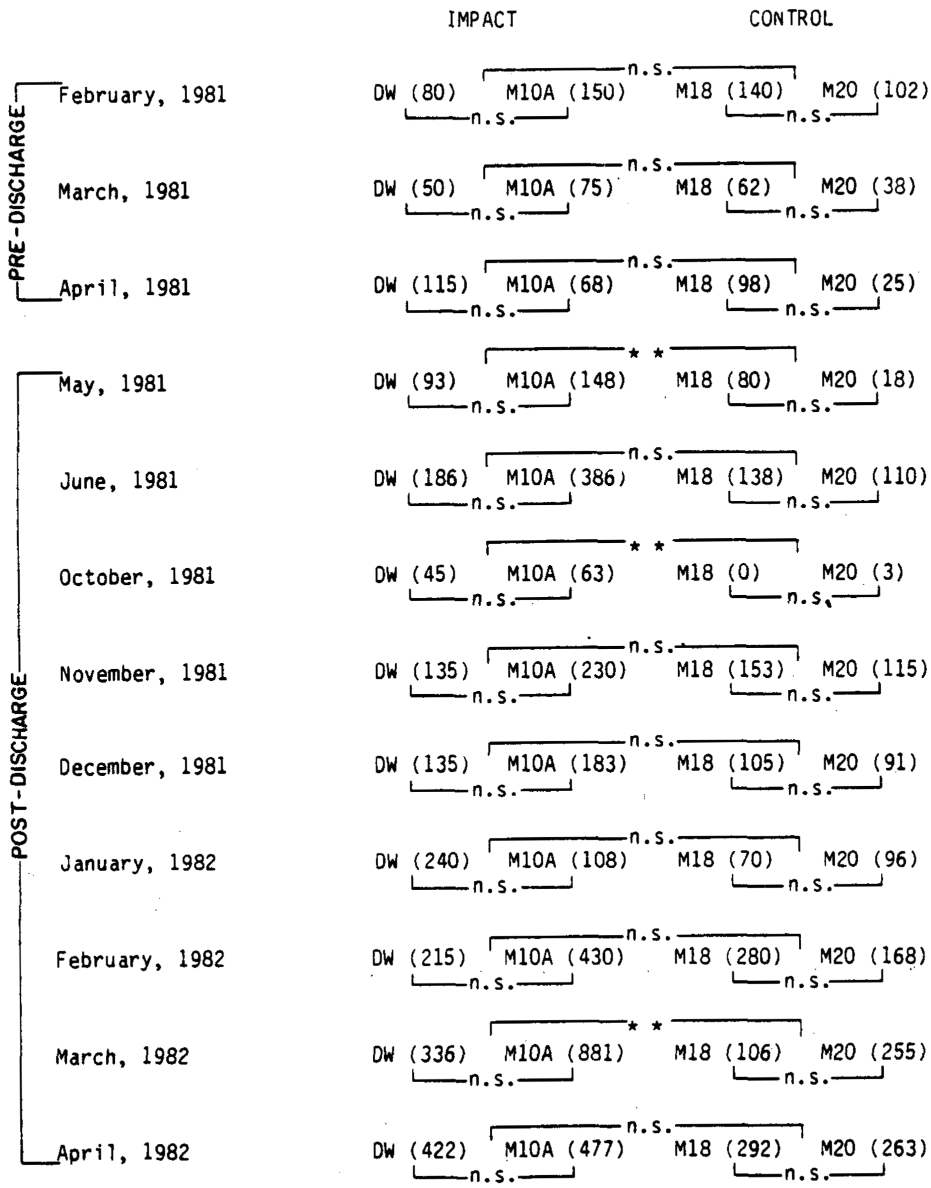


Figure 6-54. Population density of *Mediomastus californiensis* (average number per m^2) at selected matched sites as analyzed by Mann-Whitney U test ($\alpha < .05$).

months. *M. californiensis* does not show the extreme patchiness of *P. pinnata*, with no significant differences evident in the within-control or within-impact site comparisons.

Cirratulus cf. *filiformis* is only a numerically dominant species from November 1981 to April 1982. Prior to this time, including the pre-discharge period, its densities are very low and its occurrence sporadic. In the three month period of November 1981 to January 1982 the Mann-Whitney U test shows a statistically significant difference in the densities of *C.* cf. *filiformis* between the impact and control stations (Figure 6-55). The densities at the control stations are about three times those at the impact sites. This trend continues through April 1982 though during the February and March the differences among the two control sites are too great to permit control vs impact comparisons.

Phoronis sp. A is found in large numbers only during the pre-discharge and early post-discharge periods. Comparison of densities at the control and impact sites (Figure 6-56) reveals no consistent trend that could be interpreted as an indication of impact. All control vs impact comparisons made during the post-discharge period show no statistically significant difference.

6.3.6 Multivariate Analysis

6.3.6.1 Marine

Numerical classification (clustering) was used to delimit habitat types and identify any consistent pattern of station similarity that

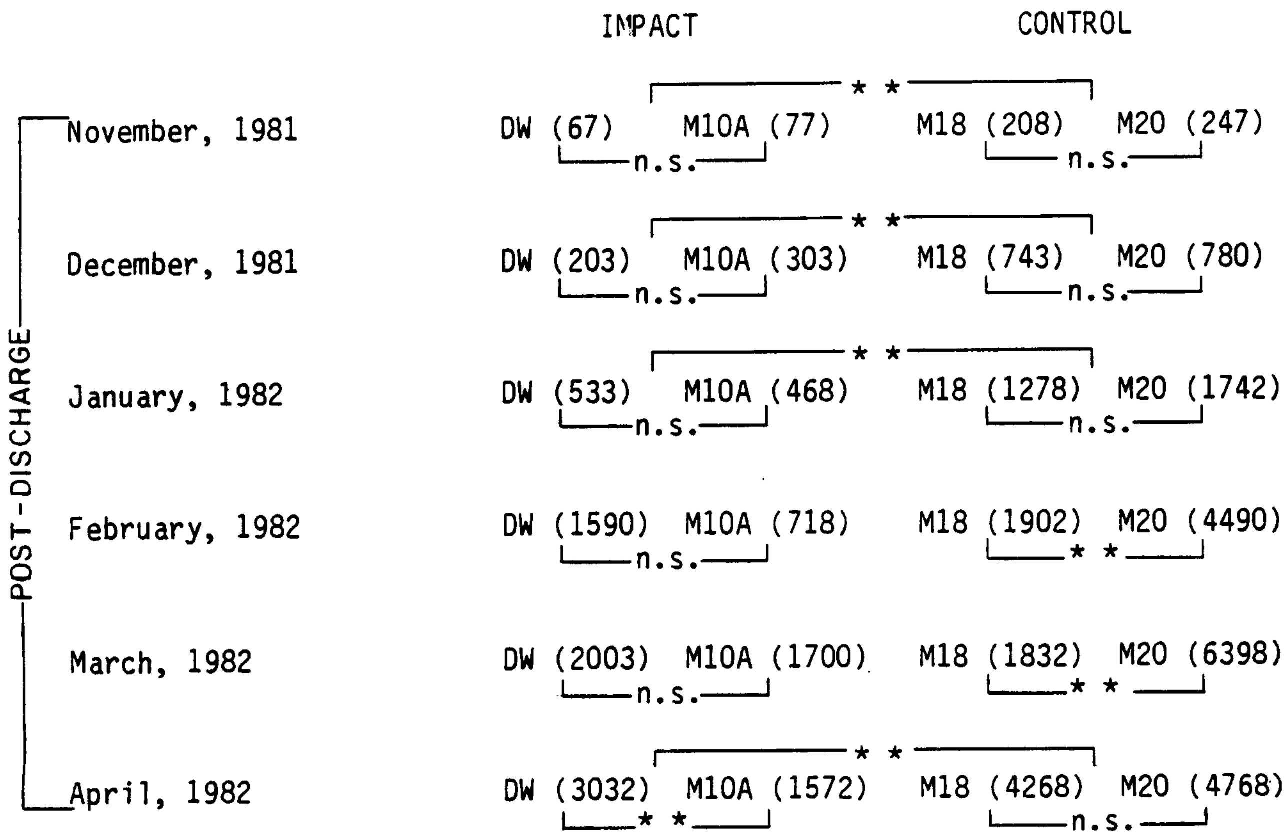


Figure 6-55. Population density of Cirratulus cf. filiformis (average number per m^2) at selected matched sites as analyzed by Mann-Whitney U test ($\alpha < .05$).

	Month	IMPACT: DW	DW vs. M10A	IMPACT: M10A	M10A vs. M18	CONTROL: M18	M18 vs. M20	CONTROL: M20
PRE-DISCHARGE	February, 1981	DW (68)	n.s.	M10A (143)	n.s.	M18 (30)	n.s.	M20 (25)
PRE-DISCHARGE	March, 1981	DW (725)	n.s.	M10A (2708)	* *	M18 (413)	n.s.	M20 (155)
PRE-DISCHARGE	April, 1981	DW (1158)	n.s.	M10A (1625)		M18 (1552)	n.s.	M20 (258)
POST-DISCHARGE	May, 1981	DW (3250)	n.s.	M10A (3250)		M18 (1750)	* *	M20 (525)
POST-DISCHARGE	June, 1981	DW (1833)	* *	M10A (10917)	n.s.	M18 (2417)	n.s.	M20 (1333)
POST-DISCHARGE	July, 1981	DW (2083)	* *	M10A (232)	n.s.	M18 (1308)		--
POST-DISCHARGE	August, 1981	DW (252)	n.s.	M10A (72)	n.s.	M18 (65)		--
POST-DISCHARGE	September, 1981	DW (7)	* *	M10A (158)	n.s.	M18 (0)	n.s.	M20 (12)

Figure 6-56. Population density of *Phoronis* sp. A (average number per m^2) at selected matched sites as analyzed by Mann-Whitney U test ($\alpha < .05$).

may be associated with brine discharge. It is potentially useful in identifying any community-wide impact of brine discharge as stations within the plume may be biologically dissimilar from unimpacted stations and therefore form a discrete cluster. Such implications of brine-induced impact by cluster analysis could then be interpreted by reviewing the species and abundances which led to such clusters.

Figures 6-57 - 6-62 illustrate numerical classification analyses (flexible sorting, $\beta = -0.25$, Bray-Curtis similarity) for each of the twelve months since initiation of discharge. Clearly evident is the high homogeneity of all offshore stations. Most linkages are formed at a similarity level greater than 0.70 and in no cases is the similarity less than 0.50. This homogeneity illustrates the absence of any dominating environmental gradient, and consequently many linkages reflect insignificant, or chance differences among the stations.

Because of the high homogeneity among the stations, there is little month to month consistency in the pattern of linkage. Stations M10A, M10 and DW frequently group together though this is not the case in all months. Notable exceptions to this are in December, 1981 (Figure 6-60) and January, 1982 (Figure 6-61) in which M10 is distinct from the remainder of the stations because of unusually low densities of Sigambra tentaculata and high densities of Owenia fusiformis. Station M3, which, because of the high percentage of sand in the surficial sediments, is the most environmentally dissimilar site, shows only slight evidence of segregation in the monthly clusters, and in

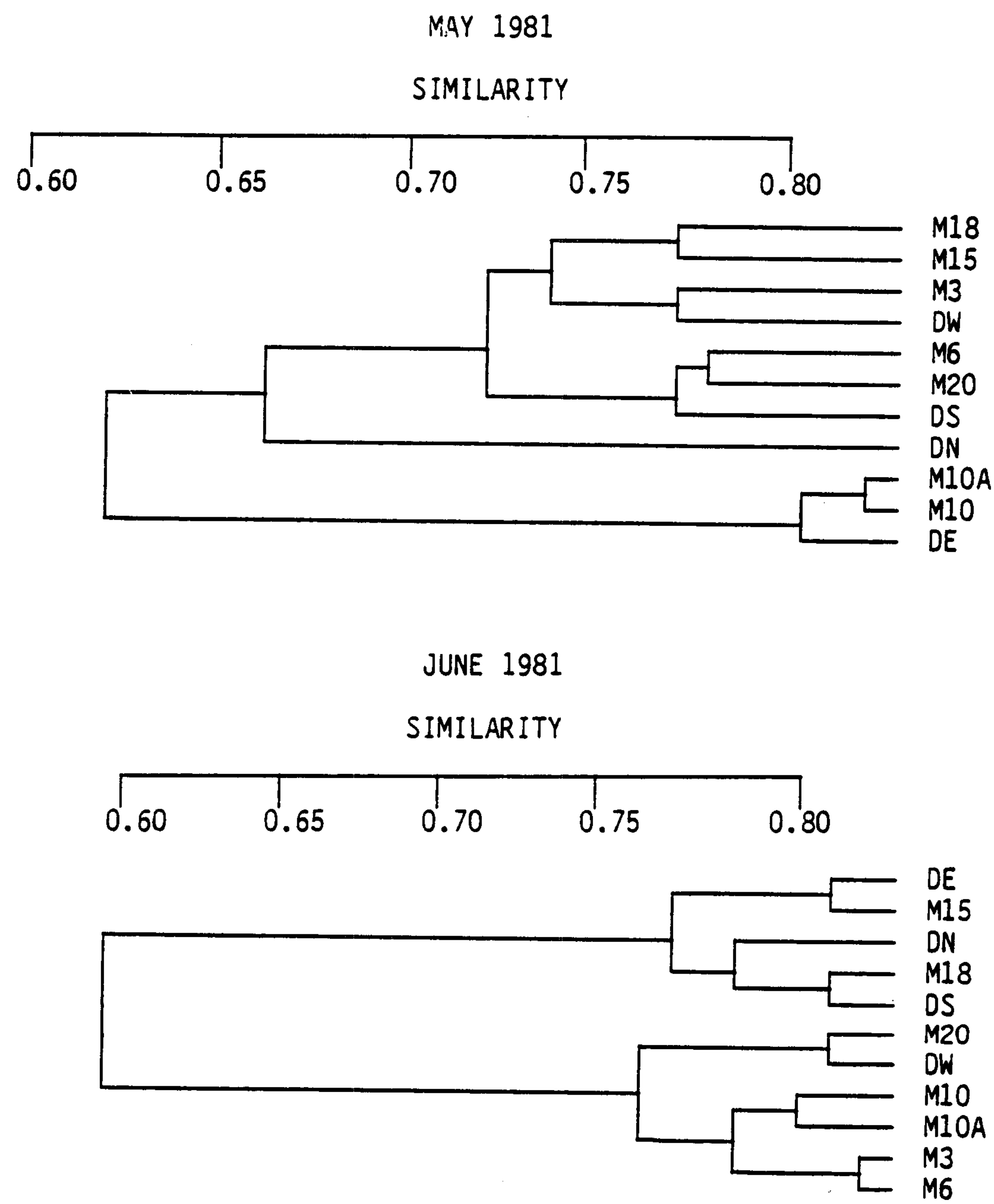
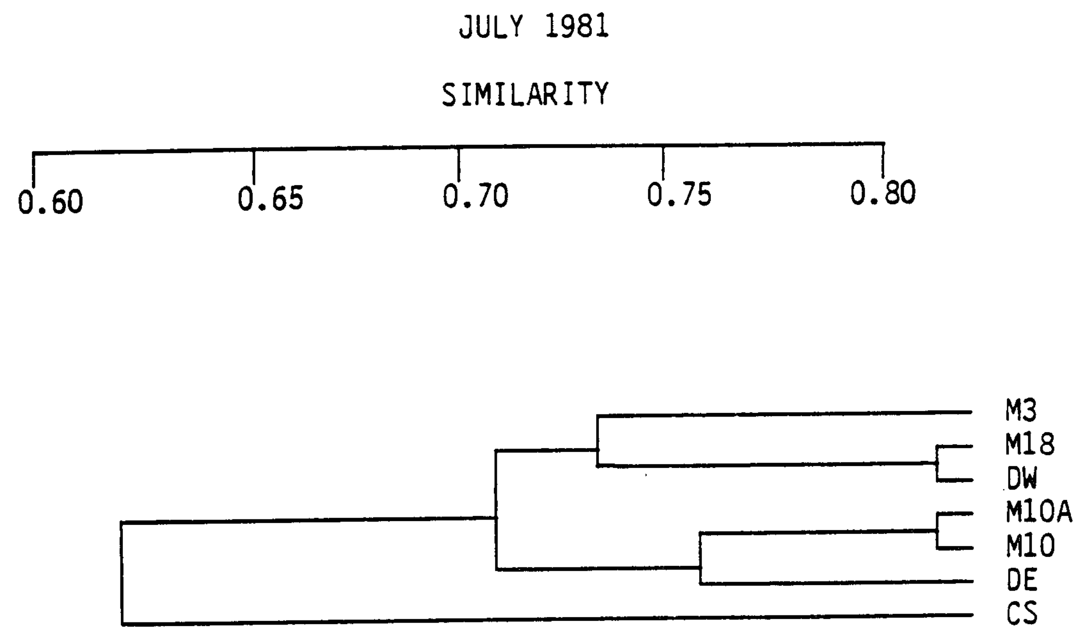


Figure 6-57. Numerical classification of marine stations by month. May 1981 (top), June 1981 (bottom. (Flexible sorting, β = -0.25).



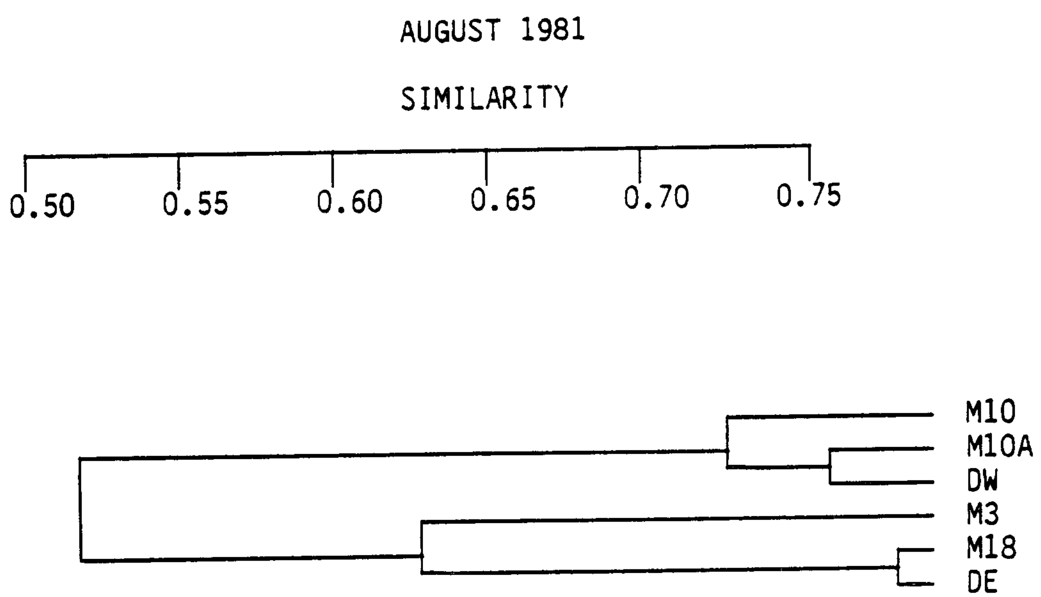


Figure 6-58. Numerical classification of marine stations by month. July 1981 (top), August 1981 (bottom). (Flexible sorting, $\beta = -0.25$).

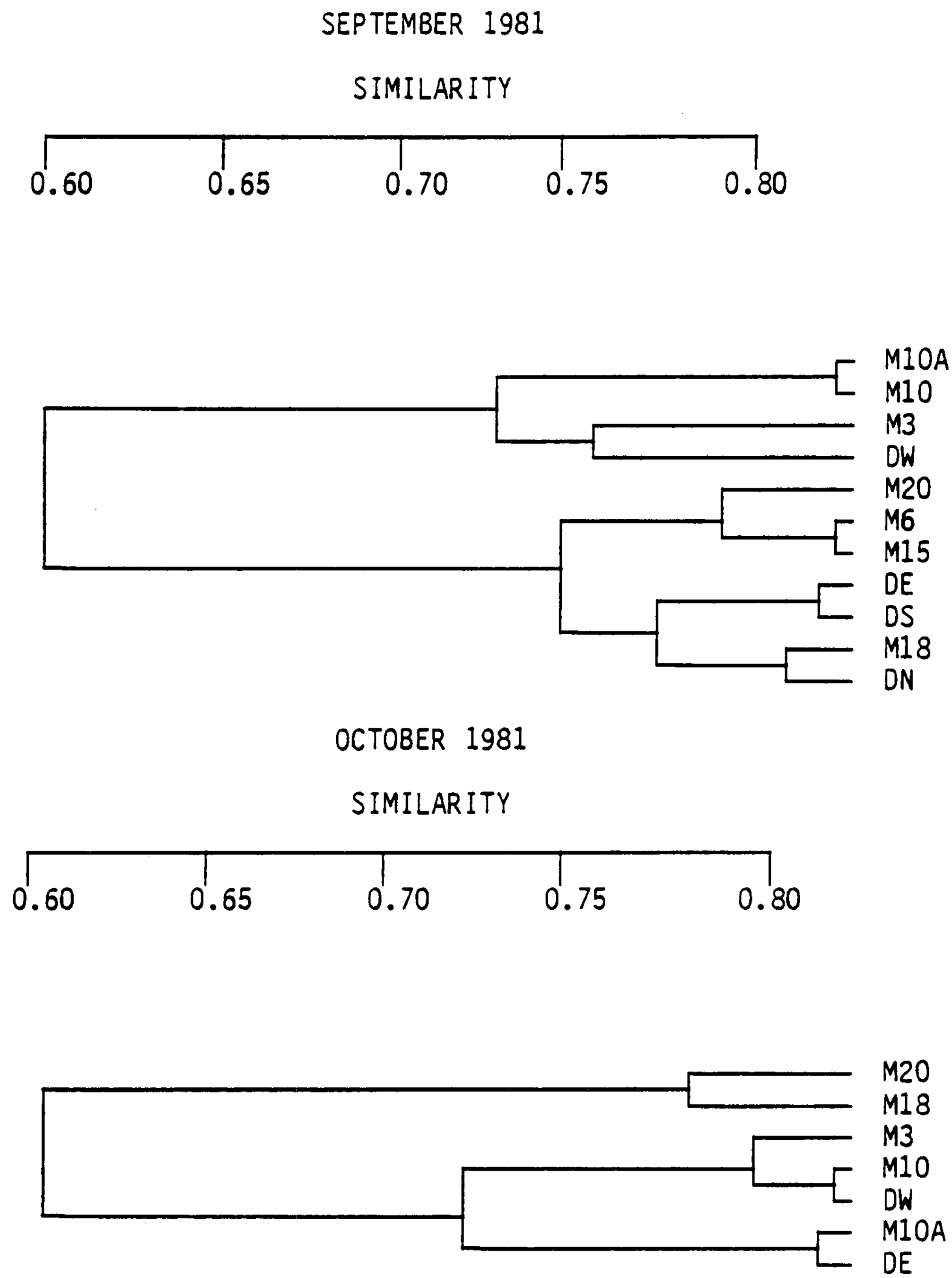


Figure 6-59. Numerical classification of marine stations by month. September 1981 (top), October 1981 (bottom). (Flexible sorting, β = -0.25).

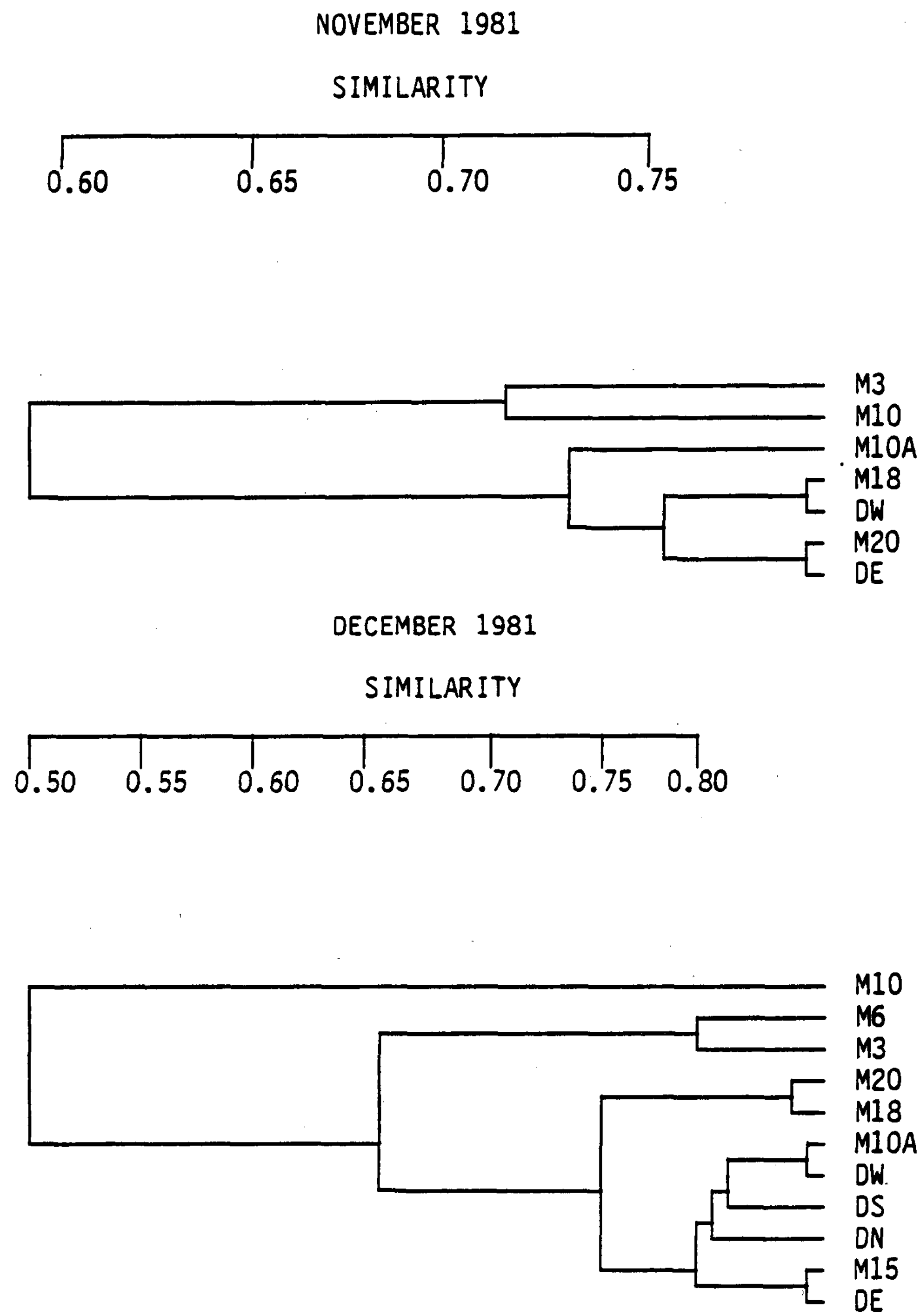


Figure 6-60. Numerical classification of marine stations by month. November 1981 (top), December 1981 (bottom). (Flexible sorting, β = -0.25).

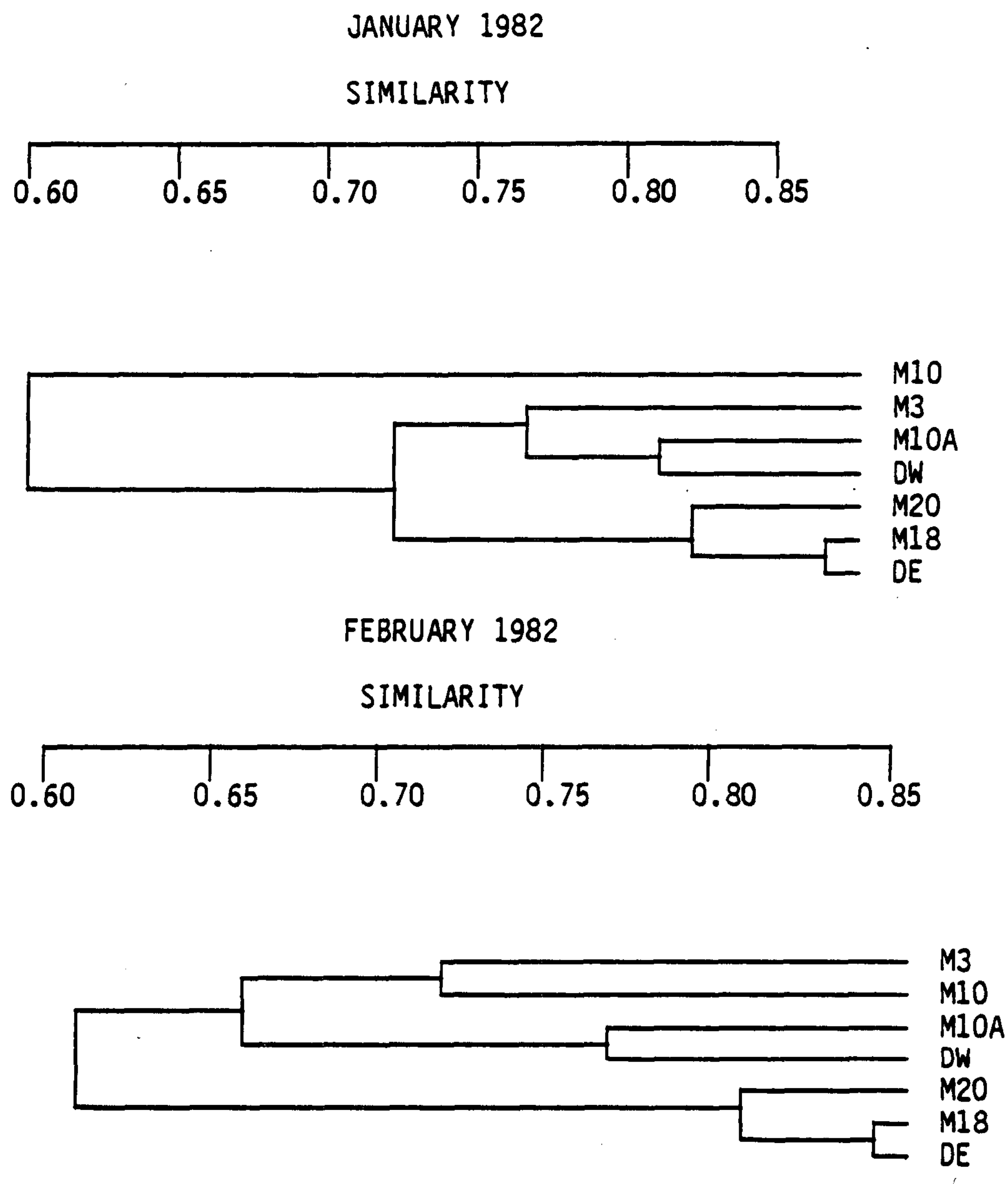


Figure 6-61. Numerical classification of marine stations by month. January 1981 (top), February 1982 (bottom). (Flexible sorting, β = -0.25).

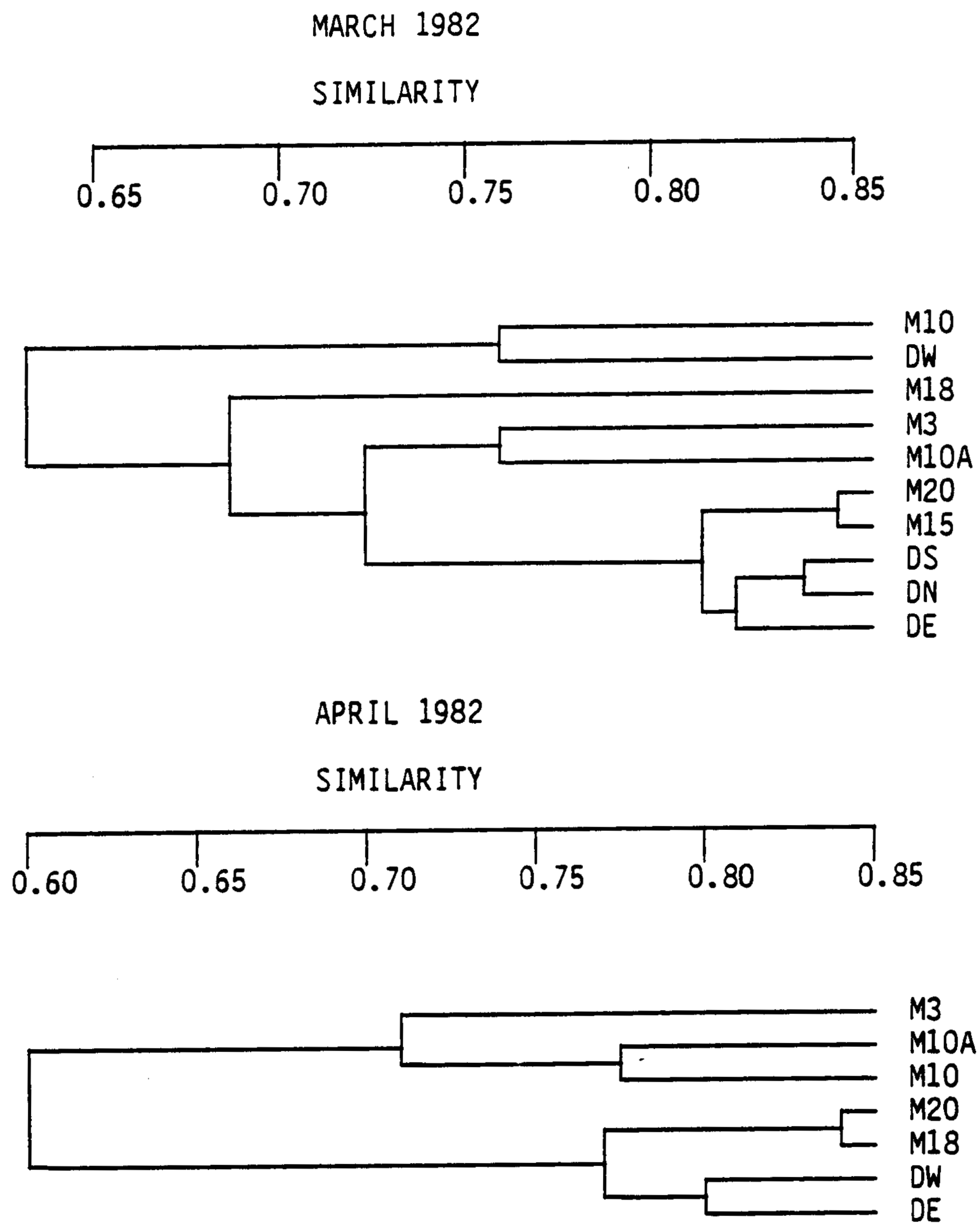


Figure 6-62. Numerical classification of marine stations by month. March 1982 (top), April 1982 (bottom). (Flexible sorting, $\beta = -0.25$).

fact most frequently groups with M10A, M10 and DW. This is the case in September, 1981 (Figure 6-59) because of high densities of *Mediomastus californiensis* at these sites, and in February, 1982 because of low densities of *Cirratulus* cf. *filiformis*. The density of *C.* cf. *filiformis* is an overriding factor in determining the order of cluster linkages during the October 1981 to April 1982 period during which M20, M18 and, to a lesser degree, DE, group together. Consistently higher densities of *C.* cf. *filiformis* occur at these stations during this period.

Numerical classification incorporating all 15 months of sampling, treating each month of collection at a site as a separate entity, is presented in Figure 6-63. Each individual entity is not labelled on the figure because of space limitations, however, those entities comprising each group are listed in Table 6-18.

It should be noted that in interpreting short-term brine-related impacts, cluster analysis on a 15-month data base is less desirable than analyses of monthly collections, due to the high temporal variability of the study area. Analyses of such large data bases are most useful in viewing general trends in the communities, and elucidating long-term events. Because of the high temporal variability of the benthic community, groupings are formed primarily on the basis of month rather than station. Three major groupings, established on the basis of season are evident: 1) the pre-discharge period of February-April 1981, 2) May-October 1981 including the hypoxic period

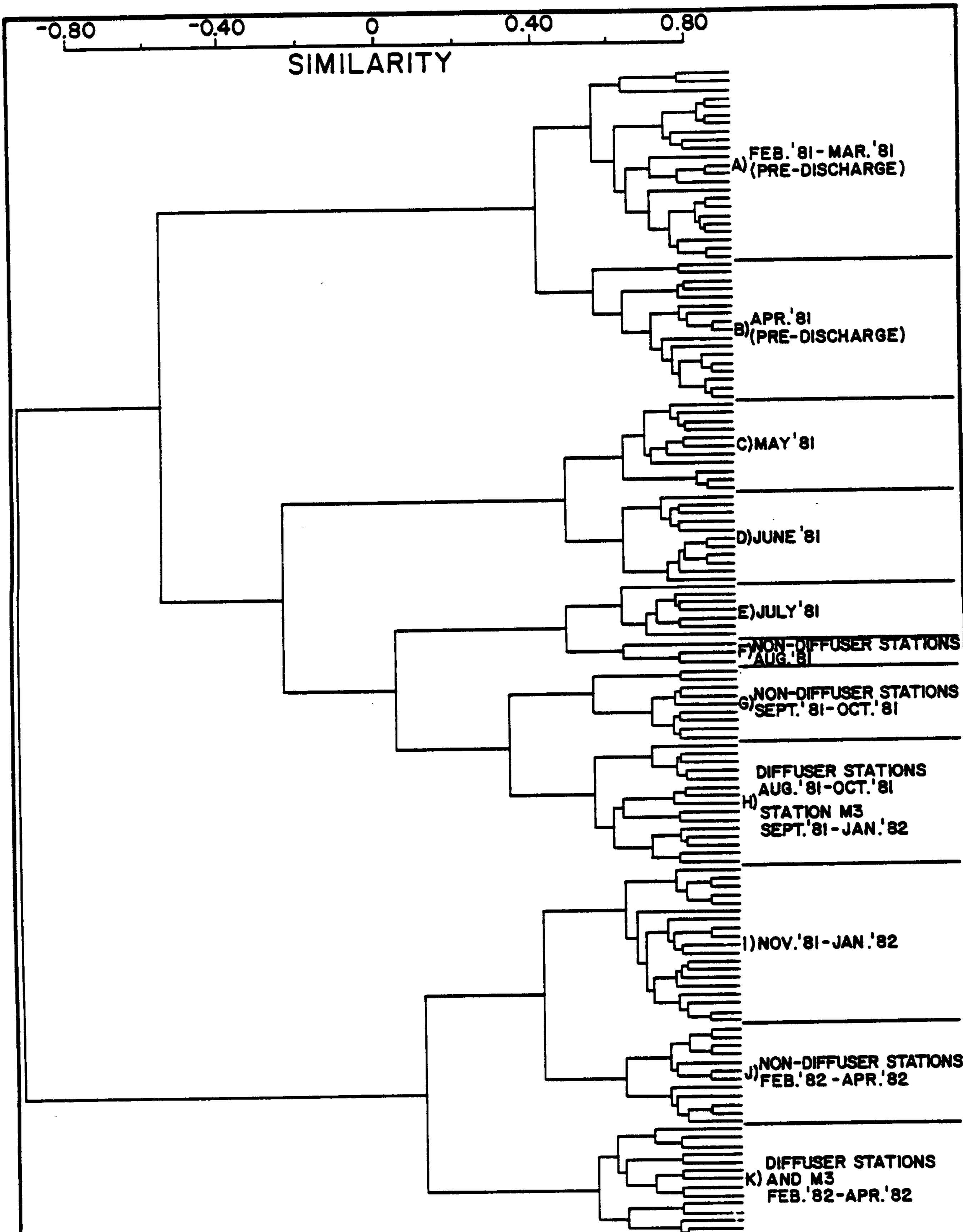


Figure 6-63. Numerical classification of marine stations including both pre-discharge and post-discharge collections. (Flexible sorting, $\beta = -0.25$).

Table 6-18. Station groups formed by numerical classification of marine stations shown in Figure 6-63.

GROUP A

M1	Feb 81
M3	Feb 81
M6	Feb 81
M9	Feb 81
M10A	Feb 81
M11	Feb 81
M15	Feb 81
M18	Feb 81
M20	Feb 81
DE	Feb 81
DN	Feb 81
DS	Feb 81
DW	Feb 81
CS	Feb 81
M6	Mar 81
M9	Mar 81
M15	Mar 81
M18	Mar 81
M20	Mar 81
DE	Mar 81
DN	Mar 81
DS	Mar 81
DW	Mar 81

GROUP B

M1	Mar 81
M3	Mar 81
M10A	Mar 81
M11	Mar 81
M1	Apr 81
M3	Apr 81
M6	Apr 81
M9	Apr 81
M10A	Apr 81
M11	Apr 81
M15	Apr 81
M18	Apr 81
M20	Apr 81
DE	Apr 81
DN	Apr 81
DS	Apr 81
DW	Apr 81

GROUP C

M3	May 81
M6	May 81
M10	May 81
M10A	May 81
M15	May 81
M18	May 81
M20	May 81
DE	May 81
DN	May 81
DS	May 81
DW	May 81

GROUP D

M3	Jun 81
M6	Jun 81
M10	Jun 81
M10A	Jun 81
M15	Jun 81
M18	Jun 81
M20	Jun 81
DE	Jun 81
DN	Jun 81
DS	Jun 81
DW	Jun 81

GROUP E

M3	Jul 81
M10	Jul 81
M10A	Jul 81
DE	Jul 81
DW	Jul 81
CS	Jul 81

GROUP F

M3	Aug 81
M18	Aug 81
DE	Aug 81

GROUP G

M6	Sep 81
M15	Sep 81
M18	Sep 81
M20	Sep 81
DE	Sep 81
DN	Sep 81
DS	Sep 81
M18	Oct 81
M20	Oct 81

Table 6-18. continued

GROUP H

M10	Aug	81
M10A	Aug	81
DW	Aug	81
M3	Sep	81
M10	Sep	81
M10A	Sep	81
DW	Sep	81
M3	Oct	81
M10	Oct	81
M10A	Oct	81
DE	Oct	81
DW	Oct	81
M3	Nov	81
M3	Dec	81
M3	Jan	82

GROUP I

M10A	Nov	81
M18	Nov	81
M20	Nov	81
DE	Nov	81
DW	Nov	81
M6	Dec	81
M10A	Dec	81
M15	Dec	81
M18	Dec	81
M20	Dec	81
DE	Dec	81
DN	Dec	81
DS	Dec	81
DW	Dec	81
M10A	Jan	82
DE	Jan	82
DW	Jan	82
M18	Jan	82
M20	Jan	82

GROUP J

M18	Feb	82
M20	Feb	82
DE	Feb	82
M15	Mar	82
M18	Mar	82
M20	Mar	82
DE	Mar	82
DN	Mar	82
DS	Mar	82
M18	Apr	82
M20	Apr	82
DE	Apr	82
DW	Apr	82

GROUP K

M10	Nov	81
M10	Dec	81
M10	Jan	82
M3	Feb	82
M10	Feb	82
M10A	Feb	82
DW	Feb	82
M3	Mar	82
M10	Mar	82
M10A	Mar	82
DW	Mar	82
M3	Apr	82
M10	Apr	82
M10A	Apr	82

during the summer months, and 3) November 1981 - April 1982. The fact that the February-April period of 1981 is more similar to May-October 1981 than to the February-April period of 1982 indicates the magnitude of faunal change in the study area and the absence of a repeated annual cycle.

Though groupings are established on the basis of month of collection in most cases, there are two instances when some stations in the vicinity of the diffuser (M10, M10A, DW) and station M3 are dissimilar from all other sites collected during the same time periods. During August-October, 1981 the diffuser stations and M3 grouped apart from the non-diffuser stations because of high densities of Magelona cf. phyllisae, Mediomastus californiensis and Sigambra tentaculata. During February-April 1982 the diffuser stations and M3 are segregated largely due to low densities of Cirratulus cf. filiformis.

6.3.6.2 Estuarine

Numerical classification of the estuarine stations, treating each monthly collection at a station as a separate entity, is presented in Figure 6-64 and Table 6-19 . Unlike the marine stations in which groupings are formed largely on the basis of month of collection, the estuarine stations cluster primarily on the basis of site and only secondarily on the basis of month. That is, in most cases, the faunal differences between the estuarine stations are considerably greater than the temporal variation at any given station, Stations E3 and E4 are the only exception to this, as they are much more similar to each

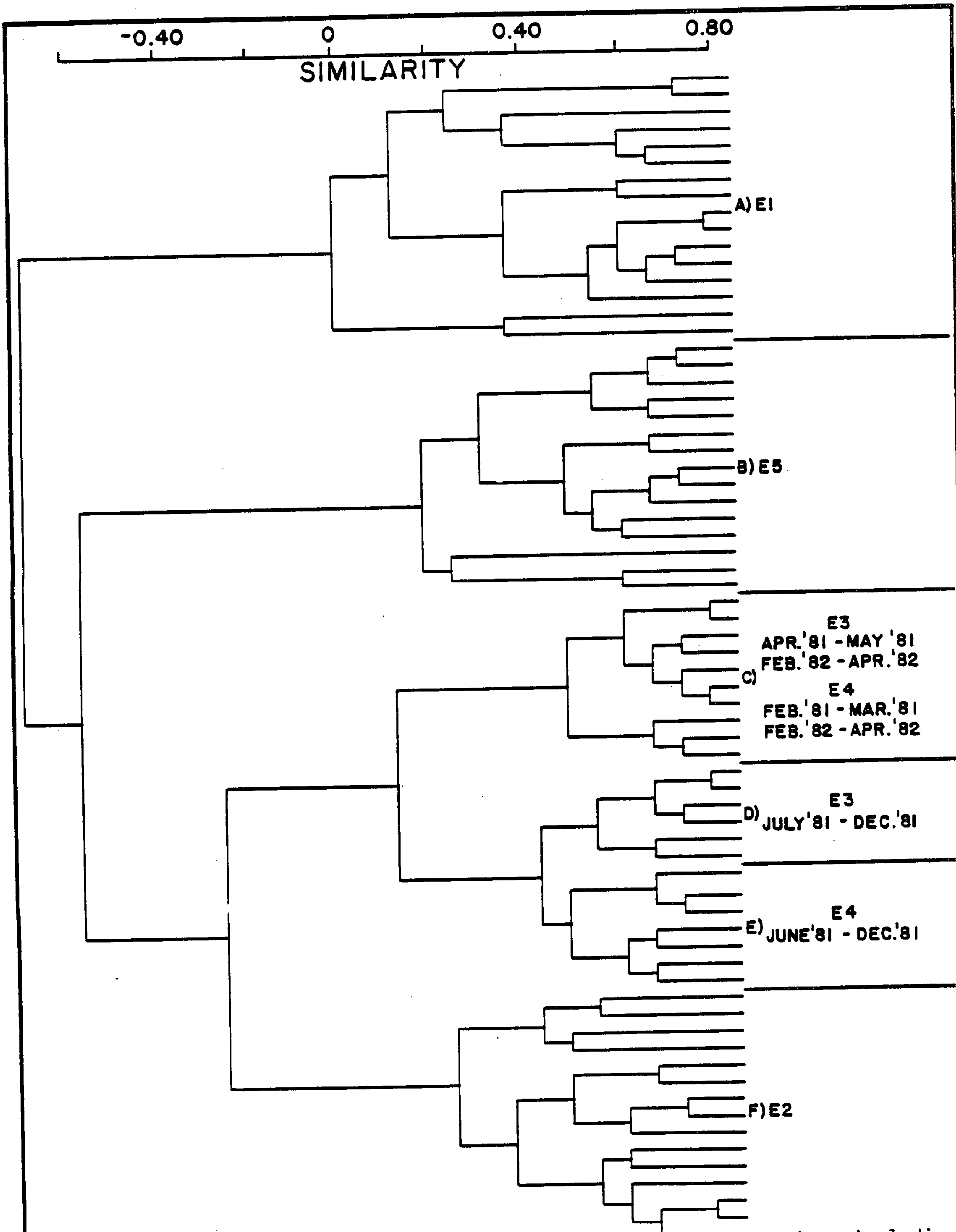


Figure 6-64. Numerical classification of estuarine stations including both pre-discharge and post-discharge collections. (Flexible sorting, β = -0.25).

Table 6-19. Station groups formed by numerical classification of estuarine stations shown in Figure 6-64.

GROUP A		
E1	Feb	81
E1	Mar	81
E1	Apr	81
E1	May	81
E1	Jun	81
E1	Jul	81
E2	Jul	81
E1	Aug	81
E2	Aug	81
E1	Sep	81
E1	Oct	81
E1	Nov	81
E1	Dec	81
E1	Jan	82
E1	Feb	82
E1	Mar	82
E1	Apr	82

GROUP D		
E3	Jul	81
E3	Aug	81
E3	Sep	81
E3	Oct	81
E3	Nov	81
E3	Dec	81

GROUP B		
E5	Feb	81
E5	Mar	81
E5	Apr	81
E5	May	81
E5	Jun	81
E5	Jul	81
E5	Aug	81
E5	Sep	81
E5	Oct	81
E5	Nov	81
E5	Dec	81
E5	Jan	82
E5	Feb	82
E5	Mar	82
E5	Apr	82

GROUP E		
E4	Jun	81
E4	Jul	81
E4	Aug	81
E4	Sep	81
E4	Oct	81
E4	Nov	81
E4	Dec	81

GROUP C		
E4	Feb	81
E4	Mar	81
E3	Apr	81
E3	May	81
E3	Feb	82
E4	Feb	82
E3	Mar	82
E4	Mar	82
E3	Apr	82
E4	Apr	82

GROUP F		
E2	Feb	81
E2	Mar	81
E2	Apr	81
E4	Apr	81
E2	May	81
E4	May	81
E2	Jun	81
E4	Jun	81
E2	Sep	81
E2	Oct	81
E2	Nov	81
E2	Dec	81
E2	Feb	82
E2	Mar	82
E2	Apr	82

other in salinity than are any other stations, and therefore temporal variations are of greater consequence. Winter months at both E3 and E4 (Group C) cluster together, apart from the summer and fall months at these same sites (Groups D and E). The reason for the segregation of the winter months is the rapid population increase of *Mulinia lateralis* at both E3 and E4, an occurrence observed in both the winter of 1981 and 1982.

6.4 Discussion

6.4.1 Marine

The West Hackberry brine disposal area can be characterized as a relatively homogeneous area in regards to both physical and biological parameters. It is an area in which the macrobenthic communities are highly variable with time as evidenced by the rapidly changing suite of dominant species. In the months immediately following initiation of brine discharge (May 1981 through September 1981) Phoronis sp. A comprises up to 72% of all individuals collected, attaining an average density among all stations of nearly 4000 individuals/m^2. In later months its abundance decreases to the point that it is only sporadically collected. During November 1981 - March 1982 the polychaete Cirratulus cf. filiformis dominates, attaining a density of 6400 individuals/m^2 at some sites. Magelona cf. phyllisae and Paraprionospio pinnata are the most consistently dominant species with relatively high densities throughout the study period.

Though the relative abundance of many species shows erratic and unpredictable fluctuations there appears to be some consistency in the species composition of the study area. Table 6-20 lists the ten dominant species of the present study and those of three earlier studies in the region. Eight of the ten dominant species were found as dominants in previous investigations. All dominant species of the earlier studies were present during this investigation, though they were not always among the most abundant species. This comparison

Table 6-20. The ten dominant species of the present study in comparison to the dominant species of three previous investigations of the West Hackberry diffuser site. Presumed synonomy of species named are indicated by parentheses.

PRESENT STUDY MAY 81 - APR 82	WESTON & GASTON 1981 FEB 81 - APR 81	PARKER et al., 1980 JUN 78 - MAY 79	S.A.I., 1978 SEP 77 - MAY 78
Magelona cf. phyllisae	(Magelona cf. pacifica)	(Magelona sp.)	(Magelona sp.)
Paraprionospio pinnata	Paraprionospio pinnata	Paraprionospio pinnata	Paraprionospio pinnata
Mediomastus californiensis	Mediomastus californiensis	Mediomastus californiensis	. . . .
Cirratulus cf. filiformis	. . . .	(Cirriformia sp.)	. . . .
Phoronis sp. A	Phoronis sp. A	. . . .	. . . .
Sigambra tentaculata	. . . .	Sigambra tentaculata	Sigambra tentaculata
Owenia fusiformis	. . . .	. . . .	. . . .
Pseudeurythoe paucibranchiata	. . . .	. . . .	. . . .
Diopatra cuprea	Diopatra cuprea		Diopatra cuprea
Cossura soyeri	. . . .	(Cossura delta)	(Cossura delta)
. . . .	Sabellides sp. A	(Sabellides oculta (sic))	(Sabellides oculta (sic))
. . . .	Balanus improvisus	. . . .	. . . .
. . . .	Mulinia lateralis	Mulinia lateralis	Mulinia lateralis
. . . .	Nemertea sp. B	. . . .	. . . .
. . . .	Oxyurostylis sp. A	. . . .	. . . .
. . . .	. . . .	Lumbrineris tenuis	Lumbrineris tenuis
. . . .	. . . .	Glycera dibranchiata	. . . .
. . . .	. . . .	. . . .	Clymenella torquata
. . . .	. . . .	. . . .	Ancistrosyllis papillosa

indicates that, though population irruptions may be dramatic and annually unpredictable, there is some consistency among the species which exhibit these irruptions.

