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WEST HACKBERRY BRINE DISPOSAL PROJECT
PRE-DISCHARGE CHARACTERIZATION

Final Report

By
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L. M. Jeffrey

January 1982

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 BRINE DISPOSAL PROJECT

PRE-DISCHARGE CHARACTERIZATION

FINAL REPORT

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ABSTRACT

The physical, chemical and biological attributes are described for:

- 1) a coastal marine environment centered about a Department of Energy Strategic Petroleum Reserve (SPR) brine disposal site 11.4 km off the south west coast of Louisiana; and 2) the lower Calcasieu and Sabine estuarine systems that provide leach waters for the SPR project. A three month sampling effort, February through April 1981, and previous investigations from the study area are integrated to establish baseline information for evaluation of impacts from brine disposal in the nearshore marine waters and from freshwater withdrawal from the coastal marsh of the Chenier Plain. January data are included for some tasks that sampled while testing and mobilizing their instruments prior to the February field effort.

The physical oceanographic conditions in the inner coastal zone offshore Calcasieu Pass, Louisiana, were analyzed for January through April 1981 using monthly hydrographic surveys and in situ continuous recorders. January through March coastal waters were relatively homogeneous. In April, pulses of relatively low salinity water were advected intermittently through the area from the east. The average flow of water in Calcasieu Pass was inward during this time.

Salinity data from estuarine hydrographic surveys show Calcasieu Lake increases in salinity from north to south and east to west. Salinity in the Intracoastal Waterway increases from west to east. Calcasieu Lake had much higher salinities than Sabine Lake or the Intracoastal Waterway.

Chemical nutrient data collected from February through April 1981 were within the ranges of information known from previous studies of the area.

Nutrient levels tended to be higher for the inshore stations than for the offshore stations. Results indicated expected effects of runoff. Data from the water and sediment quality studies were compared with data from other studies.

The macrobenthic, fish and nektonic macrocrustacean, phytoplankton and zooplankton communities are described at species and community levels in terms of distribution, abundance, size, composition and diversity. Emphasis is placed on dominant taxa and those species which support commercial and recreational fisheries.

The marine fauna and flora of the diffuser area are characteristic of coastal assemblages of the northwestern Gulf coast. Although dramatic population fluctuations were documented, communities were generally homogeneous within sampling cruises. The macrobenthic community was dominated by polychaetes and phoronids; the nekters were typical of the white shrimp community; the phytoplankton community was dominated by estuarine and neritic species; and the zooplankton community was dominated by copepods with Penaeus spp. and Brevoortia spp. common in the area.

The fauna and flora of the estuarine stations were typical of coastal plains estuaries. The data varied greatly among stations primarily based on sediment type, salinity, or depth regimes.

EXECUTIVE SUMMARY

The West Hackberry salt dome was selected as a Strategic Petroleum Reserve (SPR) site to have a storage capacity of 210 million barrels. The desired storage capacity requires newly mined caverns which are formed by solution mining. Water is to be withdrawn from the Intracoastal Waterway for the leaching process. The resultant brine is disposed offshore through a pipeline and diffuser system. The seaward end of the brine disposal pipeline is located approximately 6.2 nautical miles (11.4 km) offshore Holly Beach, Louisiana, in 30 feet (9.1 m) of water. The diffuser section of the pipelines approximately 3240 feet (98.5 m) in length and has 55 ports. The ports are space on 60-foot (18.2 m) centers. The diffuser system was designed to disperse 1.1 million barrels per day of saturated brine.

The National Pollutant Discharge Elimination System (NPDES) permit for the discharge of brine from this facility requires that monitoring be done in accordance with an EPA approved monitoring plan which is part of the permit.

The monitoring plan includes this pre-discharge characterization and a post-discharge impact assessment. The general objectives of this pre-discharge characterization are to:

1. characterize the existing environment in terms of physical, chemical, and biological attributes;
2. establish baseline information from which evaluations of impacts from brine disposal may be determined; and
3. determine the magnitude of change that will be required to ascertain impact.

An interdisciplinary team of scientists was assembled from McNeese State University, to bear responsibility for the biological tasks (benthos, nekton, phytoplankton, and zooplankton) and the special pollutant task, and from Texas A & M University, to bear responsibility for the offshore physical and chemical oceanography of the study area and the estuarine hydrology and hydrography studies. A total of 34 stations were identified for study: 24 stations in the offshore are in the vicinity of the diffuser and 10 stations in the Calcasieu and Sabine estuarine systems (Figure 1). A three month sampling effort February through April 1981 and previous investigations from the study area are integrated to establish baseline information for evaluation of impacts from brine disposal in the nearshore marine waters and from freshwater withdrawal from the coastal marsh of the Chenier Plain.

The physical oceanographic conditions in the inner coastal zone region offshore of Calcasieu Pass, Louisiana, were analyzed for the period January through April 1981. The analysis is based on a combination of monthly hydrographic surveys and in situ continuously recorded time series of current velocity, temperature and salinity.

From the latter half of January through March, the coastal waters were relatively homogeneous. The temperature and salinity gradients were typically less than 1°C and $1^{\circ}/\text{oo}$ in the vertical, and horizontal gradients were less than 2°C and $3^{\circ}/\text{oo}$ within 20 nm of the coast. Absolute salinity values ranged between $29.5^{\circ}/\text{oo}$ and $33.5^{\circ}/\text{oo}$ during the period, while temperature values followed the annual cycle for the period, warming from about 9°C in late January to about 19°C by late March. Water temperatures dropped by 2°C after the passage of a strong cold front

Figure 1. West Hackberry Offshore Sampling Stations.

Station #	Latitude	Longitude	Loran C		Depth (ft.) (m)	
M-1	29°39'51.4"N	93°33'34.6"W	26522.4	46966.9	31	9.4
M-3	29°39'52.4"N	93°30'34.6"W	26550.6	46966.7	31	9.4
M-6	29°39'52.4"N	93°29'34.6"W	26560.0	46966.7	32	9.8
M-8	29°41'52.2"N	93°28'34.8"W	26580.0	46971.2	26	7.9
M-9	29°40'52.2"N	93°28'35.2"W	26574.8	46968.9	30	9.1
M-10	29°39'52.4"N	93°28'34.6"W	26568.8	46966.7	32	9.8
M-11	29°38'52.2"N	93°28'34.2"W	26564.6	46964.3	34	10.4
M-12	29°37'52.2"N	93°28'34.8"W	26559.6	46962.0	36	11.0
M-13	29°34'52.2"N	93°28'34.8"W	26544.0	46954.9	38	11.6
M-15	29°39'52.2"N	93°27'34.2"W	26579.4	46966.6	32	9.8
M-18	29°39'52.2"N	93°26'34.8"W	26588.4	46966.6	32	9.8
M-20	29°39'52.2"N	93°23'34.8"W	26617.0	46966.4	32	9.8
M-21	29°43'54.6"N	93°28'34.8"W	26598.8	46975.8	18	5.5
M-22	29°31'50.9"N	93°28'34.6"W	26528.9	46947.8	37	11.3
M-23	29°29'48.0"N	93°28'34.6"W	26513.2	46940.6	34	10.4
10-A	29°40'09.0"N	93°28'12.6"W	26574.3	46967.2	31	9.4
DN	29°40'39.6"N	93°28'12.6"W	26577.4	46968.4	30	9.1
DS	29°39'35.0"N	93°28'12.6"W	26572.3	46966.0	33	10.1
DE	29°40'09.0"N	93°27'36.0"W	26580.3	46967.1	31	9.4
DW	29°40'09.0"N	93°28'43.0"W	26569.5	46967.2	32	9.8
CS	29°40'50.0"N	93°18'12.0"W	26668.6	46966.4	33	10.1
NW	29°40'39.6"N	93°28'48.0"W	26571.5	46968.4	30	9.1
SW	29°39'37.2"N	93°28'48.0"W	26566.5	46966.1	33	10.1
NE	29°40'39.6"N	93°27'40.8"W	26582.5	46968.4	30	9.1
SE	29°39'37.2"N	93°27'36.0"W	26577.6	46966.1	32	9.8
Buoy P (E5)	29°46'11"N	93°20'38"W	in pass		20	6.0
D	29°39'54"N	93°28'44"W	46966.7	26568.8	32	9.8
S	29°27'07"N	93°26'00"W	46936.5	26530.2	41	12.5
N	29°42'50"N	93°28'24"W	46973.4	26585.8	21	6.4
W	29°38'30"N	93°40'00"W	46963.7	26454.8	31	9.4
E-1	30°03'32"N	93°26'09"W				
E-2	30°03'05"N	93°18'41"W				
E-3	29°51'33"N	93°22'00"W				
E-4	29°51'20"N	93°18'47"W				
E-5	29°46'11"N	93°20'38"W				
E-6	30°03'47"N	93°20'55"W				
E-7	30°03'35"N	93°41'55"W				
E-8	29°57'32"N	93°42'40"W				
E-9	29°54'07"N	93°48'13"W				
E-10	29°51'45"N	93°55'06"W				

Figure 1. (continued)

on February 10. Dissolved oxygen content was also relatively uniform, and as the vertical sections show, the values ranged between 8 and 9 mg l⁻¹

In April 1981, pulses of relatively low salinity water advected intermittently through the coastal area from the east. The lower salinity water lay close to the coast since it was not recorded by the in situ meters located about 20 nm offshore. Vertical and cross shelf gradients of salinity increased to about 3 ‰ and 7 ‰ respectively. Daily variations as large as 6 or 7 ‰ were recorded at the diffuser site by both the near surface and near bottom instruments. Absolute salinity values in April ranged from about 23 ‰ to 32.5 ‰ at the diffuser site. Temperature values continued to increase to about 26.5°C. Daily temperature fluctuations increased slightly in the inshore waters. The variation in dissolved oxygen had increased slightly by the April 10 cruise when values varied between 7.0 and 8.6 mg l⁻¹.

Average currents were generally weakly westward and onshore during the late January through March time period. In April, the average westward flow increased in magnitude to 21 cm s⁻¹; average cross shelf currents continued to be onshore. Before April, the preferred scalar speed range was usually 5 - 10 cm s⁻¹ often a close second. In April, the preferred scalar speed range increased to 10 - 15 cm s⁻¹.

Flow through Calcasieu Pass (site P) was found to follow the tidal cycle in general, but strong offshore or onshore winds effectively overrode the normal cycle producing longer than normal periods of outflow or inflow. Speeds of up to 150 cm s⁻¹ (about 3 knots) were recorded in February. The average direction of flow was outward but the magnitude decreased through March. During the first half of April, the average flow was

inward. Salinity values followed the daily cycle very closely, decreasing during outflow and increasing during inflow. There was little vertical salinity gradient at site P, which indicates the water in the pass was well mixed.

There has been some question about the offshore extent of the influence of the relatively fresh outflow from Calcasieu Pass, particularly with respect to the diffuser site. In April, when low salinities were recorded offshore, the data show that the average flow at site P was inward, the average cross shelf current at site D was weakly onshore, and there was relatively strong westward along shore flow. It is concluded, therefore, that the low salinities recorded at site P during April were a result of an influx of relatively low salinity water which was being advected from the east along the coast rather than an increase in freshwater discharge through the pass. The extent of the influence of outflow from the Pass during periods of strong outflow and weak offshore currents is not yet documented.

The estuarine hydrography pre-disposal study indicates that the Calcasieu and Sabine Lakes were well mixed estuaries, and only slight stratification in the Intracoastal Waterway was detected. The entrance to the Calcasieu Lake, Calcasieu Pass, was also well mixed except for one sampling day when the salinity increased near the bottom.

The salinity data showed the salinity in the Calcasieu Lake increased from north to south and the west side of the lake tended to be saltier than the east. The salinity in the Intracoastal Waterway increased from west to east. Calcasieu Lake had a much higher average salinity than that found in the Intracoastal Waterway of Sabine Lake. For example, the average

salinity differences between estuaries in January was 19.8 ‰ and it was 6.3 ‰ in April. There were no unexpected results uncovered in this estuarine hydro- graphy study.

The chemical oceanographic nutrient data collected from February through April 1981 were within the ranges of information known from previous studies for the area and for season sampled. Nitrate and nitrite nitrogen concentrations ranged from $< 0.01 \text{ mg l}^{-1}$ to 0.15 mg l^{-1} and < 0.01 to 0.03 mg l^{-1} respectively. Levels for both were higher for inshore stations and in the case of nitrate usually higher at the surface. The range of phosphate phosphorus was < 0.01 to 0.17 mg l^{-1} while total phosphorus levels were < 0.01 to 0.14 mg l^{-1} . That some of the phosphorus is associated with particulate material is indicated by the fact that several sample phosphate values exceeded total phosphorus probably as a result of difficulty in obtaining uniform samples when they are not filtered.

Dissolved oxygen values ranged from 5.1 to 12.1 mg l^{-1} and were lower in April as expected partially as a result of temperature increases within the water column.

Both turbidity and oil and grease were highest in April suggesting both parameters are influenced by runoff. Turbidity levels were from 2 - 62 NTU. Oil and grease ranged from < 0.5 to 2.0 mg l^{-1} ; however, with the exception of April most samples were below the detection limit of 0.5 mg l^{-1} . In that high values in April suggest association with runoff, there appeared to be no difference between inshore and offshore stations.

The sediment pore water salinities at the inshore stations (E1 to E5) were highly variable with both time and location. The pore water salinities in the nearshore sediments are consistently less saline than those offshore, i.e., the range of pore water salinities at stations E1 to E5 are 9.1 ‰ to 26.3 ‰ from February through April 1981. The range of the pore water salinities for the offshore stations were 26.4 ‰ to 33.4 ‰.

Organic carbon in the sediments of West Hackberry ranged from 0.16 to 1.04% (dry weight), but the majority of the samples ranged from 0.4 to 0.8% dry weight. The low percentages were found in sandy sediments and the high ones in clay-rich sediments. In general, the estuarine sediments (E1 to E5) were somewhat richer by 0.1 to 0.2% in organic carbon than the offshore sediments at a given sampling period.

The percentages of sand, silt and clay indicate that the estuarine stations were apparently variable in texture with time. The sediments offshore generally had higher percentages of clay and lower mean diameters than the estuarine stations, but both areas were poorly sorted.

In general, water and sediment quality appears to be as expected for summer months.

Samples were collected for the Special Pollutant survey on March 13 and May 5, 1981. Samples of water and sediment were collected station E1, intake structure, and sediment and two species of benthic biota were collected at station M10, the diffuser. The survey included the measurement of pH, Eh, the major ions (Ca, Cl, K, Mg, Na, SO₄), total metals (As, Cd, Cr, Cu, Hg, Pb, Zn) and common pesticides, herbicides and high molecular weight hydrocarbons. The concentrations of major ions and

total metals closely paralleled previously determined values reported for the Gulf coast area. No detectable levels of pesticides and herbicides were found in any of the samples collected. However, high molecular weight hydrocarbons were found in the sediment samples particularly during the March 1981 survey.

The biological communities of the diffuser area and Calcasieu River estuary were characterized employing monthly data collected during the pre-discharge study, February through April, 1981, as well as previous investigations. Species and community parameters investigated included distribution, abundance, size, composition and diversity. The macrobenthos, fish and macrocrustaceans, phytoplankton and zooplankton communities were studied in detail. Emphasis was placed on dominant taxa and on those species which support commercial and recreational fisheries. The purpose of this characterization was to establish baseline information to assist in evaluation of environmental impacts from brine discharge.

The marine macrobenthic fauna of the diffuser area was characterized by strong numerical dominance of relatively few species which show dramatic population fluctuations both spatially and temporally. In this regard the macrobenthos were more typical of an estuarine community than a true continental shelf fauna. Such a community would be maintained by the high turbidity and low salinity associated with river runoff, seasonal variations in temperature, and general inconstancy of the area due to severe perturbations caused by storms and seasonal anoxic conditions. The ampharetid polychaete, Sabellides sp. A, and the phoronid, Phoronis sp. A, were the numerically dominant species throughout the study area.

Sediment type in the study area ranged from silty clay to sand mud,

never with more than 48% sand. The percentage of sand was lowest at the diffuser and immediately to the north, and increased to the east, south and west. Some habitat and faunal differences were revealed by the multivariate analyses between those stations near the diffuser and the perimeter stations (M1, M3, M11 and CS). However, even considering substrate-related faunal differences, the benthic fauna of the study area is remarkably homogeneous. The homogeneity should greatly enhance the ability of the station to station comparisons to detect environmental impacts following brine discharge. Pre-discharge and post-discharge comparisons will be less useful since dramatic and unpredictable population irruptions of many species occurs.

The white shrimp community is the major soft bottom nekton community that dominate in the bathymetric range between 3.7 - 21.9 m. Typical dominant species included: invertebrates Penaeus setiferus (white shrimp), Lolligunula brevis (thumbstall squid), Squilla empusa (mantis shrimp), and Callinectes similis (blue crab); the vertebrates Micropogonias undulatus (Atlantic croaker), Cynoscion arenarius (sand sea trout), Cynoscion nothus (silver sea trout), Stellifer lanceolatus (star drum), Arius felis (sea catfish), Menticirrhus americanus (southern kingfish), Prionotus tribulus (bighead searobin), and Anchoa hepsetus (striped anchovy). Species compositions at the diffuser area stations was characteristic of this white shrimp community. The area was remarkedly homogeneous with nekton community structures essentially alike, particularly at the 10 m contour. Nekton communities at station M21 (inshore control) and M22 (offshore control) were noticeably different from the 10 m stations, presumably because of depth differences. Abundance in biomass and in numbers of individuals increased from February to March.

The phytoplankton community characterization was based on: biomass, chlorophyll-a, numerical dominance, species composition and diversity. There were 110 taxa of phytoplankton identified during this study. The diatoms (73%) and dinoflagellates (14%) were the predominant groups present in the community. Thirty-six (36) genera and eighty-one (81) species of diatoms were identified, and nine (9) genera and fifteen (15) species of dinoflagellates were identified.

The most frequently encountered taxa were species of Prorocentrum, Coscinodiscus, Skeletonema, Thalassiosira, Biddulphia, Chaetoceros, Bhizosolenia, Asterionella, Navicula, Nitzschia, and Thalassiothrix. This assemblage is indicative of the saline Gulf waters and species of these genera were found during all three months of the study.

During February there was a good vertical mixing of the water column with a tendency for weak stratification by late March. Winter mixing of the benthic and pelagic phytoplankton community was noted, with separation of these two assemblages by late March. In general the marine stations were dominated by estuarine and neritic species although some oceanic species of diatoms and dinoflagellates were also present. The spring warming trend permitted the development of a nanoplankton bloom in the surface waters by March 31, 1981, as noted in the chlorophyll data. Pigment data, species diversity indices, total organisms, and species composition were comparable with the results of other studies. No significant differences were noted between our study area and other coastal areas in the north central Gulf of Mexico. Minor differences were noted in species composition between this study and that reported for the delta region of the Mississippi River.

Statistical comparisons were made between stations for both the surface and bottom samples for chlorophyll-a, Shannon-Weaver species information index, and total organism data. Although one-way analysis of variance (ANOVA) showed significant differences between stations, the Duncan's new multiple range test revealed no established pattern of variation. This was probably caused by patchiness of the phytoplankton in the study area. It is therefore concluded that all the marine pre-discharge stations were similar, and among-station comparisons could be used to monitor the possible impact of brine discharge on the neritic phytoplankton community in the study area.

The zooplankton and meroplankton communities in the vicinity of the diffuser site were examined for small-scale variability which may change with perturbation. The hypothesis was that no consistent patterns of variability exist which could mask diffuser effects and prevent an adequate assessment of impacts once brine discharge began.

Triplicate daytime samples were collected monthly at each of three depth strata (near-surface, mid-depth, and near-bottom) at nine offshore stations. The zooplankton community in the vicinity of the West Hackberry brine disposal site is typical of the coastal assemblage from the northwestern Gulf of Mexico and should be expected to follow the seasonal patterns outlined by other investigators. A significant finding was the presence of Penaeus postlarvae in the diffuser area in February and again in April. The common occurrence of postlarval Penaeus sp. and Brevoortia sp. at the diffuser area implies a potential for impact to these fisheries from brine discharge at the West Hackberry site.

In the analyses of variance (ANOVA) of zooplankton biomass, significant variance among stations were found in nine (9) of 18 subsets, all but three of which were collected with .333 mm mesh nets. Since no consistent areal patterns of similarity among stations were described by numerical classification of Student-Newman-Keuls (SNK) analyses of the samples, this variance in biomass among stations was probably a result of the scale of patchiness in the small zooplankton which are retained in the .333 mm mesh but not in the .505 mm mesh. This interpretation is supported by the ANOVA and SKN analyses of copepod abundance. If a physical feature of the system was causing faunal heterogeneity, it should show up as a consistent areal pattern in the fauna. Although there were patterns in these data which could mask diffuser effects for a given month, a long-term study would document impacts as a consistent vector superimposed on the community dynamics of the coastal zooplankton.

The fauna and flora of the estuarine stations were typical of coastal plains estuaries. Most species collected are able to withstand a wide range of environmental conditions and are widely distributed throughout estuaries of the northern Gulf of Mexico. The estuarine stations represented distinct habitats separable on the basis of salinity, sediment types or depth regimes. Station E5 at Calcasieu Pass was qualitatively similar to the coastal community of the marine study area.

The estuarine benthic fauna was numerically dominated by polychaetes and molluscs, particularly Paraprionospio pinnata, Mediomastus californiensis, Streblospio benedicti, Mulinia lateralis and Macoma mitchilli. Differences among stations was primarily attributable to the salinity gradient with station E5 more comparable to marine stations than

to the other estuarine stations both in species composition and abundance.

Forty-nine species of nekters were collected in the estuary of which thirteen species comprised 98% of the total number caught. The dominants were: Micropogonias undulatus (Atlantic croaker), Anchoa mitchilli (bay anchovy), Penaeus aztecus (brown shrimp), Callinectes sapidus (blue crab), Brevoortia patronus (Gulf menhaden), and Penaeus setiferus (white shrimp). Cluster and discriminate analyses suggest marked differences among the estuarine stations perhaps associated with depth and salinity differences.

The five estuarine stations were separated into two groups, the northern (E1 and E2) and the southern (E3, E4, and E5), by distance, physical parameters and phytoplankton communities. The lower salinities at stations E1 and E2 demonstrated the pronounced influence of the Calcasieu River, which was also reflected in the freshwater diatom assemblage of Anomoeoneis, Navicula and Melosira. Stations E3, E4 and E5 were characterized by higher salinities and common estuarine phytoplankton species. Station E5, being nearest to the Gulf of Mexico, was higher in salinity and frequently supported phytoplankton species from the adjacent neritic community. The pigment values and number of organisms were much higher E5 than in the nearby offshore stations, but this was not unusual for a shallow estuary with high productivity and eutrophication caused by phosphate loading from adjacent agricultural activities. Both biological and statistical analyses indicated that the phytoplankton communities of the estuarine stations were not sufficiently similar for matched-site comparisons.

The zooplankton community of the Calcasieu River estuary was typical of Gulf coast estuaries and was dominated by the copepod Acartia tonsa.

Similarly, the meroplankton identified are common in estuaries along the Gulf coast. Normal seasonal changes in the zooplankton community can be expected to follow those that have been described for other similar estuaries.

Numerical classification indicated an along-estuary gradient, with Calcasieu Pass station E5 particularly distinct from the rest of the estuary. Station E5 was qualitatively similar to the coastal community of the marine study area. It therefore seems likely that displacement of the community up-estuary should be detectable by increased similarity between station E5 and the other estuarine stations.

The data for this pre-disposal study is compiled on tape and available through the Environmental Data and Information Service (EDIS).

CHAPTER 1

INTRODUCTION

1.1 Overview of the Strategic Petroleum Reserve Program

The Strategic Petroleum Reserve (SPR) is a program currently being implemented by the U.S. Department of Energy (DOE) as mandated by Congress through the Energy Policy and Conservation Act of 1975. The purpose is to provide the United States with sufficient petroleum reserves to minimize the effects of any future oil supply interruption. In the Act, Congress declared the policy of the United States Government to provide for storing up to one billion barrels of crude oil and petroleum products.

Storing up to one billion barrels of oil is a difficult logistics problem to solve, and several alternatives were proposed in the early stages of the SPR program. Some of these were: (1) using existing surface tankage and building new surface tanks as needed; (2) using surplus tanker ships; (3) using existing salt mines in salt formations; and (4) constructing new solution mine cavities in salt formations. The concept of storing oil in solution mine caverns in salt domes was the most attractive option because of relatively low cost of such storage, and the geological stability of rock salt masses.

Of approximately 800 salt domes and 300 existing salt mines, five were selected as Early Storage Reserve sites (ESR). Four of these sites were in Louisiana, and one site was in Texas. These sites are centered around major interstate oil terminals and pipeline systems which transport crude oil from the Gulf coast to upper Midwest markets or to East coast and Caribbean refineries.

Developing underground storage for a billion barrels of oil requires a system of wells to pump the oil into the ground, and a way to create enough storage space for the oil itself. The oil storage caverns are formed by injecting water into the salt deposits, and pumping out the resulting brine. It is known as "solution mining." The process requires a large volume of water, about 7 barrels of fresh water, or about 8 barrels of sea water for every barrel of space created.

1.2 Scope of West Hackberry Predischarge Studies

This project centers around the SPR site known as the West Hackberry salt dome and is currently designed to store 210 million barrels of crude oil. The dome is located in north-central Cameron Parish of southwestern Louisiana. The site is approximately 20 mi (32.2 km) southwest of Lake Charles, Louisiana. The Sun terminal at Nederland, Texas, serves as the oil supply and distribution terminal for West Hackberry. It is about 40 mi (64.4 km) west of the site.

At West Hackberry, the resultant brine from solution mining is disposed offshore through a pipeline and diffuser system (Figure 1-1). The seaward end of the brine disposal pipeline is located about 6.2 nm (11.4 km) offshore in 30 ft (9.1 m) of water. The diffuser section of the pipeline is approximately 3240 ft (987.5 m) long and has 55 brine discharge ports. The ports are spaced 60 ft (18.2 m) apart.

The National Pollutant Discharge Elimination System (NPDES) permit for discharging brine from this facility required that environmental studies be done concomitant with discharge according to an EPA monitoring plan.

The general objectives of this predischarge characterization study are to

1. Characterize the existing environment in terms of physical,

Figure 1-1. Brine disposal site for West Hackberry.

chemical and biological attributes.

2. Establish baseline information from which determination of impacts from brine disposal may be determined.

3. Determine the magnitude of change that might be required to ascertain impact.

An interdisciplinary team of scientists from McNeese State University made biological measurements of phytoplankton, zooplankton, nekton, and benthic organisms, as well as a special pollutants study. Texas A&M University scientists worked on characterizing the offshore physical and chemical oceanography of the region as well as the estuarine hydrology and hydrography. Measurements were taken at 34 stations at the West Hackberry SPR site: 24 stations were located in the offshore area in the vicinity of the diffuser, and 10 stations were in the Calcasieu and Sabine estuarine systems. Table 1-1 and Figure 1-2 identify the approximate locations of these stations. Exact locations may vary slightly for each task based on task-specific requirements or instrument locations for a site. In the following chapters, the specific hypotheses, sampling designs, statistical analyses, results, and interpretations of the predischage study are detailed for each task.

1.3 Characteristics of the SPR West Hackberry Study Area

1.3.1 Nearshore Hydrologic Processes

The coastal waters of the western Louisiana area are driven by several forces: wind, waves, tide, atmospheric pressure gradients, and semipermanent currents. Wave-driven currents control the circulation patterns in the immediate nearshore zone. Rainfall and freshwater inflows from rivers, such as the Calcasieu, Mermentau, Atchafalaya and Mississippi, mix with Gulf waters to bring about density gradients that are important in

Station #	Latitude	Longitude	Loran C		Depth (ft.) (m)	
M-1	29°39'51.4"N	93°33'34.6"W	26522.4	46966.9	31	9.4
M-3	29°39'52.4"N	93°30'34.6"W	26550.6	46966.7	31	9.4
M-6	29°39'52.4"N	93°29'34.6"W	26560.0	46966.7	32	9.8
M-8	29°41'52.2"N	93°28'34.8"W	26580.0	46971.2	26	7.9
M-9	29°40'52.2"N	93°28'35.2"W	26574.8	46968.9	30	9.1
M-10	29°39'52.4"N	93°28'34.6"W	26568.8	46966.7	32	9.8
M-11	29°38'52.2"N	93°28'34.2"W	26564.6	46964.3	34	10.4
M-12	29°37'52.2"N	93°28'34.8"W	26559.6	46962.0	36	11.0
M-13	29°34'52.2"N	93°28'34.8"W	26544.0	46954.9	38	11.6
M-15	29°39'52.2"N	93°27'34.2"W	26579.4	46966.6	32	9.8
M-18	29°39'52.2"N	93°26'34.8"W	26588.4	46966.6	32	9.8
M-20	29°39'52.2"N	93°23'34.8"W	26617.0	46966.4	32	9.8
M-21	29°43'54.6"N	93°28'34.8"W	26598.8	46975.8	18	5.5
M-22	29°31'50.9"N	93°28'34.6"W	26528.9	46947.8	37	11.3
M-23	29°29'48.0"N	93°28'34.6"W	26513.2	46940.6	34	10.4
10-A	29°40'09.0"N	93°28'12.6"W	26574.3	46967.2	31	9.4
DN	29°40'39.6"N	93°28'12.6"W	26577.4	46968.4	30	9.1
DS	29°39'35.0"N	93°28'12.6"W	26572.3	46966.0	33	10.1
DE	29°40'09.0"N	93°27'36.0"W	26580.3	46967.1	31	9.4
DW	29°40'09.0"N	93°28'43.0"W	26569.5	46967.2	32	9.8
CS	29°40'50.0"N	93°18'12.0"W	26668.6	46966.4	33	10.1
NW	29°40'39.6"N	93°28'48.0"W	26571.5	46968.4	30	9.1
SW	29°39'37.2"N	93°28'48.0"W	26566.5	46966.1	33	10.1
NE	29°40'39.6"N	93°27'40.8"W	26582.5	46968.4	30	9.1
SE	29°39'37.2"N	93°27'36.0"W	26577.6	46966.1	32	9.8
Buoy P (E5)	29°46'11"N	93°20'38"W	in pass		20	6.0
D	29°39'54"N	93°28'44"W	46966.7	26568.8	32	9.8
S	29°27'07"N	93°26'00"W	46936.5	26530.2	41	12.5
N	29°42'50"N	93°28'24"W	46973.4	26585.8	21	6.4
W	29°38'30"N	93°40'00"W	46963.7	26454.8	31	9.4
E-1	30°03'32"N	93°26'09"W				
E-2	30°03'05"N	93°18'41"W				
E-3	29°51'33"N	93°22'00"W				
E-4	29°51'20"N	93°18'47"W				
E-5	29°46'11"N	93°20'38"W				
E-6	30°03'47"N	93°20'55"W				
E-7	30°03'35"N	93°41'55"W				
E-8	29°57'32"N	93°42'40"W				
E-9	29°54'07"N	93°48'13"W				
E-10	29°51'45"N	93°55'06"W				

Table 1-1. West Hackberry Offshore Sampling Stations

Figure 1-2. Area map of Texas-Louisiana showing inland and offshore station locations of West Hackberry brine discharge studies.

the circulation at tidal passes and estuary mouths.

Wind speed and direction are the primary factors controlling orientation and size of wave trains approaching the coastline and consequently the overall circulation pattern. Winds along the Louisiana and eastern Texas coast generally come out of the east and southeast, at velocities of 4 to 10 km/hr (5 to 12 mi/hr) in summer, and at slightly higher velocities in winter (Murray, 1976). These winds drive longshore currents toward the west.

Prevailing southeasterly winds often develop swells that contact the bottom of the smooth, gently sloping shallow shelf and shoreface, causing wave trains and currents that control deposition and erosion along the coast. Nearshore waters are very turbid during high river discharge periods and when waves are breaking along the coast. Investigations along muddy coasts indicate that highly turbid waters have a dampening effect on waves (Wells, 1977).

Approximately 92% of the waves along coastal Louisiana are 1 to 2 m (3.3 to 6.6 ft) in height and have a period of 4.5 to 6 sec when wind speeds are greater than 10 km/hr (6.2 mi/hr) (Louisiana Superport Studies, 1972). Waves greater than 2.5 m (8.2 ft) in height occur approximately 30% of the time during winter but only 2% of the time in mid summer. Thus, the Cameron coast is a relatively low-to-moderate energy coastline in terms of offshore waves. The shallow slope of the continental shelf apparently attenuates the offshore wave power sufficiently to yield the low energy environment of the coast.

Winds associated with winter frontal passages or hurricanes produce large and sustained waves offshore. Hurricanes usually have a net drift toward the northwest. They can cause considerable modification to the

shelf waters and generally drive oceanic waters onto the shore and into estuaries. The intense wave action associated with hurricanes reworks the shelf sediments and can transport large quantities of sediments shoreward.

The significant inflow of fresh turbid water from the Mississippi and the Atchafalaya River reduces nearshore salinities. During the flood season, the salinity levels in the Hackberry diffuser area are similar to salinity levels in the estuaries, i.e., 10 o/oo to 20 o/oo.

Tides in the vicinity of Sabine and Calcasieu lakes are as high as 0.7 m (2.3 ft) and are capable of producing significant tidal currents.

Mudflats result from the net effect of sedimentary input from local rivers, the Mississippi and Atchafalaya Rivers and the general westward drift, and the erosional forces of the coastal waves and longshore currents. When sedimentation exceeds erosion, mudflats may develop offshore of the beach. During severe storms the mud, along with whatever beach material is present, may be driven landward over the adjacent marshes.

Turbidity is high along the nearshore zone when waves are breaking, and each breaking wave injects plumes of fine-grained sediment into the water column. On long stretches of the coast, water energies are essentially working against shoal mud bottoms. Coarse-grained sediments are deficient except at locations where the beaches are either holding their own or experiencing slight accretion. The remainder of the coast is experiencing retreat over marshlands and bay bottoms that provide the source of fine-grained sediments and much of the broken shell that makes up the beach. The Atchafalaya Bay is becoming an increasingly important source of fine-grained material, which drifts westward and enhances the sediment supply. Evidence indicates that Atchafalaya suspended sediments

drift westward as far as the Sabine River (Wells, 1977).

Deficiencies of course-grained sediments are also reflected in the general absence of extensive dune fields along the coast and of well-developed offshore bars. Hackberry Beach constitutes the only area of important dune activity. Offshore bars that constitute conspicuous features along the Texas coast are only subtly developed along western Louisiana.

Despite local geomorphic variation, the Calcasieu area can be characterized by the following general subunits (Figure 1-3):

A) Tidal region -- responds to direct exchanges of water with the Gulf via tidal action.

B) Riverine region -- primarily controlled by freshwater inflows.

C) Wind-driven region -- responds to tides and river discharge but is dominated by wind-driven circulation.

D) Wetland region -- responds to tides, winds, rain and evaporation.

1.3.2 Hydrology around the Hackberry Diffuser Area

Murray (1976) demonstrated that offshore salinity patterns are similar along western Louisiana except for the Calcasieu area. He found the salinities were close to deep ocean salinity during months of low river discharge. Salinity values were low during months of high river discharge (Figure 1-4). During the flood month (December) of 1963 (a dry year in Louisiana), estuarine levels of salinity existed along most of the open Louisiana coast. The dilution of Gulf waters occurred because of the large amount of river discharge. The Calcasieu area has salinities lower than the surrounding area. We have not ascertained the cause of this.

The Calcasieu estuary is shallow (1 to 2 m or 3.3 to 6.6 ft). In the past, Calcasieu Pass had a shallow sill that prevented formation of a salt

Figure 1-3. Idealized Hydrologic Regions and Habitats of the Calcasieu Area (from Gosselink, Cordes, and Parsons, 1979).

Figure 1-4. Average surface salinity (o/oo) contours along the Louisiana coast during (A) high river stage, April 21-29, 1963 and (B) low river stage, December 11-16, 1963 (Murray, 1976)

wedge that could move inland. However, deep dredged channels (15 m or 49 ft) now exist in the Calcasieu and Sabine basins and these have allowed significant salt water intrusion directly into the northern end of both Lakes.

Tidal ranges along western Louisiana are low in comparison to tides along other coasts. They fall in the micro-tidal range, i.e., tidal ranges less than 2 m (6.6 ft). The mean tidal range at the coast is about 60 cm (24 in), varying from about 30 cm (12 in) at East Bay to about 75 cm (30 in) at Calcasieu Pass (Table 1-2). This range attenuates upstream depending on the depth, bottom, and shape of the channel.

The water regime displays high tides in spring and in late fall (Figure 1-5). The spring high may be associated with river stages and abundant local rainfall. The fall peak seems to be a result of the predominant southerly summer winds that gradually build up the water level along the northern Gulf coast. This seasonal cycle means that wetland inundation does not occur equally throughout the year.

Salt marshes receive regular flooding from tidal waters. As tides attenuate upstream meteorological forces affecting water levels become more dominant. If marsh elevation is assumed to be at local MHW, at Calcasieu Pass water exceeds this elevation 243 times per year and remains over the marsh for an average of 6.9 h/inundation. Upstream at Hackberry where freshwater runoff primarily controls water levels, the same elevation (e.g., local MHW) was exceeded only 200 times but the mean inundation was of longer duration (Table 1-3).

Seasonal flooding of marshes near Hackberry occurs most often during the fall and winter months (Figure 1-6). This does not correspond with the months of highest mean water, May through September (Figure 1-5). However,

Table 1-2. Mean coastal tidal fluctuations for Chenier Plain basins.

Basin	Tidal fluctuations	
	Mean (cm)	Standard deviation (cm)
Vermilion	37.5	±15
Mermentau ^a	0.0	0.0
Chenier	24-42	±19
Calcasieu	75	±41
Sabine	40	±47
East Bay	30	

^aHas no tide.

Figure 1-5. Monthly water-level fluctuations for 1963-1966, and monthly mean and standard deviation, 1963-1974 in the Calcasieu Basin (U.S. Army Corps of Engineers)

Table 1-3. Duration of water above local MHW, frequency of inundation, and mean inundation duration in 1971 in the Calcasieu Basin
(data from U.S. Army Corps of Engineers).

Hydrologic unit	Time above MHW (% of Yr)	Frequency (inundations/yr)	Mean duration of inundations (hr)
Calcasieu Basin			
Cameron Pass	19.2	243	6.9
Hackberry	29.1	200	12.7

Figure 1-6. The hours per month that the water levels are above mean high water in marshes at Hackberry, Louisiana (U.S. Army Corps of Engineers)

it does correspond with the months when the variation in water level is high, as indicated by the standard deviation curve. During the summer, water levels are high but are below marsh elevation. In the early winter and spring, the mean water level is lower, but the marshes are flooded more often and there is a greater range in water level fluctuations. The increased variability in winter is probably associated with storms and illustrates the importance of rain and wind for marsh flooding.

The pattern of inundation is important for another reason (Figure 1-6). During the months of June, July, and August, salinities are highest in the estuaries because of a combination of high sea stage (Figure 1-5) and low rain surplus. During this period, marshes can flood with water more saline than normal. When such floods occur during a period without rain and with high evapotranspiration rates, salts accumulate in marsh sediments. This may have serious consequences in fresh, intermediate, brackish, and salt marshes. For instance, there is some indication that periodic salt accumulation has killed stands of saltmeadow cordgrass in brackish marshes along Calcasieu Lake. The salt accumulation is a result of the overall salinity increase accompanying dredging of the Calcasieu Ship Channel (Gosselink, Cordes, and Parsons, 1979).

Generally, man has modified the hydrologic regime of this area to such an extent that there are few, if any, areas unaffected by human intervention. The quantitative evaluation of the effects of modification in the hydrologic regime is limited because there are few good hydrodynamic models for the area. Good models should be a priority item for water resource management because water flows are the key to the productivity of the area. Existing models have demonstrated their usefulness. The U.S. Army Corps of Engineers (1950) predicted saltwater intrusion from a model

CHAPTER 2

PHYSICAL OCEANOGRAPHY

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2.1 Introduction

This chapter discusses the physical oceanographic data collected during the period January through April of 1981. The objectives of this pre-discharge phase are to characterize the physical oceanographic conditions which existed during this period and to provide environmental data for the other tasks.

The results of the hydrographic surveys are presented and interpreted first in section 2.2. The time series data from the in situ recording current meters are presented next in section 2.3. The data from the wave/tide recorders are not discussed at this time because of hardware problems with the wave/tide magnetic tape reader which have delayed the analyses of this data. In section 2.4 the meteorological data, collected by NOAA/NDBO, are discussed.

The field procedures, data processing methods and data quality assurance procedures have been described in detail in previous reports (Kelly and Randall, 1980; Kelly et al., 1981; Randall and James, 1981).

This data adds to the data base developed by previous D.O.E. funded

studies of the area (DOE, 1978; Frey, et al., 1981). However, in order to be responsive to the need for timely dissemination and analysis of this new data, a comprehensive comparison with previously collected data is beyond the scope of this report. The conclusions in this chapter about average or typical ambient conditions are restricted to the period covered by the data: January through April 1981. Both annual and interannual variations in this area are large. It is hoped that in future reports larger data sets can be analyzed with a view towards a quantitative description of the average annual cycle of the study area.

2.2 Monthly Offshore Hydrographic Data

2.2.1 Sampling Station Locations and Data Collection Equipment and Procedures

The monthly hydrography of the coastal waters off Cameron, Louisiana, has been evaluated using conductivity, temperature, depth, and dissolved oxygen (CTD/DO) data which were collected at fifteen offshore stations as shown in Figure 2-1. The offshore stations are arranged in an alongshore transect (stations 20, 18, 15, 10A, 6, 3, and 1) and a cross shelf transect which includes stations 21, 8, 9, 10A, 11, 12, 13, 22, and 23. (The designation "M" has been omitted from offshore (i.e., marine) numbering in the text of of this report.) The latitude and longitude and the LORAN C coordinates for the offshore stations are tabulated in Table 2-1. The offshore hydrographic data are collected synoptically once a month during a one-day (about 10 hours) cruise.

A Hydrolab 8000 CTD/DO water quality instrument (Hydrolab, 1980) was used to measure the hydrographic data at the offshore stations. This instrument consists of a data transmitting unit (probe), the data bus cable (conductor cable), and the data control unit (remote readout). The probe

Table 2-1. Latitude, longitude and LORAN C coordinates for the monthly offshore hydrographic sampling stations.

Station Number	Offshore			
	Latitude	Longitude	Loran C	
M-1	29°39'51.4"N	93°33'34.6"W	26522.4	46966.9
M-3	29°39'52.4"N	93°30'34.6"W	26551.1	46966.7
M-6	29°39'52.4"N	93°29'34.6"W	26560.3	46966.7
M-8	29°41'52.2"N	93°28'34.8"W	26580.0	46971.2
M-9	29°40'52.2"N	93°28'34.2"W	26574.8	46968.9
M-10 A	29°40'09.0"N	93°28'12.6"W	26574.5	46967.2
M-11	29°38'52.2"N	93°28'34.2"W	26564.6	46964.3
M-12	29°37'52.2"N	93°28'34.8"W	26559.6	46962.0
M-13	29°34'52.2"N	93°28'34.8"W	26544.0	46954.9
M-15	29°39'52.2"N	93°27'34.2"W	26579.4	46966.6
M-18	29°39'52.2"N	93°26'34.8"W	26588.4	46966.6
M-20	29°39'52.2"N	93°23'34.8"W	26617.0	46966.4
M-21	29°43'54.6"N	93°28'34.8"W	26590.8	46975.8
M-22	29°31'50.9"N	93°28'34.6"W	26528.9	46947.8
M-23	29°29'48.0"N	93°28'34.6"W	26513.2	46940.6

is capable of measuring conductivity (0 - 200 mmho/cm), depth (0 - 200 m), temperature (-5°C - +45°C), dissolved oxygen (0 - 20 ppm), and pH/ORP. The latter parameter is used in the water quality component of the project.

The accuracy of the conductivity sensor (four electrode type) is $\pm 0.5\%$ of full scale which is 200 mmho/cm at 25°C, and this corresponds to ± 1 mmho/cm or ± 0.7 o/oo. The accuracy of conductivity sensor was improved to at least ± 0.5 o/oo by calibrating it with standard solutions using a Grundy laboratory salinometer which has an accuracy of ± 0.003 o/oo (Grundy, 1978). The temperature and depth sensors have an accuracy of $\pm 0.2^\circ\text{C}$ and ± 1 m, respectively. The dissolved oxygen sensor was calibrated before and after each field trip using ambient saturated air and Winkler analysis of selected water samples.

The procedure for collecting the monthly hydrographic data was to start at station 21 and proceed directly offshore along the cross shelf transect to station 23. At each station, the Hydrolab 8000 CTD/DO system was lowered from the surface to near bottom. The CTD/DO data were collected 1 m above the bottom, every 3 m and 1 m below the surface. When the cross shelf transect was completed, the ship proceeded to station 1 and began sampling the alongshore transect. The data collected were recorded in a bound data book and returned to the laboratory for calibration corrections and further analysis. More information on the procedures and equipment is contained in the field and laboratory procedures manual (Randall and James, 1981).

2.2.2 Conversion and Calibration of Field Data

The conductivity data, which are corrected to 25°C by the instrument's own internal temperature compensation circuit, were converted to salinity using:

$$S = 1.80655 \times 10^{\frac{\log_{10} C - 0.57627}{0.892}}$$

after Weyl (1964) where C is the conductivity in mmho/cm at 25°C. After the salinity was determined, it had to be corrected according to calibration results. A calibration curve was determined before and after each sampling cruise by making standard solutions, or collecting water samples, which covered the range of salinities expected in the study area. In the laboratory, the CTD/DO probe was submerged in each water sample and the conductivity was recorded and converted to salinity. The same samples were then processed through the laboratory salinometer. A calibration curve was obtained from the data and used to correct all the salinity data. A more detailed description of these procedures is described in the laboratory and procedures manual (Randall and James, 1981) or in the Bryan Mound predisposal study (Kelly and Randall, 1981).

The temperatures have been used as read from the instrument since they have been within the manufacturer's accuracy specifications. The depth measurement is set to zero with the calibration adjustment. In the field, the depth sensor has frequently required a correction which was determined by a surface (zero depth) reading and a bottom reading which was checked with the ship's depth sounder and the marked winch or lifting line.

The salinity, temperature and depth data were used to compute the density of the water column. This is presented in the customary oceanographic form of sigma-t (σ_t) which is defined as

$$\sigma_t = (\rho - 1.0) \times 10^{-3} \quad (2-1)$$

where the density (ρ) is expressed in gm/cm^3 . Sigma-t values are computed from salinity, temperature and depth using the equation of LaFond (1951).

The dissolved oxygen (DO) sensor was calibrated before and after each field trip. The DO sensor is adjusted to read the DO value for water saturated air at the local atmospheric conditions as described in the operations manual (Hydrolab, 1980). The field data are then corrected for salinity and temperature effects. During the collection of DO data, selected water samples at the same location as the DO sensor are collected and chemically fixed aboard the research vessel. These samples are brought back to the laboratory and analyzed using the Winkler titration procedures. The resulting data are then plotted, and a linear curve fit to the data is determined. Finally, the data are corrected based upon the calibration results.

2.2.3 Vertical Cross-Sections of Temperature, Salinity, Sigma-t, and Dissolved Oxygen

Beginning in January 1981, conductivity, temperature, depth, and dissolved oxygen (CTD/DO) data were collected from the specified sampling stations shown previously in Figure 2-1 at depth of 1 m above the bottom, every 3 m and 1 m below the surface. The conductivity was converted to salinity which was combined with temperature to compute the density. These data were collected to assess the hydrographic conditions in the Cameron, Louisiana, coastal waters prior to the discharge of brine.

The presentation of the monthly CTD/DO data is in the form of vertical cross-sections for an alongshore transect which is nearly parallel to the 10 m isobath and a cross shelf transect which is normal to it. The stations for the cross shelf transect are numbers 21, 8, 9, 10A, 11, 12,

13, 22, and 23, and for the alongshore transect, they are numbers 1, 3, 6, 10A, 15, 18, and 20. The data presented are for the period January through April 1981, and they should be considered as supplemental to the predisposal studies conducted by the National Ocean Survey (Frey et al., 1981) and the Environmental Impact Statement (DOE, 1978).

2.2.3.1 January 1981 Hydrographic Data

The January hydrographic data was collected on January 18, 1981, and the results of the cross shelf transect are shown in Figure 2-2. These data show the temperature increased from 8.9°C inshore to 11.6°C offshore and no thermocline was present. The salinity data show a similar trend with a salinity of 29.6 o/oo at station 21 and 32.4 o/oo at station 22, and the vertical distribution shows the water column was isohaline. The sigma-t data show the water was stable with the density increasing with distance offshore. The dissolved oxygen was near 9 parts per million (ppm) and showed a slight increase with depth. Figure 2-3 shows the hydrographic data for the alongshore transect, and the data indicate the temperature, salinity, sigma-t, and dissolved oxygen were essentially constant with depth and distance alongshore. It should be noted that the data at station 10A was omitted in the alongshore transect because it was collected several hours earlier in the day.

2.2.3.2 February 1981 Hydrographic Data

Two cross shelf transects were sampled during this month on February 3 and 4 as shown in Figures 2-4 and 2-5 respectively. On both days, the temperature increased with distance offshore from 10.8°C to 12.0°C. Vertically, the temperature decreased slightly (0.3°C) with depth. A similar trend was observed with salinity in that it increased with distance offshore from 30.8 o/oo to 32.7 o/oo, and it was isohaline with depth. The

Figure 2-2. Hydrography for cross-shelf transect offshore Cameron, Louisiana for January 18, 1981.

Figure 2-3. Hydrography for alongshore transect offshore Cameron, Louisiana, for January 18, 1981.

Figure 2-4. Hydrography for cross-shelf transect offshore Cameron, Louisiana, for February 3, 1981.

Figure 2-5. Hydrography for cross-shelf transect offshore Cameron, Louisiana, for February 4, 1981.

sigma-t data show there was only one isopycnal (24.0) which was vertical, and thus, the water was stable and well mixed. The dissolved oxygen was essentially constant from top to bottom and increased slightly with distance offshore. For example, on February 3, the dissolved oxygen increased from 8.0 ppm at the bottom of station 21 to 8.5 ppm at station 23. In the alongshore direction, Figure 2-6, the temperature, salinity, sigma-t, and dissolved oxygen were constant both vertically and horizontally. Thus, the February data indicate the water column was well mixed, and no anoxic conditions were observed. These conditions were similar to the conditions in 1979 reported by Frey et al. (1981), but their data showed an increase in salinity and sigma-t from west to east in the alongshore direction.

2.2.3.3 March 1981 Hydrographic Data

The hydrographic data for March 1981 was collected on the seventh day of the month, and these data are plotted on Figures 2-7 and 2-8 for the cross shelf and alongshore transects respectively. The cross shelf transect shows that the inshore temperature had increased to near 15°C and that there was a decreasing trend with distance offshore (15.5°C at station 21 to 14.8°C at station 23). Again, the temperature variations with depth was isothermal. The salinity data showed the salinity was isohaline with depth at all stations except station 13 where it ranged from 32.7 o/oo at the top to 33.7 o/oo at the bottom. As in previous months, the salinity was increased with distance offshore. For example, salinity increased from 31.0 o/oo at station 21 to 33.6 o/oo at station 23. The sigma-t data showed the same increasing trend with distance offshore and there was no evidence of vertical stratification or instability. As in the previous months, no anoxic conditions were detected, and the dissolved oxygen

Figure 2-6. Hydrography for alongshore transect offshore Cameron, Louisiana, for February 4, 1981.

Figure 2-7. Hydrography for cross-shelf transect offshore Cameron, Louisiana, for March 7, 1981.

Figure 2-8. Hydrography for alongshore transect offshore Cameron, Louisiana, for March 7, 1981.

measured near 8.7 ppm. There was only a slight change in the alongshore data from the previous months. For example, the temperature decreased from 15°C at station 1 to 14.8°C at station 20 and the dissolved oxygen decreased from 8.7 ppm to 8.4 ppm.

2.2.3.4 April 1981 Hydrographic Data

Hydrographic data were collected again on April 10, 1981, and the results are presented in the cross shelf direction (Figure 2-9) and in the alongshore direction (Figure 2-10). The temperature data show that temperature increased with distance offshore, and the range was 21.0°C to 19.8°C at the surface and 21.8°C to 19.8°C at the bottom. There still was only a small vertical temperature variation with the warmer temperature at the surface. For example, the temperature at the diffuser site (station 10A) was 21.3°C at the surface and 20.6°C at the bottom.

The salinity data showed a stronger cross shelf gradient than in the previous months. The salinity increased from 25.6 o/oo at the nearshore station 21 to 33.1 o/oo at the farthest offshore station 23 which is a change of 7.5 o/oo. The vertical salinity variation was small as evidenced by the absence of a halocline and the fact that the isohalines were nearly vertical. The surface salinity at the diffuser site (station 10A) was 27.8 o/oo and the bottom salinity was 28.9 o/oo, a difference of 1.1 o/oo. As expected, the sigma-t data show a trend similar to salinity with denser water offshore, and the density increased with depth which indicated no instability. Like the isohalines, the isopycnals were nearly vertical.

The dissolved oxygen data showed the DO was lowest (6.9 ppm) inshore; it increased to 8.6 ppm at station 11 and decreased to 7.6 ppm at station 23. The largest vertical variation was 1.0 ppm at station 8 where it decreased from 8.0 ppm at the top to 7.0 ppm at the bottom.

Figure 2-9. Hydrography for cross-shelf transect offshore Cameron, Louisiana, for April 10, 1981.

Figure 2-10. Hydrography for alongshore transect offshore Cameron, Louisiana for April 10, 1981.

In the alongshore transect, Figure 2-10, the temperature increased from 20.9°C at station 20 and a slight thermocline was present as evidenced by the 21.0°C isothermal which was located at approximately the 6 m depth. The salinity data indicate the existence of a small volume of fresher water (~27 o/oo) in the center of the transect (stations 15 and 18). At station 15, the salinity increased to 26.3 o/oo at the surface to 28.4 o/oo at the bottom which represents a small halocline. However, at the east and west extremes of the transect, the vertical salinity variation was only 0.3 o/oo. The fresher water was as evident in the sigma-t data. A pocket of higher dissolved oxygen readings was also present as is shown in Figure 2-10 by the 8.0 ppm contour. The dissolved oxygen was the lowest measured during this period at 6.2 ppm on the surface and 5.7 ppm at the bottom. Although the dissolved oxygen values were lower than previous readings, there still was no evidence of anoxia.

2.3 Oceanographic Time Series Data

Time series of current velocity (i.e., speed and direction), temperature and conductivity/salinity are recorded at five sites designated D (the diffuser site), N (about 2.8 n.m. north of the diffuser), W (about 10 n.m. west of the diffuser), S (about 13 n.m. south of the diffuser), and P (just inside Calcasieu Pass). At sites D, S, W and P instruments are located 3.7 meters (12 ft.) below the surface and 1.8 meters (6 ft.) above the bottom, and at site N there is just one instrument located 1.8 meters (6 ft.) above the bottom. The location of each instrument is shown in Figure 1-2, and Table 1-1 summarizes the information about each site.

Each site is marked and protected by a large surface witness buoy which has an elastically tethered mooring system to virtually eliminate its watch circle. The instruments are attached to a separate, low tension,

subsurface mooring line located about 7 meters from the witness buoy. The instruments are Environmental Devices Corporation (ENDECO) Type 174 current meters with conductivity and temperature sensors. For further details concerning the instruments and mooring configuration see Kelly et al. (1981).

The first buoy was deployed on December 18, 1980 at site D, and current meters were first deployed at this site on January 18, 1981. Deployment of the remainder of the buoys and instruments was completed by February 26, 1981. However, the buoys and instruments at sites N and W were lost in separate incidents of interference by commercial ships. In addition, some malfunctions occurred in a few of the new ENDECO instruments. Thus no data were obtained at site N and the near surface position at site W, and only a short record was obtained at the near bottom position at site W. Table 2-2 lists the deployment period at each instrument position for which good data was collected.

These data have been analyzed by means of basic statistics (Tables 2-3 through 2-6), current roses and time series plots (Figures 2-11 through 2-39).

The basic statistics for the time series, i.e. minimum, maximum, mean and standard deviation about the mean, were computed for intervals of 366 hours (15-1/4 days) beginning on January 16, 1981 at 0600 hours (CST). This length of averaging interval is long enough to smooth daily and weekly variations but short enough to not mask the significant changes in hydrographic variables. The statistics were computed using hourly values of time series which had been filtered with a 3-hour low pass filter. The low pass filter does not significantly alter the mean value of a series but will reduce spurious spikes in the data which can give unrealistic minimum

Table 2-2. Deployment period at each instrument position for which good data was collected.

Site	TOP	C	T	S	BOTTOM	C	T	S
D	1-21-81 to 2-17-81	X	X	X	1-21-81 to 2-17-81	X	X	X
D	2-17-81 to 3-06-81	X	X	X	2-17-81 to 3-06-81		X	X
D	3-06-81 to 4-04-81		X	X	3-14-81 to 4-04-81	X	X	X
D	4-04-81 to 4-28-81	X	X	X	4-04-81 to 4-16-81		X	X
D					4-16-81 to 4-28-81	X	X	X
D	4-28-81 to 5-12-81	X	X	X	4-28-81 to 5-12-81	X	X	X
P	2-07-81 to 3-15-81	X	X	X	2-07-81 to 2-21-81	X	X	X
P	3-15-81 to 4-04-81	X	X	X	3-15-81 to 4-04-81	X	X	X
P	4-04-81 to 4-29-81	X	X	X	4-04-81 to 4-29-81	X	X	X
P	4-29-81 to 5-20-81	X	X	X	4-29-81 to 5-20-81	X	X	X
S					2-17-81 to 3-06-81	X	X	X
S	3-06-81 to 3-30-81	X	X	X	3-06-81 to 4-04-81	X	X	X
S	4-04-81 to 4-28-81	X	X	X	4-04-81 to 4-28-81	X	X	X
S	4-28-81 to 5-20-81	X	X	X	4-28-81 to 5-20-81	X	X	X
W					2-06-81 to 4-04-81		X	X
					4-04-81 to 4-17-81	X	X	X
N					4-28-81 to 5-12-81	X	X	X

C = current data

T = temperature data

S = salinity data

Table 2-3. Site P. Basis statistics in intervals of 366 hours (15 1/4 days).

SITE P, TOP		ALONG PASS (cm/s)					CROSS PASS (cm/s)					TEMPERATURE (°C)					SALINITY (o/oo)				
START	STOP	N	MIN	MAX	MEAN	S.D.	N	MIN	MAX	MEAN	S.D.	N	MIN	MAX	MEAN	S.D.	N	MIN	MAX	MEAN	S.D.
1-16-81 (0600)	1-31-81 (1100)																				
2-8-81 (0100)	2-15-81 (1700)	185	-2	17	4.1	3.5	185	-147	97	-14.7	62.9	185	5.7	12.1	9.3	1.6	185	18.4	28.9	25.3	2.9
2-15-81 (1800)	3-2-81 (2300)	366	-2	17	3.5	3.3	366	-153	105	-11.1	59.0	366	9.0	17.2	13.3	2.1	366	18.2	31.3	27.3	3.2
3-3-81 (0200)	3-18-81 (0500)	366	-67	13	2.9	7.1	366	-118	108	-8.6	50.7	366	15.0	17.4	16.2	0.6	366	20.2	31.2	29.5	3.1
3-18-81 (0600)	4-2-81 (1100)	366	-2	12	2.4	2.2	366	-128	98	-7.8	57.5	366	14.7	20.4	17.4	1.7	366	19.2	31.2	27.5	2.7
4-2-81 (1200)	4-17-81 (1700)	366	-3	10	1.9	2.2	366	-85	102	3.7	49.0	366	19.9	25.6	22.1	1.7	366	19.4	26.6	22.8	1.6
4-17-81 (1800)	5-2-81 (2300)	366	-10	23	1.6	3.4	366	-87	92	-0.9	40.6	366	22.4	26.2	24.6	0.9	366	21.7	29.3	26.1	1.7
5-3-81 (0000)	5-18-81 (1500)	366	-3	13	2.7	2.4	366	-107	112	-0.4	54.3	366	22.1	25.5	24.1	0.6	366	24.0	31.2	29.5	1.8

SITE P, Bottom		ALONG PASS (cm/s)					CROSS PASS (cm/s)					TEMPERATURE (°C)					SALINITY (o/oo)				
START	STOP	N	MIN	MAX	MEAN	S.D.	N	MIN	MAX	MEAN	S.D.	N	MIN	MAX	MEAN	S.D.	N	MIN	MAX	MEAN	S.D.
1-16-81 (0600)	1-31-81 (1100)																				
2-8-81 (0100)	2-15-81 (1700)	185	-12	7	-1.0	4.2	185	-11	84	-6.4	50.1	185	5.3	12.0	9.2	1.6	185	19.0	29.2	26.3	2.6
2-15-81 (1800)	2-21-81 (0800)	135	-13	6	-1.5	4.0	135	-102	88	-4.9	48.7	135	8.9	13.3	10.7	0.9	135	18.7	30.7	27.3	3.0
3-3-81 (1700)	3-18-81 (0500)	61	08	6	-1.2	3.1	61	-72	80	-2.1	47.4	61	16.4	17.3	16.9	0.3	61	21.1	29.3	25.6	2.1
3-18-81 (0600)	4-2-81 (1100)	366	-13	6	-0.8	3.7	366	-85	79	-2.2	44.0	366	14.4	20.6	17.6	1.7	366	19.4	31.2	27.8	2.6
4-2-81 (1200)	4-17-81 (1700)	366	-4	6	1.1	2.0	366	-88	79	1.1	41.4	366	19.9	25.6	22.0	1.6	366	20.4	26.6	23.3	1.4
4-17-81 (1800)	5-2-81 (2300)	366	-7	6	0.4	2.6	366	-65	71	-0.9	38.2	366	22.5	26.0	24.6	0.9	366	21.6	30.1	26.0	1.5
5-3-81 (0000)	5-18-81 (0500)	366	-10	8	0.5	2.8	366	-76	85	1.2	42.1	366	22.0	25.5	24.1	0.5	366	24.4	31.1	28.5	1.7

Table 2-4. Site D. Basic statistics in intervals of 366 hours (15 1/4 days).

SITE D, Top		ALONGSHORE (cm/s)					CROSS SHELF (cm/s)					TEMPERATURE (°C)					SALINITY (o/oo)				
START	STOP	N	MIN	MAX	MEAN	S.D.	N	MIN	MAX	MEAN	S.D.	N	MIN	MAX	MEAN	S.D.	N	MIN	MAX	MEAN	S.D.
1-21-81 (2100)	1-31-81 (1000)	232	-24	14	-2.1	7.9	232	-12	11	0.2	3.7	232	9.4	12.0	10.3	0.7	232	30.3	37.7	31.4	0.4
1-31-81 (1700)	2-15-81 (1700)	166	-33	16	-9.5	10.6	166	-8	14	3.0	4.1	366	9.1	12.1	10.7	0.8	366	29.5	31.8	30.9	0.7
2-15-81 (1800)	3-2-81 (2300)	366	-13	38	2.2	8.9	366	-11	17	0.1	4.9	366	9.1	14.4	11.3	1.4	366	29.5	32.9	31.3	0.7
3-3-81 (0000)	3-6-81 (0300)	76	-23	22	-2.7	12.1	76	-6	14	1.2	4.3	366	14.0	16.5	15.4	0.7	366	27.2	32.4	30.4	1.5
3-18-81 (0600)	4-2-81 (1100)											366	15.6	19.4	16.8	1.1	366	25.2	31.1	30.2	1.0
4-5-81 (0200)	4-17-81 (1700)	304	-44	0	-20.9	9.0	304	-23	19	3.1	6.1	366	18.9	24.1	21.1	1.3	366	22.8	32.5	27.8	2.3
4-17-81 (1800)	5-2-81 (2300)	366	-48	17	-15.6	15.3	366	-28	16	2.2	6.3	366	23.3	26.5	24.4	0.7	366	25.0	32.4	29.2	1.6
5-2-81 (0000)	5-18-81 (0500)	366	-49	22	-10.9	17.6	366	-16	18	2.1	5.9	366	23.3	25.4	24.3	0.4	366	27.0	31.4	29.4	0.9

SITE D, Bottom		ALONGSHORE (cm/s)					CROSS SHELF (cm/s)					TEMPERATURE (°C)					SALINITY (o/oo)				
START	STOP	N	MIN	MAX	MEAN	S.D.	N	MIN	MAX	MEAN	S.D.	N	MIN	MAX	MEAN	S.D.	N	MIN	MAX	MEAN	S.D.
1-21-81 (1930)	1-31-81 (1030)	232	-18	8	-0.4	7.3	232	-6	10	0.4	2.4	232	10.7	11.8	11.1	0.2	232	31.0	32.5	31.9	0.5
1-31-81 (1200)	2-15-81 (1700)	366	-74	21	-4.8	7.8	366	-5	13	2.8	3.4	366	9.4	12.1	10.8	0.8	366	29.5	31.5	30.7	0.5
2-15-81 (1800)	2-16-81 (2300)	30	-2	0	-0.9	0.6	30	0	6	2.0	1.4	366	9.4	12.0	11.0	0.8	366	30.0	37.5	31.4	0.7
3-15-81 (0100)	3-18-81 (0500)	76	-15	11	0.9	5.7	76	-8	21	1.7	6.5	151	12.0	15.8	14.8	1.1	151	28.4	32.2	30.9	0.8
3-18-81 (0600)	4-2-81 (1100)	366	-26	37	-2.4	10.4	366	-21	30	0.8	6.4	366	15.5	19.0	16.5	1.0	366	28.7	31.5	30.4	0.5
4-2-81 (1200)	4-17-81 (1700)	77	-25	12	-7.1	8.3	77	-17	12	-0.3	6.0	366	18.3	23.3	20.6	1.3	366	24.1	32.6	29.3	1.8
4-17-81 (1800)	5-2-81 (2300)	366	-27	14	-6.2	8.9	366	-17	14	0.8	5.5	366	22.9	25.1	23.8	0.5	366	26.3	33.7	30.9	1.6
5-2-81 (0000)	5-18-81 (0500)	366	-33	15	-6.1	12.0	366	-14	16	1.9	5.9	366	23.6	25.1	24.2	0.3	366	28.5	32.5	30.3	1.0

Table 2-5. Site S. Basic statistics in intervals of 366 hours (15 1/4 days).

SITE S, Top		ALONGSHORE (cm/s)					CROSS SHELF (cm/s)					TEMPERATURE (°C)					SALINITY (o/oo)				
START	STOP	N	MIN	MAX	MEAN	S.D.	N	MIN	MAX	MEAN	S.D.	N	MIN	MAX	MEAN	S.D.	N	MIN	MAX	MEAN	S.D.
1-16-81 (0600)	1-31-81 (1100)											275	14.4	16.7	15.5	0.5	275	31.6	33.6	32.6	0.4
1-31-81 (1200)	2-15-81 (1700)											273	15.5	17.5	16.3	0.5	273	31.1	33.0	32.0	0.5
2-15-81 (1800)	3-2-81 (2300)											309	18.8	22.6	20.3	1.1	309	29.4	34.5	33.1	1.2
3-2-81 (1900)	3-18-81 (0500)	275	-41	22	-8.4	10.4	275	-20	15	0.5	7.0	366	21.7	25.5	23.5	0.8	366	31.5	34.3	33.4	0.6
3-18-81 (0600)	3-29-81 (1400)	273	-34	37	-1.3	15.3	273	-26	26	-0.4	7.7	366	23.2	24.6	23.9	0.3	366	31.3	34.0	33.1	0.7
4-4-81 (2100)	4-17-81 (1700)	309	-37	1	-13.5	7.3	309	-22	18	1.9	8.4										
4-17-81 (1800)	5-2-81 (2300)	366	-37	25	-6.6	12.8	366	-29	31	1.4	7.9										
5-2-81 (0000)	5-18-81 (0500)	366	-49	26	-13.2	13.3	366	-23	18	-1.3	9.1										

SITE S, Bottom		ALONGSHORE (cm/s)					CROSS SHELF (cm/s)					TEMPERATURE (°C)					SALINITY (o/oo)				
START	STOP	N	MIN	MAX	MEAN	S.D.	N	MIN	MAX	MEAN	S.D.	N	MIN	MAX	MEAN	S.D.	N	MIN	MAX	MEAN	S.D.
1-1-81 (0000)	1-16-81 (0500)											315	11.3	13.5	12.6	0.7	315	32.6	34.9	33.9	0.5
1-31-81 (1200)	2-15-81 (1700)											366	12.9	16.2	14.9	0.8	366	32.1	33.9	33.1	0.5
2-17-81 (2100)	3-2-81 (2259)	315	-18.	27.	0.5	4.2	315	-4.	14.	1.1	2.9	366	15.6	18.0	16.4	0.7	366	31.2	33.5	32.6	0.5
3-3-81 (0000)	3-18-81 (0459)	366	-27.	13.	-4.4	7.5	366	-14.	21.	-1.1	5.8	366	18.0	21.3	19.6	0.9	366	31.4	34.3	32.2	0.8
3-18-81 (0600)	4-2-81 (1059)	366	-27.	27	-2.8	12.4	366	-14.	22.	-1.3	6.8	366	21.5	24.9	23.1	0.7	366	32.2	34.1	33.4	0.5
4-2-81 (1200)	4-17-81 (1659)	366	-21.	21.	-8.7	5.9	366	-17.	15.	-2.2	5.6	366	23.5	24.4	23.9	0.3	366	32.0	33.9	33.4	0.5
4-17-81 (1800)	5-2-81 (2259)	366	-20.	16.	-5.6	8.2	366	-13.	15.	-1.1	5.6	366	24.0	26.0	24.7	0.5	366	31.5	34.0	32.9	0.7
5-2-81 (0000)	5-18-81 (0500)	366	-35.	18.	-6.1	11.9	366	-16.	16.	-0.4	6.1	366	25.4	28.4	27.0	0.7	366	26.5	33.5	31.2	1.4

Table 2-6. Site W. Basis statistics in intervals of 366 hours (15 1/4 days).

SITE W, Bottom		ALONGSHORE (cm/s)					CROSS SHELF (cm/s)					TEMPERATURE (°C)					SALINITY (o/oo)				
START	STOP	N	MIN	MAX	MEAN	S.D.	N	MIN	MAX	MEAN	S.D.	N	MIN	MAX	MEAN	S.D.	N	MIN	MAX	MEAN	S.D.
1-14-81 (0500)	1-31-81 (1100)																				
1-31-81 (1200)	2-15-81 (1700)																				
2-15-81 (1000)	3-2-81 (2300)											96	11.9	12.9	12.2	0.2	96	31.2	32.2	31.8	0.2
3-2-81 (0500)	3-18-81 (0500)											366	12.3	15.9	15.0	0.8	366	28.9	32.0	31.2	0.7
3-18-81 (0500)	4-2-81 (1100)											366	15.4	19.3	16.5	1.0	366	27.4	31.9	30.8	0.6
4-2-81 (1100)	4-17-81 (0900)	299	-26	20	-8.1	8.2	299	-25	19	0.6	8.0	358	18.5	23.2	20.6	1.2	358	25.4	32.0	29.0	1.6

Figure 2-11. January 1981, Site D (top). Time series plots of current velocity, temperature and salinity.

Figure 2-12. January 1981, Site D (bottom). Time series plots of current velocity, temperature and salinity.

Figure 2-13. January 1981, Site D. Top and bottom current roses and associated joint frequency tables.

Figure 2-14. February 1981, Site P (top). Time series plots of current velocity, temperature and salinity.

Figure 2-15. February 1981, Site P (bottom). Time series plots of current velocity, temperature and salinity.

Figure 2-16. February 1981, Site D (top). Time series plots of current velocity, temperature and salinity.

Figure 2-17. February 1981, Site D (bottom). Time series plots of current velocity, temperature and salinity.

Figure 2-18. February 1981, Site D (top and bottom) current roses and associated joint frequency tables.

Figure 2-19. February 1981, Site S (bottom). Time series plots of current velocity, temperature and salinity.

Figure 2-20. February 1981, Site S (bottom) current roses and associated joint frequency table.

Figure 2-21. March 1981, Site P (top). Time series plots of current velocity, temperature and salinity.

Figure 2-22. March 1981, Site P (bottom). Time series plots of current velocity, temperature and salinity.

Figure 2-23. March 1981, Site D (top). Time series plots of current velocity, temperature and salinity.

Figure 2-24. March 1981, Site D (bottom). Time series plots of current velocity, temperature and salinity.

Figure 2-25. March 1981, Site D (top and bottom) current roses and associated joint frequency tables.

Figure 2-26. March 1981, Site S (top). Time series plots of current velocity, temperature and salinity.

Figure 2-27. March 1981, Site S (bottom). Time series plots of current velocity, temperature and salinity.

Figure 2-28. March 1981, Site S (top and bottom) current roses and associated joint frequency tables.

Figure 2-29. March 1981, Site W (bottom). Time series plot of temperature and salinity.

Figure 2-30. April 1981, Site P (top). Time series plots of current velocity, temperature and salinity.

Figure 2-31. April 1981, Site P (bottom). Time series plots of current velocity, temperature and salinity.

Figure 2-32. April 1981, Site D (top). Time series plots of current velocity, temperature and salinity.

Figure 2-33. April 1981, Site D (bottom). Time series plots of current velocity, temperature and salinity.

Figure 2-34. April 1981, Site D (top and bottom). Current roses and associated joint frequency tables.

Figure 2-35. April 1981, Site S (top). Time series plots of current velocity, temperature and salinity.

Figure 2-36. April 1981, Site S (bottom). Time series plots of current velocity, temperature and salinity.

Figure 2-37. April 1981, Site S (top and bottom) current roses and associated joint frequency tables.

Figure 2-38. April 1981, Site W, (bottom). Time series plots of current velocity, temperature and salinity.

0 10 20 30 40 50 60 70 80 90 100
 CURRENT ROSE, SITE W BOTTOM
 81/04/04 (2329) - 81/04/17 (0829) (CST)

DIR	RANGE (CM/S) E.G. 2 < V ≤ 5								TOTAL	AVG SPEED
	2-5	5-10	10-15	15-20	20-30	30-40	40-50	50+		
N		3.3	3.7	1.3					8.4	11.6
NE	0.7	1.7	1.0						3.3	8.8
E			0.7	1.3	1.0				3.0	17.6
SE			0.7	0.7	0.3				1.7	16.1
S		0.3	1.0	3.0	1.0				5.4	16.8
SW	0.3	2.7	10.7	7.7	2.7				24.1	14.6
W	1.3	9.7	15.1	10.7	3.0				39.8	13.2
NW	0.3	5.7	5.7	1.0	0.7				13.4	11.0
TOTAL	2.7	23.4	38.5	25.8	8.7				99.0	13.2
CALM									1.0	

Figure 2-39. April 1981, Site W (bottom) current rose and associated joint frequency table.

and maximum values. Prior to filtering and averaging, short gaps (on the order of a few hours) in a series were filled by linear interpolation. The interpolated values were included in the computation of basic statistics. Gaps on the order of days to weeks in duration, however, were not interpolated and were not included in the statistics. Thus some intervals have fewer than 366 values.

For the current roses and associated joint frequency tables the percentage of joint frequency in eight speed ranges and eight direction sectors was computed for intervals of 732 hours (30 1/2 days). The first interval begins on January 1, 1981 at 0000 hours (CST). This length of interval approximates the calendar month but provides a uniform number of points in each, provided there are no gaps in the data. The percentages of joint frequency were computed using hourly values of time series which had been filtered with a 3-hour low pass filter. Prior to filtering, short gaps (on the order of a few hours) in the series were filled by linear interpolation. Gaps of days to weeks in duration were excluded from the computations. The speed ranges were selected to provide an optimum amount of resolution in the lower ranges. Calm conditions were defined to be less than 2 cm/s which is the approximate threshold of the current meter's impeller.

Each value in the joint frequency table represents the percentage of observations which fell in a given speed range and direction sector. The total for a given row gives the percentage of observations which fell in that direction sector regardless of speed (e.g., NE is from 22.5° to 67.5°). The average speed for each direction sector (on the far right side of each row) is the arithmetic average speed for all observations in that direction sector. The total for a given column gives the percentage of

observations which fell in a given speed range regardless of direction.

For ease in visualizing the tables, a rose diagram has been plotted above each one. Each rose petal corresponds to a direction sector of the table. Each segment of a petal corresponds to a speed range and the length of each segment is proportional to the percentage expressed in the table. At the tip of each petal the total percentage in that direction is printed. Thus each petal corresponds to a row in the table.

A cumulative speed graph has been plotted below each rose. It expresses the percentage of observations which fell in a given speed range regardless of direction, and it corresponds to the row of totals (second row from the bottom) in the table. The graph runs from 0 to 100 percent. The scale of the graph and the scale of the rose petals are the same. Thus if all the petals of a rose were laid end-to-end the total length would equal the length of the graph less the percent of calms.

The total number of observations on which the percentages are based is printed in the upper half of the center of each rose. (As noted above, hourly observations have been used.) The percent of calms is printed in the lower half of the center of each rose.

The time series plots were accomplished by means of the FESTSA (Brooks, 1976) and PLOTSA (Reid, 1980) software packages for time series analysis. The rose plotting program was developed by members of this project. Prior to plotting, each time series was filtered with a 3-hour and then a 40-hour low-pass filter (symmetric Lanczos filters). The stick vectors were reconstructed from the 40-hour-low-pass-filtered orthogonal components at six hour intervals (000,0600,1200, 1800(CST)). At all sites but site P, the x-axis of the stick plot is oriented north-south and the y-axis is oriented east-west. At site P the x-axis is oriented west-east

and the y-axis north-south. In the orthogonal component plots of sites D, N and S the alongshore component is approximately parallel to the local isobathes (086°T) and the cross shelf component is perpendicular to this direction (356°T). The positive directions are chosen to be 086°T for alongshore and 356°T for cross shelf. A similar convention holds for site W except that the orientations are 075°T for positive alongshore and 345°T for positive cross shelf. At the location of site P, Calcasieu Pass is oriented approximately along 356°T , and this direction represents inflow or positive alongpass flow. The local time zone, Central Standard Time, rather than the scientific standard, Greenwich Meridian Time (GMT), is used in order to facilitate comparison with the collection times of hydrographic and biological samples and the observations of local meteorological events, and also because it is believed that this report may be of more interest to the non-scientific community than usual.

Salinity is computed from temperature and conductivity data (at the original, unfiltered sample rate) using the equation of Daniel and Collias (1971). This equation is a simple polynomial in temperature and conductivity. The effects of pressure are ignored because of the shallow depth. We have compared the results of this equation with those from the equation used by the NOAA Environmental Data and Information Service (EDIS) and found that in the ranges of temperature and conductivity encountered in the oceanic region of this study the difference is always less than 0.05 o/oo and typically less than 0.01 o/oo. Since the accuracy of the ENDECO instrument is about 0.5 o/oo the computationally simpler equation of Daniel and Collias is used.

In the following three subsections the results of the time series data are discussed for February, March and April of 1981. During January, data

was obtained only during the last week at site D. Therefore, these data are presented but not discussed; they are in agreement with the hydrographic survey results obtained on January 18, 1981.

2.3.1 February 1981

Useful intervals of time series data were obtained during February at sites D, P and the bottom at site S. The in situ recorded temperature and salinity values agree well with those collected during the hydrographic cruise of February 3 and 4, 1981. In general the water column appears to have been fairly well mixed at site D throughout February. Temperatures ranged between 9.1 and 13.5°C at the surface and 9.4 and 12.1°C at the bottom. A decrease of about 2°C occurred during the period of February 10-12 when a strong cold front moved out across the coastal waters. After February 15, there was a warming trend. Salinities ranged between 29.5 and 32.8 at the surface and 29.5 and 32.5 o/oo at the bottom. After February 15, there was an increasing salinity trend. Both temperature and salinity were more variable in the surface layer than in the bottom layer after February 15. The temperature and salinity data from the bottom meter at site S are warmer and saltier than at site D in the latter part of February, which indicates that a cross shelf gradient may have developed.

At the surface, currents were generally westward and onshore during the first half of February, but during the second half they were weakly eastward with approximately zero average cross shelf flow. Near the bottom they were also westward and onshore during the first half of February, but there is insufficient data to draw conclusions about the average near bottom currents during the second half of February. The current roses indicate that the preferred scalar speed range was 5-10 cm/s at the surface and 2-5 cm/s at the bottom (based on the available bottom data). All

available data indicate that the currents were quite weak during the last four days in February.

The data recorded in Calcasieu Pass reflect the dominant tidal nature of the flow through the Pass. It should be kept in mind that the instruments are located on the east side of the channel, where the water depth is only about 6.1 meters (20 feet). Thus while the data are probably representative of flow through the Pass, the extreme values which are recorded may be less than the extreme values which actually occur in other parts of the channel. The values of temperature and salinity respond quickly to the direction of flow. During periods of outflow the salinity drops quickly and during periods of inflow the salinity rises to a value which probably corresponds to that of the coastal waters just outside the Pass. The salinity trace, therefore, has the general appearance of a truncated sinusoid. Temperature values follow a similar pattern since the coastal waters are warmer than the inland waters in February, but the daily range of variation is much smaller.

At the surface in February temperatures at site P ranged between 5.7 and 17.2°C and salinities between 18.2 and 31.3 o/oo. For the portion of February recorded at the bottom at site P, temperature and salinity ranged between 5.3 and 13.3°C and 18.7 and 30.7 o/oo, respectively. For salinity, the greatest daily range appears to be almost as great as the monthly range, while the daily temperature ranges are smaller and modulate a longer period temperature trend. During the period in February when both top and bottom data were recorded at site P, there was little difference between the top and bottom salinity and temperature values, which indicates that, at the location of site P at least, the water flowing through the pass was well mixed.

The strong cold front which moved southward through the area on February 10 shows up dramatically in the data of site P. Strong northerly winds forced an outflow which overrode the normal tidal cycle. The water temperature dropped rapidly, and a large pulse of low salinity water exited the pass.

A transverse circulation may exist in the pass since there appears to be generally eastward flow near the surface and westward flow near the bottom at site P. However, the magnitude of this transverse flow must be viewed with caution since small changes in the direction selected for along pass flow will significantly affect the magnitude of this transverse flow.

The average flow through the pass was outward at both the top and bottom during the time periods for which data was recorded in February. A maximum speed of about 150 cm/s (about 3 knots) was recorded.

2.3.2 March 1981

The hydrographic data recorded on March 7 are in excellent agreement with the in situ recorded values on that date. The cross shelf vertical section indicates that there was little vertical stratification and that there was some cross shelf stratification. The in situ recorded data indicate that these conditions persisted throughout the month, and a comparison of top and bottom temperatures and salinities for sites D, S, and P indicates little vertical stratification, but some cross shelf stratification (about 1°C and 2.5 o/oo).

At site D, temperatures and salinities ranged from 13 to 19°C and 27.2 to 32.3 o/oo at the surface, while at the bottom they ranged from 12 to 18.8°C and 28.5 to 32.3 o/oo. At site S, temperatures and salinities ranged from 14 to 17.5°C and 31.2 to 33.5 o/oo at the top, but data was not recorded for the entire month. At the bottom, they ranged from 12.8 to

17.4°C and 31.2 to 33.8 o/oo.

The salinity data from the top meters at both sites P and D indicate that lower salinity water passed through the area between about March 11 and March 19. However, it was apparently a relatively shallow event confined to the inshore waters since it was not recorded at site S, and a much attenuated low salinity signal was recorded by the bottom meter at site W (No data was recorded at site D, bottom, during this event).

Currents were recorded for the entire month only at sites P, top, and S, bottom. Long partial records were obtained at sites S, top, and D, bottom. Together these records indicate that the currents were relatively weak with alternating periods of westward and eastward alongshore flow. The net or average alongshore flow was westward at both top and bottom. The preferred scalar speed range was 5 to 10 cm/s at the bottom at sites D and S and 10 to 15 cm/s at the top at site S.

At site P, the flow was weaker than in February. Although the monthly range of salinity values was still large, 19 to 32 o/oo, the daily range was smaller in the second half of the month. Again, there is little difference between the top and bottom salinities which indicates well mixed water in the pass. March 18 - 19 was followed by a longer period of inflow during March 19 - 22 at both the top and bottom. The average flow for the entire month was still outward. The decrease in salinity between about March 10 and March 20 corresponds to a period of decreasing salinity in the offshore waters. The decrease in salinity is probably a result of advection of low salinity water along the coast from the east, rather than an increase in freshwater discharge through the Pass, but there is not sufficient data to firmly conclude this.

Temperature ranges were much smaller than in February, and a gentle

warming trend began about March 25.

The cause of the westward transverse flow at site P, top, on March 11 is not known, but the instrument appears to have been functioning properly. It is quite possible that a shrimp boat, barge or dredge was hove to nearby with its screws engaged. Similar such events have appeared occasionally in subsequent records.

2.3.3 April 1981

The hydrographic data collected on April 10 indicate a significant increase in cross shelf stratification because of lower salinity water near the coast. The in situ recorded data collected on this date agree very well with the hydrographic data. The in situ data show that salinity variability increased significantly in April at both the surface and bottom at sites P and D and at the bottom at site W. At site D at the surface, the monthly salinity range was from 22.8 to 32.3 o/oo. A maximum daily variation of 7.5 o/oo was recorded on April 20 - 21. At the bottom, salinities ranged from 24 to 33.8 o/oo, and the greatest one-day change recorded was 6 o/oo on April 12.

At site S, however, salinity variations were much smaller. At the surface, the values ranged from 29.6 to 34.5 o/oo, and at the bottom from 31 to 34.5 o/oo. The maximum short term variation was only about 2 o/oo. This implies that strong cross shelf stratification existed, and that the low salinity water was confined to the inner coastal zone.

Low values of salinity were recorded in Calcasieu Pass throughout much of the month, but the principal periods of decreasing salinity were April 1 - 5, April 10 - 13, and April 17 - 20. Salinity values during the month ranged from 19.5 to 29 o/oo at the surface and 20.3 to 30 o/oo at the bottom. Again, the data indicate that the pass was fairly well mixed.

Daily salinity variations were greatly reduced through about April 20 as compared to the previous two months. The greatest daily variation prior to April 20 was about 3.7 o/oo. This implies that there was little difference between the inflowing and outflowing waters.

Currents in the pass were less strong in April than in the previous two months. They reached a maximum of only about 100 cm/s (2 knots) at the surface and 75 cm/s (1.5 knots) at the bottom. In addition, the inflow speeds generally exceeded the outflow speeds through about April 20, and, in fact, the average flow was positive (inflow) at both the top and the bottom during the period April 2 - 17 (Table 2-3).

Westward currents were recorded by both top and bottom meters at sites D and S, and the bottom meter at site W throughout April, except for a brief period of eastward flow during April 20 - 22. Cross shelf flow was generally directed onshore at site D, top, during April.

2.4 Meteorological time series data

Time series of wind velocity (speed and direction), barometric pressure and air temperature are collected by the NOAA Data Buoy Office (NOAA/NDBO) with an instrument package placed atop an offshore oil platform located about 5 nm east of the diffuser. The data are transmitted hourly via satellite to a ground station. Magnetic tapes of processed data are sent monthly to Texas A&M University.

The wind velocity data have been converted to Central Standard Time (CST) and oceanographic direction convention (the direction towards which the wind blows) and then decomposed into orthogonal components parallel to the local orientation of the coast (086°T) and perpendicular to it (356°T). The data were then processed in the same manner as described in section 2.3 for oceanographic time series data.

The basic statistics for the orthogonal components of wind velocity are shown in Table 2-7 and the monthly time series plots and wind roses are shown in Figures 2-40 through 2-45. (The data prior to February 17, 1981 are the unfiltered hourly values because the segments of data between the gaps are too short to be filtered).

In general February 1981 was relatively mild except for the strong cold front which passed through the area on February 10. Temperatures dropped below freezing and there were strong winds blowing towards offshore.

During March a series of fronts passed through the area, the strongest of which occurred on March 18. There is fairly good qualitative agreement between periods of strong cross shelf winds (onshore as well as offshore) and periods in which the normal tidal cycle of flow through Calcasieu Pass was interrupted. There was a fairly persistent onshore component of the wind during April.

2.5 Summary and Conclusions

The physical oceanographic conditions in the inner coastal zone region offshore of Calcasieu Pass, La. have been analyzed for the period January-April, 1981. The analysis is based on a combination of monthly hydrographic surveys and in situ, continuously recorded time series of current velocity, temperature and salinity.

From the latter half of January through March the coastal waters were relatively homogeneous. The temperature and salinity gradients were typically less than 1°C and 1 o/oo in the vertical, and horizontal gradients were less than 2°C and 3 o/oo within 20 nm of the coast. At site D, absolute salinity values ranged between about 29.5 o/oo and 33.5 o/oo during the period, while temperatures values followed the annual cycle for

Table 2-7. NDBO Wind. Basic statistics in intervals of 366 hours (15 1/4 days).

NDBO WIND			ALONGSHORE (cm/s)				CROSS SHELF (cm/s)				
START	STOP	N	MIN	MAX	MEAN	S.D.	N	MIN	MAX	MEAN	S.D.
1-1-81 (0000)	1-16-81 (0500)										
1-16-81 (0600)	1-31-81 (1100)										
1-31-81 (1800)	2-15-81 (1700)	229	-12.2	6.0	-3.1	3.8	229	-15.3	12.0	-1.3	5.2
2-15-81 (1800)	3-02-81 (2300)	333	- 4.7	7.7	0.6	2.9	333	- 9.0	6.1	1.3	2.6
3-03-81 (0000)	3-18-81 (0500)	366	- 9.8	9.6	-1.4	4.0	366	- 8.6	11.6	-0.5	4.1
3-18-81 (0600)	4-02-81 (1100)	366	-10.2	10.6	-1.2	4.8	366	-13.0	7.7	0.5	4.7
4-02-81 (1200)	4-17-81 (1700)	366	- 9.4	6.1	-1.6	3.2	366	- 8.5	8.4	3.3	3.2
4-17-81 (1800)	5-02-81 (2300)	366	-11.5	8.0	-0.6	4.8	366	- 9.3	7.9	0.2	3.7
5-03-81 (0000)	5-18-81 (0500)	366	-11.2	9.6	-2.1	3.8	366	-10.3	10.4	2.5	5.1
5-18-81 (0600)	5-31-91 (0900)	316	-10.1	6.8	-3.0	3.7	316	-11.3	15.4	2.7	5.0

Figure 2-40. February 1980. Meteorological data. Time series plots of wind velocity, barometric pressure and air temperature from the NOAA/NDBO instruments located atop an oil platform about 5 n.m. east of the diffuser site.

Figure 2-41. February 1980. Wind rose and associated joint frequency table of speed and direction.

NDBO MET DATA, W. HACK OCT 82 OCEAN DIRECTION CONVENTION

Figure 2-42. March 1981. Meteorological data. Time series plots of wind velocity, barometric pressure and air temperature from the NOAA/NDBO instruments located atop an oil platform about 5 n.m. east of the diffuser site.

Figure 2-43. March 1981. Wind rose and associated joint frequency table of speed and direction.

NDBO MET DATA.W. HACK CST & OCEAN DIRECTION CONVENTION

Figure 2-44. April 1981. Meteorological data. Time series plots of wind velocity, barometric pressure and air temperature from the NOAA/NDBO instruments located atop an oil platform about 5 n.m. east of the diffuser site.

Figure 2-45. April 1981. Wind rose and associated joint frequency table of speed and direction.

the period, warming from about 9°C in late January to about 19°C by late March. Water temperatures dropped by 2°C after the passage of a strong cold front on February 10. Dissolved oxygen content was also relatively uniform, and as the vertical sections show, the values ranged between 8 and 9 ppm.

In April 1981, pulses of relatively low salinity water were advected intermittently through the coastal area from the east. The lower salinity water lay close to the coast since it was not recorded by the in situ meters located about 20 nm offshore. Vertical and cross shelf gradients of salinity increased to about 3 o/oo and 7 o/oo respectively. Daily variations of as large as 6 or 7 o/oo were recorded at the diffuser site by both the near surface and near bottom instruments. Absolute salinity values in April ranged from about 23 o/oo to 32.5 o/oo at the diffuser site. Temperature values continued to increase to about 26.5°C. Daily temperature fluctuations increased slightly in the inshore waters. The variation in dissolved oxygen had increased slightly by the April 10 cruise when values varied between 7.0 and 8.6 ppm.

Average currents were generally weakly westward and onshore during the late January through March time period. In April the average westward flow increased in magnitude to 21 cm/s; average cross shelf currents continued to be onshore. Before April the preferred scalar speed range was usually 5-10 cm/s with 2-5 cm/s often a close second. In April, the preferred scalar speed range increased to 10 - 15 cm/s.

Flow through Calcasieu Pass was found to follow the tidal cycle in general, but strong offshore or onshore winds effectively overrode the normal cycle producing longer than normal periods of outflow or inflow. Speeds of up to 150 cm/s (about 3 knots) were recorded in February. The

average direction of flow was outward but the magnitude decreased through March. During the first half of April, the average flow was inward. Salinity values followed the daily cycle very closely, decreasing during outflow and increasing during inflow. There was little vertical salinity gradient at site P, which indicates the water in the pass was well mixed.

There has been some question about the offshore extent of the influence of the relatively fresh outflow from Calcasieu Pass, particularly with respect to the diffuser site. In April, when low salinities were recorded offshore, the data show that the average flow at site P was inward, the average cross shelf current at site D was weakly onshore, and that there was relatively strong westward along shore flow. It is concluded, therefore, that the low salinities recorded at site P during April were a result of an influx of relatively low salinity water which was being advected from the east along the coast rather than an increase in freshwater discharge through the pass. The extent of the influence of outflow from the Pass during periods of strong outflow and weak offshore currents is not yet documented.

CHAPTER 3

ESTUARINE HYDROLOGY AND HYDROGRAPHY

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3.1 Introduction

The West Hackberry site of the Department of Energy's Strategic Petroleum Reserve Program began discharging brine into the Cameron, Louisiana, coastal waters in May 1981. The brine discharge is the result of leaching storage caverns in an underground salt dome and the subsequent filling with crude oil. The leaching process and subsequent withdrawal of crude oil requires large volumes of raw water which is obtained from the nearby intracoastal waterway. The purpose of this chapter is to estimate the impact of the water diversion on the water resources of the area and to characterize the estuarine environment of Lake Sabine, Intracoastal Waterway, and Lake Calcasieu prior to the initiation of brine discharge.

A predisposal study of estuarine hydrology and hydrography of the Lake Calcasieu, Intracoastal Waterway and Lake Sabine was initiated in January and completed in April 1981. Prior to this study, an Environmental Impact Statement was published by the Department of Energy (DOE, 1978). Estuarine hydrographic data have also been collected by the Louisiana State Wildlife and Fisheries Commission in the late 1960's and mid 1970 and reports have been published by Barrett (1971) and Barrett et al (1978). The data from these studies, and other available literature, along with the data collected from January through April 1981 are discussed in this chapter.

In the predisposal study, data were collected at ten estuarine stations shown in Figure 3-1. Three stations (E2, E3, and E4) are located in Lake Calcasieu where conductivity, temperature, depth, and dissolved oxygen (CTD/DO) were measured monthly, and temperature and water level were measured continuously at station E2. There are three stations (E1, E6, and E7) located in the Intracoastal Waterway where monthly CTD/DO data and continuous water level and temperature data were collected. Stations E8, E9, and E10 are located in Lake Sabine where monthly CTD/DO data were collected at all three stations, and continuous water level and temperature data were measured at E8. A final station (E5) is located in Calcasieu Pass, and monthly CTD/DO data were collected there as well as a continuous current velocity, salinity, temperature, and water level data which are discussed in Chapter 2 of this report. Continuous measurement of conductivity is planned for stations E2, E6, E1, E7, and E8 when instrumentation is available.

The data collected at the stations shown in Figure 3-1 are analyzed and described in the following sections of this chapter. The general organization of the remainder of this chapter is to discuss the impact of the water diversion for the leaching process in the section entitled "Hydrology" and to characterize the estuarine environment in the section entitled "Estuarine Hydrography."

3.2 Hydrology

Freshwater inflow is important in that it affects the salinity levels in Calcasieu and Sabine Lakes. In this section of the report we will estimate the change in salinity in Calcasieu and Sabine Lakes resulting from pumping water from the Intracoastal Waterway (ICW). We will also

Figure 3-1. Station locations for estuarine hydrology and hydrography stations.

discuss the results of a model study to evaluate the influence of pumping from the ICW on the salinity in the ICW presented in the environmental impact statement of the West Hackberry project.

3.2.1 Freshwater Flow

The effect of water diversion on the salinity levels in Calcasieu and Sabine Lakes will be greatest during low freshwater inflow periods. For Calcasieu Lake this period generally extends from July through November. For Sabine Lake the low flow period is generally limited to October and November. Freshwater flow into the Calcasieu/Sabine system is discussed as measured or gaged flow and ungaged flow in the following sections. Excellent records are available on the gaged flow into the system. However, the ungaged flow can only be estimated. There was not adequate time available in the predisposal study to accurately evaluate the ungaged flow.

3.2.1.1 Gaged Flow

Surface waters in the major rivers and streams entering the Calcasieu/Sabine system have been measured by the U.S. Geological Survey. Observations have been taken at the following gaging stations:

- A. Calcasieu River near Kinder, La.
- B. Beckwith Creek near Quincy, La.
- C. Bear Head Creek near Starks, La.
- D. Sabine River near Ruliff, Tx.
- E. Cow Bayou near Mauriceville, Tx.
- F. Neches River at Evadale, Tx.
- G. Village Creek near Kountze, Tx.
- H. Pine Island Bayou near Sour Lake, Tx.

The locations of the gaging stations are shown in Figure 3-2. The

Figure 3-2. Location of gaging stations and ungaged drainage areas.

letters A through H in Figure 3-2 refer to the letters in the above list of gaging stations.

The average monthly freshwater inflow in cfs entering the Calcasieu system is tabulated in Table B-1 (Appendix B) for the period October 1967 through October 1980. The table includes gaged flows in the Calcasieu River with a drainage area of 4303 sq km (1700 sq mi), Beckwith Creek with a drainage area of 383 sq km (148 sq mi), and Bear Head Creek with a drainage area of 458 sq km (177 sq mi). The gaged flow into the Calcasieu Lake is from a drainage area of 5244 sq km (2025 sq mi). The total gaged inflow or sum of the three stations is also included in the table. It can be observed that the average monthly total gaged freshwater inflow for Calcasieu Lake is often below 11.3 cms (400 cfs) during the period July through November. The minimum average monthly gaged inflow to Calcasieu Lake during the period of record was 7.25 cms (256 cfs) in October 1978. Figure 3-3 is the flow-duration curve for Calcasieu Lake. The curve is based on the total monthly average gaged inflow listed in Table B-1.

The average monthly gaged freshwater inflow to Sabine Lake is tabulated in Table B-2 (Appendix B). Total drainage area of the gaged inflow is 48,070 sq km (18,560 sq mi) and includes Sabine River (24,165 sq km; 9,330 sq mi), Cow Bayou (215 sq km; 88 sq mi), Neches River (20,593 sq km; 7,951 sq mi), Village Creek (2,227 sq km; 860 sq mi), and Pine Island Bayou (870 sq km; 336 sq mi). Most of the inflow is from the Sabine and Neches Rivers which represent 93 percent of the gaged drainage area. The total average monthly gaged freshwater inflow to Sabine Lake is often less than 56.64 cms (2,000 cfs) during October and November. The minimum gaged inflow 23.0 cms (812 cfs) occurred in November 1967.

Figure 3-4 is the flow-duration curve for Sabine Lake based on the

Figure 3-3. Flow-duration curve for Calcasieu Lake, 1967-1980.

Figure 3-4. Flow-duration curve for Sabine Lake, 1967-1980.

total monthly average gaged flow for the period 1967 - 1980. It can be observed that the gaged flow into Calcasieu is about 20 percent of the gaged flow into the Sabine. The shape of the flow-duration curve for Sabine Lake is considerably different from that of Calcasieu Lake. Approximately 57 percent of the Sabine Lake gaged drainage area is controlled by Toledo Bend and Sam Rayburn reservoirs. Floodwaters stored in the winter and early spring are released during late spring and summer. As a result the low flow period for Sabine Lake is shorter than the low flow period for Calcasieu Lake.

Flow duration curves for the low flow periods are shown in Figures 3-5 and 3-6 for Calcasieu Lake and Sabine Lake, respectively. The low flow period for Calcasieu Lake extended from July through November. During this period the average monthly gaged freshwater inflow to Calcasieu Lake ranged from 7.3 to 232 cms (256 to 8,200 cfs). The low flow period for Sabine Lake included only October and November. Average monthly gaged freshwater inflow during this period ranged from 24 to 660 cms (860 to 23,400 cfs).

3.2.1.2 Ungaged Flow

Ungaged flow into the Calcasieu/Sabine system includes surface runoff, groundwater, direct lake precipitation, lake evaporation, wetland evapotranspiration irrigation-industrial-municipal return flows, and diversions.

3.2.1.2.1 Surface Water

Large drainage areas around Calcasieu and Sabine Lakes contribute freshwater inflow into the system that is not measured at the gaging stations. The areas or subbasins contributing ungaged inflow to Calcasieu Lake are shown in Figure 3-2 and tabulated in Table 3-1. The gaged inflow into Calcasieu Lake is from a drainage area of 5245 sq km (2025 sq mi)

Figure 3-5. Flow-duration curve for Calcasieu Lake during the low flow period from July through November, 1967-1980.

