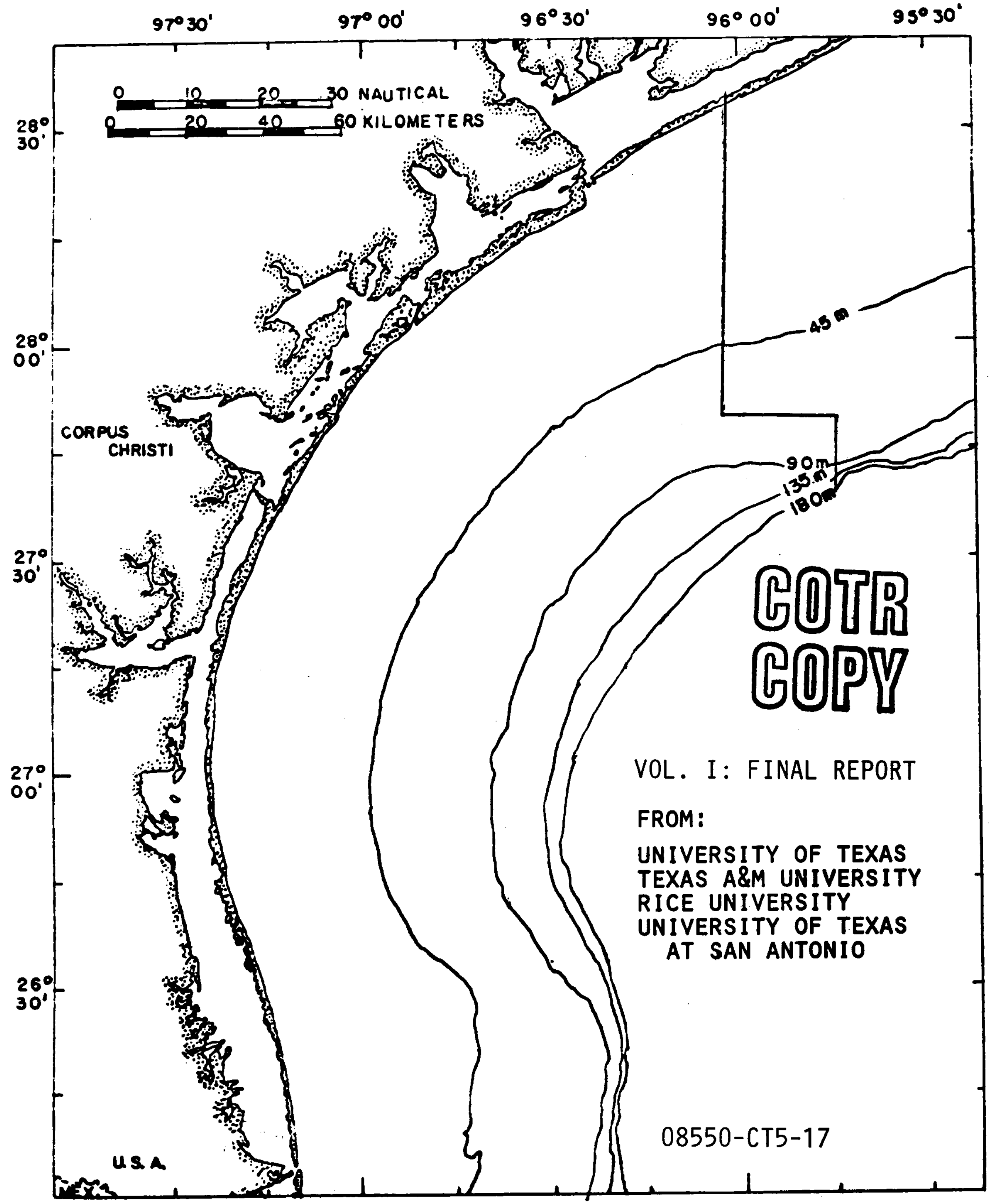
ENVIRONMENTAL STUDIES,
SOUTH TEXAS OUTER CONTINENTAL SHELF, 1975
BIOLOGY AND CHEMISTRY



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VOL. I: FINAL REPORT

FROM:

UNIVERSITY OF TEXAS
TEXAS A&M UNIVERSITY
RICE UNIVERSITY
UNIVERSITY OF TEXAS
AT SAN ANTONIO

08550-CT5-17

ENVIRONMENTAL STUDIES, SOUTH TEXAS OUTER CONTINENTAL SHELF, 1975, BIOLOGY AND CHEMISTRY

A report to the Bureau of Land Management
in fulfillment of Contract 08550-CT5-17

submitted by

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Texas A&M University
Rice University

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ENVIRONMENTAL ASSESSMENT OF THE SOUTH TEXAS OUTER CONTINENTAL SHELF

CHEMICAL AND BIOLOGICAL

SURVEY COMPONENT

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TRACE METALS, Bobby J. Presley, Texas A&M University.

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FOREWORD

This study is the result of the combined efforts of scientists and support personnel from three Universities. The study was carried out on behalf of the U.S. Bureau of Land Management and with the close cooperation of that agency. It is part of a four element study* of the South Texas Outer Continental Shelf. The hard work of all participants is a measure of their concern that the living resources of the outer continental shelf be protected while the area is being used for petroleum production. Thanks to each one.

* The other elements are (1) Geological Investigations, U.S. Geological Survey, (2) Physical Oceanography and Fisheries, U.S. National Marine Fisheries Service, and (3) Topographic Features Study, Texas A&M University.

INTRODUCTION

Purpose and Scope of Study

The purpose of this study was to carry out detailed observations and measurements of the biology and chemistry of the South Texas outer continental shelf. The study was ordered so as to include a broad survey in terms of the number of stations and the frequency of sampling. The study is for the most part descriptive as contrasted to specific process studies which could have been made. However, this first year's report demonstrates that the study plan has resulted in a large and highly significant mass of new environmental data. This study is an excellent example of a national and a scientific need coinciding.

In 1974, the Bureau of Land Management was authorized to initiate a National Outer Continental Shelf Environmental Studies Program. The objectives of the program as stated by the BLM are:

- provide information about the OCS environment that will enable the Department and the Bureau to make sound management decisions regarding the development of mineral resources;
- provide basis for predicting the impact of oil and gas exploration and development on the marine environment;
- establish a basis for predication of impact of OCS oil and gas activities in frontier areas;
- provide impact data that would result in modification of leasing regulations, operating regulations, or operating orders.

The initial study approach to the program, as outlined by the BLM, is to establish environmental baselines; benchmarks in selective OCS regions prior to oil and gas exploration.

Biological Setting

The Texas coastline is biologically and chemically a two-part marine system; the coastal estuaries and the broad continental shelf. The area is rich in finfish and crustaceans. The area also plays a key role in the life cycle of many estuarine organisms in that it is the site of their spawning (Galtsoff, 1954; Gunter, 1954). The broad shelf with its muddy bottom supports a valuable shrimp fishery as well as a significant sports fishery. In general the area is somewhat nutrient depleted with relatively low primary productivity (El-Sayed et. al., 1972). Nevertheless, as a living resource the area is valuable, contributing directly to the local economy. More detailed descriptions of the biological setting are given in the invididual chapters of this document.

Location of Area and Bathymetry

The South Texas OCS as described herein corresponds to the area outlined by the Department of the Interior for oil and gas leasing. The area covers approximately 8,760 sq km (5,444 sq mi) and extends northward from the International Boundary to the northern end of Matagorda Island, Texas and seaward from the Federal-State territorial boundary 16.6 km (10.3 mi) to the approximate position of the 200 m isobath, or outer edge of the continental shelf. The location of the area is shown by Figure 1 and the bathymetry by Figure 2.

Work Plan

Time Frame and Organization for Biological and Chemical Investigations.

The investigations reported herein were initiated November 1, 1974.

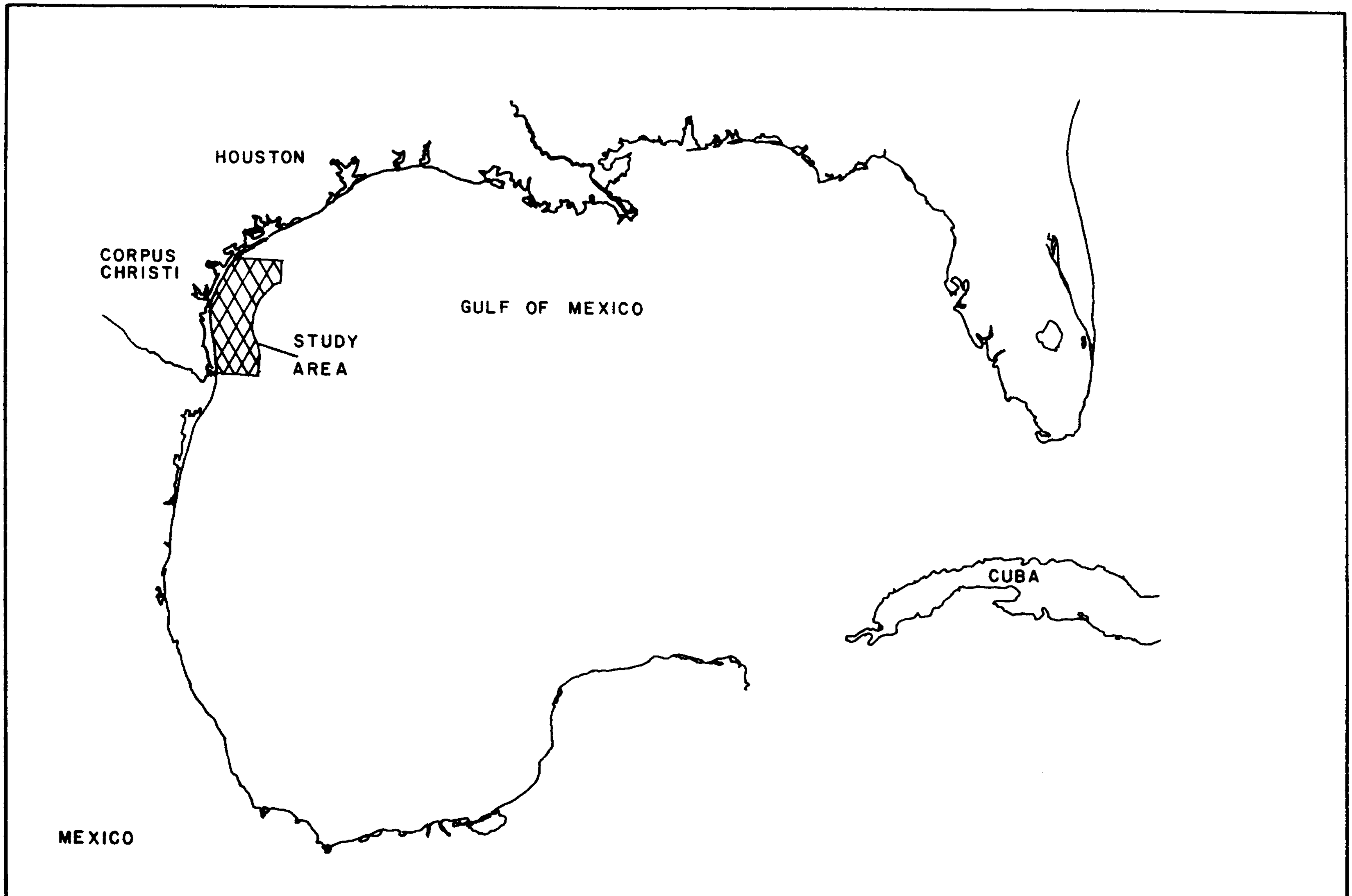


Figure 1. Location of the study area in relation to the entire Gulf of Mexico.

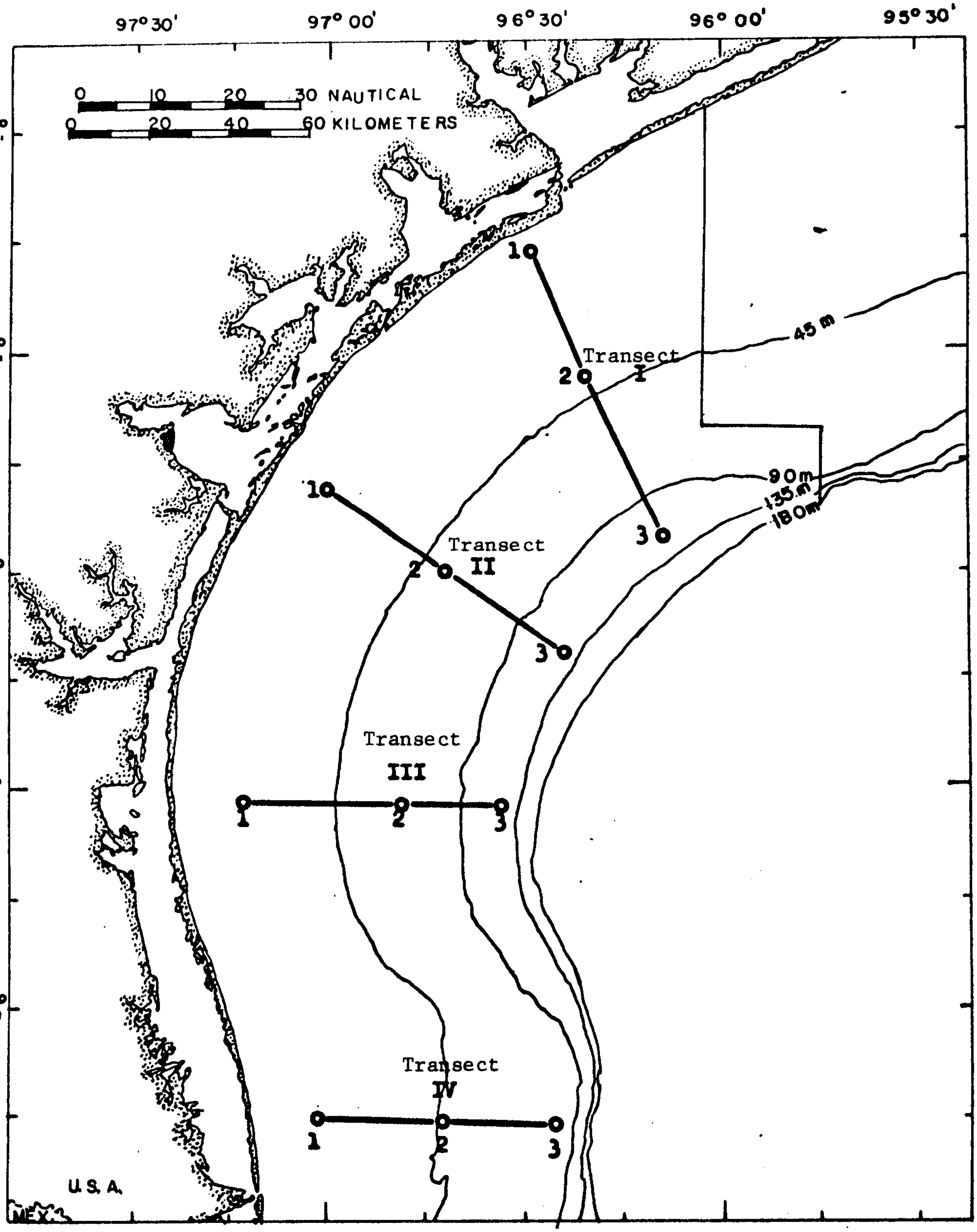


Figure 2. Station locations and bathymetry of the South Texas continental shelf. Depths in meters.

The field sampling was started in December 1974, and completed in September 1975. The laboratory analysis was complete by January 30, 1976. The University of Texas Marine Science Laboratory at Port Aransas was contracted by the Bureau of Land Management to provide logistics, ship time, management and certain scientific efforts. The balance of the scientific effort was provided by sub-contract between the University of Texas and Texas A&M University and between the University of Texas and Rice University. Those aspects of data management which required a computer were sub-contracted to the Texas Water Development Board, an agency of the State of Texas.

The biological and chemical investigations are part of a coordinated, multi-institutional, interdisciplinary study which includes geological, fisheries and physical oceanography. This total effort was under the overall coordination of Henry Berryhill, U.S. Geological Survey, Corpus Christi office. An integrated final report for the project will be produced by August 1976.

Objectives.

The central objective of the biological and chemical studies is to provide an understanding of the living resources of the shelf so that the impact of drilling for and production of petroleum may be assessed and controlled. In order to approach this objective a broad program has been designed. The specific program objectives include:

- water mass characterization;
- primary productivity as described by phytoplankton abundance, chlorophyll-standing crop and nutrient levels;
- secondary productivity as described by zooplankton abundance, ATP-standing crop and neuston abundance;
- benthic productivity as described by infaunal and epifaunal abun-

dance;

- petroleum hydrocarbon baseline levels in biota, water and sediment;
- trace metal baseline levels in biota (sediment levels measured by USGS).

While the program is almost entirely descriptive in nature the magnitude of the sampling effort and the fact that it was spread over three seasons permit significant generalizations as to biological trends.

Survey Vessel.

The collections and at sea measurements were made aboard the University of Texas, R/V LONGHORN. The R/V LONGHORN, designed and constructed as a coastal research vessel in 1971, is a steel-hulled 80' by 24', 7' draft ship; she carries a crew of 5 and a scientific party of 10. The R/V LONGHORN is a medium endurance vessel which means that weather is a factor in her operation. Fortunately, weather and well planned cruise transects combined to permit the complete sampling plan to be carried out in 60 days rather than the 75 that were planned.

Navigation and sample station locations were by Loran A. Water depth as measured by Simrad fathometer was used as an aid to locate the benthic sample stations.

The sampling program was repeated three times to provide seasonal coverage; December-January, April-May and August-September. A total of 37 scientists and technicians participated in the cruises. Chief scientists were: Gerald P. Pfeiffer, Ned P. Smith, Richard K. Tinnin and J. Selmon Holland.

Sampling Plan.

The sampling plan was based on 12 stations located on 4 transects as shown in Figure 2. Each station was occupied three times during the one year study period to allow for seasonal variations. The exact locations are given in Table 1. The rationale for this plan was based on the experience of the program scientists. The cruise transect approach was selected because the area is rather uniform in changes in bottom bathymetry (offshore and north-south wise), physical and chemical parameters. The three seasons were selected to permit study of the water column during a cold period, a period of mixing and a period of temperature maximum. The first year's results have shown that the sampling plan was a sound one although as expected more stations and more frequent sampling are recommended for a second year study.

At each station the following sample efforts were made.

Hydrography. A PLESSEY (STD) Self-Contained Profiling System was lowered at each of the 12 stations. The resulting salinity and temperature profiles provided a general characterization of the water mass. These profiles were supplemented with surface calibration data, using a bucket thermometer for temperature and a BECKMAN RS-7 Laboratory Salinometer for salinity.

Primary Production. Water samples were taken by Niskin bottles at two depths: surface and one-half the depth of the photic zone (determined with a Secchi disk). Subsamples were set aside for phytoplankton taxonomy, chlorophyll, ATP, low-molecular-weight hydrocarbons and dissolved oxygen.

Zooplankton. Two oblique tows were made for zooplankton (day and night) using 250 micrometer mesh, one meter nets equipped with flow meters and a BENTHOS time-depth recorder. Vertical tows were made with a 30 cm net (74 micrometer), and water samples were taken at several depths for microzooplankton studies.

Table 1. Station Location and Depths.

LINE	STATION	LATITUDE	LONGITUDE	DEPTH (meters)
I	1	28°12'	96°27'	18
	2	27°54.5'	96°19.5'	42
	3	27°33.5'	96°06.5'	134
II	1	27°40'	96°59'	22
	2	27°30'	96°44.5'	49
	3	27°17.5'	96°23'	131
III	1	26°57.5'	97°11'	25
	2	26°57.5'	96°48'	65
	3	26°57.5'	96°32.5'	106
IV	1	26°10'	97°00.5'	27
	2	26°10'	96°39'	47
	3	26°10'	96°24'	91

Neuston. A day-time sample was taken using a one meter, 250 micrometer net held at the sea surface by a sled.

Benthic fauna. Seven replicate bottom grab samples were taken using a SMITH-MACINTYRE sampler having 0.1 m^3 capacity. Four were reserved for taxonomic study, one was archived and two reserved for chemical analysis. Two trawls (day and night) were made using a 35-foot (10.7 m), standard otter trawl and samples reserved for taxonomic and chemical analysis.

Hydrocarbon. Water, zooplankton, neuston, epifauna, sediment and macronekton samples were taken for hydrocarbon analysis. Subsamples of 30-liter water-bottle casts were reserved for dissolved low-molecular-weight hydrocarbon determination; special 19-liter collections were performed to collect water for dissolved high-molecular-weight hydrocarbon determination. Zooplankton net tows (day and night) were made using a standard 1 meter net mounted on a specially constructed metal-free frame. Subsamples of sediments were taken from the benthic grabs. Neuston net tows were made with a 1/2-meter plankton net equipped with non-contaminating grommets and mounted on a fiber-glassed sled. Epifaunal samples consisting of crustaceans, molluscs and fishes were collected with the otter trawl. Macronekton was supplied to us by Dr. Bright (Texas A&M University, Topographic High project) in accordance with BLM. All STOCS biological material and sediment was frozen at sea in glass containers. Macronekton was frozen at sea in 4 mil plastic bags. Water samples were preserved with mercuric chloride.

Trace metals. The collections of zooplankton, neuston and benthic fauna designated for hydrocarbon analysis were also subsampled for trace metal analysis. Macronekton was also supplied by Dr. Bright. All samples were frozen at sea in plastic and held in this condition until analyzed.

A summary of samples collected by type and number is given in Table 2. Details of methods are given in the project report.

Sample Identification. Each sample was given a preassigned, unique identification code which consists of three letters. This was done to simplify data management. A dictionary to this code was provided for each investigator.

Table 2. Summary of Samples Collected by Type and Number.

Type	Number
Phytoplankton	72
Zooplankton	144
Neuston	36
Benthos	313
Hydrography	72
Light Hydrocarbon	146
Heavy Hydrocarbon	432
Trace Metal	396
Microzooplankton	201
Quality Control	140

HYDROGRAPHIC PROJECT

University of Texas, Marine Science Laboratory

Principal Investigator:
Ned P. Smith

Associate Investigator:
James C. Evans

INTRODUCTION

The hydrographic component of the Texas OCS Study had two primary purposes. The first was to provide temperature and salinity data in support of other components of the OCS Study which may have need of hydrographic data to explain various aspects of biological or chemical characteristics of the water column. The second purpose was to improve the present understanding of the hydrography of the Texas OCS. Historical data are comprised primarily of routine observations made on military, commercial or research vessels over a period of many years. Little synoptic survey work has been carried out in the northwestern Gulf of Mexico.

The general design of the hydrographic study involved the collection of salinity and temperature profiles (STD data), followed by laboratory digitization and the construction of cross-sections and sigma-t plots. STD data were supplemented with surface calibration data, using a certified bucket thermometer for temperatures and a BECKMAN RS-7 Laboratory Salinometer to determine the salinity of surface water samples. A PLESSEY Model 9060 was borrowed from the State University System Institute of Oceanography in St. Petersburg, Florida, for the January OCS cruises. The instrument worked intermittently on the first three legs of the cruise and the data set is incomplete.

During the April-May cruises, a brackish lens of water originating at the mouth of the Mississippi River produced salinities too low to be recorded by the STD, which has a range of 30-40 parts per thousand. Thus, some STD profiles are lacking salinity data through the upper 10-12 meters of the water column.

A total of 44 profiles are complete; an additional 15 are missing salinity data in the upper layers. Over the first year, 11 profiles are missing altogether.

The missing STD profiles are due to instrument malfunction. The STD being used on the first seasonal cruise was one that had been borrowed from SUSIO. Difficulties were encountered both by the Principal Investigator (Smith) and by the SUSIO Marine Services Supervisor (Olsen), who accompanied the Principal Investigator on one leg of the winter seasonal cruise. In all cases sufficient temperature and salinity data were pieced together from several sources to produce temperature and salinity cross-sections which reflect the major features of the two-dimensional temperature and salinity structure.

METHODS

Raw data are presented in Appendix I. STD data were obtained in analog form, using a PLESSEY Model 9060 Self-Contained Profiling System. The unit senses temperature between -2° and +35°C to within 0.1°C, and salinity between 30 and 40 parts per thousand to within 0.08 ppt. Differences between the time constants of the temperature and conductivity sensors produces a high frequency "spiking", which tended to obscure the salinity trace. The depth range of the instrument was 0-300 m with an accuracy of 1.15 m.

Temperature and salinity data were digitized generally at three or six meter intervals, depending on the water depth and vertical variations in temperature or salinity, as indicated by the analog record.

Temperatures were read to tenths of a degree, while salinity was read to hundredths of a part per thousand. The STD was generally lowered to within three meters of the bottom depth as indicated by the ship's echo sounder, a SIMRAD, with a resolution of approximately one meter.

STD data were collected day and night while the ship was at anchor or adrift in deeper water. Drops were scheduled at times that were convenient, given the requirements and priorities of the other components of the program. Daytime drops were made between mid-morning and late afternoon; night drops were between early evening and approximately 0300 CST.

Sigma-t diagrams were constructed from tabular data presented in the Handbook of Oceanographic Tables. Cross-sectional base maps across the Texas Continental Shelf along Tracks I and IV were constructed using bathymetric data from USCGS Chart 1117.

RESULTS

Raw temperature and salinity data are included in Appendix I. The Salinity-Temperature-Depth (STD) profiles may be used individually to support the chemical and biological water column data, however, the hydrography of the Texas Outer Continental Shelf is best shown by combining profiles obtained along a given track to form a two-dimensional cross-section of temperature and salinity. Data have thus been grouped according to season and track. Only data obtained from the day STD drop were used in constructing the cross-section.

Winter Temperature Data

The water column along Track I (Figure 1), obtained between 4 and 6 December, 1974 is largely isothermal at the inner two stations. There is an isothermal layer extending through the upper 70 m at Station 3/III, which rests on the top of the permanent thermocline. Surface waters increase in temperature with increasing distance from shore as a consequence of greater winter cooling in the shallower nearshore waters. The isothermal upper layer is characteristically found in coastal waters during the fall and winter overturn.

A similar pattern is seen in the temperatures collected along Track II (Figure 2) between January 9 and 12, 1975. The offshore waters are approximately 2° cooler in the upper layers. This is likely a result of continued winter cooling, rather than part of a static spatial pattern. Again, at the outer station, the water column appears well mixed through the upper 60 m. Track III temperatures (Figure 3), obtained between December 13-15, 1974, and January 26, 1975, are quite similar to those along Track II, however, overturning at Station 3/III extends only through the upper 40-45 m.

Somewhat cooler surface temperatures are found along Track IV (Figure 4) between January 22-24, 1975. The lower part of the water column remains above 20°C, due at least in part to the fact that the profile extends only to 95 m. The 20°C isotherm occurs at approximately that level along the other tracks.

Winter Salinity Data

A substantial cross-shelf salinity gradient is found along Track I between the inner two stations. A lens of slightly lower salinity water is found near the surface at the outer two stations (Figure 5), and salinities of over 36 parts per thousand (ppt) have penetrated nearly into Station 1/I in the lowest layers.

Tracks II and III (Figures 6 and 7) show salinities increasing from just under 33 ppt at the inner stations to near 36 ppt at the outer stations. At Station 3/III, the upper 80 m are very nearly isohaline.

Maximum cross-shelf gradients along Track IV (Figure 8) are found inside Station 2/IV. At and beyond the middle station, the water column is nearly isohaline, and salinities increase slightly from just over 35 ppt to approximately 36 ppt.

Spring Temperature Data

The temperature cross-section along Track I (Figure 9), obtained between April 8-10, 1975, is characterized by relatively small gradients, both in the vertical and in a cross-shelf direction. There has been essentially no net warming since the winter cruises. Nearshore waters are from 1-2°C warmer, while offshore waters are approximately 3°C cooler.

The rapid warming characteristic of the spring months is evident in the temperature differences found in the Track I and II cross-sections (Figure 10). These should be thought of as primarily temporal, rather than spatial variations. Cross-shelf gradients along Track II obtained between April 16-18, 1975, are nearly absent through the inner two stations, and the water appears vertically mixed as well. There is an increase of approximately 4°C in surface layers between the outer two stations. A vertical temperature difference of over 7°C is recorded at Station 3/II, however, there is no particularly well developed thermocline.

Substantial nearshore warming is noted in the temperature cross-section for Track III (Figure 11), obtained between May 14 and 16, 1975. Cross-shelf surface temperatures are nearly uniform at just above 25°C. A thermocline has developed at the outer station, with a drop of 4°C between 10 and 55 m.

Somewhat cooler surface temperatures are found along Track IV (Figure 12) between April 29 and May 2, 1975, but again surface waters are very nearly isothermal. A slightly warmer, near-bottom layer is seen at Station 2/IV

Spring Salinity Data

Salinities of under 25 ppt and a strong vertical salinity gradient were recorded at and below the surface at Station 1/I (Figure 13). Salinities increase to just over 35 ppt between the inner two stations. The water column between the middle and outer stations is nearly isohaline, and increases only slightly to approximately 36 ppt.

Salinities along Track II (Figure 14) are characterized by values below 30 ppt through the upper 10 m at the inner two stations. The 35 ppt isohaline slopes down from near the surface at the outer station through the middle of the water column at the middle station, forming the base of a well developed halocline. Salinities above 36 ppt are found through the lower half of the water column at the outer station.

Salinities increase from below 31 ppt to nearly 35 ppt in the upper layers of Track III between the inner two stations (Figure 15). Strong vertical salinity gradients are found only at the inner station.

A layer of lower salinity water is found in the upper part of the water column at all stations of Track IV (Figure 16), with all of Station 1/IV and the upper 10 m of Station 3/IV below 33 ppt. The 35 ppt isohaline forms the base of the halocline and penetrates nearly into the inner station.

Summer Temperature Data

The August-September cruises were conducted at a time when the shelf waters of the northwestern Gulf reach an annual maximum. Surface temperatures along Track I (Figure 17), obtained between August 26 and 29, 1975, are nearly isothermal and just over 27°C, and temperatures vary little within a mixed layer extending through the upper 35 m. Thus, the waters are nearly isothermal at Stations 1/I and 2/I. The seasonal thermocline appears at about the 40 m level, with a secondary marked drop in temperature with increasing depth just above the bottom. This latter decrease is probably associated with the top of the permanent thermocline.

Somewhat warmer surface and nearshore waters were recorded along

Tracks II and III (Figures 18 and 19), between September 4-6 and 7-9, respectively. Temperatures are over 28°C through the upper 30 m at all three stations, and above 29°C at the surface at Station 1/IV and Station 1/III. The seasonal thermocline is found approximately at the 35 m level at the outer stations, followed by a fairly uniform decrease in temperature with increasing depth.

The 29°C surface water extends out to the middle stations along Track IV (Figure 20), as shown in the data collected 11 and 13 September, 1975. Temperatures are generally warmer throughout the water column. The 24°C isotherm at the outer station is over 20 m deeper than at Station 3/III, though this may reflect a transient phenomenon associated with internal waves.

Summer Salinity Data

Greatest cross-shelf gradients along Track I (Figure 21) are found between Stations 1/I and 2/I. At all stations, the water column appears to be well mixed, and very nearly isohaline. The outer station seems to be the approximate boundary of the 36 ppt isohaline.

The cross-shelf salinity gradients along Track II (Figure 22) are displaced toward the coast, and there is no indication of salinities much below 34 ppt at the inner station. The 36 ppt isohaline extends shoreward through the lower part of the water column at Station 2/II. Both of the outer two stations show very nearly isohaline conditions.

An extremely well developed halocline is seen at the inner station along Track III (Figure 23). Again, the water column at the outer two stations is very nearly isohaline, increasing from just under 36 ppt at the surface to just above 36 ppt near the bottom.

A similar pattern is found along Track IV (Figure 24), with a sharp halocline separating water with salinities below 30 ppt at the surface to over 35 ppt below approximately 15 meters. Water with salinities below 35 ppt extends out to beyond Station 2/IV. The outer station is nearly isohaline, with the 36 ppt isopleth found at about 45 m, bisecting the water column.

DISCUSSION

The three sampling cruises provide an overview of the annual variability that can be expected for temperature and salinity in the northwestern corner of the Gulf of Mexico. In a hydrographic sense, one can define two seasons for the waters of the Texas Outer Continental Shelf. From late winter or early spring, the water column begins to stratify in response to increasing daily amounts of incoming solar radiation (insolation), and as a result of warm water coming out of the shallow bays and estuaries.

A pycnocline forms and begins to descend, perhaps as a series of steps, as insolation continues to increase, and with intermittent periods of intense wind mixing. The data indicate that a seasonal thermocline characteristically descends to the 30-40 m level by late August or early September.

Maximum surface temperatures of 28-29°C are reached by the end of August. The combination of decreasing insolation and the first of the fall frontal passages produce surface cooling and the start of the fall overturn. An increasingly thick layer, characterized by isothermal and isohaline water, destroys the seasonal thermocline, then continues to the top of the permanent thermocline at a depth of approximately 100 m. Minimum temperatures through this layer are between 17°C and 22°C, depending upon distance from shore and thus the thickness of the water column through which heat is lost. Minimum temperatures generally occur in late February or early March.

The thickness of the surface mixed layer, whether occurring in response to surface cooling or wind mixing, is an important factor in determining the vertical distribution of any number of chemical and biological properties of the shelf waters. The observed vertical distribution of the hydrographic variables, together with the known thermodynamic properties of sea water, provide a reliable indicator of the susceptability or resistance of the water column to vertical motions.

The hydrographic data are best suited for depicting the long-period annual variations in shelf waters. One must be cautious when interpreting the composite of, for example, surface temperatures and salinities as a snapshot of an instantaneous, synoptic pattern. Baer, Adamo and Adelfang (1968) have shown in a theoretical study that large-scale patterns in the three-dimensional temperature or salinity fields can change substantially over a time interval of just a few weeks. The triennial cruises characteristically lasted between three and four weeks.

Nevertheless, the spring salinity data may be used to define a surface layer of relatively low salinity water which is probably moving southward along the Texas Gulf coast from the mouth of the Mississippi River. Current data are not available to confirm this, however. On some occasions, this low salinity water reached the middle station of a given track, nearly 60 km from the coast.

Sigma-t data, corresponding to the individual STD profile, appears in Appendix II. These will not be discussed individually, but may be used to characterize the stability and thus the resistance to vertical mixing at a given place and time.

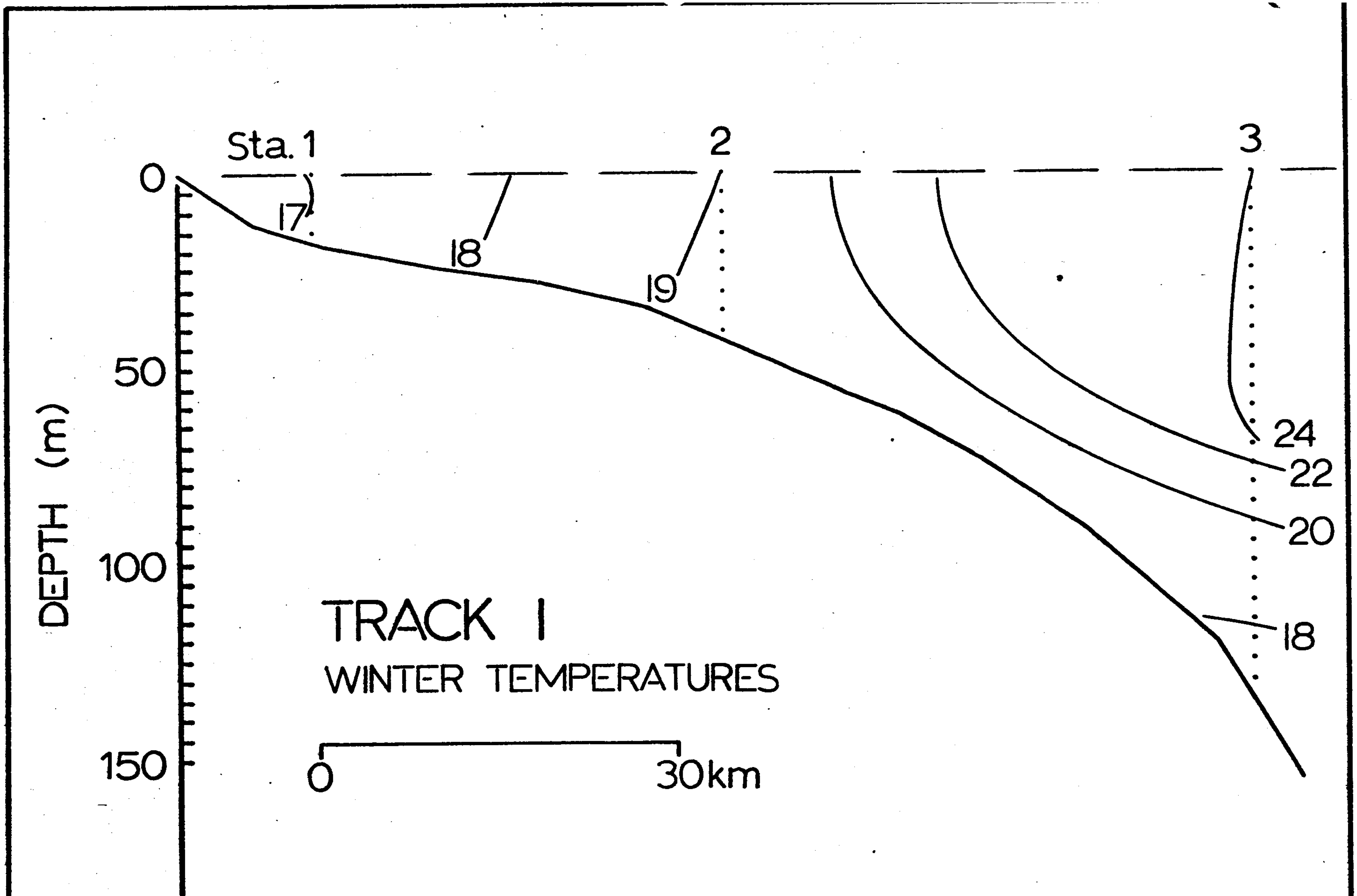

Sta. 1
2
3
0
50
100
150
DEPTH (m)
17
18
19
24
22
20
18
WINTER TEMPERATURES
0
30km

FIG. I

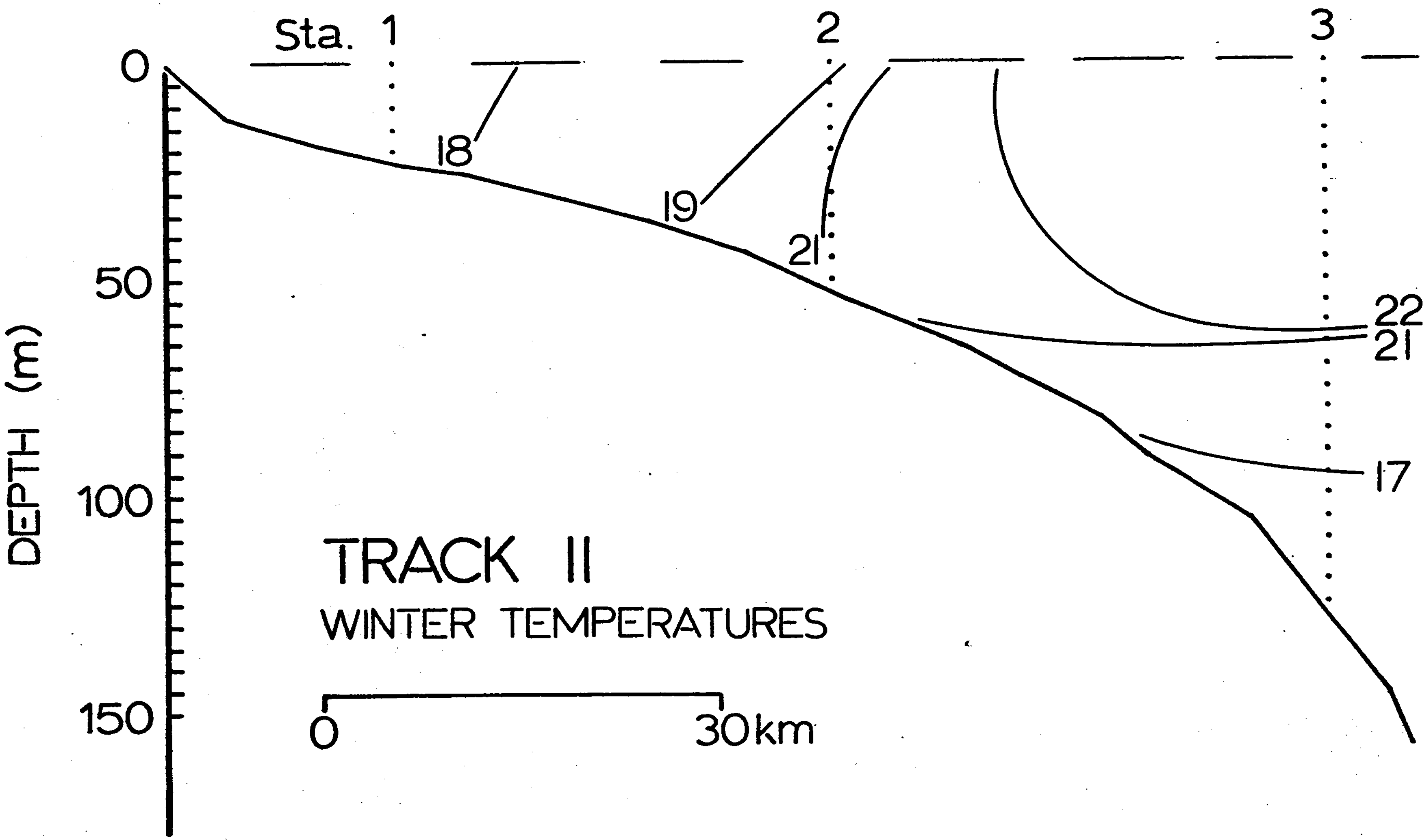
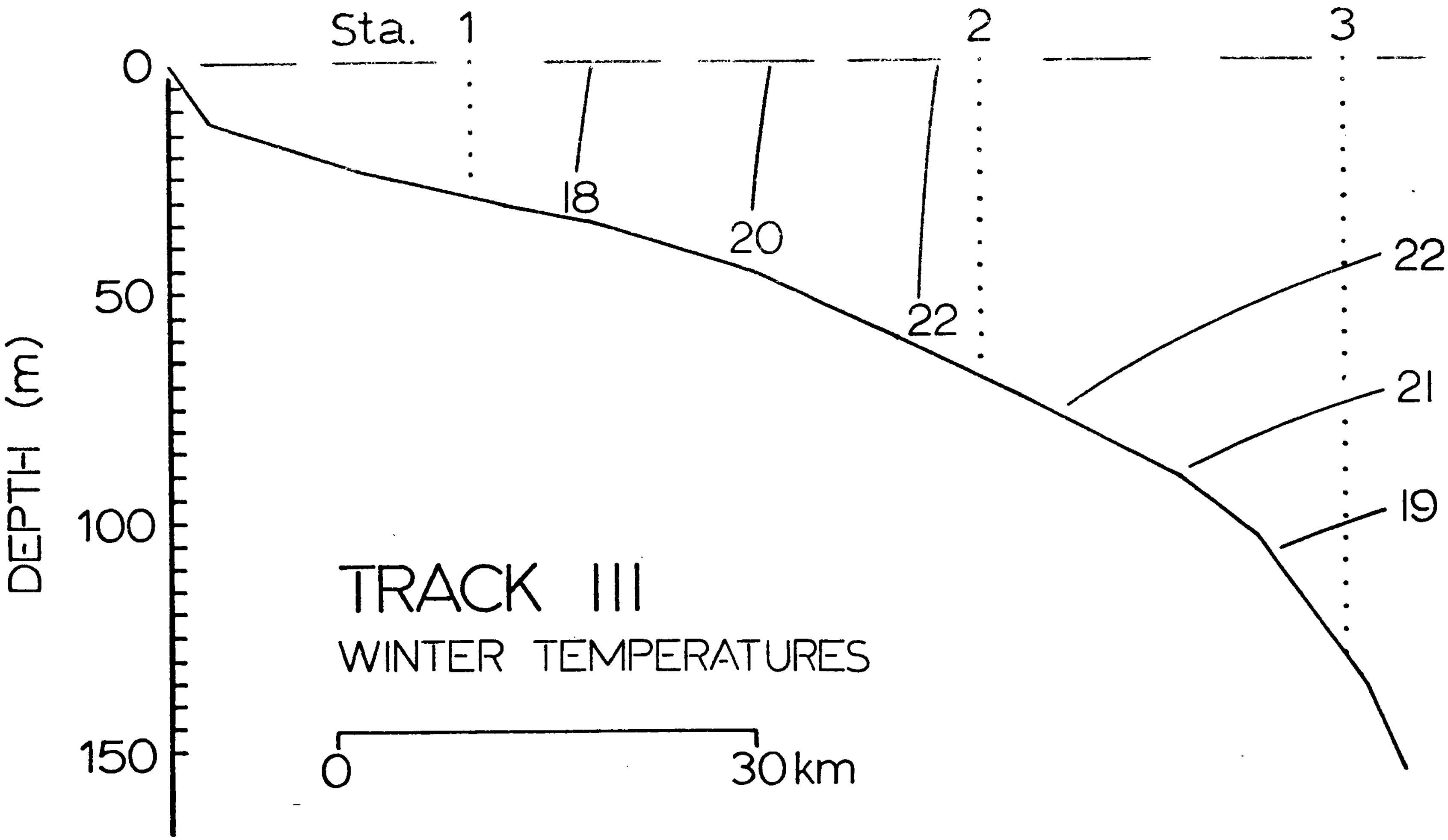

