# EXECUTIVE SUMMARY

# ENVIRONMENTAL STUDIES, SOUTH TEXAS OUTER CONTINENTAL SHELF, CHEMISTRY AND BIOLOGY

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by

University of Texas Marine Science Institute
Port Aransas Marine Laboratory
Port Aransas, Texas 78373

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Compiled and Edited by:

R. Warren Flint, Program Manager
Craig W. Griffin, Technical Coordinator

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# FOREWORD

The chemical, physical and biological interactions both within and external to the world's oceans are among the most complex within the natural sciences. If, in fact, the aspects and processes of these various interactions were understood, their scope and magnitude could be predicted for a given time and place. There are, however, many unknowns that still must be quantified.

The information contained within this report is a summary of a multidisciplinary study conducted during 1977 on the South Texas Outer Continental Shelf (STOCS) to obtain a better definition of some of these processes within a marine ecosystem. It should be noted by the reader that since this material is presented in the form of an executive summary, there are a number of general statements made concerning the results of the 1977 research. For a more detailed account of the conclusions implicated, one is referred to the Draft Final Report to the Bureau of Land Management, edited by R. W. Flint and C. W. Griffin (1978).

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## CONCLUSIONS

### WATER COLUMN

1. The 1977 hydrographic data clearly showed the dominance of the annual time scale factors associated with meteorologically driven advection or energy exchanges, which occurred over periods on the order of a week or two. Hydrographic features which appeared to recur annually included: deep convective overturning, especially in the late winter months; a brackish water plume in late spring; summer heating and stratification through mid-September; and fall cooling, starting with the first cold fronts.

2. The availability of current data from two time periods during the year made possible some preliminary generalizations regarding the annual variation in circulation patterns in STOCS waters. The annual sequence appeared to include a strong longshore transport from late fall through early summer (approximately early November through early June) with little net motion the rest of the year.

3. The major source of methane in STOCS waters appeared to be *in situ* production. High concentrations of methane measured in the near bottom samples from Station 3/IV were the result of a natural gas seepage across the sea-sediment interface. The unsaturated hydrocarbons (*e.g.* ethene and propene) generally followed productivity patterns, being low in winter with higher values in the spring, summer and fall.

4. Particulate high-molecular-weight (HMW) hydrocarbon concentrations generally decreased with distance offshore; dissolved HMW hydrocarbons concentrations showed less variation.

5. Ratios of measured oxygen to equilibrium oxygen concentrations indicated that oxygen variations in the upper 60 m were generally controlled by physical processes (*i.e.* seasonal changes in seawater temperature and salinity) rather than productivity fluctuations. The intrusion of oxygen-depleted 200-300 m western Gulf water was evident year-round below approximately 70 m in the STOCS region.

6. Nutrient concentrations were representative of open ocean Gulf surface water in most of the water above 60 m depth, but continental run-off influenced nearshore concentrations, especially in the spring.

7. Seasonal surface patterns drawn from phytoplankton counts and productivity measurements indicated an offshore decrease in both biomass and production and also suggested decreasing activity from north to south within the study area. The continuous measurement of chlorophyll a, temperature and salinity along Transect II identified the major incursions of freshwater into the STOCS area, an upwelling at mid-shelf in February and possible wind mixing in September due to Hurricane Anita.

8. Protozoan biomass ranged from 1 to 348% of the macrozooplankton biomass, indicating that protozoa are a significant component of the zooplankton community.

9. Macrozooplankton abundances, in terms of both biomass and number, usually showed a seaward decrease. Copepods were the most abundant group, comprising approximately 50% of the zooplankton by number. Salinity and chlorophyll a values were strongly correlated with the zooplankton.

10. About one-half (28/60) of the zooplankton hydrocarbon samples showed the possible presence of petroleum-like organic matter. Of all species groups and animal organs analyzed for trace metal content, the zooplankton as a group exhibited the highest concentration of metals.

## SEA FLOOR

1. Sediment texture characterizations of the STOCS study area showed that the sediment ranged from silty clays to muddy sands.

2. There was a very clear trend of increasing total organic carbon in the sediment with distance from shore. There was a less well defined but significant change in Delta $C^{13}$ with slightly more positive ($C^{13}$ enriched) values nearer shore. The rather uniform pattern of Delta $C^{13}$ and the low values of total organic carbon suggested that petroleum pollution at a fairly gross level could be detected by Delta $C^{13}$ shifts.

3. Concentrations of light hydrocarbons in the top few meters of Texas continental shelf and slope sediments were highest nearshore and decreased regularly in an offshore direction. Production rates were related to microbial activity, organic content, and temperature of the sediments. One area of anomalously high ethane and propane was found indicating an input of thermocatalytic gas from the sub-surface.

4. The high-molecular-weight hydrocarbon analyses of sediment samples produced results in agreement with the Delta $C^{13}$ and total organic carbon results in that the very low level of saturated hydrocarbons detected pointed to a natural biogenic population of hydrocarbon molecules.

5. The meiofaunal populations of the STOCS exhibited seasonally related population peaks in March-April, July-August, and November. The meiofaunal populations on the shelf and upper slope decreased substantially with increasing depth.

6. Development of the harpacticoid/nematode ratio indicated that it was reasonably stable from year to year and that at least some of its departure from the all-station mean of 0.04 could be accounted for by bringing either chemical or biological factors to bear. It was still considered as a potential way of estimating the degree of environmental perturbation, whether such impacts were more likely physical or chemical in nature, and possibly the degree of recovery.

7. The general spatial pattern of infaunal species richness on each transect remained very stable temporally. This implied that benthic macroinfaunal communities in the area displayed little seasonal fluctuation in major component species. The relatively small biomass and the constancy with which various infaunal species were collected indicated that most of the infaunal species exhibited a very short life span and consequently a relatively high turn-over rate in the warm waters of the northwestern Gulf.

8. A definite pattern of decreasing density (number of individuals per unit area) with increasing water depth was observed on all transects for infauna, although minor peaks in density occurred on some transects at deeper sites. The inshore waters had richer supplies of nutrients in the form of detritus, phytoplankton and dissolved materials. This afforded a greater carrying capacity in the ecosystem which may have directly affected the benthos. The nature of the inshore sediments (sandy-shelly), also provided greater niche availability.

9. Several stations had chronically low infaunal diversities and low equitability (*i.e.* Station 1/III and 5/IV) at which one or two species were found to generally dominate the samples. This tendency for dominance by a few species was characteristic of physically controlled communities.

10. Linear additive models indicated that epifaunal species distributions were significantly correlated with abiotic variables but only a small amount of the variation was explained. Preliminary non-linear, multiplicative models, using the same physical variables, reduced the mean square by as much as 80% and were therefore superior models for predicting species distribution.

11. Demersal fish community distributions were directly related to depth. In addition a greater number of species were caught in night trawls than in day trawls during the seasonal sampling cruises. The difference between the numbers of night and day trawls taken during the seasonal cruises was rather small, and it appeared reasonable to conclude that some biological reason existed for those observations.

12. The lowest demersal fish biomasses were taken during the winter for both day and night trawls. The fall night trawls yielded the highest seasonal biomasses. Spring and fall day trawls yielded much higher biomasses than did winter day trawls.

13. General seasonal changes in abundance of the demersal fishes were quite evident from the 1977 collections. Seasonal changes were also observed in the constellation of predominant species in each of the three station groups. For example, a large number of species predominated in a faunal assemblage only during a single season, such as *Anchoa mitchilli* and *Caulolatilus intermedius*. Equally large numbers of species, on the other hand, were abundant all year round.

14. The total concentrations of aliphatic hydrocarbons in epifaunal and demersal fish muscle were in the low parts per million (μg/g dry weight) with n-pentadecane, n-heptadecane and pristane being the dominant hydrocarbons. Aromatic compounds were found at very low levels, generally from 5 to 30 parts per billion (ng/g dry weight). Overall, the data suggested very little, if any, petroleum contamination of the study area.

15. No indication of substantial heavy metal pollution was observed in the epifaunal and demersal fish samples. Shrimp and fish organs and tissues in order of decreasing total trace metals were liver, hepatopancreas, gill and muscle tissue. No significant changes in annual mean trace metal concentrations were found for any organ group between 1976 and 1977. Fish and shrimp muscle had generally low uniform trace metal levels with few apparent geographical, seasonal or interspecific differences.

16. The qualitative information obtained in the histopathologic study of demersal fish demonstrated that parasitism was the major cause of lesions. Approximately two-fifths of the fish organ samples collected had lesions. Lesions that may be related to other pathologic agents were not observed. Parasitism caused varying degrees of necrosis, especially in the liver and stomach. Adjacent to such lesions, however, the general integrity of the tissues was maintained.

17. A variety of pathological conditions was observed in the gonads of species sampled. From these analyses, 16.9% displayed some pathological condition. Of the organisms examined there were 88 infected specimens (10%) of vertebrates and 61 infected specimens (6.9%) of invertebrates. The highest incidence of parasites in the vertebrates was during the coldest part of the year. Invertebrate gonads had an increase of parasitism during the warmer months.

## MICROBIOLOGY

1. Marine bacteria of the water column were relatively few in number when compared with those in the sediments. Oil degrading bacteria made up 0 to 2.05% of the water column populations and from 0.10 to 20.68% for the sediment populations.

2. Oil biodegradation rates of benthic bacteria varied seasonally, with highest rates recorded at all stations during fall.

3. Highest populations of aerobic heterotrophic bacteria occurred at shallow depth stations near terrestrial influences.

4. The addition of oil to sediment increased bacterial populations, suggesting that it serves as a nutrient source for growth. The addition of oil did not alter growth time of selected strains of water column bacteria.

5. Oil degradation rates for Gulf of Mexico water tested were insignificant or essentially zero unless minimal nutrients were added to the water samples.

6. STOCS benthic fungi were generally over one thousand times more abundant than detectable fungi in near-surface waters.

7. The percentage of water column fungi that were able to degrade SLCO ranged from a low of 0% at the inshore station during the spring and summer months to a high of 70 and 67% in the November and December samples, respectively. The percentage increased with distance offshore. The calculated percentage of benthic fungi capable of degrading oil varied from a low of 12% to a high of 90%; most values exceeded 50%.

# INTRODUCTION

The Gulf of Mexico, South Texas Outer Continental Shelf (STOCS) serves as a prime marine area for two important natural resources; commercial-recreational fisheries and oil and gas reserves. Inferences are often made implicating the incompatibility of these two activities. Before it is possible to understand the effect of the latter on the former, however, one must be able to characterize the natural spatial and temporal variability of the ecosystem that supports the fisheries.

The Texas coastal area is biologically and chemically a two-part marine system, the coastal estuaries and the broad continental shelf. These two components are separated by barrier islands and connected by inlets or passes. The area is rich in finfish and crustaceans, many of which are commercially and recreationally important. Many of the finfish and decapod crustaceans of the STOCS area exhibit a marine-estuarine dependent life cycle, *i.e.* spawning offshore, migrating shoreward as larvae and postlarvae, and utilizing the estuaries as nursery grounds (Galtsoff, 1954; Gunter, 1945). The broad continental shelf supports a valuable shrimp fishery which, as a living resource, contributes significantly to the local economy. An excellent overview of the zoogeography of the northwestern Gulf of Mexico is provided by Hedgepeth (1953).

In 1974, the Bureau of Land Management (BLM), as the administrative agency responsible for leasing of submerged federal lands, was authorized to initiate a National Outer Continental Shelf Environmental Studies Program. The broad objectives of this program are:

a) to provide information about the OCS environment to enable the Department of the Interior to make management decisions regarding OCS oil and gas development; and

b) to fill environmental information needs of management, regulatory and advisory agencies, both Federal and State, for a broad range of OCS activities. These include the preparation and review of environmental impact statements under the National Environmental Policy Act (NEPA) of 1969, issuance of regulations and permits, and implementation of certain other laws, such as the OCS Lands Act, Fish and Wildlife Coordination Act, the Coastal Zone Management Act, and counterpart state laws.

As part of this national program to meet the above two objectives, the BLM developed the Marine Environmental Study Plan for the STOCS. This plan was developed to meet the following four specific study objectives for the STOCS:

a) provide information for predicting the effects of OCS oil and gas development activities upon the components of the ecosystem;

b) provide a description of the physical, chemical, geological and biological components, and their interactions, against which subsequent changes or impacts could be compared;

c) identify critical parameters that should be incorporated into a monitoring program; and,

d) identify and conduct experimental and other special studies as required to meet the basic objectives.

BLM contracted the University of Texas to act for and on behalf of a consortium program of research conducted by Rice University, Texas A&M University and the University of Texas to implement the Environmental Study Plan. The University of Texas Marine Science Institute, Port Aransas Marine Laboratory (UTMSI/PAML), provided overall project management, logistic ship time, data management and certain scientific efforts. Additional scientific effort was provided by subcontracts between the University of Texas and the above listed institutions. This plan called for an intensive multidisciplindry three-year period of study to characterize the physical, geological, chemical and biological temporal and spatial variation of the outer shelf marine ecosystem.

The central theme of the biological and chemical studies was to provide an understanding of the living resources of the outer shelf so that the impact of drilling for and production of petroleum could be assessed and controlled. In order to approach the outlined objectives a broad program was designed which included:

a) water mass characterization;

b) pelagic primary and secondary productivity as described by floral and faunal abundances, standing crop, and nutrient levels;

c) benthic productivity as described by infaunal and epifaunal densities;

d) natural petroleum hydrocarbon levels in biota, water and sediment; and,

e) natural trace metal levels in biota and particulate matter.

The general study area corresponded to an area outlined by the Department of the Interior for oil and gas leasing. The area covered approximately 19,250 $km^2$ and was bounded by 96°W longitude on the east, the Texas coastline on the west, and the Mexico-United States international border on the south (Figure 1). The continental shelf off Texas has an average width of approximately 88.5 km and a relatively gentle seaward gradient that averages 2.3 m/km.

The field investigations for the first year of study began in late October 1974, and were completed by mid-September 1975. Laboratory analyses were completed by January 30, 1976. The final report for the chemical and biological component of the 1975 study was submitted to BLM in July 1976,

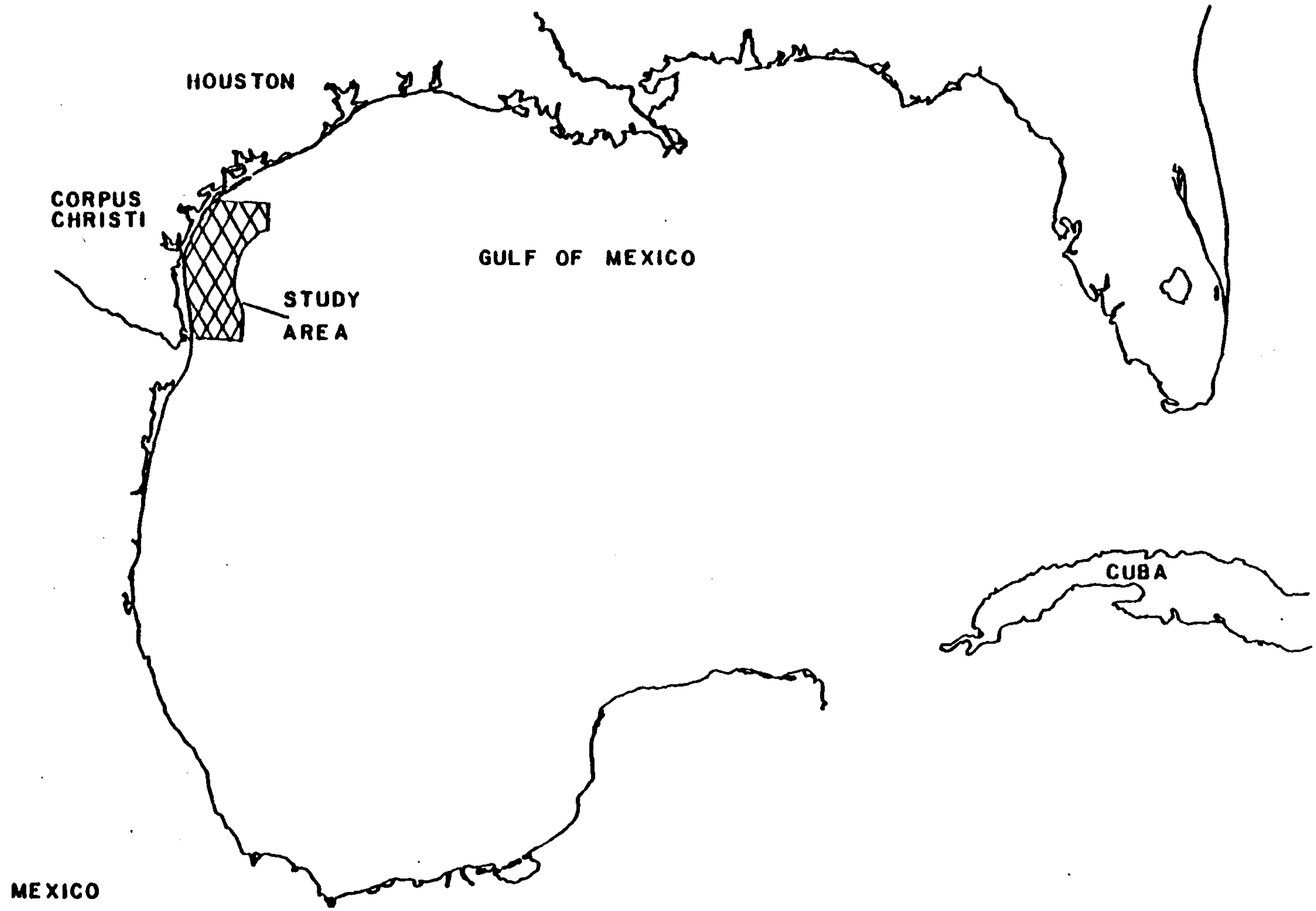


Figure 1. Location of the Study Area in Relation to the Entire Gulf of Mexico.

and the final integrated report of all components of the STOCS study was submitted to BLM in April 1977.

The field sampling for the second year of study was initiated in mid-January 1976, and was completed in mid-December 1976. Laboratory analyses were complete by February 1977. The final report for the chemical and biological components of the 1976 study was submitted to BLM in April 1978.

Based on the initial results from 1976 it was determined both by BLM and the contractors that additional information was needed in certain study elements to meet the objectives of the investigation. Consequently, several supplemental studies were initiated in September of 1977 and completed in February 1978. The results of these studies were reported to BLM in March 1978. An Executive Summary of all work carried out under the 1976 contract was submitted to BLM in July of 1978.

The field sampling for the third and final year of study, for which results are summarized here, was initiated in mid-January 1977, and was completed in mid-December 1977. Laboratory analyses were completed by June 15, 1978. A report for the chemical and biological components of the 1977 study was submitted to BLM in August 1978.