Figure 3-6. Flow-duration curve for Sabine Lake during the low flow period from July through November, 1967-1980.

Table 3-1. Drainage area contributing to ungaged surface runoff.

Ungaged Watershed Areas*	Area (sq mi)		Area (sq km)	
Calcasieu Lake	1863		4825	
Coastal Wetlands	420		1088	
Subbasin 16	420		1088	
Upland	1443		3737	
Subbasin 5	187		484	
Subbasin 6	267		691	
Subbasin 7	304		787	
Subbasin 9	196		508	
Subbasin 10	176		456	
Subbasin 11	62		161	
Subbasin 12	251		650	
Sabine Lake	2400		6216	
Coastal Wetlands	640		1658	
Subbasin 14	328		850	
Subbasin 15	312		808	
Upland	1760		4558	
Subbasin 1	864		2238	
Subbasin 2	555		1437	
Subbasin 3	104		269	
Subbasin 4	162		420	
Subbasin 8	75		194	
Gulf of Mexico	136		352	
Subbasin 13	136		352	

* See Figure 3-2 for the location of subbasins.

while the ungaged drainage area contributing to freshwater inflow in Calcasieu Lake is 4,825 sq km (1,863 sq mi). The gaged inflow drainage area represents 52 percent of the total drainage area of Calcasieu Lake.

For Sabine Lake the gaged inflow drainage area (48,070 sq km; 18,560 sq mi) represents 89 percent of the total drainage area (54,286 sq km; 20,960 sq mi). According to a study of the influence of freshwater inflows on the Sabine-Neches Estuary by the Texas Department of Water Resources (1981), the gaged freshwater inflow represents an average of 85 percent of the total freshwater inflow.

To accurately evaluate ungaged freshwater inflow, many hydrologic factors would have to be considered including evapotranspiration in the wetlands, lake evaporation, river diversion below gaging stations, municipal- industrial-irrigation return flows, precipitation, and runoff. Because of time constraints of this report, it was not possible to properly analyze the ungaged freshwater inflow into the Calcasieu/Sabine system. For the purpose of this report, it will be assumed that for average conditions the gaged inflow represents 50 percent of the total freshwater inflow to Calcasieu Lake and 85 percent of the total freshwater inflow to Sabine Lake. This assumption may not be correct for dry periods of low flow conditions when the flows in minor streams (ungaged streams) will probably decrease faster than the flows in the major streams (gaged streams).

3.2.1.2.2 Groundwater

The Chicot aquifer is the primary source of groundwater in southwestern Louisiana. Most of the groundwater pumped is used for industry and rice irrigation. In the vicinity of the Calcasieu Parish, the Chicot separates into three units named 200-ft, 500-ft and 700-ft sands. The

500-ft and 700-ft sands are hydraulically connected while the 200-ft and 500-ft sands are not hydraulically connected. Most of the groundwater is pumped from the 500-ft sand unit (Zack, 1971).

In much of Cameron Parish, the 200-ft sand is the only aquifer containing fresh water. East of Lake Charles the 200-ft sand is thick and is a very important source of water; however, west of Lake Charles, the sand thins and becomes discontinuous.

Groundwater pumpage in the Lake Charles industrial area has resulted in considerable drawdown in the piezometer surfaces of both 200-ft sand and 500-ft sands. Water level in the 500-ft sand has declined as much as 4.3 m (14 ft) per year. The saltwater interface in the 500-ft sand unit is moving northward at a rate of about 21.3 m (70 ft) per year (Harder, et al, 1967).

The Chicot aquifer outcrops in Beauregard and Allen Parishes. Precipitation on the sandy outcrop area recharges the aquifer. The 200-ft sand unit is also recharged from vertical leakage through overlying clay beds.

Driller's geological well logs for the Chenier Coastal Plain west of Sabine Lake were reviewed by the project staff. A typical profile consists of alternating layers of clay and sand. The layers are usually 1.5 to 9.1 m (5 to 30 ft) thick. Generally at the surface there is about a 30-ft (9.1 m) thick clay layer over a 3 m (10 ft) sand layer (Texas Water Development Board, 1971).

From the Soil Survey Report of Jefferson County, Texas (Soil Conservation Service, 1965), the surface soils in the Chenier Coastal Plain tend to be poorly drained clay with a permeability in the order of 0.025 cm (0.01 in) per hour. The permeability of sand outcrops is generally in the

order of 25.4 cm (10 in) per hour.

It was assumed that the general hydrogeological conditions observed west of Sabine Lake were applicable to the ICW between Sabine and Calcasieu Lakes. A groundwater flow net for a north-south section through the ICW was developed based on this assumption. The flow net is shown in Figure 3-7. The groundwater recharge rate and groundwater seepage into the ICW between Sabine and Calcasieu Lakes was estimated based on Darcy's equation. This equation is:

$$Q = KAS$$

Where Q is the flow in cfs, K is the permeability in feet per second, A is the cross-sectional area of flow in sq ft, and S is the slope of the hydraulic gradient. In these calculations the flow net was utilized to estimate S. An accurate estimate of S would require the installation and observation of piezometers in the field. However, in this study we are only interested in a rough estimate of the groundwater contribution to the freshwater inflow to the Calcasieu/Sabine system. The computations indicate that groundwater does not contribute a significant amount of freshwater inflow (0.2 cms; 6 cfs) to the system. The computations also indicate that groundwater recharge is approximately 1.3 cm (0.5 in) per year through the clay surface soils.

3.2.2 Freshwater Inflow and Salinity Relations

Salinity patterns in the Calcasieu/Sabine system are influenced primarily by freshwater inflows, tidal mixing, wind induced mixing, and the salinity of Gulf water. The mean tidal range at Sabine and Calcasieu passes is approximately 0.6 m (2 ft). While this is small compared to the tidal ranges on the East and West Coast of the United States, the estuaries are large in area but shallow (1 to 2 m; 3 to 6 ft) resulting in a

Recharge Rate

$$K_{\text{clay}} = 0.01 \text{ in/hr}$$

$$S = \Delta H / \text{length} = .006$$

$$Q = KAS = 0.01 \times 1 \times .006 = 6 \times 10^{-5} \text{ in/hr} = 0.5 \text{ in/yr}$$

Channel Seepage

$$K_{\text{clay}} = 0.01 \text{ in/hr} = 2.3 \times 10^{-7} \text{ ft/sec}$$

$$S = 0.2$$

$$A = 200 \times 123,600 = 2.5 \times 10^7 \text{ ft}^2$$

$$Q = 5.8 \text{ cfs}$$

Figure 3-7. Groundwater flow net for the ICW between Calcasieu and Sabine Lakes.

significant tidal exchange with the Gulf. The salinity of the offshore water will generally range from 20 to 36 o/oo. Gulf salinity is high during periods of low river discharge and low during periods of high river discharge.

Estuarine salinity near the Gulf passes vary with the stage of the tide. The influence of tidal mixing decreases with the distance away from the pass. The influence of freshwater inflow on estuarine salinity is greatest near the source of the inflow and decreases towards the Gulf. The relation between freshwater inflow and salinity developed for one area of an estuary may not be applicable for another area of the same estuary.

More information on the freshwater inflow-salinity relation was available for Sabine Lake than Calcasieu Lake. As a result the freshwater inflow-salinity relation for Sabine Lake will be discussed first.

The Texas Department of Water Resources (1981) in their report on the Sabine- Neches Estuary developed relationships between average monthly gaged freshwater inflow and the average monthly salinity for upper Sabine Lake. Salinity measurements used in the study were from a site west of station E-8 but they can be considered representative of upper Sabine Lake and of station E-8. Regression equations relating salinity to freshwater inflow were developed for each month of the year. The equations are listed in Table 3-2. For periods of low inflow the exponent of Q is approximately -0.6 while for periods of high inflow the exponent of Q is approximately -1.50.

For the low flow period (July through November) the regression equations and their derivatives are:

July	$S = 8100 Q^{-0.82}$	$\Delta S / \Delta Q = 6640 Q^{-1.82}$
Aug.	$S = 2760 Q^{-0.69}$	$\Delta S / \Delta Q = 1900 Q^{-1.69}$

Table 3-2. Salinity/Freshwater inflow regression analysis for Sabine Lake.

Month	Regression Equation S in o/oo and Q in cfs	Range of Q cfs	Standard Error of Estimate
January	$S = 920,400 Q^{-1.32}$	2,600 - 66,000	0.67
February	$S = 6,695,000 Q^{-1.54}$	4,000 - 73,000	0.73
March	$S = 2,875,000 Q^{-1.46}$	3,500 - 67,000	0.58
April	$S = 4,034,000 Q^{-1.50}$	3,000 - 90,000	0.68
May	$S = 563,000 Q^{-1.28}$	3,000 - 113,000	0.66
June	$S = 1,438,000 Q^{-1.42}$	2,000 - 65,000	0.62
July	$S = 8,100 Q^{-0.82}$	1,000 - 26,000	0.32
August	$S = 2,760 Q^{-0.69}$	750 - 32,000	0.16
September	$S = 1,320 Q^{-0.58}$	730 - 17,000	0.24
October	$S = 1,290 Q^{-0.58}$	650 - 20,000	0.27
November	$S = 2,500 Q^{-0.64}$	1,000 - 44,000	0.33
December	$S = 93,000 Q^{-1.06}$	2,500 - 92,000	0.65

From SABINE-NECHES EXTUARY: A Study of the Influence of Freshwater Inflows.
Texas Department of Water Resources, LP-116, July 1981.

Sept.	$S = 1320 Q^{-0.58}$	$\Delta S/\Delta Q = -766 Q^{-1.58}$
Oct.	$S = 1290 Q^{-0.58}$	$\Delta S/\Delta Q = -748 Q^{-1.58}$
Nov.	$S = 2500 Q^{-0.64}$	$\Delta S/\Delta Q = -1600 Q^{-1.64}$

where S is salinity in o/oo, Q is the gaged freshwater inflow in cfs, ΔS is the change in salinity in o/oo, and ΔQ is the changed in gaged freshwater inflow in cfs.

The Louisiana Department of Wildlife and Fisheries conducted a study of Louisiana's major estuaries and adjacent offshore waters. The two-year study, published in April 1978, provided monthly salinity observations in the upper and lower Calcasieu Lake for the period October 1974 through September 1976. Salinity observations in upper Calcasieu Lake were taken near station E-2 (Barrett, et al, 1978).

Figure 3-8 is a log-log plot of average monthly gaged freshwater inflow into Calcasieu Lake and salinity in upper Calcasieu Lake for the low flow period of July through November for the two years of salinity data. The relation between salinity (S) in o/oo and inflow (Q) in cfs expressed by the straight line in the plot is:

$$S = 508 Q^{-0.54}$$

The derivative of this expression is:

$$\frac{\Delta S}{\Delta Q} = -274 Q^{-1.54}$$

Sufficient data were not available to develop a relation between salinity and inflow for each month.

The West Hackberry project will pump various amounts of freshwater from the Calcasieu/Sabine system. During periods of high freshwater

Figure 3-8. Log-log plot of average monthly gaged freshwater inflow into Lake Calcasieu and salinity in upper Calcasieu Lake for the low flow period of July through November.

inflow, the project will have no measureable impact on salinity. However, during periods of low freshwater inflow, the project might have an observable impact on salinity.

A significant change in salinity is difficult to define because it depends on many factors. However, for the purpose of this discussion, a significant change in salinity is defined simply as an observable change that could be detected with normal instrumentation.

If 0.1 o/oo change in salinity is considered significant, the critical low freshwater inflow can be computed from the above equations relating change in inflow to change in salinity. Critical low freshwater inflow is defined as the average monthly gaged inflow below which freshwater diversion will cause a significant change in salinity.

Natural salinity variations of several o/oo occur in the estuaries and a change in salinity of 0.1 o/oo may not represent an observable or significant change. Low freshwater inflow rates (Q_L) were computed for several changes in salinity (ΔS) and diversions (ΔQ).

Critical low flows for Calcasieu Lake and Sabine Lake are listed in Tables 3-3 and 3-4, respectively. The critical low flows were computed for diversions ranging from 0.14 to 1.8 cms (5 to 65 cfs) and changed in salinity of 0.1, 1.0 and 2.0 o/oo. The percent of time during the dry period of the year that the gaged freshwater inflow is less than the critical low flow value is also listed in the tables.

3.2.3 Flow Characteristics of the Intracoastal Waterway

A one-dimensional hydrodynamic model developed by Harleman and Lee (1969) is being applied to the Calcasieu/Sabine Intracoastal Waterway system to evaluate the flow characteristics between the two lakes. This model takes instantaneous water levels at both ends of the canal as input

Table 3-3. Critical low flows for Calcasieu Lake and percent of time during the dry period (July-November) that flow is less than critical.

Freshwater Diversion Calcasieu Lake (ΔQ) cms (cfs)	$\Delta S = 0.1$ o/oo		DS = 1 o/oo		$\Delta S = 2$ o/oo	
	Low Gaged Inflow ¹ (Q_L) cms (cfs)	% Time July- Nov. Flow < ²	Low Gaged Inflow ¹ (Q_L) cms (cfs)	% Time July- Nov. Flow < ²	Low Gaged Inflow ¹ (Q_L) cms (cfs)	% Time July- Nov. Flow < ²
1.84 (65)	72.5 (2560)	87	16.2 (570)	46	10.5 (370)	28
1.55 (55)	64.9 (2290)	85	14.5 (510)	42	9.4 (330)	21
1.28 (45)	57.0 (2010)	82	12.8 (450)	36	8.2 (290)	14
0.99 (35)	48.5 (1710)	80	10.8 (380)	29	6.8 (240)	0
0.71 (25)	39.1 (1380)	74	8.8 (310)	17	5.7 (200)	0
0.43 (15)	28.1 (990)	65	6.2 (220)	0	4.0 (140)	0
0.14 (5)	13.6 (480)	39	3.1 (110)	0	2.0 (70)	0

$$^1Q_L = (274 \frac{\Delta Q}{\Delta S})^{0.649}$$

²From Figure 3-5

Table 3-4. Critical low flows for Sabine Lake and percent of time during the dry period (October-November) that flow is less than critical.

Freshwater Diversion Sabine L. (ΔQ) cms (cfs)	$\Delta S = 0.1$ o/oo		DS = 1 o/oo		$\Delta S = 2$ o/oo	
	Low Gaged Inflow ¹ (Q_L) cms (cfs)	% Time Oct.- Nov. Flow < ²	Low Gaged Inflow ¹ (Q_L) cms (cfs)	% Time Oct.- Nov. Flow < ²	Low Gaged Inflow ¹ (Q_L) cms (cfs)	% Time Oct.- Nov. Flow < ²
1.84 (65)	122.7 (4330)	47	29.5 (1040)	11	19.3 (680)	5
1.55 (55)	110.5 (3900)	42	26.6 (940)	9	17.3 (610)	4
1.28 (45)	99.8 (3450)	37	23.5 (830)	8	15.3 (540)	2
0.99 (35)	83.6 (2950)	31	20.1 (710)	6	13.0 (460)	0
0.71 (25)	67.7 (2390)	25	16.2 (570)	2	10.5 (370)	0
0.43 (15)	49.3 (1740)	19	11.9 (420)	0	7.7 (270)	0
0.14 (5)	24.9 (880)	8	6.0 (210)	0	4.0 (140)	0

$$^1Q_L = 0.5 (748 \frac{\Delta Q}{\Delta S})^{0.633} + 0.5 (1600 \frac{\Delta Q}{\Delta S})^{0.610}$$

²From Figure 3-6

and computes the instantaneous water surface elevations and flow rates at selected locations along the canal. Five sampling stations are located in the Calcasieu/Sabine system. Instrumentation at these sites will ultimately provide a continuous time series record of water level, conductivity, and temperature. Locations of the sampling stations are shown in Figure 3-1. Station E-1 is located at the raw water pump intake structure on the Intracoastal Waterway approximately 8.0 km (5.0 statute miles) west of the Ellender Bridge. Station E-2 is located at the north end of Calcasieu Lake near West Pass. Station E-6 is located in the Intracoastal Waterway at Ellender Bridge. Station E-7 is located about 300 m (1,000 ft) north of the confluence of the Intracoastal Waterway and the Sabine River. Station E-8 is located in the north end of Sabine Lake about 1.8 km (1 nm) south of the Intracoastal Waterway.

The instrument presently being used on the project is Sea Data Corporation's TDR-1. This instrument measures and records temperature and depth. Sea Data is adding a third sensor to the instrument to measure and record conductivity. The instruments are serviced monthly. The data is recorded on a tape waffer which is read with a Sea Data micro-reader and transferred to the TAMU computer. After the data has been processed it can be displayed as plots (Figure 3-9) and/or used as input to the Intracoastal Waterway hydrodynamic model. All the data has not been processed and the plot in Figure 3-9 is only an example. The depth in Figure 3-9 has been corrected for changes in atmospheric pressure observed at Lake Charles airport. A plot at a much larger scale was made of the data and this plot did not show any time difference between the tide at the bridge (E-6) and the ICW West (E-7).

For modeling purposes the Intracoastal Waterway between stations E-6

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Figure 3-9. Time series data recording temperature and depth at Ellender Bridge and west end of Intracoastal Waterway (corrected for atmospheric pressure changes).

and E-7 was divided into four segments each 8.45 km (5.25 mi) long. Bottom width of the channel was assumed to 38 m (125 ft), top width was scaled from the chart and the depth taken from the Corps of Engineers fathometer record along the centerline of the channel. The depth of the channel ranged from 4.7 to 7.3 m (15.5 to 24.0 ft). The incremental time period used for computations was 10 minutes.

Plots of the model input data are shown in Figure 3-10 for station E-6 at bridge and station E-7 at west end ICW. The data is for the period March 5 to April 6, 1981. The model has not been calibrated to field observations so the model results are of limited value. Figures 3-11 and 3-12 are examples of the model output at the pumping plant site. Figure 3-11 includes plots of the velocity and flow rate in the ICW. The model was established to run from Calcasieu Lake to Sabine Lake. Calcasieu Lake represents the origin and positive discharge. The flow rate is towards Sabine Lake. Figure 3-12 is a plot of cumulative flow (or mass inflow) in the ICW in ac-ft for the period March 7, 1981 to April 6, 1981. Since one cfs flowing for one day represents a volume of 1.98 ac-ft, the volume of flow begins at 0 and is accumulated throughout the period with flow towards the west being positive and flow towards the east being negative. There was not adequate time available in this predisposal study to calibrate the model. The model was calibrated for the ICW between Sabine and Galveston Bay in a previous Sea Grant Study (James, et al, 1977). The model parameters determined in the Sea Grant study were also used for this study. Before this project is completed it will be necessary to calibrate the model to the ICW between Sabine and Calcasieu Lakes. Field observations of water levels and current velocities will be required at each end of the ICW. The model parameters will be adjusted so that the observed water

Figure 3-10. Water levels at the west (ICW west) and east (Ellendor Bridge) ends of the Intracoastal Waterway for the period March 5 to April 6, 1981.

Figure 3-11. Computed discharge rate and current velocity in the Intracoastal Waterway at the raw water intake station for the period March 5 to April 6, 1981.

Figure 3-12. Cumulative flow in the Intracoastal Waterway from model study for the period March 5 to April 6, 1981.

velocities are reproduced by the model.

Model results indicating that the flow in early March is towards the east while the flow in early April is towards the west (See Figure 3-11). Salinity observations taken along the ICW at stations E-6 (bridge), E-1 (RWIS - pump), and E-7 (end ICW) on March 8, 1981, indicate a flow towards the east while salinity observations taken on April 9, 1981, indicate a flow in the ICW towards the west (see Figure 3-13). Salinity observations at the east end of the ICW are much higher than the salinity observations at the west end of the ICW. A steady state, one-dimensional dispersion model of the ICW is

$$D \frac{\partial^2 S}{\partial X^2} = V \frac{\partial S}{\partial X}$$

where D is the dispersion coefficient, S is the salinity, V is velocity and X is distance. X and V are positive towards the west. Since $\partial S / \partial X$ is negative, V must be negative (east) when $\partial^2 S / \partial X^2$ is positive and V must be positive (west) when $\partial^2 S / \partial X^2$ is negative. $\partial^2 S / \partial X^2$ is positive for the March 8, 1981 salinity profile and negative for the April 9, 1981 salinity profile.

3.2.4 Raw Water Diversion from the ICW

The West Hackberry project will divert various amount of water from the ICW at the pumping plant located approximately 12.1 km (7.5 mi) west of Calcasieu Lake and 24.1 km (15 mi) east of Sabine River. The maximum project diversions from the ICW is expected to be 1.98 cms (70 cfs). The amount of water that is diverted from the ICW is relatively small in comparison to the flow in the ICW. When the net flow in the ICW is from Sabine River to Calcasieu Lake, the water that will be diverted from the system is from the Sabine River but this water also represents ungaged inflow that will be diverted primarily from the Calcasieu Estuary.

Figure 3-13. Model results of salinity along the ICW. Concave upward curve indicates flow from the Sabine to the Calcasieu; concave downward curve indicates flow from Calcasieu to Sabine.

When the pumps are started, the water surface elevation in the ICW at the RWIS will be drawn down by an amount (Δh) such that the change in flow from the Sabine River (ΔQ_s) plus the change in Flow from Calcasieu Lake (ΔQ_c) is equal to the water diverted (Q_p) or

$$Q_p = \Delta Q_c + \Delta Q_s$$

If the amount of water diverted (Q_p) is small in comparison to the flow in the ICW (Q_{icw}), it follows from Manning's Equation that

$$Q_p = \frac{Q_{icw}}{2S_{icw}} \Delta S_c + \Delta S_s$$

where S is the water surface slope in the ICW, ΔS_c is the change in slope of the water surface in the ICW from the pumping plant to Calcasieu Lake, and ΔS_s is the change in slope of the water surface in the ICW from the pumping plant to Sabine. Since

$$\Delta S_c = 2\Delta S_s,$$

$$\Delta Q_c = 0.67 Q_p \text{ and}$$

$$\Delta Q_s = 0.33 Q_p.$$

If the amount of water diverted from the ICW is not small in comparison to the flow in the ICW, then the change in flow would be

$$\Delta Q_c = 0.60 Q_p \text{ and}$$

$$\Delta Q_s = 0.40 Q_p.$$

For the purpose of this study we will assume that 65 percent of the diverted water is from the Calcasieu and 35 percent is from the Sabine.

For example, if the flow in the ICW is Q from Sabine to Calcasieu, after the pumps are started the flow in the ICW from Sabine to the pumping station would increase to approximately $Q + 0.35 Q$ and the flow from the pumping station to Calcasieu would decrease to approximately $Q - 0.65 Q$. Thirty-five percent of the pumped water is diverted from the Sabine and 65 percent is diverted from the Calcasieu. If the net flow in the ICW is Q towards the west before the pumps are started, then after pumps are started, the flow in the ICW east of the pump station would increase to approximately $Q + 0.65 Q$ and the flow in the ICW west of the pump station will decrease to approximately $Q - 0.35 Q$. Again, approximately 65 percent of the pumped water will be diverted from the Calcasieu system and 35 percent from the Sabine system.

3.2.5 Impact of Diversions from the ICW on the Salinity in Upper Calcasieu and Sabine Lakes

Water diverted from the ICW at the pumping plant will include both freshwater and Gulf water. During the low freshwater inflow period (July - November) the salinity of the pumped water will be high. During this period there is little freshwater flowing directly into the ICW and the salinity at the pump intake is expected to be nearly the same as that in the upper Calcasieu Lake or upper Sabine Lake. The salinity and percent freshwater in the diverted water is estimated in Table 3-5. The salinity can be expected to vary from about 4 o/oo to about 26 o/oo during the dry season.

The estimated changes in salinity for the upper Calcasieu Lake and upper Sabine Lake caused by pumping water from the ICW are listed in Tables 3-6 and 3-7. Table 3-6 is for a diversion of 1.98 cms (70 cfs) and Table 3-7 is for a diversion of 1.42 cms (50 cfs). It can be observed that only

Table 3-5. Estimated salinity of the diverted water.

% Time Inflow Less Than ¹	Calcasieu Lake		Sabine Lake		Estimated Salinity of Div. Water (o/oo)	Freshwater ⁶ %
	Inflow ² (cfs)	Salinity ³ (o/oo)	Inflow ⁴ (cfs)	Salinity ⁵ (o/oo)		
10	270	25	950	28	26	26
20	320	23	1800	19	22	39
30	90	20	2800	14	18	49
40	480	18	3700	12	16	54
50	640	16	4500	11	14	60
60	850	13	5100	10	12	66
70	1170	11	5800	9	10	72
80	1750	9	6800	8	9	74
90	3200	7	9500	7	7	80
100	8500	4	24000	4	4	89

¹ Percent of time during the low flow period that the average monthly gaged freshwater inflow is less than the value indicated.

² Average monthly gaged freshwater inflow from Figure 3-5.

³ Salinity in Upper Calcasieu Lake = $508 Q^{-0.54}$.

⁴ Average monthly gaged freshwater inflow from Figure 3-6.

⁵ Salinity in Upper Sabine Lake = $645 Q^{-0.58} + 1250 Q^{-0.64}$.

⁶ Percent freshwater based on a Gulf salinity of 35 o/oo.

Table 3-6. Estimated change in salinity caused by pumping 70 cfs water from the Intracoastal Waterway

% Time Gaged Inflow Less Than	Salinity Diverted Water (o/oo)	ΔQ_f (cfs)	ΔQ_g (cfs)	Calcasieu Lake				Sabine Lake			
				Q_{cig} (cfs)	ΔQ_c (cfs)	ΔQ_{cg} (cfs)	ΔS_c (o/oo)	Q_{sig} (cfs)	ΔQ_s (cfs)	ΔQ_{sg} (cfs)	ΔS_s (o/oo)
10	26	18.2	51.8	270	11.8	5.9	0.29	950	6.37	5.4	0.05
20	22	25.9	44.1	320	16.8	8.4	0.32	1800	9.1	7.7	0.02
30	18	34.3	35.7	390	22.3	11.1	0.31	2800	12.0	10.2	0.02
40	16	37.8	32.2	480	24.6	12.3	0.25	3700	13.2	11.2	0.01
50	14	42.0	28.0	640	27.3	13.6	0.18	4500	14.7	12.5	0.008
60	12	46.2	23.8	850	30.0	15.0	0.13	5100	16.2	13.7	0.008
70	10	50.4	19.6	1170	32.8	16.4	0.08	5800	17.6	15.0	0.007
80	9	51.8	18.2	1750	33.7	16.8	0.05	6800	18.1	15.4	0.005
90	7	56.0	14.0	3200	36.4	18.2	0.02	9500	19.6	16.7	0.003
100	4	62.3	7.7	8500	40.5	20.2	0.005	24000	21.8	18.5	0.001

Q_{cig} = gaged freshwater inflow to Calcasieu.

Q_{sig} = gaged freshwater inflow to Sabine.

ΔQ_f = amount of freshwater diverted from the ICW.

ΔQ_g = amount of Gulf water diverted from the ICW.

ΔQ_c = amount of freshwater diverted from Calcasieu = $0.65 Q_f$.

ΔQ_{cg} = amount of gaged freshwater diverted from Calcasieu = $0.5 \Delta Q_c$.

$\Delta S_c = 274 \Delta Q_{cg} Q_{cig}^{-1.54}$ = change in salinity in the upper Calcasieu Lake.

ΔQ_s = amount of freshwater diverted from Sabine = $0.35 Q_f$.

ΔQ_{sg} = amount of gaged freshwater diverted from Sabine = $0.85 \Delta Q_s$.

$\Delta S_s = 374 \Delta Q_{sg} Q_{sig}^{-1.58} + 800 \Delta Q_{sg} Q_{sig}^{-1.64}$ = change in salinity in upper Sabine Lake.

Table 3-7. Estimated change in salinity caused by pumping 50 cfs of water from the Intracoastal Waterway.

% Time Gaged Inflow Less Than	Salinity Diverted Water (o/oo)	ΔQ_f (cfs)	ΔQ_g (cfs)	Calcasieu Lake				Sabine Lake			
				Q_{cig} (cfs)	ΔQ_c (cfs)	ΔQ_{cg} (cfs)	ΔS_c (cfs)	Q_{sig} (cfs)	ΔQ_s (cfs)	ΔQ_{sg} (cfs)	ΔS_s (cfs)
10	26	13.0	37.0	270	8.4	4.2	0.21	950	4.6	3.9	0.04
20	22	19.5	30.5	320	12.7	6.3	0.24	1800	6.8	5.8	0.02
30	18	24.5	25.5	390	15.9	8.0	0.22	2800	8.6	7.3	0.01
40	16	27.0	23.0	480	17.6	8.8	0.18	3700	9.4	8.0	0.008
50	14	30.0	20.0	640	19.5	9.8	0.13	4500	10.5	8.9	0.006
60	12	33.0	17.0	850	21.5	10.7	0.09	5100	11.6	9.8	0.005
70	10	36.0	14.0	1170	23.4	11.7	0.06	5800	12.6	10.7	0.005
80	9	37	13.0	1750	24.1	12.0	0.03	6800	12.9	11.0	0.004
90	7	40	10.0	3200	26.0	13.0	0.01	9500	14.0	11.9	0.002
100	4	44.5	5.5	8500	28.9	14.5	0.003	24000	15.6	13.2	0.0006

Q_{cig} = gaged freshwater inflow to Calcasieu.

Q_{sig} = gaged freshwater inflow to Sabine.

ΔQ_f = amount of freshwater diverted from the ICW.

ΔQ_g = amount of Gulf water diverted from the ICW.

ΔQ_c = amount of freshwater diverted from Calcasieu = $0.65 Q_f$.

ΔQ_{cg} = amount of gaged freshwater diverted from Calcasieu = $0.5 \Delta Q_c$.

$\Delta S_c = 274 \Delta Q_{cg} Q_{cig}^{-1.54}$ = change in salinity in the upper Calcasieu Lake.

ΔQ_s = amount of freshwater diverted from Sabine = $0.35 Q_f$.

ΔQ_{sg} = amount of gaged freshwater diverted from Sabine = $0.85 \Delta Q_s$.

$\Delta S_s = 374 \Delta Q_{sg} Q_{sig}^{-1.58} + 800 \Delta Q_{sg} Q_{sig}^{-1.64}$ = change in salinity in upper Sabine Lake.

in Calcasieu Lake is the change in salinity expected to be more than 0.1 o/oo. The maximum increase in salinity is estimated at 0.32 o/oo and is expected to occur with a diversion of 1.98 cms (70 cfs) and an average monthly gaged freshwater inflow to Calcasieu Lake of 9.07 cms (320 cfs). A gaged inflow of 9.07 cms (320 cfs) or less is expected to occur approximately 20 percent of the time during the low flow period of July through November. If the diversion is 1.42 cms (50 cfs), the maximum increase in salinity in the upper Calcasieu Lake is estimated at 0.24 o/oo. For a diversion of 1.42 cms (50 cfs) the increase in salinity in the upper Calcasieu Lake is expected to be greater than 0.1 o/oo approximately 50 percent of the time during the low flow period of July through November.

Figure 3-14 shows the percent of time during the low flow period of July through November that the change in salinity is expected to be greater than 0.1 o/oo in the upper Calcasieu Lake for pumping rates from the ICW ranging from 0 to 1.98 cms (0 to 70 cfs). The maximum expected change in the upper Calcasieu Lake as a function of pumping rate is shown in Figure 3-15.

3.2.6 EIS Model Study

The Environmental Impact Statement for the West Hackberry project presented the results of a modeling study to evaluate the influence of pumping from the Intracoastal Waterway (ICW) on the salinity in the ICW. The study was based on the following assumptions:

I. ICW at Sabine

A. Tide

1. Sinusoidal variation
2. 1.0 ft range
3. 12 hr period

Figure 3-14. Percent of time during the low flow period that the change in salinity is expected to be greater than 0.1 o/oo in the upper Calcasieu Lake.

Figure 3-15. Maximum change in salinity for upper Calcasieu Lake.

4. 113 min lag time

B. Salinity 14 o/oo constant

II. ICW at Calcasieu

A. Tide

1. Sinusoidal Variation

2. 1.25 ft range

3. 12 hr period

4. 4 min lag time

B. Salinity 15 o/oo constant

III. Lateral inflow

A. 0.004 cfs/ft

B. Salinity 0.1 o/oo constant

Because of the high salinity levels selected for Calcasieu Lake and Sabine River, the results of the EIS model study were intended to represent low freshwater inflow conditions. The assumed lateral inflow to the ICW of 0.004 cfs/ft was extremely high. The ICW is 37,700 m (123,600 ft) long and this represents a lateral flow into the ICW of 14 cms (494 cfs). This is a very poor assumption in that only two small ungaged drainage areas contribute lateral inflow to the ICW (Figure 3-2) and groundwater seepage into the ICW is expected to be less than 0.3 cms (10 cfs) (Figure 3-7). It can be observed that 14 cms (494 cfs) is more freshwater than the monthly average gaged freshwater inflow into Calcasieu Lake 40 percent of the time (Figure 3-5) during the low flow period of July through November.

Water levels observed at the end of the ICW (stations E-6 and E-7, Figure 3-1) did not indicate a 109-minute time difference between the tide in Sabine and the tide in Calcasieu as assumed for the EIS study.

With these assumptions the EIS model study gave a salinity profile

along the ICW that began at 15 o/oo at the Calcasieu, decreased to 3 o/oo 3.2 km (2 mi) east of Sabine River and then increased to 14 o/oo at the Sabine. With this unique salinity profile, the project diversion from the ICW would decrease the salinity in the ICW west of the pump station for a length of 24.1 km (15 mi) and increase the salinity in the ICW east of the pump station for a length of 12.1 km (7.5 mi).

3.2.7 Hydrology Summary and Conclusions

The U.S. Geological Survey's daily streamflow records for Calcasieu and Sabine Lakes were obtained for the period October 1967 through October 1980. The streamflow records indicated that the low flow period for Calcasieu Lake extended from July through November. Because of reservoir storage in the drainage area the low flow period for Sabine Lake included only October and November. It was estimated that the gaged freshwater inflow to Sabine Lake represented 85 percent of the total freshwater inflow to Sabine and the gaged inflow to Calcasieu Lake represented 50 percent of the total freshwater inflow to Calcasieu Lake. There was not adequate time available in the predischage study to accurately evaluate the ungaged freshwater inflow to the Calcasieu-Sabine system.

Texas Department of Water Resources conducted a study of Sabine Lake and developed equations relating average monthly gaged freshwater inflow to average monthly salinity in upper Sabine Lake. Two years of salinity data were available for Calcasieu Lake and a similar expression was developed for Calcasieu Lake relating average monthly gaged freshwater inflow to salinity in the upper Calcasieu Lake. From these equations, changes in salinity resulting from changes in gaged freshwater inflow were computed for each lake.

The flow characteristics of the Intracoastal Waterway (ICW) were

evaluated to determine (1) how much water flows in the ICW from Sabine to Calcasieu or from Calcasieu to Sabine and (2) how much of the water pumped from the ICW is from Calcasieu and how much is from Sabine. Water level recorders have been installed at each end of the ICW and a one-dimensional hydrodynamic model applied to the ICW to determine velocities and flow rates. There was not sufficient time in the predischage study to calibrate the model. The model results shown in this report are examples only and should not be used for evaluation.

The raw water intake structure is located closer to Calcasieu Lake than Sabine Lake. It was estimated the 65 percent of the pumped water would represent a diversion from Calcasieu and 35 percent of the pumped water would represent a diversion from Sabine regardless of the direction of flow in the ICW.

During the period of low freshwater inflow to the Calcasieu/Sabine system, the salinity of the diverted water increases and much of the pumped water is from the Gulf of Mexico rather than freshwater inflow. During the low freshwater inflow period it was estimated that the salinity of the pumped water would be nearly the same as that computed for the upper Calcasieu Lake and the upper Sabine Lake. The salinity of the pumped water during the low flow period was estimated to range from 4 to 26 o/oo depending on the level of freshwater inflow.

Changes in salinity caused by pumping 1.98 cms (70 cfs) and 1.42 cms (50 cfs) from the ICW were estimated for upper Calcasieu Lake and upper Sabine Lake. These computations indicated that a diversion of 1.98 cms (70 cfs) from the ICW would cause a maximum increase in salinity of 0.32 o/oo in Calcasieu Lake and 0.05 o/oo in Sabine Lake. A diversion of 1.42 cms (50 cfs) from the ICW would cause a maximum increase in salinity of 0.24

o/oo in Calcasieu and 0.04 o/oo in Sabine. For a diversion of 1.42 cms (50 cfs), 50 percent of the time during the low freshwater inflow period (July - November) the increase in salinity in upper Calcasieu Lake would be greater than 0.1 o/oo.

No conclusion was reached as to whether or not the pumping would cause a significant increase in salinity. When these changes are compared to the natural variations that occur in these estuaries, it can be concluded that the project by itself will probably not cause a significant increase in salinity. However, the effects of the diversions are additive and when the effects of all present and future diversions are considered there will be a significant change in salinity. At some level of diversion, it will be necessary to limit or restrict additional diversions from the system.

The model study presented in the West Hackberry EIS was reviewed. The EIS model study was conducted to evaluate the influence of pumping from the ICW on the salinity in the ICW. An extremely large freshwater inflow to the ICW was assumed for the model run. This resulted in a very unusual salinity profile being produced by the model. Results of the EIS model study should not be considered representative of the influence of pumping on the salinity in the ICW.

3.3 Estuarine Hydrography

3.3.1 General Comments

The estuarine hydrography of Lake Calcasieu, Lake Sabine, and the Intracoastal Waterway have been briefly studied prior to brine disposal by collecting monthly conductivity, temperature, depth and dissolved oxygen (CTD/DO) data at ten stations which are shown in Figure 3-1 in section 3.1 and their locations are tabulated in Table 3-8. These stations have been sampled since January 1981, and the data are discussed up to May 1981 when

Table 3-8. Latitude and longitude for the estuarine hydrology and hydrography sampling stations.

Station Number	Latitude	Longitude
E1 (Pump Intake)	30°03'32"N	93°26'00"W
E2 (N. Calcasieu Lake)	30°03'05"N	93°18'40"W
E3 (SW Calcasieu Lake)	29°51'33"N	93°22'00"W
E4 (SE Calcasieu Lake)	29°51'12"N	93°18'47"W
E5 (Calcasieu Pass)	29°46'11"N	93°20'38"W
E6 (Ellender Bridge)	30°03'47"N	93°20'55"W
E7 (ICWW West)	30°03'35"N	93°41'55"W
E8 (N. Sabine Lake)	29°57'32"N	93°42'40"W
E9 (SE Sabine Lake)	29°54'07"N	93°48'13"W
E10 (SW Sabine Lake)	29°51'45"N	93°55'00"W

brine disposal was initiated. The instrumentation and sampling procedures are summarized in this report and are described in more detail in the field operations manual (Randall and James, 1981). The remainder of this section will discuss the results of the estuarine data collected during the predisposal period January through April 1981.

3.3.2 Description of Instrumentation

A Hydrolab 8000 CTD/DO water quality instrument (Hydrolab, 1980) has been used for the collection of CTD/DO data. This instrument consists of a data transmitter (probe), data bus cable (conductor cable), and a data control unit (remote readout). The probe is capable of measuring conductivity (0-200 mmho/cm), depth (0-200 m), temperature (-5 to +45° C), dissolved oxygen (0-20 ppm), and ph/ORP.

The accuracy of the conductivity sensor (four electrode type) is ± 0.5 % of full scale which corresponds to ± 1 mmho/cm or ± 0.7 o/oo. The conductivity sensor accuracy is improved to at least ± 0.5 o/oo by calibrating it with standard solutions using a Grundy laboratory salinometer which has an accuracy of ± 0.003 o/oo (Grundy, 1978). The temperature and depth sensors have an accuracy of ± 0.2 °C and ± 1 m. The dissolved oxygen sensor was calibrated before and after each field trip against water saturated air and Winkler analysis of selected water samples. The remote readout device displays digitally the conductivity to 0.1 mmho/cm, the temperature to 0.1 °C, the depth to 0.1m , and dissolved oxygen to 0.01 ppm.

3.3.3 Conversion and Calibration of Data

The conductivity data from the CTD/DO instrument are corrected to a temperature of 25°C by an internal compensation circuit. The conductivity data collected were then converted to salinity using Equation 3-1

$$S = 1.80655 \times 10^{\frac{\log_{10} C - 0.57627}{0.892}} \quad (3-1)$$

after Weyl (1964), where C is the conductivity in mmho/cm at 25°C. The salinity data were then corrected as required by the calibration results.

The temperature data were used as read from the instrument because these data have been within the manufacturer's accuracy specifications. The depth sensor was adjusted to zero in the laboratory, but the depth measurements frequently required a correction which was determined by a surface measurement and a bottom measurement which was checked with the ship's depth sounder and the marked winch or liftline line.

The raw dissolved oxygen data were corrected for salinity and temperature effects using the correction procedures described in the Hydrolab 8000 Operations Manual (Hydrolab, 1980). These data were then calibrated with data obtained by Winkler titration procedures.

The salinity, temperature, and depth data were used to compute the density of the water column. The density data is presented in the customary oceanographic form of sigma - t (σ_t) which is defined as

$$\sigma_t = (\rho - 1.0) \times 10^{-3} \quad (3-2)$$

where the density (ρ) is expressed in gm/cm³. Sigma - t values were computed from salinity, temperature and depth data using the equation of LaFond (1951).

3.3.4 Sampling procedures

The CTD/DO measurements at the estuarine stations E-1 through E-10 were conducted once a month on a one day cruise using the Hydrolab 8000 CTD/DO system. The CTD/DO data were collected at one meter above the bottom, mid-depth, and one meter below the surface except at shallow water stations in the lakes (E-2, E-3, E-4, E-8, E-9 and E-10) where only near

bottom and near surface measurements were made. The data were recorded in a bound field data book, and it was returned to the laboratory along with the instrument for further data analysis and calibration checks.

3.3.5 Presentation of Estuarine Hydrographic Data

3.3.5.1 Calcasieu Lake and Calcasieu Pass

The hydrographic data from Calcasieu Lake which was collected from January through April 1981 are tabulated in Table 3-9. The data were collected at stations E2 located in the north end of the lake (see Figure 3-1) and at stations E3 and E4 which are situated in the southern portion on the west and east side respectively. The data were collected near the surface and near the bottom.

The conductivity data referenced to 25°C is shown for completeness and were converted to salinity as described in section 3.3.3. The January data show the salinity was 23.5 o/oo near the surface at E2 and increased to 25.4 o/oo at E4 in the southern end of the lake, and a similar trend was observed at the bottom indicating the presence of a well mixed condition. At station E3 near Rabbit Island in the west cove of the lake, the salinity was 23.0 o/oo near the surface and 25.3 o/oo near the bottom indicating a slightly stratified condition. During the months of February and March, all stations showed the lake to be well mixed with salinities the same from top to bottom. However, the water was fresher at station E2 in the northern end where fresher water is input from the Intracoastal Waterway and Calcasieu River. The salinity at station E2 was 15.5 o/oo and increased to 23.6 o/oo and 21.2 o/oo at E3 and E4 respectively. For these months, the salinity was higher in the west side of the lake. In April, the lake was basically isohaline (-23.0 o/oo) in the southern portion and slightly stratified at station E2. Thus, the limited data indicate

Table 3- 9. Predisposal hydrographic data from the Calcasieu Lake for the period January through April 1981.

Date	Station Number	Time CST	Depth (m)	Conductivity mmho/cm at 25°C	Salinity (o/oo)	Temp. (°C)	D.O. (ppm)	Sigma-t
1/23/81	E4	0840	0.5	39.9	25.4	7.8	9.6	19.81
			0.9	40.1	25.5	7.8	9.8	19.92
	E3	0955	0.2	36.5	23.0	7.1	12.5	18.00
			0.6	39.8	25.3	8.7	10.6	19.63
	E2	1200	0.8	37.2	23.5	9.8	7.5	18.04
			1.2	37.4	23.6	9.6	7.7	18.18
2/14/81	E4	0855	0.5	34.1	21.2	5.4	8.9	16.75
			0.9	34.2	21.2	5.3	8.9	16.81
	E3	1000	0.2	37.6	23.6	5.2	10.5	18.69
			0.6	37.6	23.6	5.2	10.0	18.69
	E2	1200	0.8	25.8	15.5	8.7	7.9	11.99
			1.2	25.9	15.6	8.5	7.9	12.06
3/8/81	E4	0735	0.5	35.4	22.3	15.1	8.1	16.24
			0.9	35.4	22.3	15.2	8.1	16.22
	E3	0835	0.2	36.7	23.2	15.0	8.3	16.96
			0.6	36.6	23.2	15.0	8.3	16.91
	E2	1045	0.8	30.2	18.7	15.9	6.9	13.31
			1.2	30.2	18.7	15.9	7.0	13.31
4/9/81	E4	0710	0.5	36.3	22.9	20.9	7.7	15.40
			0.9	36.3	22.9	20.9	7.5	15.41
	E3	0745	0.2	36.8	23.3	21.1	7.4	15.62
			0.6	36.4	23.0	21.1	7.4	15.41
	E2	0900	0.8	34.7	21.8	21.3	7.3	14.45
			1.2	36.6	23.1	21.1	7.0	15.52

Calcasieu Lake is generally well mixed and the salinity tends to increase from north to south with the fresh water input at the northern end of the lake. A similar trend was found by Barrett, (1978 and 1971). Also, the salinity in the west side of lake (by Rabbit Island) is saltier than on the east side.

The temperature data showed no evidence of a thermocline in the lake. The lowest temperatures (5.2°C) were measured in February in the southern portion and the warmest temperatures (21.3°C) were recorded in April. In general, the temperatures decrease from the northern to the southern portions of the lake which was also reported by Barrett (1978 and 1971).

The dissolved oxygen data showed the highest value (12.5 ppm) was measured in January near the surface at station E3, and the lowest value was 6.9 ppm which was recorded at station E2 in March. The dissolved oxygen was found to increase from the northern station E2 to the southern stations E3 and E4 in every month sampled although the variation was very small in April. In January through March, the western portion of the lake had higher dissolved oxygen values than in the eastern or northern areas.

The hydrographic data measured at station E5 in Calcasieu Pass is tabulated in Table 3-10. The salinity, temperature, and dissolved oxygen data show essentially no variation from top to bottom except on February 14 when there was a small increase (1.3 o/oo) in salinity at the bottom. Vertical profiles of the salinity data are illustrated in Figure 3-16, and they indicate the well mixed conditions found so far in Calcasieu Pass. These data agree with continuous data described in Chapter 2 of this report. The continuous data clearly shows the tidal effects on the salinity and temperature of the water in Calcasieu Pass.

Table 3-10. Predisposal hydrographic data for Calcasieu Pass for the period January through April 1981.

Date	Station Number	Time CST	Depth (m)	Conductivity mmho/cm at 25°C	Salinity (o/oo)	Temp. (°C)	Dissolved Oxygen (ppm)	Sigma-t
1/23/81	E5	0730	1.0	47.0	30.5	9.1	8.9	23.63
			3.0	47.0	30.5	9.1	9.2	23.63
			6.0	47.1	30.6	9.3	9.1	23.66
2/14/81	E5	0645	1.0	32.3	19.9	6.0	10.2	15.72
			3.0	32.4	20.0	5.9	10.7	15.78
			6.0	34.1	21.2	6.3	10.6	16.67
3/8/81	E5	0630	1.0	47.9	31.3	15.6	7.9	23.01
			3.0	47.9	31.3	15.6	7.9	23.02
			6.0	47.9	31.3	15.5	7.9	23.04
4/9/81	E5	0610	1.0	38.3	24.3	21.2	7.5	16.40
			3.0	38.5	24.5	21.3	7.4	16.49
			6.0	38.5	24.5	21.4	7.4	16.46

Figure 3-16. Vertical salinity profiles at station E-5 (Calcasieu Pass).

3.3.5.2 Intracoastal Waterway

Three sampling stations are located in the Intracoastal Waterway. One station (E6) is located at the Ellender Bridge which crosses the Intracoastal Waterway just west of the head of Calcasieu Lake and east of the raw water intake used for leaching of storage caverns. The second station (E1) is located at the raw water intake structure, and the third station (E7) is located near the confluence of the Sabine River and the Intracoastal Waterway. The location of these stations are illustrated in the previous Figure 3-1 and their latitude and longitude are given in Table 3-8.

The hydrographic data recorded at the stations in the Intracoastal Waterway are tabulated in Table 3-11. In January, station E7 was not sampled and in February, it was sampled the day after stations E1 and E6. Beginning in March, the stations were all sampled on the same day. The salinity data in January show the water column was well mixed with little variation (0.8 o/oo at E6) from top to bottom. In February, the water column was well mixed at stations E6 and E1 with salinities of 11.9 o/oo and 11.5 o/oo, but stratification was evident at station E7 where the salinity and sigma-t varied from top to bottom by 11.2 o/oo and 8.7 sigma-t units. The March data show the water column had a slight halocline and pycnocline at all stations indicating some stratification. These data also showed that the salinity increased from west to east with surface values ranging from 3.0 o/oo at E7 to 17.4 o/oo at E6. The April salinity data show that isohaline conditions returned at stations E6 and E1 with salinities of 17.1 o/oo and 16.5 o/oo respectively. Data at station E7 show a slight halocline with salinity varying from 8.0 o/oo at top to 9.3 o/oo at bottom. A similar trend of increasing salinity from west to east was also apparent in the April data.

Table 3-11. Predisposal hydrographic data from the Intracoastal Waterway between Lake Sabine and Calcasieu for the period January through April 1981.

Date	Station Number	Time	Depth (m)	Conductivity mmho/cm at 25°C	Salinity (o/oo)	Temp (°C)	Dissolved Oxygen (ppm)	Sigma-t
1/23/81	E6	1425	1.0	18.6	10.8	9.2	10.4	8.3
			1.5	19.1	11.1	9.2	10.5	8.5
			4.5	19.8	11.6	9.2	10.5	8.9
	E1	1615	0.5	8.8	4.6	8.8	10.4	3.5
			2.1	8.8	4.6	8.9	10.6	3.5
			3.7	8.8	4.6	9.1	10.9	3.5
	E6	1320	1.0	20.4	11.9	6.9	8.8	9.4
			1.5	20.3	11.9	6.9	8.7	9.3
			4.5	20.4	11.9	6.9	8.7	9.4
2/14/81	E1	1420	0.5	19.7	11.5	6.8	9.3	9.0
			2.1	19.7	11.5	6.8	9.8	9.0
			3.7	19.7	11.5	6.9	10.3	9.0
	E7	0715	1.0	6.7	3.5	8.9	8.8	2.6
			2.5	10.4	5.6	8.7	8.5	4.3
			5.5	24.6	14.7	9.0	7.8	11.3
	E6	1145	1.0	28.3	17.4	16.5	7.0	12.2
			1.5	28.3	17.4	16.5	7.1	12.2
			4.5	32.6	20.3	16.3	6.4	14.5
3/8/81	E1	1245	0.5	17.9	10.4	17.0	8.9	6.8
			2.1	19.0	11.1	16.7	8.2	7.4
			3.7	20.4	12.0	16.5	8.1	8.1
	E7	1435	1.0	5.9	3.0	17.9	8.1	1.0
			2.5	9.0	4.8	17.5	8.2	2.5
			5.5	12.6	7.0	17.0	7.3	4.2

Table 3-11 . (continued)

Date	Station Number	Time	Depth (m)	Conductivity mmho/cm at 25°C	Salinity (o/oo)	Temp (°C)	Dissolved Oxygen (ppm)	Sigma-t
4/9/81	E6	0930	1.0	28.1	17.2	21.2	6.8	11.01
			1.5	28.0	17.1	21.1	7.1	10.99
			4.5	28.0	17.1	21.2	7.4	10.97
	E1	1150	0.5	27.0	16.5	21.8	7.5	10.30
			2.1	27.0	16.5	21.6	7.7	10.35
			3.7	26.9	16.4	21.5	7.9	10.33
	E7	1340	1.0	14.2	8.0	22.4	9.0	3.79
			2.5	15.3	8.7	21.9	8.4	4.44
			5.5	16.2	9.3	21.7	7.2	4.92

The temperature and dissolved oxygen data indicated very little variation over the water column. The warmer water was found at station E7 and it decreased slowly from west to east. The lowest temperatures were measured in February as 6.8°C, and they increased to a maximum value of 22.4°C in April which is the normal seasonal trend. Values of dissolved oxygen ranged from 10.9 ppm in January to 6.4 ppm in March, and these were considered to be in a normal range.

3.3.5.3 Sabine Lake

Hydrographic data was collected at three stations in Sabine Lake beginning in February 1981. Station E8 was located at the northern end of the lake, and E9 was situated on the eastern side about in the middle of the lake. The last station E10 was located in the lower southwestern side.

The salinity data for all three months indicate the water column was isohaline except for station E9 in February when a 1.4 o/oo difference in salinity was measured between top and bottom waters. The lowest salinity was recorded at station E10 at 7.8 o/oo in February, and the highest salinity of 20.1 o/oo was also recorded at station E10 in April. There was no clear trend of increasing salinity from north to south as found in Calcasieu Lake, but the salinities were consistently lower in Sabine than in Calcasieu Lake as shown in Table 3-12.

The temperature and dissolved oxygen data showed very little vertical variation which again indicates the well mixed condition of the estuary. The minimum temperature was measured as 7.5°C in February at station E9, and the maximum was 23.9°C in April at station E8. The maximum dissolved oxygen reading was 12.0 ppm at the surface of station E8 in April and the minimum value was 7.9 ppm at the same station in February. The data indicate the salinity and temperature increased from February through April

Table 3-12. Predisposal hydrographic data from the Sabine Lake for the period
January through April 1981

Date	Station Number	Time (CST)	Depth (m)	Conductivity mmho/cm at 25°C	Salinity (o/oo)	Temp (C°)	Dissolved Oxygen (ppm)	Sigma-t
2/15/81	E8	0955	1.0	15.5	8.8	9.1	7.9	6.71
			1.5	15.8	9.0	9.1	8.0	6.86
	E9	0915	1.0	15.6	8.8	7.6	9.4	6.90
			1.8	17.8	10.2	7.5	9.2	8.00
	E10	0950	0.5	14.0	7.8	8.3	9.5	6.05
			0.9	14.0	7.8	8.3	9.6	6.05
3/8/81	E8	1610	1.0	21.0	12.4	17.5	8.7	8.25
			1.5	21.0	12.4	17.4	8.7	8.22
	E9	1625	1.0	22.4	13.4	16.8	8.9	9.09
			1.8	22.5	13.4	16.8	8.8	9.14
	E10	1654	0.5	18.9	11.1	16.9	9.3	7.31
			0.9	18.9	11.1	17.0	9.3	7.29
4/9/81	E8	1500	1.0	24.6	15.1	23.9	12.0	8.76
			1.5	24.6	15.1	23.9	11.6	8.76
	E9	1550	1.0	23.5	14.4	22.4	10.0	8.59
			1.8	23.5	14.4	22.4	10.0	8.59
	E10	1615	0.5	31.8	20.1	23.0	8.6	12.70
			0.9	31.8	20.1	23.0	8.4	12.71

and the dissolved oxygen was in a normal range with no evidence of anoxic conditions.

3.3.5.4 Average Predisposal Hydrographic Data for Calcasieu Lake, Raw Water Intake, and Sabine Lake

The average values of the predisposal hydrographic data for Calcasieu Lake, the raw water intake, and Sabine Lake which were collected from January through April 1981 are summarized in Table 3-13. These data show the average salinity in Calcasieu Lake was highest (24.4 o/oo) in January, lowest (20.1 o/oo) in February, and was increasing through April to 22.8 o/oo. These average salinity values were higher than the 14 o/oo average value reported by Barrett (1971, 1978) but well within the reported range of 2.4 through 30.1 o/oo. The average temperature was 8.5°C in January and it reached a minimum of 6.4°C in February after which it increased rapidly to 21.1°C in April. The average dissolved oxygen data showed that it was high (9.6 and 9.0 ppm) in January and February, and it dropped to 7.8 and 7.4 ppm in March and April respectively. Thus, no anoxia conditions were observed during this four-month period.

At the raw water intake in the Intracoastal Waterway, the average salinity was lowest (4.6 o/oo) in January, and it increased to 16.5 o/oo in April. The average temperature reached its lowest value of 6.8°C in February and sharply increased to 21.6°C in April. The average dissolved oxygen was the highest (10.6 ppm) in January and it gradually decreased to 7.7 ppm by April. The density of the water was lowest in January when the average sigma-t value was 3.5 sigma-t units. Sigma-t increased to 9.0 in February and dropped again in March to 7.5. In April, the density increased with a sigma-t value of 10.3.

In Sabine Lake, no data was collected in January. The average

Table 3-13. Average predisposal hydrographic data for Calcasieu Lake, Raw Water Intake, and Sabine Lake during the period January through April 1981.

Date	Conductivity m mho/cm at 25°C	Salinity o/oo	Temp °C	D.O. (ppm)	Sigma-t
CALCASIEU LAKE					
1/23/81	38.5	24.4	8.5	9.6	18.9
2/14/81	32.5	20.1	6.4	9.0	15.8
3/8/81	30.1	21.4	15.4	7.8	15.5
4/9/81	36.2	22.8	21.1	7.4	15.3
RAW WATER INTAKE (Station E1)					
1/23/81	8.8	4.6	8.9	10.6	3.5
2/14/81	19.7	11.5	6.8	9.8	9.0
3/8/81	19.1	11.2	16.7	8.4	7.5
4/9/81	27.0	16.5	21.6	7.7	10.3
SABINE LAKE					
1/23/81	----	No data	----	---	----
2/15/81	15.7	8.7	8.3	8.9	6.8
3/8/81	20.8	12.3	17.1	9.0	8.2
4/9/81	26.6	16.5	23.1	8.4	10.0

salinity data show the lake salinity gradually increased from 8.7 o/oo in February to 16.5 o/oo in April. The average temperature increased more sharply from 8.3°C in February to 23.1°C in April.

A comparison of the temporal variation of the average salinity and conductivity for Calcasieu Lake, Sabine Lake, and the raw water intake during the four-month period is illustrated in Figure 3-17. The main result of this comparison shows the average salinity in Calcasieu Lake was much higher than that in the Intracoastal Waterway or Sabine Lake which was also indicated by the data collected by Barrett (1971). The difference in salinity was 19.8 o/oo in January and 6.3 o/oo in April. The average salinity in Sabine Lake and at the raw water intake were very close (within 1 o/oo) as shown in Figure 3-17.

The temporal variation of temperature and sigma-t are illustrated in Figure 3-18. This figure shows that the temperature was generally 2°C lower in Calcasieu Lake than in Sabine Lake. The difference in density (sigma-t) reflects the same picture as observed in salinity between the two lakes. Figure 3-19 shows the comparison of dissolved oxygen data, and it shows that except for the month of February, the dissolved oxygen in Sabine Lake was higher (about 1 ppm) than that found in Calcasieu Lake. The data collected by Barrett (1971) indicated the reverse situation existed.

3.4 Summary of Results

A four-month predisposal study of the estuarine hydrography has been presented which indicates that during this study, the Calcasieu and Sabine Lakes were found to be well mixed estuaries and only slight stratification in the Intracoastal Waterway was detected. The entrance to the Calcasieu Lake, Calcasieu Pass, was also found to be well mixed except for one sampling day when the salinity increased near the bottom.

Figure3-17. Temporal variation of average salinity and conductivity.

Figure 3-18. Temporal variation of the average temperature and sigma-t.

Figure 3-19. Temporal variation of average dissolved oxygen.

The salinity data showed the salinity in the Calcasieu Lake increased from north to south and that the west side of the lake tended to be saltier than the east. The salinity in the Intracoastal Waterway increased from west to east. Calcasieu Lake had a much higher average salinity than that found in the Intracoastal Waterway or Sabine Lake. For example, the average salinity difference in January was 19.8 o/oo and it was 6.3 o/oo in April.

The dissolved oxygen data indicated no anoxic conditions were observed, and the average dissolved oxygen was about 1 ppm higher in Sabine Lake than in Calcasieu. The temperature data showed the minimum temperature in the two lakes and waterway occurred in February. The average temperature in Sabine Lake was 2°C higher than in the Calcasieu Lake, and it decreased from west to east in the Intracoastal Waterway.

There were no unexpected results uncovered in this estuarine hydrography study. The results of this study and other recently completed baseline studies will be used in the evaluation of the effect of the brine discharge operations on the Calcasieu-Sabine estuary system. .

CHAPTER 4

WATER AND SEDIMENT QUALITY

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4.1 Water Quality Studies

4.1.1 Introduction

The characterization of water quality in the predisposal and postdisposal periods enables the determination of impacts (if any) from the brine discharge on the chemical, biological and physical environment. In order to accomplish this, it is necessary to determine not only anticipated pollutants from the brine but also general water quality parameters that determine the chemical fertility of the area. The latter includes those factors influenced by natural processes such as nutrients, dissolved oxygen, and turbidity. The sampling scheme was designed to determine if any observed changes occur as a result of the brine discharge.

During the three-month predischarge study period, monthly water quality samples were collected at stations shown in Figure 4-1. Several stations (DN, DW, and DS) were sampled on occasion although not required. Analyses performed on the samples included the nutrients (nitrate nitrogen,

Figure 4-1. Inshore and offshore station locations for predischarge water quality.

nitrite nitrogen, ammonia nitrogen, total and orthophosphate phosphorus, and silica), dissolved oxygen, turbidity, and oil and grease. All stations were sampled at the surface and bottom depths except for the shallow Calcasieu Lake stations located at E-2, E-3, and E-4. These were sampled only at the surface.

Results of the water quality characterization are presented in several tables and are discussed in the context of causative factors such as runoff patterns, biological activity, seasonality, etc. This is followed by comparisons of the results from the present study with those of others from the same general area.

4.1.2 Sampling and Analytical Methods

Water samples were collected using 1.8 l Niskin water samplers. Samples were taken from the Niskin samplers and divided into 4 fractions. About 300 ml were placed in plastic bottles and frozen for nutrient analysis later in the laboratory. Another sample was placed into 300 ml BOD bottles for dissolved oxygen analysis which was commenced immediately. Samples for oil and grease analyses were placed in glass bottles, acidified and kept refrigerated (iced) until return to the laboratory. The remainder of the sample was placed in one liter plastic Cubitainers and returned to shore for determination of turbidity.

Dissolved oxygen was determined by the modified Winkler Method described under method #422B of Standard Methods (APHA, 1975).

Turbidity was determined by the nephelometric method using a Hach Model 2100A turbidity meter (method #214A, Standard Methods).

Total Phosphorous was determined by persulfate digestion to orthophosphate and determination of the orthophosphate. The method for digestion is #425C-III in Standard Methods. Orthophosphate was determined

colorimetrically by the ascorbic acid-molybdate method #425F in Standard Methods.

Nitrate and nitrite nitrogen were determined using a Technicon Autoanalyzer II system. The nitrite was determined by the azo dye colorimetric method and the nitrate reduced to nitrite using the cadmium reduction method and the resultant nitrite, including original nitrite, was determined by the azo dye method. Nitrate was obtained by difference. This procedure is described in method #605 of Standard Methods.

Reactive silica will be determined colorimetrically by the molybdosilicate method #426B in Standard Methods.

Ammonia was determined by the phenate colorimetric method of Strickland and Parsons (1972).

Grease and Oil was determined using the freon partition - infrared method listed under method #502B of Standard Methods.

4.1.3 Results

Results of these analyses are presented in Tables 4-1 through 4-9 and indicate water quality typical of nearshore and inshore stations for the area and season sampled. Nitrite and nitrite nitrogen concentrations ranged from <0.01 to 0.15 mg/l and <0.01 to 0.03 mg/l, respectively. Levels for both were higher for the inshore stations and in the case of nitrate usually higher at the surface. Ammonia nitrogen ranged from <0.01 to 12.19 mg/l with inshore stations considerably higher at the surface. The range of phosphate phosphorus was <0.01 to 0.17 mg/l while total phosphorus levels were <0.01 to 0.14 mg/l. That some of the phosphorus is associated with particulate material is indicated by the fact that for several samples phosphate values exceeded total phosphorus probably as a result of difficulty in obtaining uniform samples when they are not

Table 4-1. Nitrate nitrogen levels during predischARGE study, 1981.

(NO ₃ -N, mg/l)				
Station No.	Depth*	February	March	April
M1	S	0.01	<0.01	0.05
	B	<0.01	<0.01	0.05
M3	S	<0.01	0.02	0.02
	B	<0.01	0.01	0.02
M6	S	<0.01	0.01	0.05
	B	<0.01	<0.01	0.02
M9	S	0.01	0.01	0.11
	B	<0.01	<0.01	0.03
M10	S	<0.01	0.01	0.06
	B	<0.01	0.01	0.02
M10A	S	----	0.01	0.11
	B	----	<0.01	0.02
M11	S	<0.01	0.02	0.01
	B	<0.01	0.01	<0.01
M15	S	<0.01	0.01	0.10
	B	<0.01	0.01	<0.01
M18	S	----	0.03	0.07
	B	<0.01	<0.01	0.04
M20	S	0.01	0.01	0.04
	B	<0.01	<0.01	0.04
E1	S	0.07	0.11	0.12
	B	0.07	----	0.12
E2	S	0.01	0.10	0.15
E3	S	0.01	0.12	0.07
E4	S	0.01	0.10	0.13
E5	S	0.01	0.06	0.13
	B	0.01	0.08	0.15
DN	S	0.02	0.02	----
	B	0.01	0.02	----
DS	S	0.01	<0.01	----
	B	0.01	<0.01	----
DW	S	----	<0.01	----
	B	----	<0.01	----
Range		<0.01 - 0.07	<0.01 - 0.11	<0.01 - 0.15

* S = Surface
B = Bottom

Table 4-2. Nitrite nitrogen levels during predischARGE study, 1981.

(NO₂-N, mg/l)

Station No.	Depth*	February	March	April
M1	S	<0.01	<0.01	<0.01
	B	<0.01	<0.01	<0.01
M3	S	<0.01	<0.01	<0.01
	B	<0.01	<0.01	<0.01
M6	S	<0.01	<0.01	<0.01
	B	<0.01	<0.01	<0.01
M9	S	<0.01	<0.01	<0.01
	B	<0.01	<0.01	<0.01
M10	S	<0.01	<0.01	<0.01
	B	<0.01	<0.01	<0.01
M10A	S	----	<0.01	0.01
	B	----	<0.01	0.01
M11	S	<0.01	<0.01	0.01
	B	<0.01	<0.01	<0.01
M15	S	<0.01	<0.01	<0.01
	B	<0.01	<0.01	<0.01
M18	S	----	<0.01	0.01
	B	<0.01	<0.01	0.01
M20	S	<0.01	<0.01	0.01
	B	<0.01	<0.01	0.01
E1	S	0.01	0.01	0.03
	B	0.01	<0.01	0.03
E2	S	0.01	0.01	0.03
E3	S	0.01	<0.01	0.03
E4	S	0.01	<0.01	0.02
E5	S	0.01	<0.01	0.02
	B	0.01	<0.01	0.02
DN	S	<0.01	<0.01	----
	B	<0.01	<0.01	----
DS	S	<0.01	<0.01	----
	B	0.01	<0.01	----
Range		<0.01 - 0.01	<0.01 - 0.01	<0.01 - 0.03

* S = Surface
B = Bottom

Table 4-3. Ammonia nitrogen levels during predischARGE study, 1981.

(NH₃-N, mg/l)

Station No.	Depth ^a	February	March	April
M1	S	----	<0.01	0.06
	B	0.89	0.01	0.08
M3	S	0.78	0.01	<0.01
	B	0.41	0.02	0.03
M6	S	0.94	0.01	<0.01
	B	0.07	0.04	0.03
M9	S	0.69	0.01	<0.01
	B	0.56	0.04	0.04
M10	S	----	<0.01	<0.01
	B	----	0.02	0.03
M10A	S	0.31	<0.01	<0.01
	B	0.44	0.01	0.03
M11	S	0.28	<0.01	<0.01
	B	0.25	<0.01	<0.01
M15	S	0.41	<0.01	0.03
	B	0.31	0.02	0.02
M18	S	----	0.01	<0.01
	B	0.23	<0.01	0.03
M20	S	<0.01	<0.01	0.05
	B	0.36	<0.01	0.02
E1	S	4.21	0.38	0.22
	B	2.75	----	0.14
E2	S	12.19	0.43	0.26
E3	S	0.49	0.06	0.04
E4	S	6.19	0.08	0.07
E5	S	10.19	0.21	0.10
	B	9.69	0.15	0.07
DN	S	1.44	0.02	----
	B	<0.01	0.03	----
DS	S	0.41	<0.01	----
	B	<0.01	0.01	----
DW	S	----	<0.01	----
	B	----	0.01	----
Range		<0.01 - 12.19	<0.01 - 0.43	<0.01 - 0.26

* S = Surface
B = Bottom

Table 4-4. Phosphate phosphorus levels during predischARGE study, 1981.

(PO₄-P, mg/l)

Station No.	Depth*	February	March	April
M1	S	0.03	<0.01	0.02
	B	0.03	0.01	0.02
M3	S	0.03	0.02	0.01
	B	0.04	0.03	0.03
M6	S	0.04	0.01	0.01
	B	0.05	0.02	0.02
M9	S	0.03	0.03	0.03
	B	0.04	0.03	0.03
M10	S	0.04	0.01	0.01
	B	0.10	0.04	<0.01
M10A	S	----	0.02	0.02
	B	----	0.10	0.02
M11	S	0.03	<0.01	<0.01
	B	0.06	0.02	<0.01
M15	S	0.03	<0.01	0.02
	B	0.04	<0.01	0.01
M18	S	----	0.02	<0.01
	B	0.04	0.02	0.03
M20	S	0.03	0.32	0.01
	B	0.04	0.01	<0.01
E1	S	0.08	0.11	0.02
	B	0.10	----	0.04
E2	S	----	0.05	0.03
E3	S	0.04	0.04	0.04
E4	S	0.06	<0.01	0.01
E5	S	0.17	0.07	0.07
	B	0.13	0.06	0.08
DN	S	0.01	0.03	----
	B	0.07	0.03	----
DS	S	0.01	<0.01	----
	B	0.13	0.01	----
DW	S	----	0.02	----
	B	----	0.02	----
Range		<0.01 - 0.17	<0.01 - 0.11	<0.01 - 0.08

* S = Surface
B = Bottom

Table 4-5. Total phosphorus levels during predischARGE study, 1981.

(P, mg/l)

Station No.	Depth*	February	March	April
M1	S	0.03	0.02	0.02
	B	0.03	0.02	0.02
M3	S	0.03	0.02	0.01
	B	0.04	0.04	0.08
M6	S	0.04	0.02	0.02
	B	0.05	0.03	0.06
M9	S	0.03	0.06	0.03
	B	0.04	0.04	0.05
M10	S	0.04	0.01	0.02
	B	0.09	0.05	0.01
M10A	S	----	0.02	0.03
	B	----	0.05	0.02
M11	S	0.06	0.02	0.01
	B	0.06	0.04	0.02
M15	S	0.03	0.02	0.02
	B	0.03	0.05	0.02
M18	S	----	0.02	<0.01
	B	0.04	0.02	0.03
M20	S	0.03	0.02	0.01
	B	0.03	0.02	0.01
E1	S	0.08	0.08	0.05
	B	0.10	----	0.11
E2	S	0.03	0.07	0.10
E3	S	0.04	0.04	0.14
E4	S	0.07	0.02	0.10
E5	S	0.09	0.10	0.10
	B	0.13	0.09	0.14
DN	S	0.03	0.03	----
	B	0.06	0.04	----
DS	S	0.02	0.02	----
	B	0.10	0.02	----
DW	S	----	0.02	----
	B	----	0.03	----
Range		0.02 - 0.10	0.01 - 0.10	<0.01 - 0.14

* S = Surface
B = Bottom

Table 4-6. Silica levels during predischARGE study, 1981.

(SiO₂, mg/l)

Station No.	Depth*	February	March	April
M1	S	2.3	1.4	1.1
	B	0.5	1.5	0.9
M3	S	0.7	0.9	0.8
	B	1.1	2.0	1.0
M6	S	0.8	1.0	0.3
	B	2.3	1.4	0.9
M9	S	0.8	1.8	2.3
	B	0.9	1.8	0.9
M10	S	0.9	1.1	1.1
	B	1.1	1.5	0.6
M10A	S	----	1.0	1.5
	B	----	1.8	0.9
M11	S	1.1	1.1	0.9
	B	0.8	0.6	0.9
M15	S	0.8	1.1	1.6
	B	1.1	2.3	----
M18	S	----	1.1	1.4
	B	0.7	1.0	1.2
M20	S	0.6	1.1	1.1
	B	0.6	0.9	1.2
E1	S	4.3	6.2	2.6
	B	3.9	----	2.4
E2	S	4.4	3.8	3.0
E3	S	1.5	2.1	2.3
E4	S	3.7	2.3	3.3
E5	S	4.9	5.4	2.8
	B	5.9	4.6	2.6
DN	S	0.8	1.6	----
	B	2.4	1.9	----
DS	S	1.1	0.3	----
	B	0.7	0.4	----
DW	S	0.7	1.0	----
	B	0.3	1.3	----
Range		0.3 - 5.9	0.3 - 6.2	0.3 - 3.0

* S = Surface
B = Bottom

Table 4-7. Dissolved oxygen levels during predischage study, 1981.

(O₂, mg/l)

Station No.	Depth*	February	March	April
M1	S	9.2	10.8	6.0
	B	9.0	9.0	5.1
M3	S	9.2	10.4	9.4
	B	9.0	8.4	8.0
M6	S	9.3	10.0	7.9
	B	8.9	8.9	6.2
M9	S	9.4	12.1	7.2
	B	9.1	8.4	7.6
M10	S	9.2	9.3	8.0
	B	9.6	8.3	8.0
M10A	S	----	9.8	7.8
	B	----	8.9	7.5
M11	S	9.5	9.7	----
	B	9.2	8.6	7.4
M15	S	9.3	9.0	7.9
	B	9.2	8.1	----
M18	S	----	9.0	7.7
	B	9.4	8.6	8.1
M20	S	9.2	9.1	7.8
	B	9.1	8.9	6.6
E1	S	9.7	8.4	7.4
	B	9.9	----	8.6
E2	S	8.0	7.6	6.7
E3	S	10.2	8.7	7.7
E4	S	8.4	8.8	8.0
E5	S	9.7	7.3	7.4
	B	9.8	8.0	6.9
DN	S	9.4	11.7	----
	B	8.7	9.2	----
DS	S	8.8	8.5	----
	B	8.4	8.3	----
DW	S	----	9.4	----
	B	----	9.1	----
Range		8.0 - 10.2	7.3 - 12.1	5.1 - 9.4

* S = Surface
B = Bottom

Table 4-8. Turbidity levels during predischARGE study, 1981.

(NTU)

Station No.	Depth*	February	March	April
M1	S	2	2	9
	B	9	9	7
M3	S	8	2	2
	B	19	10	24
M6	S	3	2	28
	B	26	10	36
M9	S	3	3	7
	B	16	11	9
M10	S	-	2	3
	B	-	10	4
M10A	S	3	2	4
	B	14	11	13
M11	S	3	2	2
	B	16	4	2
M15	S	3	2	4
	B	7	13	-
M18	S	-	2	4
	B	3	4	9
M20	S	2	2	3
	B	9	3	3
E1	S	-	35	7
	B	-	-	28
E2	S	-	7	5
E3	S	-	8	7
E4	S	-	3	17
E5	S	-	41	22
	B	-	39	62
DN	S	4	2	-
	B	29	11	-
DS	S	2	1	-
	B	8	4	-
DW	S	-	2	-
	B	-	7	-
Range		2 - 31	1 - 39	20 - 62

* S = Surface
B = Bottom

Table 4-9. Oil and grease levels during predischARGE study, 1981.

(mg/l)

Station No.	Depth*	February	March	April
M1	S	0.7	<0.5	1.0
	B	0.5	<0.5	0.7
M3	S	<0.5	<0.5	2.0
	B	<0.5	<0.5	1.2
M6	S	0.6	<0.5	1.5
	B	0.5	<0.5	1.2
M9	S	<0.5	0.7	1.0
	B	0.5	<0.5	1.0
M10	S	---	<0.5	1.0
	B	---	<0.5	1.2
M10A	S	0.5	<0.5	0.9
	B	0.5	<0.5	1.4
M11	S	0.5	<0.5	0.8
	B	<0.5	<0.5	1.2
M15	S	0.6	0.9	0.8
	B	0.6	<0.5	1.0
M18	S	0.6	<0.5	1.1
	B	<0.5	<0.5	1.0
M20	S	<0.5	<0.5	1.2
	B	0.8	<0.5	1.0
E1	S	0.8	1.2	1.0
	B	0.5	---	1.0
E2	S	0.8	<0.5	0.8
E3	S	<0.5	0.7	1.2
E4	S	0.5	---	1.0
E5	S	0.6	0.9	0.8
	B	<0.5	<0.5	1.5
DN	S	0.6	<0.5	---
	B	<0.5	<0.5	---
DS	S	---	<0.5	---
	B	---	0.8	---
DW	S	---	0.8	---
	B	---	<0.5	---
Range		<0.5 - 0.8	<0.5 - 1.2	0.7 - 2.0

* S = Surface
B = Bottom

filtered. Silica levels were between 0.3 and 6.2 mg/l with inshore stations higher than offshore. Nitrate and nitrite nitrogen were highest in April while ammonia nitrogen and both phosphate and total phosphorus were highest in February. Since April is traditionally the month of highest runoff for this area and since both nitrate and nitrite are usually highest during periods of high runoff, the pattern observed for both nutrients is as expected (Barrett, 1971; Barrett, et al., 1978; and Brooks, 1979). In addition, ammonia, phosphorus and silica are usually highest during periods of biological decomposition. Such periods are most likely to occur during summer and late winter; therefore, ammonia and phosphorus levels should have been highest in February. Of the nutrients, only silica appeared to change little during this three-month period.

Dissolved oxygen values ranged from 5.1 to 12.1 mg/l and were lower in April as expected partially as a result of temperature increases within the water column. No trend in difference between surface and bottom water oxygen levels occurred during this period, suggesting a mixed state existed much of the period although other investigators indicated slight stratification part of the time.

Both turbidity and oil and grease were highest in April suggesting both parameters are influenced by runoff. Turbidity levels were from 2 to 62 NTU. Oil and grease ranged from <0.5 to 2.0 mg/l; however, with the exception of April, most samples were below the detection limit of 0.5 mg/l. Although high values in April suggest association with runoff, there appeared to be no difference between inshore and offshore stations.

Although a number of published studies have reported water quality measurements in the general study area, only a few contain data for stations sufficiently close to those used for the present study during the

three months covered by this report. Among the more useful are studies by Barrett (1971), Barrett, et al. (1978), and Brooks (1979) as well as the U.S. Geological Survey's analyses of waters from the vicinity of the Calcasieu Ship Channel carried out for dredging studies during the 1976 water year (October 1975 through September 1976). Where possible, the range of concentrations observed for the various parameters during the present study have been compared with those from the earlier studies. These comparisons are presented in Figures 4-2 through 4-10 and suggest levels during early 1981 were generally close to that of other years.

4.2 Sediment Quality

4.2.1 Pore Water Salinity

The sediment pore water salinities at the inshore stations E1 through E5 were highly variable with both time and location (see Table 4-10). The pore water salinities in the nearshore sediments are considerably less saline than those offshore, i.e. the range of the pore water salinities at stations E1-E5 are 9.104 to 26.310 o/oo in the time period of February 1981 through April 1981. The range of the pore water salinities for the offshore stations were 26.496 to 33.419 o/oo.

The pore water salinities at stations E1 and E2 increased from February to April 1981, but there was no clear pattern of change at E3, E4 and E5. Except for E5, however, all inshore stations were more saline in April than in February at the times sampled.

At most of the offshore stations, there was a slight decrease in pore water salinity from February to March and a stronger decrease in April 1981.

The salinity of the overlying water at the deepest depth sampled were always somewhat different. In February, and March the overlying water

Figure 4-2. Range of nitrite nitrogen in study area in spring.

Figure 4-3. Range of nitrate nitrogen in study area in spring.

Figure 4-4. Range of ammonia nitrogen in study area in spring.

Figure 4-5. Range of phosphate in study area in spring.

Figure 4-6. Range of total phosphorus in study area in spring.

Figure 4-7. Range of silica in study area in spring.

— Offshore surface stations
 Offshore bottom stations
 — Inshore surface stations
 - - - Inshore bottom stations

Figure 4-8. Range of dissolved oxygen in study area in spring.

Figure 4-9. Range of turbidity in study area in spring.

Figure 4-10 Range of oil and grease in study area in spring.

Table 4-10. Pore Water Salinity (o/oo)
(o/oo)

Sites	February 1981		March 1981		April 1981	
	I.W. Sal.	Water Sal.	I.W. Sal.	Water Sal.	I,W. Sal.	Water Sal.
E1	9.104	11.50	12.061	12.00	15.758	16.40
E2	16.146	15.60	17.736	18.70	21.661	23.10
E3	23.640	23.60	22.278	23.20	23.753	23.00
E4	21.480	21.20	19.980	22.30	23.318	22.90
E5	26.310	21.20	24.914	31.30	25.468	24.30
M1	30.432	32.30	29.935	31.70	-----	28.00
M3	30.588	32.20	30.483	31.80	29.179	28.60
M6	30.495	32.20	30.851	31.80	30.154	29.20
M9	30.340	32.10	30.029	31.80	28.598	28.50
M10	30.554	32.20	30.846	31.90	29.534	28.90
M10A	30.632	-----	30.755		29.621	28.70
M11	30.857	32.40	31.417	32.10	29.903	28.90
M15	30.648	32.30	30.005	31.80	29.310	28.40
M18	31.416	32.10	33.419	31.80	29.783	28.60
M20	30.718	32.30	31.061	32.00	29.348	28.00
DS	26.496		32.881		-----	----
DN	29.419		29.283		-----	----
DW	-----		30.799		-----	----

I.W. Sal. = interstitial water salinity

salinity was higher than the pore water salinity, but in April, generally the overlying water salinity was higher (see Table 4-10).

Matisoff et al. (1975) found seasonal variable surface pore water salinity in Chesapeake bay sediments as deep as 20 cm. Below that depth, however, the pore water salinity stayed relatively constant. The pore water salinity in estuarine sediments responds relatively rapidly to salinity changes at the sediment-water interface, but not quite as rapidly as the salinity of the overlying water, as shown in Table 4-10.

4.2.2 Total Organic Carbon

Organic carbon in sediments of the West Hackberry site were in the range of 0.160 to 1.040 % (by dry weight), but the majority of the samples were in the range of 0.4 to 0.8 % organic carbon by weight. The low percentages were found in sandy sediments and the high ones in clay-rich sediments. In general the nearshore sediments (stations E-1 to E-5) were somewhat richer by 0.1 to 0.2 % in organic carbon than the offshore sediments at a given sampling period.

With the exception of E3, M6 and M9, there was an increase in organic carbon percentage from February to April 1981. At stations E3, M6 and M9 there was an increase from February to March and then a slight decrease in percent organic carbon from March to April. Data are summarized in Table 4-11.

The changes in percentage organic carbon were generally associated with an increase in percentage clay of the sediment at a given station, but this was possibly also caused by increased primary productivity.

Our data on percentage organic carbon is somewhat higher than that reported previously for the West Hackberry study area (Final Env. Impact Statement, 1978). The range of percentage of organic carbon in 1977 was

Table 4-11. Percent (%) organic carbon by weight of dry West Hackberry sediments.

% Organic Carbon			
Site	February	March	April
E1	.540	.538	.820
E2	.690	.797	.830
E3	.490	1.094	.880
E4	.500	.737	.930
E5	.240	.914	1.040
E6	.370	----	----
E7	.560	----	----
M1	.320	.520	.550
M3	.400	.418	.630
M6	.420	.846	.710
M9	.450	.840	.800
M9	.580	----	----
M10	.390	.650	1.000
M10A	.420	.756	.890
M11	.500	.477	.740
M15	.550	.707	.750
M18	.450	.593	.760
M20	.680	.766	.780
DS	.160	.175	----
DN	.630	.765	----
DW	----	.582	----

.043 to .590 % and the range for the offshore sediments was .160 to .890 %.

Previous organic carbon data for the sediments in the West Hackberry area were collected in November and December 1977, when the organic content may have been lower than it is in the spring months. Data for organic carbon of sediments collected in this study in February 1981 were more comparable to the samples collected previously in November and December of 1977.

4.2.3 Grain Size Distribution of Surface Sediments

The percentages of sand, silt and clay shown in Table 4-12 indicate that the nearshore sediments were apparently variable in texture with time. The most severe changes in grain size were apparent at the nearshore stations E3, E4 and E5 (Table 4-12). E1 and E2 stayed relatively constant from February through April 1981, although there appeared to be a slight increase in percentage clay during the period February to April 1981. (It should be noted here that the exact sampling location was changed for E5 in March 1981.)

The mean and median diameters (calculated by the methods of Folk, 1966) also reflected the variability of grain size distribution at stations E3, E4 and E5. Table 4-13 includes the statistical parameters of all sediment grain size analyses made for February, March and April 1981. All parameters were calculated by Folk's (1966) methods.

The sorting parameter (σ) indicates that the nearshore sediments are very poorly sorted with values of σ between 2.58 and 4.09. Skewness values for the nearshore sediments range from -.23 to +.81, with most values being between 0.30 and 0.70, which means they are strongly fine skewed. The negative values mean they are either near symmetrical (+.10 to -.10) or coarse skewed (-.10 to -.30). The kurtosis or peakedness (K_g) of the

Table 4-12. Percentage sand, silt and clay at the West Hackberry site.

Site	Sediment	February	March	April
E1	Sand	19.22	16.22	15.17
	Silt	52.14	45.51	40.82
	Clay	28.64	38.10	44.01
E2	Sand	9.43	8.15	5.14
	Silt	48.40	49.07	41.92
	Clay	42.16	42.78	52.93
E3	Sand	11.50	0.72	15.58
	Silt	70.67	30.57	24.54
	Clay	17.83	68.71	59.88
E4	Sand	70.23	18.22	24.41
	Silt	11.13	28.12	22.26
	Clay	18.64	53.54	53.33
E5	Sand	59.17	84.17	21.21
	Silt	23.15	4.46	29.29
	Clay	17.67	11.39	49.50
M1	Sand	32.64	31.96	23.04
	Silt	28.93	25.84	31.16
	Clay	38.42	42.20	45.80
M3	Sand	2.01	34.89	14.39
	Silt	56.54	22.94	30.73
	Clay	41.44	42.18	54.87
M6	Sand	27.26	5.12	4.32
	Silt	30.60	22.39	29.81
	Clay	42.14	72.49	65.88
M9	Sand	2.51	0.68	1.08
	Silt	38.48	22.77	22.00
	Clay	59.01	76.44	76.91
M10	Sand	10.58	8.93	5.67
	Silt	39.87	32.89	32.72
	Clay	49.56	58.18	61.61
M10A	Sand	18.94	1.96	0.84
	Silt	35.44	32.45	26.79
	Clay	45.73	64.60	72.38

Table 4-12. Continued.

Site	Sediment	February	March	April
M11	Sand	19.18	20.29	6.44
	Silt	37.79	38.03	50.63
	Clay	42.24	41.63	42.92
M15	Sand	2.53	4.92	3.04
	Silt	53.28	29.40	30.28
	Clay	44.19	63.55	66.68
M18	Sand	4.69	2.40	2.00
	Silt	47.63	30.37	27.95
	Clay	47.68	67.23	70.05
M20	Sand	5.08	4.06	6.67
	Silt	39.05	26.15	26.39
	Clay	55.88	69.78	66.93
DS	Sand	19.99	67.77	-----
	Silt	61.94	16.56	-----
	Clay	18.07	15.65	-----
DN	Sand	1.63	0.43	-----
	Silt	20.71	21.36	-----
	Clay	77.66	78.41	-----
DW	Sand	-----	24.71	-----
	Silt	-----	29.84	-----
	Clay	-----	45.43	-----

Table 4-13. Surface sediment statistical parameters.

Station No.	Date	Median diameter M_ϕ	Mean diameter M_σ	Sorting σ_1	Skewness Sk_I	Kurtosis K_g
E1	Feb	5.3	6.8	3.43	0.59	0.85
	Mar	5.8	7.1	3.64	0.46	0.68
	Apr	5.8	7.3	3.91	0.54	0.60
E2	Feb	6.7	7.8	3.69	0.34	0.64
	Mar	6.1	7.5	3.61	0.47	0.63
	Apr	7.9	8.2	3.66	0.13	0.56
E3	Feb	4.1	5.6	2.81	0.81	6.62
	Mar	10.1	9.7	3.08	-0.23	0.71
	Apr	8.3	8.5	3.99	-0.05	0.57
E4	Feb	2.8	4.8	3.45	0.76	1.15
	Mar	8.1	8.0	3.85	-0.001	0.59
	Apr	8.0	7.9	4.09	0.013	0.54
E5	Feb	3.8	5.5	3.73	0.62	1.33
	Mar	1.1	1.8	2.58	0.70	2.13
	Apr	7.3	7.4	4.50	0.03	0.64
M1	Feb	5.6	6.7	3.90	0.381	0.66
	Mar	5.4	10.4	4.32	0.427	0.63
	Apr	6.0	7.1	4.09	0.333	0.61
M3	Feb	6.4	7.5	3.36	0.470	0.60
	Mar	5.4	6.5	4.21	0.354	0.59
	Apr	8.1	8.0	3.88	-0.039	0.65
M6	Feb	6.8	7.3	4.07	0.164	0.66
	Mar	10.0	9.5	3.30	-0.243	0.80
	Apr	9.8	8.9	3.67	-0.261	0.65
M9	Feb	10.2	9.5	3.24	-0.279	0.88
	Mar	10.3	9.9	2.96	-0.185	0.80
	Apr	---	---	---	---	---
M10	Feb	7.6	8.0	2.63	0.131	0.63
	Mar	8.8	8.5	3.66	-0.106	0.66
	Apr	9.1	8.7	3.75	-0.142	0.60
M10A	Feb	6.3	7.3	3.85	0.293	0.75
	Mar	9.6	9.1	3.40	-0.174	0.65
	Apr	10.2	9.6	3.30	-0.235	0.74

Table 4-13. Continued.

Station No.	Date	Median diameter	Mean diameter	Sorting	Skewness	Kurtosis
		M_ϕ	M_σ	σ_1	Sr_I	K_g
M11	Feb	6.1	7.2	3.68	0.361	0.69
	Mar	5.2	6.7	3.99	0.427	0.74
	Apr	5.7	7.2	3.63	0.530	0.62
M15	Feb	6.7	7.6	3.29	0.380	0.60
	Mar	9.6	9.0	3.44	-0.205	0.71
	Apr	9.8	9.1	3.51	-0.232	0.66
M18	Feb	8.2	8.2	3.43	0.046	0.60
	Mar	9.1	8.6	3.40	-0.127	0.79
	Apr	---	---	----	----	----
M20	Feb	8.8	8.3	3.44	-0.091	0.70
	Mar	9.9	9.3	3.36	-0.239	0.77
	Apr	10.3	9.2	3.78	-0.345	0.59
DS	Feb	2.8	3.1	1.40	0.536	1.92
	Mar	2.8	3.9	2.80	0.761	2.03
	Apr	---	---	----	----	----
DN	Feb	9.5	9.3	3.25	-0.112	0.74
	Mar	10.2	9.9	2.90	-0.160	0.85
	Apr	---	---	----	----	----
DW	Feb	---	---	----	----	----
	Mar	6.6	7.2	4.17	0.188	0.65
	Apr	---	---	----	----	----

sediment samples were mostly in the range of 0.5 to 1.33. Generally it is thought that kurtosis has little geological significance.

The sediments at the offshore stations generally had a higher percentage clay and lower mean diameters than the nearshore stations but they were also poorly sorted (Tables 4-12 and 4-13). Most of the offshore sediments would be classed as silty clays, except for station DS, which incidentally was most variable.

As was indicated with the nearshore stations E1 and E2, there seemed to be a slow increase in the percentage clay from February to April 1981 for most of the offshore stations (Table 4-12). The mean diameters also decreased with time in most cases (note: an increase in M_g indicates finer material). The only major change in sediment grain size for the offshore sediments was at station DS.

The sediment textural data for the offshore stations collected in this study in 1981 were compared to those collected in 1977 and reported in 1978 in the Final Environmental Impact Statement for the Texoma Group Salt Domes. The general picture of mean diameters of 6.0 to 10.62 ϕ and percentages of sand, silt and clay were comparable in both studies.

4.3 Special Pollutants Survey

4.3.1 Introduction

Special pollutant samples were collected at two stations, E1, intake structure and M10, brine diffuser for the March survey. The brine pond was added as an additional sampling station for the May survey. Sampling in May was selected in order for that cruise to correspond to the sampling time; two weeks prior to start of discharge, as required for post discharge sampling. Sampling was conducted at the two sampling stations 60-90 days after start of the growing season and during the week prior to brine disposal. The objectives of the special pollutant sampling were to determine:

- (a) what pollutants presently exist in both Calcasieu Lake and offshore, in the are of the diffuser, which are likely to be seen in the post-brine discharge phase of this study;
- (b) what pollutants exist in the Intracoastal Waterway and northern most environs of the estuarine systems that are likely to be transferred as foreign pollutants into the marine ecosystem by the leaching process; and
- (c) what pollutants have been introduced into the West Hackberry leaching and pumping systems that will likely find their way down the pipeline to the diffuser site and ultimately become introduced into the marine sediments, water column, and biota.

This survey was undertaken to establish pre-discharge concentrations of pollutants prior to the start-up of brine discharge.

4.3.2 Sampling method

Stations E1 and M10 were sampled on the same day 60-90 days after the start of the growing season (March 13, 1981), and during the week prior to brine disposal (May 5, 1981). Water samples were taken on May 5 at the brine pond as an additional sampling station. For both sampling periods, station E1 was sampled for sediment and water

collection, station number, and cruise number), and stored on ice until returned to the laboratory.

4.3.2.2 Sediment samples

The sediment samples were collected at station E1 using a 0.05 m² Ekman grab sampler. The upper few centimeters of the samples were placed in acid rinsed glass bottles for pesticide analysis and Whirl-Pak bags for metal and major ion analysis. The sediment samples at station M10 were collected using a 0.1 m² Smith-McIntyre grab sampler with the samples stored in acid rinsed glass bottles or Whirl-Pak bags. All samples were labeled with string bound labels with the information: time and date of collection, station number and cruise number. All sediment samples were stored in ice until transfer to the laboratory.

4.3.2.3 Benthic biota

The two species of benthic biota collected at station M10 were collected during fifteen minute trawls using an untreated 4.9 m otter trawl with 1.9 cm bar mesh netting. When insufficient animals were found the trawls were repeated. The samples were wrapped in aluminum foil, taped closed with freezer tape, and labeled with time and date of collection, station number and cruise number. The samples were packed in ice until transfer to the laboratory.

4.3.2.4 Data forms

The samples for pesticide and hydrocarbons analyses were transferred to the accountable subcontractor using a letter of transmittal, with copies going to the subcontractor and a copy being

held by the Principal Investigator and by the Technical Director. The letter contains the information: date of transmittal, type(s) of sample(s), type of vehicle used to transport samples, person(s) transferring the samples and to whom samples were transferred.

4.3.3 Lab procedures

Water and sediment samples were analyzed for major ions, total metals, pesticides, herbicides and hydrocarbons. Benthic biota samples were analyzed for total metals, pesticides, herbicides and hydrocarbons.

4.3.3.1 Major ions

4.3.3.1.1 Calcium

The concentration of calcium in water and sediment samples were analyzed by the EDTA titrimetric procedure. Murexide or Eriochrome Blue-Black R were used as indicators in the EDTA titration (Methods for Chemical Analysis of Water and Wastes EPA-600 4-79-020, method 215.2).

4.3.3.1.2 Chloride

The concentration of chloride in water and sediment samples were analyzed by the mercuric nitrate titration of an acidified sample with a mixed diphenylcarbazone-bromophenol blue indicator (Methods for Chemical Analysis of Water and Wastes EPA-600 4-79-020, method 325.3).

4.3.3.1.3 Sodium and Potassium

The sodium and potassium levels in water and sediment samples were analyzed by the flame photometric method (Standard Methods for the Examination of Water and Wastewater, 14th edition, 1975).

4.3.3.1.4 Magnesium

The concentration of magnesium ions in water and sediment samples were analyzed by the photometric (B & L Spec. 20) method. The magnesium ions in a dechlorinated sample were precipitated as magnesium hydroxide in the presence of brilliant yellow (Standard Method for the Examination of Water and Wastewater, 14th edition, 1975).

4.3.3.1.5 Sulfate

The water and sediment levels of sulfate were analyzed by the turbidimetric method. Sulfate was converted to a barium sulfate suspension under controlled conditions. The resulting turbidity was measured on a spectrophotometer and concentration determined from standard curves (Methods for Chemical Analysis of Water and Wastes EPA-600 4-79-020, method 375.4).

4.3.3.2 Total metals

4.3.3.2.1 Water

4.3.3.2.1.1 Copper, magnesium and zinc

Whole water samples are acidified to pH 2.4, chealated with ammonium pyrrolidine dithiocarbamate (APDC), extracted with methyl isobutyl ketone (MIBK) and analyzed by flame atomic absorption (Methods for Chemical Analysis of Water and Wastes EPA-600 4-79-020, method 220.1, copper; method 242.1, magnesium; method 289.1, zinc).

4.3.3.2.1.2 Arsenic

Whole water samples were chealated and extracted by the method presented for copper, magnesium and zinc. The MIBK extracts were evaporated to dryness, the residues dissolved in nitric acid and

analyzed by flameless atomic absorption (Methods for Analysis of Water and Wastes EPA-600 4-79-020, method 206.2).

4.3.3.2.1.3 Mercury

Whole water samples were analyzed by the cold vapor flameless atomic absorption technique (Methods for Analysis of Water and Wastes EPA-600 4-79-020, method 245.1).

4.3.3.2.1.4 Chromium

Whole water samples were oxidized with potassium permanganate and sodium azide, chealated with APDC, extracted with MIBK and analyzed by flame atomic absorption (Methods for Anaylsis of Water and Wastes EPA-600 4-79-020, method 218.3).

4.3.3.2.2 Sediment

4.3.3.2.2.1 Arsenic, Chromium, Copper, Magnesium, and Zinc

Sediment samples were extracted with nitric and hydrochloric acids with heat. The extracts were cooled, filtered, and analyzed by flame atomic absorption (chromium, copper, magnesium, and zinc) or flameless atomic absorption (arsenic) by the methods referenced under the section on water (Interim Method for the Sampling and Analysis of Elemental Priority Pollutants in Sludge, EPA-EMSL-Cincinnati, 1978).

4.3.3.2.2.2 Mercury

Sediment samples were digested in aqua regia, oxidized with potassium permanganate and analyzed by the cold vapor flameless atomic absorption technique (Methods for Analysis of Water and Wastes EPA-600 4-79-020, method 245.5).

4.3.3.2.3 Tissue

4.3.3.2.3.1 Arsenic

Tissue samples were digested with nitric and sulfuric acid with gentle heating, refluxed with hydrogen peroxide and analyzed by gaseous hydride flame atomic absorption (Interim Method for the Sampling and Analysis of Priority Pollutants in Sediments and Fish Tissue, EPA-EMSL - Cincinnati, 1978).

4.3.3.2.3.2 Chromium, copper, magnesium, and zinc

Tissue samples were charred with sulfuric acid in an oven followed by a muffle furnace. The ash was dissolved in nitric acid and the aqueous solution analyzed by flame atomic absorption (Interim Method for the Sampling and Analysis of Priority Pollutants in Sediments and Fish Tissues, EPA-EMSL - Cincinnati, 1978).

4.3.3.2.3.3 Mercury

Tissue samples were digested with nitric and sulfuric acid with gentle heating, oxidized with potassium permanganate and analyzed by the cold vapor flameless atomic absorption technique (Interim Method for the Sampling and Analysis of Priority Pollutants in Sediments and Fish Tissue, EPA-EMSL - Cincinnati, 1978).

4.3.3.3 Pesticides, herbicides, and hydrocarbons

The pesticides, herbicides and hydrocarbon samples were analyzed on a Hewlett Packard 5985 microprocessor controlled dual source electron impact/chemical ionization mass spectrometer interfaced with a Model 5840 gas chromatograph. GC columns: J & W 25 meter SE 54 fused silica, Temperature Program: 60°C for 2 min. to 300°C at 10°C per minute, hold at 300°C for 15 min., Injection: 1 ul sample and 100 mg d-10 anthracene as internal standard.

4.3.3.3.1 Water

Water samples were extracted with methylene chloride, at pH 9-11 and 2. The extracts were dried over anhydrous sodium sulfate and cleaned up by florisil column chromatography. The fractions were concentrated by Kuderna-Danish and the herbicide extracts derivitized. The concentrated extracts were analyzed by total scan and selective ion monitoring GC/MS runs (Federal Register, December 3, 1979, methods 608, 614, 615, and 625 Analysis of Pesticide Residues in Human and Environmental Samples Industrial Environmental Research Laboratory, Edison, N.J.).

4.3.3.3.2 Sediment

Sediment samples were air dried, and extracted on a Soxhlet apparatus with an acetone-hexane (1:1) mixture overnight. The extracts were washed with sodium sulfate solution and extracted into hexane at pH 9 and 2. The hexane extracts were concentrated, analyzed by GC/MS (Federal Register, December 3, 1979, methods 608 and 625; Analysis of Pesticide Residues in Human and Environmental Samples, Industrial Environmental Research Laboratory, Edison, N.J.).