Sta. 1
2
3
0
50
100
150
DEPTH (m)
18
19
21
22
21
17
TRACK II
WINTER TEMPERATURES
0
30km

FIG. 2


Sta. 1
2
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50
100
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DEPTH (m)
18
20
22
22
21
19
TRACK III
WINTER TEMPERATURES
0
30 km

FIG. 3

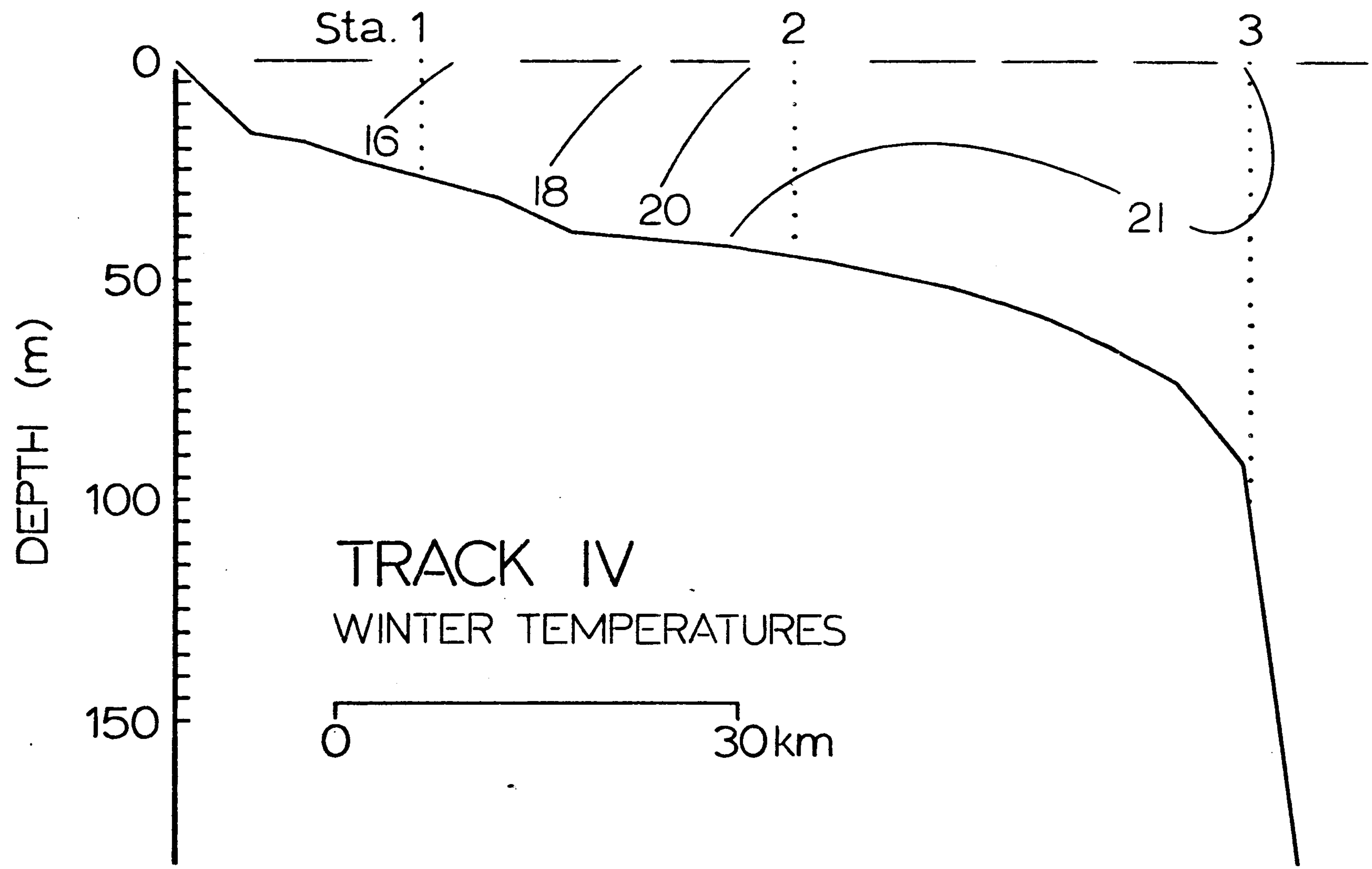

Sta. 1
2
3
0
50
100
150
DEPTH (m)
16
18
20
21
TRACK IV
WINTER TEMPERATURES
0
30km

FIG. 4

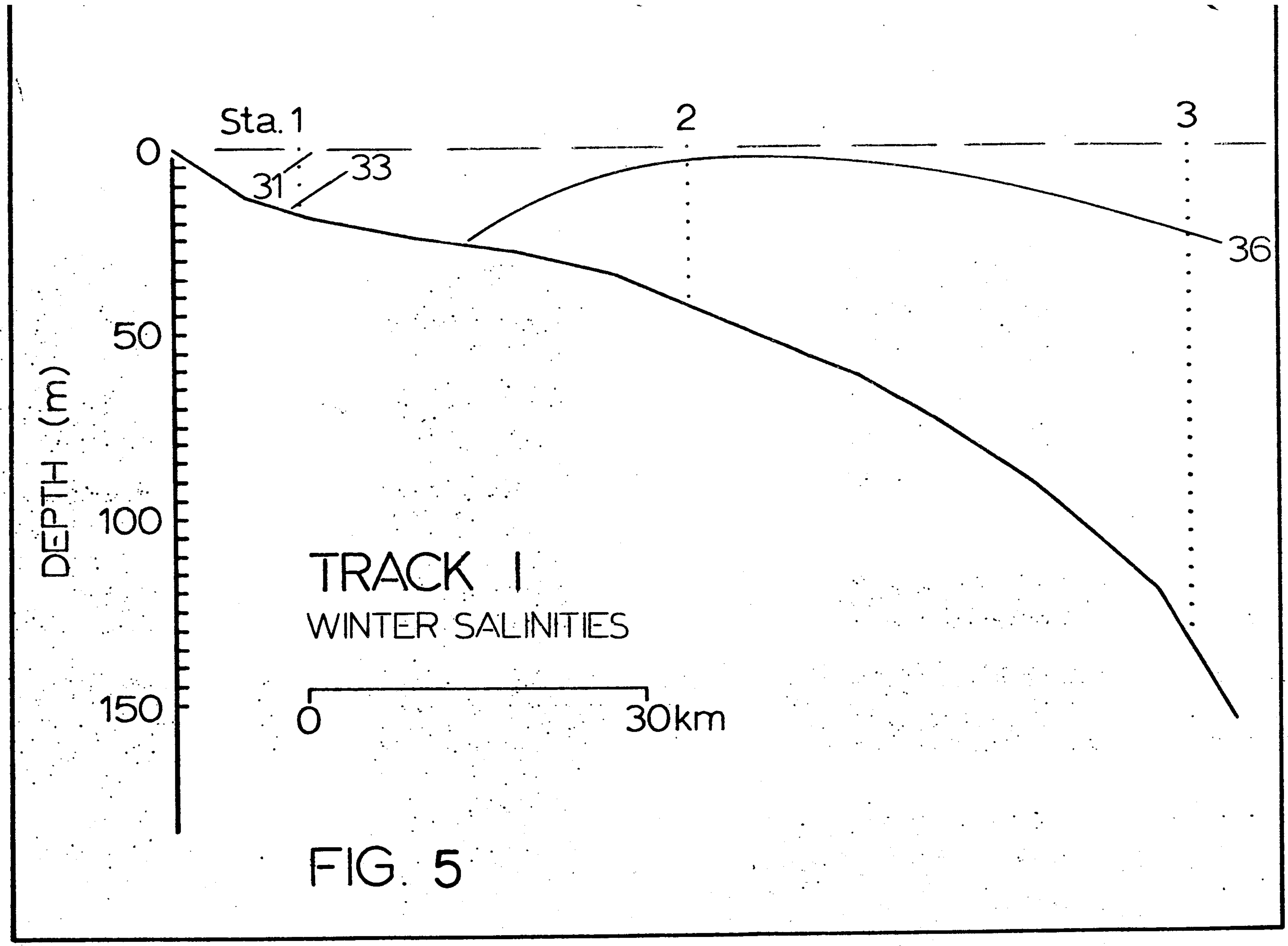

Sta. 1
2
3
0
50
100
150
DEPTH (m)
31
33
36
TRACK I
WINTER SALINITIES
0
30km

FIG. 5

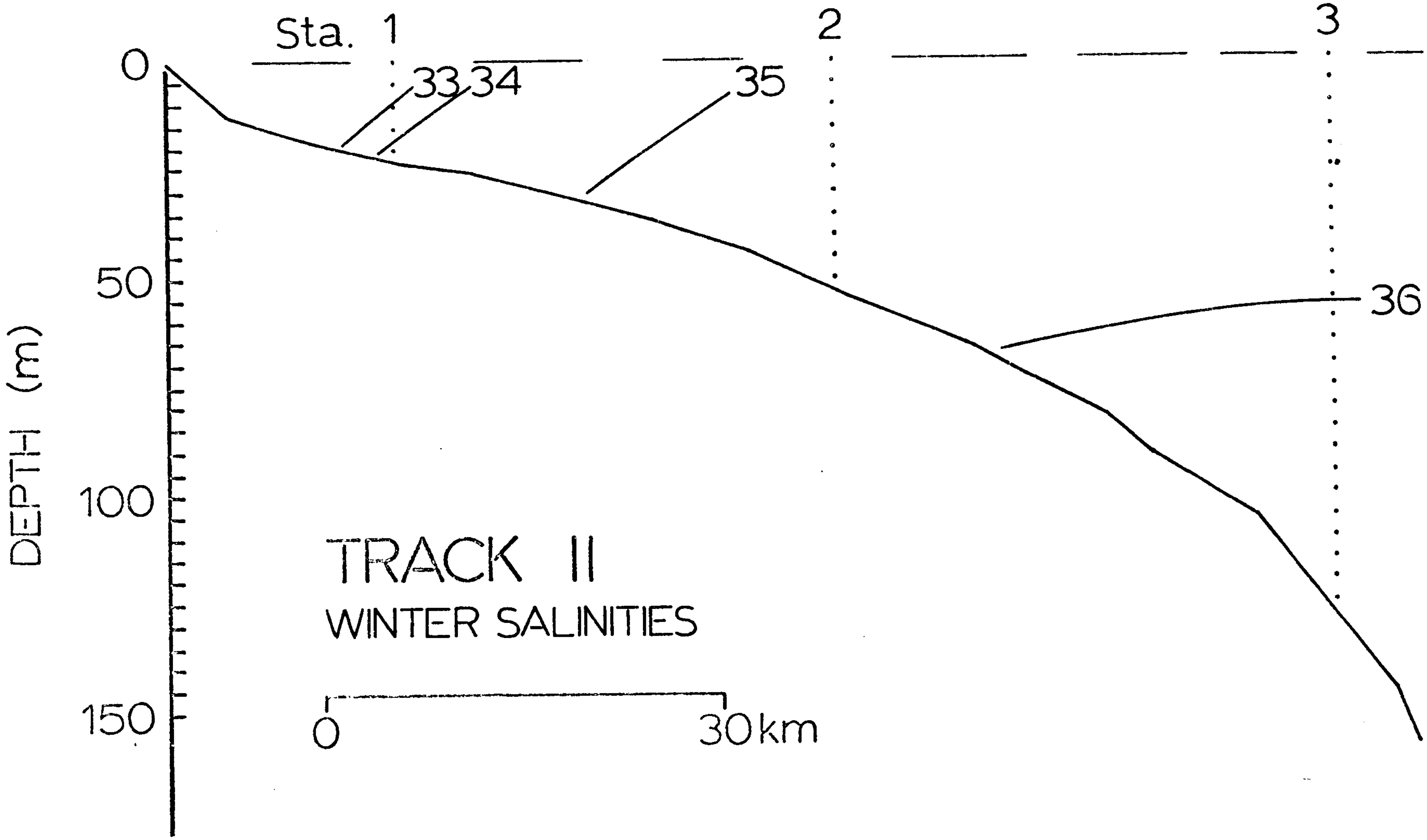
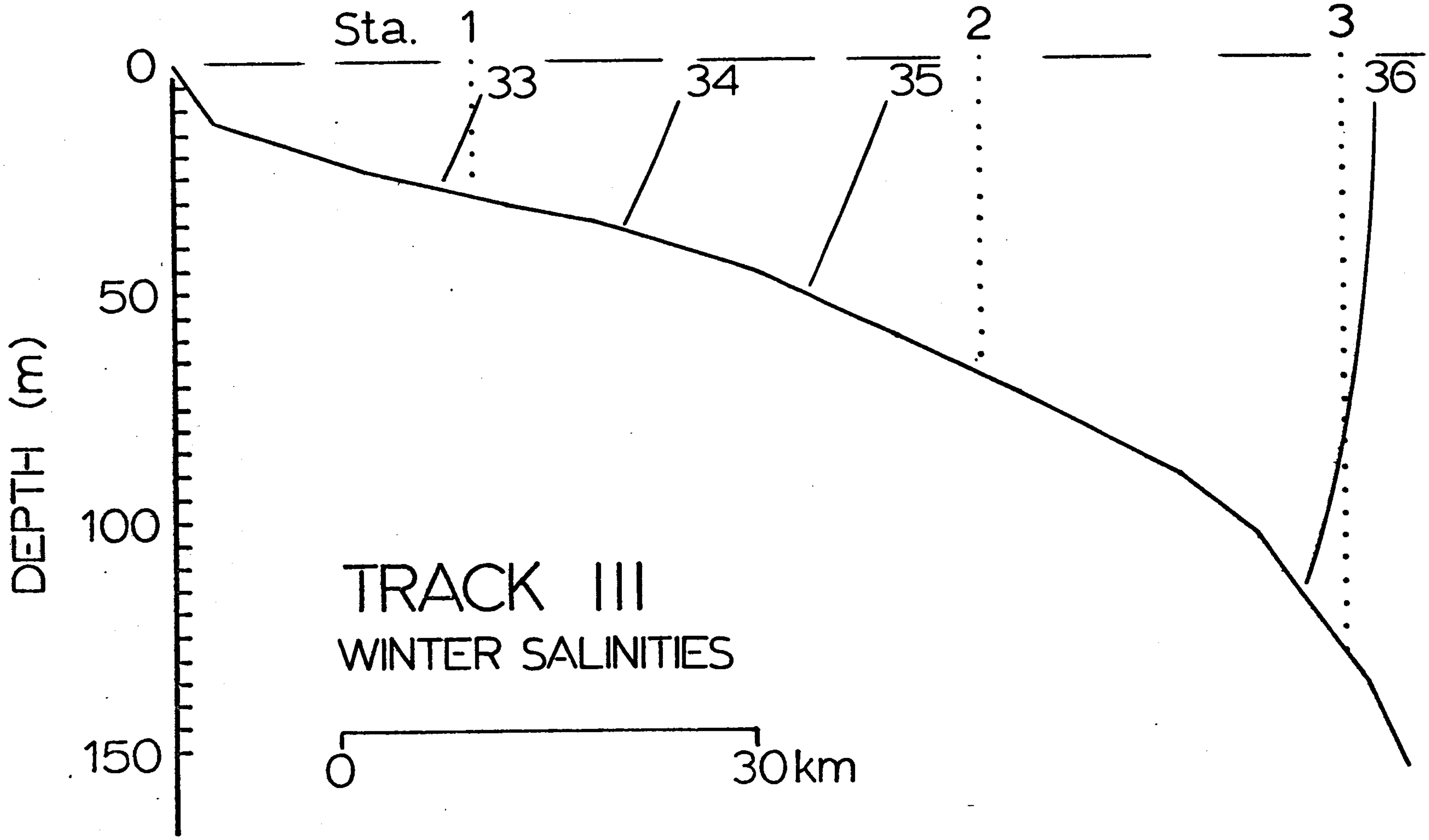
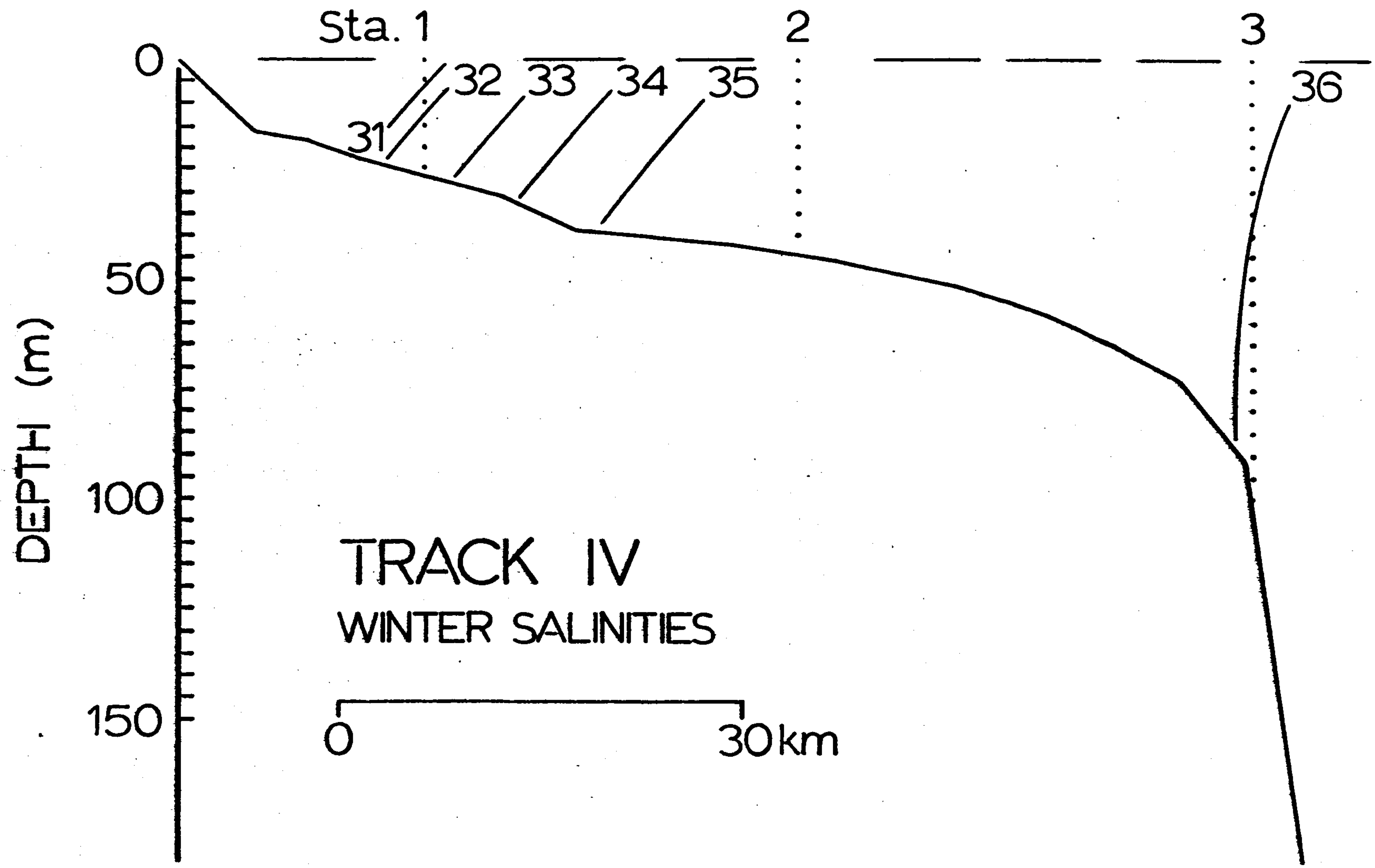