The occurrence of low oxygen conditions, hypoxia, in the study area during summer 1981 results in reduced numbers of macrobenthic species, and reduced populations of most species. The effects of hypoxia are most dramatically evidenced in population reductions of the dominant species Phoronis sp. A (Figure 6-37), Mediomastus californiensis (Figure 6-44) and Cirratulus cf. filiformis (Figure 6-42). Though M. californiensis and C. cf. filiformis are abundant throughout the year, their lowest population levels occur during middle and late summer following conditions of hypoxia and anoxia in the study area. As demonstrated in Figure 6-35, species richness values similarly drop dramatically during hypoxia, indicating elimination of numerous of the moderately abundant and rare species from the area (e.g. Amphipoda, Figure 6-48). Reduction of populations of dominant species by hypoxia is also reflected in values for species evenness (Figure 6-35). Evenness values are elevated during the summer since no species overwhelmingly dominate the communities, increasing the relative abundances of the other species.

Since the primary goal of this study is the identification of any biological perturbation resulting from brine discharge, comparisons have been made of species composition and abundance between those sites most frequently impacted by the brine plume and the remaining stations.

At the most heavily-impacted site (station M10A), biological alterations are subtle and there is no evidence of catastrophic impact or mass mortality of macrobenthic organisms. However, the subtle changes in macrobenthic fauna, including reduced densities of some species and increased densities of others, appear to extend up to at least 1 km from the diffuser (station DW)

Curiously, station M3, 4 km to the west of the diffuser, shows the greatest similarity to the diffuser stations M10A, M10 and DW but this is not considered to be indicative of any brine-induced perturbations at this site. In fact, the faunal similarity between stations M3 and M10A has decreased since discharge began, though this decrease in similarity has not been as rapid as at many of the other stations. Additionally, results from the plume tracking efforts (Chapter 4) show little likelihood that the plume extends to station M3, making any suggestion of brine-induced alteration implausible.

Cirratulus cf. *filiformis* is the only dominant in which densities are dramatically reduced in the vicinity of the diffuser. The lower abundances at the impact sites are evident not only in the earlier stages of the population irruption (November - December) but are clearly apparent for at least six months during which population densities at all sites continue to increase. It is not known whether *Cirratulus* cf. *filiformis* recruits by lecithotrophic larvae with a brief planktonic life or by direct development (Blake, 1975). If the former were the case, the persistence of higher recruitment rates at the control sites would be strong evidence of unfavorable conditions in the vicinity of the diffuser.

There are also increased densities of some species in the vicinity of the diffuser. Of the dominant species, only Magelona cf. phyllisae shows this trend. This tendency is much more evident in many rare to moderately abundant species (e.g. Hexapanopeus angustifrons, Owenia fusiformis, Corophium sp. B, and Pagurus spp.). Most of these species are not typically considered opportunists and their elevated densities around the diffuser may be due to either substrate modification resulting from dredging or the increased salinity associated with brine discharge.

More than any other station, M10A exhibits brief, but dramatic, irruptions of species populations, particularly during the first months of brine discharge (e.g. Mediomastus californiensis, Nassarius acutus, and Phoronis sp. A in June 1981). Population irruptions of opportunistic species such as these may be in response to some environmental stress imposed on the community, reducing the density or competitive advantage of other species. While elevated salinity or other physical factors associated with brine discharge may be the causative agents for these irruptions, it is impossible to ascertain. Such conclusions of brine-induced population increases would be speculative since the limited physical and biological parameters measured during this investigation provide little information on the range of variables (e.g. food availability, reproductive success, competition, predation) which are responsible for such irruptions.

6.4.2 Estuarine

The benthic macrofauna of Calcasieu Lake are generally similar to other northern Gulf of Mexico estuaries. Habitats included in this investigation are numerically dominated by polychaetes and molluscs such as Mediomasutus californiensis, Paraprionospio pinnata, Streblospio benedicti, Parandalia fauveli, Mulinia lateralis and Macoma mitchelli. Stations E5, at the mouth of the estuary, additionally includes Phoronis sp. A, a species more abundant on the inner shelf than other estuarine habitats.

Most of these species are tolerant of wide salinity and temperature fluctuations, which account for their presence in the estuary. Bottom salinities at station E1, for instance, vary from 2^{o}/oo to 22^{o}/oo during the year, and temperatures range from 8°C to 35°C. Though the bottom water of the estuarine sites never becomes anoxic, as periodically occurs offshore, dissolved oxygen levels are reduced to near 2 ml/l during late summer at station E5.

As might be expected, separation of stations and species groups by multivariate analyses can be interpreted largely on the basis of salinity differences between sites sampled. Each cluster generally contains only collections from a particular site, indicating that the species and populations of that site are characteristic of only a single habitat. Though the sites may, over the course of the entire year, include many of the same dominant species, each habitat is unique in its relative abundance of species and unique presence of rare species.

Finally, it is important to note that the brine discharge did not reach the estuary during this investigation, and there is no evidence that it will reach Calcasieu Lake under the discharge rates currently anticipated. For this reason, projections of the effects of brine discharge on the estuarine macrobenthos are excluded from this report.

6.5 Conclusions

6.5.1 Marine

1. The macrobenthic community of the West Hackberry diffuser area is numerically dominated by a few species which undergo rapid and unpredictable changes in population density.

2. During the course of the year-long investigation (May 1981 - April 1982) the most dramatic changes in density are exhibited by the phoronid, *Phoronis* sp. A, and the polychaetous annelid, *Cirratulus* cf. *filiformis*. The polychaetes *Magelona* cf. *phyllisae* and *Paraprionospio pinnata* are the most stable dominants, being found in relatively high numbers during all months.

3. Hypoxic conditions during the summer months greatly reduce populations of most macrobenthic species, and totally eliminate many of the less common and rare species.

4. A number of species (e.g. *Phoronis* sp. A, *Mediomastus californiensis*, *Nassarius acutus*) exhibit concurrent population irruptions at the station nearest the diffuser during the first months of brine discharge.

5. The impact of brine diffusion on the benthic community is not catastrophic, though matched site comparisons of control and near-diffuser sites indicate consistent, statistically significant differences in populations within at least 1 km of the diffuser. These differences include:

a. statistically significant differences in population densities of certain numerically dominant species (e.g *Magelona* cf. *phyllisae* and *Cirratulus* cf. *filiformis*);

b. no statistically significant differences in total macrofaunal density between impact and control sites;

c. significantly greater number of species at the impact sites than at the control sites, evident in both pre- and post-discharge.

6.5.2 Estuarine

1. Data presented elsewhere in this report indicate no evidence of discharged brine entering Calcasieu Lake nor intake operations resulting in salt water intrusion. Thus, interpretation of macrobenthic community changes in regards to Strategic Petroleum Reserve Program operations would be unjustified. The utility of this data base is limited to baseline monitoring should any future perturbations occur.
2. Stations E3 and E4 show the greatest similarity among the estuarine stations, though each of the stations generally represent distinct habitat types, separable from the other sites on the basis of salinity.
3. Species found in Calcasieu Lake are typical of northern Gulf of Mexico estuaries. The fauna is numerically dominated by polychaetes and molluscs such as *Mediomastus californiensis*, *Paraprionospio pinnata*, *Streblospio benedicti*, *Parandalia fauveli*, *Mulinia lateralis*, and *Macoma mitchelli*.

CHAPTER 7

NEKTON

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7.1 Introduction

Nekton, for purposes of this report, can be defined as demersal finfish and macrocrustaceans. The group includes virtually all commercially and recreationally important marine animals. The possibility of impact resulting from brine discharge on the nekton community were studied over a 12 month period. From May 1981 through April 1982, monthly trawl samples were taken from marine and estuarine waters in southwest Louisiana.

Sampling followed a three month pre-brine discharge program from February through April 1981 (Ilg et al., 1982). In the pre-discharge study, the nekton community was described and baseline information was established from which post-brine discharge comparisons could be made.

Nekton populations at each sampling site were assessed to determine distribution, abundance, size composition, seasonality, and diversity at both species and community levels. Detailed study was directed towards fish and macrocrustacean species which support commercial and recreational fisheries.

Statistical analyses were employed to determine the roles of both biological and physical parameters in shaping observed trends in the spatial and temporal distribution of nekton.

7.1.1 Marine Environment

Two major soft bottom, demersal communities have been described for the northern Gulf of Mexico. The white shrimp, Penaeus setiferus, community dominates in the bathymetric range between 3.7-21.9 m, and the brown shrimp, Penaeus aztecus, community dominates between 21.9-109.7 m (Hildebrand, 1954; Chittenden and McEachran, 1976; Chittenden and Moore, 1977).

Within the white shrimp community off the southeastern Texas coast, Chittenden et al. (1980) noted that P. setiferus comprised 78% of the total penaeid shrimp catch while P. aztecus and P. duorarum comprised 21% and 2%, respectively. Dominant among the 121 ichthyofaunal species captured in that study were Chloroscombrus chrysurus (24%), Micropogonias undulatus (21%), Cynoscion nothus (12%), Stellifer lanceolatus (10%), Cynoscion arenarius (4%), Anchoa mitchilli (4%), Peprilus burti (3%) and Arius felis (2%).

Two additional studies in the northwest Gulf of Mexico (Landry and Armstrong, 1980; Scientific Applications, Inc., 1978) revealed similar dominant species characteristic of the white shrimp community. A trawl survey conducted over a broader bathymetric range (7-82 m) yielded species characteristic of both brown and white shrimp communities (Angelovic, 1975).

Sediment type and bathymetry place all sampling stations for the present study within the described range of the white shrimp community. The substrate throughout the sampling area is generally composed of unconsolidated sediments being 60-90% silt/clay and 10-40% sand (Hausknecht, 1980). Weston and Gaston (1982) reported 59-97% silt/clay and 3-42% sand in the study area. Depths range between 4.0 and 11.0 m.

In the three month pre-discharge study Ilg et al. (1982) reported that P. setiferus comprised 95% of the total penaeid shrimp catch while P. aztecus comprised 4.5%. Numerically dominant among the 69 ichthyofaunal species captured were: Peprilus burti (27%), Cynoscion nothus (18%), Trachypenaeus similis (7%), Lolliguncula brevis (7%), Squilla empusa (7%), Trichiurus lepturus (5%), Micropogonias undulatus (4%), Callinectes similis (3%), Urophycis floridanus (3%), Penaeus setiferus (2%) and Cynoscion arenarius (2%). The remaining 58 species comprised approximately 15% of the catch.

7.1.2 Estuarine Environment

Estuaries are generally considered to play important trophic and refuge roles for many species of nekters including those of commercial and recreational importance (Skud and Wilson, 1960; Rounsefell, 1963; Sykes, 1965; McHugh, 1966; Gunter, 1967). Many nektonic organisms spawn in the open Gulf. The eggs and larvae are carried by tides and currents toward the shore and eventually enter the estuaries where the young organisms grow and develop. Other species utilize the estuary as spawning or feeding grounds.

Among those species that spawn in the Gulf yet use the estuary as a nursery are: the white shrimp, Penaeus setiferus (Lindner and Cook, 1970); the brown shrimp, Penaeus aztecus (Cook and Lindner, 1970;

Weinstein, 1979); the pink shrimp, Penaeus duorarum (Costello and Allen, 1970); the red drum, Sciaenops ocellatus (Perret et al., 1980); the menhaden, Brevoortia patronus (Idyll et al., 1968); the Atlantic croaker, Micropogonias undulatus (Chao and Musick, 1977; Shenker and Dean, 1979); and the spot, Leiostomus xanthurus (Chao and Musick, 1977; Shenker and Dean, 1979; Weinstein, 1979). Cynoscion nebulosus, the spotted seatrout, normally spend their entire lives in the estuary, although some are found in coastal waters (Perret et al., 1980). The black drum, Pogonias cromis, and the silver perch, Bairdiella chrysoura, spawn either in the estuary or offshore, but use the estuary as a nursery (Chao and Musick, 1977; Silverman, 1979).

Calcasieu Lake is the largest estuary in southwest Louisiana, having a surface area of 42,792 acres and an average depth of approximately two meters. Barrett (1971) reported salinities from five stations in Calcasieu Lake ranging from 2.4^{o}/oo to 30.1^{o}/oo with an average of 14.0^{o}/oo. Ilg et al. (1982) reported salinities in Calcasieu Lake ranging from 14^{o}/oo to 30^{o}/oo with an average of 21.4^{o}/oo for a three month study (February through April, 1981). The total fifteen month average of stations E2, E3 and E4 was 18.34^{o}/oo with a range of 2.0^{o}/oo to 27.96^{o}/oo.

Perret (1971) reported results of 198 trawl samples in various southwest Louisiana estuaries including Calcasieu Lake. Dominant fish species reported were Brevoortia patronus, Cynoscion arenarius, Leiostomus xanthurus, Micropogonias undulatus and Anchoa mitchilli.

Dominant macroinvertebrates included Penaeus setiferus, P. aztecus and Callinectes sapidus. These dominant species were also present in seine haul samples taken in Calcasieu Lake (SPR-Final Environmental Impact Statement, 1977).

Ilg et al. (1982) reported results of 24 trawl samples in Calcasieu Lake. Dominant species (in order of abundance) included: Micropogonias undulatus, Anchoa mitchilli, Penaeus aztecus, Callinectes sapidus, Brevoortia patronus, Penaeus setiferus and Leiostomus xanthurus.

Although Rounsefell (1975) reported that at specific locations within the estuarine environment species composition is likely to be determined by the existing salinity regime, Ilg et al. (1982) did not find a significant relationship between species composition and salinity during the three month pre-discharge study.

7.2 Materials and Methods

7.2.1 Field Procedures

7.2.1.1 Marine

Nekton samples were collected monthly during the post-brine discharge period--May 1981 through April 1982. All collections for this study were made during daylight hours aboard the Captain Brady Joseph, a 19.4 m steel hulled shrimp trawler.

Stations sampled included M3, M10A, M18, M21, M22, DE, DW, DN, and DS (Figure 7-0). West and east control stations, M1 and M20

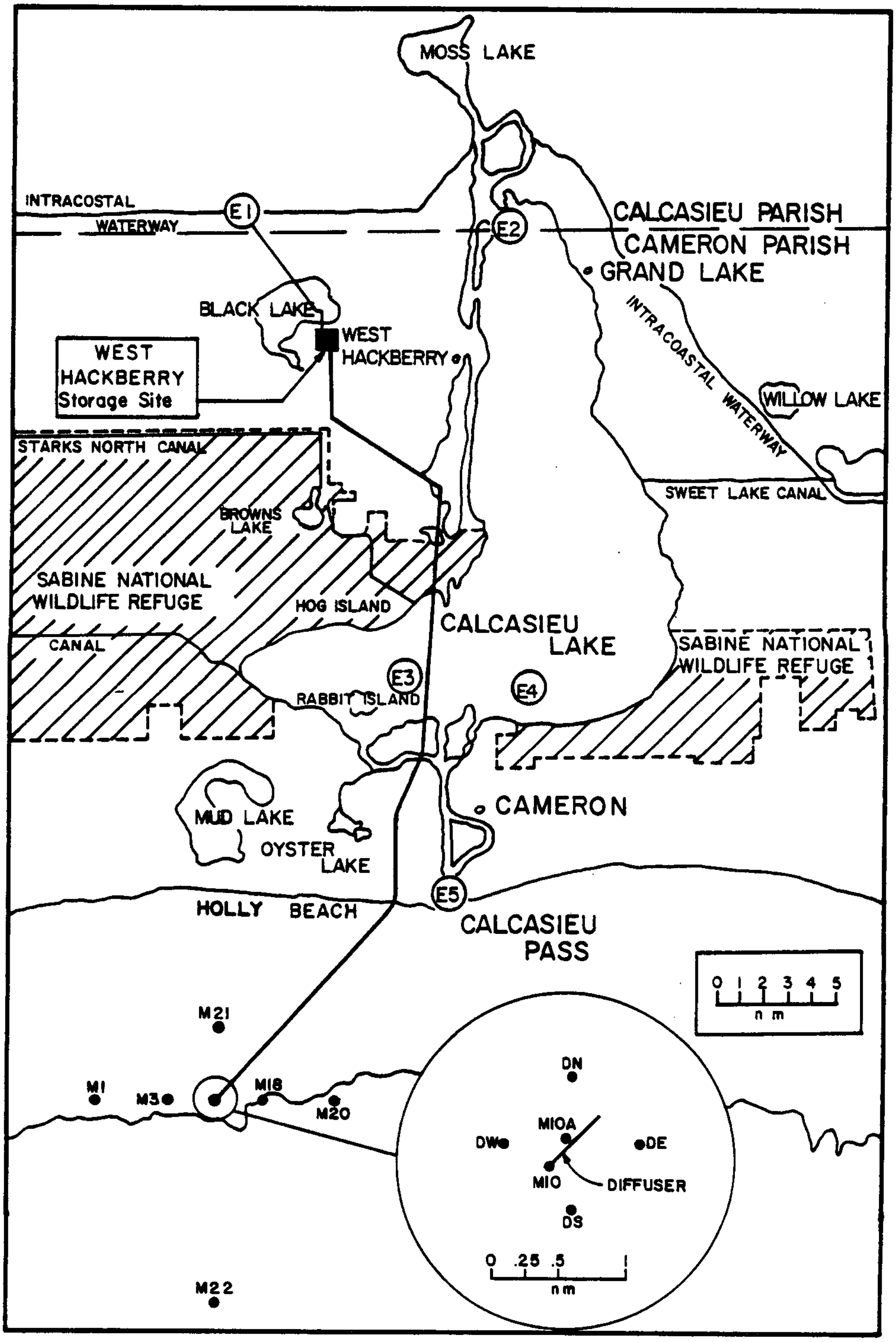

Figure 7-0. Location of marine and estuarine sampling sites in coastal waters of southwestern Louisiana.

pespectively, were added in November 1981 after evidence was presented that previous control stations, M3 and M18, may occasionally be included in the plume area.

Prior to sampling at each station, depth, conductivity, temperature, pH and dissolved oxygen were measured at 3m intervals with a Hydrolab Series 8000 meter. These readings were recorded on field data sheets along with weather and sea state observations. Turbidity samples were taken at the surface, bottom and at mid-water depth using a three liter Van Dorn sampler. Turbidity samples were iced and retained for laboratory analyses.

Collections were made using a single 15.2 m commercial otter trawl, deployed from the stern, equipped with a tickler chain and 1.9 cm square mesh (3.8 cm stretch mesh) netting. Otter boards measured 2.1 m by 1.0 m. Stations were located using Loran C coordinates. Tows were made in a circular pattern around the sites at a speed of 3.7 to 5.6 km hr^{-1} (2-3 knots). Two replicate tows were made at all stations with a bottom time duration of ten minutes each.

The sampling strategy was altered in July, 1981 and two trawls were deployed from 7 m booms on either side of the boat. While there are advantages and disadvantages to both techniques, both methods are essentially identical (Prof. H.D. Hoese, personal communication).

Catches were roughly sorted into fish and invertebrates. Samples were then bagged, labeled and iced for transport to laboratory freezers. Replicate tows were labeled A (starboard) or B (port) and treated separately throughout the study.

When a trawl contained a large number of a single species, the total number of individuals and their group weight were determined in the field. When this occurred and the individual fish were small ($\leq$ 50g), the total weight was determined as accurately as possible in the field using a spring scale. An aliquot was retained and an average weight determined in the laboratory. The total number of individuals was then calculated based on the subsample. Larger fish were weighed as a group and counted. A minimum of 50 individuals of each species from each trawl within the family Sciaenidae and the genera *Brevoortia* and *Penaeus* was retained for more detailed laboratory analyses.

7.2.1.2 Estuarine

Nekton samples were collected monthly during the post-brine discharge period--May 1981 through April 1982. These collections were made aboard a 6.8 m flat bottom aluminum outboard motor boat. After February 1982 the hull was modified to a V-hull.

Estuarine stations sampled included E1, E2, E3 and E4. Due to low water levels, station E3 was inaccessible during November 1981.

A CTD/DO profile was made at each station prior to sampling. Measurements were made at the surface and the bottom at all stations. A water sample was taken at the surface for turbidity. Nekton samples were taken with a 4.9 m commercial otter trawl equipped with a tickler chain and with 1.9 cm square mesh netting in the net and a 0.6 cm square mesh cod end liner. Otter boards measured 60.5 cm by 31 cm.

Tows were made in a straight line at E1 (Intracoastal Waterway) and in a circular pattern at E2, E3, and E4 at a speed of 3.7 to 5.6 km hr^{-1} (2-3 knots). Two replicate tows were made per station with a ten minute bottom time duration for each tow. Catches were roughly sorted into fish and invertebrates. Samples were then bagged, labeled and iced for transport to laboratory freezers.

7.2.2 Laboratory Procedures

Samples were thawed and the sample and haul numbers were recorded on sample data sheets. After sorting, all fish, squid, portunid crabs and penaeid shrimp were identified to the species level, counted, and a total species weight was obtained. Individual lengths and weights were recorded for at least 50 representatives of each species (if available) from the family Sciaenidae and the genera Brevoortia and Penaeus.

Standard length (SL) for fish was measured from the tip of the snout to the end of the hypural plate; total length (TL) for shrimp was measured from the tip of the rostral spine to the end of the telson.

Individual weights were made to the nearest 0.1 g, group weights to the nearest 1 g.

Representative specimens were fixed in 10% buffered formalin, then transferred to 70% ethanol and labeled for permanent retention as a reference collection.

References for fish identification were Parker (1972), Walls (1975), Hoese and Moore (1977), and the U.S. Fish and Wildlife Service (1978). For scientific nomenclature, Robins et al. (1980) was used. Invertebrates were identified using the following taxonomic keys: Williams (1965), Felder (1973) and Wood (1974).

7.2.3 Data Analysis

Data were analyzed on an individual specimen basis and on a weight basis. Both measurements may be used to indicate abundance, and it is possible that analyses based on one set of data will uncover differences that are hidden in the other data base. This did not prove to be the case in this study and analyses on both data bases were similar. Only one of the analyses is therefore reported.

The approach used to determine impact was to use the cluster analyses as indicator tests. In the pre-discharge study all stations except M21 and M22 were homogeneous. Changes from that norm would be taken to indicate the possibility of impact. All further analyses were used to elucidate the nature and magnitude of any change.

1. Cluster analysis (Bray and Curtis, 1957)

Clustering using flexible sorting and the Bray-Curtis similarity coefficient with no standardization, $\log_{10}$ (X-1) transformation and a beta factor of -0.25 was performed on all pre-discharge data. The similarity measure may be expressed as:

$$S_{jk} = 1 - \left(\frac{\sum_{i=1}^{n} | X_{ji} - X_{ki} |}{\sum_{i=1}^{N} (X_{ji} + X_{ki})} \right)$$

where in normal clustering, S_{jk} equals the similarity between stations j and K and X_{ji} and X_{ki} equal the abundances of species i in station j and k respectively.

2. Species Diversity (Shannon-Weaver method)

Diversity was measured using Shannon's formula (Pielou, 1966):

$$H' = -\sum_{i=1}^{s} P_i \log_2 P_i$$

where P_i is the proportion of the i-th species and s equals the number of species in the sample.

3. Species Richness, Equitability, and Probability of Interspecific Encounters (PIE) (Hurlbert, 1971)

Species richness (S.R.) and evenness (J) were calculated using the formulae:

$$S.R. = \frac{s-1}{\ln N} \qquad J = \frac{H'}{\log_2 s}$$

where N equals the total number of individuals.

$$PIE = \left(\frac{N}{N-1}\right)\left(1 - \sum_{i=1}^{s} \Pi_i^2\right)$$

where N_i = number of individuals of the i-th species in the community (or collection)

$N = \Sigma N_i$ = total number of individuals in the community i

$\Pi_i = N_i/N$, and

s = Number of species in the community

4. Analysis of Variance

Monthly collection results were subjected to a one-way analysis of variance (ANOVA) for abundance of each species. Stations M21 and M22 were consistently different from the other marine stations during the pre-discharge study. These two stations clustered separately, had markedly different species composition, abundance and diversity indices. Since this trend continued during the post-discharge study and since both stations are outside the observed brine plumes these stations were not included in the analyses of variance. It was felt that results including these stations would only serve to obscure the tests designed to determine impacts. When ANOVA demonstrated significant between station differences, a Student-Newman-Keuls (SNK) test was performed to determine the pattern of heterogeneity.

Species diversity (H') results for these stations were also subjected to ANOVA and SNK tests.

Target species (species of the family Sciaenidae and the genera Penaeus and Brevoortia) were examined by means of a multivariate analysis of variance and covariance (MANOVA). Stations compared were M3, M10A and M18, the diffuser and the control stations. The covariates included physical variables such as temperature, pH, salinity and dissolved oxygen. Percentage of sand, silt and clay plus mean grain size were used to determine the effect of the sediment on fish distribution.

5. Condition

The physical condition of individual members of the target species was also analyzed. Condition was determined in two ways:

$$K = W(10^5)/L^3$$

where K is the coefficient of condition,

W = weight in grams, and

L = length in millimeters

In addition, a linear regression of the form $\log_{10} W = a + b \log_{10} L$ was used with b equalling the coefficient of condition. Standard lengths of fish species and total length of penaeid shrimp were used as L in these calculations.

7.2.4 Significance Levels

In several instances alpha levels greater than 0.05 have been used. While 0.05 is generally accepted as the best significance level it is not universally applicable. This level is best if one has the luxury of an optimum sampling strategy. Due to economic considerations, optimal sampling with a high number of replicates is not always possible.

Consider the following study:

In 1979 Texas Instruments made a trawl study of nekton in Chesapeake Bay. They found that 252 samples were necessary to gain an 80% chance of detecting a 50% difference in white perch density among three locations. This was established with an alpha of 0.10.

The implication is clear that there must be some compromise in a cost effective monitoring program. Furthermore, the alpha level protects one from making a type one error in statistics. That is, assuming a null hypothesis that there is no difference between stations, an alpha of 0.10 gives a 10% chance of saying there is a difference when in fact there is none. The reciprocal, of course, is a type two error which in this case is the possibility of saying there is no difference when in fact there is one. The probability of committing a type two error is denoted by beta. If one increases the alpha level one decreases the beta level and vice versa. If one wishes to decrease the chances of both types of errors one must increase the sample size. Since the avowed purpose of this study is to protect the environment our only option is to increase our alpha levels.

Most biologists agree that tests significant at an alpha of 0.05 are conclusive. This is because biological phenomena rarely occur at a frequency of 100%. In this report, probabilities as low as 75 or 80% are mentioned. While we accept that such results are not conclusive, we feel that a 75 or 80% chance of impact should be mentioned and at the very least merits further investigation and continued monitoring.

7.3 Results

7.3.1 Marine

A total of 324,102 organisms representing 99 species was collected at marine stations during post-brine discharge sampling. Table 7-1 lists the total number of individuals and total weights for each species collected. Fourteen species comprised 90% of the total number of organisms collected. The ten dominant species by both weight and total number for each of the twelve sampling months are in Appendix H, tables H-39 through H-50.

Table 7-1. Total abundance of all species caught during the study at marine stations. Species are listed in order of abundance by number of individuals. Total species weights, in grams, are also included.

SPECIES	TOTAL #	TOTAL WEIGHT
Chloroscombrus chrysurus	89,716	580,312
Stellifer lanceolatus	46,670	379,902
Micropogonias undulatus	22,346	300,243
Penaeus aztecus	20,515	143,050
Callinectes similis	20,107	89,297
Trachypenaeus similis	19,170	43,549
Portunus gibbesii	17,564	43,854
Lolliguncula brevis	9,092	88,963
Anchoa mitchilli	8,960	21,352
Peprilus burti	8,744	190,217
Cynoscion nothus	8,634	147,267
Cynoscion arenarius	7,299	161,590
Squilla empusa	7,209	43,927
Penaeus setiferus	7,160	126,200
Arius felis	4,346	270,586
Trichiurus lepturus	3,690	74,817
Leiostomus xanthurus	3,395	151,983
Etropus crossotus	3,146	22,279
Peprilus alepidotus	2,974	66,350
Xiphopenaeus kroyeri	2,447	10,088
Larimus fasciatus	2,058	9,940
Menticirrhus americanus	1,604	65,941
Prionotus tribulus	1,373	8,456
Brevoortia patronus	1,056	41,782
Anchoa hepsetus	915	11,657
Citharichthys spilopterus	767	8,744
Urophycis floridana	372	11,305
Callinectes sapidus	352	14,467
Prionotus rubio	259	1,468
Chaetodipterus faber	244	2,214

Table 7-1. continued

SPECIES	TOTAL #	TOTAL WEIGHT
Selene setapinnis	172	1,371
Bagre marinus	149	18,908
Porichthys plectrodon	118	1,135
Polydactylus octonemus	99	597
Loligo plei	95	860
Dorosoma petenense	95	1,628
Harengula jaguana	92	2,220
Symphurus civitatus	85	1,308
Symphurus plagiusa	77	1,231
Lagodon rhomboides	68	2,214
Sicyonia brevirostris	61	191
Orthopristis chrysoptera	56	2,869
Sphoeroides parvus	50	456
Synodus foetens	49	918
Paralichthys lethostigma	49	8,751
Lutjanus synagris	48	522
Sardinella aurita	38	669
Bairdiella chrysoura	37	1,407
Opisthonema oglinum	34	730
Centropristis philadelphica	34	874
Ancylopsetta quadrocellata	32	244
Sicyonia dorsalis	29	50
Portunus sayi	24	123
Lutjanus campechanus	23	153
Rhizoprionodon terraenovae	21	4,434
Scomberomorus maculatus	20	1,163
Pogonias cromis	18	111,966
Caranx hippos	15	702
Ovalipes floridanus	14	38
Astroscopus y-graecum	14	160
Symphurus sp.	13	219

Table 7-1. continued

SPECIES	TOTAL #	TOTAL WEIGHT
Lagocephalus laevigatus	13	108
Chilomycterus schoepfi	13	554
Archosargus probatocephalus	12	22,137
Prionotus scitulus	11	46
Trachinotus carolinus	11	1,671
Hemicaranx amblyrhynchus	11	297
Sphyraena guachancho	11	176
Trinectes maculatus	10	159
Ophidion welshi	8	196
Stenotomus caprinus	8	43
Scomberomorus cavalla	8	649
Portunus spinimanus	7	35
Elops saurus	7	805
Cynoscion nebulosus	7	193
Monacanthus hispidus	7	33
Sphyrna tiburo	6	4,483
Gobionellus hastatus	4	64
Pomatomus saltatrix	3	372
Sciaenops ocellatus	3	17,100
Achirus lineatus	3	38
Arenaeus cribrarius	2	28
Etrumeus teres	2	60
Ogcocephalus radiatus	2	285
Syngnathus louisianae	2	3
Caranx crysos	2	24
Eucinostomus argenteus	2	14
Menticirrhus littoralis	2	231
Aluterus schoepfi	2	25
Pteroctopus tetracirrhus	1	19

Table 7-1. continued

SPECIES	TOTAL #	TOTAL WEIGHT
Sicyonia sp.	1	3
Carcharhinus isodon	1	4,400
Mustelus canis	1	112
Dasyatis sayi	1	450
Ophichthus gomesi	1	231
Serraniculus pumilio	1	5
Oligoplites saurus	1	14
Mugil cephalus	1	19
Mugil curema	1	21

Total number of species 99 TOTAL COUNT 324,102 ind TOTAL WEIGHT 3,355,014 g

Clustering was performed on the basis of species composition. Species composition was determined by numerical and weight totals of each species in each trawl. Clusters were constructed both including and excluding rare species. Those species that were excluded were found in two trawls or less out of the 18 monthly trawls (May through October) or 22 monthly trawls (November through March). For simplicity, replicate trawls were combined so that only one value per station appears on the cluster dendograms. In April, 1981 station M10A was sampled on both days of sampling. It was included twice on the April dendogram and designated as M10 and M10A. Figures 7-1 through 7-10 show representative cluster dendograms for the post-brine discharge period. May and July results are not given. In May, brine discharge was felt to be inadequate to produce discernible changes. On May 14 brine, at a salinity of 57 $^{o}/oo$, was discharged for two hours and on May 15, 73 $^{o}/oo$ brine was discharged for two hours. There was no discharge on May 16, 17 or 18. On May 19 41 $^{o}/oo$ brine was discharged for three hours. There was no discharge on May 20. Nekton sampling was conducted on May 19 and 20 in accordance with contractual obligations. In July there was a severe bottom hypoxia in the sampling area which precluded the capture of all but a few individuals of pelagic species.

A major cluster for all ten months is given in Figure 7-11. Figures 7-12 through 7-15 show enlargements of major cluster elements in Figure 7-11.

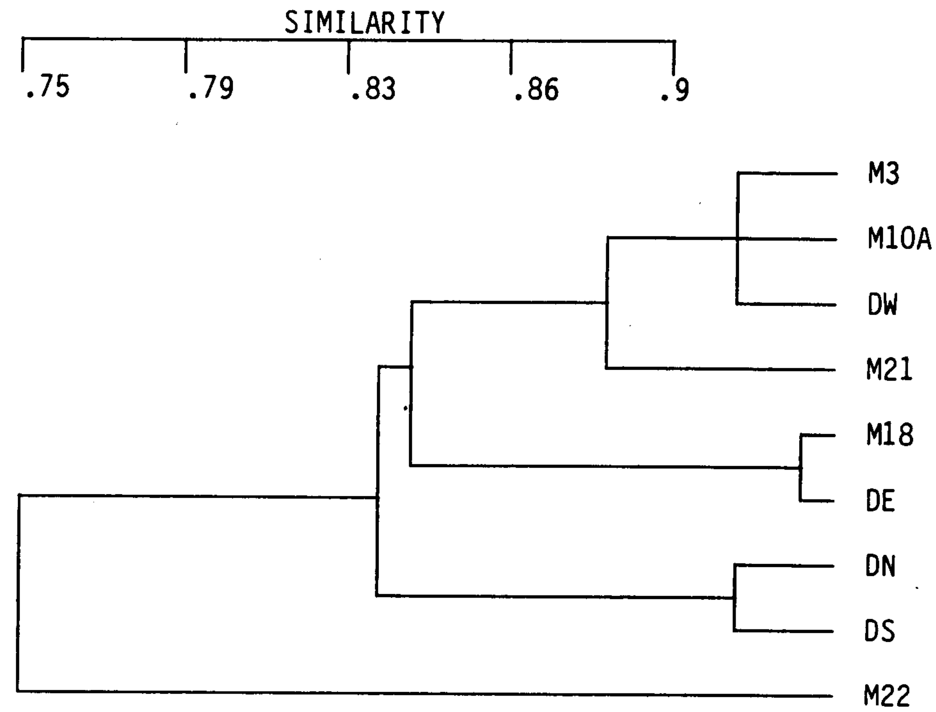

Figure 7-1. Cluster dendogram of June 1981 marine stations. Stations were clustered on the basis of the number of individuals collected at each station. Replicates were combined.

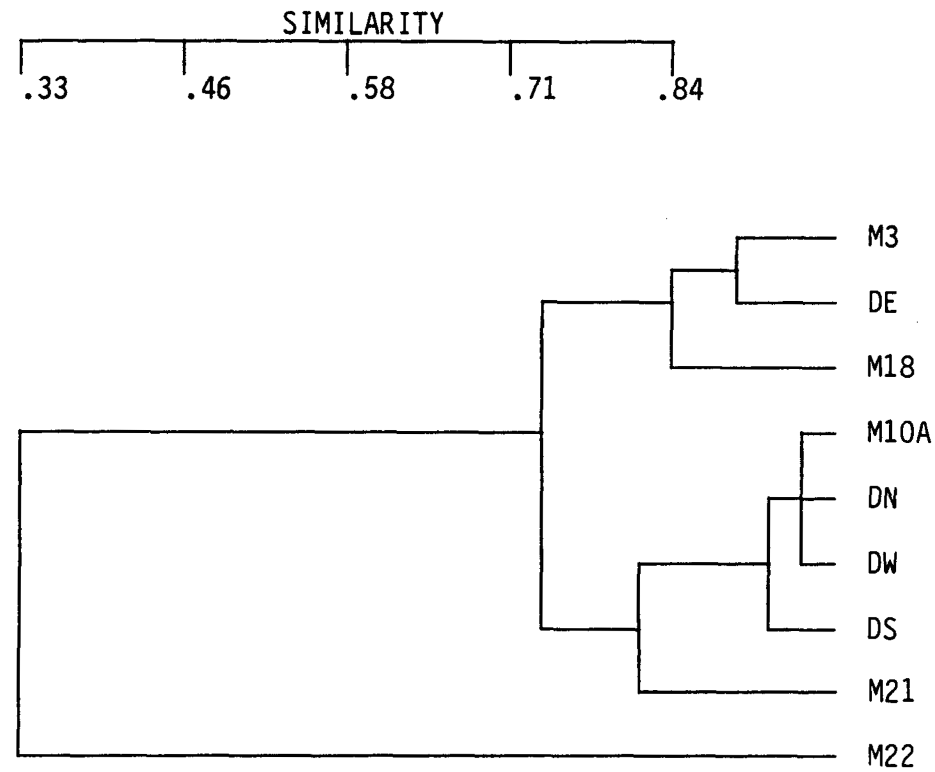

Figure 7-2. Cluster dendogram of August 1981 marine stations. Stations were clustered on the basis of the number of individuals collected at each station. Replicates were combined.

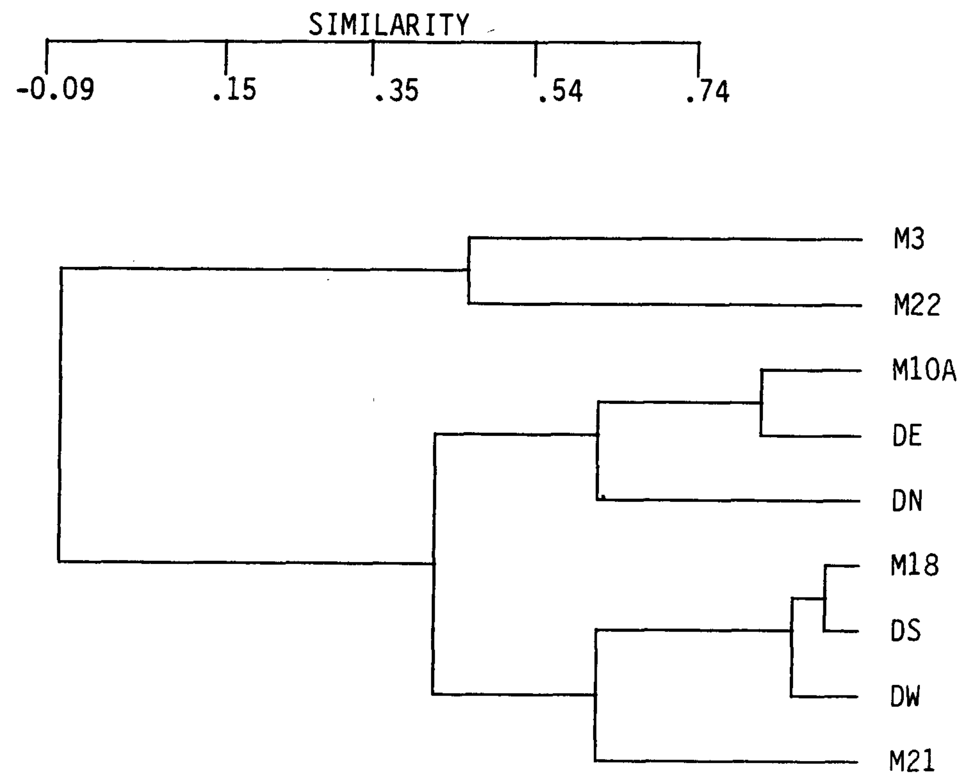

Figure 7-3. Cluster dendogram of September 1981 marine stations. Stations were clustered on the basis of the number of individuals collected at each station. Replicates were combined.

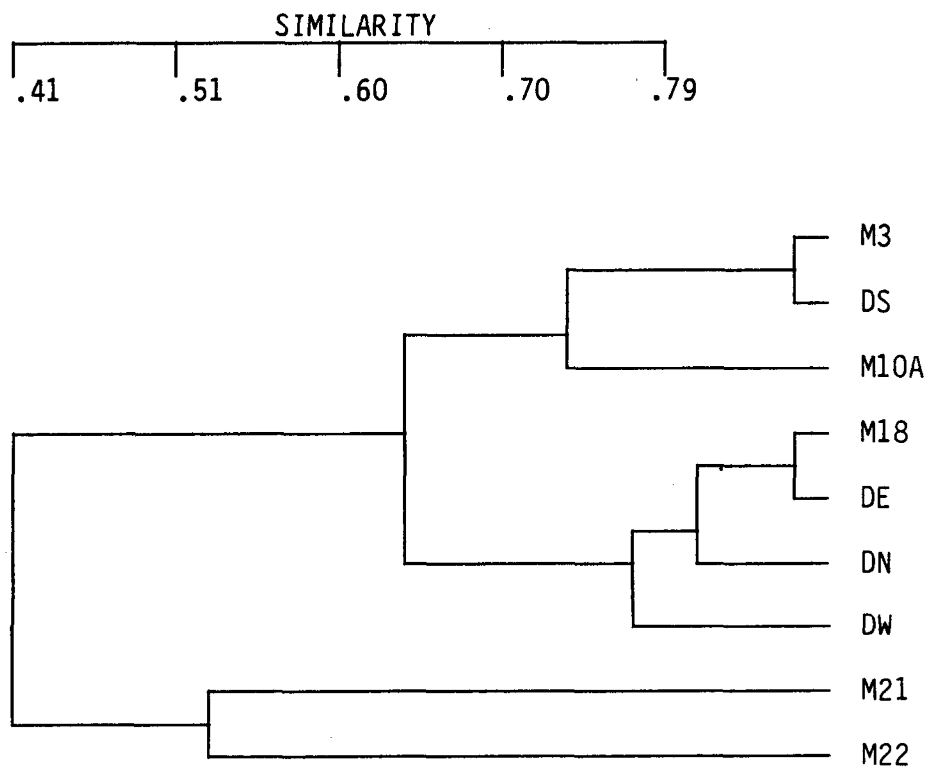

Figure 7-4. Cluster dendogram of October 1981 marine stations. Stations were clustered on the basis of the number of individuals collected at each station. Replicates were combined.

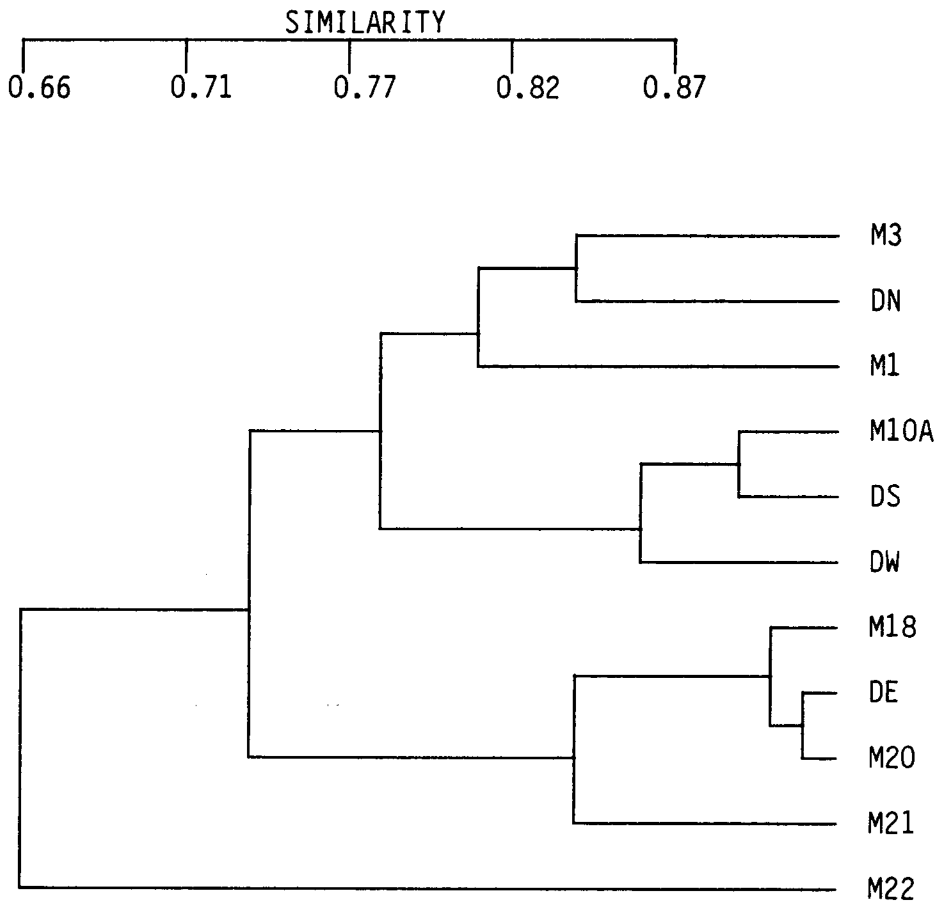

Figure 7-5. Cluster dendogram of November 1981 marine stations. Stations were clustered on the basis of the number of individuals collected at each station. Replicates were combined.

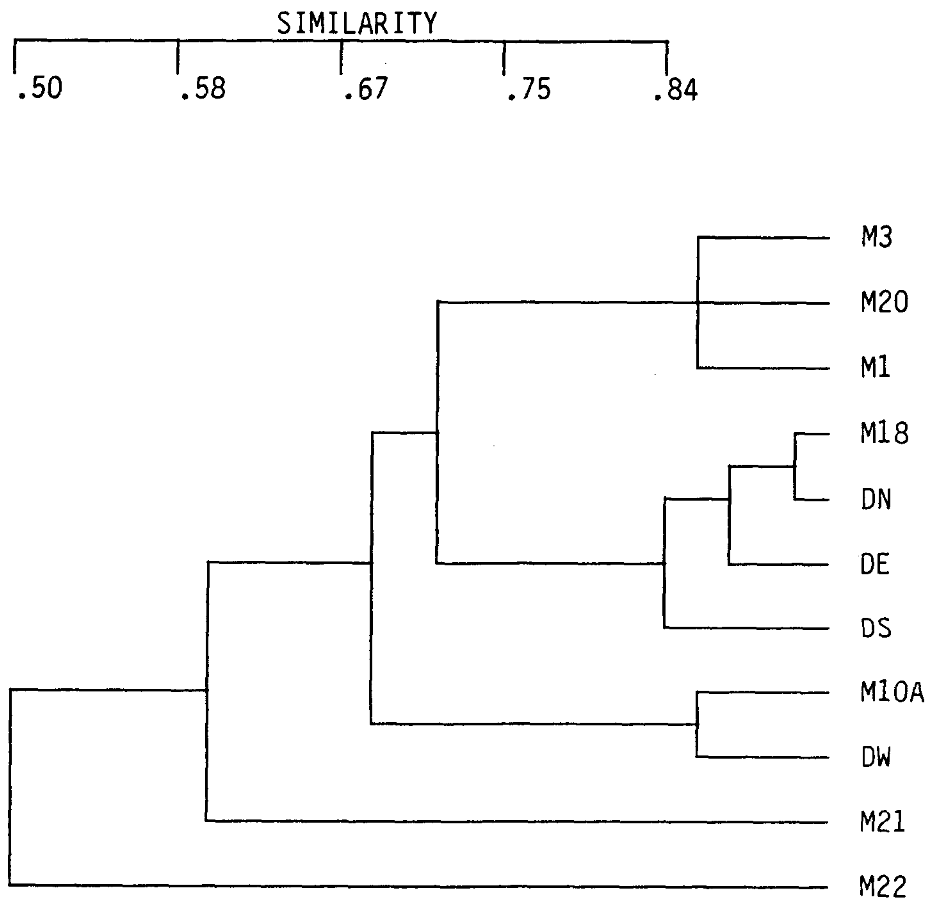

Figure 7-6. Cluster dendogram of December 1981 marine stations. Stations were clustered on the basis of the number of individuals collected at each station. Replicates were combined.

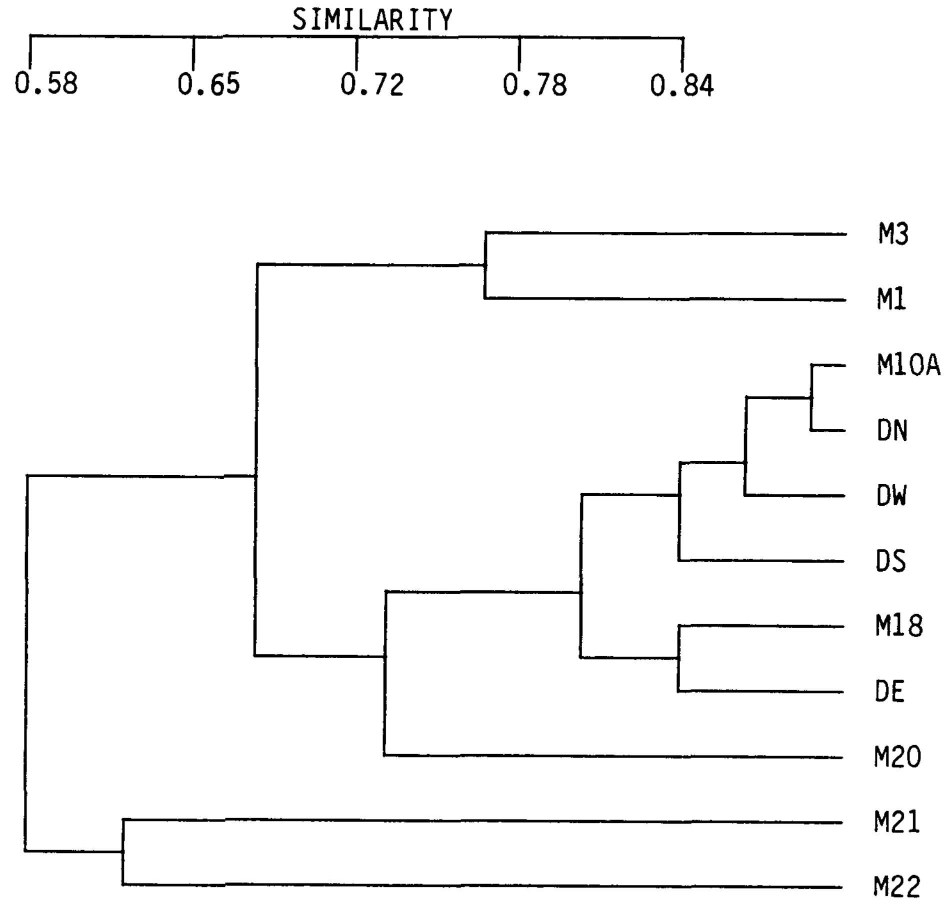

Figure 7-7. Cluster dendogram of January 1982 marine stations. Stations were clustered on the basis of the number of individuals collected at each station. Replicates were combined.