The broad objectives of the 1977 study effort of the STOCS area were to continue describing the natural temporal and spatial variability of all major components of the OCS marine ecosystem. It was assumed that understanding the natural inherent variability of this ecosystem would contribute immensely to evaluating potential impacts of the environment from unnatural perturbations such as oil and gas exploration and production.

During the first year of study (1975), twelve stations on four transects were sampled (Figure 2). Thirteen additional transect stations were sampled during the second year (1976) to increase coverage of three special

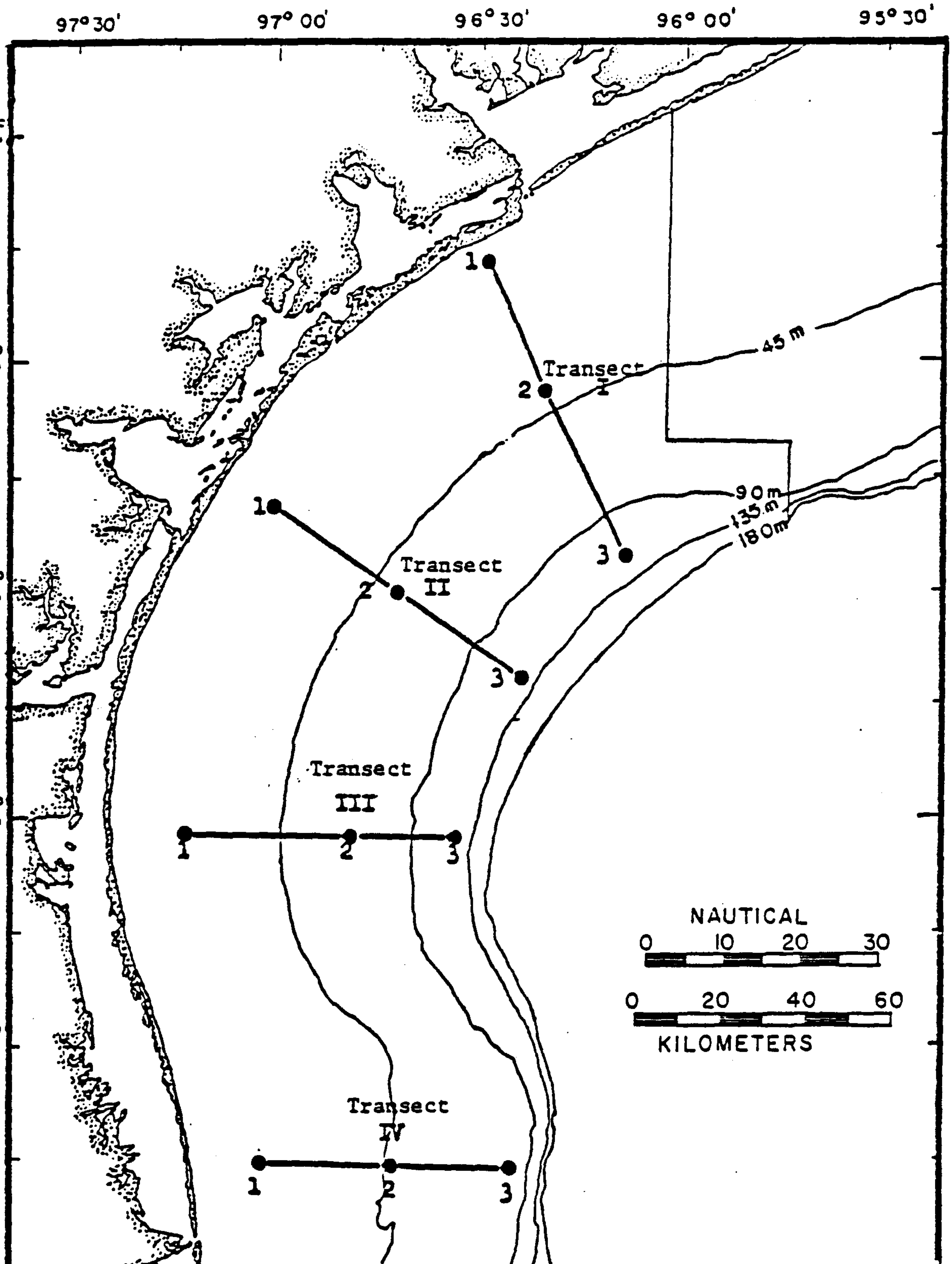


Figure 2 Station Locations for the 1975 South Texas Outer Continental Shelf Study. Depth in Meters.

areas: 1) the shallower shelf environment (about 15 m depth) and its associated sandier sediment; 2) a zone in the middle of the study area that appeared anomalous in its sediment characteristics, sediment trace metal content and distributions of certain biological populations; and 3) a zone of active gas seepage near the shelf-slope break. In addition to the transect stations, four stations on each of two submarine carbonate reefs, Hospital Rock and Southern Bank, were sampled in 1976 (Figure 3).

All transect stations sampled in 1976 were also sampled in the 1977 study. The number of collection sites at each reef, however, was decreased from four to two. Table 1 presents the LORAN and LORAC coordinates, latitude, longitude, and depth of each site sampled during the three year study.

Samples were collected in 1977 during three biological-meteorological seasons from all transects and four of the bank stations. The three seasons were winter (January and February), spring (May and June), and fall (September and October). In addition to the seasonal samplings some of the elements sampled Transect II during the six months (March, April, July, August, November and December) not included in the three seasonal sampling periods.

The sampling effort was broken up into four types of sampling: water column, benthos, histopathology and microbiology. Table 2 provides a complete list of cruises by date and type of sampling performed. Tables 3 through 6 give breakdowns of the different scientific elements by sampling frequency. Table 7 lists the sampling gear deployed for each sample type. Complete descriptions of sampling methods are included in each work element report (Flint and Griffin, editors, Draft Final Report for 1977).

Navigation and station location for water column, histopathology, and microbiology cruises were by LORAN-A. Navigation and station location for

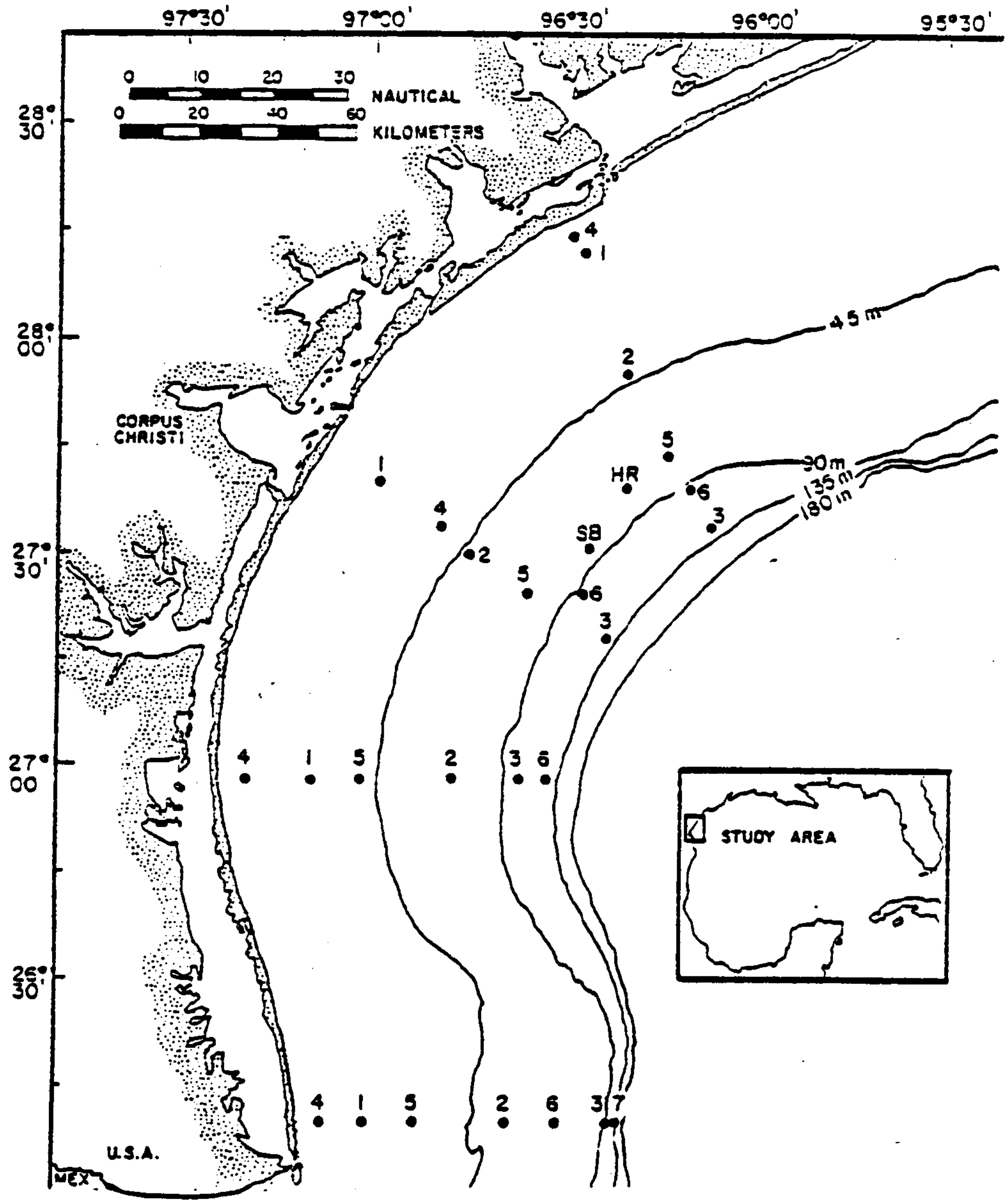


Figure 3. Station Locations for the South Texas Outer Continental Shelf Study. Depths in Meters.

TABLE 1

BLM STOCS MONITORING STUDY STATION LOCATIONS

| TRAN. | STA. | LORAN 3H3 | LORAN 3H2 | LORAC LG | LORAC LR | LATITUDE | LONGITUDE | DEPTH METERS | DEPTH FEET |
|---|---|---|---|---|---|---|---|---|---|
| I | 1 | 2575 | 4003 | 1180.07 | 171.46 | 28°12'N | 96°27'W | 18 | 59 |
| | 2 | 2440 | 3950 | 961.49 | 275.71 | 27°55'N | 96°20'W | 42 | 138 |
| | 3 | 2300 | 3863 | 799.45 | 466.07 | 27°34'N | 96°07'W | 134 | 439 |
| | 4 | 2583 | 4015 | 1206.53 | 157.92 | 28°14'N | 96°29'W | 10 | 33 |
| | 5 | 2360 | 3910 | 861.09 | 369.08 | 27°44'N | 96°14'W | 82 | 269 |
| | 6 | 2330 | 3892 | 819.72 | 412.96 | 27°39'N | 96°12'W | 100 | 328 |
| II | 1 | 2078 | 3962 | 373.62 | 192.04 | 27°40'N | 96°59'W | 22 | 72 |
| | 2 | 2050 | 3918 | 454.46 | 382.00 | 27°30'N | 96°45'W | 49 | 161 |
| | 3 | 2040 | 3850 | 564.67 | 585.52 | 27°18'N | 96°23'W | 131 | 430 |
| | 4 | 2058 | 3936 | 431.26 | 310.30 | 27°34'N | 96°50'W | 36 | 112 |
| | 5 | 2032 | 3992 | 498.85 | 487.62 | 27°24'N | 96°36'W | 78 | 256 |
| | 6 | 2068 | 3878 | 560.54 | 506.34 | 27°24'N | 96°29'W | 98 | 322 |
| | 7 | 2045 | 3835 | | | 27°15'N | 96°18.5'W | 182 | 600 |
| III | 1 | 1585 | 3880 | 139.13 | 909.98 | 26°58'N | 97°11'W | 25 | 82 |
| | 2 | 1683 | 3841 | 286.38 | 855.91 | 26°58'N | 96°48'W | 65 | 213 |
| | 3 | 1775 | 3812 | 391.06 | 829.02 | 26°58'N | 96°33'W | 106 | 348 |
| | 4 | 1552 | 3885 | 95.64 | 928.13 | 26°58'N | 97°20'W | 15 | 49 |
| | 5 | 1623 | 3867 | 192.19 | 888.06 | 26°58'N | 97°02'W | 40 | 131 |
| | 6 | 1790 | 3808 | 411.48 | 824.57 | 26°58'N | 96°30'W | 125 | 410 |
| IV | 1 | 1130 | 3747 | 187.50 | 1423.50 | 26°10'N | 97°01'W | 27 | 88 |
| | 2 | 1300 | 3700 | 271.99 | 1310.61 | 26°10'N | 96°39'W | 47 | 154 |
| | 3 | 1425 | 3663 | 333.77 | 1241.34 | 26°10'N | 96°24'W | 91 | 298 |
| | 4 | 1073 | 3763 | 163.42 | 1456.90 | 26°10'N | 97°08'W | 15 | 49 |
| | 5 | 1170 | 3738 | 213.13 | 1387.45 | 26°10'N | 96°54'W | 37 | 121 |
| | 6 | 1355 | 3685 | 304.76 | 1272.48 | 26°10'N | 96°31'W | 65 | 213 |
| | 7 | 1448 | 3659 | 350.37 | 1224.51 | 26°10'N | 96°20'W | 130 | 426 |
| HR | 1 | 2159 | 3900 | 635.06 | 422.83 | 27°32'05" | 96°28'19" | 75 | 246 |
| | 2 | 2169 | 3902 | 644.54 | 416.95 | 27°32'46" | 96°27'25" | 72 | 237 |
| | 3 | 2163 | 3900 | 641.60 | 425.10 | 27°32'05" | 96°27'35" | 81 | 266 |
| | 4 | 2165 | 3905 | 638.40 | 411.18 | 27°33'02" | 96°29'03" | 76 | 250 |
| SB | 1 | 2086 | 3889 | 563.00 | 468.28 | 27°26'49" | 96°31'18" | 81 | 266 |
| | 2 | 2081 | 3889 | 560.95 | 475.80 | 27°26'14" | 96°31'02" | 82 | 269 |
| | 3 | 2074 | 3890 | 552.92 | 475.15 | 27°26'06" | 96°31'47" | 82 | 269 |
| | 4 | 2078 | 3890 | 551.12 | 472.73 | 27°26'14" | 96°32'07" | 82 | 269 |

TABLE 2

SCHEDULE OF CRUISES

| Cruise Number | Dates | Sampling Period | Cruise Type | Transects |
|---|---|---|---|---|
| 51 | 1/11-12 | Winter | Water Column | II & SB |
| 53 | 1/17-22 | Winter | Water Column | III & IV |
| 54 | 1/27-2/3 | Winter | Benthos | III & IV |
| 55 | 2/9-15 | Winter | Benthos | I, II, SB & HR |
| 56 | 2/17-18 | Winter | Water Column & Histopathology | II |
| 57 | 2/21-22 | Winter | Water Column | I, II & HR |
| 60 | 3/4-8 | Winter | Benthic Micro & Benthos Make-up | I, II, III & IV |
| 61 | 3/10-11 | March | Histopathology & Epifauna Trawls | II & SB |
| 62 | 3/14-15 | March | Water Column | II |
| 63 | 3/25 | March | Water Column Micro | II |
| 64 | 4/17-18 | April | Histopathology & Epifauna Trawls | II & SB |
| 65 | 4/20-21 | April | Water Column | II |
| 66 | 4/23-24 | April | Water Column Micro | II |
| 67 | 5/15-21 | Spring | Water Column | I, II, III & IV |
| 68 | 5/23-27 | Spring | Benthos | III & IV |
| 69 | 5/21-6/4 | Spring | Benthos | I, II, HR & SB |
| 70 | 6/9-10 | Spring | Histopathology & Water Column Micro | II & SB |
| 71 | 6/13-15 | Spring | Benthic-Micro | I, II, III & IV |
| 72 | 7/6-7 | July | Water Column | II |
| 73 | 7/8-9 | July | Water Column-Micro & Epifauna Trawls | II |
| 74 | 7/28-29 | July | Histopathology | II & SB |
| 75 | 8/4-5 | August | Water Column | II |
| 76 | 8/6-7 | August | Water Column Micro Epifauna Trawls | II |
| 77 | 8/18-19 | August | Histopathology | II |
| 78 | 9/6-12 | Fall | Water Column | I, II, III & IV |
| 79 | 9/25-29 | Fall | Benthos | III & IV |
| 80 | 10/4-7 | Fall | Benthos | I, II, HR & SB |
| 81 | 10/10-11 | Fall | LMWH[1] Cores & Extra Epifauna HC[2] | I, II, III, IV & additional stations |
| 82 | 10/15-18 | Fall | Benthic Micro | I, II, III, IV |
| 83 | 10/20-21 | Fall | Histopathology & Water Column Micro | II |
| 84 | 11/3-4 | Fall | LMWH Cores | I, II, III, IV & additional stations |
| 85 | 11/5-6 | November | Water Column | II |
| 86 | 11/18-19 | November | Histopathology | II & SB |
| 87 | 11/20-21 | November | Water Column & Epifauna Trawls | II |

TABLE 2 CONT.'D

| Cruise Number | Dates | Sampling Period | Cruise Type | Transect |
|---|---|---|---|---|
| 88 | 11/20-12/1 | November | Epifauna Trawls Make-up | II |
| 89 | 12/2-3 | December | Water Column | II |
| 90 | 12/14-15 | December | Histopathology | II & SB |
| 91 | 12/16 | December | Water Column Micro & Epifauna Trawls | II |
| 92 | 12/18-19 | December | Epifauna Trawls Make-up | II |

SB - Southern Bank
HR - Hospital Rock
[1]Low-Molecular-Weight Hydrocarbons
[2]Epifauna hydrocarbons