Sta. 1
2
3
0
50
100
150
DEPTH (m)
33
34
35
36
TRACK II
WINTER SALINITIES
0
30km

FIG. 6



Sta. 1
2
3
0
33
34
35
36
50
100
150
DEPTH (m)
TRACK III
WINTER SALINITIES
0
30km

FIG. 7



Sta. 1
2
3
0
50
100
150
DEPTH (m)
31
32
33
34
35
36
TRACK IV
WINTER SALINITIES
0
30km

FIG. 8

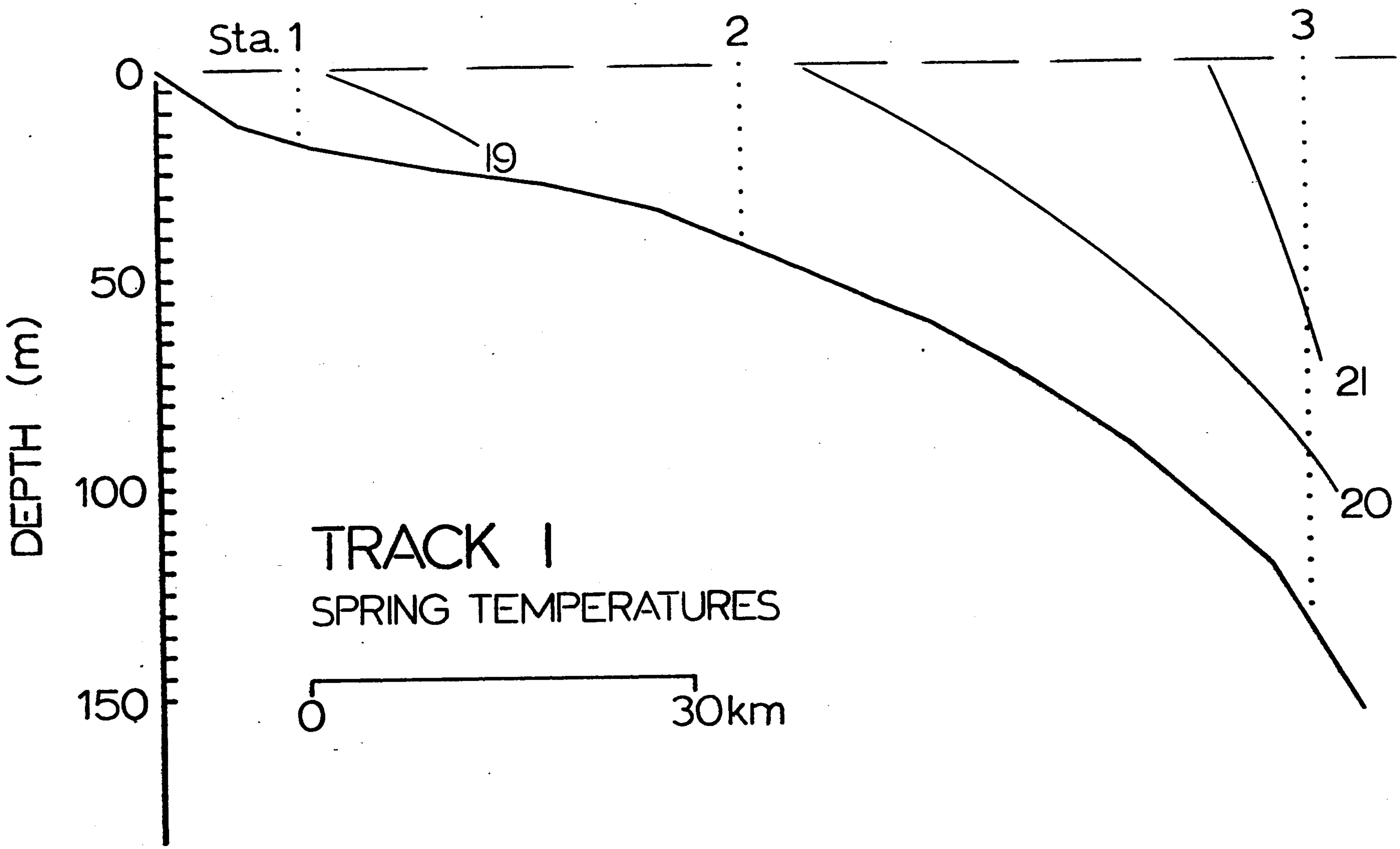

Sta. 1
2
3
0
50
100
150
DEPTH (m)
19
20
21
TRACK I
SPRING TEMPERATURES
0
30km

FIG. 9

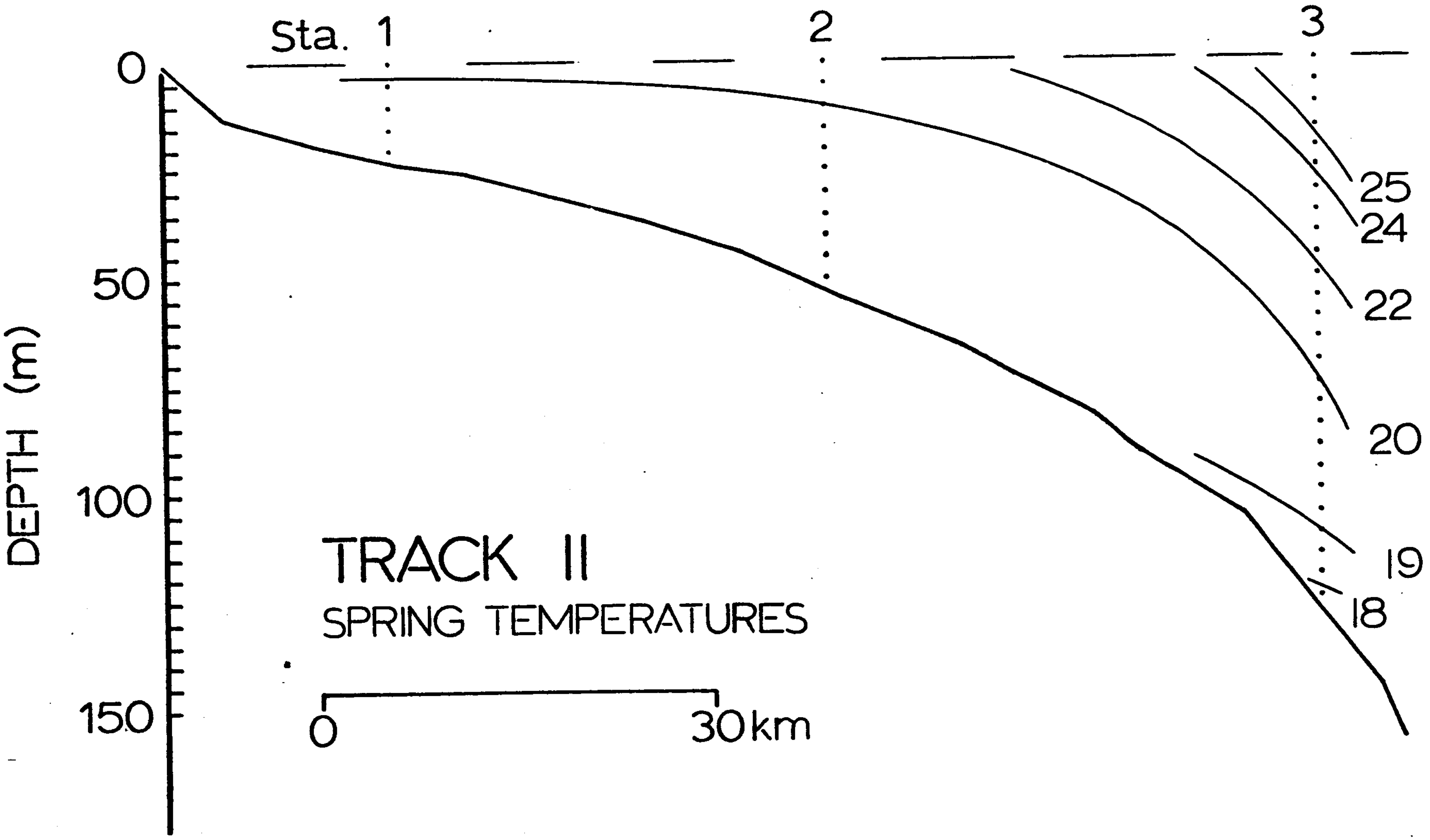

Sta. 1
2
3
0
50
100
150
DEPTH (m)
25
24
22
20
19
18
TRACK II
SPRING TEMPERATURES
0
30 km

FIG. 10

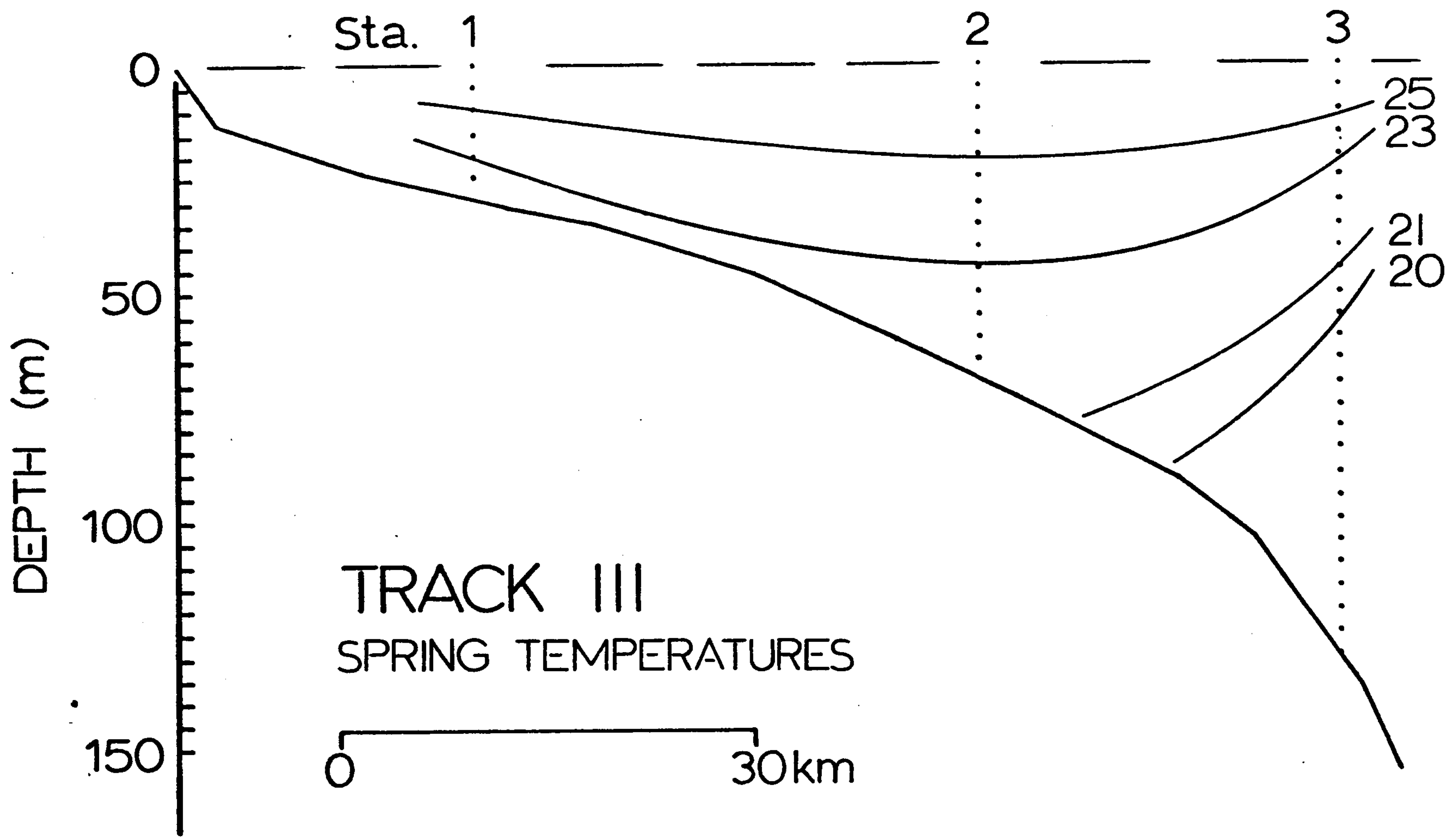

Sta. 1
2
3
0
50
100
150
DEPTH (m)
25
23
21
20
TRACK III
SPRING TEMPERATURES
0
30km

FIG. II

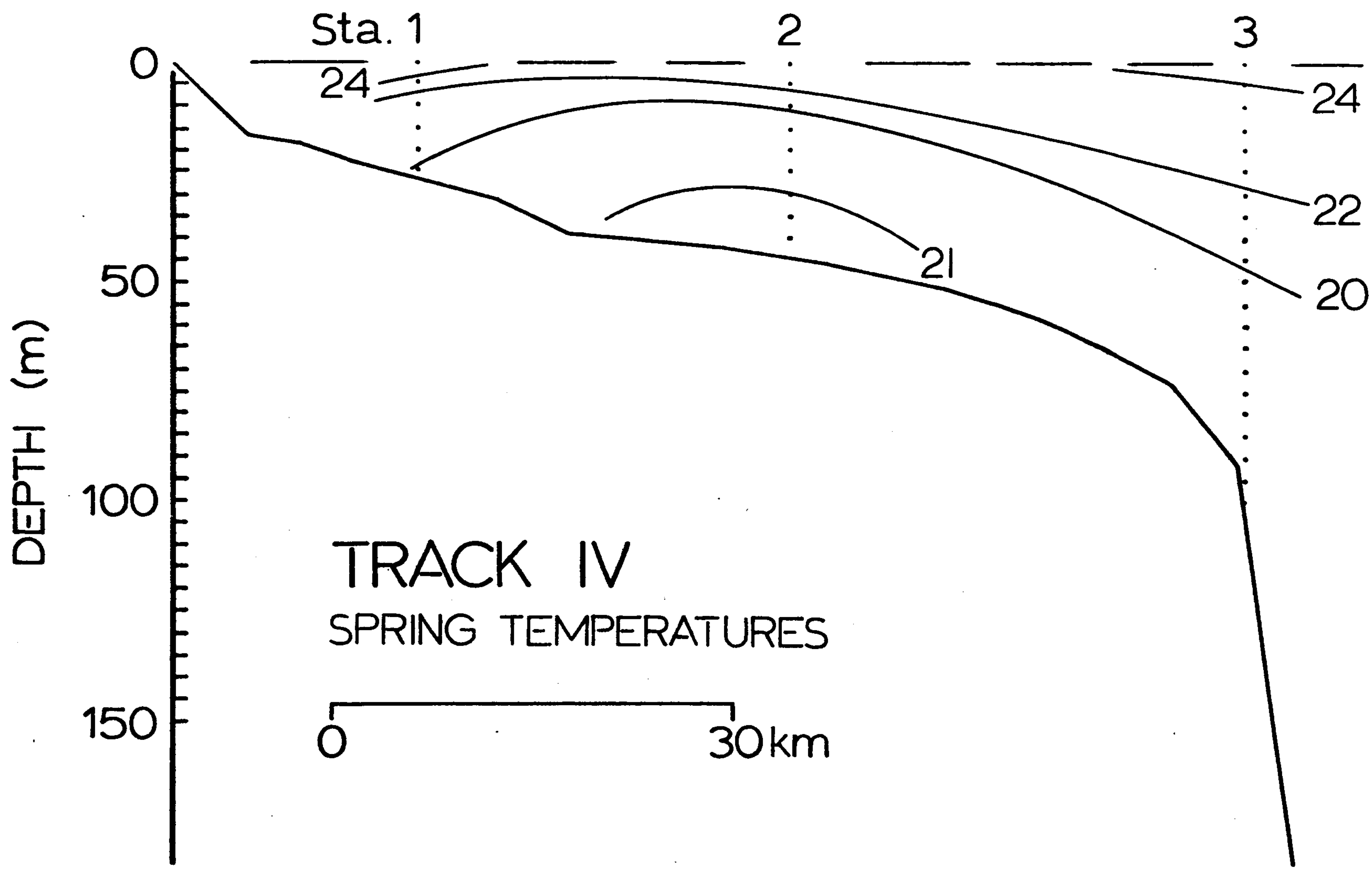

Sta. 1
2
3
0
50
100
150
DEPTH (m)
24
24
22
20
21
TRACK IV
SPRING TEMPERATURES
0
30 km

FIG. 12

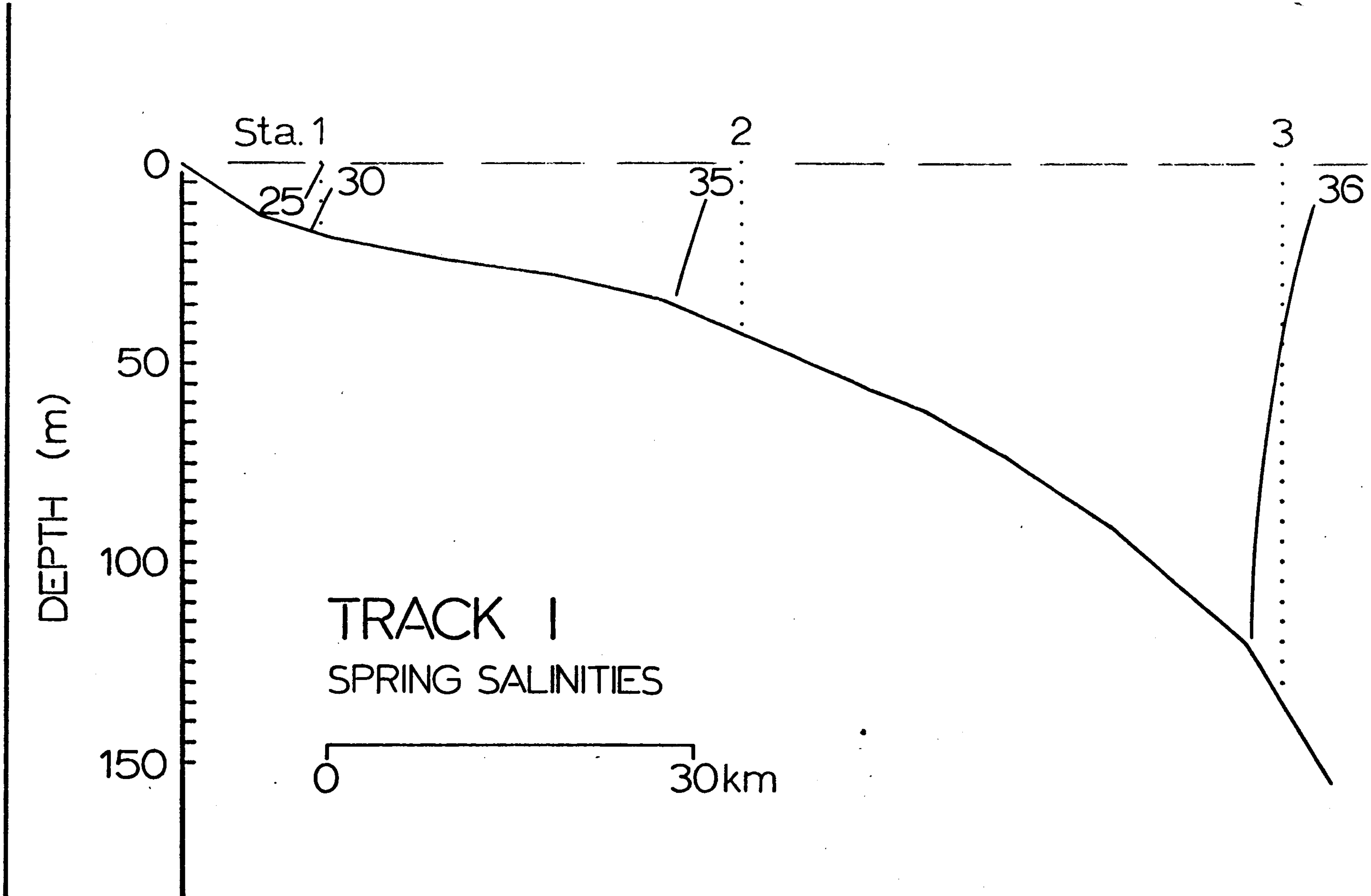

Sta. 1
2
3
0
50
100
150
DEPTH (m)
25
30
35
36
TRACK I
SPRING SALINITIES
0
30km

FIG. 13

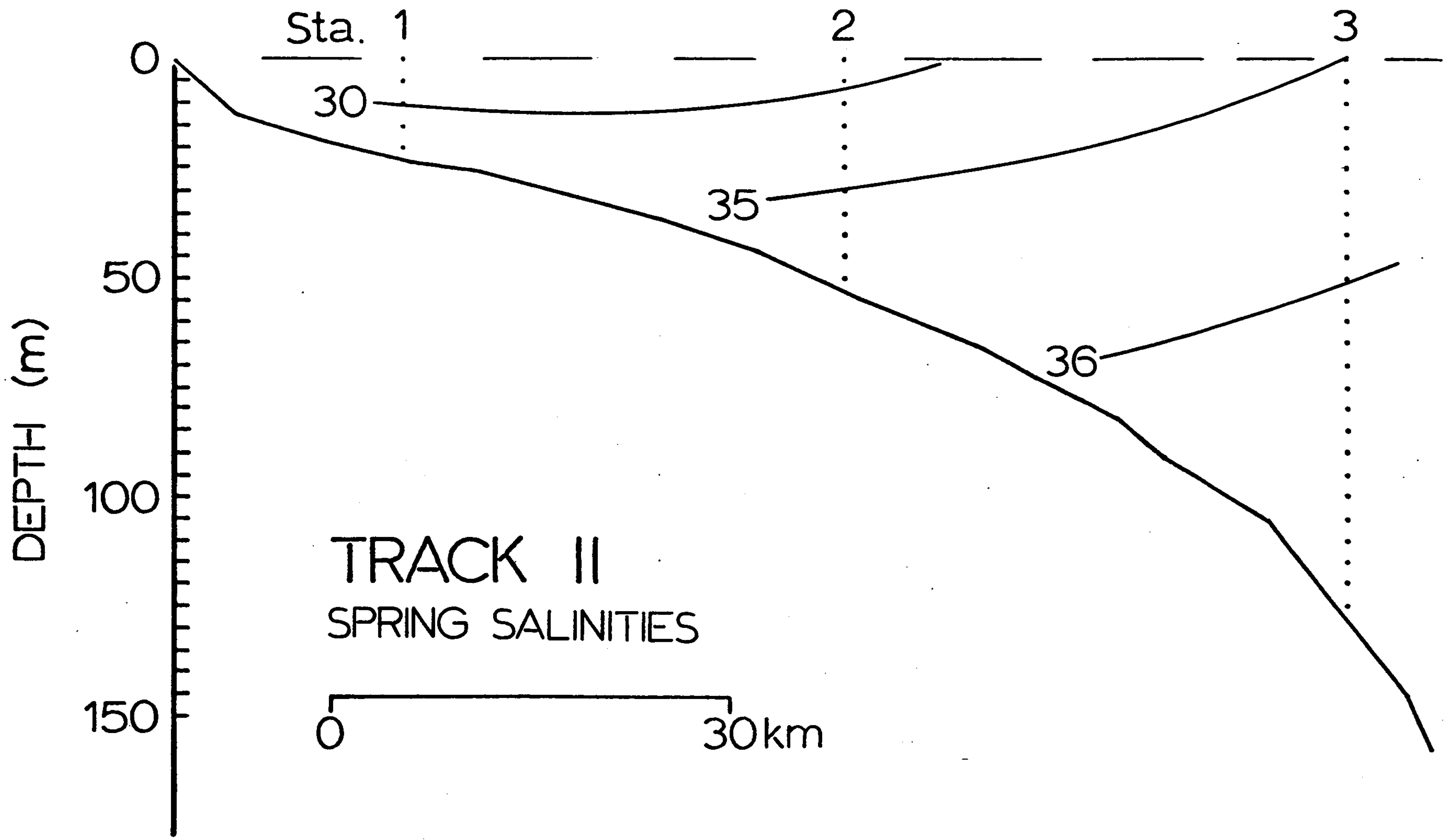

Sta. 1
2
3
0
50
100
150
DEPTH (m)
30
35
36
TRACK II
SPRING SALINITIES
0
30km

FIG. 14

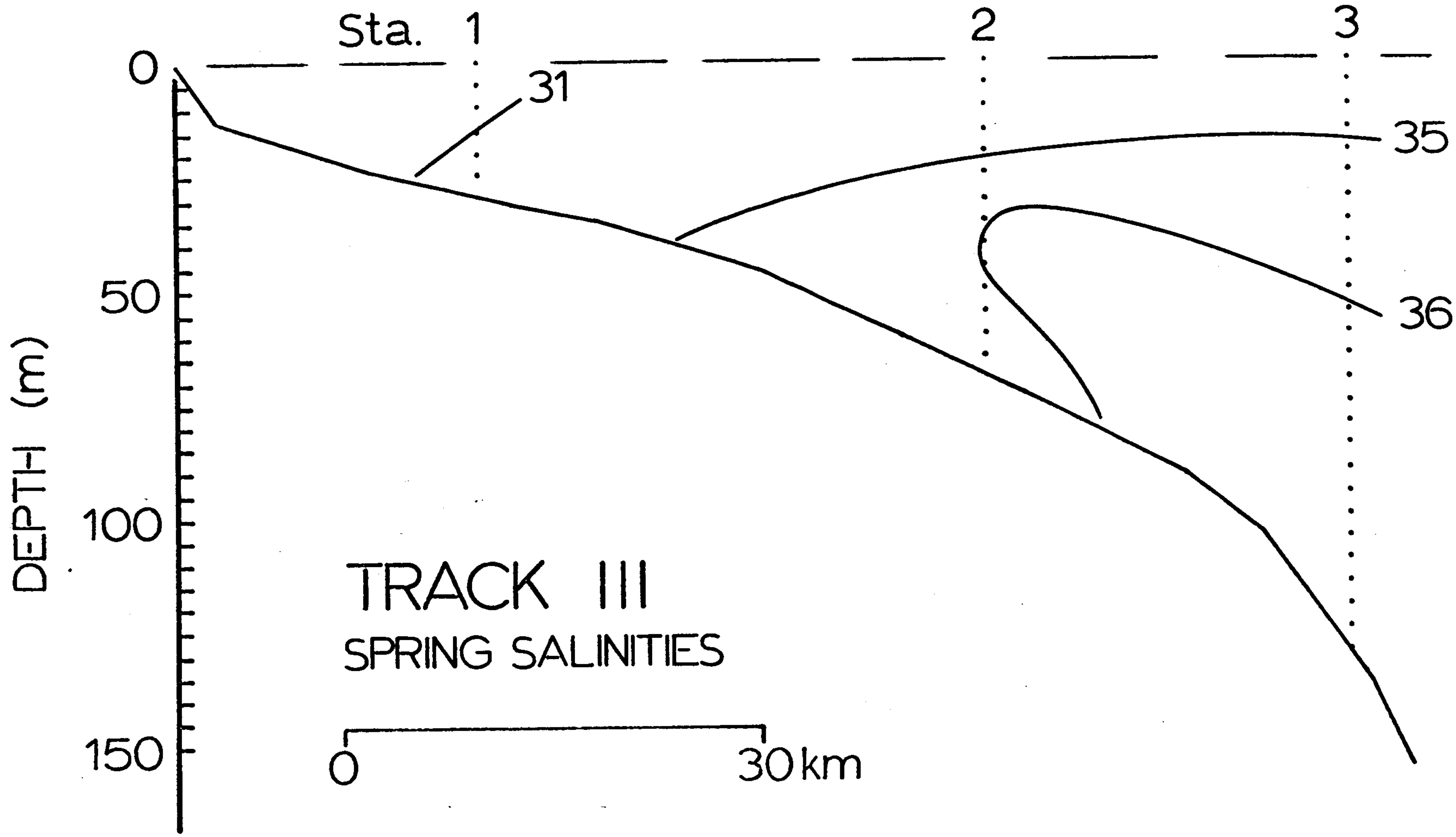

Sta. 1
2
3
0
50
100
150
DEPTH (m)
31
35
36
TRACK III
SPRING SALINITIES
0
30 km

FIG. 15

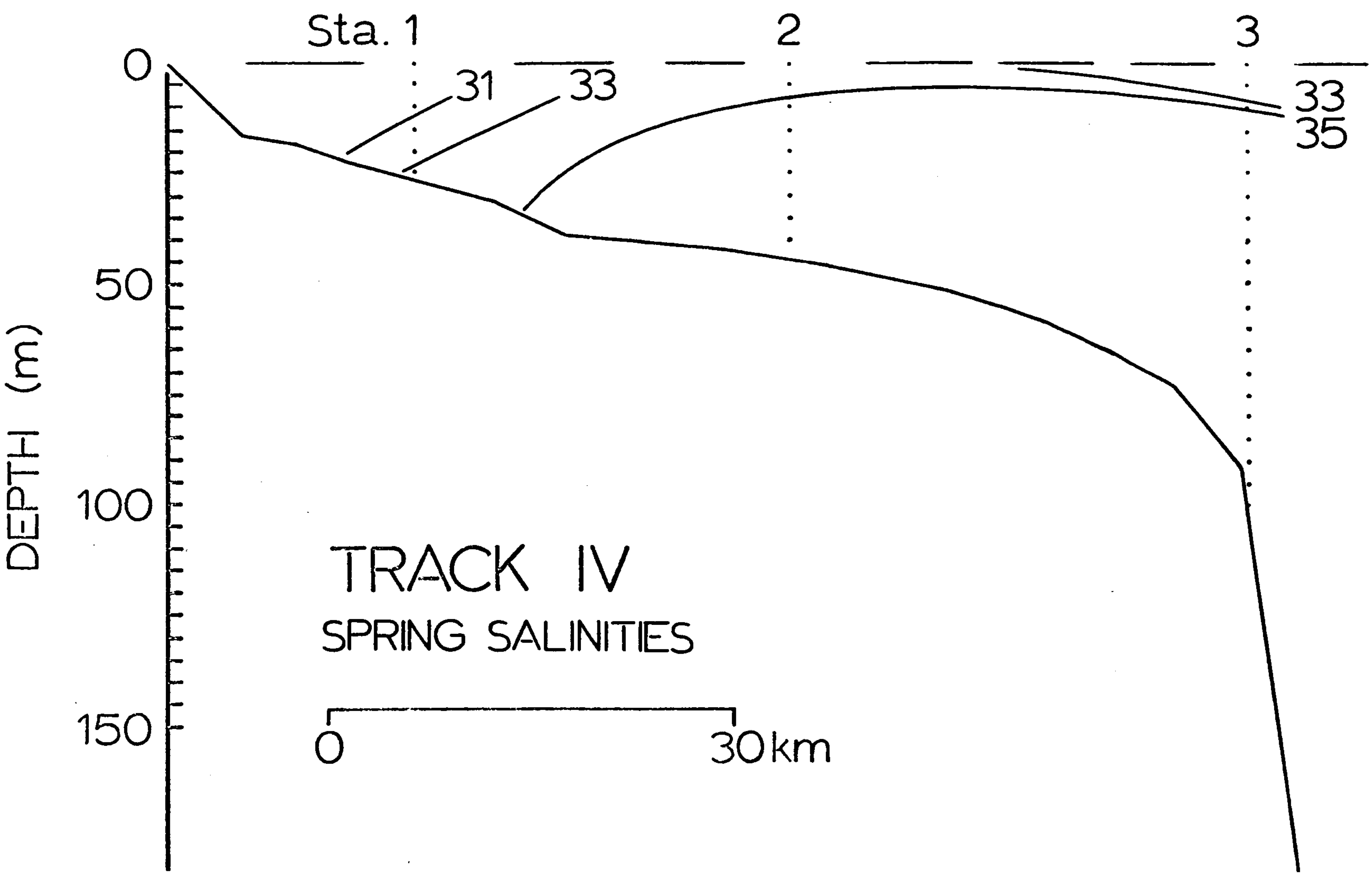

Sta. 1
2
3
31
33
33
35
0
50
100
150
DEPTH (m)
TRACK IV
SPRING SALINITIES
0
30km

FIG. 16

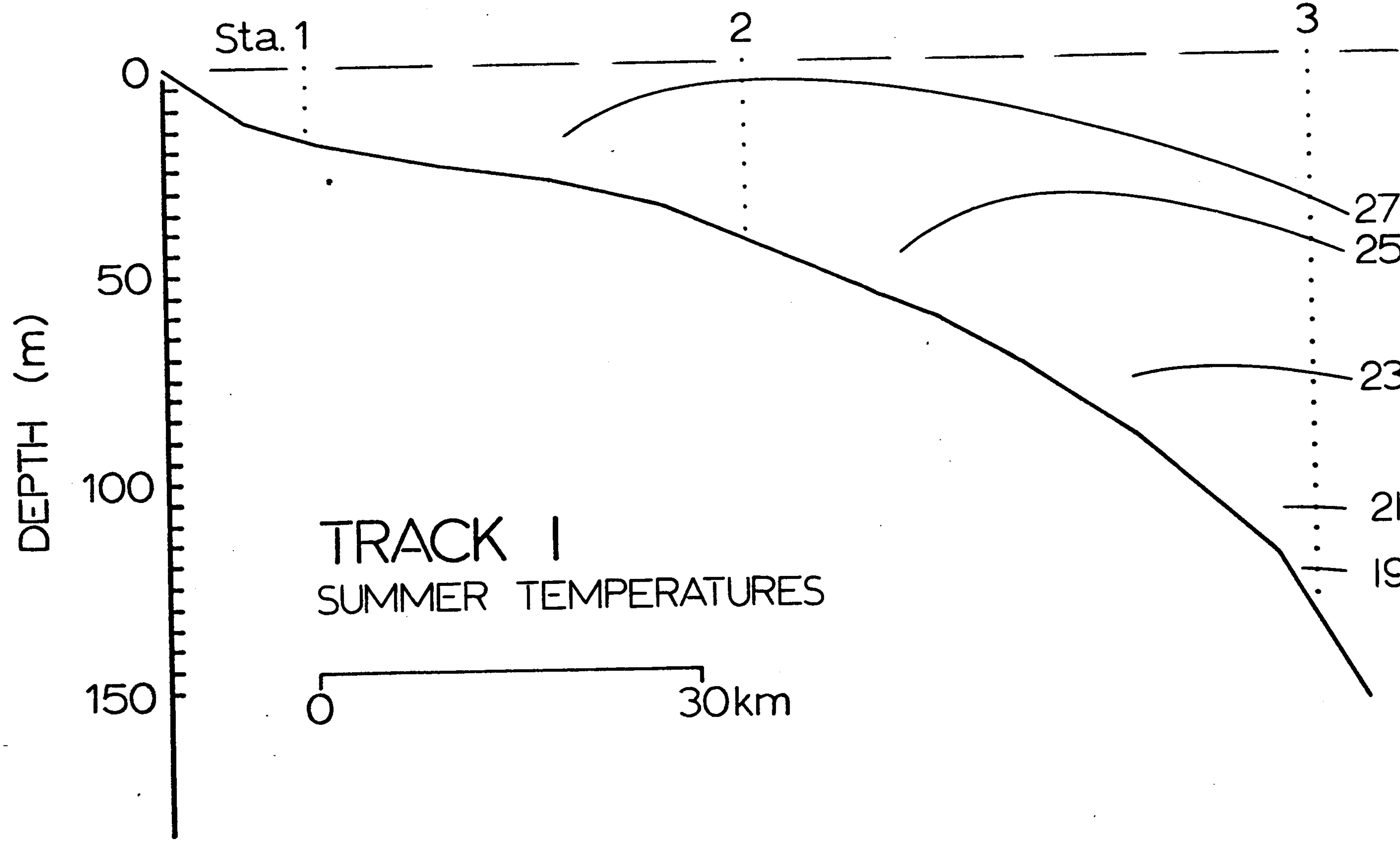

Sta. 1
2
3
0
50
100
150
DEPTH (m)
27
25
23
21
19
TRACK I
SUMMER TEMPERATURES
0
30km

FIG. 17

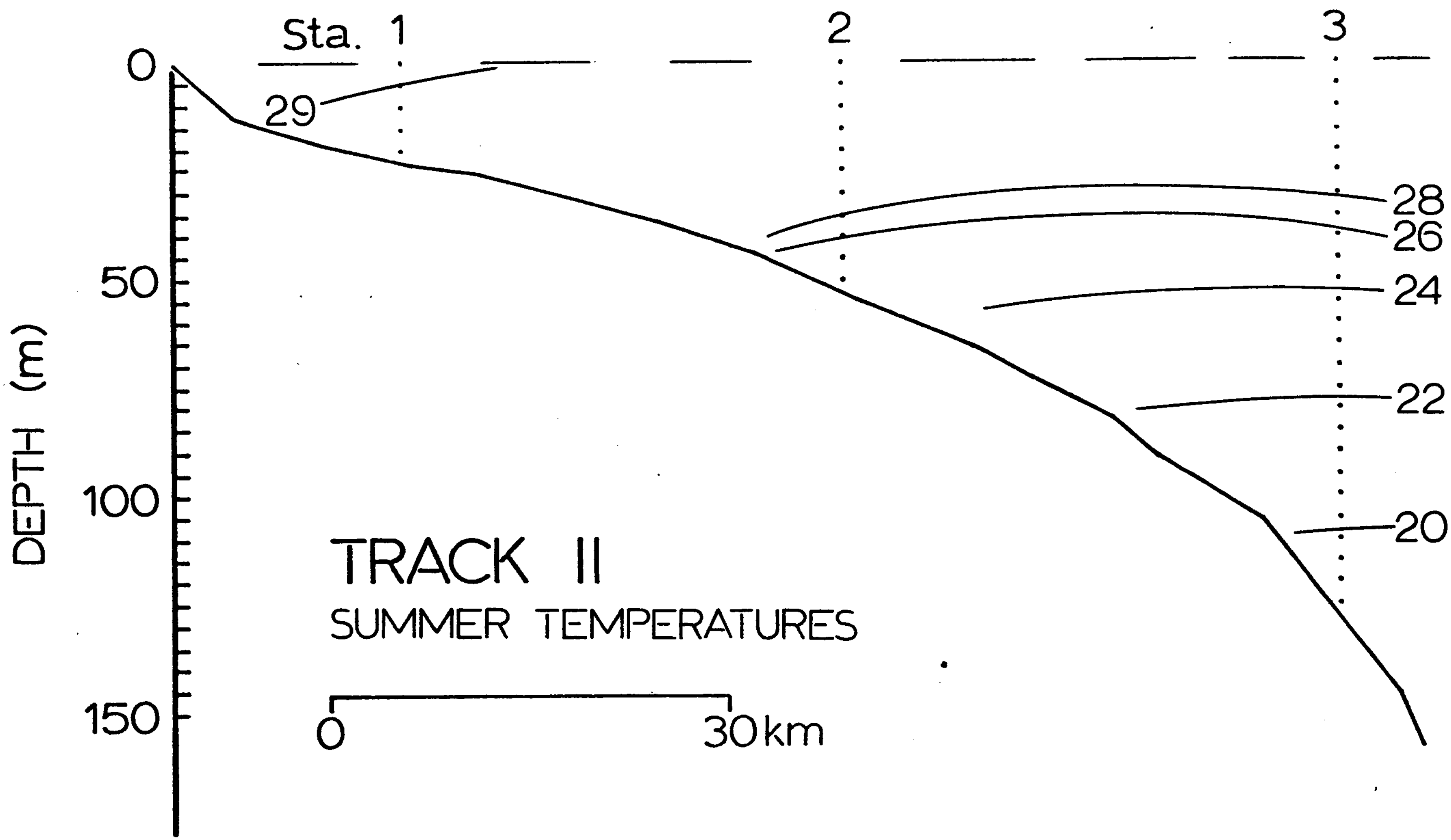
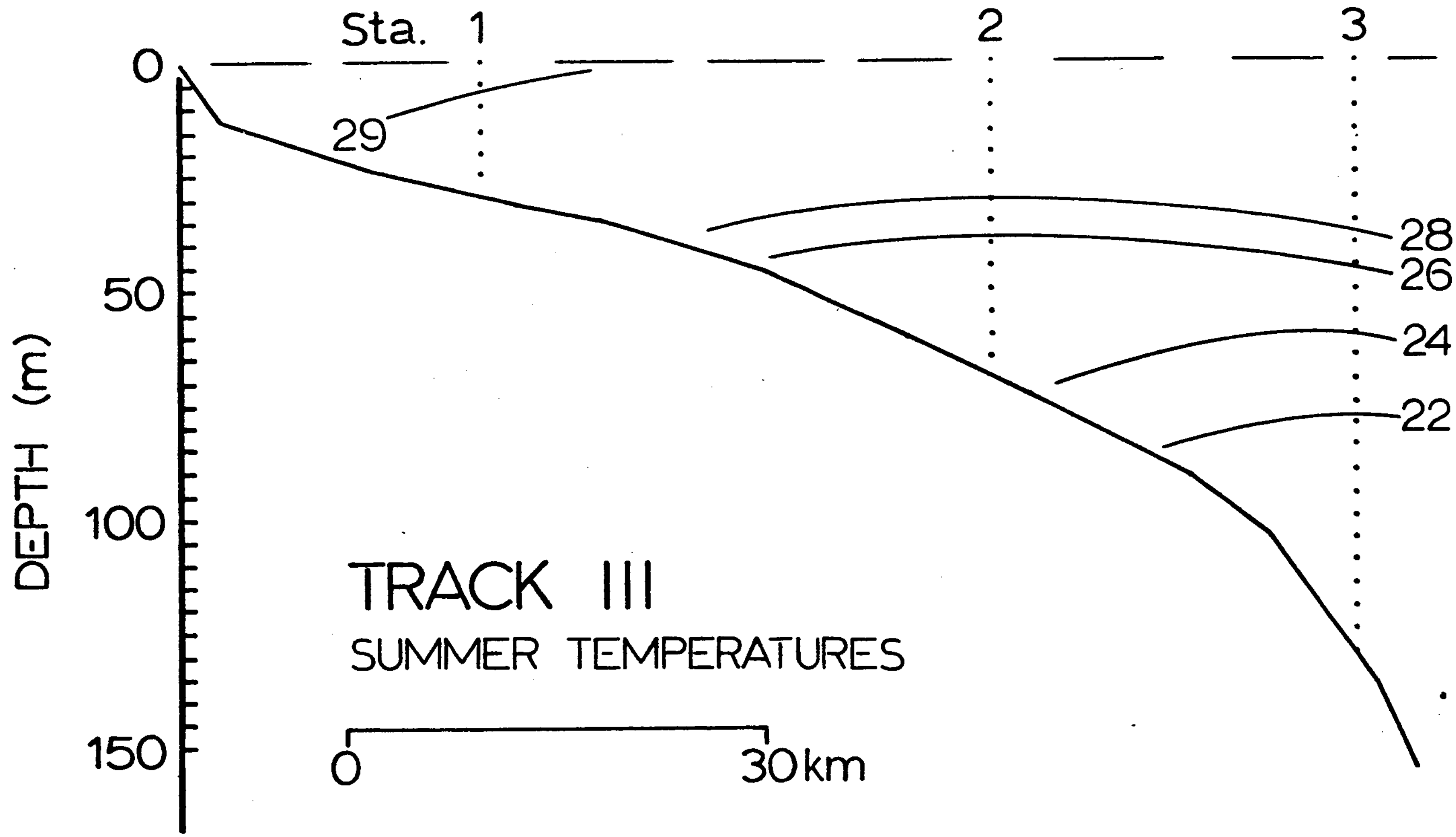
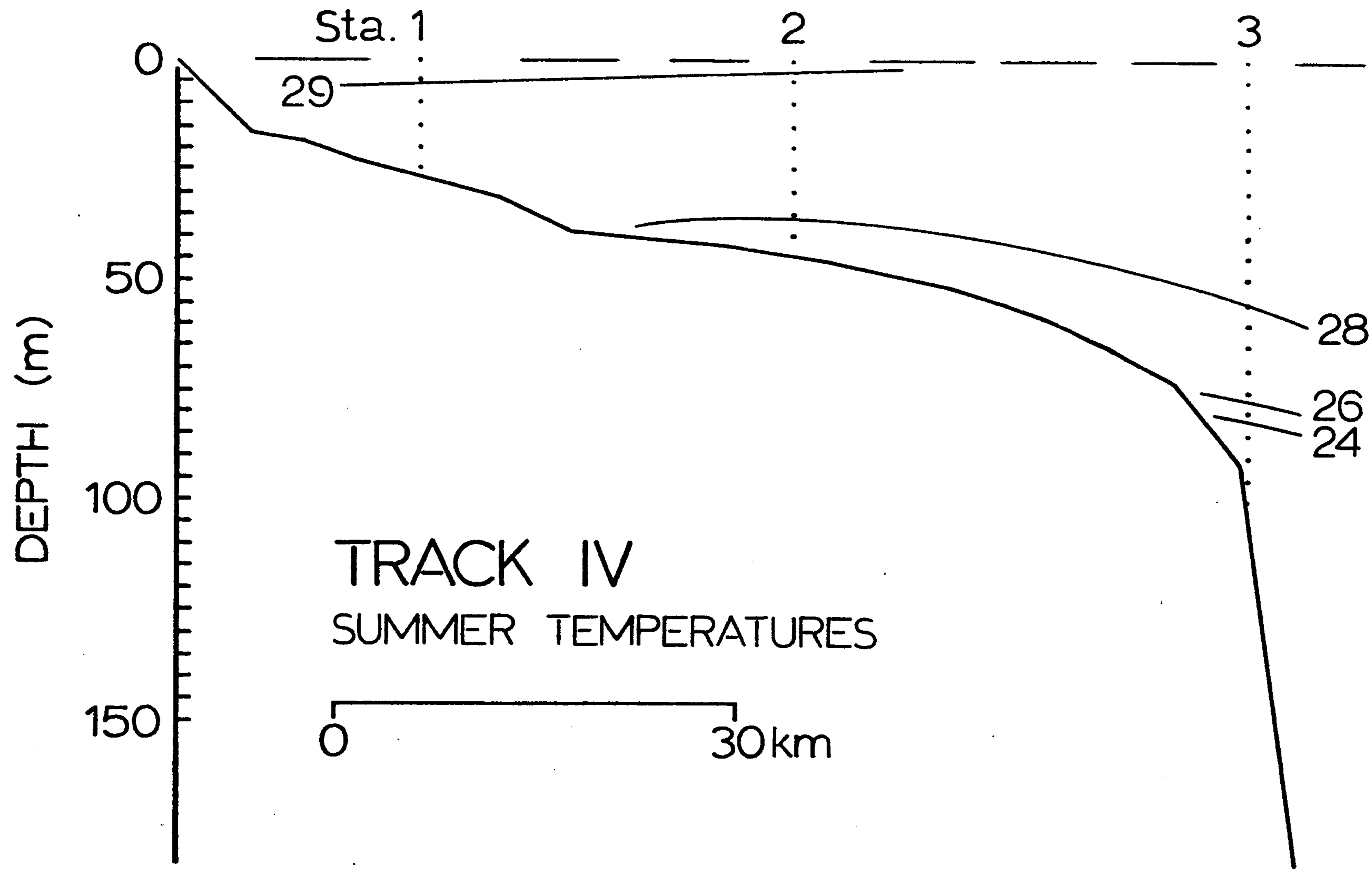

Sta. 1
2
3
0
29
28
26
50
24
DEPTH (m)
22
100
20
TRACK II
SUMMER TEMPERATURES
150
0
30km

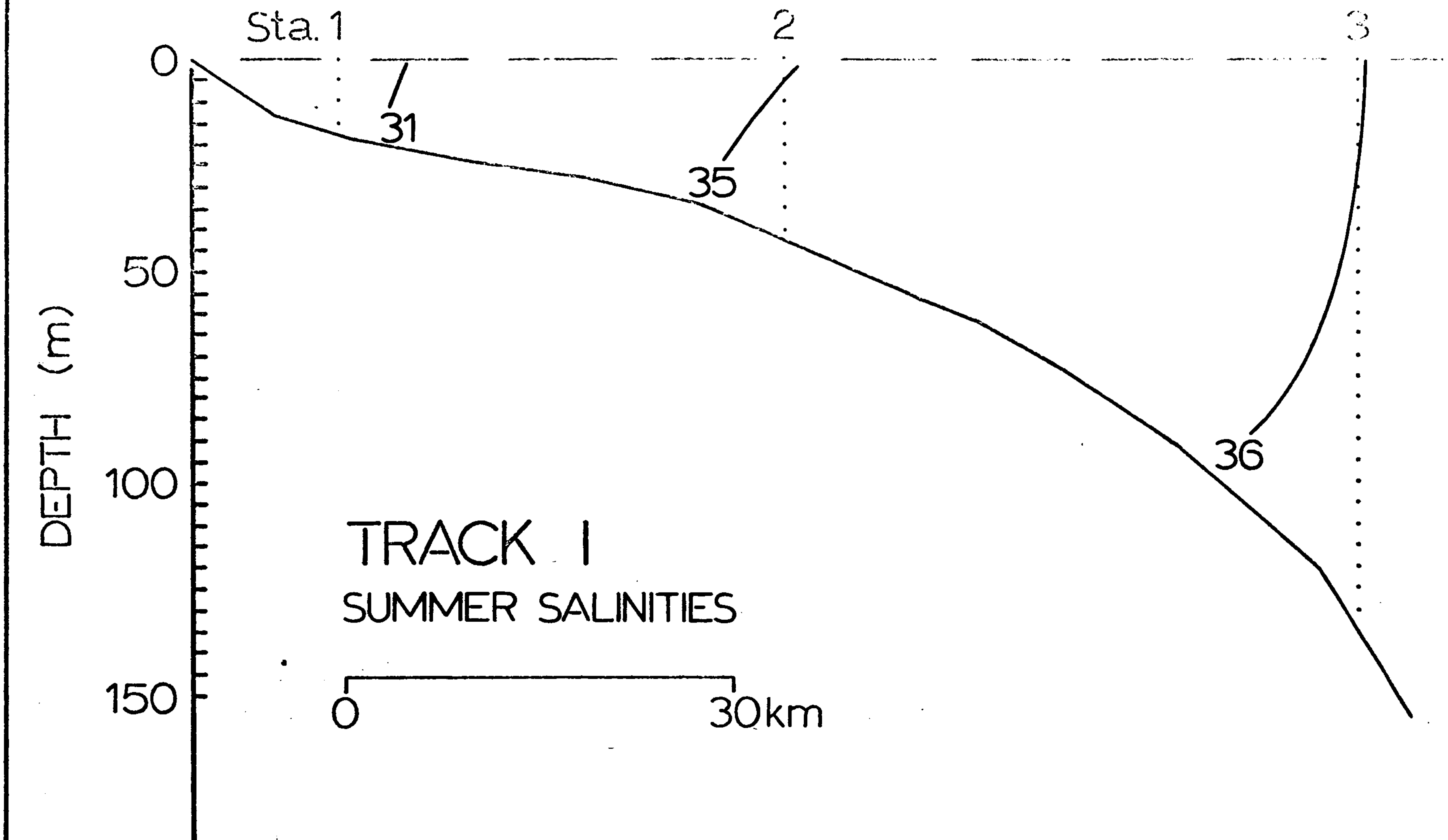
FIG. 18



Sta. 1
2
3
0
50
100
150
DEPTH (m)
29
28
26
24
22
TRACK III
SUMMER TEMPERATURES
0
30km

FIG. 19


Sta. 1
2
3
0
50
100
150
DEPTH (m)
29
28
26
24
TRACK IV
SUMMER TEMPERATURES
0
30 km
FIG. 20



Sta. 1
2
3
0
50
100
150
DEPTH (m)
31
35
36
TRACK I
SUMMER SALINITIES
0
30km

FIG. 21

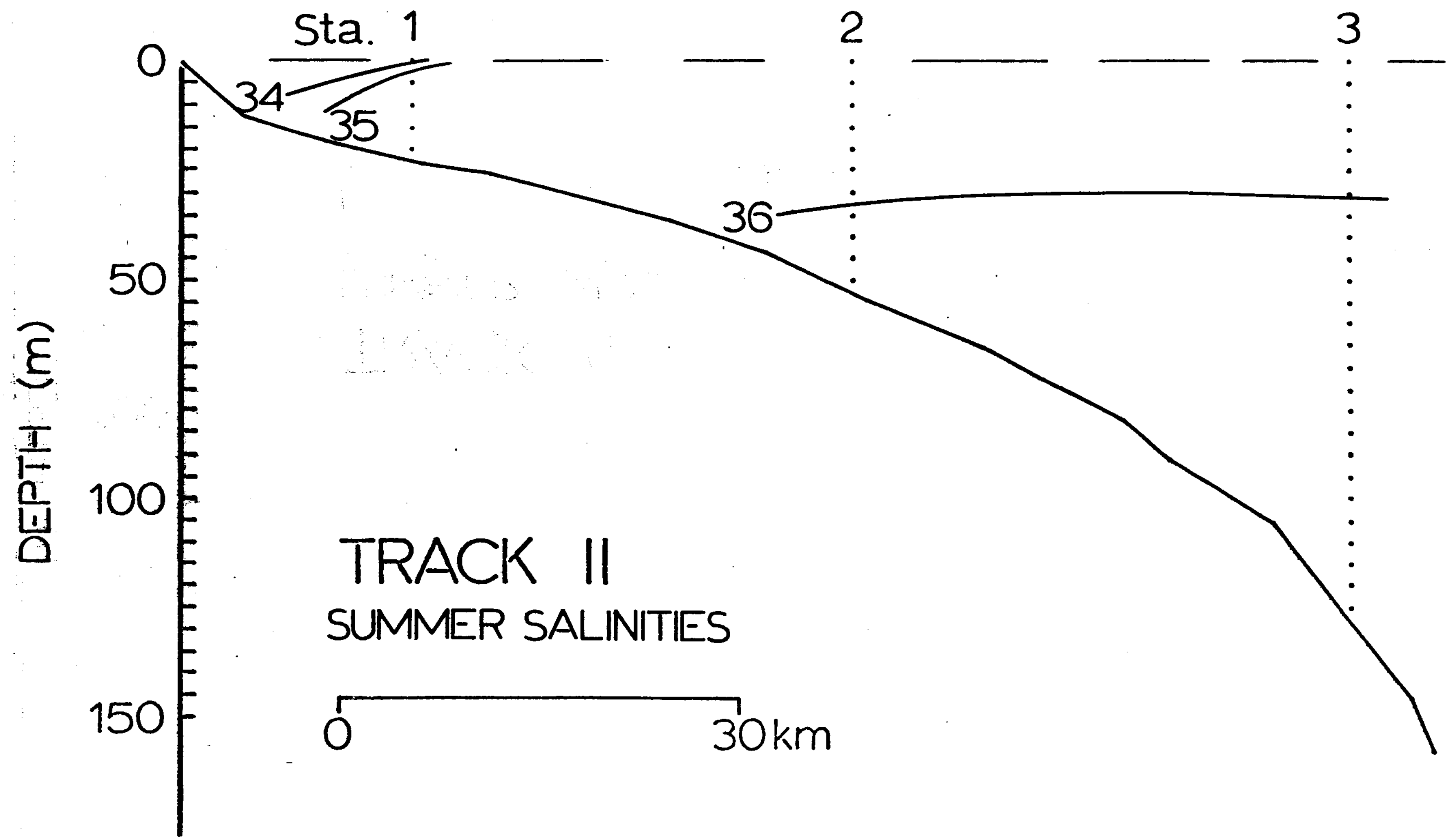

Sta. 1
2
3
0
50
100
150
DEPTH (m)
34
35
36
TRACK II
SUMMER SALINITIES
0
30km

FIG. 22

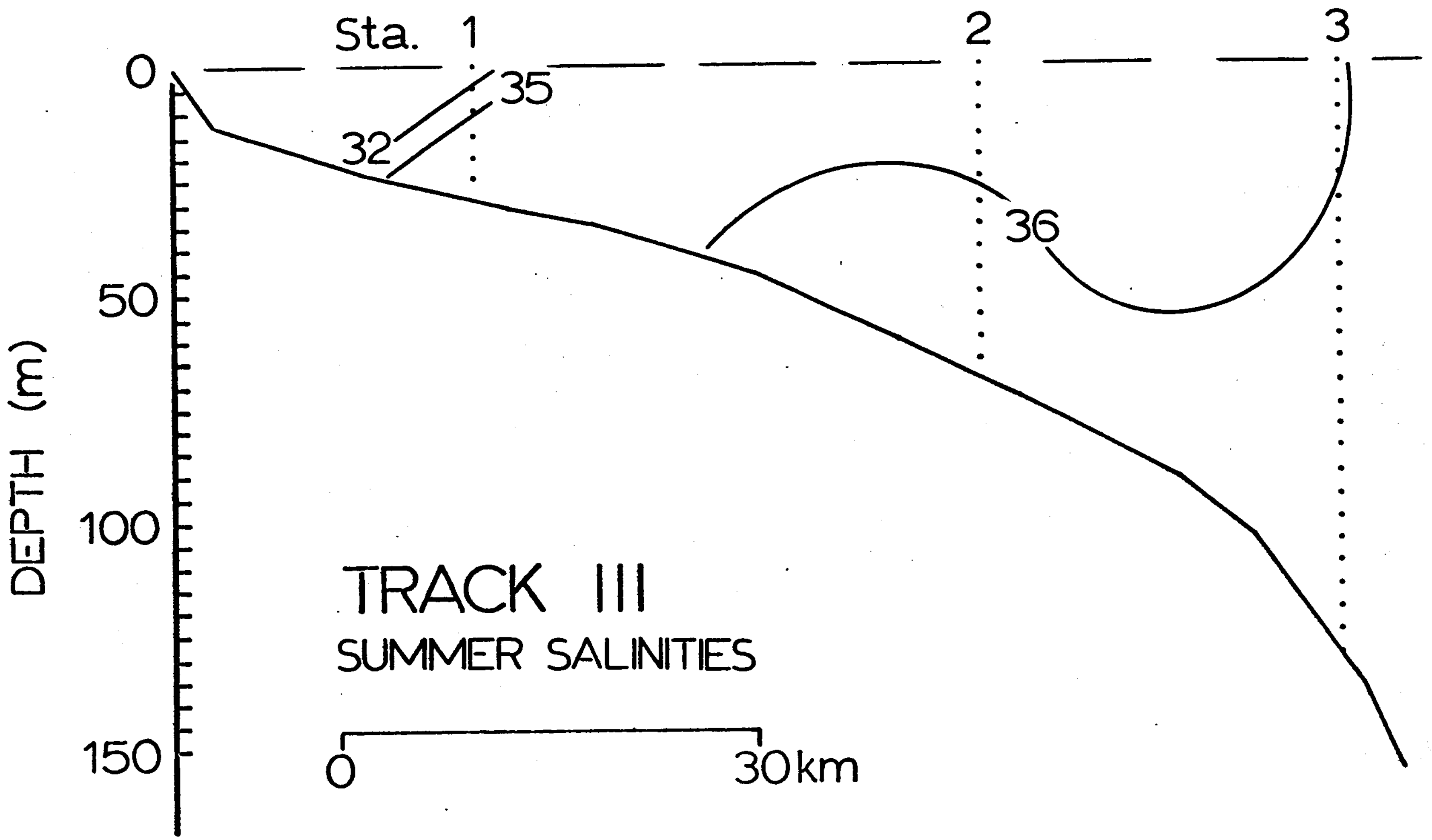

Sta. 1
2
3
0
35
32
36
50
100
150
DEPTH (m)
TRACK III
SUMMER SALINITIES
0
30km

FIG. 23

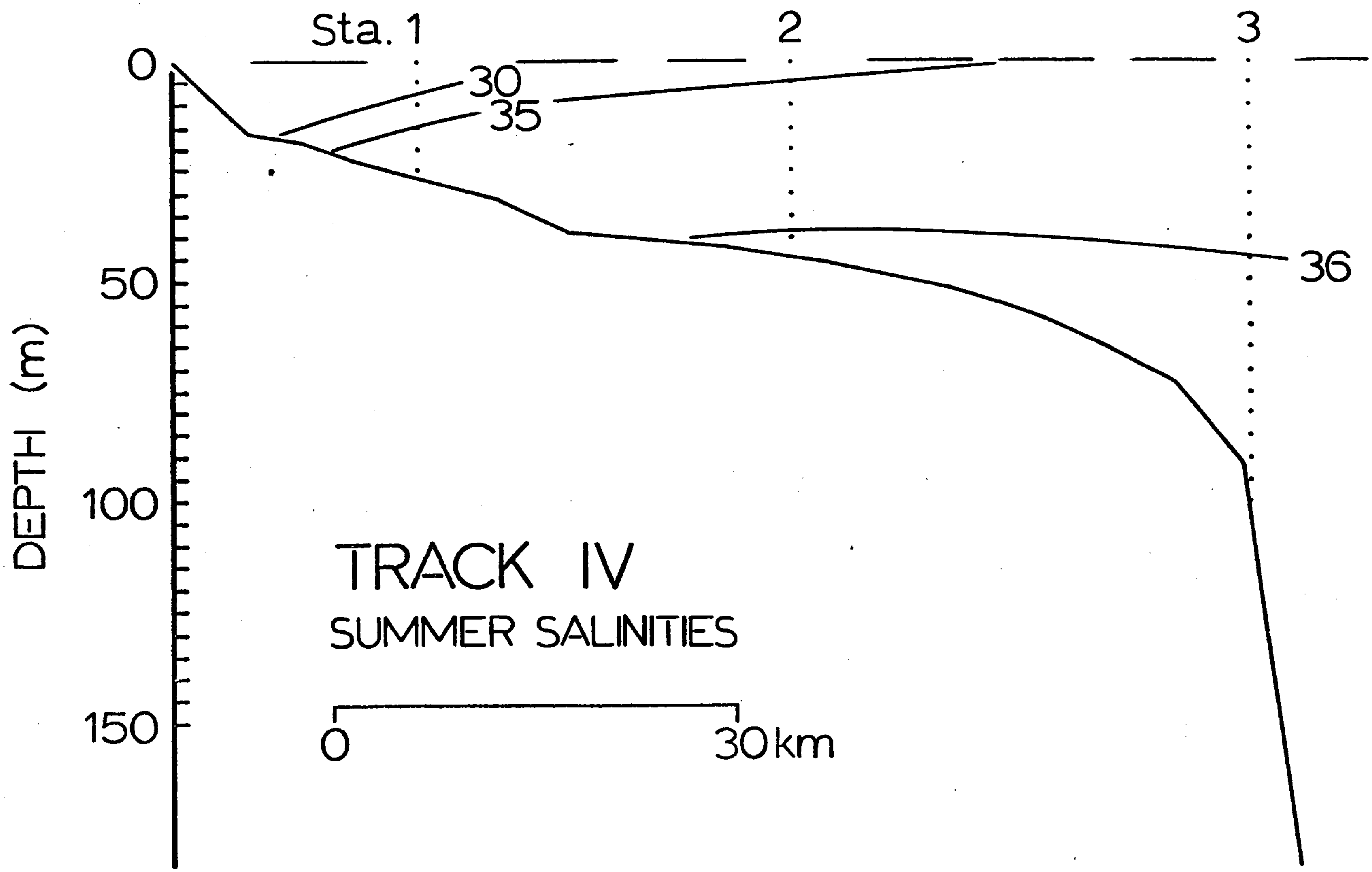

Sta. 1
2
3
30
35
36
0
50
100
150
DEPTH (m)
TRACK IV
SUMMER SALINITIES
0
30km

FIG. 24

PHYTOPLANKTON AND PHYTOPLANKTON BIOMASS

University of Texas, Marine Science Laboratory

Principal Investigator:
Chase Van Baalen

Associate Investigators:
Adrian Heston
Mike Hoban
Joe Morgan
Rita O'Donnell

INTRODUCTION

As part of the Texas Outer Continental Shelf Study, Productivity Section, estimates of chlorophyll a, ATP (adenosine 5'-triphosphate), and net-plankton counts, on samples from the water column, have been carried out. Chlorophyll a values (in μg/liter) are roughly related to the standing crop of phytoplankton. Strickland (1971) quotes values for the carbon:chlorophyll a ratio of 30 for well nourished coastal phytoplankton crops to 90 for phytoplankton in oligotrophic tropical oceans. Estimates of the microflora carbon can be made from the ATP values, carbon:ATP ratio of 250 being reasonable (Strickland, 1971). The phytoplankton counts, species and numbers/liter, are partially compromised by the nannophytoplankton problem (e.g. McCarthy, et al., 1974). To help alleviate this problem, in the second year of the Productivity work the chlorophyll a measurements have been broken down into nanno- and net- phytoplankton via sample sizing during collection. The above measures, together with the nutrient values, provide baseline information on the level of primary production in the study area and possibly modest insight into the factors controlling it.