4.3.3.3.3 Biota

Samples of biota were ground with dry ice and the dry ice allowed to sublime in the freezer and the ground tissue extracted in a Soxhlet apparatus with acetonitrile overnight. The extracts were washed with sodium sulfate solution and extracted into hexane at pH 9 and 2. The hexane extracts were concentrated and analyzed by GC/MS (Federal Register, December 3, 1979, methods 608 and 625; Analysis of Pesticide

esidues in Human and Environmental Samples, Industrial Environmental Research Laboratory, Edison, N.J.).

4.3.4 Results and conclusion

4.3.4.1 Major ions

Table 4-14 gives the major ion concentration in water and sediment samples collected March 13 and May 5, 1981 at the intake structure, El, brine pond, and diffuser site, M10. The table presents the data for EH, pH, and the concentrations of the major ions: Ca, Cl, K, Mg, Na, SO_4 in the water and sediment samples. The March 13 survey corresponds to the sampling period 60-90 days after the start of the growing season and the May 5 cruise was conducted the week prior to start of discharge.

4.3.4.1.1 Water

The water samples showed positive EH values and normal pH values during both sampling periods showing absence of anoxic conditions. The major ion concentration in water samples were measured in samples collected from station El, the intake structure in March and May, at station M10, the diffuser and the brine pond for the May cruise. The results for station M10 are in good agreement with those expected for typical seawater (Riley and Skirrow, 1965): Na = 10,500 mg l^{-1} , K = 380 mg l^{-1} , Ca = 400 mg l^{-1} , Cl = 19,000 mg l^{-1} , SO_4 = 2920 mg l^{-1} . The variation from these typical concentrations can be understood since average composition tends to become altered in coastal waters. Intrusion of fresh water at the diffuser site could alter the average ratios. The concentrations of major ions at station El have increased from the March to May survey. This may be due to

Table 4-14. Major ion concentrations in water and sediment at the intake structure, brine pond and diffuser site.

DATE OF COLLECTION	STATION	EH	pH	Ca	Cl	K	Mg	Na	SO ₄
(CONCENTRATION)									
<u>WATER</u> (mg l ⁻¹)									
3-13-81	E1	+0.088	7.36	180	7260	210	435	4300	1050
5-05-81	E1	+0.182	7.19	250	10600	308	635	5200	1800
5-05-81	BRINE POND	ND*	ND	570	149000	98	90	99500	1580
5-05-81	M10	+0.171	8.15	355	15100	465	950	8300	2480
<u>SEDIMENT</u> (ug g ⁻¹ dry weight)									
3-13-81	E1	+0.078	7.30	4700	8100	800	3920	1700	500
5-05-81	E1	+0.170	7.25	2300	8000	770	5920	6600	440
3-13-81	M10	+0.167	8.04	5500	18900	3100	13260	11800	450
5-05-81	M10	ND	ND	5200	23300	2960	13160	18600	780

* ND - not determined

below average rainfall and river levels during the spring of 1981 allowing salinity of water in the Intracoastal Waterway to increase. These concentrations are expected to return to normal when rainfall levels reach normal levels. The water collected at the brine pond contained high levels of the major ions Na and Cl as expected which lowered the concentration of other major ions due to lowered solubility in the presence of high salt concentrations.

4.3.4.1.2 Sediments

The sediments were collected the same day along with the water samples on March 13 and May 5 at the station El, the intake structure, and M10, the diffuser site. The sediments also show positive redox potentials and pH values similar to the water samples collected simultaneously. Major ion concentration in 1 N HNO₃ leachates of the sediments are given in Table 4-1. The concentrations of major ions were higher in the marine sediments as expected. The major ions increased inshore, during the May cruise indicating the intrusion of high salinity water at station El contaminating the sediments with major ions.

4.3.4.2 Total metals

Table 4-15 presents the total metal concentrations in water, sediments and selected benthic biota. The samples were collected on March 13 and May 5 at the intake structure, El, brine pond and diffuser site, M10. Water was collected at each sampling station, sediments at El and M10, and benthic biota collected only at station M10. The selected benthic biota were Polinicies duplicatus (moon snails) and Penaeus setiferus (white shrimp). However, during the

Table 4-15. Total metal concentrations in water and sediments at the intake structure, brine pond, and diffuser site and selected benthic biota at the diffuser site.

DATE	STATION OR SPECIES	As	Cd	Cr	Cu	Hg	Mg	Zn
(CONCENTRATION)								
<u>WATER</u> ($\mu\text{g l}^{-1}$)								
3-13-81	E1	<2.0	<2.0	<10	1.4	<0.1	435,000	<20
5-05-81	E1	<2.0	<2.0	<10	1.2	1.0	635,000	<20
5-05-81	BRINE POND	<2.0	<2.0	<10	0.7	<0.1	90,000	135
5-05-81	M10	<2.0	<2.0	<10	0.9	<0.1	950,000	<20
<u>SEDIMENT</u> ($\mu\text{g g}^{-1}$ dry weight)								
3-13-81	E1	<1.0	<0.5	12.8	10.8	0.2	3,920	55.4
5-05-81	E1	<1.0	<0.5	12.2	14.4	<0.1	5,920	60.6
3-13-81	M10	<1.0	<0.5	25.0	25.0	0.2	13,260	110.2
5-05-81	M10	<1.0	<0.5	24.0	25.6	0.1	13,160	112.2
<u>BENTHIC BIOTA</u> ($\mu\text{g g}^{-1}$ wet weight)								
3-13-81	<u>Penaeus</u> <u>setiferus</u>	<1.0	<0.05	1.10	8.2	0.05	580	13.6
5-05-81	<u>Penaeus</u> <u>setiferus</u>	<1.0	<0.05	0.55	14.6	0.06	575	18.4
5-05-81	<u>Polinicies</u> <u>duplicatus</u>	<1.0	<0.05	0.91	9.0	0.03	1080	26.0
5-05-81	<u>Libinia</u> <u>dubia</u>	<1.0	<0.05	1.06	12.0	0.05	4580	44.0

first cruise of March 13 insufficient moon snails were found so Libinia dubia (spider crab) was selected as an alternate sample.

4.3.4.2.1 Water

The data for total metals measured in water samples indicate low concentrations for most elements with several (As, Cd, Cr, and Hg) being below the detection limit. The brine pond liquid contained lower concentrations of copper and magnesium and higher concentrations of zinc than the waters of the intake structure site or diffuser site.

4.3.4.2.2 Sediment

Sediment concentrations in the 1 N HNO₃ leachates appear to agree poorly with the evaluation of the West Hackberry site by Tillery (1980). Tillery reported the following values in sediments collected during the winter at West Hackberry to be: Cd = 0.060 ug g⁻¹, Cr = 6.3 ug g⁻¹, Cu = 7.4 ug g⁻¹, Hg = 0.059 ug g⁻¹ and Zn = 38 ug g⁻¹ as dry weight. The biggest differences between the study of Tillery and the present investigation was the higher concentrations of Hg. Our values agree well with other studies along the Gulf Coast (Hann et al., 1980; Science Applications, Inc., 1978) using 1 N HNO₃ leachates. It should be noted that the trace metal values cited in this section should only be compared to the corresponding offshore diffuser site (M10) data given in Table 4-15. No prior trace metal data appears to exist for the intake structure located in the Intracoastal water so no comparisons can be made.

4.3.4.2.3 Benthic biota

Table 4-15 shows the total metal concentration in three species of benthic biota: Libinia dubia (spider crab), Polinicies duplicates (moon snails) and Penaenus setiferus (white shrimp). Because of the difficulty of finding a large enough sample of moon snails and white shrimp during the March cruise comparisons of metal concentrations were not possible. However, the values of total metal concentrations given in Table 4-15 are in good agreement with the concentrations given by Tillery (1980). Little change in total metals was found for the white shrimp collected in March and May or between species of benthic biota.

4.3.4.3 Pesticides, herbicides and high molecular weight hydrocarbons

The results of the pesticide, herbicide and high molecular weight hydrocarbons analyses of water, sediment and benthic biota are presented in Tables 4-16 through 4-18.

4.3.4.3.1 Water and sediment

The waters of station E1 and the brine pond contained no detectable levels of pesticides, herbicides or high molecular weight hydrocarbons. The sediments of stations E1 and M10 contains only high molecular weight hydrocarbons. In March 1981 station E1 contained hydrocarbons ranging from pentadecane to large alkanes (greater than hentriacontene) while station M10 contains octadecane, nonadecane, pentacosane, heptacosane, octacosane and large alkanes. In May 1981, the sediment at station E1 contained tetracosane while the sediment of station M10 contained eicosane and docosane (Table 4-16). Major peaks

Table 4-16. Pesticides, herbicides and hydrocarbons in water and sediment at the intake structure, brine pond and diffuser site in the units of $\mu\text{g.l}^{-1}$ for water and $\mu\text{g.kg}^{-1}$ for sediment.

Station Date Collected	WATER			SEDIMENT			
	El		Brine Pond	El		M10	
	3-13-81	5-5-81		3-13-81	5-5-81	3-13-81	5-5-81
Compound							
Molinate	ND*	ND	ND	ND**	ND	ND	ND
Dieldrin	ND	ND	ND	ND	ND	ND	ND
Propanil	ND	ND	ND	ND	ND	ND	ND
2, 4-D	ND	ND	ND	ND	ND	ND	ND
Trifluralin	ND	ND	ND	ND	ND	ND	ND
Vernolate	ND	ND	ND	ND	ND	ND	ND
Aldrin	ND	ND	ND	ND	ND	ND	ND
Total DDT	ND	ND	ND	ND	ND	ND	ND
Chlordane	ND	ND	ND	ND	ND	ND	ND
Silvex	ND	ND	ND	ND	ND	ND	ND
2, 4, 5-T	ND	ND	ND	ND	ND	ND	ND
Parathion	ND	ND	ND	ND	ND	ND	ND
Guthion	ND	ND	ND	ND	ND	ND	ND
Toxaphere	ND	ND	ND	ND	ND	ND	ND
HCB	ND	ND	ND	ND	ND	ND	ND
PCB ARI232	ND	ND	ND	ND	ND	ND	ND
ARI242	ND	ND	ND	ND	ND	ND	ND
ARI248	ND	ND	ND	ND	ND	ND	ND
ARI254	ND	ND	ND	ND	ND	ND	ND
ARI260	ND	ND	ND	ND	ND	ND	ND
High Molecular Weight Hydrocarbons							
carbons	ND	ND	ND	ND**	ND	ND	ND
Pentadecane	ND	ND	ND	320	ND	ND	ND
Hexadecane	ND	ND	ND	480	ND	ND	ND
Heptadecane	ND	ND	ND	640	ND	ND	ND
Heptadecane-isomer	ND	ND	ND	920	ND	ND	ND
Octadecane	ND	ND	ND	520	ND	160	ND
Octadecane-isomer	ND	ND	ND	640	ND	ND	ND
Nonadecane	ND	ND	ND	480	ND	160	ND
Eicosane	ND	ND	ND	480	ND	ND	1520
Heneicosane	ND	ND	ND	280	ND	ND	ND
Docosane	ND	ND	ND	280	ND	ND	600
Tricosane	ND	ND	ND	240	ND	ND	ND
Tetracosane	ND	ND	ND	ND	80	ND	ND
Pentacosane	ND	ND	ND	240	ND	120	ND
Leptacosane	ND	ND	ND	ND	ND	200	ND
Heptacosane	ND	ND	ND	320	ND	ND	ND
Octacosane	ND	ND	ND	ND	ND	120	ND
Nonacosane	ND	ND	ND	160	ND	ND	ND
Nonacosane-isomer	ND	ND	ND	280	ND	ND	ND

Table 4-16. Pesticides, herbicides and hydrocarbons in water and sediment at the intake structure (El), brine pond and diffuser site (M10). Page 2

Station Date Collected	WATER			SEDIMENT			
	El		Brine Pond	El		M10	
	3-13-81	5-5-81		3-13-81	5-5-81	3-13-81	5-5-81
Compound							
Hentriacontane	ND	ND	ND	80	ND	ND	ND
Hentriacontane- isomer	ND	ND	ND	200	ND	ND	ND
Hentriacontane- isomer	ND	ND	ND	120	ND	ND	ND
Hentriacontane- isomer	ND	ND	ND	80	ND	ND	ND
Hentriacontane- isomer	ND	ND	ND	40	ND	ND	ND
Hentriacontene	ND	ND	ND	80	ND	ND	ND
Hentriacontene- isomer	ND	ND	ND	40	ND	ND	ND
Large alkane (greater than hentriacontane with hentriacontene)		ND	ND	120	ND	160	ND

*ND - none detected, less than the minimum detectable level of 10 ug l⁻¹ in water

**ND - none detected, less than the minimum detectable level of 80 ug kg⁻¹ in sediment

Table 4-17. Major peaks identified in the sediment samples at the intake structure and diffuser site.

<u>Station</u>	<u>Date</u>	<u>Identification of Top Peaks</u>
E1	3-13-81	Dodecanoic acid Tetradecanoic acid Pentadecanoic acid Pentadecanoic acid-isomer Hexadecenoic acid Hexadecanoic acid Octadecanoic acid Tetracosanoic acid Hexacosanoic acid Octacosanoic acid
	5-5-81	none detected
M-10	3-13-81	Dodecanoic acid Tetradecanoic acid Pentadecanoic acid Pentadecanoic acid-isomer Hexadecenoic acid Hexadecanoic acid Octadecenoic acid Octadecanoic acid Tetracosanoic acid
	5-5-81	none detected

Table 4-18. Pesticides, herbicides, hydrocarbons and top peaks in biota collected from the diffuser site.

Organism	<u>Penaeus setiferus</u>		<u>Polinicies duplicatus</u>	<u>Libinia dubia</u>
Date	3-13-81	5-5-81	5-5-81	5-5-81
Compound				
Molinate	ND*	ND	ND	ND
Dieldrin	ND	ND	ND	ND
Propanil	ND	ND	ND	ND
2, 4-D	ND	ND	ND	ND
Trifluralin	ND	ND	ND	ND
Vernolate	ND	ND	ND	ND
Aldrin	ND	ND	ND	ND
Total DDT	ND	ND	ND	ND
Chlordane	ND	ND	ND	ND
Silvex	ND	ND	ND	ND
2, 4, 5-7	ND	ND	ND	ND
Parathion	ND	ND	ND	ND
Guthion	ND	ND	ND	ND
Toxaphene	ND	ND	ND	ND
HCB	ND	ND	ND	ND
PCB ARL232	ND	ND	ND	ND
1242	ND	ND	ND	ND
1248	ND	ND	ND	ND
1254	ND	ND	ND	ND
1260	ND	ND	ND	ND
High molecular weight hydrocarbons	ND	ND	ND	ND
Top peaks				
	ND	ND	ND	phenylacetaldehyde
d ₈ -naphthalene		d ₈ -naphthalene	d ₈ -naphthalene	d ₈ -naphthalene
ND		ND	ND	octanal isomer
ND		ND	ND	dodecanal isomer
tridecanal		ND	ND	tridecanal
tetradecanoic acid		ND	ND	tetradecanoic acid
d ₁₀ -anthracene	d ₁₀ -anthracene	d ₁₀ -anthracene	d ₁₀ -anthracene	d ₁₀ -anthracene
pentadecanoic acid isomer		ND	ND	ND
heptadecanal		ND	ND	heptadecanal
heptadecenol isomer	heptadecenol isomer		ND	heptadecenol isomer
	hexadecanoic acid		hexadecanoic acid	hexadecanoic acid
ND				

Table 4-18. Pesticides, herbicides, hydrocarbons and top peaks in biota collected a from the diffuser site. Page 2.

Organism Date	<u>Penaeus setiferus</u>		<u>Polinicies duplicatus</u>	<u>Libinia dubia</u>
	3-13-81	5-5-81	5-5-81	5-5-81
heptadecanoic acid isomer		ND	ND	ND
heptadecanoic acid isomer		ND	ND	ND
heptadecanoic acid isomer		ND	ND	ND
nonadecenol isomer		ND	ND	ND
heptadecanoic acid		ND	ND	heptadecanoic acid
nonadecenol acid		nonadecenol acid	ND	nonadecenol acid
nonadecenol isomer		nonadecenol isomer	ND	nonadecenol isomer
ND		ND	ND	nonadecenol isomer
ND		ND	ND	C ₂₁ -branched alkane
d ₁₂ -chrysene		d ₁₂ -chrysene	d ₁₂ -chrysene	ND
cholesterol isomer		cholesterol isomer	cholesterol isomer	cholesterol isomer

ND- none detected, less than the minimum detectable level of 150 ug kg⁻¹ in tissue

d₈naphthalene; d₁₀anthracene, and d₁₂chrysene are internal standards

were identified in the sediment of stations E1 and M10 in March but not in May 1981 (Table 4-17).

4.3.4.3.2 Benthic biota

The benthic biota collected at station M10 (diffuser) in March and May 1981 contained no detectable quantities of pesticides, herbicides, or high molecular weight hydrocarbons.

CHAPTER 5

BENTHOS

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Lake Charles, LA 70609

5.1 Introduction

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 phyla. 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 6.

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. The latter points aid in interpretation of these data as they relate to impacts due to man's activities.

5.1.1 Objective

The primary objective of this study was to characterize the macrobenthic communities of Calcasieu Lake and the West Hackberry diffuser area in light of their potential for usage in impact assessment following brine discharge. These data will later be used as baseline information, though due to the relatively short (3 month) duration of this baseline study, a great deal of emphasis has been placed on previous investigations of both the study area and similar habitats along the Gulf of Mexico coastline.

5.1.2 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 three 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 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).

The West Hackberry study area was examined in preliminary investigations by Science Applications Incorporated (S.A.I.), though only limited data from these investigations are now available (S.A.I., 1978). Comparisons of results of this study with those of the present investigations are discussed at length below. A second study of the West Hackberry area was conducted by Parker et al. (1980) from June 1978 through May 1979; however, only quarterly samples were collected.

The following lists conclusions reached by Parker et al. concerning the West Hackberry study site:

1. The species composition and numbers of benthic animals from the nearshore Louisiana coast appears to be affected by season, storm surges, and low dissolved oxygen in the bottom water during the summer.
2. A large area of the nearshore Gulf off the Louisiana coast, especially near Calcasieu Pass, is characterized by critically low bottom dissolved oxygen values during the summer. The very low dissolved oxygen values at West Hackberry may control larval settlement and survival.
3. The benthic communities at West Hackberry have a rapid turnover rate, and most species appear to complete their life cycles in a year or less. Larvae of polychaetes and molluscs settle out in the fall and winter; therefore, they are less subject to the critical environmental conditions (low dissolved oxygen and high temperature) of summer.
4. No consistent station to station correlations were found between sediment type and benthic abundance and diversity.
5. Mulinia lateralis and Nassarius acutus are the most abundant molluscs at the West Hackberry site. The numbers of individuals and biomass of Mulinia lateralis were greatest during the winter and spring.
6. As a group, the polychaetes were most important throughout

the year in terms of biomass and numbers of individuals.

There were seasonal trends in dominance within this group, and there were distinct differences in the polychaete species composition at each site.

7. The types of benthic organisms present and extremes and means of temperature-salinity data indicate that the West Hackberry site is more characteristic of estuarine habitats than of open Gulf waters.
8. Lack of large numbers of peracarid crustaceans in the meiofauna and megafauna suggests that normal environmental conditions at both sites are unpredictable and beyond normal ranges for open ocean conditions.
9. An analysis of species diversity, evenness, and richness revealed that the central portion of the sampling area is of lower overall quality than the rest of the region. This exercise suggests that the planned location of the diffuser will least affect benthic diversity and abundance.

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 (U.S. Dept. Commerce, 1977; Armstrong et al., 1979). Since the study site is also within an area of active oil platforms, data from certain of these other areas may provide some insight into interpretation of benthic community patterns off Cameron.

Five benthic sampling sites in the present study are located within the Calcasieu Lake estuary. This estuary was not included in the preliminary studies of West Hackberry by S.A.I. (1978) or Parker et al. (1980). The only comprehensive macrobenthic baseline study of Calcasieu Lake benthos was conducted by Shirley (in prep.), though these data are not yet available. Other estuaries in central and western Louisiana have been investigated by Day et al. (1973), Waller (1979), and Wells and Demas (1979), though none of these investigations parallels the present study in methodology or objective.

5.2 Materials and Methods

5.2.1 Field Sampling

5.2.1.1 Marine

During predischARGE sampling, extending from February through April of 1981, thirteen benthic stations were sampled at monthly intervals. An additional station, CS, was sampled only in February. Marine sampling sites (Figure 5-1) were located primarily on an east-west transect along the 10 meter depth contour to minimize the effects of bathymetric faunal variation. Since sediment type may vary with depth on the continental shelf, the narrow depth range also reduced sediment variability among the stations.

Station M10A was located at the center of the diffuser, 0.67 km northeast of M10. The D stations (DE, DN, DS, DW) were all located in the immediate vicinity of the diffuser, 0.9 km to the north, south, east and west of M10A. Station CS was located 16.7 km east of the

diffuser, to the east of the Calcasieu ship channel. All other marine stations were in common with the other disciplines.

Marine stations were 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 were made of time, sea state, and weather conditions. A vertical profile at three meter intervals was made of conductivity, temperature, dissolved oxygen and pH with a Hydrolab Series 8000 meter.

Six replicate grab samples were taken at all marine stations using a 0.1 m² stainless steel Smith-McIntyre grab (Figure 5-2a). The number of replicates necessary to adequately sample the community was determined during a special cruise in January, prior to regular benthic sampling, in which stations M9, M10 and M11 were sampled by taking 10 replicates at each site. Based on analysis of this data using techniques of Saila et al. (1976), Brower and Zar (1977), Boesch et al. (1977) and Green (1979), and with consideration of realistic requirements of the program, six replicates per station were determined necessary for all marine sites. Though most data presented in this report is from February-April, January data obtained during this special cruise is presented where applicable.

After each sample was retrieved, the upper doors of the grab were opened and depth of penetration was measured. A 2.7 cm diameter x 12 cm length core was inserted into the sediment to obtain a sample for grain size analysis. The contents of the core were transferred to a

(a)

(b)

Figure 5-2. 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)

Whirl-Pak bag and stored on ice. The contents of the grab were immediately washed through a 0.5 mm screen. The material retained on the sieve was preserved in 7% buffered formalin containing Rose Bengal as a vital stain, and stored in a container labelled with station, replicate, and cruise number.

5.2.1.2 Estuarine

Five estuarine stations (Figure 5-3) were sampled monthly from February-April, 1981, with the exception of station E3, which, because of low water was accessible only in April. The location of estuarine stations was determined by dead reckoning. At each site, observations were made of weather conditions and water quality as at the marine stations.

Five replicate grab samples were taken at all estuarine stations using a 0.05 m² Ekman grab (Figure 5-2b), with the exception of E5, where, because of strong tidal currents, a 0.1 m² Smith-McIntyre grab was used. The number of replicates required was determined during the preliminary January cruise discussed earlier, during which 10 replicates were taken near station E4. Field processing of the estuarine samples was identical to that of the marine samples discussed above.

5.2.1.3 Oyster Survey

An oyster (Crassostrea virginica) survey was conducted during April in Calcasieu Lake in conjunction with the benthic sampling program. The purpose of the survey was to assess changes in oyster abundance, size composition, and densities of oyster drills (Thais

Figure 5-3. Macrobenthic estuarine sampling sites.

haemastoma). Two sampling sites, stations E3 and E4 (Figure 5-3), were selected for the survey. Both were areas of commercial oyster harvest. This study was part of an ongoing research program established by the Department of Louisiana Wildlife and Fisheries. The methodology, therefore, follows their specifications to insure standardization of sampling and production of comparable data.

Oysters were collected by SCUBA divers. Once the oyster beds were located by divers a one meter-square quadrat was dropped. All oysters and oyster drills encompassed within the quadrat were then removed and placed in a large burlap bag. Care was taken to insure that loss of the attached oyster drills was minimal. Two samples from each study area were thus collected. The samples were returned to the laboratory in collection bags. Lengths of the individual oysters were then measured and size classes established. Densities of oysters and oyster drills were determined for each sample by simply counting numbers of these species per meter-square quadrat sample.

5.2.2 Laboratory Analyses

Benthic samples preserved in formalin were stored in the laboratory until analyses began. Analyses included rinsing, sorting to major taxa, and identification of macrofaunal species.

The rinsing procedure was 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 was washed free of the formalin preservative, and all light-bodied organisms were concentrated on the 0.5 mm screen.

Heavy-bodied organisms, such as large molluscs, remained in the enamel tray and were later removed by sorting with the naked eye. Organisms retained on the 0.5 mm screen were examined under a dissecting microscope, and sorted to major taxa (e.g. Decapoda, Mollusca, etc.). Each major taxon was placed in an individual vial and stored in 70% ethanol pending species determination.

Identification and enumeration of macrofaunal organisms was performed under stereomicroscopy, and when necessary, compound microscopy. Each organism was identified to the lowest possible taxonomic level, generally species, and placed in separate vials containing 70% ethanol. Major taxonomic references used for identification of benthic species are listed in Table 5-1. 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 species collected in each replicate was recorded on laboratory data sheets. Each species was then identified by a 10 digit taxonomic code, which is used in all computer manipulations.

A reference, or voucher, collection of each major species collected was maintained to insure taxonomic standardization within this study. Specimens were preserved in glass jars containing 70% ethanol preservative, and labelled inside. All labels indicate, at a minimum, the date, location, depth of specimen collection, and

Table 5-1. Major taxonomic references by phylum 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

contract number of this contract. The reference collection will be maintained by McNeese State University until its deposition in the United States National Museum, Smithsonian Institution.

5.2.3 Grain Size Analysis

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

5.2.4 Statistical Analyses

Several indices of community structure were employed in data analysis of the benthic collections. 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. This index is dependent on both the number of species in the sample as well as their relative dominance. To examine these two parameters independently, species richness (S.R.) and evenness (J) were computed separately using the formulae:

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

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.

In order to present the large data set in an interpretable form, as well as determine zones of rapid faunal change, multivariate analysis techniques were employed. In analyses of the marine stations, rare species were eliminated. These species were identified as those which met the following three criteria: (1) occurrence at only one station; (2) occurrence in three or less replicates; (3) density of six or less individuals m^{-2} . In analyses of the estuarine stations, no species were dropped because of the smaller size of the data set and the greater habitat heterogeneity between stations, causing many species to be unique to one particular site.

Clustering was 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) were 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 .

The clustering hierarchy is in part determined by the sorting strategy chosen and its inherent degree of space dilation. Space-contracting strategies (e.g. nearest neighbor) tend to cause excessive chaining, in which, as a cluster grows, new entities are added to a few existing nuclear groups instead of forming new groups. The resulting dendrogram is difficult to interpret as most entities must be treated as individuals. A space-dilating strategy (e.g. farthest neighbor) favors the opposite effect, in that, as new entities are joined to the cluster, they are more likely to form new

groups. Space dilation causes intense clustering with minimal chaining.

Two sorting strategies were used in the numerical classification analyses. A group average sorting strategy (Sneath and Sokal, 1973, as "unweighted pair-group method using unweighted arithmetic averages") was 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 caused undesirable chaining among the entities. Flexible sorting (Lance and Williams, 1967), with β established at -0.25 was also employed. Though flexible sorting seldom induces chaining, it has the drawback of occasionally causing misclassifications. Both sorting strategies were employed on all data sets, and the more informative of the two presented in the text.

To supplement the cluster analysis, the ordination technique of reciprocal averaging (Hill, 1973) was performed using the ORDIFLEX program (Gauch, 1977) with square root transformation of abundances. Reciprocal averaging was chosen over other forms of ordination as some studies (Gauch et al., 1977) have demonstrated it causes less distortion in the ordination of simulated community gradients. It also permits both species and station ordinations to be performed in the same space, a feature assisting in interpretation.

While cluster analysis is beneficial in delineating zones of similarity along a wide environmental gradient, ordination is

advantageous in other respects. Ordination may be more desirable for establishing relationships among stations within a relatively homogeneous area. The multi-dimensional character of ordination allows a better appreciation of the inter-entity relationships than does the single axis of the cluster analysis. Interfacing the two techniques, such as by plotting the species groups derived from the cluster analysis in ordination space, gives added insight into biological relationships.

5.3 Results

5.3.1 Oyster Survey

A survey of oyster populations at stations E3 and E4 was conducted in April. The object of the survey was to determine size of the oysters at the two sites, and determine whether oyster drills, predators of oysters, were present. Two replicate samples, A and B, were collected for each site.

The oysters were measured by length, and size classes established (Figures 5-4, 5-5). One centimeter classes were selected as adequate to demonstrate distribution. Specimens at station E3 ranged from 3 to 19 cm (Figure 5-4). Replicate A had a mean of 9.5 cm (s.d. = 4.7) and replicate B had one of 13.8 cm (s.d. = 2.7). Evidently, the spatial distribution is more varied than was adequately sampled with two replicates of meter-square samples. It should be indicated that State Wildlife and Fisheries sampling does not include replicate sampling, and methodology used herein was undertaken to better understand the

Figure 5-4. Length frequency histograms for oysters collected at station E-3.
(a) first replicate (b) second replicate.

Figure 5-5. Length-frequency histograms for oysters collected at station E4.
(a) first replicate (b) second replicate.

distribution at these two sites. The mean number of individuals at station E3 was 35 oysters m^{-2} .

Station E4 was populated by 51 oysters m^{-2} . Individuals ranged in size from slightly over 2 to 23 cm (Figure 5-5). Replicate A had a mean of 8.5 cm (s.d. = 3.4) and replicate B that of 10.9 (s.d. = 4.5). A single oyster drill was collected at E4. None were present at E3.

Though not usually included in oyster surveys conducted in Calcasieu Lake, the presence of the mussel, Brachidontes exustus, should be noted. This species attaches to oyster shells by byssal threads. Their presence is a hindrance to commercial harvesting because of additional time expended in their removal from adult oysters. B. exustus was abundant on oysters collected at E3, but nearly absent at E4.

5.3.2 Hydrology

The hydrology of the marine and estuarine study areas is discussed at length in Chapter 3. The brief discussion below is intended to provide only a general characterization of the study areas. Data herein presented are from CTD/DO measurements made during the benthic cruises. Only bottom measurements are included in this treatment.

5.3.2.1 Marine

The marine stations showed remarkable consistency in all physical measurements during any given sampling period (Appendix D-1) and are clearly inundated by the same water mass at any given time. On any

cruise, temperature varied $<1^{\circ}\text{C}$, salinity varied $<1^{\circ}/\text{oo}$, and dissolved oxygen varied $<2 \text{ ml l}^{-1}$ among the stations.

Bottom temperatures showed a gradual warming trend during the study period from a mean of 10.2°C in February to 20.5°C in April. Salinity of bottom water showed an increase from February ($\bar{x} = 28.5^{\circ}/\text{oo}$) to March ($\bar{x} = 31.8^{\circ}/\text{oo}$) and then a slight decrease in April ($\bar{x} = 30.4^{\circ}/\text{oo}$). Dissolved oxygen in the bottom water showed a gradual decrease throughout the study period, reaching a low value of 3.6 ml l^{-1} at station M1 in April, though its concentration never became so low as to be limiting to macrobenthic organisms (Baker, et al., 1981). The highest levels of dissolved oxygen were found in February ($\bar{x} = 6.5 \text{ ml l}^{-1}$) from which it dropped to a mean value of 5.2 ml l^{-1} in March and 5.0 ml l^{-1} in April.

5.3.2.2 Estuarine

Physical measurements made at the estuarine stations (Appendix D-2) frequently showed strong variation both between cruises and among the stations on any given cruise. Because of the high variation in physical parameters depending on tidal and weather conditions, values presented can only be considered approximations and not precise characterizations of the physical environment at these sites. Bottom temperatures showed an increase up-estuary in both February and March, though this trend was reversed in April. Concurrent with atmospheric

warming estuarine waters showed a near doubling of temperature during the study period (means = 11.7 to 20.3°C). Not unexpectedly, bottom salinity increased considerably towards the mouth of the estuary, though the freshwater influence was still evident at station E5, which consistently had a salinity several parts per thousand less than the offshore stations. Though no clear temporal trend in salinity was evident at station E5, all other estuarine stations showed a pronounced increase during the study period attributable to abnormally low rainfall during this time. Bottom dissolved oxygen showed no consistent pattern among the stations, ranging from a low of 3.3 ml l⁻¹ at E4 in April to 7.0 ml l⁻¹ at E5 in February. There was some evidence of a decrease in dissolved oxygen during the study period at stations E4 and E5, though these scant data cannot be considered conclusive.

5.3.3 Sediments

Grain size analysis of sediment samples taken directly from the biological grab samples was made primarily to provide supportive data to assist in the interpretation of macrobenthic distribution patterns. A complete analysis of the sediments at each station, broken down in grain size classes from -2 to >10 phi is presented in Appendices D-3, D-4, D-5 and D-6. Only those data in Appendices D-3 and D-4 are discussed.

5.3.3.1 Marine

Surficial sediments in the marine study area were entirely soft mud, with the percentage of sand never exceeding 48%, and frequently less than 20%. With few exceptions, the substrate may be characterized as either silty clay or sandy mud (Figure 5-6). Other

Figure 5-6. Ternary textural diagrams of surficial sediments at the marine sampling stations. (a) February (b) March (c) April.

than a slight increase in the percentage of clay in the sediments at most sites from February to March, there was little change in the sediment at all sites throughout the pre-discharge period.

Figure 5-7 illustrates the percentage of sand in the sediments at all marine sites. Comparable data collected for the Texoma study (Hausknecht, 1980) in the same area during January of 1979 is also presented. As shown, the results were nearly identical, illustrating either seasonal persistence or at least a repeatable annual cycle. Stations M9 and DN, to the north of the diffuser, had the lowest percentage of sand found in the study area (about 3%). Station M10A, at the mid-point of the diffuser, had 5.9-8.8% sand ($\bar{x}$ = 7.4) throughout the study period. The percent composition of sand in the sediments generally increased to the east, south and west of these sites, with those stations on the perimeter of the study area having the greatest percentages of sand. Station M1, 9.3 km to the west of the diffuser, had 39.0-44.1% sand ($\bar{x}$ = 41.5) while station CS, 16.7 km to the east, had 29.6% sand.

5.3.3.2 Estuarine

Surficial sediments at the estuarine stations generally had less clay and more silt than the marine sites, and were more temporally variable over the sampling period (Figure 5-8). Station E1 varied from a clayey silt to a sandy mud. The percentage of sand varied considerably during the study period from a low of 12.2% in February to 32.9% in March. Station E2 consistently had the least clay and the

Figure 5-8. Ternary textural diagrams of surficial sediments at the estuarine sampling stations.
(a) February (b) March (c) April.

greatest percentage of sand of any site, either estuarine or marine, most likely indicating higher current velocities at the site. Station E3 was only sampled in April, but at that time the sediment was a silty clay with the greatest percentage of clay of any site. A consistent decrease in the percentage of silt at station E4 was observed from February to April, with a concomitant increase in sands and clays. With the exception of E3, station E4 had the highest median grain size of the estuarine sites. Station E5 was the least temporally variable of the estuarine stations. Its sediments can be best characterized as sandy mud, though they were a sandy silt in March because of a lower percentage of clay.

5.3.4 Dominant Species

5.3.4.1 Marine

In the marine sampling, 134 benthic species were identified from three monthly collections at 14 stations. Species which contributed over 4% of the individuals of a particular cruise were arbitrarily considered to be numerical dominants (Table 5-2). A total of seven species were thus selected. Spatial trends are herein analyzed by cruise, and temporal trends by species (Table 5-3). General temporal trends have additionally been analyzed by combining all stations within 1 nautical mile (1.8 km) of the diffuser midpoint (station M10A). These have been compared with data collected at the same site by S.A.I. (1978) and Parker et al. (1980).

During February (Tables 5-2, 5-3), four polychaetes (Sabellides sp.A, Magelona cf. pacifica, Paraprionospio pinnata, Mediomastus

Table 5-2. Numerically dominant marine species of 14 stations by mean abundance (individuals m^{-2}) and percentage of benthic community. (A = Amphipod, An = Anthozoan, B = Barnacle, C = Cnidarian, M = Mollusk, N = Nemertean, P = Polychaete, Ph = Phoronid).

February				March				April			
	$\bar{x}$	%	cum. %		$\bar{x}$	%	cum. %		$\bar{x}$	%	cum. %
<u>Sabellides</u> sp. A (P)	1102	43.2	43.2	<u>Sabellides</u> sp.A (P)	1517	35.4	35.4	<u>Phoronis</u> sp.A (Ph)	2573	49.7	49.7
<u>Balanus improvisus</u> (B)	308	12.1	55.3	<u>Phoronis</u> sp.A (Ph)	1402	32.8	68.2	<u>Sabellides</u> sp.A (P)	1653	29.1	78.8
<u>Mulinia lateralis</u> (M)	178	7.0	62.3	<u>Balanus improvisus</u> (B)	356	8.3	76.5	<u>Magelona</u> cf. <u>pacifica</u> (P)	154	2.7	81.5
<u>Magelona</u> cf. <u>pacifica</u> (P)	162	6.3	68.6	<u>Oxyurostylis</u> sp.A (C)	137	3.2	79.7	<u>Balanus improvisus</u> (B)	134	2.4	83.9
<u>Paraprionospio pinnata</u> (P)	110	4.3	72.9	<u>Nemertea</u> sp.B (N)	112	2.6	82.3	<u>Nemertea</u> sp.B (N)	129	2.3	86.2
<u>Mediomastus</u>				<u>Magelona</u> cf. <u>pacifica</u> (P)	85	2.0	84.3	<u>Paraprionospio pinnata</u> (P)	94	1.6	87.8
<u>californiensis</u> (P)	106	4.1	77.0	<u>Mulinia lateralis</u> (M)	71	1.7	86.0	<u>Mediomastus</u>			
<u>Nemertea</u> sp.B (N)	88	3.4	80.4	<u>Mediomastus</u>				<u>californiensis</u> (P)	91	1.6	89.4
<u>Oxyurostylis</u> sp.A (C)	72	2.8	83.2	<u>californiensis</u> (P)	70	1.6	87.6	<u>Diopatra cuprea</u> (P)	76	1.3	90.7
<u>Phoronis</u> sp.A (Ph)	72	2.8	86.0	<u>Paraprionospio pinnata</u> (P)	65	1.5	89.1	<u>Cossura soyeri</u> (P)	49	0.9	91.6
<u>Cossura soyeri</u> (P)	38	1.5	87.5	<u>Cerebratulus lacteus</u> (N)	1	0.6	89.7	<u>Oxyurostylis</u> sp.A (C)	46	0.8	92.4

Table 5-3. Abundance (individuals m⁻²) of numerically dominant species at marine stations.

Station																
Month	M1	M3	M6	M9	DW	DN	M10A	DS	DE	M11	M15	M18	M20	CS	Mean	S.D
<u>Sabellides sp. A</u>																
February	1060	1338	862	482	1613	1077	1898	1727	880	817	535	828	1110	1202	1102	423
March	1008	1258	1383	842	1100	1325	1308	1733	2532	1178	2133	2217	1700	—	1517	512
April	1183	1417	1450	1367	2002	1775	1550	2083	1358	1633	2450	1628	1592	—	1653	349
Mean	1084	1338	1232	897	1572	1392	1585	1848	1590	1209	1706	1558	1467			
<u>Mulinia lateralis</u>																
February	28	292	537	53	290	72	102	112	17	15	40	58	315	562	178	189
March	8	75	112	120	130	23	57	42	18	45	147	100	43	—	71	46
April	3	7	5	2	27	62	25	103	18	12	37	48	15	—	28	29
Mean	13	125	218	58	149	52	61	86	18	24	75	69	124			
<u>Balanus improvisus</u>																
February	15	418	908	88	780	162	185	257	23	0	53	62	598	765	308	324
March	2	280	452	845	750	148	222	147	170	73	573	478	487	—	356	264
April	2	78	125	3	333	343	385	93	123	0	155	83	15	—	134	136
Mean	6	259	495	312	621	218	264	166	105	24	260	208	367			

Table 5-3. (continued - page 2)

	Station															
Month	M1	M3	M6	M9	DW	DN	M10A	DS	DE	M11	M15	M18	M20	CS	Mean	S.D
	<u>Magelona cf pacifica</u>															
February	313	108	172	73	118	92	123	143	75	193	73	115	77	590	162	139
March	83	118	52	92	98	63	103	43	103	142	132	0	70	—	85	39
April	218	112	68	102	203	88	152	168	172	225	205	183	105	—	154	53
Mean	205	113	97	89	140	81	126	118	117	187	137	99	84			

<u>Phoronis sp. A</u>																
February	82	215	92	25	68	15	143	88	68	95	15	30	25	50	72	55
March	1108	4167	0	958	725	3167	2875	667	700	2500	692	413	258	—	1402	1312
April	4000	8250	660	3590	1158	4925	1792	1408	1225	6208	1658	1550	258	—	2822	2414
Mean	1730	4211	251	2180	650	2702	1603	721	664	2934	788	664	180			

<u>Paraprinospio pinnata</u>																
February	153	80	95	78	63	138	188	72	37	98	42	53	68	378	110	88
March	113	127	52	65	25	52	82	48	65	78	55	38	45	—	65	29
April	177	112	90	0	95	110	125	67	73	153	83	90	42	—	94	45
Mean	148	106	79	48	61	100	132	62	58	110	60	60	52			

Table 5-3. (continued - page 3)

Month	Station														Mean	S.D
	M1	M3	M6	M9	DW	DN	M10A	DS	DE	M11	M15	M18	M20	CS		
<u>Mediomastus californiensis</u>																
February	205	108	110	28	80	38	150	47	38	120	43	140	102	275	106	71
March	83	87	40	37	50	25	87	37	155	72	133	62	38	—	70	39
April	147	70	80	37	115	103	68	107	72	167	70	117	25	—	91	41
Mean	145	88	77	34	82	55	102	64	88	120	82	106	55			

californiensis), a barnacle (Balanus improvisus) and a bivalve mollusc (Mulinia lateralis) were numerical dominants among the marine benthic fauna. Sabellides sp.A (Figure 5-9) was the most abundant species collected, composing 43.2% of the individuals. It was distributed at all marine stations, and occurred in numbers in excess of 535 individuals m^{-2} at all 10 stations along the east-west transect. Sabellides sp.A reached a maximum of 1898 individuals m^{-2} at station M10A, the diffuser midpoint. A similar species of ampharetid polychaete (Asabellides oculata) has been observed to undergo periodic population irruptions along the U.S. east coast (personal observation). Species of Sabellides are surface deposit-feeding polychaetes which inhabit temporary mucus tubes that open at the sediment-water interface. Magelona cf. pacifica (Figure 5-9) also occurred at all marine stations, but was most abundant at the perimeter collection sites, M1 (313 individuals m^{-2}), CS (590 individuals m^{-2}) and M11 (193 individuals m^{-2}). Magelonid polychaetes are motile surface deposit feeders that typically inhabit sandy sediments (Jones, 1968). Their high abundance at M1, M11 and CS could have been due solely to the greater percentage of sand at these particular sites. Mediomastus californiensis and Paraprionospio pinnata (Figure 5-10) are most abundant at station CS (275 and 378 individuals m^{-2} respectively). They were also more abundant at stations M1 (205 and 153 individuals m^{-2}) and M10A (150 and 188 individuals m^{-2}) than elsewhere. These latter two species typically inhabit frequently disturbed fine sediment habitats of both

Figure 5-9. Mean abundance of (a) *Magelona cf. pacifica* and (b) *Sabellides* sp. A at marine stations. Number of individuals (m^{-2}) at each station is indicated by cumulative bars (solid=February, striped=March, stipled=April).

Figure 5-10. Mean abundance of (a) Mediomastus californiensis and (b) Paraprionospio pinnata at marine stations. Number of individuals (m^{-2}) at each station is indicated by cumulative bars (solid=February, striped=March, stippled=April).

the Gulf and U.S. east coasts. Their occurrence in the study area may result from local disturbance of the fine sediments at the sediment-water interface. The co-occurrence of Mulinia lateralis and Balanus improvisus (Figure 5-11) is discussed below (see estuarine dominant species, Section 5.3.4.2). Mulinia lateralis was most abundant at the following stations: CS (562 individuals m^{-2}), M6 (537 individuals m^{-2}), M20 (315 individuals m^{-2}), M3 (292 individuals m^{-2}) and DW (290 individuals m^{-2}). Balanus improvisus was most abundant at these stations as well ($\bar{x}$ = 693 individuals m^{-2}). The distribution of M. lateralis elsewhere in the study area was erratic.

During March (Tables 5-2, 5-3), Sabellides sp.A (Figure 5-9) was again the most abundant species, comprising 35.4% of the individuals collected. Its abundance increased from February (1102 individuals m^{-2}) to March (1517 individuals m^{-2}). It was present in excess of 1000 individuals m^{-2} at all stations along the east-west transect, but most abundant at the stations just east of the diffuser midpoint: DE (2532 individuals m^{-2}), M15 (2133 individuals m^{-2}), M18 (2217 individuals m^{-2}). The phoronid, Phoronis sp.A, (Figure 5-12) underwent a dramatic population increase from February (72 individuals m^{-2}) to March (1402 individuals m^{-2}). It was most abundant at stations M3 (4167 individuals m^{-2}), M11 (2500 individuals m^{-2}), M10A (2875 individuals m^{-2}) and DN (3167 individuals m^{-2}). Phoronis was ubiquitous within the study

Figure 5-11. Mean abundance of (a) *Balanus improvisus* and (b) *Mulinia lateralis* at marine stations. Number of individuals (m^{-2}) at each station is indicated by cumulative bars (solid=February, striped=March, stippled=April).

only at station M6 during March. Phoronis sp.A is a filter-feeding tube-dweller which constructs its tube from sand grains. Balanus improvisus was the third most numerically dominant species (356 individuals m^{-2}) collected in March. Most every specimen collected was attached to the valves of Mulinia lateralis. Both species were most abundant at stations M6, M9, and DW. (Figure 5-11).

In April (Tables 5-2, 5-3) two species numerically dominated the fauna: Phoronis sp.A (Figure 5-12) and Sabellides sp.A (Figure 5-9). These species were so abundant that no other species contributed over 2.7% of the benthic fauna. Phoronis densities nearly doubled from those of March, and the species was present at all 13 marine stations sampled. It was most abundant, as in March, at stations M3 (8250 individuals m^{-2}), M11 (6208 individuals m^{-2}), and DN (4925 individuals m^{-2}); however, Phoronis populations slightly decreased at station M10A. Sabellides sp.A populations increased slightly to 1653 individuals m^{-2} in April. It was found in densities in excess of 1100 individuals m^{-2} at all stations, and least abundant at station M1.

Temporal trends of the dominant marine species discussed above were compared with those collected in the same area by S.A.I. (1978) and Parker et al. (1980). Only individuals collected within 1 nautical mile (1.8 km) of the diffuser midpoint in the present study (stations M10A, M9, DE, DN, DS, DW) were used in this analysis (Figure 5-13). The mean values of these stations were compared with those of 17 stations sampled by S.A.I. (1978) than the present study during the

Figure 5-12. Mean abundance of *Phoronis* sp. A at marine stations. Number of individuals (m^{-2}) at each station is indicated by cumulative bars (solid=February, striped=March, stippled=April).

Figure 5-13. Mean abundance (individuals m^{-2}) and 95% confidence limits of numerically dominant species collected within 2 nautical mile (1.8 km) of diffuser midpoint.

winter (9051 individuals m^{-2}) and spring (3367 individuals m^{-2}). S.A.I. found scant populations of Mulinia lateralis in 1978. The species was absent in February and March collections, and increased to only 10 individuals m^{-2} by April.

Marine populations of Mediomastus californiensis increased during the present study. The population density was lowest in January (20 individuals m^{-2}) and increased steadily to a maximum in April (82 individuals m^{-2}). Parker et al. (1980) found abundant populations in January (327 individuals m^{-2}) and April (389 individuals m^{-2}). S.A.I. did not report collection of any specimens of Mediomastus.

Paraprionospio pinnata abundance was erratic from January (58 individuals m^{-2}) to April (79 individuals m^{-2}) in the present study with no consistent population trends. S.A.I. (1978) reported a population increase from February (70 individuals m^{-2}) to March (245 individuals m^{-2}), and a gradual decrease to May (135 individuals m^{-2}). Parker et al. (1980) found that the species generally decreased between January (162 individuals m^{-2}) and April (68 individuals m^{-2}).

A number of additional macrobenthic species were numerical dominants (i.e. > 4% of the fauna) in studies by S.A.I. (1978) and Parker et al. (1980), but were not present in sufficient numbers to be considered numerical dominants in this investigation. This is partially due to the overwhelming numbers of phoronids in the present study, which reduced the percentage composition of many other species.

Phoronids were not recorded in investigations conducted by S.A.I. or Parker et al. During February, March and April, S.A.I. collections included the following additional dominant species: Cossura delta (= our Cossura soyeri?), 10%; Lumbrineris tenuis, 6%; Ancistrosyllis papillosa (= our Ancistrosyllis jonesi?), 4%; Clymenella torquata, 4%. Parker et al. reported the same dominant species for January and April collections as in the present study, with the exception of Cirriformia sp. (= our Cirratulus filiformis?), 12%.

5.3.4.2 Estuarine

A total of 87 benthic species were identified from five estuarine sampling sites. Of these, seven species were selected for detailed analyses of numerical dominance (Figures 5-14, 5-15). Numerical domination by a particular species or species group varied both spatially and temporally during the study. Spatial trends are herein treated by collection date (i.e. month). Temporal trends are treated individually by species. Only species which composed 4% or more of the total individuals of a given collection have been included.

During February (Tables 5-4, 5-5), three polychaete species (Mediomastus californiensis, Paraprionospio pinnata, Polydora ligni) and two bivalve molluscs (Mulinia lateralis, Macoma mitchelli) numerically dominated the estuarine fauna. Mulinia lateralis (Figure 5-14) was the most abundant species (25.9%). It was fairly evenly distributed ($\bar{x}$ = 659 individuals m^{-2}) at stations E2, E4, and E5, but absent in E1. Salinities at station E1 during February were below those typically encountered in Mulinia lateralis' distribution range. Macoma mitchelli (Figure 5-15) was abundant at stations E1,

Figure 5-14. Mean abundance (individuals m^{-2}) and 95% confidence limits of dominant estuarine species in February, March, and April. (a) *Mediomastus californiensis* (b) *Phoronis* sp. A (c) *Balanus improvisus* (d) *Mulinia lateralis*. Asterisk indicates station not sampled.

Figure 5-15. Mean abundance (individuals m^{-2}) and 95% confidence limits of numerically dominant estuarine species in February, March, and April. (a) *Macoma mitchelli* (b) *Polydora ligni* (c) *Paraprionospio pinnata*. Asterisk indicates station not sampled.

Table 5-4. Abundance (individuals m⁻²) of numerically dominant species at estuarine stations.

Station								Station							
Month	E1	E2	E3	E4	E5	Mean	S.D.	Month	E1	E2	E3	E4	E5	Mean	S.D.
<u>Mulinia lateralis</u>								<u>Macoma mitchelli</u>							
February	0	1068	—	424	486	495	439	February	164	332	—	1380	0	469	622
March	0	1352	—	656	394	601	569	March	68	340	—	632	24	266	281
April	8	748	476	1408	6852	1898	2815	April	228	16	412	532	0	238	236
Mean	3	1056		829	2577			Mean	153	229		848	8		
<u>Mediomastus californiensis</u>								<u>Paraprionospio pinnata</u>							
February	24	268	—	1104	82	370	501	February	0	0	—	220	246	117	135
March	288	492	—	956	46	446	386	March	0	0	—	272	64	84	129
April	184	196	344	468	158	270	132	April	0	0	88	272	184	109	119
Mean	165	319		843	95			Mean	0	0		255	165		
<u>Polydora ligni</u>								<u>Phoronis sp.A</u>							
February	84	316	—	4	0	101	148	February	0	0	—	0	76	19	38
March	16	32	—	0	0	12	15	March	0	0	—	0	4500	1125	2250
April	0	12	0	0	0	2	5	April	0	0	4	0	2650	531	1185
Mean	33	120		1	0			Mean	0	0		0	2409		
<u>Balanus improvisus</u>															
February	0	320	—	8	0	82	159								
March	8	2288	—	36	10	586	1135								
April	0	916	16	4588	572	1218	1923								
	3	1161		1520	194										

Table 5-5. Numerically dominant estuarine species by mean abundance (individuals m^{-2}) and percentage of benthic community. (A = Amphipod, An = Anthozoan, B = Barnacle, M = Mollusk, P = Polychaete, Ph = Phoronid).

	February				March				April		
	$\bar{x}$	%	cum %		$\bar{x}$	%	cum %		$\bar{x}$	%	cum %
<u>Mulinia lateralis</u> (M)	495	25.9	25.9	<u>Phoronis</u> sp.A (Ph)	1125	44.4	44.4	<u>Mulinia lateralis</u> (M)	1898	44.8	44.8
<u>Macoma mitchelli</u> (M)	469	19.7	45.6	<u>Mulinia lateralis</u> (M)	601	13.8	58.2	<u>Balanus improvisus</u> (B)	1218	18.3	63.1
<u>Mediomastus</u>				<u>Balanus improvisus</u> (B)	586	11.6	69.8	<u>Phoronis</u> sp.A (Ph)	531	14.5	77.6
<u>californiensis</u> (P)	370	16.4	62.0	<u>Mediomastus</u>				<u>Mediomastus</u>			
<u>Paraprionospio pinnata</u> (P)	117	7.5	69.5	<u>californiensis</u> (P)	446	9.0	78.8	<u>californiensis</u> (P)	270	4.1	81.7
<u>Polydora ligni</u> (P)	101	4.3	73.8	<u>Macoma mitchelli</u> (M)	266	5.4	84.2	<u>Macoma mitchelli</u> (M)	238	3.3	85.0
<u>Balanus improvisus</u> (B)	82	3.5	77.3	<u>Loandalia fauveli</u> (P)	105	2.6	86.8	<u>Streblospio benedicti</u> (P)	196	2.7	87.7
<u>Loandalia fauveli</u> (P)	69	3.2	80.5	<u>Streblospio benedicti</u> (P)	122	2.4	89.2	<u>Paraprionospio pinnata</u> (P)	109	2.0	89.7
<u>Streblospio benedicti</u> (P)	68	3.0	83.5	<u>Paraprionospio pinnata</u> (P)	84	2.0	91.2	<u>Anthozoa</u> sp.B (An)	70	1.9	91.6
<u>Glycinde solitaria</u> (P)	55	2.7	86.2	<u>Glycinde solitaria</u> (P)	74	1.8	93.0	<u>Sabellides</u> sp.A (P)	45	1.2	92.8
<u>Corophium</u> sp.A (A)	47	2.5	88.7	<u>Anthozoa</u> sp.B (An)	22	0.9	93.9	<u>Glycinde solitaria</u> (P)	49	0.8	93.6

E2, and E4 ($\bar{x}$ = 625 individuals m^{-2}), but absent at station E5. Macoma mitchelli is a widespread inhabitant of low-salinity estuaries of Louisiana. Its exclusion from E5 may be due to its intolerance of the higher salinity habitats. It is an uncommon inhabitant of continental shelf or high-salinity estuarine communities of the Gulf coast. The three polychaete species (Mediomastus californiensis, Paraprionospio pinnata, and Polydora ligni) all commonly inhabit estuaries and inner shelf communities.

During March (Tables 5-4, 5-5), some of the same species of molluscs (Mulinia lateralis and Macoma mitchelli) and a polychaete (Mediomastus californiensis) were among the dominant species, but a phoronid (Phoronis sp.A) and a barnacle (Balanus improvisus) accounted for most of the individuals. As in February, Mulinia lateralis was abundant ($\bar{x}$ = 801 individuals m^{-2}) at all stations except E1. Macoma mitchelli occurred at all stations during March ($\bar{x}$ = 266 individuals m^{-2}); however, at station E5 it was only sparsely represented (24 individuals m^{-2}). It was most common at stations E2 and E4 ($\bar{x}$ = 486 individuals m^{-2}). Balanus improvisus (Figure 5-14) was present at all stations, but most abundant at E2 (2288 individuals m^{-2}). Most specimens of this species collected at estuarine sites were attached to the valves of Mulinia lateralis. The presence of Balanus improvisus, therefore was dependent on the occurrence of M. lateralis. The greatest population of M. lateralis collected in March was, not surprisingly also at station E2 (1352 individuals m^{-2}). The most abundant species collected in March

was Phoronis sp.A. It occurred, however, only at station E5 (4500 individuals m^{-2}). Phoronis sp.A is more typically a marine than an estuarine species.

The numerically-dominant species collected in April (Tables 5-4, 5-5) included only Mulinia lateralis, Balanus improvisus, Phoronis sp.A, and Mediomastus californiensis (Figure 5-14). Mulinia lateralis was found at all stations, but was most abundant at E5 (6852 individuals m^{-2}). Similarly, Balanus improvisus was more abundant at higher salinity stations, being most common at E4 (4588 individuals m^{-2}). Mediomastus californiensis was again abundant at all sites, but most abundant at E4 (468 individuals m^{-2}). Station E3 was occupied only during April in this study. The numerically dominant species were Mulinia lateralis (476 individuals m^{-2}), Macoma mitchelli (412 individuals m^{-2}), and Mediomastus californiensis (344 individuals m^{-2}). Balanus improvisus, which paralleled the distribution of Mulinia lateralis at other sites, was uncommon at E3 (16 individuals m^{-2}). This may be in part due to the presence of an extensive oyster population at E3, thus providing ample alternate substrate for attachment of cypris larvae.

Temporal trends of the dominant species were more difficult to discern than spatial trends due to the relatively short temporal scope of this project. The most salient variations in population occurred in Phoronis sp.A as described above. Polydora ligini population decreased at E1 and E2 from a mean of 200 individuals m^{-2} in February to 6 individuals m^{-2} in April (Figure 5-15). Numbers of Mulinia lateralis and Balanus improvisus increased dramatically at

stations E4 and E5 during March, then decreased in April. Populations of the other dominant species, Macoma mitchelli, Mediomastus californiensis and Paraprionospio pinnata, fluctuated during the sampling period (Table 5-5), but trends were limited to particular sampling sites (Table 5-4). At station E4 Macoma mitchelli populations decreased from February (1380 individuals m^{-2}) to April (532 individuals m^{-2}), Mediomastus californiensis decreased from 1104 to 468 individuals m^{-2} , and Paraprionospio pinnata remained at about 250 individuals m^{-2} throughout the sampling. At E1 Mediomastus californiensis increased to a maximum of 288 individuals m^{-2} in March then decreased. It had a similar pattern of population increase at E2, reaching 492 individuals m^{-2} in March.

5.3.5 Population Statistics

5.3.5.1 Marine

During pre-discharge sampling, 98,771 macrobenthic organisms were collected at the marine sites and identified to the species level. One hundred and thirty-five species were collected, including 54 species of polychaetes, 32 crustaceans, 25 molluscs, and 24 miscellaneous taxa.

Among the marine stations, the number of individuals m^{-2} (Appendix D-7) showed much variability, both spatially, due to the patchiness of macrobenthic organisms, and temporally, because of larval recruitment. Stations DS, M11, and particularly M3 consistently yielded more individuals with each sampling than the other marine sites (Figure 5-16). Stations M6, M9, DE, and M20

Figure 5-16. Mean values of (a) number of individuals (m^{-2}) and (b) number of species of all monthly collections at marine stations.

were regularly among those sites with the fewest individuals.

Between 32 and 63 species were obtained in each sampling at the marine sites (Appendix D-7), far greater than the 12-48 obtained at the estuarine stations (see below). Stations M10A, M1 and M11 were the most speciose, due in part to the greater percentage of sand which provided a greater diversity of micro-habitats at the latter two sites. Stations M9 and M20 had the fewest species averaging only 38 and 40 species, respectively, over the 3-month pre-discharge period.

Values for diversity, evenness, and richness for the marine stations are presented in Appendix D-7 and Figures 5-17, 5-18, and 5-19. The high number of species at M1 and M11 is clearly evident in the species richness values (Figure 5-19). These stations scored consistently higher than the other marine stations throughout the pre-discharge period. Many stations to the east and north of the diffuser (DE, M18, M20, M9) were among the least species rich. Values for evenness (Figure 5-18) and Shannon diversity (Figure 5-17) were closely correlated ($r = 0.973$) indicating that variations in diversity among the marine stations were due almost entirely to changes in the relative abundance of the species than to differences in the number of species inhabiting the sites. Stations DN and M3 were consistently lower than average among the marine stations in both diversity and evenness, while stations M6, DW, and M15 were usually among the highest. These trends were due largely to the relative abundance of Phoronis sp.A and Sabellides sp.A, which were abundant at those

Figure 5-17. Shannon diversity values for (a) February (b) March and (c) April at marine stations.

Figure 5-18. Evenness values for (a) February (b) March and (c) April at marine stations.

Figure 5-19. Species richness values for (a) February (b) March and (c) April at marine stations.

stations with low diversity and evenness, and less numerous at those stations with higher scores of these indices.

Temporally, the marine stations generally showed an increase in the number of individuals during the February to April sampling period (Appendix D-7) due to larval recruitment. This was consistent among all stations with the exception of M20, which had fewer individuals in April than when it was initially sampled in February. Sampling in the same region, during February to April of 1978, S.A.I. (1978) found either a decrease or little change, depending on station, in the number of benthic megafauna. Parker et al. (1980) found a clear decrease in numbers in the same region from January to April of 1979. Differences between these observations and the increase in individuals noted in the present study may be accounted for by differences in collection techniques (S.A.I. used a 1.0 mm sieve which would not retain newly-metamorphosed juveniles), or differences in species considered (Phoronis was either not collected or not recorded by S.A.I. and Parker et al.)

The number of species (Appendix D-7) and, to a lesser extent, species richness showed an increase during the sampling period. Station M20 again proved an exception, being the only station which had fewer species in April than in February.

Shannon diversity and evenness (Appendix D-7) showed a decrease at nearly all sampling sites during the sampling period. This was due to the increased dominance from February to April of only a few species (e.g. Phoronis sp A and Sabellides sp A). In some cases this

was dramatic, as at station M9, which had one of the highest values of evenness in February, but one of the lowest values in April.

5.3.5.2 Estuarine

During pre-discharge sampling from February to April, 1981, a total of 16,689 estuarine specimens were collected and identified to species level. Eighty-seven species were collected including 31 species of polychaetes, 24 crustaceans, 14 molluscs and 18 miscellaneous taxa.

The number of individuals m^{-2} showed a pronounced decrease in stations farthest up-estuary, paralleling the salinity gradient (Appendix D-8). Station E1, in the Intracostal Waterway above Calcasieu Lake, averaged only 777 individuals m^{-2} per monthly sampling, while station E5, at the mouth of the estuary, had an average of 6268 individuals m^{-2} per monthly sampling period. Stations E2, E3, and E4 generally followed this trend, being intermediate between E1 and E5, both geographically and on the basis of number of individuals.

The number of species at each station showed a trend similar to that of the number of individuals (Appendix D-8). Station E1 had the lowest number of species, with between 12 and 17 species depending on the sampling period. The number of species at stations E5 ranged from 35-48 during the February to April sampling period. It should be noted that the Smith-McIntyre grab used at E5 sampled an area twice that of the Ekman grab used at the other estuarine sites; a greater number of species might be expected on this basis alone.

Shannon diversity (Figure 5-20; Appendix D-8) showed no consistent pattern among the estuarine stations, due to the confounding of its components, species richness and evenness. Species richness (Figure 5-21; Appendix D-8) reaches its greatest value at station E5 where, because of the higher salinity, many marine species were able to survive. Station E1 has the lowest species richness in all months but February. A similar decrease in species richness in proceeding from the polyhaline to mesohaline region of an east coast estuary has been noted by Boesch (1972). Evenness (Figure 5-22; Appendix D-8) shows precisely the opposite trend to that of species richness; that is, evenness shows a general increase in stations up-estuary. This is in contradiction to the gradient usually found in estuaries in which evenness commonly decreases as salinity decreases. This discrepancy is most likely a local effect, and it is expected that evenness would decrease if sites in fresher water had been included in the sampling program. Station E1 consistently had the highest evenness during the 3-month sampling period, indicating the lack of dominance by any particular species or group of species. Evenness is lower at the other estuarine stations, particularly E5, because of the dominance of species such as Mulinia lateralis, Mediomastus californiensis, Balanus improvisus, and Phoronis sp.A.

Temporally, the number of individuals collected showed an increase throughout the pre-discharge period at some of the estuarine stations, though this trend was not consistent among all stations. The increase in number of individuals was particularly dramatic at station E5, owing to increases in Phoronis sp.A and Mulinia lateralis.

Figure 5-20. Shannon diversity values for (a) February (b) March and (c) April at estuarine stations.

Figure 5-21. Species richness values for (a) February (b) March and (c) April at estuarine stations.

Figure 5-22. Evenness values for (a) February (b) March and (c) April at estuarine stations.

At station E1, Streblospio benedicti and Macoma mitchelli were responsible for much of the increase.

The number of species showed a consistent decrease from February through April at all estuarine sites with the exception of station E5 which showed an increase during the same period. This increase parallels that observed in the marine sites, illustrating the greater comparability of E5 with the marine stations than with the other estuarine sites.

All indices (diversity, evenness, and richness) showed a pronounced decrease in March from a peak in February. April values were comparable to those found in March in most cases.

5.3.6 Multivariate analysis

5.3.6.1 Marine

Numerical classification (clustering) and reciprocal averaging ordination were used to delimit habitat types and their associate species among the marine stations. Because of the simplicity of presentation and interpretation, the results of cluster analyses are preferentially presented, but supplemented by ordination in cases where the latter technique provides additional information.

Interpretation of results from these multivariate techniques is made difficult by the general homogeneity of habitat among the marine stations. Without the influence of a dominant environmental gradient among the stations, linkages formed by the cluster analyses, or spatial separation in the ordinations, may reflect insignificant or chance differences among the stations. The high similarity among all stations is evident in the monthly cluster analyses in which all

linkages are formed at a similarity level of 0.59 or greater, and in the ordinations in which no axis accounts for more than 21% of the total variations.

Numerical classification of marine stations (Figure 5-23) is similar among all months, and interpretable largely on the basis of geographic distance and sediment differences. Stations are generally divisible into two major groups; those with 25 to 45% sand (M1, M3, M11, CS), and the remaining stations, all generally with less than 25% sand. As discussed above, (Section 5.3.5.1) faunal differences between these two groups are relatively small, resulting more from differences in the relative abundance of species than in species composition. Species such as Mediomastus californiensis, Magelona cf. pacifica, Cirratulus filiformis, Phoronis sp.A and Paraprionospio pinnata generally had their highest abundance at the sandier sites during the entire sampling period. Among the muddier stations, two sub-groups were formed, comprising those stations to the immediate south and to the east of the diffuser (DS, DE, M15, M18 and M20), and stations to the north and west in the vicinity of the diffuser (M10A, DN, DW, M6, M9). Station M6 did not join the cluster in the usual manner in March, due to the total absence of Phoronis sp.A at this site.

Clustering of all stations, treating each monthly collection at a station as a separate entity, is shown in Figure 5-24. Using this technique, tight clustering of all monthly collections at a particular station would be indicative of little temporal variability, whereas clustering on the basis of month rather than station would indicate

Figure 5-23. Numerical classification of marine stations. (a) February (b) March (c) April.
(Flexible sorting, $\beta = -0.25$).

Figure 5-24. Numerical classification of marine stations.
Station and month of collection indicated at right.
(Flexible sorting, $\beta = -0.25$).

strong seasonal influence. As Figure 5-24 illustrates, the latter situation is clearly evident, for with only one exception (DN during April), stations are grouped entirely on the basis of month. This is due to the strong seasonality in the populations of dominant species, which far overshadows any habitat differences among the marine stations. Collections made in March and April are more similar than those in February, for much of the population increase in dominant species occurs between the February and March sampling periods.

Ordination (Figure 5-25) shows the same strong seasonality as clustering, with each month clearly separated in ordination space. The general homogeneity among the stations with the exception of M1, M3, M11, and CS is evident as well. These stations generally scored higher on axis 3 than the other stations sampled during the same month.

Inverse clustering of species collected at the marine sites is presented in Figure 5-26 and Table 5-6, treating each monthly collection at a station as a separate occurrence. The four species groups determined by clustering are distinguishable on the basis of sediment type and abundance.

Species Group A is comprised of the dominant species which occur in large numbers at nearly all marine stations.

Species of Group B have a similar distribution to those of Group A, that is, they were found in nearly all collections, however their abundance is much lower. Though not usually among the numerical dominants, they ranked high in constancy and ubiquity.

Figure 5-25. Reciprocal averaging ordination on Axis 2 (6.5% of variation) and 3 (6.2% of variation) of all marine stations. Monthly collections presented as separate entities.

SIMILARITY

Figure 5-26. Inverse numerical classification of marine species. Species groups are indicated at right. Cluster hierarchy of individual species not shown. (Flexible sorting, $\beta = -0.25$)

Table 5-6. Marine species groups A-D formed by inverse clustering.

Species Group A

Nemertea sp.B
Oxyurostylis sp.A
Magelona cf. pacifica
Mediomastus californiensis
Paraprionospio pinnata
Mulinia lateralis
Balanus improvisus
Phoronis sp.A
Sabellides sp.A

Species Group B

Corophium sp.A
Notomastus latericeus
Anthozoa sp.B
Sigambra wassi
Spiochaetopterus oculatus
Callinectes similis
Cerebratulus lacteus
Nemertea sp.D
Glycera americana
Glycinde solitaria
Sthenolopis sp.A
Cirratulus filiformis
Cossura soyeri
Diopatra cuprea
Sigambra tentaculata
Pseudeurythoe paucibranchiata
Balanoglossus aurantiacus
Solen viridis
Nassarius acutus
Armandia maculata
Ancistrosyllis jonesi
Bhawania goodei

Species Group C

Aricidea cf. alisdairi
Nemertea sp.G
Callianassa latispina
Eulimastoma weberi
Phascolion strombi
Megalomma bioculatum
Polydora socialis
Macoma mitchelli
Nereis succinea
Limbrinerides sp.A
Myriowenia sp.A
Owenia fusiformis

Species Group D

Trachypenaeus similis
Pagurus pollicaris
Golfingia sp.A
Holothuroidea sp.A
Polinices duplicatus
Polycladia sp.B
Hemipholis elongata
Thalassoma sp.A
Nuculana concentrica
Solariorbis blakei
Prionospio cirrifer
Nemertea sp.F
Nereis micromma
Ampelisca abdita
Polycladia sp.A
Axiiothella sp.A
Parametopella sp.A
Phyllodoce arenae
Corophium sp.B
Lepidonotus sublevis
Limbrineris ernesti
Gyptis brevipalpa
Pinnixa pearsei
Paranthus rapiformis
Sthenelais boa
Aglaophamus verrilli
Pagurus longicarpus
Ogyrides alphaerostris
Anthozoa sp.A
Schistomeringos rudolphi
Anadara ovalis
Polydora ligni
Glycera capitata
Ampharete cf. acutifrons
Persephone crinata
Chione clenchi
Clymenella torquata
Ninoe nigripes

Group C is composed of species with their highest abundances and most frequent occurrences at those stations with the highest percentage of sand (stations M1, M3, M11, CS). However, they were not entirely excluded from the other stations, but were found sporadically throughout the study area. Group D is comprised of a large number of species with no consistent pattern of distribution among the stations. Because of the environmental homogeneity of the study area, these species are capable of living at all stations in near equal numbers. The only common trait among them is their low to intermediate abundance, never being numerically dominant.

5.3.6.2 Estuarine

Numerical classification was performed on the estuarine data set to group stations and species on the basis of species composition and abundance. Reciprocal averaging ordination was used to develop a spatial model of species distributions and distinguish individual species assemblages. These data are based on species abundance at each station, but are interpretable in light of the numerous physical and biological variables, e.g. salinity, sediment grain size distribution, species ecology, which govern species distribution. Combined data sets of all cruises were used for clarification in presentation of these patterns as they occurred over the 3-month study.

Cluster analyses were performed on estuarine data, treating each monthly collection at a station as a separate entity. A total of 13 entities were thus separated into four groups. The unique nature of the habitat characteristics of each station led to grouping of each

regularly-sampled station independently (Figure 5-27). Temporal changes at the stations were overwhelmed by the habitat heterogeneity among the stations causing separation of the entities entirely on the basis of station rather than month. Only station E3 showed close similarity to any other station, and it was produced within the E4 cluster. E3 was sampled only once. The restriction of certain site-specific fauna to station E1 and E5 account for their distinction from other collection areas. Benthic fauna of areas E2, E3, and E4 are relatively similar in composition, but population abundance variations within the stations distinguishes E2 from E3 and E4.

Inverse cluster analyses were performed on data sets for each cruise. These analyses placed 88 species into seven distinct groups. Two other groups, composed solely of rare species, were discarded. Most groups were common to all three cruise data sets, and were recognizable in a cluster analysis performed on the combined data of the three cruises (Figure 5-28, Table 5-7). The groups separated in accordance with species-habitat fidelity and faunal abundance of dominants.

Species Group A included numerically abundant species of station E5, the station at the mouth of Calcasieu Lake. The fauna closely resembles that of many marine collection sites in species composition, though not necessarily in relative abundance. The most numerically dominant species was Phoronis sp.A as it was for marine stations. None of the species of Group A were in abundance at any other estuarine sites.

Figure 5-27. Numerical classification of estuarine stations. Station and month indicated at left. (Flexible sorting, $\beta = -0.25$)

Figure 5-28. Inverse numerical classification of estuarine species. Species groups are indicated at right. Cluster hierarchy of individual species not shown. (Flexible sorting, $\beta = -0.25$)

Table 5-7. Estuarine species groups A-G formed by inverse clustering.

Species Group A

Pseudeurythoe paucibranchiata
Cossura soyeri
Sigambra tentaculata
Nemertea sp.D
Nemertea sp.B
Owenia fusiformis
Polydora socialis
Oxyurostylis sp.A
Paranthus rapiformis
Petricola pholadiformis
Spiophanes bombyx
Anthozoa sp.B
Sabellides sp.A
Phoronis sp.A

Species Group B

Macoma mitchelli
Mediomastus californiensis
Streblospio benedicti
Mulinia lateralis
Balanus improvisus
Loandalia fauveli
Glycinde solitaria
Paraprionospio pinnata

Species Group C

Hargeria rapax
Corophium simile
Solen viridis
Grandidierella bonnieroides

Species Group D

Edotea triloba
Eteone heteropoda
Nemertea sp.F
Nemertea sp.G
Polydora ligni
Cerebratulus lacteus
Sigambra bassi
Nereis succinea
Hobsonia florida
Corophium sp.A
Brachiodontes exustus
Tagelus plebius

Species Group E

Capitella capitata
Edwardsia sp.A
Nudibranchia sp.B
Odostomia cf. weberi
Macoma tenta
Callinectes sapidus
Gammarus mucronatus
Monoculodes sp.A

Species Group F

Abra aequalis
Cassidinidea ovalis
Polycladia sp.D
Doridella obscura
Cerapus benthophilus
Nemertea sp.C
Polycladia sp.C

Table 5-7. (continued)

Species Group G

Pinnixa pearsei
Thalassema sp.A
Cirratulus filiformis
Cyrtopleura costata
Nemertea sp.H
Spiochaetopterus oculatus
Nemertea sp.A
Eumida sanguinea
Sigambra wassi
Cistena regalis
Marphysa sanguinea
Glycera americana
Anadara transversa
Nassarius acutus
Gyptis brevipalpa
Penaeus aztecus
Callinectes similis
Polycladia sp.B
Melita nitida
Corophium sp.B
Polinices duplicatus
Dendronotus sp.A
Munna sp.A

Species in Group B were the most abundant ubiquitous estuarine species collected in this study. Several of the species (e.g. Balanus improvisus, Mediomastus californiensis, Paraprionospio pinnata) also were numerical dominants at marine collection stations. They occur abundantly in estuaries throughout the northern Gulf coast, and in many East Coast estuaries. They are tolerant of local variations in environmental conditions, and are adapted to varied estuarine conditions on a broad latitudinal scale.

Species Groups C and F include species collected in low abundance at stations E1 and E2, respectively. Group C species are most tolerant of mesohaline or up-estuary conditions. Such habitats typically support a relative paucity of species and individuals in the estuary due to physiological and reproductive limitations. Group F includes species restricted to station E2. None were collected in abundance during the 3-month sampling period.

Species Group D includes species which are ubiquitous to estuarine habitats, but present only in moderate abundances. Like Group B, most of these species inhabit estuaries throughout the northern Gulf.

Species group E includes species with greatest fidelity to station E4. Their presence at E4 is not indicative of a particular ecological habitat at that site, but simply a function of the limited estuarine sampling. This is evident in collections made since April when these species occurred at various other sites. None of these species occurred in abundance.

The species of Group G were, like Group A, present almost exclusively at station E5. These fauna occurred in low abundance and usually only during a single cruise. Group G species are more typical of inner shelf habitats, where they occur in low or moderate abundance. They inhabit the estuary when conditions permit.

Reciprocal averaging ordination performed on the data provides a spatial distribution of station and species groups along a community continuum. The results of this procedure, which in this case treated each monthly collection at a site as a separate entity, is shown in Figure 5-29. Axis 1, which accounts for 30% of the variation, is clearly correlated with salinity, with low salinity sites (E1) scoring low on this axis and high salinity sites (E5) scoring high. The species groups created by the numerical classification (Table 5-7) are plotted in ordination space as the centroids of the scores of the individual species comprising the groups. Species groups composed of ubiquitous species (i.e. Groups B and D) are located in the center of the station distribution, while those groups containing species unique to particular sites (e.g. Groups C and G) are superimposed over that particular station.

5.4 Discussion

5.4.1 Marine

Previous investigations in the study area by S.A.I. (1978) and Parker et al. (1980), performed under the auspices of the Strategic Petroleum Reserve Program, have been heavily relied upon in this report to provide a larger data base than that available in this study alone. Though the present baseline study encompasses a necessarily

Figure 5-29. Reciprocal averaging ordination on Axis 1 (30% of variation) and 2 (15% of variation) of all estuarine stations. Monthly collections presented as separate entities. Species groups (A-G) are plotted as centroids of scores of the individual species of each group.

brief time period (3 month use of these earlier studies provides information on the predictability of macrobenthic species composition abundances from one year to the next, and consequently permits identification of brine-induced perturbations to be made with a greater degree of confidence. Limitations on the usage of the previous studies is discussed below.

The dominant species collected in the West Hackberry diffuser site are remarkably consistent among the present study and those of S.A.I. and Parker et al., with a few notable exceptions. Phoronis sp.A, which occurred in our samples in densities sometimes exceeding 8000 m^{-2} , was not reported by either S.A.I. or Parker et al. It is difficult to comprehend how a species as conspicuous as Phoronis sp.A could have been overlooked in previous studies, or go from complete absence in one year to the most numerically dominant species in the next. Mediomastus californiensis was similarly absent in the S.A.I. data, however, this may be attributable to its small size and the S.A.I. methodological techniques. The present study and Parker et al. rinsed samples through a 0.5 mm sieve and identified all taxa retained on the sieve to species level. S.A.I. identified benthic organisms retained on a 1.0 mm sieve to the species level, but those which passed through the 1.0 mm screen and were retained on a 0.063 mm screen were identified only to major taxon (usually phylum). Taxonomic difficulties also undoubtedly account for some inconsistencies among the three West Hackberry S.P.R. studies. For instance, Cossura delta and Ancistrosyllis papillosa of S.A.I. and Parker et al. are probably the same as Cossura soyeri and Ancistrosyllis jonesi of the present

study. Identifications among these studies must be standardized using reference collection material before the data are entirely comparable.

Abundance of macrobenthic organisms in the marine study area ranged from a low of 624 individuals m^{-2} at M11 in January to 10,478 individuals m^{-2} at M3 in April. The mean abundance for all sites over all months was 3307 individuals m^{-2} . The values are comparable to those of Parker et al. (1980) who reported 1133-11,200 individuals m^{-2} at the same site in late 1978 and early 1979. S.A.I. (1978) found far fewer individuals, reporting only 232-1128 individuals m^{-2} . This difference is partially due to the larger mesh size employed by S.A.I., as it has been estimated that a 1.0 mm sieve retains only 57% of the fauna retained by a 0.5 mm sieve (Swartz, 1978). However, even if this correction value is applied to the S.A.I. data, total macrobenthic abundance is still only one-fifth of that reported in the present study.

In number of macrobenthic taxa collected, this study exceeds both S.A.I. and Parker et al. At the marine site, 135 species were collected, while S.A.I. and Parker et al. reported 128 and 89, respectively. This difference is especially significant when one considers that the other studies sampled for a full year during which one could expect seasonal recruitment or immigration of additional species that were not collected in the present study.

The marine macrobenthic community is characterized by high numbers of a relatively few dominant species. For example, Sabellides

sp.A and Phoronis sp.A comprised 46-79% of the total number of benthic organisms collected during each of the three months of the study. Many of the most numerically dominant species such as Mulinia lateralis, Paraprionospio pinnata, Mediomastus californiensis and probably Sabellides sp.A are highly opportunistic species characteristic of physically variable environments such as estuaries. In fact, their dominance at the marine site is indicative of the predominantly estuarine character of the area. In many regards the marine fauna may be considered an extension of the Gulf Coast estuarine community, especially in light of the similarity of species collected at the marine area to those of station E5, and in many instances, even station E4. The estuarine character of this continental shelf community is maintained by factors such as the high turbidity and low salinity associated with the outflow of Louisiana Rivers, seasonal variations in temperature, and severe perturbations caused by periodic storms and seasonal, hypoxic conditions.

The opportunistic species which dominate the marine community are capable of unpredictable and dramatic population fluctuations induced by environmental conditions during recruitment or in response to any number of physical or biological stimuli. For example, Mulinia lateralis was by far the most abundant species collected by Parker et al. in January of 1979, comprising 79% of the total benthic population and occurring at an average density of greater than 8800 individuals m^{-2} . In April it was still the most dominant species, though its density had decreased to about 3200 individuals m^{-2} . In contrast,

its density in the present study was about two orders of magnitude less, varying from 178 individuals m^{-2} in February to 28 individuals m^{-2} in April.

If temporal changes in abundance of any species can be used in evaluation of impact, it will be of species less numerically dominant, but seasonally persistent, or at least with predictable population fluctuations (K-strategists sensu MacArthur and Wilson, 1967). The irruptive, unpredictable nature of population changes of most of the dominant species in the diffuser area will probably hinder impact assessment made on the basis of temporal evidence alone. Comparison of impacted vs. non-impacted sites sampled during the same time frame may be more valuable in evaluation of the environmental impact of brine disposal than pre-discharge vs. discharge temporal comparisons at any given site, especially if the results are dramatic.

The high similarity at which the marine stations cluster in the numerical classification, their clustering on the basis of month rather than site, and the commonality of species composition at all marine sites are all indicative of a highly homogeneous environment. Some faunal differences were observed at the sandier sites (M1, M3, M11, CS), but these variations were in species abundance rather than composition. Similarity of the fauna throughout the study area should greatly enhance the capacity for impact assessment following brine discharge since a homogeneous environment eliminates the difficulties associated with habitat comparability. Faunal population variations occurring in the area of the diffuser and not elsewhere following

initiation of brine discharge may be attributable to the effects of the discharge itself rather than any existing habitat differences.

In the fine sediment environment off Cameron, it is significant to note that the dominant species were predominately tubicolous. These include Sabellides sp.A, Phoronis sp.A, Paraprionospio pinnata, and Diopatra cuprea. Recent investigations of the relationship between tube-dwelling benthos and geochemical processes (Aller, 1978, 1980; Aller and Yingst, 1978) provide additional insight into the importance of these species. This is particularly important in the soft muds of the study area in which oxygen penetration is minimal. Irrigation of tubes by benthic organisms provides an avenue for transport of oxygen below the sediment surface allowing subsequent colonization by non-tubicolous species. Irrigation of burrows may also provide a transport mechanism for solutes in the brine which may be concentrated in the sediments above the levels in the brine itself, though this increase should be detectable in the sediment quality analyses (see Chapter 4).

5.4.2 Estuarine

The fauna of Calcasieu Lake was found to be generally similar to that of other northern Gulf of Mexico estuaries (personal observation). The fauna was numerically dominated by polychaetes and molluscs such as Paraprionospio pinnata, Mediomastus californiensis, Streblospio benedicti, Mulinia lateralis, and Macoma mitchelli, which are common in estuaries throughout the northern Gulf of Mexico and United States East Coast. Populations of these species varied moderately both spatially and temporally. Moderate fluctuations in

populations of opportunistic species such as these are not generally considered indicative of pollution impact; however, radical irruptions of some opportunists (e.g. Capitella capitata, Mediomastus ambiseta) have been attributed to poor environmental quality (see Sanders et al., 1980).

Most of the numerical dominants were ubiquitous throughout the estuary, and may be considered euryhaline. Not only does the distribution of each species encompass a broad salinity range, but salinity changes with time are dramatic in Calcasieu Lake as in other Louisiana estuaries (Barrett et al., 1978). Denoux (1976) reported a change in bottom salinity from 2 ‰ to 14 ‰ over a twenty month period at a site near our station E2. Station E1 showed a change of bottom salinity from 7.2 ‰ to 16.5 ‰ over the three month predischage sampling period.

As might be expected, separation of stations and species groups illustrated by the multivariate analyses can be interpreted largely on the basis of salinity differences. In some cases, fidelity of a species to a particular site may be due entirely to chance, and probably merely reflective of inadequate sampling (e.g. Spiophanes bombyx at station E5), particularly if the species is rare at that site. However, in many cases, fidelity of species to particular sites was the result of the physical environment (e.g. salinity) at that site.

5.5 Conclusions

5.5.1 Marine

1. Sediment type in the study area ranged from silty clay to sandy mud, never with more than 48% sand. The percentage of sand was lowest at the diffuser and immediately to the north, and increased 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, were the numerically dominant species throughout the study area.

4. The fauna of the diffuser area was 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 due to severe perturbations caused by periodic storms and seasonal hypoxic conditions.

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

6. Some habitat differences based on the percentage of sand in the sediments were revealed by the multivariate analyses between those

stations near the diffuser and the perimeter stations (M1, M3, M11, and CS). These faunal differences were 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.

5.5.2 Estuarine

1. Sediments at the estuarine stations were generally clayey silts and sandy silts, though there was considerable spatial and temporal variation in and among sites.

2. Estuarine fauna was 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, represented distinct habitat types separable primarily on the basis of salinity.

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

CHAPTER 6

NEKTON

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6.1 Introduction

To describe the nekton community of both marine and estuarine waters in southwest Louisiana, data were compiled from a three month pre-brine discharge sampling program from February through April 1981. Baseline information was established from which post-brine discharge comparisons could be drawn.

Specific parameters investigated include distribution, abundance, size composition and diversity at both species and community levels. Detailed study was directed towards fish and macrocrustacean species which support commercial and recreational fisheries.

6.1.1 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, Hann and Randall, 1981.)

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). In this study sand was 3.1-41.5% of bottom surficial sediments. (See Figure 5-7). Depths range between 4.0 and 11.0 m.

6.1.2 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.

mong those species that spawn in the Gulf yet use the estuary as a nursery are: the white shrimp, Penaeus setiferus (Lincoln 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 (Weaver and Perret, 1979); 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 (Weaver and Perret, 1979). 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 ‰ to 30.1 ‰ with an average of 14.0 ‰.

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). At specific locations within the estuarine environment, species composition is likely to be determined by the existing salinity regime (Rounsefell, 1975).

6.2 Methods and Materials

6.2.1 Field Procedures

6.2.1.1 Marine

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

Stations sampled in February 1981 included M1, M3, M6, M9, M10, M11, M15, M18, M20, DE, and DW (Figure 6.0). Inshore and offshore (with respect to the diffuser site) control stations, M21 and M22 respectively, were added to the March and April sampling programs. Station locations and depths are presented in Table 1-1.

Before sampling at each station, depth, conductivity, temperature, pH and dissolved oxygen were measured at surface, bottom and mid-water depths with a Hydrolab Series 8000 meter. These readings were recorded on field data sheets along with other parameters (time, date, cruise and station number, depth, wind direction and speed, weather, cloud cover and sea state).

Collections were made using a single 15.2 m commercial otter trawl 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.

LEGEND

○ = BIOTA SAMPLING STATIONS

Figure 6-0. Marine sampling stations.

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 kts). Two replicate tows, in opposite directions, were made at all stations with a bottom time duration of ten minutes each. 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 or B 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 (< 50 g) the total weight was determined as accurately as possible in the field. An aliquot was retained and an average weight determined in the laboratory. The total number of individuals was then calculated. Larger fish were weighted as a group and counted. A minimum of 50 individuals of each species from each trawl within the family Sciaenidae and the genus Brevoortia were retained for more detailed laboratory analyses.

6.2.1.2 Estuarine

Nekton samples were collected monthly during the pre-brine discharge period--February 1981 through April 1981. These collections were made aboard a 6.8 m flat bottom aluminum outboard motor boat.

Estuarine stations sampled included E1, E2, E3, E4, and E5. Due to low water levels, station E3 was inaccessible during February and March. Station E5 was dropped after April sampling due to abundant bottom obstructions and resultant net damage.

A CTD/DO profile was made at each station prior to sampling. Measurements were made at the surface, bottom, and at midwater for the deepwater stations (E1 and E5) and at the surface and bottom for the other, shallow water, stations. Nekton samples were taken with a 4.9 m commercial otter trawl (equipped with a tickler chain during March and April) 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 E5 (Calcasieu Pass) and in a circular pattern at E2, E3 and E4 at a speed of 3.7 to 5.6 km hr⁻¹ (2-3 kts). 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.

6.2.2 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. References for fish identification were Parker (1972), Walls (1975), Hoese and Moore (1977), and the U.S. Fish and Wildlife (1978). For scientific nomenclature, Bailey et al. (1970) was used with a few exceptions. Invertebrates were identified using the following taxonomic keys: Williams (1965) for all decapod crustaceans, Felder (1973) for crabs and Wood (1974) for shrimp. 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 (S.L.) for fish was measured from the tip of the snout to the end of the hypural plate; total length (T.L.) 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 5 grams.

Representative specimens were fixed in 10% buffered formalin, then transferred to 75% ethanol and labeled for permanent retention as a reference collection.

6.2.3 Data Analysis

Data were analyzed on an individual specimen basis and on a weight basis. The following analyses were performed to aid in characterizing the sampling area:

1. Cluster analysis (Bray-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 -0.025 was performed on all pre-discharge data. The similarity measure may 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.

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.)

$$S.R. = \frac{s-1}{\ln N}$$

evenness (J)

$$J = \frac{H'}{\log_2 s}$$

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)

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

i

$\pi_i = N_i/N$, and

s = Number of species in the community

6.3 Results

6.3.1 Marine

A total of 46,054 organisms representing 69 species was collected during pre-brine discharge sampling. Table 6-1 lists the total number of individuals and total weights for each species collected. Nineteen species comprised 95% of the total number of organisms collected.

Table 6-1. 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.

<u>Name</u>	<u>Count</u>	<u>Weight</u>
<u>Peprilus burti</u>	12428	173929
<u>Cynoscion nothus</u>	8352	49478
<u>Trachypenaeus similis</u>	3429	8137
<u>Lolliguncula brevis</u>	3270	35226
<u>Squilla empusa</u>	3206	24421
<u>Trichiurus lepturus</u>	2412	58656
<u>Micropogonias undulatus</u>	1683	18097
<u>Callinectes similis</u>	1427	5427
<u>Urophycis floridanus</u>	1357	29097
<u>Penaeus setiferus</u>	1119	24852
<u>Cynoscion arenarius</u>	1100	26156
<u>Arius felis</u>	632	100871
<u>Chloroscombrus chrysurus</u>	602	33305
<u>Stellifer lanceolatus</u>	597	5921
<u>Menticirrhus americanus</u>	594	49592
<u>Prionotus tribulus</u>	584	2588
<u>Anchoa hepsetus</u>	523	9302
<u>Cynoscion</u>	377	10727
<u>Larimus fasciatus</u>	295	1502
<u>Portunus gibbesii</u>	256	796
<u>Leiostomus xanthurus</u>	253	12879
<u>Citharichthys spilopterus</u>	245	2892
<u>Etropus crossotus</u>	189	1501
<u>Anchoa mitchilli</u>	151	404
<u>Harengula pensacolatae</u>	135	4464
<u>Symphurus civitatus</u>	114	1841
<u>Symphurus plagiusa</u>	107	1977
<u>Prionotus rubio</u>	80	888
<u>Brevoortia patronus</u>	70	1142
<u>Orthopristis chrysoptera</u>	67	3350
<u>Penaeus aztecus aztecus</u>	53	456
<u>Synodus foetens</u>	35	1197
<u>Chaetodipterus faber</u>	33	211
<u>Sphoeroides parvus</u>	29	268
<u>Symphurus</u>	26	377
<u>Peprilus paru</u>	21	604
<u>Menticirrhus littoralis</u>	20	1200
<u>Vomer setapinnis</u>	18	1005
<u>Ovalipes floridanus</u>	17	19
<u>Sicyonia dorsalis</u>	16	25
<u>Callinectes sapidus</u>	14	1216
<u>Pogonias cromis</u>	14	63087
<u>Opisthonema oglinum</u>	12	1155
<u>Synganthus louisianae</u>	11	13
<u>Dorosoma petenense</u>	11	259
<u>Loligo plei</u>	10	130
<u>Paralichthys lethostigma</u>	8	2219
<u>Sardinella anchovia</u>	6	508

Table 6-1. (cont'd). Total abundance of all species caught during the study at marine stations. Species are listed in order of abundance by numbers of individuals. Total species weights, in grams, are also included.

<u>Name</u>	<u>Count</u>	<u>Weight</u>
<u>Gobiesox strumosus</u>	6	39
<u>Bairdiella chrysoura</u>	4	206
<u>Penaeus duorarum duorarum</u>	4	37
<u>Chilomycterus schoepfi</u>	4	748
<u>Syngnathus fuscus</u>	3	4
<u>Trinectes maculatus</u>	2	41
<u>Archosargus probatocephalus</u>	2	277
<u>Myrophis punctatus</u>	2	5
<u>Sicyonia brevirostris</u>	2	5
<u>Dasyatis americana</u>	2	1450
<u>Rhizoprionodon terraenovae</u>	2	3632
<u>Sphyraena gauchancho</u>	2	266
<u>Arenaeus cribrarius</u>	1	1
<u>Ancyclopsetta quadrocellata</u>	1	3
<u>Monacanthus hispidus</u>	1	3
<u>Ophichthus gomesi</u>	1	48
<u>Sciaenops ocellata</u>	1	5900
<u>Sphyrna tiburo</u>	1	1816
<u>Scomberomorus maculatus</u>	1	290
<u>Trachinotus carolinus</u>	1	568
<u>Xiphopenaeus kroyeri</u>	1	12
Number of species caught 69	Total count 46054	Total weight 788718

Tables 6-2 through 6-4 list the ten dominant marine species by both weight and total number for each of the three sampling months.

Trawls, identified by station and A or B replicates were clustered by species composition. Species composition was determined by numerical and weight totals of each species in each trawl. Clusters were determined both including and excluding rare species. Those species that were excluded were found in two trawls or less out of the 22 (February) or 26 (March and April) marine trawls taken each month. The clusters were essentially the same in all cases. Representative clusters are shown in Figures 6-1 through 6-3.

Species were also clustered by trawl occurrence using the same parameters. The results are shown in Figures 6-4 through 6-6. Species are represented by a numerical designation according to the list of all species collected given in Table 6-5.

The Shannon-Weaver species diversity index (H') was determined for each trawl. In addition, species richness (S.R.), evenness and the probability of interspecific encounters were determined. Results are presented in Tables 6-6 through 6-8.

The abundance of each species by percentage occurrence at each station was determined. Occurrence was examined in two ways. The two methods of representing abundance were: 1) percentage of each species in the trawl, and 2) percentage of each species collected at each station. For both methods the basis of occurrence was weight rather than number of individuals and the two replicate trawls were averaged. The results of these analyses are reported in Tables 6-9 through 6-14.

Table 6-2. Most abundant species collected during February at marine stations.

Ten most abundant species by weight in grams

<u>Species</u>	<u>Total Weight</u>
<u>Penaeus setiferus</u>	10810
<u>Squilla empusa</u>	10588
<u>Cynoscion arenarius</u>	10519
<u>Menticirrhus americanus</u>	6473
<u>Leiostomus xanthurus</u>	2832
<u>Cynoscion nothus</u>	2347
<u>Trachypenaeus similis</u>	2173
<u>Lolliguncula brevis</u>	1868
<u>Stellifer lanceolatus</u>	1779
<u>Symphurus plagiusa</u>	1421

Ten most abundant species by number of individuals

<u>Species</u>	<u>Total Number</u>
<u>Squilla empusa</u>	1217
<u>Trachypenaeus similis</u>	979
<u>Penaeus setiferus</u>	693
<u>Cynoscion arenarius</u>	693
<u>Cynoscion nothus</u>	527
<u>Lolliguncula brevis</u>	286
<u>Prionotus tribulus</u>	169
<u>Portunus gibbesii</u>	164
<u>Stellifer lanceolatus</u>	123
<u>Menticirrhus americanus</u>	90

Table 6-3. Most abundant species collected during March at marine stations.

Ten most abundant species by weight in grams

<u>Species</u>	<u>Total Weight</u>
<u>Pogonias cromis</u>	63087
<u>Arius felis</u>	24624
<u>Cynoscion nothus</u>	24405
<u>Menticirrhus americanus</u>	20983
<u>Urophycis floridanus</u>	9374
<u>Squilla empusa</u>	7604
<u>Cynoscion arenarius</u>	7072
<u>Lolliguncula brevis</u>	6045
<u>Sciaenops ocellata</u>	5900
<u>Leiostomus xanthurus</u>	5353

Ten most abundant species by number of individuals

<u>Species</u>	<u>Total Number</u>
<u>Cynoscion nothus</u>	5784
<u>Trachypenaeus similis</u>	2021
<u>Squilla empusa</u>	1261
<u>Lolliguncula brevis</u>	719
<u>Urophycis floridanus</u>	670
<u>Cynoscion arenarius</u>	307
<u>Menticirrhus americanus</u>	287
<u>Prionotus tribulus</u>	258
<u>Arius felis</u>	172
<u>Penaeus setiferus</u>	153

Table 6-4. Most abundant species collected during April at marine stations.

Ten most abundant species by weight in grams

<u>Species</u>	<u>Total Weight</u>
<u>Peprilus burti</u>	172685
<u>Arius felis</u>	76177
<u>Trichiurus lepturus</u>	56736
<u>Chloroscombrus chrysurus</u>	33305
<u>Cynoscion nothus</u>	28445
<u>Lolliguncula brevis</u>	27313
<u>Menticirrhus americanus</u>	22136
<u>Urophycis floridanus</u>	18829
<u>Micropogonias undulatus</u>	15508
<u>Cynoscion arenarius</u>	13555

Ten most abundant species by number of individuals

<u>Species</u>	<u>Total Number</u>
<u>Peprilus burti</u>	12257
<u>Cynoscion nothus</u>	2360
<u>Lolliguncula brevis</u>	2265
<u>Trichiurus lepturus</u>	2251
<u>Micropogonias undulatus</u>	1521
<u>Callinectes similis</u>	1251
<u>Squilla empusa</u>	728
<u>Chloroscombrus chrysurus</u>	602
<u>Urophycis floridanus</u>	601
<u>Anchoa hepsetus</u>	523

Figure 6-1 Cluster analysis of February marine stations. The A or B station suffixes represent replicate trawls. Stations were clustered on the basis of species weight (See text).

BRAY-CURTIS SIMILARITY

Figure 6-2 Cluster analysis of March marine stations. The A or B station suffixes represent replicate trawls. Stations were clustered on the basis of species weight (See text).

Figure 6-3. Cluster analysis of April marine stations. The A or B station suffixes represent replicate trawls. Stations were clustered on the basis of species weight (See text).

Figure 6-4 Cluster analysis of February marine species. The numerical designation of species follows those in Table 6-5. Species were clustered on the basis of the number of individuals collected at each station (See text).

Figure 6-5 Cluster analysis of March marine species. The numerical designation of species follows those in Table 6-5. Species were clustered on the basis of the number of individuals collected at each station (See text).

Figure 6-6 Cluster analysis of April marine species. The numerical designation of species follows those in Table 6-5. Species were clustered on the basis of the number of individuals collected at each station (See text).

Table 6-5. List of all nekton species collected during study.