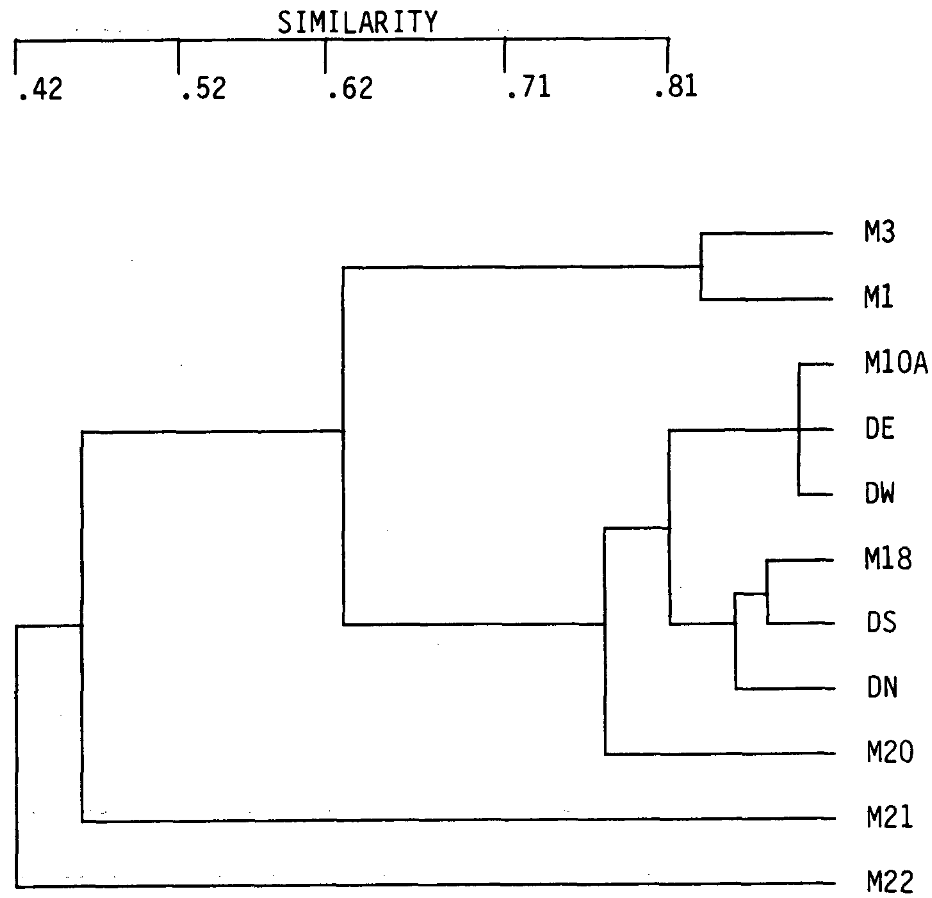

Figure 7-8. Cluster dendogram of February 1982 marine stations. Stations were clustered on the basis of the number of individuals collected at each station. Replicates were combined.

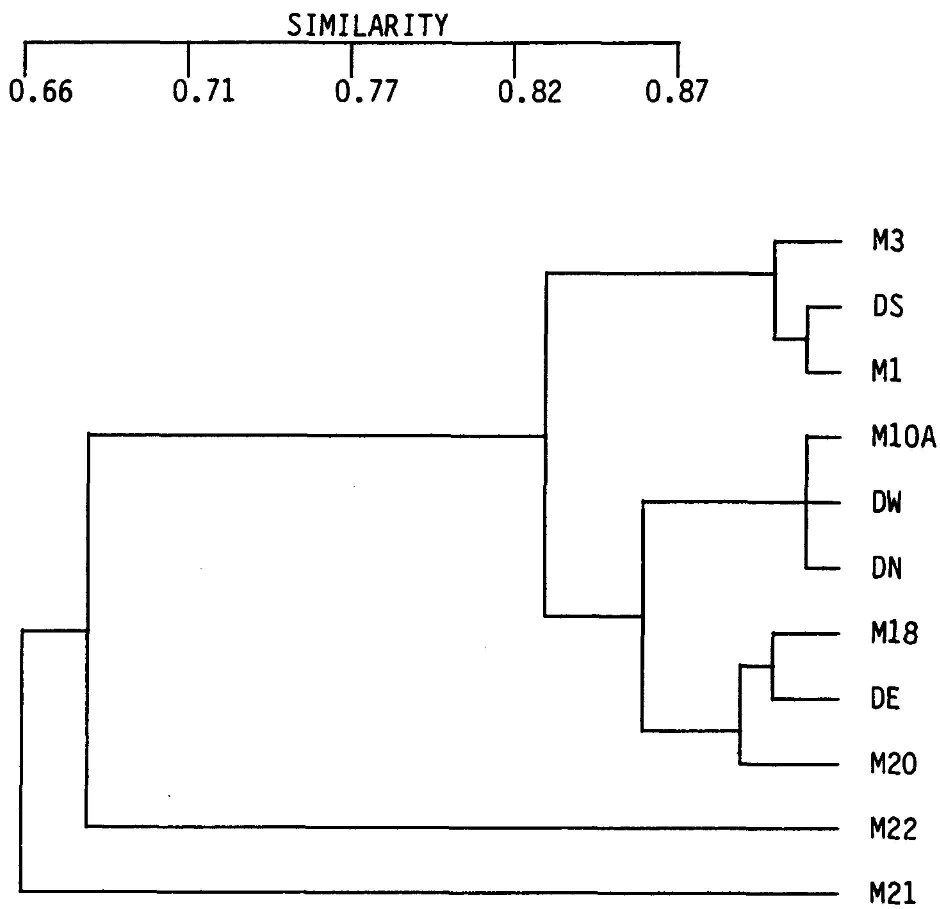

Figure 7-9. Cluster dendogram of March 1982 marine stations. Stations were clustered on the basis of the number of individuals collected at each station. Replicates were combined.

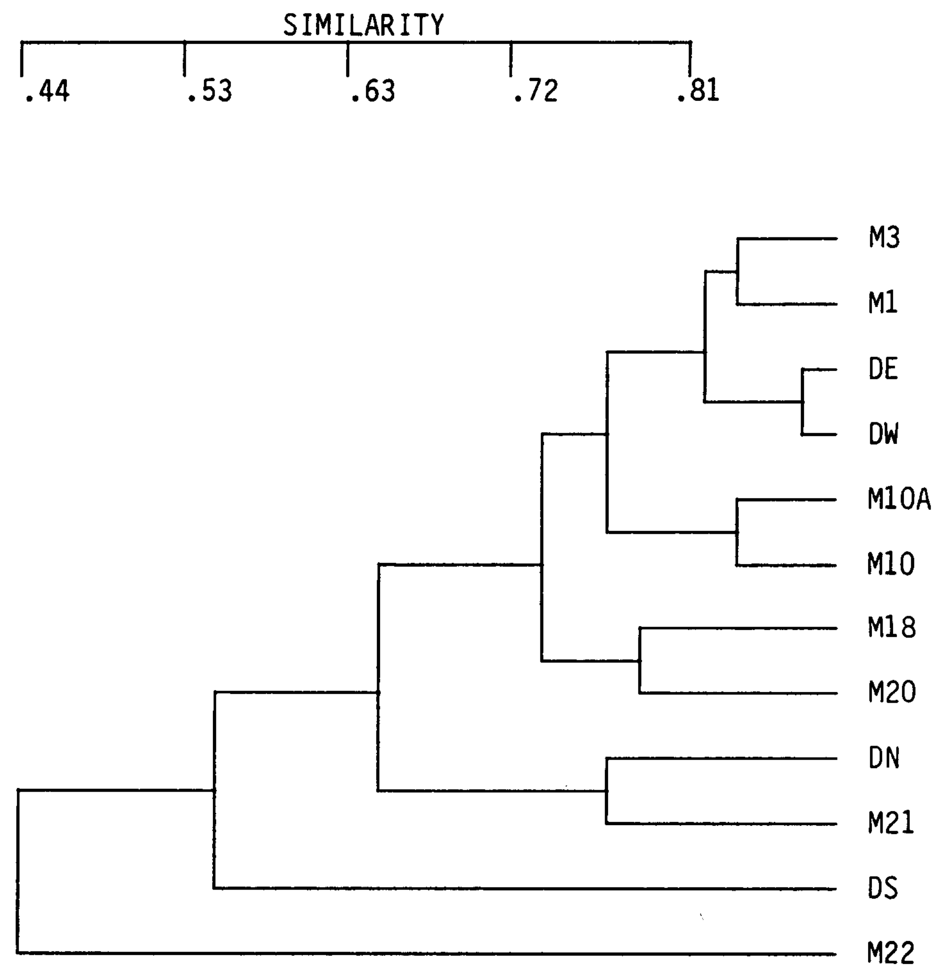

Figure 7-10. Cluster dendogram of April 1982 marine stations. Stations were clustered on the basis of the number of individuals collected at each station. Replicates were combined.

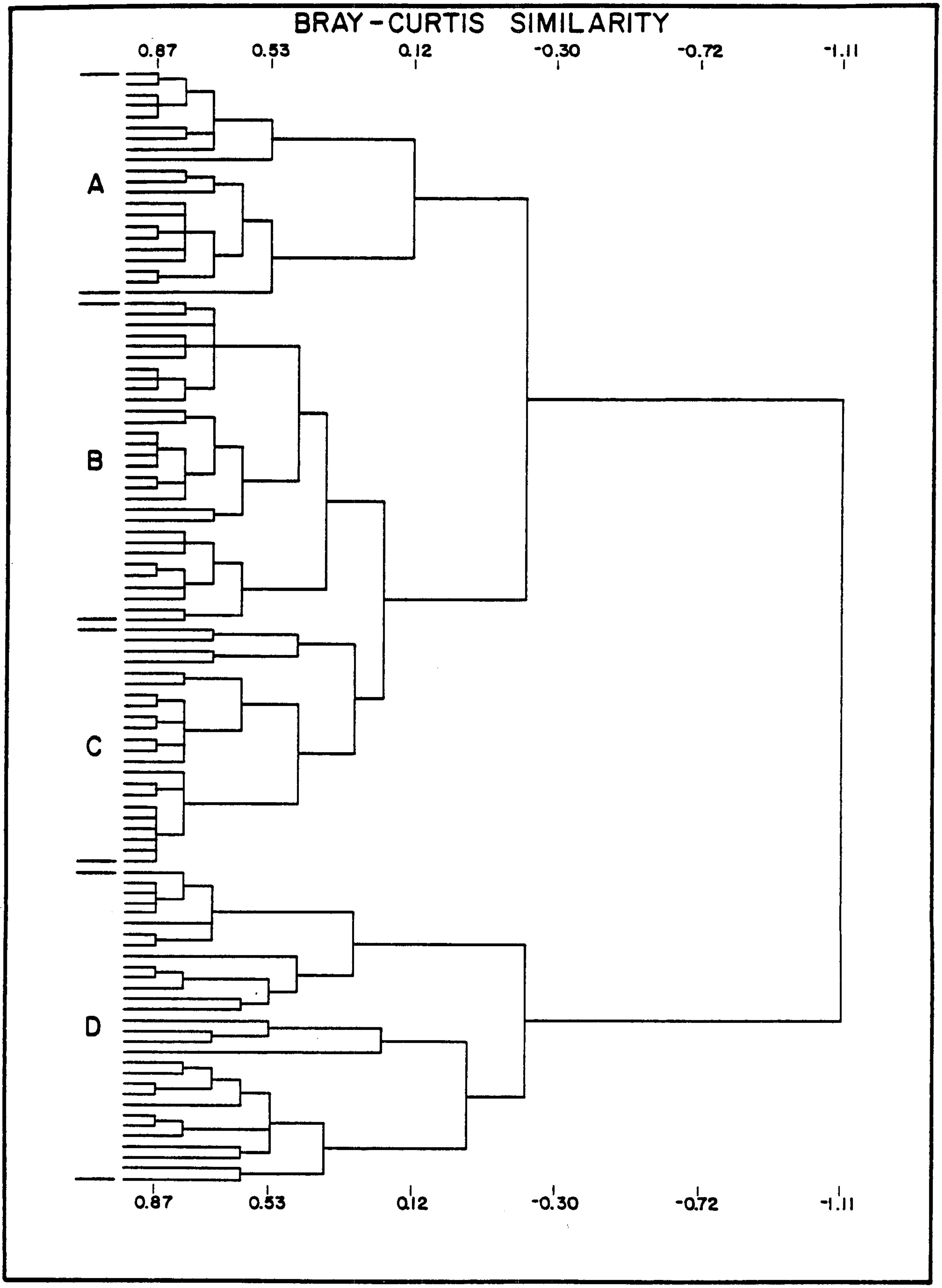

Figure 7-11. Cluster dendogram for ten months combined. Stations were clustered on the basis of number of individuals caught at each station. Replicate trawls were combined and species with no more than five occurrences were dropped.

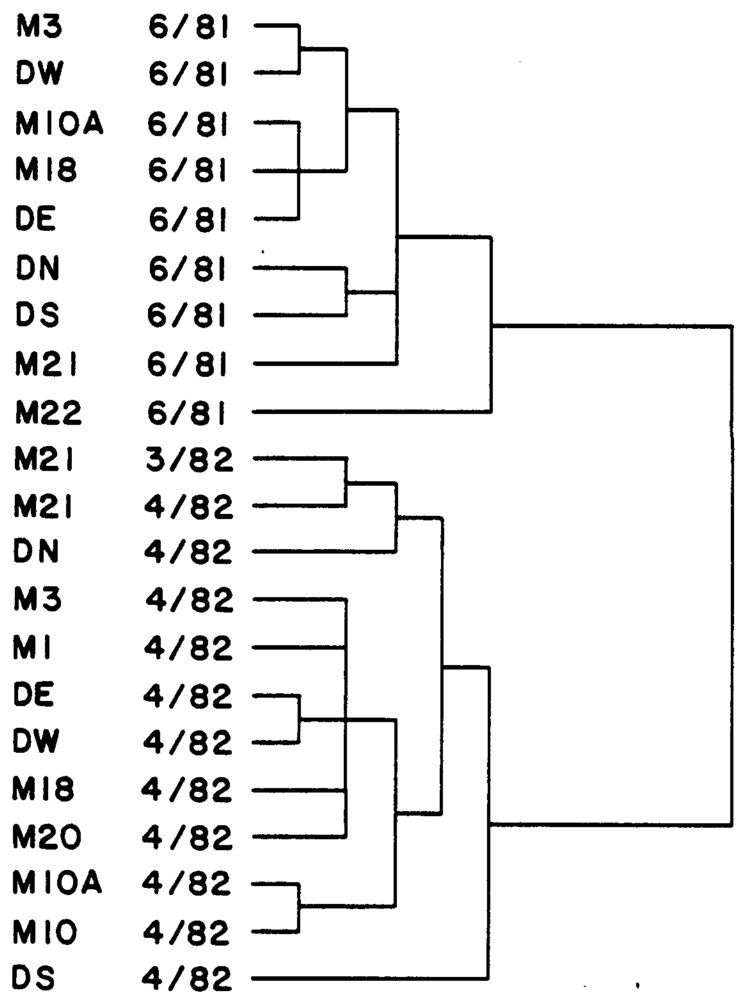

Figure 7-12. Enlargement of upper cluster, represented as A in Figure 7-11 showing station and month designations.

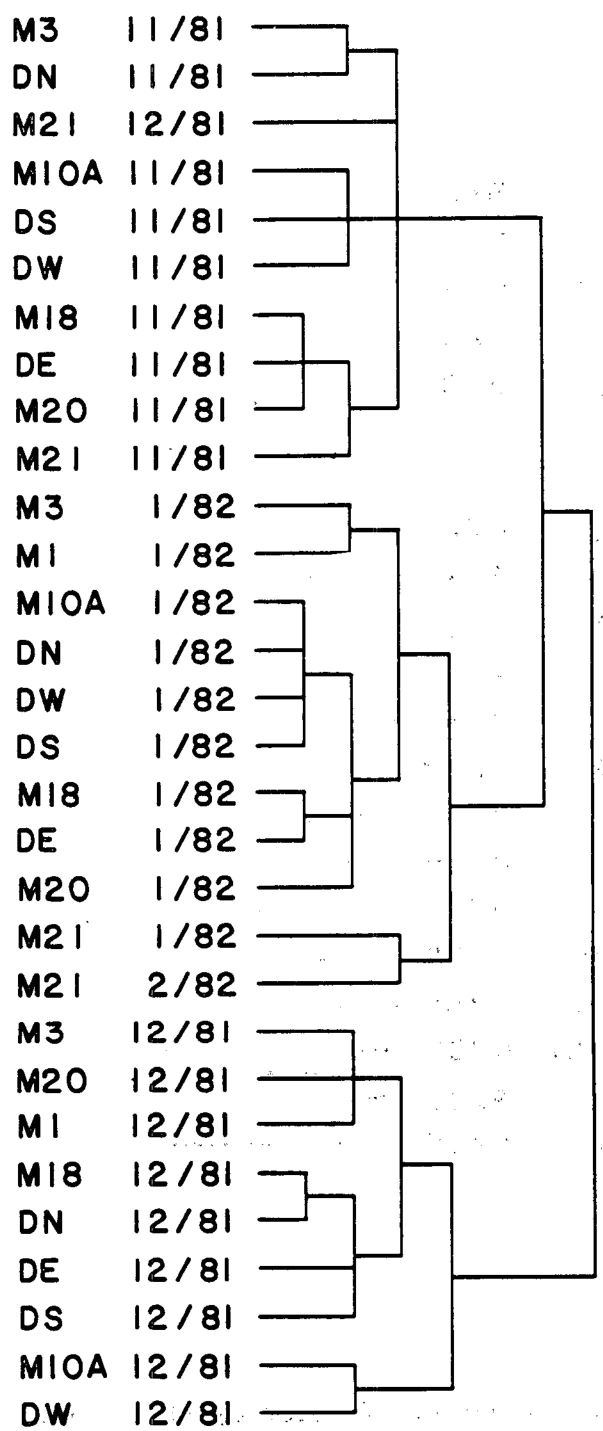

Figure 7-13. Enlargement of second cluster, represented as B in Figure 7-11 showing station and month designations.

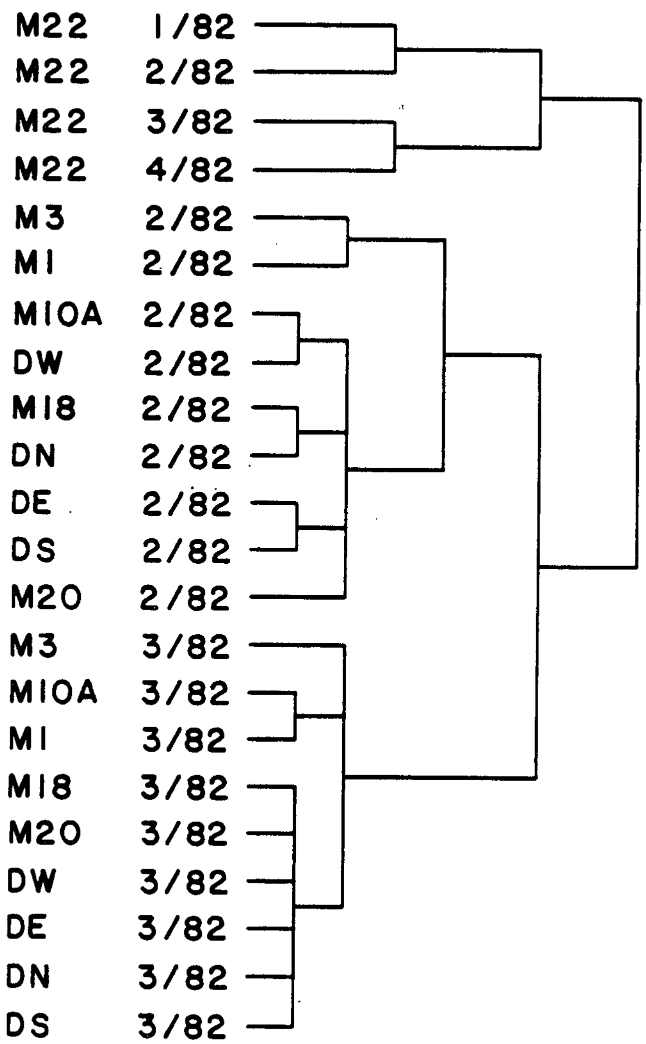

Figure 7-14. Enlargement of third cluster, represented as C in Figure 7-11 showing station and month designations.

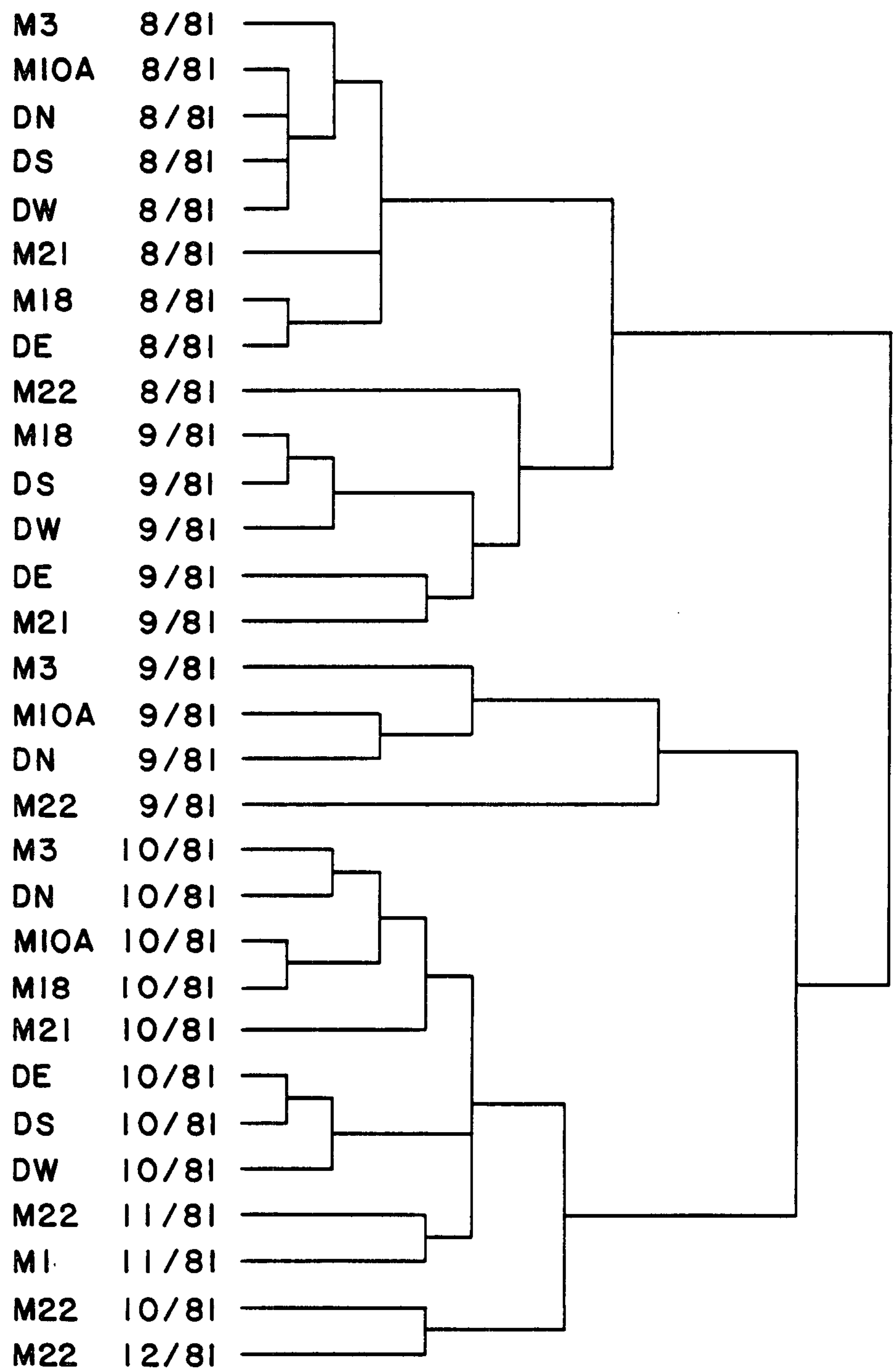

Figure 7-15. Enlargement of bottom cluster, represented as D in Figure 7-11 showing station and month designations.

Species were clustered on the basis of trawl occurrence to determine persistent species relationships. This cluster is given in Figure 7-16. Species have been given a numerical designation according to the list of all species in Table 7-2.

The Shannon-Weaver species diversity index (H') was determined for each station each month (except May and July). In addition, species richness, evenness and the probability of interspecific encounters were determined. These data are given in Tables 7-3 through 7-12. Results from Student-Newman-Keuls tests on H' are given in Table 7-13; for species richness the results are presented in Table 7-14, and the evenness results are presented in Table 7-15.

Tables 7-16 through 7-25 show the monthly results of Student-Newman-Keuls tests for ten species that frequently show significant ANOVA results ($\alpha = 0.05$). The ANOVA tests have not been reproduced in this report. ANOVAS were performed on the distribution of all species of nekters each month and on the diversity indices for all months. It was felt that inclusion of these myriad tables would only obfuscate results. In addition the ANOVA only indicate that there is a difference in distribution each month. The SNK results show what the difference is. If the ANOVA results were not significant there would be no significant difference between stations in the SNK tables.

The significant results of MANOVA analyses on target species are presented in Tables 7-26 through 7-29. Table 7-26 shows the significant results for the MANOVA using observed physical conditions

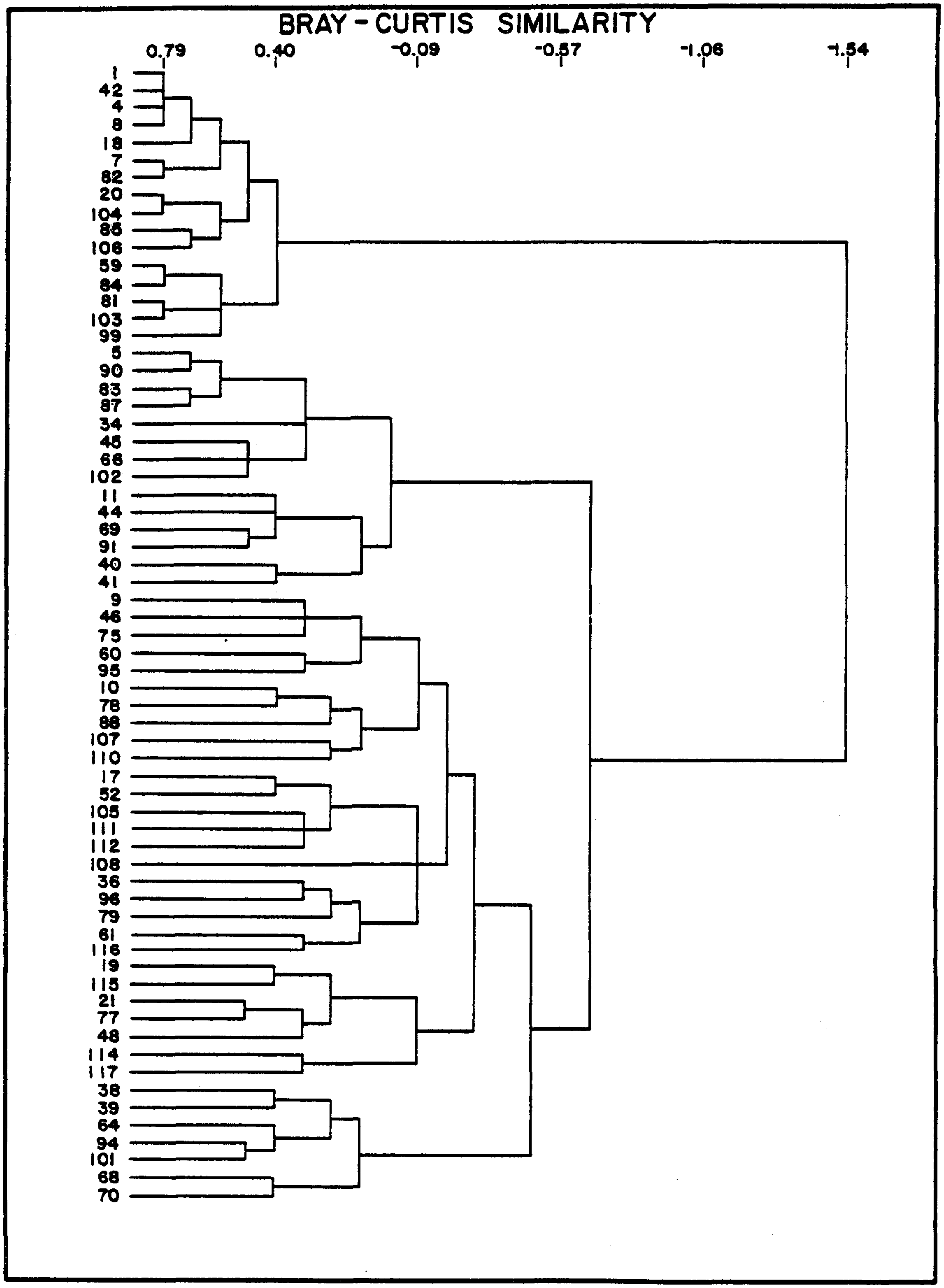

Figure 7-16. Cluster dendogram of marine species for all ten valid sampling months. Species are clustered on the basis number of individuals caught at each station each month. Species with fewer than five occurrences are dropped. Species are identified by number in the total species list in Table 7-14.

Table 7-2. Total species list for Nekton--February 1981 through April 1982.

1. *Lolliguncula brevis*
2. *Loligo plei*
3. *Pteroctopus tetracirrhus*
4. *Squilla empusa*
5. *Penaeus aztecus*
6. *Penaeus duorarum*
7. *Penaeus setiferus*
8. *Trachypenaeus similis*
9. *Sicyonia brevirostris*
10. *Sicyonia dorsalis*
11. *Xiphopenaeus kroyeri*
12. *Acetes americanus*
13. *Macrobrachium ohione*
14. *Palaemonetes vulgaris*
15. *Lysmata wurdemanni*
16. *Arenaeus cribrarius*
17. *Callinectes sapidus*
18. *Callinectes similis*
19. *Ovalipes floridanus*
20. *Portunus gibbesii*
21. *Portunus sayi*
22. *Portunus spinimanus*
23. *Rhizoprionodon terraenovae*
24. *Mustelus canis*
25. *Carcharhinus isodon*
26. *Sphyrna tiburo*
27. *Sphyrna lewini*
28. *Dasyatis americana*
29. *Dasyatis sabina*
30. *Dasyatis sayi*
31. *Elops saurus*
32. *Ophichthus gomesi*
33. *Myrophis punctatus*
34. *Brevoortia patronus*
35. *Dorosoma cepedianum*
36. *Dorosoma petenense*
37. *Etrumeus teres*
38. *Opisthonema oglinum*
39. *Sardinella aurita*
40. *Harengula jaguana*
41. *Anchoa hepsetus*
42. *Anchoa mitchilli*
43. *Ictalurus melas*
44. *Bagre marinus*
45. *Arius felis*
46. *Synodus foetens*
47. *Opsanus beta*
48. *Porichthys plectrodon*
49. *Gobiesox strumosus*
50. *Histrio histrio*
51. *Ogcocephalus radiatus*
52. *Urophycis floridana*
53. *Ophidion welshi*
54. *Cyprinodon variegatus*
55. *Lucania parva*
56. *Menidia beryllina*
57. *Syngnathus louisianae*
58. *Prionotus scitulus*
59. *Prionotus tribulus*
60. *Prionotus rubio*

Table 7-2. continued

61. Centropristis philadelphica
62. Serraniculus pumilio
63. Pomatomus saltatrix
64. Caranx hippos
65. Caranx crysos
66. Chloroscombrus chrysurus
67. Oligoplites saurus
68. Trachinotus carolinus
69. Selene setapinnis
70. Hemicaranx amblyrhynchus
71. Lutjanus campechanus
72. Lutjanus synagris
73. Lobotes surinamensis
74. Eucinostomus argenteus
75. Orthopristis chrysoptera
76. Stenotomus caprinus
77. Lagodon rhomboides
78. Archosargus probatocephalus
79. Bairdiella chrysoura
80. Cynoscion nebulosus
81. Cynoscion nothus
82. Cynoscion arenarius
83. Leiostomus xanthurus
84. Larimus fasciatus
85. Menticirrhus americanus
86. Menticirrhus littoralis
87. Micropogonias undulatus
88. Pogonias cromis
89. Sciaenops ocellatus
90. Stellifer lanceolatus
91. Chaetodipterus faber
92. Mugil cephalus
93. Mugil curema
94. Sphyraena guachancho
95. Polydactylus octonemus
96. Astroscopus y-graecum
97. Gobionellus hastatus
98. Gobiosoma bosci
99. Trichiurus lepturus
100. Scomberomorus cavalla
101. Scomberomorus maculatus
102. Peprilus alepidotus
103. Peprilus burti
104. Etropus crossotus
105. Paralichthys lethostigma
106. Citharichthys spilopterus
107. Ancylopsetta quadrocellata
108. Trinectes maculatus
109. Achirus lineatus
110. Symphurus sp.
111. Symphurus plagiusa
112. Symphurus civitatus
113. Aluterus schoepfi
114. Monacanthus hispidus
115. Lagocephalus laevigatus
116. Sphoeroides parvus
117. Chilomycterus schoepfi

Table 7-3. Species diversity indices for the June marine sampling. Indices are referenced in text. Also included are number of individuals collected at each station and the number of species collected at each station.

STATION NAME	NUMBER SPECIES	TOTAL IND	DIVERSITY H'	RICHNESS S R	EVENNESS J	P I E
M3	23	4973	2.71162	2.58465	0.59944	0.81056
M10A	24	4150	2.86900	2.76082	0.62574	0.82575
M18	24	3201	2.83276	2.84963	0.61784	0.81883
DE	21	3144	2.93787	2.48347	0.66887	0.83795
DW	24	4026	2.74992	2.77091	0.59977	0.78171
DN	20	2976	2.68019	2.37549	0.62014	0.80106
DS	22	3131	2.64418	2.60898	0.59294	0.78791
M21	25	9920	2.08819	2.60804	0.44967	0.63556
M22	22	6411	2.35387	2.39568	0.52784	0.72350

Table 7-4. Species diversity indices for the August marine sampling. Indices are referenced in text. Also included are number of individuals collected at each station and the number of species collected at each station.

STATION NAME	NUMBER SPECIES	TOTAL IND	DIVERSITY H'	RICHNESS S R	EVENNESS J	P I E
M3	17	1991	2.18848	2.10626	0.53541	0.62717
M10A	19	3406	1.42252	2.21313	0.33487	0.38342
M18	18	1193	2.43638	2.39970	0.58427	0.70309
DE	13	2168	1.58725	1.56218	0.42894	0.42915
DW	21	4834	1.11215	2.35754	0.25320	0.29376
DN	15	3870	1.36115	1.69471	0.34840	0.36372
DS	21	3919	1.24055	2.41733	0.28244	0.31827
M21	19	3985	0.82333	2.17121	0.19382	0.20543
M22	26	1417	2.70575	3.44528	0.57564	0.78897

Table 7-5. Species diversity indices for the September marine sampling. Indices are referenced in text. Also included are number of individuals collected at each station and the number of species collected at each station.

STATION NAME	NUMBER SPECIES	TOTAL IND	DIVERSITY H'	RICHNESS S R	EVENNESS J	P I E
M3	7	43	2.14605	1.59523	0.76444	0.73311
M10A	15	89	3.40889	3.11899	0.87253	0.88943
M18	17	4039	1.95340	1.92684	0.47790	0.64571
DE	15	193	2.96617	2.66024	0.75922	0.81396
DW	17	1061	2.65016	2.29655	0.64836	0.79708
DN	12	89	2.63548	2.45063	0.73515	0.76251
DS	15	2675	1.74094	1.77401	0.44561	0.53772
M21	13	2768	1.05609	1.51403	0.28540	0.30744
M22	8	20	2.77095	2.33666	0.92365	0.87368

Table 7-6. Species diversity indices for the October marine sampling. Indices are referenced in text. Also included are number of individuals collected at each station and the number of species collected at each station.

STATION NAME	NUMBER SPECIES	TOTAL IND	DIVERSITY H'	RICHNESS S R	EVENNESS J	P I E
M3	20	1634	1.95608	2.56799	0.45259	0.51055
M10A	26	4504	2.39334	2.97169	0.50917	0.68464
M18	22	2312	2.59328	2.71112	0.58153	0.73723
DE	15	195	3.04260	2.65504	0.77878	0.84589
DW	18	382	3.00994	2.85934	0.72182	0.83963
DN	17	368	3.17485	2.70815	0.77673	0.85923
DS	13	227	3.09629	2.21200	0.83674	0.85954
M21	20	2767	2.77335	2.39732	0.64169	0.82723
M22	13	327	2.17980	2.07255	0.58906	0.62070

Table 7-7. Species diversity indices for the November marine sampling. Indices are referenced in text. Also included are number of individuals collected at each station and the number of species collected at each station.

STATION NAME	NUMBER SPECIES	TOTAL IND	DIVERSITY H'	RICHNESS S R	EVENNESS J	P I E
M3	19	1390	2.74493	2.48720	0.64618	0.73864
M10A	18	2544	2.47963	2.16795	0.59465	0.76290
M18	21	2895	2.37426	2.50918	0.54055	0.70358
DE	19	2730	2.29915	2.27501	0.54124	0.71159
DW	19	1216	2.57373	2.53403	0.60588	0.73127
DN	18	1405	2.67187	2.34554	0.64075	0.79100
DS	18	1549	2.37386	2.31438	0.56928	0.70765
M20	20	1630	2.53279	2.56884	0.58603	0.72155
M21	22	3492	2.69851	2.57409	0.60513	0.77002
M22	26	778	3.32734	3.75560	0.70788	0.86705
M1	20	483	2.89217	3.07442	0.66918	0.76911

Table 7-8. Species diversity indices for the December marine sampling. Indices are referenced in text. Also included are number of individuals collected at each station and the number of species collected at each station.

STATION NAME	NUMBER SPECIES	TOTAL IND	DIVERSITY H'	RICHNESS S R	EVENNESS J	P I E
M3	17	642	3.02813	2.47502	0.74083	0.82361
M10A	21	485	3.14633	3.23407	0.71633	0.83369
M18	18	826	3.25951	2.53104	0.78167	0.86831
DE	18	514	3.15242	2.72339	0.75599	0.84483
DW	17	348	3.16901	2.73401	0.77530	0.86805
DN	19	915	3.10027	2.63971	0.72983	0.82860
DS	18	474	3.28227	2.75920	0.78713	0.86717
M20	19	492	2.64431	2.90394	0.62250	0.70941
M21	20	1868	2.97313	2.52236	0.68792	0.81842
M22	20	367	2.98270	3.21741	0.69013	0.77177
M1	21	606	2.62283	3.12164	0.59714	0.72851

Table 7-9. Species diversity indices for the January marine sampling. Indices are referenced in text. Also included are number of individuals collected at each station and the number of species collected at each station.

STATION NAME	NUMBER SPECIES	TOTAL IND	DIVERSITY H'	RICHNESS S R	EVENNESS J	P I E
M3	20	4843	3.30568	2.23917	0.76486	0.85402
M10A	21	13139	3.15544	2.10896	0.71840	0.83352
M18	26	10953	3.09034	2.68778	0.65746	0.79319
DE	23	12378	3.27040	2.33455	0.72297	0.83766
DW	21	9046	3.37440	2.19537	0.76825	0.87117
DN	23	13916	3.44020	2.30589	0.76051	0.87066
DS	24	11479	3.14473	2.46035	0.68588	0.81359
M20	23	17232	3.29059	2.25536	0.72743	0.83658
M21	22	5627	2.95279	2.43187	0.66215	0.78409
M22	20	2450	3.54393	2.43470	0.81999	0.88422
M1	22	3774	3.00685	2.54982	0.67427	0.81050

Table 7-10. Species diversity indices for the February marine sampling. Indices are referenced in text. Also included are number of individuals collected at each station and the number of species collected at each station.

STATION NAME	NUMBER SPECIES	TOTAL IND	DIVERSITY H'	RICHNESS S R	EVENNESS J	P I E
M3	16	332	2.80845	2.58392	0.70211	0.80059
M10A	21	1699	2.97565	2.68897	0.67747	0.82644
M18	22	998	2.99026	3.04094	0.67055	0.82234
DE	21	1105	3.25806	2.85404	0.74176	0.86424
DW	20	971	3.35890	2.76230	0.77718	0.88052
DN	22	913	2.90565	3.08065	0.65157	0.76738
DS	19	727	2.98524	2.73186	0.70275	0.82005
M20	19	500	3.26776	2.89640	0.76926	0.87149
M21	21	481	3.53965	3.23841	0.80587	0.88526
M22	18	228	2.61876	3.13113	0.62801	0.69159
M1	18	323	3.24598	2.94237	0.77843	0.86610

Table 7-11. Species diversity indices for the March marine sampling. Indices are referenced in text. Also included are number of individuals collected at each station and the number of species collected at each station.

STATION NAME	NUMBER SPECIES	TOTAL IND	DIVERSITY H'	RICHNESS S R	EVENNESS J	P I E
M3	25	1852	2.63383	3.18978	0.56717	0.76213
M10A	24	1464	2.62929	3.15547	0.57346	0.70274
M18	19	1213	2.74799	2.53491	0.64690	0.75013
DE	20	1100	3.29054	2.71310	0.76136	0.86365
DW	22	2027	2.45643	2.75796	0.55084	0.71643
DN	23	983	3.17398	3.19275	0.70166	0.81589
DS	23	953	2.94940	3.20718	0.65201	0.80745
M20	23	1372	2.72449	3.04539	0.60229	0.74803
M21	24	2488	1.47429	2.94146	0.32155	0.36595
M22	26	743	3.16743	3.78175	0.67386	0.83118
M1	21	643	3.44919	3.09303	0.78528	0.87132

Table 7-12. Species diversity indices for the April marine sampling. Indices are referenced in text. Also included are number of individuals collected at each station and the number of species collected at each station.

STATION NAME	NUMBER SPECIES	TOTAL IND	DIVERSITY H'	RICHNESS S R	EVENNESS J	P I E
M3	23	601	3.12745	3.43825	0.69137	0.84261
M10A	19	400	3.04445	3.00427	0.71669	0.76920
M18	14	181	3.24515	2.50072	0.85234	0.86808
DE	18	621	2.79095	2.64331	0.66930	0.76605
DW	22	699	3.16976	3.20628	0.71080	0.85581
DN	25	2992	2.43204	2.99861	0.52371	0.67768
DS	14	100	3.18702	2.82291	0.83707	0.85818
M20	17	710	2.87648	2.43707	0.70373	0.80890
M21	19	2377	1.31322	2.31553	0.30914	0.37693
M22	24	719	2.59903	3.49658	0.56686	0.72669
M1	19	407	3.06593	2.99560	0.72175	0.81641
M10	22	321	3.54013	3.63861	0.79385	0.88442

Table 7-13. Results of Student-Newman-Keuls tests for east-west transect stations. Results are for those months that show significant variance of the Shannon-Weaver diversity index (H') in an ANOVA (α = 0.05).

SPECIES DIVERSITY (H')

Aug 81	M3 2.733	M10A 1.757	DW 1.633	M18 1.233	DE 1.131
Sep 81	DE 2.544	M18 2.447	DW 1.948	M10A 0.159	M3 0.083
Nov 81	M3 3.08	DW 2.83	M10A 2.713	DE 2.489	M18 2.48
Dec 81	M10A 3.481	DE 3.425	M18 3.373	M3 3.263	DW 2.824
Jan 82	M3 3.522	M18 3.425	DE 3.412	DW 3.265	M10A 3.074
Mar 82	DE 3.55	M18 3.099	M10A 2.958	M3 2.873	DW 2.767

Table 7-14. Results of Student-Newman-Keuls tests for east-west transect stations. Results are for those months that show significant variance of the species richness in an ANOVA (α = 0.05).

SPECIES RICHNESS

Aug 81	M3 2.945	DW 2.938	M10A 2.733	M18 2.342	DE 2.092
Sep 81	DE 3.349	M18 3.066	DW 3.006	M10A 2.167	M3 0.849
Oct 81	DW 3.304	M10A 3.195	M18 2.852	M3 2.713	DE 2.5

Table 7-15. Results of Student-Newman-Keuls tests for east-west transect stations. Results are for those months that show significant variance of the evenness in an ANOVA ($\alpha = 0.05$).

EVENNESS

Aug 81	M3 0.613	M10A 0.397	DW 0.361	M18 0.286	DE 0.266
Sep 81	DE 0.585	M18 0.521	DW 0.422	M10A 0.037	M3 0.028
Nov 81	M3 0.676	DW 0.646	M10A 0.639	DE 0.554	M18 0.539
Dec 81	DE 0.806	M18 0.787	M10A 0.77	M3 0.769	DW 0.667
Jan 82	M3 0.802	M18 0.752	DE 0.744	DW 0.733	M10A 0.690
Mar 82	DE 0.816	M18 0.718	M10A 0.642	M3 0.637	DW 0.608
Apr 82	M18 0.856	DE 0.763	M3 0.741	DW 0.719	M10A 0.691

Table 7-16. Student-Newman-Keuls multiple range test for <u>Lolliguncula brevis</u>. Results are presented for those months which show significant variance in abundance at the 10 m stations according to an ANOVA ($\alpha = 0.05$).

Jul 81	M3 359	DN 317	DS 139.5	DW 90	M10A 70	DE 1	M18 0
Aug 81	DE 24.5	M18 15	DS 8.5	M3 7.5	DN 5.5	M10A 2.5	DW 2
Dec 81	DN 155	M3 100	M18 90.5	DE 79	M10A 73.5	DS 62	DW 36
Jan 82	DN 46	M10A 40.5	DS 29	DW 24.5	M18 21	DE 20.5	M3 19
Feb 82	DW 64.5	M10A 57.5	M3 56.5	DE 28.5	M18 13.5	DN 12.5	DS 9

Table 7-16. continued

Mar 82	DW	DE	M10A	M3	DN	M18	DS
	80	56	48.5	31	28	20.5	18
Apr 82	DN	M3	DW	DE	M10A	DS	M18
	34	18.5	18.5	17.5	9.5	7	5

Table 7-17. Student-Newman-Keuls multiple range test for *Penaeus setiferus*. Results are presented for those months which show significant variance in abundance at the 10 m stations according to an ANOVA ($\alpha = 0.05$).

Jun 81	DW 45	M3 35.5	DE 26.5	DS 20	M10A 18.5	M18 17.5	DN 14
Sep 81	M18 42.5	DS 21	DN 19.5	DW 15	M10A 11	DE 9.5	M3 5
Oct 81	DW 48	DN 37.5	M10A 28	DE 27	M3 26.5	DS 24.5	M18 6
Jan 82	M18 148	DE 147.5	M10A 144	DS 142.5	DN 131.5	DW 72.5	M3 45
Apr 82	DW 19.5	DN 12.5	DE 9	M10A 5	M18 4.5	M3 3.5	DS 1.5

Table 7-18. Student-Newman-Keuls multiple range test for <u>Cynoscion nothus</u>. Results are presented for those months which show significant variance in abundance at the 10 m stations according to an ANOVA (α = 0.05).

Sep 81	M18	DS	DW	DE	M10A	DN	M3
	375.5	192.5	112.5	11	5	1	.5
Nov 81	M3	DN	M18	M10A	DW	DS	DE
	13.5	5.5	3	1.5	0	0	0
Feb 82	M10A	DE	DW	M18	M3	DN	DS
	97.5	87.5	84.5	51	37	19	14
Mar 82	DW	M3	DS	DE	M10A	M18	DN
	193	177	161	104	101.5	89	74

Table 7-19. Student-Newman-Keuls multiple range test for Cynoscion arenarius. Results are presented for those months which show significant variance in abundance at the 10 m stations according to an ANOVA ($\alpha = 0.05$).

Jun 81	M3	DN	DW	DS	M18	M10A	DE
	172	132.5	76.5	70	65	63	63
Aug 81	M3	DS	DW	DE	DN	M18	M10A
	96	74.5	59.5	49	45.5	29.5	27
Oct 81	DN	M10A	DE	M3	DW	DS	M18
	23	9	6	5	3.5	3.5	2.5
Nov 81	M18	M3	M10A	DN	DE	DW	DS
	38.5	29	24	13	10.5	8	2
Dec 81	DW	M3	M10A	DE	M18	DN	DS
	27.5	10	9.5	7	5	5	0
Feb 82	DE	M18	DW	DN	M10A	DS	M3
	16.5	15.5	11.5	11	9	5	1

Table 7-19. continued

Apr 82	DN 26.5	DW 5	DE 3.5	M10A 2.5	M3 1.5	M18 1.5	DS 1.5

Table 7-20. Student-Newman-Keuls multiple range test for Larimus fasciatus. Results are presented for those months which show significant variance in abundance at the 10 m stations according to an ANOVA (α = 0.05).

Apr 82	DN	M3	DE	M18	DW	M10A	DS
	60.5	53.5	12.5	10.5	10	4.5	2.5

Table 7-21. Student-Newman-Keuls multiple range test for <u>Leiostomus xanthurus</u>. Results are for those months which show significant variance in abundance at the 10 m stations according to an ANOVA (α = 0.05).

Jun 81	DW	DS	M10A	DE	M3	M18	DN
	92.5	41	34	33	15.5	13.5	8.5
Sep 81	DW	DS	M18	DE	M10A	M3	DN
	152	53	51.5	10.5	3.5	0	0
Nov 81	DS	M18	DW	DE	M3	M10A	DN
	3.5	.5	.5	.5	0	0	0
Feb 82	DE	M10A	M18	M3	DW	DS	DN
	4.5	1	.5	0	0	0	0
Mar 82	DE	M18	M10A	DN	DW	DS	M3
	52.5	21.5	19	15.5	14	11	1.5

Table 7-22. Student-Newman-Keuls multiple range tes for <u>Micropogonias undulatus</u>. Results are presented for those months which show significant variance in abundance at the 10 m stations according to an ANOVA (α = 0.05).

May 81	M10A	DW	M3	M18	DE	DS	DN
	814.0	355.0	354.5	231.0	173.0	170.5	122.0
	———						
		———	———	———	———	———	———
Jun 81	M3	DW	DS	M10A	DN	DE	M18
	443	300	263.5	190.5	161.5	103	67.5
	———	———	———				
		———	———	———	———	———	———
Sep 81	DS	M18	DW	DN	DE	M10A	M3
	75	53	30	8	5	2	0
	———	———					
			———	———	———	———	———
Apr 82	DN	DE	DW	M3	M18	DS	M10A
	799	135.5	72.5	59.5	24	15	10.5
	———						
		———	———	———	———	———	———

Table 7-23. Student-Newman-Keuls multiple range test for Stellifer lanceolatus. Results are presented for those months which show significant variance in abundance at the 10 m stations according to an ANOVA ($\alpha = 0.05$).

May 81	M18	DW	DE	M10A	DS	DN	M3
	764	591	544	362	258	229.5	128.5
Jun 81	M3	DS	DN	M10A	DE	DW	M18
	679	310.5	293	204	141.5	140.5	70
Nov 81	M18	DE	M10A	DS	DW	M3	DN
	29	15	6	4.5	1.5	1	.5
Apr 82	DN	M10A	DW	DE	DS	M3	M18
	11	4	2.5	2.5	1	.5	0

Table 7-24. Student-Newman-Keuls multiple range test for *Trichiurus lepturus*. Results are presented for those months which show significant variance in abundance at the 10 m stations according to an ANOVA (α = 0.05).

May 81	DS	DN	DE	M18	M10A	M3	DW
	71.5	52	34	10	8	6	6
Jun 81	DS	M18	DN	M3	DW	M10A	DE
	31.5	3.5	3	2	1	.5	.5
Aug 81	DE	M18	M10A	DN	M3	DS	DW
	12.5	8.5	4.5	3	1	1	.5
Nov 81	M3	DN	M18	DW	DE	DS	M10A
	42	19	7	4	4	2	0
Dec 81	DW	M10A	DE	DS	M3	M18	DN
	218.5	37.5	24.5	11.5	10	7.5	1.5

Table 7-24. continued

Feb 82	DW	M10A	M3	DE	DN	DS	M18
	68.5	49.5	13	2	1.5	1	0
Apr 82	DW	M3	DE	M10A	DN	M18	DS
	144.5	103.5	77.5	45	45	35.5	8

Table 7-25. Student-Newman-Keuls multiple range test for *Peprilus burti*. Results are presented for those months which show significant variance in abundance at the 10 m stations according to an ANOVA (α = 0.05).