METHODS

The detailed experimental procedures used in making the measurements are given in the following flow diagrams.

Chlorophyll a and ATP Determinations.

30-liter Niskin Bottle

Chlorophyll a	ATP
2 to 4.8 liters water filtered through 0.4μm, 47mm, Nucleopore filter (2 filters) with gentle suction, time 30-40 minutes.	2 to 4.8 liters water filtered through 0.4μm, 47mm, Nucleopore filter (2 filters) with gentle suction, filtering time 30-40 minutes.

Place filters in Corning 8446 tube and freeze immediately, return sample to lab.

Add 4ml of 90% acetone (redistilled) and approx. 1mg $NaHCO_3$, extract at room temperature in the dark for 1 hour.

Filter through fine porosity sintered glass filter (Corning 36060, size 15F, wash tube and filter and make to 5 ml.

Record absorbance 400 to 720nm, 1cm cuvette, Cary 118C spectrophotometer, acidify sample and rerun spectrum.

Filters placed in 4-dram vial, add 5ml of 0.02M TRIS buffer, pH 7.6, and heat at 100°C for 5 minutes, immediately freeze, return sample to lab.

Thaw just before assay, 0.4ml placed in quartz vial, 16mm OD, positioned in front of photomultiplier, add 0.1ml of FLE-50 (Sigma Chemical Co., St. Louis) firefly extract, record light output curve for 1 minute. Photomultiplier RCA 4473, operated at 720 volts (Keithley 246), anode signal detected on Keithley 414s Picoammeter and recorded. ATP content of sample compared to crystalline ATP (Sigma Chemical Co.) standards run at same time.

Phytoplankton Counts.

Remainder above 30-liter Niskin Bottle plus 5-liter Niskin collected at same time pooled

20 liters passed through 20μm NITEX net (Tetko, Inc. Elmsford, N.Y., HC-20)

Net contents (netplankton) washed off in 250ml seawater into 500ml bottle, add 8.0ml buffered (Sodium Acetate) formalin, allow to settle 3 to 7 days, decant supernatant to 12 ml, archive 2ml, count aliquot of remainder under phase contrast, 200x, in Sedgewick-Rafter Counting Chamber, record species and numbers.

2 liters of filtrate (nannoplankton) passed through 0.4μm Nucleopore filter, wash filter with 10ml of filtered seawater, and preserve with 0.25ml buffered formalin. Samples prepared after the method of Patrick (1966, Diatoms of the United States) for permanent mounting. Slides examined under oil immersion, 1000x. Data limited here to scanning slides and qualitatively recording samples with high incidence identifiable microalgae.

RESULTS

Table 1 records the chlorophyll *a* values in the water column. These values are calculated from the absorbance curves, copies of which are in Appendix III. The ATP values were calculated using the integrated area of the first 15-30 seconds of the recorded curves, and comparing this area to one or occasionally two standards per every three samples run. All chloro-

Table 1. Chlorophyll a and ATP values in μg/liter.

Transect	I			I		
Station	1			2		
Sample Identification and Type of Assay						
Date		1-15-75			1-16-75	
Depth (m)	1.5	4	16	3	11	40
Sample No.	AFZ	AGE	AGJ	ADN	ADS	ADX
Chlorophyll a[1]	2.36	2.78	2.66	0.98	0.99	0.94
	1.80	2.79	2.18	0.75	0.17	0.75
			AV= 2.60			AV= 0.97
			AV= 2.26			AV= 0.56
Chloro a[2] / Phaeo a	1.46	1.72	1.51	1.45	1.21	1.49
Sample No.	AGA	AGF	AGK	ADO	ADT	ADY
ATP[3]	0.20	0.29	0.57	0.25	0.14	0.15
			AV= 0.35			AV= 0.18
Date		4-7-75			4-9-75	
Depth (m)	4	10	20	5	20	40
Sample No.	CBW	CCB	CCG	CFB	CFG	CFL
Chlorophyll a[1]	13.40	12.30	5.78	0.43	0.67	0.66
	11.90	10.54	3.96	0.30	0.51	0.47
			AV=10.49			AV= 0.59
			AV= 8.80			AV= 0.43
Chloro a[2] / Phaeo a	1.59	1.57	1.40	1.40	1.46	1.41
Sample No.	CBV	CCA	CCF	CFA	CFF	CFK
ATP[3]	0.15	0.12	0.03	0.07	0.09	0.05
			AV= 0.10			AV= 0.07
Date		8-26-75			8-27-75	
Depth (m)	1	8	15	1	20	40
Sample No.	EBW	ECB	ECG	EFB	EFG	EFL
Chlorophyll a[1]	2.96	1.96	1.79	N.D.[4]	0.19	1.39
	2.31	1.37	1.11		0.07	1.05
			AV= 2.24			AV= 0.29
			AV= 1.60			AV= 0.56
Chloro a[2] / Phaeo a	1.48	1.40	1.34		1.17	1.44
Sample No.	EBU	ECA	ECF	EFA	EFF	EFK
ATP[3]	0.15	0.29	0.17	0.05	0.06	0.22
			AV= 0.20			AV= 0.11

Table 1. Cont.'d

I			II			II		
3			1			2		
	1-16-75			12-17-74			1-9-75	
3	42	130	1	9	20	3	15	45
AAY	ABN	ABT	AJW	AKB	AKG	AMV	ANA	ANG
0.58	0.68	N.D.	1.78	2.07	1.24	0.60	0.53	0.78
0.42	0.47		1.45	1.63	0.99	0.43	0.31	0.52
		AV= 0.63			AV= 1.70			AV= 0.64
		AV= 0.45			AV= 1.36			AV= 0.42
1.42	1.40		1.51	1.48	1.49	1.40	1.30	1.37
AAX	ABO	ABU	AJX	AKC	AKH	AMW	ANB	ANF
0.11	0.02	.003	0.26	0.34	0.11	0.42	0.26	0.06
		AV= 0.04			AV= 0.24			AV= 0.25
	4-10-75			4-17-75			4-18-75	
1	25	125	1	5	20	1	15	30
CIF	CIK	CIP	CLL	CLQ	CLV	COO	COT	COY
0.19	0.30	N.D.	15.95	17.06	3.19	4.33	1.47	1.23
0.11	0.16		13.65	14.96	2.41	3.38	1.14	0.94
		AV= 0.25			AV=12.07			AV= 2.34
		AV= 0.14			AV=10.34			AV= 1.82
1.28	1.28		1.57	1.59	1.46	1.49	1.47	1.46
CIE	CIJ	CIO	CLK	CLP	CLU	CON	COS	COX
0.06	0.15	0.02	0.15	0.12	0.01	0.18	0.21	0.17
		AV= 0.08			AV= 0.09			AV= 0.19
	8-28-75			9-4-75			9-5-75	
1	25	120	1	11	20	1	25	45
EIF	EIK	EIP	ELL	ELQ	ELV	EOP	EOU	EOZ
N.D.	0.21	0.27	0.66	0.78	1.36	N.D.[4]	0.18	1.14
	0.10	0.11	0.41	0.45	0.88		0.10	0.78
		AV= 0.24			AV= 0.93			AV= 0.66
		AV= 0.11			AV= 0.58			AV= 0.44
	1.22	1.20	1.34	1.31	1.36		1.26	1.39
EIE	EIJ	EIO	ELK	ELP	ELU	EOO	EOT	EOV
0.07	0.11	0.02	0.19	0.08	0.26	0.03	0.07	0.56
		AV= 0.07			AV= 0.18			AV= 0.22

Table 1. Cont.'d

II			III			III		
	3			1			2	
	12-12-74			12-15-74			12-14-74	
10	23	105	2.5	10	20	10	25	55
APX	AQC	AQH	ASZ	ATH	ATM	AWB	AWF	AWL
0.53	0.56	N.D.	0.74	1.12	0.77	0.34	0.38	0.40
0.33	0.37		0.47	0.82	0.46	0.22	0.16	0.24
		AV= 0.55			AV= 0.88			AV= 0.37
		AV= 0.35			AV= 0.58			AV= 0.21
1.34	1.37		1.35	1.43	1.32	1.34	1.21	1.32
APY	AQD	AQI	ATA	ATI	ATN	AWC	AWH	AWM
0.01	0.09	0.01	0.11	0.25	0.25	0.06	0.02	0.05
		AV= 0.04			AV= 0.20			AV= 0.04
	5-16-75			5-1-75			5-2-75	
1	23	115	1	7.5	16	1	23	60
CRQ	CRV	CSA	CUY	CWD	CWI	CYY	CZD	CZI
0.20	0.20	N.D.	4.39	2.25	1.38	0.66	0.29	0.67
0.08	0.08		4.19	2.32	1.17	0.82	0.31	0.54
		AV= 0.20			AV= 2.67			AV= 0.54
		AV= 0.08			AV= 2.56			AV= 0.56
1.18	1.30		1.67	1.75	1.54	1.97	1.75	1.49
CRP	CRU	CRZ	CUX	CWC	CWH	CYX	CZC	CZH
0.07	0.04	0.01	0.12	0.13	0.05	0.08	0.18	0.003
		AV= 0.04			AV= 0.10			AV= 0.09
	9-6-75			9-8-75			9-7-75	
1	29	120	1	9	20	1	26	60
ERQ	ERV	ESA	EUY	EWD	EWI	EYY	EZD	EZI
N.D.	0.18	0.25	1.15	0.87	0.80	0.20	0.24	1.69
	0.08	0.10	0.87	0.59	0.53	0.08	0.10	1.50
		AV= 0.22			AV= 0.94			AV= 0.71
		AV= 0.09			AV= 0.66			AV= 0.56
	1.22	1.18	1.45	1.39	1.36	1.19	1.19	1.38
ERP	ERU	ERZ	EUX	EWC	EWH	EYX	EZC	EZH
0.02	0.02	0.07	0.05	Lost	0.03	0.09	0.05	0.06
		AV= 0.04			AV= 0.04			AV= 0.07

Table 1. Cont.'d

III			IV			IV		
3			1			2		
	12-13-74			1-21-75			1-24-75	
10	25	100	2	7	25	2	18	45
AYZ	AZE	AZJ	BBX	BCC	BCH	BEZ	BFE	BFJ
N.D.[4]	0.64	0.63	0.78	0.77	0.57	0.55	0.55	0.57
	0.45	0.47	0.47	0.48	0.31	0.41	0.33	0.33
		AV= 0.64			AV= 0.71			AV= 0.56
		AV= 0.46			AV= 0.42			AV= 0.36
	1.41	1.44	1.33	1.33	1.28	1.43	1.36	1.31
AZA	AZF	AZK	BBY	BCD	BCI	BFA	BFF	BFK
0.01	0.09	0.03	0.11	0.17	0.15	0.19	0.03	0.01
		AV= 0.04			AV= 0.14			AV= 0.08
	5-16-75			5-1-75			5-2-75	
1	19	100	1	14	25	1	11	45
DCK	DCP	DMO	DEW	DFB	DFG	DHV	DHZ	DIF
0.27	0.22	N.D.	0.64	1.38	1.27	2.15	1.34	0.57
0.19	0.10		0.52	0.95	0.89	1.85	1.05	0.42
		AV= 0.25			AV= 1.10			AV= 1.35
		AV= 0.15			AV= 0.79			AV= 1.11
1.39	1.22		1.49	1.41	1.40	1.49	1.46	1.42
DCJ	DCO	DMN	DEV	DFA	DFF	DHU	DIA	DIE
0.04	0.11	0.05	0.44	1.08	0.10	0.18	0.40	0.12
		AV= 0.07			AV= 0.54			AV= 0.23
	9-7-75			9-12-75			9-12-75	
1	29	100	1	13	22	1	13	40
FCM	FCR	FCW	FFE	FFJ	FFO	FIF	FIK	FIP
0.19	0.21	0.25	0.91	0.95	1.23	0.55	0.46	1.15
0.04	0.10	0.11	0.47	0.53	0.73	0.28	0.21	0.75
		AV= 0.22			AV= 1.03			AV= 0.72
		AV= 0.08			AV= 0.58			AV= 0.41
1.09	1.23	1.21	1.25	1.28	1.31	1.29	1.21	1.36
FCL	FCQ	FCV	FFD	FFI	FFN	FIE	FIJ	FIO
0.04	0.02	0.02	0.77	0.51	Lost	0.08	1.45	0.31
		AV= 0.04			AV= 0.64			AV= 0.61

Table 1. Cont.'d

IV		
3		
	1-25-75	
2	36	85
BPZ	BOE	BOJ
0.43	0.37	0.40
0.33	0.22	0.22
	AV=	0.40
	AV=	0.26
1.47	1.33	1.28
BOA	BOF	BOK
0.03	0.08	0.08
	AV=	0.06
	4-29-75	
1	17	85
DKZ	DLE	DLJ
0.33	0.24	0.49
0.25	0.13	0.25
	AV=	0.35
	AV=	0.21
1.43	1.24	1.25
DLA	DLF	DLK
1.70	0.09	0.10
	AV=	0.63
	9-13-75	
1	31	85
FLI	FLN	FLS
N.D.[4]	N.D.[4]	0.68
		0.43
		1.35
FLJ	FLO	FLT
0.09	0.07	0.02
	AV=	0.06

FOOTNOTES:

1. First value calculated from equation of Parsons and Strickland (J. Mar. Res., 21:155, 1963; Parsons and Strickland, A Practical Handbook of Seawater Analysis, pp. 189, 1968). Second value calculated from equation of Lorenzen (Limnol. Oceanog., 12: 343, 1967).

2. Chlorophyll a/Phaeophytin a = O.D. 663/O.D. 666.

3. Average of duplicate analyses.

4. N.D. means not detectable, value below 0.02μg Chl a/l, or A_{663}<.0015A.

phyll a samples (108) were collected and processed. All ATP samples (108) were collected but samples EWC and FFN were lost during transit to the lab.

Table 2 records only the dominant netplankton identification and abundance, cells/liter. The complete species list and cell count/liter is given in Appendix IV. All samples (72) were collected and processed except AVX which was accidentally thrown overboard. The upper number in the Table indicates the surface sample, the lower number the sample taken from approximately 1/2 the photic zone.

Species diversity index, H", was calculated from the equation, Shannon and Weaver (1963).

$$H'' = -\Sigma(n_i/N)\log_e(n_i/N)$$

The values are given in Table 3.

DISCUSSION

The seasonal patterns of chlorophyll a in the water column are shown in Figure 1. Highest values occur nearest shore with indications that stations 2/I and 1/II are higher (more productive?) than 1/III and 1/IV. The chlorophyll a values in the study area are not as high as those recorded by Steidinger (1973) for the Eastern Gulf of Mexico, particularly in inshore regions. Our values also fall off more quickly from shore. In comparison to the surface values recorded in the American Geographical Society Folio 22 (El-Sayed, et al., 1972) for stations which roughly correspond to the outermost stations in this study, our values are comparable.

On Transect IV, all three stations, there were some high ATP values (Figure 2). These high ATP values are not reflected in correspondingly high chlorophyll a values (Figure 1) nor in phytoplankton counts. Transect averages of phytoplankton counts for the three cruises show that Transect II was highest followed by I, IV and III in that order. The annual mean ash-

Table 2. Dominant Phytoplankton as Percentages of Total Population.[1]
Cruise 1 - Winter (December-January 1974-75)

	Transect I			Transect II			Transect III			Transect IV		
	1	2	3	1	2	3	1	2	3	1	2	3
1. Bacteriastrum hyalinum	2	3	1	-	2	2	*	3	1	5	2	-
	*	4	-	*	3	4	*	-	-	2	3	-
2. Cerataulina bergoni	11	*	*	7	*		1	*	*		2	3
	56	*	-	10	3	*	1	-	*	*	3	5
3. Chaetoceros curvisetus	-	*	2	1	*	*	-	-	5	-	-	6
	-	1	*	-	*	5	1	-	7	-	-	7
4. C. decipiens	1	10	20	-	-	18	-	17	17	*	3	6
	-	4	11	-	-	21	-	-	13	2	1	2
5. C. lorenzianus	3	7	8	2	4	7	4	2	5	*	4	*
	2	4	-	*	2	5	3	-	11	3	*	*
6. C. pelagicus	-	*	10	-	*	1	*	*	2	*	*	1
	-	1	*	-	4	-	16	-	2	*	-	-
7. Nitzschia seriata	1	*	3	*	8	1	*	2	3	18	18	-
	*	2	-	-	6	-	-	-	5	32	11	-
8. Rhizosolenia stolterfothii	1	*	*	22	*	*	*	2	2	-	*	2
	3	*	-	13	*	*	*	-	1	-	-	1
9. Skeletonema costatum	7	11	3	*	24	-	20	*	-	*	-	-
	2	9	*	-	10	-	16	-	*	-	2	2
10. Thalassionema nitzschioides	8	18	5	3	6	12	-	17	8	*	4	*
	1	10	11	2	2	10	18	-	13	6	-	7
11. Thalassiosira rotula	35	14	*	3	-	*	*	*	*	2	4	*
	12	12	*	2	-	*	6	-	-	2	*	*
12. Thalassiosira subtilis	6	6	-	6	-	-	2	*	9	-	-	*
	-	3	-	24	-	-	2	-	*	-	-	*
Total Cells per Liter, X 10^4	.586	.638	.315	.548	.548	.602	.648	.815	.478	.100	.096	.226
	.601	.866	.016	.793	.084	.497	.583	lost	.503	.108	.117	.418

Table 2. Cont.'d

Cruise 2 - Spring (April-May 1975)

ORGANISM	Transect I 1	Transect I 2	Transect I 3	Transect II 1	Transect II 2	Transect II 3	Transect III 1	Transect III 2	Transect III 3	Transect IV 1	Transect IV 2	Transect IV 3
1. Asterionella japonica	4	10	-	8	6	*	2	9	-	-	*	-
	3	7	-	21	9	-	10	*	-	29	*	-
2. Cerataulina bergoni	-	-	-	-	-	35	*	15	3	8	7	-
	*	-	*	-	2	20	*	17	4	1	4	-
3. Chaetoceros affinis	*	-	-	4	*	-	-	2	-	-	*	-
	10	-	1	-	1	-	-	*	-	*	*	-
4. C. brevis	-	-	-	5	*	*	-	*	-	*	5	-
	-	-	-	5	1	-	-	2	-	*	2	-
5. C. curvisetus	-	-	-	-	*	2	-	2	-	2	1	-
	-	-	-	-	*	2	-	9	-	*	29	-
6. C. decipiens	*	3	*	*	*	3	4	9	3	-	3	*
	-	-	10	-	2	2	1	9	7	*	3	2
7. C. lacinosus	-	-	5	*	-	-	4	2	4	-	2	1
	-	2	*	-	*	-	5	2	13	-	*	6
8. C. mitra	*	-	-	-	-	-	-	1	-	-	7	1
	*	-	-	-	-	1	-	-	2	-	-	-
9. C. pelagicus	-	-	-	*	*	-	-	*	-	-	3	-
	-	-	-	*	*	*	-	1	1	-	-	4
10. Ditylum brightwelli	2	3	2	3	5	-	10	1	-	*	*	*
	2	4	*	7	6	-	12	-	-	3	*	1
11. Leptocylindricus minimum	60	6	-	8	9	13	12	3	2	*	*	*
	61	*	3	30	*	*	11	2	2	-	*	-
12. Nitzschia delicatissima	-	7	25	*	7	12	*	22	41	2	10	47
	-	10	41	2	6	42	*	29	21	*	4	28
13. N. pungens	-	-	-	*	3	2	24	4	-	1	17	-
	-	-	-	2	5	2	25	4	-	*	3	-

Table 2. Cont.'d

Cruise 2 - Cont.'d

ORGANISM	Transect I 1	2	3	Transect II 1	2	3	Transect III 1	2	3	Transect IV 1	2	3
14. Nitzschia seriata	2	-	4	*	*	-	-	1	-	-	3	*
	3	*	3	1	*	-	-	-	1	*	1	2
15. Skeletonema costatum	13	16	-	37	50	*	6	6	-	47	6	2
	14	14	-	72	58	-	2	*	-	61	19	4
16. Thalassionema nitzschioides	12	3	-	*	3	*	4	*	*	-	3	3
	8	2	*	4	*	*	6	2	2	*	*	2
17. Thalassiosira rotula	3	*	-	1	2	-	-	-		-	*	-
	2	*	-	4	*	-	*	*		*	*	-
18. Thalassiothrix mediterranea	-	*	-	*	*	*	*	1	*	-	2	
	-	-	-	*	*	-	*	2	*	-	*	-
Total Cells per Liter, X 10^4	220.	.208	.115	333.	90.6	.571	7.97	1.44	.930	.304	54.8	.322
	142.	.320	.131	221.	17.9	.274	1.70	.660	.653	20.8	10.0	.129

Cruise 3 - Summer (August-September 1975)

ORGANISM	Transect I 1	2	3	Transect II 1	2	3	Transect III 1	2	3	Transect IV 1	2	3
1. Bacteriastrum hyalinum	*	-	-	5	-	*	-	*	-	*	9	-
	4	-	-	6	-	-	4	-	-	5	21	7
2. Chaetoceros curvisetus	5	-	-	9	*	10	1	-	-	6	27	*
	8	-	-	54	10	-	13	-	-	21	10	6
3. C. decipiens	11	-	-	*	-	-	-	3	-	*	*	2
	4	-	-	2	-	-	-	-	-	-	6	-
4. C. diversus	32	-	-	9	15	4	*	-	-	*	6	*
	31	-	-	11	3	-	15	-	-	2	11	*
5. C. gracilis	3	-	-	-	-	-	-	*	-	-	*	-
	3	-	-	-	-	-	*	-	-	*	-	-
6. C. lacinosus	17	-	-	*	-	-	*	15	-	*	-	-
	10	-	-	1	-	-	1	17	7	-	*	-

Table 2. Cont.'d Cruise 3 - Cont.'d

ORGANISMS	Transect I			Transect II			Transect III			Transect IV		
	1	2	3	1	2	3	1	2	3	1	2	3
7. Nitzschia	-	-	-	34	7	8	54	-	-	62	32	27
delicatissima	-	5	-	13	-	39	8	-	-	35	4	13
8. N. seriata	-	-	-	2	*	-	18	6	18	2	*	-
	2	-	*	-	-	-	5	10	14	13	*	-
9. R. alata v.	*	16	12	-	5	10	-	6	13	*	*	27
gracillima	1	7	22	*	9	7	-	13	16	*	*	21
10. Thalassionema	4	12	*	5	-	*	5	-	-	11	4	-
nitzschioides	6	14	-	1	-	-	*	-	-	2	1	*
11. Trichodesmium	*	9	-	5	3	*	*	8	*	*	5	*
thiebautii	*	*	*	-	3	-	*	-	-	*	9	*
12. Rhizosolenia hebetata	2	7	*	-	-	-	*	6	*	-	-	-
v. semispina	*	6	*	-	-	-	-	4	*	-	-	-
Total Cells per Liter,	13.8	.010	.009	.428	.047	.025	.629	.033	.008	2.84	.882	.054
X 10^4	3.19	.019	.004	3.00	.029	.045	.201	.029	.010	1.33	.236	.020

* Indicates organism present but less than 1% of total.
\- Organism not present
1 Upper number is surface sample, lower number is sample from 1/2 photic zone.

Table 3. Phytoplankton Diversity Indices (H") for Texas OCS Stations.

Winter Seasonal (December 1974 - January 1975)

Station	Transect	Date	Sample Code	Depth	H"	Total Spp.	Total cells/ liter
1	I	12-6-74	AFT	10	2.54	43	5855
1	I	12-6-74	AFR	2.5	1.68	28	6013
2	I	12-5-74	ADG	10	2.93	54	6378
2	I	12-5-74	ADF	5	2.57	53	8663
3	I	12-4-74	ABW	3	3.00	52	3154
3	I	12-4-74	ABX	25	3.23	32	157*
1	II	12-17-74	AJQ	1	3.13	56	5478
1	II	12-17-74	AJS	9	2.83	51	7932
2	II	1-9-75	AMM	3	2.53	45	5475
2	II	1-9-75	AMQ	15	3.39	44	281
3	II	12-12-74	APP	10	3.02	60	6018
3	II	12-12-74	APS	23	2.86	51	4974
1	III	12-15-74	ASR	2.5	2.81	52	6483
1	III	12-15-74	ASU	10	2.74	43	5833
2	III	12-14-74	AVV	10	3.03	60	8148
2	III	12-14-74	AVX	25	Lost	Lost	Lost
3	III	12-13-74	AYR	10	3.09	43	4777
3	III	12-13-74	AYU	25	3.15	53	5033
1	IV	1-21-75	BBP	2	3.03	37	1003
1	IV	1-21-75	BBR	7	2.54	30	1078
2	IV	1-24-75	BER	2	2.99	41	956
2	IV	1-24-75	BEU	18	3.42	52	1172
3	IV	1-25-74	BPR	2	3.21	61	2260

Table 3. Cont.'d

Station	Transect	Date	Sample Code	Depth	H"	Total Spp.	Total cells/ liter
3	IV	1-25-75	BPU	36	3.26	73	4176
			Spring Seasonal (April - May 1975)				
1	I	4-7-75	CBL	4	1.44	26	2,200,830
1	I	4-7-75	CBP	10	1.32	21	1,427,460
2	I	4-9-75	CEQ	5	3.07	46	2087
2	I	4-9-75	CEW	20	2.64	42	3204
3	I	4-10-75	CHU	1	2.83	37	1146
3	I	4-10-75	CHZ	25	2.50	39	1315
1	II	4-17-75	CLA	1	1.84	53	2,211,840
1	II	4-17-75	CLE	5	1.78	40	3,332,160
2	II	4-18-75	COD	1	2.06	36	906,720
2	II	4-18-75	COH	15	1.89	45	179,400
3	II	5-16-75	CRF	1	2.54	42	5706
3	II	5-16-75	CRU	23	2.19	34	2736
1	III	5-13-75	CUN	1	2.74	46	79,753
1	III	5-13-75	CUR	7.5	2.82	41	17,005
2	III	5-14-75	CYN	1	2.76	41	14,400
2	III	5-14-75	CYR	23	2.58	38	6600
3	III	5-16-75	DBN	1	1.66	31	9296
3	III	5-16-75	DBR	19	2.49	34	6527
1	IV	5-1-75	DEL	1	2.08	26	3036
1	IV	5-1-75	DEP	14	1.13	18	208,320
2	IV	5-2-75	DHK	1	2.81	38	548,160
2	IV	5-2-75	DHO	11	2.62	41	99,960

Table 3. Cont.'d

Station	Transect	Date	Sample Code	Depth	H"	Total Spp.	Total cells/ liter
3	IV	4-29-75	DKP	1	2.05	41	3215
3	IV	4-29-75	DKT	17	2.90	35	1290
		Summer Seasonal (August - September 1975)					
1	I	8-26-75	EBL	1	2.76	45	138,407
1	I	8-26-75	EBP	7.5	2.67	41	31,857
2	I	8-27-75	EEQ	1	2.67	18	95
2	I	8-27-75	EEU	20	2.58	19	189
3	I	8-28-75	EHU	1	2.14	12	91
3	I	8-28-75	EHY	20	2.31	14	41
1	II	9-4-75	ELE	1	2.64	45	4278
1	II	9-4-75	ELE	11	1.69	36	30,024
2	II	9-5-75	EOE	1	2.84	31	465
2	II	9-5-75	EOI	25	2.77	24	294
3	II	9-6-75	ERF	1	2.80	22	249
3	II	9-6-75	ERJ	29	2.26	21	453
1	III	9-8-75	EUN	1	1.83	37	6288
1	III	9-8-75	EUR	9	2.83	38	2014
2	III	9-7-75	EYN	1	2.53	20	327
2	III	9-7-75	EYR	26	2.59	20	228
3	III	9-12-75	FBN	1	2.63	23	78
3	III	9-12-75	FBR	29	2.71	24	100
1	IV	9-12-75	FET	1	1.60	38	28,440
1	IV	9-12-75	FEX	13	2.30	40	13,320
2	IV	9-13-75	FHU	1	2.24	40	8820

Table 3. Cont.'d

Station	Transect	Date	Sample Code	Depth	H"	Total Spp.	Total cells/ liter
2	IV	9-12-75	FHY	13	2.95	48	2358
3	IV	9-13-75	FKY	1	2.27	23	543
3	IV	9-13-75	FLC	31	2.55	18	204

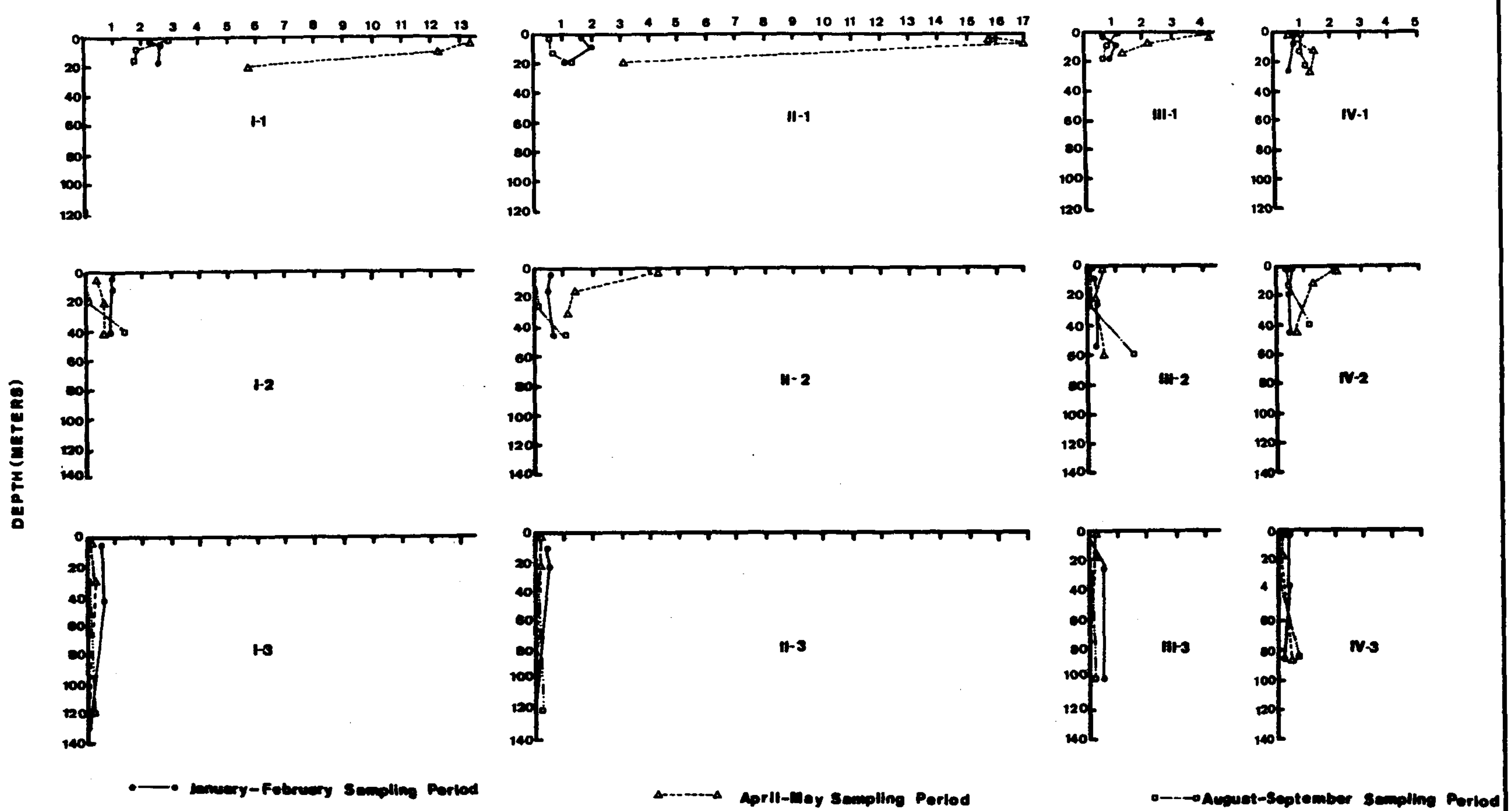


Figure 1. SEASONAL VARIATIONS IN CHLOROPHYLL A μg/liter

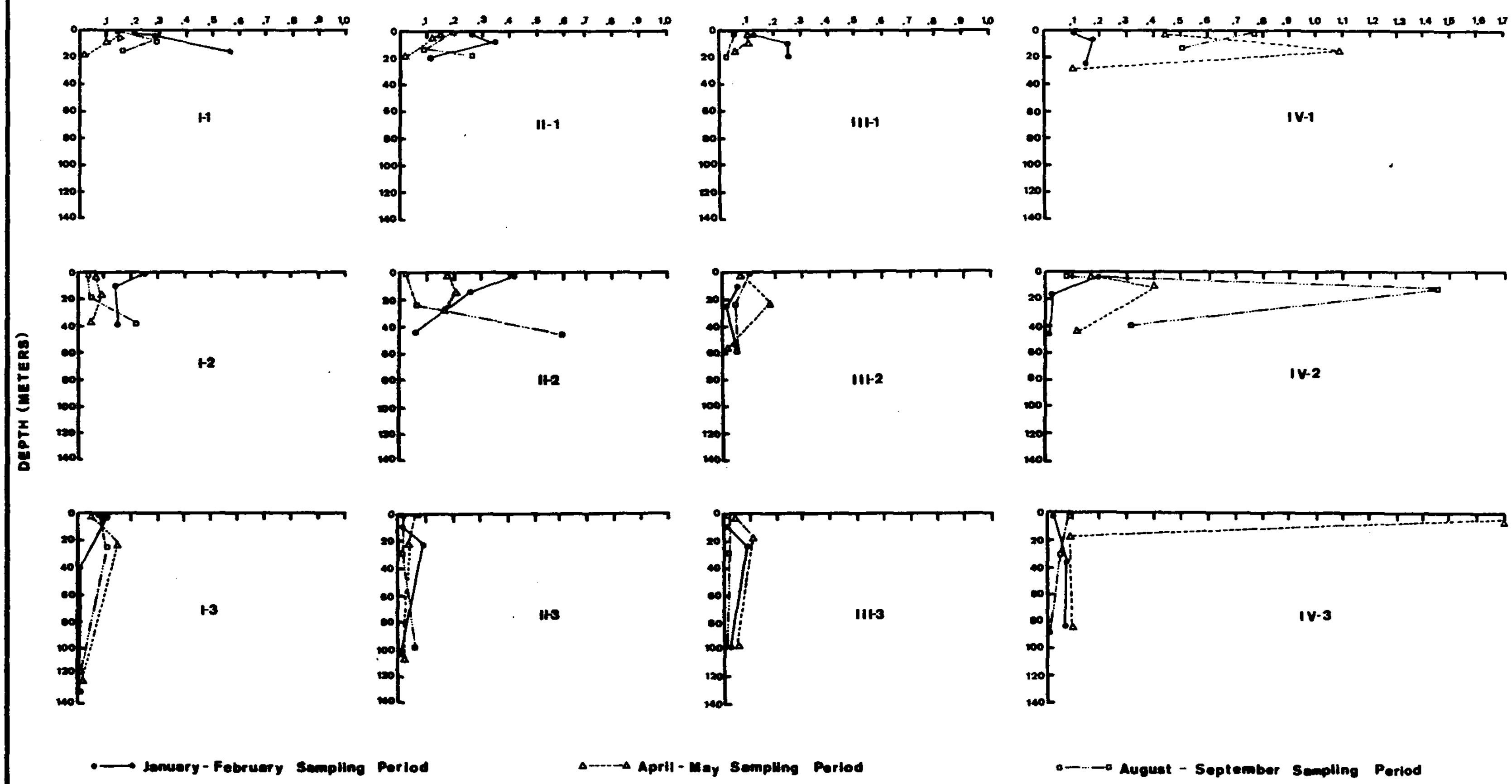


Figure 2. SEASONAL VARIATIONS IN ATP µg/liter

free dry weight of the zooplankton was also highest along Transects I and II, nearshore stations, roughly correlated with the chlorophyll a and to some extent with the average phytoplankton counts. However, the benthic population was richest, both species and numbers, along Transect IV (Holland, personal communication and this volume).

In Figures 3 through 15 we have looked for possible correlations of temperature, salinity, silicate, phosphate, nitrate, dissolved oxygen, with chlorophyll a or ATP. Chlorophyll A-1 refers to the value calculated using the Parsons and Strickland equation (upper value in Table 1). Correlation (R) is significant (P=.01) at any values greater than ± 0.4. The only evident relationship is an inverse correlation of salinity with chlorophyll a (Figure 5), which may be a reflection of nutrient supply from land run-off.

The species diversity index, H'', calculated for each of the stations is recorded in Table 3. The species diversity was greatest during the winter cruise, January-December. For the spring cruise (April-May) and the summer cruise (August-September) species diversity was very similar.

Reports on the numbers and distribution of the phytoplankton in the Gulf of Mexico (hereinafter referred to as Gulf), especially along the western shore, are sketchy at best. The Florida coast (Saunders and Glenn, 1969; Steidinger and Williams, 1970; Hurlburt et al., 1960) and the Mississippi River delta area (Simmons and Thomas, 1962) have been well studied, and there are others (Curl, 1959; Freese, 1952), but the continental shelf of the Western Gulf has been largely ignored.

One recent attempt to put it all together is Folio 22 of the American Geographical Society (El-Sayed, et al., 1972) which relies on the above mentioned works and Balech's (1967) report to plot distributional patterns of the most common phytoplankton. The report, however, largely leaves out numbers and seasonal distribution of the organisms. Obviously, the work

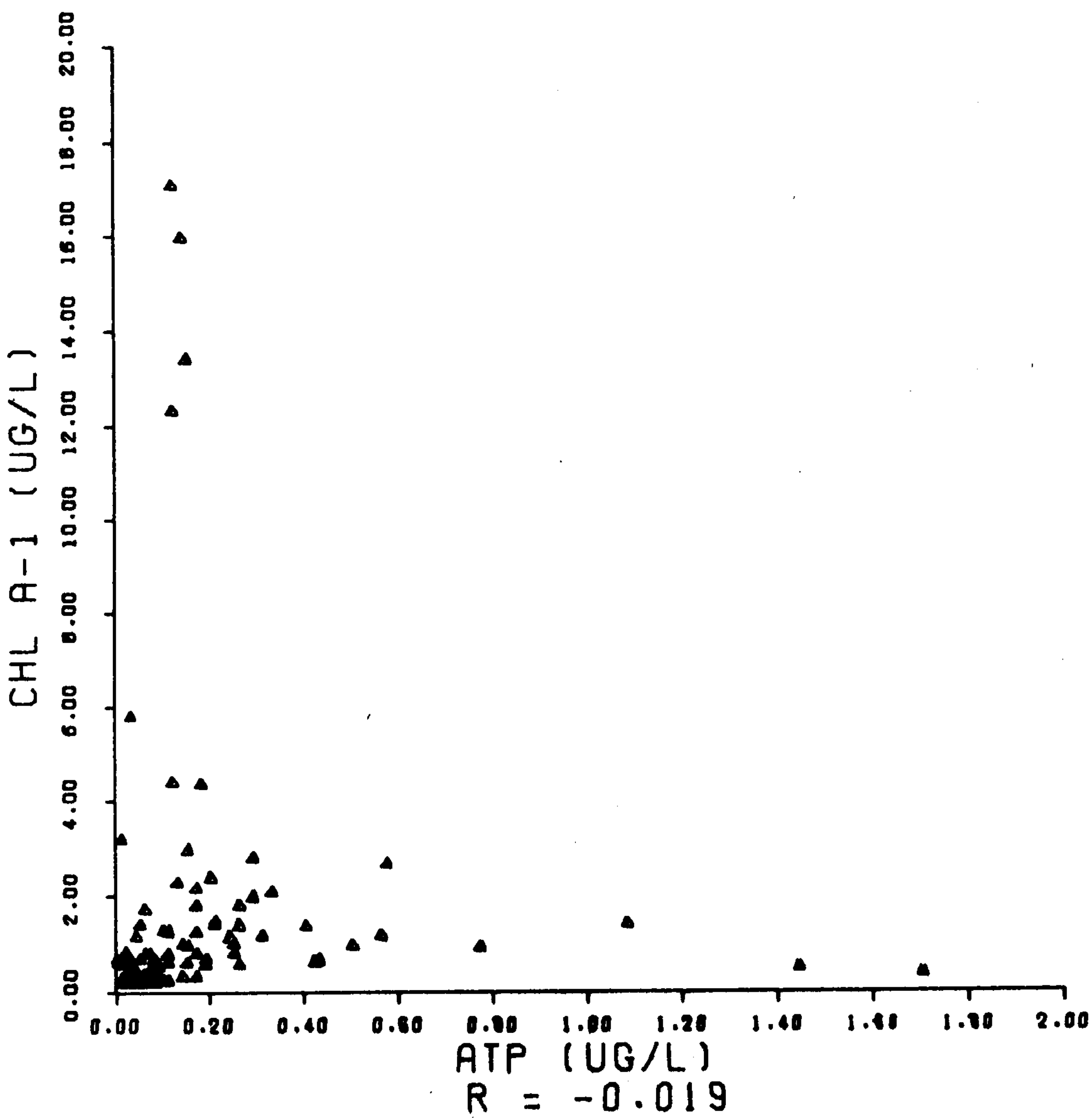


Figure 3. Scatter diagrams of chlorophyll a values against ATP values.