# TABLE 3
## WATER COLUMN SAMPLING

| Sample Type | Collected Seasonally[1] | Stations | Collected Monthly[2] | Stations | Collected Periodically | Stations |
|---|---|---|---|---|---|---|
| Meteorology | X | All stations occupied | X | All stations occupied | X | All stations occupied |
| STD Profiles | X | All transect stations & two bank stations | X | Stations 1-6, Transect II | | |
| Light Penetration | X | Stations 1-3, Transects I, III & IV: Stations 1-6, Transect II; & two bank stations | X | Stations 1-6, Transect II | | |
| Dissolved Oxygen | X | Stations 1-3; Transects I, III & IV; Stations 1-6, Transect II; & two bank stations | X | Stations 1-6, Transect II | | |
| Nutrients | X | Stations 1-3, all transects, & two bank stations | X | Stations 1-3, Transect II | | |
| Dissolved LMW[3] Hydrocarbons | X | Stations 1-3, all transects | X | Stations 1-3, Transect II | | |
| Dissolved and Particulate HMW[4] Hydrocarbons | X | Stations 1-3, all transects | | | | |
| Particulate Trace Metals | Winter & Spring | Stations 1 and 3, all transects | | | | |
| Chlorophyll a | X | Stations 1-3, all transects | X | Stations 1-3, Transect II | | |
| Fluorescence Transects | X | Along Transect II | X | Along Transect II | | |
| Phytoplankton | | | | | | |
| a. $C^{14}$ Productivity | X | Stations 1-3, all transects | X | Stations 1-3, Transect II | | |
| b. Taxonomy | X | Stations 1-3, all transects | X | Stations 1-3, Transect II | | |
| Shelled Microzooplankton | X | Stations 1-3, all transects | X | Stations 1-3, Transect II | | |
| Ciliated Protozoa | X | Stations 1-3, all transects | X | Stations 1-3, Transect II | | |
| Zooplankton | | | | | | |
| a. Taxonomy | X | Stations 1-3, all transects | X | Stations 1-3, Transect II | | |
| b. Trace Metals | X | Stations 1-3, all transects | X | Stations 1-3, Transect II | | |
| c. Hydrocarbons | X | Stations 1-3, all transects | X | Stations 1-3, Transect II | | |
| Neuston | X | Stations 1-3, all transects | X | Stations 1-3, Transect II | | |
| Currents | | | | | X | Two studies during the year (see Chapter 2) |

[1]Winter (Jan-Feb), Spring (May-June), Fall (Sept-Oct)
[2]March, April, July, August, November, December
[3]Low-Molecular-Weight
[4]High-Molecular-Weight

## TABLE 1.4

## BENTHOS SAMPLING

| Sample Type | Collected Seasonally[1] | Stations | Collected Monthly[2] | Stations | Collected Periodically | Stations |
|---|---|---|---|---|---|---|
| Meteorology | X | All stations occupied | X | All stations occupied | X | All stations occupied |
| Sediment-Texture | X | All transect and bank stations | X | Stations 1-6, Transect II | X | From sediment HMWH samples |
| Sediment Total Organic Carbon | X | All transect and bank stations | | | | |
| Sediment Delta $C^{13}$ | X | All transect and bank stations | | | | |
| Sediment HMW[3] Hydrocarbons | | | | | X | Stations 1-3, all transects (each station sampled once during the year) |
| Sediment LMW[4] Hydrocarbons | | | | | X | 50 stations in STOCS area (each station sampled once during the year) |
| Sediment Trace Metals | X | All transect stations | | | | |
| Meiofauna | X | All transect and bank stations | X | Stations 1-6, Transect II | | |
| Macroinfauna | X | All transect and bank stations | | | | |
| Macroepifauna and Demersal Fish | | | | | | |
| a. Taxonomy | X | All transect stations | X | Stations 1-3, Transect II | | |
| b. Trace Metals | X | Stations 1-3, all transects | | | | |
| c. Hydrocarbons | X | Stations 1-3, all transects | | | X | Stations 1-3, all transects |
| Macronekton | | | | | | |
| a. Trace Metals | X | Hospital Rock and Southern Bank | | | | |
| b. Hydrocarbons | X | Hospital Rock and Southern Bank | X | Southern Bank | | |

[1]Winter (Jan-Feb), Spring (May-June), Fall (Sept-Oct)
[2]March, April, July, August, November, December
[3]Low-Molecular-Weight
[4]High-Molecular-Weight

TABLE 5

HISTOPATHOLOGY SAMPLING

| Sample Type | Collected Seasonally[1] | Stations | Collected Monthly[2] | Stations |
|---|---|---|---|---|
| Meteorology | X | All stations occupied | X | All stations occupied |
| Histopathology | | | | |
| a. Macroepifauna | X | Stations 1-3, Transect II | X | Stations 1-3, Transect II |
| b. Demersal Fish | X | Stations 1-3, Transect II and Southern Bank | X | Stations 1-3, Transect II and Southern Bank |
| c. Gonadal Tissues | X | Stations 1-3, Transect II and Southern Bank | X | Stations 1-3, Transect II and Southern Bank |

[1]Winter (Jan-Feb), Spring (May-June), Fall (Sept-Oct)
[2]March, April, July, August, November, December

TABLE 6

MICROBIOLOGY SAMPLING

| Sample Type | Collected Seasonally[1] | Stations | Collected Monthly[2] | Stations |
|---|---|---|---|---|
| Meteorology | X | All stations occupied | X | All stations occupied |
| Mycology | | | | |
| a. Water Column | | | X | Stations 1-3, Transect II |
| b. Benthic | X | Stations 3/I, 1/II, 2/II 3/II, 2/III and 1/IV | | |
| Bacteriology | | | | |
| a. Water Column | X | Stations 1-3, Transect II | X | Stations 1-3, Transect II |
| b. Benthic | X | Stations 1-3, all transects | | |
| Sediment Texture | X | Stations 1-3, all transects | | |

[1]Winter (Jan-Feb), Spring (May-June), Fall (Sept-Oct)
[2]March, April, July, August, November, December

TABLE 7

SAMPLING GEAR USED DURING THE 1977 STOCS STUDY

| Type Of Sampling | Gear Used |
|---|---|
| STD Profiles | Plessey Salinity/Temperature/Depth Profiling System and Nansen Bottles Equipped with Reversing Thermometers |
| Light Penetration | Lambda Photometer or Secchi Disc |
| Dissolved Oxygen | Nansen Bottles Equipped with Reversing Thermometers |
| Nutrients | 30-ℓ Niskin Bottles |
| Dissolved LMW[1] Hydrocarbons | 30-ℓ Niskin Bottles |
| Dissolved and Particulate HMW[2] Hydrocarbons | 19-ℓ Glass Carboy in Stainless Steel Cage |
| Particulate-Trace Metals | 19-ℓ Plastic Carboy |
| Chlorophyll _a_ | 30-ℓ Niskin Bottles |
| Fluorescence Transects | |
| Phytoplankton | |
| a. $C^{14}$ Productivity | 30-ℓ Niskin Bottles |
| b. Taxonomy | 30-ℓ Niskin Bottles |
| Shelled Microzooplankton | |
| a. Discrete Depth | 30-ℓ Niskin Bottles |
| b. Integrated Depth | 30-cm Nansen Net, 76 μm Mesh |
| Ciliated Protozoa | 30-ℓ Niskin Bottles |
| Zooplankton | |
| a. Taxonomy | 1-m dia., 250 μm Mesh Net, equipped with a Flowmeter and a Time-Depth Recorder |
| b. Trace Metals and HMW Hydrocarbons | 1-m dia., 250 μm Mesh Net, with PVC Frame, Towed with a Nylon Rope from a Boom at the Side of Survey Vessel |
| Neuston | 2 x .5 m Frame Partitioned into Four Equal Areas with Four 505 μm Mesh Nets |
| Sediment Texture | Smith-McIntyre Grab Sampler (.0125 $m^3$) |
| Sediment Total Organic Carbon | Smith-McIntyre Grab Sampler (.0125 $m^3$) |
| Sediment Delta $C^{13}$ | Smith-McIntyre Grab Sampler (.0125 $m^3$) |

TABLE 7 CONT.'D

| Type of Sampling | Gear Used |
|---|---|
| Sediment HMW Hydrocarbons | Smith-McIntyre Grab Sampler (.0125 $m^3$) |
| Sediment Trace Metals | Smith-McIntyre Grab Sampler (.0125 $m^3$) |
| Meiofauna | Smith-McIntyre Grab Sampler (.0125 $m^3$) |
| Macroinfauna | Smith-McIntyre Grab Sampler (.0125 $m^3$) |
| Macroepifauna Demersal Fish | |
| a. Taxonomy | 35-ft (10.7 m) Otter Trawl |
| b. Trace Metals | 35-ft (10.7 m) Otter Trawl |
| c. Hydrocarbons | 35-ft (10.7 m) Otter Trawl |
| d. Histopathology | 35-ft (10.7 m) Otter Trawl |
| Macronekton | |
| a. Trace Metals | Hook and Line |
| b. Hydrocarbons | Hook and Line |
| Benthic Mycology | Smith-McIntyre Grab Sampler (.0125 $m^3$) |
| Benthic Bacteriology | Smith-McIntyre Grab Sampler (.0125 $m^3$) |
| Water Column Mycology | 1-ℓ Niskin Sterile Sampler or Peristaltic Pump and Tygon Tubing |
| Water Column Bacteriology | 1-ℓ Niskin Sterile Sampler or Peristaltic Pump and Tygon Tubing |
| Sediment LMW Hydrocarbons | Gravity Core with Plastic Liner |
| Current Measurements | ENDECO Type 105 Recording Current Meter |

[1]Low-Molecular-Weight
[2]High-Molecular-Weight

the benthos cruises were by LORAC navigational system.

All sampling and measurements, except the placement and recovery of current meters were taken aboard the University of Texas research vessel, the R/V LONGHORN. The R/V LONGHORN, designed and constructed as a coastal research vessel in 1971, is a steel-hulled 24.38 (80 ft) by 7.42 cm (24 ft), 2.13 m (7 ft) draft ship. She carries a crew of five and can accomodate a scientific party of ten. The R/V LONGHORN is equipped with a stern-mounted crane, a trawling winch, scan sonar, radar, LORAN-A and LORAC navigational systems, and dry and wet laboratory space.

A total of 28 principal investigators participated in the project. Table 8 lists the principal investigators by institutions represented and scientific responsibility. Ship time was provided for the NOAA/NMFS ichthyoplankton sampling. Supportive work was performed by the United States Geological Survey's Corpus Christi, Texas Office of Marine Geology (sediment texture and sediment trace metals) and the BLM Topographic Features Program based at Texas A&M University (sediment texture).

For convenience in presenting the extensive data base derived from the 1976 study, the remaining sections of this summary have been broken into water column, sea floor and microbiology sections.

## WATER COLUMN

The availability of hydrographic data from the 1977 sampling program made possible some tentative conclusions regarding the year-to-year repetition of hydrographic events and patterns in South Texas OCS waters. Considering the temporal and spatial variability characteristics of shelf waters, the extent to which broad-scale patterns and seasonal events were repeated was somewhat surprising.

TABLE 8

STOCS BIOLOGICAL AND CHEMICAL COMPONENT PARTICIPANTS BY WORK ELEMENT AND INSTITUTION

Rice University

Microplankton and Shelled Microzoobenthon. . . . . R. E. Casey

Texas A&M University

HMW Hydrocarbons in Macroepifauna, Demersal Fish and Macronekton. . . . . . . . . . . . . . . . . . . C. S. Giam, H. S. Chan
Trace Metals in Macroepifauna, Demersal Fish Macronekton and Plankton . . . . . . . . . . . . . B. J. Presley, P. N. Boothe
LMW Hydrocarbons, Nutrients and Dissolved Oxygen . W. M. Sackett, J. M. Brooks
Zooplankton. . . . . . . . . . . . . . . . . . . . . E. T. Park
Neuston. . . . . . . . . . . . . . . . . . . . . . . J. H. Wormuth
Meiofauna. . . . . . . . . . . . . . . . . . . . . . W. E. Pequegnat
Histopathology of Macroepifauna. . . . . . . . . . J. M. Neff
Histopathology of Demersal Fishes. . . . . . . . . W. E. Haensly
Benthic Bacteriology . . . . . . . . . . . . . . . J. R. Schwarz

University of Texas

Austin:

Water Column and Benthic Mycology. . . . . . . . . P. J. Szaniszlo

Marine Science Institute/Galveston Geophysical Laboratory:

Sediment Texture . . . . . . . . . . . . . . . . . E. W. Behrens

Marine Science Institute/Port Aransas Marine Laboratory:

Ciliated Protozoa. . . . . . . . . . . . . . . . . . P. L. Johansen
Hydrography. . . . . . . . . . . . . . . . . . . . . N. P. Smith
HMW Hydrocarbons in Zooplankton, Sediment, Water . P. L. Parker, R. S. Scalan, J. K. Winters
Phytoplankton and Productivity . . . . . . . . . . C. Van Baalen, D. L. Kamykowski
Macroinfauna and Macroepifauna . . . . . . . . . . J. S. Holland
Demersal Fishes. . . . . . . . . . . . . . . . . . . D. E. Wohlschlag

San Antonio:

Histopathology:Gonadal Tissues of Macroepifauna and Demersal Fish. . . . . . . . . . . . . . . . . . S. A. Ramirez
Water Column Bacteriology. . . . . . . . . . . . . . M. N. Guentzel, H. V. Oujesky, O. W. Van Auken

It was clear from the data that the dominant time scale in Texas shelf waters was an annual progression in both temperature and salinity. This was best brought out on a T-S diagram by plotting data obtained from repeated sampling at a given location. The result was an elongated, clockwise loop-like pattern, indicating a dominance of temperature variations over changes in salinity (for example, Figure 4).

The slow, simultaneous variations of temperature and salinity were used to define hydrographic seasons. Temperature variations were a conceptually straight-forward result of the annual heating and cooling. The annual temperature range in surface waters appeared to be inversely related to the distance offshore. The sampling program was not particularly well suited to detect temperature variations occurring over time scales of less than several weeks. Given the magnitude of the annual temperature curve, however, it was probable that diurnal temperature variations and those associated with advective processes were minor perturbations on the annual pattern.

Highest late summer temperatures in surface waters have been shown to be nearly uniform across the shelf, and indeed across the entire Gulf of Mexico (Rivas, 1968). Thus, the local magnitude of the annual temperature curve was determined primarily by the late winter low temperature reached at a given location. This was largely a function of the heat content of the water column, which, in turn, was directly related to the water depth. A second, though probably relatively minor effect, was the fact that the cold air following a frontal passage began to warm as it moved out over shelf waters. Thus, the most intense cooling probably occurred over the inner shelf.

At sub-surface levels, highest late-summer temperatures decreased with increasing depth. This was especially true below the layer of wind mixing

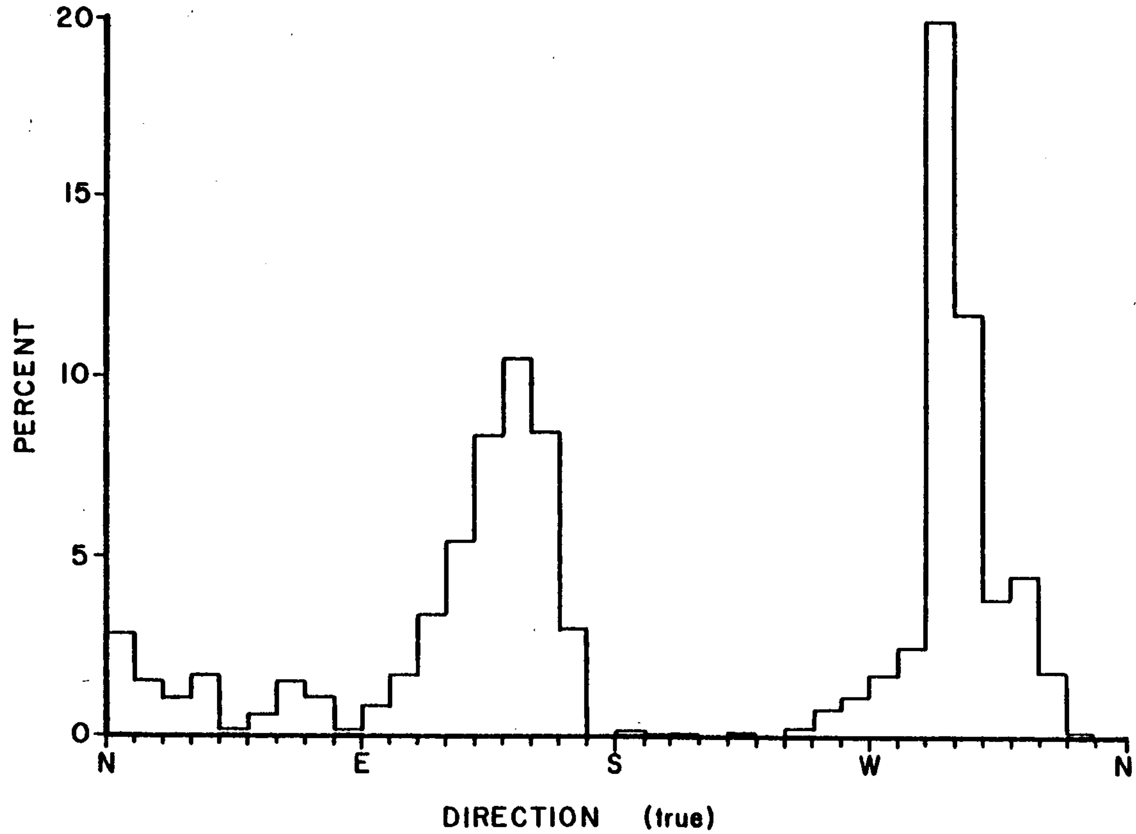


Figure 4 Histogram of Current Directions Recorded 10 m Above the Bottom in 18 m of Water off Port Mansfield, 22 June through 13 August.

(upper 20-30 m), which capped the top of the seasonal thermocline. Still, an annual progression of warming and cooling was clearly apparent over the inner and middle shelf.

Near-bottom temperature variations at the outer edge of the shelf, and at the top of the permanent thermocline, were occurring over time scales considerably shorter than the annual heating and cooling noted elsewhere. There, advective processes and/or perhaps vertical migrations in the top of the permanent thermocline produced temporal changes that could not be defined by the approximately monthly monitoring during 1977.

Where the annual temperature curve was apparent, it could be used to define hydrographic seasons in a general way. The winter months were characterized by surface cooling and the development and slow thickening of an isothermal surface layer. This extended through the entire water column over the inner and middle continental shelf. Over the outer shelf, the isothermal layer reached a depth of 70-80 m. In some cases, a slight reverse thermocline developed where vertical variations in salinity were great enough to preserve the stability of the water column. An important distinguishing feature of the winter months was the cross-shelf variation of surface temperature. Figure 5, for example, shows a cross-shelf gradient of approximately 8°/60 km over the inner and middle shelf.

Spring, in a hydrographic sense, was best defined by the transient decrease in surface layer salinity associated with the spring runoff. For the waters of the South Texas coast, this time period extended from approximately late April into early June. The entire Texas shelf exhibited noticeably lowered salinities. The strongest haloclines were found, however, as might be expected, over the inner and middle shelf. Strong cross-shelf surface temperature gradients almost disappeared as the shallower waters of the inner shelf responded more quickly to seasonal warming.