May 81	DN	DS	M18	DE	M10A	DW	M3
	502.5	349	169	123	100	93	32.5
Sep 81	DS	M18	DW	DE	M10A	M3	DN
	289.5	193	98	16.5	3	0.5	0
Dec 81	M10A	DW	M18	DE	DS	M3	DN
	61.5	51	17	11.5	10	6.5	4.5
Feb 82	DW	M10A	DE	DN	DS	M18	M3
	22.5	20	10	5	3.5	0.5	0
Apr 82	M10A	DS	DN	DW	M3	DE	M18
	177.5	120.5	77.5	48.5	43	24.5	16.5

Table 7-26. Multivariate analysis of variance and covariance for Penaeus setiferus, Cynoscion nothus, Menticirrhus americanus and physical variables. (P is probability of significance based on F values)

	M3	M10A	M18
Cell means for variable 1 - Penaeus setiferus	20.04999	34.14999	30.70000
Cell means for variable 2 - Cynoscion nothus	38.95000	23.04999	61.34999
Cell means for variable 3 - Menticirrhus americanus	9.15000	13.50000	5.20000
Cell means for variable 4 - Salinity	30.58798	31.34299	31.14494

Analysis of covariance for dependent variable 1 - Penaeus setiferus

SOURCE	SUM OF SQUARES	DEGREES OF FREEDOM	MEAN SQUARE	F	P*
Mean	3.4414	1	3.4414	0.0074	ns
Cruise	15799.0742	9	1755.4526	3.7630	.975
Station	1653.9805	2	826.9902	1.7727	.8
Covariates	1754.3086	5	350.8616	0.7521	ns
Covariate 2 Cynoscion nothus	524.6489	1	524.6489	1.1246	ns
Covariate 3 Menticirrhus americanus	199.2345	1	199.2345	0.4271	ns
Covariate 4 Salinity	327.7542	1	327.7542	0.7026	ns
Covariate 5 Temperature	114.2949	1	114.2949	0.2450	ns
Covariate 6 Dissolved oxygen	402.2427	1	402.2427	0.8622	ns
Full Model	6064.5742	13	466.5056		

	M3	M10A	M18
Adjusted cell means	15.63616	35.77338	33.48946

* ns is not significant at a level of 0.75 or greater

Table 7-26. continued

Analysis of covariance for dependent variable 2 - Cynoscion nothus

SOURCE	SUM OF SQUARES	DEGREES OF FREEDOM	MEAN SQUARE	F	P*
Mean	1300.8750	1	1300.8750	0.2356	ns
Cruise	68167.6875	9	7574.1875	1.3718	ns
Station	21114.8125	2	10557.4063	1.9120	.8
Covariates	26270.8750	5	5254.1719	0.9516	ns
Covariate 1 Penaeus setiferus	6209.7148	1	6209.7148	1.1246	ns
Covariate 3 Menticirrhus americanus	10034.4414	1	10034.4414	1.8173	ns
Covariate 4 Salinity	148.2267	1	148.2267	0.0268	ns
Covariate 5 Temperature	1283.9312	1	1283.9312	0.2325	ns
Covariate 6 Dissolved oxygen	3046.4297	1	3046.4297	0.5517	ns
Full Model	71779.9375	13	5521.5313		

Adjusted cell means	M3	M10A	M18
	53.35061	-1.74471	71.75258

Analysis of covariance for dependent variable 3 - Menticirrhus americanus

SOURCE	SUM OF SQUARES	DEGREES OF FREEDOM	MEAN SQUARE	F	P*
Mean	173.8042	1	173.8042	4.4049	.9
Cruise	860.4128	9	95.6014	2.4229	.9
Station	246.8782	2	123.4391	3.1284	.95
Covariates	471.0054	5	94.2011	2.3874	.9
Covariate 1 Penaeus setiferus	16.8512	1	16.8512	0.4271	ns
Covariate 2 Cynoscion nothus	71.7064	1	71.7064	1.8173	.8
Covariate 4 Salinity	128.2347	1	128.2347	3.2500	.90
Covariate 5 Temperature	44.5379	1	44.5379	1.1288	ns
Covariate 6 Dissolved oxygen	16.0510	1	16.0510	0.4068	ns
Full Model	512.9412	13	39.4570		

Adjusted cell means	M3	M10A	M18
	10.31330	12.59031	4.94462

Table 7-27. Multivariate analysis of variance and covariance for Penaeus setiferus adjusting for sediment attributes, salinity and temperature (P is probability of significance based on F values)

	M3	M10A	M18
Cell means for variable 1 - Species abundance	18.33333	35.88889	32.16666
Cell means for variable 2 - Shell	0.99778	0.14333	0.04444
Cell means for variable 3 - Sand	40.21886	11.69444	8.72444
Cell means for variable 4 - Silt	25.82999	33.73219	37.12106
Cell means for variable 5 - Clay	32.94884	54.42216	54.15549

Analysis of covariance for dependent variable 1 - Species abundance

SOURCE	SUM OF SQUARES	DEGREES OF FREEDOM	MEAN SQUARE	F	P*
Mean	4651.0820	1	4651.0820	24.5100	>.9995
Cruise	23056.8555	8	2882.1069	15.1879	>.9995
Station	954.4834	2	477.2417	2.5149	.85
Covariates	5256.7969	6	876.1328	4.6170	.975
Covariate 2 Shell	3881.7051	1	3881.7051	20.4556	> .9995
Covariate 3 Sand	4660.5781	1	4660.5781	24.5600	> .9995
Covariate 4 Silt	4748.5195	1	4748.5195	25.0234	> .9995
Covariate 5 Clay	4739.8047	1	4739.8047	24.9775	> .9995
Covariate 6 Salinity	0.4196	1	0.4196	0.0022	ns
Covariate 7 Temperature	63.0727	1	63.0727	0.3324	ns
Full Model	1897.6289	10	189.7629		

	M3	M10A	M18
Adjusted cell means	7.19545	44.68924	34.42009

* ns - not significant at the 0.75 level

Table 7-28. Multivariate analysis of variance and covariance for Menticirrhus americanus adjusting for sediment attributes, salinity and temperature (P is probability of significance based on F values)

	M3	M10A	M18
Cell means for variable 1 - Species abundance	9.77778	14.22222	5.72222
Cell means for variable 6 - Salinity	30.76109	31.60220	31.33333

Analysis of covariance for dependent variable 1 - Species abundance

SOURCE	SUM OF SQUARES	DEGREES OF FREEDOM	MEAN SQUARE	F	P*
Mean	89.0310	1	89.0310	1.8424	.75
Cruise	993.9565	8	124.2446	2.5711	.90
Station	275.5200	2	137.7600	2.8508	.90
Covariates	498.9028	6	83.1505	1.7207	.75
Covariate 2 Shell	43.3204	1	43.3204	0.8965	ns
Covariate 3 Sand	71.5378	1	71.5378	1.4804	ns
Covariate 4 Silt	76.2243	1	76.2243	1.5774	ns
Covariate 5 Clay	75.4018	1	75.4018	1.5603	ns
Covariate 6 Salinity	101.4571	1	101.4571	2.0995	> .80
Covariate 7 Temperature	37.7630	1	37.7630	0.7815	ns
Full Model	483.2402	10	48.3240		

Adjusted cell means	M3	M10A	M18
	17.92723	10.16905	1.61465

* ns - not significant at the 0.75 level

Table 7-29. Multivariate analysis of variance and covariance for *Micropogonias undulatus* adjusting for sediment attributes, salinity and temperature (P is probability of significance based on F values)

	M3	M10A	M18
Cell means for variable 1 - Species abundance	9.44444	6.50000	17.00000
Cell means for variable 2 - Shell	0.99778	0.14333	0.04444
Cell means for variable 6 - Salinity	30.76109	31.60220	31.33333

Analysis of covariance for dependent variable 1 - Species abundance

SOURCE	SUM OF SQUARES	DEGREES OF FREEDOM	MEAN SQUARE	F	P*
Mean	353.1716	1	353.1716	2.6118	.8
Cruise	6621.5586	8	827.6948	6.1374	.995
Station	709.6926	2	354.8462	2.6312	.85
Covariates	2619.6450	6	436.6074	3.2375	.95
Covariate 2 Shell	816.0732	1	816.0732	6.0513	> .95
Covariate 3 Sand	295.2029	1	295.2029	2.1890	.8
Covariate 4 Silt	303.9883	1	303.9883	2.2541	.8
Covariate 5 Clay	300.0989	1	300.0989	2.2253	.8
Covariate 6 Salinity	1835.2759	1	1835.2759	13.6087	> .95
Covariate 7 Temperature	39.3512	1	39.3512	0.2918	ns
Full Model	1348.6011	10	134.8601		

	M3	M10A	M18
Adjusted cell means	-5.17920	12.38487	25.71797

* ns - not significant at the 0.75 level

as variables. Tables 7-27 through 7-29 show the results corrected for sediment attributes.

To analyze any effect of salt discharge on the physical condition of the nekters, the condition of the animals at station M10A was compared to the condition at the control stations (M3 and M18). The

condition coefficients for shrimp proved to be bi-modal rather than normally distributed. Therefore, the non-parametric Wilcoxon's sign-rank test (Sokal and Rohlf, 1969) was performed on the data. Significant results for Penaeus aztecus are presented in Table 7-30.

The coefficients of condition for Sciaenid species did prove to be normally distributed and a paired t-test was run on each species for which we had sufficient data. The significant results are presented in Tables 7-31 through 7-34.

7.3.2 Estuarine

A total of 83,434 organisms representing 59 species was collected at estuarine stations during the post-brine discharge period. Table 7-35 lists the total number of individuals and the total weights for each species collected. Eight species comprised 98% of the total number of organisms collected. The ten dominant estuarine species by both weight and total number for each of the twelve sampling months are listed in Appendix H, tables H-51 through H-62.

The estuarine clustering results are shown in Figures 7-17 through 7-28. Replicate trawls for each station are identified as A or B. In

Table 7-30. Wilcoxon's signed-rank test on coefficient of condition in *Penaeus aztecus*.

MONTH	CONTROL STATIONS	STATION M10A	DIFFERENCE	RANK
8/81	1.213015	0.83168	0.381335	7
9/81	0.904055	0.76884	0.135215	4
10/81	0.90293	0.76562	0.13731	5
11/81	1.083605	1.03819	0.045415	3
12/81	0.77236	0.73341	0.03895	2
1/82	0.61665	0.85718	-0.24053	-6
2/82	1.22125	0.68815	0.5331	8
3/82	0.72136	0.70124	0.02012	1

Absolute sum of neg. ranks 6
sum of pos. ranks 30

$n = 8$ $T_s = 6$

Critical values
$\alpha = .0391$ c.v. = 5

$\alpha = .0547$ c.v. = 6

Difference at $\geq .0547$

Table 7-31. Paired t-test on coefficient of condition in *Cynoscion arenarius*

MONTH	CONTROL STATIONS	STATION M10A	DIFFERENCE (D)	DIFFERENCE^2 (D^2)
6/81	1.7555	1.769	-0.0135	0.00018225
8/81	1.423	1.496	-0.073	0.005329
10/81	1.618	1.451	0.167	0.027889
11/81	1.842	1.602	0.24	0.0576
12/81	1.7465	1.689	0.0575	0.00330625
1/82	1.606	1.609	-0.003	0.000009
2/82	1.554	1.542	0.012	0.000144
4/82	1.619	1.558	0.061	0.003721

$\Sigma D = 0.448$ $\Sigma D^2 = 0.09289$

$n = 8$

$\overline{D} = 0.448/8 = 0.056$

$S_{\overline{D}} = .0361278$

$t_s = \frac{\overline{D}}{S_{\overline{D}}} = 1.55$

critical value

df = 7 $\alpha = .05$ cv = 1.895
$\alpha = .10$ cv = 1.415

Table 7-32. Paired t-test on coefficient of condition in *Larimus fasciatus*

MONTH	CONTROL STATIONS	STATION M10A	DIFFERENCE (D)	DIFFERENCE^2 (D^2)
11/81	3.676	2.551	1.125	1.265625
12/81	2.2595	2.979	-0.7195	0.51768
1/82	2.9475	2.781	0.1665	0.02772
2/82	2.5935	2.423	0.1705	0.02907
3/82	2.7475	2.488	0.2595	0.06734
4/82	2.757	2.649	0.108	0.011664

$\Sigma D = 1.11$ $\Sigma D^2 = 1.919102$

$n = 6$

$\bar{D} = 1.11/6 = 0.185$

$S_{\bar{D}} = .239$

$t_s = \underline{.774}$

critical value

df = 5 $\alpha = .20$ cv = .920
$\alpha = .25$ cv = .727

Table 7-33. Paired t-test on coefficient of condition in *Menticirrhus americanus*

MONTH	CONTROL STATIONS	STATION M10A	DIFFERENCE (D)	DIFFERENCE^2 (D^2)
6/81	1.831	1.793	0.038	0.001444
8/81	1.8815	1.897	-0.0155	0.00024
10/81	1.551	1.591	-0.04	0.0016
11/81	1.9225	1.920	0.0025	0.0^5625
12/81	1.893	1.805	0.088	0.007744
1/82	1.7655	1.796	-0.0305	0.00093
2/82	1.83	1.674	0.156	0.024336
3/82	1.843	1.827	0.016	0.000256
4/82	1.915	1.555	0.36	0.1296

$\Sigma D = 0.5745$ $\Sigma D^2 = 0.16615675$

$n = 9$

$\bar{D} = 0.5745/9 = 0.063833$

$S_{\bar{D}} = .0424073$

$$t_s = \frac{\bar{D}}{S_{\bar{D}}} = 1.505$$

critical value

df = 8 $\alpha = .05$ cv = 1.860
$\alpha = .10$ cv = 1.397

Table 7-34. Paired t-test on coefficient of condition in *Leiostomus xanthurus*.

MONTH	CONTROL STATIONS	STATION M10A	DIFFERENCE (D)	DIFFERENCE^2 D^2
6/81	2.36155	2.07254	0.28901	0.08352
8/81	2.71531	2.83088	-0.11557	0.013356
11/81	3.689395	2.55140	1.137995	1.295
12/81	2.863775	2.54310	0.320675	0.10283
1/82	2.527355	2.40748	0.119875	0.01437
3/82	2.642355	2.59491	0.047445	0.00225
4/82	2.75703	2.64937	0.10766	0.01159

$\Sigma D = 1.90709$ $\Sigma D^2 = 1.52296$

$n = 7$ $\bar{D} = 1.90709/7 = 0.27244$

$S_{\bar{D}} = .154564$

$t_s = \frac{\bar{D}}{S_{\bar{D}}} = \underline{1.7626}$

critical value

df = 6 $\alpha = .05$ cv = 1.943
$\alpha = .10$ cv = 1.440

Table 7-35. Total abundance of all species caught during the study at estuarine stations. Species are listed in order of abundance by number of individuals. Total species weights, in grams are also included.

SPECIES	TOTAL #	TOTAL WEIGHT
Anchoa mitchilli	48,003	33,438
Micropogonias undulatus	13,287	41,480
Penaeus aztecus	6,765	29,972
Penaeus setiferus	5,133	28,213
Callinectes sapidus	3,752	83,714
Cynoscion arenarius	1,981	7,847
Brevoortia patronus	1,437	2,739
Leiostomus xanthurus	955	17,661
Arius felis	425	14,711
Symphurus plagiusa	137	593
Stellifer lanceolatus	129	664
Chloroscombrus chrysurus	124	229
Citharichthys spilopterus	124	718
Polydactylus octonemus	121	223
Pogonias cromis	102	15,992
Sphoeroides parvus	97	219
Caranx hippos	86	550
Paralichthys lethostigma	83	10,666
Palaemonetes vulgaris	70	39
Prionotus tribulus	57	157
Callinectes similis	53	150
Dorosoma petenense	47	463
Lolliguncula brevis	46	162
Bairdiella chrysoura	44	1,084
Mugil cephalus	41	3,463
Cynoscion nebulosus	40	1,495
Anchoa hepsetus	27	85

Table 7-35. continued

SPECIES	TOTAL #	TOTAL WEIGHT
Bagre marinus	24	347
Synodus foetens	21	434
Macrobrachium ohione	17	43
Trichiurus lepturus	17	151
Etropus crossotus	17	127
Trinectes maculatus	16	205
Archosargus probatocephalus	15	4,533
Chaetodipterus faber	15	439
Symphurus sp.	15	70
Lagodon rhomboides	14	478
Peprilus burti	14	24
Menticirrhus americanus	9	42
Gobiosoma bosci	9	10
Gobionellus hastatus	6	4
Achirus lineatus	6	20
Dorosoma cepedianum	5	762
Squilla empusa	4	42
Trachypenaeus similis	4	11
Porichthys plectrodon	4	45
Selene setapinnis	4	26
Sciaenops ocellatus	4	261
Xiphopenaeus kroyeri	3	17
Mugil curema	3	134
Urophycis floridana	2	9
Syngnathus louisianae	2	3
Symphurus civitatus	2	6
Myrophis punctatus	1	1
Ophidion welshi	1	23
Menidia beryllina	1	3

Table 7-35. continued

SPECIES	TOTAL #	TOTAL WEIGHT
Hemicaranx amblyrhynchus	1	10
Scomberomorus maculatus	1	20
Peprilus alepidotus	1	1

Total number of species	59	TOTAL COUNT 83,434	TOTAL WEIGHT 305,028 g

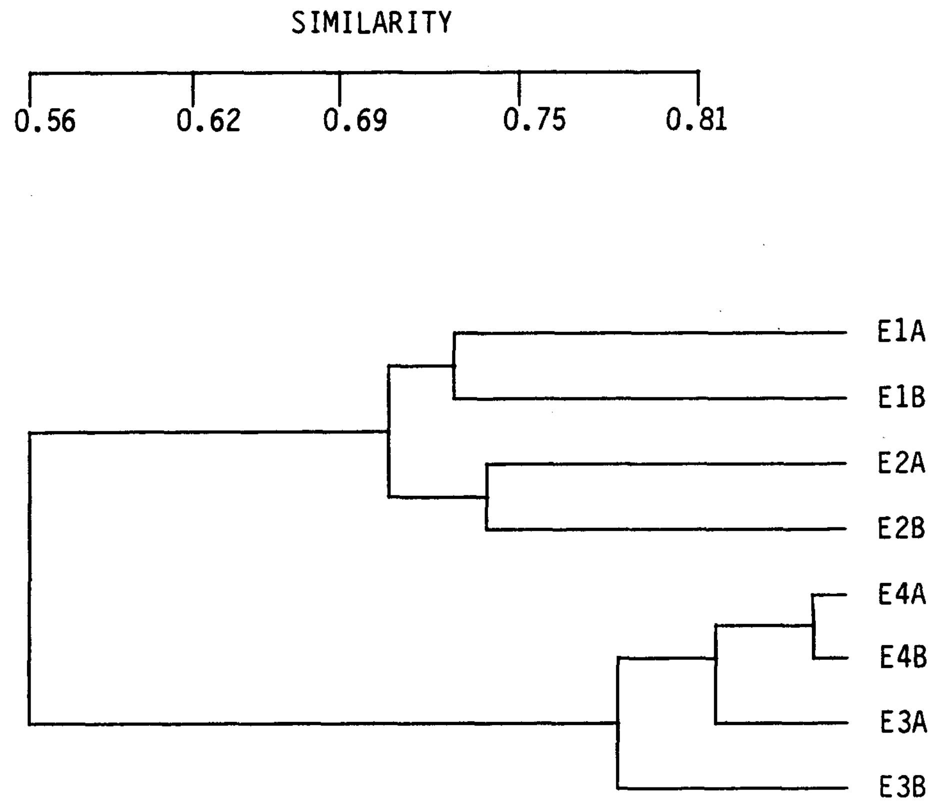

Figure 7-17. Cluster dendogram of May 1981 estuarine stations. Stations are clustered on the basis of number of individuals caught in each trawl at each station. Station suffixes (A or B) represent replicate trawls.

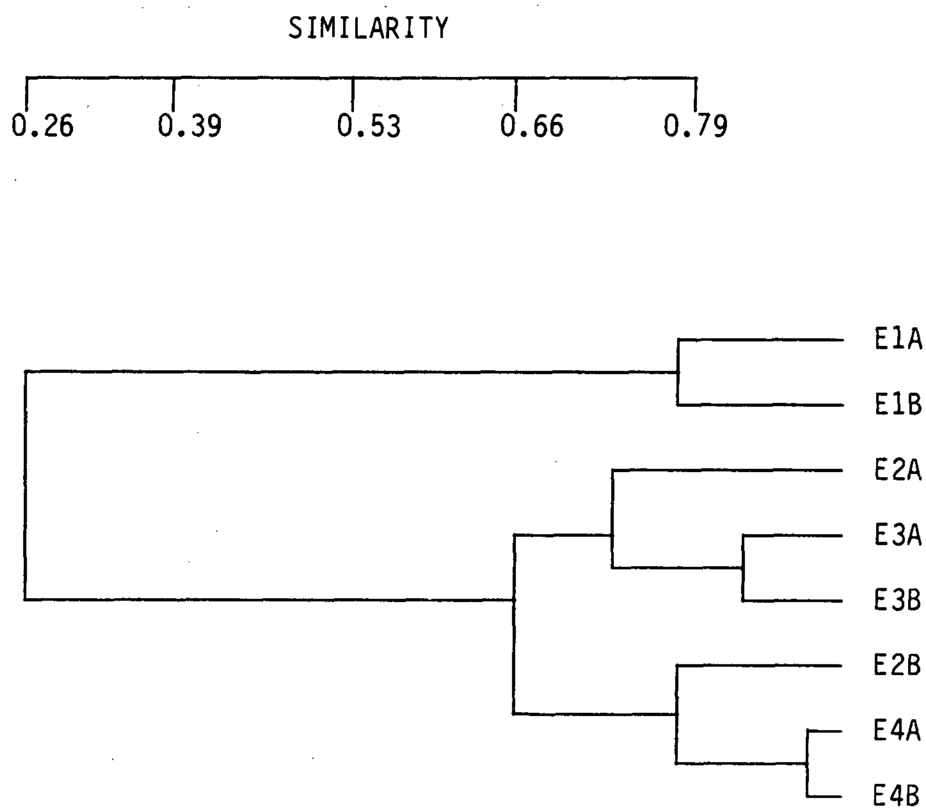

Figure 7-18. Cluster dendogram of June 1981 estuarine stations. Stations are clustered on the basis of number of individuals caught in each trawl at each station. Station suffixes (A or B) represent replicate trawls.

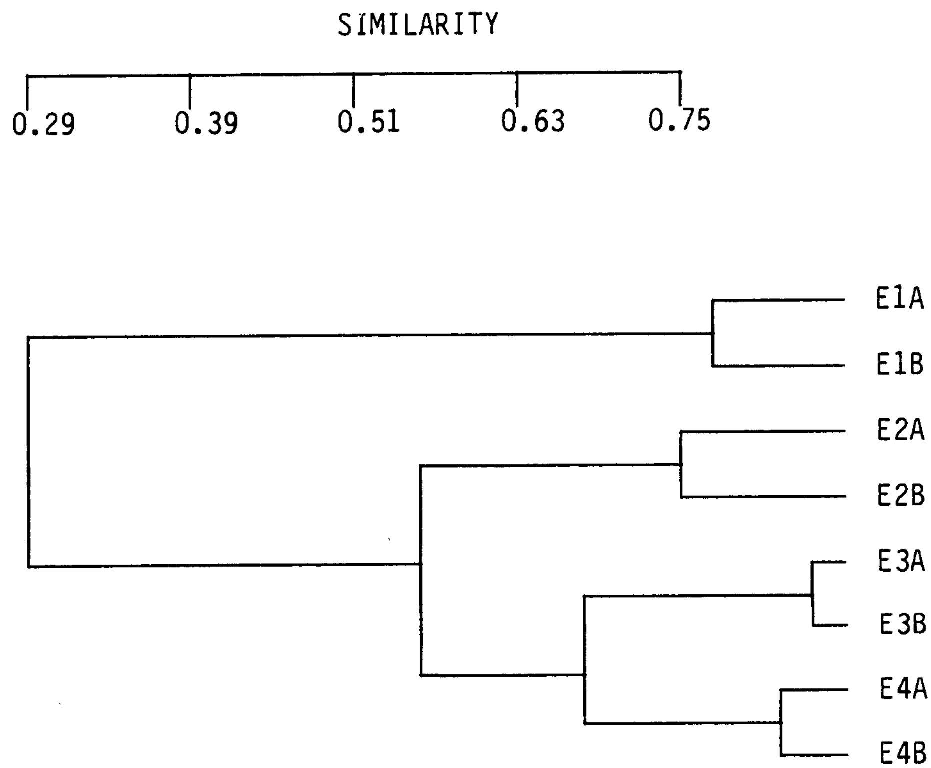

Figure 7-19. Cluster dendogram of July 1981 estuarine stations. Stations are clustered on the basis of number of individuals caught in each trawl at each station. Station suffixes (A or B) represent replicate trawls.

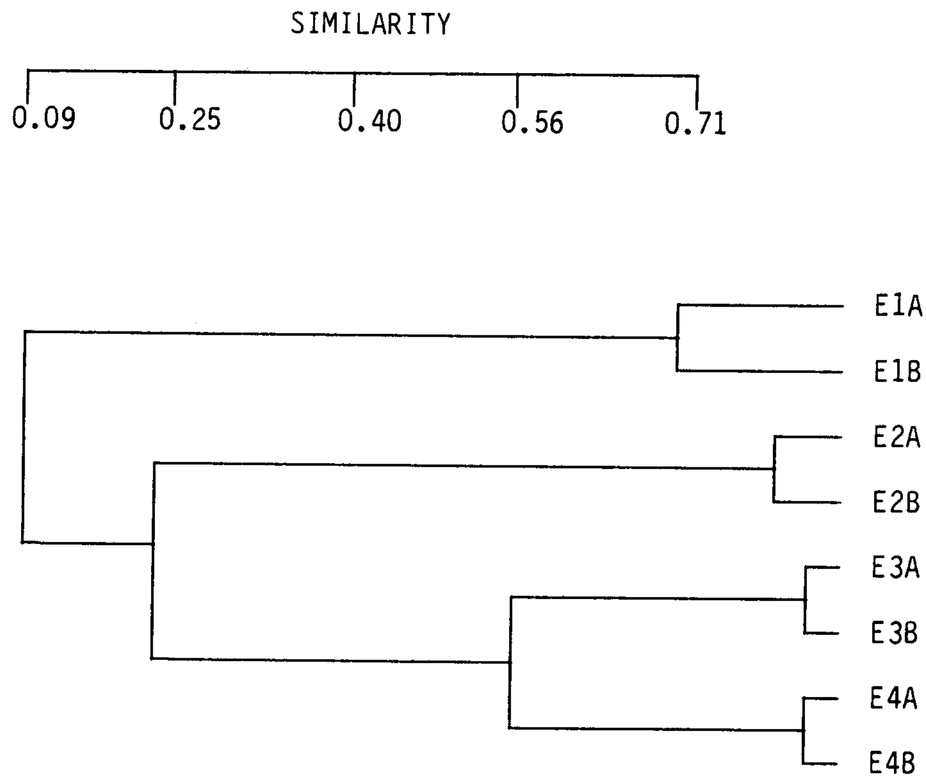

Figure 7-20. Cluster dendogram of August 1981 estuarine stations. Stations are clustered on the basis of number of individuals caught in each trawl at each station. Station suffixes (A or B) represent replicate trawls.

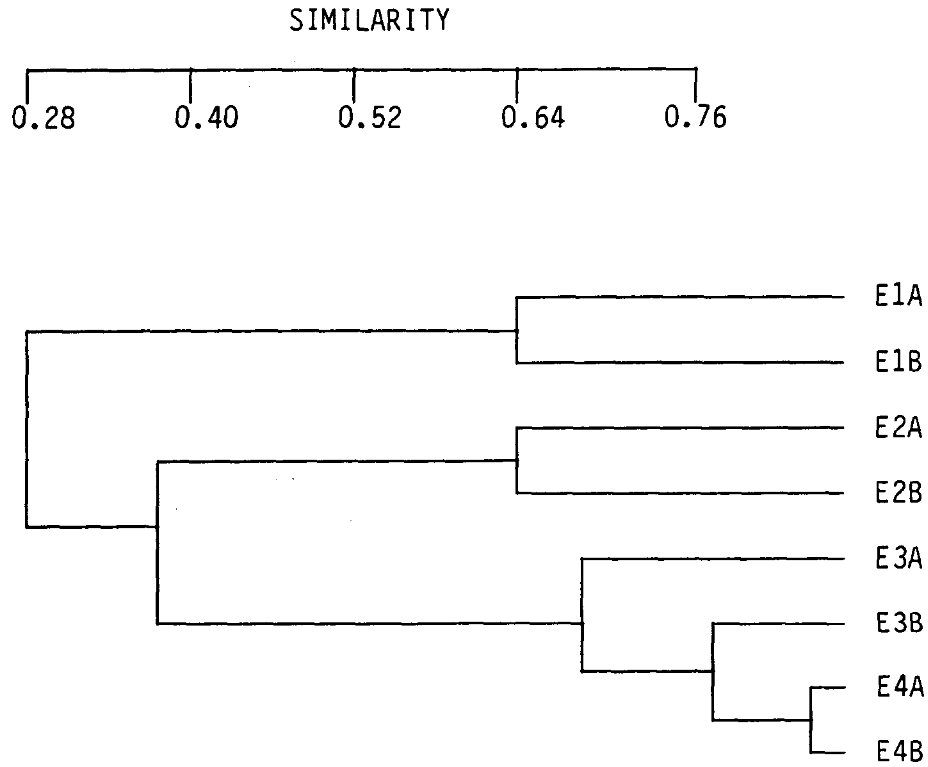

Figure 7-21. Cluster dendogram of September 1981 estuarine stations. Stations are clustered on the basis of number of individuals caught in each trawl at each station. Station suffixes (A or B) represent replicate trawls.

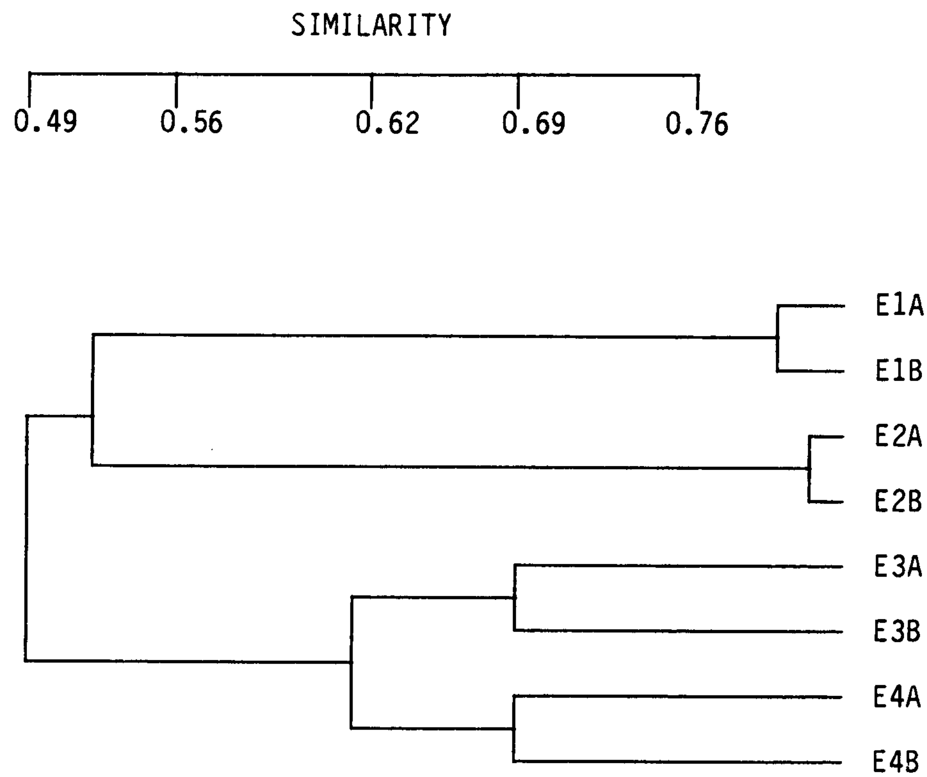

Figure 7-22. Cluster dendogram of October 1981 estuarine stations. Stations are clustered on the basis of number of individuals caught in each trawl at each station. Station suffixes (A or B) represent replicate trawls.

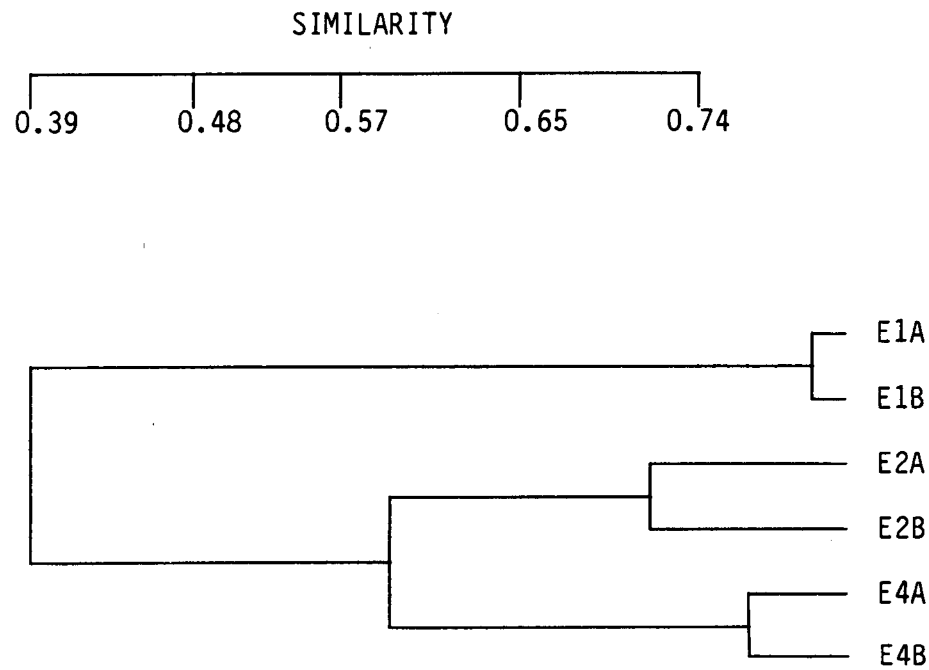

Figure 7-23. Cluster dendogram of November 1981 estuarine stations. Stations are clustered on the basis of number of individuals caught in each trawl at each station. Station suffixes (A or B) represent replicate trawls.

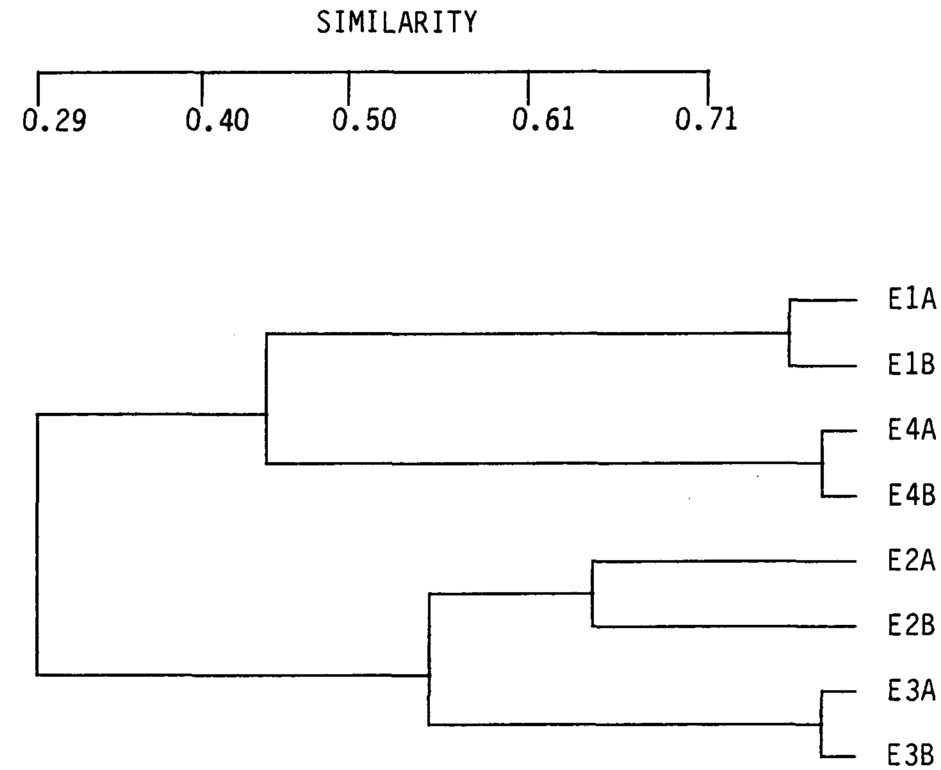

Figure 7-24. Cluster dendogram of December 1981 estuarine stations. Stations are clustered on the basis of number of individuals caught in each trawl at each station. Station suffixes (A or B) represent replicate trawls.

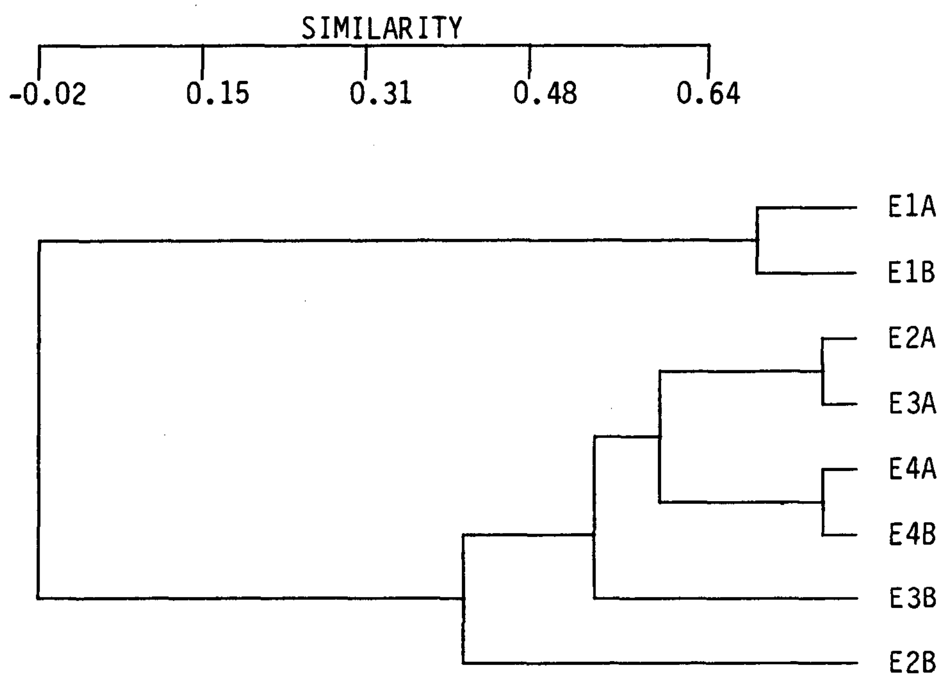

Figure 7-25. Cluster dendogram of January 1982 estuarine stations. Stations are clustered on the basis of number of individuals caught in each trawl at each station. Station suffixes (A or B) represent replicate trawls.

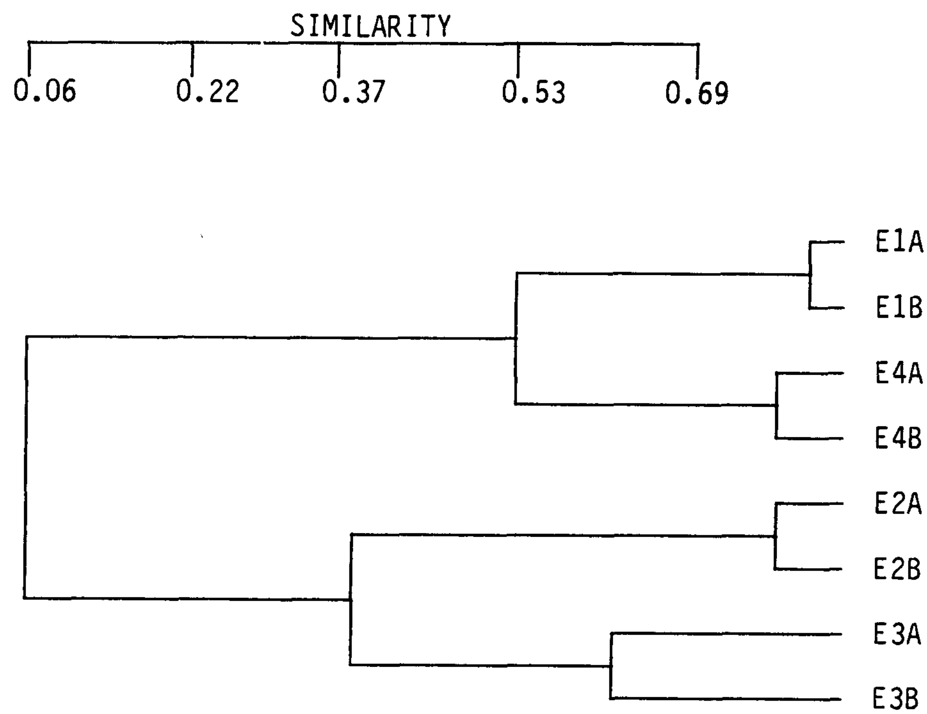

Figure 7-26. Cluster dendogram of February 1982 estuarine stations. Stations are clustered on the basis of number of individuals caught in each trawl at each station. Station suffixes (A or B) represent replicate trawls.

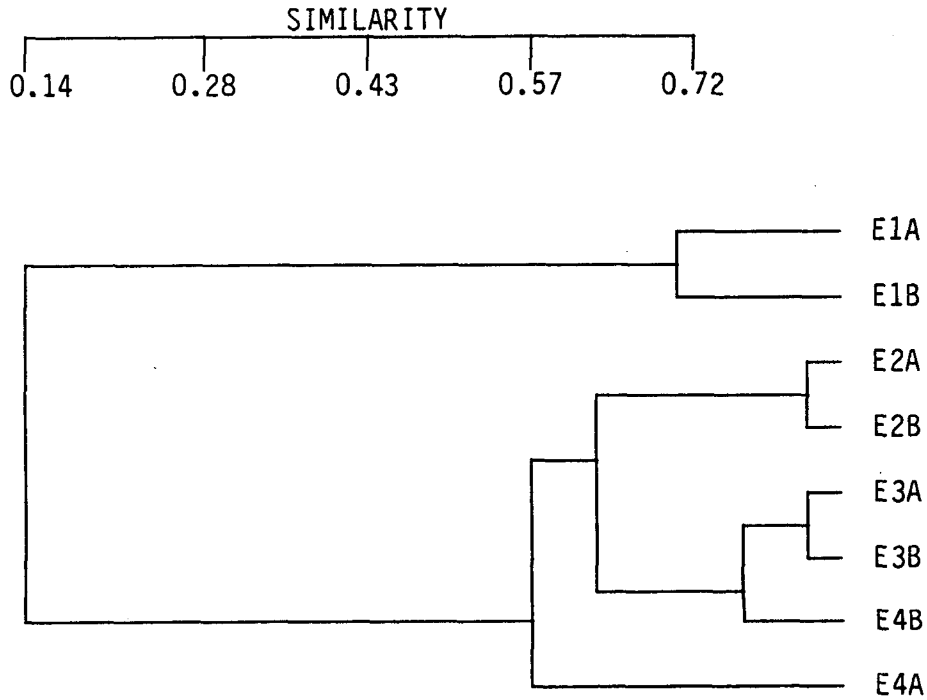

Figure 7-27. Cluster dendogram of March 1982 estuarine stations. Stations are clustered on the basis of number of individuals caught in each trawl at each station. Station suffixes (A or B) represent replicate trawls.

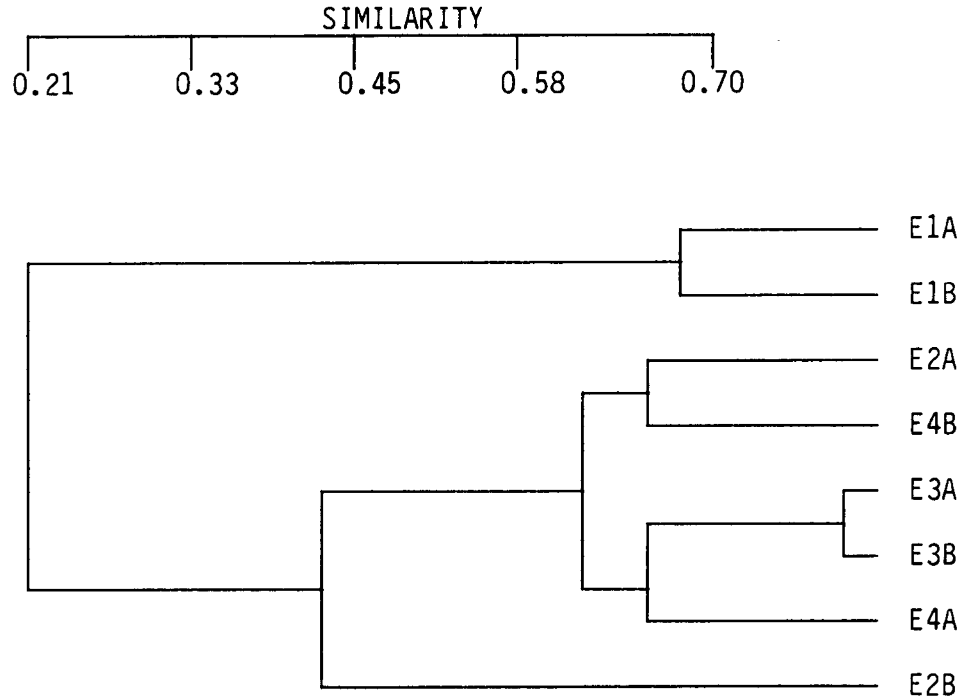

Figure 7-28. Cluster dendogram of April 1982 estuarine stations. Stations are clustered on the basis of number of individuals caught in each trawl at each station. Station suffixes (A or B) represent replicate trawls.

this case, only four stations are included and the separation of replicate trawls does not noticeably confuse the results.

7.4 Discussion

Detecting an environmental impact on nekton is difficult unless that impact is catastrophic. The primary reason for this difficulty is variability in distribution and abundance. Much of the variation seen in samples can be ascribed to the random nature of fish assemblages. Many species of nekters school or aggregate, leading to patchiness in distribution. Variability may also be caused by physical factors such as temperature, dissolved oxygen, salinity or substrate, and biological factors such as presence or absence of prey and/or predators. Several statistical analyses are designed to attribute variation to physical or biological variables. A multivariate analysis of variance and covariance (MANOVA) is one of the more useful analyses. This technique analyzes several variables simultaneously and assesses the positive or negative effects of each one. The simpler analysis of variance (ANOVA) associated with a Duncan's multiple range test or a Student-Newman-Keuls test can also be useful. While these tests help investigate some variables, the overall problem may be insurmountable.

For example, in a recent comprehensive study, Yoshiyama et al. (1982) analyzed the spatial and temporal patterns of distribution and abundance ex- hibited by benthic ichthyofauna. The study covered three years of data and 569 trawls. The study area was large (19,250 km^2) and covered a great depth range (15-134 m). Despite this wide range of habitats fewer than one third of the species collected (51 of 160) were captured frequently enough to be subjected to statistical analyses. Of these only one third showed a significant relationship to measured abiotic or biological variables. Of these species the amount of explained variation ranged from 30-57%. A maximum of 16% of the variation for one species was related to salinity. Spatial and temporal variability was related to salinity in only 3% of the species. Such studies serve to demonstrate the difficulty in attributing variability in species distribution to a single environmental factor.

Salinity variations affect fish in different fashions both physiologically and ecologically. Most of the fish found in estuaries and the shallow Gulf of Mexico waters are euryhaline. The degree of euryhalinity or the tolerance of salinity variations for a species varies considerably. In addition, a species tolerance for salinity is affected by the size of the fish. Non-optimal salinity is a stress. Farmer and Beamish (1969) found that in Tilapia nilotica the metabolic cost of osmoregulation was 20% of total metabolism at $10^{o}/oo$ on either side of the optimum salinity and reached a total of 30% of total metabolism at extreme tolerance levels. This metabolic cost of osmoregulation decreases the amount of energy that a fish can devote to non-maintenance activities such as growth or reproduction. Thus salinity stress can lead not only to mortality but to lower fecundity and lower recruitment.

In an open body of water it is certainly possible for a nekter to escape adverse conditions. However, it is unknown if or at what level of stress a fish will avoid that stress. Laboratory experiments have indicated that a few species of fish exhibit a behavorial preference for an "optimum" salinity. While such preferences may be demonstrated in a laboratory where all other conditions are equal, in the wild all other conditions are seldom equal and it is impossible to predict what will happen.

Another problem that should be addressed is the variability of discharge rate. Table 7-36 shows the hours pumped, salinity, barrels/ day and salt loading for the nekton sampling dates.

The week of May 18, 1981 was scheduled for intensive sampling at the beginning of discharge. Nekton was sampled primarily on May 19 when discharge occurred for three hours at a salinity of $41^{o}/oo$. On May 20 when sampling was completed there was no discharge. Discharge occurred around the clock during June sampling. In July discharge again was conducted around the clock but the marine waters were extremely hypoxic and few demersal nekters were collected. In August there was no discharge during nekton sampling. In September, discharge occurred for an average of 13.5 hours/day during our sampling. In October, discharge occurred for approximately 16 hours each day of sampling. In November and December we had full time discharge but in January, discharge dropped back to nine hours. February had full time discharge as did April but March discharge during the primary sampling

Table 7-36. Brine discharge on Nekton sampling dates.

DATE	DISCHARGE TIME HR DAY^{-1}	SALINITY $^0/oo$	VOLUME BBL DAY^{-1}	LOADING 10^3 METRIC TONS DAY^{-1}
19 May	3	41	89,796	583.9
20 May	0	0	0	0
10 June	24	179	565,920	16,066.1
11 June	24	180	549,517	15,687.6
24 July	24	187	716,681	21,255.5
27 August	0	0	0	0
28 August	0	0	0	0
24 September	15	236	322,500	12,071.0
25 September	12	223	255,694	9,043.3
20 October	16.5	235	371,250	13,836.9
21 October	16	236	376,000	14,073.5
19 November	24	209	557,500	18,479.7
9 December	24	210	516,000	17,185.9
10 December	24	207	516,000	16,940.4
15 January	9	250	201,788	8,000.9
24 February	24	220	588,000	20,516.5
25 February	24	209	732,000	22,522.5
23 March	19.5	244	744,800	28,822.6
24 March	24	242	700,400	26,882.2
14 April	24	245	796,200	30,937.9
15 April	24	245	847,500	32,931.3

day was down to 19.5 hours. The second day of March sampling discharge was back up to full time.

Some of these data are therefore difficult to use in showing impact. While we are interested in presenting as much data as possible, May data is excluded from this report because discharge had essentially not begun. The July data was also excluded from this report. During nekton sampling, hypoxia was so severe that virtually all demersal nekters had disappeared from the sampling area (Table H-41). It was felt that no useful results could be garnered from such data.

Yet another uncontrollable variable is fishing pressure. The diffuser is located in the center of the apparently preferred along shelf transect of commercial shrimpers. The diffuser is protected from shrimpers by five buoys and an instrument platform. The northeast to southwest configuration of the diffuser tends to protect some of the D stations as well. Station DN is protected from shrimping due to its proximity to the pipeline. Station DW appears closer to the diffuser buoys than does DE. This is probably due to the location of the Texas A & M buoy located somewhat west (approximately 270 m) of the other diffuser buoys. Shrimpers tend to shrimp in an east-west or west-east direction. When approaching the diffuser they deflect their course to travel just south of the buoy configuration. This would make station DS the least protected station.

Another variable that deserves mention is sediment type. It has been known for some time that certain species vary with sediment variables (Caldwell, 1955; Moore et al., 1970). Recently this variable has received greater attention (Chittenden and McEachran, 1976; Flint and Rabelais, 1980; Yoshiyama et al., 1982). The sediment composition in the present study has a great deal of within station and between station variability. This variable is addressed to some extent in the MANOVA analyses on the target species. The variability of the sediment composition and the relatively short duration of this study preclude a complete analysis, however.

This study is largely predicated on the assumption that fish will avoid an impacted area. The brief pre-discharge study indicated that all the marine stations except M21 and M22 are homogeneous. The thrust of this study therefore is on between station comparisons. Some pre-discharge versus post-discharge comparisons are made, however. Since it is possible that impact without avoidance has occurred, some attempt is also made to examine the condition of the commercially important nekters captured at the diffuser versus those captured at control stations.

7.4.1 Marine Environment

The monthly station cluster analyses (Figures 7-1 through 7-10) show persistent clustering of the diffuser station (M10A) with one or more of the near field stations. This represents a change from the pre-discharge period when no significant clustering of the 10 m stations was seen. In general, the clustering of the diffuser station with near field stations follows the bottom current data from site D (diffuser). The current data is highly variable from hour to hour. However, an inspection of the data from site D on nekton sampling dates indicates that if the currents were generally westerly (as was usually the case) the diffuser was more similar to station DW than to other staions. This type of analysis is hardly quantitative and could not be seen statistically but it did provide an indication that brine from the diffuser might be causing a change in some aspect of the nekton community.