1. <u>Cynoscion nebulosus</u>	26. <u>Menticirrhus littoralis</u>
2. <u>Trinectes maculatus</u>	27. <u>Menticirrhus americanus</u>
3. <u>Anchoa mitchilli</u>	28. <u>Larimus fasciatus</u>
4. <u>Gobiosoma bosci</u>	29. <u>Cynoscion arenarius</u>
5. <u>Ictalurus melas</u>	30. <u>Cynoscion nothus</u>
6. <u>Callinectes sapidus</u>	31. <u>Stellifer lanceolatus</u>
7. <u>Micropogonias undulatus</u>	32. <u>Etropus crossotus</u>
8. <u>Symphurus plagiosa</u>	33. <u>Citharichthys spilopterus</u>
9. <u>Brevoortia patronus</u>	34. <u>Trichiurus lepturus</u>
10. <u>Paralichthys lethostigma</u>	35. <u>Peprilus paru</u>
11. <u>Macrobrachium</u>	36. <u>Peprilus burti</u>
12. <u>Dorosoma petenense</u>	37. <u>Syngnathus louisianae</u>
13. <u>Brevoortia</u>	38. <u>Squilla empusa</u>
14. <u>Lucania parva</u>	39. <u>Trachypenaeus similis</u>
15. <u>Prionotus tribulus</u>	40. <u>Sicyonia dorsalis</u>
16. <u>Macrobrachium ohione</u>	41. <u>Portunus gibbesii</u>
17. <u>Cyprinodon variegatus</u>	42. <u>Penaeus setiferus</u>
18. <u>Pogonias cromis</u>	43. <u>Arius felis</u>
19. <u>Clupeidae</u>	44. <u>Symphurus civitatus</u>
20. <u>Bairdiella chrysoura</u>	45. <u>Symphurus</u>
21. <u>Leiostomus xanthurus</u>	46. <u>Penaeus aztecus aztecus</u>
22. <u>Gobiesox strumosus</u>	47. <u>Syngnathus fuscus</u>
23. <u>Urophycis floridanus</u>	48. <u>Prionotus rubio</u>
24. <u>Lolliguncula brevis</u>	49. <u>Sphoeroides parvus</u>
25. <u>Callinectes similis</u>	50. <u>Ovalipes floridanus</u>

Table 6-5 (cont'd) List of all nekton species collected during study.

51. <u>Arenaeus cribrarius</u>	76. <u>Rhizoprionodon terraenovae</u>
52. <u>Ancyclopsetta quadrocellata</u>	77. <u>Sphyraena guachancho</u>
53. <u>Monacanthus hispidus</u>	78. <u>Loligo plei</u>
54. <u>Archosargus probatocephalus</u>	79. <u>Trachinotus carolinus</u>
55. <u>Myrophis punctatus</u>	80. <u>Xiphopenaeus kroyeri</u>
56. <u>Ophidion welshi</u>	
57. <u>Palaemonetes vulgaris</u>	
58. <u>Penaeus duorarum duorarum</u>	
59. <u>Chaetodipterus faber</u>	
60. <u>Sicyonia brevirostris</u>	
61. <u>Chilomycterus schoepfi</u>	
62. <u>Ophichthus gomesi</u>	
63. <u>Synodus foetens</u>	
64. <u>Sciaenops ocellata</u>	
65. <u>Sardinella anchovia</u>	
66. <u>Opisthonema oglinum</u>	
67. <u>Harengula pensacolae</u>	
68. <u>Orthopristis chrysoptera</u>	
69. <u>Chloroscombrus chrysurus</u>	
70. <u>Anchoa hepsetus</u>	
71. <u>Vomer setapinnis</u>	
72. <u>Sphyrna tiburo</u>	
73. <u>Dasyatis americana</u>	
74. <u>Cynoscion</u>	
75. <u>Scomberomorus maculatus</u>	

Table 6-6. 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. The A or B suffixes to station names indicate replicate trawls.

<u>Station name</u>	<u>Number species</u>	<u>Total IND</u>	<u>Diversity H'</u>	<u>Richness S R</u>	<u>Evenness PIELOU</u>	<u>P I E DELTA</u>
M1A	24	2616	3.23923	2.92271	0.70649	0.84808
B	24	3186	3.26906	2.85129	0.71300	0.85853
M3A	18	1312	3.34555	2.36792	0.80230	0.86602
B	17	1554	3.15796	2.17729	0.77260	0.86227
M6A	26	3467	3.30820	3.06709	0.70381	0.85264
B	19	2398	3.06916	2.31291	0.72251	0.83789
M9A	27	3219	3.05595	3.21909	0.64270	0.81035
B	25	2296	2.82964	3.10121	0.60933	0.79910
M10A	25	4333	3.38837	2.86601	0.72965	0.86632
B	21	7093	2.77770	2.25559	0.63240	0.79629
M11A	21	2231	3.43946	2.59396	0.78306	0.86832
B	21	1510	3.17035	2.73229	0.72179	0.82788
M15A	16	812	2.82390	2.23897	0.70597	0.79063
B	22	1448	3.67552	2.88543	0.82421	0.89365
M18A	19	1042	2.83416	2.59034	0.66719	0.77065
B	24	1923	3.42163	3.04167	0.74627	0.86244
M20A	21	3432	2.45916	2.45673	0.55988	0.71624
B	24	3751	2.91776	2.79473	0.63638	0.77808
DEA	24	3540	3.85519	2.81453	0.84083	0.90921
B	27	3815	3.42449	3.15278	0.72021	0.85210
DWA	24	2757	3.48509	2.90334	0.76011	0.87942
B	24	2560	3.39183	2.93077	0.73977	0.86735

Table 6-7. Species diversity indices for the March marine sampling. Indices are referenced in text. Also included are number of individuals collected at each station. The A or B suffixes to station names indicate replicate trawls.

<u>Station name</u>	<u>Number species</u>	<u>Total IND</u>	<u>Diversity H'</u>	<u>Richness S R</u>	<u>Evenness P I E</u>	<u>PIELOU DELTA</u>
M1A	23	3337	3.55294	2.71175	0.78543	0.89294
B	22	2437	3.48818	2.69282	0.78220	0.87398
M3A	21	6543	3.19676	2.27631	0.72781	0.83839
B	22	4639	3.07057	2.48749	0.68856	0.83752
M6A	22	47724	1.02508	1.94928	0.22987	0.25581
B	22	5098	3.19830	2.45999	0.71720	0.85750
M9A	23	10328	2.60365	2.38028	0.57557	0.69834
B	21	10915	2.42285	2.15102	0.55161	0.66891
M10A	20	3794	3.51157	2.30550	0.81250	0.88225
B	23	5192	3.12766	2.57163	0.69141	0.82287
M11A	22	4311	3.20492	2.50928	0.71868	0.84761
B	20	3960	3.25045	2.29358	0.75208	0.85424
M15A	22	4553	2.87119	2.49301	0.64385	0.79696
B	20	3234	2.82722	2.35106	0.65416	0.77309
M18A	21	4738	3.07344	2.36312	0.69973	0.81674
B	25	14724	1.73801	2.50072	0.37426	0.46726
M20A	24	3491	3.34117	2.81934	0.72872	0.85500
B	24	3588	3.32101	2.80990	0.72433	0.84692
DEA	23	4601	3.36954	2.60848	0.74489	0.85996
B	23	4109	3.45983	2.64393	0.76485	0.84694
DWA	24	4212	3.32467	2.75591	0.72513	0.85939
B	20	4350	3.08115	2.26786	0.71291	0.81433

Table 6-7 (cont'd). 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 numbers of species collected at each station. The A or B suffixes to station names indicate replicate trawls.

<u>Station name</u>	<u>Number Species</u>	<u>Total IND</u>	<u>Diversity H'</u>	<u>Richness S R</u>	<u>Evenness PIELOU</u>	<u>P I E DELTA</u>
M21A	22	4086	3.25321	2.52546	0.72951	0.85376
B	26	3409	3.65453	3.07345	0.77749	0.89101
M22A	12	17802	1.40741	1.12393	0.39259	0.53944
B	8	10747	0.67529	0.75412	0.22510	0.22452

Table 6-8. Species diversity indices for the April marine sampling. Indices are referenced in text. Also included are number of individuals collected at each station. The A or B suffixes to station names indicate replicate trawls.

Station name	Number Species	Total IND	Diversity H'	Richness S R	Evenness P I E LOU	P I E DELTA
M1A	22	30760	2.92719	2.03213	0.65640	0.78795
B	25	29138	2.36414	2.33468	0.50909	0.64052
M3A	25	19941	2.64946	2.42411	0.57053	0.74483
B	23	14745	2.45905	2.29199	0.54361	0.71687
M6A	26	26205	2.60077	2.45731	0.55330	0.71080
B	21	21983	2.13333	2.00039	0.48570	0.61747
M9A	18	78647	2.15829	1.50806	0.51758	0.63394
B	18	31481	2.58624	1.64138	0.62021	0.75766
M10A	22	13659	2.69949	2.20538	0.60534	0.69584
B	21	10865	3.24164	2.15209	0.73802	0.83890
M11A	21	7014	3.29323	2.25844	0.74977	0.84235
B	17	5892	2.95570	1.84303	0.72311	0.82609
M15A	20	6199	3.28864	2.17587	0.76092	0.87223
B	18	5329	2.96065	1.98114	0.71000	0.82706
M18A	18	6190	2.67470	1.94715	0.64143	0.78670
B	18	5323	3.24723	1.98140	0.77873	0.86299
M20A	26	26962	2.86235	2.45046	0.60895	0.79094
B	27	21868	3.26990	2.60188	0.68769	0.84492
M22A	11	18549	0.91053	1.01748	0.26320	0.29302
B	11	39093	1.04661	0.94574	0.30254	0.42664
DEA	14	8873	2.59102	1.43002	0.68053	0.79607
B	18	8665	2.92792	1.87492	0.70215	0.80952

Table 6-8 (cont'd). 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. The A or B suffixes to station names indicate replicate trawls.

<u>Station name</u>	<u>Number species</u>	<u>Total IND</u>	<u>Diversity H'</u>	<u>Richness S R</u>	<u>Evenness PIELOU</u>	<u>P I E DELTA</u>
DWA	23	32533	2.65674	2.11742	0.58731	0.72794
B	24	27401	2.63297	2.25086	0.57426	0.73429
M21A	19	11448	2.93559	1.92605	0.69106	0.81666
B	17	12634	2.90540	1.69417	0.71081	0.82810

Table 6.9. Distribution of abundant species collected in the Gulf during February. Results are presented as percentage of specimens, by weight, caught at each station.

<u>SPECIES NAME</u>	<u>M1</u>	<u>M3</u>	<u>M6</u>	<u>M9</u>	<u>M10</u>	<u>M11</u>	<u>M15</u>	<u>M18</u>	<u>M20</u>	<u>DE</u>	<u>DW</u>
<u>Brevoortia patronus</u>	9.47	0.00	4.32	15.61	9.97	0.00	1.83	1.16	25.08	29.73	2.82
<u>Menticirrhus americanus</u>	0.43	2.49	11.06	0.06	26.91	12.76	9.02	7.62	6.09	16.55	7.01
<u>Cynoscion arenarius</u>	12.74	6.45	15.32	8.95	28.42	2.03	1.71	0.98	4.32	7.59	11.51
<u>Cynoscion nothus</u>	14.66	14.53	18.24	4.86	6.60	6.48	3.24	1.53	2.90	14.83	12.14
<u>Stellifer lanceolatus</u>	3.65	2.42	11.97	17.48	24.40	0.00	1.91	3.77	8.49	15.06	10.85
<u>Symphurus plagiusa</u>	6.47	1.83	6.54	19.28	11.61	6.76	2.46	12.81	1.34	27.16	3.73
<u>Etropus crossotus</u>	4.34	7.23	1.93	3.22	15.59	9.49	9.49	12.22	5.47	24.28	6.75
<u>Citharichthys spilopterus</u>	7.44	12.52	4.54	5.26	8.35	5.44	6.53	13.07	10.16	13.43	13.25
<u>Urophycis floridanus</u>	15.77	13.98	5.82	4.59	1.23	16.78	5.03	4.70	14.54	12.42	5.15
<u>Prionotus tribulus</u>	7.31	9.47	5.68	4.87	12.58	3.52	5.82	8.93	8.66	33.15	0.00
<u>Squilla empusa</u>	11.18	4.03	7.63	11.35	8.94	9.23	1.25	8.93	18.83	13.08	5.54
<u>Trachypenaeus similis</u>	6.58	5.89	15.42	6.76	12.89	6.03	7.46	6.30	6.44	18.36	7.87
<u>Lolliguncula brevis</u>	13.65	14.24	2.57	8.67	6.00	11.99	5.67	4.07	17.13	13.65	2.36
<u>Portunus gibbesii</u>	14.04	2.81	7.34	4.75	5.18	8.86	1.51	6.91	6.05	34.56	7.99

Table 6-9 (cont'd) Distribution of abundant species collected in the Gulf during February. Results are presented as percentage of specimens, by weight, caught at each station.

<u>SPECIES NAME</u>	<u>M1</u>	<u>M3</u>	<u>M6</u>	<u>M9</u>	<u>M10</u>	<u>M11</u>	<u>M15</u>	<u>M18</u>	<u>M20</u>	<u>DE</u>	<u>DW</u>
<u>Penaeus setiferus</u>	7.60	3.52	8.21	16.37	10.99	2.62	4.01	3.43	26.58	9.07	7.58
<u>Dorosoma petenense</u>	26.25	0.00	13.51	0.00	21.62	8.49	0.00	0.00	11.97	8.49	9.65
<u>Symphurus civitatus</u>	13.70	0.00	8.29	12.74	15.63	0.00	18.15	0.00	5.89	0.00	25.60
<u>Leiostomus xanthurus</u>	0.00	1.38	0.00	0.00	77.65	0.00	1.77	1.06	0.00	3.74	14.41
<u>Micropogonias undulatus</u>	0.00	3.72	31.40	0.00	22.62	15.33	5.21	0.00	0.00	13.84	7.89
<u>Prionotus rubio</u>	0.00	0.00	16.10	16.70	0.00	40.76	8.95	0.00	8.75	0.00	8.75
<u>Callinectes sapidus</u>	0.00	0.00	0.00	3.74	19.54	30.17	0.00	46.55	0.00	0.00	0.00
<u>Paralichthys lethostigma</u>	0.00	0.00	0.00	0.00	79.91	0.00	0.00	0.00	0.00	0.00	20.09
<u>Bairdiella chrysoura</u>	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	100.00	0.00

Table 6-10. Most abundant species in marine trawls during February. Results are percentage of catch, by weight, for abundant species.

<u>SPECIES NAME</u>	<u>M1</u>	<u>M3</u>	<u>M6</u>	<u>M9</u>	<u>M10</u>	<u>M11</u>	<u>M15</u>	<u>M18</u>	<u>M20</u>	<u>DE</u>	<u>DW</u>
<u>Brevoortia patronus</u>	0.98	0.00	0.44	1.70	0.53	0.00	0.49	0.24	2.10	2.43	0.32
<u>Menticirrhus americanus</u>	0.48	5.62	12.21	0.07	15.25	22.08	25.84	16.63	5.49	14.56	8.54
<u>Cynoscion arenerius</u>	23.10	23.66	27.47	17.06	26.16	5.72	7.96	3.47	6.32	10.85	22.78
<u>Cynoscion nothus</u>	5.93	11.90	7.30	2.07	1.36	4.06	3.36	1.21	0.95	4.73	5.36
<u>Stellifer lanceolatus</u>	1.12	1.50	3.63	5.64	3.80	0.00	1.50	2.26	2.10	3.64	3.63
<u>Symphurus plagiusa</u>	1.59	0.91	1.59	4.97	1.44	2.57	1.55	6.14	0.26	5.25	1.00
<u>Etropus crossotus</u>	0.47	1.57	0.20	0.36	0.85	1.58	2.61	2.56	0.47	2.05	0.79
<u>Citharichthys spilopterus</u>	0.71	2.41	0.43	0.53	0.40	0.80	1.59	2.43	0.78	1.01	1.37
<u>Urophycis floridanus</u>	2.43	4.36	0.89	0.74	0.10	4.01	1.99	1.42	1.81	1.51	0.87
<u>Prionotus tribulus</u>	0.93	2.44	0.72	0.65	0.81	0.70	1.90	2.23	0.89	3.33	0.00
<u>Squilla empusa</u>	20.41	14.90	13.78	21.80	8.29	26.12	5.84	31.87	27.76	18.83	11.04
<u>Trachypenaeus similis</u>	2.46	4.47	5.71	2.67	2.45	3.50	7.17	4.62	1.95	5.42	3.22
<u>Lolliguncula brevis</u>	4.40	9.28	0.82	2.94	0.98	5.99	4.69	2.56	4.45	3.47	0.83
<u>Portunus gibbesii</u>	1.12	0.45	0.58	0.40	0.21	1.10	0.31	1.08	0.39	2.18	0.70

Table 6-10 (cont'd) Most abundant species in marine trawls during February. Results are percentage of catch, by weight, for abundant species.

<u>SPECIES NAME</u>	<u>M1</u>	<u>M3</u>	<u>M6</u>	<u>M9</u>	<u>M10</u>	<u>M11</u>	<u>M15</u>	<u>M18</u>	<u>M20</u>	<u>DE</u>	<u>DW</u>
<u>Penaeus setiferus</u>	14.17	13.29	15.14	32.09	10.40	7.56	19.20	12.51	40.00	13.34	15.40
<u>Dorosoma petenense</u>	1.17	0.00	0.60	0.00	0.49	0.59	0.00	0.00	0.43	0.30	0.47
<u>Symphurus civitatus</u>	1.96	0.00	1.18	1.92	1.14	0.00	6.68	0.00	0.68	0.00	4.01
<u>Leiostomus xanthurus</u>	0.00	1.36	0.00	0.00	19.25	0.00	2.21	1.01	0.00	1.44	7.67
<u>Micropogonias undulatus</u>	0.00	0.87	3.60	0.00	1.33	2.75	1.55	0.00	0.00	1.26	1.00
<u>Prionotus rubio</u>	0.00	0.00	1.38	1.52	0.00	5.48	1.99	0.00	0.61	0.00	0.83
<u>Callinectes sapidus</u>	0.00	0.00	0.00	0.24	0.60	2.81	0.00	5.46	0.00	0.00	0.00
<u>Paralichthys lethostigma</u>	0.00	0.00	0.00	0.00	3.17	0.00	0.00	0.00	0.00	0.00	1.71
<u>Bairdiella chrysoura</u>	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.18	0.00

Table 6-11. Distribution of abundant species collected in the Gulf during March. Results are presented as percentage of specimens, by weight, caught at each station.

SPECIES NAME	M1	M3	M6	M9	M10	M11	M15	M18	M20	DE	DW	M21	M22
<u>Micropogonias undulatus</u>	6.52	7.25	16.22	5.37	9.18	5.69	3.60	2.66	7.36	12.00	4.33	19.82	0.00
<u>Leiostomus xanthurus</u>	10.91	16.79	18.21	1.21	1.20	5.17	15.37	14.65	3.42	9.62	3.44	0.00	0.00
<u>Menticirrhus americanus</u>	2.74	13.30	15.81	8.07	11.60	2.45	8.65	6.30	4.62	6.30	11.87	7.06	1.22
<u>Arius felis</u>	1.77	0.92	2.19	3.74	1.23	5.96	0.37	0.81	0.42	0.88	0.55	0.35	80.82
<u>Urophycis floridanus</u>	3.65	8.35	9.23	6.42	12.47	4.70	6.20	5.80	6.86	8.02	9.73	16.79	1.77
<u>Peprilus burti</u>	2.99	7.04	0.26	0.09	6.87	39.08	2.02	4.23	3.08	2.90	2.29	29.14	0.00
<u>Prionotus tribulus</u>	7.46	7.05	7.46	0.75	10.03	7.46	14.34	12.69	2.65	15.01	12.94	0.50	1.66
<u>Etropus crossotus</u>	12.36	0.77	2.32	6.95	5.41	3.86	5.02	5.41	34.36	6.56	12.74	0.00	4.25
<u>Larimus fasciatus</u>	28.99	8.09	7.42	7.87	3.60	3.82	4.94	6.52	8.54	2.25	11.24	6.74	0.00
<u>Symphurus civitatus</u>	8.42	7.43	5.15	4.16	11.00	1.68	10.11	0.89	3.27	13.78	8.42	25.67	0.00
<u>Trichiurus lepturus</u>	6.41	3.08	4.09	4.51	14.29	39.21	1.25	3.50	4.09	6.41	7.18	5.99	0.00
<u>Cynoscion arenarius</u>	9.16	9.13	10.07	24.70	6.09	0.64	4.23	4.48	3.41	8.65	8.39	11.04	0.00
<u>Cynoscion nothus</u>	5.10	11.79	8.31	8.04	6.73	9.36	11.44	12.84	8.69	10.58	6.61	0.50	0.00
<u>Squilla empusa</u>	6.46	12.95	13.74	12.35	11.59	0.97	4.54	4.18	9.77	7.18	11.32	4.33	0.62
<u>Lolliguncula brevis</u>	7.86	8.32	7.76	5.82	2.99	19.12	1.70	2.25	1.62	2.71	4.32	2.20	33.32
<u>Trachypenaeus similis</u>	3.42	8.87	19.46	8.44	10.74	4.07	6.10	9.48	10.70	7.28	9.64	1.65	0.18
<u>Penaeus setiferus</u>	2.32	3.69	4.25	13.23	6.54	7.38	0.00	10.07	14.90	9.33	5.89	22.39	0.00
<u>Citharichthys spilopterus</u>	4.45	11.44	2.12	4.24	3.81	15.25	3.39	3.18	4.03	15.89	10.81	21.40	0.00
<u>Callinectes sapidus</u>	0.00	31.29	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	68.71	0.00
<u>Symphurus plagiura</u>	0.00	7.42	0.00	3.52	34.57	0.00	12.89	7.42	10.55	4.30	10.16	4.69	4.49
<u>Pogonias cromis</u>	0.00	0.00	65.13	18.07	0.00	0.00	0.00	16.80	0.00	0.00	0.00	0.00	0.00
<u>Stellifer lanceolatus</u>	0.00	0.00	0.00	21.00	10.05	0.00	0.00	0.00	17.81	0.00	0.00	51.14	0.00
<u>Paralichthys lethostigma</u>	0.00	0.00	0.00	0.00	0.00	0.00	0.00	76.35	23.65	0.00	0.00	0.00	0.00
<u>Chilomycterus schoepfi</u>	0.00	0.00	0.00	0.00	0.00	0.00	0.00	30.06	0.00	40.28	0.00	0.00	29.66
<u>Sciaenops ocellata</u>	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	100.00

Table 6-12. Abundant species in marine trawls during March. Results are percentage of catch, by weight, for abundant species.

SPECIES NAME	M1	M3	M6	M9	M10	M11	M15	M18	M20	DE	DW	M21	M22
<u>Micropogonias undulatus</u>	2.16	1.24	0.59	0.48	1.96	1.32	0.89	0.26	1.99	2.64	0.97	5.07	0.00
<u>Leiostomus xanthurus</u>	10.11	8.04	1.85	0.31	0.71	3.35	10.57	4.03	2.59	5.91	2.15	0.00	0.00
<u>Menticirrhus americanus</u>	9.96	24.96	6.28	7.97	27.08	6.23	23.32	6.79	13.70	15.18	29.09	19.76	0.90
<u>Arius felis</u>	7.53	2.02	1.02	4.34	3.37	17.75	1.18	1.02	1.47	2.48	1.58	1.13	69.70
<u>Urophycis floridanus</u>	5.92	7.00	1.64	2.83	13.01	5.33	7.46	2.80	9.08	8.63	10.65	21.00	0.58
<u>Peprilus burti</u>	0.59	0.72	0.01	0.00	0.87	5.37	0.30	0.25	0.49	0.38	0.30	4.42	0.00
<u>Prionotus tribulus</u>	1.56	0.76	0.17	0.04	1.35	1.09	2.22	0.79	0.45	2.08	1.82	0.08	0.07
<u>Etropus crossotus</u>	0.55	0.02	0.01	0.08	0.16	0.12	0.17	0.07	1.26	0.20	0.39	0.00	0.04
<u>Larimus fasciatus</u>	2.23	0.32	0.06	0.16	0.18	0.21	0.28	0.15	0.54	0.11	0.58	0.40	0.00
<u>Symphurus civitatus</u>	1.47	0.67	0.10	0.20	1.24	0.21	1.31	0.05	0.47	1.60	0.39	3.46	0.00
<u>Trichiurus lepturus</u>	1.87	0.47	0.13	0.36	2.68	7.99	0.27	0.30	0.97	1.24	1.41	1.35	0.00
<u>Cynoscion arenarius</u>	11.22	5.78	1.35	8.22	4.80	0.54	3.84	1.63	3.40	7.03	6.93	10.42	0.00
<u>Cynoscion nothus</u>	21.56	25.74	3.84	9.24	18.28	27.61	35.87	16.10	29.98	29.64	18.84	1.63	0.00
<u>Squilla empusa</u>	8.50	8.81	1.98	4.42	9.80	0.89	4.43	1.63	10.50	6.27	10.06	4.39	0.16
<u>Lolliguncula brevis</u>	8.23	4.50	0.89	1.66	2.01	13.98	1.32	0.70	1.38	1.88	3.05	1.77	7.05
<u>Trachypenaeus similis</u>	2.91	3.90	1.81	1.95	5.88	2.42	3.85	2.39	7.43	4.11	5.54	1.08	0.03
<u>Penaeus setiferus</u>	1.73	1.42	0.35	2.68	3.14	3.84	0.00	2.23	9.07	4.62	2.97	12.88	0.00
<u>Citharichthys spilopterus</u>	0.36	0.48	0.02	0.09	0.20	0.87	0.21	0.08	0.27	0.86	0.60	1.35	0.00
<u>Callinectes sapidus</u>	0.00	1.97	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	6.44	0.00
<u>Symphurus plagiusa</u>	0.00	0.34	0.00	0.08	1.97	0.00	0.85	0.20	0.76	0.25	0.61	0.32	0.08
<u>Pogonias cromis</u>	0.00	0.00	77.78	53.66	0.00	0.00	0.00	54.47	0.00	0.00	0.00	0.00	0.00
<u>Stellifer lanceolatus</u>	0.00	0.00	0.00	0.22	0.24	0.00	0.00	0.00	0.55	0.00	0.00	1.49	0.00
<u>Paralichthys lethostigma</u>	0.00	0.00	0.00	0.00	0.00	0.00	0.00	2.40	2.05	0.00	0.00	0.00	0.00
<u>Chilomycterus schoepfi</u>	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.77	0.00	2.31	0.00	0.00	0.52
<u>Sciaenops ocellata</u>	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	20.67

Table 6-13. Distribution of abundant species collected in the Gulf during April. Results are presented as percentage of specimens, by weight, caught at each station.

SPECIES NAME	M1	M3	M6	M9	M10	M11	M15	M18	M20	DE	DW	M21	M22
<u>Leiostomus xanthurus</u>	89.50	1.53	1.36	6.67	0.00	0.00	0.00	0.00	0.00	0.00	0.94	0.00	0.00
<u>Menticirrhus americanus</u>	11.84	7.68	6.65	54.72	0.10	0.09	0.25	0.00	0.16	0.05	15.86	2.61	0.00
<u>Cynoscion arenarius</u>	27.23	8.15	6.39	8.10	16.43	3.05	3.14	0.00	6.98	2.98	16.07	1.49	0.00
<u>Cynoscion nothus</u>	3.23	1.60	2.17	4.23	6.32	2.22	15.85	6.98	14.67	19.08	9.26	14.39	0.00
<u>Micropogonias undulatus</u>	0.39	1.05	0.86	23.97	5.13	0.41	5.77	0.47	5.18	1.11	7.34	48.30	0.00
<u>Sardinella anchovia</u>	16.34	10.04	0.00	0.00	0.00	49.61	0.00	0.00	21.26	0.00	2.76	0.00	0.00
<u>Opisthonema oglinum</u>	66.67	0.00	8.14	0.00	8.92	0.00	8.66	7.62	0.00	0.00	0.00	0.00	0.00
<u>Harengula pensacola</u>	40.43	4.48	1.37	0.00	22.69	1.12	14.78	2.93	10.82	0.52	0.85	0.00	0.00
<u>Urophycis floridanus</u>	7.20	2.43	4.91	10.81	10.91	9.11	9.17	9.23	10.34	9.88	13.06	0.00	2.95
<u>Citharichthys spilopterus</u>	11.77	4.98	4.92	0.00	19.32	8.61	14.39	6.53	16.75	4.07	6.58	1.07	1.02
<u>Etropus crossotus</u>	20.16	0.00	1.61	0.00	0.00	47.26	1.13	1.94	0.81	0.00	0.00	0.00	27.10
<u>Orthopristis chrysoptera</u>	3.85	4.51	12.81	56.27	0.00	0.00	0.00	0.00	2.09	0.00	20.48	0.00	0.00
<u>Arius felis</u>	11.32	0.88	1.67	4.17	1.35	0.69	8.75	0.76	12.34	0.06	1.21	0.17	56.62
<u>Peprilus burti</u>	16.83	7.62	14.72	33.13	6.31	0.33	1.09	0.39	1.46	0.39	15.77	1.91	0.05
<u>Chloroscombrus chrysurus</u>	11.69	1.13	0.26	0.00	2.31	7.47	12.52	3.80	22.10	0.45	0.39	0.00	37.88
<u>Lolliguncula brevis</u>	8.15	6.67	5.33	11.62	8.63	8.88	13.42	8.97	8.66	10.09	6.04	1.31	2.23
<u>Callinectes similis</u>	4.34	6.91	8.25	2.74	2.66	0.26	1.54	0.16	1.52	1.04	11.83	58.75	0.00
<u>Trachypenaeus similis</u>	1.72	2.58	4.21	14.34	9.85	1.72	5.35	3.92	9.56	8.32	11.47	25.33	1.63
<u>Squilla empusa</u>	6.98	5.67	13.97	9.50	6.16	1.67	13.13	0.77	4.83	4.98	27.69	4.64	0.00
<u>Penaeus setiferus</u>	6.68	20.03	12.84	14.80	5.13	2.15	3.78	1.07	4.58	4.28	16.95	7.71	0.00
<u>Anchoa hepsetus</u>	0.17	0.31	0.00	0.00	0.62	9.60	9.27	28.33	11.75	39.24	0.08	0.00	0.63
<u>Vomer setapinnis</u>	8.46	0.00	0.00	0.00	0.00	0.00	39.30	4.58	47.66	0.00	0.00	0.00	0.00
<u>Synodus foetens</u>	3.07	15.61	0.00	0.00	0.00	56.14	7.76	9.81	7.59	0.00	0.00	0.00	0.00
<u>Brevoortia patronus</u>	0.00	9.07	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	90.93	0.00
<u>Trichiurus lepturus</u>	0.00	20.00	17.60	38.01	0.02	0.00	0.04	0.00	0.07	0.00	24.01	0.25	0.00
<u>Sphyrna tiburo</u>	0.00	0.00	100.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
<u>Dasyatis americana</u>	0.00	0.00	68.97	0.00	0.00	0.00	0.00	0.00	0.00	0.00	31.03	0.00	0.00
<u>Stellifer lanceolatus</u>	0.00	0.00	0.00	6.42	0.00	0.00	0.00	0.00	0.00	0.00	0.99	92.58	0.00
<u>Paralichthys lethostigma</u>	0.00	0.00	0.00	0.00	48.74	0.00	0.00	39.03	12.23	0.00	0.00	0.00	0.00
<u>Scomberomorus maculata</u>	0.00	0.00	0.00	0.00	100.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
<u>Rhizoprionodon terraenovae</u>	0.00	0.00	0.00	0.00	0.00	43.75	0.00	0.00	0.00	56.25	0.00	0.00	0.00
<u>Sphyrna guachancho</u>	0.00	0.00	0.00	0.00	0.00	0.00	45.11	54.89	0.00	0.00	0.00	0.00	0.00
<u>Trachinotus carolinus</u>	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	100.00	0.00	0.00	0.00

Table 6-14. Most abundant species in marine trawls during April. Results are percentages of catch, by weight, for abundant species.

SPECIES NAME	M1	M3	M6	M9	M10	M11	M15	M18	M20	DE	DW	M21	M22
<u>Leiostomus xanthurus</u>	7.01	0.21	0.13	0.28	0.00	0.00	0.00	0.00	0.00	0.00	0.07	0.00	0.00
<u>Menticirrhus americanus</u>	4.37	4.90	3.05	11.00	0.09	0.15	0.20	0.00	0.11	0.07	5.86	2.40	0.00
<u>Cynoscion arenarius</u>	3.89	2.01	1.14	0.63	5.74	2.02	0.99	0.00	1.85	1.45	2.30	0.53	0.00
<u>Cynoscion nothus</u>	1.23	1.05	1.03	0.87	5.86	3.91	13.24	12.80	10.33	24.72	3.51	13.58	0.00
<u>Micropogonias undulatus</u>	0.10	0.47	0.28	3.38	3.25	0.50	3.29	0.59	2.49	0.98	1.90	31.11	0.00
<u>Sardinella anchovia</u>	0.14	0.15	0.00	0.00	0.00	1.95	0.00	0.00	0.33	0.00	0.02	0.00	0.00
<u>Opisthonema oglinum</u>	1.29	0.00	0.20	0.00	0.42	0.00	0.37	0.71	0.00	0.00	0.00	0.00	0.00
<u>Harengula pensacolae</u>	3.01	0.58	0.13	0.00	4.13	0.39	2.43	1.06	1.50	0.13	0.06	0.00	0.00
<u>Urophycis floridanus</u>	2.26	1.32	1.92	1.85	8.38	13.29	6.35	14.02	6.03	10.61	4.10	0.00	0.96
<u>Githarichthys spilopterus</u>	0.37	0.27	0.19	0.00	1.47	1.25	0.99	0.98	0.97	0.43	0.21	0.08	0.03
<u>Etropus crossotus</u>	0.21	0.00	0.02	0.00	0.00	2.27	0.03	0.10	0.02	0.00	0.00	0.00	0.29
<u>Orthopristis chrysoptera</u>	0.22	0.44	0.89	1.71	0.00	0.00	0.00	0.00	0.22	0.00	1.14	0.00	0.00
<u>Arius felis</u>	14.40	1.92	2.65	2.89	4.20	4.04	24.51	4.66	29.12	0.28	1.54	0.54	74.82
<u>Peprilus burti</u>	48.51	37.96	52.76	51.94	44.43	4.48	6.93	5.44	7.79	3.81	45.45	13.70	0.14
<u>Chloroscombrus chrysurus</u>	6.50	1.09	0.18	0.00	3.14	19.28	15.34	10.21	22.80	0.86	0.22	0.00	21.89
<u>Lolliguncula brevis</u>	3.71	5.26	3.02	2.88	9.61	18.79	13.48	19.78	7.33	15.71	2.75	1.49	1.06
<u>Callinectes similis</u>	0.36	1.00	0.86	0.12	0.54	0.10	0.28	0.06	0.24	0.30	0.99	12.21	0.00
<u>Trachypenaeus similis</u>	0.03	0.08	0.09	0.14	0.42	0.14	0.21	0.33	0.31	0.50	0.20	1.10	0.03
<u>Squilla empusa</u>	0.73	1.02	1.81	0.54	1.57	0.81	3.01	0.39	0.93	1.77	2.88	1.20	0.00
<u>Penaeus setiferus</u>	1.09	5.62	2.59	1.31	2.03	1.62	1.35	0.84	1.38	2.38	2.75	3.11	0.00
<u>Anchoa hepsetus</u>	0.03	0.08	0.00	0.00	0.24	6.92	3.17	21.27	3.39	20.81	0.01	0.00	0.10
<u>Vomer setapinnis</u>	0.14	0.00	0.00	0.00	0.00	0.00	1.45	0.37	1.48	0.00	0.00	0.00	0.00
<u>Synodus foetens</u>	0.06	0.53	0.00	0.00	0.00	5.10	0.33	0.93	0.28	0.00	0.00	0.00	0.00
<u>Brevoortia patronus</u>	0.00	0.12	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.79	0.00
<u>Trichiurus lepturus</u>	0.00	32.72	20.73	19.58	0.04	0.00	0.08	0.00	0.11	0.00	22.72	0.60	0.00
<u>Sphyrna tiburo</u>	0.00	0.00	3.77	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
<u>Dasyatis americana</u>	0.00	0.00	2.08	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.75	0.00	0.00
<u>Stellifer lanceolatus</u>	0.00	0.00	0.00	0.23	0.00	0.00	0.00	0.00	0.00	0.00	0.07	15.08	0.00
<u>Paralichthys lethostigma</u>	0.00	0.00	0.00	0.00	2.29	0.00	0.00	3.63	0.44	0.00	0.00	0.00	0.00
<u>Scomberomorus maculata</u>	0.00	0.00	0.00	0.00	1.18	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
<u>Rhizoprionodon terraenovae</u>	0.00	0.00	0.00	0.00	0.00	12.31	0.00	0.00	0.00	11.65	0.00	0.00	0.00
<u>Sphyrna guachancho</u>	0.00	0.00	0.00	0.00	0.00	0.00	0.44	1.18	0.00	0.00	0.00	0.00	0.00
<u>Trachinotus carolinus</u>	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	3.24	0.00	0.00	0.00

In an attempt to determine whether any of the ten meter stations clustered consistently, the data for all three months were combined and clustered. The whole cluster is given in Figure 6-7. This figure shows three large clusters, which are enlarged in Figures 6-8, 6-9, and 6-10.

Table 6-15 describes the variability of marine samples for this study. Based on weight, the mean value of all trawls, variance, 90 and 95% confidence limits for each month and the overall study period is given. These statistics are also given for some of the more common species collected in Table 6-16.

Linear regressions of weight versus length of all species in the family Sciaenidae and for species of the genus Brevortia were determined each month and for the study period as a whole. These results are presented briefly in the discussion. While only the lengths of penaeid shrimp were recorded, the range and mean for both species of the genus Penaeus are also presented in the discussion.

6.3.2 Estuarine

A total of 28,864 organisms representing 49 species were caught during pre-brine discharge sampling. Table 6-17 lists the total number and total weights for each species collected. Thirteen species made up 98% of the total number of nekters collected. Tables 6-18 through 6-20 list the ten dominant estuarine species by both weight and total number for each of the three sampling months.

The same analyses were performed on the data from the estuarine stations as were performed on the marine stations.

Figure 6-7. Cluster analysis of marine stations for February, March and April. The three major clusters are enlarged and the trawl numbers identified in Figures 6-8, 6-9 and 6-10.

Figure 6-8. Enlargement of upper cluster in Figure 6-7. Trawls are identified by station number, A or B replicate and month (02 is February).

Figure 6-9. Enlargement of center cluster in Figure 6-7. Trawls are identified by station number, A or B replicate and month (03 is March).

Figure 6-10. Enlargement of lower cluster in Figure 6-7. Trawls are identified by station number, A or B replicate and month (04 is April).

Table 6-15. Means, standard deviation, and confidence limits of trawl catch weights.

	FEBRUARY	MARCH	APRIL	COMBINED THREE MONTHS
MEAN	2753.1	7271.0	20469.9	10164.7
STANDARD DEVIATION	1386.0	9498.5	16925.8	13405.0
LOWER 95% CI LIMIT	2138.5	3058.8	12964.0	6930.6
UPPER 95% CI LIMIT	3367.8	11483.2	27975.7	13398.8
LOWER 90% CI LIMIT	2244.6	3785.8	14259.5	7450.3
UPPER 90% CI LIMIT	3261.7	10756.2	26680.3	12879.0

Table 6-16. Means, standard deviation, and confidence limits for the ten most abundantly captured nekters.

SPECIES	MEAN	S.D.	LOWER 95%	UPPER 95%	LOWER 90%	UPPER 90%
<u>Lolliguncula brevis</u>						
February	84.9	51.9	61.9	107.9	65.9	104.0
March	177.2	158.4	106.9	247.4	119.1	235.3
April	1197.5	362.5	1036.8	1358.2	1064.5	1330.5
<u>Squilla empusa</u>						
February	481.3	291.4	352.1	610.5	374.4	588.2
March	328.5	184.4	246.8	410.3	260.9	396.2
April	270.0	242.8	162.3	377.7	180.9	359.1
<u>Penaeus setiferus</u>						
February	491.4	382.5	321.7	661.0	351.0	631.7
March	152.0	118.9	99.3	204.7	108.4	195.6
April	408.3	328.1	262.8	553.8	287.9	528.7
<u>Trachypenaeus similis</u>						
February	98.8	55.0	74.4	123.2	78.6	119.0
March	219.5	120.4	166.1	272.8	175.3	263.6
April	34.7	29.2	21.8	47.7	24.0	45.4
<u>Callinectes similis</u>						
February	5.1	7.4	1.8	8.4	2.4	7.8
March	14.0	13.5	8.1	20.0	9.1	19.0
April	93.8	96.9	50.8	136.8	58.2	129.4

Table 6-16. Means, standard deviation, and confidence limits for the ten most abundantly captured nekters.

SPECIES	MEAN	S.D.	LOWER 95%	UPPER 95%	LOWER 90%	UPPER 90%
<u>Urophycis floridana</u>						
February	40.6	30.4	27.2	54.1	29.5	51.8
March	347.0	141.8	284.1	410.0	295.0	399.0
April	830.6	337.2	681.1	980.2	706.9	954.4
<u>Cynoscion nothus</u>						
February	106.7	76.4	72.8	140.6	78.7	134.7
March	1103.8	310.6	966.0	1241.5	989.8	1217.7
April	884.4	907.1	482.1	1286.6	551.5	1217.2
<u>Micropogonias undulatus</u>						
February	30.5	51.6	7.7	53.4	11.6	49.5
March	69.9	45.2	49.8	89.9	53.3	86.4
April	360.7	549.6	116.9	604.4	159.0	562.3
<u>Trichiurus lepturus</u>						
February	10.6	12.8	5.0	16.3	5.9	15.3
March	72.0	92.1	31.2	112.9	38.3	105.8
April	2572.4	3901.7	842.1	4302.6	1140.8	4004.0
<u>Peprilus burti</u>						
February	4.9	7.0	1.8	8.0	2.3	7.5
March	36.6	63.0	8.6	64.5	13.5	59.7
April	7695.8	10079.4	3226.0	12165.6	3997.4	11394.1

Table 6-17. 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.

<u>Name</u>	<u>Count</u>	<u>Weight</u>
<u>Micropogonias undulatus</u>	10064	46137
<u>Anchoa mitchilli</u>	9592	4477
<u>Penaeus aztecus aztecus</u>	5981	10045
<u>Callinectes sapidus</u>	1026	34419
<u>Brevoortia patronus</u>	692	2245
<u>Penaeus setiferus</u>	528	6956
<u>Leiostomus xanthurus</u>	193	2362
<u>Macrobrachium</u>	166	122
<u>Citharichthys spilopterus</u>	114	167
<u>Arius felis</u>	57	2423
<u>Palaemonetes vulgaris</u>	51	22
<u>Lolliguncula brevis</u>	46	979
<u>Urophycis floridanus</u>	38	856
<u>Cynoscion arenarius</u>	35	98
<u>Clupeidae</u>	33	2
<u>Trachypenaeus similis</u>	28	27
<u>Prionotus tribulus</u>	26	109
<u>Paralichthys lethostigma</u>	23	2569
<u>Symphurus plagiusa</u>	22	82
<u>Brevoortia</u>	18	6
<u>Stellifer lanceolatus</u>	15	41
<u>Ictalurus melas</u>	13	45
<u>Gobiesox strumosus</u>	11	47
<u>Dorosoma pentenense</u>	10	79
<u>Macrobrachium ohione</u>	10	28
<u>Trichiurus lepturus</u>	8	77
<u>Cynoscion nebulosus</u>	7	332
<u>Gobiosoma boscii</u>	7	8
<u>Trinectes maculatus</u>	6	60
<u>Bairdiella chrysoura</u>	6	165
<u>Archosargus probatocephalus</u>	5	938
<u>Synodus foetens</u>	5	11
<u>Peprilus burti</u>	4	68
<u>Callinectes similis</u>	3	7
<u>Sphoeroides parvus</u>	3	27
<u>Chaetodipterus faber</u>	3	43
<u>Symphurus</u>	2	8
<u>Ophidion welshi</u>	2	5
<u>Symphurus civitatus</u>	2	15
<u>Lucania parva</u>	1	1
<u>Cyprinodon variegatus</u>	1	2
<u>Pogonias cromis</u>	1	334
<u>Myrophis punctatus</u>	1	4
<u>Penaeus duorarum duorarum</u>	1	2
<u>Larimus fasciatus</u>	1	2
<u>Cynoscion nothus</u>	1	9
<u>Etropus crossotus</u>	1	10
Number of species caught 47	Total count 28854	Total weight 116471

Table 6-18. Most abundant species collected during February at estuarine stations.

Ten most abundant species by weight in grams

<u>Species</u>	<u>Total Weight</u>
<u>Paralichthys lethostigma</u>	1604
<u>Callinectes sapidus</u>	1311
<u>Brevoortia patronus</u>	1284
<u>Micropogonias undulatus</u>	1042
<u>Pogonias cromis</u>	334
<u>Anchoa mitchilli</u>	177
<u>Leiostomus xanthurus</u>	176
<u>Macrobrachium sp.</u>	122
<u>Dorosoma petenense</u>	73
<u>Cynoscion nebulosus</u>	73

Ten most abundant species by number of individuals

<u>Species</u>	<u>Total Number</u>
<u>Micropogonias undulatus</u>	1268
<u>Anchoa mitchilli</u>	657
<u>Brevoortia patronus</u>	419
<u>Callinectes sapidus</u>	186
<u>Macrobrachium sp.</u>	166
<u>Clupeidae</u>	33
<u>Brevoortia sp.</u>	18
<u>Ictalurus melas</u>	13
<u>Paralichthys lethostigma</u>	11
<u>Dorosoma petenense</u>	9

Table 6-19. Most abundant species collected during March at estuarine stations.

Ten most abundant species by weight in grams

<u>Species</u>	<u>Total Weight</u>
<u>Callinectes sapidus</u>	11687
<u>Micropogonias undulatus</u>	4102
<u>Arius felis</u>	1052
<u>Anchoa mitchilli</u>	938
<u>Paralichthys lethostigma</u>	871
<u>Brevoortia patronus</u>	697
<u>Urophycis floridanus</u>	521
<u>Penaeus setiferus</u>	375
<u>Bairdiella chrysoura</u>	141
<u>Archosargus probatocephalus</u>	77

Ten most abundant species by number of individuals

<u>Species</u>	<u>Total Number</u>
<u>Micropogonias undulatus</u>	1530
<u>Anchoa mitchilli</u>	1065
<u>Callinectes sapidus</u>	263
<u>Brevoortia patronus</u>	138
<u>Penaeus setiferus</u>	128
<u>Palaemonetes vulgaris</u>	36
<u>Urophycis floridanus</u>	30
<u>Trachypenaeus similis</u>	28
<u>Arius felis</u>	19
<u>Stellifer lanceolatus</u>	15

Table 6-20. Most abundant species collected during April at estuarine stations.

Ten most abundant species by weight in grams

<u>Species</u>	<u>Total Weight</u>
<u>Micropogonias undulatus</u>	40993
<u>Callinectes sapidus</u>	21421
<u>Penaeus aztecus</u>	10038
<u>Penaeus setiferus</u>	6581
<u>Anchoa mitchilli</u>	3362
<u>Leiostomus xanthurus</u>	2125
<u>Arius felis</u>	1371
<u>Lolliguncula brevis</u>	954
<u>Archosargus probatocephalus</u>	861
<u>Urophycis floridanus</u>	317

Ten most abundant species by number of individuals

<u>Species</u>	<u>Total Number</u>
<u>Anchoa mitchilli</u>	7870
<u>Micropogonias undulatus</u>	7266
<u>Penaeus aztecus</u>	5980
<u>Callinectes sapidus</u>	577
<u>Penaeus setiferus</u>	400
<u>Leiostomus xanthurus</u>	185
<u>Brevoortia patronus</u>	135
<u>Citharichthys spilopterus</u>	114
<u>Lolliguncula brevis</u>	41
<u>Arius felis</u>	38

The estuarine clustering results are shown in Figures 6-11 through 6-13. The only difference between this clustering procedure and the marine clustering was that rarity was determined by occurrence in only one trawl. Estuarine species clusters are in Figures 6-14 through 6-16. Species are represented by a numerical designation according to the list of all species collected given in Table 6-5. Species diversity results are given in Tables 6-21 through 6-23. Percentage abundances are in Tables 6-24 through 6-29.

6.4 Discussion

In studying possible environmental impact on an open system of water, presence or absence of species is generally accepted as the best criterion. Downgrading species also leads to lower species diversity (Patrick, 1953; Sprague, 1971; Warren, 1971). Downgrading here means to lower the importance of a species in the ecosystem. The major difficulty in such a study is time. Nekton species are generally quite patchy or random in their distribution. The apparent randomness leads to a high variability in trawl collections. Naturally, one can reduce the significance of such variability by increasing the number of samples. One cannot, however, increase frequency of sampling to a great degree. High frequency might mean a high fishing pressure and could decrease the population which would, in turn, skew the results.

In addition, since most nekters exhibit circum-annular (approximately yearly) rhythms which are reflected in seasonal abundance, sampling cannot be greatly increased within a single year. Sufficient sampling thus is a process which requires several years. It is impossible to say how many years would be sufficient; as more data points are added, random variation is eliminated and confidence

Figure 6-11 Cluster analysis of February estuarine stations. The A or B station suffixes represent replicate trawls. Stations were clustered on the basis of species weight (See text).

Figure 6-12 Cluster analysis of March estuarine stations. The A or B station suffixes represent replicate trawls. Stations were clustered on the basis of species weight (See text).

Figure 6-13 Cluster analysis of April estuarine stations. The A or B stations suffixes represent replicate trawls. Stations were clustered on the basis of weight (See text).

Figure 6-14 Cluster analysis of February estuarine species. The numerical designation of species follows those in Table 6-5. Species were clustered on the basis of the number of individuals collected at each station (See text).

Figure 6-15 Cluster analysis of March estuarine species. The numerical designation of species follows those in Table 6-5. Species were clustered on the basis of the number of individuals collected at each station (See text).

Figure 6-16 Cluster analysis of April estuarine species. The numerical designation of species follows those in Table 6-5. Species were clustered on the basis of the number of individuals collected at each station (See text).

Table 6-21. Species diversity indices for the February estuarine sampling. Indices are referenced in text. Also included are number of individuals collected at each station and the numbers of species collected at each station. The A or B suffixes to station names indicate replicate trawls.

<u>Station name</u>	<u>Number Species</u>	<u>Total IND</u>	<u>Diversity H'</u>	<u>Richness S R</u>	<u>Evenness PIELOU</u>	<u>P I E DELTA</u>
E1A	8	803	1.01654	1.04659	0.33885	0.30432
B	7	776	2.08869	0.90169	0.74401	0.72753
E2A	10	442	1.34437	1.47751	0.40469	0.42143
B	7	1766	1.39636	0.80252	0.49739	0.56389
E4A	7	16	2.30504	2.16404	0.82107	0.79167
B	7	682	1.37924	0.91954	0.49130	0.56355
E5A	7	612	1.78096	0.93506	0.63439	0.64818
B	8	1250	1.25061	0.98164	0.41687	0.39533

Table 6-22. Species diversity indices for the March estuarine sampling. Indices are referenced in text. Also included are number of individuals collected at each station. The A or B suffixes to station names indicate replicate trawls.

<u>Station name</u>	<u>Number species</u>	<u>Total IND</u>	<u>Diversity H'</u>	<u>Richness S R</u>	<u>Evenness PIELOU</u>	<u>P I E DELTA</u>
E1A	10	1863	0.61423	1.19523	0.18490	0.19801
B	5	484	0.78574	0.64703	0.33840	0.24437
E2A	10	3776	1.65118	1.09271	0.49705	0.54260
B	15	2767	1.93814	1.76645	0.49608	0.67890
E4A	9	1880	1.32641	1.06114	0.41844	0.44640
B	13	2334	1.53283	1.54732	0.41423	0.50636
E5A	15	5414	2.05641	1.62852	0.52635	0.64534
B	14	2339	1.32416	1.67580	0.34779	0.35485

Table 6-23. Species diversity indices for the April estuarine sampling. Indices are references in text. Also included are number of individuals collected at each station and the number os species collected at each station. The A or B suffixes to station names indicate replicate trawls.

<u>Station name</u>	<u>Number species</u>	<u>Total IND</u>	<u>Diversity H'</u>	<u>Richness S R</u>	<u>Evenness PIELOU</u>	<u>P I E DELTA</u>
E1A	12	12119	1.02039	1.16990	0.28463	0.33931
B	16	13158	1.53733	1.58148	0.38433	0.54396
E2A	15	17156	2.51132	1.43588	0.64279	0.77883
B	12	16093	2.34829	1.13564	0.65504	0.75811
E4A	16	8187	2.03253	1.66476	0.50813	0.58664
B	14	9942	1.63791	1.41235	0.43020	0.48253
E3A	13	4378	2.68617	1.43124	0.72591	0.81271
B	15	8226	2.23009	1.55296	0.57081	0.70019

Table 6-24. Distribution of abundant species collected in the estuary during February. Results are presented as percentage of specimens, by weight, caught at each station.

<u>Species name</u>	<u>E1</u>	<u>E2</u>	<u>E4</u>	<u>E5</u>
<u>Cynoscion nebulosus</u>	75.34	0.00	0.00	24.66
<u>Anchoa mitchilli</u>	1.69	75.71	22.60	0.00
<u>Ictalurus melas</u>	100.00	0.00	0.00	0.00
<u>Callinectes sapidus</u>	13.27	54.46	0.08	32.19
<u>Micropogonias undulatus</u>	95.01	2.30	0.86	1.82
<u>Brevoortia patronus</u>	2.18	97.43	0.39	0.00
<u>Paralichthys lethostigma</u>	8.98	0.12	18.83	72.07
<u>Macrobrachium</u> sp.	98.36	1.64	0.00	0.00
<u>Pogonias cromis</u>	0.00	0.00	100.00	0.00
<u>Bairdiella chrysoura</u>	0.00	0.00	0.00	100.00
<u>Leiostomus xanthurus</u>	0.00	0.00	0.00	100.00
<u>Dorosoma petenense</u>	0.00	100.00	0.00	0.00

Table 6-25. Most abundant species in estuarine trawls during February. Results are percentage of catch, by weight, for abundant species.

<u>Species names</u>	<u>E1</u>	<u>E2</u>	<u>E4</u>	<u>E5</u>
<u>Cynoscion nebulosus</u>	3.48	0.00	0.00	0.97
<u>Anchoa mitchilli</u>	0.19	6.07	5.73	0.00
<u>Ictalurus melas</u>	2.85	0.00	0.00	0.00
<u>Callinectes sapidus</u>	11.02	32.34	0.14	22.66
<u>Micropogonias undulatus</u>	62.70	1.09	1.29	1.02
<u>Brevoortia patronus</u>	1.77	56.66	0.72	0.00
<u>Paralichthys lethostigma</u>	9.12	0.09	43.27	62.08
<u>Macrobrachium sp.</u>	7.60	0.09	0.00	0.00
<u>Pogonias cromis</u>	0.00	0.00	47.85	0.00
<u>Bairdiella chrysoura</u>	0.00	0.00	0.00	1.29
<u>Leiostomus xanthurus</u>	0.00	0.00	0.00	9.45
<u>Dorosoma petenense</u>	0.00	3.31	0.00	0.00

Table 6-26. Distribution of abundant species collected in the estuary during March. Results are presented as percentage of specimens, by weight, caught at each station.

<u>Species name</u>	<u>E1</u>	<u>E2</u>	<u>E4</u>	<u>E5</u>
<u>Callinectes sapidus</u>	1.65	32.13	24.92	41.30
<u>Penaeus setiferus</u>	2.40	68.80	18.93	9.87
<u>Micropogonias undulatus</u>	50.68	22.67	20.36	6.29
<u>Leiostomus xanthurus</u>	47.54	0.00	0.00	52.46
<u>Anchoa mitchilli</u>	0.00	84.01	15.99	0.00
<u>Urophycis floridanus</u>	0.00	15.74	6.91	77.35
<u>Paralichthys lethostigma</u>	0.00	0.46	12.74	86.80
<u>Brevoortia patronus</u>	0.00	98.13	1.87	0.00
<u>Arius felis</u>	0.00	0.00	2.09	97.91
<u>Bairdiella chrysoura</u>	0.00	0.00	0.00	100.00

Table 6-27. Most abundant species in estuarine trawls during March. Results are percentage of catch, by weight, for abundant species.

<u>Callinectes sapidus</u>	8.22	57.39	69.10	62.26
<u>Penaeus setiferus</u>	0.38	3.94	1.68	0.48
<u>Micropogonias undulatus</u>	88.58	14.21	19.81	3.33
<u>Leiostomus xanthurus</u>	1.24	0.00	0.00	0.41
<u>Anchoa mitchilli</u>	0.00	12.04	3.56	0.00
<u>Urophycis floridanus</u>	0.00	1.25	0.85	5.20
<u>Paralichthys lethostigma</u>	0.00	0.06	2.63	9.75
<u>Brevoortia patronus</u>	0.00	10.45	0.31	0.00
<u>Arius felis</u>	0.00	0.00	0.52	13.29
<u>Bairdiella chrysoura</u>	0.00	0.00	0.00	1.82

Table 6-28. Distribution of abundant species collected in the estuary during April. Results are presented as percentage of specimens, by weight, caught at each station.

<u>Species name</u>	<u>E1</u>	<u>E2</u>	<u>E4</u>	<u>E3</u>
<u>Urophycis floridanus</u>	100.00	0.00	0.00	0.00
<u>Arius felis</u>	11.96	40.77	8.68	38.58
<u>Micropogonias undulatus</u>	43.36	17.34	29.60	9.70
<u>Archosargus probatocephalus</u>	12.43	0.00	57.26	30.31
<u>Leiostomus xanthurus</u>	10.49	60.28	23.67	5.55
<u>Penaeus aztecus</u>	10.39	69.21	10.94	9.46
<u>Callinectes sapidus</u>	25.12	54.03	2.75	18.11
<u>Anchoa mitchilli</u>	0.59	41.73	12.02	45.66
<u>Penaeus setiferus</u>	0.20	56.89	28.63	14.28
<u>Lolliguncula brevis</u>	0.00	0.00	74.74	25.26

Table 6-29. Most abundant species in estuarine trawls during February. Results are percentage of catch, by weight, for abundant species.

<u>Urophycis floridanus</u>	1.25	0.00	0.00	0.00
<u>Arius felis</u>	0.65	1.68	0.66	4.20
<u>Micropogonias undulatus</u>	70.31	21.38	66.94	31.55
<u>Archosargus probatocephalus</u>	0.42	0.00	2.72	2.07
<u>Leiostomus xanthurus</u>	0.88	3.85	2.77	0.94
<u>Penaeus aztecus</u>	4.13	20.89	6.06	7.54
<u>Callinectes sapidus</u>	21.28	34.81	3.25	30.78
<u>Anchoa mitchilli</u>	0.08	4.22	2.23	12.18
<u>Penaeus setiferus</u>	0.05	11.26	10.39	7.46
<u>Lolliguncula brevis</u>	0.00	0.00	3.93	1.91

limits are tightened. Since this long sampling regime is normally not feasible, a short sampling period and dependence on the results of similar studies becomes the norm.

There has been, to date, little standardization in methodology. This makes direct comparison between various sets of data quite difficult. The 1978 SAI study of the West Hackberry site utilized a 4.3 m trawl with two centimeter square mesh. They did not specify day or night trawls so that day trawling may be assumed. Landry and Armstrong's (1980) Texoma study of West Hackberry utilized a 12.2 m trawl with 47.6 mm stretch (23.8 mm square) mesh and trawls were conducted at night. Moving further away from southwest Louisiana, Chittenden (1980) used a 10.4 m trawl with 44.5 mm stretch mesh and sampled day and night. Wohlschlag (1980) in the STOCS study used a 10.7 m flat trawl with 44.5 mm stretch mesh and sampled day and night. Perret et al. in their 1971 estuarine study used the same gear as was employed in this study. The ongoing Louisiana Offshore Oil Platform (LOOP) study uses the same trawls as were used in this study but their data is unavailable as of this writing. The Gulf of Mexico Estuarine Inventory (GMEI) also used identical trawls in their estuarine study.

Other investigators made their trawls in a straight line. In this study, when brine discharge actually begins it will be from only the distal ports along the diffuser, a distance of some 1500 feet. A ten minute trawl at two-three knots will cover 2000-3000 feet. A trawl at station M10A then could be within the direct path of a brine plume for only half its distance. A circular trawling pattern would keep the entire sample in the presumed path of discharge even though

it would be at a greater mean distance from the diffuser. The circular pattern trawling was thus employed at all stations, even in this pre-discharge phase. This difference in trawling pattern adds to the difficulty in making direct data comparisons to other studies.

Wohlschlag (1980) emphasizes the difference in day versus night trawling which makes comparisons of such trawls impossible.

No evidence has been found to suggest that other investigators have tried to quantify the effects of different size trawls; however, it should be apparent that comparisons of such data is at best approximate.

In general, these other studies suggest that depth is the greatest factor affecting community structure. Since the great majority of this study was in nine to ten meter water only, any direct comparisons are even more difficult.

6.4.1 Marine Study Area

In general, the offshore study area is quite homogeneous in both depth and substrate. The bottom slope is extremely gradual in this area. For example it is 12.9 km to station M22 from the diffuser, directly offshore. The depth changes from about ten meters to eleven meters.

While little relief in the bottom contour exists, the diffuser site does have a ridge of dredge material parallel to the diffuser. Generally, heterogeneity of ecosystems is positively correlated with diversity, but it is not clear if this area of irregularity would add to community diversity. Only in February did this site have larger samples (by weight) than the other stations. The number of species

collected at the diffuser site was not greater than the number from other stations in any month.

The homogeneity of the offshore study area is reflected in the cluster analyses. There were, generally, no distinctive clusters (see Figures 6-1 to 6-3). Since otter trawl samples are well known to be highly variable, the primary guideline for determining meaningful clusters was replicate sample clustering. No clusters were considered to be meaningful at similarity levels higher than that at which all replicates clustered. For example, in Figure 6-1 trawls M3A and M3B, as well as M10A and M10B, do not cluster until a similarity level of about 0.53. At this level everything is clustered. There are clusters at higher similarity levels but these must be ignored until all the replicates have clustered and sampling variability is eliminated. Using this guideline, the only dissimilar station was M22, the sole eleven meter station. Station M22 was only sampled in March and April, after it was learned that this station was part of the post-brine discharge sampling regime. M21, the inshore control station (four meters deep), clustered separately in March but not in April. All physical characteristics measured on the bottom were compared to the cluster results for possible ordination analyses or discriminate analyses. No station was significantly different from the others in physical characteristics (temperature, pH, salinity, and dissolved oxygen) so discriminate analyses were not performed. Thus depth is presumed to be the only measured variable that was significant.

The April data did show some clustering. As can be seen in Figure 6-3, all replicates clustered at a similarity level of 0.44, leaving three clusters. Cluster 1 was comprised of stations M1, M10, 11, 15, 18, 20, and DE. Cluster 2 included stations M3, 6, 9, 21, and DW, while station M22 clustered alone. Cluster 1 thus represents all the stations west of and including the diffuser plus the easternmost station. Cluster 2 included all the remaining stations east of the diffuser plus the four meter station, M21. Again, physical characteristics were examined to determine the efficacy of discriminate analyses and found to be essentially similar. Sediments at the various stations are different but the pattern of sediment distribution does not correspond to the clusters. This clustering was thus deemed to be an artifact.

The offshore species diversity indices (Tables 6-6 to 6-8) were also difficult to interpret. Diversity indices were measured on the basis of species weight or number of specimens. Both results were highly variable. Generally, species diversity (H') decreased each month of the study, although a few stations would increase in either March or April (but not both). On a weight basis H' ranged from 2.50-3.85 in February, 1.03-3.65 in March and 2.13-3.29 in April. Station M22 was the least diverse station in both March and April. It contained the fewest number of species and the fewest number of nekters each month. Total catch weight was high both months, but this was probably due to a greater number of large Arius felis caught at this location.

Station M21, the shallow water station, was the most diverse station in March, but not in April. The catch abundance, based on number of species, catch weight, or number of individuals was similar to the ten meter stations. This is contrary to the findings of Chittenden (1980) and Landry and Armstrong (1980). Both found abundance to be inversely related to depth. However, this station (M21) is shallower than those studied by either investigator.

It is difficult, if not impossible, to determine seasonal variation in distribution and abundance in a three month study. Abundance in this study increased each month on an individual and weight basis (Tables 6-2 to 6-4). This generally agrees with other studies. Workers generally found an abundance peak in summer and a minimum in winter. Spring levels were generally higher than fall levels. No trend in offshore or inshore movement has been detected at this time.

The cluster analysis for the whole study period (Figure 6-7) has three distinct clusters. These clusters represent the February, March, and April samples (See Figures 6-8, 6-9, and 6-10, respectively). The two clusters within the April data mentioned earlier (Figure 6-3) persist in this analysis. The station clusters are somewhat different than those seen in Figure 6-1, 6-2 and 6-3. This is because rare species (occurring in five or fewer trawls) were dropped in this analysis. This analysis indicates that monthly variations in trawl catch overshadow station variations. It further indicates the impossibility of using pre-brine discharge data to indicate impact in other months.

The high degree of variability seen in our marine trawls (Table 6-15) further points out the difficulty of using a small pre-brine discharge data base to help determine impact. Of the sixty-six trawls used to compute the mean weight given in Table 6-15 only seven fall within the 95% confidence interval. Statistically, the data in this table can only be compared to similarly obtained data from other years for the same period of time. Even if the time frame is shortened to one month, the data show a high degree of variability. In February and April only 36.4% of the samples fall within the 95% confidence limits of the mean. In March 86.4% of the stations were in the 95% confidence limits of the mean. However, this variability cannot be used to say that one set of samples is different from the others. As a guideline to comparing means of different sample sets, if the mean values, plus or minus two standard deviations, are overlapping, the samples cannot be considered as different. The wide range of variability seen in Table 6-15 all but precludes this type of analysis. Impact from brine disposal would have to be virtually catastrophic in order for us to detect it by using these criteria. The means, standard deviations, and confidence limits for the species in Table 6-16 reflect similar variability on the species level.

In lieu of this type of analysis, the best chance of detecting impact will be by using a multivariate analysis of variance and/or covariance. At this time our variables outnumber our observations and this test cannot be used. It will be employed in the post-discharge study, primarily for between station differences.

Another possibility for detecting impact is by seeing changes in the condition of our target species. Sufficient data have been collected to determine length versus weight linear regressions. Variations from those lines could help to determine any impact.

The short pre-discharge study did show that the ten meter stations are homogeneous. A persistent trend in captures of the more susceptible nekters may also be seen later, either by the multivariate analyses mentioned above or by scrupulous inspection of the data.

6.4.2 Estuarine Study Area

Station E3 could not be studied during February and March because of low water. Station E5 could not be studied in April due to bottom obstructions. These problems led to difficulties in characterizing the estuarine community.

Stations E1 and E5 are relatively deep water stations (approximately four meters) while stations E2, E3, and E4 are in shallow water (one to two meters). The salinities found at these stations indicate that salinities were lowest at E1 and highest at E5. Stations E3 and E4 were similar when they could both be sampled and E2 was intermediate between E1 and E4. Generally, salinity increased in a north to south direction rather than by distinctive bodies of water.

In February, cluster analysis (Figure 6-11) showed little similarity of stations (> 0.50 similarity). Stations E2 and E4 were close to that level, however. Stations E1 and E5 were more similar to each other than to E2 and E4. Bottom salinities at the four stations ranged from 9.5 ‰ at E1 to 15.5 ‰ at E2 to 19.5 ‰ at

E4 and 21.0 ‰ at E5. This apparently did not affect the clusters. By clustering again and dropping all species with no more than one occurrence, the species list for these stations dropped from 25 to 12. Nevertheless, the clusters remained the same. Discriminate analyses could show no relationship to any physical parameter with the possible exception of depth.

March clustering (Figure 6-12) showed sites E2 and E4 to be quite similar (0.73). In April stations E3 and E4 clustered at the 0.72 level and stations E1 and E2 clustered at the 0.52 level (Figure 6-13). For both months clustering was somewhat related to salinity. The relationship is not altogether clear. In March stations E1, E2, E4, and E5 had salinities of 14, 17, 19.5 and 30 ‰ respectively. In April these stations had salinities of 17.5, 19.5, 25.5 and 25.5 ‰ respectively. The data are too sketchy to make any definite predictions. This study period, particularly March and April, was somewhat unusual due to lack of rain. Salinities generally increased each month.

Species diversity indices (Tables 6-21 to 6-23) showed little change from February to March. However H' and PIE rose in April while evenness declined. This is probably due primarily to the development of the penaeid shrimp in the estuary.

Abundance, measured by number of species, number of specimens or catch weight, rose each month at all stations (Tables 6-18 to 6-20).

6.4.3 Species Discussion

Of the 80 species collected, 49 were caught in the estuary (Table 6-17) and 69 were caught in the Gulf (Table 6-1). Thus, 11 species

were caught only in the estuary and 31 species were caught only in the Gulf.

6.4.3.1 Penaeidae

No shrimp were caught in the estuary during February. In March a total of 153 white shrimp were caught in the estuary. The size ranged from 20-123 mm with a 51.4 mm mean. Total weight was 375 g. Only one brown shrimp (99 mm) was caught. In April 400 white shrimp were caught in the estuary; total weight was 6.6 kg. The size range was 90-170 mm with a 127.5 mm mean. The brown shrimp also showed up in April; 5980 were caught weighing 10.0 kg. The size ranged from 25-130 mm with a 62.0 mm mean length.

The brown shrimp catch in the Gulf increased from eight in February to seventeen in March to twenty-one in April. The size also increased from a mean of 87 mm in February to 93 mm in March and 114 mm in April. This was a fairly rare catch however; the brown shrimp did not move out of the estuaries until May.

It is difficult to assess movement of white shrimp. In Calcasieu Lake the catch increased each month and the shrimp increased in size. This trend was to continue until May when the concentration of both white and brown shrimp was drastically reduced. Our May sampling occurred after a two day shrimping season in Calcasieu Lake. The heavy fishing pressure, along with presumed offshore migrations probably caused this change in estuarine community structure. During February marine sampling, Penaeus setiferus was the most prevalent nekter by weight and ranked third in numerical abundance. A total of

10.81 kg were collected comprised of 693 individuals. The size ranged from 50-195 mm and the mean length was 127 mm. A total of 153 white shrimp weighing 4.3 kg were collected in marine waters during March. They ranked tenth in numerical abundance. The mean length was 150.5 mm with a range of 100-194 mm. In April 273 white shrimp weighing 9.7 kg were caught. The length ranged from 130-190 mm with a mean of 151 mm.

6.4.3.2 Brevoortia patronus

The only species of Brevoortia collected was Brevoortia patronus. Brevoortia gunteri is known to occur in this area but is fairly rare. In February, 419 were collected in the estuary weighing 1284 g. The weights ranged from 0.1 g to 18.3 g with a mean of 6.43 g. Lengths ranged from 21 mm to 95 mm with a mean of 64.0 mm. In March 138 were collected weighing 697 g. The weights ranged from 0.1 g to 14.7 g. with a mean of 5.0 g. The lengths ranged from 23 mm to 99 mm with a mean of 63.9 mm. In April 135 menhaden were collected weighing 264 g. Weights ranged from 0.3 g to 32.5 g and the mean was 2.4 g. Lengths ranged from 25 mm to 121 mm with a mean value of 41.1 mm. In the marine environment in February, 52 specimens were collected weighing 602 g. Weights ranged from 3.0 g to 32.0 g with a mean of 11.5 g. Lengths ranged from 60 mm to 115 mm with a mean of 84.1 mm. In March only three specimens were caught weighing a total of 66 g. In April, 15 specimens were collected weighing a total of 474 g. Weights ranged from 21 g to 43 g with a 31.9 g mean. Lengths ranged from 97 mm to 124 mm with a 109.1 mm mean. Overall the length versus weight regression for this species was: $\text{Log}_{10} \text{ Wt} = -4.504 +$

2.877 Log_{10} S.L. (S.L. = standard length), R (the correlation coefficient for this regression) = 0.954. This is based on the 357 fish that were aliquoted.

6.4.3.3 Sciaenidae

Of the eleven species of sciaenids that were captured, sufficient specimens were captured to analyze nine species.

6.4.3.4 Cynoscion nebulosus

Although only seven specimens of this species were captured, data will be included because of the commercial importance of this species. Two specimens were caught in February, one at station E1 and one at station E5. In April five specimens were caught, one at E1 and four at E2. The size range was 110 mm to 175 mm with a mean of 153.6 mm. Weights ranged from 17.5 g to 72.1 g with a mean of 47.3 g. The length versus weight correlation was: $\text{Log}_{10} \text{ Wt} = -4.606 + 2.862 \text{ Log}_{10} \text{ S.L.}$, $R = 0.912$. This catch was not indicative of the presence of this species. This species is pelagic and highly motile and trawl avoidance is probably a major factor accounting for low abundance. Post-brine disposal study use of a gill net has resulted in many more specimens being collected.

6.4.3.5 Pogonias cromis

One small black drum was captured in the estuary in February and 14 large black drum were captured in the Gulf during March. The marine specimens were in spawning condition and apparently heading into deep water to spawn. Overall, black drum lengths ranged from 220 mm to 740 mm with a mean of 577 mm. Weights ranged from 333.5 g to 6.81 kg with a mean of 4228 g. The length versus weight regression was $\text{Log}_{10} \text{ Wt} = -3.599 + 2.602 \text{ Log}_{10} \text{ S.L.}$, $R = 0.970$.

6.4.3.6 Micropogonias undulatus

The Atlantic croaker was the most abundant species collected in Calcasieu Lake and was prevalent in the Gulf as well. Collections were larger, both in the estuary and in the Gulf, each month. In April 7266 specimens weighing 40.993 kg were collected in the estuary and 1521 specimens weighing 15.508 kg were collected in the Gulf. The mean size decreased in both areas each month indicating offshore recruitment of recently spawned juveniles from Calcasieu Lake. The addition of stations M22, and M21 in particular, makes direct correlation of monthly statistics somewhat difficult. For example, in March the average weight of all 144 croakers caught in the Gulf was 13.3 g. But the average weight of the 106 croakers caught at station M21 was 3.58 g. Overall, 1623 croakers were individually measured. The lengths ranged from 15 mm to 170 mm with a mean length of 64.2 mm. The weights ranged from 0.1 g to 105.4 g with a mean of 8.24 g. The length versus weight regression was $\text{Log}_{10} \text{ Wt} = -4.639 + 2.977 \text{ Log}_{10} \text{ S.L.}$, $R = 0.978$.

6.4.3.7 Cynoscion arenarius and Cynoscion nothus

Cynoscion arenarius is generally considered to be the inshore counterpart of Cynoscion nothus. The general concensus among biologists is that both species share the same niche but are separated by depth (Hoese and Moore, 1977). Our sampling depth (approximately 10 m) seems to be an area of overlap. Hoese and Moore (1977) report 8-12 m to be the depth of overlap. However, at station M21, depth four meters, in March, 57 C. arenarius were caught and 38 C. nothus.

In April, at this station, six C. arenarius were caught and 331 C. nothus. Apparently this question is not completely settled.

Only 35 C. arenarius were collected in Calcasieu Lake, two in March and the rest in April. Only one C. nothus was collected in the estuary. C. arenarius is known to frequent the estuaries in the summer months but their tolerance for cold is apparently low (Vetter, 1977) so that they leave the estuaries for deeper water in winter. C. nothus is uncommon in estuaries. The C. arenarius collected in the estuary were all small. The range of weights was 0.1 g to 22.8 g with a mean of 2.8 g. C. arenarius captured in the Gulf ranged from 0.5 g to 314.5 g with a mean of 24.5 g. The sole estuarine C. nothus weighed 9 g.

For Cynoscion arenarius, 1131 individual weights and lengths were measured. The weights ranged from 0.1 g to 314.5 g with a mean of 23.8 g. The lengths ranged from 20 mm to 245 mm with a mean of 103.3 mm. The length versus weight relationship was $\text{Log}_{10} \text{ Wt} = -4.777 + 2.989 \text{ Log}_{10} \text{ S.L.}$, $R = 0.974$. For Cynoscion nothus, 2639 individuals were measured. The weights ranged from 1.0 g to 93.1 g with a mean of 7.51 g. The lengths ranged from 40 mm to 185 mm with a mean of 71.3 mm. The length versus weight relationship was $\text{Log}_{10} \text{ Wt} = -3.966 + 2.579 \text{ Log}_{10} \text{ S.L.}$, $R = 0.942$.

6.4.3.8 Menticirrhus americanus

Menticirrhus americanus was the only species of Menticirrhus positively identified in this study. A student identified twenty Menticirrhus littoralis from the Gulf in February but the sample was disposed of before this identification could be verified.

Menticirrhus littoralis is known to be almost entirely a surf species and its appearance in our trawls would be most unlikely. Data on the suspect species have been ignored. M. americanus was about the fourth most abundant species, by weight, in Gulf samples for the sampling period. Mean weight increased each month as did total weight of the catch but number collected and mean length varied. Combining all three monthly catches, the weights of 568 specimens ranged from 2.0 g to 436.8 g with a mean of 82.7 g. The lengths ranged from 45 mm to 275 mm with a mean of 148.4 mm. The length versus weight regression was $\text{Log}_{10} \text{ Wt} = -4.654 + 2.967 \text{ Log}_{10} \text{ S.L.}$, $R = 0.983$.

6.4.3.9 Leiostomus xanthurus

This is a fairly ubiquitous species captured on all cruises. Only six specimens were captured in Calcasieu Lake during February and two during March but 185 were collected there in April. Again, this species is known to escape estuaries during the colder months. No particular trend was seen for L. xanthurus collected in the Gulf except growth. Altogether, 433 specimens were measured. The weights ranged from 1.8 g to 114.4 g with a mean of 34.9 g. The lengths ranged from 42 mm to 215 mm with a mean of 102.4 mm. The length versus weight regression was $\text{Log}_{10} \text{ Wt} = -4.819 + 3.109 \text{ Log}_{10} \text{ S.L.}$, $R = 0.983$.

6.4.3.10 Larimus fasciatus

A single two gram specimen of banded croaker was collected in the Lake. In the Gulf, 295 specimens were collected. This species is a shallow water inhabitant that rarely enters the estuaries (Hoese and

Moore, 1977)). This species is of no commercial importance and little is known of its life history. Of the 296 specimens collected, the weights ranged from 0.7 g to 17.5 g with a mean of 5.2 g. Lengths ranged from 30 mm to 82 mm with a mean of 53.6 mm. The length versus weight relationship for this species was $\text{Log}_{10} \text{ Wt} = -3.990 + 2.693 \text{ Log}_{10} \text{ S.L.}$, $R = 0.936$.

6.4.3.11 Stellifer lanceolatus

Most of the star drum were collected in the Gulf, but fifteen were collected at station E5 in March. Station E5 is within the Calcasieu Pass jetties and is more a marine station than an estuarine station. Only sixteen star drum were collected offshore in March. In February, 123 were collected and in April, 450. This fish is so common that collecting only sixteen seems unlikely. However, the randomness of trawl collections could certainly account for this variation. It is also possible that this species moves into deeper water during winter and the increasing monthly collections indicate a return to shallow water. In all, 276 members of this species were individually weighed and measured. Weights ranged from 1.5 g to 34.5 g with a mean of 11.1 g. Lengths ranged from 43 mm to 110 mm with a mean of 73.3 mm. The length versus weight relationship for this species was $\text{Log}_{10} \text{ Wt} = -4.016 + 2.692 \text{ Log}_{10} \text{ S.L.}$, $R = 0.895$. This species is generally found over mud bottoms and Louisiana is considered to be the center of its distribution. This species is not commercially important at present.

Cluster analysis by species distribution resulted in only ubiquitous species showing persistent clustering (See Figures 6-4 to

6-6 and 6-14 to 6-16). No species clustered for even two months in the estuary area above a 0.67 similarity index. In marine waters, two persistent clusters were uncovered. Cynoscion nothus, the sand trout, Urophycis floridamus, the southern hake, and Lolliguncula brevis, the thumbstall squid, all had a 0.84 similarity index each month. In addition, Prionotus tribulus, the bighead sea robin and Citharichthys spilopterus, the bay whiff, clustered together each month. The similarity indices were 0.84, 0.63, and 0.75 in February, March, and April, respectively. Very little can be said of these relationships because of the short duration of the study and the ubiquitous distribution of those species. If this clustering persists in future months, the relationships will be more thoroughly investigated.

An examination of the percentage abundance results (Tables 6-9 to 6-14 and 6-23 to 6-28) revealed no noticeable trends associating certain species with particular stations.

6.5 Conclusions

1. The marine study area is quite homogeneous and all nekton community structures are essentially alike at the 10 m contour.
2. The species composition at marine stations is characteristic of the white shrimp community described in previous studies.
3. The nekton communities at station M21 and in particular at station M22 were noticeably different from those at the 10 m contour. This difference was most likely due to depth differences.
4. Differences among estuarine station community structures do not correlate to any physical variables.

CHAPTER 7

PHYTOPLANKTON

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7.1 Introduction

In a grazing ecosystem, energy flow begins with the photosynthetic organisms known as the primary producers. In aquatic and marine habitats this important community of organisms is known as the phytoplankton. Any disruption in the structure or function of this community may potentially damage the entire food web. It is the purpose of the present study to characterize this important community in an offshore area near Calcasieu Pass, Louisiana and in an estuarine area known as Calcasieu Lake, Louisiana. This task may be accomplished by investigating community function (primary productivity), biomass, numerical abundance, and community structure (species composition and diversity). Although there are several approaches, a few simple techniques were selected to render our short term study compatible with similar investigations in the Gulf of Mexico. It was believed that measurements of pigment, namely chlorophyll-a, was a suitable method to generate data on the relative biomass of the phytoplankton community. Numerical abundance and species composition were used as indicators of biomass and to generate species diversity indices. Because of the brevity of this investigation, comparisons of our data with that from other studies should strengthen the usefulness of this study for baseline purposes.

7.2 Materials and Methods

7.2.1 Field Procedures

Monthly phytoplankton samples were collected at eleven marine stations and five estuarine stations, Figures 7-1 and 7-2. The dates for the marine cruises are February 4, 1981, March 3, 1981, April 1, 1981 and for the estuarine cruises February 12, 1981 March 10, 1981 and April 7, 1981. Collections at M21 and M22 were initiated on the March cruise. 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 replicates 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 E2, E3, and E4. At these stations near surface and bottom readings were recorded.

7.2.2 Laboratory Procedures

Water samples were analyzed in the laboratory for chlorophyll-a, phaeopigment, phytoplankton number and dominant organisms. Pigment extractions were accomplished by mechanically grinding the samples and

FIGURE 7-1 LOCATION OF MARINE SAMPLING STATIONS

FIGURE 7-2 LOCATION OF ESTUARINE SAMPLING STATIONS

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 Fluorometer 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. & M. Peragallo (1897-1908), Kofoed 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).

7.3 Results

7.3.1 Marine

7.3.1.1 Physical Parameters

The physical parameters measured in conjunction with the phytoplankton cruises were salinity, temperature, dissolved oxygen, and pH using a Hydrolab Series 8000 meter. Salinity was measured as conductivity and converted to parts per thousand (‰) using a calibration curve. The values for salinity at each station and monthly cruise are presented in Table 7-1. The lowest salinity recorded was 29.0 ‰ in the surface waters at station M21 on March 3, 1981. The highest value was 35.0 ‰ in the bottom waters at station M22 on March 31, 1981. The mean values in the surface waters were 32.45 ‰ for February, 29.79 ‰ for March and 31.87 ‰ for April. The mean values in the bottom samples were 32.48 ‰ for February, 30.82 ‰ for March and 32.38 ‰ for April.

Temperature was measured with a thermal probe. The values for temperatures at each station and monthly cruise are presented in Table

Table 7-1. Salinity (‰) values for each marine station and monthly cruise.

		Stations										
Month		<u>M1</u>	<u>M3</u>	<u>M6</u>	<u>M9</u>	<u>M10</u>	<u>M11</u>	<u>M15</u>	<u>M18</u>	<u>M20</u>	<u>M21</u>	<u>M22</u>
February	*S	32.5	32.5	32.5	32.0	32.5	32.8	32.5	32.5	32.3	----	----
	**B	32.5	32.5	32.5	32.0	32.5	32.8	32.5	32.5	32.5	----	----
March	S	29.8	29.8	29.9	29.5	29.8	30.1	29.8	29.8	30.0	29.0	30.2
	B	30.8	30.6	31.3	30.8	30.9	30.7	31.2	30.2	31.0	29.0	32.5
April	S	32.0	32.1	32.0	31.2	31.7	31.8	31.7	31.7	31.7	30.7	34.0
	B	32.8	32.5	32.5	32.0	32.0	32.5	32.0	32.1	32.0	30.8	35.0

*S = Surface

**B = Bottom

7-2. The lowest temperature recorded was 10.9°C at most of the stations in February, and the highest temperature recorded was 19.7°C in the surface waters at station M21 on March 31, 1981. The mean value in the surface waters was 10.98°C for February, 14.68°C for March, and 18.90°C for April. The mean values in the bottom samples were 10.97°C for February, 12.86°C for March, and 17.95°C for April.

Dissolved oxygen was measured with a membrane dissolved oxygen probe in ml l^{-1} . The values for dissolved oxygen at each station and monthly cruise are presented in Table 7-3. The lowest value recorded was 2.66 ml l^{-1} in the bottom sample at station M9 on March 3, 1981, and the highest value was 5.80 ml l^{-1} in the surface waters at station M11 on February 4, 1981. The means for dissolved oxygen in surface samples were 5.58 ml l^{-1} for February, 5.56 ml l^{-1} for March, and 4.74 ml l^{-1} for April. The mean values in the bottom samples were 5.56 ml l^{-1} for February, 3.87 ml l^{-1} for March, and 4.12 ml l^{-1} for April.

The pH was measured direct with the Kahlsico Hydrolab Series 8000. The values at each station and monthly cruise are presented in Table 7-4. The lowest value recorded was 7.60 at station M9 on March 3, 1981, and the highest value of 8.33 at station M22 on April 1, 1981. The mean pH values in the surface waters were 8.22 for February, 8.12 for March and 8.22 for April. The mean pH values in the bottom samples were 8.22 for February, 7.85 for March and 8.16 for April.

Table 7-2. Temperature (°C) values for each marine station and monthly cruise.

		Stations										
Month		<u>M1</u>	<u>M3</u>	<u>M6</u>	<u>M9</u>	<u>M10</u>	<u>M11</u>	<u>M15</u>	<u>M18</u>	<u>M20</u>	<u>M21</u>	<u>M22</u>
February	*S	11.0	10.9	10.9	10.9	11.0	11.3	10.9	11.0	10.9	---	---
	**B	11.0	10.9	10.9	10.9	10.9	11.3	10.9	11.0	10.9	----	----
March	S	14.6	14.6	14.6	14.8	14.7	14.3	14.7	14.8	14.7	15.2	14.5
	B	12.7	12.8	12.2	12.8	12.6	12.9	12.3	12.6	12.4	15.2	13.0
April	S	18.5	18.5	18.4	19.5	19.4	19.5	18.7	18.9	18.6	19.7	18.2
	B	17.4	17.5	17.6	18.1	18.1	18.0	17.8	18.1	18.7	18.9	17.2

*S = Surface

**B = Bottom

Table 7-3. Dissolved oxygen (ml l^{-1}) values for each marine station and monthly cruise.

		Stations										
Month		<u>M1</u>	<u>M3</u>	<u>M6</u>	<u>M9</u>	<u>M10</u>	<u>M11</u>	<u>M15</u>	<u>M18</u>	<u>M20</u>	<u>M21</u>	<u>M22</u>
February	*S	5.80	5.50	5.50	5.50	5.50	5.80	5.50	5.50	5.60	----	----
	**B	5.60	5.70	5.50	5.50	5.50	5.70	5.50	5.60	5.70	----	----
March	S	5.60	5.72	5.66	5.43	5.54	5.72	5.60	5.54	5.60	5.20	5.54
	B	3.35	3.00	2.94	2.66	3.58	4.39	3.07	4.13	4.62	5.31	5.49
April	S	4.79	4.67	4.67	4.92	4.95	5.12	4.71	4.61	4.36	4.29	5.06
	B	4.34	4.24	4.31	3.69	3.80	3.80	3.85	4.07	4.24	4.17	4.76

*S = Surface

**B = Bottom

Table 7-4. pH values for each marine station and monthly cruise.

		Stations										
Month		<u>M1</u>	<u>M3</u>	<u>M6</u>	<u>M9</u>	<u>M10</u>	<u>M11</u>	<u>M15</u>	<u>M18</u>	<u>M20</u>	<u>M21</u>	<u>M22</u>
February	*S	8.27	8.24	8.20	8.26	8.20	8.30	8.20	8.20	8.10	-----	-----
	**B	8.28	8.24	8.20	8.26	8.20	8.30	8.20	8.20	8.10	-----	-----
March	S	8.15	8.14	8.15	8.12	8.12	8.15	8.12	8.13	8.10	8.06	8.15
	B	7.80	7.71	7.72	7.60	7.84	7.90	7.75	7.90	7.90	8.06	8.15
April	S	8.23	8.24	8.18	8.25	8.25	8.30	8.17	8.14	8.05	8.16	8.33
	B	8.22	8.20	8.21	8.14	8.13	8.19	8.10	8.08	8.06	8.16	8.31

*S = Surface

**B = Bottom

7.3.1.2 Species Composition and Relative Abundance

There were 110 taxa of phytoplankton identified during this study. The diatoms and dinoflagellates were the predominant groups present in the assemblage. Thirty-six (36) genera and eighty-one (81) species of diatoms were identified, and nine (9) genera and fifteen (15) species of dinoflagellates were identified. Among the minor members of the assemblage, two cryptophytes, two euglenoids, eight greens and four blue-greens were identified. A systematic list of all species identified in this study is presented in Table 7-5.

The most frequently encountered taxa were species of Prorocentrum, Coscinodiscus, Skeletonema, Thalassiosira, Biddulphia, Chaetoceros, Rhizosolenia, Asterionella, Navicula, Nitzschia, and Thalassiothrix (see Appendix Table E-1). This assemblage is indicative of the saline Gulf waters and species of these organisms were found during all three months of the study, (Werner, 1977). A number of species were considered rare for this study because these were found to be less than 1% of the total number of organisms for a given month. These are presented in Table 7-6. Of these, Dinophysis caudata, Ceratium furca, Bellerochea horologicalis and Grammatophora marina were found only once.

The dominant phytoplankton species based the percentage of the total number of organisms, monthly cruise and position in the water column are presented in Table 7-7. The mid and late winter community was dominated by three diatoms, Navicula distans, Skeletonema costatum, and Pleurosigma formosum and supported by four minor species, Thalassiosira decipiens, Asterionella glacialis, Cerataulina

Table 7-5. 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
Prorocentrum gracile

Gymnodiniaceae

Gymnodinium splendens
Gymnodinium sp.

Noctilucaeae

Noctiluca scintillans

Dinophysiaceae

Dinophysis caudata
Dinophysis ovum

Peridinaceae

Peridinium sp.
Oxytoxum scolopax

Gonyaulaceae

Gonyaulax sp.

Ceratiaceae

Ceratium furca
Ceratium trichoceros
Ceratium tripos
Ceratium tripos var. atlantica

Pyrophacaceae

Pyrophacus horologium

Chlorophyta

Chlamydomonadaceae

Chlamydomonas sp.

Pedinomonadaceae

Heteromastix pyriformis

Pyramimonaceae

Pyramimonas sp.

Tetraselmiaceae

Tetraselmis sp.

Oocystaceae

Ankistrodesmus sp.
Oocystis sp.

Scenedesmaceae

Scenedesmus sp.

Table 7-5. (continued)

Euglenophyta

Euglenaceae

Euglena sp.
Eutrephia sp.

Cryptophyta

Cryptochrysidaceae

Chroomonas sp.
Cryptomonas sp.

Chrysophyta

Coscinodiscaceae

Actinopterychus undulatus
Coscinodiscus centralis
Coscinodiscus excentricus
Coscinodiscus radiatus
Coscinodiscus wailesii
Coscinodiscus sp.
Cyclotella sp.
Melosira distans
Melosira granulata
Melosira moniliformis
Skeletonema costatum
Skeletonema tropicum
Stephanopyxis palmeriana
Thalassiosira decipiens
Thalassiosira subtilis

Biddulphiaceae

Bellerrochea horologicalis
Biddulphia alternans
Biddulphia mobiliensis
Biddulphia sinesis
Cerataulina pelagica
Ditylum brightwellii
Eucampia cornuta
Eucampia zodiacus
Hemiaulus hauckii
Lithodesmium undulatum
Streptotheca thamensis

Chaetoceraceae

Chaetoceros affinis
Chaetoceros brevis
Chaetoceros coarctatus
Chaetoceros compressus
Chaetoceros curvisetus
Chaetoceros decipiens
Chaetoceros didymus
Chaetoceros lorenzianus

Table 7-5. (continued)

	<u>Chaetoceros peruvianus</u>
	<u>Chaetoceros socialis</u>
	<u>Chaetoceros subtilis</u>
	<u>Chaetoceros</u> sp.
Bacteriastraceae	<u>Bacteriastrum delicatulum</u>
	<u>Bacteriastrum</u> sp.
Leptocylindraceae	<u>Leptocylindrus danicus</u>
Rhizosoleniaceae	<u>Guinardia flaccida</u>
	<u>Rhizosolenia alata</u>
	<u>Rhizosolenia alata</u> f. <u>indica</u>
	<u>Rhizosolenia calcar-avis</u>
	<u>Rhizosolenia castracanei</u>
	<u>Rhizosolenia delicatula</u>
	<u>Rhizosolenia imbricata</u>
	<u>Rhizosolenia robusta</u>
	<u>Rhizosolenia setigera</u>
	<u>Rhizosolenia stolterfothii</u>
Fragilariaceae	<u>Asterionella glacialis</u>
	<u>Campylosira cymbelliformis</u>
	<u>Synedra</u> sp.
Tabellariaceae	<u>Grammatophora marina</u>
	<u>Thalassionema nitzschioides</u>
	<u>Thalassiothrix mediterranea</u>
	var. <u>pacifica</u>
	<u>Thalassiothrix frauenfeldii</u>
Naviculaceae	<u>Amphiprora gigantea</u>
	<u>Amphiprora</u> sp.
	<u>Anomoeoneis</u> sp.
	<u>Diploneis smithii</u>
	<u>Diploneis weissflogii</u>
	<u>Gyrosigma balticum</u>
	<u>Gyrosigma</u> sp.
	<u>Navicula distans</u>
	<u>Navicula</u> sp.
	<u>Pleurosigma formosum</u>
	<u>Pleurosigma normali</u>
	<u>Pleurosigma</u> sp.
	<u>Stauroneis membranacea</u>
	<u>Stauroneis</u> sp.

Table 7-5. (continued)

Bacillariaceae

Cylindrotheca sp.
Nitzschia closterium
Nitzschia longissima
Nitzschia paradoxa
Nitzschia pungens
 var. atlantica
Nitzschia seriata
Nitzschia sigma
Nitzschia subfraudulenta

Surirellaceae

Surirella fastuosa

Table 7-6. Species of phytoplankton found to be less than 1% of the total number of organisms for a given month.

Dinophysis caudata
Ceratium furca
Ceratium trichoceros
Ceratium tripos
Skeletonema tropicum
Thalassiosira subtilis
Bellerophora horologicalis
Biddulphia alternans
Grammatophora marina*
Nitzschia subfraudulenta

*Attached to thallus of Polysiphonia

Table 7-7. Dominant species of phytoplankton for each monthly marine cruise.

Month	<u>Surface</u>	<u>Bottom</u>
February	<u>Navicula distans</u> (30.39)*	<u>Skeletonema costatum</u> (29.12)
	<u>Skeletonema costatum</u> (27.49)	<u>Navicula distans</u> (27.38)
	<u>Pleurosigma formosum</u> (6.82)	<u>Pleurosigma formosum</u> (7.98)
	<u>Thalassiosira decipiens</u> (3.67)	<u>Cerataulina pelagica</u> (2.83)
	<u>Asterionella glacialis</u> (3.13)	<u>Asterionella glacialis</u> (2.80)
	<u>Rhizosolenia delicatula</u> (1.90)	<u>Chaetoceros decipiens</u> (2.07)
	<u>Hemiaulus hauckii</u> (1.09)	<u>Thalassiosira decipiens</u> (1.81)
		<u>Rhizosolenia delicatula</u> (1.08)
March	<u>Skeletonema costatum</u> (77.01)	<u>Skeletonema costatum</u> (64.08)
	<u>Cerataulina pelagica</u> (7.03)	<u>Rhizosolenia alata</u> (6.48)
	<u>Asterionella glacialis</u> (2.54)	<u>Cerataulina pelagica</u> (5.45)
		<u>Navicula distans</u> (4.45)
		<u>Asterionella glacialis</u> (4.25)
April	<u>Prorocentrum compressum</u> (31.03)	<u>Navicula distans</u> (38.56)
	<u>Thalassiosira decipiens</u> (15.55)	** <u>Skeletonema costatum</u> (17.98)
	<u>Coscinodiscus radiatus</u> (13.69)	** <u>Rhizosolenia setigera</u> (15.25)
	<u>Navicula distans</u> (8.81)	<u>Thalassiosira decipiens</u> (10.75)
	<u>Coscinodiscus centralis</u> (4.50)	<u>Coscinodiscus radiatus</u> (9.51)
	<u>Nitzschia longissima</u> (2.48)	** <u>Leptocylindrus danicus</u> (4.98)
	<u>Melosira distans</u> (2.10)	** <u>Cerataulina pelagica</u> (4.57)
	<u>Coscinodiscus wailesii</u> (1.52)	<u>Nitzschia seriata</u> (4.37)
	<u>Skeletonema costatum</u> (1.33)	<u>Chaetoceros affinis</u> (2.37)
	<u>Chaetoceros affinis</u> (1.22)	<u>Melosira distans</u> (2.09)
		<u>Nitzschia pungens</u> (1.52)
		<u>Nitzschia sigma</u> (1.52)
		<u>Rhizosolenia alata</u> (1.20)
		<u>Coscinodiscus wailesii</u> (1.08)
		<u>Pleurosigma normale</u> (1.04)

*Number in parenthesis represents percentage of total number of individuals.

**Dominance result of density at single station (M22).

pelagica, and Rhizosolenia alata. The most notable event of this period was the bloom of Skeletonema costatum found on the March 3, 1981 cruise. The early spring surface community was dominated by three major taxa, Prorocentrum compressum, Thalassiosira decipiens, and Coscinodiscus radiatus, and enriched by several minor taxa, notably, Navicula distans, Coscinodiscus centralis, and Nitzschia longissima. The dominance by the dinoflagellate, P. compressum, correlates well with the seasonal warming trend of the surface waters. The surface waters apparently contained a large population of nanoplankton (10-20 μ m). This population was not enumerated but its influence can be seen in the chlorophyll data presented elsewhere in this report. The bottom community in the early spring was very diverse but consisted of five major taxa, Navicula distans, Skeletonema costatum, Rhizosolenia setigera, Thalassiosira decipiens, and Coscinodiscus radiatus. There was a large group of minor species and the most notable were Leptocylindrus danicus, Cerataulina pelagica and Nitzschia seriata. Four species, Skeletonema costatum, Rhizosolenia setigera, Leptocylindrus danicus, and Cerataulina pelagica, were considered important members of this community even though their presence was due to an unusual density at a single station (M22).

7.3.1.3 Pigment Analysis

The mean chlorophyll values for each station and monthly cruise are given in Table 7-8. The lowest value for the study period was 0.26 mg m^{-3} at station M22 on March 3, 1981. The highest value was 8.74 mg m^{-3} at station M9 on April 1, 1981. The grand mean

Table 7-8. Mean chlorophyll-a (mg m^{-3}) values for each marine station and monthly cruise.

		Stations										
Month		<u>M1</u>	<u>M3</u>	<u>M6</u>	<u>M9</u>	<u>M10</u>	<u>M11</u>	<u>M15</u>	<u>M18</u>	<u>M20</u>	<u>M21</u>	<u>M22</u>
February	*S	2.07	2.08	2.57	2.14	1.41	1.58	1.66	1.69	1.18	----	----
	**B	2.08	2.23	1.97	2.05	1.24	1.37	1.50	1.20	1.01	----	----
March	S	1.05	2.45	2.82	3.79	2.29	2.10	2.23	1.58	2.25	----	0.21
	B	1.17	1.54	1.92	2.33	2.07	0.68	1.76	1.35	0.94	----	----
April	S	2.93	3.68	4.51	8.74	4.36	6.80	2.25	2.70	2.18	1.24	0.26
	B	0.19	0.45	0.29	0.90	1.39	0.44	0.96	0.70	0.98	0.30	0.70

*S = Surface

**B = Bottom

values in the surface sample were 1.75 mg m⁻³ for February, 2.25 mg m⁻³ for March and 3.60 mg m⁻³ for April. The grand mean value in the bottom samples was 1.70 mg m⁻³ for February, 1.53 mg m⁻³ for March and 0.66 mg m⁻³ for April. The mean phaeopigment values for each station and monthly cruise are given in Table 7-9. The lowest calculated value for the study was (-)0.28 mg m⁻³ at station M3 on February 4, 1981. The highest calculated value was 7.09 mg m⁻³ at station M9 on April 1, 1981. The grand mean values in the surface samples were 0.69 mg m⁻³ for February, 2.38 mg m⁻³ for March and 3.13 mg m⁻³ for April. The grand mean values for the bottom samples were 0.99 mg m⁻³ for February, 1.81 mg m⁻³ for March and 1.31 mg m⁻³ for April.

7.3.1.4 Species Diversity and Phytoplankton Density

Diversity is a mathematical measurement of the distribution of the population into subsets (species). The formula used was that of Shannon and Weaver (1949) and is referred to herein as the Shannon-Weaver information index (H'):

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

In February the H' value for the surface community was 2.13 and for the bottom samples it was 2.10. There was a sharp decline in these values, surface 0.80 and bottom 1.25, for the March cruise. The sharp decline was due to the dominance of the community by Skeletonema costatum. For April the H' values were 1.78 for the surface and 1.58 for the bottom communities. The distribution of these values can be seen in Table 7-10.