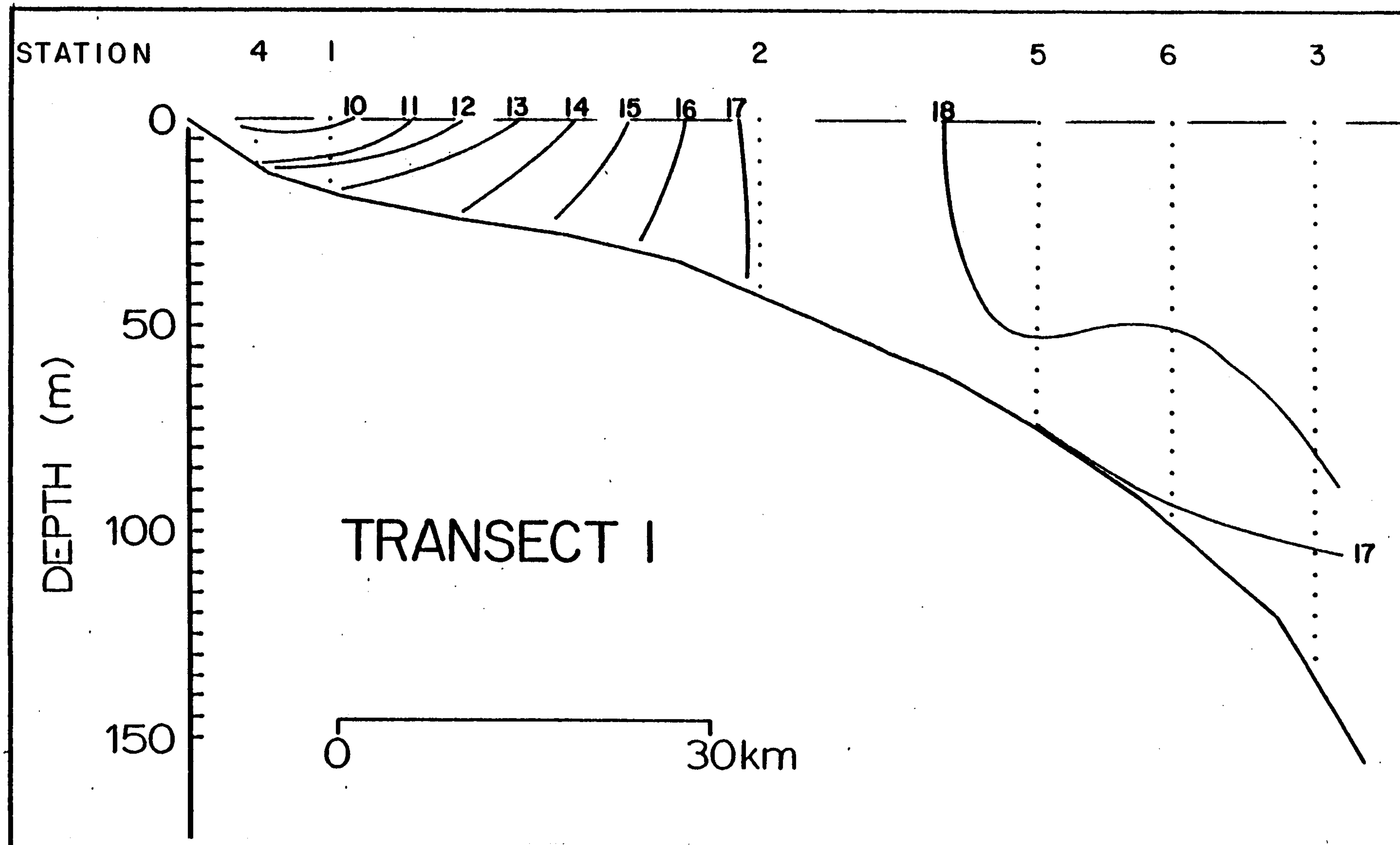


Figure 5 Winter Temperatures (°C) for 21 January (Stations 4, 1 and 2) and 21 February 1977.

The summer season was also defined in terms of the temperature structure of shelf waters. The characteristic feature at this time of year was the strong thermal stratification through the seasonal thermocline. There was a nearly isothermal wave-mixed layer extending through the upper 35-40 m and capping the seasonal thermocline. Highest mid-summer surface temperatures reached 29-30° in the study area during 1977.

The fall season began with the first cold front during the latter part of the year. This could have occurred anywhere from mid-September to early October. The movement of relatively cool air out over the shelf produced a slight decrease in surface water temperatures from the annual maximum, and started to erode the seasonal thermocline. The waters of the inner shelf showed a more rapid cooling, and by the end of the year the cross-shelf gradient appeared again, superimposed onto a net cooling effect on the order ot 6-8°C.

The hydrographic features discussed herein were those which appeared to recur annually: deep convective overturning, especially in the late winter months; the brackish water plume in late spring; summer heating and stratification through mid-September; and fall cooling, starting with the first cold fronts. Perhaps the important point was that the selection of discrete hydrographic seasons was based upon an accumulation of data, rather than just mirroring the calendar seasons.

Figure 6 considers the relationship between surface salinity and Secchi depth. All data tended to fall within the solid line with the exception of collections from May. This clear mass was probably related to the influence of Mississippi River water in the STOCS area. Trends within the solid line show that salinities less than 33 ‰ were associated with Secchi depths less than 4 m. Salinities above 33 ‰ showed

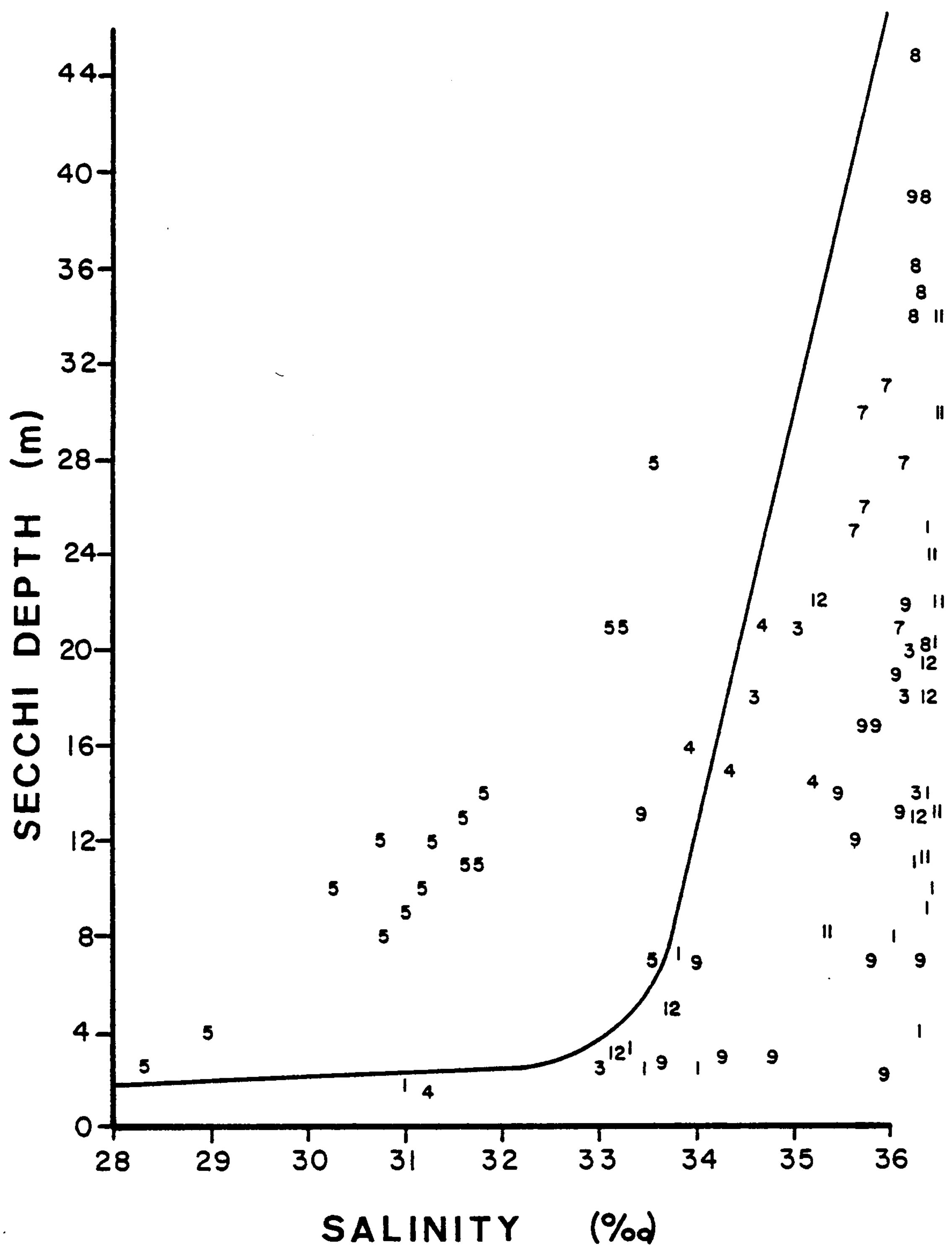


Figure 6 Relationship Between Salinity and Secchi Depth for all Stations. Solid Line is Arbitrary Curve. Numbers Refer to Months of Year.

increasing variability as oceanic salinities ($\simeq 37\ ‰$) were approached.

The 1977 hydrographic data clearly showed the dominance of the annual time scale over factors associated with meteorologically driven advection or energy exchanges, which occurred over periods on the order of a week or two. The sampling program was not intended to monitor these higher frequency variations, but the continuity apparent from one approximately monthly sample to the next suggested that little of importance had occurred simultaneously to disrupt the slowly unfolding annual pattern.

The availability of current data from two time periods during the year made possible some preliminary generalizations regarding the annual variation in circulation patterns in Texas shelf waters. The most obvious difference between the data coming out of these two field experiments was in the computed net transport. During a March-April study, transport past most of the current meters was longshore to the south-southwest. The two notable exceptions were at the lower level at the inner station and at the upper most level at the outer station, where a strong offshore deflection was recorded. This was most probably a direct response to surface wind-stress, which, in turn, had a longshore component almost continuously to the south-southwest.

In sharp contrast to this, the data from the summer months showed little preference for longshore motion in either direction. The annual pattern that emerged was one of transport to the south-southwest occurring in distinct spurts. For the central Texas coast, at least, the annual sequence appeared to include a strong longshore transport from late fall through early summer (approximately early November through early June) with little net motion the rest of the year. At any given time there was generally a significant current. The net long-term effect, however, was a north-

northeasterly to south-southwesterly transport along the central Texas coast.

Based on all of the above, the most important physical processes for controlling the hydrography of the South Texas OCS study area may be listed chronologically and, at the same time, in the approximate order of decreasing importance. Cold fronts moving off the central Texas coast are responsible for intense surface cooling, for a deep convective overturning of the water column, and for providing the wind-driven push responsible for the annual net transport to the south-southwest. The spring runoff, entering the Gulf of Mexico primarily through the mouth of the Mississippi River, gets caught up in the last of the westerly and southwesterly circulation along the northern rim of the Gulf, and arrives as a brackish water near-surface plume in late spring. The pycnocline presumably decouples the upper, wind-driven part of the water column from motion at greater depths, though this has not been documented with data from a properly designed study.

Summer heating, through characteristically clear to partly cloudy skies, takes over as the dominant physical process in July and August, resulting in the formation and intensification of the seasonal thermocline. This form of stratification may also decouple the motion through the water column. More data are required, however, to verify this possibility. At this time of year, the veering of surface winds into the southeasterly quadrant halts the south-southeasterly transport and produces instead a slowly alternating longshore current with a much slower speed.

There appears in some of the hydrographic data, evidence for an offshore transport in near-surface layers. This probably occurs as a small, cross-shelf deflection of a predominantly longshore current. Such a secondary circulation may explain the axis of the low-salinity plume over the middle shelf rather than against the coast (Figure 7), the displacement of surface waters and a corresponding onshore encroachment of water at near-bottom levels (Smith, in Groover, 1977).

Lastly, the arrival of the first cold front of the season puts an end to (or at least largely skews) the alternating longshore motion and establishes the net transport to the south-southwest. At the same time, the seasonal thermocline is lost through surface cooling and motions in the unstratified water column become more vertically coherent.

Comments on the year-to-year repetition of physical processes in shelf waters must necessarily be restricted to hydrographic events. Appropriate current data are not available from previous years to provide a comparison. Several broad-scale features in the hydrographic patterns do appear to have been repeated in the 1977 data. Most notable were the recurrence of the low salinity plume in Mississippi River water in late spring and the spring cross-shelf temperature gradients characteristic of the late winter months. It is somewhat surprising that the small cyclonic loop in the T-S polygon appeared again in the 1977 data. This may, in fact, be a quasi-permanent feature of the annual hydrographic cycle for Texas shelf waters, due to the interaction of the local precipitation and heating cycles. The rapid warming during the late spring and early summer months and the most intense cooling occurring in the mid-winter months suggested that more closely spaced sampling might be in order at these times of year to properly monitor the transitional periods.

The STOCS is relatively "clean" with respect to hydrocarbons, as low-molecular-weight hydrocarbons in the area are chiefly derived from natural sources. The major source of methane appeared to be *in situ* production in the water column with a seasonal pattern to the vertical distributions.

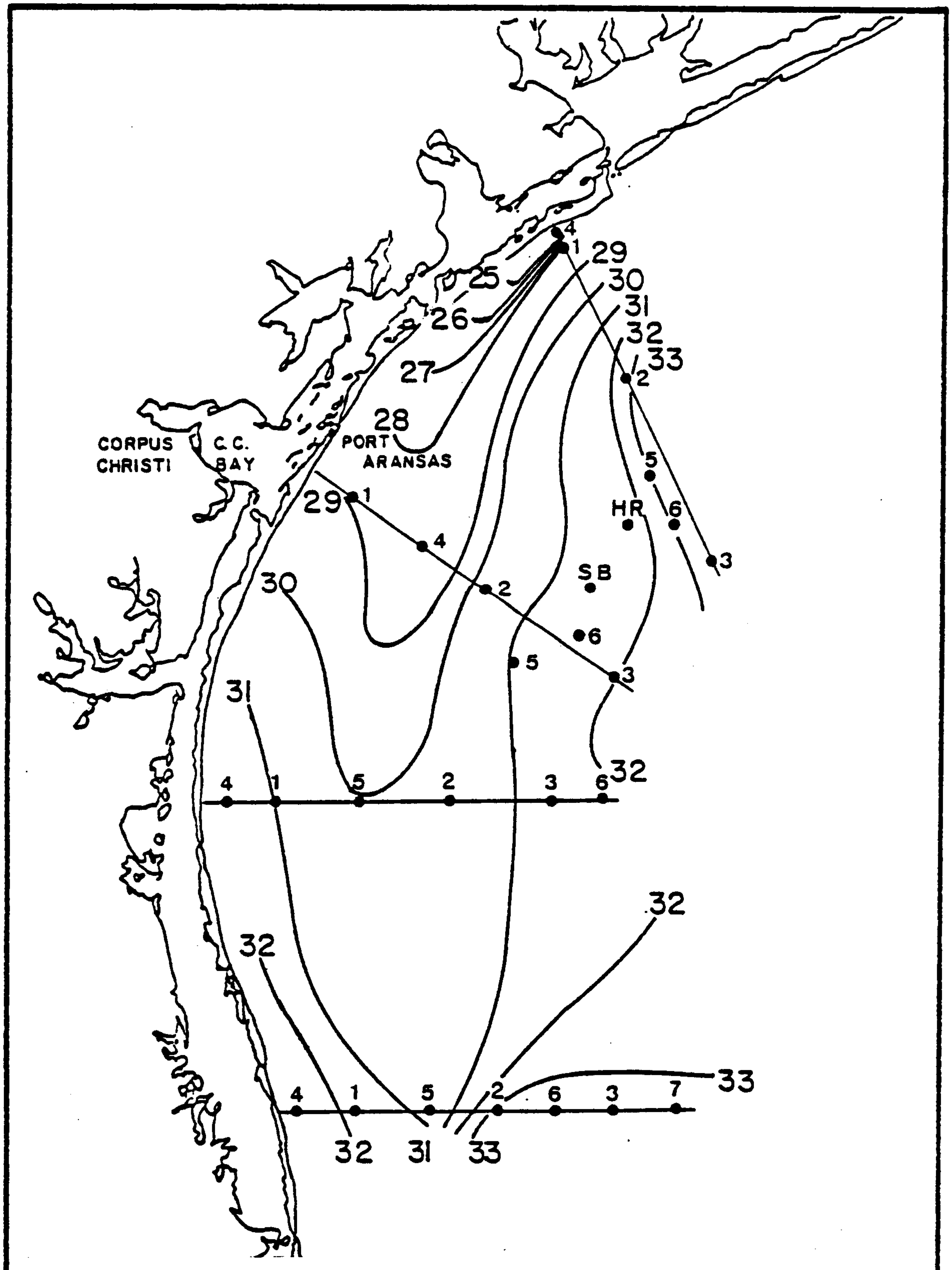


Figure 7 Spring Salinity Pattern, 16-20 May 1977.

In the winter, due to turbulent mixing, the water column was fairly uniform with respect to saturated low-molecular-weight hydrocarbons. During the summer and fall, as stratification of the water column developed, a maximum in methane associated with the thermocline developed. This concentration maximum could be almost an order of magnitude higher than levels above and below. The maximum probably resulted from accumulation of suspended matter on the stratification boundary due to restriction of settling velocities across the density gradient, with subsequent production of methane in small micro-reducing environments of suspended particles.

The unsaturated hydrocarbons (*e.g.* ethene and propene) generally followed productivity patterns, being low in winter with higher values in the spring, summer and fall. Ethene and propene are known to be produced by biological processes, thus their strong correlations with phytoplankton productivity parameters were to be expected. Ethene also showed a shallow subsurface maximum associated with a productivity maximum. The unsaturates dominated over their saturated analogs in the STOCS area.

An anomalous observation during 1977 was that the winter sampling showed high methane throughout the water column in most of the STOCS area. The source of these high methane levels was unknown. Figure 8 shows the highest levels were found at Stations 2 and 3 along all transects indicating it was not a coastal source. A possible source of the intrusion of high methane into STOCS waters may have been a major well blowout that occurred about 100 miles south of Galveston during late November and December 1976 (Brooks *et al.*, in press). The high levels produced by this blowout could have been advected by currents in STOCS waters.