One would expect an adverse environmental condition to reduce rather than increase the number of species present, but changes in the relative abundance of several species are not predictable. If the most abundant species is also most sensitive to an adverse condition, the population size of rarer species could increase and equalize overall abundance. The response of a species not subject to predation is likely to be a change in the size of the population. Population changes for species subject to predation can be buffered because decreases in prey can also reduce the number of predators after a lag time.

Increased diversity at a given trophic level can lead to smaller changes in total biomass as conditions fluctuate within a range that may or may not be optimal for different species. It can also lead to greater fluctuations in the composition of species. A disturbance is usually most severe at the upper levels of a food chain but uneven effects are possible. If impact reduces the ability of prey to avoid predators then there can be an increase in predators despite a decrease in prey.

Our sampling technique tends to limit our catch to species in lower trophic levels. Due to imperfect understanding of life histories it is difficult to assign most collected species to a specific trophic level. Generally, pelagic fish are filter feeders and can be ecologically separated from demersal fish. In addition, the otter trawl is designed to capture demersal nekters and the catch of pelagic fish may not accurately reflect their true distribution. Cluster analyses and diversity studies on demersal species alone were either similar to the studies documented in this report or showed no trends that would indicate an impact. Results, therefore, have not been included in this report.

The overall clusters (Figures 7-11 through 7-15) are quite similar to the monthly results but differences are not as well defined. Clustering reflected temporal variability to a greater extent than spatial variability. Only stations M21 and M22 differed from this pattern. Often these stations would cluster with the same station from one or more different months. This indicates that stations M21 and M22 are quite dissimilar from the balance of the marine stations. Since the clustering in Figures 7-11 through 7-15 are seasonal it is possible to cluster on a seasonal basis but the results would be expanded versions of Figures 7-12 through 7-15. With minor exceptions, the results cluster monthly before they cluster seasonally and these results have been presented.

An analysis of variance was performed on the east-west transect stations for species diversity, species richness and evenness. The results showed significant differences in August, September, October, November, December, January, March and April. However, the SNK multiple range test results (Tables 7-13 through 7-15) did not agree with the clustering results in any way. Nor did they show any consistency over time.

An analysis of variance was then conducted on each species collected each month. Generally speaking, the species that showed significant results were the most abundant and/or the least abundant. For those species that showed frequently significant results SNK multiple range tests were run on the monthly data (Table 7-16 through 7-25). Again, these results did not agree with the clustering results. These significant ANOVA results must therefore be ascribed to random variation.

It is conceivable that an impact could cause numerous diversity and population changes that cannot be separated by these tests. The cluster analyses reported above indicate a change from the pre-discharge period. However, it may be a cumulative result of many small changes that are masked to other analyses by random variation.

Finally, analyses of variance and covariance were run on our target species. Due to the limited amount of data, only stations M3, M10A and M18 were compared. Significant results are based on between station differences. Between cruise or monthly differences are significant in most instances but would not show an impact. The between station results were significant for *Penaeus setiferus*, *Menticirrhus americanus* and *Cynoscion nothus* (Table 7-26). *Penaeus setiferus* and *Menticirrhus americanus* were found in significantly greater abundance at M10A, and *Cynoscion nothus* was found in significantly fewer numbers at station M10A. There is a slight interaction between *M. americanus* and *C. nothus*. However, the only significant measured physical variable was salinity which indicates that *M. americanus* might be attracted to the higher salinity water at the diffuser.

In consideration of the important role that the sediment seems to play in determining species composition, another set of MANOVA analyses were run on the target species using monthly sediment data collected by the benthic discipline as variables. In addition, observed bottom salinity and bottom temperature at the time of sampling was included as a variable. Variables then were species abundance, percent shell, percent sand, percent silt, percent clay, bottom salinity and temperature. Results were significant for three species, *Penaeus setiferus*, *Micropogonias undulatus* and *Menticirrhus americanus*.

For *Penaeus setiferus*, the four sediment attributes, percentage of shell, sand, silt and clay, were all significant (Table 7-27). When differences in the sediment attributes are adjusted there is a significant difference in the abundance of white shrimp at these three stations. White shrimp abundance is positively correlated to clay and silt and negatively correlated to shell and sand.

Sediment attributes do not affect the abundance of *Menticirrhus americanus* (Table 7-28). The only significant covariate is salinity which was also seen in Table 7-26. Abundance of southern kingfish is positively correlated to salinity at a probability greater than 80%.

The abundance of *Micropogonias undulatus* is negatively correlated to percentage of shell and salinity (Table 7-29). There is also a lower level of significance to the percentage of sand, silt and clay. Croaker abundance is negatively related to percentage of sand and clay but positively related to percentage of silt. When these differences are adjusted there is a significant difference in the abundance of croaker at the three stations examined. The adjusted abundance of croaker at the diffuser is intermediate between the two control stations.

To summarize the MANOVA studies, there were significant results for four species: *Penaeus setiferus*, *Cynoscion nothus*, *Menticirrhus americanus* and *Micropogonias undulatus*.
Salinity was a significant covariate for two species: *Menticirrhus americanus* and *Micropogonias undulatus*. Sediment attributes also

affected only two species: Penaeus setiferus and Micropogonias undulatus. None of these species showed consistent differences in the ANOVA and SNK tests but do show significant results when covariates are accounted for. Other covariates, such as fishing pressure, cannot be quantified and used as a covariate. While these studies do not show impact there is a likelihood that the protected nature of the diffuser has skewed these results. The protected diffuser station and lack of fishing pressure would account for greater abundance at the diffuser for some species.

The analyses of coefficient of condition are significant for Penaeus aztecus, Cynoscion arenarius, Larimus fasciatus, Menticirrhus americanus and Leiostomus xanthurus (Tables 7-30 through 7-34). These results indicate that at least some species are not avoiding the diffuser area. Furthermore, these results reflect a stress in the vicinity of station M10A.

Based on length weight regressions ($\log_{10} W = a + b \log_{10} L$), these results mean that a 125 mm long brown shrimp would weigh 15.6 g at the diffuser and 19.9 g at the control stations. A 100 mm long sand seatrout would weigh 14.5 g at the diffuser and 15.4 g at the control stations. A 50 mm long banded drum would weigh 3.2 g at the diffuser and 3.5 g at the control stations. A 17.1 g, 100 mm long southern kingfish at the diffuser would be 18.5 g at the control stations. A typical, 75 mm long spot would weigh 8.2 g at the diffuser and 9.7 g at the control stations. These weights represent a 21.6%

decrease in weight for brown shrimp, 6% for the sand seatrout, 8.6% for the banded drum, 7.7% for the southern kingfish and 15.5% for the spot. These values for weight decrease may not be statistically meaningful. They are provided to indicate the probable magnitude of impact only.

7.4.2 Estuarine Environment

Generally, the estuarine stations serve as a salinity gradient (Table 7-37). That is: station E1 has the lowest salinity, E2 is intermediate and either E3 or E4 is most saline. There were a few exceptions to this however. In June 1981, station E2 had the lowest salinity followed by E4, stations E1 and E3 were highest. The respective salinities were 5.5, 6.5, and 9.5^{o}/oo. In April 1981, station E2 had a lower salinity than did E1 (8.5 to 9.33^{o}/oo). In November 1981 E2 had the highest salinity; however, E3 could not be sampled that month due to low water conditions. Aside from these events the highest salinity was observed at station E3 or station E4.

Cluster analyses (Figures 7-17 through 7-28) were compared to physical variables to ascertain any general correlation. In September and November the cluster results agreed somewhat with the bottom salinity. In October the clustering results agreed with the temperature. Only in January was there a good correlation between cluster results and salinity. These results agree with the pre-discharge results which also showed no correlation of catch to salinity. The data disagree with Rounsefell (1975) who found species composition determined by the existing salinity regime. This is likely due to the fact that Rounsefell sampled stations that showed no overlap in salinity regime. Species would then occur in a preferred area. In this study area no such zonation occurs (Table 7-37). Species in this estuary must therefore be more euryhaline. Rounsefell's study area allows the presence of stenohaline species. In addition, euryhaline species can remain in a preferred salinity regime.

Average salinities this year are somewhat higher than reported historical values but this is determined primarily by rainfall. Physical oceanography data indicate no plume effects are possible in the estuarine environment. It is conceivable that the withdrawal of freshwater at the intracoastal waterway could cause a greater salt water incursion and elevated salinities.

The estuarine community structure is dominated both numerically and in terms of biomass by only a few species (Tables H-51 through H-62). The anchovy, Anchoa mitchilli, ranks first or second numerically every month. The Atlantic croaker, Micropogonias undulatus, is among the top three in terms of numbers each month from November through June and ranks fourth to sixth numerically from July through October. This species is always in the top ten in biomass as well. Callinectes sapidus, the blue crab, is in the top three in terms of biomass each month except December. It is also in the top four numerically from January through April. Penaeus setiferus is another year round dominant but is particularly abundant from July through December. P. setiferus was also a dominant species in April 1981 as

Table 7-37. Near-bottom measurements of physical variables at estuarine stations on nekton sampling dates.

DATE/STATIONS	BOTTOM SALINITY $^{0}/oo$	BOTTOM TEMPERATURE °C	BOTTOM DISSOLVED OXYGEN ml/l
May 26, 1981			
E1	19.00	25.10	3.57
E2	21.00	25.90	4.01
E3	25.00	25.50	4.18
E4	25.00	25.40	4.29
June 25			
E1	9.50	28.70	3.59
E2	5.50	29.40	2.44
E3	9.50	28.20	4.30
E4	6.50	28.40	4.17
July 15			
E1	1.50	30.90	3.61
E2	2.00	29.60	2.77
E3	7.00	29.80	4.14
E4	7.50	29.70	3.40
August 13			
E1	2.50	30.80	3.78
E2	20.50	30.40	3.31
E3	21.00	29.50	3.79
E4	23.50	30.30	3.03
September 21			
E1	7.68	24.90	4.74
E2	20.85	24.00	4.94
E3	20.50	22.30	4.65
E4	21.48	23.20	4.95
October 26			
E1	7.30	18.50	5.61
E2	21.55	18.60	5.07
E3	24.23	15.50	5.87
E4	21.55	16.10	5.89

Table 7-37. continued

DATE/STATIONS	BOTTOM SALINITY $^{o}/oo$	BOTTOM TEMPERATURE °C	BOTTOM DISSOLVED OXYGEN ml/l
November 13			
E1	7.74	16.20	5.88
E2	24.02	17.70	4.94
E3	--	--	--
E4	20.64	15.40	5.93
December 7			
E1	11.93	15.00	6.37
E2	25.66	16.50	5.20
E3	27.96	13.50	5.79
E4	26.16	13.90	5.79
January 28, 1982			
E1	13.99	13.40	4.37
E2	18.62	12.60	5.01
E3	23.24	13.00	4.47
E4	24.66	11.30	5.22
February 19			
E1	5.45	16.50	4.99
E2	5.82	15.50	5.00
E3	21.34	15.90	5.95
E4	20.78	15.20	6.59
March 18			
E1	11.08	22.00	4.48
E2	13.86	22.80	5.07
E3	17.45	21.90	5.12
E4	16.49	21.10	4.56
April 9			
E1	9.33	21.20	4.64
E2	8.50	22.30	4.85
E3	13.72	23.00	5.19
E4	12.66	22.80	4.79

well as in April 1982 but not in May or June. Therefore it may be that the white shrimp is dominant from April through December. Penaeus aztecus was in the top three species in terms of biomass from April through July and in the top ten in terms of numbers from March through December.

Cynoscion arenarius, the sand seatrout, is a summer dominant and appears in the top ten from May through December. Brevoortia patronus is a spring dominant and appears in the top ten from January through July.

The black drum, Pogonias cromis, often appears in the top ten in terms of biomass as does the spot, Leiostomus xanthurus, the southern flounder, Paralichthys lethostigma, and the sea catfish, Arius felis. These species were captured year-round in the estuary except for Arius felis which was not caught from November through February.

It must be remembered that this information is based on trawl net collections which tend to miss the large, highly mobile fish. For instance, the sand seatrout was caught in great numbers in the lake, but the average weight was less than ten grams. Certainly large individuals are present in the estuary but are rarely captured with a trawl. Many of these species will be discussed in greater detail in the section on our target species. Since the species discussion does not relate to impact it is presented, along with supporting data, in Appendix H.

7.5 Conclusions

1. The post-discharge period shows persistent clustering of the diffuser station (M10A) with one or more of the near field diffuser stations based on species composition. This represents a change from the pre-discharge period when all stations were homogeneous.

2. ANOVA and SNK analyses of species diversity, species richness, evenness and individual species could not be related to the clustering results. We must conclude that natural variability obscures the reasons for the cluster results.

3. Results of MANOVA studies on target species and physical variables were significant for only three species: Penaeus setiferus, Menticirrhus americanus and Cynoscion nothus. These results do not appear to be related to brine discharge.

4. MANOVA studies on target species that adjusted for sediment attributes as well as salinity and temperature were also significant for three species: Penaeus setiferus, Micropogonias undulatus and Menticirrhus americanus. No adverse effects were deduced from these analyses.

5. Significant differences in coefficient of condition between animals caught at the diffuser station versus those caught at control stations are perhaps the most interesting results from this study. Based on significant decreases in condition coefficient Penaeus aztecus, Cynoscion arenarius, Larimus fasciatus, Menticirrhus americanus and Leiostomus xanthurus, it would appear that at least some species are not avoiding the diffuser area. Furthermore, one must

deduce from the lowered condition coefficients that animals in the diffuser area are experiencing a stress.

6. Based on comparisons of length vs weight regressions obtained for affected species at the diffuser and also at the control stations the probable magnitude of the stress varies with different species. The weight decrease for animals at the diffuser was greatest for brown shrimp. This species weighed 21.6% less in the vicinity of the diffuser than at control stations. Stresses of these magnitudes would be expected to decrease fecundity and growth. In the case of brown shrimp in particular, the magnitude of difference must be close to causing morbidity. The values from these regressions have not been statistically proven and may only be used to estimate probable degree of impact.

7. Abundance records for target species reflect natural variability rather than impact. For example, post study period sampling reflects a great change in shrimp abundance in 1982 versus 1981. Our studies indicate this change is not due to brine discharge but to natural variation.

8. Impact, indicated by clustering results and coefficients of condition comparisons, is limited to near field effects (within a half mile radius).

9. Due to the fact that there is a stress on at least some species, increased discharge would be expected to increase the magnitude of stress and the area stressed.

10. No estuarine impacts were investigated because there were no abnormal salt water incursions into the estuarine area.

11. Differences in estuarine species composition are not determined by any physical variables. This conclusion agrees with the earlier indications of the pre-discharge study.

CHAPTER 8

PHYTOPLANKTON

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8.1 Introduction

8.1.1 Introductory Remarks

Phytoplankton as defined in this study is a heterogeneous association of autotrophic, photosynthetic algae, which may exist as benthic, tychoplankton or true plankton forms in aquatic, estuarine, or marine habitats. Algae are ecologically important because of their role in the energy budgets of aquatic and marine ecosystems. Their significance lies in both their ability to fix carbon and for their contribution to complex food webs. Round (1981) found that oceanic production by primary producers is as much as 31 x 10^9 tons of carbon per year, which exceeds estimates of terresterial fixation. Phytoplankton is also a major food item in the diets of copepods (Cushing and Vucetic, 1963) and for pelagic filter feeders such as the commercially important menhaden, Brevoortia spp. (June and Carlson, 1971).

8.1.2 Other Studies

Phytoplankton and primary productivity studies of the Gulf of Mexico nearshore region are few. El-Sayed et al. (1972) reviewed the pertinent taxonomic literature for the Gulf of Mexico. Productivity studies for the Chenier Plain Coastal ecosystem of Louisiana and Texas are discussed by Gosselink et al. (1979). Selected areas along the Louisiana, Mississippi and Texas coasts have been surveyed for phytoplankton by Freese (1972), Fucik and El-Sayed (1979), Housley (1976), Lobleich and Matthews (1981), Maples (1981), Simmons and Thomas (1962), Sullivan (1982), and Wood (1963). Lobleich and Matthews (1981) evaluated the impact of brine disposal on Gulf phytoplankton during Bryan Mound SPR project in Texas.

8.1.3 Objectives of the Present Study

The present study was designed to:

1. Provide seasonal data for chlorophyll _a_ (phaeopigment corrected) levels in the vicinity of the brine diffuser and Calcasieu Lake.

2. Provide samples of preserved phytoplankton for taxonomic analysis, ancillary to chlorophyll _a_ measurements.

3. Determine the composition, standing crop and diversity of phytoplankton monthly for a period of one year (May 1981 - April 1982).

4. Provide ancillary data on salinity, temperature, dissolved oxygen and water transparency.

5. Determine whether any of the above parameters are demonstrably affected by the operation of the brine diffuser.

6. Provide statistical analysis of the experimental and control sites near the diffuser in the Gulf of Mexico and analysis of potential impact at select estuarine sites near and in Calcasieu Lake.

8.1.4 Reporting Format

This study is treated as two subunits: the marine habitat and the estuarine habitat. The findings for both units will be reported in three sections: species composition, species diversity, and biomass. Biomass will be further divided into cell numbers and chlorophyll a values.

8.2 Material and Methods

8.2.1 Field Procedures

Monthly phytoplankton samples were collected at nine marine stations and five estuarine stations, Figure 8-1. The dates for the marine and estuarine cruises are presented in Table 8-1. Water samples were collected at two levels in the water column, near surface and one meter off the bottom, at all marine stations and two of the estuarine stations (E1 and E5). Only near surface samples were taken at three estuarine stations (E2, E3 and E4). Water samples were collected with a three liter Van Dorn sampler and three samples were procured at each sampling level for both marine and estuarine stations. One liter of each sample was preserved with Lugols iodine and used for species identification and enumeration. For determination of pigments, one liter water samples were vacuum filtered at 25 psi, through 47 mm Gelman glass filters (GF/C). Each filter was wrapped in aluminum foil, placed in a Petri dish and frozen. The filters were then transported to the laboratory and placed in a freezer until processed. CTD/DO profiles were taken at three meter intervals at all stations, except

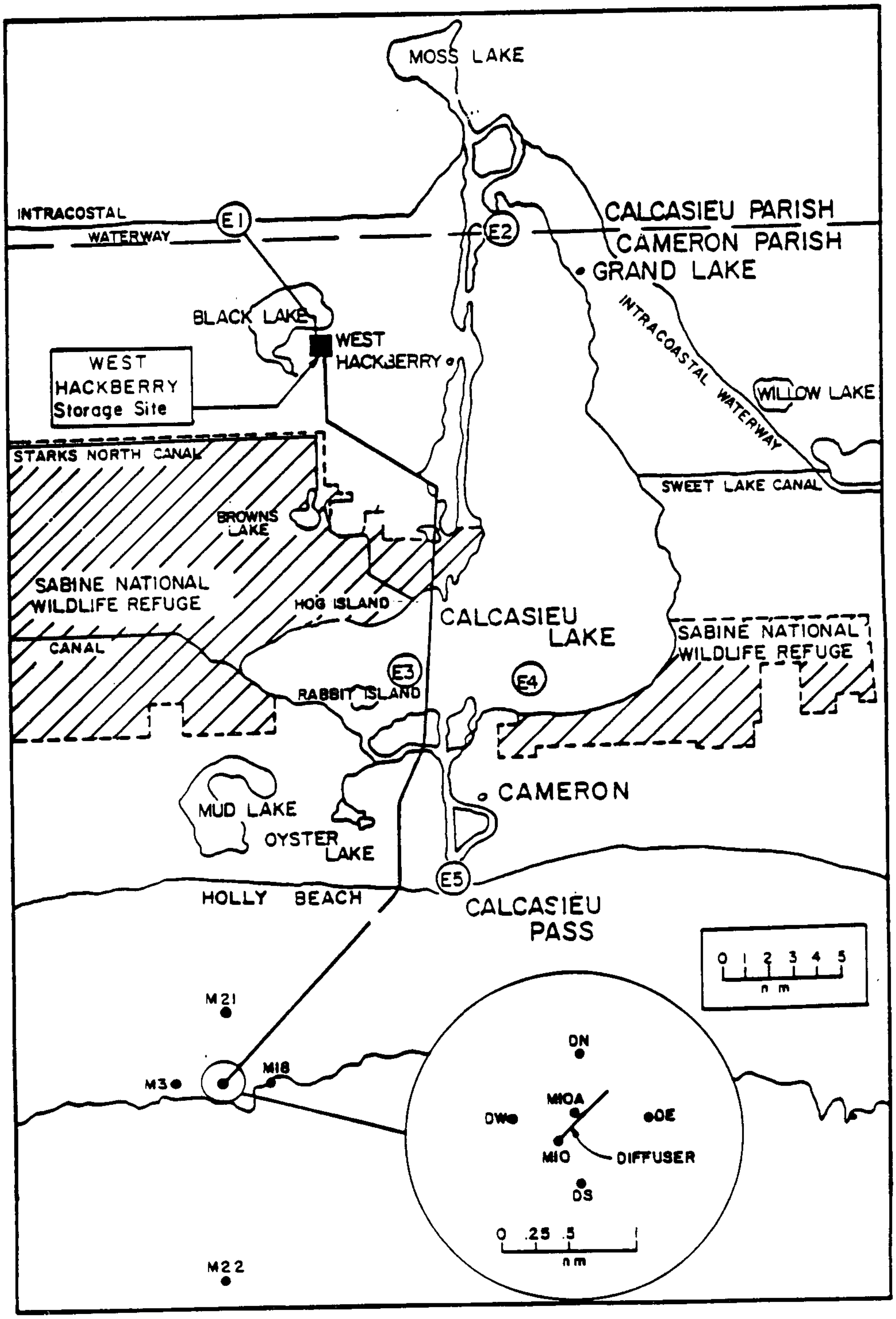

Figure 8-1 Location of marine and estuarine sampling sites in coastal waters of southwestern Louisiana.

Table 8-1. Sampling dates for marine and estuarine cruises.

MARINE CRUISES	ESTUARINE CRUISES
May 21, 1981	May 13, 1982
June 17-18, 1981	June 26, 1981
July 8, 1981	July 14, 1981
August 13-14, 1981	August 10, 1981
September 14-15, 1981	September 9, 1981
October 7-8, 1981	October 1, 1981
November 3-4, 1981	November 11, 1981
December 3-4, 1981	December 10, 1981
January 18-19, 1982	January 5, 1982
February 16-17, 1982	February 10, 1982
March 17-18, 1982	March 29, 1982
April 26-27, 1982	April 23, 1982

E2, E3, and E4. At these stations near surface and bottom readings were recorded.

8.2.2 Laboratory Procedures

Water samples were analyzed in the laboratory for chlorophyll-a, phaeopigments, phytoplankton number and dominant organisms. Pigment extractions were accomplished by mechanically grinding the samples and filter in a Wheaton teflon-glass tissue grinder with two milliliters of chilled 90% acetone and 0.1 g of magnesium carbonate. This mixture was ground for one minute to achieve complete extraction. The volume of this extract was brought to five milliliters with 90% acetone and centrifuged for one minute. These tubes were then allowed to reach room temperature in the dark. The fluorescence of the supernate solution was measured with a Turner Model #111 Flourometer equipped with a high intensity F4T-5 blue lamp, photomultiplier tube R-136 (red sensitive), sliding window orifices of 1x, 3x, 10x and 30x and filters for light emission (primary - 430; secondary - 650 N). The formula for calibrating the Turner Fluorometer are found in Standard Methods (1975) and the procedures and pigment calculation methods are described in Strickland and Parsons (1968).

Identification of the organisms was aided by the works of Van Heurck (1896), H. and M. Peragallo (1897-1908), Kofoid and Swezy (1921), Hustedt (1930 et. seq.), Cupp (1943), Smith (1950), Hustedt (1955), Curl (1959), Hendey (1964), Patrick and Reimer (1966), Wood (1968), Saunders and Glenn (1969), Steidinger and Williams (1970), Patrick and Reimer (1975), Housley (1976), and Tester and Steidinger (1979). In the laboratory the preserved one liter samples were allowed to settle for 96 hours. At the end of this period the supernate was siphoned leaving 200 ml of concentrate. Each bottle was mixed by inverting several times and a 10 ml aliquot was centrifuged for ten minutes at 1000-1200 RPM in a Beckman Model T5-6 centrifuge. The resultant pellet was resuspended in 0.05 ml of supernate and placed under a 22 x 22 mm coverglass. Organisms were examined with a Lietz Dialux-20 phase contrast compound microscope using a 25x phaco objective with a 0.50 N.A. The normal procedure was to count a single transect through the center of the coverglass and two additional transects equidistance from the initial one. By knowing the area examined and using the known volume, a calculation of the number of organisms per liter was made for each species. The dominant species and number of organisms per liter were recorded. This procedure is a modified method described by Campbell (1973).

Data analysis was accomplished by the use of Analysis of Variance (ANOVA), Duncan's New Multiple Range Test (DMRT) and Multiple Analysis of Covariance (Brunning and Kintz, 1977). Cell numbers were transformed to $\log_{10}$ to facilitate data processing and to normalize the data (Sournia, 1978). Standard deviations and ranges were determined for both cell numbers and chlorophyll-*a*. Species diversity values were calculated using the Shannon-Weaver diversity formula (Sournia, 1978).

Because of the variability found at stations M21 and M22, it was decided to exclude them from the data analysis. It is believed that the cause of this variability at these stations is due to their location in different hydrographic regions from the other study stations. The stations selected for the purposes of data analysis are basically located on the along-shore transect. It was thought that these stations (M3, M18, M10A, DN, DE, DW and DS) were more suitable for comparison since they are all near the 10 meter isobath. A matched site study design using M3 and M18 as control sites was the intent of this investigation, however the data analysis curtailed the development of this concept.

Two analytical approaches were used for data analysis. First, comparisons were made on a monthly regime using an ANOVA followed by a Duncan's test when deemed appropriate. All Duncan's test were run with a protection level of 0.05. Because the near bottom community is more likely to be subject to the effect of the brine plume, the surface and bottom samples for each month were separated for analysis. Second, comparisons were made for three variables (cruises, stations, and salinities) by Multiple Analysis of Covariance. This mathematical model provided analysis of station differences over time while adjusting for the salinity variable.

8.3 Results

8.3.1 Marine

8.3.1.1 Species Composition

There were 144 taxa of phytoplankton identified during this study. Forty-four (44) genera, one hundred (100) species and two varieties of diatoms were identified. Ten (10) genera, twenty-one (21) species and two varieties of dinoflagellates were identified. Among the minor members of the assemblage, two cryptophytes, two euglenoids, eight greens, four blue-green, one chrysophyte and one silicoflagellate were identified. Diatoms dominated the phytoplankton for most of the year with substantial populations of dinoflagellates and microflagellates occurring in the late spring and summer months. The major diatoms were Skeletonema costatum, Cerataulina pelagica, Asterionella glacialis, Leptocylindrus danicus, Hemaulis sinesis and Rhizosolenia fragilissma. Species of Nitzschia, Chaetoceros and Rhizosolenia formed important secondary associations. The dinoflagellate community was dominated by species of Prorocentrum, notably P. compressum, Ceratium, and Dinophysis. It is of interest to note that five species of red tide organisms were found. These are Prorocentrum minimum, Glenodinum splendens, Noctiluca milaris, Oscillatoria erythraea and Gonyaulax monilata. Only Gonyaulax is known to be toxic. A bloom of G. monilata occurred in the late summer and early fall of 1981. This is unusual since this organism is rarely reported in offshore waters.

In general the species composition of the phytoplankton was typical of assemblages found in coastal waters of the Gulf of Mexico. A systematic list of all species identified in this study is presented in Table 8-2.

Table 8-2. Systematic list of phytoplankton species found in the marine and estuarine study areas.

Cyanophyta	
Oscillatoriaceae	*Microcoleus lyngbyacea*
	Oscillatoria erythraea
	Schizothrix arenaria
	Spirulina subsalsa
Pyrrophyta	
Prorocentraceae	*Prorocentrum compressum*
	P. gracile
	P. minimum
Gymnodiniaceae	*Glenodinium splendens*
	Gymnodinium sp.
	Gyrodinium sp.
Noctilucaceae	*Noctiluca milaris*
Dinophysiaceae	*Dinophysis caudata*
	D. caudata var. *acuminiformis*
	D. ovum
Peridinaceae	*Peridinum* sp.
	Oxytoxum milneri
	O. scolopax
Gonyaulaceae	*Gonyaulax polygramma*
	G. monilata
	Gonyaulax sp.
Ceratiaceae	*Ceratium furca*
	C. fusus
	C. massiliense
	C. trichoceros
	C. tripos
	C. tripos var. *atlanticum*
Pyrophacaceae	*Pyrophacus horologium*

Table 8-2. continued

Chlorophyta	
Chlamydomonadaceae	*Chlamydomonas* sp.
Pedinomonadaceae	*Heteromastix pyriformis*
Pyramimonaceae	*Pyramimonas* sp.
Tetraselmiaceae	*Tetraselmis* sp.
Oocystaceae	*Ankistrodesmus falcata* *Oocystis* sp.
Scenedesmaceae	*Scenedesmus* sp.
Euglenophyta	
Euglenaceae	*Euglena* sp. *Eutrepia* sp.
Cryptophyta	
Cryptophysidaceae	*Chroomonas* sp. *Cryptomonas* sp.
Chrysophyta	
Chrysophyceae	*Calycomonas ovalis*
Dictyochaceae	*Dictyocha fibula*
Thalassiosiraceae	*Cyclotella atomus* *C. kutzingiana* *C. striata* *Lauderia borealis* *Skeletonema costatum* *S. tropicum* *Thalassiosira decipiens* *T. gravida* *T. subtilis* *T. excentricus*

Table 8-2. continued

Melosiraceae	Corethron criophilum
	Leptocylinidrus danicus
	L. minimus
	Melosira distans
	M. granulata
	M. moniliformis
	Stephanopyxis palmeriana
Coscinodiscaceae	Coscinodiscus centralis
	C. granii
	C. lineatus
	C. radiatus
	C. rothii
	C. wailesii
	Coscinodiscus sp.
Hemidiscaceae	Palmeriana hardmanianus
Heliopeltaceae	Actinoptychus senarius
Rhizosolenizceae	Dactyliosolen antarcticus
	Guinardia flaccida
	Rhizosolenia alata
	R. alata f. gracillima
	R. alata f. indica
	R. calcar-avis
	R. castracanei
	R. fragilissima
	R. imbricata
	R. robusta
	R. setigera
	R. stolterfothii
Biddulphiaceae	Biddulphia alternans
	B. aurita
	B. mobiliensis
	B. sinesis
	Campylosira cymbelliformis
	Cerataulina pelagica
	Eucampia cornuta
	E. zoodiacus
	Hemiaulus hauckii
	H. membranaceus
	H. sinensis

Table 8-2. continued

Chaetoceraceae	*Bacteriastrum delicatulum*
	B. varians
	Chaetoceros affine
	C. breve
	C. coarctatum
	C. compressum
	C. curvisetum
	C. danicum
	C. didymum
	C. lorenzianum
	C. peruvianum
	C. sociale
	C. subtilis
	C. tortissimum
Lithodesmiaceae	*Bellerochea malleus*
	Ditylum brighwelli
	Lithodesmium undulatum
	Streptotheca thamesis
Diatomaceae	*Asterionella glacialis*
	Grammatophora marina
	Licmophora abbreviata
	Synedra sp.
	Thalassionema nitzschioides
	Thalassiothrix frauenfeldii
	T. longissima
	T. mediterranea var. *pacifica*
Achnanthaceae	*Achnanthes brevipes*
	A. longipes
Naviculaceae	*Amphiprora alata*
	Amphiprora sp.
	Anomoeoneis sp.
	Diploneis smithii
	Gyrosigma balticum
	D. weissflogii
	Navicula abunda
	N. distans
	Navicula sp.

Table 8-2. continued

	Pleurosigma angulatum
	P. formosum
	P. normanii
	Pleurosigma sp.
	Stauroneis membranacea
Nitzchiaceae	Bacillaria paxillifer
	Cylindrotheca gracilis
	Cymatonitzschia marina
	Nitzschia closterium
	N. longissima
	N. panduriformis
	N. pungens var. atlantica
	N. seriata
	N. sigma
	N. subfraudulenta
Surirellaceae	Surirella fastuosa
Phaeophyta	
Sargassaceae	Sargassium natans
Rhodophyta	
Rhodomelaceae	Polysiphonia sp.

8.3.1.2 Temporal Distribution of Phytoplankton

Temporal data of species blooms revealed several major trends. The diatoms tend to dominate in the spring, fall and winter, while the blue-greens and dinoflagellates are more prominant in the summer months. These trends are correlated with seasonal water temperature (Figure 8-2).

All of the dominant diatoms occurred throughout the year. Three of the dominants, *Rhizosolenia fragilissima*, *Hemaulis sinesis*, and *Leptocylindrus danicus*, bloomed in the fall and winter months. *Skeletonema costatum*, *Cerataulina pelagica* and *Asterionella glacialis* had important population increases in the spring and winter months (Figure 8-3). The population graphic (Figure 8-3) features two events of interest. First the summer blooms of *Skeletonema* and *Cerataulina* and secondly the population depression of all three species during February, 1982. These two events are probably the result of freshwater intrusion, from land runoff, into the study area (Figure 8-4) and the accompanying pulses of nitrate (NO_3) concentrations in the study area (Figure 8-5). Measurements of other nutrients e.g. nitrite, NO_2, (Figure 8-6), ammonia, NH_3, (Figure 8-7), and phosphates, PO_4, (Figure 8-8) would indicate that the study area is a nitrate-nitrogen dependent system. The dominant dinoflagellates are species of *Prorocentrum* and these are present throughout the year. The occurrance of *O. erythraea* and *G. monilata* during the summer months has been previously described by Maples et al. (1982). Environmental

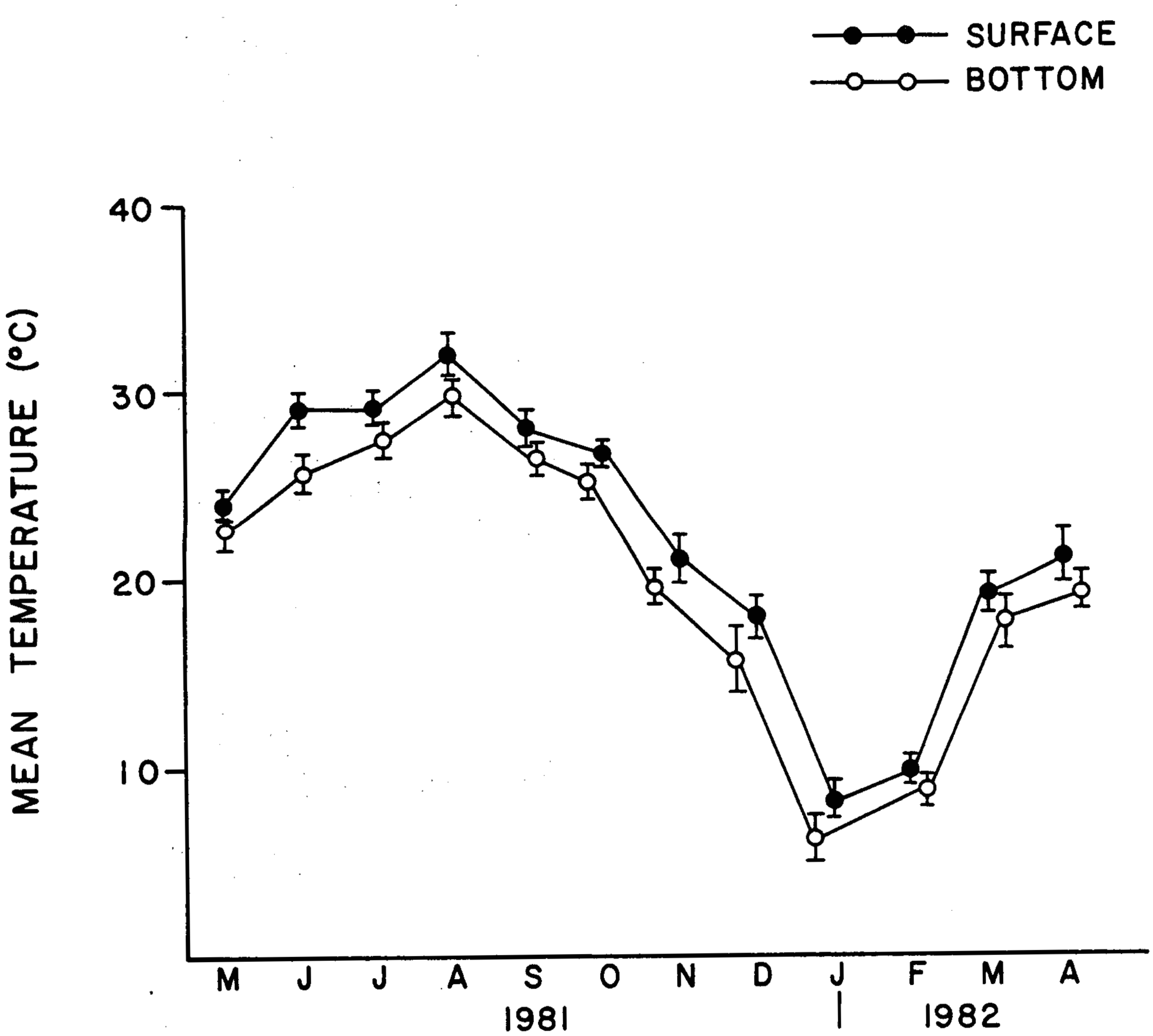

Figure 8-2. Seasonal changes in temperatures at marine stations in coastal waters of southwestern Louisiana. Means with one standard deviation are plotted.

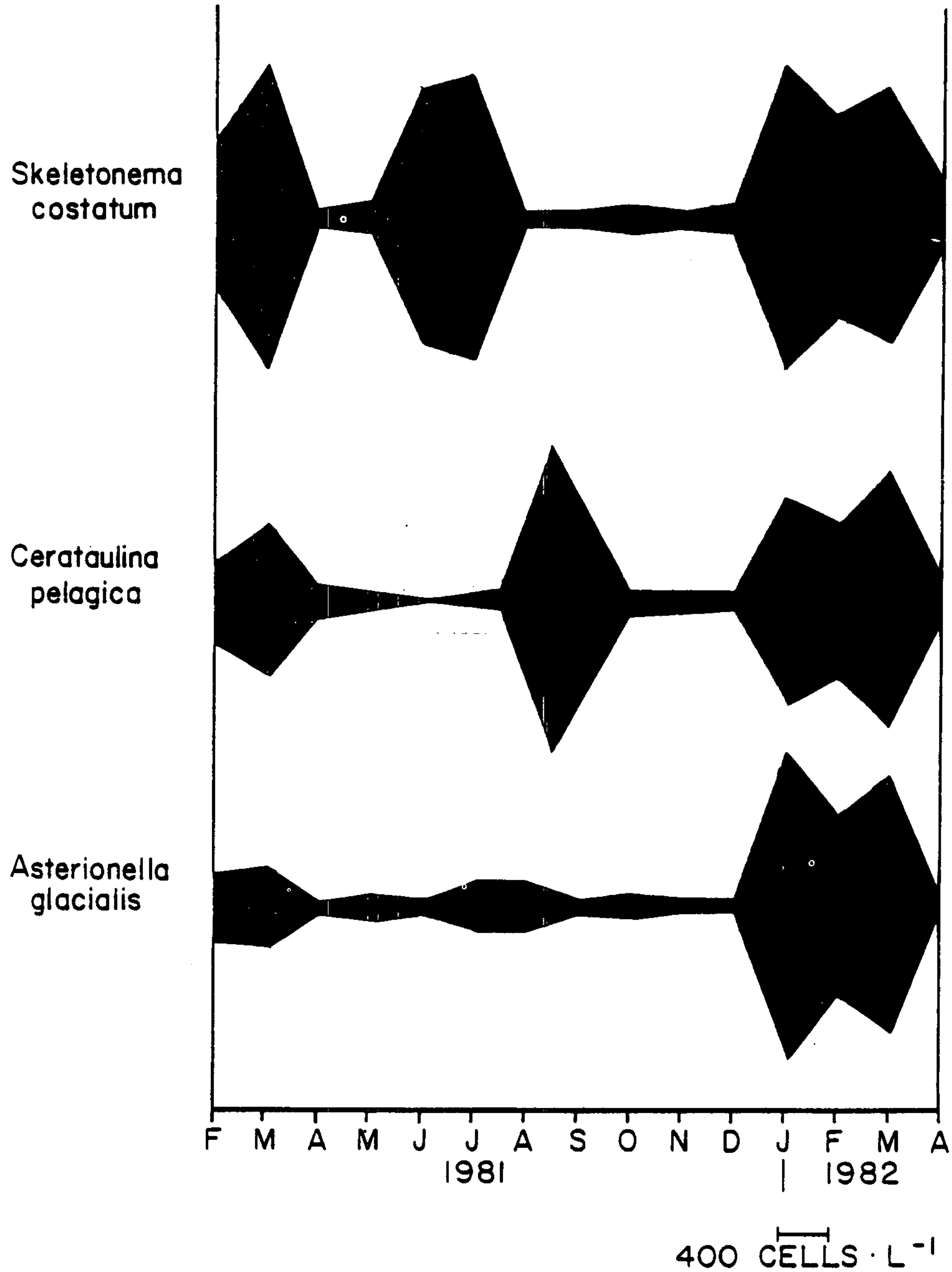

Figure 8-3. Seasonal distribution of phytoplankton in coastal waters of southwestern Louisiana.

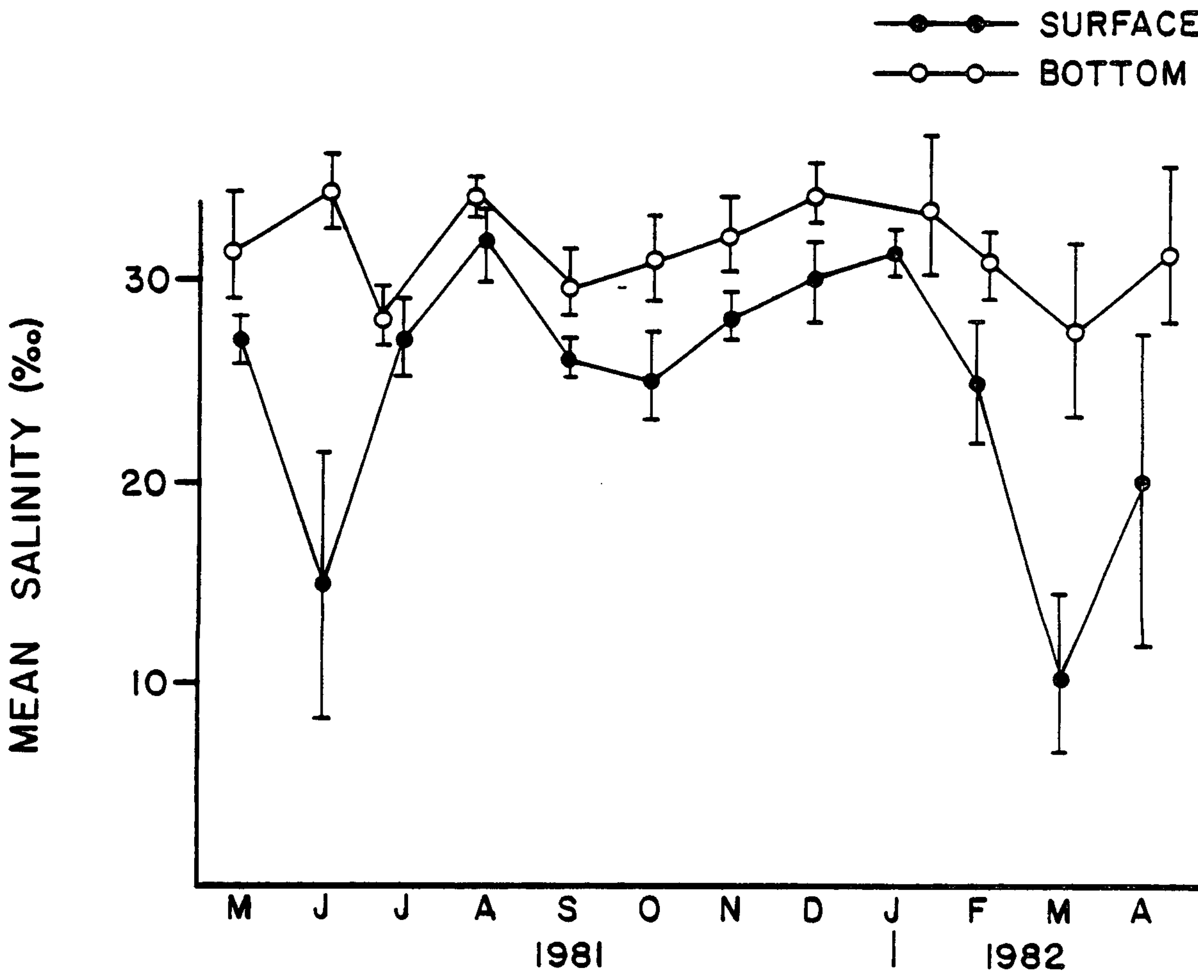

Figure 8-4. Seasonal changes in salinities at marine stations in coastal waters of southwestern Louisiana. Means with one standard deviation are plotted.

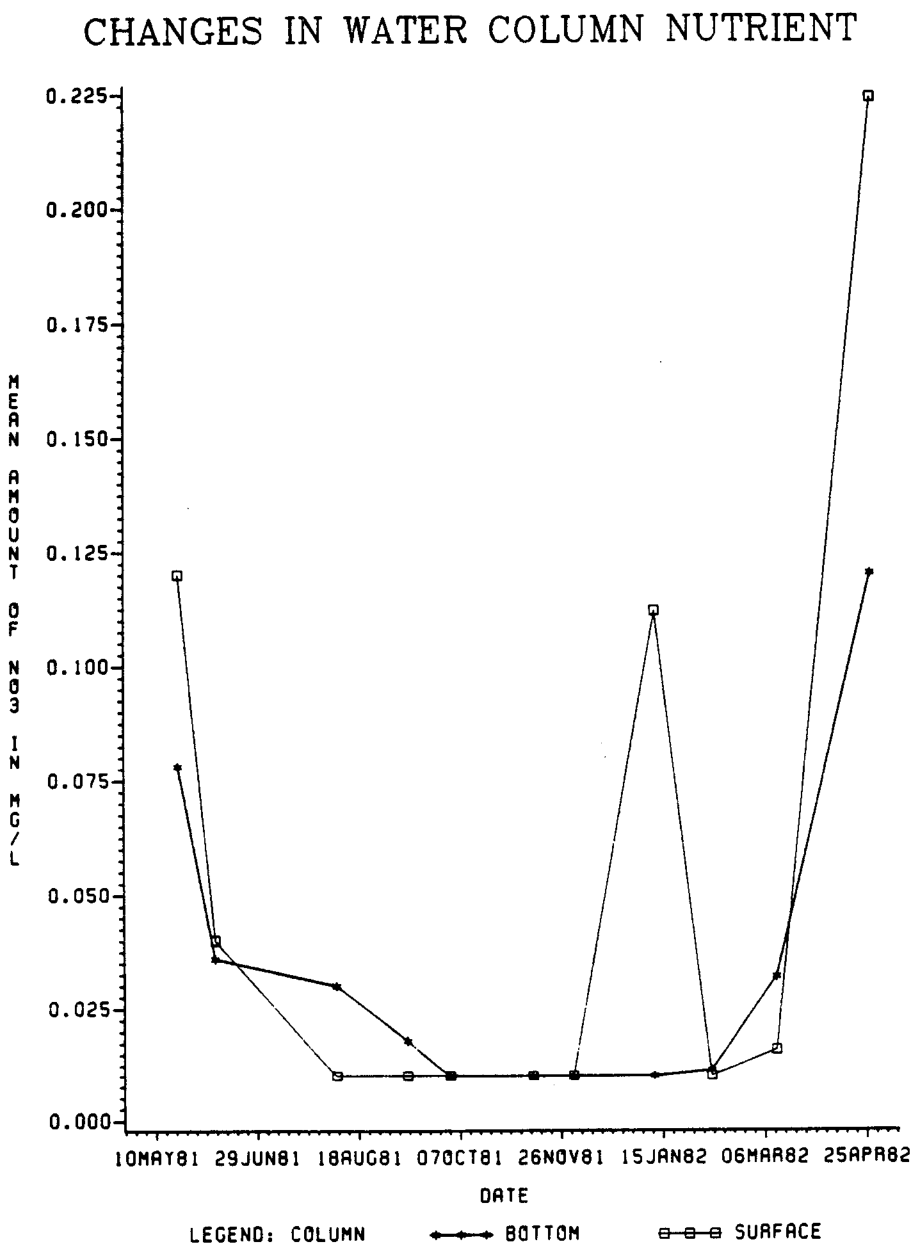

Figure 8-5. Seasonal changes in nitrate-nitrogen (NO_3) concentration in coastal waters of southwestern Louisiana.

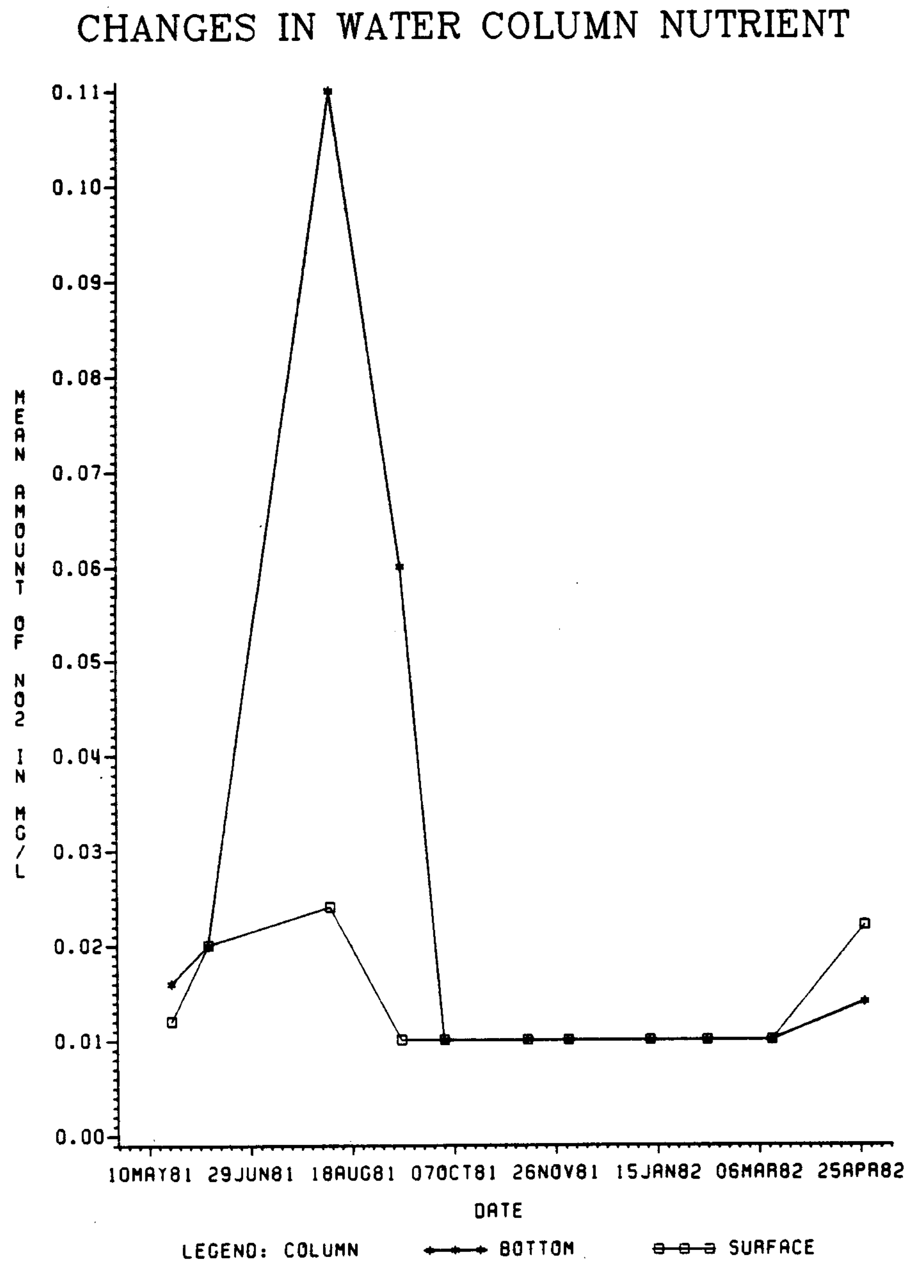

Figure 8-6. Seasonal changes in nitrite-nitrogen (NO_2) concentrations in coastal waters of southwestern Louisiana.