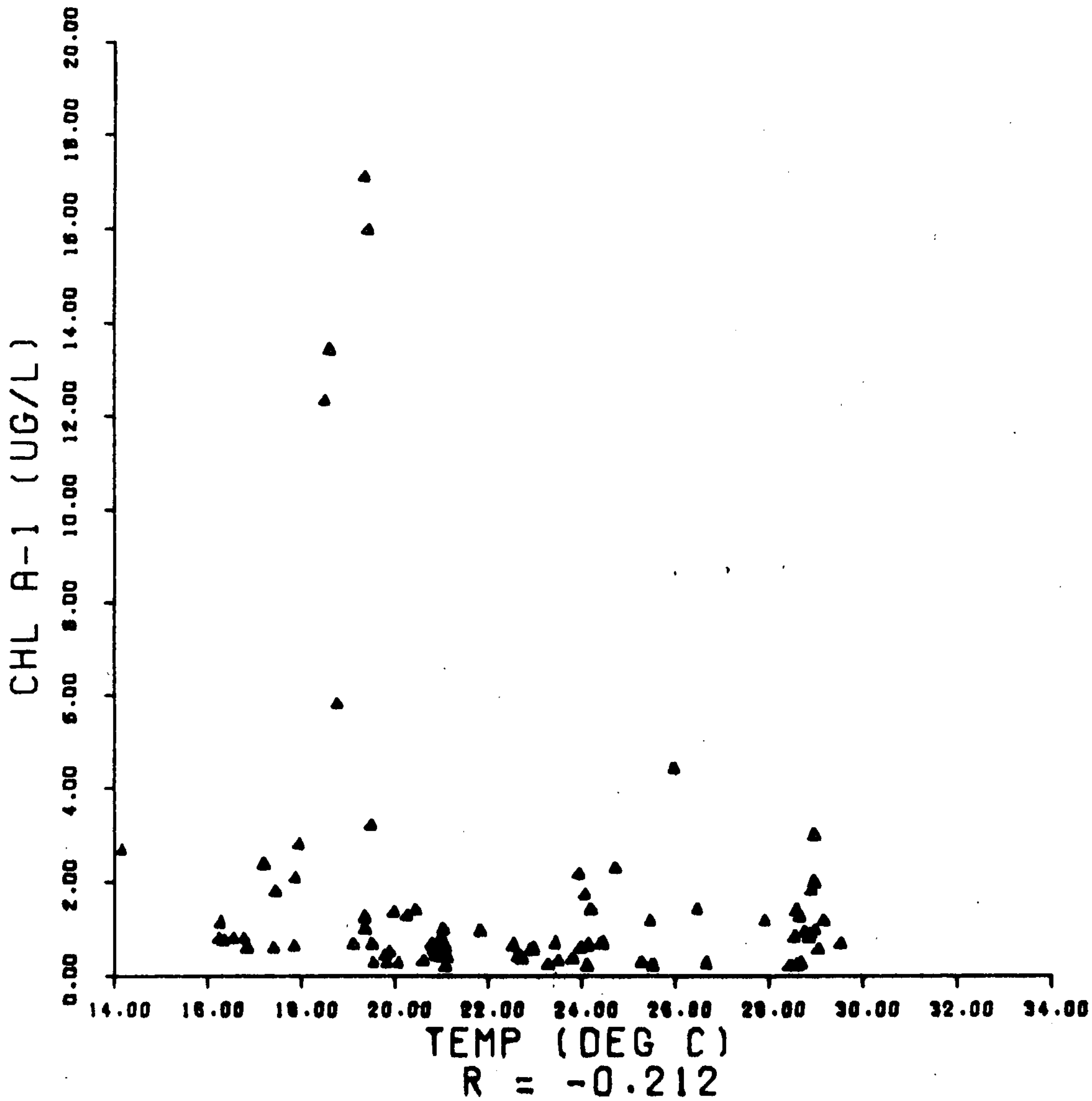


Figure 4. Scatter diagrams of chlorophyll *a* values against temperature values.

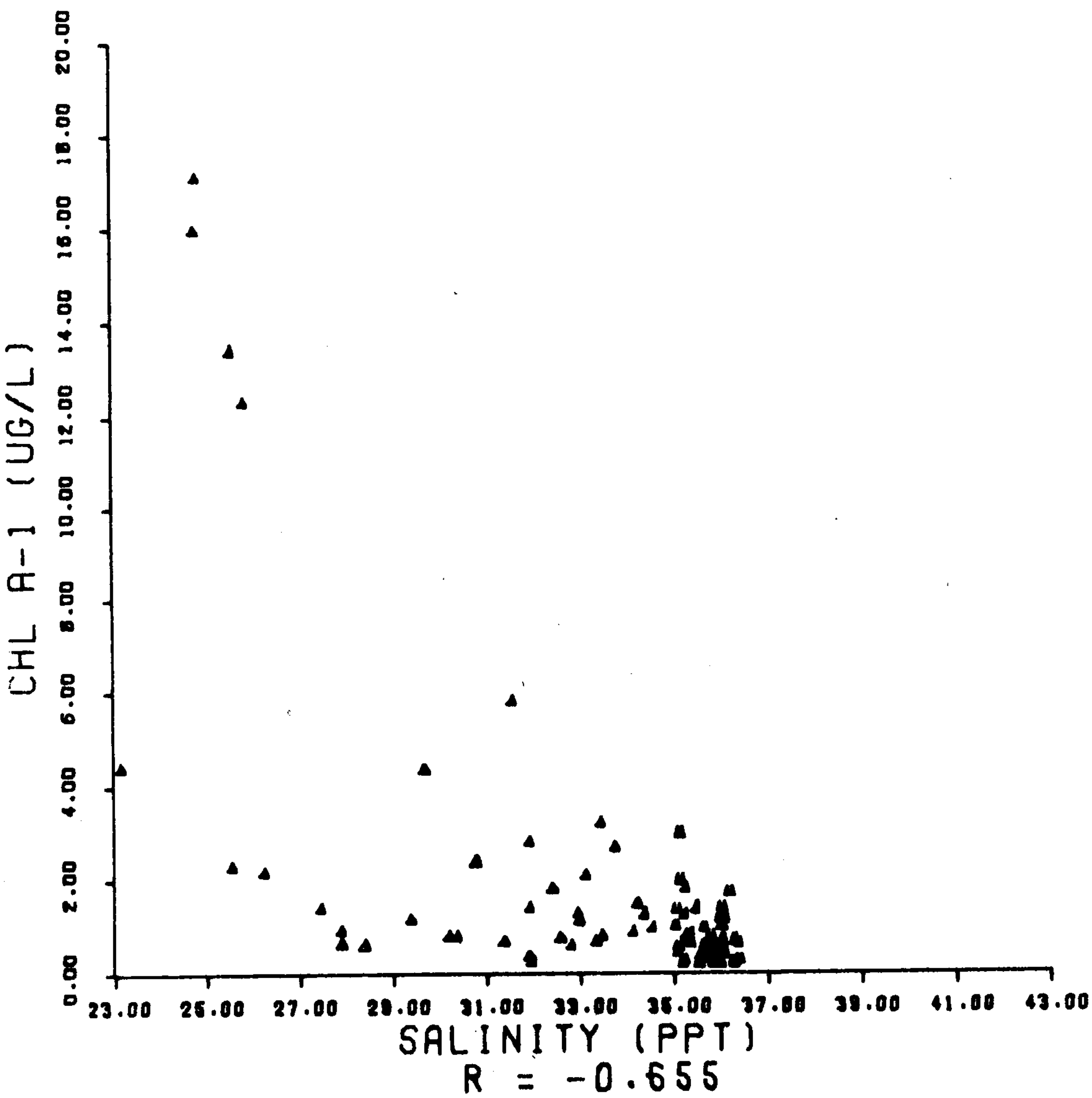


Figure 5. Scatter diagrams of chlorophyll a values against salinity values.

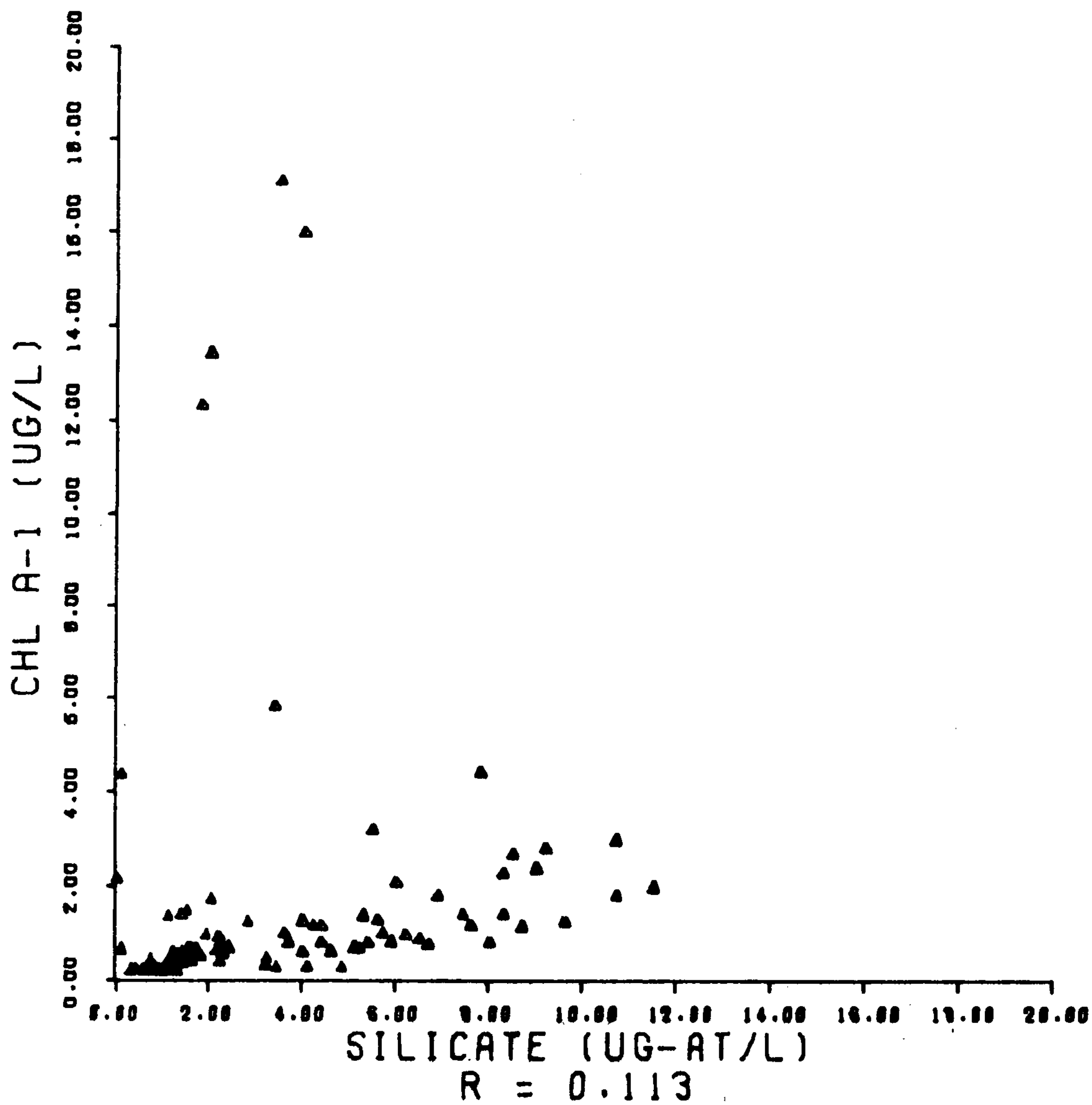


Figure 6. Scatter diagrams of chlorophyll a values against silicate values.

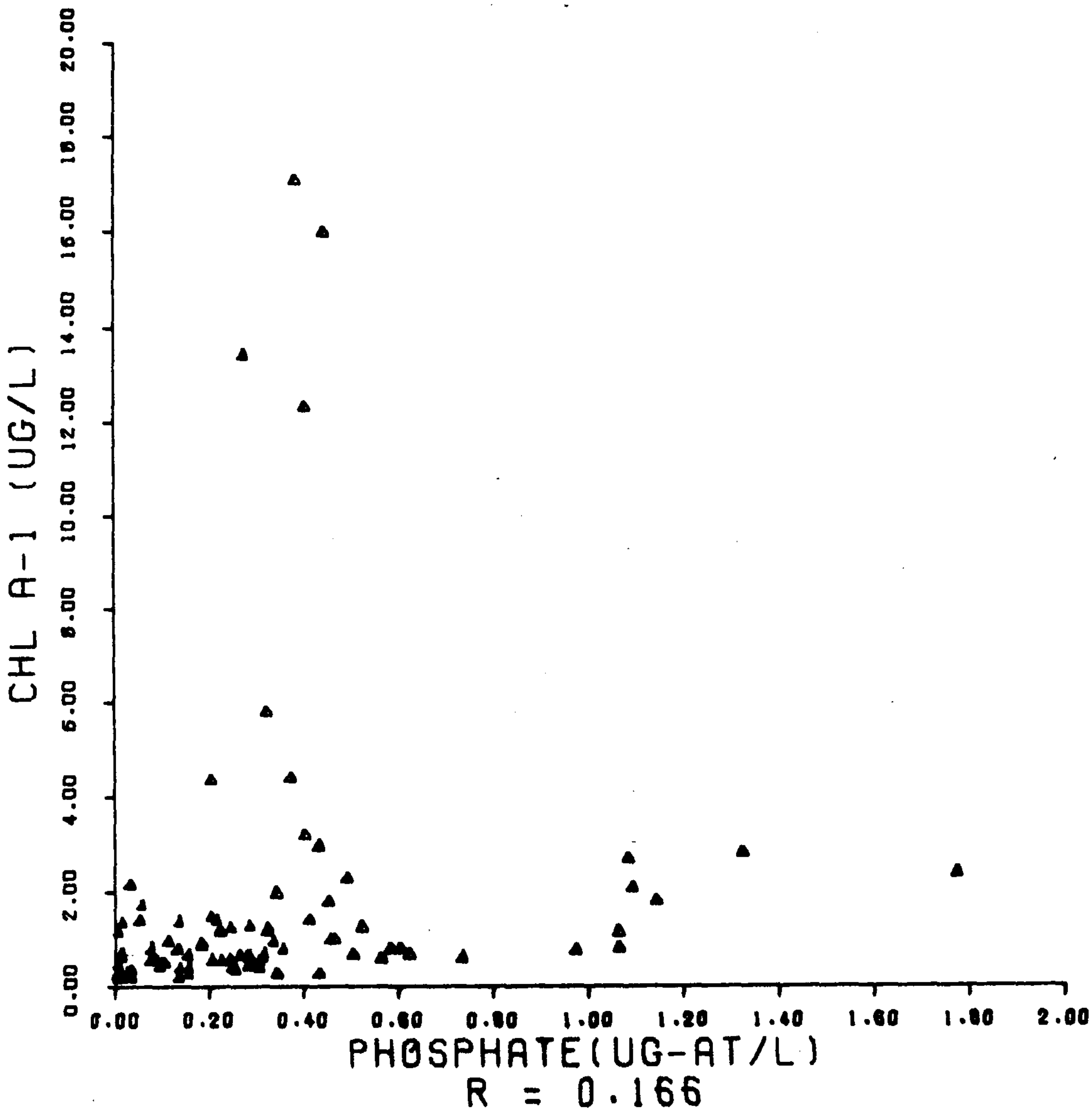


Figure 7. Scatter diagrams of Chlorophyll *a* values against phosphate values.

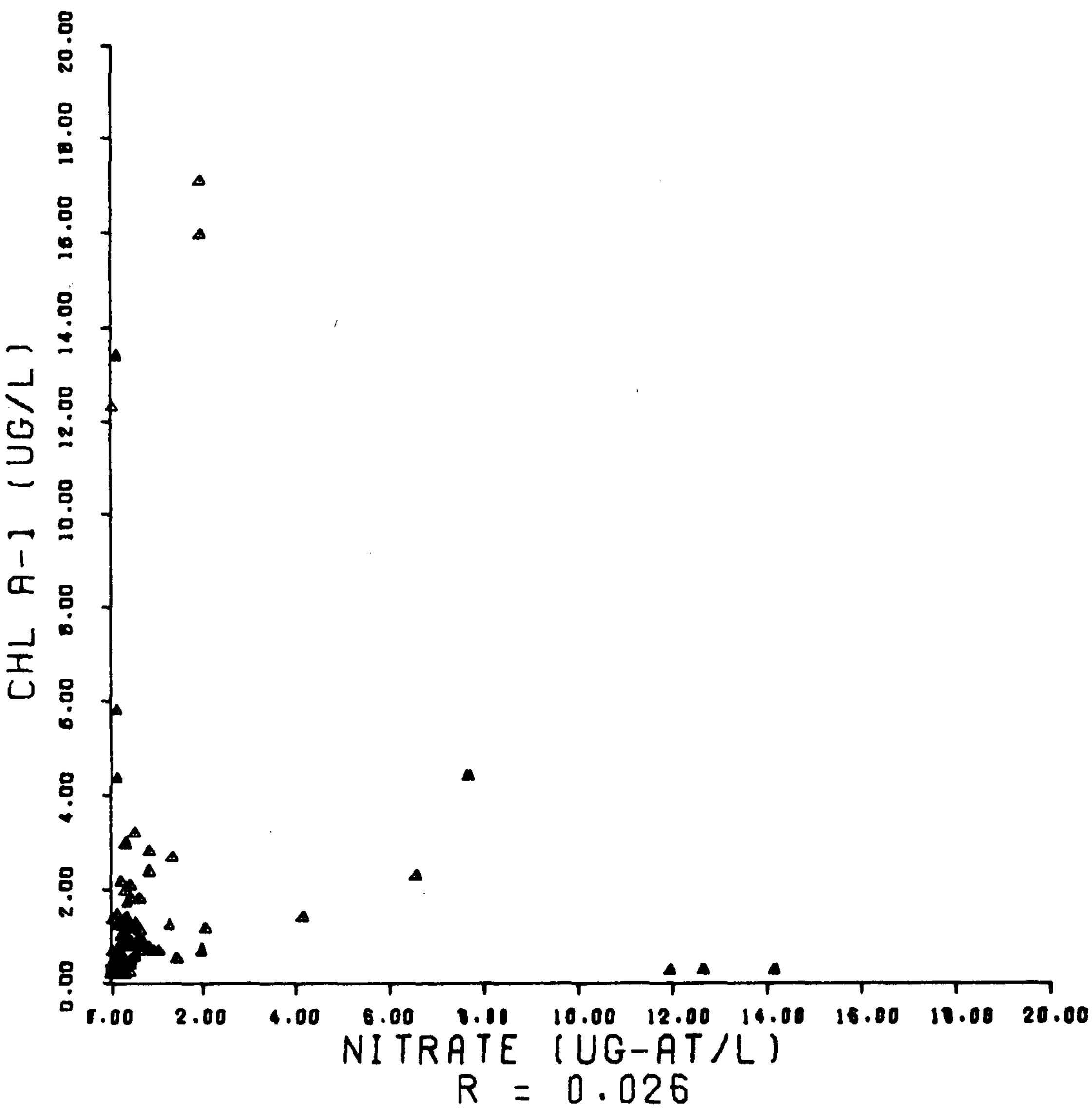


Figure 8. **Scatter diagrams of chlorophyll *a* values against nitrate values.**

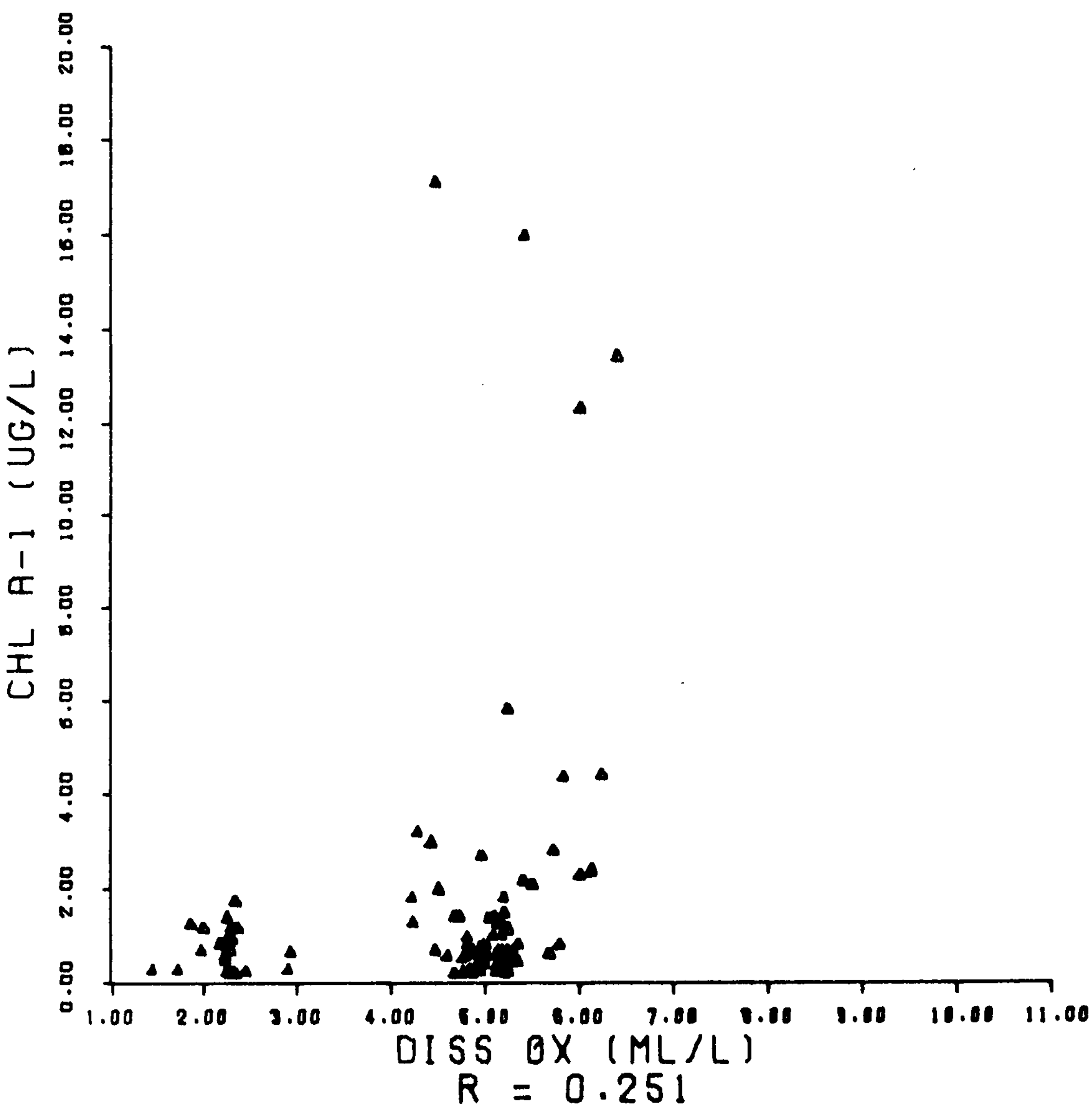


Figure 9. Scatter diagrams of Chlorophyll a values against dissolved oxygen values.

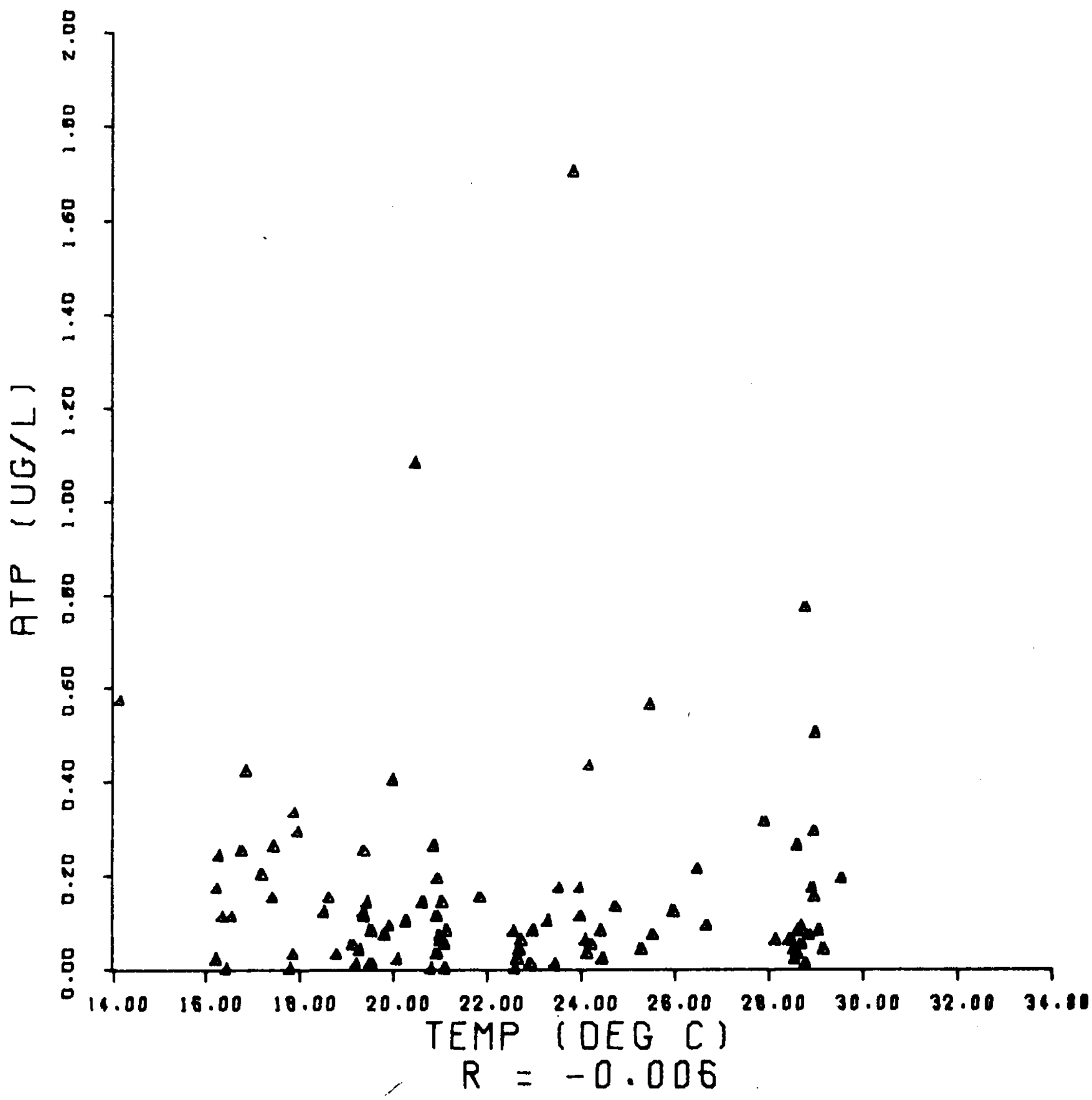


Figure 10. Scatter diagrams of ATP values against temperature values.

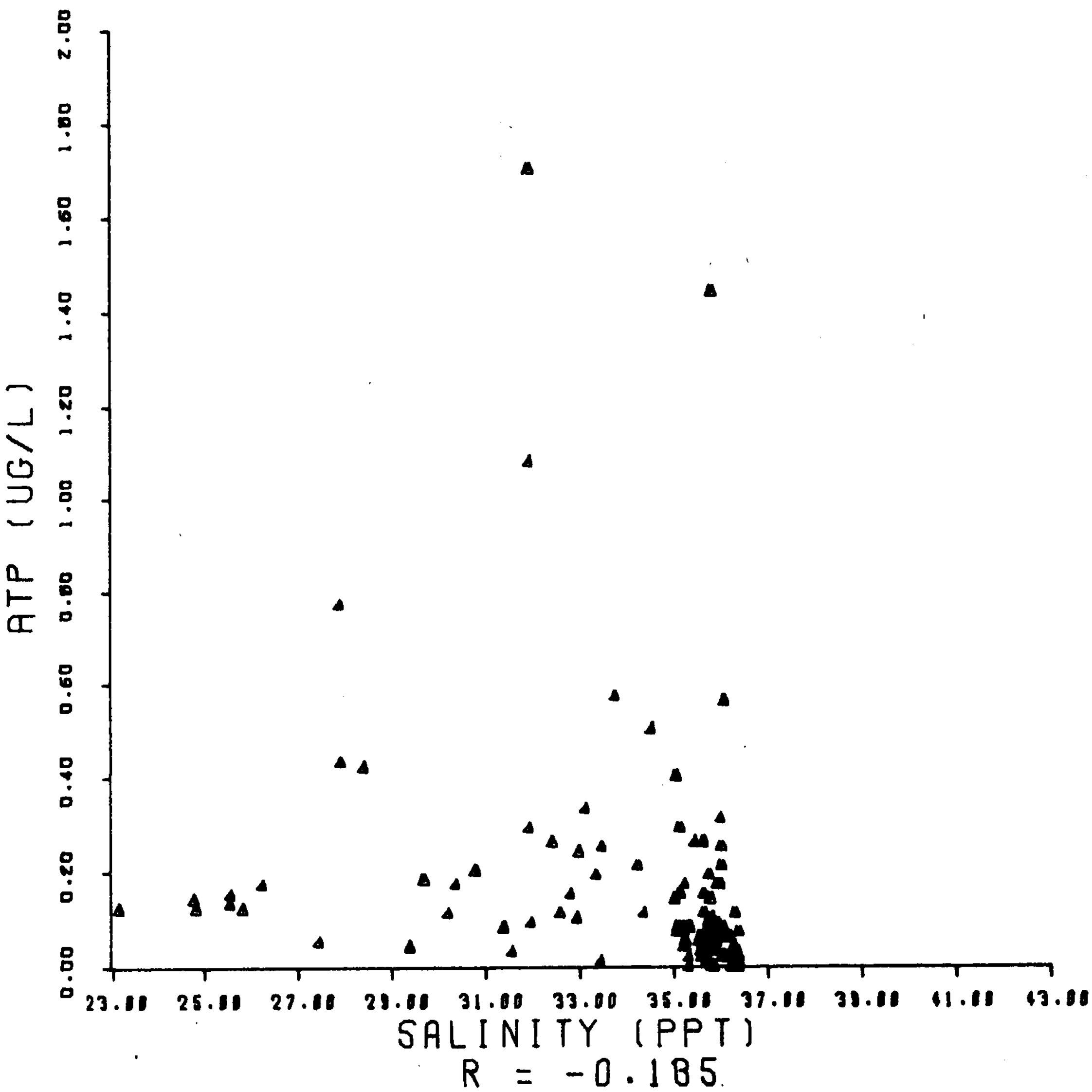


Figure 11. Scatter diagrams of ATP values against Salinity values.

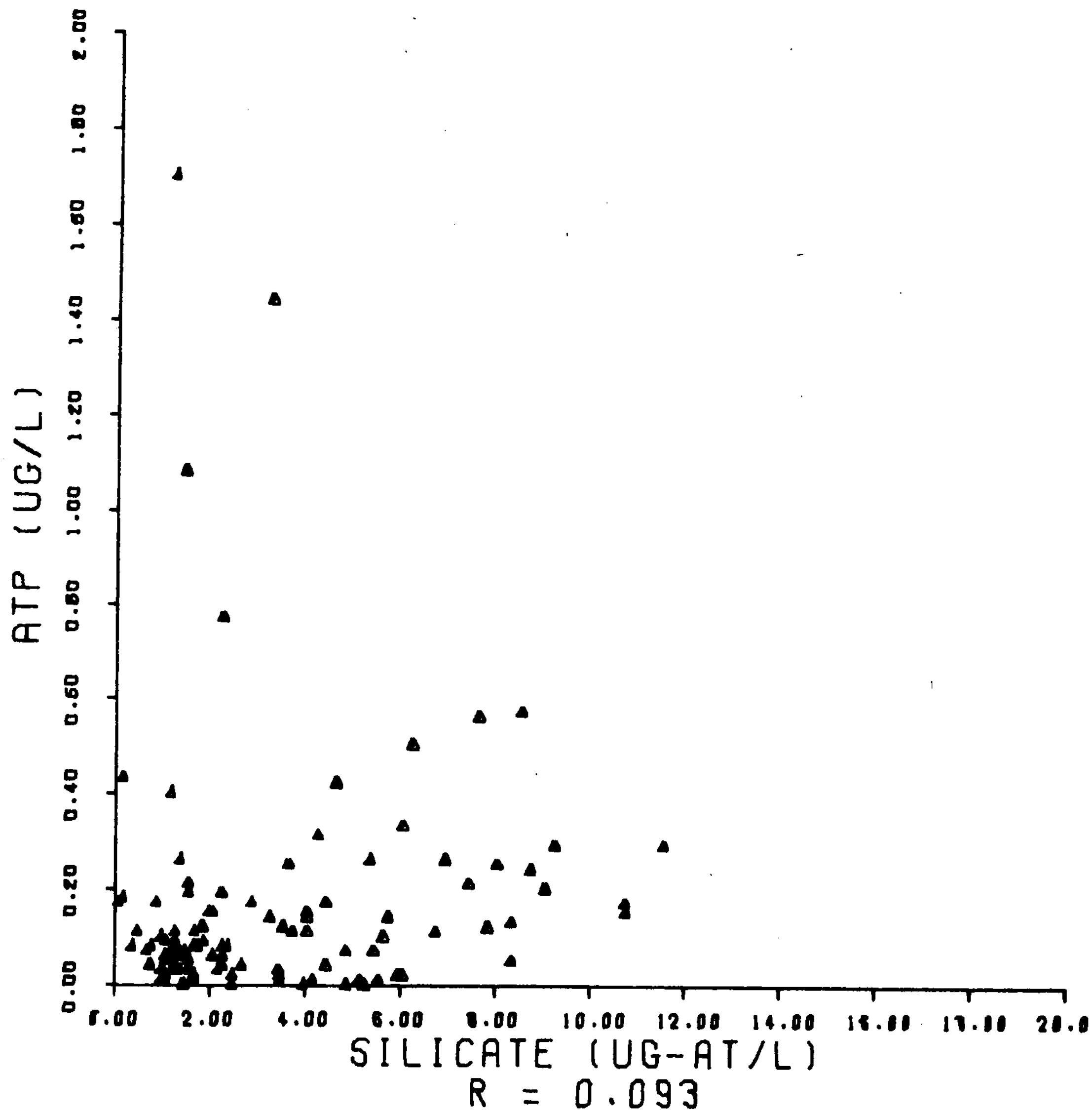


Figure 12. Scatter diagrams of ATP values against silicate values.

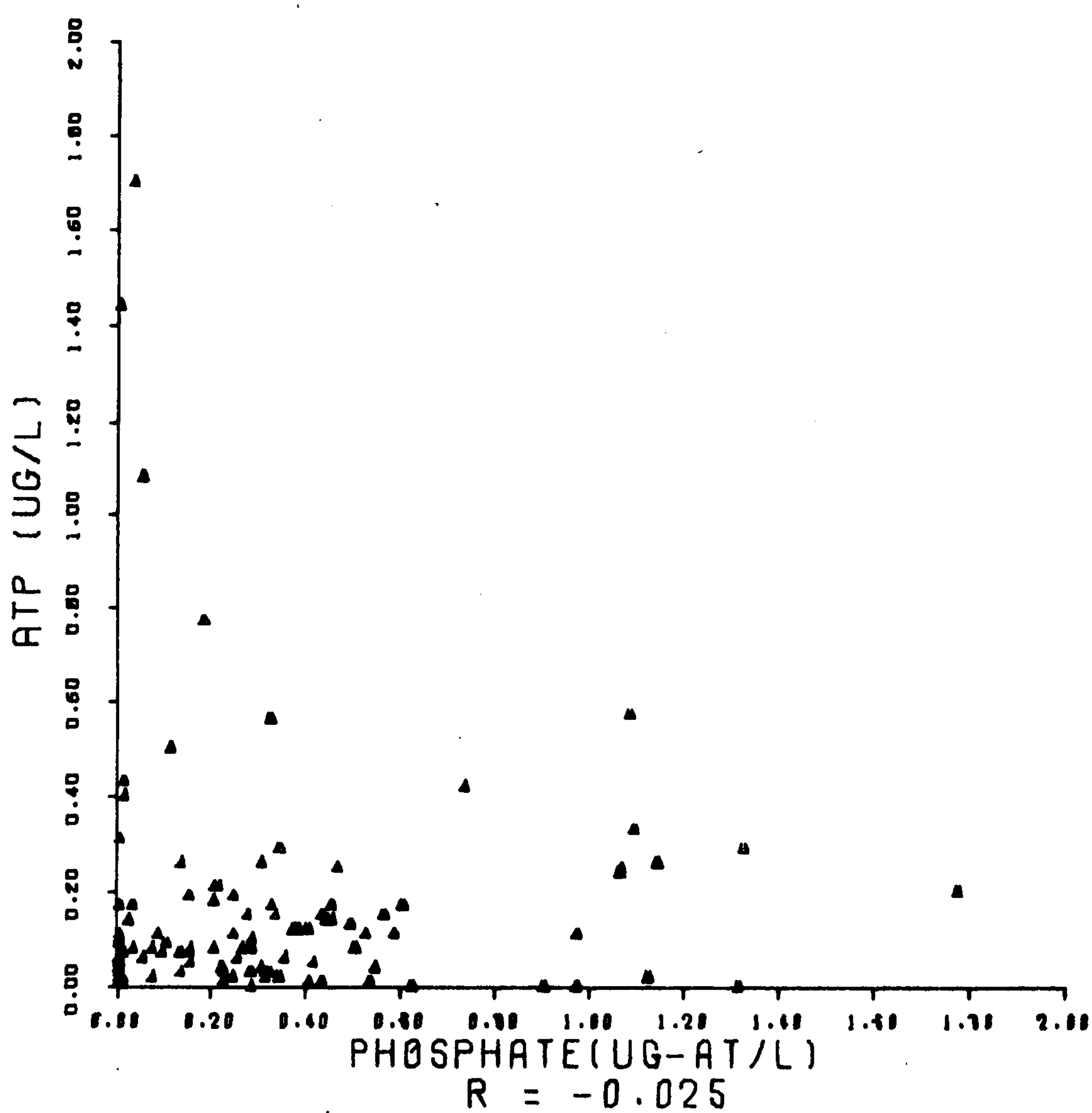


Figure 13. Scatter diagrams of ATP values against phosphate values.

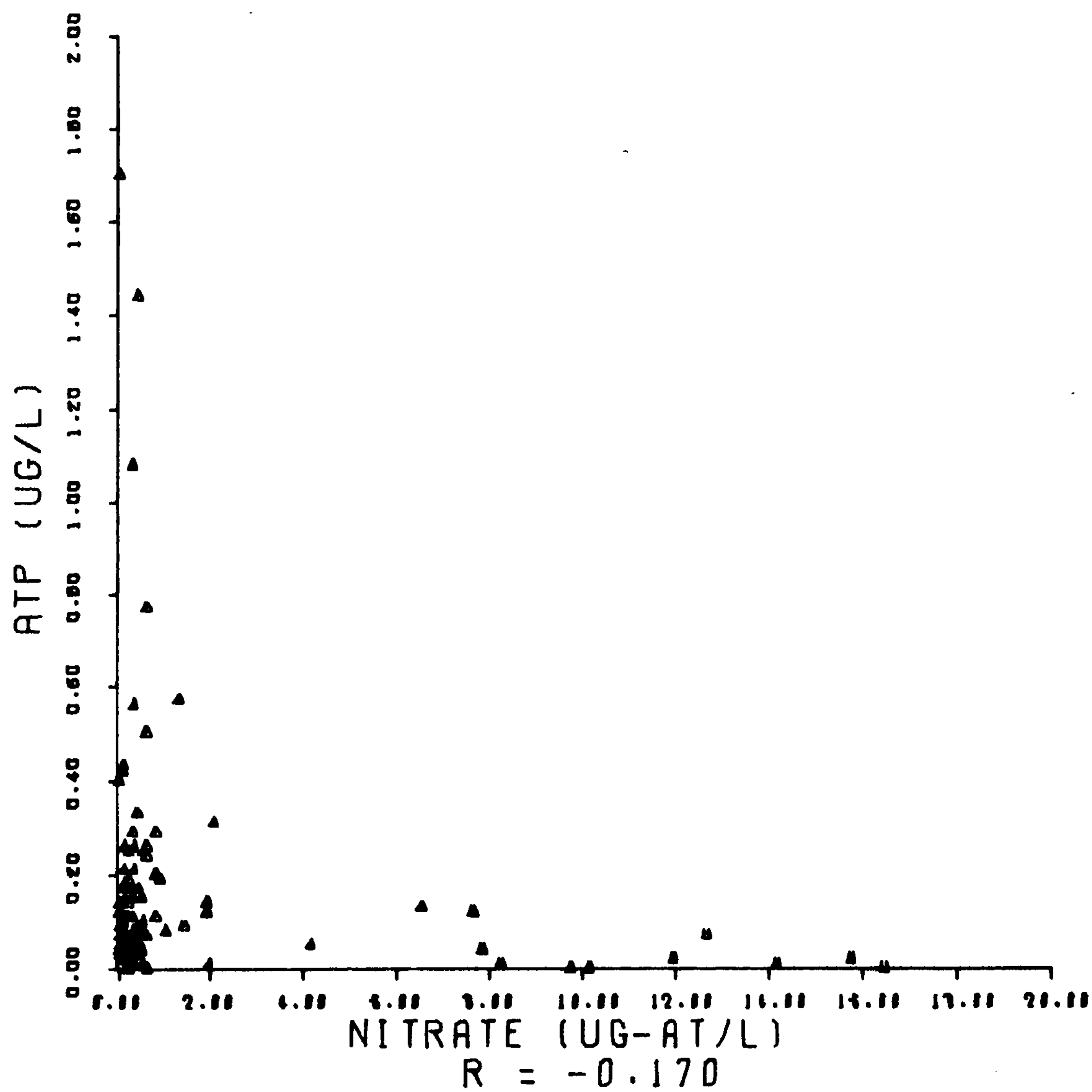


Figure 14. Scatter diagrams of ATP values against nitrate values.