Of the twelve stations sampled, Station 3/IV was unique in that the near-bottom samples from this station always showed very high methane con-

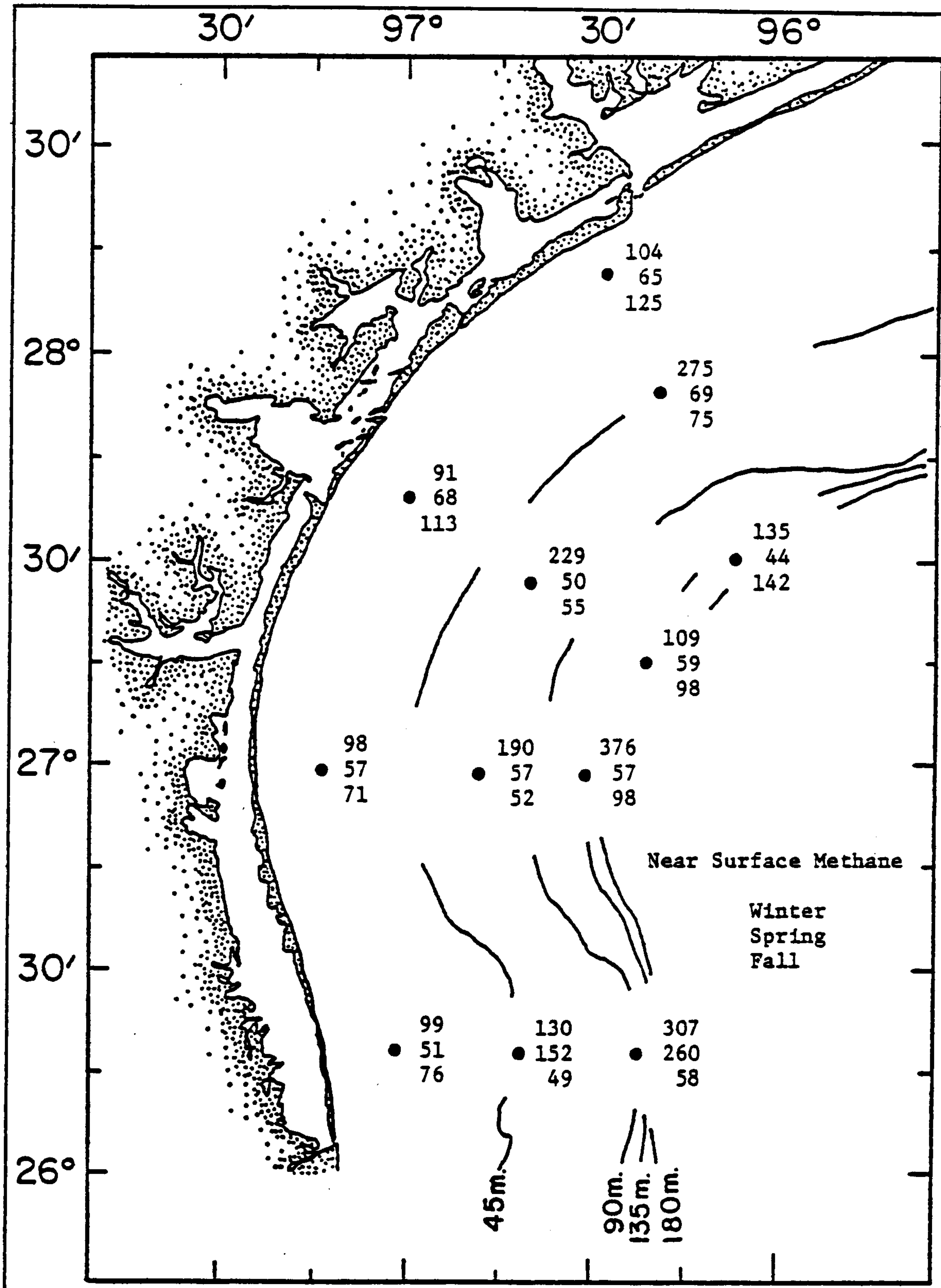


Figure 8 Near-Surface Methane Concentrations (nl/ℓ) in the STOCS During the Seasonal Cruises in 1977.

centrations. The concentrations were measured as high as 400 nl/ℓ, with no seasonal influence. Methane concentrations typically remained above 100 nl/ℓ, 20-40 m above the bottom. These high concentrations measured continuously over a three year period were the result of a natural gas seepage across the sea-sediment interface.

The level of total dissolved and particulate organic matter generally found in the Gulf of Mexico aquatic ecosystem is in the range of 0.1 to 10 μg/ℓ. Not as accurate knowledge has been obtained to date on ranges of hydrocarbon values in these same waters. Recent data collected from other systems (McAullife, 1976; Koons, 1977) have indicated that generally the highest concentrations of hydrocarbons are located in the surface microlayer of the water column and that these concentrations decrease rapidly with the first 10 m of water depth.

Concentrations of dissolved and particulate hydrocarbons were similar in magnitude. Particulate hydrocarbon concentrations generally decreased with distance offshore. Dissolved hydrocarbon concentrations showed less variation. Winter and spring samples had higher average concentrations than fall samples. The hydrocarbon composition of dissolved and particulate samples was similar. The most abundant n-alkanes were in the $C_{27}$-$C_{33}$ range with a slight preference for odd carbon numbers.

Oxygen concentrations in the upper 60 m of the STOCS region varied seasonally, being generally highest at nearshore stations in the winter and lowest in the summer. Temperature and salinities were measured on subsamples of water taken for oxygen determinations so that equilibrium oxygen concentrations could be calculated and compared to measured values. Ratios of measured oxygen to equilibrium oxygen concentrations indicated that oxygen variations in the upper 60 m were generally controlled by physical processes (seasonal changes in seawater temperature and salinity) rather than productivity fluctuations. The mass of highly oxygenated water could be traced by cross-sectional concentration contours as it was formed near shore in the winter and displaced by warming in the spring and summer. The intrusion of oxygen-depleted 200-300 m western Gulf water was evident year-round below approximately 70 m in the STOCS region. Seasonal variations in stratification of the water column could be seen by the extent of vertical mixing with this bottom water.

Nutrient concentrations were representative of open Gulf surface water in most of the water above 60 m depth, but continental run-off influenced nearshore concentrations, especially in the spring. Nitrate as the limiting nutrient to productivity disappeared after the spring phytoplankton blooms through the summer and early fall. Phosphate and silicate were affected by the high spring productivity but not completely removed. These nutrients were gradually replenished during the summer and fall to moderately high values by December. The intrusion of the nutrient-rich 200-300 m western Gulf water could again be clearly seen below 70 m from nutrient concentration contours across cross-sectional diagrams of Transect II.

Seasonal surface patterns drawn from phytoplankton counts and productivity measurements indicated an offshore decrease in both biomass and production and also suggested decreasing activity from north to south within the study area. Figure 9 provides an index of phytoplankton biomass as measured by chlorophyll a. The general offshore and north to south decreases are evident. Inshore, Transects II, III and IV displayed biomass peaks in winter and fall. Offshore, the highest concentrations generally occurred in winter, Phytoplankton biomass was low in spring and fall.

The nannophytoplankton (<.20 μm) generally dominated the biomass across

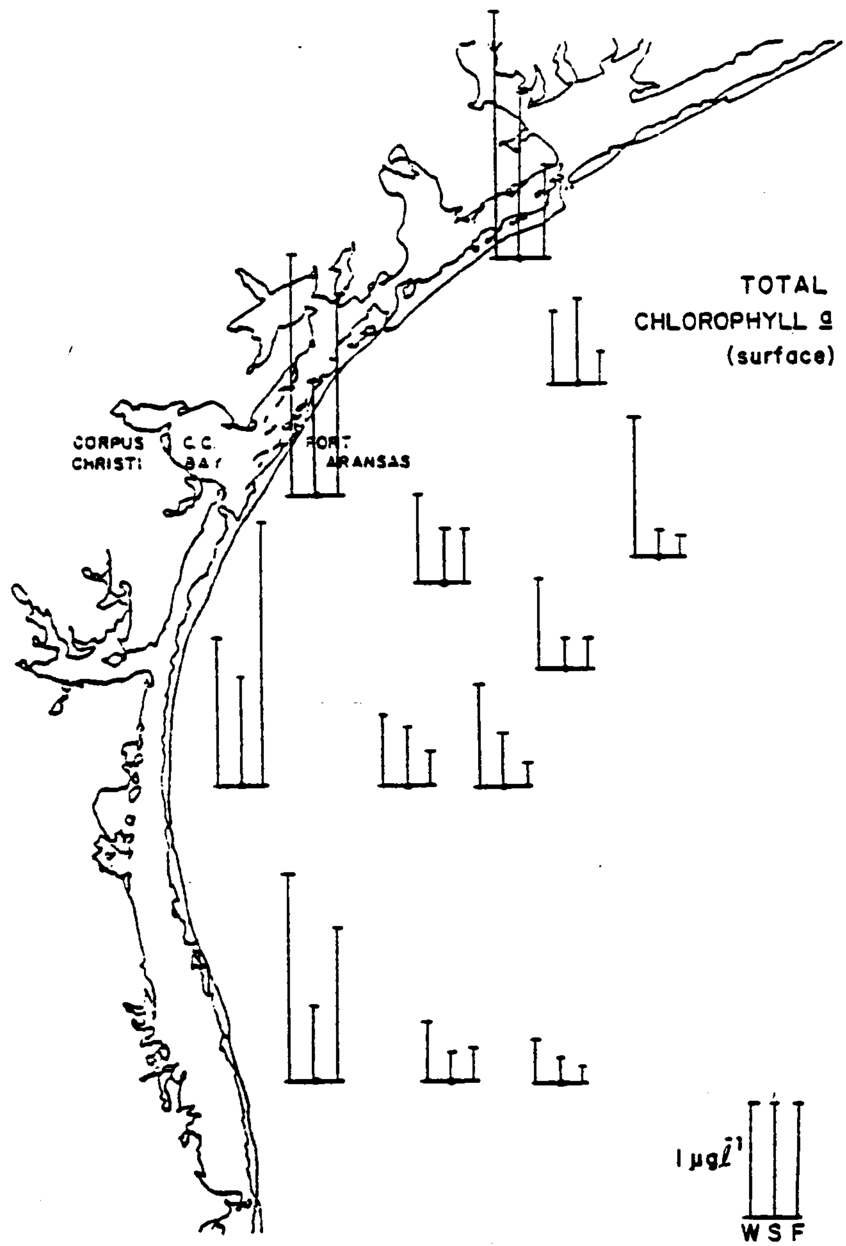


Figure 9 Seasonal Total Chlorophyll a (µg $\ell^{-1}$) Variation at the Surface in the STOCS Study Area.

the shelf; especially in offshore waters. *Skeletonema costatum* was the dominant netphytoplankton. The nanno-fraction dominance was less in winter than in spring and fall. Generally, nanno-fraction biomass peaks followed net-fraction (> 20 μm) biomass peaks in the spring and preceded the net-fraction peaks in the fall.

A succession of phytoplankton types was evident. In January, diatoms dominated along Transects I and II while coccolithophorids were significant along Transects III and IV. Dinoflagellates became dominant at some stations in March. An onshore-offshore gradient developed in March with diatoms dominant inshore and either coccolithophorids or dinoflagellates dominant offshore. This pattern continued through August with the coccolithophorid dominance moving in toward the coast. The last four months of 1977 were characterized by mixed communities that gradually changed to dominance by very small forms.

The continuous measurement of chlorophyll a, temperature and salinity along Transect II identified the major incursions of freshwater into the STOCS area, an upwelling at mid-shelf in February and possible wind mixing in September due to Hurricane Anita. Nearshore chlorophyll a plumes may have extended up to 25 nautical miles offshore.

Good relationships were observed among the various measured primary productivity parameters. The assimilation numbers [$mgC(mgChla)^{-1}(hr)^{-1}$] were anomalously high in May, possibly reflecting the influence in Mississippi River water in the STOCS area. Possible phytoplankton stress was identified in January and between August and November, due to decreasing numbers.

Several general oceanographic trends could be derived from the 1977 shelled microzooplankton and general microplankton data interpretation using indicator species or groups. These indicators included the planktonic foraminiferans, which appeared to be good indicators of seasonality and of surface and shallow water intrusions onto the shelf from offshore. The radiolarians also appeared to be indicative of the same trends as the foraminiferans and of several other physical phenomena such as, upwelling, deeper water movements, and the provenance of waters.

These groups indicated the following oceanographic trends on the STOCS in 1977. During the winter, ponds of shallow and deeper open-ocean Gulf water moved onto the STOCS probably due to eddies breaking off from the general southerly movement of the offshore wind driven current. Upwelling of deep open-ocean Gulf water occurred all along the STOCS at mid-shelf; this upwelled water then moved offshore at the surface resulting in eutrophism of the STOCS in winter. In spring a lens of brackish water (from local and Mississippi River runoff) moved south across the STOCS with an offshore component at the surface that dragged surface and deeper open-ocean Gulf water shoreward under the pycnocline. Some of this "salt water wedge" of open Gulf water upwelled resulting in continued eutrophism in the STOCS in spring. In the fall, the zooplankton group indicated the presence of a general encroachment of open-ocean Gulf water throughout the water column. The nearshore surface currents in fall alternated north and south with a general deep bottom current to the north on the outer shelf.

Protozoa on the STOCS reached a maximum in abundance in early spring (March-April). A second protozoan abundance peak was noted in September 1977 but this peak was thought to be abnormal and a result of Hurricane Anita which passed through the area at that time. Oligotrichs were the dominant protozoan group on the STOCS, both spatially and temporally. The other protozoan groups tended to be more restricted both in space and time. Protozoan biomass ranged from 1 to 348% of the macrozooplankton biomass, indicating that protozoa are a significant component of the zooplankton community. Species diversity was high during most of the year and varied erratically.

The abundance of protozoa was positively correlated with nannoplankton chlorophyll a and with silicate. Correlation with salinity was negative, but not significant. Correlations with temperature, dissolved oxygen, net-phytoplankton chlorophyll a, nitrate and phosphate were not significant. Although some data exist that indicate a significant correlation between protozoan abundance and temperature, salinity and net-phytoplankton, the relatively low sampling frequency in this study may have masked such relationships.

Zooplankton abundances, in terms of both biomass and number, displayed a considerable degree of spatial and temporal variations and these variations were progressively extensive toward shore. The zooplankton usually showed a seaward decrease. This decrease was highly pronounced in spring and summer when the zooplankton generally increased to an annual maximum at Stations 1 and 2 and decreased to the lowest annual value at Station 3.

Copepods were the most abundant group, comprising approximately 50% of the zooplankton by number. When the zooplankton increased in spring and summer, the relative abundance of copepods decreased, indicating that other organisms were increasing faster than copepods. Numerically important groups other than copepods were Ostracoda, Amphipoda, Cnidaria, Mollusca, Chaetognatha, Cladocera and Larvacea.

Species diversity indices and coefficients of equitability, based on adult female copepods, generally increased seaward in conformity to the number of species. Of the other biological and physical data obtained at the time of zooplankton collections, salinity and chlorophyll a values seemed to be most closely correlated with the zooplankton. This correlation was most readily discernible in spring when the zooplankton were highly productive in low-salinity water.

A comparison of data from historical samples with the three years of BLM data showed more similarity than dissimilarity in the abundance and taxonomic composition of the zooplankton. The fact that smaller forms and some estuarine species of copepods were more abundant in historical samples may be the result of the differences in sampling gear deployed and location of stations sampled.

The most encouraging generalization which could be made about the neuston results was the high degree to which they followed the important trends seen in the 1976 data. The most remarkable and most interesting of these patterns was that of *Anomalocera ornata*. Males, females and immature forms of this species showed the same trends. Immatures were found in their highest abundance in the winter sampling and showed a decline in March. The adults increased by about an order of magnitude in the winter and then peaked in March with the maturation of the immature forms. This species completely disappeared from the sampling area from the April to the spring cruise. During this time interval the water temperature increased from an average of 21.94 to 25.28°C. Their reappearance in the December samples went along with a decrease in average temperature from 25.52 in November to 23.07°C in December. The similarities in "critical temperatures" were remarkable. The possibility of a resting egg in this species seems very strong and warrants further work.

During the 1977 neuston ichthyofauna survey the greatest abundance of eggs was collected during the spring seasonal cruise and on the July monthly cruise indicating that spawning was most intense during the spring and early summer. Larvae were also most abundant during the spring and early summer with mullids, clupeids and engraulids making up the majority of the larvae. These three families were probably responsible for the high concentration of eggs during the spring and early summer. In 1976 the greatest abundance of eggs occurred in the winter and the greatest abundance of larvae occurred in the spring. Clupeids and engraulids were the most abundant larval forms.

Distribution of larvae along the transects indicated that most fishes, *i.e.* Sciaenidae and Gerreidae, spawn nearshore while a few fishes, *i.e.* Mugilidae, spawn offshore. The majority of the larvae during 1977, as in 1976, were captured during the night, indicating either that larvae are more abundant in the neuston zone during the night or that larvae are less able to avoid the sampling gear during the night. However, larvae of the families Exocoetidae, Mullidae and Mugilidae were more abundant during the day than during the night indicating that either they sink below the neuston zone during the night or are less able, than other larvae, to avoid the sampling gear during the day.

Similarities in the 1976 and 1977 day and night neuston groups were very encouraging. These similarities strongly suggested that there are groups of species that tend to be a fairly constant feature of the STOCS environment. More detailed analysis of quantitative aspects of these associations will be carried out as part of the data integration effort.

About one-half (28/60) of the zooplankton hydrocarbon samples showed the possible presence of petroleum-like organic matter. This was slightly more than was observed in samples collected in 1976 (30%) and considerably higher than observed in 1975 (7%). This apparent increase may reflect the increased import activities for crude oils in the STOCS area. It is not likely that STOCS exploration activities have grown to a size that pollution effects would be observed.

The criteria for presence of petroleum-like organic matter are smooth distribution of n-alkanes in the region of molecular size greater than $C_{21}$ and odd/even preference (OEP) values close to unity. In the case of samples analyzed by gas chromatography/mass spectrometry techniques, the presence of aromatic compounds is usually indicative of petroleum-like material.

Seven zooplankton samples were investigated by GC/MS analyses. One sample, 3/IV, spring, contained polynuclear aromatic hydrocarbons (PAH) in quantities such that they were readily identified even though the quantities were too inadequate for the components to be observable in the gas chromatographic analysis. Four samples (1/II, spring; 2/III, spring; 3/II, spring; 1/IV, spring), showed possible trace quantities of PAH's by GC/MS analysis, though quantities were inadequate to permit certain identification. Two samples (2/IV, winter; 1/III, fall) showed no indication of presence of PAH's. All seven of these samples met the n-alkanes distribution criterion as possibly having petroleum-like organic matter present.

Of all species groups and animal organs analyzed for trace metal content, the zooplankton as a group exhibited the highest concentration of metals. In general for zooplankton, lead concentrations decreased offshore and cadmium levels showed the reverse trend. The levels of all metals, except cadmium, were highest in the zooplankton in the fall season.