Phytoplankton densities were highest for March and lowest for

Table 7-9. Mean phaeopigment (mg m^{-3}) values for each marine station and monthly cruise.

		Stations										
Month		<u>M1</u>	<u>M3</u>	<u>M6</u>	<u>M9</u>	<u>M10</u>	<u>M11</u>	<u>M15</u>	<u>M18</u>	<u>M20</u>	<u>M21</u>	<u>M22</u>
February	*S	-0.35	-0.39	0.07	1.19	0.99	1.47	1.01	1.02	1.19	----	----
	**B	0.41	-0.28	1.13	1.02	1.05	1.56	0.99	1.51	1.51	----	----
March	S	1.05	1.50	2.29	2.85	2.76	2.16	2.37	3.35	3.07	----	0.44
	B	0.43	1.56	1.69	1.88	1.78	0.62	2.75	2.82	2.75	----	----
April	S	5.29	3.83	2.52	7.09	2.68	2.85	2.46	3.42	2.39	1.27	0.66
	B	1.13	0.63	0.64	2.30	2.01	1.03	2.15	1.12	1.56	0.69	1.14

*S = Surface

**B = Bottom

Table 7-10. Shannon-Weaver information index for each marine station and monthly cruise.

		Stations										
Month		<u>M1</u>	<u>M3</u>	<u>M6</u>	<u>M9</u>	<u>M10</u>	<u>M11</u>	<u>M15</u>	<u>M18</u>	<u>M20</u>	<u>M21</u>	<u>M22</u>
February	*S	2.12	2.15	2.07	2.23	2.19	2.59	1.89	1.92	2.09	----	----
	**B	2.04	2.10	1.98	1.97	2.08	2.40	2.10	2.28	1.98	----	----
March	S	0.71	0.91	0.71	0.68	1.00	0.98	0.72	0.72	0.78	----	----
	B	1.63	1.22	1.04	1.03	1.08	1.53	1.08	1.40	1.24	----	----
April	S	1.21	2.05	1.74	1.53	1.66	1.64	1.80	1.90	1.78	1.76	2.45
	B	1.57	1.64	1.18	1.47	1.45	1.37	1.47	1.45	1.52	1.79	2.50

*S = Surface

**B = Bottom

April. On February 4, 1981, the highest count was 50,000 organisms per liter at station M11 and the lowest was 11,000 organisms per liter at station M3. The grand mean for all surface stations was 21,000 organisms per liter and for all bottom samples 23,000 organisms per liter. On March 3, 1981, the highest count was 48,000 organisms per liter at M15 and the lowest was 4,000 organisms per liter at station M6. The grand mean for all surface stations was 33,000 organisms per liter and for all bottom samples 8,000 organisms per liter. On April 1, 1981, the highest count was 19,000 organisms per liter at M22 and the lowest was 1,500 organisms per liter at station M22. The grand mean for all surface stations was 2,600 organisms per liter and for all bottom samples 2,500 organisms per liter.

7.3.2 Estuarine Study

7.3.2.1 Physical Parameters

The depths at the estuarine stations varied from approximately one meter in West Cove, E3 to eight and one-half (8.5) meters in Calcasieu Pass, E-5. Temperatures were lowest in February with a mean of 6.7°C and warmed by April to a mean of 20.0°C, Table 7-11. The lowest water temperature recorded was 3.5°C on the February cruise, but this was an early morning reading with all others being warmer during the day. Salinities were always lowest at stations E1 and E2 and highest at station E5. The lowest salinity was 7.0 ‰ at E1 and highest 29.0 ‰ at E5 on March 10, 1981, Table 7-11. The dissolved oxygen values varied from saturation to moderately high, 4.30 ml l⁻¹, during the study period, Table 7-11. There was little variation in the recorded pH values, Table 7-11.

7.3.2.2 Species Composition and Relative Abundance

Table 7-11. Surface values for physical parameter at estuarine stations.

<u>month</u>	<u>station</u>	<u>temperature (°C)</u>	<u>salinity (‰)</u>	<u>DO(ml l⁻¹)</u>	<u>pH</u>
February	E1	7.5	12.0	7.12	7.5
	E2	9.0	13.0	6.40	7.5
	E3	3.5	21.0	7.72	7.7
	E4	5.1	23.5	6.92	8.0
	E5	7.9	29.0	6.38	7.9
March	E1	16.0	7.0	5.35	8.0
	E2	16.0	15.0	4.51	7.5
	E3	15.6	23.5	5.21	8.7
	E4	16.0	19.0	5.60	8.0
	E5	16.0	29.0	5.63	8.7
April	E1	20.0	19.0	4.33	7.2
	E2	20.0	17.0	3.94	7.1
	E3	19.0	24.0	4.59	7.5
	E4	20.0	23.0	4.00	7.5
	E5	20.0	25.0	4.24	7.0

The northernmost estuarine stations, E1 and E2, generally contained more freshwater species of phytoplankton than the more southern stations, E3, E4 and E5. The freshwater assemblage was primarily species of Anomoeoneis, Navicula, Melosira and Cyclotella. The most frequently encountered estuarine species Cerataulina pelagica, Nitzschia closterium, Asterionella glacialis, Rhizosolenia setigera, Skeletonema costatum, and various species of Chaetoceros. Station E5, located in Calcasieu Pass, also contained species of Pleurosigma, Prorocentrum, Ditylum, Coscinodiscus, and Thalassiosira.

7.3.2.3 Pigment Analysis and Organism Density

Chlorophyll values were generally higher in the surface waters on February 12, 1981 than during any other date of the study. At the surface stations the chlorophyll-a values ranged from a low of 1.69 mg m⁻³ during April to a high of 38.30 mg m⁻³ during February, Table 7-12. The grand mean values for chlorophyll at surface stations were 16.02 mg m⁻³ for February, 4.32 mg m⁻³ for March, and 4.85 mg m⁻³ for April. There was no apparent segregation of the northern stations (E1 and E2) from those in the southern part of the study area (E3, E4 and E5), Table 7-12. Phaeopigment values were high in all areas ranging from a low of 3.72 mg m⁻³ on April 7, 1981 to a high of 49.27 mg m⁻³ on February 12, 1981. The grand mean phaeopigment values at surface stations were 19.47 mg m⁻³ for February, 5.67 mg m⁻³ for March, and 7.33 mg m⁻³ for April, Table 7-13.

Organism density for the three monthly cruises varied considerably not only between stations but between monthly sampling

Table 7-12. Mean values for chlorophyll-a (mg m^{-3}) at estuarine stations.

<u>month</u>	<u>station</u>	<u>surface</u>	<u>bottom</u>
February	E1	10.47 $\pm$ 1.95*	18.79 $\pm$ 2.84
	E2	8.67 $\pm$ 1.08	
	E3	10.13 $\pm$ 1.60	
	E4	38.30 $\pm$ 6.66	
	E5	9.20 $\pm$ 0.67	10.73 $\pm$ 1.64
March	E1	5.07 $\pm$ 0.46	4.70 $\pm$ 0.53
	E2	2.44 $\pm$ 1.05	
	E3	3.57 $\pm$ 1.74	
	E4	6.01 $\pm$ 0.26	
	E5	4.51 $\pm$ 0.46	3.19 $\pm$ 0.26
April	E1	10.70 $\pm$ 2.01	8.46 $\pm$ 4.83
	E2	2.25 $\pm$ 0.46	
	E3	6.34 $\pm$ 0.53	
	E4	1.69 $\pm$ 0.00	
	E5	3.19 $\pm$ 0.53	2.25 $\pm$ 0.46

* $\pm$ one standard deviation

Table 7-13. Mean phaeopigment values (mg m^{-3}) at estuarine stations.

month	station	surface	bottom
February	E1	16.80 $\pm$ 1.61*	25.23 $\pm$ 4.83
	E2	6.87 $\pm$ 1.70	
	E3	15.13 $\pm$ 1.52	
	E4	49.27 $\pm$ 4.07	
	E5	9.30 $\pm$ 1.15	11.97 $\pm$ 3.40
March	E1	8.30 $\pm$ 2.28	10.27 $\pm$ 0.37
	E2	6.33 $\pm$ 1.80	
	E3	5.00 $\pm$ 0.75	
	E4	4.21 $\pm$ 1.03	
	E5	4.51 $\pm$ 0.33	3.19 $\pm$ 0.67
April	E1	14.09 $\pm$ 3.91	20.18 $\pm$ 1.95
	E2	4.66 $\pm$ 1.35	
	E3	9.09 $\pm$ 0.46	
	E4	3.72 $\pm$ 0.37	
	E5	5.07 $\pm$ 1.12	3.46 $\pm$ 0.39

* $\pm$ one standard deviation

periods, Table 7-14. The grand means for total organisms per liter were 183,240 per liter for February, 64,957 per liter for March, 45,746 per liter for April.

7.4 Discussion

7.4.1 Marine

7.4.1.1 Physical Data

The mean values for all the measured physical parameters in this study by cruise and position in the water column are presented in Table 7-15. The salinities in the study area remained stable during this study and there was no development of a strong vertical halocline. The dissolved oxygen (DO) and pH remained relatively stable throughout this study in both the surface and bottom waters, however there was a tendency in the last two sample periods, March 3 and April 1, for the bottom DO to decline. Both surface and bottom temperatures showed slight increases with each progressing month, but there was no development of a strong thermocline.

In summary, the values for the physical parameters were not unusual for nearshore waters in the Gulf of Mexico. All values for the water column indicate good vertical mixing and exchange between the surface and bottom waters throughout this study, Table 7-15.

7.4.1.2 Species Composition and Relative Abundance

Some of the important phytoplankton studies in the Gulf of Mexico include Balech (1967a and 1967b), Curl (1959), Freese (1952), Fucik and El-Sayed (1979), Housley (1976), Saunders and Glenn (1969), Simmons and Thomas (1962), Steidinger and Williams (1970), Wood

Table 7-14. Mean values, standard deviations for number of organisms per liter at estuarine stations.

<u>Station</u>	<u>February</u>	<u>March</u>	<u>April</u>
<u>E1</u>			
Mean	191771	26656	97078
S.D.	34574	3769	5812
Limits	156250-225312	24480-31008	90411-101079
<u>E2</u>			
Mean	63558	78438	4015
S.D.	12054	31936	1241
Limits	54478-77235	44063-107188	2667-5112
<u>E3</u>			
Mean	37124	60384	109586
S.D.	3689	10701	12468
Limits	33101-40342	50592-71808	101768-123965
<u>E4</u>			
Mean	497083	187971	9838
S.D.	50297	31096	894
Limits	464375-555000	168776-223849	8890-10668
<u>E5</u>			
Mean	126667	61005	12247
S.D.	17063	4804	2007
Limits	11500-146250	55491-64286	9961-13717

Table 7-15. Physical data for all marine stations.

		Month		
	<u>Parameter*</u>	<u>February</u>	<u>March</u>	<u>April</u>
Salinity ‰	<u>Surface</u>			
	Mean	32.45	29.79	31.87
	S.D.	0.20	0.30	0.77
	Limits	32.0 - 32.8	29.5 - 30.2	31.7 - 34.0
	<u>Bottom</u>			
	Mean	32.48	30.82	32.38
	S.D.	0.19	0.80	0.96
	Limits	32.0 - 32.8	29.0 - 32.5	30.8 - 35.0
Temperature °C	<u>Surface</u>			
	Mean	10.98	14.68	18.90
	S.D.	0.12	0.21	0.50
	Limits	10.9 - 11.3	14.3 - 15.2	18.2 - 19.7
	<u>Bottom</u>			
	Mean	10.97	12.86	17.95
	S.D.	0.12	0.78	0.50
	Limits	10.9 - 11.3	12.2 - 15.2	17.2 - 18.9
Dissolved oxygen ml l ⁻¹	<u>Surface</u>			
	Mean	5.58	5.56	4.74
	S.D.	0.12	0.14	0.25
	Limits	5.50 - 5.80	5.20 - 5.72	4.36 - 5.06
	<u>Bottom</u>			
	Mean	5.59	3.78	4.12
	S.D.	0.09	0.94	0.30
	Limits	5.50 - 5.70	2.66 - 5.49	3.80 - 4.76
pH	<u>Surface</u>			
	Mean	8.22	8.12	8.22
	S.D.	0.05	0.03	0.08
	Limits	8.10 - 8.30	8.06 - 8.15	8.05 - 8.33
	<u>Bottom</u>			
	Mean	8.22	7.85	8.16
	S.D.	0.05	0.15	0.08
	Limits	8.10 - 8.30	7.60 - 8.15	8.06 - 8.31

*values are means, +/- one standard deviation

1963), Wood (1968), and Zernova (1970). El-Sayed (1972) reviewed all the pertinent literature for the Gulf of Mexico.

The number of taxa reported for this study compares favorably with previous reports on species in neritic waters of the north central Gulf of Mexico. Our diatom association, consisting of species of Asterionella, Biddulphia, Chaetoceros, Coscinodiscus, Navicula, Nitzschia, Rhizosolenia, Skeletonema, Thalassiosira and Thalassiothrix, compares very well with other Spring diatom flora reported in the Gulf of Mexico. The pronounced dominance of Skeletonema costatum during March has been documented by Freese (1952) on the Texas coast, and Simmons and Thomas (1962) and Fucik and El-Sayed (1979) along the Louisiana coast. The river complex of Melosira, Cyclotella and Navicula reported by Simmons and Thomas (1962) in the Mississippi Delta region, never developed in our study area. The most frequently encountered dinoflagellate was Prorocentrum compressum which was also reported as abundant by Fucik and El-Sayed (1979) in their samples from Timbalier Bay, Louisiana. It should be noted that Fucik and El-Sayed's Exuvialla compressum was probably Prorocentrum compressum.

7.4.1.3 Pigment Analysis

The pigment values found during this study (Table 7-16) are within the range of values reported by El-Sayed (1973), Kamykowski et al (1977), Fucik and El-Sayed (1979) and Loeblich and Matthews (1980) for the Gulf of Mexico. El-Sayed (1973) reported that chlorophyll values off the coast of Louisiana were moderately high. Fucik and El-Sayed (1979) reported chlorophyll ranges in the vicinity of

Table 7-16. Grand mean values for pigments (mg m^{-3}) in samples taken in the marine study.

		Month		
		<u>February</u>	<u>March</u>	<u>April</u>
Chlorophyll-a	*Surface	1.75 +/- .40***	2.25 +/- .93	3.60 +/- 2.33
	Limits	1.18 - 2.57	0.21 - 3.79	0.26 - 8.74
	**Bottom	1.70 +/- .43	1.53 +/- .51	0.66 +/- .35
	Limits	1.01 - 2.23	0.68 - 2.33	0.19 - .98
Phaeopigment	*Surface	0.69 +/- .44	2.38 +/- .88	3.13 +/- 1.71
	Limits	-0.38 - 1.47	0.44 - 3.35	0.66 - 7.09
	**Bottom	0.99 +/- .43	1.81 +/- .83	1.31 +/- 0.58
	Limits	-0.28 - 1.51	0.43 - 2.82	0.63 - 2.30

*S = Surface

**B = Bottom

***values are means, +/- one standard deviation

Timbalier Bay, Louisiana to be from 0.18-10.08 mg m⁻³. The values for the earlier cruise (February) reflect good vertical mixing in the water column. One-way analysis of variance (ANOVA) for the surface samples demonstrates significant differences between stations, Table 7-17. When Duncan's new multiple range test was applied to the data, there was no significant pattern, however there was a tendency for north to south variability, Table 7-18. One-way ANOVA for the bottom stations showed no significance in the March data. It is thought that the variability between replicates was great enough to disguise any differences between stations, Table 7-19. The Duncan's multiple range test revealed the diffuser station (M10) to be significantly different during the April cruise, Table 7-20. No explanation can be offered since M10 is not different from any other stations for pigment analysis during this study.

The general trend during the study period was for the surface chlorophylls to steadily increase and the bottom chlorophylls to decline, Figure 7-3. This may be explained by two conditions: First, there was good vertical mixing between surface and bottom waters during February and early March. This was followed by a tendency for thermocline and halocline development in late March causing separation of the benthic community from the pelagic community. Second the surface water temperatures were much warmer in late March causing a bloom of nanoplankton.

7.4.1.4 Species Diversity and Organism Density

Reports of species diversity indices for diatoms in the Gulf of Mexico are not common. Housley (1976) reported a Margalef's species

FIGURE 7-3

MEAN CHLOROPHYLL - A VALUES BY
STATION AND CRUISE

Table 7-17. ANOVA for chlorophyll values at marine surface stations.

<u>Month</u>	<u>DF</u>	<u>F value</u>	<u>level of significance</u>
February	8	5.39	.995)p).999
March	8	15.89	p)).999
April	10	9.72	p)).999

Table 7-18. Duncan's new multiple range test for chlorophyll means at marine surface stations.*

Month

February	mean	1.18	1.20	1.24	1.58	1.66	2.07	2.08	2.14	2.57		
	station	M20	M18	M10	M11	M15	M1	M3	M9	M6		
		XXXXXXXXXXXXXXXXXXXX					XXXXXXXXXXXXXXXXXXXX					
March	mean	0.68	0.94	1.05	1.35	2.14	2.29	2.44	2.82	3.79		
	station	M11	M20	M1	M18	M15	M10	M3	M6	M9		
		XXXXXXXXXXXXXXXXXXXX			XXXXXXXXXXXXXXXXXXXX							
		XXXXXXXXXXXXXXXXXXXX					XXXXXXXXXXXX					
April	mean	0.26	1.24	2.18	2.25	2.70	2.93	3.68	4.36	4.51	6.80	8.70
	station	M22	M21	M20	M15	M18	M1	M3	M10	M6	M-11	M9
		XXXXXXXXXXXX	XXXXXXXXXXXXXXXXXXXX					XXXXXXXXXXXXXXXXXXXX				
		XXXXXXXXXXXXXXXXXXXX					XXXXXXXXXXXXXXXXXXXX					

*Underscored stations indicate no significant differences at the 90% confidence level.

Table 7-19. ANOVA for chlorophyll values in marine bottom samples

<u>Month</u>	<u>DF</u>	<u>F value</u>	<u>level of significance</u>
February	8	4.55	.995)p).999
March	8	0.69	.25)p).75**
April	10	8.95	p)).999

**not significant

Table 7-20. Duncan's new multiple range test for chlorophyll means in marine bottom samples.*

Month	mean	1.01	1.37	1.43	1.50	1.69	1.97	2.05	2.08	2.23		
February	station	M20	M11	M10	M15	M18	M6	M9	M1	M3		
		xxxxxxxxxxxxxxxxxxxxxxxxxxxx					xxxxxxxxxxxxxxxxxxxxxxxxxxxx					
		xxxxxxxxxxxxxxxxxxxxxxxxxxxx										
March	mean	1.17	1.54	1.58	1.76	1.92	2.07	2.10	2.26	2.33		
	station	M1	M3	M18	M15	M6	M10	M11	M20	M9		
		xxxxxxxxxxxxxxxxxxxxxxxxxxxx										
April	mean	0.29	0.30	0.32	0.44	0.45	0.60	0.70	0.90	0.96	0.98	
	station	M6	M21	M1	M11	M3	M22	M18	M9	M15	M20	
		xxxxxxxxxxxxxxxxxxxxxxxxxxxx					xxxxxxxxxxxx	xxxxxxxxxxxxxxxxxxxx				M10
		xxxxxxxxxxxxxxxxxxxxxxxxxxxx										

*Underscored stations indicate no significant differences at the 90% confidence level.

richness index for his study on Bay St. Louis, Mississippi and the Mississippi River delta region of the Gulf of Mexico. Sullivan (1978) reported a Shannon-Weaver information index (species diversity) for the diatom community in a salt marsh under tidal influence in coastal Mississippi.

One-way ANOVA for the surface stations using the Shannon-Weaver information index showed significant difference between stations in each of the sampling months, Table 7-21. Duncan's multiple range test demonstrated that a different station caused this variation each month. In general, M10 and the other stations remained clustered, Table 7-22. One-way ANOVA on the bottom samples showed significant differences between stations, Table 7-23. Duncan's multiple range test indicated no significant difference between M11 and M18 for February and March, Table 7-24. In both surface and bottom samples M22 tends to segregate from the other stations during late March. This is probably due to the increased depth and distance from shore. Comparison of the Shannon-Weaver information indices for all three sampling cruises showed a change for the March cruise, Figure 7-4. These lower values were due to the total dominance of the community by one species, Skeletonema costatum. This phenomenon has previously been reported along the Louisiana coast by Simmons and Thomas (1962), Housley (1976) and Fucik and El-Sayed (1979).

Organism densities appear at first to be considerably lower than other figures reported for the neritic waters of coastal Louisiana. Simmons and Thomas (1962) reported counts ranging from 233-998 cells

NUMBER OF SAMPLES

Figure 7-4 Shannon - Weaver

* SURFACE AND BOTTOM SAMPLES COMBINED

INFORMATION INDEX *

Table 7-21. ANOVA for Shannon-Weaver information index at marine surface stations.

<u>Month</u>	<u>DF</u>	<u>F value</u>	<u>level of significance</u>
February	8	2.80	.95)p).975
March	8	2.18	.90)p).95
April	10	6.33	p)).99

7-43

February	mean	1.89	1.92	2.07	2.09	2.12	2.14	2.15	2.23	2.59		
	station	M15	M18	M6	M20	M1	M10	M3	M9	M11		
		xxxxxxxxxxxxxxxxxxxxxxxxxxxx										
		xxxxxxxxxxxxxxxxxxxxxxxxxxxx										
		xx										
March	mean	0.68	0.71	0.71	0.72	0.72	0.78	0.91	0.98	1.00		
	station	M9	M1	M6	M15	M18	M20	M3	M11	M10		
		xx							xxxxxxxxxxxxxxxxxxxx			
		xxxxxxxxxxxx										
April	mean	1.21	1.53	1.64	1.74	1.76	1.78	1.80	1.90	2.05	2.45	
	station	M1	M9	M11	M10	M6	M21	M15	M18	M3	M22	
		xx							xxxxxxxxxxxx			
		xxxxxxxxxxxxxxxxxxxx				xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx						

*Underscored stations indicate no significant difference at the 90% confidence level.

Table 7-23. ANOVA for Shannon-Weaver information index in marine bottom samples.

<u>Month</u>	<u>DF</u>	<u>F value</u>	<u>level of significance</u>
February	8	2.80	.95)p).975
March	8	2.18	.90)p).95
April	10	6.33	p)).99

7-45

February	mean	1.97	1.98	1.98	2.04	2.08	2.10	2.10	2.28	2.40			
	station	M9	M6	M20	M1	M10	M3	M15	M18	M11			
		xx							xxxxxxxxxxxxx				
March	mean	1.03	1.04	1.08	1.08	1.22	1.24	1.40	1.53	1.63			
	station	M9	M6	M10	M15	M3	M20	M18	M11	M1			
		xx							xxxxxxxxxxxxxxxxxxxxx				
						xxxxxxxxxxxxxxxxxxxxx							
April	mean	1.18	1.87	1.45	1.45	1.47	1.47	1.52	1.57	1.64	1.79	2.50	
	station	M6	M11	M18	M10	M15	M9	M20	M1	M3	M21	M22	
		xx											
		xx							xxxxxxxxxxxxxxxxxxxxx				
		xx											
								xxxxxxxxxxxxxxxxxxxxx					

*Underscored stations indicate no significant difference at 90% confidence level.

per milliliter in the Mississippi River delta region of the Gulf of Mexico. Fucik and El-Sayed (1979) reported counts as high as 9×10^6 cells per liter in the Timbalier Bay area of Louisiana. Housley (1976) reported a range of 590 to 2,170 total organisms per liter in the Mississippi River delta region of coastal Louisiana. The values reported for this study ranged from 1,500 to 50,000 organisms per liter. If one considered each cell as a basic unit to be enumerated, then this study's counts would have ranged from 15,000-300,000 cells per liter. Lower counts were also anticipated since nanoplankters were seldom counted due to their small size and the large amount of suspended sediment in the water samples. In general it is believed that the densities found for February and March compare favorably with other studies. The densities found for April were abnormally low, but the chlorophyll values, Figure 7-3, are moderately high in the surface waters. It is known that the phytoplankton community in neritic water is quite dynamic (Balech, 1967b). Thus, there may have been dramatic changes in the phytoplankton population between sampling periods. However, it is believed that the discrepancy between organism density and chlorophyll-a values may have been caused by a nano-plankton bloom not accounted for in the enumeration of organisms. One-way ANOVA for both the surface and bottom stations for total organisms per liter showed significant difference, Tables 7-25 and 7-26. Duncan's multiple range test did not reveal any consistent pattern of differences during this study, Tables 7-27 and 7-28.

7.4.2 Estuarine

7.4.2.1 Physical Parameters

In general stations E1 and E2 were always segregated from the

Table 7-25. ANOVA for total organisms per liter at marine surface stations.

<u>Month</u>	<u>DF</u>	<u>F value</u>	<u>level of significance</u>
February	8	7.94	p)).999
March	8	6.68	p)).999
April	10	4.41	.995)p).999

Table 7-26. ANOVA for total organisms per liter in marine bottom samples.

<u>Month</u>	<u>DF</u>	<u>F value</u>	<u>level of significance</u>
February	8	2.33	.90)p).95
March	8	6.50	p)).999
April	10	62.98	p)).999

7-48

*Underscored stations indicate no significant difference at the 90% confidence level.

7-49

*Underscored stations indicate no significant differences at the 90% confidence level.

other stations by virtue of their persistently lower salinities. There was a general trend for the water temperatures to warm as the spring season progressed. Station E5, in Calcasieu Pass, always seemed to be different from the other estuarine stations because of the nearby marine influence.

7.4.2.2 Species Composition and Relative Abundance

Most of the phytoplankton found at the inshore stations were estuarine species. Stations E1 and E2 generally possessed lower salinities and a corresponding freshwater plankton assemblage of Anomoeoneis, Navicula, and Melosira. Species of estuarine diatoms, Cerataulina, Nitzschia, Asterionella, Rhizosolenia, Skeletonema and Chaetoceros, were found at all stations. There was a conspicuous absence of blue-green algae and phytoflagellates. The absence of both could be related to the colder water temperature and it is also known that most blue-greens are attached forms. The southernmost station, (E5), in the Calcasieu Pass, demonstrated the influence of the adjacent marine neritic community. Samples from station E5 often contained Prorocentrum compressum, Prorocentrum gracile, Ditylum brightwelli, Thalassiosira decipiens, Coscinodiscus centralis, Coscinodiscus radiatus, Navicula distans, Chaetoceros decipiens and Chaetoceros didymus.

7.4.2.3 Pigment Analysis and Organism Density

The high values for both chlorophyll and organism density were not unexpected. Gosselink et al. (1979) reviewed the literature on the Calcasieu Basin and reported that primary productivity was higher than most basins in the Chenier plain ecosystems. These authors also

found that the eutrophication level for this basin was considered critical because of the high phosphate loading. This would tend to favor the growth of phytoplankton in Calcasieu Lake and this was reflected in our data. One-way analysis of variance (ANOVA) was performed only on the surface samples and significant differences were found between stations for both chlorophyll and organism densities, Tables 7-29 and 7-30. Duncan's multiple range tests on chlorophyll and organism density revealed no pattern of significance to explain the variation found between stations. However, there was good correlation between both chlorophyll and organism density during each sampling cruise, Tables 7-31 and 7-32.

7.5 Conclusions

7.5.1 Marine

During February there was good vertical mixing of the water column with a tendency for weak stratification by late March. Mixing of the bottom and surface phytoplankton community was noted with separation of these two assemblages by late March. In general the marine stations were dominated by estuarine and neritic species with influence by some oceanic species of diatoms and dinoflagellates. The pronounced warming trend, as the seasons changed, allowed for the development of a nanoplankton bloom in the surface waters by March 31, 1981. The bloom was noted in the chlorophyll data. Comparisons of pigment data, species diversity indices, total organisms, and species composition with other studies were favorable. No important differences were noted between our study area and other coastal areas in the north central Gulf of Mexico. Minor differences were noted in

Table 7-29. ANOVA for chlorophyll-a at estuarine surface stations.

<u>Month</u>	<u>DF</u>	<u>F value</u>	<u>level of significance</u>
February	4	28.10	p)).999
March	4	5.60	p)).999
April	4	42.13	p)).999

Table 7-30. ANOVA for total organisms per liter at estuarine surface stations.

<u>Month</u>	<u>DF</u>	<u>F value</u>	<u>level of significance</u>
February	4	123.44	p)).999
March	4	38.48	p)).999
April	4	171.95	p)).999

Table 7-31. Duncan's new multiple range test for chlorophyll at estuarine surface stations.*

Month

February	mean	8.67	9.20	10.13	13.80	38.30
	station	E2	E5	E3	E1	E4
		xxxxxxxxxxxxxxxxxxxxxxxxxxxx				

March	mean	2.53	3.57	4.51	5.07	6.01
	station	E2	E3	E5	E1	E4
		xxxxxxxxxxxxxxxxxxxxxxxx				
		xxxxxxxxxxxxxxxxxxxxxxxx				
		xxxxxxxxxxxxxxxxxxxxxxxx				

April	mean	1.69	2.25	3.19	6.39	10.17
	station	E4	E2	E5	E3	E1
		xxxxxxxxxxxxxxxxxxxxxxxx				

*Underscored stations indicate no significant differences at the 90% confidence level.

Table 7-32. Duncan's new multiple range test for total organism density at estuarine surface stations.*

Month

February	mean	37123	63558	126666	191770	497083
	station	E3	E2	E5	E1	E4
		xxxxxxxxxxxxxx				
March	mean	1332	3019	54025	78637	18791
	station	E1	E3	E5	E2	E4
		xxxxxxxxxxxxxx		xxxxxxxxxxxxxx		
April	mean	4148	9838	12472	97078	109586
	station	E2	E4	E5	E1	E3
		xxxxxxxxxxxxxxxxxxxxxxxxxx			xxxxxxxxxxxxxxxxxx	

*Underscored stations indicate no significant difference at the 90% confidence level.

species composition between this study and that reported for the delta region of the Mississippi River.

Statistical comparisons were made between stations for both the surface and bottom samples for chlorophyll-a, Shannon Weaver information index, and total organism data. Although one-way analysis of variance (ANOVA) showed significant differences between stations, the Duncan's new multiple range test revealed no consistent pattern of variation. It is therefore concluded that all the marine sampling stations were similar, reflecting no significant differences during the pre-discharge phase of this study.

The process of determining "impact" during the post-discharge phase will involve two stages:

- (1) As a minimum necessary requirement, any marine station in the plume must be shown to be significantly (at the 90% confidence level) different by Duncan's multiple range test. This is equivalent to a variation of two standard deviations.

- (2) Based on further long term (over time) studies, principle component analysis, and multiple analysis of variance, will be evaluated to determine whether or not "impact" has occurred.

7.5.2 Estuarine

The five estuarine stations were separated into two groups, the northern (E1 and E2) and the southern (E3, E4, and E5), by distance, physical parameters and phytoplankton communities. The lower salinities at stations E1 and E2 demonstrated the pronounced influence of the Calcasieu River, which was reflected in the freshwater diatom assemblage of Anomoeoneis, Navicula and Melosira. Stations E3, E4 and E5 possessed higher salinities and common estuarine phytoplankton

species. Station E5, being nearest to the Gulf of Mexico, demonstrated higher salinities and frequently possessed phytoplankton species from the adjacent neritic community. The pigment values and number of organisms were much higher than in the nearby offshore stations, but this was not unexpected for a shallow estuary with high productivity and a critical eutrophication level caused by phosphate loading from adjacent agricultural activities. It was established through casual observations and supported by both biological and statistical analysis that the estuarine stations were not compatible for comparison of their phytoplankton communities.

CHAPTER 8

ZOOPLANKTON

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8.1 Introduction

Potential impacts of the West Hackberry Brine Disposal Project on the zooplankton community can be separated into two categories: estuarine impacts resulting from withdrawal of large volumes of water from the Calcasieu River/Intracoastal Waterway system and marine impacts resulting from brine discharge. These impact categories generate separate questions which have been investigated using distinct methodologies.

8.1.1 Marine Studies

The diffuser is designed to mix hypersaline effluent with a sufficiently large volume of coastal water to reduce the resulting salinity to nearly ambient levels; thus, a very large number of coastal zooplankters inhabiting the water may be subjected to osmotic stress. Although this situation will occur in the vicinity of the diffuser, the potential community impact is not limited to the immediate diffuser area. Nearshore circulation will result in continuous down-current transport and subsequent stress of the up-current zooplankton community.

The coastal zone in the vicinity of the diffuser site supports large commercial fisheries for shrimp (Penaeus spp.) and menhaden (Brevoortia spp.). Stress on the early life-history stages of these genera may adversely affect the future regional fishery industry:

Year-class strength may fluctuate based on survival during the egg, larval, and postlarval stages. During their early life history, marine fishes and decapods are highly susceptible to small-scale fluctuations in availability of planktonic food, predator concentration, and physical conditions such as temperature, salinity, and dissolved oxygen. Brevoortia and Penaeus have therefore been selected as targets for detailed study.

The objective of this study was to assess the inherent variability of zooplankton and meroplankton in the vicinity of the diffuser site. Our specific hypothesis was that no consistent patterns of variability exist which would mask diffuser effects and prevent an adequate assessment of impacts once brine discharge began.

8.1.2 Estuarine Studies

It is likely that water withdrawn from the Intracoastal Waterway for solution mining will be replaced by water from the Calcasieu River estuary. This could result in increased intrusion of coastal water into the estuary and entrainment of coastal zooplankton with that water. Such an intrusion would, in addition to changing holoplankton distribution, shift nursery and feeding areas of commercially and recreationally valuable species and change larval setting patterns of fouling and other benthic organisms.

In the Calcasieu River estuary, we hypothesize that water displacements caused by intake for solution mining will be accompanied by concurrent displacements in the zooplankton community. However, in

the absence of matched experimental and control sites, testing of this hypothesis must be primarily descriptive. We have therefore sampled the estuary to determine the present structure of the winter-spring zooplankton community.

8.2 Materials and Methods

8.2.1 Marine Field Procedures

In order to test the marine hypothesis, triplicate daytime samples were collected monthly at three depth strata at each of the following nine offshore stations (Figure 8-0): M1, M3, M6, M9, M10, M11, M15, M18, and M20. The depth strata chosen were near-surface, mid-depth and near-bottom. If a halocline existed, as determined from the water quality data collected at each station, near-surface and near-bottom depth strata were above and below the halocline respectively since salinity stress is of primary importance. In the absence of a halocline, a thermocline was the determining criterion, and in the absence of any thermohaline stratification samples were simply collected near surface and near bottom. In all cases the mid-depth stratum was sampled midway between the near-surface and near-bottom strata regardless of the depth of physical discontinuity.

When the vessel arrived on station, as determined by LORAN C coordinates, a buoy was deployed to mark the position and the vessel hove to for a CTD/DO cast with a Hydrolab Series 8000 meter. Parameters observed were temperature, conductivity, dissolved oxygen and pH. Except under unfavorable wind conditions, these observations were made at one meter intervals through the water column

Figure 8-0. Inshore and offshore stations sampled for zooplankton.

in order to determine as accurately as possible physical processes affecting zooplankton distribution at the time of sampling. In any case, near-surface, mid-depth, and near-bottom observations were made. Weather and sea-state observations were also made each station.

A complete series of tows in the vicinity of the station buoy was then conducted. The gear was an opening/closing 67 cm bongo frame rigged with .333 mm and .505 mm mesh nets. Each side was equipped with a flow meter to determine the volume of seawater filtered for each sample. A 68 kg depressor was used to maximize control of sampling depth. Tow length was one minute at $2.8-4.6 \text{ km hr}^{-1}$ ($1.5-2.5 \text{ nm hr}^{-1}$) to maintain a discrete interval between closely spaced stations. The .333 mm and .505 mm mesh collections were treated as separate samples since each mesh size samples a different component of the zooplankton community.

Collection data for each sample were logged and in-jar labels were used to tag each sample. Samples were preserved in a 3 - 5% solution of formaldehyde in seawater buffered with sodium borate. The station buoy was recovered before proceeding to the next station.

In summary, the marine zooplankton sampling effort consisted of 9 stations/month x 3 depths/stations x 2 nets/depth x 3 replicates/net = 162 samples/month.

8.2.2 Estuarine Field Procedures

The location of each of five regular estuarine stations (E1 through E5) was determined by dead reckoning (Figure 8-0). An additional estuarine station, designated E3A, was sampled along the ship channel near station E3 because low-water conditions occasionally

prevented access to E3. At each station the weather conditions were recorded and a water quality profile at one meter intervals (three meter intervals when the wind conditions were unfavorable) was performed similarly to the marine study. The inshore fieldwork was scheduled to coincide as closely as possible with daytime high tide.

At each station a triplicate series of one-minute tows was made with a one-half meter ring net of 0.153 mm mesh nitex netting and soft cod end. The circular ring was mounted to swivel within a rectangular frame so that the net mouth remained perpendicular to the direction of tow. This gear was lowered from a boom on the side of the boat with a 14 kg depressor attached to the bottom of the frame and the wire attached to the top to prevent avoidance because of a net bridle or the boat wake. Since the net was not designed to open or close, a double-oblique tow (surface-three meter-surface) was performed at the deeper stations, E1 and E5, and the net was towed just below the surface at the remaining shallower stations. Volume filtered was monitored with a flow meter mounted inside the mouth of the net. Data logging and sample tagging and preservation procedures were similar to those described above for the marine samples.

8.2.3 Laboratory Procedures

Analysis began after the samples were allowed to fix for one week in buffered formalin. Since zooplankton sorting and identification are extremely labor-intensive, the following laboratory protocol was used to minimize man-hour requirements while maintaining emphasis on ichthyoplankton, Penaeus postlarvae, and numerical dominants. Displacement volume was determined for all samples and logged on the

sorting sheet. All fish larvae and postlarvae and penaeid shrimp postlarvae were sorted from all samples. The first sample from each replicate set was sorted for fish eggs, decapod larvae, mollusc larvae, and numerically dominant zooplankton. When subsampling was necessary due to excessive abundance of a taxon, samples were split with a Folsom Plankton Splitter. The samples sorted for fishes and shrimps and half-splits (one-half of the sample, obtained from the first iteration with the plankton splitter) of the samples which were sorted for numerical dominants were archived in case results indicated a requirement for further analysis. For example, the copepods from all .333 mm mesh marine samples collected in March and April have been sorted and identified in order to determine the distributional variability of this important group.

Primary references for identification are listed in Table 8-1. However, because of the nature of zooplankton taxonomy many other separate references were also used. These other references are available from the authors on request.

8.2.4 Data Analysis

Total numbers for taxa sorted from splits of samples were calculated. Abundances were standardized to numbers per cubic meter of water filtered, based on the flow meter readings for each collection. In the case of questionable meter readings or missing data, the volume filtered was calculated from the average volume filtered per minute by that mesh size for that month. Log transformed abundances $\log_{10} (x + 1)$ were then calculated to

Table 8-1. Primary references for zooplankton identification.

fishes	Ahlstrom and Moser, 1976
	Daniels, 1977
	Früge and Truesdale, 1978
	Hildebrand and Cable, 1934
	Hoese and Moore, 1977
	Houde and Fore, 1973
	Lippson and Moran, 1974
	Parker, 1972
	Powles, 1980
	Powles and Stender, 1978
	Russell, 1976
	Smith, 1979
	U. S. Fish and Wildlife Service, 1978
decapods	Chuensri, 1968
	Cook, 1965
	Felder, 1973
	Gurnez, 1942
	Lough, 1974
	Perez Farfante, 1970
	Rice, 1980
	Sandifer, 1972
	Tack, 1967
	Williams, 1965
	Wood, 1974
molluscs	Abbott, 1974
	Chanley and Andrews, 1971
	Fish and Fish, 1977
	Fretter and Pilkington, 1970
	Hadfield, 1964
	LePennec, 1980
	Loosanoff, Davis and Chanley, 1966
	Rees, 1950
	Richter and Thorson, 1975
	Robertson, 1974
	Scheltema, 1962
	Stafford, 1912
	Sullivan, 1948
	Taylor, 1975
	Thiriot-Quievreux, 1969; 1980

Table 8-1. Primary references for zooplankton identification. Page 2.

copepods	Bowman, 1971
	Dahl, 1912
	Ferrari and Bowman, 1980
	Gonzalez and Bowman, 1965
	Grice, 1960
	Owre and Foyo, 1967
	Wilson, 1932a; 1932b
chaetognaths	Fraser, 1957
	Grant, 1963
	McLelland, 1980
miscellaneous	Bousfield, 1973
	Bowman and Gruner, 1973
	Della Croce, 1974
	Gosner, 1971
	Pennak, 1978
	Shoemaker, 1945
	Stuck, Perry, and Heard, 1979

moderate scalar differences and to reduce the domination of subsequent multivariate analyses by the most abundant taxa.

Because of the variety of mesh sizes and sorting strategies used, the data were organized into subsets by month, mesh size, and whether or not the sample was a first replicate. The marine data subsets analyzed for each month were: .333 mm mesh - first replicates (for meroplankton and dominant holoplankton); .333 mm mesh - all replicates (for biomass, fishes, and postlarval penaeids); .505 mm mesh - first replicates (for meroplankton and dominant holoplankton); and .505 mm mesh - all replicates (for biomass, fishes, and postlarval penaeids). So analyses were performed on 3 months x 2 mesh sizes x 2 sorting schemes = 12 marine data subsets. However, since only one mesh size and depth was sampled at each estuarine station, only the following estuarine data subsets were analyzed: 3 months x 2 sorting schemes = 6 data subsets.

Monthly marine stations were compared at separate depth strata (surface to surface, mid-depth to mid-depth, and bottom to bottom) by one-way analysis of variance (ANOVA) since comparison of samples for different depth strata among stations violates the assumption of independence. In the one-way ANOVA the assumption of additivity is not required (Sokal and Rohlf, 1969). The dependent variables for separate ANOVA analyses were zooplankton biomass and abundance of Brevoortia, Penaeus, and total copepods. When ANOVA demonstrated statistically significant differences among stations, the Student-Newman-Keuls (SNK) test was used for a posteriori comparisons among means to determine the pattern of the heterogeneity. Since the ANOVA

results did not consistently support the hypothesis of no significant variation among stations, community structure analysis was carried out as detailed below to determine the causes of the variation.

Since this study was designed based on the optimal situation of matched control and impact sites (Green, 1979) all analyses were among-stations rather than among-months. After elimination of rare taxa (those present in five percent or less of the samples in each data subset), taxa and samples in each data subset were clustered based on species abundance using the Virginia Institute of Marine Science COMPAH program with the Bray-Curtis similarity coefficient. This procedure included among-depth comparisons as well as among-station comparisons. An intensive combinatorial strategy was used with the flexible cluster intensity coefficient beta equal to -0.25. Such a strategy is somewhat space-dilating and allows formation of clusters that might be missed by less intensive strategies, but it is also prone to misclassifications (Boesch, 1977). It is therefore necessary to provide for reallocation of misclassified entities.

Reciprocal-averaging ordination (Hill, 1973), computed with the Cornell ORDIFLEX package (Gauch, 1977), was chosen to spot check for misclassifications in the numerical classification results. This procedure generates simultaneous ordinations of species and samples on the same axes (Malmgren, Oviatt, Gerber and Jeffries, 1978) allowing direct comparisons between species and sample groups. Fasham (1977) has shown this analysis to be less susceptible to gradient distortion with large turnover of variables (beta diversity) along the gradient

than the more traditional principal component analysis. Groupings of entities on the first three eigenvectors were considered and compared with the results of numerical classification. If the structure described by the numerical classification was identifiable with little or no overlap on these axes the classification was accepted; if entities or small groups were found to be misclassified, they were reallocated based on the ordination.

8.3 Results

Identified taxa and life-history stages and their monthly occurrences are listed in Appendix G. Also in Appendix G is a summary of the marine abundance data on larval and postlarval fishes and postlarval shrimps as well as mean abundance data for all taxa.

8.3.1 Marine

8.3.1.1 February

Because of a malfunction in the double-trip mechanism of the bongo system, the collecting methodology was altered in February. Rather than opening and closing at the target depth, the nets were rapidly lowered open to the desired depth, towed horizontally for one minute, and then rapidly retrieved. This technique resulted in discrete surface samples and quasi-discrete mid-depth and bottom samples at all stations.

Analyses of variance showed significant differences in zooplankton biomass among stations at all depths and mesh sizes except surface samples collected with .505 mm mesh. (Tables 8-2 and 8-3). SNK results indicated that these differences were consistently dominated by high biomass at the west end of the study area.

Table 8-2. Analysis of variance of zooplankton biomass among the marine stations, .505 mm samples, February, 1981. In the case of significant (*) ANOVA's, multiple comparisons among means are provided based on the Student-Newman-Keuls test (SNK).

<u>Source of variation</u>	<u>df</u>	<u>SS</u>	<u>MS</u>	<u>F_s</u>
Surface				
Among stations	8	0.28079	0.03510	1.3743
Within stations	<u>18</u>	<u>0.45972</u>	0.02554	
Total	26	0.74052		

$$F_{.05}[8, 18] = 2.51$$

Mid-depth				
Among stations	8	0.14758	0.01845	2.7253*
Within stations	<u>18</u>	<u>0.12190</u>	0.00677	
Total	26	0.26948		

$$F_{.05}[8, 18] = 2.51$$

SNK results:

Mean	0.045	0.061	0.070	0.085	0.113	0.121	0.195	0.253	0.262
Station	M15	M10	M20	M18	M6	M11	M9	M1	M3
	XX								
	XX								

Bottom				
Among stations	8	0.20560	0.02570	6.0047*
Within stations	<u>18</u>	<u>0.07696</u>	0.00428	
Total	26	0.28256		

$$F_{.05}[8, 18] = 2.51$$

SNK results:

Mean	0.031	0.054	0.067	0.094	0.171	0.176	0.206	0.213	0.314
Station	M18	M10	M15	M11	M6	M1	M9	M20	M3
	XX								
	XX								

Table 8-3. Analysis of variance of zooplankton biomass among the offshore stations, .333 mm samples, February, 1981. In the case of significant (*) ANOVA's, multiple comparisons among means are provided based on the Student-Newman-Keuls test (SNK).

<u>Source of variation</u>	<u>df</u>	<u>SS</u>	<u>MS</u>	<u>F_s</u>
Surface				
Among stations	8	0.93276	0.11660	3.7783*
Within stations	<u>18</u>	<u>0.55541</u>	0.03086	
Total	26	1.48817		

$$F_{.05}[8, 18] = 2.51$$

SNK results:

Mean	0.092	0.094	0.129	0.326	0.336	0.354	0.461	0.542	0.639
Station	M15	M10	M18	M11	M20	M9	M3	M6	M1
	XX								
				XX					

Mid-depth									
Among stations	8	0.96128	0.12016	3.4829*					
Within stations	<u>18</u>	<u>0.62089</u>	0.03450						
Total	26	1.58217							

$$F_{.05}[8, 18] = 2.51$$

SNK results:

Mean	0.105	0.107	0.131	0.143	0.160	0.164	0.227	0.443	0.698
Station	M10	M18	M15	M11	M20	M6	M9	M1	M3
	XX								
								XXXXXXXXXXXXXXXXXX	

Bottom									
Among stations	8	0.81738	0.10217	7.5402*					
Within stations	<u>18</u>	<u>0.24381</u>	0.01355						
Total	26	1.06120							

$$F_{.05}[8, 18] = 2.51$$

SNK results:

Mean	0.095	0.123	0.171	0.205	0.227	0.351	0.469	0.493	0.616
Station	M15	M10	M11	M18	M9	M20	M6	M3	M1
	XX								
							XXXXXXXXXXXXXXXXXXXX		
							XXXXXXXXXXXXXXXXXXXX		
									XXXXXXXXXXXXXXXXXXXX

Significant variance among stations was also demonstrated for Brevoortia sp. abundance. Although the significant difference was between eastern station M20 and western station M3, the data did not describe an east-west gradient (Table 8-4). No significant differences among stations were demonstrated for Penaeus sp. postlarvae (Table 8-5).

The fish assemblage sampled by .505 mm mesh in February was dominated by larval and postlarval Brevoortia sp., which were abundant in all surface samples. Other common fishes were larval and postlarval Myriophis punctatus, postlarval Lagodon rhomboides, and larval Citharichthys spilopterus. Postlarval Penaeus sp. were common shrimps in the February .505 mm mesh samples.

Numerical classification of the .505 mm mesh samples formed two main clusters (Figure 8-1) separated primarily by depth. The first of these can further be subdivided into two subgroups: 1) surface samples from stations M1, M6, M9, M11, and M20; 2) surface samples from stations M3, M10, M15, and M18, mid-depth samples from station M11, and bottom samples from station M9. The second main cluster is also divisible into two subgroups: 1) mid-depth samples mostly from stations M6 and M18 and bottom samples also from station M18; 2) bottom samples primarily from stations M10, M11, and M15, and mid-depth and bottom samples with no apparent areal pattern.

Holoplankton in the .505 mm mesh first replicates was dominated by the copepods Acartia tonsa, Centropages hamatus, Labidocera aestiva, and Temora turbinata and immature chaetognaths, Sagitta sp.

Numerical classification of the February .505 mm mesh first

Table 8-4. Analysis of variance of Brevoortia larvae and postlarvae concentration (numbers per m³) among the marine stations, .505 mm February 1981 samples. In the case of significant (*) ANOVA's, multiple comparisons among means are provided based on the Student-Newman-Keuls test (SNK).

<u>Source of variation</u>	<u>df</u>	<u>SS</u>	<u>MS</u>	<u>F_s</u>
Surface				
Among Stations	8	7.8785	0.9848	3.597*
Within Stations	<u>18</u>	<u>4.9283</u>	0.2738	
Total	26	12.8068		

$$F_{.05}[8, 18] = 2.51$$

SNK results:

Mean	0.267	0.333	0.367	0.383	0.433	0.667	1.367	1.400	1.767
Station	M3	M15	M18	M10	M1	M9	M11	M6	M20
	XX								
	XX								

Mid-depth				
Among Stations	8	0.2017	0.0252	2.269
Within Stations	<u>18</u>	<u>0.2000</u>	0.0111	
Total	26	0.4017		

$$F_{.05}[8, 18] = 2.51$$

Bottom				
Among Stations	8	0.1435	0.0179	0.596
Within Stations	<u>18</u>	<u>0.5417</u>	0.0301	
Total	26	0.6852		

$$F_{.05}[8, 18] = 2.51$$

Table 8-5. Analysis of variance of Penaeus postlarvae concentration (numbers per m³) among the marine stations, .505 mm February 1981 samples.

<u>Source of variation</u>	<u>df</u>	<u>SS</u>	<u>MS</u>	<u>F_s</u>
Surface				
Among Stations	8	.0035	.0004	.6786
Within Stations	<u>18</u>	<u>.0117</u>	.0007	
Total	26	.0152		

$$F_{.05}[8, 18] = 2.51$$

Mid-depth				
Among Stations	8	.0207	.0025	1.5556
Within Stations	<u>18</u>	<u>.0300</u>	.0017	
Total	26	.0507		

$$F_{.05}[8, 18] = 2.51$$

Bottom				
Among Stations	8	.0246	.0031	2.375
Within Stations	<u>18</u>	<u>.0233</u>	.0013	
Total	26	.0479		

$$F_{.05}[8, 18] = 2.51$$

Figure 8-1. Cluster dendrogram based on abundances of fishes and shrimps for marine February .505 mm all-replicate samples. See Table 8-6 for identification of samples in clusters.

Table 8-6. Subcluster identification of specific samples in order of appearance on cluster dendrogram, marine February .505 mm all replicates.

<u>Subcluster</u>	<u>Station</u>	<u>Depth</u>	<u>Replicate</u>	<u>Subcluster</u>	<u>Station</u>	<u>Depth</u>	<u>Replicate</u>
IA	M1	S	1	IIA (cont'd.)	M20	B	2
	M1	M	1		M9	B	3
	M1	S	2		M18	B	3
	M6	B	1		M18	M	1
	M6	S	1		M20	M	1
	M6	S	2		M11	B	2
	M6	S	3		M3	B	3
	M20	S	1		M6	B	3
	M20	S	3		M20	M	3
	M11	S	1	IIB	M1	M	3
	M20	S	2		M1	B	3
	M11	S	3		M3	B	1
	M9	S	1		M20	B	1
	M11	S	2		M10	B	3
	M9	S	2		M11	B	1
IB	M3	S	1		M11	B	3
	M9	B	2		M6	B	2
	M20	B	3		M10	B	2
	M3	M	1		M15	B	1
	M10	S	3		M15	B	2
	M9	S	3		M1	B	2
	M15	S	2		M10	S	2
	M9	M	2		M6	M	1
	M18	S	3		M10	M	2
	M3	S	2		M3	M	2
	M11	M	1		M10	B	1
	M18	S	2		M15	S	3
	M9	B	1		M20	M	2
	M3	S	3		M9	M	1
	M10	M	1		M18	S	1
	M10	S	1		M18	M	2
	M15	S	1		M18	M	3
	M11	M	2		M18	B	1
IIA	M1	S	3		M18	B	2
	M9	M	3		M6	M	2
	M1	M	2		M15	M	3
	M3	M	3		M6	M	3
	M15	M	1		M11	M	3
	M1	B	1				
	M3	B	2				
	M10	M	3				

replicates was dominated by areal, rather than vertical, pattern (Figure 8-2). The diffuser site, station M10, was most similar to the two stations east of it, M15 and M18. These stations were quite distinct from those of the other two clusters: the western stations M1, M3, and M6; and the outlying stations M9, M11, and M20.

The common fishes and shrimps of the .333 mm mesh samples in February were similar to those of the .505 mm mesh samples with the addition of larval Micropogonias undulatus. Classification of the .333 mm mesh samples based on fish and shrimp composition formed clusters related mostly to depth strata. Of the 27 surface samples, 19 were in one of the four major groups whereas the mid-depth and bottom samples were intermixed with little apparent areal pattern (Figure 8-3).

The February .333 mm mesh first replicates were numerically dominated by barnacle nauplii in addition to the species which dominated the .505 mm mesh first replicates. Clustering of the .333 mm mesh first replicates again showed areal pattern in the data (Figure 8-4). Whereas the bottom sample from the diffuser station, M10, was similar to the eastern stations, the mid-depth and surface samples from the diffuser were similar to the western stations.

The areal pattern observed in both the .505 mm and .333 mm mesh samples is not explained by the ancillary data collected in February. The system was well mixed in temperature (Figure 8-5), salinity (Figure 8-6), and dissolved oxygen (Figure 8-7).

8.3.1.2 March

With the resolution of our trip-mechanism problems, discrete depth sampling was implemented in March.

Figure 8-2. Cluster dendrogram based on abundances of all taxa for marine February .505 mm first-replicate samples.

Figure 8-3. Cluster dendrogram based on abundances of fishes and shrimps for marine February .333 mm all-replicate samples. See Table 8-7 for identification of samples in clusters.

Table 8-7. Subcluster identification of specific samples in order of appearance on cluster dendrogram, marine February .333 mm all replicates.

<u>Subcluster</u>	<u>Station</u>	<u>Depth</u>	<u>Replicate</u>	<u>Subcluster</u>	<u>Station</u>	<u>Depth</u>	<u>Replicate</u>
IA	M1	S	1	IC (cont'd.)	M15	M	1
	M1	S	2		M18	M	1
	M20	B	3		M10	S	1
	M11	B	3		M20	M	3
	M1	B	1		M11	M	3
	M6	B	3		M9	M	1
	M1	M	2		M18	B	1
	M3	B	2		M18	B	2
	M6	B	2		M18	B	3
	M10	B	3		M10	M	1
	M15	B	2		M10	M	3
					M15	S	2
IB	M15	B	3	II	M1	S	3
	M20	S	2		M15	S	3
	M20	M	1		M18	S	2
	M20	B	2		M10	S	3
	M11	M	1		M20	S	3
	M9	M	3		M3	M	1
	M9	B	2		M11	S	3
IC	M9	B	3		M9	S	1
					M3	S	1
	M1	M	1		M3	S	2
	M1	M	3		M9	M	2
	M3	B	3		M9	B	1
	M15	M	3		M20	M	2
	M1	B	2		M11	B	1
	M3	B	1		M3	S	3
	M10	M	2		M6	S	2
	M1	B	3		M10	S	2
	M10	B	2		M3	M	3
	M18	S	3		M6	S	1
	M15	S	1		M6	S	3
	M15	M	2		M20	S	1
	M3	M	2		M9	S	2
	M10	B	1		M11	S	2
	M6	B	1		M9	S	3
	M20	B	1		M11	S	1
	M18	M	2				
	M18	M	3				
	M6	M	1				
	M18	S	1				
	M11	M	2				
	M11	B	2				
	M6	M	3

Figure 8-4. Cluster dendrogram based on abundances of all taxa for marine February .333 mm first-replicate samples.

Figure 8-5. Vertical distribution of temperature ($^{\circ}\text{C}$), 13 February 1981 based on observations at 1 m intervals.

Figure 8-6. Vertical distribution of salinity (‰), 13 February 1981 based on observations at 1 m intervals.

Figure 8-7. Vertical distribution of dissolved oxygen (ml l⁻¹), 13 February 1981 based on observations at 1 m intervals.

Analyses of March biomass variability showed no significant variance among stations in the .505 mm mesh samples at any depth (Table 8-8). In the .333 mm mesh samples, however, there were significant differences in biomass among stations in both the surface and bottom samples although the differences were not significant at mid-depth (Table 8-9). Although the surface biomass was significantly higher at diffuser station M10 than at any other station, bottom biomass was lowest at station M10. Significant variance in Brevoortia sp. abundance was again detected at the surface in March because of anomalously high catches at station M15 (Table 8-10). Penaeus sp. postlarvae were too rare in the March samples for analysis of variance. Total copepod concentrations varied significantly among stations at all depths but the patterns of variation were largely reversed between the surface and bottom (Table 8-11).

The common fishes in the .505 mm mesh samples were Brevoortia sp., Anchoa spp., Cynoscion arenarius, and Haemulon (?) sp. There were no postlarval penaeid shrimps which were common in these samples. Cluster analysis revealed similarity patterns among the March .505 mm mesh samples dominated by the vertical component (Figure 8-8). Most of the surface samples clustered apart from the mid-depth and bottom samples.

Dominant organisms in the .505 mm mesh first replicates included the copepods A. tonsa, C. hamatus, L. aestiva, Nannocalanus minor, and T. turbinata, the chaetognath Sagitta friderici, barnacle larvae, and

Table 8-8. Analysis of variance of zooplankton biomass among the marine stations, .505 mm samples, March, 1981. In the case of significant (*) ANOVA's, multiple comparisons among means are provided based on the Student-Newman-Keuls test (SNK).

<u>Source of variation</u>	<u>df</u>	<u>SS</u>	<u>MS</u>	<u>F_s</u>
Surface				
Among stations	8	0.20852	0.02607	.6525
Within stations	<u>18</u>	<u>0.71913</u>	0.03995	
Total	26	0.92766		

$$F_{.05}[8, 18] = 2.51$$

Mid-depth				
Among stations	8	0.32086	0.04011	1.0511
Within stations	<u>18</u>	<u>0.68686</u>	0.03816	
Total	26	1.00772		

$$F_{.05}[8, 18] = 2.51$$

Bottom				
Among stations	7	0.30691	0.04384	1.4856
Within stations	<u>16</u>	<u>0.47213</u>	0.02951	
Total	23	0.77904		

$$F_{.05}[7, 16] = 2.66$$

Table 8-9. Analysis of variance of zooplankton biomass among the marine stations, .333 mm samples, March, 1981. In the case of significant (*) ANOVA's multiple comparisons among means are provided based on the Student-Newman-Keuls test (SNK).

<u>Source of variation</u>	<u>df</u>	<u>SS</u>	<u>MS</u>	<u>F_s</u>
Surface				
Among stations	8	6.22318	0.77790	5.0294*
Within stations	<u>18</u>	<u>2.78408</u>	0.15467	
Total	26	9.00726		

$$F_{.05}[8, 18] = 2.51$$

SNK results:

Mean	0.489	0.739	0.743	0.764	0.841	1.077	1.148	1.204	2.239
Station	M1	M18	M11	M20	M3	M9	M6	M15	M10
	XX								

Mid-depth									
Among stations	8	7.67850		0.95981		0.4733			
Within stations	<u>18</u>	<u>36.50408</u>		2.02800					
Total	26	44.18258							

$$F_{.05}[8, 18] = 2.51$$

Bottom									
Among stations	8	4.85852		0.60731		5.1185*			
Within stations	<u>18</u>	<u>2.13564</u>		0.11865					
Total	26	6.99415							

$$F_{.05}[8, 18] = 2.51$$

SNK results:

Mean	0.381	0.391	0.577	0.814	0.851	1.022	1.350	1.452	1.587
Station	M10	M18	M15	M6	M3	M9	M1	M11	M20
	XX								
	XX								
	XX								

Table 8-10. Analysis of variance of Brevoortia larvae and postlarvae concentration (numbers per m³) among the marine stations, .505 mm March 1981 samples. In the case of significant (*) ANOVA's, multiple comparisons among means are provided based on the Student-Newman-Keuls test (SNK).

<u>Source of variation</u>	<u>df</u>	<u>SS</u>	<u>MS</u>	<u>F_s</u>
Surface				
Among stations	8	14.7133	1.8392	7.857*
Within stations	<u>18</u>	<u>4.2133</u>	0.2341	
Total	26	18.9266		

$$F_{.05}[8, 18] = 2.51$$

SNK results:

Mean	0.167	0.367	0.367	0.433	0.600	0.767	1.267	1.367	2.667
Station	M9	M1	M18	M20	M10	M3	M11	M6	M15
	XX								

Mid-depth									
Among stations					8	0.2763	0.0345	0.8477	
Within stations					<u>18</u>	<u>0.7333</u>	0.0407		
Total					26	1.0096			

$$F_{.05}[8, 18] = 2.51$$

Bottom									
Among stations					7	0.1129	0.0161	1.3827	
Within stations					<u>16</u>	<u>0.1867</u>	0.0117		
Total					23	0.2996			

$$F_{.05}[7, 16] = 2.66$$

Table 8-11. Analysis of variance of total copepod concentration (numbers per m³) among the marine stations, .333 mm March 1981 samples. In the case of significant (*) ANOVA's, multiple comparisons among means are provided based on the Student-Newman-Keuls test (SNK).

<u>Source of variation</u>	<u>df</u>	<u>SS</u>	<u>MS</u>	<u>F_s</u>
Surface				
Among stations	8	803570259.8	100446282.5	2.992*
Within stations	<u>18</u>	<u>604198904.7</u>	33566605.8	
Total	26	1407769165.0		

$$F_{.05}[8, 18] = 2.51$$

SNK results:

Mean	94	704	1133	2484	3346	5250	7813	9757	18124
Station	M1	M3	M20	M11	M6	M9	M18	M15	M10
	XX								
	XX								

Mid-depth									
Among stations				8	81303486.9		10162935.9	10.248*	
Within stations				<u>18</u>	<u>17850615.9</u>		991700.9		
Total				26	99154102.8				

$$F_{.05}[8, 18] = 2.51$$

SNK results:

Mean	73	288	423	773	982	1142	1177	2471	6024
Station	M18	M1	M10	M3	M15	M20	M6	M9	M11
	XX								

Bottom									
Among stations				8	116988618.5		14623577.3	5.396*	
Within stations				<u>18</u>	<u>48785359.7</u>		2710297.8		
Total				26	165773978.2				

$$F_{.05}[8, 18] = 2.51$$

SNK results:

Mean	190	742	959	1451	1742	2225	2359	5426	6732
Station	M18	M10	M15	M3	M6	M9	M1	M20	M11
	XX								
	XX								
	XXXXXXXXXXXX

Figure 8-8. Cluster dendrogram based on abundances of fishes and shrimps for marine March .505 mm all-replicate samples. See Table 8-12 for identification of samples in clusters.

Table 8-12. Subcluster identification of specific samples in order of appearance on cluster dendrogram, marine March .505 mm all replicates.

<u>Subcluster</u>	<u>Station</u>	<u>Depth</u>	<u>Replicate</u>	<u>Subcluster</u>	<u>Station</u>	<u>Depth</u>	<u>Replicate</u>
I	M10	S	1	IIB	M15	M	3
	M6	S	3		M18	S	3
	M10	S	2		M11	M	2
	M11	M	1		M6	M	2
	M10	S	3		M3	S	1
	M18	S	2		M1	M	3
	M20	S	2		M1	B	3
	M11	S	2	IIC			
	M6	B	1		M10	M	3
	M1	S	2		M10	B	1
	M3	S	2		M11	B	3
	M1	S	1		M11	B	1
	M15	S	1		M20	S	3
	M15	S	2		M1	B	1
	M15	S	3		M3	B	2
	M11	S	1		M6	B	3
	M11	S	3		M9	S	3
	M3	S	3		M3	M	2
	M6	S	1		M6	M	1
	M6	S	2		M20	M	3
IIA				IID			
	M10	M	2		M11	M	3
	M9	S	1		M9	M	1
	M9	S	2		M9	B	2
	M20	S	1		M20	M	1
	M11	B	2		M9	M	2
	M3	M	1		M9	M	3
	M18	B	3		M9	B	1
	M20	B	3		M20	M	2
	M10	B	2	IIE			
	M15	B	2		M1	S	3
	M1	M	2		M18	S	1
	M6	B	2		M18	M	3
	M18	B	2		M18	B	1
	M20	B	1				
	M20	B	2				
	M10	B	3				
	M3	B	3				
	M3	B	1				
	M15	M	2				
	M15	B	3				
	M1	B	2				
	M3	M	3				

sciaenid-type fish eggs. The primary pattern in numerical classification of the March .505 mm first replicates was depth related, although some areal pattern was also identifiable. Six of the nine surface samples clustered together but the western-most surface samples from stations M1, M3, and M6 clustered with the more eastern mid-depth and bottom samples (Figure 8-9).

Fishes common in the March .333 mm mesh samples were the same as those in the .505 mm mesh samples. Again there were no common postlarval penaeids. In contrast to the .505 mm mesh samples, there was no apparent areal pattern to the numerical classification of the .333 mm mesh data. In addition, the tendency to cluster by depth was less pronounced (Figure 8-10).

A speciose assemblage (See Table F-9) found in the March .333 mm first replicates was dominated by the copepods A. tonsa, C. hamatus, and L. aestiva, the cladoceran Podon polyphemoides, the larvacean Oikopleura sp., barnacle larvae, and sciaenid-type fish eggs. There was no obvious spatial pattern to the numerical classification of this data subset (Figure 8-11).

The study area was stratified in temperature (Figure 8-12), salinity (Figure 8-13), and dissolved oxygen (Figure 8-14) during March sampling.

8.3.1.3. April

No significant biomass variance among stations was detected in April for either mesh size at any depth except the bottom samples taken with .505 mm mesh nets and mid-depth samples collected with .333 mm mesh (Tables 8-14 and 8-15). Station patterns within these

Figure 8-9. Cluster dendrogram based on abundances of all taxa for marine March .505 mm first-replicate samples.

Figure 8-10. Cluster dendrogram based on abundances of fishes and shrimps for marine March .333 mm all-replicate samples. See Table 8-13 for identification of samples in clusters.

Table 8-13. Subcluster identification of specific samples in order of appearance on cluster dendrogram, marine March .333 mm all replicates.

<u>Subcluster</u>	<u>Station</u>	<u>Depth</u>	<u>Replicate</u>	<u>Subcluster</u>	<u>Station</u>	<u>Depth</u>	<u>Replicate</u>
I	M10	S	1	IIA (cont'd.)	M10	B	2
	M15	S	2		M11	B	3
	M3	S	1		M6	M	2
	M15	M	1	IIB	M10	M	3
	M1	M	3		M6	M	3
	M15	M	2		M15	B	1
	M10	S	2		M3	M	1
	M3	S	3		M15	B	3
	M6	S	3		M3	B	3
	M10	S	3		M11	B	1
	M11	S	2		M18	M	3
	M18	S	2	IIC	M10	B	1
	M20	S	2		M9	S	1
	M15	S	1		M3	B	2
	M6	S	1		M9	M	1
	M15	S	3		M18	B	2
	M6	S	2		M18	B	3
	M1	S	1		M20	M	3
	M3	S	2		M11	M	3
	M1	S	2		M20	B	3
	M1	M	1		M9	B	2
IIA	M10	M	1		M9	B	3
	M10	B	3		M6	M	1
	M11	S	1		M15	B	2
	M11	M	2		M18	B	1
	M3	M	3		M6	B	2
	M9	S	2		M20	M	1
	M11	B	2		M9	M	2
	M20	B	2		M9	M	3
	M11	S	3		M20	M	2
	M6	B	1		M9	B	1
	M18	S	1				
	M11	M	1				
	M3	M	2				
	M6	B	3				
	M9	S	3				
	M18	M	1				
	M1	B	1				
	M3	B	1				
	M1	B	2				
	M1	B	3				
	M20	B	1				
	M18	S	3				
	M20	S	1				
	M20	S	3				

BRAY-CURTIS SIMILARITY

Figure 8-11. Cluster dendrogram based on abundances of all taxa for marine March .333 mm first-replicate samples.

Figure 8-12. Vertical distribution of temperature ($^{\circ}\text{C}$), 17 March 1981 based on observations at 1 m intervals.

Figure 8-13. Vertical distribution of salinity (‰), 17 March 1981 based on observations at 1 m intervals.

Figure 8-14. Vertical distribution of dissolved oxygen (ml l⁻¹), 17 March 1981 based on observations at 1m intervals.

Table 8-14. Analysis of variance of zooplankton biomass among the marine stations, .505 mm samples, April, 1981. In the case of significant (*) ANOVA's, multiple comparisons among means are provided based on the Student-Newman-Keuls test (SNK).

<u>Source of variation</u>	<u>df</u>	<u>SS</u>	<u>MS</u>	<u>F_s</u>
Surface				
Among stations	6	6.09277	1.01546	1.9112
Within stations	<u>14</u>	<u>7.43858</u>	0.53133	
Total	20	13.53135		

$$F_{.05}[6, 14] = 2.85$$

Mid-depth				
Among stations	8	8.91884	1.11486	2.4125
Within stations	<u>18</u>	<u>8.31824</u>	0.46212	
Total	26	17.23708		

$$F_{.05}[8, 18] = 2.51$$

Bottom				
Among stations	8	35.51964	4.43996	11.3621*
Within stations	<u>18</u>	<u>7.03391</u>	0.39077	
Total	26	42.55355		

$$F_{.05}[8, 18] = 2.51$$

SNK results:

Mean	0.372	0.408	0.496	1.261	1.291	1.445	1.696	2.577	4.159
Station	M15	M20	M9	M10	M6	M1	M18	M11	M3

XX

XX

Table 8-15. Analysis of variance of zooplankton biomass among the marine stations, .333 mm samples, April, 1981. In the case of significant (*) ANOVA's, multiple comparisons among means are provided based on the Student-Newman-Keuls test (SNK).

<u>Source of variation</u>	<u>df</u>	<u>SS</u>	<u>MS</u>	<u>F_s</u>
Surface				
Among stations	7	5.78771	0.82682	0.7176
Within stations	<u>16</u>	<u>18.43486</u>	1.15217	
Total	23	24.22258		

$$F_{.05}[7, 16] = 2.66$$

Mid-depth				
Among stations	8	12.74773	1.59347	3.1787*
Within stations	<u>18</u>	<u>9.02326</u>	0.50129	
Total	26	21.77099		

$$F_{.05}[8, 18] = 2.51$$

SNK results:

Mean	0.470	0.498	0.757	1.029	1.319	1.515	1.919	1.951	2.081
Station	M1	M20	M11	M9	M10	M6	M3	M18	M15
	XX								
	XX								

Bottom				
Among stations	8	52.78529	6.59816	2.1607
Within stations	<u>18</u>	<u>54.96787</u>	3.05377	
Total	26	107.75317		

$$F_{.05}[8, 18] = 2.51$$

two data subsets showed no consistent trends. Although significant differences among stations in Brevoortia sp. abundance were indicated for mid-depth samples in April (Table 8-16), the concentrations were so low that the analysis is questionable based on the assumption of homogeneity. No significant variance was demonstrated for postlarval Penaeus sp. abundance (Table 8-17). Total copepod concentrations varied significantly among stations because of anomalously high numbers found at station M1 (Table 8-18).

The postlarval shrimps, Lucifer faxoni and Penaeus sp., were common in the April .505 mm mesh samples as were the fishes Anchoa mitchilli, Brevoortia sp., C. arenarius, Gobiesox strumosus, Harengula pensacolae, unidentified Blenniidae, Menticirrhus americanus, Opisthonema oglinum, and Archosargus probatocephalus. As in March, the April .505 mm mesh samples clustered primarily by depth, with surface samples distinct from mid-depth and bottom samples (Figure 8-15).

The zooplankton assemblage sorted from the .505 mm mesh first replicates was speciose and exhibited oceanic influences. Numerical dominants included the following:

copepods

A. tonsa

C. hamatus

Eucalanus pileatus

L. aestiva

Paracalanus quasimodo

Temora stylifera

Table 8-16. Analysis of variance of Brevoortia larvae and postlarvae concentration (numbers per m³) among the offshore stations, .505 mm April 1981 samples. In the case of significant (*) ANOVA's, multiple comparisons among means are provided based on the Student-Newman-Keuls test (SNK).

<u>Source of variation</u>	<u>df</u>	<u>SS</u>	<u>MS</u>	<u>F_s</u>
Surface				
Among stations	6	0.2962	0.0494	1.460
Within stations	<u>14</u>	<u>0.4733</u>	0.0338	
Total	20	0.7695		

$$F_{.05}[6, 14] = 2.85$$

Mid-depth				
Among stations	8	0.0452	0.0057	3.813*
Within stations	<u>18</u>	<u>0.0267</u>	0.0015	
Total	26	0.0719		

$$F_{.05}[8, 18] = 2.51$$

SNK results:

Mean	0.000	0.000	0.000	0.000	0.000	0.033	0.033	0.033	0.133
Station	M3	M6	M10	M18	M20	M9	M15	M11	M1
	XX								

Table 8-17. Analysis of variance of Penaeus postlarvae concentration (numbers per m³) among the marine stations, .505 mm April 1981 samples.

<u>Source of variation</u>	<u>df</u>	<u>SS</u>	<u>MS</u>	F_s
Surface				
Among stations	6	.0229	.0038	0.8000
Within stations	<u>14</u>	<u>.0667</u>	.0048	
Total	20	.0896		
	$F_{.05}[6, 14] = 2.85$			
<hr/>				
Mid-depth				
Among stations	8	.0133	.0017	2.2500
Within stations	<u>18</u>	<u>.0133</u>	.0007	
Total	26	.0266		
	$F_{.05}[8, 18] = 2.51$			
<hr/>				
Bottom				
Among stations	8	.0274	.0034	2.3125
Within stations	<u>18</u>	<u>.0267</u>	.0015	
Total	26	.0541		
	$F_{.05}[8, 18] = 2.51$			

Table 8-18. Analysis of variance of total copepod concentration (numbers per m³) among the marine stations, .333 mm April 1981 samples. In the case of significant (*) ANOVA's, multiple comparisons among means are provided based on the Student-Newman-Keuls test (SNK).

<u>Source of variation</u>	<u>df</u>	<u>SS</u>	<u>MS</u>	<u>F_s</u>
Surface				
Among stations	7	639065.3	91295.04	1.41
Within stations	<u>16</u>	<u>1036799.2</u>	64799.95	
Total	23	1675864.5		

$$F_{.05}[7, 16] = 2.66$$

Mid-depth				
Among stations	7	9852934.09	1407562.01	2.20
Within stations	<u>16</u>	<u>10221859.32</u>	638866.21	
Total	23	20074793.41		

$$F_{.05}[7, 16] = 2.66$$

Bottom				
Among stations	8	5811944.41	726493.05	4.03*
Within stations	<u>18</u>	<u>3245652.85</u>	180314.05	
Total	26	9057597.26		

$$F_{.05}[8, 18] = 2.51$$

SNK results:

Mean	453.2	676.0	714.0	719.4	728.1	769.1	784.0	1237.0	2103.1
Station	M20	M10	M11	M15	M6	M9	M18	M3	M1
	XX								

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Figure 8-15. Cluster dendrogram based on abundances of fishes and shrimps for marine April .505 mm all-replicate samples. See Table 8-19 for identification of samples in clusters.

Table 8-19. Subcluster identification of specific samples in order of appearance on cluster dendrogram, marine. April .505 mm all replicates.

<u>Subcluster</u>	<u>Station</u>	<u>Depth</u>	<u>Replicate</u>	<u>Subcluster</u>	<u>Station</u>	<u>Depth</u>	<u>Replicate</u>
I	M1	S	1	II (cont'd.)	M1	B	3
	M20	S	1		M1	B	2
	M20	S	3		M11	B	3
	M20	M	1	III	M3	M	1
	M18	M	1		M10	B	3
	M18	B	2		M3	M	2
	M20	M	2		M18	M	2
	M1	S	3		M10	M	3
	M9	S	1		M6	M	3
	M3	S	2		M3	M	3
	M15	S	2		M6	M	2
	M9	S	2		M6	B	1
	M6	S	3		M10	B	1
	M9	S	3		M10	M	1
	M11	M	2		M10	M	2
	M1	S	2		M18	M	3
	M9	M	3		M18	S	1
	M20	M	3		M18	S	2
	M20	B	2		M18	S	3
	M3	S	3		M3	B	1
	M11	S	2		M3	B	2
	M1	M	1		M18	B	3
	M3	S	1		M3	B	3
	M6	S	1		M18	B	1
	M9	M	1		M10	B	2
	M9	M	2		M15	B	3
	M9	B	1		M6	B	2
	M9	B	3		M6	B	3
	M20	B	1		M15	M	1
	M11	M	1		M15	M	3
	M20	B	3		M15	M	2
II	M1	M	2		M15	B	1
	M10	S	2		M15	B	2
	M10	S	3				
	M10	S	1				
	M15	S	1				
	M6	M	1				
	M9	B	2				
	M6	S	2				
	M11	M	3				
	M11	B	1				
	M11	B	2				
	M1	M	3				
	M1	B	1				

T. turbinata

thecosome pteropod

Creseis conica

decapod larvae

Hexapanopeus angustifrons

L. faxoni

Pagurus sp.

Pinnixa spp.

fish eggs

Anchoa hepsetus

A. mitchilli

H. pensacolae

sciaenid-type

chaetognaths

S. friderici

larvaceans

Oikopleura sp.

barnacle larvae

polychaete larvae

Numerical classification of the .505 mm mesh first replicates generated two major clusters, one composed of surface and mid-depth samples and one of bottom and mid-depth samples (Figure 8-16.)

Analyses of the April .333 mm mesh samples and first replicates yielded results very similar to those of the .505 mm mesh in both taxonomic composition and numerical classification (Figures 8-17 and 8-18).

Figure 8-16. Cluster dendrogram based on abundances of all taxa for marine April .505 mm first-replicate samples.

Figure 8-17. Cluster dendrogram based on abundances of fishes and shrimps for marine April .333 mm all-replicate samples. See Table 8-20 for identification of samples in clusters.

Table 8-20. Subcluster identification of specific samples in order of appearance on cluster dendrogram, marine. April .333 mm all replicates.

<u>Subcluster</u>	<u>Station</u>	<u>Depth</u>	<u>Replicate</u>	<u>Subcluster</u>	<u>Station</u>	<u>Depth</u>	<u>Replicate</u>
I	M1	S	1	II	M1	B	3
	M1	S	3		M11	B	3
	M9	S	1		M11	B	1
	M9	S	3		M15	S	3
	M20	S	1		M1	M	2
	M20	M	1		M1	M	3
	M9	M	2		M1	B	1
	M18	B	1		M1	B	2
	M20	S	3		M10	S	1
	M20	S	2		M10	S	2
	M11	S	1	III			
	M3	S	1		M3	S	1
	M20	M	2		M18	B	2
	M20	B	2		M3	B	2
	M20	B	1		M6	M	2
	M15	B	3		M18	S	1
	M9	M	2		M18	S	3
	M18	B	3		M3	M	2
	M9	M	3		M10	M	3
	M20	B	3		M10	B	1
	M9	M	1		M6	M	1
	M11	M	1		M6	B	1
	M9	B	1		M10	M	1
	M9	B	2		M3	M	3
	M3	S	3		M6	M	3
	M3	B	1		M6	B	3
	M11	M	2		M15	B	2
	M20	M	3		M10	B	3
	M9	B	3		M10	B	2
	M3	B	3		M18	M	1
	M11	S	2		M18	M	2
	M6	B	2		M15	B	1
	M18	S	2		M18	M	3
	M1	S	2		M10	M	2
	M15	S	1		M15	M	2
	M10	S	3		M15	M	1
	M3	S	2		M15	M	3
	M6	S	3				
	M6	S	1				
	M15	S	2				
	M6	S	2				
II	M1	M	1				
	M11	M	3				
	M11	B	2

Figure 8-18. Cluster dendrogram based on abundances of all taxa for marine April .333 mm first-replicate samples.

An unusual hydrographic regime was observed during April sampling. A very strong east-west surface current, confined to the top one to two meters of the water column made CTD/DO casts and consistent tows difficult. This situation was reflected particularly in the salinity profile from that cruise (Figure 8-19). A strong halocline was detected at less than one meter depth, especially at the diffuser and near-field stations, M6, M10, and M15. A thermocline was present in the same area and depth (Figure 8-20). The surface water at these stations was also characterized by comparatively high dissolved oxygen concentrations (Figure 8-21). Meanwhile, bottom and mid-depth salinities were very high at stations M3, M6, M10, M15, and M18, compared to the data of Frey, Szabados, and Hickman (1981). The next day, bottom salinities were also very high at stations M11 and M9 (32-34 ‰). The intensity of this near-surface event is not apparent in the continuous monitoring of physical parameters at the diffuser site (Chapter 2, this report) because the near-surface instruments were located 3.7 m below the surface, beneath the event horizon.

8.3.2 Estuarine

8.3.2.1 February

Postlarval Penaeus sp. were common in the February estuarine samples as were the fishes A. mitchilli, Brevoortia sp., Micropogonias undulatus, and M. punctatus. Dominant taxa in the first replicates included the copepods A. tonsa, C. hamatus, Oithona colcarva, and Parvocalanus crassirostris, as well as unidentified

Figure 8-19. Vertical distribution of salinity (‰), 14 April 1981 based on observations at 1 m intervals.

Figure 8-20. Vertical distribution of temperature ($^{\circ}\text{C}$), 14 April 1981 based on observations at 1 m intervals.

Figure 8-21. Vertical distribution of dissolved oxygen (ml l⁻¹), 14 April 1981 based on observations at 1 m intervals.

bivalves and barnacle larvae. Numerical classification of the data subsets indicated strong within-station similarity and similarity between stations decreasing with increasing distance apart. (Figures 8-22 and 8-23).

8.3.2.2 March

Common meroplankton in March included Penaeus sp., A. mitchilli, Brevoortia sp., C. arenarius, and M. undulatus. Other common taxa from the first replicates were A. tonsa, C. hamatus, Eurytemora affinis, and barnacle larvae. These data exhibited a less pronounced along-estuary gradient of similarity (Figures 8-24 and 8-25) than did the February data. Only the Calcasieu Pass station E5 separated out distinctly.

8.3.2.3 April

April meroplankton which were most common were A. mitchilli, Brevoortia sp., C. arenarius, G. strumosus, unidentified Gobiidae, Menidia beryllina, and Penaeus sp. The first replicates in April were strongly dominated by A. tonsa and barnacle larvae. Because of this dominance there was strong similarity among all of the first replicates whereas when all samples were clustered based only on meroplankton, the two extreme stations, E1 and E5, each clustered separately from the mid-estuary stations (Figures 8-26 and 8-27).

8.4 Discussion

8.4.1 Marine

Other studies have described the gross faunal composition and seasonal changes of the coastal zooplankton community in the

Figure 8-22. Cluster dendrogram based on abundances of fishes and shrimps for estuarine February .153 mm all-replicate samples.

BRAY-CURTIS SIMILARITY

Figure 8-23. Cluster dendrogram based on abundances of all taxa for estuarine February .153 mm first-replicate samples.

Figure 8-24. Cluster dendrogram based on abundances of fishes and shrimps for estuarine March .153 mm all-replicate samples.

Figure 8-25. Cluster dendrogram based on abundances of all taxa for estuarine March .153 mm first-replicate samples.

Figure 8-26. Cluster dendrogram based on abundances of fishes and shrimps for estuarine April .153 mm all-replicate samples.

BRAY-CURTIS SIMILARITY

Figure 8-27. Cluster dendrogram based on abundances of all taxa for estuarine April .153 mm first-replicate samples.

northwestern Gulf of Mexico (Gillespie, 1971; Marum, 1979; Park and Minello, 1980; Park and Turk, 1980; Reitsema, 1980; Wormuth, 1980). The present study is not a duplication of that effort. Rather, we have examined the community for small-scale variability which might change with perturbation.

The taxa found to be numerically dominant in this study were, with a few exceptions, the same as those described by other investigators. A significant finding, though, was the common presence of Penaeus postlarvae in the diffuser area in February and again in April. Reitsema (1980) reported only a single questionable Penaeus specimen from the same area after a full year of seasonal sampling; Galloway and Reitsema (1981) found no Penaeus postlarvae in their bongo samples collected off Texas in February and May, 1980. Our finding that postlarval Penaeus sp. as well as Brevoortia sp. are common in the diffuser area shows that there is a potential for impact to these fisheries from brine discharge at the West Hackberry site. The relative importance of such an impact would have to be determined from regional recruitment patterns.

In the analyses of variance in zooplankton biomass from 18 data subsets, significant variance among stations was found in nine subsets, all but three of which were collected with .333 mm mesh nets. Since no consistent areal patterns of similarity among stations were described by numerical classification or SNK analyses of the samples, this variance in biomass among stations is probably a result of the scale of patchiness in the smaller zooplankton which are retained in the .333 mm mesh but not in the .505 mm mesh. This interpretation is supported by the ANOVA and SNK analyses of copepod

abundance. If a physical feature of the system was causing faunal heterogeneity, it should show up as a consistent areal pattern in the fauna. Although there were patterns in these data which could mask diffuser effects for a given month, a long-term study would document impacts as a consistent vector superimposed on the community dynamics of the coastal zooplankton. Such a vector would be manifested as statistically significant differences between control and impact stations. The differences would be unidirectional for a given parameter (e.g. increased abundance or biomass) and consistent among periods of observation when the brine diffuser is operating.

The mid-depth samples confused rather than contributed to this analysis. The pelagic regime of the study area is essentially two-layered and attempting to sample the interface between the layers results in samples taken indiscriminantly from one or the other of the layers and therefore having fluctuating similarity patterns.

8.4.2 Estuarine

Numerical dominance of zooplankton by A. tonsa is typical of the warm temperate estuaries of the southeastern United States. Similarly, the meroplankton identified are common in estuaries along the Gulf coast and either the same species (e.g. A. mitchilli) or similar geminate species (e.g. C. arenarius - C. regalis which appear to be undergoing allopatric speciation and are therefore the subject of taxonomic debate) are abundant in Atlantic estuaries. Normal seasonal changes in the zooplankton community can be expected to follow those that have been described for other similar estuaries.

Numerical classification indicated an along-estuary gradient, with Calcasieu Pass station E5 particularly distinct from the rest of the estuary. Station E5 was qualitatively similar to the coastal community described above for the marine study. Similar patterns have been identified by investigators of other biological disciplines (Chapters 5-7, this report). It therefore seems likely that displacement of the community up-estuary should be detectable by increased similarity between station E5 and the other estuarine stations.

8.5 Conclusions

8.5.1 Marine

1) The zooplankton community in the vicinity of the West Hackberry brine disposal site is typical of the coastal assemblage from the northwestern Gulf of Mexico and should be expected to follow the seasonal patterns outlined by other investigators.

2) Planktonic stages of Penaeus and Brevoortia are common in the diffuser area and are subject to potential impacts of brine discharge.

3) Although there is some inherent areal variability in the system, these changing patterns should be separable from consistent patterns resulting from the impact of brine discharge.

8.5.2 Estuarine

The zooplankton community of the Calcasieu River estuary is typical of Gulf coast estuaries. Dramatic changes in the community resulting from water displacement can be documented by changes in similarity patterns among stations and comparison with similar estuaries.

CHAPTER 9

DATA MANAGEMENT

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9.1 MSU Data Management

9.1.1 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. Principle 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 file organization
- (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 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 Administration (NOAA).

9.1.2 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.

9.1.3 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.

9.1.4 Data Processing

After a sample was collected by the principal investigator, it was analyzed in the laboratory, data was compiled on preformatted coding forms and the raw data was sent to the data management office. Through screen design aid 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, backup storage, statistical analyses, and report generation. The cycles and flow of data and its processing are illustrated in Figure 9-1.

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 existing list; old and unwanted taxonomic codes and names were deleted. The files were updated periodically.

Figure 9-1. Flowchart of data entry, verification, storage and retrieval, and archival of data for EDIS.

9.1.4 Software Development

9.1.4.1 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 are 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 9-1 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, one for inshore or offshore cruise, one character for month of the year, and last character indicative of purpose of file. There were twelve master files and approximately 64 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. 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 usable specific purpose files. These activities are illustrated in Figure 9-2.

Figure 9-2. Construction of specific purpose files and statistical analyses.

Table 9.1. Nomenclature for computer files.

<u>Name of file</u>	<u>Description</u>
BR.004	Master file for CTD/DO data, NOAA format code <u>004</u>
BR.028	Master file for Phytoplankton data, NOAA format code <u>028</u>
BR.029	Master file for Phytoplankton data, NOAA format code <u>029</u>
BR.032	Master file for Benthos data, NOAA format code <u>032</u>
BR.123	Master file for Nekton data, NOAA format code <u>123</u>
BR.124	Master file for Zooplankton data, NOAA format code <u>124</u>
BR.144	Master file for Special Pollutant data, NOAA format code <u>144</u>
BRK.B002	<u>Benthos</u> <u>Offshore</u> <u>February</u> data
BRK.B102	<u>Benthos</u> <u>Inshore</u> <u>February</u> data
BRK.NO3W	<u>Nekton</u> <u>Offshore</u> <u>March</u> data by the species <u>Weight</u>
BRK.NI4C	<u>Nekton</u> <u>Inshore</u> <u>April</u> data by the species <u>Count</u>
BRK.NOAW	<u>Nekton</u> <u>Offshore</u> for <u>All</u> months by the species <u>Weight</u>

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 inter-relationships. 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 program supplied by International Business Machine (IBM) was used whereas indigenous programs for 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 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. Commerically 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.

9.1.4.2 Benthic Data

In January 1981, samples were taken to determine the suitable number of replicates of samples at each station. It was determined that five and six replicates should be taken in subsequent field sampling of the estuarine and marine areas, respectively. 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 ordination analysis were created from this master file.

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 at very few stations 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 $\beta = -.25$, (Boesch, 1977). To crosscheck clustering strategy, group averaging method was used. 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.

To support the interpretation of the classification developed with cluster analysis and to examine gradational relationship among the samples based upon their resemblance to one another, hierarchical

ordination using square root transformation and reciprocal averaging was employed. The results are described in the Benthos section elsewhere. Taxonomic codes and names of species were the same as used by VIMS.

9.1.4.3 Nekton Data

Master files were constructed to include data from all cruises. Cluster analysis was employed on estuarine and marine data for each month and then on combined data for all months, estuarine and marine, taking the options which were described in the Benthic data section. Regression analyses were performed on logarithmic transformed data on individual length and weight of species. Species abundance, diversity indices and distributional characteristics statistics were calculated.

9.1.4.4 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. Diversity indices were calculated for all samples.

9.1.4.5 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 and different measurements were made at each depth. On logarithmic transformed data cluster analysis was done with Bray-Curtis method of similarity

measurements with "flexible" cluster strategy and $\beta = -.25$. For numerical classification of this multivariate data, hierarchical ordination technique was used employing reciprocal averaging on logarithmic transformed data. Both R-type and Q-type ordinations were performed on data representing the abundances of species at the different sampling stations. R-type analyses identified co-occurring groups of species while Q-type identified groups of stations with similar species composition, (Boesch, 1977).

9.1.4.6 CTD/DO Data

Whenever a sampling cruise took place, measurements on some physical parameters, such as, conductivity, temperature, salinity, and dissolved oxygen were made at each station. Differences between stations were evaluated using factor analysis and 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.

One master file was created and extracts of monthly data were sent to EDIS. Special purpose files were created using this master file to prepare statistical reports.

9.1 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. The first field sampling for special pollutants took place on March 13, 1981 and the second on May 5, 1981. Statistical analyses were not performed for these limited data.

Detailed description of results and their findings in each of the disciplines were discussed in the previous chapters.

9.2 TAMU Data Management

The management and processing of information and data collected by Texas A&M personnel are critical to the overall performance in this contract. The data manager uses data processing services, equipment and facilities whenever such services are cost-effective and increase productivity. This includes the use of remote terminals or main frame facilities to recall stored data files, to create or update new files, to print or report total files or subsets, to prepare accounting and fiscal reports, to implement or update a master schedule or report, and to implement any other technique or method for analyzing, integrating, and synthesizing data which will provide decision-making information. The data manager reviews computer-generated reports and all pertinent data. These data and cognitive information are subsequently integrated by the principal investigators in order to arrive at specific conclusions and recommendations.

The data management functions consist of total systems planning, data and sample collection, data reduction, data and sample analysis, data integration and synthesis, data evaluation and reporting, and data base generation and archiving (Figure 9-3). Furthermore, once these data and samples are processed, scientific techniques are applied, and in a cognitive manner, data are integrated and synthesized into meaningful information. This latter effort culminates with this report.

SITE	DATE	DEPTH (M)	SI02 (MG/L)	NH3-N (MG/L)	TOTAL PHOSPHOROUS (MG/L)	OP04-P (MG/L)	NO2-N (MG/L)	NO3-N (MG/L)	TURBIDITY (NTU)	DISSOLVED OXYGEN (MG/L)	OIL & GREASE (MG/L)
M1	02/14/81	0.00	2.36	99999	0.03	0.03	-1.00	0.01	2.50	9.15	0.70
M1	02/14/81	9.40	0.54	0.89	0.03	0.03	-1.00	-1.00	9.20	9.00	0.50
M3	02/14/81	0.00	0.68	0.78	0.03	0.03	-1.00	-1.00	8.50	9.20	0.30
M3	02/14/81	9.40	1.14	0.41	0.04	0.04	-1.00	-1.00	19.00	9.00	0.40
M6	02/14/81	0.00	0.80	0.94	0.04	0.04	-1.00	-1.00	3.10	9.30	0.60
M6	02/14/81	9.80	2.34	0.07	0.05	0.05	-1.00	-1.00	25.50	8.90	0.50
M9	02/14/81	0.00	0.76	0.69	0.03	0.03	-1.00	0.01	3.30	9.40	0.30
M9	02/14/81	9.10	0.90	0.56	0.04	0.04	-1.00	-1.00	16.50	9.10	0.50
M10	02/14/81	0.00	0.86	0.31	0.04	0.04	-1.00	-1.00	2.90	9.20	0.50
M10	02/14/81	9.80	1.06	0.44	0.05	0.10	-1.00	-1.00	14.00	9.65	0.50
M11	02/14/81	0.00	1.08	0.28	0.06	0.03	-1.00	-1.00	3.30	9.50	0.50
M11	02/14/81	10.40	0.80	0.25	0.06	0.06	-1.00	-1.00	16.50	9.25	0.30
M15	02/14/81	0.00	0.84	0.41	0.03	0.03	-1.00	-1.00	3.00	9.30	0.60
M15	02/14/81	9.80	1.12	0.31	0.03	0.04	-1.00	-1.00	7.00	9.20	0.60
M18	02/14/81	9.80	0.66	0.23	0.04	0.04	-1.00	-1.00	2.60	9.40	0.60
M20	02/14/81	0.00	0.60	-1.00	0.03	0.03	-1.00	0.01	2.40	9.20	0.30
M20	02/14/81	9.80	0.60	0.36	0.03	0.04	-1.00	-1.00	9.00	9.10	0.80

SITE	DATE	PHI SIZES EACH COLUMN IN PER CENT									
		1-1.5	1.5-2	2-2.5	2.5-3	3-3.5	3.5-4	4-5	5-6	6-7	7-8
E1	02/03/81	0.20	0.32	1.26	1.69	7.75	2.25	23.76	15.98	10.57	5.33
E2	02/03/81	1.77	0.50	0.91	1.09	1.52	1.54	15.89	15.61	9.77	8.24
E3	02/13/81	1.33	1.45	2.50	2.81	1.47	0.99	64.16	3.17	1.90	2.08
E4	02/03/81	0.89	2.17	16.41	32.26	12.58	1.15	4.62	2.94	2.95	3.49
E5	02/03/81	2.58	3.90	9.10	9.38	18.58	6.96	17.79	3.76	4.23	2.21

SITE	DATE	TIME (CST)	DEPTH (M)	SALINITY (PPT)	WATER TEMP (DEGREES C)	DISSOLVED OXYGEN (MG/L)
M23	03/07/81	1210	1.00	33.60	14.80	8.60
M23	03/07/81	1210	3.40	33.60	14.80	8.60
M23	03/07/81	1210	6.40	33.60	14.80	8.60
M23	03/07/81	1210	9.40	33.70	14.80	8.60
M22	03/07/81	1245	1.00	33.60	14.80	8.50
M22	03/07/81	1245	4.30	33.60	14.90	8.60
M22	03/07/81	1245	7.30	33.60	14.80	8.60
M22	03/07/81	1245	10.30	33.60	14.90	8.60
M13	03/07/81	1325	1.00	32.70	14.70	8.70
M13	03/07/81	1325	4.60	32.80	14.70	8.70
M13	03/07/81	1325	7.60	33.00	14.50	8.50
M13	03/07/81	1325	10.60	33.70	14.40	7.90
M12	03/07/81	1405	1.00	32.10	14.70	8.20
M12	03/07/81	1405	4.00	32.10	14.60	8.20
M12	03/07/81	1405	7.00	32.30	14.60	8.00
M12	03/07/81	1405	10.00	32.30	14.60	8.50

SITE	DATE	%SAND	%SILT	%CLAY	PORE WATER SALINITY (PPT)	%ORGANIC CARBON
M10A	04/10/81	00.310	16.460	83.230	29.148	00.730
M10	04/10/81	05.670	32.720	61.610	29.534	01.000
M11	04/10/81	06.440	50.630	42.920	29.903	00.740
M15	04/10/81	03.040	30.280	66.680	29.310	00.750
M18	04/10/81	02.000	27.950	70.050	29.783	00.760
M20	04/10/81	06.670	26.390	66.930	29.348	00.780

SITE	DATE	TIME (CST)	WATER TEMP (DEGREES C)	SEA STATE	WAVE HEIGHT	WAVE PERIOD	WAVE DIRECTION	COLOR
M20	03/13/81	0546	15.20	04	04	02	13	03
M15	03/13/81	1026	15.00	04	04	02	13	03
M10A	03/13/81	1105	15.40	04	04	02	13	03
B-S	03/13/81	1246	15.50	04	04	02	13	03
M11	03/13/81	1421	24.00	01	00	02	12	03
B-W	03/13/81	1623	16.40	01	00	02	12	03
M9	03/13/81	1758	16.00	02	01	02	20	03

SITE	DATE	TIME (CST)	DEPTH (M)	WATER TEMP (DEGREES C)	PH
M6	02/16/81	0724	10.06	10.00	7.50
M9	02/16/81	0916	9.14	10.00	6.30
M9	02/16/81	0916	0.00	9.50	6.50
M10	02/16/81	0939	10.36	10.00	6.40
M10	02/16/81	0939	0.00	10.00	6.50
M11	02/16/81	1012	10.97	10.00	6.40
M11	02/16/81	1012	0.00	10.00	6.60
M15	02/16/81	0707	10.06	9.00	7.40
M15	02/16/81	0707	0.00	10.00	7.60

Figure 9-3. Sample format of data collected from the SPR West Hackberry project: 1) water chemistry, 2) grain size, 3) CTD/DO, 4) sediment chemistry, 5) sea state, 6) pH.

9.2.1 Data Management

The goals of the project data management component are twofold. The first is to provide liaison with the Environmental Data Information Service in Washington, D.C. to insure appropriate data exchange. The second is to provide a centralized program to meet the data processing needs of the other principal investigators.

The functions of a data manager are manifold. They may include, but are not limited to, the following:

- a) To assist principal investigators and to identify, document and support data and information requirements;
- b) To define the data requirements associated with collection, reduction, analysis, reporting, quality and inventory control, interfaces, integration, and data base structures;
- c) To assist principle investigators in handling digitized/ analog data and in presenting acceptable tabular or graphical representations of analytical data;
- d) To assist principle investigators in integrating data bases and in preparing supporting computer programs and software; and
- 3) To assist the program manager in selecting correct hardware, firmware, and software for data and information requirements.

It is also the responsibility of the project data manager to consult with each principal investigator or with the field operations manager to gather the appropriate data for inclusion into a report which is sent to EDIS. This document, a Report of Observations/ Samples Collected by Oceanographic Programs (ROSCOP II) is filed with EDIS following each sampling cruise in accordance with applicable instructions. The data manager also transmits data to EDIS on a

monthly basis using first class mail. Normally, data are transmitted via magnetic tape provided by EDIS along with a Data Documentation Form (DDF), which describes the type of data included in a printout of all data. A letter of transmittal is also sent to EDIS under separate cover to notify the agency that the data are en route. A copy of the letter is returned to the project data manager as soon as the data are received by EDIS to verify receipt of the data. A printout and DDF of all data sent to EDIS are maintained by the data manager.