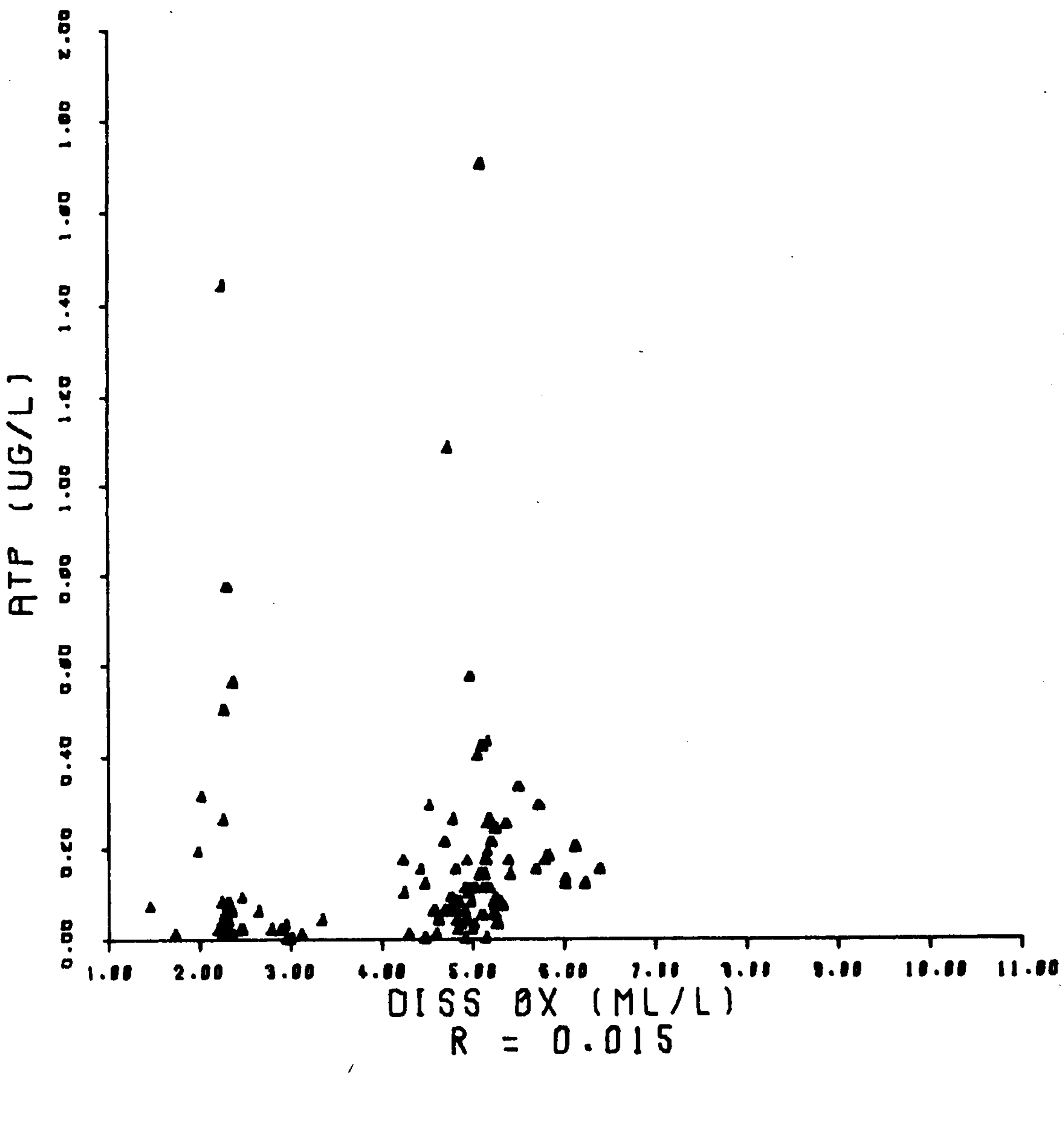


Figure 15. Scatter diagrams of ATP values against dissolved oxygen values.

would have been greatly enhanced if data from the Texas continental shelf had then been available.

In comparison with other data recorded for different parts of the Gulf the total cells per liter found in this work are comparable. As might be expected the Eastern Gulf is a somewhat more productive area. Saunders and Glenn (1969) found a decrease from an annual average of $1.1X10^6$ cells per liter at the shore to $8.5X10^3$ cells per liter off the western coast of Florida. Under normal circumstances diatoms greatly outnumber the dinoflagellates (Steidinger, et al., 1967; Steidinger and Williams, 1970). Saunders, et al., (1967) reports at least a dozen species exceeding $1.0X10^6$ cells per liter close to Florida's west coast. Hulburt, et al., (1960) record cell counts of $1X10^3$ to $2X10^6$ cells per liter in the Sargasso Sea. The most dominant organism found there, a coccolithophorid (*Cocoolithithus huxleyi*), was seen in our samples but was never very numerous. This corresponds with Hulburt and Corwin's (1972) observation that a change from a coccolithophorid dominated flora to one dominated by diatoms occurs in the shallower water over the continental shelves.

Yearly averages along the Texas transects were 4.1×10^5 cells per liter at the inshore stations, 7.8×10^4 at the middle stations, and 2.6×10^3 offshore. The yearly averages were greatly affected by the very large numbers found at the time of the spring cruise. The spring average for all stations and depths was $4.7 X10^5$ cells per liter. The summer and winter averaged were 1.1×10^4 and 4.9×10^3, respectively. The summer average is a little misleading because of large counts at a couple of inshore stations. More than half of the stations (14) during the summer cruise showed less than 1,000 cells per liter. Winter samples on the other hand were consistent with very little variation from inshore to offshore. See Table 2 for total counts per liter at each station.

The dominant species seen in this study are generally the same common phytoplankters seen in other studies. *Thalassionema nitzschioides* was present and common year round, as were *Rhizosolenia alata, Bacteriastrum hyalinum, Chaetoceros curvisetus, C. decipiens, C. diversus, Nitzschia delicatissima* and *Nitzschia seriata. Leptocylindricus minimus* and *Astrionella japonica* were two of the dominants during the spring flowering but were not significant during the other two cruises. *Skeletonema costatum* was the most numerous organism during the spring (1.6×10^6 cells per liter at one station) and was common during the winter, but was not significant during the summer months. *Cerataulina bergoni* followed much the same pattern. *Rhizosolenia alata, Nitzschia delicatissima* and several species of *Chaetoceros* were dominant during the summer cruise. *Thalassionema nitzschioides* and *Thalassiosira rotula* were the most common phytoplankton during the winter but were not as dominant as other species during the spring and summer. The winter cruise was perhaps the most diverse in terms of numbers of species seen. However, this could be attributed to the fact that smaller volumes of samples, because of much greater numbers of cells/liter, were being counted during the spring.

For the netplankton the diatoms greatly outnumber any other group. *Thalassionema nitzschioides, Rhizosolenia alata, Nitzschia delicatissima, Bacteriastrum hyalinum* and *Chaetoceros curvisetus* could be potentially useful as indicator species if further distributional studies bear out the results seen herein.

With the nannoplankton either in wet mounts of preserved material or with cleaned and mounted material we could not with certainty identify microalgae. *Nitzschia delicatissima, Pleurosigma* spp. and *Navicula* spp.

were the most frequently observed organisms in the nannoplankton samples but were never very numerous and in all cases had already been noted in the netplankton.

While perhaps not pertinent to these environmental studies dealing with the biology and chemistry of the South Texas Outer Continental Shelf, I (CVB) feel that the following comment should be made. The extent to which effluents resulting from any offshore gas and oil operations may pollute and overstress any phytoplankton population is moot. Bearing upon this point, however, are several field and laboratory studies suggesting that petroleum and derived materials can inhibit photosynthesis and growth of microalgae (e.g. Gordon and Prouse, 1973; Pulich, et al., 1974; Winters, et al., 1976).

It is therefore my (CVB) view that, if and when drilling operations proceed in the South Texas OCS region, care be taken to minimize initial environmental impact. In addition, some effort should be made to gauge any continuing or chronic impact, for example by monitoring chlorophyll fluorescence profiles.

MICROZOOPLANKTON AND MICROZOOBENTHOS PROJECT

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INTRODUCTION

Some of the more exciting and unexpected findings are: (1) a relict population of microzooplankton exists in the Gulf (and Caribbean) that apparently had died out everywhere else about 5 million years ago; (2) this relict population may date a major worldwide oceanographic change which would help explain the reasons for it and the reasons for some of the problems in trying to date fossil sediments; (3) another is the occurrence of supposedly bottom living creatures (benthonic forams) in the water column (in concentrations sometimes as high as the planktonic foraminifera that are supposed to be there). We believe that these forms, thought to be bottom dwellers all of their lives, take advantage of the water column during their younger stages for feeding and dispersal.

Some of the more significant findings of direct interest to our contractual goals are: (1) the shelled microplankton and microbenthon are probably even better environmental indicators than anyone has ever thought, and they were believed to be very good; (2) we have determined what the natural seasonal trends (density and species wise) are and feel that prediction may be possible; (3) the microplankton type and abundance from the plankton tows of the area are related to the salinity and temperature patterns so well that a strong correlation is possible. Further, the sediment distribution of these shelled organisms may give information on past water mass characteristics; (4) finally, the presence of deep water radiolarians in some of the shelf water samples suggests that at times deeper Gulf water may encroach on the shelf. In this report this process is referred to as encroachment or upwelling, but it should be understood that upwelling in the classical sense has not been demonstrated to be active in the study area.

MATERIALS AND METHODS

All twelve stations on the South Texas OCS cruise track were sampled for shelled microzooplankton. These samples were taken from a day-time vertical tow of a 30 cm Nansen net (70 micrometer mesh) and were preserved with buffered formalin and stained with Rose Bengal. Samples from ten meters and one-half of the photic zone at stations 1 and 2 of each transect and from ten meters, one-half the photic zone, the photic zone, between the bottom of the photic zone and the sea floor and near the sea floor at station 3 of each transect were taken using 30 liter Niskin bottles. One liter of each sample was preserved unfiltered; the rest was filtered through a 38μm stainless steel screen, stained and preserved with buffered formalin.

Sediment samples were taken from a bottom grab using a plexiglass tube to sample only the surface layer. These samples were stained with Rose Bengal and preserved with buffered formalin.

The plankton were treated with Rose Bengal so that living and dead ratios could be determined with the use of inverted and reflected light microscopes. The Nansen net samples were split with a Folsom Plankton Splitter and one-half of each sample was counted (the other one-half was archived).

The filters from the Niskin bottles were washed into a plankton counting tray and an aliquot was counted for the common planktonic groups (such as total foraminiferans, radiolarians, tintinnids, other ciliates, copepods, polychaetes, chaetognaths, etc.). These samples were also archived.

The sediment samples were washed through a 62 micrometer screen, and the large fraction was saved and dried; the shelled microzooplankton were counted and identified. Sediment splits are being maintained as archives.

RESULTS AND DISCUSSION

Results and discussion of this component of BLM STOCS will be dealt with in the following order: general distributions, indicators of water mass distribution and movements, areas of possible upwelling and volumes and routes of currents and possible upwellings, notes on the niches of radiolarians and planktonic foraminifera, benthonic foraminifera in the water column, relict populations, efficiency of shelled microplankton and microbenthon as environmental indicators and comments on contractual obligations.

General Distributions

Planktonic Foraminifera and Radiolaria

Fifteen live planktonic foraminiferan and about 100 live radiolarian species were collected and studied from the past year along with about a dozen pteropods. In general the planktonic foraminifera and radiolaria are sparse or absent in the innermost stations and increase in density and diversity offshore; these trends for radiolarians are illustrated on Figure 1. Figure 1 illustrates some of the general seasonal trends seen in the radiolarians; many of these trends are shared with the planktonic foraminifera. The nearshore stations are dominated by spumellarian radiolarians with the number of nassellarian radiolarians increasing offshore (Figure 1). The ratio for the total collecting area is broken down seasonally on Figure 2 as a ratio of total live nassellarians (TLN) to total live spumellarians (TLS) for the entire study area. These ratios are 1/3 for winter, 1/1 for spring and 1/8 for summer. Here again the spummellarians dominate in all but the spring sample. The reason for the one to one ratio in the spring is due to the almost total exclusion of radiolarians from the inner and mid-shelf stations due to the intrusion of "Mississippi water" and its resulting bloom of large centric diatoms excluding the radiolarians (see section on radiolarian niche herein). The greatest standing crop of radiolarians (and planktonic foraminifera) occurred in the summer with a standing crop almost as high occurring in the winter and a standing crop of about 1/2 that of winter or summer occurring in the spring. Here again we believe that the radiolarian niche was almost "eliminated" due to the spring bloom of large centric diatoms. The lowest diversity of radiolarians (and planktonic foraminifera) occurred in the summer with higher and almost equal diversities occurring in winter and spring, respectively (diversity here refers to number of species represented per season). There appears to be a distinct winter and summer assemblage of radiolarians and a mixed or transitional assemblage in the spring (this also holds for the planktonic foraminifera but not as well due to fewer species). The winter radiolarian assemblage is dominated by a *Theopilium tricostatum*-*Spriocyrtis scalaris* fauna and the summer by a *Lamprocyclas maritalis*-*Euchitonia elegans* fauna. Dominant radiolarians are radiolarians that are relatively abundant and more or less "endemic" to that season (this is an eyeball dominance). The spring appears to show no real dominance, however, the *Acantharian*-? *Acanthocyrtidium ophiurensis* fauna might be considered such. The R-mode planktonic foraminifera, Figure 3, contains two significant groups: the *Globigerinoides ruber* and *Globigerina bulloides* cluster and the *Globigerina falconensis* and *Globigerina quinqueloba* cluster. Deficiency in cluster tightness evident in low similarities for the remaining clusters is indicative of the low densities encountered for many of the species.

Using the clusters from the R-mode dendrogram as a guide, distinct winter and summer foraminiferan assemblages were constructed. The winter assemblage is characterized by very dominant Globigerina falconensis and Globigerina quinqueloba. Less abundant but also winter characterizing species are Globigerina rubescens, Globorotalia truncatulinoides, Globigerina pachyderma, Globigerina cf. incompta, Globigerinoides tenellus, and Globorotalia cf. tosaensis.

A summer assemblage contains dominant Globigerina bulloides and Globigerinoides ruber with subordinate numbers of Globigerina falconensis and Globigerina quinqueloba. Orbulina universa is more abundant and Bolivina lowmani assumes position of a dominant fauna. Hastigerina pelagica first appears in a spring sample but becomes moderately abundant in the summer.

The spring sampling period seems to be transitional between the two more distinct winter and summer seasons. Globigerina quinqueloba is the most abundant species; however, there does not appear to be any other distinctly dominant species. Although diversity has only slightly decreased for the spring period, density exhibits a significant decrease. Figures 3 through 12 were generated using multivariant analysis; they illustrate the distributions of the populations of planktonic foraminifera, radiolaria and pteropods in the shelled microzooplankton component of this study and are dealt with in the next section on indicators of water mass distribution and movements.

Benthonic Foraminifera

Originally one season's sampling was to be done to determine the distributional patterns of the benthonic foraminifera in the study area. Studies of this first season suggested that the populations may well show some seasonal trends that would make the projected down-core studies (of an undetermined number of down-core samples to be obtained from the USGS) less than desirable. The collecting and examination of the spring sampling confirmed these suspicions, and therefore it was decided to work up a full year of benthonic samples even though the contract called for only one season. To date the winter and spring seasons have been worked up and are reported herein. The summer samples are currently being studies, however, these are not complete as the researcher of this part (Miss Jane Anepohl) is having to work in her spare time on this material and is receiving no salary. Miss Anepohl's thesis on this material (Anepohl, 1976) is complete and gives a good coverage of the material.

Basically a seasonal variation in the distribution of living benthonic foraminifera is apparent from specimens recovered during winter and spring samplings. *Nonionella basiloba* and *Brizalina lowmani* dominate winter samples; whereas during the spring other forms, notably *Brizalina spinata* and species of *Buliminella*, *Cibicides* and *Fursenkoina* dominate. Lowest species diversity and greatest test density occur during the spring corresponding to increased standing crops of *Nonionella* basiloba, Brizalina lowmani, Ammonia beccarii and Buliminella cf. bassendorfensis.

Variations in the living faunal composition occur from north to south in the study area; the shallow stations (18-26 meters) to the north being dominated by Ammonia beccarii and Brizalina lowmani while those to the south are dominated by Nonionella basiloba and species of Buliminella. Faunal changes with depth generally agree with earlier studies (Phleger and Parker, 1951).

Multivariant analyses have been performed on these data, and the data are displayed on Figures 13 through 16. The Q-mode cluster of live benthonic foraminifera (winter and spring) (Figure 13) generate three groups which are displayed in Figure 14 (winter) and 15 (spring). These depict fairly stable inner and outer groups with a "stable" or constant southern transect (IV) group. The R-mode cluster (Figure 16) generates a dendrogram and clusters the following groups: outer shelf winter (OSW), outer-shelf winter and summer (OSWS), inner-shelf winter and summer (ISWS), mid and outer-shelf winter and summer (MOWS) and an inner and mid-winter shelf (IMWS) assemblages. These data substantiate the "eyeball" investigations illustrating that there appears to be a distinct inner and a distinct outer assemblage with a mixed mid-shelf fauna. Figure 16 also suggests a seasonality is superimposed on the dominant "depth" zonation; however, confirmation will have to await the working up of the summer data and perhaps the next year's data.

This distinct "depth" zonation fits well with published reports from the study area and other areas (Anepohl, 1976). Various explanations have been suggested for this depth zonation such as temperature and/or salinity changes, etc. Winter and spring bottom temperature and salinity contours have been constructed (Figures 17 through 20). It is tempting to infer that these data suggest the inner fauna may be a euryhaline and eurythermal fauna while the other fauna may be more of a stenohaline and stenothermal fauna; however, it is too early for such suggestions. It is also intriguing to imagine that the nepheloid layer described by the USGS in the study area may have some significance in this "depth" zonation. Perhaps the inner fauna is a nephelophobic fauna and the outer fauna a nephelophilic fauna; only more research may clear up this "cloudy" problem.

Indicators of Water Mass Distribution and Movements

All the temperature and salinity curves for the study year have been plotted on Figure 21, and "water mass" envelopes have been drawn around the seasons of collections. These are replots of the oceanographic data given in the Hydrography Project section. For this year we are suggesting four "water masses" on this water mass characterization diagram. The "core" of about about 36 ppt water we believe to be Western Gulf Surface Water (WGSW) in the sense of Armstrong and Grady (1967). This water (WGSW) is always present in the study area. It is always present at depth on the outer shelf and appears to encroach on the shelf in the winter and especially in the summer of the study area. Shoreward of this water we suggest three shelf water masses (SW); these are labeled on Figure 21 as: South Texas Summer Shelf Water (STSmSW), South Texas Spring Shelf Water (STSpsw) and South Texas Winter Shelf Water (STWSW). Radiolarians have been considered to be more or less endemic to specific water masses (Casey, in press a). With this in mind, a temperature-salinity-plankton diagram or more specifically a temperature-salinity-radiolarian diagram has been constructed (Figure 22). The subpackets denoted by the 5 symbols represent radiolarian groups (faunas or populations) generated by multivariant analysis and coded (symbol coded) on the Q-mode cluster dendrogram of live radiolarians (Figure 7). The temperature-salinity-radiolarian diagram (Figure 22) suggests the following: specific radiolarians and specific radiolarian populations (Q-mode groups) are indeed "endemic" to "specific water masses"; radiolarians are in general "open ocean" forms; radiolarian faunas may be used as indices of water mass incursion onto a shelf environment; radiolarians are indicative of seasonality on the shelf and spring in the study area is a "mixed" period of both water masses and endemic radiolarian faunas.

The above statement that radiolarians are endemic to specific water masses is made due to the fact that most Q-mode faunas are restricted to one of the herein defined water masses. In fact there is a fauna that depicts the South Texas Winter Shelf Water Mass and one that perhaps depicts the South Texas Summer Shelf Water Mass (Figures 2 and 22). The statement that radiolarians are in general "open ocean" forms seem apparent from our studies showing their density and diversities increasing offshore (Figure 1), but this trend also appears on the temperature-salinity-radiolarian diagram which illustrates that three of the five Q-mode groups are "endemic" to the Western Gulf Surface Water. These three groups "endemic" to the Western Gulf Surface Water Mass occupy different but overlapping subpackets within this water mass envelop which may suggest that they occupy different depths within this water mass, a seasonality within the water mass, a "patchiness" within the water mass or something else that may be elucidated with further studies. Radiolarians obviously are indicative of a seasonality on the shelf. This is illustrated by the representation of a winter and summer shallow shelf faunas.

"Water masses" are also represented in a loose context by the information displayed on the R-mode cluster of live radiolarians (Figure 8). Here we have a winter group (W), a winter offshore group (O), a nearshore group (NS), a weak spring assemblage (S)(it clusters well only because there are individual occurrences of some species), a spring upwelling group (SU) and a summer group (SM). These are not as neatly associated with water masses as generated by the Q-mode but they do represent nearshore, winter-offshore, spring-upwelling etc, indices.

Water mass movements may be derived from comparing the temperature-salinity-radiolarian diagram (Figure 22) with the maps of the Q-mode radiolarian clusters (Figures 9 through 11). The winter Q-mode cluster is very complicated as is the planktonic foraminiferan cluster for the same period (see Bauer's thesis, Bauer, 1976). There does appear to be an incursion of offshore (Western Gulf Surface Water Fauna) into the study area along transect III of the study area in the winter (Figure 9), and therefore this has been depicted as such on Figure 3. This incursion shows up dramatically as a finger of high radiolarian density on the winter radiolarian density map (Figure 23), and as a finger of high radiolarian diversity in the winter radiolarian diversity map (Figure 24). This is substantiated to some extent by the inflection of the 22 degree isotherm shoreward along transect III on the winter 10 meter temperature map (Figure 25), although it is not apparent on the 10 meter salinity contours (Figure 26).

The spring Q-mode cluster map (Figure 10) shows only two clusters. This is due to the fact that the spring diatom bloom and the "Mississippi River Water Mass" which are of course related have apparently "eliminated" the radiolarian niche which will be discussed under the section on such later. The foraminiferan Q-mode cluster map (Figure 5) illustrates the spring water movements much better than the radiolarian cluster, because the cluster (Figure 5) includes benthonic foraminifera that are in the water column (planktonic-benthonics). However both maps (Figures 5 and 10) do show an incursion of offshore water faunas (Western Gulf Surface Water Mass Faunas) impinging on the shelf edge at stations 3/II and 3/III, and the radiolarian evidence suggests an extension of this water into 2/III, therefore explaining the current arrow as such on Figure 2. This is substantiated by both spring radiolarian density (Figure 27) and diversity (Figure 28) maps, with fingers of high density and diversity coming in along these two middle outer stations. The spring 10 meter temperature (Figure 29) shows this very well with the 25 degree isotherm extending all the way to station 1/III. The spring 10 meter salinity (Figure 30) appears to confirm the "bowing up" of water that might be related to this incursion which is illustrated in this report in Figure 19 of the Hydrographic Project report. The Q-mode of the foraminifera for the spring illustrates very well the incursion of the low salinity water from the north ("Mississippi water"). This incursion is also well illustrated by the physical oceanography as can be seen by the bulging 30 ppt. salinity contour on Figure 30 which matches very well with the inshore bulge of Figure 3 which is characterized by the foraminiferan indicator species Bolivina lowmani (see Table 1).

The summer Q-mode maps for radiolarians (Figure 11) and foraminifera (Figure 6) both show an extensive "pushing" of offshore faunas (and offshore waters) shoreward. The summer radiolarian density (Figure 31) and diversity (Figure 32) maps also illustrate this phenomenon. The summer 10 meter temperature (Figure 33) illustrates this for the southern portion of the study area anyway, and the summer 10 meter salinity shows the 35 ppt. contour "pushing" into stations one on both transects II and III.

Areas of Possible Upwelling and Volumes and Routes of Currents and Possible Upwellings

Radiolarians exhibit a vertical zonation in the water column. Upwelled waters or water which has encroached upon the shelf may therefore carry expatriate radiolarians from their normal living depths into shallower waters. This has been found in thewaters off southern California (Casey, in press a). In this current BLM STOCS study deeper living radiolarians have been found at some shelf stations (outer stations) during different seasons in differing densities. Possible indices of upwelling (or bulging up and encroachment of deeper Gulf waters, deeper than the Western Gulf Surface Water Mass or deeper than about 200 meters probably) are the radiolarians of the Superorder

Phaeodarina. The species Conchasma sphaerulites and Conchoceras caudatum are large and easilty recognized species and therefore probably the best indicators. Other radiolarians that are also indices of upwelling are the polycystines Spongotrochus glacialis (both juvenile and adult forms). and Tetrapyle octacantha. The exact depths from which these upwell will have to await studies on samples taken in March of 1976 by the author in offshore waters from the R. V. Gyre for comparison of this study with a study on the radiolarian distribution in the Gulf and Caribbean supported by the National Science Foundation. Until those data are evaluated we must be satisfied with a relative measure of not only the depth from which upwelling occurs but also a relative magnitude of the upwelling. The relative magnitude noted on Figure 2 describes the upwelling as minor off transect III in winter, strongest off transect III (with components off transects I and II) for the spring, and fairly strong (intermed-Iate between the two) off these transects during the summer. These relative magnitudes of upwelling are only crude now and are determined by the relative densities of the upwelled species, more upwelled species is interpreted as stronger upwelling.

Winter bottom temperatures (Figure 17) suggest an encroachment of upwelling of waters at 3/II and 3/III and the offshore winter fauna (0 on Figure 8) might represent this upwelling (S. scalaris may be an upwelling species). Winter bottom salinities (Figure 18) might suggest an encroachment of deeper waters illustrated by the shoreward displacement of the 36 ppt. contour. Spring bottom temperatures (Figure 19) and spring bottom salinities (Figure 20) both suggest encroachment shoreward through 3/II by the displacement shoreward of the 22 degree isotherm and the 36 ppt. salinity contour respectively. The spring season upwelling group (SU on Figure 8) clusters out. Summer upwelling (Figure 8) appears to be of intermediate magnitude between the winter "minimum" and the spring "maximum". It is interesting to note that all these upwellings occur "under" encroachments of offshore "shallow" radiolarian faunas. This probably means that a large package of shallow to deep water is pushed onto the shelf, or that the encroachment of shallow water "drags" the deeper water with it. A way to investigate this would be to sample the outer stations with closing nets. We may attempt to do this during the summer of 1976. If we do not get this opportunity we already have taken a series of closing-depth stratified tows off the Galveston shelf (March, 1976) which might answer this question. It should be emphasized that what we are terming upwelling is not a boiling up of deep water to the surface which might create a phytoplankton bloom but rather a bowing up of deeper water and an encroachment of this deeper water on to the shelf.

The routes of currents have been determined by the same manner as described for the determination of upwelling. It is hoped that with more data and more "eyeballing" rough volumes transport, in meters per second or some such notation, may be derived. The upwelling regions are designated by the u's on Figure 2 (the larger the u the greater the upwelling) and the current transports are designated by the open arrows (the width of the arrow designating the boundaries of the current and the number of lines in the arrow the relative strength (a double line stronger than a single line) (Figure 2).

Notes on the Niches of Radiolarians and Planktonic Foraminifera

The possible niches of radiolarians has been suggested by Casey (in press a). The term niche refers to the organisms place in the ecosystem, and possible radiolarian niches are illustrated on Figure 35. The current study (BLM STOCS) suggests that many radiolarians do indeed occupy the niche labeled POLYCYSTINS (herbivores and microherbivores) on Figure 35. In fact most of the radiolarians probably occupy this niche or (in other words eat small phytoplankton). The existence of such a niche is suggested by plankton samples in the spring when the radiolarians were excluded from the innermost spring stations which were occupied by the large centric diatom bloom. We suggest that radiolarians feed mainly on nannoplankton and their food source was eliminated by the bloom of large centric diatoms that were too large to be eaten by the polycystin radiolarians. This niche is also suggested in a less dramatic way (but perhaps better) in the general increase in radiolarian density and diversity offshore on the south Texas and apparently other shelves of the world ocean. Hulburt and Corwin (1972) observe a change from a coccolithophorid dominated flora (probably what radiolarians eat) to one dominated by diatoms in going from offshore into the shallow waters over the continental shelf. They noted this in the eastern and central Gulf and have suggested it to be a wide geographic phenomena (Hulburt and Corwin, 1972). In fact all the radiolarian niches suggested by Casey (in press) are occupied by radiolarians in the BLM STOCS study area. The polycystins (with symbiotic zooxanthellae) are represented in the study area by Choenicosphaera sp., Collosphaera tuberosa, Disolenia zanquebarica and Siphonosphaera polysiphonia. The upwelling species most likely represent the bacteria and suspended and settling organic feeder niche. In fact many more than those herein designated as upwelling species probably fall within this niche for the radiolarians occur at depths below reasonable phytoplankton densities and in some cases peak below the pigment depth.

Bauer (Bauer, 1976) in investigating stratified tows from the Florida Gulf shelf, noted that planktonic foraminifera occur mainly in the upper 50 meters but radiolarians not only occur in abundance in the upper 50 meters but also to the depths of the shelf break. This and the other data referred to suggest that radiolarians and planktonic foraminifera are important intermediaries in the relatively longer food chains of offshore waters (say, four or five trophic levels), and their "importance" in the food chain decreases inshore especially under conditions of large centric diatom blooms (where there may only be two or three trophic levels).

Benthonic Foraminifera in the Water Column

Benthonic foraminifera have been noted previously in plankton tows from nearshore and offshore regions (Casey, 1966); however, their occurrences in such tows has generally been ascribed to a stirring up from the bottom. In this study (BLM STOCS) a number of living (stained with Rose Bengal) benthonic foraminifera have been collected in our plankton tows (see Table 1 for a list of occurrences showing species, number per tow, station number and depth of each station). Many of these, in fact most, are probably the result of a stirring of the water column and perhaps a suspension in the nepheloid layer. However, the consistant occurrence of at least one species, Bolivina lowmani, suggests that it is a meroplanktonic stage of the adult benthonic form (Table 1). This species is especially abundant in the inner spring stations and appears to be associated with the incursion of the spring "fresh" water lens (Mississippi water"). Another planktonic-benthonic which may be a potential indicator is _Uvigerina_ _peregrina_. _Uvigerina_ _peregrina_ is a well known indicator of outershelf and upper-slope depths and its occurrence in the outer most plankton tows during the spring gives even more substance to the suggestion of a strong spring upwelling in this region.

Relict Populations

One of the most interesting aspects of this study has been the finding of a relict population of radiolarians in the study area. Plankton tows from the study area have yielded radiolarians previously believed to have been extinct. From other current studies we have found that these radiolarians appear to occur in other portions of the Gulf and to some extent in the Caribbean but are best represented (density and diversity wise) in the BLM STOCS area. These findings are of course of great interest as shall be discussed but it also is of economic interest since a number of these species have been used in biostratigraphy (in fact one species has a biostratigraphic zone named after it) which is of importance to geologic dating and therefore in such ventures as oil exploration.

Relict radiolarians collected in plankton tows and stained with rose Bengal include _Spongaster_ _pentas_, _Spongaster_ _berminghami_, _Spongaster_ _cruciferus_, "Circular" spongaster and an "elliptical" spongaster (all alive and well). The evolution of _Spongaster_ _pentas_ from _Spongaster_ _berminghami_ occurred about 4.5 million years ago in the tropical Pacific (Theyer and Hammond, 1974) and is used to define the base of the Spongaster pentas Zone (Riedel and Sanfilippo, in press). Spongaster berminghami apparently became extinct (in the Pacific anyway) shortly thereafter, and Spongaster pentas apparently became extinct (in the Pacific) at about 3.6 million years ago (Casey, in press b). The "circular" and "elliptical" spongodiscids are believed to have been the ancestors of Spongaster berminghami, and they also are found in the plankton tows as are specimens of Spongaster cruciferus which appear similar to the same species in the Eocene of California.

These species represent a relict radiolarian fauna, and their presence suggests some interesting consequences of both biostratigraphic and paleooceanographic significance. Of biostratigraphic significance is the conclusion that the geologic and geographic ranges of some of the species used in Riedel and Sanfilippo's zonations are provincial. This provinciality is a real problem because the late Neocene part of Riedel and Sanfilippo's zonation was mainly developed using tropical Pacific cores, and the findings here suggest that the radiolarian biostratigraphy (and perhaps other microfossil biostratigraphies) in the stratotype localities of the late Neocene in Europe should be quite different from the "warm-water" Pacific zonation of Riedel and Sanfilippo. Correlation attempts of the Pacific and European stratotype radiolarians have met with limited success, probably due in large part to the problem of provinciality herein mentioned.

This problem has not been noted before probably due to the fact that the sediments and rocks of the low-latitude Atlantic and its margin are usually void of radiolarians in the post-Miocene. We have studied the upper few centimeters of Holocene sediments in the Gulf of Mexico and Caribbean since this finding in the BLM area and have found specimens of Spongaster pentas and Spongaster berminghami.

The paleooceanographic significance is perhaps of even more importance than the biostratigraphic importance. The Atlantic and Pacific appear to exhibit more or less "cosmopolitan warm water" radiolarian biostratigraphies up to at least mid-Miocene. Sometime post mid-Miocene there appears to have been a divergence of the radiolarian faunas and a development of greater provincialism. The reasons for this divergence are apparently related to geographic and climatic isolation and resultant allopatric speciation and differential geologic ranges of these isolated populations.

We believe the geographic isolation of the tropical Pacific from the tropical Atlantic was due to uplift of the Panamanian Block during the Miocene to "effective sill" at about 4.5 million years ago. Isolation is placed at about 4.5 million years ago, or at about the Miocene-Pliocene boundary, for prior to this time the spongaster faunas of the Gulf and Caribbean resemble those of the Pacific but diverge shortly thereafter. At 4.5 million years ago, the sill depth of the Panamanian Block would have been about

500 meters (Bandy and Casey, 1973). Therefore, the isolation may well be twofold: restricted circulation due to the emergence of the Panamanian Block, and cooling that resulted in the initiation and development of Neocene glaciations and water mass regimes (Casey, 1973).

We believe that water mass regimes and radiolarian faunas similar to today's were established by mid-Miocene, and that Atlantic and Pacific warm-water faunas have been isolated from one another since about the base of the Spongaster pentas Zone, or about 4.5 million years ago, or about the Miocene-Pliocene boundary. We further suggest that the BLM STOCS study area, and perhaps to a lesser extent the rest of the Gulf of Mexico and Caribbean, have maintained relict radiolarian faunas in part (Casey, McMillen and Bauer, 1975).

The waters that we now see over the study area and the adjacent regions may well be close to "Miocene type waters". If so why have the spongasters been the only or main ones to survive? What about the hundreds of other Miocene radiolarian species that died? We believe that we may have generated the answer to this question on the dendrograms derived from multivariant analysis.

The R-mode cluster of live radiolarians (Figure 5) separates the relict radiolarians from the others (they are not associated with any season and only associate at a low similarity level with anything). Spongaster pentas attaches at a low (and probably insignificant) level with the winter group which is somewhat interesting for it is within the winter group that Spongaster cruciferus associates. However Spongaster cruciferus associates at a "high level" with a few others and again this high level is due to few occurrences so this may be thrown out with more sampling. Spongaster ? pentas, and the "circular" and "elliptical" spongasters all cluster out together between the spring upwelling (SU) and summer (S) radiolarian assemblages.

We believe that this "throwing out" of the radiolarian seasonal cluster groups represents that either the relict radiolarians can get along with any group (which would be a way to survive) or that they have an unspecialized niche (can eat a variety of nannophytoplankton or are detritus feeders) and have been able to survive as the other populations have evolved "around them". This last suggestion is intriguing and to some extent may be enforced by the location of these relict radiolarians on the R-mode cluster of radiolarians, foraminifera and pteropods (Figure 12). Here again the Spongaster pentas and Spongaster cruciferus are well removed from all other groups, with the Spongaster cruciferus being so removed due to few specimens collected. The "circular" and "elliptical" spongasters separate out with, but are somewhat removed from, Globigerina pachyderma and Uvigerina peregrina. These are separated into relict shallow (Rs) and relict deep (Rd) components with the spongasters being shallow and the foraminifera deep. We believe that this is very significant. All the relict radiolarians are associated with very shallow water radiolarians and perhaps this is associated in some way with their survival such as being adapted to "Miocene eurythermal and euryhaline conditions" that have been maintained in their present distributional ranges. *Globigerina pachyderma* is the only "relict" foraminiferan seen in the plankton except for one occurrence of what we believe might have been *Globrotalia tosaensis*. *Globigerina pachyderma* is not a relict in the sense that we have been using the term as applied to the radiolarians. Perhaps a better term for it would be a "local relict" for it lives today in high latitude faunas. It was found in the Gulf by Phleger (1951), and he suggested that it was relict either as a hold over from the colder Pleistocene conditions of the Gulf, or it is introduced sporatically around the southern tip of Florida. Our data to date can not distinguish which, if either, of Phleger's suggestions are correct, but it does give a clue to where and why *Globigerina pachyderma* exists today as a cold water form in the tropical and subtropical Gulf. *Globigerina pachyderma* clusters out with *Uvigerina peregrina*. *Uvigerina peregrina* is a benthonic indicative of outer-shelf and upper-slope regions which ~~is~~ found occasionally in the plankton. *Uvigerina peregrina* associated with *Globigerina pachyderma* may then suggest that both are upwelling forms and that *Globigerina pachyderma*'s natural habitat is in the deeper and colder waters of the offshore region which would be more conducive for a normally high latitude form.

Efficiency of Shelled Microplankton and Microbenthon as Environmental Indicators

From the previous results and discussions it is apparent to us that the shelled microplankton and microbenthon are very good environmental indicators. Our studies indicate that these organisms may be used to: suggest water mass distributions and movements by use of indicator species and cluster groupings, denote areas and relative magnitudes of upwellings and volumes and routes of currents, and give indications of such things as the length of food chains (through the niche examples), and short term "health" (plankton tows), medium term "health" (the benthonic foraminifera), and long term "health" (the relict populations) of the study area.

To illustrate their usefulness and the usefulness of the multivariant techniques herein employed refer to Figure 12 for the following discussion. This dendrogram separates the following clusters: an upwelling cluster (U); an inner-mid-shelf cluster subdivided into spring-summer (SS), winter (W), summer (S) and spring (SP) packets; a mid-outer-shelf cluster subdivided into winter (W), winter offshore (WO), outer-shelf upwelling (OU), relict (R) with shallow (s) and deep (d) components, outer-shelf rare (OR) summer (S) and another but not subdivided relict assemblage (R). These are groups that we believe are indicator groups.

However it must be emphasized that care must be taken in working with multivariant analysis - especially in the interpretation of the dendrographs and clusters generated. It is very tempting to try to read too much into such displays. In these cases the person working up the original samples followed the entire procedure and is aware of the strengths and weaknesses of the original data. For example almost all of the very high similarity clusters (those on the far left of Figure 12) exhibit a high similarity due to their being rare and associated to others very strongly because in the few cases they were found so were the others. Currently we are "throwing these out" of the interpretation; however, should this phenomenon occur again in next years sampling it will have to be reevaluated. Another years sampling will reinforce many of the clusters and perhaps change our interpretation of many others.

We do consider the clusters very useful, but it is best interpreted by one who has followed the entire practice and also was responsible for the taxonomic decisions. Therefore Table 2 is a conservative list of what we currently believe to be indicators of various environmental parameters. By indicator we mean a good indicator, one that is relatively easy to identify, has shown some consistancy as an index and is abundant enough to be reliable.

The appendices contain the raw and processed data supportive of this report from Rice University on the shelled microplankton and microbenthon of the South Texas Outer Continental Shelf.

Comment of Contractual Obligations

I would like to state where we are as far as our contractual obligations are and why in some cases we are doing more and why in some cases we have not fully completed all phases. However, I must state that all obligations will be completed.

One problem is the "underway plankton sampling". In our original proposal we included an "underway plankton net", but it was taken off the budget. Somehow it keeps popping up again; however, I did bring this up at one of our meetings with BLM in Austin last year (the meeting in February, or so I believe). Even though it was cut from the program I thought it might be a good idea so I purchased an "underway net" with another grant and discovered it was not worthwhile anyway. We hope to be funded to design one that will work.

A program that is still to be done is the down core sampling program. Originally we were going to look at 12 bottom samples for shelled microbenthos and then to look down core to see past natural changes in the environment. After investigating the 12 bottom samples (from the first winter's collecting), it appeared that the living populations either might show considerable seasonality or that the "dead" fauna might be relict (left over from ancient times, such as Pleistocene outcrop). We decided that we should look at another season's sampling even though the contract did not stipulate it. The spring sampling was quite different and we are currently looking at the summer component. Although this is time consuming (and has taken some time from other parts of the project), we believe that it must be done. When the full year is complete (when we complete 36 instead of 12 samples), we plan to investigate down core. We have communicated with Henry Berryhill and know in general what cores would be "excellent" ones to work on.

There is some question about the sieve sizes used (whether 62 or 38 micrometer are used). The problem is that both are; the 62 micrometer is used as stated in the original proposal (for the sediments) and the 38 micrometer is used as the "filtering device" for the Niskin samples.

The Niskin samples have not been worked up in time for this report. They will be done, but this work has lagged because of the additional work that had to be done (which we could in no way anticipate and that is mentioned in the next paragraph). We are also "behind" due to: (1) we started out by collecting all we could thinking that some of the collecting would not produce too much, well it did and we really had too much to work up for the amount of money ($17,000) for our first year, but we will complete it; (2) due to various problems the money was not available for a number of months at the start of the project (the main problem being Rice did not react to the letter of intent but waited for a complete contract) so we were behind from the start; (3) we ran into some unknown species that produced problems that were time consuming (the relict populations) etc. However all the work and more than was called for in the original contract will be completed.

I must admit that some of our "slowness" in some contractual obligations is due to investigating some "academic" findings that the BLM project has discovered. We have found a relict population that is fully discussed in this report.

Another interesting finding has been the finding of previously considered benthonic organisms (bottom dwellers) floating alive in the water as plankton, and this is discussed in the report.

We are very pleased with the way our component has and is going. We are especially pleased with the developing ability to utilize shelled microorganisms as indicators of seasonality, current movement, water masses, upwelling, etc. We believe that we will be able to determine current and upwelling movement in more than relative amounts. We more than anyone wish we had all our contractual obligations completed. We could have them completed if we had been able to start on time (had money), and had not "taken the time" to work on relict faunas, "planktonic" benthonics, extend the bottom program three fold to do a better job on the down core sampling, etc. We are very excited about our findings and believe that the investigation of all these problems fulfill the nature and intent of the program in the best sense (scientifically and contract wise). Have no fear the unworked samples will all be done plus quite a few extras.