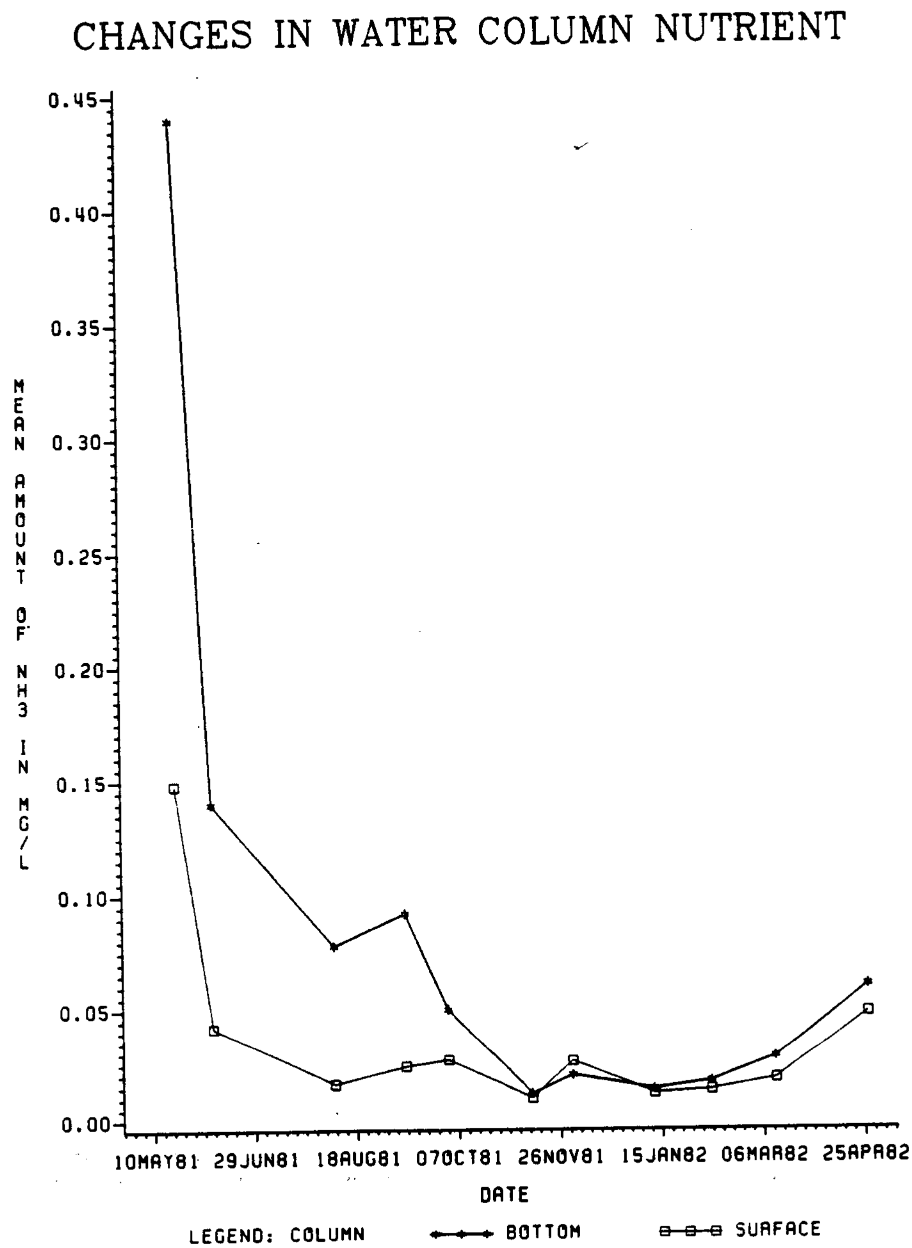

Figure 8-7. Seasonal changes in ammonia-nitrogen (NH_3) concentrations in coastal waters of southwestern Louisiana.

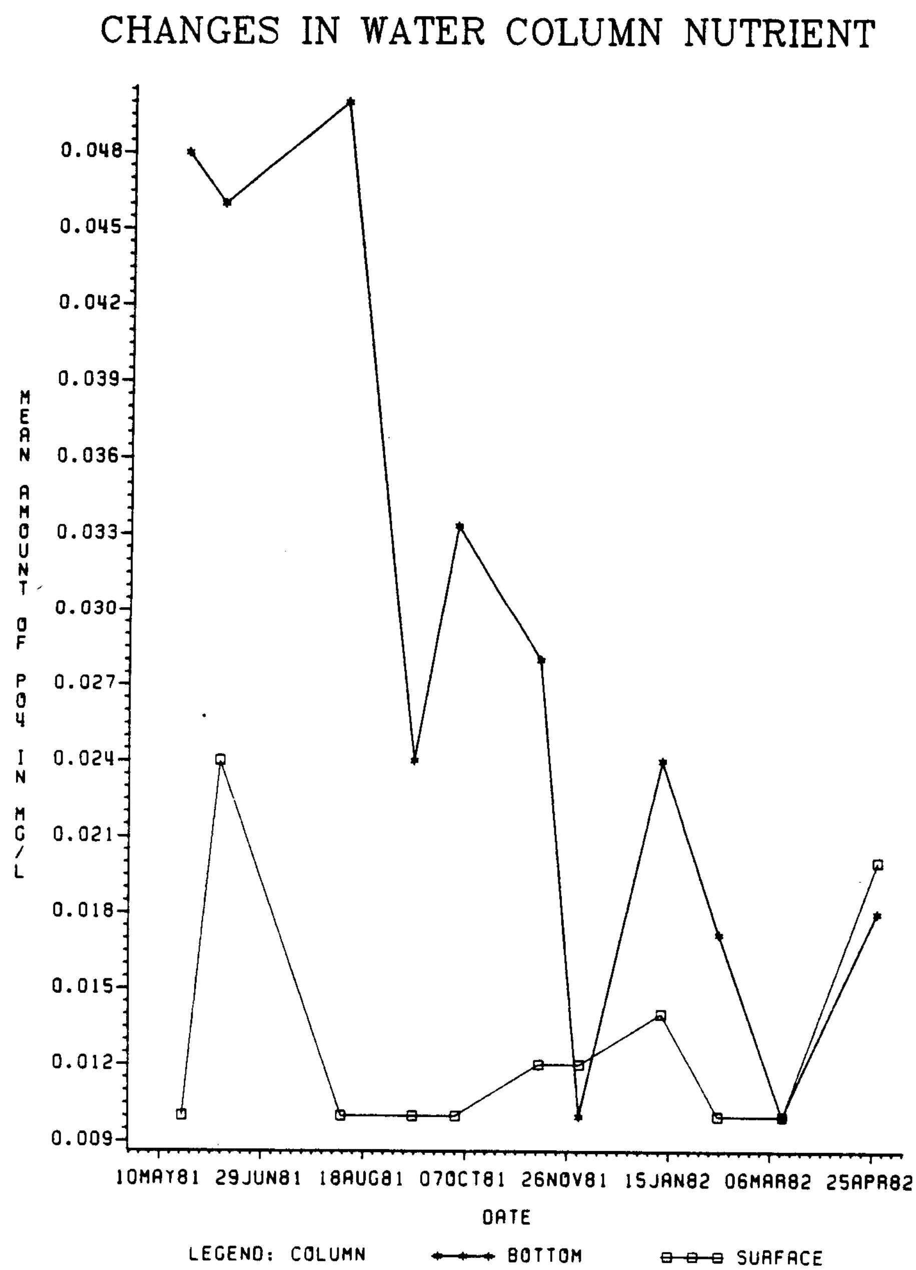

Figure 8-8. Seasonal changes in total phosphates (PO_4) in coastal waters of southwestern Louisiana.

conditions prior to these blooms were: low rainfall, stratified water column, low nitrate- nitrogen (2.0-3.0 μg at. · L^{-1}), high water temperature (29-30°C), high salinity (30-32 $^{0}/oo$), and basic pH (8.0). The seasonal distribution of phytoplankton is characteristic of near shore temperate and subtropical marine ecosystems. All of the unusual events (blooms) can be explained within the framework of the environmental parameters associated with such occurrances.

8.3.1.3 Species Diversity Values

Reports of species diversity values for marine phytoplankton are not common. Housley (1976) reported a Margalef's species richness index for his study on Bay St. Louis, Mississippi and the Mississippi River delta region of the Gulf of Mexico. Briand (1975) calculated Shannon-Weaver diversity values for a phytoplankton community in coastal waters of California. Sullivan (1978) reported a Shannon-Weaver information index for the diatom community in a salt marsh under tidal influence in coastal Mississippi.

Species diversity values for this study were calculated using the Shannon-Weaver formula. These values ranged from 0.25 to 3.5 during the study. The distribution of these values showed no drastic variation throughout most of the study period, Figure 8-9.

8.1.3.4 Biomass

Biomass values were determined by two methods: 1) direct cell counts and 2) chlorophyll a measurements. Cell counts in this study refer to morphological units, i.e. distinction was not made between

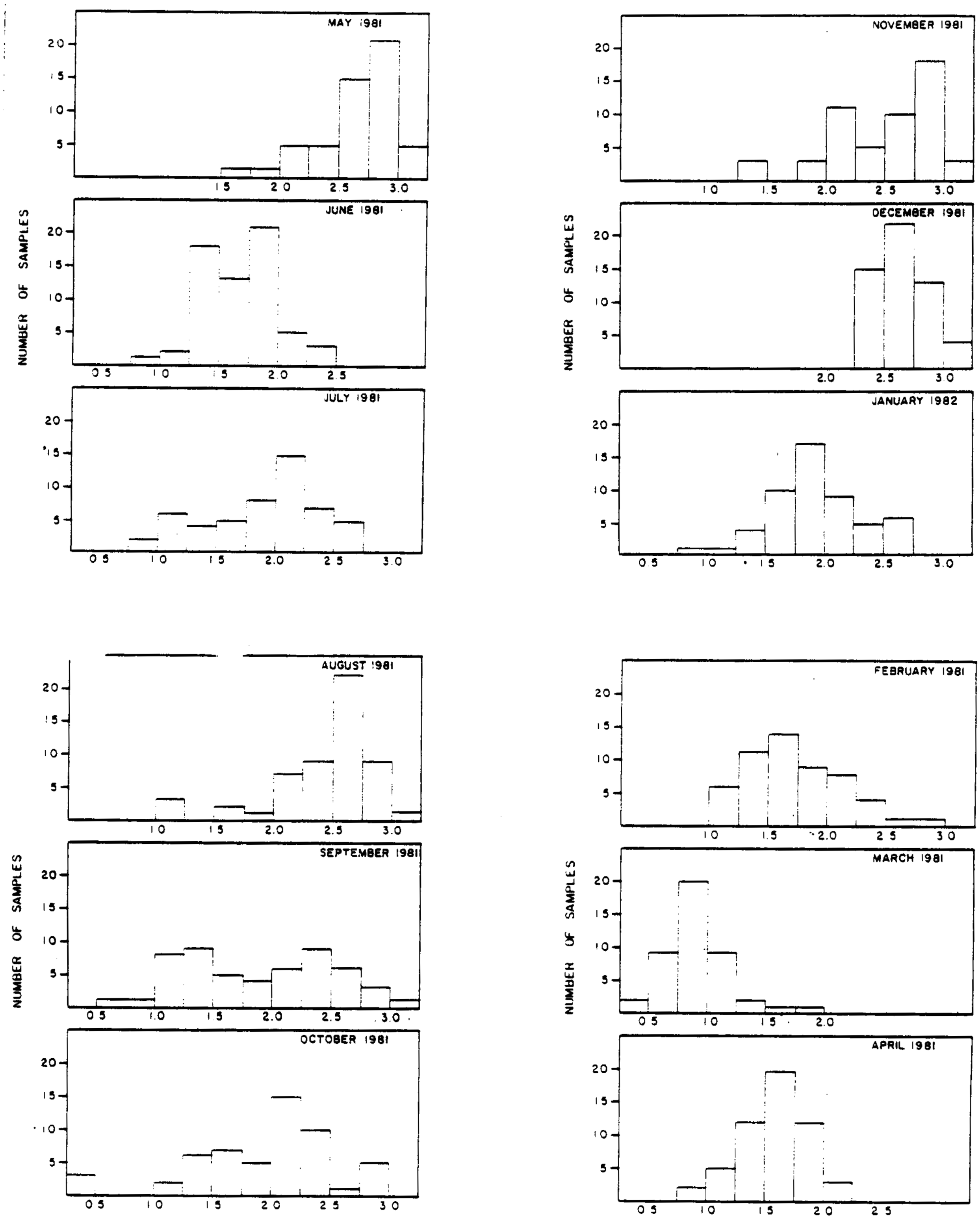

Figure 8-9. Shannon-Weaver species diversity values for phytoplankton in the coastal waters of southwestern Louisiana.

single cells, colonies, or trichomes. Cell totals ranged from 3000 to 600,000 cells per liter for this study. As mentioned earlier in this report, the cell totals were transformed to a $\log_{10}$ base to facilitate data analysis. The seasonal distribution of the mean for $\log_{10}$ cell totals by stations and depth are presented in Table 8-3. Counts were generally higher in the winter months, however large spring and fall blooms occurred, Figure 8-10. It should be noted that in the winter months the diatoms were the prevalent species.

In general, the cell counts for the study area compare favorably with others reported for coastal areas of the Gulf of Mexico, although there is a tendency for some species, e.g. Rhizosolenia alata, to be less dense than reported elsewhere.

An analysis of variance was performed for the cell totals ($\log_{10}$) per liter for both the surface and bottom marine stations by monthly cruise. For the surface stations it was found that in all but two months, July and September, there were significant ($\alpha < .05$) differences between stations, Tables 8-4 through 8-15. For the bottom stations it was found that in all but one month, July, there were significant ($\alpha < .05$) differences between stations, Tables 8-4 through 8-15. A multiple comparison of means was performed using Duncan's New Multiple Range Test (DMRT) for those cruises having significant ANOVA's for cell totals ($\log_{10}$). The results of the DMRT's are presented in Tables 8-4 through 8-15.

Table 8-3. Distribution of means for cell totals.L^{-1} ($\log_{10}$) by station, depth and date of collection in coastal waters of southwestern Louisiana.

DATE	DEPTH	M3	M10	M18	DE	DW	DN	DS
MAY 81	*S	2.8084	2.9474	3.1780	2.6198	2.5978.	2.7561	3.4583
	**B	3.0449	3.1608	3.5155	2.9181	2.5548	3.0578	3.2183
JUN 81	S	3.1170	3.0644	3.0125	2.7602	3.2991	3.4101	3.0824
	B	2.9798	2.8125	2.8831	2.6578	2.8236	2.6903	2.7002
JUL 81	S	3.0706	3.1936	3.1803	3.1616	3.0973	3.2708	2.9903
	B	3.0331	3.4274	2.8590	3.1530	3.2947	3.1212	3.5986
AUG 81	S	3.4580	3.4080	3.1885	3.2326	3.4453	3.6265	3.3293
	B	3.4819	3.2831	3.0908	3.3661	3.3294	3.3986	3.1796
SEP 81	S	3.7277	3.8238	4.1456	3.6758	3.8579	4.0963	4.1123
	B	3.5685	3.0848	3.7148	3.2878	3.2574	3.2036	3.4104
OCT 81	S	3.3391	3.1223	3.5127	3.0970	3.5017	3.0938	3.2324
	B	2.9170	3.3367	3.3356	3.3994	3.5460	3.2849	3.3748
NOV 81	S	3.4072	3.1421	3.4654	3.4458	3.3232	3.4020	3.3961
	B	3.1480	3.1623	3.5571	3.4178	3.5239	3.2849	3.3701
DEC 81	S	2.6806	2.8638	2.7736	2.7273	2.8622	2.9107	2.7569
	B	2.7784	2.9542	2.8345	2.8431	2.8405	2.8100	2.5999
JAN 82	S	3.6933	4.1160	3.9978	3.3653	3.9187	3.9556	4.0481
	B	3.9233	4.0570	4.0105	3.6759	4.0415	4.0528	4.1139
FEB 82	S	3.2820	3.1421	3.6630	3.5626	3.4033	3.1499	3.3570
	B	3.1936	3.1145	3.6974	3.2505	2.3916	3.2478	3.3493
MAR 82	S	3.4505	3.5074	3.4279	3.8114	3.3941	3.2475	3.6795
	B	3.1227	3.1348	3.3441	3.4412	3.3921	3.5969	3.1622
APR 82	S	3.6102	3.7657	3.7441	3.4115	3.1994	3.4554	3.5830
	B	3.4374	3.8865	3.7336	3.6694	3.4570	3.4967	3.6395

* S = Surface
** B = Bottom

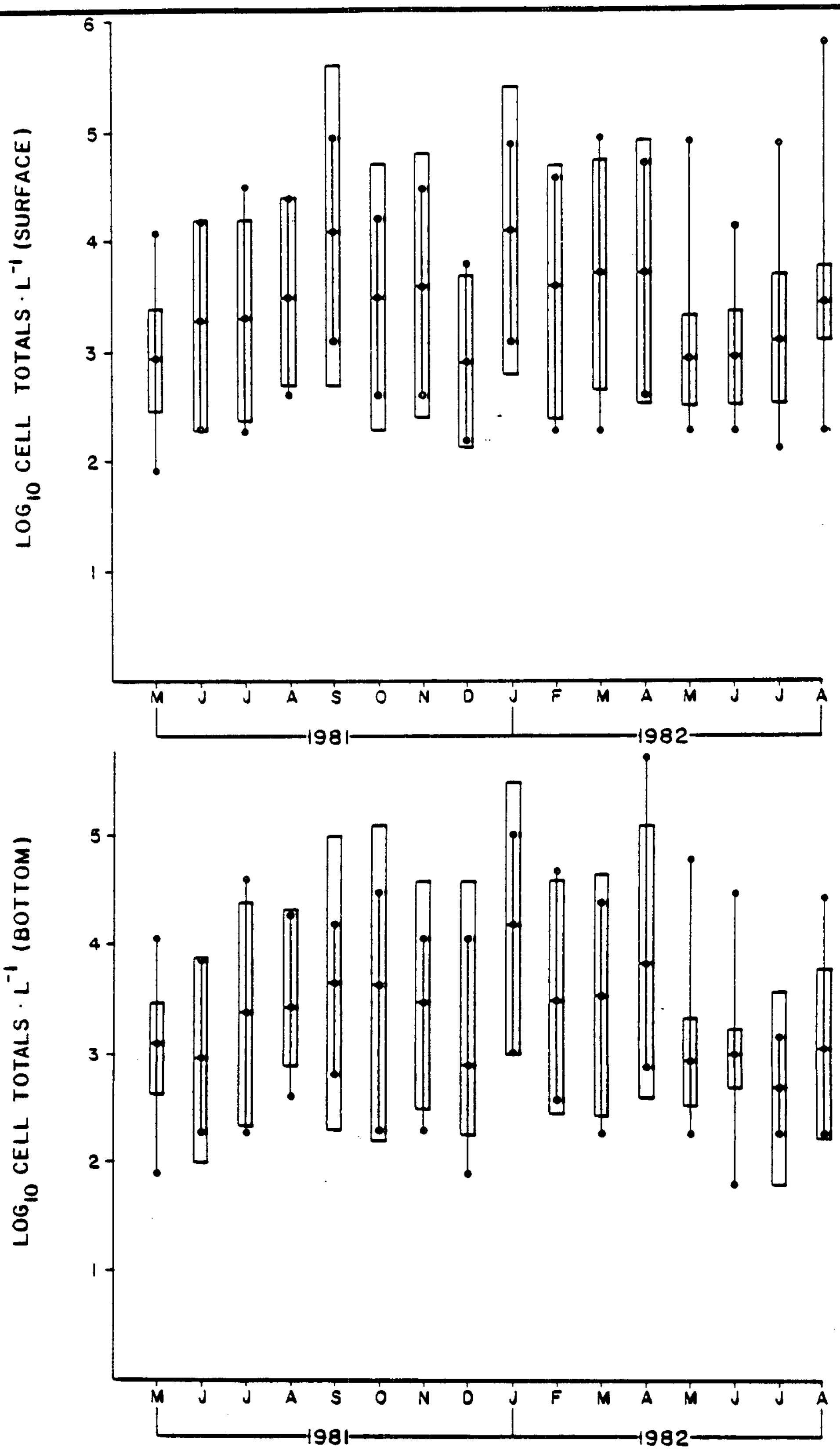

Figure 8-10. Seasonal distribution of means with ranges and one standard deviation for cell totals $.L^{-1}$ ($\log_{10}$) at all marine surface and bottom stations.

Table 8-4. ANOVA for cell totals ($\log_{10}$) per liter among marine stations, May 1981. For significant (*) ANOVA's, Duncan's New Multiple Range Test (DMRT) are presented.

Source of variation	df	SS	MS	F_s
SURFACE				
Among stations	6	1.902	0.317	25.005*
Within stations	14	0.177	0.126	
Totals	20	2.079		

F.05 (6,14) = 2.85

DMRT results:

Stations	DS	M18	M10	DW	DN	M3	DE
Means	4.460	4.377	4.104	3.815	3.807	3.762	3.624

Source of variation	df	SS	MS	F_s
BOTTOM				
Among stations	6	1.602	0.267	12.427*
Within stations	14	0.300	0.215	
Totals	20	1.902		

F.05 (6,14) = 2.85

DMRT results:

Stations	M18	DS	M10	M3	DN	DE	DW
Means	4.650	4.419	4.284	4.216	4.094	3.981	3.734

Table 8-5. ANOVA for cell totals ($\log_{10}$) per liter among marine stations, June 1981. For significant (*) ANOVA's, Duncan's New Multiple Range Test (DMRT) are presented.

	Source of variation	df	SS	MS	F_s
SURFACE					
	Among stations	6	0.415	0.669	7.821*
	Within stations	14	0.124	0.009	
	Totals	20	0.539		

F.05 (6,14) = 2.85

DMRT results:

Stations	DN	DW	M10	M18	M3	DS	DE
Means	4.300	4.279	4.202	4.075	4.031	4.004	3.894
	———	———	———				
			———	———	———		
				———	———	———	
					———	———	———

	Source of variation	df	SS	MS	F_s
BOTTOM					
	Among stations	6	0.269	0.045	4.634*
	Within stations	14	0.135	0.010	
	Totals	20	0.404		

F.05 (6,14) = 2.85

DMRT results:

Stations	M3	M10	DS	DN	M18	DE	DW
Means	3.852	3.773	3.748	3.683	3.669	3.531	3.623
	———	———	———	———	———		
				———	———	———	———

Table 8-6. ANOVA for cell totals ($\log_{10}$) per liter among marine stations, July 1981. For significant (*) ANOVA's, Duncan's New Multiple Range Test (DMRT) are presented.

Source of variation	df	SS	MS	F_s
SURFACE				
Among stations	6	0.439	0.073	2.6205
Within stations	14	0.391	0.028	
Totals	20	0.830		

$F_{.05}$ (6,14) = 2.85

Source of variation	df	SS	MS	F_s
BOTTOM				
Among stations	6	0.303	0.051	1.443
Within stations	14	0.490	0.035	
Totals	20	0.793		

$F_{.05}$ (6,14) = 2.85

Table 8-7. ANOVA for cell totals ($\log_{10}$) per liter among marine stations, August 1981. For significant (*) ANOVA's, Duncan's New Multiple Range Test (DMRT) are presented.

Source of variation	df	SS	MS	F_s
SURFACE				
Among stations	6	0.285	0.048	9.330*
Within stations	14	0.071	0.005	
Totals	20	0.356		

F.05 (6,14) = 2.85

DMRT results:

Stations	M3	DN	M10	DE	M18	DW	DS
Means	4.740	4.635	4.572	4.485	4.480	4.436	4.373
	—	—		—	—	—	—
		—	—				
			—	—	—		

Source of variation	df	SS	MS	F_s
BOTTOM				
Among stations	6	0.564	0.094	34.488*
Within stations	14	0.038	0.003	
Totals	20	0.602		

F.05 (6,14) = 2.85

DMRT results:

Stations	M3	DW	DE	DN	M10	DS	M18
Means	4.639	4.469	4.425	4.357	4.290	4.184	4.119
		—	—			—	—
			—	—			
				—	—		

Table 8-8. ANOVA for cell totals ($\log_{10}$) per liter among marine stations, September 1981. For significant (*) ANOVA's, Duncan's New Multiple Range Test (DMRT) are presented.

Source of variation	df	SS	MS	F_s
SURFACE				
Among stations	6	0.079	0.013	0.937
Within stations	14	0.197	0.014	
Totals	20	0.276		

F.05 (6,14) = 2.85

Source of variation	df	SS	MS	F_s
BOTTOM				
Among stations	6	1.080	0.180	9.108*
Within stations	14	0.277	0.020	
Totals	20	1.357		

F.05 (6,14) = 2.85

DMRT results:

Stations	M18	DE	M3	DS	DN	DW	M10
Means	4.544	4.221	4.212	4.183	4.098	3.915	3.778

(Underlines: DE–DN; DN–DW; DW–M10)

Table 8-9. ANOVA for cell totals ($\log_{10}$) per liter among marine stations, October 1981. For significant (*) ANOVA's, Duncan's New Multiple Range Test (DMRT) are presented.

Source of variation	df	SS	MS	F_s
SURFACE				
Among stations	6	0.286	0.048	7.931*
Within stations	14	0.084	0.006	
Totals	20	0.370		

$F_{.05}\ (6,14) = 2.85$

DMRT results:

Stations	M18	DW	M3	DS	DE	DN	M10
Means	4.434	4.294	4.250	4.232	4.141	4.097	4.072

Source of variation	df	SS	MS	F_s
BOTTOM				
Among stations	6	1.178	0.196	11.345*
Within stations	14	0.242	0.017	
Totals	20	1.420		

$F_{.05}\ (6,14) = 2.85$

DMRT results:

Stations	DW	DE	M10	M18	DS	DN	M3
Means	4.319	4.316	4.276	4.080	4.031	3.980	3.601

Table 8-10. ANOVA for cell totals ($\log_{10}$) per liter among marine stations, November 1981. For significant (*) ANOVA's, Duncan's New Multiple Range Test (DMRT) are presented.

Source of variation	df	SS	MS	F_s
SURFACE				
Among stations	6	0.287	0.048	3.517*
Within stations	14	0.190	0.014	
Totals	20	0.477		

$F_{.05}(6,14) = 2.85$

DMRT results:

Stations	DE	M18	DS	M3	DN	DW	M10
Means	4.491	4.483	4.398	4.385	4.255	4.204	4.194

Underlined groups: DE–M3; DS–M10.

Source of variation	df	SS	MS	F_s
BOTTOM				
Among stations	6	0.479	0.080	16.865*
Within stations	14	0.066	0.005	
Totals	20	0.545		

$F_{.05}(6,14) = 2.85$

DMRT results:

Stations	M18	DW	DN	DS	DE	M3	M10
Means	4.443	4.425	4.412	4.400	4.348	4.087	4.067

Underlined groups: M18–DE; M3–M10.

Table 8-11. ANOVA for cell totals ($\log_{10}$) per liter among marine stations, December 1981. For significant (*) ANOVA's, Duncan's New Multiple Range Test (DMRT) are presented.

Source of variation	df	SS	MS	F_s
SURFACE				
Among stations	6	0.454	0.076	14.469*
Within stations	14	0.073	0.005	
Totals	20	0.527		

$F_{.05}$ (6,14) = 2.85

DMRT results:

Stations	DN	M10	DE	M18	DW	DS	M3
Means	4.211	3.988	3.956	3.906	3.893	3.866	3.681

Source of variation	df	SS	MS	F_s
BOTTOM				
Among stations	6	0.777	0.129	36.476*
Within stations	14	0.050	0.004	
Totals	20	0.827		

$F_{.05}$ (6,14) = 2.85

DMRT results:

Stations	M18	DN	M10	DE	DW	M3	DS
Means	4.372	4.111	4.105	4.064	4.016	3.930	3.684

Table 8-12. ANOVA for cell totals ($\log_{10}$) per liter among marine stations, January 1982. For significant (*) ANOVA's, Duncan's New Multiple Range Test (DMRT) are presented.

Source of variation	df	SS	MS	F_s
SURFACE				
Among stations	6	1.952	0.325	45.942*
Within stations	14	0.099	0.007	
Totals	20	2.051		

F.05 (6,14) = 2.85

DMRT results:

Stations	M10	DS	M18	DW	DN	M3	DE
Means	5.092	4.979	4.923	4.715	4.621	4.550	4.115

Source of variation	df	SS	MS	F_s
BOTTOM				
Among stations	6	1.274	0.212	70.461*
Within stations	14	0.042	0.003	
Totals	20	1.316		

F.05 (6,14) = 2.85

DMRT results:

Stations	DS	M10	DW	DN	M3	M18	DE
Means	5.194	5.127	5.031	4.975	4.842	4.841	4.392

Table 8-13. ANOVA for cell totals (log_{10}) per liter among marine stations, February 1982. For significant (*) ANOVA's, Duncan's New Multiple Range Test (DMRT) are presented.

Source of variation	df	SS	MS	F_s
SURFACE				
Among stations	6	1.471	0.245	42.886*
Within stations	14	0.080	0.006	
Totals	20	1.551		

F.05 (6,14) = 2.85

DMRT results:

Stations	M18	DE	M3	M10	DW	DS	DN
Means	4.767	4.751	4.563	4.347	4.283	4.154	4.038
	—	—		—	—	—	—
					—	—	

Source of variation	df	SS	MS	F_s
BOTTOM				
Among stations	6	1.550	0.258	17.099*
Within stations	14	0.212	0.015	
Totals	20	1.762		

F.05 (6,14) = 2.85

DMRT results:

Stations	M18	M3	DS	DE	DN	DW	M10
Means	4.976	4.415	4.311	4.280	4.278	4.236	4.038
		—	—	—	—	—	
						—	—

Table 8-14. ANOVA for cell totals ($\log_{10}$) per liter among marine stations, March 1982. For significant (*) ANOVA's, Duncan's New Multiple Range Test (DMRT) are presented.

Source of variation	df	SS	MS	F_s
SURFACE				
Among stations	6	1.094	0.182	12.123*
Within stations	14	0.210	0.015	
Totals	20	1.304		

F.05 (6,14) = 2.85

DMRT results:

Stations	DE	M10	M3	DW	DS	M18	DN
Means	5.085	4.692	4.687	4.590	4.583	4.535	4.258

Source of variation	df	SS	MS	F_s
BOTTOM				
Among stations	6	1.248	0.208	190.566*
Within stations	14	0.015	0.001	
Totals	20	1.263		

F.05 (6,14) = 2.85

DMRT results:

Stations	M18	DE	DS	DW	DN	M3	M10
Means	4.615	4.535	4.440	4.422	4.214	4.030	3.915

Table 8-15. ANOVA for cell totals ($\log_{10}$) per liter among marine stations, April 1982. For significant (*) ANOVA's, Duncan's New Multiple Range Test (DMRT) are presented.

Source of variation	df	SS	MS	F_s
SURFACE				
Among stations	6	0.688	0.115	16.795*
Within stations	14	0.096	0.007	
Totals	20	0.784		

F.05 (6,14) = 2.85

DMRT results:

Stations	DS	M18	M10	DE	M3	DN	DW
Means	4.764	4.649	4.630	4.514	4.419	4.357	4.195

(Underlines: DS–M10; M18–DE; DE–M3; M3–DN)

Source of variation	df	SS	MS	F_s
BOTTOM				
Among stations	6	1.228	0.205	5.0809*
Within stations	14	0.564	0.045	
Totals	20	1.792		

F.05 (6,14) = 2.85

DMRT results:

Stations	DE	DS	M18	DN	M10	DW	M3
Means	5.136	4.863	4.798	4.680	4.643	4.612	4.284

(Underlines: DE–M18; DS–DW; M10–M3)

It was the intent of the experimental design to apply ANOVA's in combination with DMRT's on a matched station study grid to monitor brine impact on the phytoplankton community. Stations M3 and M18 were selected to serve as control sites, station M10A as the treatment site, and stations DN, DE, DW and DS possibly showing disturbance depending upon current directions and plume characteristic. Examination of the results of the DMRT's shows that the mean of the treatment site (M10A) is significantly different from the control sites (M3 or M18) in only four months for the surface stations and six months at the bottom stations. There are three possible interpretations of these results. First, the experimental model is only sensitive to potential impact for short term studies, e.g. a monthly regime, and may lose its sensitivity in long term studies. This interpretation may be possible if one supports the concept that new populations of phytoplankton are presented to the experimental model each month, due to seasonal oscillations, and that these new populations have different interactions with the environmental parameters encountered. This interpretation may be tested by a long term study which bridges seasonal oscillations of phytoplankton species over several years. Second, the effect of brine discharge into the study area is greater than anticipated by the experimental model, and third, the magnitude of the seasonal biological and environmental variability within each station is larger than the variability between stations. The second interpretation can be tested by modifying the experimental design so that the control sites, are placed at a greater distance (e.g. M1 and M20) from the treatment site (M10A). The third interpretation can be tested by application of a Multiple Analysis of Covariance. An analysis of covariance for cell totals ($\log_{10}$) from both the surface and bottom stations in the study area was performed. The results are presented in Tables 8-16 and 8-17. The F statistic for between stations in both surface and bottom samples was not significant ($\alpha > .05$). The only significant values ($\alpha < .05$) for both surface and bottom stations were between cruises. This is not unexpected because of observed seasonal differences in several environmental parameters, e.g. temperature (Figure 8-2) and salinity (Figure 8-4), and the seasonality of the phytoplankton, Figure 8-3. Therefore, the third interpretation appears to be a viable explanation, but the first and second remain to be tested.

The second method of examining biomass is by phaeopigment corrected chlorophyll _a_ measurements. Chlorophyll _a_ values were determined using the _in vitro_ fluorometric technique described earlier (see Methods section of this chapter). Measurements of biomass by pigment analysis are considerably less susceptible to the subsampling and human error associated with the more direct cell count method. It should be noted that neither of the two methods can account for the inherit error of differential cell volumes and variable photosynthetic efficiency. Therefore, biomass cannot be construed to imply

Table 8-16. Analysis of covariance for cell totals ($\log_{10}$) in surface samples from marine stations.

SOURCE	SUM OF SQUARES	DEGREES OF FREEDOM	MEAN SQUARE	F
Mean	941.3508	1	941.3508	26704.7578
Cruises	8.8726	11	0.8066	22.8820*
Stations	0.3391	6	0.0565	1.6032
Cruises & Stations	2.3265	66	0.0353	

* Significant ($\alpha < .05$)

Table 8-17. Analysis of covariance for cell totals ($\log_{10}$) in bottom samples from marine stations.

SOURCE	SUM OF SQUARES	DEGREES OF FREEDOM	MEAN SQUARE	F
Mean	907.4646	1	907.4646	25740.0547
Cruises	7.9236	11	0.7203	20.4318*
Stations	0.1855	6	0.0309	0.8771
Cruises & Stations	2.3268	66	0.0353	

* Significant ($\alpha < .05$)

measurements of community function, but rather only one aspect of community structure within the limits of known error.

Chlorophyll a values ranged during the study from 0.5 - 60.0 $\mu g.L^{-1}$. The largest values occurring during a bloom of *Prorocentrum minimum* at marine station M21 during March 21, 1982. The seasonal distribution of the mean for chlorophyll a $\mu g.L^{-1}$ by station and depths are presented in Table 8-18.

Monthly plots of integrated chlorophyll values showed several important trends. First the chlorophyll a values in general are greater in the surface samples as opposed to the bottom samples, Figures 8-11 and 8-12. Second, during the spring and early fall months there was a tendency for the chlorophyll a values to be larger. A comparison of the values in January, February, March and April (Figures 8-11 and 8-12) show the impact of the nitrate-nitrogen (NO_3) pulses described earlier in this section. The chlorophyll values found in this study compare favorably with those of Fucik and El-Sayed (1979) and Sklar and Turner (1981) for Louisiana coastal waters.

An analysis of variance was performed for the chlorophyll a ($\mu g.L^{-1}$) values for both the surface and bottom marine stations by monthly cruise. For the surface stations it was found that in every month, except March, there were significant ($\alpha < .05$) differences between stations, Tables 8-19 through 8-30. For the bottom stations it was found that in all but two months, November and April, there were significant ($\alpha < .05$) differences between stations, Tables 8-19

Table 8-18. Distribution of means for chlorophyll a in $\mu g.L^{-1}$ by station, depth, and date of collection in coastal waters of southwestern Louisiana.

DATE	DEPTH	M3	M10	M18	DE	DW	DN	DS
MAY 81	*S	3.8133	2.8067	5.2433	1.6933	2.4500	1.6600	2.7300
	**B	3.0067	1.6967	4.0467	1.1000	0.8567	1.4367	2.1333
JUN 81	S	3.5000	1.4833	1.0100	2.4933	3.6700	7.7967	7.2633
	B	1.8967	0.1467	0.6300	0.7867	0.9533	0.6800	1.1167
JUL 81	S	5.3800	5.7900	5.8600	4.2433	3.5333	6.5600	4.3300
	B	2.1167	2.0633	2.8900	4.7333	2.5167	2.2300	2.2400
AUG 81	S	2.9767	2.0633	11.5833	2.8800	1.5567	2.5333	1.5733
	B	1.4000	0.9933	1.3667	1.4167	1.4333	1.5733	1.0133
SEP 81	S	11.1133	3.7600	3.8933	4.9867	8.0467	8.6600	3.4100
	B	2.6667	0.7500	1.0267	0.9100	0.9700	1.8867	1.2433
OCT 81	S	4.3767	4.8733	5.6300	5.4300	4.7767	4.3233	6.6833
	B	1.5100	2.9267	1.5300	3.4767	1.6900	2.7900	1.7100
NOV 81	S	4.1733	3.3700	2.8667	4.2733	3.0167	3.0167	3.7200
	B	2.0100	3.0200	3.0200	2.9167	3.0200	2.8167	4.2000
DEC 81	S	5.1767	4.5733	3.4200	4.0700	3.8167	4.1200	3.6700
	B	2.4300	2.0900	1.8700	2.0700	1.8300	3.0667	1.9300
JAN 82	S	7.0900	5.6300	6.1300	5.1300	6.2300	6.2333	6.7367
	B	6.3367	5.4267	6.3133	5.6300	6.2833	7.4400	7.1567
FEB 82	S	9.7567	9.4700	7.5800	11.4367	8.6300	10.8767	9.7500
	B	6.8767	7.7900	7.4400	8.9800	9.8233	9.1200	8.4200
MAR 82	S	7.2267	6.4600	5.1900	7.9267	7.1600	6.5967	8.2100
	B	1.3167	2.0333	3.5067	2.1400	3.7533	3.0500	3.6133
APR 82	S	7.2300	10.1033	16.0867	9.6833	15.1600	11.5867	9.3300
	B	4.3467	3.2267	4.7733	3.7533	3.9300	5.3667	4.4567

* S = Surface
* * B = Bottom

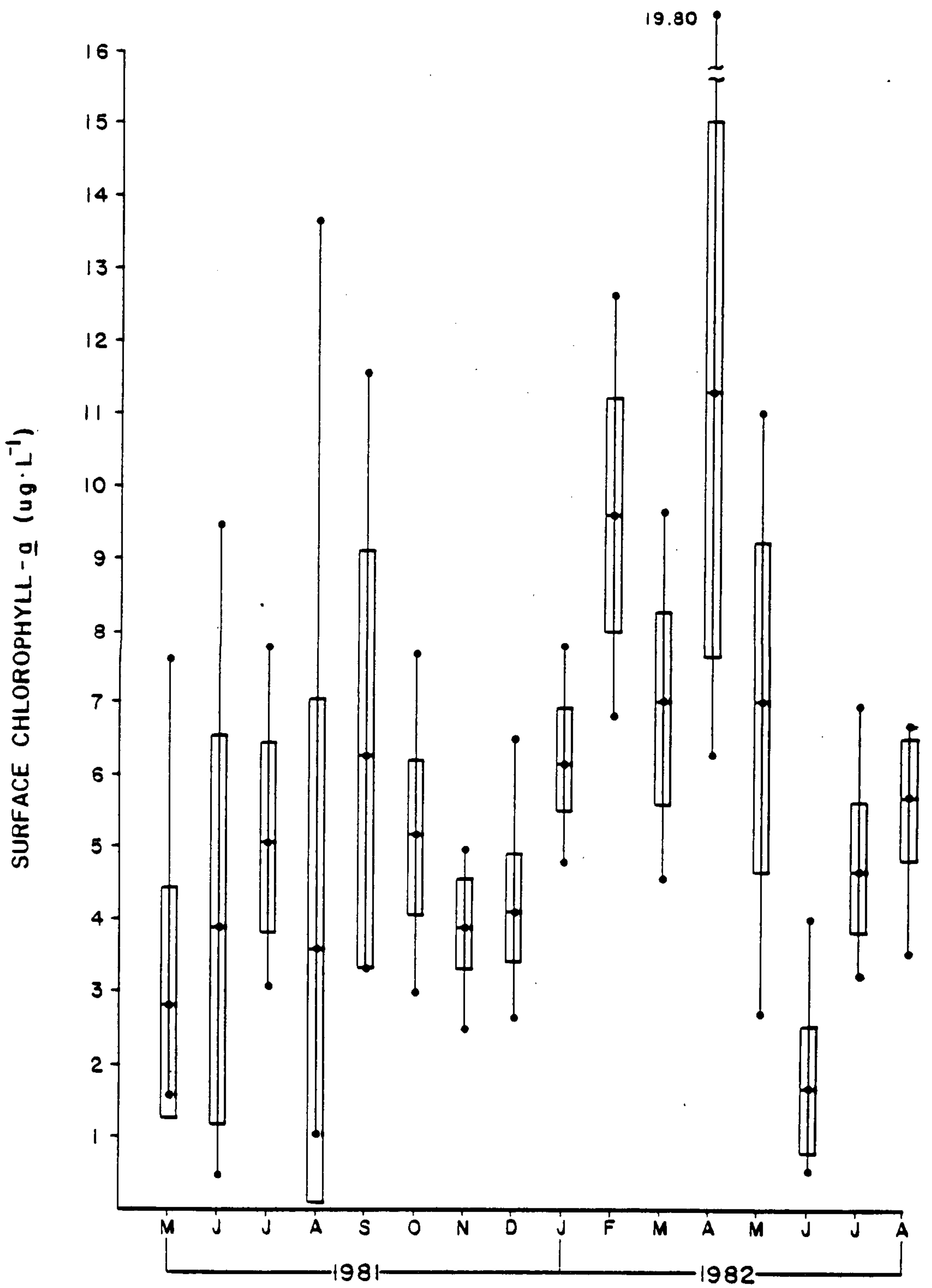

Figure 8-11. Seasonal distribution of means with ranges and one standard deviation for chlorophyll a in µg.L^{-1} at the marine surface stations.

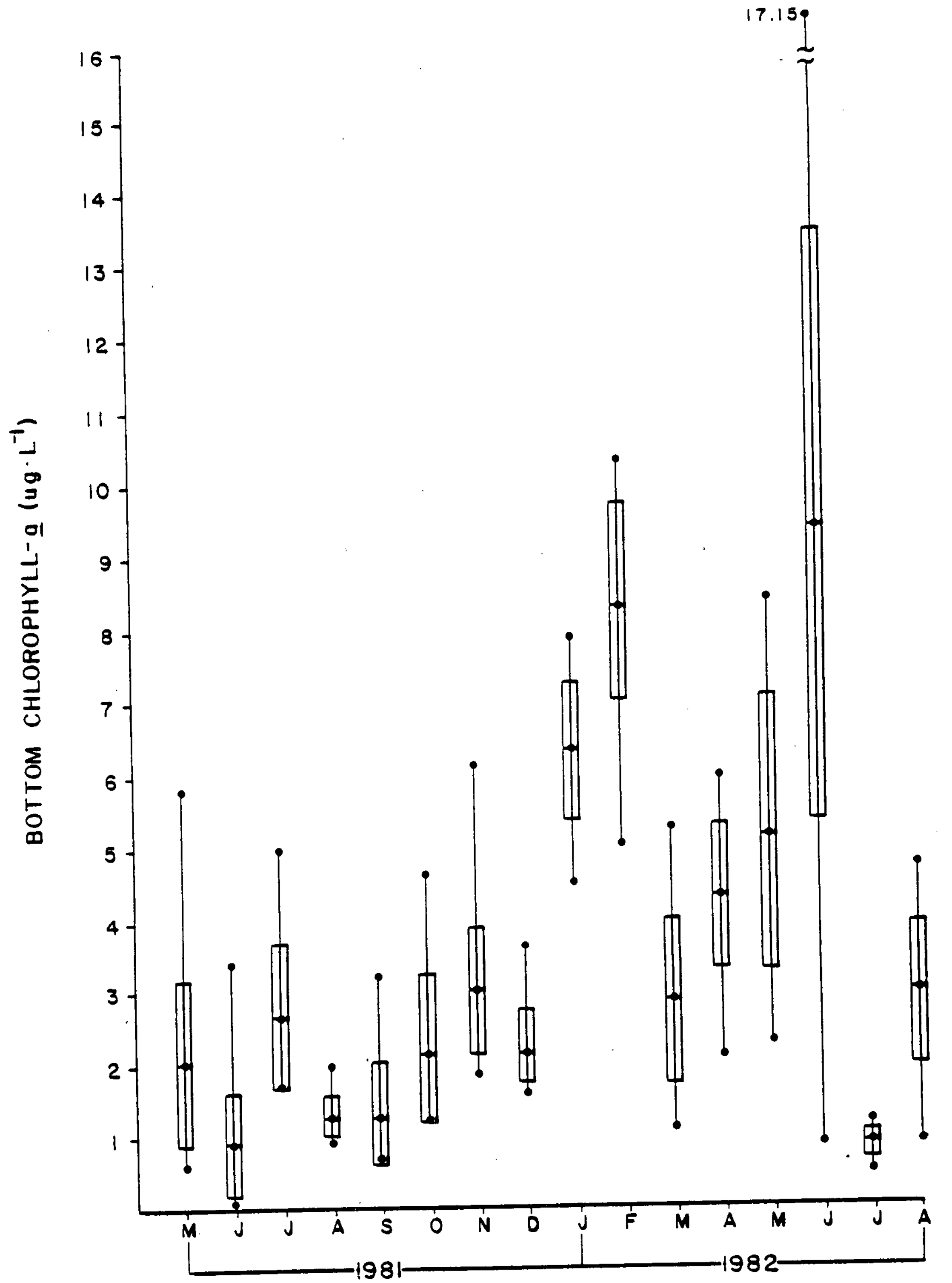

Figure 8-12. Seasonal distribution of means with ranges and one standard deviation for chlorophyll a in µg.L^{-1} at the marine bottom stations.

Table 8-19. ANOVA for chlorophyll *a* $\mu g.L^{-1}$ among marine stations, May 1981. For significant (*) ANOVA's, Duncan's New Multiple Range Test (DMRT) are presented.

Source of variation	df	SS	MS	F_s
SURFACE				
Among stations	6	29.637	4.940	4.745*
Within stations	14	14.973	1.041	
Totals	20	43.610		

F.05 (6,14) = 2.85

DMRT results:

Stations	M18	M3	DS	DW	M10	DE	DN
Means	5.243	3.813	2.730	2.450	2.307	1.693	1.660

Source of variation				
BOTTOM				
Among stations	6	23.207	3.868	8.5706*
Within stations	14	6.318	0.451	
Totals	20	29.525		

F.05 (6,14) = 2.85

DMRT results:

Stations	M18	M3	DS	M10	DN	DE	DW
Means	4.047	3.007	2.133	1.697	1.437	1.100	0.857

Table 8-20. ANOVA for chlorophyll a $\mu g.L^{-1}$ among marine stations, June 1981. For significant (*) ANOVA's, Duncan's New Multiple Range Test (DMRT) are presented.

Source of variation	df	SS	MS	F_s
SURFACE				
Among stations	6	128.637	21.439	17.610*
Within stations	14	17.044	1.217	
Totals	20	145.681		

F.05 (6,14) = 2.85

DMRT results:

Stations	DN	DS	DW	M3	DE	M10	M18
Means	7.797	7.263	3.670	3.500	2.493	1.483	1.010

Source of variation	df	SS	MS	F_s
BOTTOM				
Among stations	6	5.645	0.941	23.00*
Within stations	14	5.726	0.041	
Totals	20	11.371		

F.05 (6,14) = 2.85

DMRT results:

Stations	M3	DS	DW	DE	M18	DN	M10
Means	1.897	1.117	0.953	0.787	0.630	0.453	0.147

Table 8-21. ANOVA for chlorophyll a $\mu g.L^{-1}$ among marine stations, July 1981. For significant (*) ANOVA's, Duncan's New Multiple Range Test (DMRT) are presented.

Source of variation	df	SS	MS	F_s
SURFACE				
Among stations	6	21.135	3.522	4.134*
Within stations	14	11.930	0.852	
Totals	20	33.065		

F.05 (6,14) = 2.85

DMRT results:

Stations	DN	M18	M10	M3	DS	DE	DW
Means	6.560	5.860	5.790	5.380	4.330	4.243	3.533

Source of variation				
BOTTOM				
Among stations	6	16.141	2.690	9.205*
Within stations	14	4.092	0.292	
Totals	20	20.233		

F.05 (6,14) = 2.85

DMRT results:

Stations	DE	M18	DW	DS	DN	M3	M10
Means	4.733	2.890	2.517	2.240	2.230	2.117	2.063

Table 8-22. ANOVA for chlorophyll *a* μg.L^{-1} among marine stations, August 1981. For significant (*) ANOVA's, Duncan's New Multiple Range Test (DMRT) are presented.

Source of variation	df	SS	MS	F_s
SURFACE				
Among stations	6	229.267	38.211	33.451*
Within stations	14	15.992	1.142	
Totals	20	245.199		

F.05 (6,14) = 2.85

DMRT results:

Stations	M18	M3	DE	DN	M10	DS	DW
Means	11.583	2.977	2.880	2.533	2.063	1.573	1.557

Source of variation	df	SS	MS	F_s
BOTTOM				
Among stations	6	0.886	0.148	2.9833*
Within stations	14	0.693	0.049	
Totals	20	1.579		

F.05 (6,14) = 2.85

DMRT results:

Stations	DN	DW	DE	M3	M18	DS	M10
Means	1.573	1.433	1.417	1.400	1.367	1.013	0.993

Table 8-23. ANOVA for chlorophyll a $\mu g.L^{-1}$ among marine stations, September 1981. For significant (*) ANOVA's, Duncan's New Multiple Range Test (DMRT) are presented.

Source of variation	df	SS	MS	F_s
SURFACE				
Among stations	6	162.305	27.051	54.62*
Within stations	14	6.934	0.495	
Totals	20	169.239		

F.05 (6,14) = 2.85

DMRT results:

Stations	M3	DN	DW	DE	M18	M10	DS
Means	11.113	8.660	8.047	4.987	3.893	3.760	3.410

Source of variation				
BOTTOM				
Among stations	6	8.507	1.418	15.479*
Within stations	14	1.282	0.091	
Totals	20	9.789		

F.05 (6,14) = 2.85

DMRT results:

Stations	M3	DN	DS	M18	DW	DE	M10
Means	2.667	1.887	1.243	1.027	0.970	0.910	0.750

Table 8-24. ANOVA for chlorophyll a $\mu g.L^{-1}$ among marine stations, October 1981. For significant (*) ANOVA's, Duncan's New Multiple Range Test (DMRT) are presented.

Source of variation	df	SS	MS	F_s
SURFACE				
Among stations	6	12.471	2.078	3.23*
Within stations	14	9.028	0.645	
Totals	20	21.499		

F.05 (6,14) = 2.85

DMRT results:

Stations	DS	M18	DE	M10	DW	M3	DN
Means	6.683	5.630	5.430	4.873	4.777	4.377	4.323

Source of variation	df	SS	MS	F_s
BOTTOM				
Among stations	6	11.770	1.962	3.1104*
Within stations	14	8.830	0.631	
Totals	20	20.600		

F.05 (6,14) = 2.85

DMRT results:

Stations	DE	M10	DN	DS	DW	M18	M3
Means	3.477	2.927	2.790	1.710	1.690	1.530	1.510

Table 8-25. ANOVA for chlorophyll a μg.L^{-1} among marine stations, November 1981. For significant (*) ANOVA's, Duncan's New Multiple Range Test (DMRT) are presented.