9.2.2 Data Processing

Data processing activities include the maintenance of a centralized data storage and retrieval system based on file processing techniques and the provision of programming support for project principal investigators as required (Figures 9-4 and 9-5). Each principal investigator encloses his data onto appropriate data forms which are used in similar projects. The forms are given to the data manager, who is responsible for entering the data into the on-line disk storage system. Data are further processed as requested by each principal investigator to facilitate individual analysis and for use in reports as required. The Data Management appendix is a compilation of the data collected during the predischARGE portion of the project.

All computer time is controlled and allocated by the data manager, who employs appropriate security techniques both for the safeguard of computerized data and data processing accounts. The data manager also insures that project data are backed up onto magnetic tape as required.

DATA PROCESSING

Figure 9-4. Flow chart of data processing activity.

SOFTWARE DEVELOPMENT

Figure 9-5. Flow chart of software development.

9.2.3 Data Documentation Procedures

There are several forms required for internal and external documentation and data storage. A detailed explanation is given for the following in the lab and field manual written for this project (Hann and Giammona, 1981).

1. Report of Observations/Samples Collected by Oceanographic Programs (ROSCOP)
2. Letter Transmitting Data Form
3. Data Documentation/Data Format Forms
4. Record Format Description Form
5. Data Entry Form
6. Monthly Report Form

Forms 1 through 4 are associated with transmitting data to various government agencies. Forms 5 and 6 are used for internal management.

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APPENDIX A. Supporting Data for Data Management

Table 1. Field Data

SEA WEATHER CONDITIONS										
SITE	DATE	TIME (CST)	AIR TEMP (C)	PRESSURE (HG)	WIND SPEED	WIND DIR	CLOUD COVER	CLOUD TYPE	VISIBILITY	CONDITION
M21	02/03/81	0858	99999	99999	2	14	0	99	99	B
M21	02/04/81	0810	06.70	99999	2	07	8	99	99	A
M8	02/04/81	0840	06.70	99999	2	07	8	99	99	A
M9	02/04/81	0905	06.70	99999	4	07	8	99	99	A
M10	02/04/81	0923	06.70	99999	4	07	8	99	99	A
M11	02/04/81	1029	06.70	99999	4	07	8	99	99	A
M12	02/04/81	1053	06.70	99999	4	07	8	99	99	A
M13	02/04/81	1128	06.70	99999	4	07	8	99	99	A
M22	02/04/81	1225	06.70	99999	4	07	8	99	99	A
M23	02/04/81	1258	06.70	99999	4	07	8	99	99	A
M1	02/04/81	1425	06.70	99999	4	07	8	99	99	A
M3	02/04/81	1445	06.70	99999	4	07	8	99	99	A
M6	02/04/81	1513	06.70	99999	4	07	8	99	99	VS
M15	02/04/81	1535	06.70	99999	4	07	8	99	99	A
M18	02/04/81	1552	06.70	99999	4	07	8	99	99	VS
M20	02/04/81	1620	06.70	99999	4	07	8	99	99	VS
E5	02/14/81	0640	03.00	99999	1	36	8	1	9	A
E4	02/14/81	0852	03.50	99999	1	5	4	3	9	A
E3	02/14/81	0957	05.70	99999	1	5	7	3	9	A
E2	02/14/81	1150	11.00	99999	1	36	7	6	9	A
E6	02/14/81	1312	14.00	99999	0	0	7	6	9	A
E1	02/14/81	1420	12.00	99999	0	0	7	6	9	A
E7	02/15/81	0710	07.50	99999	1	5	1	8	9	A
E8	02/15/81	0850	99999	99999	3	9	5	4	9	A
E9	02/15/81	0910	99999	99999	2	7	6	4	5	A
E10	02/15/81	0950	99999	99999	2	7	8	5	4	A
M20	02/16/81	0620	11.50	99999	0	0	99	99	99	A
M18	02/16/81	0649	11.00	99999	0	32	8	5	99	A
M15	02/16/81	0707	11.00	99999	0	32	8	5	4	A
M9	02/16/81	0916	12.00	99999	0	0	8	5	4	A
M10	02/16/81	0939	12.00	99999	0	0	8	5	4	A
M11	02/16/81	1012	11.00	99999	1	29	8	5	5	A
M20	03/07/81	0900	14.00	99999	5	5	8	6	4	O
M18	03/07/81	0953	14.00	99999	5	5	8	6	4	O
M15	03/07/81	1015	14.50	99999	4	9	7	6	4	O

A-1

SEA WEATHER CONDITIONS

SITE	DATE	TIME (CST)	AIR TEMP (C)	PRESSURE (HG)	WIND SPEED	WIND DIR	CLOUD CLOVER	CLOUD TYPE	VISIBILITY	CONDITION
M6	03/07/81	1039	14.50	99999	3	9	7	6	4	0
M23	03/07/81	1213	15.00	99999	3	9	8	6	4	0
M22	03/07/81	1249	15.60	99999	2	9	8	6	4	0
M13	03/07/81	1327	16.00	99999	3	9	7	6	4	C
M12	03/07/81	1406	16.00	99999	5	9	8	6	4	0
M11	03/07/81	1420	16.00	99999	5	9	8	6	4	0
M10	03/07/81	1510	16.00	99999	5	9	8	6	4	0
M3	03/07/81	1600	15.60	99999	5	9	8	6	4	0
M1	03/07/81	1631	15.30	99999	5	9	8	6	4	0
M9	03/07/81	1720	15.00	99999	3	9	8	6	4	0
M8	03/07/81	1740	15.00	99999	4	9	8	6	4	0
M21	03/07/81	1820	15.50	99999	6	9	8	6	4	0
E5	03/08/81	0625	11.00	99999	3	36	8	6	4	0
E4	03/08/81	0735	13.00	99999	4	36	8	6	4	0
E3	03/08/81	0835	13.00	99999	4	36	8	6	4	0
E2	03/08/81	1044	19.50	99999	1	09	6	6	4	C
E6	03/08/81	1145	18.00	99999	2	9	6	6	4	C
E1	03/08/81	1245	19.00	99999	1	9	6	6	4	C
E7	03/08/81	1435	22.50	99999	3	9	4	6	3	C
M8	03/08/81	1610	99999	99999	2	99	2	6	3	C
M9	03/08/81	1625	99999	99999	2	99	2	6	3	C
M10	03/08/81	1654	99999	99999	2	99	1	6	3	C
M20	03/13/81	0946	13.00	30.10	3	5	8	6	6	0
M15	03/13/81	1026	12.20	30.10	3	5	8	6	6	0
M10A	03/13/81	1105	14.50	30.10	3	5	8	6	6	0
M11	03/13/81	1421	24.00	30.00	1	99	2	5	8	B
M9	03/13/81	1758	16.50	30.00	2	20	2	6	8	B
E5	03/15/81	0600	16.00	30.10	2	13	1	6	5	B
E4	03/15/81	0900	17.80	30.10	2	18	2	6	7	C
E3	03/15/81	0950	17.80	30.10	3	18	4	6	7	C
E2	03/15/81	1126	18.20	30.10	4	18	8	5	6	0
E5	04/09/81	0607	21.00	30.10	03	18	07	05	05	0
E4	04/09/81	0710	21.00	30.10	03	18	07	05	06	C
E3	04/09/81	0745	21.00	30.10	02	18	06	05	06	C
E2	04/09/81	0855	21.00	30.15	01	18	06	05	07	C
E1	04/09/81	1140	25.00	30.10	01	99	03	06	07	C

SEA WEATHER CONDITIONS

SITE	DATE	TIME (CST)	AIR TEMP (C)	PRESSURE (HG)	WIND SPEED	WIND DIR	CLOUD CLOVER	CLOUD TYPE	VISIBILITY	CONDITION
M23	04/10/81	0945	22.00	30.15	02	11	08	09	01	FG
M22	04/10/81	1015	23.00	30.15	02	11	08	09	04	F
M13	04/10/81	1055	22.50	30.15	02	11	07	09	05	F
M12	04/10/81	1125	25.00	30.15	02	11	04	08	06	C
M11	04/10/81	1142	24.00	30.15	02	11	01	08	06	C
M10	04/10/81	1215	23.00	30.15	02	11	02	08	06	C
M9	04/10/81	1230	23.00	30.10	02	11	02	08	06	C
M8	04/10/81	1250	24.00	30.10	02	11	02	08	06	C
M21	04/10/81	1314	99999	30.10	02	11	02	08	06	C
M1	04/10/81	1410	24.00	30.10	02	13	02	08	06	C
M3	04/10/81	1450	25.00	30.10	02	11	01	06	06	C
M6	04/10/81	1511	26.00	30.10	02	11	01	06	06	C
M10A	04/10/81	1534	27.00	30.10	04	11	01	06	06	C
M15	04/10/81	1612	25.00	30.10	04	11	01	06	06	C
M18	04/10/81	1630	24.00	30.10	04	11	01	06	06	C
M20	04/10/81	1658	24.00	30.10	04	11	00	00	06	B

SEA SURFACE CONDITIONS

SITE	DATE	TIME (CST)	WATER TEMP (DEGREES C)	SEA STATE	WAVE HEIGHT	WAVE PERIOD	WAVE DIRECTION	COLOR
M21	02/03/81	0658	10.90	03	01	02	14	03
E5	02/14/81	0640	05.80	99	99	99	99	06
E4	02/14/81	0652	05.30	01	99	99	05	06
E3	02/14/81	0957	05.20	02	00	99	05	06
E2	02/14/81	1150	08.60	01	00	99	36	06
E6	02/14/81	1312	06.90	00	00	99	00	06
E1	02/14/81	1420	06.90	00	00	99	99	06
E7	02/15/81	0710	08.60	00	00	99	99	99
E8	02/15/81	0850	09.10	03	01	99	99	99
E9	02/15/81	0910	07.70	03	01	99	99	99
E10	02/15/81	0950	08.30	03	01	99	99	99
M20	02/16/81	0620	10.00	00	00	99	00	03
M18	02/16/81	0649	10.00	00	00	10	00	03
M15	02/16/81	0707	10.00	00	00	10	00	03
M10	02/16/81	0939	10.00	00	00	10	00	03
M11	02/16/81	1012	10.00	00	00	10	32	03
M20	03/07/81	0900	14.80	99	99	99	99	99
M18	03/07/81	0953	14.80	99	99	99	99	03
M15	03/07/81	1014	14.80	99	99	99	99	03
M6	03/07/81	1039	14.90	99	99	99	99	03
M23	03/07/81	1213	14.80	03	02	02	99	02
M22	03/07/81	1247	14.80	03	02	02	99	02
M13	03/07/81	1327	14.70	03	02	02	99	02
M12	03/07/81	1406	14.70	03	02	02	99	03
M11	03/07/81	1430	14.70	03	02	02	99	02
M10	03/07/81	1510	14.80	03	02	02	99	05
M3	03/07/81	1600	14.90	03	02	02	99	05
M1	03/07/81	1631	15.00	03	02	02	99	04
M9	03/07/81	1720	14.90	03	02	02	99	04
M8	03/07/81	1740	15.10	03	02	02	99	06
M21	03/07/81	1820	15.50	99	99	99	99	06
E5	03/08/81	0625	15.60	01	00	10	99	06
E4	03/08/81	0735	15.00	03	01	10	99	06
E3	03/08/81	0835	15.90	03	01	10	99	06
E2	03/08/81	1044	16.50	02	01	10	99	04

SEA SURFACE CONDITIONS

SITE	DATE	TIME (CST)	WATER TEMP (DEGREES C)	SEA STATE	WAVE HEIGHT	WAVE PERIOD	WAVE DIRECTION	COLOR
E6	03/08/81	1145	17.00	01	01	10	99	04
E1	03/08/81	1245	17.90	01	01	10	99	06
E7	03/08/81	1435	99999	01	01	10	99	04
E8	03/08/81	1610	99999	02	01	10	99	06
E9	03/08/81	1625	99999	99	99	99	99	99
E10	03/08/81	1654	99999	99	99	99	99	99
M20	03/13/81	0946	15.20	04	04	02	13	03
M15	03/13/81	1026	15.00	04	04	02	13	03
M10A	03/13/81	1105	15.40	04	04	02	13	03
M11	03/13/81	1421	24.00	01	00	02	12	03
M9	03/13/81	1758	16.00	02	01	02	20	03
E5	03/15/81	0600	15.60	02	00	02	18	03
E4	03/15/81	0900	17.00	02	00	02	20	03
E3	03/15/81	0950	17.30	03	01	02	18	03
E2	03/15/81	1136	17.50	03	02	02	18	03
E1	03/15/81	1258	18.00	02	00	02	24	03
E5	04/09/81	0607	21.00	03	01	02	18	03
E4	04/09/81	0710	21.00	03	01	02	18	03
E3	04/09/81	0745	21.00	03	01	02	18	03
E2	04/09/81	0855	22.00	01	00	02	18	03
E1	04/09/81	1140	23.00	01	00	00	00	03
M23	04/10/81	0945	19.80	03	02	02	11	03
M22	04/10/81	1015	20.40	03	02	02	11	03
M13	04/10/81	1055	20.60	03	02	02	11	03
M12	04/10/81	1125	20.90	03	02	02	11	03
M11	04/10/81	1142	22.00	03	02	02	11	03
M10	04/10/81	1215	22.00	03	02	12	11	03
M9	04/10/81	1230	23.00	03	02	12	11	03
M8	04/10/81	1250	22.00	03	02	12	11	03
M21	04/10/81	1314	22.00	03	02	02	11	03
M1	04/10/81	1410	20.90	03	02	02	11	03
M3	04/10/81	1450	22.00	03	02	02	11	03
M6	04/10/81	1511	22.00	03	02	02	11	03
M10A	04/10/81	1534	22.00	04	03	02	11	03
M15	04/10/81	1612	22.00	04	03	02	11	03
M18	04/10/81	1630	22.00	04	03	02	11	03

SEA SURFACE CONDITIONS

SITE	DATE	TIME (CST)	WATER TEMP (DEGREES C)	SEA STATE	WAVE HEIGHT	WAVE PERIOD	WAVE DIRECTION	COLOR
M20	04/10/81	1658	22.00	04	03	02	11	03

OVER THE SIDE DATA

SITE	DATE	TIME (CST)	DEPTH (M)	SALINITY (PPT)	WATER TEMP (DEGREES C)	DISSOLVED OXYGEN (MG/L)
M21	02/03/81	0904	01.00	30.80	10.80	6.40
M21	02/03/81	0904	01.50	30.80	10.80	6.50
M21	02/03/81	0904	04.50	30.80	10.80	6.30
M8	02/03/81	0920	01.00	31.30	10.90	7.70
M8	02/03/81	0920	03.90	31.30	10.90	7.70
M8	02/03/81	0920	06.90	31.30	10.90	6.50
M9	02/03/81	1000	01.00	32.10	11.10	8.00
M9	02/03/81	1000	02.10	32.10	11.10	8.00
M9	02/03/81	1000	05.10	32.10	11.10	8.00
M9	02/03/81	1000	08.10	32.10	10.90	8.10
M10	02/03/81	1100	01.00	32.10	11.30	7.90
M10	02/03/81	1100	02.80	32.10	11.30	8.00
M10	02/03/81	1100	05.80	32.10	11.20	8.00
M10	02/03/81	1100	08.80	32.20	11.00	8.10
M11	02/03/81	1300	01.00	32.40	11.60	8.30
M11	02/03/81	1300	03.40	32.40	11.60	8.30
M11	02/03/81	1300	06.40	32.40	11.50	8.30
M11	02/03/81	1300	09.40	32.40	11.40	8.30
M12	02/03/81	1400	10.00	32.70	11.60	8.30
M12	02/03/81	1400	01.00	32.60	11.80	8.30
M12	02/03/81	1400	04.00	32.60	11.70	8.30
M12	02/03/81	1400	07.00	32.60	11.70	8.30
M13	02/03/81	1440	10.60	32.80	11.60	8.30
M13	02/03/81	1440	01.00	32.80	11.90	8.20
M13	02/03/81	1440	04.60	32.80	11.90	8.30
M13	02/03/81	1440	07.60	32.80	11.90	8.30
M22	02/03/81	1515	10.30	32.70	11.70	8.20
M22	02/03/81	1515	01.00	32.60	11.90	8.10
M22	02/03/81	1515	04.30	32.60	11.90	8.10
M22	02/03/81	1515	07.30	32.70	11.80	8.20
M23	02/03/81	1600	01.00	32.70	12.00	8.20
M23	02/03/81	1600	03.40	32.70	12.00	8.20
M23	02/03/81	1600	06.40	32.70	12.00	8.20
M23	02/03/81	1600	09.40	32.70	11.80	8.20
M21	02/04/81	0810	01.00	30.20	10.40	8.20
M21	02/04/81	0810	01.50	30.20	10.40	8.20
M21	02/04/81	0810	04.50	30.20	10.40	8.40
M8	02/04/81	0845	01.00	31.50	10.90	8.30
M8	02/04/81	0845	03.90	31.50	10.90	8.30

OVER THE SIDE DATA

SITE	DATE	TIME (CST)	DEPTH (M)	SALINITY (PPT)	WATER TEMP (DEGREES C)	DISSOLVED OXYGEN (MG/L)
M8	02/04/81	0845	06.90	31.50	10.90	8.40
M9	02/04/81	0905	01.00	31.90	11.00	8.40
M9	02/04/81	0905	03.10	31.90	11.00	8.40
M9	02/04/81	0905	05.10	31.90	11.00	8.40
M9	02/04/81	0905	08.10	31.90	11.10	8.40
M10	02/04/81	0923	01.00	32.10	11.10	8.50
M10	02/04/81	0923	03.80	32.10	11.20	8.40
M10	02/04/81	0923	05.80	32.10	11.10	8.40
M10	02/04/81	0923	08.80	32.10	11.10	8.50
M11	02/04/81	1030	01.00	32.30	11.40	8.50
M11	02/04/81	1030	03.40	32.30	11.40	8.50
M11	02/04/81	1030	06.40	32.30	11.40	8.50
M11	02/04/81	1030	09.40	32.30	11.40	8.50
M12	02/04/81	1100	10.00	32.60	11.60	8.50
M12	02/04/81	1100	01.00	32.60	11.60	8.40
M12	02/04/81	1100	05.50	32.60	11.60	8.50
M13	02/04/81	1130	10.60	32.80	11.70	8.50
M13	02/04/81	1130	01.00	32.80	11.70	8.40
M13	02/04/81	1130	04.60	32.80	11.70	8.40
M13	02/04/81	1130	07.60	32.80	11.70	8.50
M22	02/04/81	1230	10.30	32.60	11.80	8.50
M22	02/04/81	1230	01.00	32.60	11.80	8.50
M22	02/04/81	1230	04.30	32.60	11.80	8.50
M22	02/04/81	1230	07.30	32.60	11.80	8.50
M23	02/04/81	1300	01.00	32.70	11.80	8.50
M23	02/04/81	1300	04.40	32.70	11.80	8.60
M23	02/04/81	1300	06.40	32.70	11.80	8.60
M23	02/04/81	1300	09.40	32.70	11.80	8.60
M1	02/04/81	1430	01.00	32.30	11.40	8.90
M1	02/04/81	1430	04.70	32.30	11.40	8.90
M1	02/04/81	1430	08.40	32.30	11.40	9.00
M3	02/04/81	1500	01.00	32.10	11.30	8.80
M3	02/04/81	1500	04.70	32.10	11.30	8.90
M3	02/04/81	1500	08.40	32.20	11.30	8.90
M6	02/04/81	1515	01.00	32.20	11.30	8.80
M6	02/04/81	1515	04.90	32.20	11.30	8.90
M6	02/04/81	1515	08.80	32.20	11.30	8.90
M15	02/04/81	1535	01.00	32.30	11.40	8.80
M15	02/04/81	1535	04.90	32.30	11.40	8.80
M15	02/04/81	1535	08.80	32.30	11.40	8.90

OVER THE SIDE DATA

SITE	DATE	TIME (CST)	DEPTH (M)	SALINITY (PPT)	WATER TEMP (DEGREES C)	DISSOLVED OXYGEN (MG/L)
M18	02/04/81	1550	01.00	32.10	11.30	8.60
M18	02/04/81	1550	04.90	32.10	11.30	8.80
M18	02/04/81	1550	08.80	32.10	11.20	8.90
M20	02/04/81	1620	01.00	32.20	11.30	8.70
M20	02/04/81	1620	04.90	32.30	11.30	8.70
M20	02/04/81	1620	08.80	32.30	11.30	8.90
E5	02/14/81	0645	01.00	19.90	6.00	10.20
E5	02/14/81	0645	04.00	20.00	5.90	10.70
E5	02/14/81	0645	06.00	21.20	6.30	10.60
E4	02/14/81	0855	00.50	21.20	5.40	8.90
E4	02/14/81	0855	00.90	21.20	5.30	8.90
E3	02/14/81	1000	00.20	23.60	5.20	10.50
E3	02/14/81	1000	00.60	23.60	5.20	10.00
E2	02/14/81	1200	00.80	15.50	8.70	7.90
E2	02/14/81	1200	01.20	15.60	8.50	7.90
E6	02/14/81	1320	00.90	11.90	6.90	8.80
E6	02/14/81	1320	02.70	11.90	6.90	8.70
E6	02/14/81	1320	04.50	11.90	6.90	8.70
E1	02/14/81	1420	00.50	11.50	6.80	9.80
E1	02/14/81	1420	02.10	11.50	6.80	10.30
E1	02/14/81	1420	03.70	11.50	6.90	10.30
E7	02/15/81	0715	01.00	3.50	8.90	8.90
E7	02/15/81	0715	04.10	5.60	8.70	8.50
E7	02/15/81	0715	07.20	14.70	9.00	7.90
E9	02/15/81	0915	00.50	8.80	7.60	9.30
E9	02/15/81	0915	01.00	10.20	7.50	9.20
E10	02/15/81	0950	00.50	7.80	8.30	9.60
E10	02/15/81	0950	01.00	7.80	8.30	9.60
E8	02/15/81	0955	00.50	8.80	9.10	7.90
E8	02/15/81	0955	01.00	9.00	9.10	8.00
M20	03/07/81	0900	01.00	31.80	14.80	8.40
M20	03/07/81	0900	02.80	31.80	14.80	8.40
M20	03/07/81	0900	05.80	31.80	14.80	8.40
M20	03/07/81	0900	08.80	32.00	14.60	7.80
M18	03/07/81	0950	01.00	31.90	14.80	8.50
M18	03/07/81	0950	02.80	31.80	14.80	8.50
M18	03/07/81	0950	05.80	31.80	14.80	8.40

OVER THE SIDE DATA

SITE	DATE	TIME (CST)	DEPTH (M)	SALINITY (PPT)	WATER TEMP (DEGREES C)	DISSOLVED OXYGEN (MG/L)
M18	03/07/81	0950	08.80	31.80	14.80	8.40
M15	03/07/81	1010	01.00	31.80	14.80	8.50
M15	03/07/81	1010	02.80	31.80	14.80	8.50
M15	03/07/81	1010	05.80	31.80	14.80	8.40
M15	03/07/81	1010	08.80	31.80	14.80	8.50
M6	03/07/81	1035	01.00	31.80	14.90	8.50
M6	03/07/81	1035	02.80	31.80	14.90	8.50
M6	03/07/81	1035	05.80	31.80	14.80	8.40
M6	03/07/81	1035	08.80	31.80	14.90	8.30
M23	03/07/81	1210	01.00	33.60	14.80	8.60
M23	03/07/81	1210	03.40	33.60	14.80	8.60
M23	03/07/81	1210	06.40	33.60	14.80	8.60
M23	03/07/81	1210	09.40	33.70	14.80	8.60
M22	03/07/81	1245	10.30	33.60	14.90	8.60
M22	03/07/81	1245	01.00	33.60	14.80	8.50
M22	03/07/81	1245	04.30	33.60	14.90	8.60
M22	03/07/81	1245	07.30	33.60	14.80	8.60
M13	03/07/81	1325	10.60	33.70	14.40	7.90
M13	03/07/81	1325	01.00	32.70	14.70	8.70
M13	03/07/81	1325	04.60	32.80	14.70	8.70
M13	03/07/81	1325	07.60	33.00	14.50	8.50
M12	03/07/81	1405	10.00	32.30	14.60	8.50
M12	03/07/81	1405	01.00	32.10	14.70	8.20
M12	03/07/81	1405	04.00	32.10	14.60	8.20
M12	03/07/81	1405	07.00	32.30	14.60	8.00
M11	03/07/81	1430	01.00	32.00	14.70	8.80
M11	03/07/81	1430	03.40	32.00	14.70	8.80
M11	03/07/81	1430	06.40	32.00	14.70	8.80
M11	03/07/81	1430	09.40	32.10	14.70	8.80
M10	03/07/81	1505	01.00	31.90	14.80	8.80
M10	03/07/81	1505	02.80	31.90	14.90	8.80
M10	03/07/81	1505	05.80	31.90	14.90	8.90
M10	03/07/81	1505	08.80	31.90	14.90	8.80
M3	03/07/81	1600	01.00	31.80	14.90	8.70
M3	03/07/81	1600	02.40	31.80	14.90	8.70
M3	03/07/81	1600	05.40	31.80	14.90	8.70
M3	03/07/81	1600	08.40	31.80	14.90	8.70
M1	03/07/81	1630	01.00	31.70	15.00	8.70
M1	03/07/81	1630	02.40	31.70	15.00	8.70
M1	03/07/81	1630	05.40	31.70	15.00	8.70

OVER THE SIDE DATA

SITE	DATE	TIME (CST)	DEPTH (M)	SALINITY (PPT)	WATER TEMP (DEGREES C)	DISSOLVED OXYGEN (MG/L)
M1	03/07/81	1630	08.40	31.70	15.00	8.80
M9	03/07/81	1720	01.00	31.80	14.90	8.70
M9	03/07/81	1720	02.10	31.80	14.90	8.70
M9	03/07/81	1720	05.10	31.80	14.90	8.70
M9	03/07/81	1720	08.10	31.80	14.90	8.70
M8	03/07/81	1740	01.00	31.60	15.10	8.60
M8	03/07/81	1740	03.90	31.60	15.00	8.60
M8	03/07/81	1740	06.90	31.60	15.00	8.60
M21	03/07/81	1820	01.00	31.00	15.50	8.30
M21	03/07/81	1820	01.50	31.00	15.50	8.30
M21	03/07/81	1820	04.50	31.00	15.50	8.30
E5	03/08/81	0630	01.00	31.30	15.60	7.90
E5	03/08/81	0630	03.00	31.30	15.60	7.90
E5	03/08/81	0630	06.00	31.30	15.50	7.90
E4	03/08/81	0735	00.50	22.30	15.10	8.10
E4	03/08/81	0735	00.90	22.30	15.20	8.10
E3	03/08/81	0835	00.20	23.20	15.00	8.30
E3	03/08/81	0835	00.60	23.20	15.00	8.30
E2	03/08/81	1045	00.80	18.70	15.90	6.90
E2	03/08/81	1045	01.20	18.70	15.90	7.00
E6	03/08/81	1145	01.00	17.40	16.50	7.00
E6	03/08/81	1145	01.50	17.40	16.50	7.10
E6	03/08/81	1145	04.50	20.30	16.30	6.40
E1	03/08/81	1245	00.50	10.40	17.00	8.90
E1	03/08/81	1245	02.10	11.10	16.70	8.20
E1	03/08/81	1245	03.70	12.00	16.50	8.10
E7	03/08/81	1435	01.00	3.00	17.90	8.10
E7	03/08/81	1435	02.50	4.80	17.50	8.20
E7	03/08/81	1435	05.50	7.00	17.00	7.30
E8	03/08/81	1610	01.00	12.40	17.50	8.70
E8	03/08/81	1610	01.50	12.40	17.40	8.70
E9	03/08/81	1625	01.00	13.40	16.80	8.90
E9	03/08/81	1625	01.80	13.40	16.80	8.80
E10	03/08/81	1654	00.50	11.10	16.90	9.30
E10	03/08/81	1654	00.90	11.10	17.00	9.30
E5	04/09/81	0610	01.00	24.30	21.20	7.30
E5	04/09/81	0610	03.00	24.50	21.30	7.20
E5	04/09/81	0610	06.00	24.50	21.40	7.20

OVER THE SIDE DATA

SITE	DATE	TIME (CST)	DEPTH (M)	SALINITY (PPT)	WATER TEMP (DEGREES C)	DISSOLVED OXYGEN (MG/L)
E4	04/09/81	0710	00.50	22.90	20.90	7.40
E4	04/09/81	0710	00.90	22.90	20.90	7.30
E3	04/09/81	0745	00.20	23.30	21.10	7.20
E3	04/09/81	0745	00.60	23.00	21.10	7.20
E2	04/09/81	0900	00.80	21.80	21.30	7.20
E2	04/09/81	0900	01.20	23.10	21.10	7.10
E6	04/09/81	0930	01.00	17.20	21.20	7.00
E6	04/09/81	0930	01.50	17.10	21.10	7.10
E6	04/09/81	0930	04.50	17.10	21.20	7.20
E1	04/09/81	1150	00.50	16.50	21.80	7.30
E1	04/09/81	1150	02.10	16.50	21.60	7.40
E1	04/09/81	1150	03.70	16.40	21.50	7.50
E7	04/09/81	1340	01.00	8.00	22.40	8.00
E7	04/09/81	1340	02.50	8.70	21.90	7.70
E7	04/09/81	1340	05.50	9.30	21.70	7.10
E8	04/09/81	1500	01.00	15.10	23.90	9.40
E8	04/09/81	1500	01.50	15.10	23.90	9.10
E9	04/09/81	1550	01.00	14.40	22.40	8.40
E9	04/09/81	1550	01.80	14.40	22.40	8.40
E10	04/09/81	1615	00.50	20.10	23.00	7.70
E10	04/09/81	1615	00.90	20.10	23.00	7.70
M23	04/10/81	0940	01.00	33.10	19.80	7.60
M23	04/10/81	0940	03.40	33.10	19.70	7.60
M23	04/10/81	0940	06.40	33.10	19.70	7.60
M23	04/10/81	0940	09.40	33.10	19.90	7.70
M22	04/10/81	1025	10.30	32.50	20.10	7.30
M22	04/10/81	1025	01.00	30.30	20.40	8.10
M22	04/10/81	1025	04.30	31.40	19.80	7.00
M22	04/10/81	1025	07.30	31.90	19.90	7.80
M13	04/10/81	1100	10.60	30.20	20.40	8.00
M13	04/10/81	1100	01.00	29.70	20.60	8.20
M13	04/10/81	1100	04.60	29.90	20.40	8.20
M13	04/10/81	1100	07.60	30.10	20.40	8.20
M12	04/10/81	1130	10.00	29.40	20.70	8.10
M12	04/10/81	1130	01.00	28.80	20.90	8.30
M12	04/10/81	1130	04.00	28.80	20.70	8.30
M12	04/10/81	1130	07.00	28.90	20.70	8.20
M11	04/10/81	1150	01.00	28.60	21.00	8.60
M11	04/10/81	1150	03.40	28.40	20.70	8.60

OVER THE SIDE DATA

SITE	DATE	TIME (CST)	DEPTH (M)	SALINITY (PPT)	WATER TEMP (DEGREES C)	DISSOLVED OXYGEN (MG/L)
M11	04/10/81	1150	06.40	28.90	20.70	8.40
M10	04/10/81	1215	01.00	27.80	21.30	7.90
M10	04/10/81	1215	02.80	27.90	20.90	8.00
M10	04/10/81	1215	05.80	28.90	20.70	8.10
M10	04/10/81	1215	08.80	28.90	20.60	7.80
M9	04/10/81	1240	01.00	26.90	21.70	7.80
M9	04/10/81	1240	02.10	26.90	21.60	7.80
M9	04/10/81	1240	05.10	27.20	21.30	7.40
M9	04/10/81	1240	08.10	28.50	20.70	7.50
M8	04/10/81	1300	01.00	26.10	21.60	8.00
M8	04/10/81	1300	03.90	26.50	21.40	7.60
M8	04/10/81	1300	06.90	27.10	21.10	7.00
M21	04/10/81	1320	01.00	25.40	22.00	7.10
M21	04/10/81	1320	01.50	25.40	22.00	6.90
M21	04/10/81	1320	04.50	25.60	21.80	6.90
M1	04/10/81	1420	01.00	27.70	20.90	6.20
M1	04/10/81	1420	02.40	27.90	20.90	6.20
M1	04/10/81	1420	05.40	27.90	20.50	6.00
M1	04/10/81	1420	08.40	28.00	20.40	5.70
M3	04/10/81	1500	01.00	28.60	21.20	8.90
M3	04/10/81	1500	02.40	28.60	21.20	9.00
M3	04/10/81	1500	05.40	28.60	21.20	8.70
M3	04/10/81	1500	08.40	28.60	20.50	7.40
M6	04/10/81	1515	01.00	27.90	21.60	8.50
M6	04/10/81	1515	02.80	27.90	21.50	8.70
M6	04/10/81	1515	05.80	28.40	21.00	8.30
M6	04/10/81	1515	08.80	29.20	20.50	7.40
M10A	04/10/81	1535	01.00	26.40	21.90	8.50
M10A	04/10/81	1535	02.00	26.40	21.90	8.40
M10A	04/10/81	1535	05.00	27.40	21.00	7.20
M10A	04/10/81	1535	07.00	28.70	20.60	7.20
M15	04/10/81	1615	01.00	26.30	21.40	8.20
M15	04/10/81	1615	02.80	26.20	21.30	8.00
M15	04/10/81	1615	05.80	27.30	21.00	7.30
M15	04/10/81	1615	08.80	28.40	20.10	7.60
M18	04/10/81	1630	01.00	26.80	21.50	7.90
M18	04/10/81	1630	02.80	26.80	21.50	7.80
M18	04/10/81	1630	05.80	27.00	21.00	7.70
M18	04/10/81	1630	08.80	28.60	20.80	7.40
M20	04/10/81	1700	01.00	27.70	21.30	7.80

OVER THE SIDE DATA

SITE	DATE	TIME (CST)	DEPTH (M)	SALINITY (PPT)	WATER TEMP (DEGREES C)	DISSOLVED OXYGEN (MG/L)
M20	04/10/81	1700	02.80	27.80	21.30	7.90
M20	04/10/81	1700	05.80	27.80	21.30	7.90
M20	04/10/81	1700	08.80	28.00	20.80	7.00

CHEMICAL OCEANOGRAPHY-SEDIMENTOLOGY

SITE	DATE	%SAND	%SILT	%CLAY	PORE WATER SALINITY (PPT)	%ORGANIC CARBON
E2	02/03/81	09.43	48.40	42.16	16.146	0.690
E3	02/03/81	11.50	70.67	17.83	23.640	0.490
E1	02/03/81	19.22	52.14	28.64	9.104	0.540
E5	02/03/81	59.17	23.15	17.67	26.310	0.240
E4	02/03/81	70.23	11.13	18.64	21.480	0.500
E6	02/03/81	99999	99999	99999	999999	0.370
E7	02/03/81	99999	99999	99999	999999	0.560
M3	02/14/81	02.01	56.54	41.44	30.588	0.400
M15	02/14/81	02.53	53.28	44.19	30.648	0.550
M9	02/14/81	02.51	38.48	59.01	30.340	0.450
M18	02/14/81	04.69	47.63	47.68	31.416	0.450
M20	02/14/81	05.08	39.05	55.88	30.718	0.680
M10	02/14/81	10.58	39.87	49.56	30.554	0.390
M11	02/14/81	19.18	37.79	42.24	30.857	0.500
M6	02/14/81	27.26	30.60	42.14	30.495	0.420
M1	02/14/81	32.64	28.93	38.42	30.432	0.320
M9	03/16/81	00.68	22.77	76.44	30.029	0.840
E3	03/16/81	00.72	30.57	68.71	22.278	1.094
M10A	03/16/81	01.96	32.45	64.60	30.755	0.756
M18	03/16/81	02.40	30.37	67.23	33.419	0.593
M20	03/16/81	04.06	26.15	69.78	31.061	0.766
M15	03/16/81	04.92	29.40	63.55	30.005	0.707
M6	03/16/81	05.12	22.39	72.49	30.851	0.846
E2	03/16/81	08.15	49.07	42.78	17.736	0.797
M10	03/16/81	08.93	32.89	58.18	30.846	0.650
E1	03/16/81	16.22	45.51	38.10	12.061	0.538
E4	03/16/81	18.22	28.12	53.54	19.980	0.737
M11	03/16/81	20.29	38.03	41.63	31.417	0.477
M1	03/16/81	31.96	25.84	42.20	29.935	0.520
M3	03/16/81	34.89	22.94	42.18	30.483	0.418
E5	03/16/81	84.17	04.46	11.39	24.914	0.914
E2	04/09/81	05.14	41.92	52.93	21.661	00.83
E1	04/09/81	15.17	40.82	44.01	15.758	00.82
E3	04/09/81	15.58	24.54	59.88	23.753	00.88
E5	04/09/81	21.21	29.29	49.50	25.468	01.04
E4	04/09/81	24.41	22.26	53.33	23.318	00.93

CHEMICAL OCEANOGRAPHY-SEDIMENTOLOGY

SITE	DATE	%SAND	%SILT	%CLAY	PORE WATER SALINITY (PPT)	%ORGANIC CARBON
M10A	04/10/81	00.31	16.46	83.23	29.148	00.73
M9	04/10/81	01.08	22.00	76.91	28.598	00.80
M1E	04/10/81	02.00	27.95	70.05	29.783	00.76
M15	04/10/81	03.04	30.28	66.68	29.310	00.75
M6	04/10/81	04.32	29.81	65.88	30.154	00.71
M10	04/10/81	05.67	32.72	61.61	29.534	01.00
M11	04/10/81	06.44	50.63	42.92	29.903	00.74
M20	04/10/81	06.67	26.39	66.93	29.348	00.78
M3	04/10/81	14.39	30.73	54.87	29.179	00.63
M1	04/10/81	23.04	31.16	45.80	999999	00.55

PHI SIZES
EACH COLUMN IN PER CENT

SITE	DATE	1-1.5	1.5-2	2-2.5	2.5-3	3-3.5	3.5-4	4-5	5-6	6-7	7-8	8-9	9-10	10-14
E1	02/03/81	00.20	00.32	1.26	1.69	7.75	2.25	23.76	15.98	10.57	5.33	4.04	2.69	23.83
M9	02/03/81	00.25	00.55	0.01	0.28	0.27	0.47	7.96	12.98	12.32	5.46	7.88	8.13	43.35
M11	02/03/81	00.57	02.27	2.81	2.72	2.63	5.08	20.71	7.18	9.16	2.93	5.44	6.80	31.52
E4	02/03/81	00.89	02.17	16.41	32.26	12.58	1.15	4.62	2.94	2.95	2.25	3.49	2.27	15.60
E3	02/03/81	01.33	01.45	2.50	2.81	1.47	0.99	64.16	3.17	1.90	2.08	2.47	2.27	12.96
E2	02/03/81	01.77	00.50	0.91	1.09	1.52	1.54	15.89	15.61	9.77	8.24	5.59	0.68	36.85
E5	02/03/81	02.58	03.90	9.10	9.38	18.58	6.96	17.79	3.76	4.23	2.21	3.97	0.52	16.87
M10	02/03/81	03.07	00.50	0.86	0.54	1.62	2.25	20.15	7.14	5.96	7.39	7.58	6.18	36.75
M15	02/14/81	00.08	00.10	0.19	0.16	0.35	0.96	31.27	10.77	5.17	6.43	4.55	7.51	32.44
M20	02/14/81	00.06	00.11	0.32	0.19	0.98	2.46	17.44	3.47	12.51	6.02	4.40	11.02	41.01
M3	02/14/81	00.05	00.12	0.17	0.40	0.44	0.38	36.83	7.91	4.14	7.78	5.64	4.21	31.68
M18	02/14/81	00.39	00.21	0.31	0.43	0.59	1.74	28.77	15.29	2.67	1.33	5.98	6.82	35.32
M1	02/14/81	00.50	01.32	4.20	5.22	13.15	2.88	13.45	8.83	5.06	3.84	6.56	4.98	29.85
M6	02/14/81	00.55	01.88	6.54	5.57	7.41	2.64	9.29	8.14	5.61	8.52	4.53	4.97	32.97
E3	03/16/81	00.02	00.01	0.08	0.11	0.30	0.20	5.32	6.07	7.03	12.15	2.59	9.15	56.99
M10A	03/16/81	00.09	00.14	0.44	0.81	1.04	0.44	7.42	11.04	7.61	6.38	7.73	6.32	50.55
M20	03/16/81	00.03	00.04	0.17	0.07	1.32	2.41	6.91	6.52	6.67	6.05	7.78	8.48	53.32
M18	03/16/81	00.27	00.22	0.26	0.44	0.88	0.33	12.88	6.48	4.75	6.26	8.28	15.19	43.76
M6	03/16/81	00.32	00.66	1.33	1.41	0.72	0.68	4.24	6.13	5.42	6.60	4.48	11.20	56.81
M15	03/16/81	00.45	00.26	0.65	0.26	1.41	1.89	8.59	6.81	6.54	7.46	6.59	8.38	50.58
E1	03/16/81	00.55	00.34	1.16	2.30	7.20	4.67	16.96	14.44	8.61	5.50	3.97	3.64	30.49
E2	03/16/81	00.52	00.42	0.99	1.22	2.30	2.70	23.19	14.21	6.91	4.76	10.14	0.00	32.64
M9	03/16/81	00.53	00.04	0.06	0.03	0.02	0.00	3.11	4.30	6.90	8.46	7.86	8.65	58.93
M11	03/16/81	00.76	02.79	4.89	5.02	4.39	2.44	23.70	7.82	3.35	3.16	4.65	5.21	31.77
M1	03/16/81	00.86	02.96	6.45	9.48	11.04	1.17	12.67	5.62	3.81	3.75	3.07	6.02	33.11
E4	03/16/81	01.51	00.16	0.94	1.57	8.14	5.90	12.86	5.65	7.05	2.56	6.43	5.42	41.69
M3	03/16/81	02.02	05.17	9.47	11.16	6.04	1.03	10.13	5.23	6.75	0.83	4.01	5.16	33.01
M10	03/16/81	02.36	00.64	1.14	1.17	1.08	2.54	10.03	10.72	4.13	5.01	6.56	6.56	45.06
E5	03/16/81	52.39	08.12	10.65	7.71	4.07	0.80	2.33	1.21	1.04	0.22	0.00	2.07	9.41

PHI SIZES
EACH COLUMN IN PER CENT

SITE	DATE	0.5-1	1-2	2-3	3-4	4-5	5-6	6-7	7-8	8-9	9-10	10-14
E3	04/09/81	00.05	00.13	02.76	12.64	10.66	04.56	07.44	01.88	09.79	02.08	48.01
E4	04/09/81	00.00	00.23	04.41	19.77	10.75	05.07	04.25	02.19	07.39	01.23	44.71
E2	04/09/81	00.16	01.10	01.92	01.96	18.52	13.15	05.64	04.61	07.02	01.58	44.33
E1	04/09/81	00.37	00.65	03.96	10.19	17.81	14.62	06.09	02.30	04.38	00.22	39.41
E5	04/09/81	01.18	05.98	10.64	03.41	13.78	06.79	06.30	02.42	07.82	00.69	40.99
M10A	04/10/81	00.00	00.03	00.13	00.15	00.35	06.46	03.48	06.17	12.13	05.04	66.06
M11	04/10/81	00.03	00.64	02.76	03.01	33.03	09.89	05.53	02.18	10.15	01.01	31.86
M15	04/10/81	00.04	00.17	00.74	02.09	09.79	08.29	08.22	03.98	05.87	07.83	52.98
M20	04/10/81	00.05	00.07	00.67	05.88	12.25	07.14	03.77	03.23	09.43	01.68	55.82
M1	04/10/81	00.14	01.57	09.44	11.89	16.64	08.22	03.53	02.77	05.50	03.43	36.87
M6	04/10/81	00.17	00.54	01.70	01.91	14.94	05.68	04.96	04.23	08.89	05.32	51.67
M3	04/10/81	00.65	01.32	05.18	07.24	15.30	09.54	04.07	01.82	08.63	06.88	39.36
M10	04/10/81	01.05	00.71	01.54	02.37	14.97	08.59	01.91	07.25	08.47	04.64	48.50

CHEMICAL OCEANOGRAPHY-WATER QUALITY

SITE	DATE	INSTR DEPTH (M)	WATER TEMP (C)	D.O. (MG/L)	PH	NH3-N (MG/L)	NO2-N (MG/L)	NO3-N (MG/L)	TOT-P (MG/L)	O-PO4 (MG/L)	SiO2 (MG/L)	OIL & GREASE (MG/L)	TURB (NTU)
M10	02/03/81	00.00	11.30	99999	99999	0.50	-1.00	-1.00	0.02	0.02	99999	99999	2.10
M10	02/03/81	04.10	11.30	99999	99999	0.19	-1.00	-1.00	0.02	0.02	0.40	99999	2.70
M10	02/03/81	07.10	11.00	9.65	8.65	0.44	-1.00	-1.00	0.09	0.10	1.06	0.50	14.00
M11	02/03/81	01.00	11.60	9.50	8.65	0.28	-1.00	-1.00	0.06	0.03	1.08	0.50	3.30
M21	02/03/81	00.00	10.80	99999	99999	99999	99999	99999	99999	99999	99999	99999	99999
M8	02/03/81	02.50	10.50	99999	8.52	99999	99999	99999	99999	99999	99999	99999	99999
M9	02/03/81	01.00	11.10	9.40	99999	0.69	-1.00	0.01	0.03	0.03	0.76	0.30	3.30
M9	02/03/81	04.30	11.10	99999	99999	0.02	-1.00	-1.00	0.02	0.02	0.50	99999	2.80
M9	02/03/81	06.30	10.90	99999	8.61	-1.00	-1.00	-1.00	0.02	0.02	0.04	99999	3.20
E1	02/14/81	00.00	6.50	9.70	6.80	4.21	0.01	0.07	0.08	0.08	4.31	0.80	99999
E1	02/14/81	06.10	6.90	9.90	7.00	2.75	0.01	0.07	0.10	0.10	3.90	0.50	99999
E2	02/14/81	00.00	8.70	7.95	6.75	12.19	0.01	0.01	0.03	0.80	4.44	0.80	99999
E3	02/14/81	00.00	5.20	10.15	6.60	0.49	0.01	0.01	0.04	0.04	1.54	0.40	99999
E4	02/14/81	00.10	5.40	8.40	7.80	6.19	0.01	0.01	0.07	0.06	3.74	0.50	99999
E5	02/14/81	00.00	5.80	9.70	6.70	10.19	0.01	0.01	0.09	0.17	4.90	0.60	99999
E5	02/14/81	04.00	6.30	9.75	6.65	9.69	0.01	0.01	0.13	0.13	5.94	0.30	99999
E6	02/14/81	00.00	6.50	9.30	8.00	8.75	0.01	0.01	0.07	0.05	4.80	0.60	99999
E6	02/14/81	04.88	6.50	9.00	7.99	8.19	0.01	0.01	0.05	0.06	5.30	0.80	99999
E10	02/15/81	00.00	8.30	99999	7.97	99999	99999	99999	99999	99999	99999	99999	99999
E7	02/15/81	00.00	8.60	99999	7.88	99999	99999	99999	99999	99999	99999	99999	99999
E7	02/15/81	08.23	9.00	99999	8.26	99999	99999	99999	99999	99999	99999	99999	99999
E8	02/15/81	00.00	9.10	99999	7.85	99999	99999	99999	99999	99999	99999	99999	99999
M1	02/16/81	00.00	9.00	9.15	6.50	99999	-1.00	0.01	0.03	0.03	2.36	0.70	2.50
M1	02/16/81	10.06	9.00	9.00	7.40	0.89	-1.00	-1.00	0.03	0.03	0.54	0.50	9.20
M10	02/16/81	00.00	10.00	9.20	6.50	0.31	-1.00	-1.00	0.04	0.04	0.86	0.50	2.90
M10	02/16/81	10.36	10.00	99999	6.40	0.33	-1.00	-1.00	0.02	0.02	0.76	99999	2.30
M11	02/16/81	00.00	10.00	99999	6.60	-1.00	-1.00	-1.00	0.02	0.02	0.20	99999	2.30
M11	02/16/81	10.97	10.00	9.25	6.40	0.25	-1.00	-1.00	0.06	0.06	0.80	0.30	16.50
M15	02/16/81	00.00	10.00	9.30	7.60	0.41	-1.00	-1.00	0.03	0.03	0.84	0.60	3.00
M15	02/16/81	10.06	9.00	9.20	7.40	0.31	-1.00	-1.00	0.03	0.04	1.12	0.60	7.00
M18	02/16/81	00.00	10.00	99999	7.60	99999	99999	99999	99999	99999	99999	99999	99999
M18	02/16/81	09.75	10.00	9.40	7.60	0.23	-1.00	-1.00	0.04	0.04	0.66	0.60	2.60
M20	02/16/81	00.00	10.00	9.20	6.80	-1.00	-1.00	0.01	0.03	0.03	0.60	0.30	2.40
M20	02/16/81	09.75	9.90	9.10	7.70	0.36	-1.00	-1.00	0.03	0.04	0.60	0.80	9.00
M3	02/16/81	00.00	9.50	9.20	7.90	0.78	-1.00	-1.00	0.03	0.03	0.68	0.30	8.50
M3	02/16/81	10.06	9.50	9.00	7.20	0.41	-1.00	-1.00	0.04	0.04	1.14	0.40	19.00
M6	02/16/81	00.00	9.50	9.30	7.30	0.94	-1.00	-1.00	0.04	0.04	0.80	0.60	3.10

CHEMICAL OCEANOGRAPHY-WATER QUALITY

SITE	DATE	INSTR DEPTH (M)	WATER TEMP (C)	D.O. (MG/L)	PH	NH3=N (MG/L)	NO2=N (MG/L)	NO3=N (MG/L)	TOT=P (MG/L)	D=PO4 (MG/L)	SI02 (MG/L)	OIL& GREASE (MG/L)	TURB (NTU)
M6	02/16/81	10.06	10.00	8.90	7.50	0.07	-1.00	-1.00	0.05	0.50	2.34	0.50	25.50
M9	02/16/81	00.00	9.50	99999	6.50	0.29	-1.00	-1.00	0.02	0.02	1.86	99999	3.50
M9	02/16/81	09.14	10.00	9.10	6.30	0.56	-1.00	-1.00	0.04	0.04	0.90	0.50	16.50
M1	03/13/81	00.00	16.50	10.80	8.35	-1.00	-1.00	-1.00	0.02	-1.00	1.44	-1.00	2.10
M1	03/13/81	10.06	16.00	9.00	8.23	0.01	-1.00	-1.00	0.02	0.01	1.52	-1.00	8.80
M10	03/13/81	00.00	15.10	9.30	8.15	-1.00	-1.00	0.01	0.01	0.01	1.10	-1.00	1.90
M10	03/13/81	09.75	15.20	8.30	7.80	0.02	-1.00	0.01	0.05	0.04	1.48	-1.00	9.80
M10A	03/13/81	00.00	15.40	9.80	8.40	-1.00	-1.00	0.01	0.02	0.02	1.04	-1.00	1.80
M10A	03/13/81	09.75	15.50	8.90	8.00	0.01	-1.00	-1.00	0.05	0.10	1.84	-1.00	11.00
M11	03/13/81	00.00	18.00	9.70	8.28	-1.00	-1.00	0.02	0.02	-1.00	1.08	-1.00	1.80
M11	03/13/81	10.97	17.00	8.60	8.22	-1.00	-1.00	0.01	0.04	0.02	0.58	-1.00	4.20
M15	03/13/81	00.00	15.00	9.00	8.10	-1.00	-1.00	0.01	0.02	-1.00	1.08	0.90	1.90
M15	03/13/81	09.75	15.20	8.10	7.80	0.02	-1.00	0.01	0.05	0.10	2.34	-1.00	13.00
M18	03/13/81	00.00	15.00	9.00	7.50	0.01	-1.00	0.03	0.02	0.02	1.08	-1.00	1.80
M18	03/13/81	09.75	15.30	8.60	7.90	-1.00	-1.00	-1.00	0.02	0.02	0.98	-1.00	3.80
M20	03/13/81	00.00	15.20	9.10	7.54	-1.00	-1.00	0.01	0.02	0.02	1.14	-1.00	1.80
M20	03/13/81	09.75	15.00	8.90	7.81	-1.00	-1.00	-1.00	0.02	0.01	0.86	-1.00	2.80
M3	03/13/81	00.00	17.00	10.40	8.25	0.01	-1.00	0.02	0.02	0.02	0.94	-1.00	2.40
M3	03/13/81	10.36	16.20	8.40	8.22	0.02	-1.00	0.01	0.04	0.03	2.00	-1.00	10.00
M6	03/13/81	00.00	17.00	10.00	8.35	0.01	-1.00	0.01	0.02	0.01	1.04	-1.00	1.90
M6	03/13/81	10.36	16.20	8.90	8.24	0.04	-1.00	-1.00	0.03	0.02	1.44	-1.00	10.00
M9	03/13/81	00.00	16.00	12.10	8.45	0.01	-1.00	0.01	0.06	0.03	1.84	0.70	3.20
M9	03/13/81	09.45	15.80	8.40	8.22	0.04	-1.00	-1.00	0.04	0.03	1.84	-1.00	11.00
E1	03/15/81	00.91	18.00	8.40	7.00	0.38	0.01	0.11	0.08	0.11	6.24	1.20	35.00
E2	03/15/81	00.91	17.50	7.60	7.60	0.43	0.01	0.10	0.07	0.05	3.84	-1.00	7.30
E3	03/15/81	00.61	17.30	8.70	7.78	0.06	-1.00	0.12	0.04	0.04	2.10	0.70	7.80
E4	03/15/81	00.91	17.00	8.80	7.70	0.08	-1.00	0.10	0.02	-1.00	2.30	-1.00	3.10
E5	03/15/81	00.00	15.60	7.30	8.00	0.21	-1.00	0.06	0.10	0.07	5.38	0.90	41.00
E5	03/15/81	09.14	16.00	8.00	7.63	0.15	-1.00	0.08	0.09	0.06	4.60	-1.00	39.00
E5	04/09/81	00.00	21.00	07.40	07.10	00.10	00.02	00.13	00.10	00.07	02.80	00.80	22.00
E5	04/09/81	06.71	21.00	06.90	06.60	00.07	00.02	00.15	00.14	00.08	02.60	01.50	62.00
E4	04/09/81	00.91	21.00	08.00	07.20	00.07	00.02	00.13	00.10	00.01	03.30	01.00	17.00
E3	04/09/81	00.61	21.00	07.70	07.00	00.04	00.03	00.07	00.14	00.04	02.30	01.20	07.00
E2	04/09/81	00.91	22.00	06.70	07.10	00.26	00.03	00.15	00.10	00.03	03.00	00.80	05.00
E1	04/09/81	00.00	23.00	07.40	07.10	00.22	00.03	00.12	00.05	00.02	02.60	01.00	07.00
E1	04/09/81	04.68	23.00	08.60	07.10	00.14	00.03	00.12	00.11	00.04	02.40	01.00	28.00

CHEMICAL OCEANOGRAPHY-WATER QUALITY

SITE	DATE	INSTR DEPTH (M)	WATER TEMP (C)	D.O. (MG/L)	PH	NH3-N (MG/L)	NO2-N (MG/L)	NO3-N (MG/L)	TOT-P (MG/L)	O-PO4 (MG/L)	SI02 (MG/L)	OIL & GREASE (MG/L)	TURB (NTU)
M23	04/10/81	00.00	19.80	07.55	08.20	99999	99999	99999	99999	99999	99999	99999	99999
M13	04/10/81	00.00	20.60	07.80	08.25	99999	99999	99999	99999	99999	99999	99999	99999
M11	04/10/81	00.00	22.00	07.40	07.20	-1.00	00.01	00.01	00.01	-1.00	00.90	00.80	01.80
M11	04/10/81	10.36	22.00	07.40	07.00	-1.00	-1.00	-1.00	00.02	-1.00	00.90	01.20	01.90
M10	04/10/81	00.00	22.00	08.00	07.20	-1.00	-1.00	00.06	00.02	00.01	01.10	01.00	03.30
M10	04/10/81	09.45	22.00	08.00	07.40	00.03	-1.00	00.02	00.01	-1.00	00.60	01.20	04.00
M9	04/10/81	00.00	23.00	07.20	07.20	-1.00	-1.00	00.11	00.03	00.03	02.30	01.00	06.60
M9	04/10/81	09.14	22.00	07.60	07.50	00.04	-1.00	00.03	00.05	00.03	00.90	01.00	09.00
M21	04/10/81	05.79	22.00	07.00	08.14	99999	99999	99999	99999	99999	99999	99999	99999
M1	04/10/81	00.00	22.00	06.00	07.00	00.03	-1.00	00.05	00.02	00.02	01.10	01.00	09.00
M1	04/10/81	09.75	22.00	05.10	07.20	00.08	-1.00	00.05	00.02	00.02	00.90	00.07	07.00
M3	04/10/81	00.00	22.00	09.40	07.50	-1.00	-1.00	00.02	00.01	00.01	00.08	02.00	02.40
M3	04/10/81	09.75	22.00	08.00	06.00	00.03	-1.00	00.02	00.08	00.03	01.00	01.20	24.00
M6	04/10/81	00.00	22.00	07.90	07.60	-1.00	-1.00	00.05	00.02	00.01	00.30	01.50	28.00
M6	04/10/81	09.75	22.00	06.20	07.60	00.03	-1.00	00.02	00.06	00.02	00.90	01.20	36.00
M10A	04/10/81	00.00	22.00	08.00	07.80	-1.00	00.01	00.11	00.03	00.02	01.50	00.90	04.20
M10A	04/10/81	09.75	22.00	07.90	07.70	-1.00	00.01	00.11	00.02	00.02	01.50	01.00	04.00
M15	04/10/81	00.00	22.00	07.90	07.70	00.03	-1.00	00.01	00.02	00.02	01.60	00.80	04.40
M15	04/10/81	10.06	22.00	07.90	07.40	99999	99999	99999	99999	99999	99999	01.00	99999
M18	04/10/81	00.00	22.00	07.70	07.40	-1.00	00.01	00.07	-1.00	-1.00	01.40	01.10	04.00
M18	04/10/81	10.06	22.00	08.10	07.60	00.03	00.01	00.04	00.03	00.03	01.20	01.00	08.70
M20	04/10/81	00.00	22.00	07.80	07.40	00.03	00.01	00.04	00.01	00.01	01.10	01.20	02.70
M20	04/10/81	10.06	22.00	07.80	07.20	00.02	00.01	00.04	00.01	-1.00	01.20	01.00	03.40

Beaufort number	Meters per second		Knots	
	Mean	Limits	Mean	Limits
0	0	<0.9	0	<1
1	1.5	0.7- 2.3	3	1- 4
2	3.4	2.4- 4.4	7	5- 8
3	5.6	4.5- 6.6	11	9-12
4	7.8	6.7- 8.9	15	13-16
5	10.2	9.0-11.3	19	17-21
6	12.6	11.4-13.8	24	22-26
7	15.1	13.9-16.4	29	27-31
8	17.7	16.5-19.0	34	32-36
9	20.4	19.1-21.8	39	37-42
10	23.3	21.9-24.9	45	43-48
11	26.5	24.9-28.2	52	49-55
12	---	>28.2	---	>55
99	Not taken or unknown			

TABLE 2: Maritime Conversion Scale for Wind Speed

Scale number	Amount of Cloud Cover
0	None
1	1 okta or 1/8 of sky covered
2	2 oktas or 2/8 of sky covered
3	3 oktas or 3/8 of sky covered
4	4 oktas or 4/8 of sky covered
5	5 oktas or 5/8 of sky covered
6	6 oktas or 6/8 of sky covered
7	7 oktas or 7/8 of sky covered
8	8 oktas or sky completely covered
9	Sky obscured (e.g. by fog) or amount of cloud cover not recorded due to darkness.
99	Observation not taken

TABLE 3: Code for Reporting Cloudiness

Code	Name of Cloud Type
0	Stratus
1	Cirrus
2	Cirrostratus
3	Cirrocumulus
4	Altostratus
5	Alto cumulus
6	Stratocumulus
7	Nimbostratus
8	Cumulus
9	Cumulonimbus
99	Data not taken

TABLE 4: Predominate type
of clouds

Code	Object not visible at	Description
0	<50 meters	Dense fog
1	50-200 meters	Thick fog
2	200-500 meters	Fog
3	500-1000 meters	Moderate Fog
4	1-2 kilometers	Thin Fog or Mist
5	2-4 kilometers	Visibility poor
6	4-10 kilometers	Visibility moderate
7	10-20 kilometers	Visibility good
8	20-50 kilometers	Visibility very good
9	>50 kilometers	Visibility excellent
99	Observation not taken or unknown	

TABLE 5: Visibility Code

Code	Description
A	Absent or data not taken
B	Blue sky, weather clear of hazy atmosphere
C	Cloudy, i.e. either detached clouds or a cloud layer with openings
D	Drizzle
E	Wet air without rain falling, a copious deposit of rain on ridings
F	Fog
FG	Ground fog
FS	Shallow fog
FE	Wet fog
G	Gale
H	Hail
KS	Drifting snow
L	Distant lightning
M	Mist: range of visibility 1-2 kilometers
MO	Intermittent slight rain
MR	Continuous moderate rain
O	Overcast, i.e. the whole sky covered with a uniform layer of thick or heavy clouds
PR	Rain showers
PS	Heavy snow showers
O	Squalls
R	Rain
RR	Continuous heavy rain
S	Snow
I	Thunder
TO	Slight rain
U	Ugly, Threatening sky
V	Unusual visibility over distant objects
VS	Sleet, i.e. rain and snow together
W	Dew
X	Hoar-frost
Y	Dry air (< 60% relative humidity)

TABLE 6: Modified Beaufort Weather Notation

Code	Description
2	5 seconds or less
3	6 or 7 seconds
4	8 or 9 seconds
5	10 or 11 seconds
6	12 or 13 seconds
7	14 or 15 seconds
8	16 or 17 seconds
9	18 or 19 seconds
0	20 or 21 seconds
1	Over 21 seconds
10	Calm or period indeterminate
99	Data not taken

TABLE 7: Modified WMC Code 3155 for recording period of dominate waves

Code	Description
00	Calm (no waves-no motion)
01	5°- 14°
02	15°- 24°
03	25°- 34°
04	35°- 44°
05	45°- 54°
06	55°- 64°
07	65°- 74°
08	75°- 84°
09	85°- 94°
10	95°- 104°
11	105°- 114°
12	115°- 124°
13	125°- 134°
14	135°- 144°
15	145°- 154°
16	155°- 164°
17	165°- 174°
18	175°- 184°
19	185°- 194°
20	195°- 204°
21	205°- 214°
22	215°- 224°
23	225°- 234°
24	235°- 244°
25	245°- 254°
26	255°- 264°
27	265°- 274°
28	275°- 284°
29	285°- 294°
30	295°- 304°
31	305°- 314°
32	315°- 324°
33	325°- 334°
34	335°- 344°
35	345°- 354°
36	355°- 4°
99	Observation not taken

TABLE 8: Codes for wind/wave direction

Code	Height of waves (M)	Description
0	0	Calm-glassy
1	0-0.1	Calm-rippled
2	0.1-0.5	Smooth-wavelet
3	0.5-1.25	Slight
4	1.25-2.5	Moderate
5	2.5-4	Rough
6	4-6	Very rough
7	6-9	High
8	9-14	Very high
9	>14	Phenomenal
99	Observation not taken	

TABLE 9: Sea State Codes

Code	Wave Height in Meters
0	Less than 0.25
1	0.25-0.5
2	0.5-1.0
3	1.0-1.5
4	1.5-2.0
5	2.0-2.5
6	2.5-3.0
7	3.0-3.5
8	3.5-4.0
9	4.0-4.5
10	4.5-5.0
11	5.0-5.5
12	5.5-6.0
13	6.0-6.5
14	6.5-7.0
15	7.0-7.5
16	7.5-8.0
17	8.0-8.5
18	8.5-9.0
19	9.0-9.5
20	> 9.5
99	Observation not taken

TABLE 10: Codes for recording dominant wave heights

Code	Color of the water
1	Blue
2	Blue-green
3	Green
4	Greenish-brown
5	Olive
6	Brown
99	Observation not taken

TABLE 11: Codes for Water Color

APPENDIX B. Supporting Data for Estuarine Hydrology and Hydrography

TableB-1. Calcasieu Lake Gaged Inflow.

CALCASIEU - AVERAGE MONTHLY INFLOWS IN CFS FOR 1967

I MONTH I	CALCASIEU I	BECKWITH I	BEAR H I	TOTAL I
I JAN I	I	I	I	I
I FEB I	I	I	I	I
I MAR I	I	I	I	I
I APR I	I	I	I	I
I MAY I	I	I	I	I
I JUNE I	I	I	I	I
I JULY I	I	I	I	I
I AUG I	I	I	I	I
I SEPT I	I	I	I	I
I OCT I	306.29 I	4.25 I	0.11 I	310.65 I
I NOV I	398.60 I	2.78 I	0.09 I	401.47 I
I DEC I	5494.39 I	534.80 I	550.17 I	6579.35 I

CALCASIEU - AVERAGE MONTHLY INFLOWS IN CFS FOR 1966

I MONTH I	CALCASIEU I	BECKWITH I	BEAR H I	TOTAL I
I JAN I	6566.45 I	660.97 I	796.71 I	8024.12 I
I FEB I	1630.15 I	98.00 I	97.55 I	1825.70 I
I MAR I	I	182.81 I	208.87 I	391.68 I
I APR I	3958.33 I	355.73 I	324.73 I	4638.80 I
I MAY I	2290.97 I	174.71 I	245.71 I	2711.39 I
I JUNE I	1116.70 I	212.82 I	286.89 I	1616.41 I
I JULY I	660.65 I	27.82 I	42.43 I	730.89 I
I AUG I	537.16 I	30.67 I	24.88 I	592.71 I
I SEPT I	709.70 I	124.89 I	359.94 I	1194.53 I
I OCT I	385.16 I	10.19 I	5.77 I	401.12 I
I NOV I	472.47 I	81.74 I	58.50 I	612.71 I
I DEC I	4225.80 I	510.35 I	695.19 I	5431.35 I

Table B-1. (Continued)

CALCASIEU - AVERAGE MONTHLY INFLOWS IN CFS FOR 1969

I MONTH I	I CALCASIEU I	I BECKWITH I	I BEAR H I	I TOTAL I
I JAN I	I 1469.45 I	I 90.03 I	I 84.45 I	I 1643.94 I
I FEB I	I 4047.68 I	I 551.79 I	I 682.96 I	I 5282.42 I
I MAR I	I 5086.77 I	I 405.61 I	I 439.65 I	I 5932.03 I
I APR I	I 5693.33 I	I 531.33 I	I 583.27 I	I 6807.93 I
I MAY I	I 3830.97 I	I 400.48 I	I 431.34 I	I 4662.79 I
I JUNE I	I 731.20 I	I 13.43 I	I 8.35 I	I 752.57 I
I JULY I	I 811.42 I	I 14.42 I	I 38.29 I	I 864.13 I
I AUG I	I 387.06 I	I 3.86 I	I 0.49 I	I 391.42 I
I SEPT I	I 320.70 I	I 2.03 I	I 9.41 I	I 332.15 I
I OCT I	I 343.84 I	I 0.51 I	I 0.11 I	I 344.46 I
I NOV I	I 313.30 I	I 4.77 I	I 0.03 I	I 318.10 I
I DEC I	I 888.84 I	I 129.49 I	I 88.21 I	I 1106.54 I

CALCASIEU - AVERAGE MONTHLY INFLOWS IN CFS FOR 1970

I MONTH I	I CALCASIEU I	I BECKWITH I	I BEAR H I	I TOTAL I
I JAN I	I 1348.32 I	I 28.95 I	I 25.31 I	I 1402.59 I
I FEB I	I 944.04 I	I 44.35 I	I 44.76 I	I 1033.15 I
I MAR I	I 1524.06 I	I 99.32 I	I 95.68 I	I 1719.06 I
I APR I	I 1509.23 I	I 153.39 I	I 119.94 I	I 1782.57 I
I MAY I	I 1234.06 I	I 22.99 I	I 12.32 I	I 1269.37 I
I JUNE I	I 324.60 I	I 70.24 I	I 40.72 I	I 435.57 I
I JULY I	I 310.84 I	I 1.53 I	I 0.09 I	I 312.45 I
I AUG I	I 310.48 I	I 1.71 I	I 0.24 I	I 312.43 I
I SEPT I	I 405.07 I	I 20.78 I	I 14.89 I	I 440.74 I
I OCT I	I 4716.55 I	I 624.20 I	I 1555.78 I	I 6896.52 I
I NOV I	I 1526.40 I	I 123.73 I	I 286.57 I	I 1936.70 I
I DEC I	I 1193.45 I	I 33.10 I	I 21.89 I	I 1248.44 I

Table B-1. (Continued)

CALCASIEU - AVERAGE MONTHLY INFLOWS IN CFS FOR 1971

I MONTH I	CALCASIEU I	BECKWITH I	BEAR H I	TOTAL I
I JAN I	1774.97 I	102.45 I	98.61 I	1976.03 I
I FEB I	2608.71 I	374.00 I	428.64 I	3411.36 I
I MAR I	3951.61 I	219.74 I	242.55 I	4413.90 I
I APR I	1241.03 I	12.07 I	3.41 I	1256.51 I
I MAY I	2200.65 I	82.02 I	76.36 I	2359.02 I
I JUNE I	391.17 I	2.51 I	3.39 I	397.07 I
I JULY I	398.97 I	2.95 I	0.11 I	402.04 I
I AUG I	802.35 I	54.00 I	51.24 I	907.59 I
I SEPT I	645.20 I	16.37 I	24.59 I	686.16 I
I OCT I	584.26 I	3.71 I	4.19 I	592.16 I
I NOV I	612.13 I	33.86 I	37.10 I	683.09 I
I DEC I	10001.29 I	631.45 I	824.06 I	11456.80 I

CALCASIEU - AVERAGE MONTHLY INFLOWS IN CFS FOR 1972

I MONTH I	CALCASIEU I	BECKWITH I	BEAR H I	TOTAL I
I JAN I	5489.35 I	504.32 I	641.48 I	6635.15 I
I FEB I	2998.62 I	170.52 I	234.79 I	3403.93 I
I MAR I	3386.45 I	323.77 I	361.61 I	4071.84 I
I APR I	897.53 I	19.59 I	13.28 I	930.40 I
I MAY I	1284.29 I	43.12 I	74.51 I	1401.92 I
I JUNE I	741.87 I	17.47 I	22.03 I	781.37 I
I JULY I	670.68 I	8.55 I	44.03 I	723.26 I
I AUG I	599.45 I	37.06 I	22.62 I	659.14 I
I SEPT I	363.13 I	23.22 I	12.12 I	398.47 I
I OCT I	1164.26 I	16.53 I	43.50 I	1224.29 I
I NOV I	1709.90 I	118.66 I	85.82 I	1914.38 I
I DEC I	5270.64 I	231.77 I	192.48 I	5694.90 I

Table B-1. (Continued)

CALCASIEU - AVERAGE MONTHLY INFLOWS IN CFS FOR 1973

I MONTH I	CALCASIEU I	BECKWITH I	BEAR H I	TOTAL I
I JAN I	4662.58 I	511.55 I	612.45 I	5786.57 I
I FEB I	6325.36 I	501.93 I	522.11 I	7349.39 I
I MAR I	10819.35 I	695.35 I	938.61 I	12453.31 I
I APR I	9145.66 I	590.63 I	725.77 I	10462.06 I
I MAY I	7850.00 I	523.68 I	572.51 I	8946.18 I
I JUNE I	2106.03 I	332.40 I	514.72 I	2953.15 I
I JULY I	766.13 I	265.52 I	239.19 I	1270.83 I
I AUG I	1124.81 I	70.79 I	55.69 I	1251.29 I
I SEPT I	3381.97 I	493.60 I	856.67 I	4732.23 I
I OCT I	3167.03 I	389.03 I	679.97 I	4236.03 I
I NOV I	2535.00 I	242.93 I	259.23 I	3037.17 I
I DEC I	4437.09 I	382.74 I	315.52 I	5135.35 I

CALCASIEU - AVERAGE MONTHLY INFLOWS IN CFS FOR 1974

I MONTH I	CALCASIEU I	BECKWITH I	BEAR H I	TOTAL I
I JAN I	12674.19 I	1127.94 I	1399.16 I	15201.29 I
I FEB I	5766.43 I	257.82 I	240.82 I	6265.07 I
I MAR I	2127.42 I	154.03 I	209.16 I	2490.61 I
I APR I	4336.46 I	269.67 I	282.22 I	4888.35 I
I MAY I	1926.45 I	76.90 I	50.18 I	2053.54 I
I JUNE I	1515.20 I	52.27 I	10.11 I	1577.58 I
I JULY I	808.90 I	50.48 I	7.82 I	867.21 I
I AUG I	637.10 I	47.10 I	24.06 I	708.25 I
I SEPT I	1048.43 I	126.02 I	70.98 I	1245.43 I
I OCT I	399.87 I	6.10 I	1.43 I	407.40 I
I NOV I	1384.20 I	84.23 I	156.00 I	1624.43 I
I DEC I	4415.48 I	458.84 I	434.74 I	5309.05 I

Table B-1. (Continued)

CALCASIEU - AVERAGE MONTHLY INFLOWS IN CFS FOR 1975

I MONTH	I CALCASIEU	I BECKWITH	I BEAR H	I TOTAL
I JAN	I 6943.55	I 570.00	I 801.19	I 8314.74
I FEB	I 2439.64	I 140.25	I 163.64	I 2743.54
I MAR	I 3100.00	I 127.42	I 127.45	I 3354.87
I APR	I 2951.33	I 214.57	I 293.87	I 3460.17
I MAY	I 10333.22	I 428.39	I 424.99	I 11186.59
I JUNE	I 4312.66	I 309.87	I 510.80	I 5133.32
I JULY	I 3584.52	I 339.16	I 128.58	I 4052.26
I AUG	I 4533.55	I 458.65	I 380.16	I 5372.35
I SEPT	I 1281.47	I 207.40	I 142.57	I 1631.44
I OCT	I 2540.90	I 249.90	I 294.91	I 3085.71
I NOV	I 1878.20	I 95.47	I 165.41	I 2139.08
I DEC	I 1761.19	I 163.42	I 191.55	I 2116.16

CALCASIEU - AVERAGE MONTHLY INFLOWS IN CFS FOR 1976

I MONTH	I CALCASIEU	I BECKWITH	I BEAR H	I TOTAL
I JAN	I 2667.94	I 240.35	I 263.29	I 3171.58
I FEB	I 1818.62	I 72.31	I 65.21	I 1956.14
I MAR	I 3936.77	I 537.35	I 798.94	I 5273.06
I APR	I 2547.87	I 113.13	I 199.93	I 2860.93
I MAY	I 2631.19	I 35.32	I 42.44	I 2708.95
I JUNE	I 1796.70	I 105.93	I 128.73	I 2031.36
I JULY	I 1044.03	I 169.61	I 216.55	I 1430.19
I AUG	I 490.03	I 13.61	I 7.49	I 511.13
I SEPT	I 389.07	I 6.61	I 3.22	I 398.89
I OCT	I 347.84	I 9.05	I 6.88	I 363.77
I NOV	I 415.40	I 24.41	I 82.99	I 522.80
I DEC	I 1537.35	I 318.13	I 611.29	I 2466.77

Table B-1. (Continued)

CALCASIEU - AVERAGE MONTHLY INFLOWS IN CFS FOR 1977

I MONTH I	CALCASIEU I	BECKWITH I	BEAR H I	TOTAL I
I JAN I	3538.06 I	374.26 I	475.77 I	4388.09 I
I FEB I	2764.64 I	204.71 I	174.00 I	3143.36 I
I MAR I	4904.06 I	346.13 I	302.13 I	5552.32 I
I APR I	2879.33 I	258.33 I	298.07 I	3435.74 I
I MAY I	2197.06 I	30.69 I	9.81 I	2237.56 I
I JUNE I	438.67 I	10.68 I	10.93 I	460.27 I
I JULY I	346.81 I	7.46 I	0.02 I	354.29 I
I AUG I	557.94 I	36.77 I	55.34 I	650.04 I
I SEPT I	583.63 I	24.85 I	24.36 I	632.85 I
I OCT I	881.32 I	86.05 I	53.45 I	1020.83 I
I NOV I	1620.83 I	231.73 I	216.37 I	2068.93 I
I DEC I	6177.42 I	475.00 I	519.87 I	7172.29 I

CALCASIEU - AVERAGE MONTHLY INFLOWS IN CFS FOR 1978

I MONTH I	CALCASIEU I	BECKWITH I	BEAR H I	TOTAL I
I JAN I	5376.13 I	662.48 I	806.10 I	6844.70 I
I FEB I	5060.00 I	259.86 I	211.43 I	5531.28 I
I MAR I	1335.90 I	34.74 I	30.78 I	1401.42 I
I APR I	738.07 I	9.89 I	4.49 I	752.45 I
I MAY I	393.90 I	4.44 I	0.33 I	398.66 I
I JUNE I	1507.23 I	41.20 I	126.42 I	1674.85 I
I JULY I	352.97 I	20.42 I	0.34 I	373.72 I
I AUG I	370.48 I	40.38 I	5.45 I	416.32 I
I SEPT I	502.20 I	22.81 I	12.76 I	537.77 I
I OCT I	254.52 I	1.20 I	0.22 I	255.93 I
I NOV I	304.53 I	5.70 I	17.25 I	327.49 I
I DEC I	714.90 I	61.19 I	53.22 I	829.31 I

Table B-1. (Continued)

CALCASIEU - AVERAGE MONTHLY INFLOWS IN CFS FOR 1979

MONTH	CALCASIEU	BECKWITH	BEAR H	TOTAL
JAN	5374.84	477.29	441.23	6293.35
FEB	7646.43	581.29	666.71	8894.42
MAR	5248.39	377.74	503.65	6129.77
APR	4633.66	477.47	752.50	5863.63
MAY	1660.71	60.53	70.76	1792.01
JUNE	2964.23	183.44	307.40	3455.07
JULY	3310.74	420.35	348.61	4079.70
AUG	1117.81	40.94	40.59	1199.33
SEPT	7285.16	371.68	538.86	8195.70
OCT	850.84	25.97	11.69	888.50
NOV	2443.90	140.41	196.68	2780.98
DEC	6209.22	297.45	281.42	6788.09

CALCASIEU - AVERAGE MONTHLY INFLOWS IN CFS FOR 1980

MONTH	CALCASIEU	BECKWITH	BEAR H	TOTAL
JAN	4372.90	397.84	593.26	5364.00
FEB	5241.03	364.24	408.34	6013.61
MAR	6723.55	542.35	503.77	7769.67
APR	9019.33	501.37	601.60	10122.29
MAY	6061.61	872.71	1504.27	8438.58
JUNE	853.73	13.82	5.84	873.40
JULY	343.68	15.12	1.19	359.99
AUG	267.39	14.03	0.70	282.11
SEPT	328.97	10.84	2.87	342.67
OCT	566.00	41.00	9.70	616.70
NOV	-	-	-	-
DEC	-	-	-	-

Table B-2. Sabine Lake Gaged Inflow.

SABINE - AVERAGE MONTHLY INFLOWS IN CFS FOR 1967

I MONTH I	SABINE I	COW B I	NECHES I	VILLAGE I	PINE IS I	TOTAL I
I JAN I	I	I	I	I	I	I
I FEB I	I	I	I	I	I	I
I MAR I	I	I	I	I	I	I
I APR I	I	I	I	I	I	I
I MAY I	I	I	I	I	I	I
I JUNE I	I	I	I	I	I	I
I JULY I	I	I	I	I	I	I
I AUG I	I	I	I	I	I	I
I SEPT I	I	I	I	I	I	I
I OCT I	291.74 I	0.05 I	547.26 I	22.81 I	2.95 I	864.80 I
I NOV I	327.30 I	0.08 I	448.03 I	34.93 I	2.55 I	812.90 I
I DEC I	1695.55 I	17.93 I	536.81 I	125.10 I	63.97 I	2439.35 I

SABINE - AVERAGE MONTHLY INFLOWS IN CFS FOR 1968

I MONTH I	SABINE I	COW B I	NECHES I	VILLAGE I	PINE IS I	TOTAL I
I JAN I	4241.29 I	267.38 I	3098.06 I	273.03 I	193.55 I	8073.30 I
I FEB I	1558.97 I	27.40 I	2707.93 I	169.14 I	37.42 I	4500.85 I
I MAR I	2531.94 I	85.52 I	3644.84 I	392.97 I	136.10 I	6791.35 I
I APR I	6335.00 I	320.66 I	11873.66 I	1042.87 I	629.90 I	20202.08 I
I MAY I	6205.48 I	162.59 I	11904.84 I	1238.06 I	550.68 I	20061.64 I
I JUNE I	17187.66 I	531.56 I	11661.33 I	1928.23 I	881.07 I	32189.85 I
I JULY I	5584.19 I	58.16 I	9136.13 I	658.77 I	387.10 I	15824.34 I
I AUG I	3278.39 I	3.18 I	4170.32 I	139.94 I	34.97 I	7626.78 I
I SEPT I	5648.33 I	97.99 I	1800.43 I	197.33 I	102.13 I	7846.21 I
I OCT I	2691.94 I	1.86 I	3005.81 I	130.87 I	109.02 I	5939.48 I
I NOV I	2170.33 I	9.84 I	3970.33 I	241.93 I	16.89 I	6409.31 I
I DEC I	17496.77 I	165.19 I	8599.35 I	670.94 I	115.61 I	27047.86 I

Table B-2. (Continued)

SABINE - AVERAGE MONTHLY INFLOWS IN CFS FOR 1969

I MONTH I	SABINE I	COB B I	NECHES I	VILLAGE I	PINE IS I	TOTAL I
I JAN I	10818.39 I	87.64 I	7622.90 I	375.32 I	26.62 I	18930.86 I
I FEB I	8899.29 I	359.61 I	8910.36 I	1370.04 I	727.23 I	20266.51 I
I MAR I	27480.64 I	230.45 I	14363.22 I	1572.84 I	930.42 I	44577.57 I
I APR I	33243.33 I	209.27 I	21176.66 I	831.83 I	485.53 I	55946.63 I
I MAY I	24003.22 I	253.88 I	24122.58 I	3595.19 I	782.74 I	52757.61 I
I JUNE I	10645.66 I	7.11 I	13983.66 I	436.87 I	139.87 I	25213.16 I
I JULY I	3354.84 I	11.58 I	2649.03 I	115.94 I	88.45 I	6219.83 I
I AUG I	3540.00 I	0.26 I	2417.42 I	58.77 I	36.07 I	6052.52 I
I SEPT I	3210.00 I	0.22 I	1783.00 I	59.33 I	18.94 I	5071.49 I
I OCT I	804.61 I	0.05 I	1267.74 I	46.00 I	2.90 I	2121.30 I
I NOV I	1469.37 I	0.12 I	931.77 I	93.87 I	6.41 I	2501.52 I
I DEC I	1762.35 I	4.61 I	1582.45 I	293.71 I	147.08 I	3790.21 I

SABINE - AVERAGE MONTHLY INFLOWS IN CFS FOR 1970

I MONTH I	SABINE I	COB B I	NECHES I	VILLAGE I	PINE IS I	TOTAL I
I JAN I	2272.58 I	5.68 I	2809.03 I	336.45 I	37.19 I	5460.93 I
I FEB I	3445.71 I	8.74 I	2355.36 I	344.11 I	62.76 I	6216.67 I
I MAR I	9766.45 I	34.94 I	4434.84 I	470.71 I	253.72 I	14960.65 I
I APR I	12821.00 I	50.87 I	5430.66 I	498.23 I	151.73 I	18952.49 I
I MAY I	8020.64 I	26.39 I	4544.52 I	1060.13 I	424.42 I	14076.10 I
I JUNE I	1427.67 I	10.82 I	1794.00 I	303.47 I	322.57 I	3858.52 I
I JULY I	1983.84 I	0.05 I	1302.81 I	59.42 I	59.81 I	3405.92 I
I AUG I	2668.87 I	0.14 I	826.55 I	38.87 I	37.71 I	3572.14 I
I SEPT I	3150.67 I	2.51 I	1059.53 I	58.07 I	80.20 I	4350.97 I
I OCT I	5452.13 I	505.35 I	1186.74 I	411.45 I	643.42 I	8199.08 I
I NOV I	2828.33 I	164.83 I	1343.27 I	266.63 I	528.23 I	5131.29 I
I DEC I	2149.84 I	3.37 I	1147.10 I	157.87 I	12.79 I	3470.96 I

Table B-2. (Continued)

SABINE - AVERAGE MONTHLY INFLOWS IN CFS FOR 1971

I MONTH I	SABINE I	COW B I	NECHES I	VILLAGE I	PINE IS I	TOTAL I
I JAN I	4391.29 I	23.53 I	1124.65 I	249.61 I	4.75 I	5793.82 I
I FEB I	3325.36 I	131.81 I	1148.11 I	174.96 I	35.34 I	4815.57 I
I MAR I	5336.13 I	82.40 I	1351.94 I	296.81 I	108.35 I	7175.61 I
I APR I	1030.43 I	0.45 I	1556.67 I	104.03 I	72.37 I	2763.95 I
I MAY I	1504.52 I	44.43 I	1234.61 I	289.81 I	145.10 I	3218.46 I
I JUNE I	2011.90 I	1.30 I	1397.13 I	72.03 I	40.00 I	3522.37 I
I JULY I	1522.13 I	0.27 I	1255.32 I	31.13 I	54.65 I	2863.50 I
I AUG I	1383.94 I	4.45 I	396.45 I	125.39 I	164.84 I	2075.06 I
I SEPT I	620.87 I	8.68 I	398.07 I	89.67 I	40.17 I	1157.44 I
I OCT I	1028.19 I	7.58 I	524.58 I	210.42 I	46.74 I	1817.51 I
I NOV I	981.40 I	0.97 I	372.63 I	192.50 I	33.90 I	1581.40 I
I DEC I	14176.87 I	345.74 I	3466.16 I	2449.42 I	1133.58 I	21575.77 I

SABINE - AVERAGE MONTHLY INFLOWS IN CFS FOR 1972

I MONTH I	SABINE I	COW B I	NECHES I	VILLAGE I	PINE IS I	TOTAL I
I JAN I	20454.84 I	269.48 I	3755.48 I	1488.03 I	485.58 I	26453.41 I
I FEB I	10540.00 I	161.17 I	2943.93 I	906.79 I	612.03 I	15163.92 I
I MAR I	4594.84 I	183.01 I	2902.10 I	1110.13 I	386.23 I	9176.29 I
I APR I	2472.00 I	7.53 I	2782.33 I	699.93 I	170.40 I	6132.19 I
I MAY I	5189.68 I	75.32 I	4140.00 I	2300.58 I	928.29 I	12633.86 I
I JUNE I	3223.13 I	5.67 I	2918.00 I	151.07 I	54.00 I	6351.87 I
I JULY I	3381.94 I	15.77 I	2104.52 I	233.26 I	94.00 I	5829.48 I
I AUG I	5584.19 I	3.24 I	1930.65 I	98.19 I	33.69 I	7649.95 I
I SEPT I	5781.00 I	5.89 I	1649.67 I	93.20 I	76.73 I	7606.47 I
I OCT I	1942.29 I	8.80 I	1418.06 I	156.65 I	20.50 I	3546.30 I
I NOV I	2468.00 I	103.73 I	2192.33 I	581.70 I	615.07 I	5960.83 I
I DEC I	7615.48 I	176.90 I	3867.10 I	927.94 I	580.29 I	13167.70 I

Table B-2. (Continued)

SABINE - AVERAGE MONTHLY INFLOWS IN CFS FOR 1973

I MONTH I	SABINE I	COW B I	NECHES I	VILLAGE I	PINE IS I	TOTAL I
I JAN I	17425.80 I	348.32 I	7555.48 I	1740.58 I	837.61 I	27907.79 I
I FEB I	17971.43 I	247.21 I	11151.79 I	3018.07 I	939.18 I	33327.67 I
I MAR I	18260.96 I	363.81 I	11921.93 I	2424.58 I	1039.35 I	34010.63 I
I APR I	26993.33 I	363.20 I	20716.66 I	4154.16 I	2133.33 I	54360.69 I
I MAY I	23225.80 I	313.15 I	18309.68 I	2292.29 I	726.16 I	44867.07 I
I JUNE I	15254.66 I	154.59 I	15484.00 I	2673.23 I	2031.53 I	35598.01 I
I JULY I	12670.64 I	30.05 I	12639.35 I	1250.81 I	436.23 I	27027.07 I
I AUG I	6263.22 I	38.67 I	3935.48 I	995.74 I	461.52 I	11694.63 I
I SEPT I	10526.33 I	292.32 I	6772.00 I	1435.10 I	1158.50 I	20184.25 I
I OCT I	6678.06 I	289.35 I	8065.16 I	1736.06 I	1164.06 I	17932.70 I
I NOV I	8724.66 I	125.03 I	11799.00 I	1759.63 I	877.17 I	23285.49 I
I DEC I	17535.48 I	100.03 I	15243.87 I	2581.19 I	606.71 I	36067.28 I

SABINE - AVERAGE MONTHLY INFLOWS IN CFS FOR 1974

I MONTH I	SABINE I	COW B I	NECHES I	VILLAGE I	PINE IS I	TOTAL I
I JAN I	32756.77 I	540.61 I	21706.45 I	5693.22 I	2205.77 I	62942.83 I
I FEB I	27992.86 I	115.64 I	21678.57 I	1784.36 I	423.29 I	51998.71 I
I MAR I	10438.71 I	65.50 I	18041.93 I	1048.68 I	185.63 I	29780.44 I
I APR I	9518.66 I	36.52 I	7256.00 I	1884.33 I	459.23 I	19196.74 I
I MAY I	9194.19 I	4.13 I	5353.87 I	579.61 I	200.26 I	15332.05 I
I JUNE I	5957.00 I	2.68 I	4364.00 I	417.83 I	155.70 I	10937.20 I
I JULY I	5690.64 I	0.62 I	3847.42 I	165.77 I	73.35 I	9777.81 I
I AUG I	5832.58 I	2.59 I	3444.84 I	178.00 I	77.68 I	9535.68 I
I SEPT I	5727.33 I	1.36 I	4564.66 I	493.43 I	138.10 I	10924.88 I
I OCT I	1256.19 I	0.23 I	2544.52 I	240.32 I	71.80 I	4113.07 I
I NOV I	6296.33 I	52.55 I	6914.66 I	1910.33 I	1527.33 I	16701.21 I
I DEC I	20561.29 I	146.68 I	10410.96 I	2485.68 I	1107.19 I	34711.80 I

Table B-2. (Continued)

SABINE - AVERAGE MONTHLY INFLOWS IN CFS FOR 1975

I MONTH I	SABINE I	COW B I	NECHES I	VILLAGE I	PINE IS I	TOTAL I
I JAN I	23680.64 I	346.45 I	14516.77 I	2919.35 I	1357.48 I	42820.70 I
I FEB I	23632.14 I	76.79 I	17035.71 I	2251.96 I	430.50 I	43427.10 I
I MAR I	20496.77 I	56.93 I	14370.96 I	1640.03 I	267.26 I	36831.95 I
I APR I	15077.33 I	211.67 I	8704.00 I	1369.37 I	879.53 I	26241.89 I
I MAY I	21513.55 I	251.93 I	15804.19 I	2268.55 I	639.48 I	40477.69 I
I JUNE I	15453.33 I	492.50 I	9708.00 I	2120.40 I	2374.00 I	30148.23 I
I JULY I	9321.61 I	105.20 I	7684.19 I	1097.81 I	255.16 I	18463.97 I
I AUG I	7982.26 I	171.80 I	6952.90 I	1579.65 I	943.94 I	17630.54 I
I SEPT I	5639.00 I	100.25 I	4588.33 I	357.00 I	74.47 I	10759.05 I
I OCT I	2692.90 I	61.77 I	3390.00 I	647.77 I	296.72 I	7089.16 I
I NOV I	1538.00 I	63.15 I	2176.33 I	784.00 I	498.27 I	5059.75 I
I DEC I	1982.26 I	108.19 I	1962.90 I	727.35 I	444.58 I	5225.28 I

SABINE - AVERAGE MONTHLY INFLOWS IN CFS FOR 1976

I MONTH I	SABINE I	COW B I	NECHES I	VILLAGE I	PINE IS I	TOTAL I
I JAN I	2583.55 I	64.35 I	1867.42 I	1084.26 I	281.90 I	5881.47 I
I FEB I	3771.03 I	22.25 I	1764.14 I	544.55 I	53.71 I	6155.68 I
I MAR I	9936.13 I	254.77 I	3333.87 I	855.55 I	291.01 I	14711.32 I
I APR I	7200.66 I	85.80 I	4118.00 I	716.33 I	235.83 I	12356.62 I
I MAY I	8416.13 I	122.07 I	8399.35 I	1574.13 I	377.39 I	18889.06 I
I JUNE I	11755.00 I	153.45 I	7039.33 I	1305.67 I	463.20 I	20756.64 I
I JULY I	8509.68 I	74.94 I	6895.48 I	715.26 I	137.03 I	16332.38 I
I AUG I	7849.35 I	1.83 I	6716.13 I	147.35 I	29.97 I	14744.63 I
I SEPT I	4972.66 I	0.18 I	5381.33 I	132.87 I	21.80 I	10508.84 I
I OCT I	1760.74 I	2.44 I	2912.90 I	222.94 I	35.75 I	4934.76 I
I NOV I	1501.57 I	33.93 I	2370.67 I	335.40 I	199.80 I	4441.36 I
I DEC I	4112.90 I	347.61 I	4171.29 I	1404.84 I	1388.35 I	11424.99 I

Table B-2. (Continued)

SABINE - AVERAGE MONTHLY INFLOWS IN CFS FOR 1977

I MONTH I	SABINE I	COW B I	NECHES I	VILLAGE I	PINE IS I	TOTAL I
I JAN I	7051.93 I	236.81 I	6123.22 I	1162.83 I	653.03 I	15227.02 I
I FEB I	8158.21 I	85.86 I	5503.57 I	992.43 I	504.61 I	15244.68 I
I MAR I	13559.35 I	62.53 I	5692.58 I	1128.74 I	127.97 I	20571.16 I
I APR I	12946.33 I	129.59 I	7665.66 I	1380.90 I	743.20 I	22865.68 I
I MAY I	6120.00 I	35.51 I	8457.74 I	577.87 I	139.39 I	15330.50 I
I JUNE I	4222.00 I	8.86 I	4832.00 I	489.10 I	349.47 I	9901.42 I
I JULY I	3707.10 I	0.38 I	3604.52 I	141.32 I	56.35 I	7509.66 I
I AUG I	4420.96 I	0.23 I	3105.81 I	178.48 I	12.25 I	7717.73 I
I SEPT I	4482.66 I	0.43 I	2482.00 I	200.87 I	54.87 I	7220.83 I
I OCT I	1180.06 I	3.07 I	1850.97 I	110.65 I	11.42 I	3156.17 I
I NOV I	1780.27 I	45.20 I	718.00 I	250.80 I	1220.78 I	4019.04 I
I DEC I	4157.42 I	164.45 I	1754.39 I	859.81 I	830.35 I	7766.41 I

SABINE - AVERAGE MONTHLY INFLOWS IN CFS FOR 1978

I MONTH I	SABINE I	COW B I	NECHES I	VILLAGE I	PINE IS I	TOTAL I
I JAN I	6225.48 I	334.90 I	3929.26 I	1810.45 I	1080.16 I	13380.25 I
I FEB I	9271.43 I	181.07 I	5423.21 I	2086.50 I	875.89 I	17838.10 I
I MAR I	5730.00 I	11.54 I	2091.61 I	615.45 I	89.13 I	8537.72 I
I APR I	2136.50 I	0.42 I	2197.67 I	234.80 I	51.63 I	4621.01 I
I MAY I	2444.71 I	0.04 I	1964.19 I	123.57 I	29.10 I	4562.00 I
I JUNE I	3620.00 I	249.36 I	2704.67 I	163.87 I	244.97 I	6982.85 I
I JULY I	2613.23 I	0.55 I	3066.77 I	93.23 I	56.58 I	5870.34 I
I AUG I	2054.16 I	0.23 I	1840.97 I	88.55 I	17.26 I	4001.17 I
I SEPT I	3371.67 I	1.15 I	552.50 I	203.77 I	33.90 I	4162.98 I
I OCT I	791.39 I	0.03 I	488.13 I	69.90 I	3.79 I	1353.23 I
I NOV I	1567.17 I	4.60 I	1385.70 I	839.90 I	110.01 I	3907.38 I
I DEC I	3762.58 I	12.80 I	2363.65 I	1288.39 I	340.03 I	7767.44 I

Table B-2. (Continued)

SABINE - AVERAGE MONTHLY INFLOWS IN CFS FOR 1979

MONTH	SABINE	CCW B	NECHES	VILLAGE	PINE IS	TOTAL
JAN	15821.93	319.19	6950.64	3712.90	1347.39	28152.06
FEB	24121.43	373.46	11587.86	3195.71	1327.07	40605.52
MAR	23529.03	322.39	17567.74	2430.65	1261.10	45110.89
APR	24600.00	841.27	20246.66	6732.73	4971.83	57392.49
MAY	17054.84	54.99	18812.90	991.23	275.94	37189.89
JUNE	17261.66	265.89	18296.66	1430.10	387.13	37641.45
JULY	5935.16	206.20	9060.96	1292.48	1893.71	18390.51
AUG	4729.03	38.38	9644.19	575.90	689.97	15677.47
SEPT	6756.33	239.32	7089.66	1793.80	1487.20	17366.31
OCT	2211.39	12.04	3494.19	386.26	71.62	6175.50
NOV	3043.00	106.43	2492.00	1448.07	342.37	7431.86
DEC	8931.93	137.61	6700.32	1109.13	160.52	17039.51

SABINE - AVERAGE MONTHLY INFLOWS IN CFS FOR 1980

MONTH	SABINE	CCW B	NECHES	VILLAGE	PINE IS	TOTAL
JAN	9705.48	441.19	6784.84	1728.52	1296.39	19956.41
FEB	16431.03	237.66	11926.55	1892.93	822.90	31311.06
MAR	12769.68	257.84	8743.87	1593.29	684.55	24049.21
APR	21380.00	234.98	13770.00	2099.63	818.60	38303.21
MAY	20973.87	438.96	13438.71	1906.94	1360.65	38119.11
JUNE	4399.66	0.83	10616.33	286.53	45.20	15348.55
JULY	3185.48	0.19	4047.10	111.58	33.35	7377.70
AUG	2893.55	0.21	3180.32	79.84	14.48	6168.39
SEPT	2525.93	10.07	2492.33	126.30	600.99	5755.62
OCT	7650.00	43.00	2550.00	114.47	-	10357.46
NOV	-	-	-	-	-	-
DEC	-	-	-	-	-	-

APPENDIX C. Conductivity, Temperature, Depth, Dissolved Oxygen,
(CTD/DO) and pH Profiles During Biological Sampling.

C.1 Introduction

This section reports on the CTD/DO and pH baseline data of the West Hackberry Brine Disposal Project. The inherent variability of environmental data collected from a dynamic system such as the nearshore and estuarine systems of the north-central Gulf Coast necessitates the concurrent acquisition of certain water quality and biological data in order to derive associations between water quality degradation and biological impacts. This aspect of the baseline study was intended to quantify natural variation of water quality variables between sample stations, depth and temporally and to assist in the interpretation of biological variation.

C.2 Materials and Methods

Monthly biological sampling occurred at five estuarine and fourteen marine stations. The estuarine stations, shown in Figure C-1, were located in the lower Calcasieu River Basin. Station E1 was located in the Intracoastal Waterway near the leach water intake structure. The other four stations were located: at the north end of Calcasieu Lake, E2; in West Cove, northeast of Rabbit Island, E3; at the south end of Calcasieu Lake, east of the ship channel, E4; and at Calcasieu Pass, E5. The station latitude/longitude coordinates are shown in Table C-1.

The marine stations, centered about the diffuser, were aligned in an east-west orientation approximately along the ten meter isopleth and in a north-south or transhore orientation. The station locations

Table C-1. Estuarine station coordinates for pre-brine discharge biological monitoring.

<u>Station</u>	<u>Latitude/Longitude</u>
E1	30°03'32"N/93°26'09"W
E2	30°03'05"N/93°18'41"W
E3	29°51'33"N/93°22'00"W
E4	29°51'12"N/93°18'47"W
E5	29°46'18"N/93°20'38"W

are illustrated in Figure C-2 and the latitude/longitude and the LORAN C coordinates are given in Table C-2.

Upon arrival at each station and prior to biological sampling, general oceanographic and meteorological observations and a successful water quality profile were recorded. Data include the field LORAN C reading, time (GMT), date (GMT), depth (m), wind direction (tens of degrees), wind speed (mph), weather, cloud cover and sea state. The weather and sea state conditions were obtained on site from the NOAA weather service, visually verified and recorded using the NOAA codes (NOAA-EDIS 1978).

Conductivity, temperature, depth, dissolved oxygen and pH profiles were taken with a Hydrolab Series 8000 meter. Depth (m), temperature ($^{\circ}\text{C}$) and pH were directly recorded from the instrument's digital display. Conductivity was measured in $\mu\text{mhos cm}^{-1}$ and converted to salinity in parts per thousand (‰). Dissolved oxygen was measured in mg l^{-1} , corrected for temperature and salinity, and converted to ml l^{-1} .