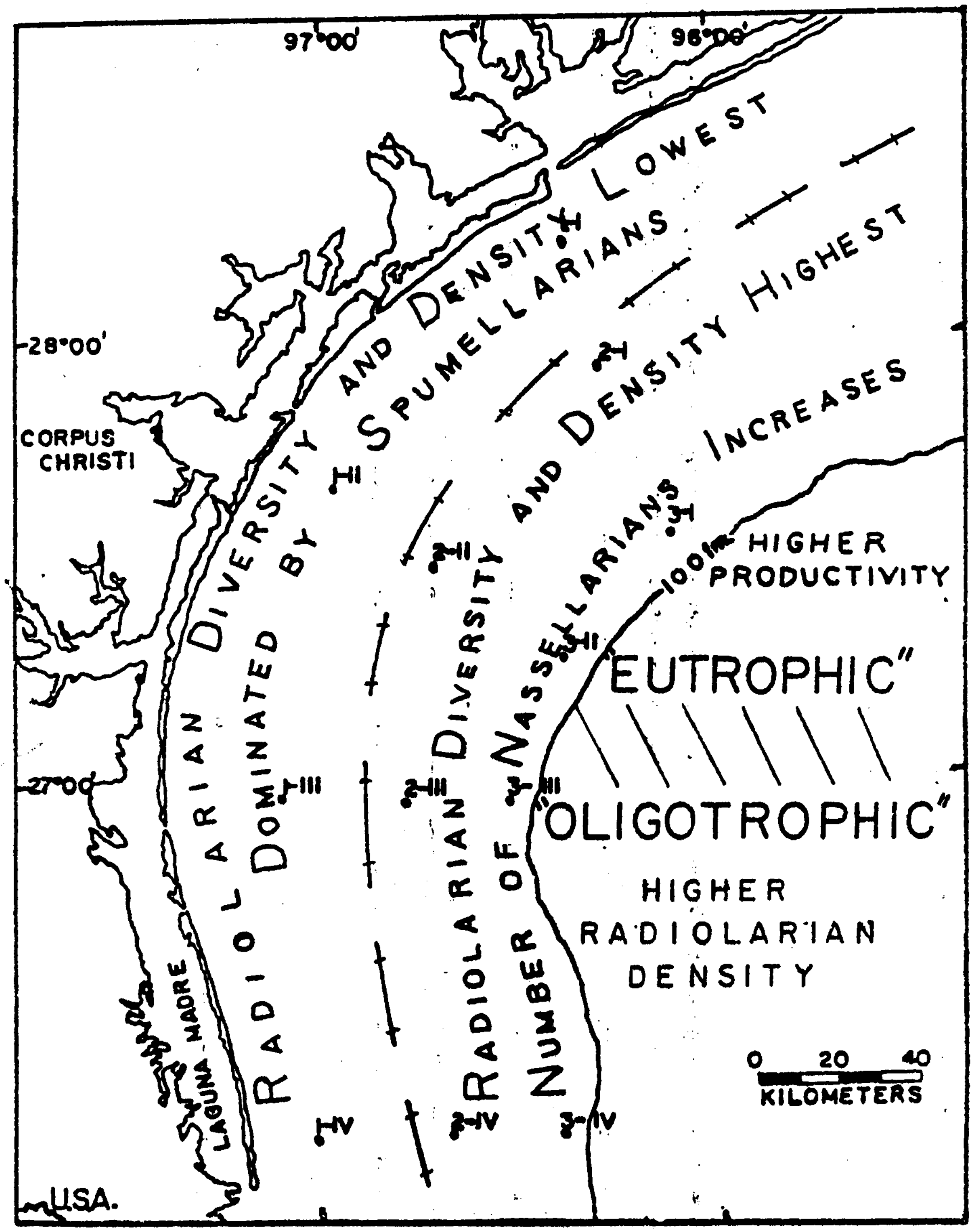


Figure 1. General radiolarian trends.

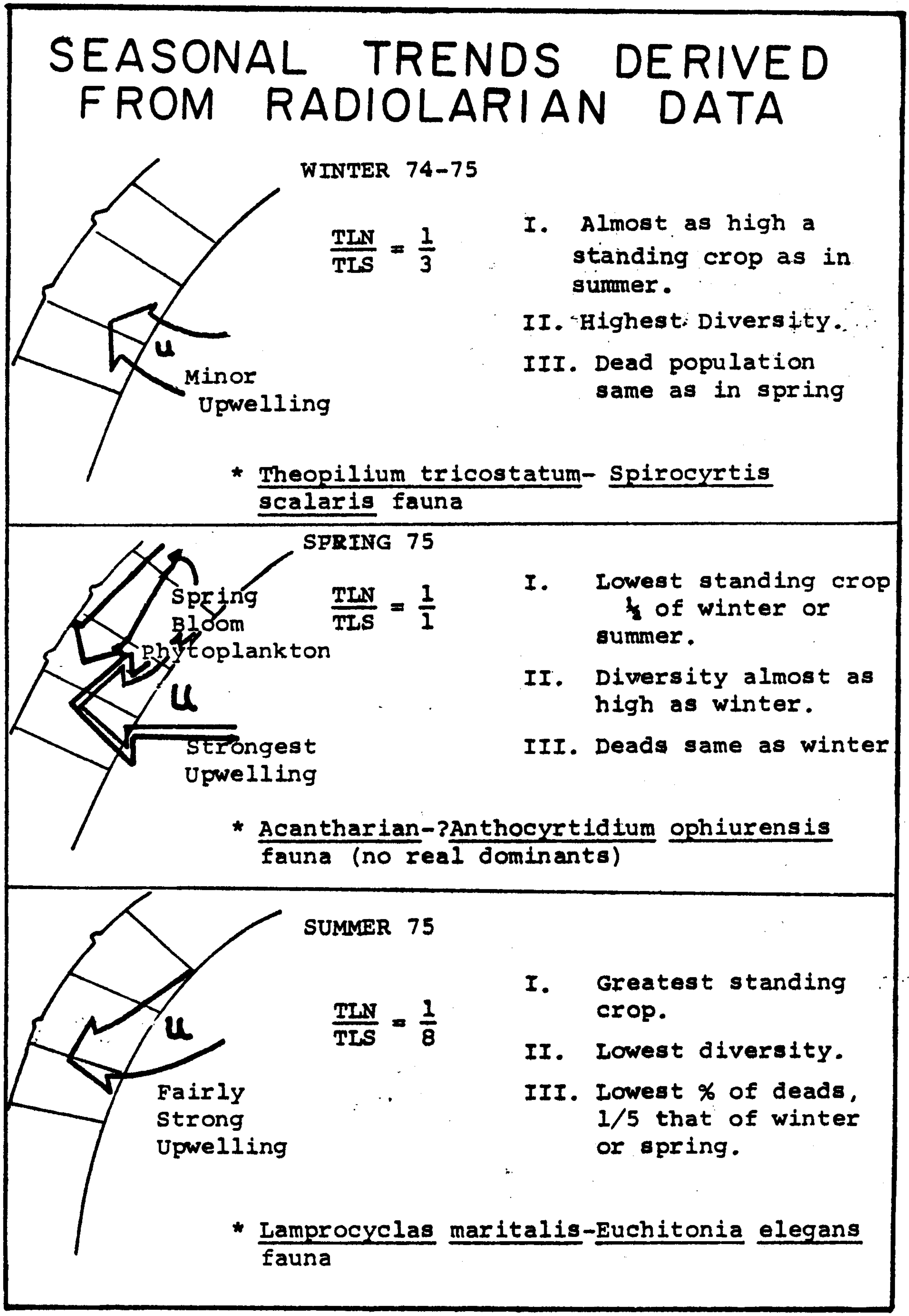
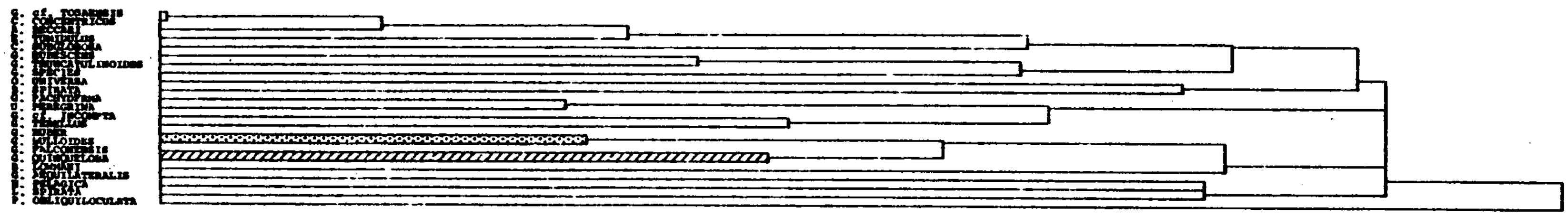


Figure 2. Seasonal trends derived from radiolarian data.

FIGURE 3.

R-MODE CLUSTER PLANKTON TOWS WINTER-SPRING SUMMER PLANKTONIC FORAMINIFERA



LEGEND: Q-MODE CLUSTER

LIVE FORAMS, PLANKTON

WINTER, SPRING, AND SUMMER (Figures 3, 4, 5 and 6)

NO FORAMINIFERA

BOLIVINA LOWMANI CLUSTER

GLOBIGERINA QUINQUELOBA CLUSTER

GLOBIGERINA FALCONENSIS CLUSTER

GLOBIGERINA BULLOIDES AND GLOBIGERINA RUBER CLUSTER

SAMPLES CLUSTERING AT LOW LEVELS

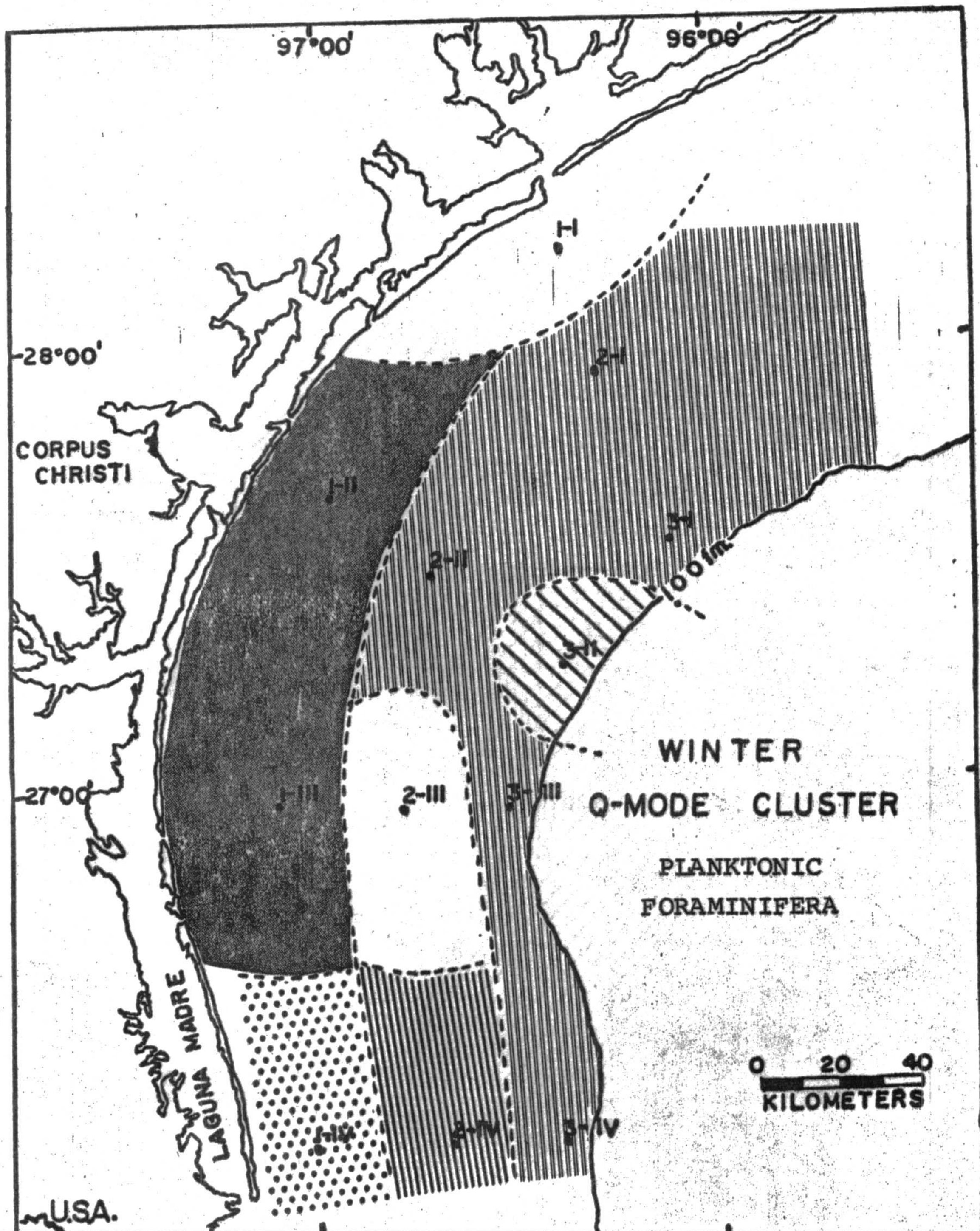


Figure 4. Winter Q-mode cluster for planktonic foraminifera.

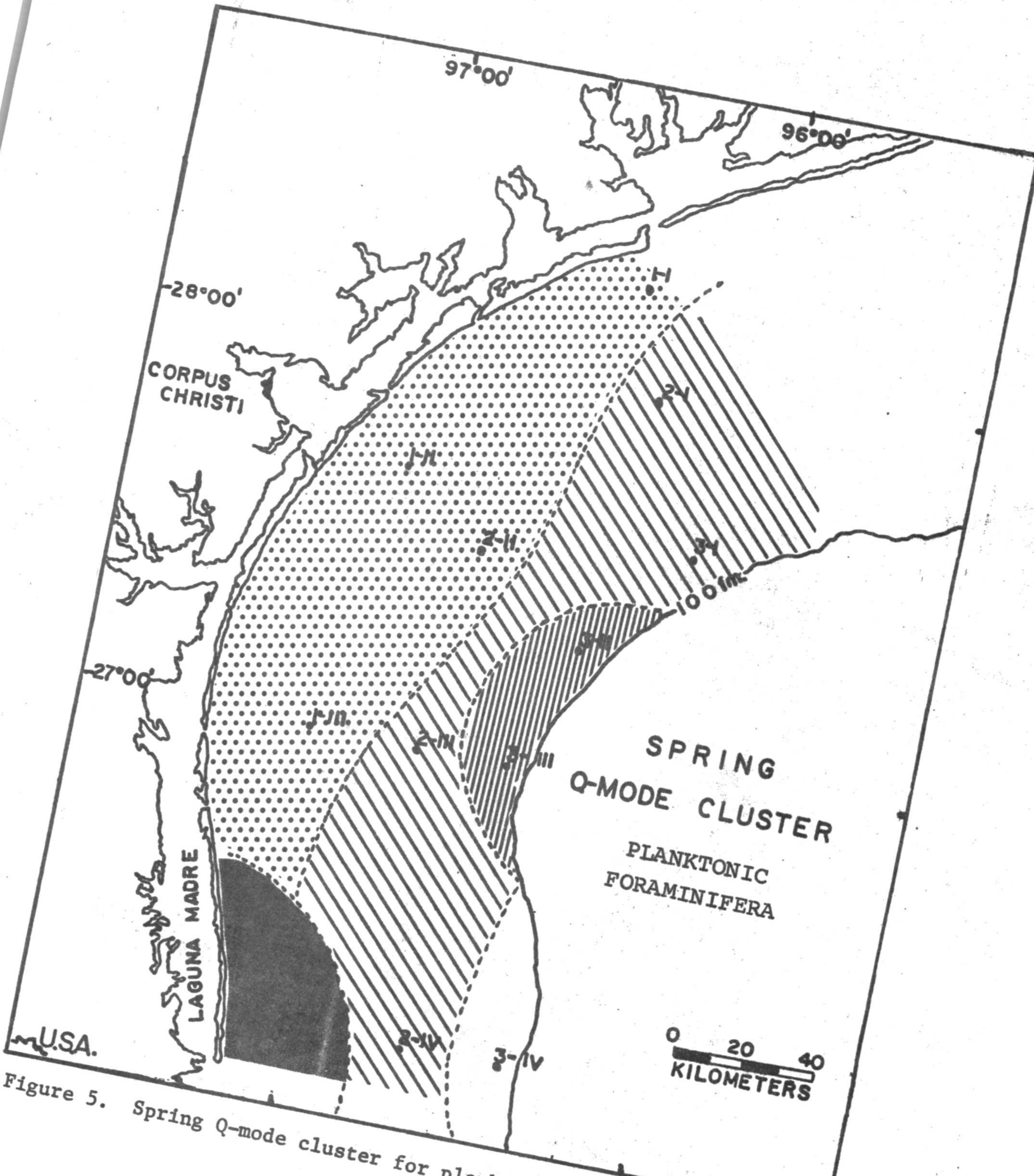


Figure 5. Spring Q-mode cluster for planktonic foraminifera.

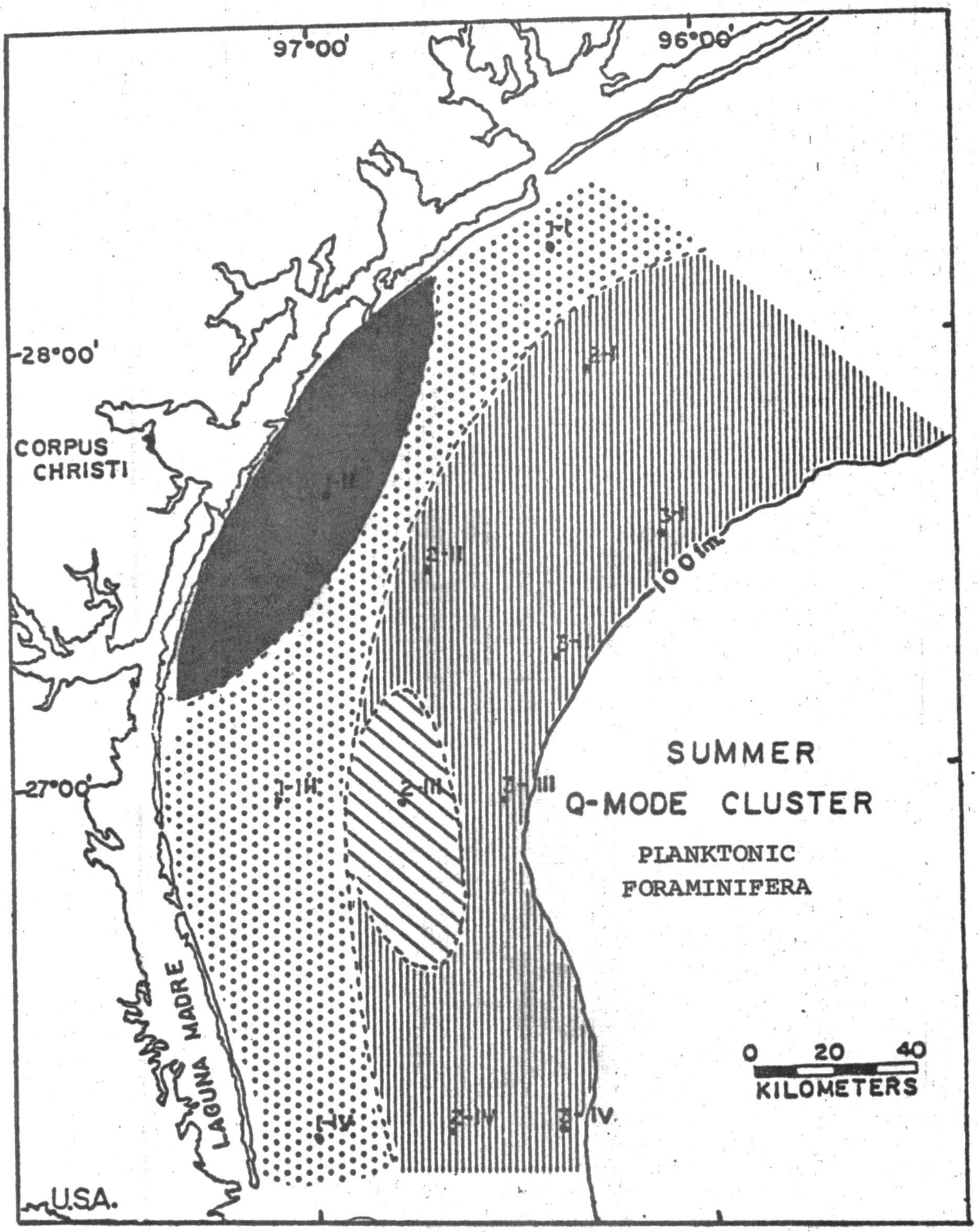
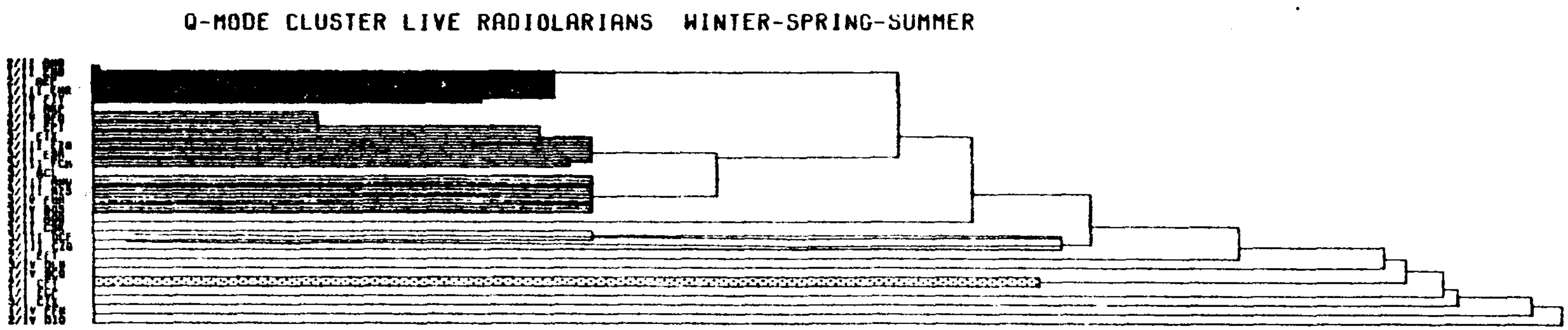


Figure 6. Summer Q-mode cluster for planktonic foraminifera.

FIGURE 7.



LEGEND: Q-MODE CLUSTER

RADIOLARIANS

WINTER, SPRING, AND SUMMER (FIGURES: 7, 9, 10, 11)

HYMENIASTRUM PROFUNDUM (ADULT AND JUVENILE) CLUSTER

PTEROCANIUM PRAETEXTUM-HYMENIASTRUM PROFUNDUM (JUVENILE) CLUSTER

PTEROCORYS ZANCLEUS-THEOPILIUM TRICOSTATUM CLUSTER

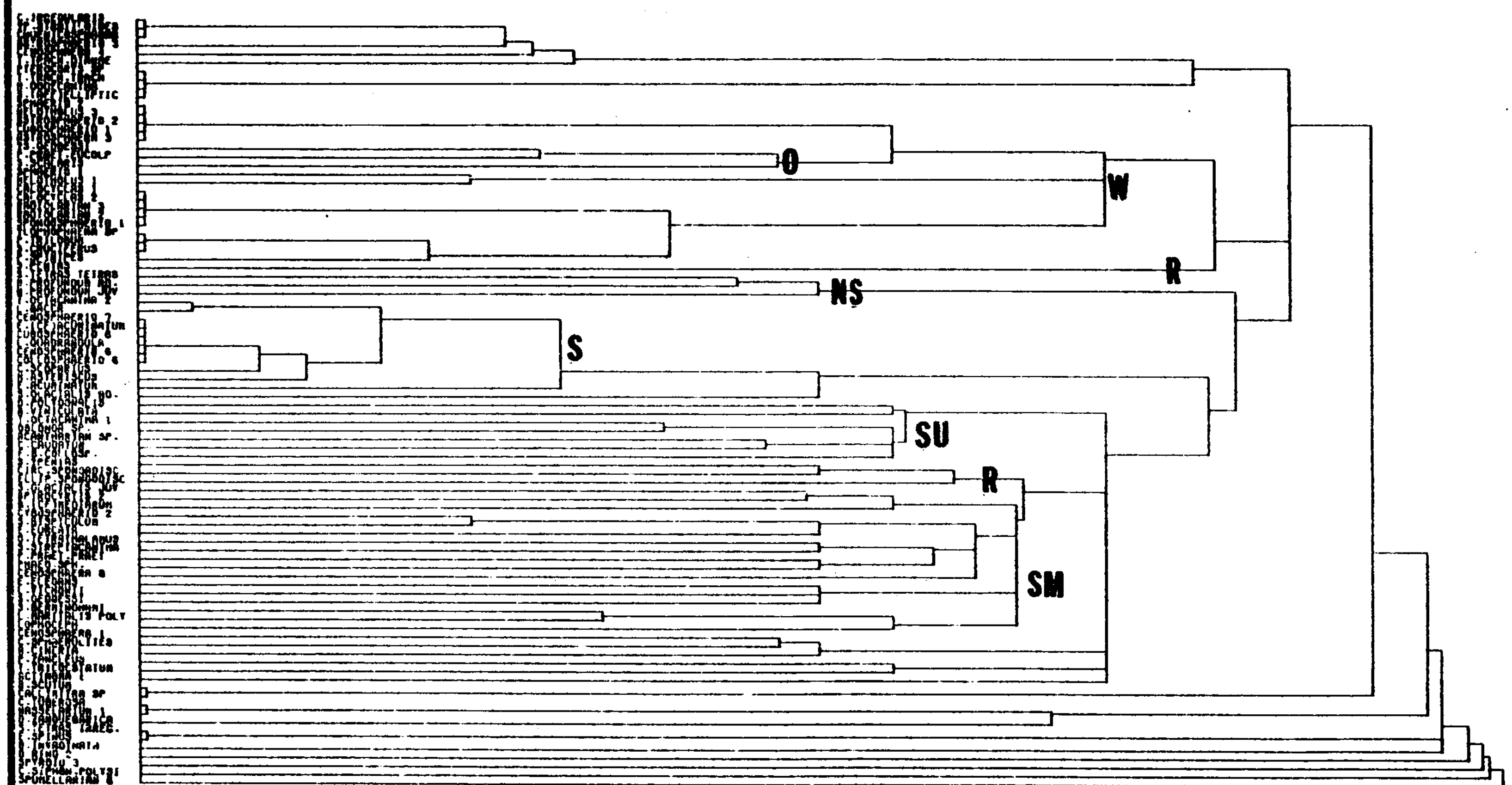
CONCHASMA UPWELLING FAUNA

SPONGOSPHAERA STREPTACANTHA CLUSTER

SAMPLES CLUSTERING AT LOW LEVELS

FIGURE 8.

R-MODE CLUSTER LIVE RADIOLARIANS WINTER-SPRING-SUMMER



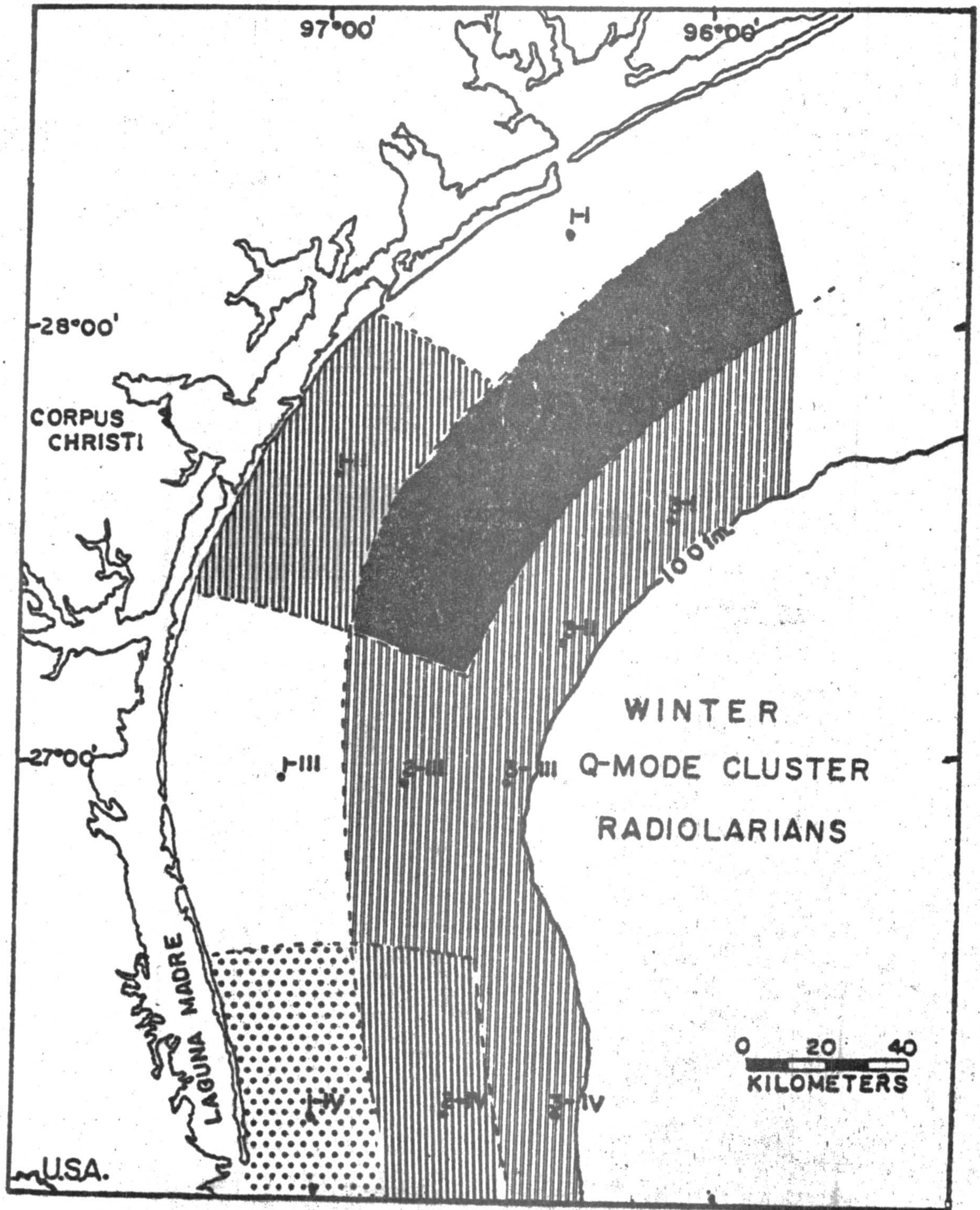


Figure 9. Winter Q-mode cluster for radiolarians.

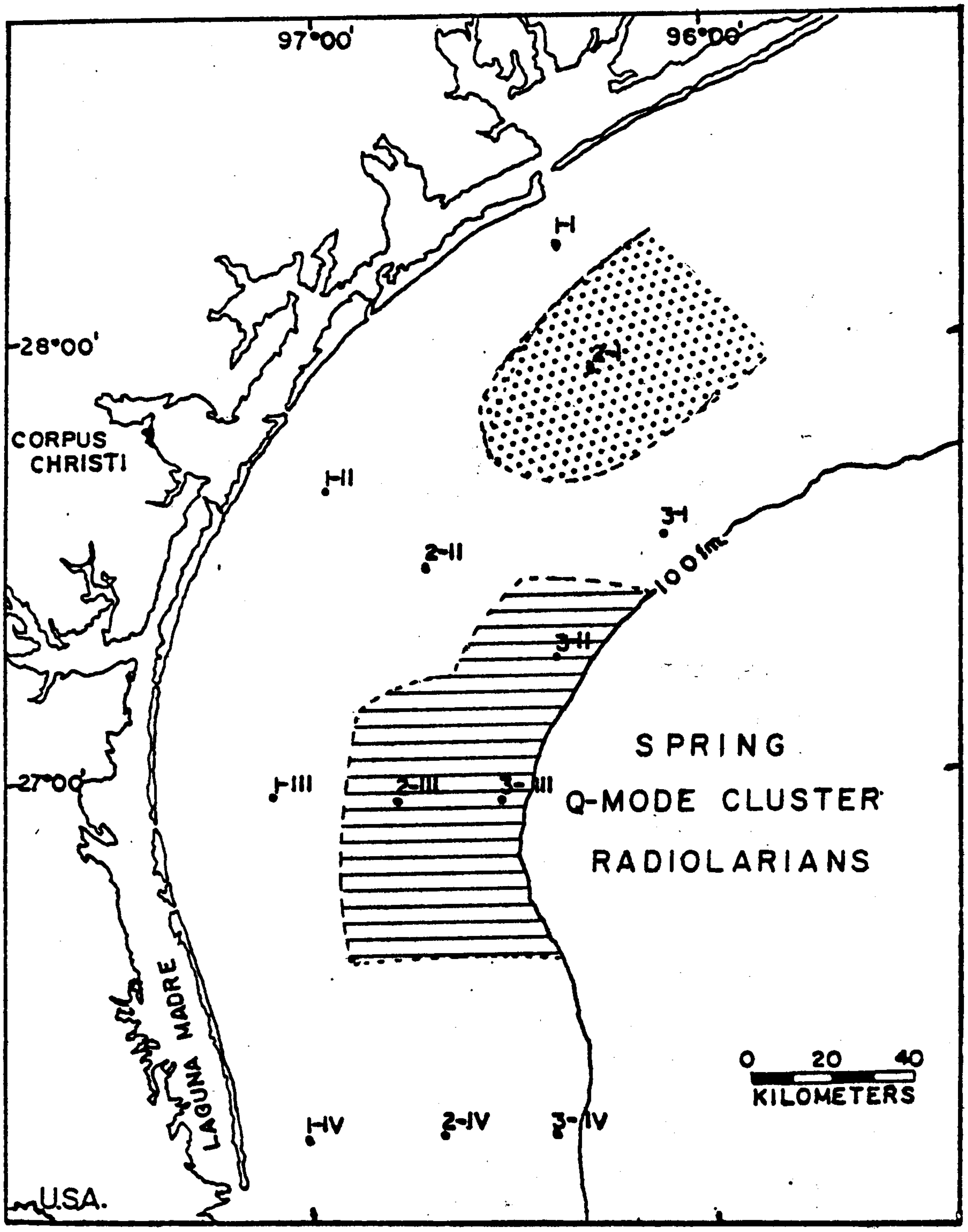


Figure 10. Spring Q-mode cluster for radiolarians.

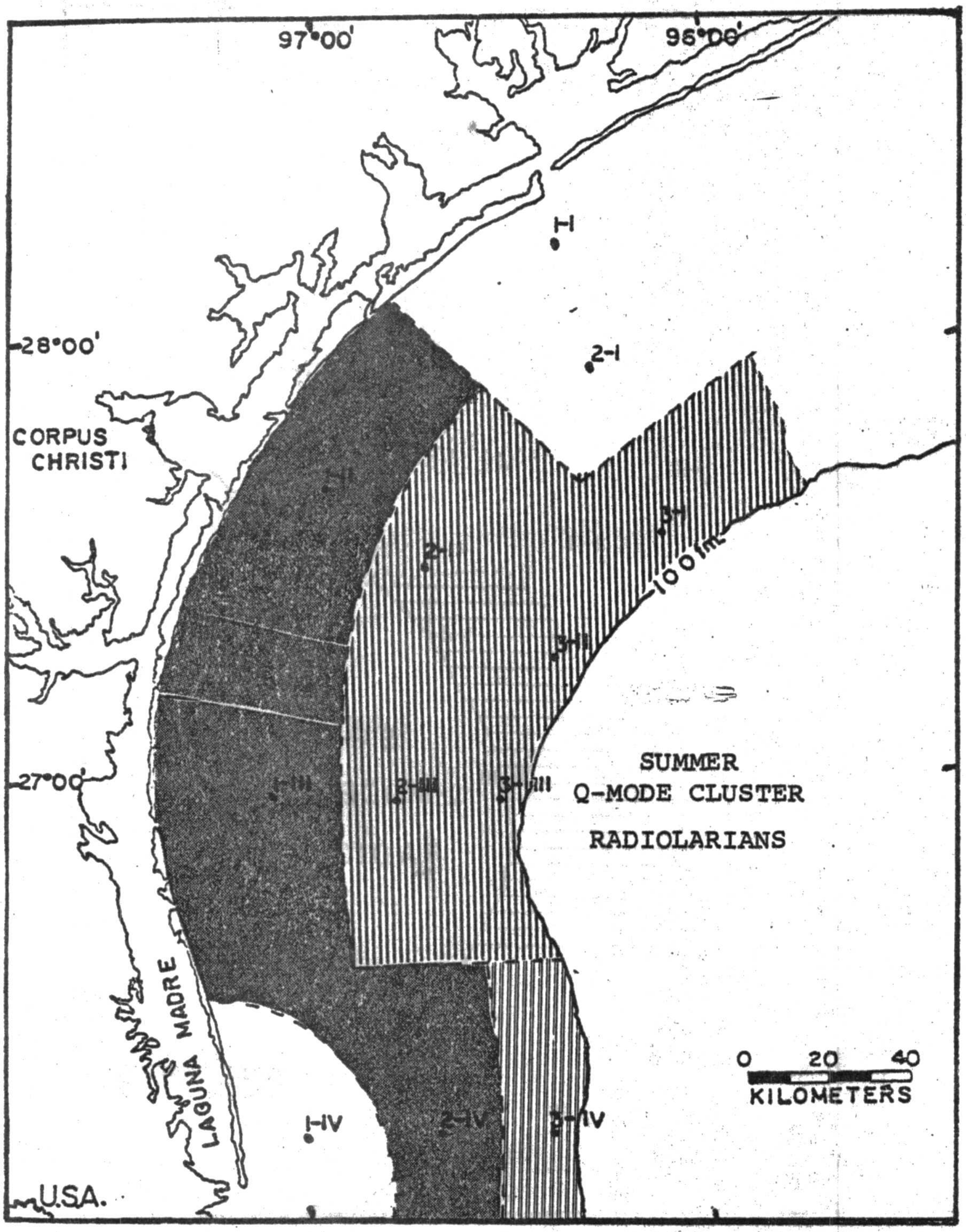


Figure 11. Summer Q-mode cluster for radiolarians.

R-MODE CLUSTER RADIOLARIANS, FORAMINIFERA, AND PTEROPODS

FIGURE 12

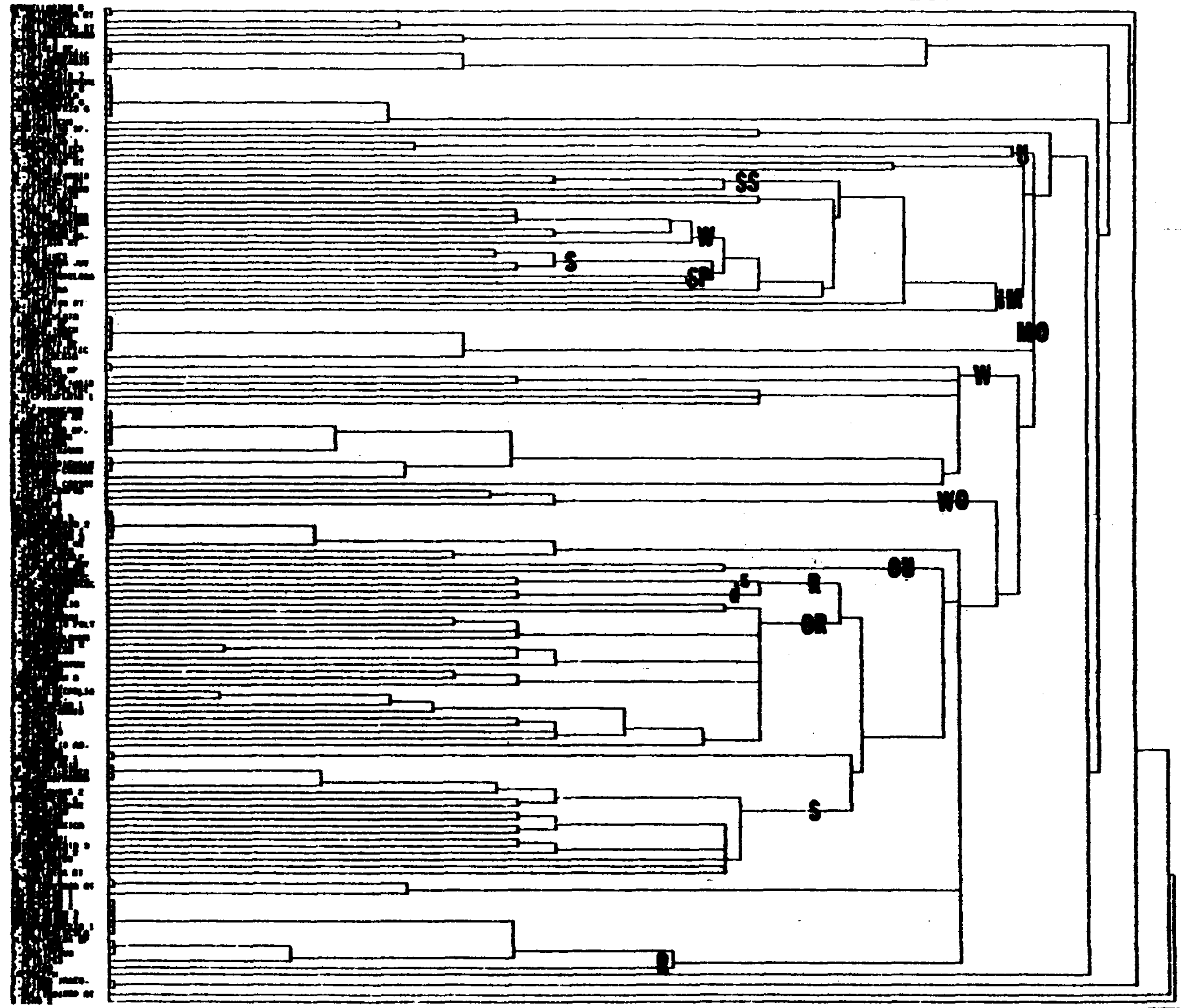
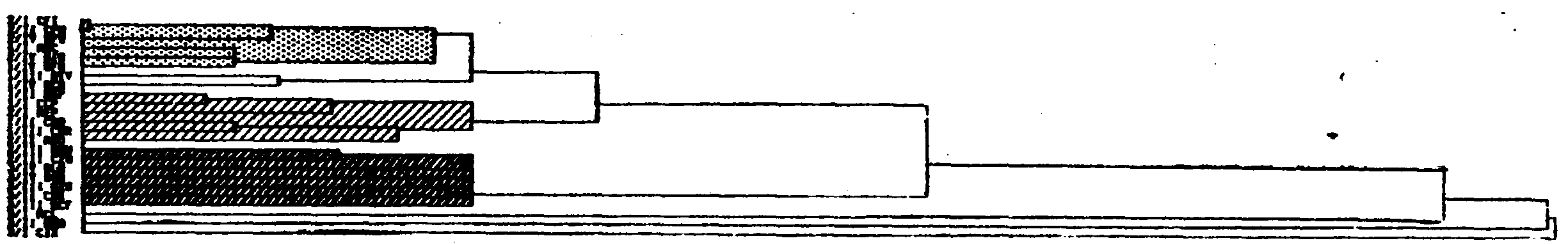


FIGURE 13.