Source of variation	df	SS	MS	F_s
SURFACE				
Among stations	6	5.953	0.992	5.116*
Within stations	14	2.715	0.194	
Totals	20	8.668		

F.05 (6,14) = 2.85

DMRT results:

Stations	DE	M3	DS	M10	DW	DN	M18
Means	4.273	4.173	3.720	3.370	3.017	3.017	2.867

Source of variation				
BOTTOM				
Among stations	6	7.530	1.255	2.455
Within stations	14	7.157	0.511	
Totals	20	14.687		

F.05 (6,14) = 2.85

Table 8-26. ANOVA for chlorophyll a $\mu g.L^{-1}$ among marine stations, December 1981. For significant (*) ANOVA's, Duncan's New Multiple Range Test (DMRT) are presented.

Source of variation	df	SS	MS	F_s
SURFACE				
Among stations	6	6.327	1.054	2.929*
Within stations	14	5.041	0.360	
Totals	20	11.368		

F.05 (6,14) = 2.85

DMRT results:

Stations	M3	M10	DN	DE	DW	DS	M18
Means	5.177	4.573	4.120	4.070	3.817	3.670	3.420

(Underlines: M3 through DE; M10 through M18)

Source of variation	df	SS	MS	F_s
BOTTOM				
Among stations	6	3.450	0.575	5.3197*
Within stations	14	1.513	0.108	
Totals	20	4.963		

F.05 (6,14) = 2.85

DMRT results:

Stations	DN	M3	M10	DE	DS	M18	DW
Means	3.067	2.430	2.090	2.070	1.930	1.870	1.830

(Underline: M3 through DW)

Table 8-27. ANOVA for chlorophyll a $\mu g.L^{-1}$ among marine stations, January 1981. For significant (*) ANOVA's, Duncan's New Multiple Range Test (DMRT) are presented.

Source of variation	df	SS	MS	F_s
SURFACE				
Among stations	6	7.650	1.275	6.820*
Within stations	14	2.617	0.187	
Totals	20	10.267		

$F_{.05}\ (6,14) = 2.85$

DMRT results:

Stations	M3	DS	DN	DW	M18	M10	DE
Means	7.090	6.737	6.233	6.230	6.130	5.630	5.130

Source of variation	df	SS	MS	F_s
BOTTOM				
Among stations	6	9.639	1.606	2.9918*
Within stations	14	7.518	0.537	
Totals	20	17.157		

$F_{.05}\ (6,14) = 2.85$

DMRT results:

Stations	DN	DS	M3	M18	DW	DE	M10
Means	7.440	7.157	6.337	6.313	6.283	5.630	5.427

Table 8-28. ANOVA for chlorophyll a $\mu g.L^{-1}$ among marine stations, February 1981. For significant (*) ANOVA's, Duncan's New Multiple Range Test (DMRT) are presented.

	Source of variation	df	SS	MS	F_s
SURFACE					
	Among stations	6	30.227	5.038	3.453*
	Within stations	14	20.426	1.459	
	Totals	20	50.653		

F.05 (6,14) = 2.85

DMRT results:

Stations	DE	DN	M3	DS	M10	DW	M18
Means	11.437	10.877	9.757	9.750	9.470	8.630	7.580

(Underlines: DE–M10; DN–DW; M3–M18)

	Source of variation	df	SS	MS	F_s
BOTTOM					
	Among stations	6	19.433	3.234	2.912*
	Within stations	14	15.570	1.112	
	Totals	20	35.003		

F.05 (6,14) = 2.85

DMRT results:

Stations	DW	DN	DE	DS	M10	M18	M3
Means	9.823	9.120	8.980	8.420	7.790	7.440	6.877

(Underlines: DW–DS; DN–M18; DS–M3)

Table 8-29. ANOVA for chlorophyll a $\mu g.L^{-1}$ among marine stations, March 1981. For significant (*) ANOVA's, Duncan's New Multiple Range Test (DMRT) are presented.

Source of variation	df	SS	MS	F_s
SURFACE				
Among stations	6	18.368	3.061	2.782
Within stations	14	15.407	1.100	
Totals	20	33.775		

F.05 (6,14) = 2.85

Source of variation	df	SS	MS	F_s
BOTTOM				
Among stations	6	16.053	2.675	4.748*
Within stations	14	7.889	0.563	
Totals	20	23.942		

F.05 (6,14) = 2.85

DMRT results:

Stations	DW	DS	M18	DN	DE	M10	M3
Means	3.753	3.613	3.507	3.050	2.140	2.033	1.317
	———	———	———	———			
			———	———	———		
				———	———	———	
					———	———	———

Table 8-30. ANOVA for chlorophyll a μg.L^{-1} among marine stations, April 1981. For significant (*) ANOVA's, Duncan's New Multiple Range Test (DMRT) are presented.

Source of variation	df	SS	MS	F_s
SURFACE				
Among stations	6	187.153	31.192	5.627*
Within stations	14	77.601	5.543	
Totals	20	264.754		

$F_{.05}$ (6,14) = 2.85

DMRT results:

Stations	M18	DW	DN	M10	DE	DS	M3
Means	16.087	15.160	11.587	10.103	9.683	9.330	7.230

Source of variation				
BOTTOM				
Among stations	6	8.903	1.484	1.646
Within stations	14	12.619	0.901	
Totals	20	21.522		

$F_{.05}$ (6,14) = 2.85

through 8-30. A multiple comparison of means was performed using Duncan's New Multiple Range Test (DMRT) for those cruises having significant ANOVA's for chlorophyll a values. The results of the DMRT's are presented in Tables 8-19 through 8-30. Examination of the results of the DMRT's shows that the mean of the treatment site (M10A) is significantly different from the control sites (M3 or M18) in only one month, May, for the bottom stations and never for the surface stations. The possible intrepretations of these results have already been presented and discussed with the cell total report of this section. For the reasons previously stated an analysis of covariance was performed for chlorophyll a values from both surface and bottom stations in the study area. The results are presented in Tables 8-31 and 8-32. The only significant values ($\alpha < .05$) for both surface and bottom stations were between cruises. Seasonality for both biological and environmental factors can account for the variability measured in the analysis of covariance. The F-statistic for between stations in both surface and bottom samples was not significant ($\alpha > .05$).

The mean chlorophyll values for both surface and bottom stations were plotted over the 12 month study for those stations on the 10 M isobath. This observation of the chlorophyll a data revealed an important trend for the biomass data. The chlorophyll a values in the surface samples at the treatment site, M10A, are lower than those of sites M3 and M18, but the chlorophyll values in the bottom samples were not much different except for the slightly lower values at stations

Table 8-31. Analysis of covariance for chlorophyll a values in surface samples from marine stations.

SOURCE	SUM OF SQUARES	DEGREES OF FREEDOM	MEAN SQUARE	F
Mean	2741.1465	1	2741.1465	681.4248
Cruises	511.6218	11	46.5111	11.5622*
Stations	14.2058	6	2.3676	0.5886
Cruises & Stations	265.4961	66	4.0227	

* Significant ($\alpha < .05$)

Table 8-32. Analysis of covariance for chlorophyll a values in bottom samples from marine stations.

SOURCE	SUM OF SQUARES	DEGREES OF FREEDOM	MEAN SQUARE	F
Mean	818.2698	1	818.2698	1372.8975
Cruises	376.2891	11	34.2081	57.3945*
Stations	4.2425	6	0.7071	1.1863
Cruises & Stations	39.3371	66	0.5960	

* Significant ($\alpha < .05$)

M10A and DW (Figure 8-13). Although these differences are not statistically significant, these observations are important considering the magnitude of the between cruise variability and the lack of substantial base line data for this study area.

Environmental data were collected on the parameters of dissolved oxygen, pH, temperature, and salinity. The values for dissolved oxygen and pH are not considered here but presented elsewhere in this report, see Appendix F. The values for water temperature and salinity do not exceed the known tolerance ranges for marine phytoplankton. The highest recorded water temperature on the phytoplankton cruises was 30.5°C in the surface waters on August 14, 1981. The lowest recorded water temperature on the phytoplankton cruises was 8.6°C in the water column on January 18, 1982. The highest recorded salinity was 38 $^{o}/oo$ on January 18, 1982, but this was unusual and only in the immediate vicinity of the diffuser at station M10A. The lowest recorded salinity was 11.0 $^{o}/oo$ in the surface water on March 18, 1982. In general, the mean values for salinities were greater at the bottom stations throughout the study period, Table 8-33. Analysis of covariance for salinity values from both surface and bottom stations in the study area was performed. The results are presented in Tables 8-34 and 8-35. There were significant values ($\alpha < .05$) for both surface and bottom stations between cruises. This is not unexpected and the seasonal variability is easily seen in Figure 8-4. The F-statistic for between stations was not significant ($\alpha > .05$) for the surface samples,

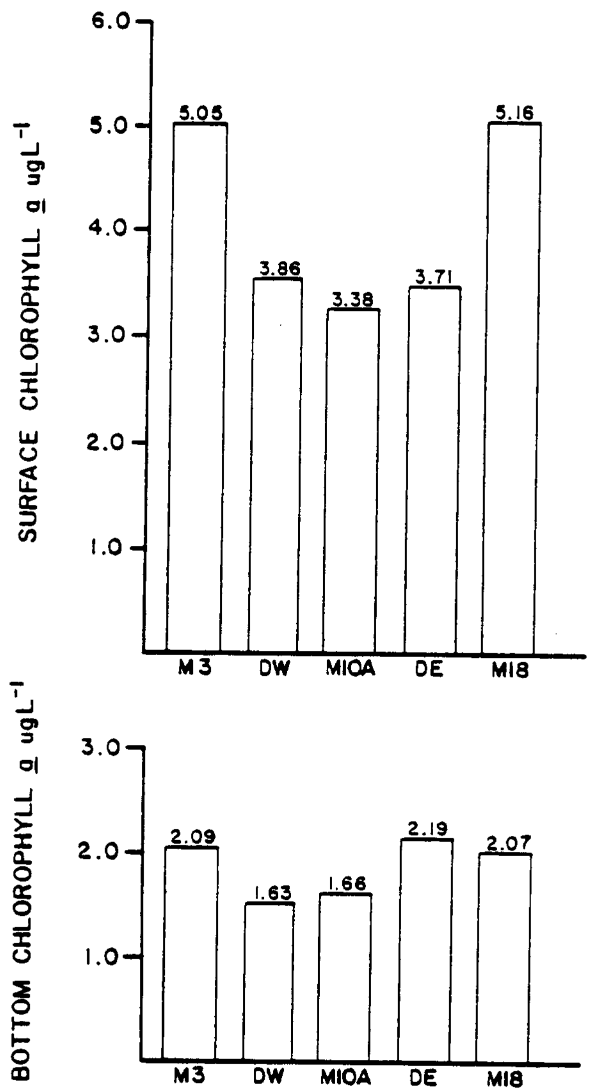

Figure 8-13. Mean chlorophyll a values for surface and bottom marine stations located on the 10 meter isobath.

Table 8-33. Distribution of means for salinities in $^{o}/oo$ by station, depth, and date of collection in coastal waters of southwestern Louisiana

DATE	DEPTH	M3	M10	M18	DE	DW	DN	DS
MAY 81	*S	27.300	27.500	27.500	27.300	27.300	27.500	27.300
	**B	31.800	31.500	29.000	31.500	31.000	31.000	31.800
JUN 81	S	15.000	15.000	15.000	14.500	15.000	18.500	18.500
	B	33.500	34.500	34.000	34.000	34.000	33.500	35.000
JUL 81	S	27.500	27.500	26.500	27.500	27.500	26.500	26.000
	B	28.500	28.000	28.000	28.500	28.000	28.000	28.500
AUG 81	S	33.000	32.000	33.000	32.000	32.000	32.500	32.000
	B	33.000	34.000	33.500	33.000	33.000	33.000	35.500
SEP 81	S	26.300	26.200	26.000	26.000	26.200	26.200	26.500
	B	28.000	29.900	28.000	27.500	29.600	27.500	29.600
OCT 81	S	25.800	25.230	26.810	24.660	25.590	26.020	26.810
	B	29.630	31.230	29.850	30.280	31.230	29.920	31.670
NOV 81	S	28.400	28.470	28.970	28.470	28.614	28.400	28.610
	B	30.790	31.520	31.380	33.140	31.670	31.600	31.300
DEC 81	S	30.940	29.340	31.890	31.890	31.450	29.480	29.180
	B	34.240	36.390	34.170	34.240	34.170	34.830	34.390
JAN 82	S	31.320	31.820	31.960	31.820	31.740	31.740	31.960
	B	31.890	37.880	31.890	31.820	33.500	31.740	32.040
FEB 82	S	25.950	29.000	26.880	29.000	29.000	29.000	29.000
	B	29.700	31.010	28.970	30.000	30.000	30.000	30.000
MAR 82	S	11.470	9.910	10.820	9.777	10.165	8.620	9.520
	B	28.400	27.240	26.520	26.660	28.470	28.180	29.340
APR 82	S	21.760	19.800	19.590	19.520	19.870	25.020	19.380
	B	28.900	31.600	28.900	30.570	30.060	28.760	30.210

* S = Surface
** B = Bottom

Table 8-34. Analysis of covariance for salinity values in surface samples from marine stations.

SOURCE	SUM OF SQUARES	DEGREES OF FREEDOM	MEAN SQUARE	F
Mean	54164.6953	1	54164.6953	48687.3984
Cruises	3430.3093	11	311.8462	280.3113*
Stations	3.0801	6	0.5134	0.4614
Cruises & Stations	73.4250	66	1.1125	

* Significant ($\alpha < .05$)

Table 8-35. Analysis of covariance for salinity values in bottom samples from marine stations.

SOURCE	SUM OF SQUARES	DEGREES OF FREEDOM	MEAN SQUARE	F
Mean	81132.6875	1	81132.6875	104729.8125
Cruises	417.7654	11	37.9787	49.0246*
Stations	25.7531	6	4.2922	5.5405*
Cruises & Stations	51.1293	66	0.7747	

* Significant ($\alpha < .05$)

but it was significant ($\alpha < .05$) for the bottom samples. This significant value is not surprising since the brine plume is located near the bottom, see the plume tracking chapter of this report. Since salinity variables are significant ($\alpha < .05$) at the bottom stations, it becomes appropriate to determine if these salinity values affected the cell total and chlorophyll _a_ data. A multiple analysis of covariance was used which adjusted the covariant salinity across all stations. This allows for a test of significance of the variability for the covariants cell total and chlorophyll _a_ between cruises and stations. The results of this analysis of covariance are presented in Tables 8-36 and 8-37. There are significant values ($\alpha < .05$) for both cell totals and chlorophyll _a_ between cruises. The F-statistic for between stations for both cell total and chlorophyll _a_ was not significant ($\alpha > .05$). Because only single observations were made of salinities each month, it was necessary to utilize means for all biomass observations in the mathematical model. This statistical procedure when applied to the experimental design removed any within station variability from the data analysis. Thus any interpretation of the analysis of covariance is not without reservations.

There does not appear to be any serious annual depletion of the nutrients in the study area (Figures 8-5 through 8-8) nor does there seem to be high concentrations of harmful chemicals in the coastal waters, see Chapter on Special Pollutants in Volume II. It is possible that the lower chlorophyll values may be a natural phenomenon

Table 8-36. Analysis of covariance for cell total values in bottom samples for which the covariant salinity has been adjusted.

REGRESSION COEFFICIENTS UNDER EACH HYPOTHESIS

COVARIATE	MEAN	C	S	FULL MODEL
3	0.10569	-0.03452	-0.00350	-0.00027

SOURCE	SUM OF SQUARES	DEGREES OF FREEDOM	MEAN SQUARE	F
Mean	0.5753	1	0.5753	16.0704
Cruises	7.3648	11	0.6695	18.7032*
Stations	0.1846	6	0.0308	0.8595
Covariates	0.0000	1	0.0000	0.0001
Covariate Salinity	0.0000	1	0.0000	0.0001
Full Model	2.3268	65	0.0358	

* Significant ($\alpha < .05$)

Table 8-37. Analysis of covariance for chlorophyll _a_ values in bottom samples for which the covariant salinity has been adjusted.

REGRESSION COEFFICIENTS UNDER EACH HYPOTHESIS

COVARIATE	MEAN	C	S	FULL MODEL
Salinity	0.10027	-0.14273	-0.17896	-0.14926

SOURCE	SUM OF SQUARES	DEGREES OF FREEDOM	MEAN SQUARE	F
Mean	3.1859	1	3.1859	5.4212
Cruises	367.8757	11	33.4432	56.9091*
Salinity	2.9192	6	0.4865	0.8279
Covariates	1.1392	1	1.1392	1.9385
Covariate Salinity	1.1392	1	1.1392	1.9385
Full Model	38.1979	65	0.5877	

* Significant ($\alpha < .05$)

of the area or that water flow from the diffuser may be disturbing the morphological structure of the community through increased turbulence or turbidity. It is also possible that there are select species sensitivites to increased salinities, notably the microflagellates. Therefore the observed differences in standing crop for this study remain speculative.

8.3.2 Estuary

The primary objective of this study was to assess the potential impact of salt water intrusion into Calcasieu Lake and the potential impact of water withdrawal from the intercoastal waterway or the resident phytoplankton community. The five estuarine stations are widely separated not only by distance, Figure 8-1, but in their physical nature, physical parameters, and phytoplankton composition. The lower salinities at stations E1 and E2 reflect the influence of drainage from the Calcasieu and Sabine basins, Table 8-38. These lower salinities are reflected in the freshwater assemblages of phytoplankton, namely Navicula, Melosira and Cyclotella, which occur at the two North most stations. Stations E3, E4 and E5 possessed higher salinities, Table 8-38, and common estuarine phytoplankton species, e.g. species of Cerataulina, Nitzschia, Asterionella, Rhizosolenia, Skeletomena and Chaetoceros. Station E5 which is located near the Gulf of Mexico had the highest salinities, Table 8-38, and frequently possessed phytoplankton species from the adjacent neritic community, e.g. species of Prorocentrum, Ditylum, Thallassiosira, Coscinodiscus,

Table 8-38. Distribution of salinities in $^{o}/oo$ by station and date of collection in the Calcasieu Lake and adjacent waters.

DATE	E1	E2	E3	E4	E5
MAY 81	17.50	23.20	26.50	25.50	30.50
JUN 81	8.50	6.00	10.00	7.00	19.00
JUL 81	1.00	4.00	6.50	7.00	17.00
AUG 81	10.00	16.00	18.00	16.00	31.00
SEP 81	9.00	20.00	20.00	19.00	22.50
OCT 81	10.10	21.13	23.67	20.92	23.10
NOV 81	8.50	23.52	--	19.31	27.38
DEC 81	8.94	22.39	25.16	23.03	28.61
JAN 82	12.06	10.29	26.23	25.09	25.23
FEB 82	15.47	21.76	24.23	23.74	25.52
MAR 82	7.55	14.50	15.40	15.34	22.46
APR 82	8.12	8.94	13.32	15.07	20.29

Navicula, Chaetoceros and Guinardia. Both the species composition and temporal distribution of species in the estuary and adjacent stations were not unusual considering the diversity of environments represented. One noteworthy event of the study period was a bloom of the toxic red tide organism, Gonyaulax monilata, in the southern end of Calcasieu Lake during late summer and early fall of 1981. This is probably a natural phenomenon within an annual cycle and not related to the SPR project.

Mean chlorophyll a values ranged from a low of 3.67 $\mu g.L^{-1}$ in the bottom samples at station E1 in June 1981 to a high of 61.03 $\mu g.L^{-1}$ in the surface samples at station E4 in February 1982.

An analysis of covariance was performed on the surface chlorophyll data. Only surface data were utilized since bottom samples were not routinely collected except at stations E1 and E5. Low tide conditions prevented the sampling at station E3 in November, 1981. In order to facilitate statistical analysis, data from E3 were also omitted from the analysis of covariance. Since station E4 is biologically and environmentally similar to station E3 the omission of E3 from the data analysis was not deemed inappropriate. The results for the analysis of covariance for chlorophyll a are presented in Table 8-39. The only significant values ($\alpha < .05$) were for the between cruise data. Seasonality can account for this measured variability. The F-statistic for between stations was not significant ($\alpha > .05$).

Table 8-39. Analysis of covariance for chlorophyll a values in surface samples from estuarine stations.

SOURCE	SUM OF SQUARES	DEGREES OF FREEDOM	MEAN SQUARE	F
Mean	6992.2422	1	6992.2422	70.6399
Cruises	4340.0859	11	394.5532	3.9860*
Stations	665.4512	3	221.8170	2.2409
Cruises & Stations	3266.4824	33	98.9843	

* Significant ($\alpha < .05$)

An analysis of covariance was performed on the cell total data. The cell counts were transformed to $\log_{10}$ in order to ease the data analysis and normalize the data. For the reasons stated above the data for, station E3 were omitted from the analysis. The annual $\log_{10}$ means for cell total varied little, e.g. E1 = 3.853, E2 = 3.745, E4 = 4.270 and E5 = 4.103. The results of the analysis of covariance for cell totals are presented in Table 8-40. The between cruise variability was found to be significant ($\alpha < .05$), but the station variability was not significant ($\alpha > .05$).

It was concluded from these analysis that neither the discharge of brine into the nearby Gulf of Mexico nor the withdrawal of water from the intercoastal waterway has had a demonstrable effect on the estuary phytoplankton assemblage.

8.4 Summary

8.4.1 Estuary Study

Diatoms dominated the phytoplankton community, while microflagellates and dinoflagellates formed an important secondary association. Freshwater forms were found at the north stations. Neither the composition nor temporal distribution of species was unexpected, considering the diversity of environments represented. The only noteworthy event of the year was a bloom of the toxic red tide organism <u>Gonyaulax monilata</u> in Calcasieu lake during the summer and early fall of 1981.

Table 8-40. Analysis of covariance for cell totals ($\log_{10}$) in surface samples from estuarine stations.

SOURCE	SUM OF SQUARES	DEGREES OF FREEDOM	MEAN SQUARE	F
Mean	765.0632	1	765.0632	2973.3604
Cruises	10.0592	11	0.9145	3.5540*
Stations	2.0343	3	0.6781	2.6354
Cruises & Stations	8.4911	33	0.2573	

* Significant ($\alpha < .05$)

It is my finding that there has been no detectable damage to the phytoplankton community in the study area due to the activity of the brine line project.

8.4.2 Marine Study

Diatoms were found to dominate the phytoplankton community with the development of a dinoflagellate and microflagellate association in the spring and summer months. In general, the phytoplankton of the study area compare well with other reports for the Gulf of Mexico for both composition and number

Based on analysis of species composition, seasonal distribution, and species diversity values, it would appear that the discharge of brine has had little effect on the phytoplankton community structure.

Although there were observed differences in the biomass levels based on chlorophyll a values, these observations are not supported by statistical analysis and any conclusions concerning this phenomenon remain speculative at this time.

Based on statistical analysis the discharge of brine into the study area at the current levels does not appear to have any adverse impact on the biomass of the phytoplankton community.

8.5 Recommendations

Based on the findings of this investigation, I recommend suspension of the estuary phase of the study. A short term investigation should be used in the event some unusual phenomenon occurs, e.g. a fish or shellfish kill, which may be attributable to this project.

Sound ecological investigations, regardless of purpose, must include studies of all the interactions of the ecological unit. Ecologists recognize that all communities are composed of three elementary units, i.e. biomass (standing crop), structure (species diversity and food webs), and function (energy flow and budgets). Studies which neglect any of these facets in ecosystem analysis suffer inherent error and must necessarily be inconclusive.

Although the present study found no impact on community structure or standing crop, any assessment or conclusions about impact on the phytoplankton community are inhibited by the lack of data on community function. The final assessment of impact must be reserved until further analysis are complete. In the spirit of the purpose of this study, I recommend continuation of the marine investigation for a period of one year. An investigation of primary productivity should be supported. Such a study would allow the investigator to draw sound ecological conclusions about the status of the ecosystem (study area) and the impact of brine discharge on the phytoplankton community.

The sampling protocal and study design need to be modified. I recommend that at minimum the along shore transect be retained to include the following stations: M1, M3, M10A, M18, M20, DE, DW, DS and DN. The field analysis should include measurements of pH, DO, temperature and conductivity at each station at one meter intervals.

CHAPTER 9
ZOOPLANKTON

THIS CHAPTER WILL BE PUBLISHED UNDER SEPARATE COVER AS AN ADDENDUM TO VOLUME III

CHAPTER 10

DATA MANAGEMENT

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10.1 MSU Data Management

10.1.1 Need and Functions

The office of Data Management at McNeese State University was established to meet the Strategic Petroleum Reserve (SPR) Program's requirement, as described in Chapter 1. Field strategies were developed to study the impact of brine on benthic; nekton, phytoplankton, and zooplankton communities, and the physical and chemical marine environment. Principal investigators were assigned to gather and analyze data in each of the above mentioned disciplines. The data management office was designated to individually coordinate the data collection activities of each discipline. Thus, it was necessary to:

(a) design and standardize recording, handling and reporting of both field and laboratory data

(b) introduce criteria for information needed by various users and for archiving

(c) design inexpensive and easily accessible data files

(d) establish norms of quality control

(e) produce scientifically sound data analysis

Data management activities consist of coordinating and scheduling the collection, validation, and storage of data; archiving with Environmental Data and Information Service (EDIS) and Center for Wetland Resources, LSU; and statistical analysis. In order to archive data with EDIS, revisions in reporting format became essential. It was the responsibility of the data management office to propose, discuss, and obtain approval of such changes from the Program Data Manager of EDIS and the National Oceanographic and Atmospheric Adminstration (NOAA).

10.1.2 Liaison

One of many important functions of the data management office was to act as a liaison between project coordinator and EDIS. Activities of all estuarine and marine cruises were reported on a prescribed form ROSCOP-II (Report of Observations and Samples Collected by Oceanographic Programs) to the Department of Energy's Technical Project Officer (TPO) and the representatives of EDIS/NOAA. All ROSCOP-II, tapes, data documentation forms, and letters of transmittal were delivered as required by DOE's program office.

10.1.3 Facilities

McNeese State University's computing facilities consist of IBM 1130 and IBM System/34 computers. System/34 which has a disk storage capacity of 128 megabytes, and main storage size of 256 KB was used by the data management office. The data entry and processing were done using IBM 5251 model 11 and 12 Cathode Ray Tube (CRT) terminals. These CRT's were linked to the main computer through telephone lines. This eliminated the use of computer cards and magnetic tapes, thereby reducing the cost of operation. Facilities of a local data center were used on a contractual basis to transfer data from diskettes to magnetic tapes.

Strict security of data was, of course, maintained at all times. Access to data files was permitted only to authorized personnel. Since access to the computers was on an on-line basis, no time loss was involved in processing the lab data as is involved in the case of batch processes.

10.1.4 Data Processing

After a sample was collected by the principal investigator, it was analyzed in the laboratory, data was compiled on preformated coding forms and the raw data was sent to the data management office. Through data file utilities this raw data was entered into the computer and validation checks performed. Cycles of verification and validation were repeated by the data management office and respective principal investigators until the stored data was error free. This error free data was made available for forwarding to EDIS, LSU, backup storage, statistical analyses, and report generation. The cycles and flow of data and its processing are illustrated in Figure 10-1.

Files of species names and their taxonomic codes were made using the tape obtained from Virginia Institute of Marine Sciences, Gloucester Point, Virginia. When new species were identified, new names and new taxonomic codes were assigned. These were added to the

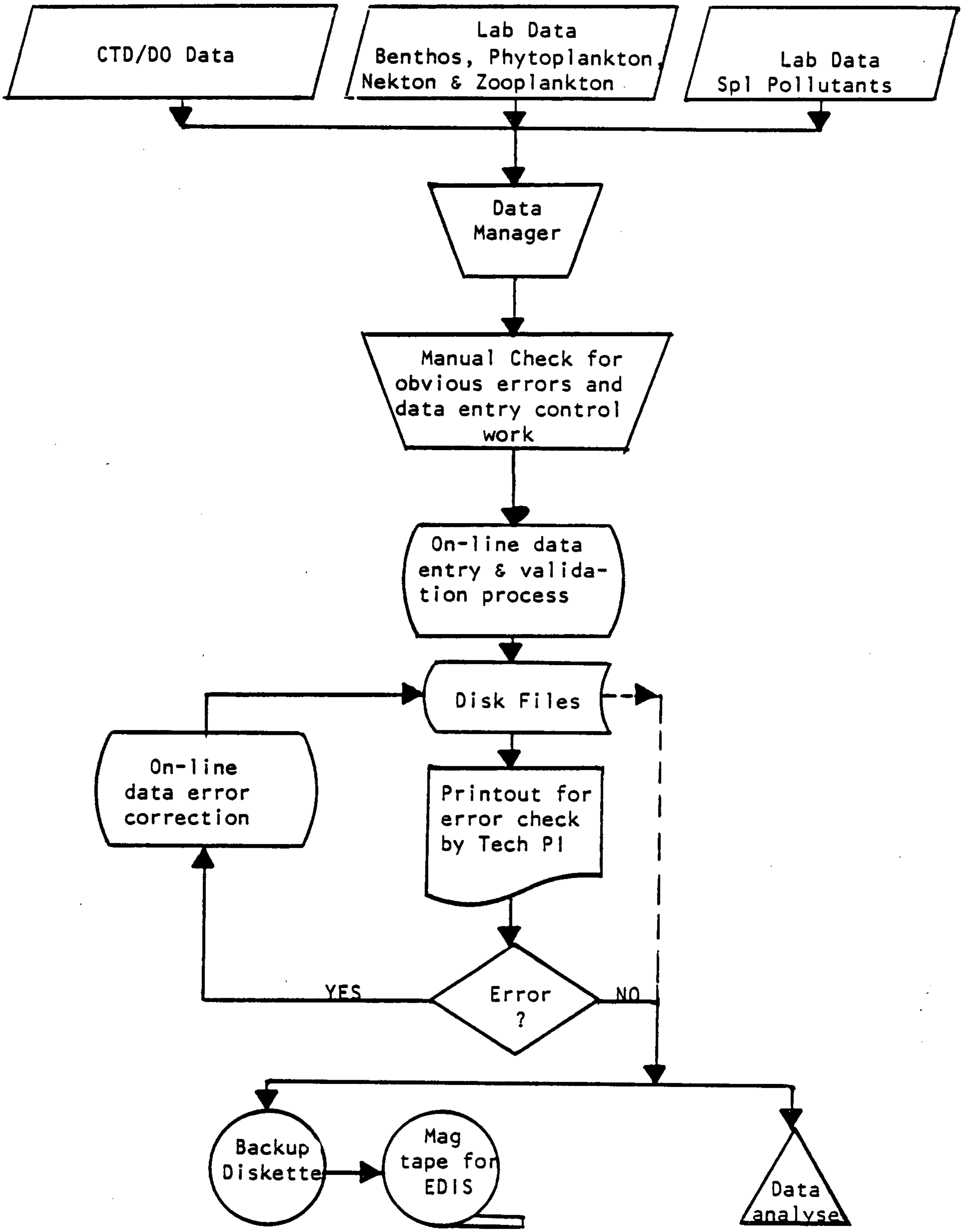

Figure 10-1. Flowchart of data entry, verification, storage and retrieval, and archival of data for EDIS.

existing list and old and unwanted taxonomic codes and names were deleted. The files were updated periodically.

10.1.4 Software Development

10.1.4.1 Computer Programs and Files

The function of the Data Management group was threefold: a) to provide data to EDIS in an unambiguous standardized format; b) to allow easy retrieval and manipulation of data; and c) statistical data analysis.

To standardize data reporting procedures and formats and to determine the method of recording data, meetings were held between the scientists, the technical director, and the data manager. Irrelevant information was discarded from the forms and duplicate recording was modified to one time recording. As a result of cycles of modifications, final reporting forms were designed for each scientist separately. A programmer was assigned to design flow charts, write and code data entry programs and test them. At this point the capabilities and the output of the program were submitted to the scientists for their review. Changes and revisions were incorporated, if necessary. The final programs were stored in the system library in the form of load modules and were used by the data entry staff to key in the data. Thus all the software for the data entry was indigenously developed. All aspects of data entry were menu-driven.

To allow easy retrieval and manipulation of data, the distributed information system technique was used and separate libraries were assigned to the programmers. This allowed strict security and protection from unauthorized users getting into various protected files, inadvertently erasing programs, removing load modules, or deleting data files. Each programmer used his own library to write, test and modify programs, to store or delete unwanted programs or load modules. Whenever access to a protected systems program was requested by a programmer, it was copied into his library; thus minimizing loss of time in obtaining files and procedures if multiple requests were made for using the same files or procedures. For the control and security of files each data file was assigned a six or eight character alphanumeric code. A partial list of files is given in Table 10-1 and it explains how each file was assigned a unique name. The first three characters of master files were BR., signifying file for Brine Line Project, followed by the discipline's format code; for example, 123 for nekton, 124 for zooplankton. All information needed by EDIS was recorded on these master files. Specific work files for statistical analyses were named with first four characters BRK., followed by one letter for discipline, and the last three characters indicative of purpose and/or contents of file. There were twelve master files and many different work files for data analysis and synthesis.

Each scientist was asked to select the variables for his study area and appropriate statistical analysis. To confirm if the underlying conditions for the requested statistical analyses were satisfied, expertise in statistics was sought from professional statisticians.

Table 10-1. Nomenclature for computer files.

Name of file	Description
BR.004	Master file for CTD/DO data, NOAA format code 004
BR.028	Master file for Phytoplankton data, NOAA format code 028
BR.029	Master file for Phytoplankton data, NOAA format code 029
BR.032	Master file for Benthos data, NOAA format code 032
BR.123	Master file for Nekton data, NOAA format code 123
BR.124	Master file for Zooplankton data, NOAA format code 124
BR.144	Master file for Special Pollutant data, NOAA format code 144
BRK.BOØ2	Benthos Offshore February data
BRK.BIØ2	Benthos Inshore February data
BRK.NOW5	Nekton Offshore Weight data for May
BRK.Z135	Zooplankton 1st Replicates Mesh 333 May data
BRK.ZA55	Zooplankton All Replicates Mesh 505 May data

Pertinent information was extracted from master files and after reformatting them, specific purpose files were obtained. Sorting and merging of files was necessary to construct usuable specific purpose files. These activities are illustrated in Figure 10-2.

Two basic types of statistical analyses were performed. First, variables were analyzed to study their distributional characteristics, such as, mean, median, variance, standard deviation, abundance and tabulation. Second, variables were grouped to study the interrelationships. Standard statistical analyses in this group include analysis of variance, linear regression, correlation analysis, and factor analysis, whereas, special purpose statistical analyses suitable for the area of ecology and marine biology include cluster and ordination analyses.

To study distributional characteristics all computer programs were written and tested by data management programmers. Factor analysis and analysis of variance programs supplied by International Business Machines (IBM) were used whereas indigenous programs for simple linear regression analysis, Shannon-Weaver (1949) diversity index, Simpson's index of evenness (1949) and Margalef (1958) index of species richness were written.

For cluster analysis as described by Anderberg (1973) and ordination analysis edited by Gauch (1977), programs were obtained from

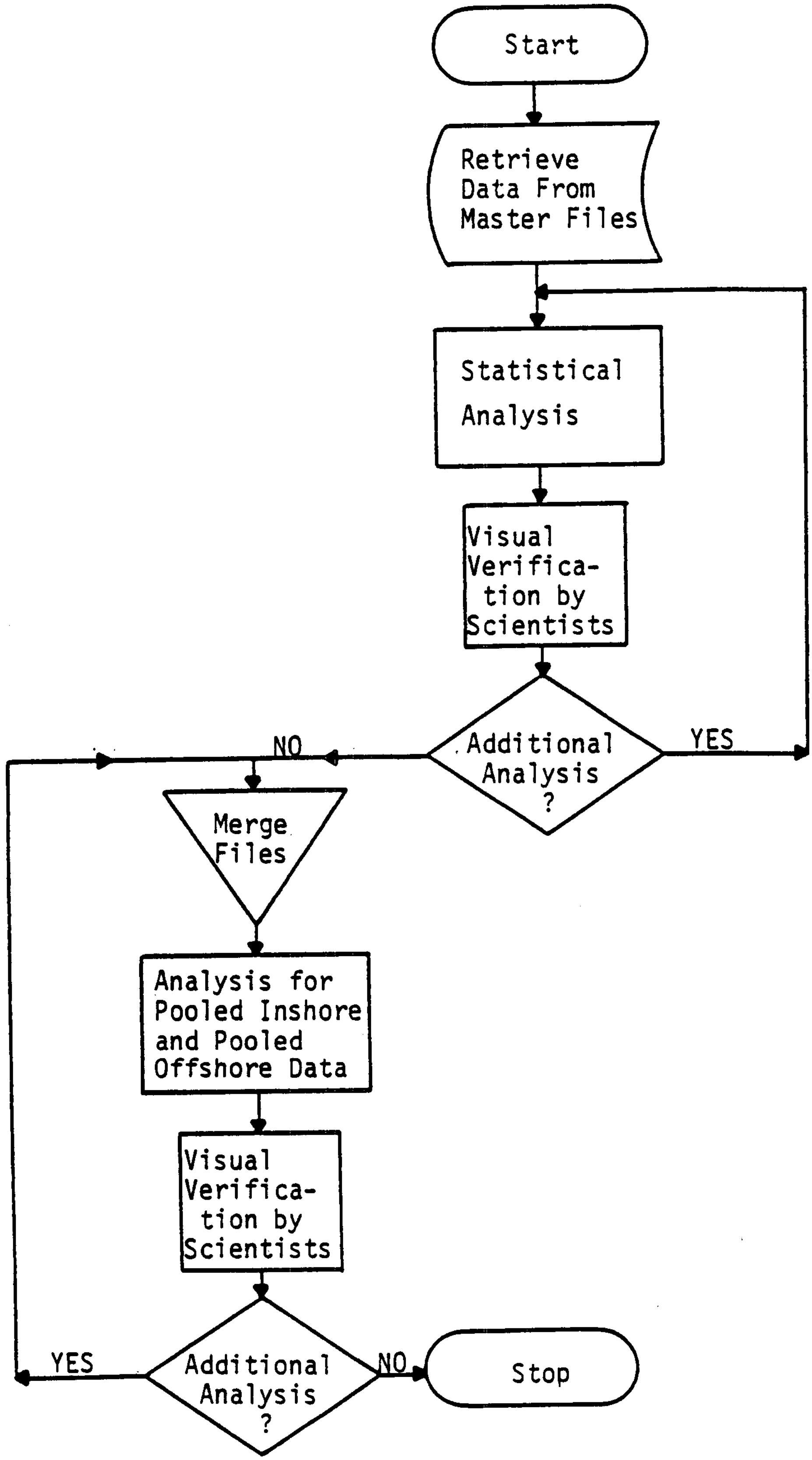

Figure 10-2. Construction of specific purpose files and statistical analyses.

Virginia Institute of Marine Science (VIMS) and Cornell University, respectively. Both of these programs, COMPAH and ORDIFLEX, are large programs and require very large size main memory computers. They were written for computer systems such as IBM 360 or IBM 370. The programs used some instructions which are not acceptable to IBM System/34; such as, format specifications at execution time, block data, and entry points in subroutines. Thus both programs had to undergo extensive modifications. It took painstaking efforts and considerable time to make these programs usable on the IBM System/34 computer. Commercially supplied programs, such as Statistical Analysis System (SAS), Statistical Programs for the Social Science (SPSS) and the like could not be adapted due to lack of large memory size at this facility.

10.1.4.2 Benthic Data

One master file was maintained and data from each cruise was added and also reported to EDIS. Separate files for diversity indices, cluster analysis and other analyses were created from this master file. In-house programs were written to help summarize data and describe the Benthic population at each station for each cruise. Species evenness, richness, and diversity were also calculated each month for marine and estuarine data.

Separate estuarine and marine cluster analyses were completed for each cruise each month, normal and inverse cluster analyses were performed on estuarine and marine data separately for each month and then combined for all months. Species occuring in only one replicate were deleted. Log transformed data were employed in the cluster analyses with the Bray-Curtis (Clifford and Stephenson, 1975) similarity measure and clustering strategy "flexible" with beta = -0.25, (Boesch, 1977). Two types of results were obtained: 1) groups of species which tended to co-occur were identified, and 2) groups of stations with similar species were identified.

The results are described in the Benthos section elsewhere. Taxonomic codes and names of species were the same as used by VIMS.

10.1.4.3 Nekton Data

Master files were constructed to include data from all cruises. Cluster analysis was employed on estuarine and marine data for each month keeping replicates separate and then on data with replicates combined for each month, taking the options which were described in the Benthic data section. Regression analyses were performed on logarithmic transformed data for individual length and weight of species. Species abundance, diversity indices and distributional characteristics statistics were computed.

Histograms depicting length frequencies were produced for two control stations, one experimental station, and overall stations sampled.

Condition factors were calculated for certain species. Differences between condition factors of species at control and experimental sites were tested by Wilcoxon's Signed-rank test.

Analysis of variance technique was used to detect differences in species occurrences and weights at stations each month. Student-Newman-Keuls multiple range test was used to identify where the significant differences occurred.

Multivariate analysis of variance and covariance technique was used to evaluate effects of physical parameters on species occurrence. Some of the physical parameters used in this analysis were temperature, salinity, dissolved oxygen and sediment sizes.

10.1.4.4 Phytoplankton Data

Two master files were maintained: 1) the number of cells per liter for each species, and 2) for chlorophyll-a and phaeopigment concentration. Analysis of variance technique was used to find interrelationship among flora. Duncan's New Multiple Range test was used to identify similar stations.

10.1.4.5 Zooplankton Data

One master file was maintained for zooplankton data, and monthly cruise data was extracted from this file to transmit data to EDIS. The samples were collected at varying depths with two different mesh size sampling devices. Differences in biomass and species abundances between stations were tested for each depth and each mesh size using analysis of variance technique. Student-Newman-Keuls multiple range test was used to detect where the significant differences occurred.

Cluster analysis was performed each month on four marine data files and two estuarine data files. The four marine data files consisted of two files for each mesh size; one with only first replicate all species data, the second containing all replicates selected species data. The first of the two estuarine data files contained first replicate all species data, and the second contained all replicate selected species data. The options taken for these cluster analyses were the same as those described in the Benthic data section with the exception of dropping species which occurred in less than 5% of the stations sampled.

10.1.4.6 CTD/DO Data

Whenever a sampling cruise took place, measurements on some physical parameters, such as, temperature, salinity, pH, turbidity and dissolved oxygen were made at each station. One master file was created and extracts of monthly data were sent to EDIS.

One special work file was created from this master file which contained all pertinent data for analyses on one record type. One additional parameter, dissolved oxygen saturation, was estimated from the measured parameters and included in this special work file. Differences between stations were evaluated using analysis of variance techniques. For each variable at each station, descriptive statistics were calculated to study distributional characteristics and then on all stations combined to study the overall distribution of the variable.

10.1.4.7 Special Pollutants Data

A master file was created to record data for pH, Eh, major ions, total metals, pesticides, and high molecular weight hydrocarbons. Only three sampling cruises took place during the post discharge period.

Statistical analyses were not performed for these limited data.

Detailed descriptions of results and interpretations of the statistical analyses performed for each of the disciplines were discussed in the previous chapters.

10.2 Texas A & M University Data Management

10.2.1 Introduction

The principal responsibilities of the data management section are the maintenance of a centralized data storage and retrieval system, the protection of the data system, the transmission of the validated data to the Environmental Data and Information Service (EDIS) in Washington, D.C., and providing programming support for project scientists and engineers. Validated data is also transmitted to the State of Louisiana designee, Dr. Richard Condrey, Louisiana State University Center for Wetland Resources, in Baton Rouge, Louisiana. Other requests are submitted through the project's managment division. In order to meet these requirements the data management section must monitor and accurately document the flow of data from the initial sampling, through validation to its final transmission and storage.

10.2.2 Facilities

The SPR Project has at its disposal the facilities of Texas A&M University's Data Processing Center (DPC). It is equipped with an Amdahl 470 V/6 and an Amdahl 470 V/7b. There are approximately 200 other computers, from micros through large scale, many of which along with about 1600 terminals of various types, access the main computer system via dial-up or dedicated communication lines. Approximately 800 terminals can be active at one time. The facility fulfills the academic, research and administrative needs of Texas A&M, while simultaneously functioning as a regional center to other educational institutions and state and federal agencies.

The Amdahl processors are each configures with 16 data channels and 8 megabytes of monolithic memory. The memory for each processor is prefixed with a high speed cache memory that is used to provide fast access to frequently used data instructions. The V/6 cache memory size is 16 kilobytes, and the V/7b size is 32 kilobytes.

Both Amdahl processors and all peripherals are combined into a loosely coupled, multiple processor complex that is connected to shared disks and tapes and is controlled by the IBM operating system MVS/JES3 (Multiple Virtual Storage/Job Entry Subsystem 3). The operating system controls the scheduling of all resources required for a job and provides the computer system operator with status information on the utilization and availability of these resources.

The following peripheral equipment is connected to the Amdahl processors:

24 IBM 3350 Disk Drives (317 megabytes each)

24 STC 8650 Disk Drives (634 megabytes each)

16 CALCOMP 230 Disk Drives (100 megabytes each)

1 CALCOMP 9-track Tape Drive (800/1600 bpi)

1 CALCOMP 7-track Tape Drive (200/556/8800 bpi)

8 STC 3670 9-track Tape Drive (1600/6250 bpi)

4 IBM 1403-N1 Printers

2 IBM 3211 Printers

2 Versatec 1200A Printers

1 Houston Instruments 36" Plotter

1 Xerox Laser Printer

WYLBUR, a text manipulation system developed at Stanford University, provides the major portion of the interaction between the computer systems and the data management section. It offers an on-line interactive capability for preparing and submitting jobs for execution. Also provided is the ability to have the output from the job held. WYLBUR can then be used to fetch and examine this output. In many cases, this preview is all that is required; the output is purged. These editing, job submission and output previewing capabilities are provided by WYLBUR with relatively low overhead. As a result, the user saves both time and money.

WYLBUR is used also by project personnel as an aid in report generation. Using office terminals, text can be entered, edited and, in conjunction with a series 1620 or 1650 Xerox word processor terminal, a high quality copy can be produced. The original text is stored on disk files and can be retrieved at any time for revision.

10.2.3 Data Processing

Data are received from all components of the project (physical oceanography, water chemistry, sediment chemistry, grain size, sea state) on formatted data sheets or on-line data files (e.g. physical oceanography). The data are stored as one or more data sets for each component of the project. In some cases, the raw data are processed by programs which arrange the data into a format compatible with existing files and programs.

After entering the data on-line, a cycle of validation is initiated through the appropriate principal investigator and the data management section to check for errors. With each cycle, the data are corrected by data management until they are error free. The data are then available for forwarding to EDIS, statistical analyses and report generation (see Figure 10-3). The status of the data from each of the project's components is shown in Table 10-2.

The ACF2 protection system, recently installed at the computer facility, enables access to project data files to be specifically controlled by data management and personnel with project accounts. Flexibility in controlling the type of access permitted (reading from files or editing files) and the degree of access permitted (limited from a specific portion of a file to the entire contents of the account) enables the authorized use of project data to be selectively controlled. This system is particularly useful with large computer accounts in which

DATA PROCESSING

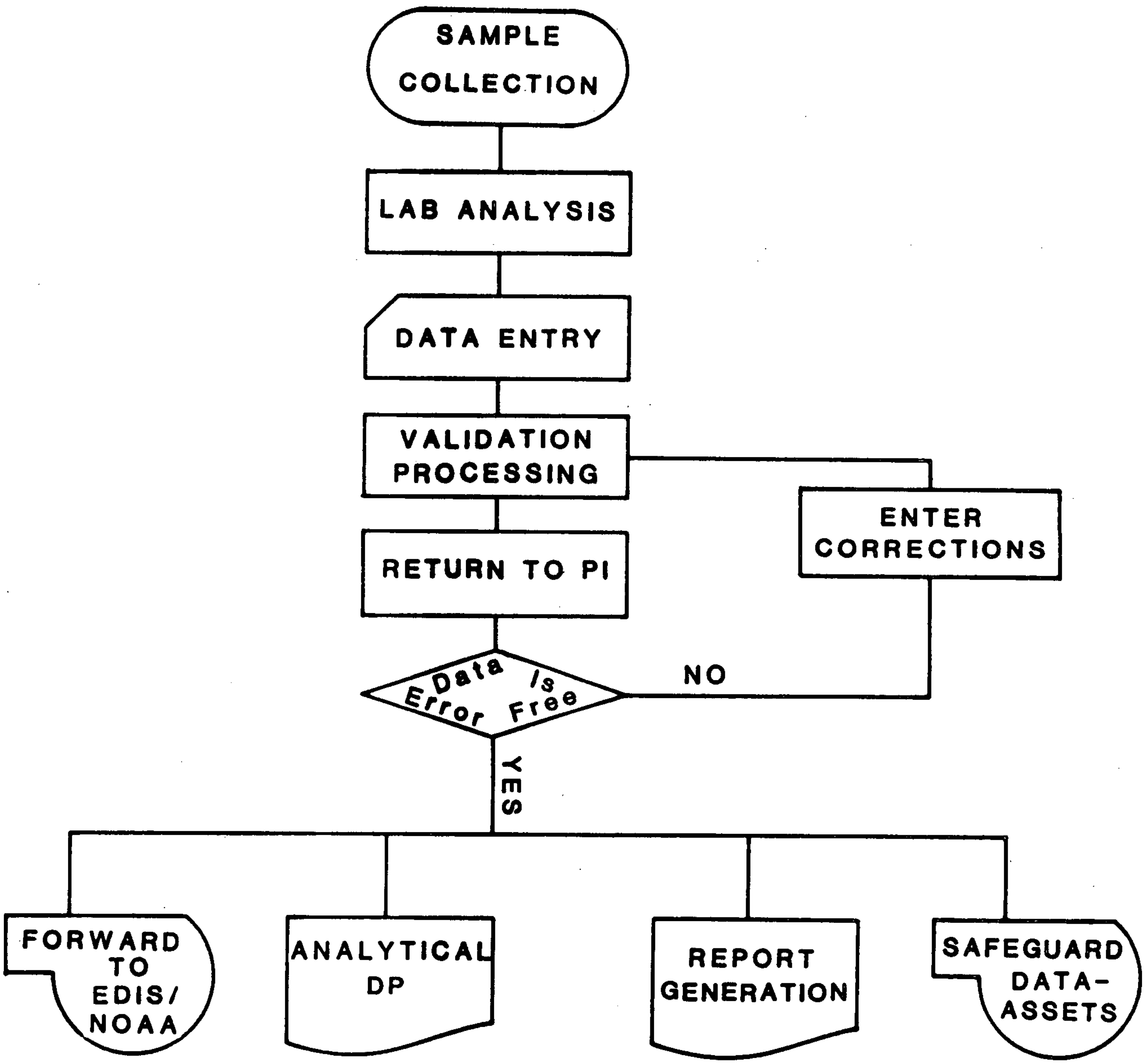

Figure 10-3. Flow chart shows data processing activity.

Table 10-2. Cumulative status of project data sets from January 1981 through September 8, 1982.

DATA SET:SURFACE WEATHER OBSERVATIONS

DATA SET NAME	MONTH	CODED	VALIDATED	TRANSMITTED
MET.MAY81	MAY 1981	X	X	X
MET.JUN81	JUNE 1981	X	X	X
MET.JUL81	JULY 1981	X	X	X
MET.AUG81	AUGUST 1981	X	X	X
MET.SEP81	SEPTEMBER 1981	X	X	X
MET.OCT81	OCTOBER 1981	X	X	X
MET.NOV81	NOVEMBER 1981	X	X	X
MET.DEC81	DECEMBER 1981	X	X	X
MET.JAN82	JANUARY 1982	X	X	X
MET.FEB82	FEBRUARY 1982	X	X	X
MET.MAR82	MARCH 1982	X	X	X
MET.APR82	APRIL 1982	X	X	X
MET.MAY82	MAY 1982	X	X	X
MET.JUN82	JUNE 1982	X	X	X
MET.JUL82	JULY 1982	X	X	
MET.AUG82	AUGUST 1982	X	X	

DATA SET:SURFACE SEA OBSERVATIONS

DATA SET NAME	MONTH	CODED	VALIDATED	TRANSMITTED
SEA.MAY81	MAY 1981	X	X	X
SEA.JUN81	JUNE 1981	X	X	X
SEA.JUL81	JULY 1981	X	X	X
SEA.AUG81	AUGUST 1981	X	X	X
SEA.SEP81	SEPTEMBER 1981	X	X	X
SEA.OCT81	OCTOBER 1981	X	X	X
SEA.NOV81	NOVEMBER 1981	X	X	X
SEA.DEC81	DECEMBER 1981	X	X	X
SEA.JAN82	JANUARY 1982	X	X	X
SEA.FEB82	FEBRUARY 1982	X	X	X
SEA.MAR82	MARCH 1982	X	X	X
SEA.APR82	APRIL 1982	X	X	X
SEA.MAY82	MAY 1982	X	X	X
SEA.JUN82	JUNE 1982	X	X	X
SEA.JUL82	JULY 1982	X	X	
SEA.AUG82	AUGUST 1982	X	X	

DATA SET: OVER THE SIDE MEASUREMENTS

DATA SET NAME	MONTH	CODED	VALIDATED	TRANSMITTED
OTS.MAY81	MAY 1981	X	X	X
OTS.JUN81	JUNE 1981	X	X	X
OTS.JUL81	JULY 1981	X	X	X
OTS.AUG81	AUGUST 1981	X	X	X
OTS.SEP81	SEPTEMBER 1981	X	X	X
OTS.OCT81	OCTOBER 1981	X	X	X
OTS.NOV81	NOVEMBER 1981	X	X	X
OTS.DEC81	DECEMBER 1981	X	X	X
OTS.JAN82	JANUARY 1982	X	X	X
OTS.FEB82	FEBRUARY 1982	X	X	X
OTS.MAR82	MARCH 1982	X	X	X
OTS.APR82	APRIL 1982	X	X	X
OTS.MAY82	MAY 1982	X	X	X
OTS.JUN82	JUNE 1982	X	X	X

Table 10-2. Continued.