## SEA FLOOR

The primary topographic features of the STOCS are the deltaic bulge seaward of the Rio Grande, the comparable outline of an ancestral delta near the shelf edge seaward of Matagorda Bay and the broad ramp-like indentation on the outer shelf between the two deltaic bulges. Second order topographic features are the north-to-northeastward trending low ridges, terraces and low scarps over the ancestral Rio Grande delta, the series of small enclosures associated with a band of irregular topography along the ramp between water depths of 64 to 91 m and the terrace-like area along the outer shelf beginning at the 91 m isobath.

In general, the remainder of the sea floor is characterized by sand-sized sediments on the inner shelf which decrease in abundance seaward. The surficial and near-surface bottom sediments are typically relatively soft and not suitable for bearing heavy structures at shallow depths. Some slumping of the sea floor sediments has been indicated along the periphery of the ancestral Rio Grande delta. Where firm relict sand and soft mud are locally adjacent, sea floor stability is highly variable over short distances. Rapid rates of local sediment deposition of scour have not been observed for this area.

The results of 1977 collections for sediment texture characterization of the STOCS study area showed that the sediment ranged from silty clays to muddy sands. Several textural characteristics could be described in terms of groups of similar stations and gradients of properties.

The textural gradients from the outermost shelf landward were as follows. There was a silty (30%) clay of very uniform texture from sample to sample which sometimes showed a seasonal tendency to coarsen by winnowing of finest clays during the early spring at Stations 3/II, 3/III, 6/III and 7/IV. A slightly coarser, more variable silty clay occurred at Stations 3/I, 5/I, 6/I, 5/II, 6/II, 2/III and 5/III. There was quite a variable sand-silt-clay, midshelf mixture at Stations 2/I, 2/II and 4/II in the northern part of the study area and a similar group with somewhat more variability at least partly because of a much coarser sand mode with some gravel at Stations 2/IV, 3/IV, 5/IV and 6/IV on the Rio Grande delta. Further landward were the most variable inner shelf sandy muds at Stations

1/II and 1/III. The most landward stations (1/I, 4/I, 1/IV and 4/IV) had moderately variable muddy sands near the barrier shoreface sand-offshore mud boundary. Finally, Station 4/III was within the shoreface sands where variability became as low as at the outermost stations due to the efficiency of wave action constantly sorting the bottom sediments in shallow water. At the inner shelf stations there was also a suggestion of seasonal coarsening in early spring and a year-long coarsening in 1977 perhaps related to hurricane generated waves between spring and fall sampling.

There was a very clear trend to increasing total organic carbon with distance from shore. This trend correlated with the percent clay in the samples. There was a less well defined but significant change in Delta $C^{13}$ with slightly more positive ($C^{13}$ enriched) values nearer shore. Seagrasses are more $C^{13}$ enriched than plankton and this trend may represent the export of seagrasses from the estuary to the shelf especially along Transects I and II. The bank stations were very uniform.

The rather uniform pattern of Delta $C^{13}$ and the low values of total organic carbon suggested that petroleum pollution at a fairly gross level could be detected by Delta $C^{13}$ shifts. Delta $C^{13}$ is a measure of carbon-$^{13}$ enrichment or depletion. A negative value under these circumstances represents an enrichment of $C^{13}$ and depletion of $C^{12}$ in respect to a standard with a value of 0. If oil of Delta $C^{13}$ equal to -30 is added to sediment at a level to shift the total organic carbon level from 0.5 to 1.0, then the Delta $C^{13}$ will shift from -20 to -25. Such a total organic carbon shift could go undetected but such a Delta $C^{13}$ shift would be easily noted.

Concentrations of light hydrocarbons in the top few meters of Texas continental shelf and slope sediments were highest near shore and decreased regularly in an offshore direction. Vertical methane profiles exhibited maxima in the top 40 cm of sediment on the shelf, in contrast to downward increasing gradients in the slope region.

Methane was apparently microbially produced in micro-reducing environments and removed by biological oxidation and diffusion into the overlying water. Production rates were related to microbial activity, organic content, and temperature of the sediments. Profiles of $C_2$ and $C_3$ hydrocarbons implied that background concentrations of these gases were also controlled by microbial processes.

These conclusions implied that methane concentrations in near-surface shelf sediments were seasonally influenced. Warmer temperatures and increased detrital and nutrient input in the spring might have enhanced microbial production, so that oscillations of methane could be observed. If real, these oscillations in methane concentration could provide an excellent means of quantitating the magnitude of the effective diffusion coefficient of methane in porous sediments.

Interstitial concentrations of ethene, ethane, propene, and propane were relatively constant with depth in the upper two meters of shelf, slope, and abyssal sediments, decreasing progressively from 160, 100, 110 and 60 nl/ℓ pore water in nearshore sediments, to fairly uniform levels of 80, 25, 30 and 25 nl/ℓ downslope, respectively. The concentrations reported above generally represented "baseline values" of the light hydrocarbons on the Texas shelf. One area of anomalously high ethane and propane was found, however, indicating an input of thermocatalytic gas from the subsurface. This gas was apparently migrating upward through natural conduits in the sediment and dispersing in near-surface sediments and bottom waters in the region. Future prospecting for reservoired hydrocarbon should include coring on or near geological features such as the unique area described above in an effort to detect additional anomalous gas zones.

The high-molecular-weight hydrocarbon analyses of sediment samples produced results in agreement with the Delta $C^{13}$ and total organic carbon results in that the very low level of saturated hydrocarbons detected (0.1 to 1.9 μg/ℓ) pointed to a natural biogenic population of hydrocarbon molecules. For example, no odd-even preference (OEP) values near unity were observed nor were high pristane to C-17 values reported. With respect to the sediment high-molecular-weight hydrocarbons, the STOCS must be viewed as a very clean area.

As was demonstrated previously (Pequegnat and Sikora, *In* Groover, 1977), the highest number of individuals of the true meiofauna was found on Transect IV and the smallest number on Transect II. Second and third positions were held by Transects III and I, respectively, as was also true in 1976 (Table 9).

These differences between transects were statistically significant. On the other hand, the totals between years were remarkably close, with the possible exception of Transect IV, which alone accounted for a smaller 1977 total.

As noted previously, Transect II appeared to be the aberrant sampling line. Since populations increased in both directions from this transect, it may be that the low populations were somehow related to the fact that the stations were in line with the Corpus Christi Harbor entrance and the effluent therefrom. There was also the possibility that the monthly trawling for epifauna along this transect could have accounted for at least part of the difference. Still, an analysis of the populations of the individual stations did not wholly support such a contention.

As was found in the 1976 study, analysis of variance demonstrated that

TABLE 9

SUMS OF THE MEANS OF INDIVIDUALS OF TRUE MEIOFAUNA TAKEN AT ALL STATIONS OF TRANSECTS I THROUGH IV DURING THE THREE SEASONAL SAMPLING PERIODS OF 1977. 1976 NUMBERS ARE IN PARENTHESES.

| SAMPLING PERIOD | TRANSECT | | | |
|---|---|---|---|---|
| | I | II | III | IV |
| WINTER | 284(241) | 97(35) | 287(176) | 297(303) |
| SPRING | 100(111) | 43(52) | 209(234) | 351(275) |
| FALL | 163(183) | 42(58) | 170(270) | 179(421) |
| | 547(535) | 182(145) | 666(680) | 827(999) |

1976 TOTAL = 2359 1977 TOTAL = 2222

the total meiofauna, true meiofauna, nematodes alone, and temporary meiofauna were significantly different (< 0.01) with respect to: 1) transect, 2) depth zones within transects; and, 3) depth zones among transects.

The meiofaunal populations of the STOCS exhibited seasonally related population peaks in March-April, July-August, and November. The lowest peak was in spring and the largest in summer, but the seasonal amplitude was far greater at shallow locations. Nevertheless, even at depths of 134 m seasonal fluctuations were clearly evident.

The meiofaunal populations on the shelf and upper slope decreased substantially with increasing depth down to 134 m. The decrease, however, was not wholly uniform. Local factors could modify the shape of the trend but not the overall trend of reduction. It was not known with certainty what happened to meiofaunal populations below the 134 m isobath in this region.

Correlations were calculated between meiofaunal populations and nine physical parameters measured during the study. The results were essentially the same as those presented in the 1976 study. For instance, sediment texture gave the best correlations with nematodes, harpacticoids, true meiofauna and temporary meiofauna, whereas temperature gave the best correlation with the forams.

Harpacticoid copepods found were not strongly influenced by grain size. Indirect evidence suggested that they responded more to labile organic inputs. Such evidence came from work on and around hard banks and from the fact that harpacticoids were more abundant at locations where one might expect inputs of detrital material.

Development of the harpacticoid/nematode ratio indicated that it was reasonably stable from year to year and that at least some of its departure from the all-station mean of 0.04 could be accounted for by bringing either chemical or biological factors to bear. It was still considered as a potential way of estimating the degree of environmental perturbation, whether such impacts were more likely physical or chemical in nature, and possibly the degree of recovery. In essence the underlying basis for interpreting the values of the ratio is the fact that nematodes are very responsive to changes in sediment granulometry whereas harpacticoids are more likely sensitive to chemical factors in the sediment (Pequegnat *et al.*, 1978). It is also to be expected that biological factors such as reproductive cycles can affect the ratio to a certain extent.

A total of 59,220 individuals representing 667 species of infauna were collected in 75 Smith-McIntyre grab samples taken during 1977. Numerically dominant infaunal species included *Magelona phyllisae, Paraprionospio pinnata* and *Lumbrineris parvapedata.* In general, the number of infaunal species collected at various stations showed a basic spatial pattern with little temporal variability. Transects I and II were similar in spatial patterns of species abundance as were Transects III and IV but there was a decided difference between the two pairs of transects.

The general spatial pattern of infaunal species richness on each transect remained very stable temporally. This implied that either benthic macroinfaunal communities in the area displayed little seasonal fluctuation in major component species or that a highly defined seasonal succession was occurring in which one species replaced another. Thus, the number of species varied little through time. There was no evidence to support the latter hypothesis from our 1977 data or from preceding years. Data from each station for each collection tended to support the former hypothesis. Consequently, with few exceptions, there was little temporal variability in the various infaunal populations comprising the communities of the shelf. The relatively small biomass and the constancy with which various infaunal species were collected indicated that most of the infaunal species exhibited a very short life span and consequently a relatively high turn-over rate in the warm waters of the northwestern Gulf.

The second pattern observed in the species richness data was that Transects I and II were similar in having little or no peak in species richness at the innermost stations and often having more species at deeper stations than at shallow ones. Transects III and IV were more nearly similar in that large peaks of species richness always occurred at the shallow station although Transect IV always had high species richness at Stations 3/IV and 6/IV also. It was felt that the major differences between transects observed in the species richness data were influenced by sediment type and environmental variability.

A definite pattern of decreasing density (number of individuals per unit area) with increasing water depth was observed on all transects although minor peaks in density occurred in some transects at deeper sites. The inshore waters had richer supplies of nutrients in the form of detritus, phytoplankton and dissolved materials. This afforded a greater carrying capacity in the ecosystem which may have directly affected the benthos. The nature of the inshore sediments (sandy-shelly), provided greater niche availability. The physically dominated nature of the inshore community may have selected for species with higher reproductive capacity while the biologically accommodated offshore community possibly could not tolerate high densities of individual populations. The number of infaunal individuals per station remained very stable through all seasonal collections adding credence to the hypothesis that many infaunal species in the study area were short lived with populations that were essentially reproducing year-round and maintaining, on the average, very stable population numbers.

Transect II was generally the most depauperate transect, lacking the inshore peak abundance common to the other three transects. The innermost station on Transect II (1/II) was about seven meters deeper than the innermost station on the other three transects. It lacked the sandy-shell stations that apparently so influenced the number of individuals on the other three transects. Transect IV, on the other hand, exhibited the highest densities of organisms throughout the study period.

Diversity of infaunal communities of the STOCS had a decided tendency to increase offshore. The increase in equitability with depth was generally much more pronounced. Equitability is a measure of how evenly the number of individuals is spread between the number of species present and as such is actually a part of the diversity measure. It was felt that the increase in infaunal diversity offshore was simply a reflection of the lack of numerical dominance by a few species which contrastingly occurred at the nearshore stations. Several stations had chronically low diversities and low equitability (*i.e.* Station 1/III and 5/IV). At these one or two species were generally found to dominate the samples. Ampeliscid amphipods (most often *Ampelisca agassizi*) dominated Station 1/III year-round and *Paraprionospio pinnata* and nemerteans were most dominant at 5/IV. This tendency for dominance by a few species was characteristic of physically controlled communities.

Cluster analysis of the infaunal data essentially paralleled the results of previous years as far as characterizing the community types based on species lists for the STOCS area. As illustrated (Figure 10) five station groups primarily related to water depth, somewhat modified by sediment type, were delineated. There were gradients of two distinct groups of

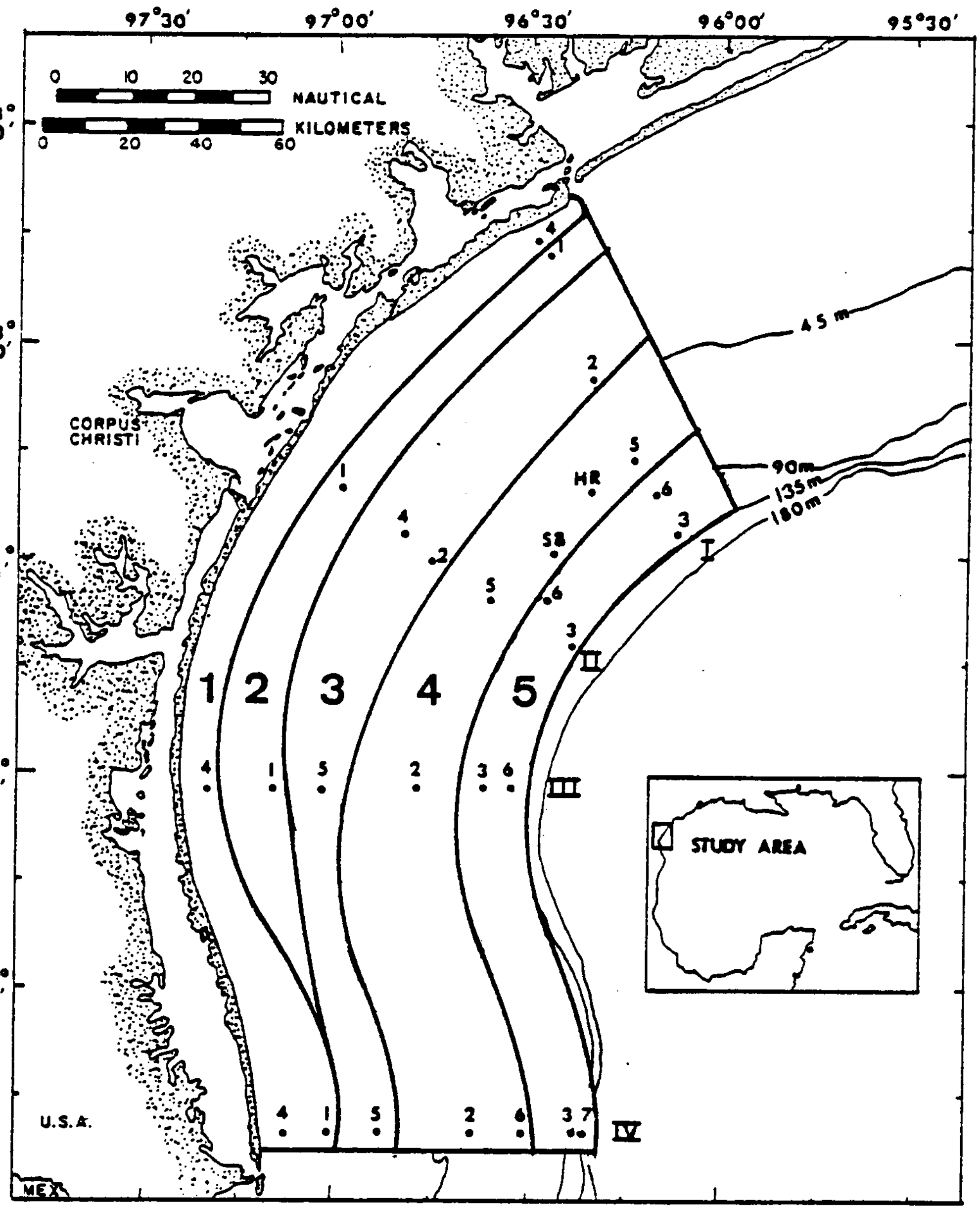


Figure 10. Location of Station-Groups (1-5) from Cluster Analysis of Infaunal Data.

benthic infauna. The first, a shallow group gradually diminished offshore and a deep group, declined in constancy and fidelity inshore. Across these two major divisions were the more cosmopolitan groups which showed high constancy across the shelf with little fidelity to any group of stations. Polychaetes, although found everywhere, were more characteristic of the nearshore stations. The deeper station species groups were characterized more by molluscs and crustaceans. It appeared that if the ubiquitous species were not included, polychaete species would diminish offshore to be gradually replaced by molluscs and crustaceans as dominants in the infaunal community.

The alignment of station groups with depth, and the results of the multivariate method of discriminant analysis suggested that several other environmental factors related to depth may influence the infaunal communities observed. These other factors included such environmental variables as salinity and temperature.

A total of 23,933 individuals representing 88 species of epifauna were collected in the 258 trawls taken during 1977. Three crustaceans (*Trachypenaeus similis*, *Penaeus aztecus*, *Sicyonia dorsalis*) comprised 60% of the total epifaunal catch by number. There were 24 species represented by only one individual.

Epifaunal community structure parameters (diversity, number of individuals, etc.) showed no spatial pattern trends. Variation in temporal and spatial abundances of dominant species in 1976 was found to be due to recruitment of young age classes (Holt and Holland, 1977). Generally, the variation in abundance was due to large numbers of young at shallow to shallow-intermediate stations and migration of the adult population, accompanied by reduction in abundance, to the deeper stations. There was a strong tendency for the large abundances to be concentrated at stations along Transects I and II.

The division of the 1977 STOCS study area into station groups based on depth and factors associated with depth was consistent with the results (Figure 11) from 1976 data analyses. Species groups characteristic of the various depth zones were also consistent for the two years. Although a species group was highly constant to a station group most individual species that comprised a group responded in a unique way to the physical environment common to the stations.

Since epifaunal species have different physical and biological needs, and move considerable distances, analysis of individual species distributions may be the best method for interpreting the STOCS data. An important aspect of this study was the evaluation of STOCS in terms of numbers and kinds of species. Further information that would be derived from the data include an understanding of the distribution of species important to man (directly or indirectly) and the identification of species with narrow or critical tolerances to change.