The measurements were taken within one meter of the bottom, within one meter of the surface and every three meters in between. If stratification was evident, the profile measurements were performed at meter intervals until the stratifying layers were located.

C.3 Results

C.3.1 Estuarine

C.3.1.1 Estuarine CTD/DO and pH Data Analyses from Biological Cruises

Figure C-2. Pre-discharge marine station locations for biological monitoring.

Table C-2. Marine station coordinates for pre-brine discharge biological monitoring.

<u>Station</u>	<u>Latitude/Longitude</u>	<u>Loran C Coordinates</u>	
M1	29°39'51"N/93°33'35"W	26522.4	46966.9
M3	29°39'52"N/93°30'35"W	26550.6	46966.7
M6	29°39'52"N/93°29'35"W	26560.0	46966.7
M9	29°40'52"N/93°28'35"W	26574.8	46968.9
M10 (Buoy)	29°39'52"N/93°28'35"W	26568.8	46966.7
M10A	29°40'48"N/93°28'13"W	26574.3	46967.2
M11	29°38'52"N/93°28'35"W	26564.6	46964.3
M15	29°39'52"N/93°27'35"W	26579.4	46966.6
M18	29°39'52"N/93°26'35"W	26588.4	46966.6
M20	29°39'52"N/93°23'35"W	26617.0	46966.4
DN	29°40'22"N/93°28'13"W	26577.4	46968.4
DE	29°40'48"N/93°27'36"W	26580.3	46967.1
DS	29°39'22"N/93°28'13"W	26572.3	46966.0
DW	29°40'48"N/93°28'43"W	26569.5	46967.2
CS	29°40'50"N/93°18'12"W	26668.6	46966.4

Water quality data from eight estuarine sample cruises, listed in Table C-3, were analyzed by the multivariate analysis of variance procedure (MANOVA). Four data sets were incomplete due to low water conditions at station E3 in West Cove and were deleted from the analyses to obtain a balanced statistical design. It was of interest to quantify variation among stations. Analyses incorporated surface observations only, since water depths of less than one meter existed at stations E2, E3 and E4. The MANOVA table is presented in Table C-4.

Table C-4. MANOVA table for pre-brine discharge water quality data for biological estuarine cruises.

<u>Sources of variation</u>	<u>Degrees of Freedom</u>	<u>U-statistic</u>	Approximate
			<u>F-statistic</u>
Stations	16 - 98.4	0.125713	5.9747*

* F-statistic significant at the 0.05 level.

The critical value of the F-statistic at the five percent level of significance with (16, 98) degrees of freedom is approximately 1.75. Since $5.9747 > 1.75$, the data do not support the null hypothesis of equality among the five estuarine stations with respect to temperature, salinity pH and dissolved oxygen. Univariate analysis

Table C-3. Estuarine cruise numbers and dates employed in MANOVA analyses.

<u>CRUISE NUMBER</u>	<u>DATE</u>		
	Year	Month	Day
PI8102	81	02	12
BI8102	81	02	19
ZI8102	81	02	25
PI8103	81	03	10
ZI8103	81	03	11
PI8104	81	04	07
ZI8104	81	04	10
ZI8105	81	05	11

of variance (ANOVA) was employed on those four variables to ascertain where those differences lay. Those data are presented in Table C-5.

The significant F-statistics for salinity and pH indicated differences among stations while the F-statistics for temperature and dissolved oxygen indicated no difference. Since dissolved oxygen saturation values vary inversely with temperature and salinity, a full model analysis of covariance (ANOCOV) was applied, employing temperature, salinity and pH as covariates. Those results are presented in Table C-6. The F-statistics for dissolved oxygen values adjusted with the covariates temperature, salinity, and pH indicated differences in dissolved oxygen concentrations among stations.

C.3.2 Marine

C.3.2.1 Marine CTD/DO and pH Data Analyses from Biological Cruises

Multivariate analysis of variance (MANOVA) was applied to water quality data taken during twelve marine cruises listed in Table C-7 using surface, bottom and mid-depth or averages of near mid-depth data values. The analyses incorporated two levels to detect variation among depths and stations. The resultant MANOVA table for the vector analysis of temperature, salinity, pH and dissolved oxygen at the specified depths of the biological marine cruises are given in Table C-8.

Table C-5. ANOVA tables for pre-brine discharge water quality data for biological estuarine cruises.

<u>Variable</u>	<u>Source of variation</u>	<u>Degrees of Freedom</u>	<u>Sums of Squares</u>	<u>Mean Square</u>	<u>F-Statistic</u>
Temperature	Station	4	17.3540	4.3385	0.1377
	Error	35	1102.9197	31.5120	
	Total	39			
Salinity	Station	4	1146.3662	286.5916	17.2077*
	Error	35	582.9209	16.6549	
	Total	39			
pH	Station	4	2.3018	0.5754	12.3452*
	Error	35	1.6314	0.0466	
	Total	39			
Dissolved Oxygen	Station	4	3.5572	0.8893	0.8055
	Error	35	38.6427	1.1041	
	Total	39			

$F_{0.05}(4, 35) = 2.69$

*F-statistic significant at 0.05 level

Table C-6. Analysis of covariance (ANOCOV) for dissolved oxygen values of the biological estuarine cruises.

<u>Variable</u>	<u>Source of variation</u>	<u>Degrees of freedom</u>	<u>Sums of Squares</u>	<u>Mean squares</u>	<u>F-statistic</u>
Dissolved oxygen	Stations (adjusted)	4	3.5230	0.8808	3.0845*
	Covariate (temperature)	1	21.1220	21.1120	73.9701*
	Covariate (salinity)	1	0.7641	0.7641	2.6760*
	Covariate (pH)	1	3.1986	3.1986	11.2018*
	Error	32	9.1375	0.2855	

* F-statistic significant at the 0.05 level.

Table C-7. Cruise numbers and dates for water quality data, analyzed by ANOVA, observed during biological sampling.

<u>Biological Cruise Number</u>	<u>Date</u>			<u>Figure Cruise Number</u>
	<u>Year</u>	<u>Month</u>	<u>Day</u>	
P08102	81	02	04	C1
Z08102	81	02	13-14	C2
N08102	81	02	15-16	C3
B08102	81	02	17	C4
P08103	81	03	03	C5
N08103	81	03	09-10	C6
Z08103	81	03	17-19	C7
B08103	81	03	24	C8
P08104	81	03	31	C9
B08104	81	04	10	C10
Z08104	81	04	14-15	C11
N08104	81	04	21-22	C12

Table C-8. MANOVA table for CTD/DO and pH data of marine biological cruises.

<u>Source of variation</u>	<u>Degrees of freedom</u>	<u>U-statistic</u>	<u>Approximate F-statistic</u>
Stations	32, 1086	0.997400	0.7786
Depth	8, 588	0.754736	11.1038*
Station X depth	64, 1153	0.967785	0.1514

* F-statistic significant at the 0.05 level.

These results indicated that there were no significant differences among the nine marine stations with respect to the four variables, temperature, salinity, pH and dissolved oxygen. The significant F-statistic for depth led to more detailed analyses, univariate analysis of variance, ANOVA. The resultant ANOVA tables are presented in Table C-9. Those differences were primarily attributed to variation in salinity and dissolved oxygen values with depth. Since dissolved oxygen saturation values varied inversely with

Table C-9. ANOVA tables for CTD/DO and pH water quality data for the marine biological cruises.

<u>Variable</u>	<u>Source of variation</u>	<u>Degrees of freedom</u>	<u>Sums of Squares</u>	<u>Mean squares</u>	<u>F-statistic</u>
Temperature	Station	8	2.3516	0.2939	0.0114
	Depth	2	47.2617	23.6306	0.9130
	Station X depth	16	3.1563	0.1973	0.0076
	Error	297			
Salinity	Station	8	29.653	3.7067	0.5157
	Depth	2	269.5676	134.7838	18.8186*
	Station X depth	16	12.0225	0.7514	0.1049
	Error	297	2127.1934		
pH	Station	8	209.1719	26.1465	1.3735
	Depth	2	2.6406	1.3203	0.0694
	Station X depth	16	32.9531	2.0596	0.1082
	Error	297	5653.9609	19.0369	
Dissolved oxygen	Station	8	7.0930	0.8866	0.9383
	Depth	2	27.9988	13.9994	14.8147*
	Station X depth	16	3.3972	0.2123	0.2247
	Error	297	280.6548	0.9450	

* F-statistic significant at the 0.05 level

Figure C-3. Plot of surface CTD/DO and pH data for Stations E1 and E5 for eight estuarine cruises.

Table C-10. ANOCOV table for dissolved oxygen data of the biological marine cruises.

<u>Variable</u>	<u>Source of variation</u>	<u>Degrees of freedom</u>	<u>Sums of Squares</u>	<u>Mean squares</u>	<u>F-statistic</u>
Dissolved oxygen	Stations (adjusted)	8	3.6747	0.4593	1.3821
	Depth (adjusted)	2	7.2765	3.6382	10.9470*
	Station X depth	16	1.9011	0.1188	0.3575
	Covariates	3	182.9433	60.9811	183.4836*
	Covariate (temperature)	1	7.5131	7.5131	22.6059*
	Covariate (salinity)	1	46.0446	46.0446	138.5419*
	Covariate (pH)	1	26.2698	26.2698	79.0421*
	Error	294	97.7114	0.3324	

* F-statistic significant at the 0.05 level.

temperature and salinity an analysis of covariance was applied using temperature, salinity, and pH as covariates. Those data are presented in Table C-10. Adjusting for those covariates did not alter the outcome. Dissolved oxygen concentrations varied with depth but not among stations.

C.4 Discussion

C.4.1 Estuarine CTD/DO and pH

The MANOVA analyses indicated differences among estuarine stations with respect to temperature, salinity, pH and dissolved oxygen. The ANOVA analyses indicated that those differences were primarily attributable to variation among stations for pH and salinity. Waters of station E-1 from the Intracoastal Waterway typically contained lower salinities < 10 ‰ and lower pH values, generally 0.5 pH units lower than those waters of Calcasieu Pass, E5. These differences are illustrated in Figure C-3. Temperature values tended to be higher at station E1 than at station E5. Those differences were negligible and partially explained by the daily variation, since sampling usually proceeded from the south end of the estuary in early morning to the upper reaches later in the day. Temporal variations in temperature were evident with values of approximately 7.5°C in February to 28°C by May.

Dissolved oxygen concentrations fluctuated without apparent trends other than a general decreasing trend inversely related to temperature for station E1. The MANOVA and the ANOVA analyses did not suggest station differences. Since dissolved oxygen saturation was affected by temperature and salinity ANOCOV was applied to the data.

The results indicated real station differences in dissolved oxygen values.

The data indicated that lower salinity waters had lower pH values and that as expected there was a detectable inverse relationship for dissolved oxygen with salinity and temperature.

C.4.2 Marine CTD/DO and pH

MANOVA analyses of marine station data indicated variations among depths for temperature, salinity, pH and dissolved oxygen but no differences were detected among stations. The ANOVA analyses indicated that differences among depths were due primarily to salinity and dissolved oxygen concentrations which varied with depth. Adjusting dissolved oxygen values, i.e. removing the effect of temperature and salinity, in the analysis of covariance dissolved oxygen variation with depth. Temperature and pH did not significantly vary among stations or depth. Interactions were not present.

Figures C-4, C-5, and C-6 are plots of means for CTD/DO and pH data by depth versus time for stations M10, M3 and M18 representing the diffuser site, the west control site and the east control site, respectively. Salinity gradients (> 5 ‰) from surface to bottom waters were evident for cruises C4 of February 17, C7 of March 17, C8 of March 24, and C12 of April 22. Stratification in dissolved oxygen concentrations were noted for cruises C5 of March 3, C7 of March 17, C11 of April 14, and C12 of April 22.

Plots of west-east and north-south transects are shown in Figures C-7, C-8, and C-9 for cruises C2 of February 4, C9 of March 31, and C12 of April 22, respectively. Data from most cruises appeared

Figure C-4. CTD/DO and pH surface and bottom data for M10 versus cruise date.

Figure C-5. CTD/DO and pH data by depth for Station M3 versus cruise date.

Figure C-6. CTD/DO and pH data by depth for Station M18 versus cruise date.

Figure C-7. Plot of west-east and north-south transects for CTD/DO and pH profiles for Cruise C2 of February 4, 1981.

Figure C-8. Plot of west-east and north-south transects for CTD/DO and pH profiles for Cruise C9 of March 31, 1981.

similar to the plots given in Figure C-7 for cruise C2 of February 13, showing little variation among or within stations. The most peculiar data set was obtained from cruise C12 of April 21-22, 1981, plotted in Figure C-9. For this two day cruise stations M9, M10, M11, M15, M18, M20 and DE were sampled on April 21, and stations M1, M3, M6, DW, M21 and M22 were sampled on April 22, 1981. During that cruise winds of five miles per hour from the southeast shifted to twenty mile per hour winds out of the southwest. The changing weather pattern evidently induced mixing of waters and decreased the magnitude of stratification in salinity and dissolved oxygen. The alternative explanation is that there appeared to be a slug of less saline water with higher dissolved oxygen content, and higher temperature. The slug was most concentrated near the diffuser site and could be detected at control stations.

C.5 Conclusions

For the three month sample period surface waters of the estuarine stations E1 through E5 varied in salinity, pH and dissolved oxygen. Marine waters were homogeneous when considered by station for all variables, salinity, temperature, pH and dissolved oxygen; however, dissolved oxygen concentrations and salinity values varied within stations or among depths.

Appendix D-1. Temperature, salinity and dissolved oxygen measurements of bottom water at the marine sampling stations.

Month	Station													
	M1	M3	M6	M9	DW	DN	M10A	DS	DE	M11	M15	M18	M20	CS
<u>Temperature (°C)</u>														
February	10.1	10.2	10.4	10.2	10.2	10.2	10.2	10.3	10.3	10.3	10.0	10.1	10.1	10.3
March	15.7	15.6	15.6	15.6	15.9	15.6	15.6	15.7	15.6	16.2	15.7	15.7	15.7	—
April	20.0	20.6	20.5	20.7	20.5	20.5	20.6	20.5	21.0	20.5	20.5	20.6	20.5	—
<u>Salinity (0/00)</u>														
February	28.5	28.2	28.2	29.1	28.6	28.2	28.2	28.8	28.3	28.5	28.2	28.2	28.2	28.9
March	31.8	31.8	31.8	31.8	31.8	31.8	31.8	31.8	31.5	31.8	31.8	31.5	31.8	—
April	30.0	30.6	30.7	29.8	30.7	30.1	30.6	30.7	29.3	30.7	30.6	30.5	30.4	—
<u>Dissolved Oxygen (ml l⁻¹)</u>														
February	6.1	7.2	6.5	5.8	6.0	6.3	5.9	7.9	7.2	5.7	7.1	6.2	6.0	7.0
March	5.4	5.5	5.5	4.9	5.1	5.1	5.3	5.1	5.1	5.2	5.2	5.3	5.0	—
April	3.6	4.7	5.1	4.3	5.0	4.4	5.0	5.1	5.0	5.2	5.3	5.2	5.1	—

Appendix D-2. Temperature, salinity and dissolved oxygen measurements of bottom water at the estuarine sampling stations.

Stations					
Month	E1	E2	E3	E4	E5
<u>Temperature (°C)</u>					
February	12.3	12.4	----	11.6	10.5
March	16.2	16.1	----	15.5	15.5
April	20.2	20.2	19.7	20.1	21.3
<u>Salinity (0/00)</u>					
February	7.5	8.7	----	19.8	26.0
March	9.1	14.0	----	17.3	30.5
April	16.2	17.0	22.4	22.5	26.5
<u>Dissolved Oxygen (ml l⁻¹)</u>					
February	4.7	4.3	----	6.1	7.0
March	5.3	4.4	----	5.4	5.1
April	4.1	4.3	3.7	3.3	4.7

Appendix D-3. Grain size distribution of surficial sediments at the marine stations, given as percentage (by weight) retained by screen mesh of given phi size. Median grain size values greater than 10 ϕ are arbitrarily assigned a value of 11 in calculation of mean and standard deviation.

															median	%	%	%	%
Replicate		-2	-1	0	1	2	3	4	5	6	7	8	10	>10	ϕ	shell	%	%	%
																gravel	sand	silt	clay
Station DE February	1	0.00	0.00	0.03	0.74	2.01	1.64	3.39	18.36	4.19	4.20	4.20	12.55	48.70	9.80	0.00	7.81	30.95	61.25
	2	0.00	0.00	0.01	0.17	0.59	0.87	2.08	10.96	5.84	0.00	11.69	14.61	53.18	>10	0.00	3.72	28.49	67.79
	3	0.00	0.00	0.07	0.33	0.62	0.45	1.52	20.59	6.51	6.51	8.69	6.51	48.19	9.45	0.00	2.99	42.30	54.70
	4	0.00	0.25	0.21	0.32	1.96	7.27	12.40	6.75	4.54	0.00	13.62	13.63	39.05	8.39	0.25	22.16	24.91	52.68
	5	0.00	0.00	0.06	0.22	0.52	0.71	2.36	22.11	10.14	0.00	5.07	12.67	46.14	9.39	0.00	3.87	37.32	58.81
	6	0.00	0.10	0.68	2.12	1.38	5.12	2.99	23.77	10.93	2.19	12.49	8.74	24.49	7.04	0.10	12.29	54.38	33.23
Mean		0.00	0.06	0.18	0.65	1.18	2.68	4.12	17.09	7.03	2.15	10.13	11.45	43.29	9.18	0.06	8.81	36.39	54.74
S.D.		0.00	0.10	0.26	0.75	0.70	2.84	4.11	6.76	2.85	2.72	5.13	3.14	10.30	1.34	0.10	7.42	10.80	11.80

															median	%	%	%	%
Replicate		-2	-1	0	1	2	3	4	5	6	7	8	10	>10	ϕ	shell	%	%	%
																gravel	sand	silt	clay
Station DE March	1	0.00	0.00	0.00	0.01	0.31	0.88	3.70	14.99	8.61	4.31	8.61	8.62	49.96	9.99	0.00	4.90	36.52	58.58
	2	0.00	0.00	0.89	0.34	0.40	0.50	4.35	0.16	5.30	5.31	10.61	10.61	61.54	>10	0.00	6.48	21.38	72.15
	3	0.00	0.03	0.08	0.27	0.60	1.48	3.68	12.05	9.85	0.00	9.86	9.85	52.24	>10	0.03	6.11	31.76	62.09
	4	0.00	0.00	0.00	0.02	0.63	0.81	2.30	19.82	11.24	0.00	11.24	8.43	45.52	9.67	0.00	3.76	42.30	53.95
	6	0.00	0.45	1.01	0.09	0.37	0.83	2.92	24.63	10.82	4.33	8.66	12.98	32.90	7.53	0.45	5.22	48.44	45.88
	Mean	0.00	0.10	0.40	0.15	0.46	0.90	3.44	14.33	9.16	2.79	9.80	10.10	48.43	9.84	0.10	5.29	36.08	58.53
S.D.		0.00	0.20	0.51	0.15	0.14	0.36	0.77	9.26	2.39	2.58	1.17	1.84	10.47	1.42	0.20	1.07	10.32	9.74

															median	%	%	%	%
Replicate		-2	-1	0	1	2	3	4	5	6	7	8	10	>10	ϕ	shell	%	%	%
																gravel	sand	silt	clay
Station DE April	1	0.00	1.05	0.24	0.26	1.19	2.81	7.49	15.39	4.06	0.00	16.27	8.14	43.11	8.30	1.05	11.99	35.72	51.25
	2	0.00	0.00	0.12	0.01	1.10	5.44	13.15	13.32	13.74	4.58	4.58	9.16	34.80	6.68	0.00	19.82	36.22	43.96
	3	0.00	0.01	0.21	1.30	1.60	1.13	10.93	15.92	15.46	2.21	6.62	11.04	33.57	7.19	0.01	15.17	40.21	44.61
	4	0.00	0.28	0.20	0.35	1.62	3.95	4.05	12.96	3.91	3.90	5.86	13.86	49.24	9.89	0.28	10.17	26.63	62.92
	6	0.00	0.00	0.15	0.33	0.99	3.03	4.14	0.00	0.00	0.00	6.75	11.38	73.24	>10	0.00	8.64	6.75	84.62
	Mean	0.00	0.27	0.18	0.45	1.30	3.27	7.95	11.51	7.43	2.14	5.39	10.86	46.79	8.61	0.27	13.15	29.10	57.47
S.D.		0.00	0.45	0.05	0.49	0.29	1.58	4.06	6.56	6.77	2.13	6.33	2.14	16.10	1.81	0.45	4.45	13.45	16.99

Appendix D-3. (continued - page 2)

		Replicate													median Φ	% shell gravel sand silt clay			
		-2	-1	0	1	2	3	4	5	6	7	8	10	>10					
Station DN February	1	0.00	0.00	0.01	0.03	0.50	0.80	2.49	12.54	10.08	0.00	10.07	5.04	58.44	>10	0.00	3.83	32.69	63.48
	2	0.00	0.00	0.04	0.12	0.38	0.32	1.31	9.35	7.54	7.55	10.05	10.06	53.29	>10	0.00	2.17	34.49	63.35
	4	0.00	0.01	0.00	0.24	0.47	0.35	2.40	1.24	2.87	8.61	14.35	11.48	57.99	>10	0.01	3.46	27.07	69.47
	5	0.00	0.09	0.18	0.35	0.24	0.30	0.89	22.21	10.03	7.53	15.05	5.01	38.12	7.54	0.09	1.96	54.82	43.13
	6	0.00	0.00	0.10	0.23	0.14	0.23	1.45	29.93	4.99	7.49	19.98	7.49	27.97	7.27	0.00	2.15	62.39	35.46
	Mean	0.00	0.02	0.07	0.19	0.35	0.40	1.71	15.05	7.10	6.24	13.90	7.82	47.16	9.56	0.02	2.71	42.29	54.98
S.D.		0.00	0.04	0.07	0.12	0.15	0.23	0.70	11.20	3.16	3.52	4.12	2.92	13.53	1.97	0.04	0.86	15.38	14.78

		Replicate													median Φ	% shell gravel sand silt clay			
		-2	-1	0	1	2	3	4	5	6	7	8	10	>10					
Station DN March	2	0.00	0.00	0.01	0.01	0.32	0.30	1.05	7.67	9.24	2.31	11.56	36.96	30.50	8.95	0.00	1.69	30.78	67.46
	3	0.00	0.00	0.02	0.04	0.09	0.18	1.31	24.92	12.16	0.00	9.72	9.72	41.82	8.32	0.00	1.64	46.80	51.54
	4	0.00	0.00	0.00	0.01	0.14	0.55	7.38	17.33	4.78	0.00	11.96	11.95	45.91	9.31	0.00	8.08	34.07	57.86
	5	0.00	0.00	0.21	0.82	0.41	0.32	2.16	28.22	4.99	7.49	7.48	9.98	37.92	7.72	0.00	3.92	48.18	47.90
	6	0.00	0.26	0.27	0.54	0.42	0.51	2.27	5.00	9.75	0.00	14.64	17.07	49.27	9.92	0.26	4.01	29.39	66.34
	Mean	0.00	0.05	0.10	0.28	0.28	0.37	2.83	16.63	8.18	1.96	11.07	17.14	41.08	8.84	0.05	3.87	37.84	58.22
S.D.		0.00	0.12	0.13	0.38	0.15	0.15	2.60	10.24	3.21	3.25	2.67	11.47	7.30	0.86	0.12	2.62	8.98	8.70

		Replicate													median Φ	% shell gravel sand silt clay			
		-2	-1	0	1	2	3	4	5	6	7	8	10	>10					
Station DN April	1	0.00	0.03	0.04	0.27	0.90	0.47	1.76	0.00	3.19	5.31	10.60	10.61	66.82	>10	0.03	3.44	19.10	77.43
	2	0.00	0.00	0.06	0.20	0.48	0.40	2.37	14.88	4.64	2.32	16.22	4.64	53.78	>10	0.00	3.51	38.06	58.42
	3	0.00	0.00	0.00	0.01	0.11	0.24	0.81	38.84	3.62	3.61	10.84	7.23	34.69	7.25	0.00	1.17	56.91	41.92
	5	0.00	0.00	0.13	0.35	0.22	0.35	1.22	29.60	2.50	7.52	5.00	10.02	43.08	8.62	0.00	2.27	44.62	53.10
	6	0.00	0.15	0.54	1.28	0.88	0.41	3.11	36.34	2.28	6.82	15.91	9.09	23.19	6.73	0.15	6.22	61.35	32.28
	Mean	0.00	0.04	0.15	0.42	0.52	0.37	1.85	23.93	3.25	5.12	11.71	8.32	44.31	8.92	0.04	3.32	44.01	52.63
S.D.		0.00	0.07	0.22	0.50	0.37	0.09	0.91	16.30	0.95	2.17	4.61	2.42	16.86	2.02	0.07	1.88	16.76	17.16

D-5

															%				
Replicate		-2	-1	0	1	2	3	4	5	6	7	8	10	>10	median Φ	shell gravel	% sand	% silt	% clay
Station	1	0.00	0.07	0.08	0.61	2.90	8.39	14.81	13.88	11.40	0.00	7.60	3.80	36.47	5.81	0.07	26.79	32.88	40.27
DS	2	0.00	0.54	0.19	0.37	1.77	7.08	8.55	14.26	4.05	0.00	12.15	8.10	42.93	8.26	0.54	17.96	30.46	51.03
March	3	0.00	0.14	0.20	0.31	1.79	6.18	8.98	10.27	8.20	0.00	12.29	8.19	43.44	8.40	0.14	17.46	30.76	51.63
	4	0.00	0.00	0.05	0.15	1.51	3.99	8.90	30.13	0.00	4.39	4.39	10.96	35.53	7.20	0.00	14.60	38.91	46.49
	6	0.00	0.04	0.24	0.31	1.24	6.05	10.12	27.19	9.88	2.47	7.40	12.35	22.71	5.49	0.04	17.96	46.94	35.06
	Mean	0.00	0.16	0.15	0.35	1.84	6.34	10.26	19.15	6.71	1.37	8.77	8.86	36.22	7.03	0.16	18.95	35.99	44.90
	S.D.	0.00	0.22	0.08	0.17	0.63	1.61	2.61	8.88	4.65	2.00	3.40	3.28	8.37	1.35	0.22	4.60	7.00	7.14

																%				
Replicate		-2	-1	0	1	2	3	4	5	6	7	8	10	>10	median Φ	shell gravel	% sand	% silt	% clay	
Station DS April	1	0.00	0.00	0.08	0.39	1.26	4.35	16.09	21.12	10.25	6.83	3.42	5.12	31.09	5.65	0.00	22.17	41.62	36.21	
	2	0.00	0.03	0.06	0.64	2.02	6.48	15.44	6.86	12.38	4.12	4.07	12.37	35.47	7.48	0.03	24.64	27.43	47.84	
	4	0.00	0.07	0.18	0.48	2.31	9.83	16.34	6.83	4.10	4.10	8.20	4.10	43.46	7.70	0.07	29.14	23.23	47.56	
	6	0.00	0.04	0.04	0.08	1.02	3.27	3.88	48.57	5.13	3.42	11.98	5.14	17.45	4.86	0.04	8.29	69.10	22.59	
	Mean	0.00	0.04	0.09	0.40	1.65	5.98	12.94	20.84	7.97	4.62	6.92	6.69	24.37	6.42	0.04	21.06	40.35	38.55	
S.D.		0.00	0.03	0.06	0.24	0.61	2.89	6.05	19.67	3.98	1.51	3.98	3.82	16.48	1.39	0.03	8.99	20.72	11.94	

Appendix D-3. (continued - page 4)

															% median shell % % % Φ gravel sand silt clay				
Replicate		-2	-1	0	1	2	3	4	5	6	7	8	10	>10					
Station	1	0.00	0.08	0.17	0.22	2.25	7.85	6.23	18.68	8.84	4.43	8.84	4.41	38.00	7.14	0.08	16.72	40.79	42.41
DW	4	0.00	0.18	0.15	0.54	3.04	8.59	8.28	18.71	11.42	0.00	5.71	11.41	31.97	5.92	0.18	20.60	35.84	43.48
February	6	0.00	0.15	0.42	1.08	1.21	2.48	6.27	13.45	10.26	0.00	10.27	10.26	44.14	8.84	0.15	11.46	33.98	54.40
	Mean	0.00	0.14	0.25	0.61	2.17	6.31	6.93	16.95	10.17	1.48	8.27	8.69	38.04	7.30	0.14	16.26	36.87	46.73
	S.D.	0.00	0.05	0.15	0.43	0.92	3.33	1.17	3.03	1.29	2.56	2.33	3.75	6.09	1.47	0.05	4.59	3.52	6.66

															% median shell % % % Φ gravel sand silt clay				
Replicate		-2	-1	0	1	2	3	4	5	6	7	8	10	>10					
Station	1	0.00	0.04	0.04	0.30	1.49	2.61	4.84	14.95	9.71	4.86	4.85	4.86	51.46	>10	0.04	9.28	34.37	56.32
DW	2	0.00	0.02	0.07	0.19	0.57	1.21	1.68	0.00	8.30	10.60	5.30	13.25	58.81	>10	0.02	3.72	24.20	72.06
March	4	0.00	0.00	0.10	0.07	0.53	2.49	2.22	2.60	11.79	5.90	5.89	5.90	62.51	>10	0.00	5.41	26.18	68.41
	5	0.00	0.00	0.04	0.10	1.05	4.09	4.81	17.96	14.30	9.53	11.91	0.00	36.21	6.80	0.00	10.09	53.71	36.21
	6	0.00	0.00	0.18	0.26	0.40	0.71	3.77	0.00	13.47	2.69	10.76	13.44	54.32	>10	0.00	5.32	26.92	67.76
	Mean	0.00	0.012	0.09	0.18	0.81	2.22	3.46	7.10	11.51	6.72	7.74	7.49	52.66	10.16	0.01	6.76	33.08	60.15
	S.D.	0.00	0.018	0.06	0.10	0.45	1.32	1.46	8.67	2.51	3.29	3.33	5.79	10.12	1.88	0.02	2.76	12.16	14.63

															% median shell % % % Φ gravel sand silt clay				
Replicate		-2	-1	0	1	2	3	4	5	6	7	8	10	>10					
Station	1	0.00	0.16	0.15	0.83	1.54	1.16	5.60	24.91	13.49	0.00	8.99	8.99	34.18	7.24	0.16	9.29	47.39	43.17
DW	2	0.00	0.25	0.15	0.61	2.45	8.88	4.94	20.66	3.74	3.73	7.48	7.48	39.63	7.61	0.25	17.03	35.61	47.11
April	3	0.00	0.02	0.15	0.87	2.57	6.73	4.18	19.18	3.56	3.57	7.12	7.13	44.92	8.58	0.02	14.50	33.43	52.05
	4	0.00	0.14	0.17	0.39	1.15	2.62	2.26	18.29	12.43	6.21	6.22	6.21	43.91	8.04	0.14	6.59	43.15	50.12
	5	0.00	0.06	0.52	0.75	0.77	1.75	7.63	39.59	6.61	2.20	11.02	8.81	20.28	4.97	0.06	11.42	59.42	29.09
	6	0.00	0.29	0.22	0.29	1.25	4.84	3.62	36.20	2.40	4.80	14.40	12.01	19.68	6.18	0.29	10.22	57.80	31.69
	Mean	0.00	0.15	0.23	0.62	1.62	4.33	4.71	26.47	6.99	3.42	9.21	8.44	33.77	7.10	0.15	11.51	46.13	42.21
	S.D.	0.00	0.10	0.15	0.24	0.73	3.05	1.84	9.20	4.84	2.14	3.05	2.04	11.33	1.32	0.10	3.75	10.91	9.67

Appendix D-3. (continued - page 5)

		Replicate														% median shell % % % Φ gravel sand silt clay				
		-2	-1	0	1	2	3	4	5	6	7	8	10	>10						
Station M1 February	2	0.00	0.00	0.02	0.17	3.60	14.40	14.19	27.10	7.65	1.91	5.73	3.82	21.40	4.65	0.00	32.38	42.39	25.22	
	3	0.00	0.00	0.09	0.11	3.21	16.48	18.97	23.50	4.14	2.07	1.77	6.20	23.17	4.47	0.00	38.86	42.39	25.22	
	4	0.00	1.38	0.59	0.57	4.52	17.94	23.14	8.13	5.91	1.97	1.97	7.88	26.01	4.23	1.38	46.75	17.98	33.89	
	5	0.00	1.14	0.43	0.54	4.35	18.47	20.92	27.61	7.37	3.68	3.69	7.37	4.42	4.15	1.14	44.71	42.35	11.79	
	6	1.96	0.37	0.49	0.52	3.00	13.28	14.77	35.11	9.53	0.00	6.35	3.18	11.44	4.44	2.33	32.06	50.99	14.62	
	Mean	0.33	0.62	0.39	0.42	3.69	15.88	18.04	20.24	5.77	1.61	3.25	5.49	24.25	4.39	0.97	39.01	37.04	22.98	
		S.D.	0.80	0.58	0.28	0.22	0.62	2.08	3.58	4.50	3.35	1.41	2.46	1.94	18.87	0.20	0.99	6.72	12.70	9.49

		Replicate														% median shell % % % Φ gravel sand silt clay				
		-2	-1	0	1	2	3	4	5	6	7	8	10	>10						
Station M1 March	1	0.22	0.33	0.21	0.52	5.24	15.11	19.40	3.72	15.64	0.00	6.63	3.35	28.64	5.34	0.55	40.48	25.99	32.00	
	2	0.00	0.73	0.23	0.28	3.37	16.37	21.35	18.71	0.00	3.09	3.09	7.73	25.04	4.44	0.73	41.60	24.78	32.77	
	4	0.00	0.30	0.36	0.53	3.87	18.84	15.60	15.70	7.41	3.70	5.55	3.70	24.44	4.67	0.30	39.20	32.36	28.14	
	5	0.00	0.00	0.41	0.33	3.76	15.93	20.48	13.87	7.18	3.59	5.39	1.79	27.28	4.66	0.00	40.91	30.03	29.07	
	6	0.00	0.33	0.46	0.42	4.80	20.02	18.17	17.34	3.18	1.59	3.17	11.13	19.39	4.33	0.33	43.87	25.28	30.52	
	Mean	0.04	0.34	0.33	0.42	4.21	17.25	19.00	13.87	6.68	2.39	4.77	5.54	24.96	4.69	0.38	41.21	27.69	30.50	
		S.D.	0.10	0.26	0.11	0.11	2.05	2.08	2.24	5.95	5.87	1.58	1.57	3.82	3.54	0.39	0.28	1.72	3.33	1.94

		Replicate														% median shell % % % Φ gravel sand silt clay				
		-2	-1	0	1	2	3	4	5	6	7	8	10	>10						
Station M1 April	1	0.00	0.29	0.29	0.34	4.79	19.65	22.72	14.29	0.00	1.62	1.62	6.49	27.90	4.13	0.29	47.79	17.53	34.39	
	2	0.00	0.29	0.33	0.39	4.56	18.12	20.37	13.02	5.88	2.94	2.94	8.82	22.35	4.47	0.29	43.77	24.78	31.17	
	4	0.00	0.23	0.18	0.39	4.05	16.59	21.30	11.99	2.90	0.00	7.26	8.70	26.42	4.61	0.23	42.51	22.15	35.12	
	6	0.00	0.59	0.39	0.46	4.81	18.04	18.57	27.32	6.56	0.00	4.91	9.83	8.52	4.26	0.59	42.27	38.79	18.35	
	Mean	0.00	0.35	0.30	0.40	4.55	18.10	20.74	16.66	3.84	1.14	4.18	8.46	21.30	4.37	0.35	44.08	25.81	29.76	
	S.D.	0.00	0.16	0.09	0.05	0.35	1.23	1.74	7.17	3.01	1.42	2.46	1.41	8.83	0.21	0.16	2.56	9.16	7.80	

Appendix D-3. (continued - page 6)

																median	%	%	%
Replicate		-2	-1	0	1	2	3	4	5	6	7	8	10	>10	Φ	gravel	sand	silt	clay
Station M3 February	1	0.00	1.69	0.70	0.48	4.66	21.14	12.51	0.00	0.00	0.00	0.00	6.42	52.41	>10	1.69	39.49	0.00	58.83
	2	0.00	0.33	0.36	2.74	3.72	15.08	8.77	30.55	3.63	3.63	3.63	3.63	23.94	4.62	0.33	30.67	41.44	27.57
	4	0.00	0.47	0.52	0.41	3.40	18.21	13.69	0.14	12.56	0.00	1.79	7.18	41.63	7.34	0.47	36.23	14.49	48.81
	5	0.00	1.52	0.47	0.59	3.95	16.93	13.19	28.00	3.68	0.00	3.69	7.36	20.61	4.48	1.52	35.13	35.37	27.97
	Mean	0.00	1.00	0.51	1.06	3.93	17.84	12.04	14.67	4.97	0.91	2.28	6.15	34.65	6.86	1.00	35.38	22.83	40.80
S.D.		0.00	0.70	0.14	1.13	0.53	2.55	2.23	16.89	5.35	1.82	1.76	1.73	15.01	3.06	0.70	3.65	19.10	15.59

																median	%	%	%
Replicate		-2	-1	0	1	2	3	4	5	6	7	8	10	>10	Φ	gravel	sand	silt	clay
Station M3 March	1	0.00	4.34	1.72	1.03	4.74	20.46	14.27	7.04	6.36	3.18	3.18	6.35	27.34	4.49	4.34	42.22	19.76	33.69
	2	0.00	1.38	0.57	0.71	2.10	15.66	10.76	20.90	9.21	0.00	3.07	7.68	27.95	4.90	1.38	29.80	33.18	35.63
	3	0.00	0.72	0.47	0.52	4.31	15.69	12.58	18.58	8.07	1.62	6.45	6.46	24.53	4.85	0.72	33.57	34.72	30.99
	4	0.00	0.00	0.17	0.61	4.18	21.07	15.00	5.94	11.75	1.95	1.95	3.90	33.54	5.26	0.00	41.03	21.54	37.44
	6	0.00	1.30	0.86	0.68	5.48	23.43	13.40	28.33	1.74	5.24	6.98	5.23	7.33	7.17	1.30	43.85	42.29	12.56
	Mean	0.00	1.55	0.76	0.71	4.16	19.26	13.20	16.16	7.42	2.40	4.33	5.92	24.14	5.33	1.55	38.09	30.30	30.06
S.D.		0.00	1.66	0.59	0.19	1.26	3.46	1.64	9.54	3.72	1.95	2.24	1.43	9.95	1.06	1.66	6.08	9.48	10.07

																median	%	%	%
Replicate		-2	-1	0	1	2	3	4	5	6	7	8	10	>10	Φ	gravel	sand	silt	clay
Station M3 April	1	0.00	0.82	0.24	0.40	4.36	24.38	18.48	15.17	3.12	0.00	0.00	9.35	23.68	4.09	0.82	47.86	18.29	33.03
	2	0.00	0.23	0.21	0.45	7.00	20.32	13.94	16.06	3.32	0.00	3.31	8.29	26.86	4.49	0.23	41.92	22.69	35.15
	3	0.00	0.30	0.38	0.45	2.42	12.66	11.81	9.13	5.86	0.00	3.90	11.71	41.39	8.53	0.30	27.72	18.89	53.10
	4	0.00	0.45	0.66	0.61	7.15	23.30	10.65	5.59	5.30	1.77	1.76	8.84	33.92	5.30	0.45	42.37	14.42	42.76
	5	0.00	1.62	0.73	0.60	6.06	21.19	12.60	21.84	5.00	3.34	8.34	3.33	15.35	4.33	1.62	41.18	38.52	18.68
	6	0.00	1.37	0.70	0.47	4.76	18.52	14.17	21.16	3.50	1.75	7.00	7.00	19.59	4.47	1.37	38.62	33.41	26.59
	Mean	0.00	0.80	0.49	0.50	5.29	20.06	13.61	14.83	4.35	1.14	3.55	8.09	26.80	5.20	0.80	39.95	24.37	34.89
S.D.		0.00	0.58	0.24	0.09	1.81	4.19	2.73	6.46	1.17	1.38	3.40	2.80	9.55	1.68	0.58	6.71	9.49	12.07

Appendix D-3. (continued - page 7)

		Replicate													% median shell % % % Φ gravel sand silt clay				
		-2	-1	0	1	2	3	4	5	6	7	8	10	>10					
Station M6 February	1	0.00	0.00	0.02	0.03	2.13	26.69	16.21	30.06	7.53	0.00	1.89	3.76	11.68	4.16	0.00	45.08	39.48	15.44
	2	0.00	0.04	0.29	0.53	3.50	12.66	11.92	30.77	7.26	3.63	1.82	5.44	22.15	4.68	0.04	28.90	43.48	27.59
	3	0.00	0.00	0.00	0.29	1.18	5.92	5.16	39.96	2.63	0.00	7.89	10.52	29.47	5.19	0.00	12.55	47.48	39.99
	4	0.00	0.44	0.15	0.50	4.02	13.31	9.94	11.16	8.29	4.14	4.14	8.29	35.62	6.53	0.44	27.92	27.73	43.91
	5	0.00	0.03	0.09	0.13	1.95	11.37	10.08	33.23	7.43	3.72	5.58	5.57	20.82	4.79	0.03	23.62	49.96	26.39
	6	0.00	0.24	0.10	0.21	2.08	8.88	7.04	30.89	6.92	0.00	10.39	6.92	26.32	5.08	0.24	18.31	48.20	33.24
Mean		0.00	0.13	0.11	0.28	2.48	13.14	10.06	28.85	6.68	1.92	5.29	6.75	24.34	5.07	0.13	26.06	42.72	31.09
S.D.		0.00	0.18	0.10	0.20	1.06	7.17	3.86	9.02	2.03	2.10	3.40	2.39	8.18	0.80	0.18	11.15	8.26	10.27

		Replicate													% median shell % % % Φ gravel sand silt clay				
		-2	-1	0	1	2	3	4	5	6	7	8	10	>10					
Station M6 March	1	0.28	0.39	0.35	0.54	4.16	14.01	12.42	12.00	6.73	3.36	3.37	10.09	32.30	5.87	0.67	31.48	25.46	42.39
	2	0.00	0.29	0.20	0.29	3.96	12.60	8.69	20.74	3.64	3.65	3.65	7.29	35.00	5.89	0.29	25.74	31.68	42.29
	3	0.00	0.82	0.38	0.49	2.40	9.21	11.27	11.71	10.28	3.42	6.86	6.85	36.31	7.00	0.82	23.75	32.26	43.16
	4	0.00	0.27	0.24	0.29	2.78	8.05	7.32	10.86	7.97	3.99	3.99	13.96	40.28	8.61	0.27	18.68	26.81	54.24
	5	0.00	0.00	0.01	0.03	1.39	6.66	7.54	26.75	12.41	9.84	2.48	0.00	32.78	5.61	0.00	15.63	51.58	32.78
	6	0.00	0.78	0.40	0.30	2.46	8.67	7.58	39.43	2.85	0.00	19.90	8.53	9.10	4.76	0.78	19.41	62.18	17.63
Mean		0.05	0.43	0.26	0.32	2.86	9.87	9.14	20.25	7.31	4.06	6.71	7.79	30.96	6.29	0.47	22.45	38.33	38.75
S.D.		0.11	0.32	0.15	0.18	1.04	2.83	2.18	11.31	3.71	3.73	6.63	4.60	11.09	1.34	0.33	5.73	14.99	12.38

		Replicate													% median shell % % % Φ gravel sand silt clay				
		-2	-1	0	1	2	3	4	5	6	7	8	10	>10					
Station M6 April	1	0.00	0.00	0.01	0.03	0.33	1.97	1.47	24.27	6.20	0.00	0.00	12.40	53.32	>10	0.00	3.81	30.47	65.72
	2	0.00	0.65	0.56	0.52	4.73	22.59	18.21	0.05	3.87	3.88	3.87	9.69	31.39	5.70	0.65	46.61	11.67	41.08
	5	1.27	0.71	0.38	0.66	2.81	9.54	6.67	36.08	5.41	1.81	7.22	5.41	22.02	4.77	1.98	20.06	50.52	27.43
	6	0.00	1.33	0.79	0.85	5.28	15.25	10.85	33.56	4.77	3.17	9.54	6.35	8.26	4.47	1.33	33.02	51.04	14.61
Mean		0.32	0.67	0.44	0.52	3.29	12.34	9.30	23.49	5.06	2.22	5.16	8.46	28.75	6.49	0.99	25.88	35.93	37.21
S.D.																			

Appendix D-3. (continued - page 8)

		Replicate													% median shell % % %				
		-2	-1	0	1	2	3	4	5	6	7	8	10	>10	Φ	gravel	sand	silt	clay
Station M9 February	1	0.00	0.00	0.01	0.01	0.23	0.30	1.14	15.19	6.12	0.00	9.16	9.17	58.67	>10	0.00	1.69	30.47	67.84
	2	0.00	0.00	0.14	0.23	3.23	0.57	2.82	20.23	7.23	0.00	4.82	14.46	46.27	9.48	0.00	6.99	32.28	60.73
	3	0.00	0.00	0.07	0.30	0.25	0.17	1.45	54.19	1.66	1.67	4.99	8.31	26.95	4.88	0.00	2.24	62.51	35.26
	4	0.00	0.00	0.06	0.48	0.38	0.17	1.54	2.23	11.13	2.78	11.13	8.34	61.76	>10	0.00	2.63	27.27	70.10
	5	0.00	0.00	0.00	0.05	0.21	0.25	1.43	27.96	11.13	2.78	8.34	11.13	36.71	7.74	0.00	1.94	50.21	47.84
	6	0.00	0.00	0.01	0.01	0.27	0.32	2.35	36.70	6.20	2.07	12.39	4.14	35.54	7.33	0.00	2.96	57.36	39.68
Mean		0.00	0.00	0.05	0.18	0.76	0.30	1.79	26.08	7.25	1.55	8.47	9.26	44.32	8.57	0.00	3.08	43.45	53.58
S.D.		0.00	0.00	0.05	0.19	1.21	0.15	0.65	18.05	3.57	1.27	3.11	3.42	13.79	2.39	0.00	1.97	15.09	14.76

		Replicate													% median shell % % %				
		-2	-1	0	1	2	3	4	5	6	7	8	10	>10	Φ	gravel	sand	silt	clay
Station M9 March	1	0.00	0.00	0.07	0.20	0.70	0.49	2.59	10.93	14.49	0.00	9.66	4.83	56.03	>10	0.00	4.05	35.08	60.86
	2	0.00	0.00	0.13	0.57	0.85	0.44	1.62	9.59	5.95	0.00	11.89	41.61	27.35	8.91	0.00	3.61	27.43	68.96
	3	0.00	0.00	0.16	0.58	0.72	0.52	2.77	1.68	14.53	0.00	11.62	14.54	52.89	>10	0.00	4.75	27.83	67.43
	4	0.00	0.00	0.01	0.41	0.49	0.33	0.09	11.05	10.25	2.56	15.38	5.12	54.32	>10	0.00	1.33	39.24	59.44
	6	0.00	0.00	0.12	0.28	0.22	0.26	1.23	16.31	10.80	5.40	13.51	13.51	38.35	8.28	0.00	2.11	46.02	51.86
	Mean	0.00	0.00	0.15	0.57	0.58	0.38	1.78	10.13	10.18	2.17	12.45	13.69	47.93	10.20	0.00	3.45	34.93	61.62
S.D.		0.00	0.00	0.13	0.43	0.22	0.13	1.01	4.74	4.05	2.57	1.93	14.54	12.34	1.26	0.00	1.44	7.06	6.14

		Replicate													% median shell % % %				
		-2	-1	0	1	2	3	4	5	6	7	8	10	>10	Φ	gravel	sand	silt	clay
Station M9 April	2	0.00	0.00	0.01	0.16	0.27	0.32	1.52	9.18	5.03	0.00	15.10	10.06	58.36	>10	0.00	2.28	29.31	68.42
	3	0.00	0.00	0.10	0.32	0.33	0.58	1.55	3.49	13.33	0.00	13.30	15.93	51.06	>10	0.00	2.28	30.12	66.99
	4	0.00	0.06	0.72	0.50	0.68	0.36	1.10	8.84	11.55	5.60	5.60	11.21	53.78	>10	0.06	3.36	31.59	64.99
	5	0.00	0.00	0.33	0.57	0.50	0.39	1.07	24.79	5.32	5.32	13.30	10.64	37.77	7.88	0.00	2.86	48.73	48.41
	Mean	0.00	0.015	0.29	0.39	0.445	0.41	1.31	11.58	8.81	2.73	11.83	11.96	50.24	10.22	0.015	2.70	34.94	62.20
S.D.		0.00	0.030	0.32	0.18	0.184	0.12	0.26	9.19	4.26	3.15	4.24	2.69	8.84	1.56	0.030	0.52	9.24	9.30

Appendix D-3. (continued - page 9)

															% median shell % % % Φ gravel sand silt clay				
Replicate		-2	-1	0	1	2	3	4	5	6	7	8	10	>10					
Station	1	0.00	0.04	0.16	0.86	2.33	1.08	2.00	12.54	11.09	5.55	5.55	13.87	44.93	9.27	0.04	6.43	34.73	58.80
	M10A	2	0.00	0.00	0.11	0.24	0.01	0.04	0.05	23.63	8.17	4.08	8.16	47.35	9.35	0.00	0.45	44.04	55.51
February	4	0.00	0.08	0.24	0.82	1.08	0.82	2.01	52.18	7.71	0.00	1.92	7.71	25.44	4.86	0.08	4.97	61.81	33.15
	6	0.00	0.29	0.15	0.44	0.85	3.79	6.55	48.02	2.32	4.64	11.61	9.29	12.07	4.79	0.29	11.78	66.59	21.36
Mean		0.00	0.10	0.17	0.59	1.07	1.43	2.65	34.09	7.32	3.57	6.81	9.76	32.45	7.07	0.10	5.91	51.79	42.21
S.D.		0.00	0.13	0.05	0.30	0.96	1.63	2.76	19.11	3.66	2.45	4.10	2.82	16.76	2.59	0.13	4.67	14.95	17.97

															% median shell % % % Φ gravel sand silt clay				
Replicate		-2	-1	0	1	2	3	4	5	6	7	8	10	>10					
Station	2	0.00	0.13	0.06	0.49	1.68	3.30	6.40	10.32	4.69	9.57	9.13	9.35	44.88	8.90	0.13	11.93	33.71	54.23
	M10A	3	0.00	0.06	0.06	0.38	1.07	3.60	4.80	16.45	6.27	4.18	10.45	42.22	8.51	0.06	9.91	37.55	52.68
March	4	0.00	0.00	0.09	0.31	0.38	0.97	2.59	3.40	12.45	0.00	6.34	6.33	67.13	>10	0.00	4.34	22.19	73.46
	6	0.00	0.41	0.19	0.40	0.80	2.83	4.82	26.78	11.00	5.49	11.00	13.74	22.54	6.50	0.41	9.04	54.27	36.28
Mean		0.00	0.15	0.10	0.40	0.98	2.68	4.65	14.24	8.60	4.81	9.23	9.97	44.19	8.73	0.15	8.81	36.88	54.16
S.D.		0.00	0.18	0.06	0.07	0.54	1.18	1.57	9.92	3.71	3.94	2.08	3.06	18.25	1.84	0.18	3.21	13.27	15.21

															% median shell % % % Φ gravel sand silt clay				
Replicate		-2	-1	0	1	2	3	4	5	6	7	8	10	>10					
Station	1	0.00	0.00	0.08	0.43	1.44	1.40	2.06	23.71	4.27	4.27	4.27	12.81	45.26	9.26	0.00	5.41	36.52	58.07
	M10A	2	0.00	0.41	0.10	0.14	1.24	4.87	6.36	25.71	5.21	3.47	10.43	8.69	7.24	0.41	12.71	44.82	42.06
April	3	0.00	0.00	0.13	0.26	0.71	1.49	2.15	1.59	16.93	0.00	16.93	11.29	48.53	9.74	0.00	4.74	35.45	59.82
	5	0.00	0.09	0.36	0.79	1.63	4.28	4.37	21.80	12.26	4.90	12.26	4.91	32.36	6.90	0.09	11.43	51.22	37.27
	6	0.00	0.00	0.00	0.12	0.15	0.48	3.00	36.42	3.12	6.23	9.35	9.35	31.79	7.05	0.00	3.75	55.12	41.14
	Mean	0.00	0.10	0.13	0.35	1.03	2.50	3.59	21.85	8.36	3.77	10.65	9.41	38.26	8.04	0.10	7.61	44.63	47.67
	S.D.	0.00	0.18	0.14	0.28	0.60	1.94	1.81	12.66	5.97	2.34	4.60	2.99	7.00	1.35	0.18	4.14	8.71	10.46

Appendix D-3. (continued - page 10)

															% median shell % % % Φ gravel sand silt clay				
Replicate		-2	-1	0	1	2	3	4	5	6	7	8	10	>10					
Station M11 February	1	0.00	0.00	0.00	0.09	2.39	8.30	17.11	25.65	6.83	3.42	3.42	6.83	25.97	4.86	0.00	27.89	39.32	32.80
	2	0.00	0.00	0.00	0.10	1.90	6.33	11.93	29.67	12.41	2.07	0.00	8.28	27.31	5.01	0.00	20.26	44.15	35.59
	3	0.00	0.00	0.09	0.29	0.95	4.87	11.80	40.74	9.38	3.13	0.00	12.50	16.25	4.79	0.00	18.00	53.25	28.75
Mean		0.00	0.00	0.03	0.16	1.75	6.50	13.61	32.02	9.54	2.87	1.14	9.20	23.18	4.89	0.00	22.05	45.57	32.38
S.D.		0.00	0.00	0.05	0.11	0.73	1.72	3.03	7.81	2.79	0.71	1.97	2.95	6.04	0.11	0.00	5.18	7.07	3.44

															% median shell % % % Φ gravel sand silt clay				
Replicate		-2	-1	0	1	2	3	4	5	6	7	8	10	>10					
Station M11 March	1	0.00	0.10	0.12	0.28	3.14	11.78	16.31	20.60	6.53	3.27	4.90	4.89	28.09	4.89	0.10	31.63	35.30	32.98
	2	0.00	0.41	0.15	0.18	1.98	6.72	13.34	17.63	11.64	3.82	1.91	9.55	32.84	5.96	0.41	22.37	34.82	42.39
	3	0.00	0.83	0.32	0.29	4.01	10.10	13.93	10.02	13.75	1.72	5.15	22.35	17.53	5.76	0.83	28.65	30.64	39.88
	4	0.00	0.12	0.19	0.13	3.00	8.21	16.02	16.42	12.54	1.79	3.59	3.58	34.41	5.47	0.12	27.55	34.34	37.99
	6	0.00	0.96	0.43	3.24	0.05	9.19	16.14	25.78	8.13	3.25	8.12	6.51	18.20	4.78	0.96	29.05	45.28	24.71
	Mean	0.00	0.48	0.24	0.82	2.44	9.20	15.15	18.09	10.52	2.77	4.73	9.38	26.21	5.37	0.48	27.85	36.08	35.59
S.D.		0.00	0.40	0.13	1.35	1.52	1.91	1.40	5.78	3.06	0.95	2.29	7.59	7.97	0.52	0.40	3.41	5.46	6.99

															% median shell % % % Φ gravel sand silt clay				
Replicate		-2	-1	0	1	2	3	4	5	6	7	8	10	>10					
Station M11 April	1	0.00	0.09	0.31	0.25	2.69	7.47	10.90	7.93	15.99	4.00	8.00	4.00	38.38	7.05	0.09	21.62	35.92	42.38
	2	0.73	0.44	0.18	0.22	2.17	5.16	19.80	16.26	13.26	0.00	6.63	6.64	28.51	5.38	1.17	27.53	36.15	35.15
	3	0.00	0.20	0.09	0.21	2.83	8.12	16.33	15.12	6.88	0.00	10.32	6.88	33.02	7.02	0.20	27.58	32.32	39.90
	4	0.00	0.50	0.29	0.26	2.85	5.52	15.67	18.82	11.16	1.59	4.78	7.97	30.59	5.55	0.50	24.59	36.35	38.56
	5	0.00	0.06	0.15	0.08	2.05	5.72	16.19	29.77	3.65	3.65	7.30	3.65	27.74	4.86	0.06	24.19	44.37	31.39
	6	0.00	0.22	0.42	0.40	7.12	10.22	15.86	0.00	5.73	1.75	7.02	8.78	42.46	8.28	0.22	34.02	14.50	51.24
	Mean	0.12	0.25	0.24	0.24	3.29	7.04	15.79	14.65	9.45	1.83	7.34	6.32	33.45	6.36	0.37	26.59	33.27	39.77
S.D.		0.30	0.18	0.12	0.10	1.91	1.95	2.84	10.09	4.78	1.72	1.82	2.08	5.85	1.30	0.42	4.28	10.01	6.80

		Replicate													% median shell % % % φ gravel sand silt clay				
		-2	-1	0	1	2	3	4	5	6	7	8	10	>10					
Station	1	0.00	0.00	0.07	6.07	0.32	0.23	2.43	0.00	0.00	0.00	1.86	8.85	80.18	>10	0.00	9.12	1.86	89.03
	M15	2	0.00	0.00	0.03	0.02	0.01	0.31	0.01	28.42	4.88	7.31	2.44	12.19	44.38	9.08	0.00	0.38	43.05
February	3	0.00	0.03	0.18	0.22	0.12	0.14	3.01	45.84	5.26	0.00	5.26	10.51	29.44	5.09	0.03	3.67	56.36	39.95
	5	0.00	7.79	0.01	0.02	0.05	0.10	2.63	40.67	2.29	2.30	4.60	9.20	30.34	4.97	7.79	2.81	49.86	39.54
	6	0.00	0.00	0.02	0.01	0.03	0.11	2.97	54.37	4.42	4.42	8.85	6.63	18.15	4.86	0.00	3.14	72.06	24.78
	Mean	0.00	1.56	0.06	1.27	0.11	0.18	2.21	33.86	3.37	2.81	3.19	9.48	40.50	7.00	1.56	3.82	44.75	49.97
S.D.		0.00	3.48	0.07	2.69	0.13	0.09	1.25	21.13	2.21	3.12	1.82	2.06	24.06	2.86	3.48	3.22	26.22	24.56

		Replicate													% median shell % % % φ gravel sand silt clay				
		-2	-1	0	1	2	3	4	5	6	7	8	10	>10					
Station	1	0.00	0.00	0.07	0.19	6.64	5.19	10.99	8.38	17.57	0.00	4.40	4.39	42.18	7.22	0.00	23.08	30.35	46.57
	M15	2	0.00	0.07	0.11	0.25	0.80	2.30	5.84	11.28	9.02	4.50	4.51	15.78	9.31	0.07	9.30	30.31	61.32
March	4	0.00	0.00	0.05	0.40	0.69	2.11	6.19	8.17	16.93	0.00	11.28	5.65	48.53	9.48	0.00	9.44	36.38	54.18
	6	0.00	0.00	0.11	0.23	0.35	0.91	3.52	38.15	6.50	4.33	8.76	17.32	19.92	6.05	0.00	5.12	57.74	37.24
Mean		0.00	0.02	0.09	0.27	2.12	2.63	6.63	14.00	12.51	2.21	7.24	10.79	39.04	8.02	0.02	11.74	38.70	49.83
S.D.		0.00	0.04	0.03	0.09	3.02	1.82	3.14	16.44	5.58	2.55	3.37	6.71	13.01	1.66	0.04	7.82	13.01	10.33

		Replicate													% median shell % % % φ gravel sand silt clay				
		-2	-1	0	1	2	3	4	5	6	7	8	10	>10					
Station	1	0.00	0.00	0.00	0.06	0.98	0.12	4.82	0.00	22.36	0.00	17.06	5.69	48.92	9.62	0.00	5.98	39.42	54.61
	M15	2	0.00	0.04	0.02	0.13	0.54	1.54	3.57	16.73	4.67	4.66	11.66	7.00	49.44	9.84	0.04	5.80	37.72
April	3	0.00	0.00	0.07	0.68	1.10	1.43	6.77	6.83	9.52	6.34	12.69	9.52	45.05	7.91	0.00	10.05	35.38	54.57
	4	0.00	0.04	0.13	0.60	1.10	2.92	16.37	0.00	0.00	0.79	4.07	20.32	53.66	>10	0.04	21.12	4.86	74.98
	5	0.00	0.04	0.19	0.60	1.26	5.42	13.16	23.00	11.19	1.87	11.19	3.73	28.35	5.57	0.04	20.63	47.25	32.08
	6	0.00	0.13	0.84	1.39	1.44	3.50	13.46	22.26	8.38	2.10	10.47	8.38	27.65	5.83	0.13	20.63	43.21	36.03
Mean		0.00	0.04	0.19	0.58	1.07	2.49	9.69	11.47	9.35	2.63	11.19	9.11	42.18	8.30	0.04	14.04	34.64	51.29
S.D.		0.00	0.05	0.32	0.48	0.30	1.87	5.30	10.60	7.52	2.41	4.20	5.86	11.32	2.24	0.05	7.56	15.18	15.26

Appendix D-3. (continued - page 12)

															% median shell % % % φ gravel sand silt clay				
Replicate		-2	-1	0	1	2	3	4	5	6	7	8	10	>10					
Station M18 February	1	0.00	0.00	0.04	0.02	0.07	0.21	6.98	0.00	0.00	0.00	0.00	3.87	88.82	>10	0.00	7.32	0.00	92.69
	2	0.00	0.00	0.01	0.03	0.06	0.23	8.59	30.91	8.25	4.08	8.25	8.24	31.33	6.47	0.00	8.92	51.49	39.57
	3	0.00	0.00	0.00	0.09	0.15	0.35	5.24	30.52	10.52	2.63	5.26	10.51	34.72	7.10	0.00	5.83	48.93	45.23
	4	0.00	0.07	0.26	0.27	0.25	0.26	5.06	10.41	15.08	0.00	5.02	10.06	53.27	>10	0.07	6.10	30.51	63.33
	5	0.00	0.02	0.05	0.08	0.04	0.21	4.49	51.17	5.11	0.00	7.66	10.17	20.95	4.88	0.02	4.87	63.94	31.12
	6	0.00	0.00	0.02	0.05	0.08	0.24	6.16	44.81	5.07	7.60	10.13	2.54	23.30	4.97	0.00	6.55	67.61	25.84
Mean		0.00	0.02	0.06	0.09	0.11	0.25	6.09	27.97	7.34	2.39	6.05	7.57	42.07	8.22	0.02	6.60	43.75	49.63
S.D.		0.00	0.03	0.10	0.09	0.08	0.05	1.51	19.63	5.19	3.07	3.53	3.49	25.61	3.10	0.03	1.40	25.11	24.78

															% median shell % % % φ gravel sand silt clay				
Replicate		-2	-1	0	1	2	3	4	5	6	7	8	10	>10					
Station M18 March	1	0.00	0.00	0.01	0.12	0.62	0.58	3.60	12.00	10.01	5.00	5.01	10.01	53.05	>10	0.00	4.93	32.02	63.06
	2	0.00	0.03	0.05	0.47	0.71	1.77	15.49	18.86	10.07	6.02	8.03	4.02	34.52	6.42	0.03	18.49	42.98	38.54
	3	0.00	0.01	0.03	0.11	0.21	0.49	3.71	11.44	14.32	0.00	11.93	9.55	48.21	9.62	0.01	4.55	37.69	57.76
	4	0.00	0.00	0.02	0.03	0.40	1.46	7.53	10.06	15.48	0.00	10.32	7.74	46.96	9.21	0.00	9.44	35.86	54.70
	5	0.00	0.02	0.19	0.36	0.44	1.75	6.41	15.53	13.61	4.54	13.61	4.54	39.01	7.53	0.02	9.15	47.29	43.55
	6	0.00	0.00	0.16	0.45	0.29	0.69	4.08	37.18	4.54	2.27	13.60	11.34	25.40	7.03	0.00	5.67	57.59	36.74
Mean		0.00	0.01	0.08	0.26	0.45	1.12	6.80	17.51	11.34	2.97	10.42	7.87	41.19	8.47	0.01	8.71	42.24	49.06
S.D.		0.00	0.01	0.08	0.19	0.19	0.60	4.55	10.15	4.02	2.61	3.39	3.01	10.22	1.76	0.01	5.24	9.25	10.92

															% median shell % % % φ gravel sand silt clay				
Replicate		-2	-1	0	1	2	3	4	5	6	7	8	10	>10					
Station M18 April	1	0.00	0.00	5.84	0.69	0.45	2.30	8.20	7.80	12.05	4.02	6.03	10.04	42.59	8.52	0.00	17.48	29.90	52.63
	2	0.00	0.06	0.04	0.19	0.51	0.61	5.29	19.32	12.61	0.00	8.41	8.40	44.56	8.70	0.06	6.64	40.34	52.96
	3	0.00	0.00	0.07	0.22	0.53	1.77	6.77	13.78	8.49	4.25	10.62	12.74	40.76	8.63	0.00	9.36	37.14	53.30
	4	0.00	0.00	0.15	0.31	0.33	0.94	5.60	20.09	5.76	0.00	5.76	14.40	46.66	9.54	0.00	7.33	31.61	61.06
	5	0.00	0.00	0.32	0.46	0.22	0.62	4.45	33.54	12.00	2.00	14.00	6.00	26.40	5.74	0.00	6.07	61.54	32.40
	6	0.00	0.08	0.34	0.80	0.80	3.20	10.85	13.14	12.06	4.03	6.03	10.07	38.61	7.78	0.08	15.99	35.26	48.68
Mean		0.00	0.02	1.13	0.45	0.47	1.57	6.86	17.95	10.50	2.38	8.48	10.28	39.93	8.15	0.02	10.48	39.30	50.21
S.D.		0.00	0.04	2.31	0.25	0.20	1.04	2.35	8.87	2.76	2.02	3.30	3.00	7.20	1.31	0.04	4.99	11.53	9.61

Appendix D-3. (continued - page 13)

		Replicate													% median shell % % % φ gravel sand silt clay				
		-2	-1	0	1	2	3	4	5	6	7	8	10	>10					
Station M20 February	1	0.00	0.00	0.07	0.19	0.21	0.70	17.25	25.84	4.42	2.20	6.64	8.85	33.63	6.60	0.00	18.42	39.10	42.48
	2	0.00	0.62	0.19	0.18	0.18	1.08	23.68	24.63	3.92	1.97	5.88	7.85	29.82	4.98	0.62	25.31	36.40	37.67
	3	0.00	0.00	0.05	0.40	0.74	1.05	9.19	26.40	15.94	2.00	1.99	7.97	34.28	5.76	0.00	11.43	46.33	42.25
	4	0.00	0.00	0.06	0.16	0.15	0.63	7.49	34.70	4.51	2.25	9.02	6.76	34.27	7.01	0.00	8.49	50.48	41.03
	5	0.00	0.00	0.14	0.02	0.12	1.92	35.25	29.71	3.57	10.71	3.56	3.57	11.42	4.42	0.00	37.45	47.55	14.99
	6	0.00	0.00	0.00	0.06	2.29	8.94	13.61	27.07	3.81	3.82	7.62	9.52	23.25	4.93	0.00	24.90	42.32	32.77
Mean		0.00	0.10	0.09	0.17	0.62	2.39	17.75	28.06	6.03	3.83	5.79	7.42	27.78	5.62	0.10	21.00	43.70	35.20
S.D.		0.00	0.25	0.07	0.13	0.85	3.24	10.37	3.67	4.87	3.44	2.60	2.11	9.07	1.02	0.25	10.57	5.37	10.56

		Replicate													% median shell % % % φ gravel sand silt clay				
		-2	-1	0	1	2	3	4	5	6	7	8	10	>10					
Station M20 March	1	0.00	0.14	0.08	0.24	0.41	0.64	8.52	13.70	10.45	0.00	10.45	5.22	50.16	>10	0.14	9.89	34.60	55.38
	2	0.00	0.00	0.00	0.03	0.21	0.60	17.98	0.00	0.00	0.00	3.85	20.00	57.33	>10	0.00	18.82	3.85	77.33
	3	0.00	0.00	0.01	0.03	0.14	0.35	10.62	17.16	2.84	2.85	11.38	11.38	43.26	8.81	0.00	11.15	34.23	54.64
	4	0.00	0.35	0.23	0.53	0.46	1.87	7.31	26.93	11.46	0.00	9.17	6.87	34.83	7.09	0.35	10.40	47.56	41.70
	5	0.00	0.04	0.01	0.20	1.96	2.38	17.95	11.09	1.88	5.66	5.66	1.88	51.30	>10	0.04	22.50	24.29	53.18
	6	0.00	0.00	0.30	0.39	0.33	1.16	19.25	39.92	4.25	2.12	10.62	6.37	15.29	4.72	0.00	21.43	56.91	21.66
Mean		0.00	0.09	0.11	0.24	0.59	1.17	13.61	18.13	5.15	1.77	8.52	8.62	42.03	8.94	0.09	15.70	33.57	50.65
S.D.		0.00	0.14	0.13	0.20	0.68	0.80	5.37	13.79	4.72	2.27	3.06	6.36	15.20	2.61	0.14	5.85	18.50	18.31

		Replicate													% median shell % % % φ gravel sand silt clay				
		-2	-1	0	1	2	3	4	5	6	7	8	10	>10					
Station M20 April	1	0.00	0.02	0.03	0.04	0.06	0.17	2.57	25.12	4.62	0.00	13.84	25.38	28.15	8.28	0.02	2.87	43.58	53.53
	2	0.00	0.00	0.01	0.04	0.10	0.43	7.03	4.86	9.41	4.71	9.41	9.41	54.59	>10	0.00	7.61	28.39	64.00
	3	0.00	0.01	0.01	0.11	0.23	0.79	16.69	16.34	3.74	3.74	7.48	11.22	39.64	8.15	0.01	17.83	31.30	50.86
	4	0.00	0.01	0.01	0.01	0.23	1.28	20.08	12.67	10.06	3.36	5.03	11.73	35.55	7.46	0.00	21.61	31.12	47.28
	6	0.00	0.06	0.18	0.28	0.02	0.95	19.89	46.34	2.28	2.27	11.36	6.82	9.54	4.62	0.06	21.32	62.25	16.36
	Mean	0.00	0.02	0.05	0.10	0.13	0.72	13.25	21.07	6.02	2.82	9.42	12.91	33.49	7.90	0.02	14.25	39.33	46.41
S.D.		0.00	0.02	0.07	0.11	0.10	0.44	7.99	15.90	3.50	1.80	3.40	7.23	16.50	2.28	0.02	8.52	14.10	17.91

Appendix D-3. (continued - page 14)

															% median shell					% gravel sand		% silt clay	
Replicate		-2	-1	0	1	2	3	4	5	6	7	8	10	>10	ϕ								
Station	1	0.00	0.00	0.12	0.28	1.11	3.23	26.09	31.39	1.96	1.97	3.94	5.90	24.01	4.61	0.00	30.83	39.26	29.91				
CS	2	0.00	0.00	0.00	0.05	1.20	4.92	24.36	37.96	4.78	0.00	4.77	7.17	14.80	4.51	0.00	30.53	47.51	21.97				
February	4	0.00	0.00	0.01	0.02	0.98	5.64	27.03	31.61	5.26	5.26	5.26	5.26	13.67	4.52	0.00	33.68	47.39	18.93				
	5	0.00	0.15	0.17	0.34	1.17	3.81	24.42	36.04	5.14	0.00	5.14	10.27	13.36	4.55	0.15	29.91	46.32	23.63				
	6	0.00	0.00	0.00	0.00	0.46	2.83	19.67	57.84	3.43	0.00	8.58	5.14	2.06	4.47	0.00	22.96	69.85	7.20				
Mean		0.00	0.03	0.06	0.14	0.98	4.09	24.31	38.97	4.11	1.45	5.54	6.75	13.58	4.53	0.03	29.58	50.07	20.33				
S.D.		0.00	0.07	0.08	0.16	0.30	1.17	2.83	10.92	1.41	2.30	1.78	2.13	7.79	0.05	0.07	3.98	11.57	8.36				

Appendix D-4. Grain size distribution of surficial sediments at the estuarine stations, given as percentage (by weight) retained by screen mesh of given phi size. Median grain size values greater than 10 ϕ are arbitrarily assigned a value of 11 in calculation of mean and standard deviation.

		Replicate														% median shell % % % Φ gravel sand silt clay				
		-2	-1	0	1	2	3	4	5	6	7	8	10	>10						
Station El February	1	7.10	4.06	1.96	1.86	1.47	2.91	9.47	25.57	15.09	3.35	5.03	6.71	15.42	4.83	11.16	17.67	49.04	22.13	
	2	0.00	0.00	0.00	0.03	0.06	0.76	5.89	43.55	10.35	5.18	7.77	7.77	18.64	4.99	0.00	6.74	66.85	26.41	
Mean		3.55	2.03	0.98	0.95	0.77	1.84	7.68	34.56	12.72	4.27	6.40	7.24	17.03	4.91	5.58	12.21	57.95	24.11	
S.D.		5.02	2.87	1.39	1.29	1.00	1.52	2.53	12.71	3.35	1.29	1.94	0.75	2.28	0.11	7.89	7.73	12.59	2.81	

		Replicate														%				
		-2	-1	0	1	2	3	4	5	6	7	8	10	>10	median ϕ	shell gravel	% sand	% silt	% clay	
Station El March	1	0.00	0.32	0.23	0.53	1.29	11.17	21.61	15.07	13.64	3.41	6.82	3.40	22.51	4.99	0.32	34.83	38.94	25.91	
	3	0.00	0.08	0.18	0.37	0.58	7.82	20.07	27.89	13.13	3.29	6.57	4.92	15.11	4.75	0.08	29.02	50.88	20.03	
	4	0.00	0.58	0.59	1.00	1.25	9.06	16.98	0.00	34.69	2.94	5.88	5.88	21.16	5.59	0.58	28.88	43.51	27.04	
	5	0.00	0.08	0.17	0.57	0.71	9.81	27.41	28.79	14.26	3.57	7.13	3.57	3.92	4.39	0.08	38.67	53.75	7.49	
	Mean	0.00	0.27	0.29	0.62	0.96	9.47	21.51	17.94	18.93	3.30	6.60	4.44	15.68	4.93	0.27	32.85	46.72	20.12	
S.D.		0.00	0.24	0.20	0.27	0.37	1.40	4.37	13.50	10.52	0.26	0.53	1.18	8.47	0.50	0.24	4.77	6.77	8.96	

		Replicate														%				
		-2	-1	0	1	2	3	4	5	6	7	8	10	>10	median ϕ	shell gravel	% sand	% silt	% clay	
Station El April	1	0.00	0.00	0.03	0.15	0.41	5.98	19.18	12.54	18.59	3.72	9.29	1.86	28.25	5.63	0.00	25.75	44.14	30.11	
	2	0.00	0.00	0.03	0.15	0.40	4.34	12.33	17.93	11.71	5.86	9.76	7.81	29.67	6.53	0.00	17.25	45.26	37.48	
	3	0.00	0.09	0.10	0.33	0.54	5.44	17.64	15.36	13.75	6.87	8.60	5.15	26.13	5.76	0.09	24.05	44.58	31.28	
	4	0.00	0.00	0.00	0.06	0.40	5.71	20.48	12.92	16.01	4.00	10.01	4.00	26.41	5.65	0.00	26.65	42.94	30.41	
	5	0.00	0.37	0.13	0.27	0.36	5.20	16.03	0.00	3.92	1.74	6.99	8.74	56.25	>10	0.37	21.99	12.65	64.99	
Mean		0.00	0.09	0.06	0.19	0.42	5.33	17.13	11.75	12.80	4.44	8.93	5.51	33.34	6.91	0.09	23.14	37.91	38.85	
S.D.		0.00	0.16	0.05	0.11	0.07	0.63	3.16	6.92	5.59	2.00	1.21	2.80	12.89	2.31	0.16	3.74	14.15	14.92	

Appendix D-4. (continued - page 2)

		Replicate													median ϕ	% shell gravel	% sand	% silt	% clay
		-2	-1	0	1	2	3	4	5	6	7	8	10	>10					
Station E2	1	0.00	0.16	0.09	0.20	0.37	14.06	32.88	37.32	6.49	3.24	4.87	0.32	0.00	4.06	0.16	47.60	51.92	0.32
	2	0.00	0.08	0.10	0.19	0.46	11.80	32.20	36.47	8.50	4.24	4.25	0.00	1.70	4.14	0.08	44.75	53.46	1.70
February																			
	Mean	0.00	0.12	0.10	0.20	0.42	12.93	32.54	36.90	7.50	3.74	4.56	0.16	0.85	4.10	0.12	46.18	52.69	1.01
	S.D.	0.00	0.06	0.01	0.01	0.06	1.60	0.48	0.60	1.42	0.71	0.44	0.23	1.20	0.06	0.06	2.02	1.09	0.98

		Replicate													median ϕ	% shell gravel	% sand	% silt	% clay
		-2	-1	0	1	2	3	4	5	6	7	8	10	>10					
Station E2	1	0.00	0.05	0.04	0.13	1.15	17.13	19.41	31.09	7.20	3.61	3.60	3.61	12.97	4.39	0.05	37.86	45.50	16.58
	3	0.00	0.00	0.05	0.63	0.61	16.86	26.46	17.49	18.05	1.50	3.01	6.02	9.32	4.31	0.00	44.61	40.05	15.34
March	4	0.00	0.00	0.00	0.10	0.61	12.13	23.86	16.78	24.23	4.84	0.00	2.42	15.02	4.79	0.00	36.70	45.85	17.44
	5	1.16	0.61	0.18	0.35	0.97	14.66	27.49	28.03	13.09	1.87	5.61	0.00	5.99	4.16	1.77	43.65	48.60	5.99
	Mean	0.29	0.17	0.07	0.30	0.84	15.20	24.31	23.55	15.64	2.96	3.06	3.01	10.78	4.41	0.46	40.71	45.00	13.84
	S.D.	0.58	0.30	0.08	0.24	0.27	2.32	3.60	7.58	7.24	1.56	2.32	2.51	3.96	0.27	0.88	4.00	3.58	5.30

		Replicate													median ϕ	% shell gravel	% sand	% silt	% clay
		-2	-1	0	1	2	3	4	5	6	7	8	10	>10					
Station E2	1	0.00	0.00	0.10	0.05	0.21	13.13	34.91	27.27	10.58	0.00	0.00	5.30	8.46	4.06	0.00	48.40	37.85	13.76
	2	0.00	0.00	0.04	0.05	0.32	10.37	31.64	24.53	11.84	5.86	0.00	5.90	9.44	4.31	0.00	42.42	42.23	15.34
April	3	0.00	0.00	0.27	0.24	0.44	25.38	28.32	30.37	4.68	0.00	0.00	9.36	0.94	3.84	0.00	54.65	35.05	10.30
	4	0.00	0.09	0.22	0.40	0.88	21.88	26.93	13.38	18.69	1.44	5.75	2.87	7.48	3.99	0.09	50.31	39.26	10.35
	5	0.00	0.04	0.37	0.37	0.57	14.07	21.34	36.71	15.61	7.80	3.12	0.00	0.00	4.36	0.04	36.72	63.24	0.00
	Mean	0.00	0.03	0.20	0.22	0.48	16.97	28.63	26.45	12.28	3.02	1.77	5.86	5.26	4.11	0.03	46.50	43.53	9.95
	S.D.	0.00	0.04	0.13	0.17	0.26	6.36	5.11	8.60	5.32	3.59	2.60	2.68	4.44	0.22	0.04	7.02	11.32	5.98

Appendix D-4. (continued - page 3)

															% median shell % % % gravel sand silt clay				
Replicate		-2	-1	0	1	2	3	4	5	6	7	8	10	>10	Φ				
Station	1	0.00	0.00	0.01	0.02	0.02	0.76	2.77	13.63	5.30	5.31	10.62	5.30	56.26	>10	0.00	3.58	34.86	61.56
	E3	2	0.00	0.04	0.01	0.02	0.04	0.89	2.63	10.35	4.89	7.33	12.22	9.78	51.81	>10	0.04	3.59	34.79
April	3	0.00	0.00	0.02	0.01	0.03	0.73	2.87	16.11	4.83	4.83	9.67	14.50	46.39	9.50	0.00	3.66	35.44	60.89
	4	0.00	0.00	0.00	0.01	0.04	1.04	3.30	5.26	6.41	6.41	12.82	9.61	55.11	>10	0.00	4.39	30.90	64.72
Mean		0.00	0.01	0.01	0.02	0.03	0.86	2.89	11.34	5.36	5.97	11.33	9.80	52.39	10.63	0.01	3.81	34.00	62.19
S.D.		0.00	0.02	0.01	0.01	0.01	0.14	0.29	4.69	0.73	1.12	1.45	3.76	4.42	0.75	0.02	0.39	2.09	1.72

Appendix D-4. (continued - page 4)

		Replicate														% median shell % % % Φ gravel sand silt clay				
		-2	-1	0	1	2	3	4	5	6	7	8	10	>10						
Station E4 February	1	0.00	0.00	0.09	0.10	0.17	0.97	4.44	33.57	3.16	9.48	12.64	3.16	32.23	6.79	0.00	5.77	58.85	35.39	
	2	0.00	0.14	0.09	0.06	0.11	9.84	4.37	43.94	8.22	1.65	6.58	6.58	18.42	4.81	0.14	14.47	60.39	25.00	
	Mean	0.00	0.07	0.09	0.08	0.14	5.41	4.41	38.76	5.69	5.57	9.61	4.87	25.33	5.80	0.07	10.12	59.62	30.20	
	S.D.	0.00	0.10	0.00	0.03	0.42	6.27	0.05	7.33	3.58	5.54	4.29	2.42	9.77	1.40	0.10	6.15	1.09	7.35	

		Replicate														median	% shell % gravel sand silt clay			
		-2	-1	0	1	2	3	4	5	6	7	8	10	>10	ϕ					
Station E4 March	1	0.00	0.00	0.01	0.01	0.06	5.03	15.63	3.75	10.35	5.17	10.34	5.18	44.48	7.97	0.00	20.74	29.61	49.66	
	2	0.00	0.18	0.16	0.03	0.20	3.25	13.84	3.63	14.22	4.74	9.49	9.48	40.78	8.05	0.18	17.48	32.08	50.26	
	3	0.00	0.05	0.14	0.19	0.13	3.35	15.50	12.50	5.87	5.88	11.74	5.88	38.77	7.54	0.05	19.31	35.99	44.65	
	5	0.00	0.00	0.00	0.06	0.48	1.41	7.97	45.26	3.67	11.02	11.02	0.00	19.10	4.89	0.00	9.92	70.97	19.10	
	Mean	0.00	0.06	0.08	0.07	0.22	3.26	13.24	16.29	8.53	6.70	10.65	5.14	35.79	7.11	0.06	16.87	42.16	40.29	
S.D.		0.00	0.09	0.08	0.08	0.18	1.48	3.60	19.76	4.70	2.92	0.96	3.90	11.38	1.50	0.09	4.82	19.38	14.76	

		Replicate														%				
		-2	-1	0	1	2	3	4	5	6	7	8	10	>10	median Φ	shell gravel	% sand	% silt	% clay	
Station E4 April	1	0.00	0.00	0.00	0.00	0.06	4.17	15.93	16.87	8.63	0.00	8.63	4.31	41.40	7.50	0.00	20.16	34.13	45.71	
	4	0.00	0.08	0.10	0.07	0.13	5.63	18.42	10.16	9.26	3.08	3.09	12.34	37.64	7.99	0.08	24.35	25.59	49.98	
	Mean	0.00	0.04	0.05	0.04	0.10	4.90	17.18	13.52	8.95	1.54	5.86	8.33	39.52	7.75	0.04	22.26	29.90	47.85	
	S.D.	0.00	0.06	0.07	0.05	0.05	1.03	1.76	4.74	0.45	2.18	3.92	5.68	2.66	0.35	0.06	2.96	6.04	3.02	

Appendix D-4. (continued - page 5)

		Replicate													% median shell % % %				
		-2	-1	0	1	2	3	4	5	6	7	8	10	>10	Φ	gravel	sand	silt	clay
Station E5 February	1	0.00	0.15	0.13	0.16	0.42	2.47	19.97	38.06	7.65	3.83	7.65	1.92	17.60	4.70	0.15	23.15	57.19	19.52
	2	0.00	0.06	0.20	0.31	0.95	9.08	3.87	51.22	7.14	0.00	7.15	3.57	16.44	4.69	0.06	14.41	65.51	20.01
	3	0.00	0.00	0.00	0.03	0.20	2.16	15.87	21.97	9.34	9.34	9.34	6.22	25.53	6.05	0.00	18.26	49.99	31.75
	4	0.00	0.55	0.73	0.83	1.13	6.91	20.49	34.59	7.64	3.82	5.73	3.82	13.76	4.56	0.55	30.09	51.78	17.58
	5	0.00	0.00	0.08	0.16	0.47	5.44	30.93	36.65	6.46	4.31	6.46	6.46	2.58	4.35	0.00	37.08	53.88	9.04
Mean		0.00	0.15	0.23	0.30	0.63	5.21	18.23	36.49	7.65	4.26	7.27	4.40	15.19	4.87	0.15	24.60	55.67	19.58
S.D.		0.00	0.23	0.29	0.31	0.39	2.95	9.76	10.41	1.06	3.33	1.37	1.92	8.30	0.67	0.23	9.11	6.12	8.11
		Replicate													% median shell % % %				
		-2	-1	0	1	2	3	4	5	6	7	8	10	>10	Φ	gravel	sand	silt	clay
Station E5 March	1	0.00	0.00	0.17	0.46	1.54	16.48	28.78	12.23	10.35	0.00	5.17	2.58	22.24	4.21	0.00	47.43	27.75	24.82
	3	0.00	0.17	0.18	0.36	1.09	7.11	27.27	17.26	11.08	3.70	7.39	5.54	18.84	4.80	0.17	36.01	39.43	24.38
	4	0.00	0.00	0.15	0.45	1.76	12.25	33.52	6.36	21.67	3.61	0.00	0.00	20.23	4.29	0.00	48.13	31.64	20.23
	Mean	0.00	0.06	0.17	0.42	1.46	11.95	29.86	11.95	14.37	2.44	4.19	2.71	20.44	4.43	0.06	43.86	32.94	23.14
	S.D.	0.00	0.10	0.02	0.06	0.34	4.69	3.26	5.46	6.34	2.11	3.79	2.77	1.71	0.32	0.10	6.80	5.95	2.53
		Replicate													% median shell % % %				
		-2	-1	0	1	2	3	4	5	6	7	8	10	>10	Φ	gravel	sand	silt	clay
Station E5 April	1	0.00	0.00	0.04	0.07	0.41	1.97	15.23	24.00	3.73	3.73	3.73	11.18	35.80	7.19	0.00	17.82	35.19	46.98
	2	0.45	0.63	0.59	1.13	2.90	17.84	16.56	27.73	6.07	0.00	3.04	3.03	20.04	4.36	1.08	39.02	36.84	23.07
	4	0.00	0.00	0.00	0.01	0.05	0.65	30.02	14.53	12.08	4.03	2.01	6.04	30.59	5.39	0.00	30.73	32.65	36.63
	5	0.00	0.00	0.04	0.08	0.51	4.90	28.72	64.33	1.43	0.00	0.00	0.00	0.00	4.24	0.00	34.25	65.76	0.00
	Mean	0.11	0.16	0.17	0.32	0.97	6.34	22.66	32.64	5.83	1.94	2.20	5.06	21.60	5.30	0.27	30.46	42.61	26.67
S.D.		0.23	0.32	0.28	0.54	1.30	7.87	7.79	21.84	4.58	2.24	1.62	4.77	15.82	1.36	0.54	9.08	15.52	20.30

Appendix D-5. Grain size distribution of surficial sediments at the marine stations as reported by Texas A & M. Values expressed as percentage (by weight) of particles in a given size range.

		Replicate	0-1	1-2	2-3	3-4	4-5	5-6	6-7	7-8	8-9	9-10	10-14	% sand	% silt	% clay
Station M1 February	1		0.81	3.34	12.48	14.76	14.98	8.29	0.04	3.05	6.69	1.60	33.95	31.39	26.36	42.24
	2		1.25	3.62	15.97	20.21	15.21	3.02	5.95	3.33	2.64	3.42	26.84	41.65	25.57	32.90
	3		0.31	4.72	16.09	16.82	15.69	2.23	2.35	2.11	4.90	3.72	31.15	37.94	22.28	39.77
	4		1.28	3.94	17.41	19.42	14.68	5.34	3.16	1.18	5.31	4.23	24.05	42.05	24.36	33.59
	6		4.40	4.01	16.71	18.17	13.88	4.78	3.11	2.43	2.64	4.00	25.87	43.29	24.20	32.57

		Replicate	0-1	1-2	2-3	3-4	4-5	5-6	6-7	7-8	8-9	9-10	10-14	% sand	% silt	% clay
Station M3 February	2		1.66	5.83	20.10	9.95	9.25	4.88	3.83	3.55	4.80	4.18	36.97	37.54	21.51	40.95
	3		3.27	3.50	15.23	8.67	9.59	5.94	4.52	2.69	6.99	5.75	38.84	30.67	22.74	46.58
	4		2.33	4.55	17.47	10.34	11.21	4.30	3.28	3.63	4.97	2.68	35.23	34.69	22.42	42.88
	5		1.94	2.88	10.44	7.29	6.86	8.77	9.79	0.52	6.09	6.16	39.14	22.65	25.94	51.39
	6		7.37	5.41	13.98	8.07	6.42	8.21	6.31	5.05	0.56	6.20	32.42	34.80	25.99	39.18
	7		1.08	3.79	14.04	9.04	9.63	6.41	3.66	2.83	6.25	3.85	39.41	27.95	22.53	49.57
	8		0.70	3.09	10.89	5.71	8.41	4.72	5.68	4.92	5.08	5.28	45.92	20.39	23.73	56.28

		Replicate	0-1	1-2	2-3	3-4	4-5	5-6	6-7	7-8	8-9	9-10	10-14	% sand	% silt	% clay
Station M6 February	1		0.38	3.47	30.41	20.84	15.73	3.46	2.93	1.47	2.87	3.21	15.28	55.10	23.59	21.31
	3		2.95	3.45	14.78	12.55	15.47	7.79	4.32	2.14	5.35	4.58	26.62	33.73	29.72	36.55
	4		1.37	5.85	14.42	10.06	10.38	6.91	4.21	4.88	3.62	5.13	33.17	31.70	26.38	41.92
	5		1.49	4.19	14.81	11.80	18.82	7.91	4.36	2.54	4.22	3.14	26.73	32.29	33.63	34.09
	6		2.77	4.85	16.14	9.51	9.05	5.62	3.62	4.59	4.56	19.98	20.23	33.27	22.88	43.86

Appendix D-5. (continued - page 2)

		Replicate	0-1	1-2	2-3	3-4	4-5	5-6	6-7	7-8	8-9	9-10	10-14	% sand	% silt	% clay
Station M9 February	1		0.07	0.09	0.29	0.64	3.55	3.71	6.73	7.79	9.96	9.06	58.09	1.09	21.78	77.11
	2		0.02	0.04	0.14	0.51	5.60	6.57	9.65	4.57	8.06	9.20	55.64	0.71	26.39	72.90
	3		0.24	0.10	0.59	2.04	9.09	8.97	7.14	7.06	8.02	7.14	49.61	2.97	32.26	64.77
	4		2.42	0.08	0.16	0.73	4.19	8.99	7.86	7.61	8.83	8.32	50.80	3.39	28.65	67.95
	5		0.04	0.07	0.06	0.73	2.92	8.38	6.92	4.88	9.11	11.88	55.90	0.90	23.10	76.00
	6		0.18	0.18	0.49	1.63	12.55	7.41	6.77	7.24	7.35	9.63	46.37	2.48	33.97	62.55
	7		0.29	0.10	0.40	3.38	12.40	8.84	7.40	4.92	6.31	8.07	47.90	4.17	33.56	62.28

		Replicate	0-1	1-2	2-3	3-4	4-5	5-6	6-7	7-8	8-9	9-10	10-14	% sand	% silt	% clay
Station M10 February	1		0.55	1.00	3.99	3.04	22.45	7.27	7.95	2.82	7.40	4.54	38.97	8.58	40.49	50.91
	2		10.32	2.86	5.10	5.72	11.30	6.26	6.15	3.49	10.19	2.60	36.01	24.00	27.20	48.80

		Replicate	0-1	1-2	2-3	3-4	4-5	5-6	6-7	7-8	8-9	9-10	10-14	% sand	% silt	% clay
Station M11 February	1		0.32	2.72	7.15	10.45	19.04	9.69	5.17	0.25	8.28	5.22	31.71	20.64	34.15	45.21
	2		0.95	3.20	8.95	12.09	17.59	8.69	3.98	3.15	4.54	4.71	32.21	25.19	33.41	41.46
	3		1.55	5.35	9.11	7.83	19.58	5.68	4.50	4.04	2.89	4.43	35.04	23.84	33.80	42.36
	4		0.49	1.11	4.36	4.83	31.19	8.33	3.47	2.51	5.30	5.06	33.34	10.79	45.50	43.70
	6		0.82	1.14	4.50	4.22	16.30	4.63	4.53	8.03	5.37	6.15	44.22	10.68	33.54	55.79

Appendix D-5. (continued - page 3)

		Replicate	0-1	1-2	2-3	3-4	4-5	5-6	6-7	7-8	8-9	9-10	10-14	% sand	% silt	% clay
Station M15 February	1		0.50	0.15	0.55	3.86	8.09	6.38	5.09	9.80	6.81	6.80	51.97	5.06	29.36	65.58
	2		0.08	0.03	0.18	1.14	3.13	8.95	7.99	5.56	9.05	7.73	56.16	1.43	25.63	72.94
	3		0.33	0.06	0.15	1.15	4.34	6.66	8.74	8.25	7.95	9.35	53.01	1.69	27.99	70.31
	5		0.06	0.14	0.39	3.46	6.84	9.62	8.29	4.99	9.51	8.17	48.53	4.05	29.74	66.21
	6		0.02	0.07	0.22	1.85	4.45	10.62	6.90	7.10	9.06	7.34	52.37	2.16	29.07	68.77
	7		0.06	0.09	0.29	3.09	8.10	9.57	7.07	3.62	9.00	8.95	50.15	3.53	28.36	68.10
	8		1.15	0.16	0.48	1.28	6.76	9.37	7.49	5.70	12.07	8.11	47.45	3.07	29.32	67.61

		Replicate	0-1	1-2	2-3	3-4	4-5	5-6	6-7	7-8	8-9	9-10	10-14	% sand	% silt	% clay
Station M18 February	1		0.04	0.18	0.67	4.77	28.40	8.66	4.90	3.86	5.59	4.26	38.69	5.66	45.82	48.54
	2		0.02	0.73	0.42	3.16	12.19	11.52	5.88	6.50	5.60	7.59	46.39	4.33	36.09	59.58
	3		0.02	0.13	0.40	1.18	21.35	6.67	7.41	4.52	7.02	5.79	45.52	1.73	39.95	58.33
	5		0.09	0.17	0.54	3.77	10.75	11.63	6.98	4.60	7.96	8.58	44.95	4.57	33.96	61.49
	6		0.10	0.02	0.39	2.90	13.03	8.71	5.20	4.54	7.54	7.02	50.56	3.41	31.48	65.12

		Replicate	0-1	1-2	2-3	3-4	4-5	5-6	6-7	7-8	8-9	9-10	10-14	% sand	% silt	% clay
Station M20 February	2		0.18	0.15	1.96	15.42	17.43	9.39	5.40	5.67	3.72	6.06	34.61	17.71	37.89	44.39
	3		0.01	0.02	0.32	2.03	7.12	12.80	8.07	2.39	9.56	7.01	50.67	2.38	30.38	67.24
	4		0.01	0.15	0.74	7.88	15.37	12.05	5.25	4.12	5.72	6.27	42.48	8.78	36.77	54.47
	5		0.25	0.29	2.11	15.66	17.36	8.60	6.33	4.79	4.82	4.66	35.12	18.31	37.08	44.60
	6		0.03	0.05	0.30	4.06	8.05	9.19	7.07	6.96	6.58	8.81	48.92	4.41	31.27	64.31

Appendix D-5. (continued - page 4)

		Replicate	0-1	1-2	2-3	3-4	4-5	5-6	6-7	7-8	8-9	9-10	10-14	% sand	% silt	% clay
Station DN February	1		0.17	7.73	0.41	0.71	4.56	7.03	8.23	7.27	7.93	7.26	48.70	9.02	27.09	63.89
	2		0.17	0.07	0.33	0.23	4.02	8.13	6.43	5.98	9.20	6.79	58.67	0.80	24.56	74.66
	3		2.09	0.25	0.42	1.10	5.65	6.87	5.65	8.08	7.40	10.14	52.35	3.86	26.25	69.89
	4		0.06	0.41	1.04	0.86	1.86	3.43	17.66	1.94	9.32	7.45	55.44	2.36	24.89	71.75
	5		0.09	0.14	0.43	0.79	4.22	4.87	0.04	14.05	8.63	5.60	61.15	1.45	23.18	75.38
	6		0.50	0.92	2.44	0.96	6.63	6.52	8.94	8.54	7.50	4.61	49.44	4.82	30.63	64.55
	8		0.02	0.09	0.45	1.63	4.34	8.06	9.25	7.28	8.35	8.29	52.84	1.59	28.93	69.48

		Replicate	0-1	1-2	2-3	3-4	4-5	5-6	6-7	7-8	8-9	9-10	10-14	% sand	% silt	% clay
Station DS February	1		2.00	3.81	13.72	14.96	15.51	6.22	3.11	21.00	6.09	4.67	27.95	34.49	26.84	38.71
	2		1.57	4.81	15.42	16.03	10.62	5.55	0.07	10.78	3.27	2.29	29.60	37.83	27.02	35.16
	3		0.23	3.66	11.67	11.11	17.99	1.79	5.60	3.46	3.87	4.47	36.16	26.67	28.84	44.50
	4		1.12	4.23	13.24	15.50	14.88	5.68	2.11	2.77	4.04	4.60	31.83	34.09	25.44	40.47
	5		7.19	4.30	13.05	15.62	14.57	6.28	3.14	2.21	5.46	13.85	14.32	40.16	26.20	33.63
	6		0.16	3.92	13.98	10.78	14.86	7.35	2.82	2.52	2.59	7.89	33.12	28.84	27.55	43.60
	7		0.81	1.40	6.08	6.72	14.87	5.16	7.87	4.12	5.35	6.76	40.87	15.01	32.02	52.98

		Replicate	0-1	1-2	2-3	3-4	4-5	5-6	6-7	7-8	8-9	9-10	10-14	% sand	% silt	% clay
Station DE February	1		0.06	0.50	2.89	3.09	12.16	11.32	4.82	10.03	1.46	29.86	23.81	6.54	38.33	55.13
	2		1.83	1.13	6.50	9.99	18.17	9.72	5.47	3.17	9.08	5.71	29.23	19.54	36.53	44.02
	4		2.16	2.21	8.56	9.42	13.72	8.28	5.09	4.53	4.95	4.84	36.24	22.35	31.62	46.03
	5		0.11	0.95	2.74	3.45	9.87	13.96	1.53	8.24	6.07	7.75	45.34	7.25	33.60	59.15
	6		0.74	0.71	3.74	8.32	17.42	8.54	5.68	4.33	3.81	7.58	39.13	13.51	35.97	50.52
	7		3.63	0.87	3.29	1.72	14.79	9.92	6.96	7.00	4.04	6.64	41.15	9.51	38.67	51.83

Appendix D-5. (continued - page 5)

	Replicate	0-1	1-2	2-3	3-4	4-5	5-6	6-7	7-8	8-9	9-10	10-14	% sand	% silt	% clay
Station	1	2.24	2.31	11.37	9.81	8.42	9.41	4.55	2.61	7.32	5.75	36.22	25.73	24.99	49.29
DW	3	2.89	1.32	5.03	16.80	21.07	6.51	3.40	3.82	3.85	4.69	30.65	26.04	34.80	39.19
February	4	2.66	3.67	14.06	10.38	11.81	6.90	1.65	5.71	6.44	6.09	30.62	30.77	26.07	43.15
	5	0.02	0.56	2.10	2.95	11.16	10.01	9.04	3.34	6.31	11.10	43.54	5.63	33.55	60.95
	6	1.07	2.95	11.93	11.57	15.09	8.42	4.83	3.98	4.37	4.08	31.78	27.52	32.32	40.23

	Replicate	0-1	1-2	2-3	3-4	4-5	5-6	6-7	7-8	8-9	9-10	10-14	% sand	% silt	% clay
Station	1	1.58	1.73	5.41	16.72	22.11	7.80	3.67	1.55	5.72	4.89	28.83	25.44	35.13	39.44
CS	2	0.38	0.86	3.67	41.81	15.60	3.14	2.24	1.49	10.71	4.84	15.26	46.72	22.47	30.81
February	3	0.52	0.79	3.24	16.26	16.79	1.92	11.62	1.48	6.85	5.27	35.26	20.81	31.81	47.38
	4	1.13	1.62	5.21	14.83	19.28	5.60	5.23	3.05	4.47	3.84	35.74	22.79	33.16	44.05
	5	0.004	1.14	2.06	7.32	9.44	6.26	8.75	3.71	7.79	6.52	46.65	10.524	28.156	60.92
	6	0.89	1.62	4.34	15.15	16.73	5.59	4.16	4.16	4.03	6.54	36.79	21.99	30.64	47.36
	7	0.94	1.51	3.65	14.50	17.73	5.45	5.16	4.95	4.83	11.22	30.06	20.60	33.29	46.11

Appendix D-6. Grain size distribution of surficial sediments at the estuarine stations as submitted by Texas A & M. Values expressed as percentage (by weight) of particles in a given size range.