DATA SET: SEDIMENT QUALITY MEASUREMENTS

DATA SET NAME	MONTH	CODED	VALIDATED	TRANSMITTED
SED.MAY81	MAY 1981	X	X	X
SED.JUN81	JUNE 1981	X	X	X
SED.JUL81	JULY 1981	X	X	X
SED.AUG81	AUGUST 1981	X	X	X
SED.SEP81	SEPTEMBER 1981	X	X	X
SED.OCT81	OCTOBER 1981	X	X	X
SED.NOV81	NOVEMBER 1981	X	X	X
SED.DEC81	DECEMBER 1981	X	X	X
SED.JAN82	JANUARY 1982	X	X	X
SED.FEB82	FEBRUARY 1982	X	X	X
SED.MAR82	MARCH 1982	X	X	X
SED.APR82	APRIL 1982	X	X	X
SED.MAY82	MAY 1982	X	X	X
SED.JUN82	JUNE 1982	X	X	X
SED.JUL82	JULY 1982	X	X	

DATA SET: PHI GRAIN SIZE ANALYSIS

DATA SET NAME	MONTH	CODED	VALIDATED	TRANSMITTED
PHI.MAY81	MAY 1981	X	X	X
PHI.JUN81	JUNE 1981	X	X	X
PHI.JUL81	JULY 1981	X	X	X
PHI.AUG81	AUGUST 1981	X	X	X
PHI.SEP81	SEPTEMBER 1981	X	X	X
PHI.OCT81	OCTOBER 1981	X	X	X
PHI.NOV81	NOVEMBER 1981	X	X	X
PHI.DEC81	DECEMBER 1981	X	X	X
PHI.JAN82	JANUARY 1982	X	X	X
PHI.FEB82	FEBRUARY 1982	X	X	X
PHI.MAR82	MARCH 1982	X	X	X
PHI.APR82	APRIL 1982	X	X	X
PHI.MAY82	MAY 1982	X	X	X
PHI.JUN82	JUNE 1982	X	X	X
PHI.JUL82	JULY 1982	X	X	

DATA SET: WATER QUALITY MEASUREMENTS

DATA SET NAME	MONTH	CODED	VALIDATED	TRANSMITTED
WATER.MAY81	MAY 1981	X	X	X
WATER.JUN81	JUNE 1981	X	X	X
WATER.JUL81	JULY 1981	X	X	X
WATER.AUG81	AUGUST 1981	X	X	X
WATER.SEP81	SEPTEMBER 1981	X	X	X
WATER.OCT81	OCTOBER 1981	X	X	X
WATER.NOV81	NOVEMBER 1981	X	X	X
WATER.DEC81	DECEMBER 1981	X	X	X
WATER.JAN82	JANUARY 1982	X	X	X
WATER.FEB82	FEBRUARY 1982	X	X	X
WATER.MAR82	MARCH 1982	X	X	X
WATER.APR82	APRIL 1982	X	X	X
WATER.MAY82	MAY 1982	X	X	X
WATER.JUN82	JUNE 1982	X	X	X

DATA SET: MAJOR IONS IN WATER QUALITY MEASUREMENTS(QUARTERLY)

DATA SET NAME	MONTH	CODED	VALIDATED	TRANSMITTED
ION.WATER.MAY81	MAY 1981	X	X	X
ION.WATER.JUN81	JUNE 1981	X	X	X
ION.WATER.SEP81	SEPT. 1981	X	X	X
ION.WATER.DEC81	DECEMBER 1981	X	X	X
ION.WATER.MAR82	MARCH 1982	X	X	X

Table 10-2. Continued.

DATA SET: MAJOR IONS IN SEDIMENT QUALITY MEASUREMENTS(QUARTERLY)

DATA SET NAME	MONTH	CODED	VALIDATED	TRANSMITTED
ION.SED.MAY81	MAY 1981	X	X	X
ION.SED.JUN81	JUNE 1981	X	X	X
ION.SED.SEP81	SEPTEMBER 1981	X	X	X
ION.SED.DEC81	DECEMBER 1981	X	X	X
ION.SED.MAR82	MARCH 1982	X	X	X

DATA SET: WES JAMES DATA--JAMES.FX

DATA SET NAME	MONTH	CODED	VALIDATED	TRANSMITTED
JAMES.F1	AUGUST 1981	X	X	X
JAMES.F2	AUGUST 1981	X	X	X
JAMES.F3	AUGUST 1981	X	X	X
JAMES.F1	NOVEMBER 1981	X	X	X
JAMES.F2	NOVEMBER 1981	X	X	X
JAMES.F3	NOVEMBER 1981	X	X	X
JAMES.F1	JANUARY 1982	X	X	X
JAMES.F2	DECEMBER 1981	X	X	X
JAMES.F3	JANUARY 1982	X	X	X
JAMES.F1	FEBRUARY 1982	X	X	X
JAMES.F2	FEBRUARY 1982	X	X	X
JAMES.F3	FEBRUARY 1982	X	X	X

DATA SET: FRANK KELLY'S FILTER AVERAGE

DATA SET NAME	MONTH	CODED	VALIDATED	TRANSMITTED
FLTRAVG.DT601211	FEB. 1981	X	X	X
FLTRAVG.DT602171	MARCH 1981	X	X	X
FLTRAVG.DT603061	APRIL 1981	X	X	X
FLTRAVG.DT604041	APRIL 1981	X	X	X
FLTRAVG.DT604281	MAY 1981	X	X	X
FLTRAVG.DT605121	JUNE 1981	X	X	X
FLTRAVG.DT606241	JULY 1981	X	X	X
FLTRAVG.DT607091	JULY 1981	X	X	X
FLTRAVG.DT607231	AUGUST 1981	X	X	X
FLTRAVG.DT608131	SEPT. 1981	X	X	X
FLTRAVG.DT609031	SEPT. 1981	X	X	X
FLTRAVG.DT609291	OCT. 1981	X	X	X
FLTRAVG.DT610221	NOV. 1981	X	X	X
FLTRAVG.DT611191	DEC. 1981	X	X	X
FLTRAVG.DB601211	FEB. 1981	X	X	X
FLTRAVG.DB602171	MARCH 1981	X	X	X
FLTRAVG.DB603141	APRIL 1981	X	X	X
FLTRAVG.DB604041	APRIL 1981	X	X	X
FLTRAVG.DB604281	MAY 1981	X	X	X
FLTRAVG.DB605121	JUNE 1981	X	X	X
FLTRAVG.DB606241	JULY 1981	X	X	X
FLTRAVG.DB607091	JULY 1981	X	X	X
FLTRAVG.DB607231	AUGUST 1981	X	X	X
FLTRAVG.DB608131	SEPT. 1981	X	X	X
FLTRAVG.DB609031	SEPT. 1981	X	X	X
FLTRAVG.DB609291	OCT. 1981	X	X	X
FLTRAVG.DB610221	NOV. 1981	X	X	X
FLTRAVG.DB611191	DEC. 1981	X	X	X
FLTRAVG.DB601242	FEB. 1982	X	X	X

Table 10-2. Continued.

FLTRAVG.DB603142	APRIL	1982	X	X	X
FLTRAVG.DB612151	AUGUST	1982	X	X	X
FLTRAVG.DB605162	AUGUST	1982	X	X	X
FLTRAVG.DX605162	MAY	1982	X	X	X
FLTRAVG.DB604012	APRIL	1982	X	X	X
FLTRAVG.DT601242	JAN.	1982	X	X	X
FLTRAVG.DT603142	MARCH	1982	X	X	X
FLTRAVG.DT604012	APRIL	1982	X	X	X
FLTRAVG.DT605162	MAY	1982	X	X	X
FLTRAVG.NB604281	APRIL	1981	X	X	X
FLTRAVG.NB605121	MAY	1981	X	X	X
FLTRAVG.NB606241	JUNE	1981	X	X	X
FLTRAVG.NB607231	JULY	1981	X	X	X
FLTRAVG.NB608131	AUGUST	1981	X	X	X
FLTRAVG.NB609041	SEPT.	1981	X	X	X
FLTRAVG.NB709291	SEPT.	1981	X	X	X
FLTRAVG.NB610221	OCT.	1981	X	X	X
FLTRAVG.NB611181	NOV.	1981	X	X	X
FLTRAVG.NB601242	AUGUST	1982	X	X	X
FLTRAVG.NB602172	AUGUST	1982	X	X	X
FLTRAVG.SB702171	FEB.	1981	X	X	X
FLTRAVG.SB603061	MARCH	1981	X	X	X
FLTRAVG.SB604041	AUGUST	1982	X	X	X
FLTRAVG.SB604281	AUGUST	1982	X	X	X
FLTRAVG.SB605201	AUGUST	1982	X	X	X
FLTRAVG.SB606231	AUGUST	1982	X	X	X
FLTRAVG.SB607231	AUGUST	1982	X	X	X
FLTRAVG.SB608131	AUGUST	1982	X	X	X
FLTRAVG.SB609031	AUGUST	1982	X	X	X
FLTRAVG.SB609291	AUGUST	1982	X	X	X
FLTRAVG.SB610221	AUGUST	1982	X	X	X
FLTRAVG.SB611181	AUGUST	1982	X	X	X
FLTRAVG.SB612151	AUGUST	1982	X	X	X
FLTRAVG.SB601242	AUGUST	1982	X	X	X
FLTRAVG.SB602172	AUGUST	1982	X	X	X
FLTRAVG.SB603142	AUGUST	1982	X	X	X
FLTRAVG.ST603061	MARCH	1981	X	X	X
FLTRAVG.ST604041	APRIL	1981	X	X	X
FLTRAVG.ST604281	APRIL	1981	X	X	X
FLTRAVG.ST605201	MAY	1981	X	X	X
FLTRAVG.ST606231	JUNE	1981	X	X	X
FLTRAVG.ST607231	JULY	1981	X	X	X
FLTRAVG.ST609031	SEPT.	1981	X	X	X
FLTRAVG.ST609291	SEPT.	1981	X	X	X
FLTRAVG.ST610221	OCT.	1981	X	X	X
FLTRAVG.ST611181	NOV.	1981	X	X	X
FLTRAVG.ST612151	DEC.	1981	X	X	X
FLTRAVG.ST601242	JAN.	1982	X	X	X
FLTRAVG.ST602172	FEB.	1982	X	X	X
FLTRAVG.ST603142	MARCH	1982	X	X	X
FLTRAVG.ST604012	APRIL	1982	X	X	X
FLTRAVG.ST605162	MAY	1982	X	X	X
FLTRAVG.WB602261	FEB.	1981	X	X	X
FLTRAVG.WB604041	APRIL	1981	X	X	X
FLTRAVG.WB606021	JUNE	1981	X	X	X
FLTRAVG.WB607091	JULY	1981	X	X	X
FLTRAVG.WB608131	AUGUST	1981	X	X	X
FLTRAVG.WB609031	SEPT.	1981	X	X	X
FLTRAVG.WB609291	SEPT.	1981	X	X	X
FLTRAVG.WB611181	NOV.	1981	X	X	X
FLTRAVG.WB612151	DEC.	1981	X	X	X
FLTRAVG.WB601242	JAN.	1982	X	X	X
FLTRAVG.WB602172	AUGUST	1982	X	X	
FLTRAVG.WB603142	AUGUST	1982	X	X	X
FLTRAVG.WB604012	AUGUST	1982	X	X	X
FLTRAVG.WB605162	AUGUST	1982	X	X	X

numerous subaccounts (principal investigators and support personnel) are interactively maintained, as in the SPR project.

The data files are protected from inadvertent loss through a series of programs which copy the data to magnetic tape of a monthly basis. Two copies of the project's complete data files are maintained in a fire-proof vault. Documentation of the contents of the backup is kept by the data management section so that any data file which is lost (e.g. hardware failure, operator error) can be restored to on-line use. Appendix J contains the validated project data to date.

10.2.4 Software Development

Specifications for the development of a computer program are forwarded from a principal investigator to the data management section. At that time the feasibiliiy of developing the program is considered and recommendations are made to the requestor as shown in Figure 10-4. After discrepancies are resolved, a programmer is assigned to the project. The programmer's responsibilities are to design the program, draw a flow chart, and code and test a program. At that point, additional programmers may be requested to continue the development process.

After the program is flow charted, a structured walk through is conducted in the presence of a programmer who is not involved with the program to insure the program undergoing development is indeed the program requested. Major design flaws can also be detected at this point.

The program is then coded and tested. If the program constitutes part of a system of programs, a system test is then performed. At this point

SOFTWARE DEVELOPMENT

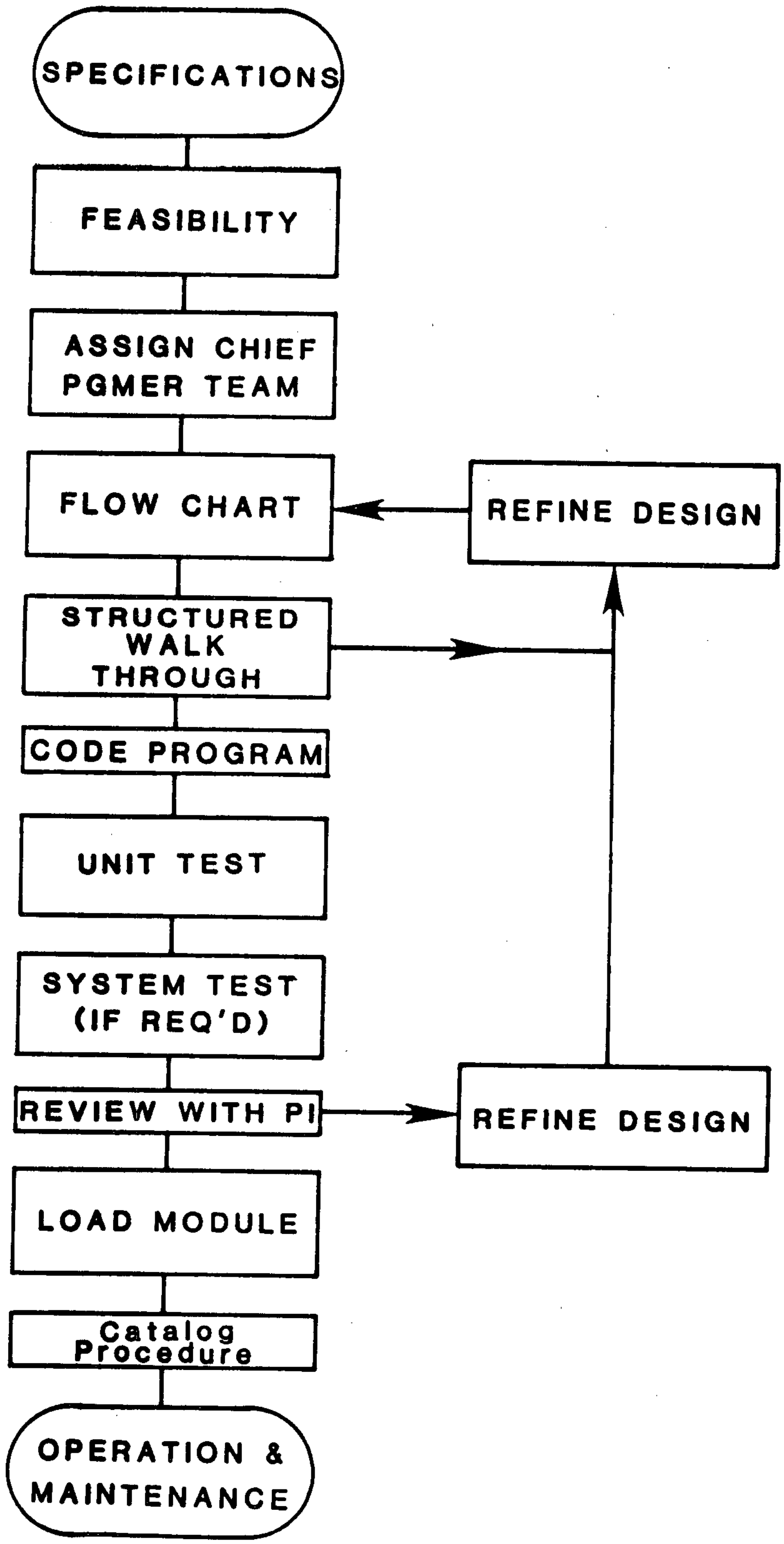

Figure 10-4. Flow chart shows software development.

the capabilities and output generated by the program are presented to the requestor for his review. Changes are then incorporated, if necessary. After the program is accepted by the requestor, it is compiled into a private job library and a procedure is stored on-line which will use the stored load module during production processing. The program is then maintained through the life of the project.

Direct on-line storage of data is convenient for the researcher's processing needs, but can lead to rather large disk storage requirements, particularly for data which is continuously collected (e.g. physical oceanography). The data management section is developing a data file management and inventory system which will substantially reduce the storage space requirements, and consequently the expense, of on-line data while approaching the convenience of direct access files.

The program allows a researcher, through a response to a series of prompts, to determine the daily cost of each file, to load files, to magnetic tape or scratch them, to store and cross-reference the files on each tape, and to restore files to on-line access from tape. All of these features are incorporated into the program, in a user inter-active system which requires no knowledge of various utility programs required to accomplish these tasks. As the project's data files continue to expand, on-line storage costs can be controlled with this system.

The data management section has developed programs that convert raw data into suitable format for use in commercial statistical packages such as SAS (Statistical Analysis System). Data management also acquires and develops programs and statistical packages that can significantly enhance a principal investigator's capabilities for data reduction and analysis. This software allows the generation of graphics as well as tables. Among the graphics generated from such programs are those for water chemistry and brine discharge parameters shown in Figures 10-5 and 10-6, respectively. The data used in producing Figure 10-6 is generated in Table 10-2.

Data management has also acquired a set of computer programs from Harvard University's Laboratory of Computer Graphics and Spacial Analysis. These programs have been adapted to run on the AMDAHL computer and are useful for plotting a variety of surface contours and reliefs.

SYMAP (Synagraphic Mapping) plots several kinds of maps on the line printer. ASPEX (Automated Surface Perspective) produces plots of three-dimensional surfaces, with different perspective views, on the Versatec plotter. Both of these programs are user-oriented. Input to SYMAP is such that data values must be entered in precisely delimited fields for each feature of the program. ASPEX requires two types of input: a data matrix and a sequence of control commands which permit altitude, azimuth, detail and various other features to be specified (Figure 10-7).

10.2.5 Data Documentation and Transmittal

One of the primary responsibilities of the data management section is the monthly transmittal of validated data to EDIS. The following section describes the process, forms and documentation involved.

Each month the newly validated data on-line is copied to magnetic tape and forwarded to the data manager at EDIS. Included with the tapes are the following:

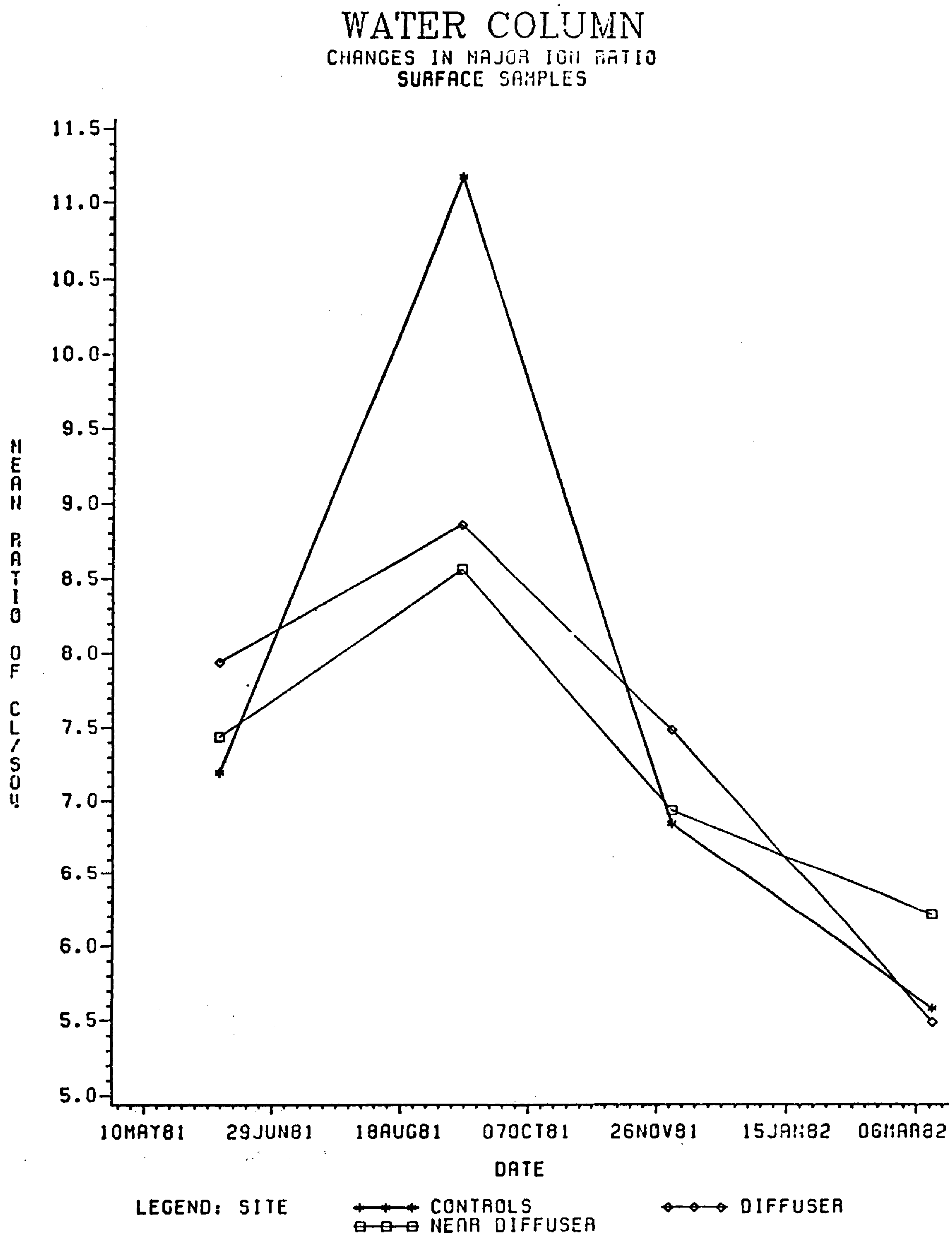

Figure 10-5. Example of a computer generated graphic showing water chemistry parameters.

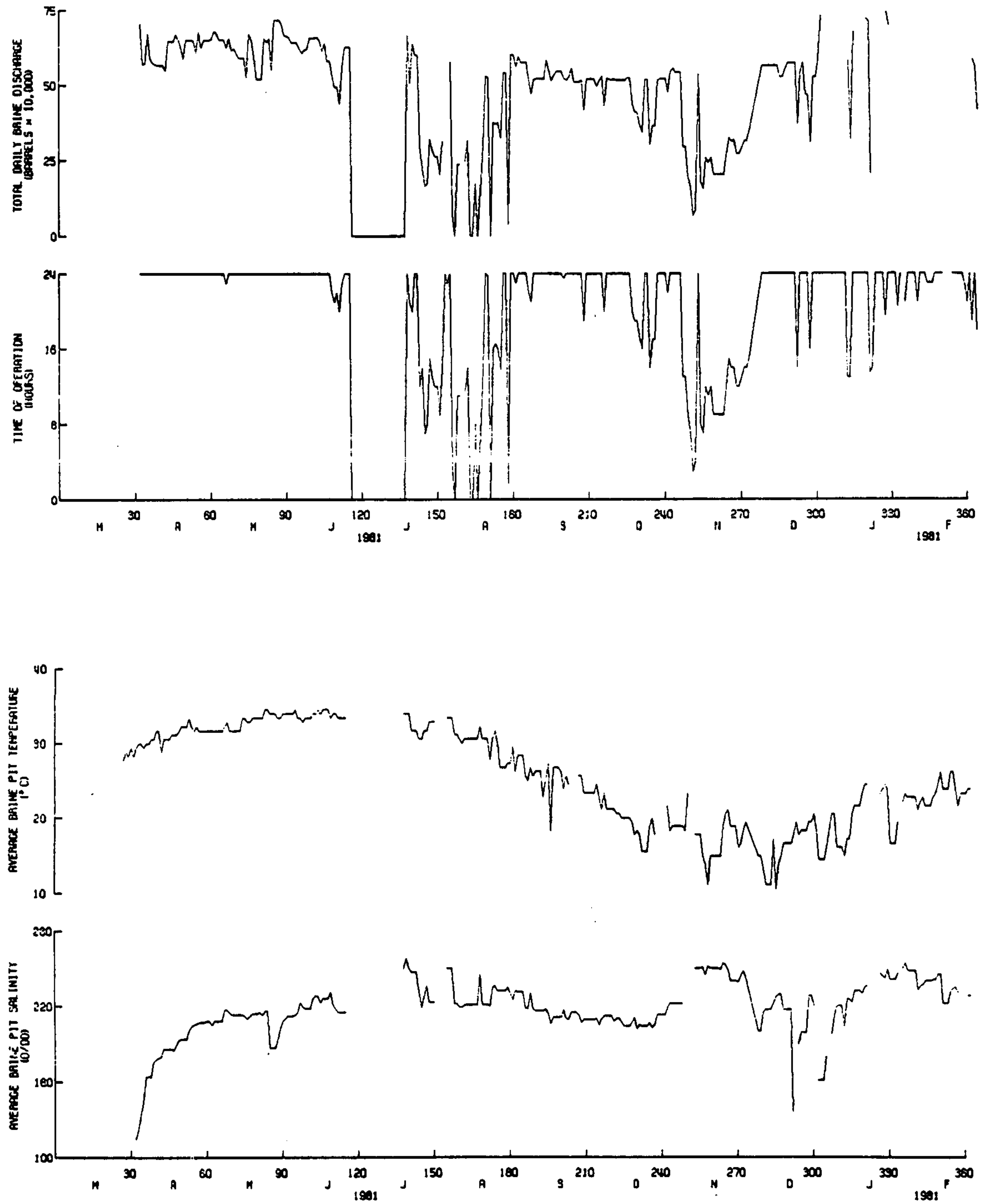

Figure 10-6. Example of a computer generated graphic showing brine discharge parameters.

Table 10-3. Example of a computer generated table showing brine discharge parameters.

DATE	TIME OF OPERATION (HOURS)	FLOW RATE (BARRELS PER HOUR)	TOTAL DAILY BRINE DISCHARGE (BARRELS)	AVERAGE BRINE PIT SALINITY (O/OO)	AVERAGE BRINE PIT TEMPERATURE (O C)
05/27/81	NO DATA	NO DATA	NO DATA	86	27
05/28/81	NO DATA	NO DATA	NO DATA	76	28
05/29/81	NO DATA	NO DATA	NO DATA	76	28
05/30/81	NO DATA	NO DATA	NO DATA	84	29
05/31/81	NO DATA	NO DATA	NO DATA	97	28
06/01/81	24.00	29465	707160	115	29
06/02/81	24.00	23790	570960	123	29
06/03/81	24.00	23833	571992	134	29
06/04/81	24.00	27914	669936	144	29
06/05/81	24.00	24532	588768	164	29
06/06/81	24.00	23995	575880	164	29
06/07/81	24.00	23693	568632	164	30
06/08/81	24.00	23580	565920	176	30
06/09/81	24.00	23580	565920	178	31
06/10/81	24.00	23580	565920	179	31
06/11/81	24.00	22897	549528	180	28
06/12/81	24.00	26917	646008	186	30
06/13/81	24.00	26917	646008	186	30
06/14/81	24.00	26917	646008	186	30
06/15/81	24.00	27832	667968	186	31
06/16/81	24.00	27263	654312	185	31
06/17/81	24.00	26214	629136	189	31
06/18/81	24.00	24544	589056	193	31
06/19/81	24.00	27098	650352	194	32
06/20/81	24.00	27098	650352	194	32
06/21/81	24.00	27098	650352	194	32
06/22/81	24.00	26977	647448	201	33
06/23/81	24.00	25452	610848	204	32
06/24/81	24.00	28208	676992	205	31
06/25/81	24.00	26152	627648	206	32
06/26/81	24.00	27119	650856	207	31
06/27/81	24.00	27119	650856	207	31
06/28/81	24.00	27119	650856	207	31
06/29/81	24.00	27271	654504	208	31
06/30/81	24.00	28307	679368	208	31
07/01/81	24.00	28129	675096	205	31
07/02/81	24.00	27142	651408	208	31
07/03/81	24.00	27142	651408	208	31
07/04/81	24.00	27142	651408	208	31
07/05/81	23.00	27142	624266	208	31
07/06/81	24.00	27391	657384	217	32
07/07/81	24.00	25655	615720	217	32
07/08/81	24.00	25988	623712	215	31
07/09/81	24.00	25319	607656	213	31
07/10/81	24.00	24653	591672	213	31
07/11/81	24.00	24653	591672	213	31
07/12/81	24.00	24653	591672	213	31
07/13/81	24.00	22018	528432	213	33
07/14/81	24.00	27923	670152	212	33
07/15/81	24.00	27266	654384	210	32
07/16/81	24.00	24848	596352	212	32
07/17/81	24.00	21675	520200	214	33
07/18/81	24.00	21675	520200	214	33
07/19/81	24.00	21675	520200	214	33
07/20/81	24.00	27305	655320	215	33

Table 10-3. Continued.

DATE	TIME OF OPERATION (HOURS)	FLOW RATE (BARRELS PER HOUR)	TOTAL DAILY BRINE DISCHARGE (BARRELS)	AVERAGE BRINE PIT SALINITY (0/00)	AVERAGE BRINE PIT TEMPERATURE (0 C)
07/21/81	24.00	26857	644568	213	33
07/22/81	24.00	27357	656568	216	34
07/23/81	24.00	22964	551136	216	34
07/24/81	24.00	29862	716688	187	33
07/25/81	24.00	29862	716688	187	33
07/26/81	24.00	29862	716688	187	33
07/27/81	24.00	29286	702864	193	33
07/28/81	24.00	27674	664176	202	33
07/29/81	24.00	27612	662688	208	33
07/30/81	24.00	27411	657864	210	33
07/31/81	24.00	26716	641184	212	33
08/01/81	24.00	26716	641184	212	33
08/02/81	24.00	26716	641184	212	33
08/03/81	24.00	26015	624360	213	34
08/04/81	24.00	25223	605352	215	33
08/05/81	24.00	25709	617016	223	33
08/06/81	24.00	25911	621864	220	32
08/07/81	24.00	27360	656640	218	33
08/08/81	24.00	27360	656640	218	33
08/09/81	24.00	27360	656640	218	33
08/10/81	24.00	27549	661176	226	33
08/11/81	24.00	27047	649128	228	33
08/12/81	24.00	25643	615432	228	34
08/13/81	24.00	26659	639816	223	33
08/14/81	24.00	24198	580752	226	34
08/15/81	24.00	24198	580752	226	34
08/16/81	22.00	24198	532356	226	34
08/17/81	21.00	23524	494004	231	33
08/18/81	22.00	22521	495462	221	33
08/19/81	20.00	21955	439100	218	33
08/20/81	23.00	24402	561246	215	33
08/21/81	24.00	26111	626664	215	33
08/22/81	24.00	26111	626664	215	33
08/23/81	24.00	26111	626664	215	33
08/24/81	NO OPR	0	0	NO DATA	NO DATA
08/25/81	NO OPR	0	0	NO DATA	NO DATA
08/26/81	NO OPR	0	0	NO DATA	NO DATA
08/27/81	NO OPR	0	0	NO DATA	NO DATA
08/28/81	NO OPR	0	0	NO DATA	NO DATA
08/29/81	NO OPR	0	0	NO DATA	NO DATA
08/30/81	NO OPR	0	0	NO DATA	NO DATA
08/31/81	NO OPR	0	0	NO DATA	NO DATA
09/01/81	NO OPR	0	0	NO DATA	NO DATA
09/02/81	NO OPR	0	0	NO DATA	NO DATA
09/03/81	NO OPR	0	0	NO DATA	NO DATA
09/04/81	NO OPR	0	0	NO DATA	NO DATA
09/05/81	NO OPR	0	0	NO DATA	NO DATA
09/06/81	NO OPR	0	0	NO DATA	NO DATA
09/07/81	NO OPR	0	0	NO DATA	NO DATA
09/08/81	NO OPR	0	0	NO DATA	NO DATA
09/09/81	NO OPR	0	0	NO DATA	NO DATA
09/10/81	NO OPR	0	0	NO DATA	NO DATA
09/11/81	NO OPR	0	0	NO DATA	NO DATA
09/12/81	NO OPR	0	0	NO DATA	NO DATA
09/13/81	NO OPR	0	0	NO DATA	NO DATA

Table 10-3. Continued.

DATE	TIME OF OPERATION (HOURS)	FLOW RATE (BARRELS PER HOUR)	TOTAL DAILY BRINE DISCHARGE (BARRELS)	AVERAGE BRINE PIT SALINITY (O/OO)	AVERAGE BRINE PIT TEMPERATURE (O C)
09/14/81	NO OPR	0	0	NO DATA	NO DATA
09/15/81	24.00	27684	664416	250	33
09/16/81	21.00	24250	509250	258	33
09/17/81	20.00	31896	637920	250	33
09/18/81	24.00	25029	600696	247	31
09/19/81	24.00	25029	600696	247	31
09/20/81	12.00	25029	300348	247	31
09/21/81	14.00	16018	224252	232	30
09/22/81	7.00	23904	167328	219	30
09/23/81	8.00	21800	174400	227	31
09/24/81	15.00	21500	322500	236	31
09/25/81	13.00	21917	284921	223	32
09/26/81	12.00	21917	263004	223	32
09/27/81	12.00	21917	263004	223	32
09/28/81	9.00	22611	203499	NO DATA	NO DATA
09/29/81	14.00	22500	315000	244	33
09/30/81	24.00	NO DATA	NO DATA	NO DATA	NO DATA
10/01/81	23.00	NO DATA	NO DATA	NO DATA	NO DATA
10/02/81	24.00	24100	578400	250	33
10/03/81	3.00	24100	72300	250	33
10/04/81	NO OPR	24100	0	250	33
10/05/81	11.00	21444	235884	222	31
10/06/81	11.00	21622	237842	222	31
10/07/81	NO DATA	21591	NO DATA	219	30
10/08/81	11.50	21500	247250	219	29
10/09/81	14.00	22556	315784	221	30
10/10/81	NO OPR	22556	0	221	30
10/11/81	NO OPR	22556	0	221	30
10/12/81	8.00	21500	172000	221	30
10/13/81	NO OPR	0	0	221	30
10/14/81	7.00	21500	150500	221	30
10/15/81	14.00	21500	301000	245	32
10/16/81	24.00	22060	529440	221	30
10/17/81	23.80	22060	525028	221	30
10/18/81	NO OPR	22060	0	221	30
10/19/81	16.00	23500	376000	220	27
10/20/81	16.50	22500	371250	235	30
10/21/81	16.00	23500	376000	236	31
10/22/81	13.80	23500	324300	232	29
10/23/81	24.00	22500	540000	232	26
10/24/81	24.00	22500	540000	232	26
10/25/81	1.70	22500	38250	232	26
10/26/81	24.00	25000	600000	235	27
10/27/81	24.00	24958	598992	230	27
10/28/81	23.00	24500	563500	225	29
10/29/81	24.00	24738	593712	232	26
10/30/81	24.00	23938	574512	231	28
10/31/81	24.00	23938	574512	231	28
11/01/31	24.00	23938	574512	231	28
11/02/81	22.00	23500	517000	218	25
11/03/81	21.00	22435	471135	218	24
11/04/81	24.00	21500	516000	230	26
11/05/81	24.00	21708	520992	218	25
11/06/81	24.00	21666	519984	216	26
11/07/81	24.00	21666	519984	216	26

Table 10-3. Continued.

DATE	TIME OF OPERATION (HOURS)	FLOW RATE (BARRELS PER HOUR)	TOTAL DAILY BRINE DISCHARGE (BARRELS)	AVERAGE BRINE PIT SALINITY (O/OO)	AVERAGE BRINE PIT TEMPERATURE (O C)
11/08/81	24.00	21666	519984	216	26
11/09/81	24.00	24298	583152	216	22
11/10/81	24.00	23017	552408	218	24
11/11/81	24.00	21427	514248	214	27
11/12/81	24.00	22263	534312	206	18
11/13/81	24.00	22761	546264	211	26
11/14/81	24.00	22761	546264	211	26
11/15/81	24.00	22761	546264	211	26
11/16/81	23.50	22262	523157	211	26
11/17/81	24.00	21563	517512	217	23
11/18/81	24.00	21979	527496	210	25
11/19/81	24.00	23229	557496	209	24
11/20/81	24.00	21283	510792	215	NO DATA
11/21/81	24.00	21283	510792	215	NO DATA
11/22/81	24.00	21283	510792	215	NO DATA
11/23/81	24.00	21500	516000	213	25
11/24/81	19.00	22052	418988	207	25
11/25/81	24.00	21680	520320	209	23
11/26/81	24.00	21680	520320	209	23
11/27/81	24.00	21680	520320	209	23
11/28/81	24.00	21680	520320	209	23
11/29/81	24.00	20680	496320	209	23
11/30/81	24.00	21500	516000	210	24
12/01/81	24.00	22104	530496	205	22
12/02/81	20.00	21681	433620	210	21
12/03/81	24.00	21788	522912	212	23
12/04/81	24.00	21639	519336	212	21
12/05/81	24.00	21639	519336	212	21
12/06/81	24.00	21639	519336	212	21
12/07/81	24.00	21500	516000	208	21
12/08/81	24.00	21500	516000	210	20
12/09/81	24.00	21500	516000	210	20
12/10/81	24.00	21500	516000	207	19
12/11/81	24.00	21850	524400	204	19
12/12/81	24.00	21850	524400	204	19
12/13/81	20.00	21850	437000	204	19
12/14/81	19.00	21552	409488	207	19
12/15/81	19.00	21500	408500	211	17
12/16/81	17.00	21500	365500	202	18
12/17/81	16.00	21500	344000	205	17
12/18/81	24.00	21653	519672	204	15
12/19/81	24.00	21653	519672	204	15
12/20/81	14.00	21653	303142	204	15
12/21/81	17.00	21500	365500	207	18
12/22/81	17.00	21500	365500	203	19
12/23/81	24.00	21500	516000	205	17
12/24/81	24.00	21708	520992	213	NO DATA
12/25/81	24.00	21708	520992	213	NO DATA
12/26/81	24.00	21708	520992	213	NO DATA
12/27/81	22.00	21708	477576	213	NO DATA
12/28/81	24.00	22625	543000	218	21
12/29/81	24.00	23167	556008	222	18
12/30/81	24.00	22586	542064	222	18
12/31/81	24.00	22586	542064	222	18
01/01/82	24.00	22586	542064	222	18

Table 10-3. Continued.

DATE	TIME OF OPERATION (HOURS)	FLOW RATE (BARRELS PER HOUR)	TOTAL DAILY BRINE DISCHARGE (BARRELS)	AVERAGE BRINE PIT SALINITY (O/OO)	AVERAGE BRINE PIT TEMPERATURE (O C)
01/02/82	13.00	22586	293518	222	18
01/03/82	13.00	22586	293618	222	18
01/04/82	9.00	21500	193500	NO DATA	18
01/05/82	7.00	23071	161497	244	23
01/06/82	3.00	22000	66000	NO DATA	NO DATA
01/07/82	4.00	21500	86000	NO DATA	NO DATA
01/08/82	24.00	22359	536616	250	17
01/09/82	8.00	22359	178872	250	17
01/10/82	7.00	22359	156513	250	17
01/11/82	12.00	21542	258504	251	14
01/12/82	11.00	21955	241505	245	13
01/13/82	12.00	21542	258504	252	11
01/14/82	9.00	22420	201780	250	14
01/15/82	9.00	22420	201780	250	14
01/16/82	9.00	22420	201780	250	14
01/17/82	9.00	22420	201780	250	14
01/18/82	9.00	22500	202500	249	14
01/19/82	12.00	22400	268800	254	18
01/20/82	15.00	21660	324900	253	20
01/21/82	14.00	22250	311500	249	21
01/22/82	14.00	22563	315882	240	18
01/23/82	12.00	22563	270756	240	18
01/24/82	12.00	22563	270756	240	18
01/25/82	13.00	22500	292500	239	16
01/26/82	14.00	22500	315000	244	16
01/27/82	14.00	22500	315000	248	18
01/28/82	15.00	23167	347505	243	19
01/29/82	15.00	23167	347505	243	NO DATA
01/30/82	19.00	22713	431547	234	NO DATA
01/30/82	19.00	22713	431547	234	NO DATA
01/31/82	18.00	22713	408834	234	NO DATA
02/02/82	24.00	23500	564000	200	14
02/03/82	24.00	23500	564000	200	14
02/04/82	24.00	23500	564000	215	13
02/05/82	24.00	23500	564000	217	11
02/06/82	24.00	23500	564000	217	11
02/07/82	24.00	23500	564000	217	11
02/08/82	24.00	23500	564000	222	17
02/09/82	24.00	22000	528000	227	10
02/10/82	24.00	22000	528000	229	13
02/11/82	24.00	23000	552000	229	14
02/12/82	24.00	23896	573504	217	16
02/13/82	24.00	23896	573504	217	16
02/14/82	24.00	23896	573504	217	16
02/15/82	24.00	23896	573504	217	16
02/16/82	14.00	26500	371000	137	17
02/17/82	24.00	22604	542496	NO DATA	19
02/18/82	24.00	24000	576000	190	17
02/19/82	24.00	19444	466656	199	18
02/20/82	24.00	19444	466656	199	18
02/21/82	16.00	19444	311104	199	18
02/22/82	24.00	21937	526488	228	19
02/23/82	24.00	21937	526488	228	19
02/24/82	24.00	24500	588000	220	20
02/25/82	24.00	30500	732000	220	18

Table 10-3. Continued.

DATE	TIME OF OPERATION (HOURS)	FLOW RATE (BARRELS PER HOUR)	TOTAL DAILY BRINE DISCHARGE (BARRELS)	AVERAGE BRINE PIT SALINITY (O/OO)	AVERAGE BRINE PIT TEMPERATURE (O C)
02/26/82	24.00	31395	753480	161	14
02/27/82	24.00	31395	753480	161	14
02/28/82	24.00	31395	753480	161	14
03/01/82	24.00	35042	841008	180	16
03/02/82	24.00	35396	849504	NO DATA	18
03/03/82	24.00	34563	829512	198	20
03/04/82	24.00	33367	800808	212	20
03/05/82	24.00	32750	786000	220	16
03/06/82	24.00	32750	786000	220	16
03/07/82	24.00	32750	786000	220	16
03/08/82	13.00	44645	580385	204	14
03/09/82	13.00	24692	320996	225	17
03/10/82	24.00	28253	678072	225	17
03/11/82	24.00	31271	750504	223	20
03/12/82	24.00	31283	750792	232	21
03/13/82	24.00	31283	750792	232	21
03/14/82	24.00	31283	750792	232	21
03/15/82	24.00	30000	720000	230	23
03/16/82	24.00	29679	712296	235	24
03/17/82	13.50	15309	206672	236	24
03/18/82	13.00	15309	199017	236	NO DATA
03/19/82	24.00	32178	772272	NO DATA	NO DATA
03/20/82	24.00	32178	772272	NO DATA	NO DATA
03/21/82	24.00	32178	772272	NO DATA	NO DATA
03/22/82	24.00	33524	804576	246	23
03/23/82	19.50	38192	744744	244	23
03/24/82	24.00	29182	700368	242	24
03/25/82	24.00	32127	771048	249	23
03/26/82	24.00	33167	796008	241	16
03/27/82	24.00	33167	796008	241	16
03/28/82	20.50	33167	679924	241	16
03/29/82	24.00	33542	805008	246	19
03/30/82	24.00	33333	799992	242	NO DATA
03/31/82	21.00	33571	704991	250	22
04/01/82	24.00	33542	805008	254	23
04/02/82	24.00	33542	805008	248	22
04/03/82	24.00	33542	805008	248	22
04/04/82	24.00	33542	805008	248	22
04/05/82	21.00	33905	712005	248	22
04/06/82	24.00	31779	762696	233	21
04/07/82	24.00	31763	762312	236	22
04/08/82	24.00	33087	794088	237	22
04/09/82	23.00	33101	761323	240	21
04/10/82	23.00	33101	761323	240	21
04/11/82	23.00	33101	761323	240	21
04/12/82	24.00	32096	770304	241	22
04/13/82	24.00	31867	764808	241	23
04/14/82	24.00	33175	796200	245	24
04/15/82	24.00	35312	847488	245	26
04/16/82	NO DATA	31722	NO DATA	222	23
04/17/82	NO DATA	31722	NO DATA	222	23
04/18/82	NO DATA	31722	NO DATA	222	23
04/19/82	24.00	29083	697992	232	26
04/20/82	24.00	32792	787008	234	26
04/21/82	24.00	34083	817992	235	23

Table 10-3. Continued.

DATE	TIME OF OPERATION (HOURS)	FLOW RATE (BARRELS PER HOUR)	TOTAL DAILY BRINE DISCHARGE (BARRELS)	AVERAGE BRINE PIT SALINITY (0/00)	AVERAGE BRINE PIT TEMPERATURE (0 C)
04/22/82	24.00	34083	817992	231	21
04/23/82	24.00	33042	793008	NO DATA	23
04/24/82	23.00	33042	759966	NO DATA	23
04/25/82	21.00	33042	693882	NO DATA	23
04/26/82	24.00	33876	813000	228	23
04/27/82	19.00	30870	586530	228	23
04/28/82	24.00	23417	562008	NO DATA	NO DATA
04/29/82	18.00	23315	419670	229	23

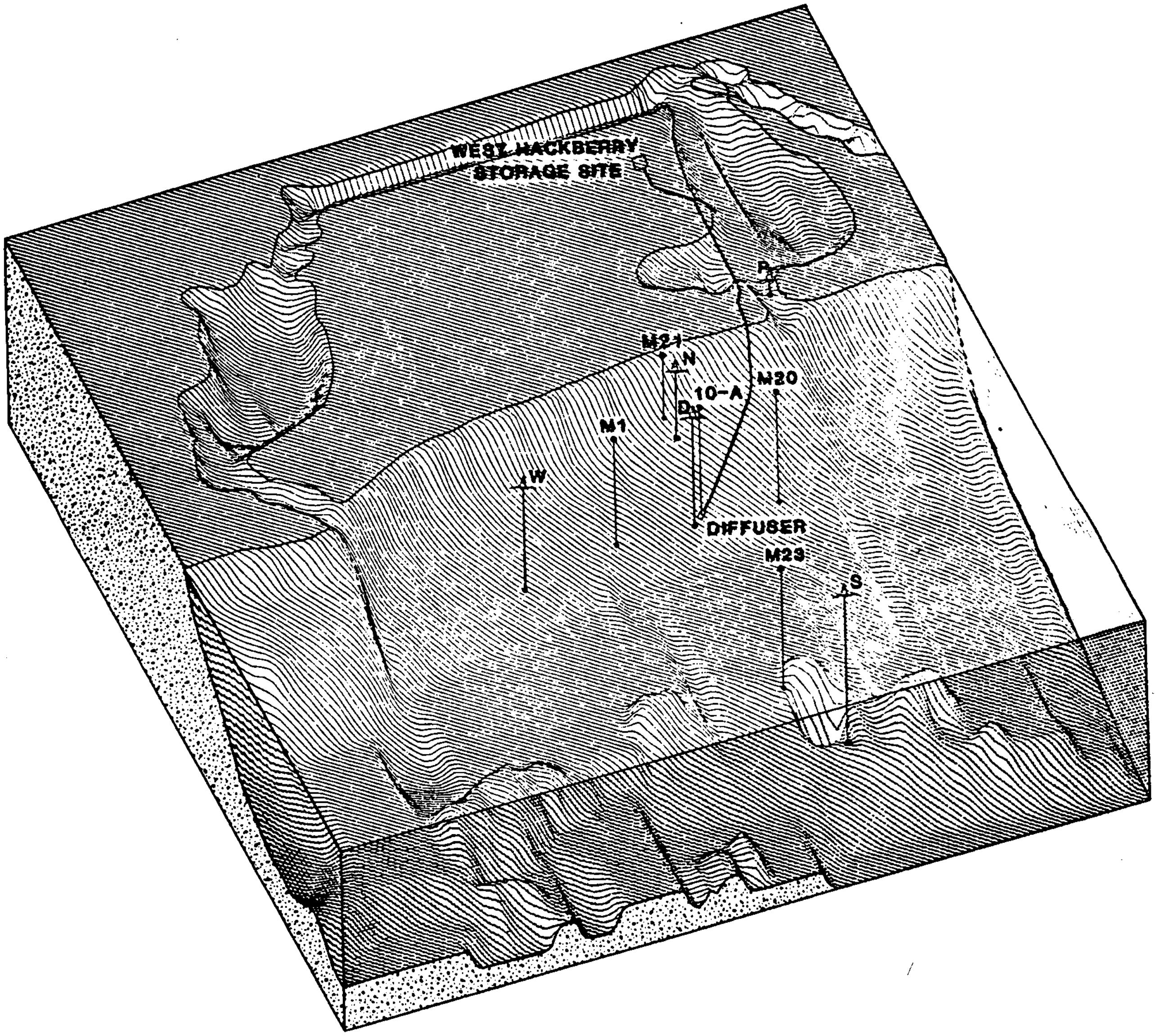

Figure 10-7. Three-dimensional plot of West Hackberry brine disposal site generated from ASPEX/SYMAP program.

1) Letter of Transmittal - a form which briefly states the contents of the tapes which is signed by EDIS staff personnel and returned to the data management section as verification that the tapes have been received.

2) Cover letter and copy of Letter of Transmittal - this is sent separately and simply informs EDIS that a tape is en route.

3) Tape dump - a hard copy of the actual contents of the data contained on the tape.

4) Data Documentation/Data Format - a form which gives specific information on the sampling parameters (location, type of vessel, etc.) and describes the data's format and variables.

5) File List - identifies the sequential location of a specific file contained on the tape.

Copies of these forms are kept by the data management section as well as the project manager for every data transmittal. The tapes are sent by certified mail in clearly marked mailing cartons which describe the contents. The certified mail receipt serves as verification that tapes were sent to EDIS and the returned certified postcard, as well as the letter of transmittal, verifies that EDIS received the tapes. A continuous monitoring of the data from validated data copied onto magnetic tapes to their arrival at EDIS is thus established.

Two additional documentation forms are used in the monthly summary of project data collection and analysis. A Report of Observations/Samples Collected by Oceanographic Programs (ROSCOP), which describes the data variables and collection parameters in an encodable form for the data base at EDIS, is sent monthly at the conclusion of each sampling cruise. The data management section also generates and updates monthly an inventory listing of the status of each project investigator's data files (see Table 10-1). This file contains information on the current status of each section's data and is used as a cross-reference between the data management section and EDIS to insure the project's data is completely transmitted and accurately identified. With the exception of a portion of the physical oceanography data (current vectors), all of the project's data has been transmitted to EDIS through July 1982.

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