Linear additive models indicated that epifaunal species distributions were significantly correlated with abiotic variables but only a small amount of the variation was explained. Relationships of species abundance to physical variables were often non-linear, better characterized by gaussian and exponential sine curves. Preliminary non-linear, multiplicative models, using the same physical variables, reduced the mean square by as much as 80% and were therefore superior models for predicting species distribution. With a thorough analysis of species distribution over the three years of study, important species and areas critical to the needs of a species could be determined.

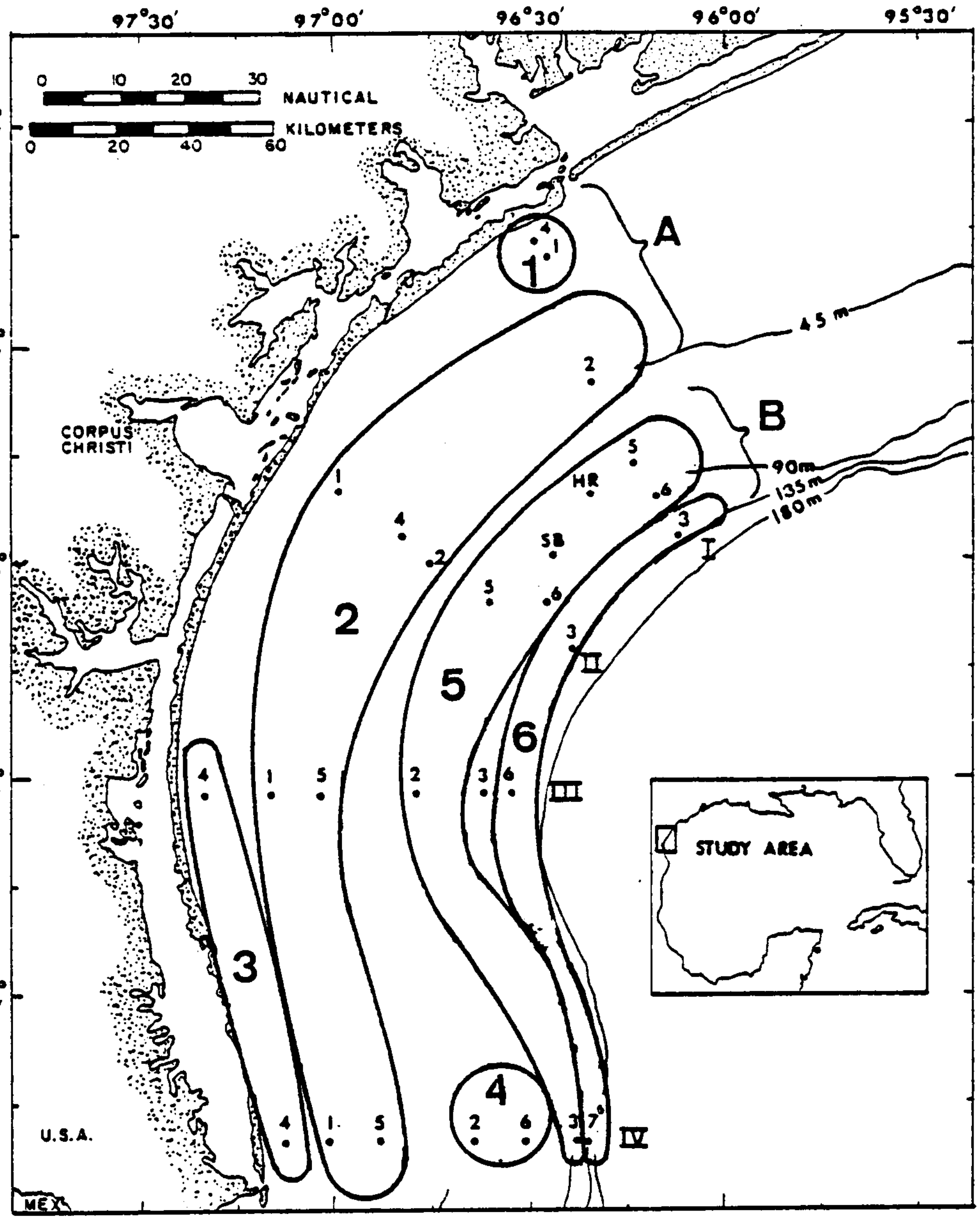


Figure 11. Location of Station Groups from Cluster Analysis of Seasonal Epifaunal Data.

There were 132 species of demersal fish captured during 1977 compared to 128 caught during 1976. Similar to previous collection years, community distributions, represented by groupings of species, were directly related to depth as illustrated by Figure 12.

A greater number of species were caught in night trawls than in day trawls during the seasonal sampling cruises. Part of this difference was attributed to the greater sampling effort expended during night cruises. However, the differences between the numbers of night and day trawls taken during the seasonal cruises were rather small, and it appeared reasonable to conclude that some biological reason existed for the observation that night trawls yielded greater numbers of species than did day trawls during both 1976 and 1977.

Other consistent trends observed for the 1977 data were: 1) Station Group 2 generally yielded the greatest numbers of species during both day and night sampling, probably due to the higher sampling effort expended on Station Group 2; and 2) fall samples yielded the greatest numbers of species.

Total catches (number of individuals per trawl) for each station group during each sampling period are given in Table 10. This table illustrates that the greatest catches occurred during the spring for day trawls and during the fall for night trawls. The lowest catches occurred in winter for both day and night trawls.

The lowest biomasses were taken during the winter for both day and night trawls. The fall night trawls yielded the highest seasonal biomasses. Spring and fall day trawls yielded much higher biomasses than did winter day trawls.

Station Group 2 appeared to show a trend of higher diversity values

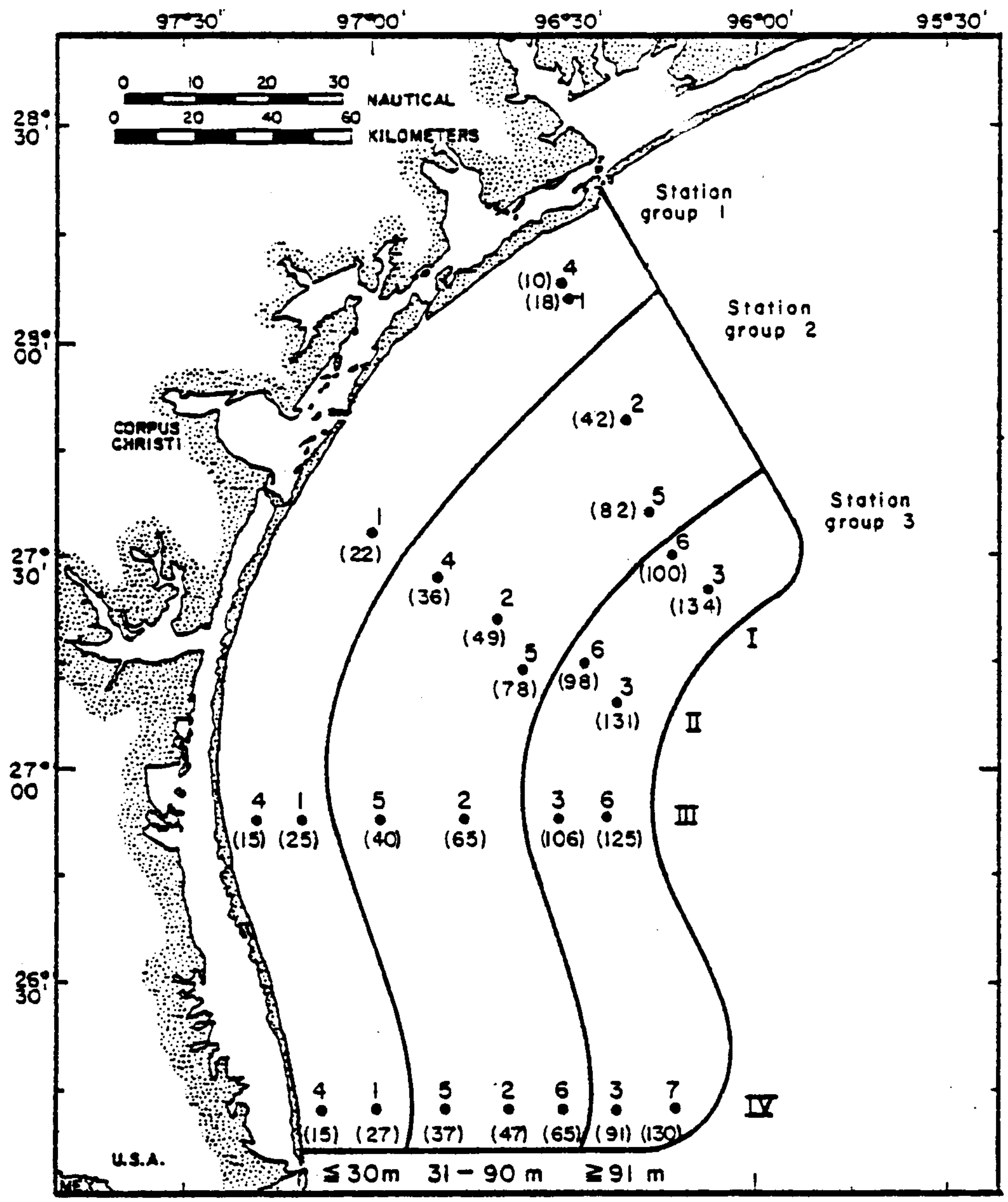


Figure 12. Station Groupings for Demersal Fish According to Cluster Analysis. Numbers in Parenthesis are Depths in Meters.

## TABLE 10

TOTAL NUMBER OF INDIVIDUALS (OF ALL SPECIES) CAUGHT (PER TRAWL) IN EACH STATION GROUP DURING 1977

| | Winter | Spring | Fall | March | April | July | August | November | December |
|---|---|---|---|---|---|---|---|---|---|
| Day | | | | | | | | | |
| Station Group 1 | 12 | 1051 | 208 | - | - | - | - | - | - |
| Station Group 2 | 28 | 188 | 125 | - | - | - | - | - | - |
| Station Group 3 | 27 | 110 | 95 | 74 | - | - | - | - | - |
| Night | | | | | | | | | |
| Station Group 1 | 20 | 85 | 178 | 37 | 75 | 95 | 103 | 58 | 109 |
| Station Group 2 | 22 | 79 | 123 | 38 | 45 | 94 | 65 | 117 | 111 |
| Station Group 3 | 48 | 80 | 156 | 42 | 82 | 135 | 199 | 119 | 148 |

($H_n''$) than the other two station groups. It also had the highest probability of interspecific encounter (P.I.E.) in all cases except for spring day trawls.

The ten most abundant species (with abundance ≥ 10 individuals) caught in each station group during each season are listed in Tables 11 (day) and 12 (night). Most of these species also occurred in the top ten listing for the corresponding station groups and time periods in 1976. Many of the species which occurred in the top ten listings for a particular station group were not found during 1977 in one or two of the other station groups. This was consistent with the premise that faunal composition changed with depth. Viewing the data without regard to the seasons, most of the species could be described as either shallow-water, shallow to mid-depth, mid-depth to deep, or deep-water.

There appeared to be relatively little segregation of the major species into particular transects or groups of transects, although a few species were absent from some transects. Most species were found on all four transects, and several species were particularly well represented over the four transects.

Comparisons of the 1977 data with 1976 data showed a number of discrepancies. In 1977, unlike 1976, fall samples yielded the greatest numbers of species. In 1976, Station Group 3 consistently had the lowest number of species; this was not apparent in 1977. The highest total catches, in terms of numbers of indiviudals, occurred during spring for day trawls and during fall for night trawls in 1977; this was not evident in 1976. The lowest total catches in 1976 generally occurred in Station Group 3, which was not true for 1976, and higher total biomasses were taken in fall than in other seasons for night trawls. The 1976 data generally showed no

TABLE 11

TEN MOST ABUNDANT SPECIES CAPTURED IN DAY TRAWLS IN EACH STATION GROUP DURING EACH SEASON.
SPECIES LISTED ALSO HAVE ABUNDANCE ≥ 10 INDIVIDUALS.
NUMBERS OF INDIVIDUALS CAPTURED ARE GIVEN FOR EACH SPECIES, 1977 DATA

Station Group 1

| WINTER Species | No. | SPRING Species | No. | Fall Species | No. |
|---|---|---|---|---|---|
| *Syacium gunteri* | 20 | √*Peprilus burti* | 4289 | √*Micropogon undulatus* | 906 |
| √*Cynoscion arenarius* | 15 | √*Trachurus lathami* | 1727 | *Cynoscion nothus* | 139 |
| √*Peprilus burti* | 14 | √*Micropogon undulatus* | 750 | √*Syacium gunteri* | 91 |
| √*Micropogon undulatus* | 10 | √*Chloroscombrus chrysurus* | 602 | *Polydactylus octonemus* | 85 |
| | | √*Cynoscion nothus* | 462 | √*Lutjanus campechanus* | 77 |
| | | *Brevoortia patronus* | 181 | *Trachurus lathami* | 67 |
| | | √*Anchoa hepsetus* | 91 | *Peprilus burti* | 46 |
| | | *Harengula pensacolae* | 88 | √*Diplectrum bivittatum* | 28 |
| | | *Etrumeus teres* | 53 | *Anchoa hepsetus* | 28 |
| | | √*Polydactylus octonemus* | 46 | *Citharichthys spilopterus* | 21 |

Station Group 2

| WINTER Species | No. | SPRING Species | No. | FALL Species | No. |
|---|---|---|---|---|---|
| √*Pristipomoides aquilonaris* | 55 | √*Trachurus lathami* | 1207 | *Harengula pensacolae* | 269 |
| √*Serranus atrobranchus* | 48 | √*Peprilus burti* | 846 | √*Trachurus lathami* | 201 |
| √*Prionotus stearnsi* | 45 | *Etrumeus teres* | 83 | √*Serranus atrobranchus* | 155 |
| *Sphoeroides parvus* | 44 | √*Serranus atrobranchus* | 50 | √*Peprilus burti* | 120 |
| √*Saurida brasiliensis* | 30 | √*Pristipomoides aquilonaris* | 47 | *Cynoscion arenarius* | 101 |
| √*Stenotomus caprinus* | 24 | √*Synodus foetens* | 47 | *Synodus foetens* | 78 |
| *Selar crumenophthalmus* | 17 | *Scomber japonicus* | 31 | *Micropogon undulatus* | 78 |
| *Trachurus lathami* | 16 | √*Saurida brasiliensis* | 25 | √*Polydactylus octonemus* | 57 |
| *Centropristis philadelphica* | 15 | √*Stenotomus caprinus* | 24 | *Diplectrum bivittatum* | 56 |
| √*Synodus foetens* | 14 | √*Upeneus parvus* | 15 | √*Stenotomus caprinus* | 56 |
| | | *Diplectrum bivittatum* | 15 | | |

TABLE 11 CONT.'D

Station Group 3

| WINTER Species | No. | SPRING Species | No. | FALL Species | No. |
|---|---|---|---|---|---|
| √*Pristipomoides aquilonaris* | 82 | *Trachurus lathami* | 708 | √*Trachurus lathami* | 183 |
| √*Serranus atrobranchus* | 37 | √*Pristipomoides aquilonaris* | 167 | √*Serranus atrobranchus* | 180 |
| √*Stenotomus caprinus* | 31 | *Stenotomus caprinus* | 71 | √*Pristipomoides aquilonaris* | 145 |
| √*Upeneus parvus* | 10 | √*Serranus atrobranchus* | 61 | √*Prionotus paralatus* | 110 |
| √*Prionotus paralatus* | 10 | *Synodus foetens* | 16 | *Stenotomus caprinus* | 99 |
| | | √*Prionotus paralatus* | 15 | √*Upeneus parvus* | 55 |
| | | *Upeneus parvus* | 11 | √*Pontinus longispinis* | 36 |
| | | | | *Caulolatilus intermedius* | 33 |
| | | | | √*Trichopsetta ventralis* | 26 |
| | | | | √*Prionotus stearnsi* | 16 |

√ - Denotes species which also occurred in the top ten list for the corresponding time period and station group in 1976.

## TABLE 12

**TEN MOST ABUNDANT SPECIES CAPTURED IN NIGHT TRAWLS IN EACH STATION GROUP DURING EACH SEASON. SPECIES LISTED ALSO HAVE ABUNDANCE ≥ 10 INDIVIDUALS. NUMBERS OF INDIVIDUALS CAPTURED ARE GIVEN FOR EACH SPECIES, 1977 DATA**

### Station Group 1

| WINTER Species | No. | SPRING Species | No. | FALL Species | No. |
|---|---|---|---|---|---|
| *Trichiurus lepturus* | 28 | √*Polydactylus octonemus* | 212 | √*Micropogon undulatus* | 724 |
| √*Syacium gunteri* | 25 | *Cynoscion nothus* | 115 | √*Lutjanus campechanus* | 138 |
| √*Cynoscion arenarius* | 23 | √*Micropogon undulatus* | 106 | √*Syacium gunteri* | 114 |
| √*Cynoscion nothus* | 18 | √*Cynoscion arenarius* | 64 | √*Polydactylus octonemus* | 96 |
| *Anchoa mitchilli* | 12 | *Peprilus burti* | 50 | *Cynoscion nothus* | 71 |
| *Peprilus burti* | 10 | *Syacium gunteri* | 35 | *Orthopristis chrysoptera* | 67 |
| | | *Upeneus parvus* | 24 | √*Sphoeroides parvus* | 57 |
| | | *Trachurus lathami* | 21 | √*Diplectrum bivittatum* | 51 |
| | | √*Sphoeroides parvus* | 17 | *Chaetodipterus faber* | 26 |
| | | *Chloroscombrus chrysurus* | 13 | √*Prionotus rubio* | 23 |

### Station Group 2

| WINTER Species | No. | SPRING Species | No. | FALL Species | No. |
|---|---|---|---|---|---|
| √*Stenotomus caprinus* | 55 | √*Stenotomus caprinus* | 196 | √*Serranus atrobranchus* | 315 |
| √*Serranus atrobranchus* | 46 | √*Serranus atrobranchus* | 153 | *Prionotus paralatus* | 181 |
| *Sphoeroides parvus* | 31 | *Prionotus paralatus* | 133 | *Diplectrum bivittatum* | 173 |
| √*Syacium gunteri* | 29 | √*Syacium gunteri* | 96 | √*Stenotomus caprinus* | 161 |
| √*Porichthys porosissimus* | 20 | √*Prionotus stearnsi* | 88 | √*Syacium gunteri* | 146 |
| *Diplectrum bivittatum* | 18 | *Upeneus parvus* | 84 | √*Centropristis philadelphica* | 124 |
| √*Centropristis philadelphica* | 14 | √*Synodus poeyi* | 60 | *Micropogon undulatus* | 121 |
| √*Trichopsetta ventralis* | 14 | √*Centropristis philadelphica* | 54 | √*Prionotus stearnsi* | 99 |
| *Kathetostoma albigutta* | 13 | *Pristipomoides aquilonaris* | 45 | *Cynoscion nothus* | 90 |
| *Synodus poeyi* | 12 | √*Bollmannia communis* | 27 | √*Pristipomoides aquilonaris* | 72 |

TABLE 12 CONT.'D

Station Group 3

| WINTER Species | No. | SPRING Species | No. | FALL Species | No. |
|---|---|---|---|---|---|
| √*Serranus atrobranchus* | 123 | √*Serranus atrobranchus* | 251 | √*Serranus atrobranchus* | 564 |
| √*Stenotomus caprinus* | 85 | √*Pristipomoides aquilonaris* | 205 | √*Prionotus paralatus* | 492 |
| √*Pristipomoides aquilonaris* | 74 | √*Stenotomus caprinus* | 162 | √*Stenotomus caprinus* | 208 |
| √*Trichopsetta ventralis* | 43 | √*Pontinus longispinis* | 49 | √*Pristipomoides aquilonaris* | 114 |
| √*Prionotus paralatus* | 31 | *Trachurus lathami* | 42 | *Trachurus lathami* | 95 |
| *Syacium gunteri* | 17 | √*Trichopsetta ventralis* | 41 | √*Trichopsetta ventralis* | 71 |
| *Pontinus longispinis* | 16 | √*Prionotus paralatus* | 40 | *Upeneus parvus* | 52 |
| √*Prionotus rubio* | 13 | *Urophycis cirratus* | 30 | √*Pontinus longispinis* | 41 |
| *Upeneus parvus* | 14 | *Hoplunnis tenuis* | 15 | √*Halieutichthys aculeatus* | 38 |
| | | *Upeneus parvus* | 15 | *Urophycis cirratus* | 24 |

√- Denotes species which also occurred in the top ten list for the corresponding time period and station group in 1976.

trends in total biomasses taken. In addition, no trends in the diversity indices, which were consistent between 1976 and 1977, were evident.