		Replicate	0-1	1-2	2-3	3-4	4-5	5-6	6-7	7-8	8-9	9-10	10-14	% sand	% silt	% clay
Station E1 February	1		0.22	1.41	4.57	8.18	16.40	15.82	10.18	5.91	2.82	5.63	30.01	14.33	48.31	37.31
	2		16.41	0.30	3.86	7.59	27.98	9.55	9.82	0.12	1.46	2.77	20.14	28.16	47.47	24.37
	3		0.58	1.06	3.58	5.17	17.30	17.30	9.34	5.74	3.19	4.33	32.41	10.39	49.65	39.93
	4		0.17	0.43	2.99	7.57	17.07	16.02	4.58	3.75	6.06	2.96	31.90	10.66	48.42	40.92
	5		0.29	0.81	4.43	10.07	14.48	16.58	9.95	4.07	5.37	4.87	29.09	15.60	45.08	39.33

		Replicate	0-1	1-2	2-3	3-4	4-5	5-6	6-7	7-8	8-9	9-10	10-14	% sand	% silt	% clay
Station E2 February	1		0.49	1.63	12.02	20.20	16.20	9.81	5.76	2.44	2.69	3.26	25.47	34.34	34.21	31.42
	2		1.15	2.56	14.38	24.05	29.14	10.89	3.75	2.41	2.69	2.41	6.62	42.14	46.14	11.72
	3		1.24	3.68	16.74	31.18	23.81	6.90	1.54	2.23	0.33	2.38	9.97	52.84	34.48	12.68
	4		1.17	2.71	21.56	32.66	13.76	5.10	1.65	3.59	0.72	1.85	15.21	58.10	24.10	17.78
	5		0.89	2.83	11.46	22.39	25.65	10.15	4.07	2.47	2.03	4.66	13.39	37.57	42.34	20.08

		Replicate	0-1	1-2	2-3	3-4	4-5	5-6	6-7	7-8	8-9	9-10	10-14	% sand	% silt	% clay
Station E3 February	1		0.35	2.60	22.77	37.92	11.36	3.13	1.39	2.01	1.98	1.95	14.00	63.58	17.89	18.53
	2		1.95	4.50	21.92	33.55	6.79	4.02	2.07	3.31	1.55	2.29	18.01	61.92	16.18	21.80
	3		4.77	6.87	41.90	21.59	7.63	1.57	1.88	0.07	2.46	1.48	9.86	75.11	11.09	13.80
	4		5.57	6.20	39.18	22.89	6.27	2.47	1.53	0.73	0.36	2.99	11.70	73.84	11.10	15.05
	5		9.43	7.10	39.33	23.45	7.24	1.80	0.64	0.53	0.84	1.50	8.13	79.31	10.21	10.47

Appendix D-6. (continued)

		Replicate	0-1	1-2	2-3	3-4	4-5	5-6	6-7	7-8	8-9	9-10	10-14	% sand	% silt	% clay
Station E4 February	1		0.78	1.56	4.85	10.30	10.63	7.74	5.90	6.00	5.38	6.04	40.84	17.49	30.27	52.22
	2		1.44	2.32	0.60	17.50	14.71	6.67	13.04	2.01	4.92	4.80	32.74	21.86	36.43	42.46
	3		3.94	1.02	4.98	13.81	14.99	7.57	4.58	5.03	4.86	4.18	35.09	23.75	32.12	44.13
	4		0.80	0.77	6.62	22.46	14.56	6.14	4.27	5.17	3.49	3.96	31.34	30.65	30.58	38.77
	5		1.17	0.51	5.70	13.70	17.38	13.24	0.05	2.30	3.63	5.73	36.51	21.16	32.97	45.87

		Replicate	0-1	1-2	2-3	3-4	4-5	5-6	6-7	7-8	8-9	9-10	10-14	% sand	% silt	% clay
Station E5 February	1		0.54	3.65	4.99	13.50	14.61	8.31	4.90	2.64	5.83	3.96	37.06	22.68	30.46	46.85
	3		0.46	2.31	3.99	8.63	9.84	11.31	10.23	2.10	5.48	6.02	39.56	15.39	33.54	51.06
	4		0.11	0.46	1.71	11.20	18.85	11.07	2.31	5.54	2.87	5.61	40.22	13.54	37.77	48.70
	5		0.33	8.99	11.55	21.55	9.09	7.56	5.91	1.12	3.60	2.07	28.23	42.32	23.68	33.90

Appendix D-7. Macrofaunal density (individuals m^{-2}), number of species collected, and population statistics at marine stations. Values for number of species are based on ten $0.1 m^2$ Smith-McIntyre grabs in January and six grabs for all other months.

Month	M1	M3	M6	M9	DW	DN	M10A	DS	DE	M11	M15	M18	M20	CS	Mean	S.D.
Individuals																
January	—	—	—	897	—	—	—	—	—	624	—	—	—	—	761	193
February	2487	2952	3343	1040	3605	2068	3448	2852	1622	1797	1282	1843	2808	4595	2553	1004
March	3075	6747	2815	3423	3487	5440	5463	3428	4422	4845	4568	4150	3533	—	4261	1137
April	6585	10478	3488	5452	4795	8065	4688	4767	3597	9508	5390	4222	2445	—	5652	2392
Mean	4049	6726	3215	2703	3962	5191	4533	3682	3214	4194	3747	3405	2929			

Species																
January	—	—	—	49	—	—	—	—	—	43	—	—	—	—	46	4
February	52	47	48	32	43	44	53	37	35	52	40	35	41	55	44	8
March	51	51	45	41	42	49	49	53	41	48	50	46	41	—	47	4
April	63	47	53	40	55	45	50	54	53	63	48	49	39	—	51	7
Mean	55	48	49	41	47	46	51	48	43	52	46	43	40			

Appendix D-7 (continued).

	Station														
Month	M1	M3	M6	M9	DW	DN	M10A	DS	DE	M11	M15	M18	M20	CS	Mean
	Diversity														
February	3.30	2.96	3.21	3.05	2.84	2.92	2.90	2.48	2.92	3.28	3.46	3.25	3.05	3.49	3.08
March	3.01	2.18	2.93	2.92	3.09	2.13	2.48	2.74	2.49	2.52	2.89	2.75	2.85	—	2.69
April	2.31	1.29	3.07	1.58	3.00	2.05	2.71	2.73	2.77	2.06	2.55	2.60	2.29	—	2.39
Mean	2.87	2.14	3.07	2.52	2.98	2.37	2.70	2.65	2.73	2.62	2.97	2.87	2.73		

Species Richness															
February	6.98	6.15	6.18	4.82	5.47	6.04	6.81	4.84	4.94	7.30	5.87	4.85	5.38	6.82	5.92
March	6.65	6.02	5.92	5.24	5.36	5.93	5.93	6.82	5.07	5.89	6.19	5.75	5.22	—	5.43
April	7.49	5.26	6.80	4.82	6.78	5.19	6.17	6.66	6.77	7.17	5.82	6.12	5.21	—	6.17
Mean	7.04	5.81	6.30	4.96	5.87	5.72	6.30	6.11	5.59	6.79	5.96	5.57	5.27		

Evenness															
February	0.58	0.53	0.57	0.61	0.52	0.53	0.51	0.48	0.57	0.58	0.65	0.63	0.57	0.60	0.57
March	0.53	0.38	0.53	0.55	0.57	0.38	0.44	0.48	0.46	0.45	0.51	0.50	0.53	—	0.49
April	0.39	0.23	0.54	0.30	0.52	0.37	0.48	0.47	0.48	0.34	0.46	0.46	0.43	—	0.49
Mean	0.50	0.38	0.55	0.49	0.54	0.43	0.48	0.48	0.50	0.46	0.54	0.53	0.51		

Appendix D-8. Macrofaunal density (individuals m^{-2}), number of species collected, and population statistics at estuarine stations. Values for number of species are based on five 0.05 m^2 Ekman Ekman grabs at E1-E4 and five 0.1 m^2 Smith-McIntyre grabs at E5.

Station							
Month	E1	E2	E3	E4	E5	Mean	S.D.
Individuals							
February	472	2780	----	3624	1362	2060	1373
March	604	5452	----	2976	5674	3676	2386
April	1256	2656	1684	7644	11768	5002	4564
Mean	777	3629		4748	6268		
Species							
February	17	26	----	22	35	25	8
March	15	24	----	21	38	25	10
April	12	23	26	19	48	26	14
Mean	15	24		21	40		
Diversity							
February	3.20	2.92	----	2.44	3.18	2.94	
March	2.64	2.55	----	2.73	1.51	2.36	
April	2.47	2.68	3.02	1.95	2.14	2.45	
Mean	2.77	2.72		2.37	2.28		
Species Richness							
February	3.35	3.82	----	3.08	5.21	3.87	
March	2.79	3.19	----	3.02	4.65	3.41	
April	1.91	3.39	4.14	2.38	5.41	3.45	
Mean	2.68	3.47		2.83	5.09		
Evenness							
February	0.78	0.62	----	0.55	0.62	0.64	
March	0.68	0.56	----	0.62	0.29	0.54	
April	0.69	0.59	0.64	0.46	0.38	0.55	
Mean	0.72	0.59		0.54	0.43		

Appendix D-9. Macrobenthic species collected at marine and estuarine stations.

CNIDARIA

Anthozoa

Anthozoa sp.A

Anthozoa sp.B

Actinostolidae

Paranthus rapiformis

PLATYHELMINTHES

Turbellaria

Polycladia sp.A

Polycladia sp.B

Polycladia sp.C

Polycladia sp.D

Polycladia sp.E

NEMERTINEA

Nemertea sp.B

Nemertea sp.C

Nemertea sp.D

Nemertea sp.F

Nemertea sp.G

Nemertea sp.J

Cerebratulus lacteus

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

Chaetopteridae

Spiochaetopterus oculatus

Chrysopetalidae

Bhawania goodei

Cirratulidae

Cirratulus filiformis

Tharyx sp.

Cossuridae

Cossura delta

Cossura soyeri

Dorvilleidae
 Schistomeringos rudolphi
Eunicidae
 Marphysa sanguinea
Glyceridae
 Glycera americana
Goniadidae
 Glycinde solitaria
Hesionidae
 Gyptis brevipalpa
 Gyptis vittata
Lumbrineridae
 Lumbrinerides sp.A
 Lumbrineris ernesti
 Lumbrineris sp.A
 Ninoe nigripes
Magelonidae
 Magelona cf. cincta
 Magelona cf. pacifica
Maldanidae
 Axiothella sp.A
 Clymenella torquata
Nephtyidae
 Aglaophamus circinata
 Aglaophamus verrilli
 Nephtys incisa
 Nephtys sp.A
Nereidae
 Nereis micromma
 Nereis succinea
 Nereis sp.A
Onuphidae
 Diopatra cuprea
Opheliidae
 Armandia maculata
Oweniidae
 Myriowenia sp.A
 Owenia fusiformis
Paraonidae
 Aricidea cf. alisdairi
 Aricidea lopezi
Phyllodocidae
 Eteone heteropoda
 Eumida sanguinea
 Phyllodoce arenae
Pilargidae
 Ancistrosyllis jonesi
 Loandalia fauveli
 Sigambra bassi
 Sigambra tentaculata
 Sigambra wassi

Polynoidae

Lepidasthenia sp.A
Lepidonotus sublevis
Polynoidae sp.D

Sabellidae

Megalomma bioculatum

Sigalionidae

Pholoe sp.A
Sthenelais boa
Sthenolepis sp.A

Spionidae

Malacoceros sp.A
Paraprionospio pinnata
Polydora ligni
Polydora socialis
Prionospio cirrifera
Spiophanes bombyx
Spiophanes missonensis
Streblospio benedicti

Terebellidae

Loimia medusa

MOLLUSCA

Gastropoda

Acteocinidae

Acteocina canaliculata

Buccinidae

Cantharus cancellarius

Columbellidae

Anachis obesa

Corabidae

Doridella obscura

Epitoniidae

Epitonium apiculatum

Nassariidae

Nassarius acutus

Naticidae

Natica canrena
Natica pusilla
Polinices duplicatus
Sinum perspectivum

Pyramidellidae

Odostomia cf. weberi
Turbonilla sp.B

Retusidae

Volvulella texasiana

Vitrinellidae

Cyclostremiscus pentagonus
Vitrinella floridana

Unidentified

Nudibranchia sp.A

Bivalvia

Arcidae

Anadara ovalis

Corbulidae

Corbula cf. swiftiana

Cuspidariidae

Cardiomya sp.A

Macridae

Mulinia lateralis

Mytilidae

Brachiodontes exustus

Nuculanidae

Nuculana sp.A

Petricolidae

Petricola pholadiformis

Pholadidae

Cyrtopleura costata

Pinnidae

Atrina serrata

Semelidae

Abra aequalis

Solecurtidae

Tagelus plebius

Solenidae

Solen viridis

Tellinidae

Macoma mitchelli

Macoma tenta

Veneridae

Agriopoma texasiana

Chione clenchi

ARTHROPODA

Cirripedia

Balanidae

Balanus improvisus

Stomatopoda

Squillidae

Squilla empusa

Mysidacea

Mysidae

Mysidopsis almyra

Mysidopsis bahia

Mysidopsis bigelow

Cumacea

Diastylidae

Oxyurostylis sp.A

- Tanaidacea
 - Paratanaididae
 - Hargeria rapax
- Isopoda
 - Idoteidae
 - Edotea triloba
 - Munnidae
 - Munna sp.A
 - Sphaeromidae
 - Cassidinidea ovalis
- Amphipoda
 - Ampeliscidae
 - Ampelisca abdita
 - Agrissidae
 - Argissa hamatipes
 - Bateidae
 - Batea catharinensis
 - Corophiidae
 - Cerapus benthophilus
 - Corophium sp.A
 - Corophium sp.B
 - Corophium simile
 - Erichthonius brasiliensis
 - Grandidierella bonnieroides
 - Gammaridae
 - Gammarus mucronatus
 - Melita nitida
 - Ischyroceridae
 - Jassa falcata
 - Isaeidae
 - Microprotopus sp.A
 - Lilgeborgiidae
 - Listriella barnardi
 - Oedicerotidae
 - Monoculodes sp.A
 - Synchelidium americanum
 - Stenothoidae
 - Parametopella sp.A
 - Stenothoidae sp.A
 - Synopiidae
 - Tiron tropakis
- Decapoda
 - Callianassidae
 - Callianassa (= Gourretia) latispina
 - Leucosiidae
 - Persephona crinata
 - Majidae
 - Libinia sp.
 - Ogryididae
 - Ogryides alphaerostris

Paguridae

Pagurus longicarpus

Pagurus pollicaris

Pagurus sp.B

Pasiphaeidae

Leptochela serratorbita

Penaeidae

Penaeus aztecus

Trachypenaeus constrictus

Trachypenaeus similis

Pinnotheridae

Pinnixa pearsei

Pinnixa sp.B

Portunidae

Callinectes sapidus

Callinectes similis

Xanthidae

Hexapanopeus augustifrons

Neopanope texana

SIPUNCULA

Aspidosiphon albus

Golfingia sp.A

Phascolion strombi

ECHIURA

Thalassemidae

Thalassema sp.A

PHORONIDA

Phoronis sp.A

ECHINODERMATA

Ophiuroidea

Hemipholis elongata

Micropholis atra

Holothuroidea

Holothuroidea sp.A

HEMICHORDATA

Balanoglossus aurantiacus

Table E-1. Phytoplankton species list and occurrences in marine study area by cruise.

Taxon	February 1981		March 1981		April 1981	
	Surfac	Bottom	Surface	Bottom	Surfac	Bottom
<u>Prorocentrum compressum</u>	+	+	+	+	+	+
<u>Prorocentrum gracile</u>				+	+	+
<u>Noctiluca scintillans</u>					+	
<u>Dinophysis caudata</u>						
<u>Dinophysis ovum</u>			+	+	+	
<u>Oxytoxum scolopax</u>			+	+	+	
<u>Ceratium furca</u>						
<u>Ceratium trichoceros</u>						
<u>Ceratium tripos</u>						
<u>Actinopterychus undulatus</u>	+	+				
<u>Coscinodiscus centralis</u>	+	+	+	+	+	+
<u>Coscinodiscus excentricus</u>		+				
<u>Coscinodiscus radiatus</u>		+			+	+
<u>Coscinodiscus wailesii</u>					+	+
<u>Melosira distans</u>					+	+
<u>Melosira granulata</u>						
<u>Melosira moniliformis</u>	+					
<u>Skeletonema costatum</u>	+	+	+	+	+	+
<u>Skeletonema tropicum</u>						
<u>Stephanopyxis palmeriana</u>	+	+				
<u>Thalassiosira decipiens</u>	+	+	+	+	+	+
<u>Thalassiosira subtilis</u>						
<u>Bellerophon horologicalis</u>						
<u>Biddulphia alternans</u>						
<u>Biddulphia mobiliensis</u>	+					
<u>Biddulphia sinensis</u>	+	+	+	+	+	+
<u>Cerataulina pelagica</u>	+	+	+	+	+	+
<u>Ditylum brightwellii</u>	+	+	+	+	+	+
<u>Eucampia cornuta</u>	+	+				
<u>Eucampia zoodiacus</u>	+	+				
<u>Hemiaulus hauckii</u>	+	+	+	+		
<u>Lithodesmium undulatum</u>			+		+	
<u>Steptotheca thamensis</u>						
<u>Chaetoceros affinis</u>			+	+	+	+
<u>Chaetoceros breve</u>						
<u>Chaetoceros coarctatus</u>						
<u>Chaetoceros compressus</u>						
<u>Chaetoceros decipiens</u>	+	+	+			+
<u>Chaetoceros didymus</u>	+	+				+
<u>Chaetoceros lorenzianus</u>						
<u>Chaetoceros pervianus</u>						+
<u>Chaetoceros socialis</u>						
<u>Chaetoceros subtilis</u>						
<u>Bacteriastrium delicatulum</u>		+				
<u>Leptocylindrus danicus</u>	+					+
<u>Guinardia flaccida</u>	+	+				+

Table E-1. (continued)

Taxon	February 1981		March 1981		April 1981	
	Surface	Bottom	Surface	Bottom	Surface	Bottom
<u>Rhizosolenia alata</u>	+	+	+	+	+	+
<u>Rhizosolenia calcar-avis</u>	+	+	+	+		
<u>Rhizosolenia delicatula</u>	+	+				
<u>Rhizosolenia imbricata</u>	+	+	+	+		+
<u>Rhizosolenia robusta</u>		+	+	+	+	
<u>Rhizosolenia setigera</u>	+	+	+	+	+	+
<u>Rhizosolenia stolterfothii</u>	+			+		
<u>Asterinsoella glacialis</u>	+	+	+	+	+	+
<u>Campylosira cymbelliformis</u>					+	
<u>Grammatophora marina</u>						
<u>Thalassionema nitzschioides</u>	+					
<u>Thalassiothrix mediterranea</u>		+		+		+
<u>Amphiprora gigantea</u>	+					
<u>Diploneis smithii</u>						
<u>Diploneis weissflogii</u>		+		+		+
<u>Gyrosigma balticum</u>		+				
<u>Navicula distans</u>	+	+	+	+	+	+
<u>Pleurosigma formosum</u>	+	+		+		+
<u>Pleurosigma normali</u>	+	+				
<u>Stauroneis membranacea</u>	+		+			
<u>Nitzschia closterium</u>	+	+	+	+	+	+
<u>Nitzschia longissima</u>	+	+	+	+	+	+
<u>Nitzschia paradoxa</u>						+
<u>Nitzschia pungens</u>		+	+	+	+	+
<u>Nitzschia seriata</u>	+	+	+			+
<u>Nitzschia sigma</u>	+	+		+	+	+
<u>Nitzschia subfraudulenta</u>						
<u>Surirella fastuosa</u>		+				

Table F-1. Systematic list of marine zooplankton and their monthly occurrences.

TAXA	LIFE HISTORY	SEX	FEB	MAR	APR
Phylum: CTENOPHORA					
Class: Nuda					
<u>Beroe ovata</u>	8	3			X
<u>Mnemiopsis mccradyi</u>	8	3			X
Phylum: MOLLUSCA					
Class: Gastropoda					
Subclass: Prosobranchia					
unid. larvae				X	X
Order: Mesogastropoda					
<u>Littorina</u> sp.				X	
<u>Crepidula</u> sp.				X	
<u>Atlanta gaudichaudi</u>					X
<u>Atlanta helicinoidea</u>					X
unid. Naticidae			X	X	X
<u>Polinices duplicatus</u>			X		
<u>Nassarius</u> sp.				X	X
Subclass: Opisthobranchia				X	X
unid. larvae				X	
Order: Thecosomata					
<u>Limacina trochiformis</u>					X
<u>Creseis acicula</u>					X
<u>Creseis conica</u>					X
Order: Nudibranchia					
unid. larvae			X	X	
Class: Bivalvia (Pelecypoda)					
unid. larvae			X	X	
Subclass: Heterodonta					
Order: Veneroida					
<u>"Planktomya henseni"</u>					X
<u>Mulinia lateralis</u>			X		X
<u>Ensis minor</u>			X	X	
<u>Tellina</u> sp.			X	X	
<u>Petricola pholadiformis</u>			X		
Class: Cephalopoda					
<u>Lolliguncula brevis</u>					X
Phylum: ANNELIDA					
Class: Polychaeta					
unid. larvae	6	0		X	X
Phylum: ARTHROPODA					
Subphylum: Crustacea					
Class: Branchiopoda					
<u>Evadne tergestina</u>	8	5			X
<u>Penilia avirostris</u>	8	5			X
<u>Podon polyphemoides</u>	8	5		X	
Class: Ostracoda					
unid. ostracod	A	0		X	

Table F-1. Systematic list of marine zooplankton and their monthly occurrences. Page 2.

TAXA	LIFE HISTORY	SEX	FEB	MAR	APR
Class: Copepoda					
Order: Calanoida					
<u>Acartia tonsa</u>	8	2	X	X	X
	8	1	X	X	X
	F	0	X	X	X
<u>Centropages hamatus</u>	8	2	X	X	X
	8	1	X	X	X
	F	0	X	X	
<u>Centropages velificatus</u>	8	1	X		X
<u>Centropages violaceus</u>	8	2	X	X	X
<u>Eucalanus sp.</u>	F	0	X	X	
<u>Eucalanus pileatus</u>	8	2			X
<u>Labidocera aestiva</u>	8	2	X	X	X
	8	1	X	X	X
	F	0	X	X	X
<u>Nannocalanus minor</u>	8	2	X	X	X
	8	1		X	
<u>Paracalanus quasimodo</u>	8	2	X	X	X
	8	1	X	X	X
<u>Pseudodiaptomus coronatus</u>	8	2			X
<u>Rhincalanus cornutus</u>	8	2	X	X	
	8	1	X		
	F	0			X
<u>Temora sp.</u>	F	0	X		
<u>Temora stylifera</u>	8	2	X	X	X
	8	1	X		X
<u>Temora turbinata</u>	8	2	X	X	X
	8	1	X	X	X
	F	0	X		X
Order: Cyclopoida					
<u>Corycaeus amazonicus</u>	8	2		X	X
	8	1		X	
<u>Corycaeus subulatus</u>	8	2	X	X	X
	8	1	X	X	X
	F	0		X	
<u>Oithona plumifera</u>	8	2	X		
<u>Oncaea mediterranea</u>	8	2	X		X
	8	1		X	
<u>Sapphirina nigromaculata</u>	8	1			X
Order: Harpacticoida					
Harpacticoid Species A	8	5			X
Order: Caligoida					
Unid. Caligoid	8	5		X	X
	8	0	X		

Table F-1. Systematic list of marine zooplankton and their monthly occurrences. Page 3.

TAXA	LIFE HISTORY	SEX	FEB	MAR	APR
Class: Branchiura					
<u>Argulus</u>	8	5			X
Class: Cirripedia					
Nauplius	2	0	X	X	X
Cypris	E	0		X	
Class: Malacostraca					
Order: Decapoda					
<u>Acetes americanus</u>	I	0	X		X
	3	0			X
	J	0			X
<u>Callinectes</u> spp.	4	0	X	X	X
	3	0			X
<u>Callinectes</u> <u>sapidus</u>	I	0			X
<u>Callinectes</u> <u>similis</u>	4	0	X		
Diogenidae	3	0			X
<u>Eucерamus</u> <u>praelongus</u>	3	0	X	X	X
<u>Hexapanopeus</u> <u>angustifrons</u>	4	0			X
	3	0			X
<u>Hippolyte</u> <u>pleuracantha</u>	3	0		X	
<u>Libinia</u> sp.	4	0			X
	3	0			X
<u>Lucifer</u> <u>faxoni</u>	I	0	X	X	X
	6	0	X		
	3	0			X
	J	0			X
<u>Ogyrides</u> <u>alphaerostris</u>	I	0	X		
	4	0		X	
	3	0	X	X	X
<u>Ovalipes</u> <u>floridanus</u>	I	0	X		
<u>Pagurus</u> spp.	4	0	X	X	X
	3	0	X	X	X
<u>Palaemonetes</u> sp.	3	0			X
<u>Penaeus</u> sp.	I	0	X	X	X
	3	0		X	
<u>Petrolisthes</u> sp.	3	0		X	X
<u>Pinnixa</u> spp.	I	0			X
	4	0		X	
	3	0	X	X	X
<u>Porcellana</u> sp.	3	0		X	X
<u>Portunus</u> spp.	3	0			X
<u>Portunus</u> <u>gibbesii</u>	3	0			X
<u>Portunus</u> <u>spinimanus</u>	3	0			X
<u>Sicyonia</u> sp.	I	0			X
	3	0			X
	J	0			X

Table F-1. Systematic list of marine zooplankton and their monthly occurrences. Page 4.

TAXA	LIFE HISTORY	SEX	FEB	MAR	APR
<u>Trachypenaeus</u> sp.	3	0			X
	J	0			X
<u>Uca</u> sp.	3	0			X
<u>Xiphopenaeus kroyeri</u>	3	0			X
Order: Mysidacea					
<u>Promysis atlantica</u>	7	0		X	
Order: Cumacea					
<u>Oxyurostylis</u> sp.	7	0			X
Order: Amphipoda					
unid. Hyperiid	7	0			X
Phylum: CHAETOGNATHA					
<u>Sagitta</u> sp.	7	0	X	X	X
<u>Sagitta enflata</u>	8	3		X	X
<u>Sagitta friderici</u>	8	3		X	X
<u>Sagitta helenae</u>	8	3			X
Phylum: CHORDATA					
Subphylum: Urochordata					
<u>Oikopleura</u> sp.	8	5		X	X
Class: Osteichthyes					
Teleostei	6	0		X	X
	1	0		X	
	*	0		X	X
Order: Anguilliformes					
<u>Myriophis punctatus</u>	I	0	X		
	6	0	X		
Order: Clupeiformes					
<u>Brevoortia</u> spp.	I	0	X	X	X
	6	0	X	X	
	1	0		X	X
<u>Brevoortia patronus</u>	I	0	X		
<u>Harengula pensacolae</u>	6	0			X
	1	0			X
	*	0			X
<u>Opisthonema oglinum</u>	1	0			X
<u>Anchoa</u> spp.	I	0			X
	6	0		X	X
	*	0			X
<u>Anchoa hepsetus</u>	I	0		X	
	6	0		X	
	1	0		X	X
<u>Anchoa mitchilli</u>	I	0	X	X	X
	6	0		X	X
	1	0		X	X
	*	0		X	X

Table F-1. Systematic list of marine zooplankton and their monthly occurrences. Page 5.

TAXA	LIFE HISTORY	SEX	FEB	MAR	APR
Order: Myctophiformes					
<u>Synodus foetens</u>	I	0		X	X
	6	0			X
Order: Gobeisociformes					
<u>Gobiesox strumosus</u>	I	0	X		X
	6	0		X	X
	*	0			X
Order: Atheriniformes					
<u>Membras martinica</u>	I	0	X		
<u>Menidia beryllina</u>	6	0			X
Order: Gasterosteiformes					
<u>Syngnathus sp.</u>	I	0			X
	6	0			X
<u>Syngnathus floridae</u>	I	0		X	
<u>Syngnathus louisianae</u>	I	0	X	X	
Order: Scorpaeniformes					
<u>Prionotus sp.</u>	I	0			X
Order: Perciformes					
Family: Pomadasyidae					
<u>Haemulon (?) sp.</u>	I	0		X	
	6	0		X	X
	*	0		X	
Family: Sparidae					
<u>Archosargus probatocephalus</u>	I	0			X
	6	0			X
<u>Lagodon rhomboides</u>	I	0	X		X
Family: Sciaenidae					
unid. Sciaenidae	6	0			X
	1	0		X	X
<u>Cynoscion arenarius</u>	I	0		X	X
	6	0	X	X	X
	*	0		X	X
<u>Leiostomus xanthurus</u>	I	0	X		
<u>Menticirrhus americanus</u>	6	0		X	X
	I	0			X
	*	0			X
<u>Micropogonias undulatus</u>	I	0	X		
	6	0	X		
Family: Mugilidae					
<u>Mugil cephalus</u>	I	0	X		
<u>Mugil curema</u>	I	0	X		

Table F-1. Systematic list of marine zooplankton and their monthly occurrences. Page 6.

<u>TAXA</u>	<u>LIFE HISTORY</u>	<u>SEX</u>	<u>FEB</u>	<u>MAR</u>	<u>APR</u>
Family: Blenniidae					
unid. Blenniidae	6	0			X
Family: Gobiidae					
unid. Gobiidae	I	0	X		
	6	0	X	X	
Family: Trichiuridae					
<u>Trichiurus lepturus</u>	I	0	X		
	6	0			X
	1	0			X
	*	0			X
Order: Pleuronectiformes					
Family: Bothidae					
<u>Paralichthys lethostigma</u>	I	0	X		
	6	0	X		
<u>Citharichthys spilopterus</u>	6	0	X		X
Family: Cynoglossidae					
<u>Symphurus</u> sp.	1	0			X
	6	0			X
Order: Tetraodontiformes					
unid. Tetraodontiform	6	0			X

Legend for life history and sex codes

<u>Life history</u>	<u>Sex</u>
1 egg	0 indeterminate
2 nauplius	1 male
3 zoea	2 female
4 megalops	3 hermaphrodite
6 larvae	5 grouped
7 juvenile	
8 adult	
* yolk sac larvae	
A juvenile and adult	
E cypris	
F copepodid	
I postlarvae	
J protozoa	
Y glaucothoe	

Table F-2. Systematic list of estuarine zooplankton and their monthly occurrences.

<u>TAXA</u>	<u>LIFE HISTORY</u>	<u>SEX</u>	<u>FEB</u>	<u>MAR</u>	<u>APR</u>
Phylum: CTENOPHORA					
Class: Nuda					
<u>Beroe ovata</u>	8	3			X
<u>Mnemiopsis mccradyi</u>	8	3			X
Phylum: MOLLUSCA					
Class: Gastropoda					
Subclass: Prosobranchia					
Larvae			X		
<u>Hydrobia sp.</u>			X		X
Class: Bivalvia (Pelecypoda)					
Larvae				X	X
Subclass: Pteriomorpha					
unid. Mytilidae			X	X	
<u>Brachidontes exustus</u>					X
Subclass: Heterodonta					
<u>Tellina sp.</u>			X	X	
<u>Petricola pholadiformis</u>				X	
Phylum: ANNELIDA					
Class: Polychaeta					
Larvae	6	0		X	
Phylum: ARTHROPODA					
Subphylum: Crustacea					
Class: Ostracoda					
unid. sp.		0	X	X	X
Class: Copepoda					
Order: Calanoida					
<u>Acartia tonsa</u>	8	1	X	X	X
	8	2	X	X	X
	F	0	X	X	X
<u>Centropages hamatus</u>	8	1	X	X	X
	8	2	X	X	X
	F	0	X	X	X
<u>Eurytemora affinis</u>	8	1		X	
	8	2		X	
	F	0	X	X	
<u>Labidocera aestiva</u>	F	0	X		X
<u>Parvocalanus crassirostris</u>	8	1	X		X
	8	2	X		X
<u>Pseudodiaptomus coronatus</u>	8	1			X
	8	2	X		X
	F	0	X		X
<u>Temora turbinata</u>	8	2		X	
Order: Cyclopoida					
<u>Oithona colcarva</u>	8	1	X	X	X
	8	2	X	X	X
Species A	8	5	X	X	X

Table F-2. Systematic list of estuarine zooplankton and their monthly occurrences. Page 2.

TAXA	LIFE HISTORY	SEX	FEB	MAR	APR
Order: Harpacticoida					
Species A	8	5	X	X	
	F	0	X		X
Order: Caligoida					
Species A	8	5			X
Class: Cirripedia					
Nauplius	2	0	X	X	X
Cypris	E	0	X	X	X
Class: Malacostraca					
Order: Decapoda					
<u>Callinectes</u> spp.	3	0			X
	4	0	X	X	X
	I	0		X	X
<u>Callinectes</u> <u>sapidus</u>	I	0			X
<u>Hexapanopeus</u> <u>angustifrons</u>	3	0			X
<u>Libinia</u> <u>emarginata</u>	4	0			X
<u>Lucifer</u> <u>faxonii</u>	I	0			X
<u>Ogyrides</u> <u>alphaerostris</u>	3	0			X
<u>Pagurus</u> spp.	3	0	X	X	X
	4	0			X
<u>Palaemonetes</u> sp.	3	0			X
<u>Penaeus</u> spp.	I	0	X	X	X
<u>Pinnixa</u> spp.	3	0			X
<u>Rhithropanopeus</u> <u>harrisii</u>	3	0			X
<u>Trachypenaeus</u> <u>similis</u>	I	0			X
Order: Mysidacea					
<u>Mysidopsis</u> sp.					X
Phylum: CHORDATA					
Class: Osteichthyes					
Order: Elopiformes					
<u>Elops</u> <u>saurus</u>	6	0			X
Order: Anguilliformes					
<u>Myriophis</u> <u>punctatus</u>	I	0			X
	6	0	X	X	
Order: Clupeiformes					
<u>Brevoortia</u> spp.	I	0	X	X	X
	6	0	X		
<u>Anchoa</u> <u>mitschilli</u>	I	0	X	X	X
	1	0		X	X
	*	0			X
	6	0		X	X
Order: Myctophiformes					
<u>Synodus</u> <u>foetens</u>	I	0			X
Order: Gobiesociformes					
<u>Gobiesox</u> <u>strumosus</u>	I	0			X
	6	0			X
Order: Atheriniformes					
Family: Atherinidae					
<u>Membras</u> <u>martinica</u>	6	0			X
<u>Menidia</u> <u>beryllina</u>	6	0			X

Table F-2. Systematic list of estuarine zooplankton and their monthly occurrences. Page 3.

<u>TAXA</u>	<u>LIFE HISTORY</u>	<u>SEX</u>	<u>FEB</u>	<u>MAR</u>	<u>APR</u>
Order: Perciformes					
Family: Sparidae					
<u>Lagodon rhomboides</u>	I	0			X
Family: Sciaenidae					
Unid. Sciaenidae	1	0	X	X	X
	*	0			X
<u>Bairdiella chrysoura</u>	6	0			X
<u>Cynoscion regalis</u>	I	0			X
	6	0		X	X
	*	0		X	X
<u>Micropogonias undulatus</u>	I	0	X	X	
Family: Blenniidae					
unid. Blenniidae	6	0			X
Family: Gobiidae					
unid. Gobiidae	I	0	X		
	6	0			X
Order: Pleuronectiformes					
<u>Citharichthys spilopterus</u>	6	0	X		

Note: Legend same as for Table F-1.

Table F-3. Data Summary of Decapod postlarvae and Fish larvae and postlarvae density (number per m³), marine, February, 1981.
All replicates, .505 mm net.

Station	Surface		Mid-depth		Bottom	
	Mean	S. D.	Mean	S. D.	Mean	S. D.
Decapods:						
<u>Acetes americanus</u> postlarvae						
M1	0.000	0.000	0.000	0.000	0.017	0.029
M6	0.000	0.000	0.000	0.000	0.017	0.029
<u>Lucifer faxoni</u> larvae						
M6	0.000	0.000	0.017	0.029	0.000	0.000
<u>Penaeus</u> postlarvae						
M1	0.133	0.058	0.067	0.029	0.083	0.029
M3	0.000	0.000	0.033	0.029	0.067	0.029
M6	0.017	0.029	0.000	0.000	0.050	0.000
M10	0.017	0.029	0.000	0.000	0.033	0.058
M15	0.000	0.000	0.017	0.029	0.000	0.000
M20	0.000	0.000	0.000	0.000	0.033	0.058
M11	0.000	0.000	0.000	0.000	0.067	0.058
M9	0.000	0.000	0.067	0.115	0.000	0.000
Fishes:						
<u>Anchoa mitchilli</u> postlarvae						
M1	0.000	0.000	0.000	0.000	0.017	0.029
M3	0.000	0.000	0.000	0.000	0.017	0.029
<u>Brevoortia</u> larvae						
M1	0.100	0.100	0.017	0.029	0.133	0.058
M3	0.100	0.000	0.050	0.000	0.033	0.029
M6	0.967	0.737	0.133	0.058	0.083	0.104
M10	0.083	0.104	0.100	0.173	0.083	0.029
M15	0.067	0.058	0.017	0.029	0.050	0.050
M20	0.033	0.058	0.033	0.058	0.033	0.058
M11	0.033	0.058	0.067	0.058	0.067	0.058
M9	0.033	0.058	0.067	0.058	0.067	0.058
M18	0.100	0.000	0.067	0.058	0.067	0.058
<u>Brevoortia</u> postlarvae						
M1	0.400	0.265	0.083	0.029	0.100	0.000
M3	0.267	0.058	0.167	0.115	0.067	0.029
M6	0.433	0.058	0.050	0.000	0.183	0.275
M10	0.300	0.200	0.133	0.058	0.033	0.058
M15	0.267	0.153	0.050	0.050	0.000	0.000
M20	1.733	0.896	0.067	0.058	0.167	0.115
M11	1.333	0.929	0.267	0.153	0.033	0.058
M9	0.733	0.208	0.233	0.153	0.200	0.100
M18	0.267	0.153	0.100	0.000	0.100	0.000
<u>Brevoortia patronus</u> postlarvae						
M6	0.017	0.029	0.000	0.000	0.000	0.000

Table F-3. Data Summary of Decapod postlarvae and Fish larvae and postlarvae density (number per m³), Marine, February, 1981. Page 2
All replicates, .505 mm net.

Station	Surface		Mid-depth		Bottom	
	Mean	S. D.	Mean	S. D.	Mean	S. D.
<u>Citharichthys spilopterus</u> larvae						
M1	0.150	0.132	0.167	0.289	0.017	0.029
M3	0.000	0.000	0.000	0.000	0.017	0.029
M10	0.000	0.000	0.000	0.000	0.017	0.029
M11	0.000	0.000	0.000	0.000	0.033	0.058
<u>Gobiidae</u> larvae						
M11	0.000	0.000	0.000	0.000	0.033	0.058
<u>Gobiidae</u> postlarvae						
M6	0.000	0.000	0.017	0.029	0.000	0.000
M10	0.000	0.000	0.000	0.000	0.017	0.029
M9	0.000	0.000	0.000	0.000	0.033	0.058
<u>Lagodon rhomboides</u> postlarvae						
M1	0.117	0.161	0.000	0.000	0.000	0.000
M3	0.033	0.058	0.033	0.029	0.033	0.058
M6	0.033	0.029	0.000	0.000	0.067	0.058
M10	0.017	0.029	0.000	0.000	0.000	0.000
M15	0.000	0.000	0.017	0.029	0.000	0.000
M20	0.033	0.058	0.033	0.058	0.067	0.058
M11	0.133	0.153	0.000	0.000	0.033	0.058
M9	0.067	0.058	0.000	0.000	0.033	0.058
M18	0.017	0.029	0.000	0.000	0.000	0.000
<u>Micropogonias undulatus</u> larvae						
M1	0.000	0.000	0.000	0.000	0.017	0.029
<u>Micropogonias undulatus</u> postlarvae						
M6	0.000	0.000	0.000	0.000	0.167	0.289
M9	0.000	0.000	0.033	0.058	0.000	0.000
<u>Mugil cephalus</u> postlarvae						
M1	0.083	0.104	0.000	0.000	0.000	0.000
<u>Myriophis punctatus</u> larvae						
M1	0.033	0.058	0.000	0.000	0.000	0.000
M3	0.000	0.000	0.000	0.000	0.017	0.029
M6	0.000	0.000	0.017	0.029	0.183	0.275
M10	0.000	0.000	0.000	0.000	0.017	0.029
M20	0.000	0.000	0.033	0.058	0.000	0.000
M11	0.000	0.000	0.033	0.058	0.000	0.000
M9	0.000	0.000	0.000	0.000	0.033	0.058
M18	0.000	0.000	0.017	0.029	0.000	0.000
<u>Myriophis punctatus</u> postlarvae						
M1	0.067	0.115	0.017	0.029	0.017	0.029
M3	0.000	0.000	0.017	0.029	0.017	0.029
M6	0.000	0.000	0.017	0.029	0.000	0.000

Table F-3. Data Summary of Decapod postlarvae and Fish larvae and postlarvae density (number per m³), marine February. Page 3
All replicates, .505 mm net

Station	Surface		Mid-depth		Bottom	
	Mean	S. D.	Mean	S. D.	Mean	S. D.
<u>Paralichthys lethostigma</u> larvae						
M1	0.083	0.104	0.000	0.000	0.000	0.000
<u>Paralichthys lethostigma</u> postlarvae						
M3	0.000	0.000	0.000	0.000	0.017	0.029
M20	0.000	0.000	0.000	0.000	0.033	0.058
<u>Syngnathus louisianae</u> postlarvae						
M6	0.000	0.000	0.000	0.000	0.017	0.029

Table F-4. Data Summary of Decapod postlarvae and Fish larvae and postlarvae density (number per m³), marine February, 1981.
All replicates, .333 mm net.

Station	Surface		Mid-depth		Bottom	
	Mean	S. D.	Mean	S. D.	Mean	S. D.
Decapods:						
<u>Lucifer faxoni</u> postlarvae						
M20	0.033	0.058	0.000	0.000	0.000	0.000
<u>Penaeus</u> postlarvae						
M1	0.017	0.029	0.050	0.050	0.067	0.029
M3	0.000	0.000	0.017	0.029	0.067	0.029
M6	0.000	0.000	0.000	0.000	0.050	0.050
M10	0.000	0.000	0.050	0.000	0.033	0.029
M15	0.017	0.029	0.017	0.029	0.000	0.000
M20	0.000	0.000	0.033	0.058	0.033	0.058
M11	0.000	0.000	0.000	0.000	0.067	0.058
Fishes:						
<u>Anchoa mitchilli</u> postlarvae						
M3	0.000	0.000	0.000	0.000	0.033	0.058
<u>Brevoortia</u> larvae						
M1	0.083	0.029	0.083	0.029	0.183	0.126
M3	0.167	0.115	0.233	0.252	0.100	0.100
M6	1.033	0.850	0.050	0.050	0.067	0.115
M10	0.167	0.115	0.100	0.087	0.100	0.100
M15	0.083	0.029	0.067	0.029	0.000	0.000
M20	0.067	0.058	0.067	0.058	0.033	0.058
M11	0.033	0.058	0.067	0.058	0.067	0.058
M9	0.000	0.000	0.067	0.058	0.033	0.058
M18	0.100	0.000	0.117	0.076	0.100	0.000
<u>Brevoortia</u> postlarvae						
M1	0.183	0.189	0.050	0.000	0.033	0.029
M3	0.233	0.058	0.267	0.153	0.017	0.029
M6	0.367	0.115	0.050	0.050	0.033	0.058
M10	0.200	0.100	0.083	0.029	0.067	0.029
M15	0.183	0.189	0.033	0.058	0.050	0.050
M20	0.600	0.700	0.133	0.058	0.100	0.000
M11	1.333	1.193	0.133	0.058	0.133	0.058
M9	0.833	0.351	0.133	0.058	0.133	0.058
M18	0.167	0.202	0.100	0.000	0.100	0.000
<u>Citharichthys spilopterus</u> larvae						
M1	0.067	0.058	0.267	0.462	0.017	0.029
M3	0.000	0.000	0.017	0.029	0.000	0.000
M6	0.000	0.000	0.000	0.000	0.033	0.029
M10	0.000	0.000	0.000	0.000	0.017	0.029
M11	0.000	0.000	0.000	0.000	0.033	0.058
<u>Cynoscion arenarius</u> larvae						
M1	0.000	0.000	0.000	0.000	0.017	0.029

Table F-4. Data Summary of Decapod postlarvae and Fish larvae and postlarvae density (number per m³), marine February, 1981. Page 2.
All replicates, .333 mm net.

Station	Surface		Mid-depth		Bottom	
	Mean	S. D.	Mean	S. D.	Mean	S. D.
<u>Gobiesox strumosus</u> postlarvae						
M6	0.017	0.029	0.000	0.000	0.000	0.000
<u>Gobiidae</u> postlarvae						
M1	0.000	0.000	0.000	0.000	0.033	0.029
M6	0.000	0.000	0.000	0.000	0.017	0.029
M20	0.000	0.000	0.000	0.000	0.033	0.058
<u>Lagodon rhomboides</u> postlarvae						
M1	0.017	0.029	0.000	0.000	0.000	0.000
M3	0.017	0.029	0.000	0.000	0.017	0.029
M6	0.050	0.050	0.017	0.029	0.033	0.029
M10	0.000	0.000	0.017	0.029	0.000	0.000
M20	0.000	0.000	0.000	0.000	0.033	0.058
M11	0.033	0.058	0.033	0.058	0.033	0.058
M9	0.033	0.058	0.000	0.000	0.000	0.000
M18	0.017	0.029	0.000	0.000	0.000	0.000
<u>Leiostomus xanthurus</u> postlarvae						
M1	0.000	0.000	0.000	0.000	0.017	0.029
M20	0.033	0.058	0.000	0.000	0.000	0.000
<u>Membras martinica</u> postlarvae						
M1	0.017	0.029	0.000	0.000	0.000	0.000
<u>Micropogonias undulatus</u> postlarvae						
M1	0.000	0.000	0.017	0.029	0.033	0.029
M3	0.000	0.000	0.033	0.058	0.017	0.029
M6	0.000	0.000	0.000	0.000	0.017	0.029
M15	0.000	0.000	0.000	0.000	0.017	0.029
<u>Mugil cephalus</u> postlarvae						
M1	0.017	0.029	0.000	0.000	0.000	0.000
<u>Mugil curema</u> postlarvae						
M10	0.000	0.000	0.017	0.029	0.000	0.000
M11	0.167	0.289	0.000	0.000	0.000	0.000
<u>Myriophis punctatus</u> larvae						
M1	0.000	0.000	0.033	0.029	0.000	0.000
M6	0.000	0.000	0.033	0.029	0.017	0.029
M20	0.000	0.000	0.000	0.000	0.033	0.058
M18	0.000	0.000	0.067	0.058	0.000	0.000
<u>Myriophis punctatus</u> postlarvae						
M3	0.000	0.000	0.017	0.029	0.000	0.000

Table F-4. Data Summary of Decapod postlarvae and Fish larvae and postlarvae density (number per m³), marine, February, 1981. Page 3
All replicates, .333 mm net.

Station	Surface		Mid-depth		Bottom	
	Mean	S. D.	Mean	S. D.	Mean	S. D.
<u>Paralichthys lethostigma</u> larvae						
M1	0.000	0.000	0.017	0.029	0.000	0.000
<u>Paralichthys lethostigma</u> postlarvae						
M3	0.000	0.000	0.017	0.029	0.000	0.000
<u>Syngnathus louisianae</u> postlarvae						
M10	0.000	0.000	0.000	0.000	0.033	0.029
M11	0.000	0.000	0.033	0.058	0.000	0.000
<u>Trichiurus lepturus</u> postlarvae						
M10	0.000	0.000	0.000	0.000	0.017	0.029

Table F-5. Data Summary of Decapod postlarvae and Fish larvae and postlarvae density (number per m³), Marine March, 1981.
All replicates, .505 mm net

Station	Surface		Mid-depth		Bottom	
	Mean	S. D.	Mean	S. D.	Mean	S. D.
Decapods:						
<u>Lucifer faxoni</u> postlarvae						
M10	0.000	0.000	0.000	0.000	0.033	0.058
<u>Penaeus</u> postlarvae						
M9	0.000	0.000	0.000	0.000	0.033	0.058
Fishes:						
<u>Anchoa mitchilli</u> larvae						
M10	0.100	0.100	0.100	0.100	0.000	0.000
M15	0.067	0.058	0.000	0.000	0.000	0.000
M11	0.033	0.058	0.133	0.153	0.033	0.058
M9	0.100	0.100	0.100	0.000	0.067	0.058
M1	0.067	0.058	0.000	0.000	0.000	0.000
M3	0.033	0.058	0.033	0.058	0.000	0.000
M6	0.133	0.058	0.000	0.000	0.000	0.000
M18	0.067	0.058	0.033	0.058	0.067	0.058
M20	0.067	0.058	0.000	0.000	0.033	0.058
<u>Anchoa mitchilli</u> postlarvae						
M10	0.067	0.058	0.000	0.000	0.000	0.000
M9	0.000	0.000	0.100	0.000	0.033	0.058
<u>Brevoortia</u> larvae						
M10	0.233	0.058	0.000	0.000	0.033	0.058
M15	0.133	0.153	0.033	0.058	0.033	0.058
M11	0.033	0.058	0.100	0.000	0.033	0.058
M9	0.000	0.000	0.033	0.058	0.033	0.058
M1	0.033	0.058	0.033	0.058	0.133	0.058
M3	0.133	0.153	0.133	0.058	0.067	0.058
M6	0.233	0.058	0.033	0.058	0.067	0.058
M18	0.033	0.058	0.000	0.000	0.033	0.058
M20	0.167	0.153	0.033	0.058	0.033	0.058
<u>Brevoortia</u> postlarvae						
M10	0.367	0.289	0.000	0.000	0.000	0.000
M15	2.533	0.404	0.033	0.058	0.000	0.000
M11	1.233	0.643	0.100	0.100	0.000	0.000
M9	0.167	0.208	0.067	0.058	0.033	0.058
M1	0.333	0.289	0.000	0.000	0.000	0.000
M3	0.633	0.611	0.000	0.000	0.033	0.058
M6	1.133	0.723	0.033	0.058	0.167	0.208
M18	0.333	0.493	0.000	0.000	0.000	0.000
M20	0.267	0.379	0.000	0.000	0.000	0.000

Table F-5. Data Summary of Decapod postlarvae and Fish larvae and postlarvae density (number per m³), marine March, 1981. Page 2
All replicates, .505 mm net

Station	Surface		Mid-depth		Bottom	
	Mean	S. D.	Mean	S. D.	Mean	S. D.
<u>Cynoscion arenarius</u> yolksac larvae						
M10	0.000	0.000	0.067	0.115	0.067	0.115
M11	0.000	0.000	0.000	0.000	0.067	0.058
M9	0.133	0.153	0.000	0.000	0.033	0.058
M1	0.000	0.000	0.000	0.000	0.067	0.115
M3	0.000	0.000	0.133	0.231	0.067	0.115
M6	0.000	0.000	0.100	0.173	0.033	0.058
M20	0.033	0.058	0.100	0.100	0.033	0.058
<u>Cynoscion arenarius</u> larvae						
M10	0.000	0.000	0.100	0.173	0.100	0.100
M15	0.000	0.000	0.067	0.058	0.067	0.058
M11	0.100	0.000	0.267	0.208	0.100	0.100
M9	0.133	0.058	1.067	0.231	0.967	1.193
M1	0.000	0.000	0.033	0.058	0.067	0.058
M3	0.000	0.000	0.233	0.153	0.167	0.058
M6	0.000	0.000	0.133	0.231	0.133	0.058
M18	0.033	0.058	0.000	0.000	0.067	0.058
M20	0.100	0.000	0.933	0.681	0.100	0.000
<u>Gobiesox strumosus</u> larvae						
M11	0.033	0.058	0.000	0.000	0.000	0.000
<u>Gobiidae</u> larvae						
M1	0.000	0.000	0.000	0.000	0.067	0.058
<u>Haemulon</u> (?) larvae						
M10	0.033	0.058	0.000	0.000	0.033	0.058
M11	0.000	0.000	0.067	0.058	0.000	0.000
M9	0.033	0.058	0.033	0.058	0.033	0.058
M20	0.000	0.000	0.067	0.115	0.033	0.058
<u>Haemulon</u> (?) postlarvae						
M9	0.000	0.000	0.033	0.058	0.000	0.000
<u>Syngnathus floridae</u> postlarvae						
M11	0.000	0.000	0.000	0.000	0.033	0.058
<u>Synodus foetens</u> postlarvae						
M9	0.000	0.000	0.033	0.058	0.000	0.000
Teleostei						
M18	0.000	0.000	0.067	0.115	0.000	0.000

Table F-6. Data Summary of Decapod postlarvae and Fish larvae and postlarvae density (number per m³), marine March, 1981.
All replicates, .333 mm net.

Station	Surface		Mid-depth		Bottom	
	Mean	S. D.	Mean	S. D.	Mean	S. D.
Decapods:						
<u>Lucifer faxoni</u> postlarvae						
M15	0.000	0.000	0.000	0.000	0.033	0.058
M11	0.033	0.058	0.000	0.000	0.000	0.000
Fishes:						
<u>Anchoa</u> larvae						
M11	0.000	0.000	0.000	0.000	0.033	0.058
M1	0.000	0.000	0.000	0.000	0.033	0.058
<u>Anchoa hepsetus</u> larvae						
M9	0.000	0.000	0.033	0.058	0.000	0.000
<u>Anchoa hepsetus</u> postlarvae						
M9	0.000	0.000	0.033	0.058	0.000	0.000
<u>Anchoa mitchilli</u> yolk sac larvae						
M9	0.000	0.000	0.033	0.058	0.000	0.000
M18	0.000	0.00	0.033	0.058	0.000	0.000
<u>Anchoa mitchilli</u> larvae						
M10	0.100	0.100	0.033	0.058	0.067	0.058
M15	0.000	0.000	0.000	0.000	0.033	0.058
M11	0.100	0.000	0.133	0.153	0.133	0.153
M9	0.067	0.058	0.033	0.058	0.233	0.153
M1	0.133	0.115	0.033	0.058	0.000	0.000
M3	0.167	0.153	0.033	0.058	0.000	0.000
M6	0.133	0.115	0.000	0.000	0.000	0.000
M18	0.067	0.058	0.000	0.000	0.033	0.058
M20	0.033	0.058	0.000	0.000	0.133	0.115
<u>Anchoa mitchilli</u> postlarvae						
M9	0.000	0.000	0.133	0.231	0.100	0.100
<u>Brevoortia</u> larvae						
M10	0.167	0.153	0.033	0.058	0.000	0.000
M15	0.067	0.058	0.067	0.058	0.000	0.000
M11	0.200	0.200	0.067	0.058	0.067	0.058
M9	0.067	0.058	0.033	0.058	0.067	0.058
M1	0.000	0.000	0.033	0.058	0.133	0.153
M3	0.067	0.058	0.167	0.058	0.033	0.058
M6	0.200	0.100	0.000	0.000	0.133	0.153
M18	0.200	0.100	0.067	0.058	0.000	0.000
M20	0.333	0.058	0.000	0.000	0.167	0.153

Table F-6. Data Summary of Decapod postlarvae and Fish larvae and postlarvae density (number per m³), marine March, 1981. Page 2
All replicates, .333 mm net.

Station	Surface		Mid-depth		Bottom	
	Mean	S. D.	Mean	S. D.	Mean	S. D.
<u>Brevoortia</u> postlarvae						
M10	0.267	0.153	0.000	0.000	0.000	0.000
M15	0.867	0.451	0.033	0.058	0.000	0.000
M11	0.100	0.100	0.033	0.058	0.000	0.000
M9	0.033	0.058	0.033	0.058	0.033	0.058
M1	0.067	0.115	0.033	0.058	0.000	0.000
M3	0.300	0.173	0.000	0.000	0.033	0.058
M6	1.000	0.500	0.033	0.058	0.067	0.115
M18	0.233	0.321	0.033	0.058	0.000	0.000
M20	0.233	0.404	0.000	0.000	0.000	0.000
<u>Cynoscion arenarius</u> yolksac larvae						
M10	0.000	0.000	0.133	0.115	0.233	0.252
M15	0.000	0.000	0.000	0.000	0.500	0.265
M11	0.067	0.115	0.233	0.231	0.167	0.153
M9	0.333	0.252	0.133	0.153	0.433	0.252
M1	0.033	0.058	0.000	0.000	0.133	0.058
M3	0.033	0.058	0.200	0.173	0.333	0.153
M6	0.033	0.058	0.267	0.379	0.433	0.666
M18	0.000	0.000	0.133	0.153	0.567	0.379
M20	0.067	0.058	0.767	1.079	0.200	0.200
<u>Cynoscion arenarius</u> larvae						
M10	0.000	0.000	0.000	0.000	0.133	0.058
M15	0.000	0.000	0.000	0.000	0.033	0.058
M11	0.200	0.100	0.333	0.153	0.133	0.058
M9	0.200	0.000	0.967	0.651	1.700	0.985
M1	0.000	0.000	0.000	0.000	0.133	0.115
M3	0.000	0.000	0.167	0.153	0.167	0.058
M6	0.033	0.058	0.233	0.321	0.400	0.100
M18	0.067	0.058	0.100	0.100	0.233	0.115
M20	0.167	0.058	1.100	1.127	0.267	0.231
<u>Cynoscion arenarius</u> postlarvae						
M15	0.000	0.000	0.200	0.346	0.000	0.000
<u>Menticirrhus americanus</u> larvae						
M9	0.000	0.000	0.000	0.000	0.033	0.058
M6	0.000	0.000	0.000	0.000	0.033	0.058

Table F-6. Data Summary of Decapod postlarvae and Fish larvae and postlarvae density (number per m³), marine March, 1981. Page 3
All replicates, .333 mm net

Station	Surface		Mid-depth		Bottom	
	Mean	S. D.	Mean	S. D.	Mean	S. D.
<u>Gobiesox strumosus</u> larvae						
M10	0.000	0.000	0.000	0.000	0.033	0.058
M15	0.000	0.000	0.033	0.058	0.000	0.000
M11	0.000	0.000	0.033	0.058	0.000	0.000
M9	0.000	0.000	0.033	0.058	0.000	0.000
<u>Gobiidae</u> larvae						
M1	0.000	0.000	0.000	0.000	0.067	0.058
M6	0.033	0.058	0.000	0.000	0.000	0.000
<u>Haemulon</u> (?) sp. yolksac larvae						
M18	0.067	0.115	0.000	0.000	0.000	0.000
<u>Haemulon</u> (?) sp. larvae						
M10	0.000	0.000	0.000	0.000	0.033	0.058
M11	0.067	0.058	0.033	0.058	0.000	0.000
M9	0.033	0.058	0.033	0.058	0.000	0.000
M6	0.000	0.000	0.000	0.000	0.033	0.058
M18	0.067	0.058	0.000	0.000	0.033	0.058
M20	0.033	0.058	0.100	0.173	0.033	0.058
<u>Haemulon</u> (?) sp. postlarvae						
M9	0.000	0.000	0.033	0.058	0.000	0.000
<u>Syngnathus floridae</u> postlarvae						
M15	0.033	0.058	0.000	0.000	0.000	0.000
<u>Syngnathus louisianae</u> postlarvae						
M9	0.000	0.000	0.033	0.058	0.000	0.000
<u>Unid. Teleostei</u> yolksac larvae						
M1	0.033	0.058	0.000	0.000	0.000	0.000
M18	0.033	0.058	0.000	0.000	0.000	0.000

Table F-7. Data Summary of Decapod postlarvae and Fish larvae and postlarvae density (number per m³), marine April, 1981.
All replicates, .505 mm net.

Station	Surface		Mid-depth		Bottom	
	Mean	S. D.	Mean	S. D.	Mean	S. D.
Decapods:						
<u>Acetes americanus</u> postlarvae						
M9	0.000	0.000	0.000	0.000	0.033	0.058
<u>Lucifer faxoni</u> postlarvae						
M1	0.067	0.058	0.000	0.000	0.067	0.115
M3	0.000	0.000	0.200	0.265	0.300	0.173
M6	0.033	0.058	0.000	0.000	0.033	0.058
M10	0.100	0.100	0.000	0.000	0.117	0.076
M15	0.000	0.000	0.067	0.058	0.067	0.058
M18	0.000	0.000	0.067	0.058	0.233	0.153
M20	0.067	0.058	0.067	0.058	0.100	0.100
M11	0.000	0.000	0.033	0.058	0.000	0.000
M9	0.067	0.058	0.033	0.058	0.067	0.058
<u>Penaeus</u> postlarvae						
M1	0.000	0.000	0.000	0.000	0.033	0.058
M3	0.033	0.058	0.033	0.058	0.100	0.100
M6	0.100	0.100	0.000	0.000	0.000	0.000
M10	0.100	0.100	0.000	0.000	0.000	0.000
M15	0.067	0.115	0.033	0.058	0.000	0.000
M9	0.033	0.058	0.000	0.000	0.000	0.000
<u>Sicyonia</u> postlarvae						
M15	0.000	0.000	0.000	0.000	0.167	0.289
Fishes:						
<u>unid. tetraodontiform</u> larvae						
M1	0.000	0.000	0.000	0.000	0.033	0.058
<u>Anchoa yolksac</u> larvae						
M3	0.000	0.000	0.033	0.058	0.000	0.000
M18	0.033	0.058	0.000	0.000	0.000	0.000
<u>Anchoa</u> larvae						
M3	0.000	0.000	0.833	0.666	0.233	0.153
M6	0.000	0.000	0.700	0.656	0.467	0.808
M10	0.000	0.000	0.233	0.115	0.633	0.681
M15	0.000	0.000	0.000	0.000	0.100	0.100
M18	0.367	0.153	0.400	0.100	0.167	0.058
<u>Anchoa</u> postlarvae						
M15	0.000	0.000	0.000	0.000	0.033	0.058
M18	0.033	0.058	0.000	0.000	0.167	0.289

Table F-7. Data Summary of Decapod postlarvae and Fish larvae and postlarvae density (number per m³), marine, April, 1981. Page 2.
All replicates, .505 mm net.

Station	Surface		Mid-depth		Bottom	
	Mean	S. D.	Mean	S. D.	Mean	S. D.
<u>Anchoa mitchilli</u> yolk sac larvae						
M1	0.000	0.000	0.100	0.173	0.067	0.058
M3	0.033	0.058	0.000	0.000	0.000	0.000
M6	0.000	0.000	0.000	0.000	0.033	0.058
M10	0.033	0.058	0.000	0.000	0.000	0.000
M15	0.033	0.058	0.000	0.000	0.000	0.000
M9	0.033	0.058	0.000	0.000	0.000	0.000
<u>Anchoa mitchilli</u> larvae						
M1	0.100	0.100	2.367	1.901	5.533	3.350
M3	0.200	0.265	0.000	0.000	0.000	0.000
M6	0.433	0.351	0.433	0.751	0.000	0.000
M10	2.167	0.153	0.000	0.000	0.000	0.000
M15	0.533	0.839	0.400	0.300	0.000	0.000
M20	0.067	0.058	0.100	0.100	0.233	0.058
M11	0.033	0.058	0.333	0.416	1.600	0.866
M9	0.100	0.100	0.367	0.306	0.833	0.404
<u>Anchoa mitchilli</u> postlarvae						
M1	0.033	0.058	0.033	0.058	0.200	0.100
M6	0.033	0.058	0.000	0.000	0.000	0.000
M15	0.000	0.000	0.033	0.058	0.000	0.000
M20	0.033	0.058	0.033	0.058	0.067	0.058
M11	0.000	0.000	0.000	0.000	0.033	0.058
M9	0.000	0.000	0.067	0.058	0.100	0.100
<u>Brevoortia</u> postlarvae						
M1	0.333	0.404	0.133	0.058	0.000	0.000
M3	0.067	0.058	0.000	0.000	0.000	0.000
M15	0.067	0.115	0.033	0.058	0.000	0.000
M18	0.033	0.058	0.000	0.000	0.000	0.000
M11	0.000	0.000	0.033	0.058	0.000	0.000
M9	0.233	0.231	0.033	0.058	0.000	0.000
<u>Cynoscion arenarius</u> yolk sac larvae						
M1	0.000	0.000	0.033	0.058	0.000	0.000
M15	0.033	0.058	0.000	0.000	0.000	0.000
M9	0.000	0.000	0.000	0.000	0.033	0.058
<u>Cynoscion arenarius</u> larvae						
M1	0.033	0.058	0.167	0.058	0.500	0.346
M3	0.033	0.058	0.200	0.000	0.200	0.100
M6	0.033	0.058	0.133	0.058	0.267	0.208
M10	0.067	0.115	0.367	0.231	0.400	0.436
M15	0.000	0.000	0.333	0.058	0.367	0.153
M18	0.267	0.115	0.267	0.306	0.100	0.000
M20	0.000	0.000	0.000	0.000	0.067	0.058
M11	0.000	0.000	0.200	0.265	1.167	0.666
M9	0.000	0.000	0.100	0.000	0.067	0.115

Table F-7. Data Summary of Decapod postlarvae and Fish larvae and postlarvae density (number per m³), marine April, 1981. Page 3
All replicates, .505 mm net

Station	Surface		Mid-depth		Bottom	
	Mean	S. D.	Mean	S. D.	Mean	S. D.
<u>Cynoscion arenarius</u> postlarvae						
M1	0.000	0.000	0.000	0.000	0.033	0.058
M11	0.000	0.000	0.000	0.000	0.067	0.058
<u>Gobiesox strumosus</u> larvae						
M1	0.000	0.000	0.033	0.058	0.067	0.115
M3	0.000	0.000	0.000	0.000	0.167	0.153
M6	0.033	0.058	0.000	0.000	0.033	0.058
M10	0.067	0.115	0.033	0.058	0.100	0.100
M15	0.000	0.000	0.000	0.000	0.033	0.058
M18	0.033	0.058	0.033	0.058	0.133	0.153
M11	0.000	0.000	0.033	0.058	0.000	0.000
M9	0.000	0.000	0.000	0.000	0.033	0.058
<u>Gobiesox strumosus</u> postlarvae						
M1	0.000	0.000	0.033	0.058	0.067	0.115
M3	0.000	0.000	0.000	0.000	0.033	0.058
M6	0.033	0.058	0.000	0.000	0.000	0.000
M10	0.033	0.058	0.000	0.000	0.000	0.000
<u>Haemulon (?) sp.</u> larvae						
M10	0.000	0.000	0.033	0.058	0.033	0.058
M18	0.000	0.000	0.033	0.058	0.000	0.000
<u>Harengula pensacolatae</u> yolksac larvae						
M6	0.000	0.000	0.000	0.000	0.033	0.058
M10	0.000	0.000	0.033	0.058	0.000	0.000
M18	0.833	0.416	0.000	0.000	0.033	0.058
M9	0.067	0.115	0.033	0.058	0.000	0.000
<u>Harengula pensacolatae</u> larvae						
M15	0.000	0.000	0.033	0.058	0.000	0.000
M18	0.000	0.000	0.133	0.231	0.067	0.058
M20	0.000	0.000	0.000	0.000	0.067	0.058
M11	0.000	0.000	0.100	0.000	0.033	0.058
M9	0.000	0.000	0.267	0.462	0.133	0.153
unid. Blenniidae larvae						
M3	0.033	0.058	0.033	0.058	0.000	0.000
M10	0.000	0.000	0.033	0.058	0.000	0.000
M18	0.067	0.058	0.033	0.058	0.000	0.000
M20	0.033	0.058	0.033	0.058	0.000	0.000
M11	0.000	0.000	0.000	0.000	0.033	0.058
<u>Lagodon rhomboides</u> postlarvae						
M1	0.033	0.058	0.000	0.000	0.000	0.000

Table F-7. Data Summary of Decapod postlarvae and Fish larvae and postlarvae density (number per m³), marine April, 1981. Page 4
All replicates, .505 mm net.

Station	Surface		Mid-depth		Bottom	
	Mean	S. D.	Mean	S. D.	Mean	S. D.
<u>Menticirrhus americanus</u> larvae						
M1	0.000	0.000	0.033	0.058	0.033	0.058
M3	0.000	0.000	0.067	0.115	0.033	0.058
M6	0.000	0.000	0.033	0.058	0.000	0.000
M10	0.000	0.000	0.033	0.058	0.300	0.116
M15	0.000	0.000	0.433	0.058	0.267	0.153
M18	0.000	0.000	0.067	0.058	0.033	0.058
M20	0.033	0.058	0.033	0.058	0.000	0.000
M11	0.000	0.000	0.100	0.100	0.100	0.100
M9	0.000	0.000	0.000	0.000	0.067	0.058
<u>Menticirrhus americanus</u> postlarvae						
M1	0.000	0.000	0.000	0.000	0.033	0.058
M3	0.000	0.000	0.000	0.000	0.033	0.058
<u>Archosargus probatocephalus</u> larvae						
M3	0.033	0.058	0.000	0.000	0.000	0.000
M6	0.100	0.000	0.033	0.058	0.000	0.000
M18	0.033	0.058	0.000	0.000	0.000	0.000
M9	0.033	0.058	0.000	0.000	0.000	0.000
<u>Archosargus probatocephalus</u> postlarvae						
M1	0.000	0.000	0.033	0.058	0.000	0.000
M3	0.000	0.000	0.033	0.058	0.000	0.000
M6	0.100	0.000	0.000	0.000	0.000	0.000
M15	0.033	0.058	0.033	0.058	0.000	0.000
M20	0.067	0.058	0.000	0.000	0.000	0.000
M11	0.000	0.000	0.033	0.058	0.000	0.000
M9	0.067	0.058	0.000	0.000	0.000	0.000
<u>Syngnathus</u> larvae						
M6	0.000	0.000	0.000	0.000	0.033	0.058
<u>Synodus foetens</u> postlarvae						
M1	0.033	0.058	0.000	0.000	0.000	0.000
<u>Trichiurus lepturus</u> larvae						
M18	0.000	0.000	0.000	0.000	0.033	0.058
<u>Unid. Teleostei</u> larvae						
M15	0.000	0.000	0.000	0.000	0.033	0.058

Table F-8. Data Summary of Decapod postlarvae and Fish larvae and postlarvae density (number per m³), marine, April, 1981.
All replicates, .333 mm net.

Station	Surface		Mid-depth		Bottom	
	Mean	S. D.	Mean	S. D.	Mean	S. D.
Decapods:						
<u>Acetes americanus</u> postlarvae						
M3	0.000	0.000	0.000	0.000	0.067	0.058
<u>Lucifer faxoni</u> postlarvae						
M1	0.000	0.000	0.067	0.058	0.067	0.058
M3	0.000	0.000	0.067	0.115	0.167	0.153
M6	0.000	0.000	0.033	0.058	0.067	0.058
M10	0.033	0.058	0.000	0.000	0.067	0.058
M15	0.033	0.058	0.067	0.115	0.033	0.058
M18	0.000	0.000	0.100	0.000	0.233	0.153
M20	0.100	0.000	0.033	0.058	0.067	0.058
M11	0.000	0.000	0.033	0.058	0.033	0.058
M9	0.067	0.058	0.067	0.058	0.067	0.058
<u>Penaeus</u> postlarvae						
M1	0.000	0.000	0.000	0.000	0.033	0.058
M3	0.067	0.058	0.000	0.000	0.033	0.058
M6	0.133	0.058	0.000	0.000	0.000	0.000
M10	0.167	0.208	0.000	0.000	0.000	0.000
M15	0.033	0.058	0.000	0.000	0.000	0.000
M20	0.067	0.115	0.000	0.000	0.000	0.000
M11	0.033	0.058	0.000	0.000	0.000	0.000
M9	0.067	0.058	0.000	0.000	0.000	0.000
Fishes:						
<u>Anchoa</u> yolksac larvae						
M3	0.000	0.000	0.033	0.058	0.000	0.000
M6	0.000	0.000	0.100	0.173	0.000	0.000
M10	0.000	0.000	0.100	0.173	0.033	0.058
M15	0.000	0.000	0.000	0.000	0.133	0.231
<u>Anchoa</u> larvae						
M3	0.000	0.000	0.967	0.351	0.167	0.289
M6	0.000	0.000	1.600	0.872	0.367	0.551
M10	0.000	0.000	1.033	0.603	0.367	0.473
M15	0.000	0.000	0.000	0.000	0.167	0.208
M18	0.367	0.306	0.433	0.252	0.267	0.306
<u>Anchoa</u> postlarvae						
M10	0.000	0.000	0.033	0.058	0.000	0.000
M15	0.000	0.000	0.000	0.000	0.033	0.058
M18	0.000	0.000	0.000	0.000	0.067	0.115
<u>Anchoa mitchilli</u> yolksac larvae						
M1	0.000	0.000	0.433	0.586	0.033	0.058
M3	0.000	0.000	0.000	0.000	0.033	0.058
M15	0.033	0.058	0.000	0.000	0.167	0.289
M18	0.000	0.000	0.000	0.000	0.067	0.115
M20	0.000	0.000	0.000	0.000	0.067	0.115

Table F-8. Data Summary of Decapod postlarvae and Fish larvae and postlarvae density (number per m³), marine, April, 1981. Page 2.
All replicates, .333 mm net.

Station	Surface		Mid-depth		Bottom	
	Mean	S. D.	Mean	S. D.	Mean	S. D.
<u>Anchoa mitchilli</u> larvae						
M1	0.600	0.361	3.533	0.551	5.467	4.082
M3	0.433	0.416	0.000	0.000	0.100	0.173
M6	1.633	0.666	0.000	0.000	0.000	0.000
M10	4.800	3.637	0.000	0.000	0.000	0.000
M15	1.233	0.551	0.900	1.153	0.067	0.115
M20	0.033	0.058	0.233	0.231	0.600	0.173
M11	0.000	0.000	1.367	1.626	2.567	0.473
M9	0.100	0.000	0.333	0.153	0.533	0.351
<u>Anchoa mitchilli</u> postlarvae						
M1	0.067	0.058	0.033	0.058	0.200	0.100
M6	0.033	0.058	0.000	0.000	0.000	0.000
M15	0.067	0.115	0.000	0.000	0.000	0.000
M20	0.067	0.058	0.033	0.058	0.033	0.058
M11	0.000	0.000	0.000	0.000	0.033	0.058
M9	0.033	0.058	0.033	0.058	0.167	0.208
<u>Brevoortia</u> postlarvae						
M1	0.367	0.321	0.100	0.100	0.000	0.000
M3	0.000	0.000	0.000	0.000	0.033	0.058
M6	0.367	0.551	0.000	0.000	0.000	0.000
M10	0.033	0.058	0.000	0.000	0.000	0.000
M15	0.200	0.265	0.000	0.000	0.000	0.000
M18	0.033	0.058	0.000	0.000	0.000	0.000
M9	0.433	0.321	0.067	0.058	0.000	0.000
<u>Citharichthys spilopterus</u> larvae						
M1	0.000	0.000	0.000	0.000	0.033	0.058
<u>Cynoscion arenarius</u> yolksac larvae						
M1	0.000	0.000	0.333	0.493	0.067	0.115
M3	0.033	0.058	0.067	0.058	0.100	0.100
M6	0.067	0.058	0.033	0.058	0.067	0.058
M10	0.000	0.000	0.333	0.351	0.233	0.321
M15	0.000	0.000	0.000	0.000	0.533	0.924
M18	0.000	0.000	0.133	0.115	0.133	0.231
M20	0.000	0.000	0.000	0.000	0.033	0.058
M11	0.033	0.058	0.100	0.173	0.033	0.058
M9	0.000	0.000	0.633	0.681	0.167	0.153
<u>Cynoscion arenarius</u> larvae						
M1	0.100	0.000	0.367	0.115	0.533	0.208
M3	0.067	0.115	0.233	0.153	0.200	0.100
M6	0.100	0.000	0.500	0.300	0.433	0.321
M10	0.333	0.058	1.433	0.306	0.633	0.306
M15	0.233	0.231	1.433	1.002	0.467	0.321
M18	0.033	0.058	0.433	0.153	0.100	0.100

Table F-8. Data Summary of Decapod postlarvae and Fish larvae and postlarvae density (number per m³), marine, April, 1981. Page 3
All replicates, .333 mm net.

Station	Surface		Mid-depth		Bottom	
	Mean	S. D.	Mean	S. D.	Mean	S. D.
<u>Cynoscion arenarius</u> larvae (cont'd)						
M20	0.000	0.000	0.067	0.058	0.000	0.000
M11	0.033	0.058	0.433	0.321	1.200	0.458
M9	0.033	0.058	0.267	0.058	0.133	0.058
<u>Cynoscion arenarius</u> postlarvae						
M1	0.000	0.000	0.033	0.058	0.033	0.058
M3	0.000	0.000	0.000	0.000	0.100	0.100
M11	0.000	0.000	0.033	0.058	0.000	0.000
<u>Gobiesox strumosus</u> yolksac larvae						
M15	0.000	0.000	0.000	0.000	0.133	0.231
<u>Gobiesox strumosus</u> larvae						
M1	0.000	0.000	0.067	0.058	0.067	0.115
M3	0.033	0.058	0.000	0.000	0.067	0.058
M6	0.000	0.000	0.033	0.058	0.067	0.058
M10	0.000	0.000	0.000	0.000	0.067	0.115
M15	0.000	0.000	0.067	0.115	0.100	0.000
M18	0.000	0.000	0.033	0.058	0.033	0.058
M20	0.033	0.058	0.000	0.000	0.000	0.000
M11	0.100	0.100	0.000	0.000	0.000	0.000
M9	0.000	0.000	0.000	0.000	0.100	0.173
<u>Gobiesox strumosus</u> postlarvae						
M1	0.000	0.000	0.000	0.000	0.067	0.115
<u>Haemulon (?) sp.</u>						
M6	0.000	0.000	0.033	0.058	0.033	0.058
M10	0.000	0.000	0.033	0.058	0.000	0.000
M15	0.000	0.000	0.067	0.115	0.000	0.000
M18	0.000	0.000	0.067	0.058	0.000	0.000
<u>Harengula pensacolae</u> yolksac larvae						
M10	0.000	0.000	0.033	0.058	0.000	0.000
M18	0.033	0.058	0.000	0.000	0.000	0.000
M11	0.000	0.000	0.033	0.058	0.100	0.173
M9	0.000	0.000	0.633	1.012	0.000	0.000
<u>Harengula pensacolae</u> larvae						
M10	0.000	0.000	0.000	0.000	0.033	0.058
M15	0.000	0.000	0.067	0.115	0.433	0.586
M18	0.000	0.000	0.333	0.493	0.000	0.000
M20	0.000	0.000	0.000	0.000	0.200	0.265
M11	0.033	0.058	0.333	0.404	0.000	0.000
M9	0.000	0.000	1.433	2.312	0.933	1.210

Table F-8. Data Summary of Decapod postlarvae and Fish larvae and postlarvae density (number per m³), marine, April, 1981. Page 4
All replicates, .333 mm net

Station	Surface		Mid-depth		Bottom	
	Mean	S. D.	Mean	S. D.	Mean	S. D.
<u>unid. Blenniidae larvae</u>						
M1	0.067	0.058	0.000	0.000	0.000	0.000
M3	0.033	0.058	0.033	0.058	0.000	0.000
M10	0.033	0.058	0.033	0.058	0.000	0.000
M15	0.000	0.000	0.067	0.115	0.067	0.058
M20	0.000	0.000	0.033	0.058	0.100	0.000
<u>Menidia beryllina larvae</u>						
M3	0.033	0.058	0.000	0.000	0.000	0.000
M6	0.033	0.058	0.000	0.000	0.000	0.000
<u>Menticirrhus americanus larvae</u>						
M1	0.033	0.058	0.066	0.116	0.000	0.000
M3	0.000	0.000	0.167	0.153	0.000	0.000
M6	0.000	0.000	0.033	0.058	0.033	0.058
M10	0.000	0.000	0.267	0.252	0.400	0.310
M15	0.000	0.000	1.600	1.217	0.367	0.462
M18	0.000	0.000	0.200	0.000	0.133	0.115
M20	0.000	0.000	0.000	0.000	0.033	0.058
M11	0.000	0.000	0.100	0.100	0.100	0.100
M9	0.033	0.058	0.033	0.058	0.033	0.058
<u>Menticirrhus americanus postlarvae</u>						
M9	0.000	0.000	0.000	0.000	0.033	0.058
M11	0.000	0.000	0.033	0.038	0.067	0.058
<u>Prionotus postlarvae</u>						
M11	0.000	0.000	0.033	0.058	0.000	0.000
<u>Sciaenidae larvae</u>						
M15	0.000	0.000	0.000	0.000	0.067	0.115
<u>Archosargus probatocephalus larvae</u>						
M3	0.033	0.058	0.000	0.000	0.000	0.000
M6	0.067	0.058	0.000	0.000	0.000	0.000
M9	0.067	0.058	0.000	0.000	0.000	0.000
<u>Archosargus probatocephalus postlarvae</u>						
M15	0.033	0.058	0.000	0.000	0.000	0.000
M18	0.033	0.058	0.000	0.000	0.000	0.000
M20	0.033	0.058	0.000	0.000	0.000	0.000
M9	0.100	0.000	0.000	0.000	0.000	0.000
<u>Symphurus larvae</u>						
M11	0.000	0.000	0.000	0.000	0.033	0.058
<u>Syngnathus postlarvae</u>						
M3	0.000	0.000	0.000	0.000	0.033	0.058
M15	0.000	0.000	0.000	0.000	0.033	0.058

Table F-8. Data Summary of Decapod postlarvae and Fish larvae and postlarvae density (number per m³), marine, April, 1981. Page 5
All replicates, .333 mm net.

Station	Surface		Mid-depth		Bottom	
	Mean	S. D.	Mean	S. D.	Mean	S. D.
<u>Synodus foetens</u> larvae						
M15	0.000	0.000	0.000	0.000	0.033	0.058
<u>Synodus foetens</u> postlarvae						
M1	0.033	0.058	0.033	0.058	0.000	0.000
<u>Trichiurus lepturus</u> yolksac larvae						
M1	0.000	0.000	0.000	0.000	0.033	0.058
<u>Trichiurus lepturus</u> larvae						
M3	0.000	0.000	0.033	0.058	0.000	0.000
Unid. Teleostei yolksac larvae						
M9	0.000	0.000	0.033	0.058	0.000	0.000

Table F-9. Mean concentration (number/cubic meter) for marine taxa based on first replicates from all depths. Page 1.

NAME	MESH SIZE	FEBRUARY	MARCH	APRIL
Annelida - (Polychaeta)	505	0.0000	0.0000	0.5074
	333	0.0000	1.5741	3.9815
<u>Littorina</u> sp.	505	0.0000	0.0000	0.0000
	333	0.0000	0.0037	0.0000
<u>Crepidula</u> sp.	505	0.0000	0.0000	0.0000
	333	0.0000	0.0037	0.0000
<u>Atlanta gaudichaudi</u>	555	0.0000	0.0000	0.0519
	333	0.0000	0.0000	0.1370
<u>Atlanta helicinoides</u>	505	0.0000	0.0000	0.0037
	333	0.0000	0.0000	0.0111
Naticidae	505	0.0037	0.0222	0.0000
	333	0.0167	0.2667	0.0037
<u>Polinices duplicatus</u>	505	0.0000	0.0000	0.0000
	333	0.0037	0.0000	0.0000
<u>Nassarius</u> sp.	505	0.0000	0.0222	0.0148
	333	0.0000	0.3481	1.3074
<u>Limacina trochiformis</u>	505	0.0000	0.0000	0.0148
	333	0.0000	0.0000	0.0444
<u>Creseis acicula</u>	505	0.0000	0.0000	0.0000
	333	0.0000	0.0000	0.0037
<u>Creseis conica</u>	505	0.0000	0.0000	0.4556
	333	0.0000	0.0148	1.6741
Prosobranchia	505	0.0000	0.0000	0.0000
	333	0.0000	0.0815	0.0037
Opisthobranchia	505	0.0000	0.0000	0.0037
	333	0.0000	0.1667	0.0259

Table F-9. (continued) Page 2.

NAME	MESH SIZE	FEBRUARY	MARCH	APRIL
Nudibranchia	505	0.0148	0.0074	0.0000
	333	0.0167	0.0037	0.0000
Pelecypoda	505	0.0019	0.0000	0.0000
	333	0.0093	0.0074	0.0000
<u>Petricola pholadiformis</u>	505	0.0000	0.0000	0.0000
	333	0.0074	0.0000	0.0000
<u>Tellina</u> sp.	555	0.0259	0.0000	0.0000
	333	0.4296	0.0148	0.0000
<u>Ensis minor</u>	505	0.0037	0.0074	0.0000
	333	0.0463	0.0296	0.0000
<u>Mulinia lateralis</u>	505	0.0000	0.0000	0.0000
	333	0.0185	0.0000	0.3667
"Planktomya henseni"	505	0.0000	0.0000	0.0037
	333	0.0000	0.0000	0.0000
<u>Lolliguncula brevis</u>	505	0.0000	0.0000	0.0074
	333	0.0000	0.0000	0.0000
<u>Penilia avirostris</u>	505	0.0000	0.0000	0.0519
	333	0.0000	0.0000	0.7926
<u>Podon polyphemoides</u>	505	0.0000	0.5370	0.0000
	333	0.0000	168.6150	0.0000
<u>Evadne tergestina</u>	505	0.0000	0.0000	0.0519
	333	0.0000	0.0000	0.4259
Ostracoda	505	0.0000	0.0000	0.0000
	333	0.0000	0.0778	0.0000
Copepoda-total	505	19.0886	230.4165	120.2146
	333	994.4038	7821.0000	1171.4292

Table F-9. (continued) Page 3.

NAME	MESH SIZE	FEBRUARY	MARCH	APRIL
<u>Harpacticoid</u> sp.A	505	0.0000	0.0000	0.0037
	333	0.0000	0.0000	0.0000
Caligoida	505	0.0333	0.0407	0.0444
	333	0.2407	0.0000	0.0000
<u>Eucalanus</u> sp. I-IV	505	0.0963	0.1370	0.2296
	333	0.5889	0.0000	0.1185
<u>Eucalanus</u> <u>pileatus</u>	555	0.0000	0.0000	0.8593
	333	0.0000	0.0000	2.2815
<u>Rhincalanus</u> <u>cornutus</u>	505	0.0370	0.0370	0.0000
	333	0.000	0.0000	0.1444
<u>Nannocalanus</u> <u>minor</u>	505	0.0222	0.0667	0.0370
	333	0.0000	0.0815	0.0000
<u>Paracalanus</u> <u>quasimodo</u>	505	0.0519	0.0000	* 0.4074
	333	9.7333	25.3333	104.1702
<u>Temora</u> sp. I-IV	505	0.0000	0.0000	0.0000
	333	0.1333	0.0000	0.0000
<u>Temora</u> <u>stylifera</u>	505	0.3333	0.0741	0.8444
	333	0.0815	0.1556	2.9518
<u>Temora</u> <u>turbinata</u>	505	0.3630	1.5074	49.0443
	333	1.7704	14.0555	189.9986
<u>Centropages</u> sp. I-IV	505	0.0000	0.0000	0.0074
	333	0.0000	0.0000	0.0000
<u>Centropages</u> <u>velificatus</u>	505	0.0148	0.0296	0.2815
	333	0.0000	0.0000	0.9000
<u>Centropages</u> <u>hamatus</u>	505	12.0414	40.1369	0.9815
	333	416.0212	1121.2114	4.5741

Table F-9. (continued) Page 4.

NAME	MESH SIZE	FEBRUARY	MARCH	APRIL
<u>Centropages violaceus</u>	505	0.0074	0.0000	0.0000
	333	0.0000	0.0000	0.0000
<u>Pseudodiaptomus coronatus</u>	505	0.0000	0.0000	0.0000
	333	0.0000	0.0000	1.5630
<u>Labidocera aestiva</u>	505	0.3667	14.8851	38.7332
	333	3.1963	48.9592	68.2258
<u>Acartia tonsa</u>	555	4.8185	167.4028	24.9517
	333	525.1401	6528.2738	752.3740
<u>Oithona plumifera</u>	505	0.0000	0.0000	0.0000
	333	0.0222	0.0000	0.0000
<u>Oncaea mediterranea</u>	505	0.0000	0.0074	0.0000
	333	0.6148	0.0000	0.8667
<u>Corycaeus amazonicus</u>	505	0.0000	0.0074	0.0667
	333	0.0000	0.7926	0.5630
<u>Corycaeus subulatus</u>	505	0.0111	0.9778	0.3419
	333	4.0444	43.3110	4.8963
<u>Sapphirina nigromaculata</u>	505	0.0000	0.0000	0.0074
	333	0.0000	0.0000	0.0000
<u>Argulus</u> sp.	505	0.0000	0.0000	0.0000
	333	0.0000	0.0000	0.5148
<u>Cirripecta</u>	505	0.1333	6.4407	41.7814
	333	203.4400	612.3691	515.5845
<u>Promysis atlantica</u>	505	0.0000	0.0444	0.0000
	333	0.0000	0.0000	0.0000
<u>Oxyurostylis</u> sp.	505	0.0000	0.0000	0.0111
	333	0.0000	0.0000	1.0296

Table F-9. (continued) Page 5.

NAME	MESH SIZE	FEBRUARY	MARCH	APRIL
<u>Hyperiid</u> ae	505	0.0000	0.0000	0.0667
	333	0.0000	0.0000	0.0000
<u>Eucarida</u> Decapoda	505	0.0000	0.0000	0.0074
	333	0.0000	0.0000	0.0074
<u>Penaeus</u> sp.	505	0.0259	0.0037	0.0222
	333	0.0148	0.0037	0.0185
<u>Trachypenaeus</u> sp.	555	0.0000	0.0000	0.0556
	333	0.0000	0.0000	0.0481
<u>Sicyonia</u> sp.	505	0.0000	0.0000	0.0259
	333	0.0000	0.0000	0.0704
<u>Xiphopenaeus</u> <u>kroyeri</u>	505	0.0000	0.0000	0.0000
	333	0.0000	0.0000	0.0037
<u>Acetes</u> <u>americanus</u>	505	0.0000	0.0000	0.0148
	333	0.0000	0.0000	0.2407
<u>Lucifer</u> <u>faxonii</u>	505	0.0000	0.0037	0.3037
	333	0.0019	0.0037	0.6926
<u>Palaemonetes</u> sp.	505	0.0000	0.0000	0.1111
	333	0.0000	0.0000	0.1148
<u>Ogyrides</u> <u>alphaerostris</u>	505	0.0000	0.1111	0.1148
	333	0.0111	0.0444	0.3185
<u>Hippolyte</u> <u>pleuracantha</u>	505	0.0000	0.0037	0.0000
	333	0.0000	0.0259	0.0000
<u>Eucramus</u> <u>praelongus</u>	505	0.0074	0.0741	0.2741
	333	0.0074	0.0333	0.1074
<u>Porcellana</u> sp.	505	0.0000	0.0037	0.0037
	333	0.0000	0.0074	0.1333

Table F-9. (continued) Page 6.

NAME	MESH SIZE	FEBRUARY	MARCH	APRIL
<u>Petrolisthes</u> sp.	505	0.0000	0.0074	0.0333
	333	0.0000	0.0333	0.0185
Diogenidae	505	0.0000	0.0000	0.0037
	333	0.0000	0.0000	0.0000
<u>Pagurus</u> spp.	505	0.0370	0.3556	0.9593
	333	0.0556	0.4370	1.5481
<u>Callinectes</u> spp.	555	0.0426	0.0444	0.0667
	333	0.0574	0.0222	0.2815
<u>Callinectes</u> <u>sapidus</u>	505	0.0000	0.0000	0.0000
	333	0.0000	0.0000	0.0111
<u>Callinectes</u> <u>similis</u>	505	0.0000	0.0000	0.0000
	333	0.0074	0.0000	0.0000
<u>Ovalipes</u> <u>floridanus</u>	505	0.0093	0.0000	0.0000
	333	0.0111	0.0000	0.0000
<u>Portunus</u> spp.	505	0.0000	0.0000	0.0000
	333	0.0000	0.0000	0.0037
<u>Portunus</u> <u>gibbesii</u>	505	0.0000	0.0000	0.0222
	333	0.0000	0.0000	0.0148
<u>Portunus</u> <u>spinimanus</u>	505	0.0000	0.0000	0.0000
	333	0.0000	0.0000	0.0037
<u>Hexapanopeus</u> <u>angustifrons</u>	505	0.0000	0.0000	1.1593
	333	0.0000	0.0000	1.0000
<u>Pinnixa</u> spp.	505	0.0796	0.6222	5.3222
	333	0.2222	0.9556	3.0815
<u>Uca</u> sp.	505	0.0000	0.0000	0.0074
	333	0.0000	0.0000	0.1259

Table F-9. (continued) Page 7.

NAME	MESH SIZE	FEBRUARY	MARCH	APRIL
<u>Libinia</u> sp.	505	0.0000	0.0000	0.0963
	333	0.0000	0.0000	0.1296
Chaetognatha-total	505	5.1667	4.3963	29.6370
	333	1.1852	15.2407	65.2407
<u>Sagitta</u> sp.	505	5.0593	1.1852	14.2445
	333	1.1852	9.0333	26.4666
<u>Sagitta enflata</u>	555	0.1074	0.0407	0.2185
	333	0.0000	0.4667	0.1259
<u>Sagitta helenae</u>	505	0.0000	0.0000	0.0037
	333	0.0000	0.0000	0.0000
<u>Sagitta friderici</u>	505	0.0000	3.1926	15.1778
	333	0.0000	5.7370	38.6518
<u>Oikopleura</u> sp.	505	0.0000	0.0519	0.6778
	333	0.0000	12.2926	27.0037
Teleostei	505	0.0000	0.0111	0.0000
	333	0.0000	0.0000	0.0000
<u>Myriophis punctatus</u>	505	0.0278	0.0000	0.0000
	333	0.0093	0.0000	0.0000
<u>Brevoortia</u> spp.	505	0.4463	0.3370	0.0556
	333	0.3685	0.2111	0.1370
<u>Brevoortia patronus</u>	505	0.0019	0.0000	0.0000
	333	0.0000	0.0000	0.0000
<u>Opisthonema oglinum</u>	505	0.0000	0.0000	0.0519
	333	0.0000	0.0000	0.0741
<u>Harengula pensacolae</u>	505	0.0000	0.0000	1.2148
	333	0.0000	0.0000	1.9444

Table F-9. (continued) Page 8.

NAME	MESH SIZE	FEBRUARY	MARCH	APRIL
<u>Anchoa</u> spp.	505	0.0000	0.0000	0.1889
	333	0.0000	0.0074	0.3074
<u>Anchoa hepsetus</u>	505	0.0000	0.0556	0.5481
	333	0.0000	0.0407	0.3000
<u>Anchoa mitchilli</u>	505	0.0000	0.6481	4.1074
	333	0.0037	0.5259	3.5667
<u>Synodus foetens</u>	555	0.0000	0.0000	0.0000
	333	0.0000	0.0000	0.0037
<u>Gobiesox strumosus</u>	505	0.0000	0.0000	0.0333
	333	0.0019	0.0074	0.0370
<u>Menidia beryllina</u>	505	0.0000	0.0000	0.0000
	333	0.0000	0.0000	0.0037
<u>Syngnathus</u> sp.	505	0.0000	0.0000	0.0000
	333	0.0000	0.0000	0.0037
<u>Syngnathus floridae</u>	505	0.0000	0.0037	0.0000
	333	0.0000	0.0000	0.0000
<u>Syngnathus louisianae</u>	505	0.0000	0.0000	0.0000
	333	0.0019	0.0000	0.0000
<u>Haemulon</u> (?) sp.	505	0.0000	0.0111	0.0000
	333	0.0000	0.0185	0.0185
<u>Archosargus probatocephalus</u>	505	0.0000	0.0000	0.0296
	333	0.0000	0.0000	0.0148
<u>Lagodon rhomboides</u>	505	0.0389	0.0000	0.0000
	333	0.0148	0.0000	0.0000
Sciaenid type eggs	505	0.0000	10.2667	6.5704
	333	0.0000	9.3518	6.4518

Table F-9. (continued) Page 9.

NAME	MESH SIZE	FEBRUARY	MARCH	APRIL
<u>Menticirrhus americanus</u>	505	0.0000	0.0000	0.0111
	333	0.0000	0.0074	0.0074
<u>Cynoscion arenarius</u>	505	0.0000	0.2407	0.2593
	333	0.0019	0.5555	0.5667
<u>Leiostomus xanthurus</u>	505	0.0000	0.0000	0.0000
	333	0.0019	0.0000	0.0000
<u>Micropogonias undulatus</u>	555	0.0185	0.0000	0.0000
	333	0.0019	0.0000	0.0000
<u>Mugil curema</u>	505	0.0000	0.0000	0.0000
	333	0.0019	0.0000	0.0000
unid. Blenniidae	505	0.0000	0.0000	0.0111
	333	0.0000	0.0000	0.0222
Gobiidae	505	0.0037	0.0037	0.0000
	333	0.0019	0.0074	0.0000
<u>Trichiurus lepturus</u>	505	0.0000	0.0000	0.0111
	333	0.0000	0.0000	0.0333
<u>Paralichthys lethostigma</u>	505	0.0000	0.0000	0.0000
	333	0.0037	0.0000	0.0000
<u>Citharichthys spilopterus</u>	505	0.0019	0.0000	0.0000
	333	0.0056	0.0000	0.0000
<u>Symphurus</u> sp. eggs	505	0.0000	0.0000	0.0259
	333	0.0000	0.0000	0.0185

Table F-10. Mean concentration (number/cubic meter) for Estuarine taxa based on first replicates from all depths. Page 1.

NAME	FEBRUARY	MARCH	APRIL
Annelida - (Polychaeta)	0.0000	23.0600	0.0000
<u>Hydrobia</u> sp.	0.0800	0.0000	0.0167
Prosobranchia	7.1800	0.0000	0.0000
Pelecypoda	14.3800	0.0800	0.0000
Mytilidae	0.0200	0.0200	0.0000
<u>Brachidontes exustus</u>	0.0000	0.0000	0.3333
<u>Petricola pholadiformis</u>	0.0000	0.0200	0.0000
<u>Tellina</u> sp.	0.7800	0.0200	0.0000
Ostracoda	50.7200	22.8000	0.0000
Copepoda-total	5749.2734	6910.4375	9416.1602
Harpacticoida	3.2200	5.0600	0.3167
Cyclopoid sp.A.	537.7798	10.9200	2.4667
<u>Parvocalanus crassirostris</u>	35.8400	0.0000	9.9667
<u>Temora turbinata</u>	0.0000	1.0800	0.0000
<u>Eurytemora affinis</u>	1937.5391	90.7399	0.0000
<u>Centropages hamatus</u>	167.6399	315.2397	9.9667
<u>Pseudodiaptomus coronatus</u>	8.8600	0.0000	47.4666
<u>Labidocera aestiva</u>	0.0000	0.0000	20.2833
<u>Acartia tonsa</u>	713.8196	4638.5547	7165.0781
<u>Oithona colcarva</u>	17.8800	25.3200	10.2333

Table F-10. (continued) Page 2.

NAME	FEBRUARY	MARCH	APRIL
<u>Cirripedia</u>	6291.9375	1142.6584	4369.5117
<u>Mysidopsis</u> sp.	0.0000	0.0000	15.2333
<u>Penaeus</u> spp.	0.1800	0.2200	0.6167
<u>Lucifer faxoni</u>	0.0000	0.0000	0.0167
<u>Palaemonetes</u> sp.	0.0000	0.0000	0.1167
<u>Ogyrides alphaerostris</u>	0.0000	0.0000	0.0333
<u>Pagurus</u> spp.	0.0100	0.0200	0.1500
<u>Callinectes</u> spp.	0.0300	0.4400	0.0500
<u>Callinectes sapidus</u>	0.0000	0.0000	0.0500
<u>Hexapanopeus angustifrons</u>	0.0000	0.0000	0.0500
<u>Rhithropanopeus harrisii</u>	0.0000	0.0000	13.0000
<u>Pinnixa</u> spp.	0.0000	0.0000	0.1833
<u>Libinia emarginata</u>	0.0000	0.0000	0.0167
<u>Elops saurus</u>	0.0000	0.0000	0.0167
<u>Myriophis punctatus</u>	0.3400	0.0200	0.0000
<u>Brevoortia</u> spp.	0.0000	0.1000	6.4667
<u>Anchoa mitchilli</u>	0.1400	0.1000	2.1500
<u>Synodus foetens</u>	0.0000	0.0000	0.0167
<u>Gobiesox strumosus</u>	0.0000	0.0000	0.2333
<u>Membras martinica</u>	0.0000	0.0000	0.0167

Table F-10. (continued) Page 3.

NAME	FEBRUARY	MARCH	APRIL
<u>Menidia beryllina</u>	0.0000	0.0000	0.0500
<u>Lagodon rhomboides</u>	0.0000	0.0000	0.0500
Sciaenid-type eggs	0.0400	0.9600	10.9500
<u>Bairdiella chrysoura</u>	0.0000	0.0000	0.0167
<u>Cynoscion arenarius</u>	0.0000	0.2200	0.0667
<u>Micropogonias undulatus</u>	0.0400	0.0400	0.0000
unid. Blenniidae	0.0000	0.0000	0.0167
Gobiidae	0.0200	0.0000	0.1667
<u>Citharichthys spilopterus</u>	0.0200	0.0000	0.0000