General seasonal changes in abundance of the fish were quite evident from the 1977 collections. Seasonal changes were also observed in the constellation of predominant species in each of the three station groups. For example, a large number of species, such as *Anchoa mitchilli* and *Caulolatilus intermedius*, predominated in a faunal assemblage only during a single season. Equally large numbers of species, on the other hand, were abundant all year round.

No strong statement on biomass trends correlated with depth could be made from the data collected. The relationships between abundances of selected fish species and some physical variables were examined by plotting abundance of these species against values of a particular variable. From this exercise it was apparent that within a given species different sizes of fish may respond differently to some environmental variables. The implication clearly is that further studies should consider the possible effects of individual size on the relations of the fish to environmental conditions.

The total concentrations of aliphatic hydrocarbons in epifaunal and demersal fish were in the low parts per million (μg/g dry weight) with n-pentadecane, n-heptadecane and pristane being the dominant hydrocarbons. Aromatic compounds were found at very low levels, generally from 5 to 30 parts per billion (ng/g dry weight). Overall, the data suggested very little, if any, petroleum contamination of the study area.

Two parameters that are generally associated with petroleum pollution are the presence of phytane or an unresolved complex mixture (UCM). Unresolved complex mixtures occurred in 56 of the epifaunal samples while phytane occurred in 30; they occurred together in 29 samples. Station 1/IV had the most samples with phytane and a UCM, with Stations 1/I, 2/II and 2/IV having the next highest frequency of these parameters. These results were suggestive of contamination from onshore and shipping activities; further studies are needed to confirm this hypothesis. As the levels found were very low (ppb) and as organisms tend to concentrate hydrocarbons when in contaminated water, these findings suggested very low levels of petroleum hydrocarbons.

The carbon preference indices (CPI) have also been used as a measure of petroleum contamination. These ratios generally yield low, consistent numbers for petroleum and high, varied numbers for biological hydrocarbons due to the odd-carbon dominance found in organisms.

The $CPI_{14-20}$ is almost always greater than two for organisms, and averages less than one for petroleum. In this study, fairly consistent CPI values were found within species, as shown in Table 13. In some cases, such as shrimp, the CPI value appeared to normally be less than two. In most cases, low CPI values did not correspond with the presence of phytane or an unresolved complex mixture in indicating the presence of petroleum. This was probably due to the dominance of the $C_{15}$ and $C_{17}$ hydrocarbons which tended to yield high CPI values and thus possibly masked the effect of petroleum on the CPI. These hydrocarbons were probably present at high levels (often 70% of more of the hydrocarbon concentration) due to the diet of the organisms; the $C_{15}$ and $C_{17}$ n-alkanes are the dominant hydrocarbons in algae.

There was also an absence of correlation between and within stations of the pristane/phytane, pristane/$C_{17}$ and phytane/$C_{18}$ ratios. These parameters are often used to identify sources of oil pollution and would be expected to be similar in organisms exposed to a single petroleum source,

TABLE 13

RANGE OF $CPI_{14-20}$ VALUES IN SELECTED SPECIES

| Species | Number of $CPI_{14-20}$ Values / Number Sampled | Range of $CPI_{14-20}$ Values |
|---|---|---|
| Brown Shrimp | 11/16 | 0.8-3.6 |
| Wenchman | 10/11 | 6.4-16.9 |
| Porgy | 8/9 | 1.3-9.3 |
| Atlantic Croaker | 5/5 | 1.9-5.0 |
| Sand Trout | 4/5 | 6.9-31.2 |

although there is some indication that biogenic hydrocarbons can affect the ratios. The lack of correlation of the ratios, however, further implied the absence of significant petroleum sources in the STOCS. The very low levels of aromatic compounds detected also suggested that there was very little petroleum pollution in the study area.

The dominant hydrocarbons in the macronekton samples were the $C_{15}$ and $C_{17}$ n-alkanes and pristane. Phytane was present in only two of 18 muscle samples, but was present in all liver and gonad samples. An unresolved complex mixture was detected in the chromatograms of almost all samples. The significance of this finding was difficult to ascertain, as the very low levels of aromatic compounds and the calculated parameters were not suggestive of the presence of petroleum contamination in the study area.

No indication of substantial heavy metal pollution was observed in biota of the STOCS during 1977. Shrimp and fish organs and tissues in order of decreasing total trace metals were liver, hepatopancreas, gill and muscle tissue. No significant changes in annual mean trace metal concentrations were found for any organ group between 1976 and 1977. Fish and shrimp muscle had generally low uniform trace metal levels with few apparent geographical, seasonal or interspecific differences.

Fish species in order of decreasing total content of trace metals (except Al, Ca, V) were *Rhomboplites aurorubens* (vermilion snapper), *Stenotomus caprinus* (longspine porgy), *Pristipomoides aquilonaris* (wenchman), *Lutjanus campechanus* (red snapper), and *Serranus atrobranchus* (blackear bass). Few significant correlations between liver trace metal concentrations and fish length were observed. Levels of Cd, Ni, and Pb were generally highest in livers of *S. caprinus* collected from the northern half of the STOCS study area.

Gill and liver tissue from *R. aurorubens* had generally higher levels of trace metals than similar tissues from *L. campechanus*. Cadmium levels were higher in livers than gills for both species. Within each species, the concentrations of all metals studied were similar for both bank stations.

Both species of shrimp analyzed had similar levels of trace metals in their hepatopancreatic tissue. This tissue contained the highest Ni levels of any sample type analyzed. Cadmium levels were similar to those in fish livers. Cadmium and Ni levels were maximum in the winter seasons. Significant differences between concentrations of various trace metals at different stations were observed, but no consistent geographical trends were apparent.

Of the sample types analyzed during this study for trace metal content, three are best suited for any future monitoring effort in the STOCS region. *Spondylus americanus* (spiny oyster) would be the best choice. This species is a sedentary, filter-feeding bivalve. It contains measurable levels of all the metals studied and the intra-station variability in metal levels is quite low. *Spondylus*, however, has a very discontinuous distribution within the STOCS area and could be difficult to obtain in suitable numbers. A solution to this limitation would be to transport individual *Spondylus* to the areas of interest and allow them to "sample" the ambient metal levels for several weeks or months.

The remaining two sample types are fish liver (*i.e.*, *L. campechanus*, *P. aquilonaris*, *R. aurorubens*, *S. caprinus*) and shrimp hepatopancreas (*Penaeus aztecus*, brown shrimp; *P. setiferus*, white shrimp). Although relatively mobile, these species are widely distributed within the STOCS area and generally available in sufficient numbers most of the year. These tissues contain measurable amounts of most of the metals studied and their intra-station variability in trace metal levels is very acceptable.

The qualitative information obtained in the histopathologic study of demersal fish demonstrated that parasitism was the major cause of lesions. Lesions that may be related to other pathologic agents were not observed. Parasitism caused varying degrees of necrosis, especially in the liver and stomach. Adjacent to such lesions, however, the general integrity of the tissues was maintained.

Quantitative analyses of the percentages of lesions between and within various groups demonstrated several important points. Approximately two-fifths of the organ samples collected had lesions. Among species, aside from significant differences between red snapper and threadfin, overall lesion percentages did not differ significantly. Within each station, lesion percentages did not differ significantly according to month or season. Within each station, gastric and hepatic lesions were observed with significantly greater frequency than were heart, kidney and muscle lesions. Kidney lesions were significantly more frequent than heart or muscle lesions. Overall lesion percentages did not differ significantly according to station. Finally, cardiac lesions were observed with significantly greater frequency at Southern Bank than at Stations 1, 2 or 3.

The total number of all epifaunal pathological conditions in the gills almost equaled that in all of the internal organs. Shrimp had the largest variety and the highest percent of gill symbionts, most of which were parasitic ciliates.

The large majority of pathological conditions in the internal organs of the invertebrates studied were caused by parasites. They most commonly invaded the gastrointestinal tract. Bivalves had the highest number and largest variety of internal parasites, particularly the paper shell scallop which averaged almost six parasites per specimen.

A variety of pathological conditions was observed in the gonads of species sampled. From these analyses, 16.9% displayed some pathological condition. Vertebrates accounted for 88 infected specimens (10%) while invertebrates accounted for 61 infected specimens (6.9%). The highest incidence of parasites in the vertebrates was during the coldest part of the year. Invertebrate gonads had an increase of parasitism during the warmer months.

The wenchman (70 specimens, 16 infected) had the highest incidence of pathological conditions among the vertebrate gonads (22.9%) and the long-spined porgy (71 specimens, 8 infected) had the lowest incidence (11.3%). Of the invertebrate gonads, the scallop (53 specimens, 18 infected) had the highest incidence of pathologies (40%) while the rough back shrimp (51 specimens, 1 infected) had the lowest incidence (1.9%).

From the 1976 and 1977 sampling, a tentative reproductive cycle has been developed for *Pristipomoides aquilonaris*, *Stenotomus caprinus*, *Cynoscion arenarius* (sand seatrout), *Rhomboplites aurorubens*, *Penaeus aztecus*, *Callinectes similis* (blue crab), and *Loligo pealei* (squid). Too much variation was noted even for organisms collected during every sampling effort to predict any of these cycles with total confidence.

## MICROBIOLOGY

Marine bacteria of the water column are relatively few in number when compared with those in the sediments. Heterotrophic water column bacteria ranged from $5.0 \times 10^2$ to $1.55 \times 10^5$ cells per liter and hydrocarbonoclastic (oil degrading) water column bacteria ranged from 0 to 12.9 cells per liter. Populations of total aerobic heterotrophic benthic bacteria ranged from $4.6 \times 10^4$ to $1.3 \times 10^6$ per milliliter of wet sediment while hydrocarbon degrading bacteria ranged from $8.0 \times 10^1$ to $1.1 \times 10^5$ per milliliter of wet sediment. The percentage of oil degraders ranged from 0 to 2.05% (but the values were usually less than 0.5%) for the water column samples and from 0.10 to 20.68% for the sediment samples. The percent hydrocarbon degrading bacteria has been directly correlated with the concentration of contaminating oil (Hood *et al.*, 1975; Walker and Colwell, 1976). For this reason, the percent hydrocarbon degrading bacteria has been proposed as an indicator of oil pollution.

A low percent hydrocarbon degrading benthic population (generally < 1%) during winter and spring indicated the pristane nature of the STOCS. However, a higher percent hydrocarbon degrading population (> 1%) occurred during the fall. The observed seasonal variations must be considered if the percent hydrocarbon degrading bacteria is used as an indicator of oil pollution on the STOCS.

Oil biodegradation rates of benthic bacteria varied seasonally, with highest rates recorded at all stations during fall. Fluctuations in degradation rates may not have been entirely due to season, because of variations in the sterilization and concentration of oil added to degradation flasks. The fall high for degradation rates of oil, however, coincided with a seasonal high in the number and pereent hydrocarbon degrading bacteria. Hydrocarbonoclastic water column bacterial populations peaked in July and August, thereby resulting in increases in percentage of oil degraders.

Sediment bacterial populations were not evenly distributed over the STOCS. Highest populations of aerobic heterotrophic bacteria occurred at shallow depth stations near terrestrial influences.

Oil biodegradation rates did not appear to vary geographically, nor did they appear to be related to transect or depth. Likewise, the number and percent hydrocarbon degrading sediment bacteria were not affected by transect or depth.

The addition of oil to sediment increased bacterial populations. Stimulation of aerobic heterotrophic bacteria by oil suggest that it serves as a nutrient source for growth. This contention is supported by two lines of evidence: 1) oil significantly increased the number of hydrocarbon degrading bacteria, and 2) a significant fraction of oil was degraded. Oil not only increased benthic bacterial populations, but also changed the relative abundance of aerobic heterotrophic bacteria. Pure culture studies indicated that certain species of sediment bacteria are stimulated by oil while others are inhibited. Studies with natural sediment populations indicated that oil increased the percent of the bacteria in the population capable of degrading oil. The fact that oil increased the percent hydrocarbon degrading bacteria during the first week only was likely due to substrate limitation after one week in oil-containing flasks.

Pure culture and mixed culture studies on the effects of South Louisiana Crude Oil (SLCO) indicate that concentrations of 0.5% or less increased the growth rate of water column bacteria after four weeks, following a decrease after the first seven to 14 days of incubation. The presence of 0.1% or 0.5% SLCO did not seem to affect the number of water column bacteria present nor the course of the successional studies. In some cases, the number of genera present in the succession cultures decreased with increasing time in the laboratory. The addition of SLCO did not alter growth time of selected strains of water column bacteria.

Hydrocarbon and turbidimetric analyses indicated that an insignificant amount of SLCO was metabolized during the water column bacterial successional stages. Oil degradation rates for Gulf of Mexico water tested were insignificant or essentially zero unless minimal nutrients were added to the water samples. Additions of nitrates, phosphates, iron, or a complement of mineral salts to the medium significantly enhanced bacterial hydrocarbon metabolism.

STOCS benthic fungi were generally over one thousand times more abundant than detectable fungi in near-surface waters. The average fungal population density for the water column samples was a rather low 0.01 colony forming unit (CFU) per milliliter in contrast to 236 CFU per milliliter of sediment. Form-species of *Penicillium*, *Cladosporium* and *Candida* predominated in the water column while form-species of *Penicillium*, *Aspergillus*, *Cladosporium* and *Fusarium* dominated in the benthos. The taxonomic composition of the STOCS mycota, with the exception of the yeasts, was similar to that of continental air spora.

Viable fungal units were much more abundant in the STOCS water column in the spring than in the summer, fall, or early winter. The population density of benthic fungi tended to increase from late winter through late spring to a fall maximum. The abundance of benthic fungi at each station was a function of the organic carbon concentration of the sediment.

The percentage of water column fungi that were able to degrade SLCO ranged from a low of 0% at the inshore station during the spring and summer months to a high of 70 to 67% in the November and December samples from Station 3/II. The percentage increased with distance offshore. The calculated percentage of benthic fungi capable of degrading oil varied from a low of 12% to a high of 90%, while most values exceeded 50%.

Fungi in pure and natural mixed cultures preferentially utilized n-alkanes of intermediate chain length. Isoalkanes were relatively resistant to fungal degradation. The fungal n-alkane degradation potentials of STOCS waters and sediments tended to decrease offshore across the shelf, especially during the summer.

Natural mixed fungal cultures were generally stimulated by SLCO after a lag period of one to four weeks. Crude oil increased the generic richness of natural mixed cultures over that of the controls. Form-species of *Penicillium*, *Aspergillus*, *Cladosporium* and *Fusarium* were frequently encountered after two weeks in both the oil-enriched water and sediment samples.

As can be seen by reading this document, large amounts of data were obtained during the 1977 BLM STOCS program. Only broad generalized conclusions have been drawn and presented in this report. More definitive statements about the STOCS ecosystem and interrelationships of the results of the various study elements await further analysis of the data. Integration of the data produced by the 1975-1977 BLM STOCS studies is to be carried out during the upcoming year. The results of this integration will be presented in a report to be completed by mid-1979.

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### The Department of the Interior Mission

As the Nation's principal conservation agency, the Department of the Interior has responsibility for most of our nationally owned public lands and natural resources. This includes fostering sound use of our land and water resources; protecting our fish, wildlife, and biological diversity; preserving the environmental and cultural values of our national parks and historical places; and providing for the enjoyment of life through outdoor recreation. The Department assesses our energy and mineral resources and works to ensure that their development is in the best interests of all our people by encouraging stewardship and citizen participation in their care. The Department also has a major responsibility for American Indian reservation communities and for people who live in island territories under U.S. administration.

### The Minerals Management Service Mission

As a bureau of the Department of the Interior, the Minerals Management Service's (MMS) primary responsibilities are to manage the mineral resources located on the Nation's Outer Continental Shelf (OCS), collect revenue from the Federal OCS and onshore Federal and Indian lands, and distribute those revenues.

Moreover, in working to meet its responsibilities, the **Offshore Minerals Management Program** administers the OCS competitive leasing program and oversees the safe and environmentally sound exploration and production of our Nation's offshore natural gas, oil and other mineral resources. The MMS **Minerals Revenue Management** meets its responsibilities by ensuring the efficient, timely and accurate collection and disbursement of revenue from mineral leasing and production due to Indian tribes and allottees, States and the U.S. Treasury.

The MMS strives to fulfill its responsibilities through the general guiding principles of: (1) being responsive to the public's concerns and interests by maintaining a dialogue with all potentially affected parties and (2) carrying out its programs with an emphasis on working to enhance the quality of life for all Americans by lending MMS assistance and expertise to economic development and environmental protection.