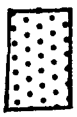
Q-MODE CLUSTER LIVE BENTHONIC FORAMS WINTER AND SPRING



LEGEND: Q-MODE CLUSTER

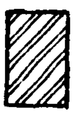
BENTHONIC FORAMS, LIVE

WINTER AND SPRING (FIGURES: 13, 14, 15)

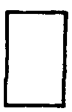


FURSENKOINA PONTONI CLUSTER

BRIZALINA LOWMANI CLUSTER



VARIABLE CLUSTER



SAMPLES CLUSTERING AT LOW LEVELS

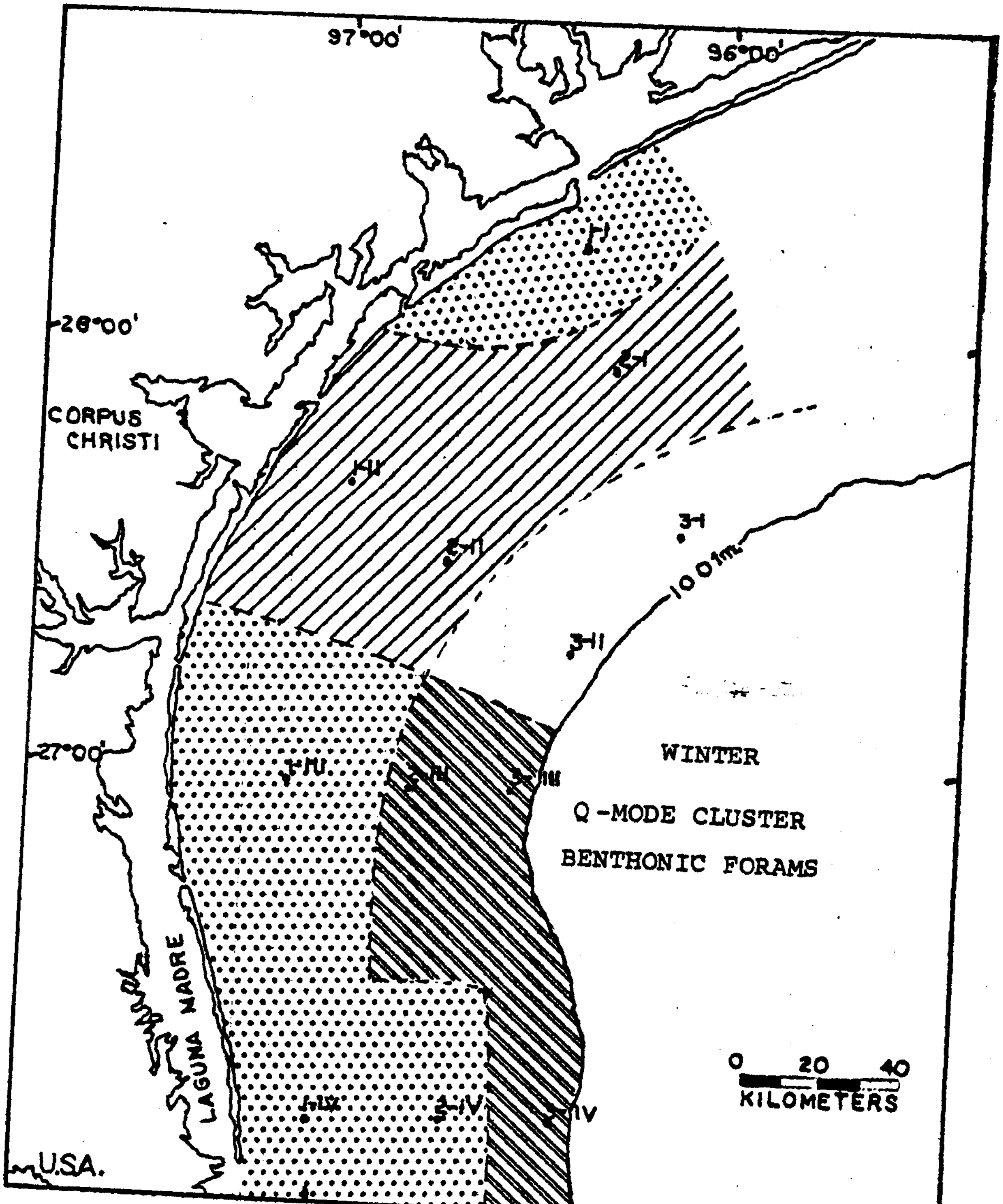


Figure 14. Winter Q-mode cluster for benthonic forams.

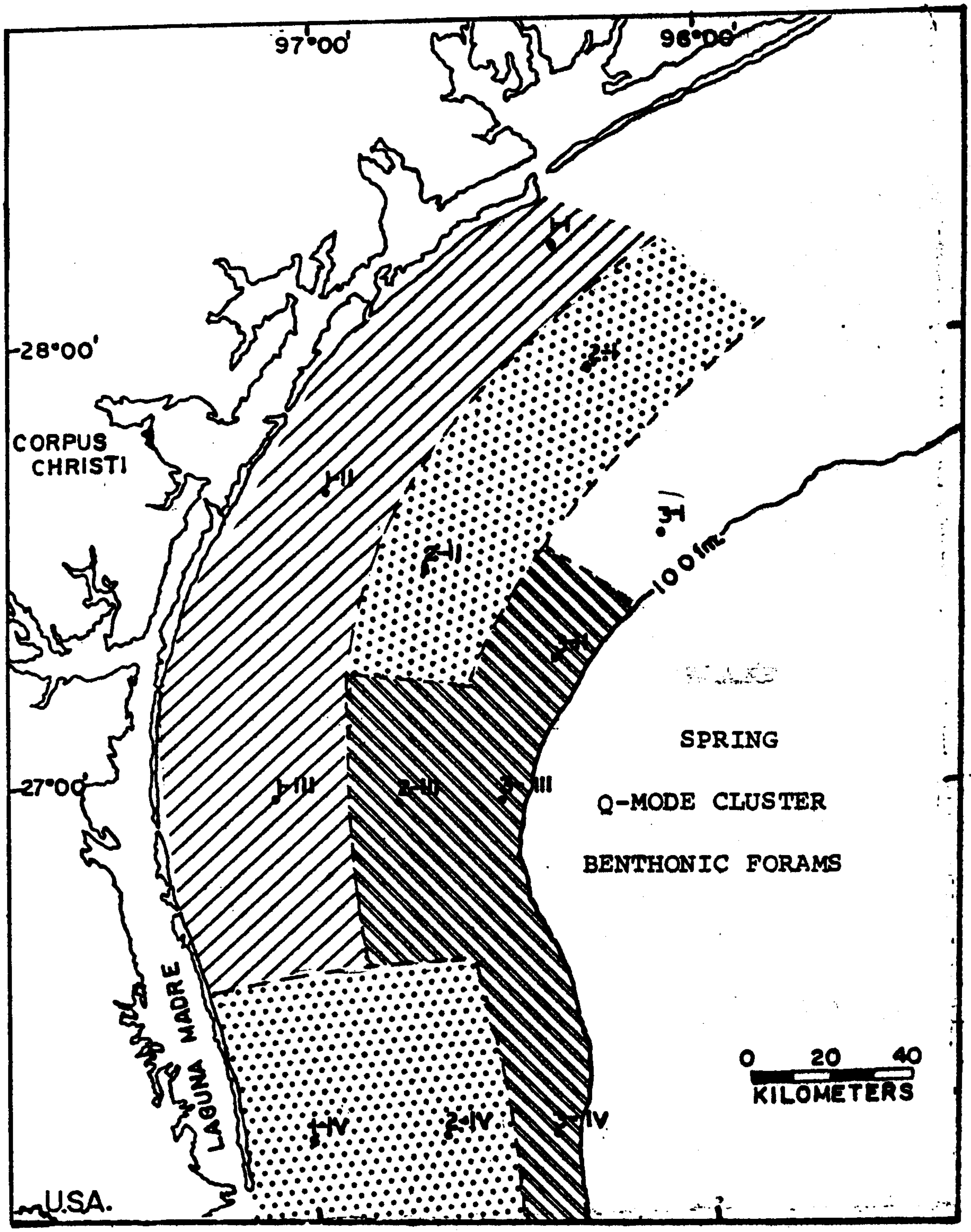
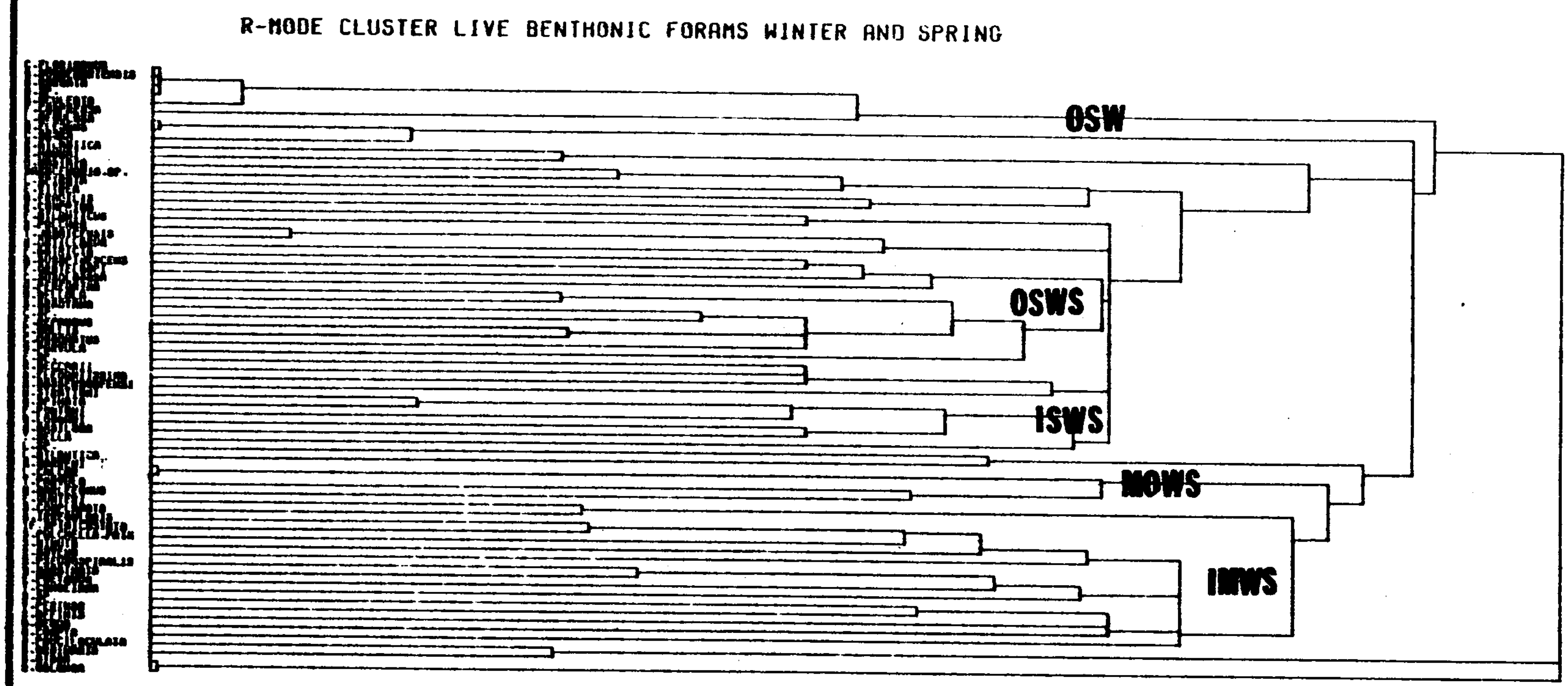


Figure 15. Spring Q-mode cluster for benthonic forams.

Figure 16.


R-MODE CLUSTER LIVE BENTHONIC FORAMS WINTER AND SPRING
OSW
OSWS
ISWS
MOWS
INWS

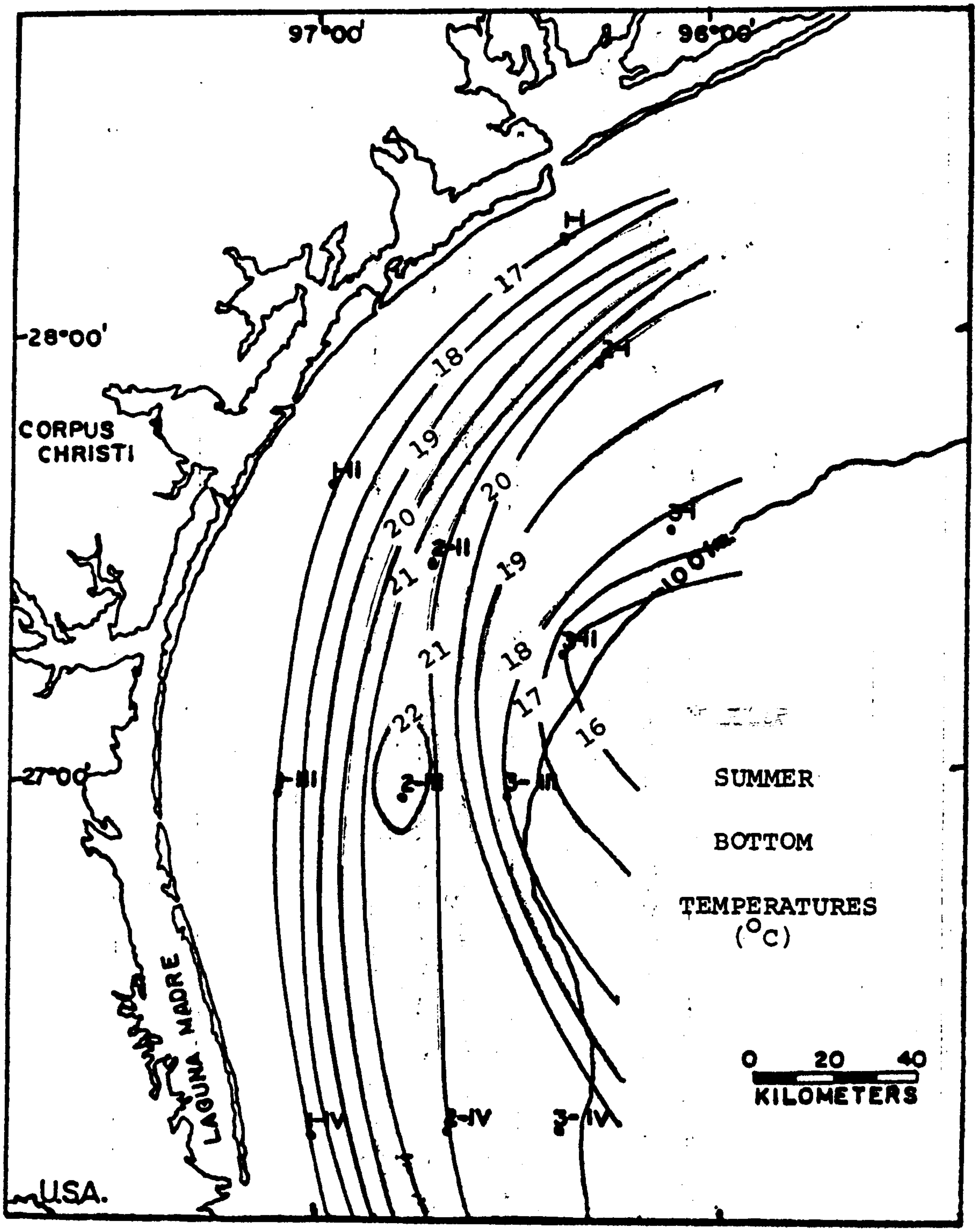


Figure 17. Summer bottom temperatures (°C).

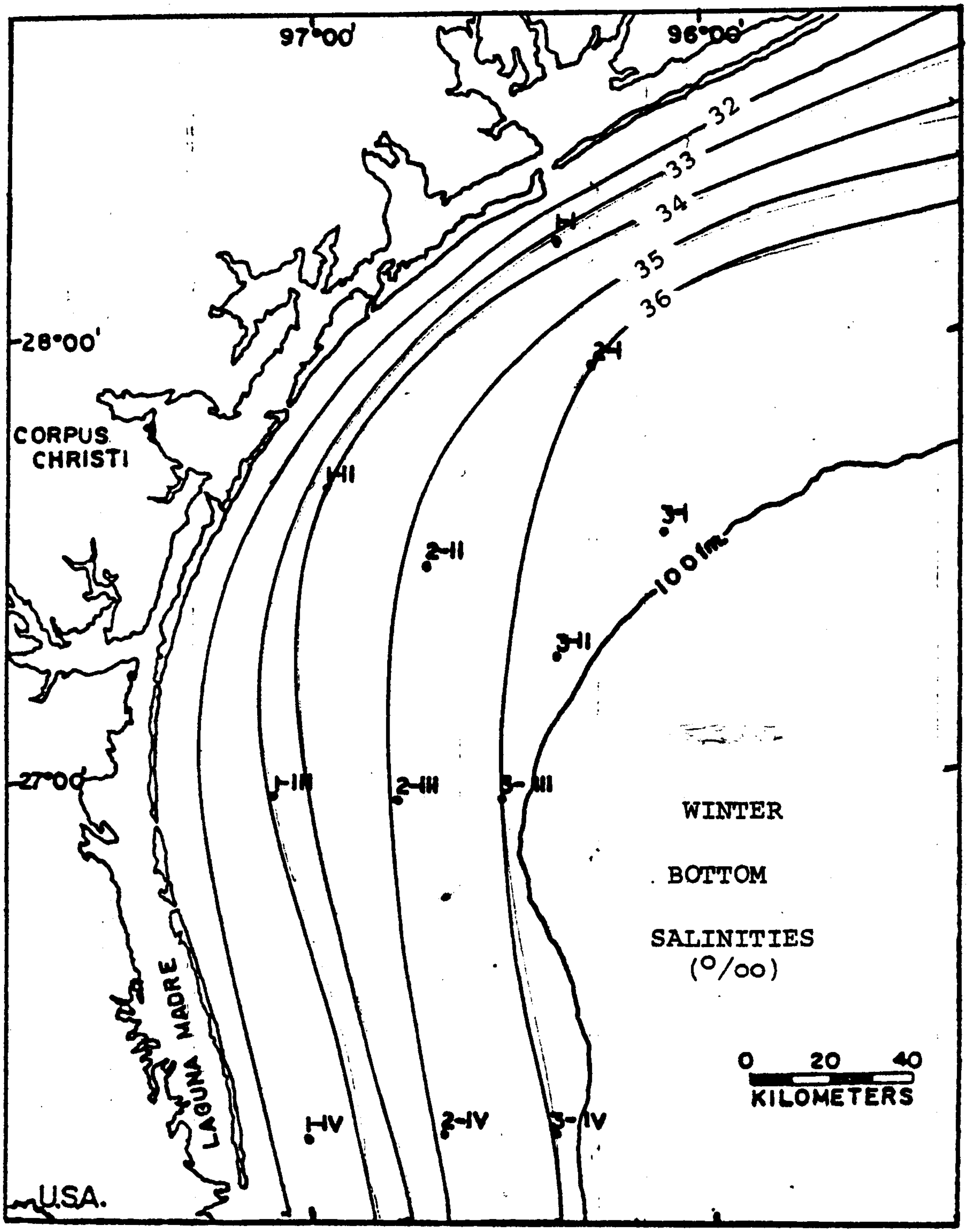


Figure 18. Winter bottom salinities (‰).

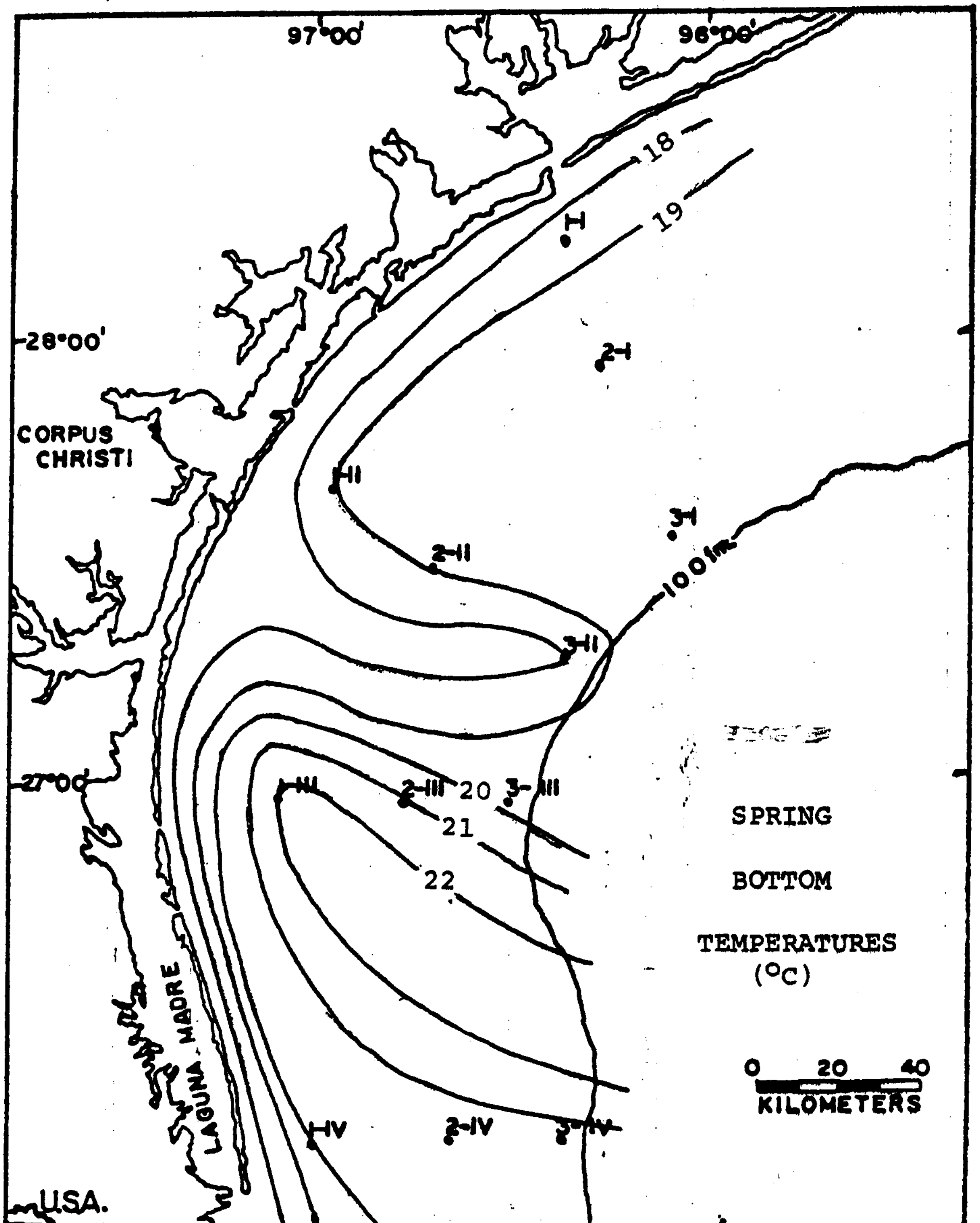


Figure 19. Spring bottom temperatures (°C).

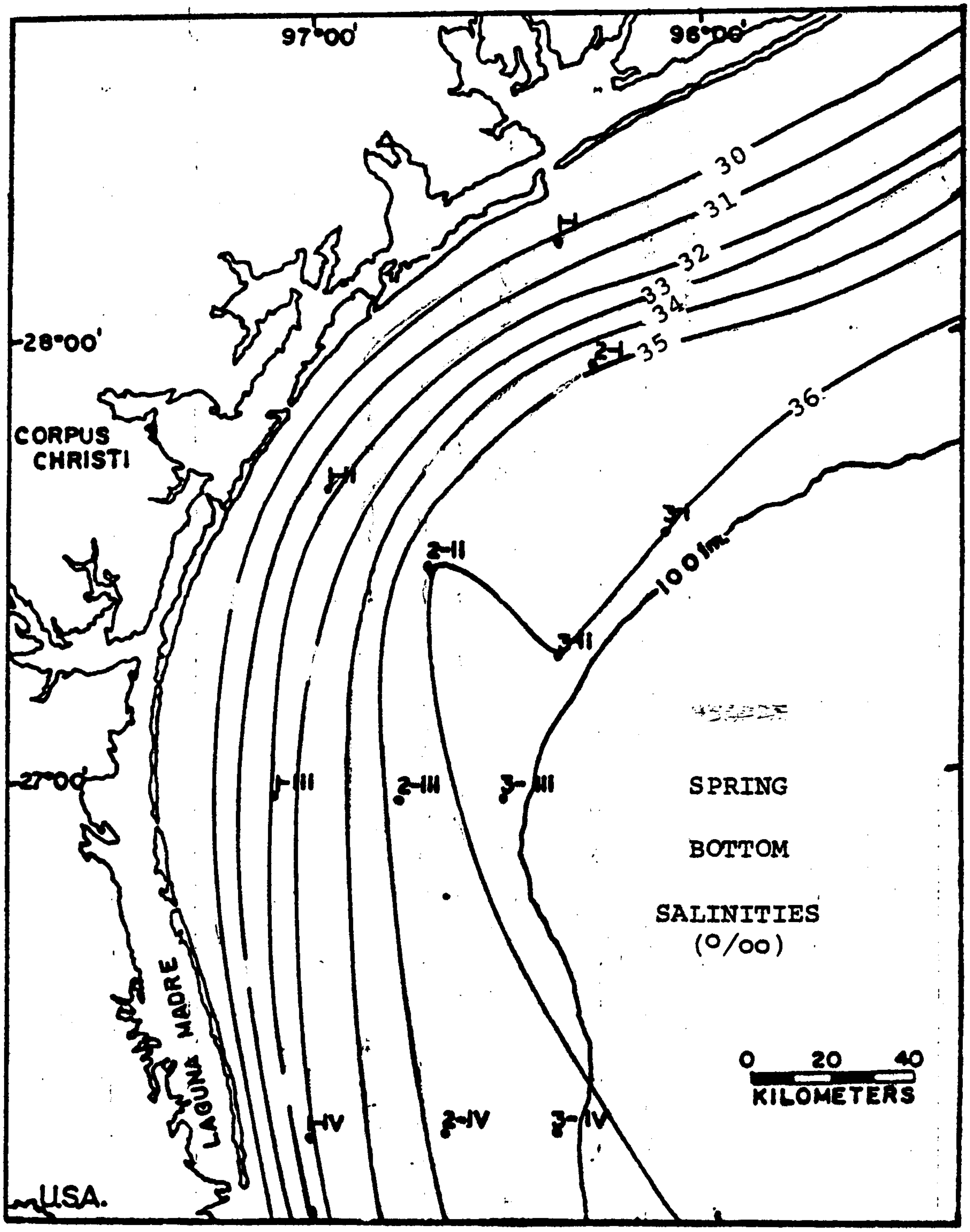
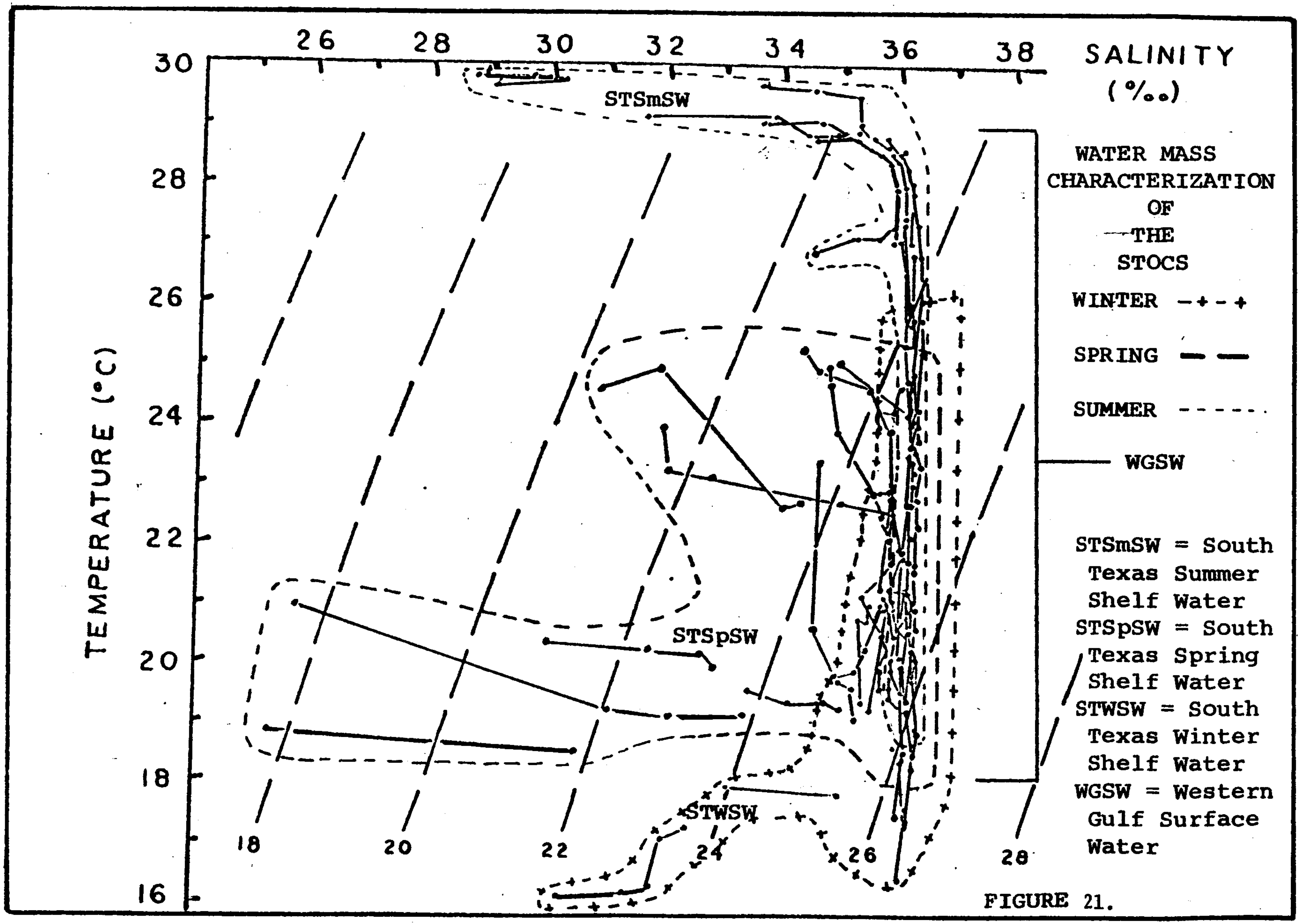


Figure 20. Spring bottom salinities (‰).


SALINITY (‰)
26
28
30
32
34
36
38
TEMPERATURE (°C)
30
28
26
24
22
20
18
16
STSmSW
STSpSW
STWSW
18
20
22
24
26
28
WATER MASS CHARACTERIZATION OF THE STOCS
WINTER
SPRING
SUMMER
WGSW
STSmSW = South Texas Summer Shelf Water
STSpSW = South Texas Spring Shelf Water
STWSW = South Texas Winter Shelf Water
WGSW = Western Gulf Surface Water
FIGURE 21.

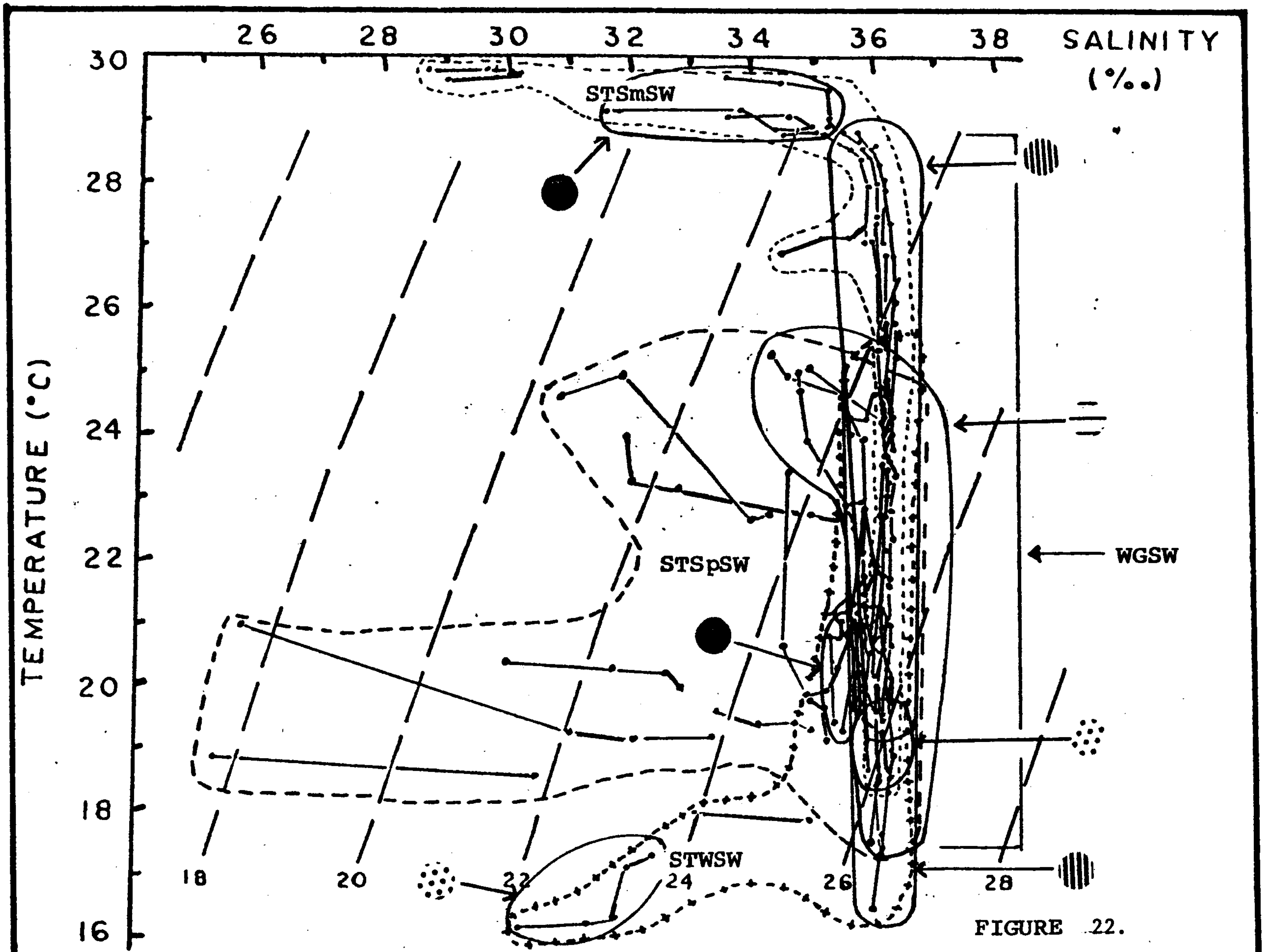


FIGURE 22.

TEMPERATURE-SALINITY-RADIOLARIAN DIAGRAM

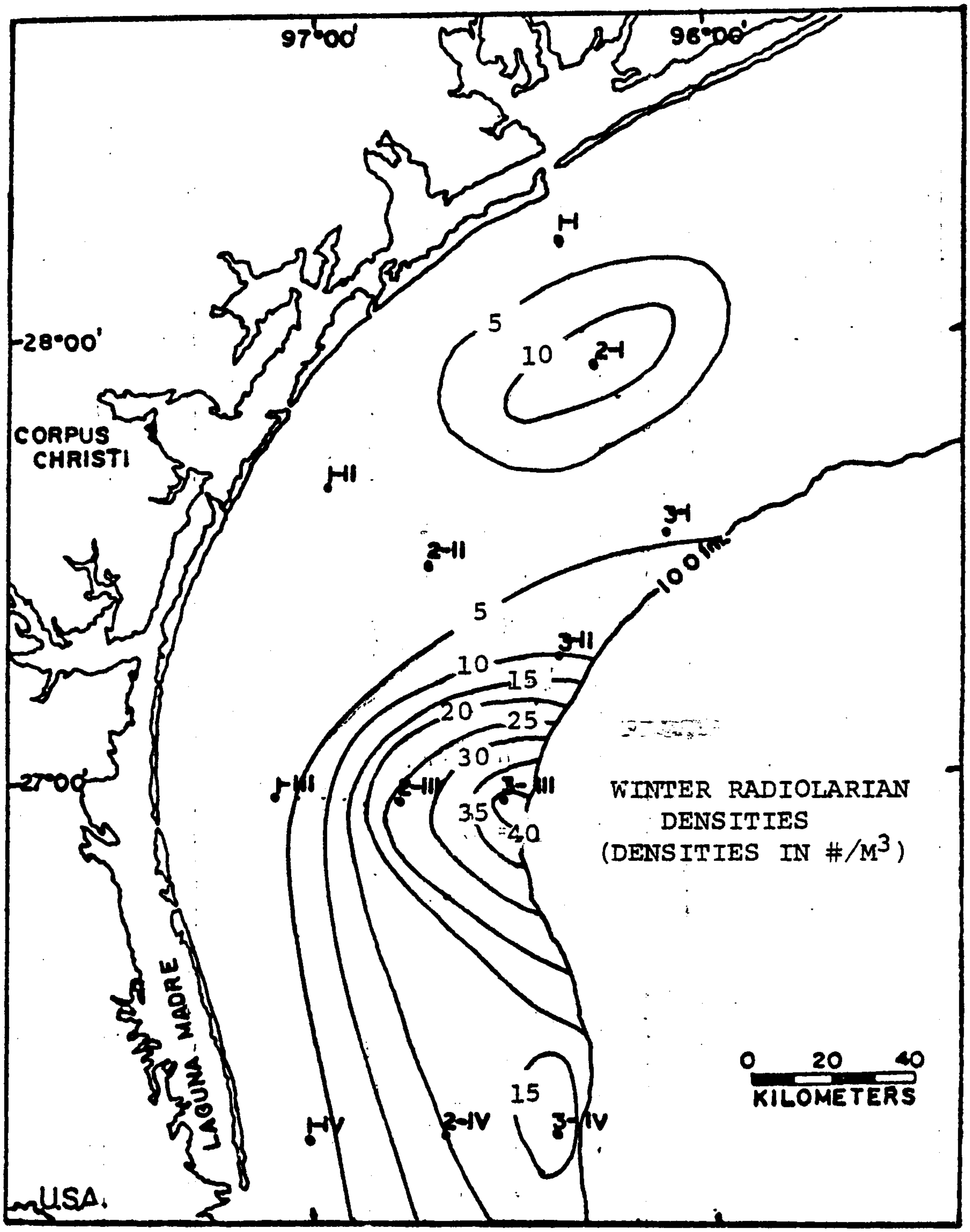


Figure 23. Winter radiolarian densities.

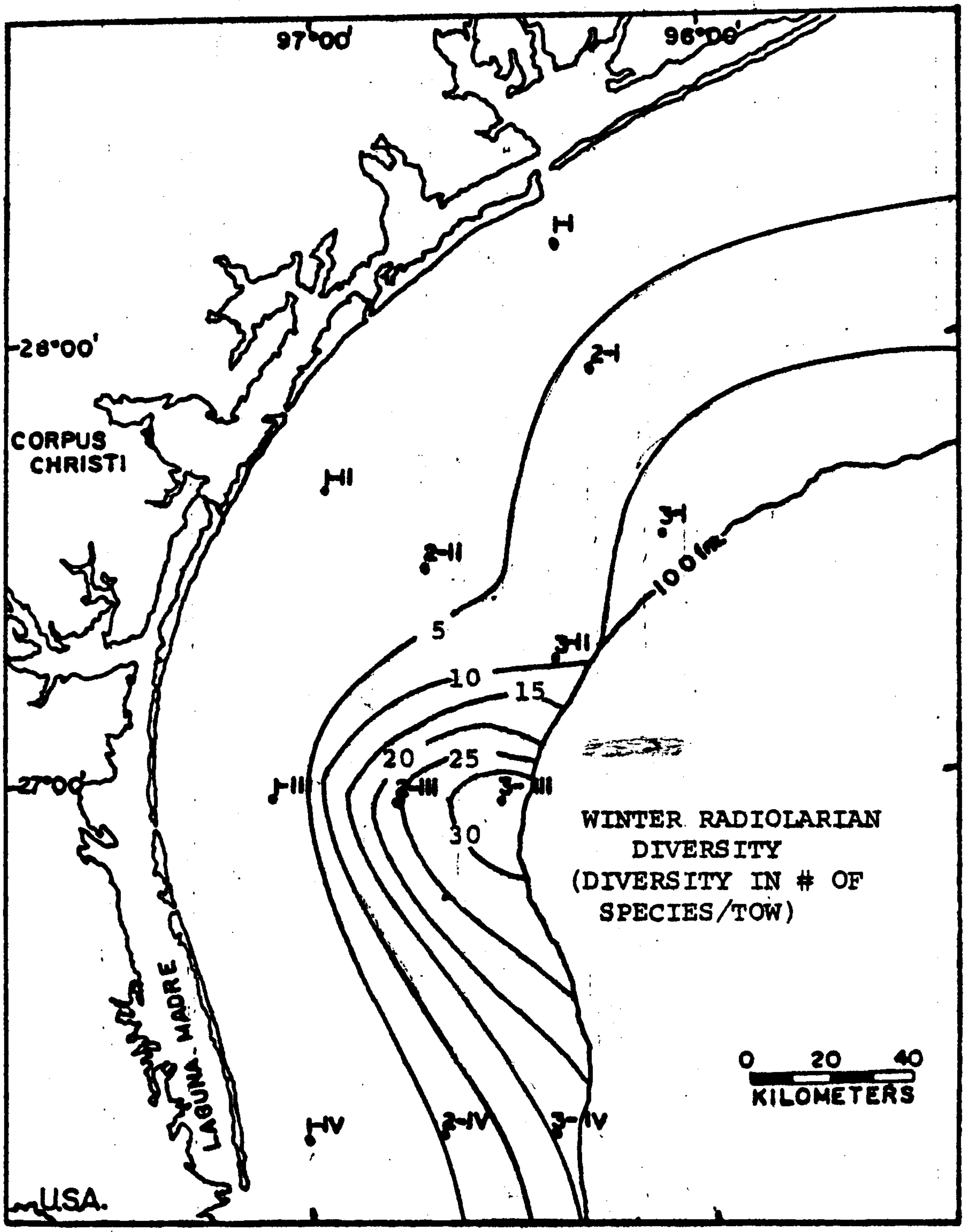


Figure 24. Winter radiolarian diversity.

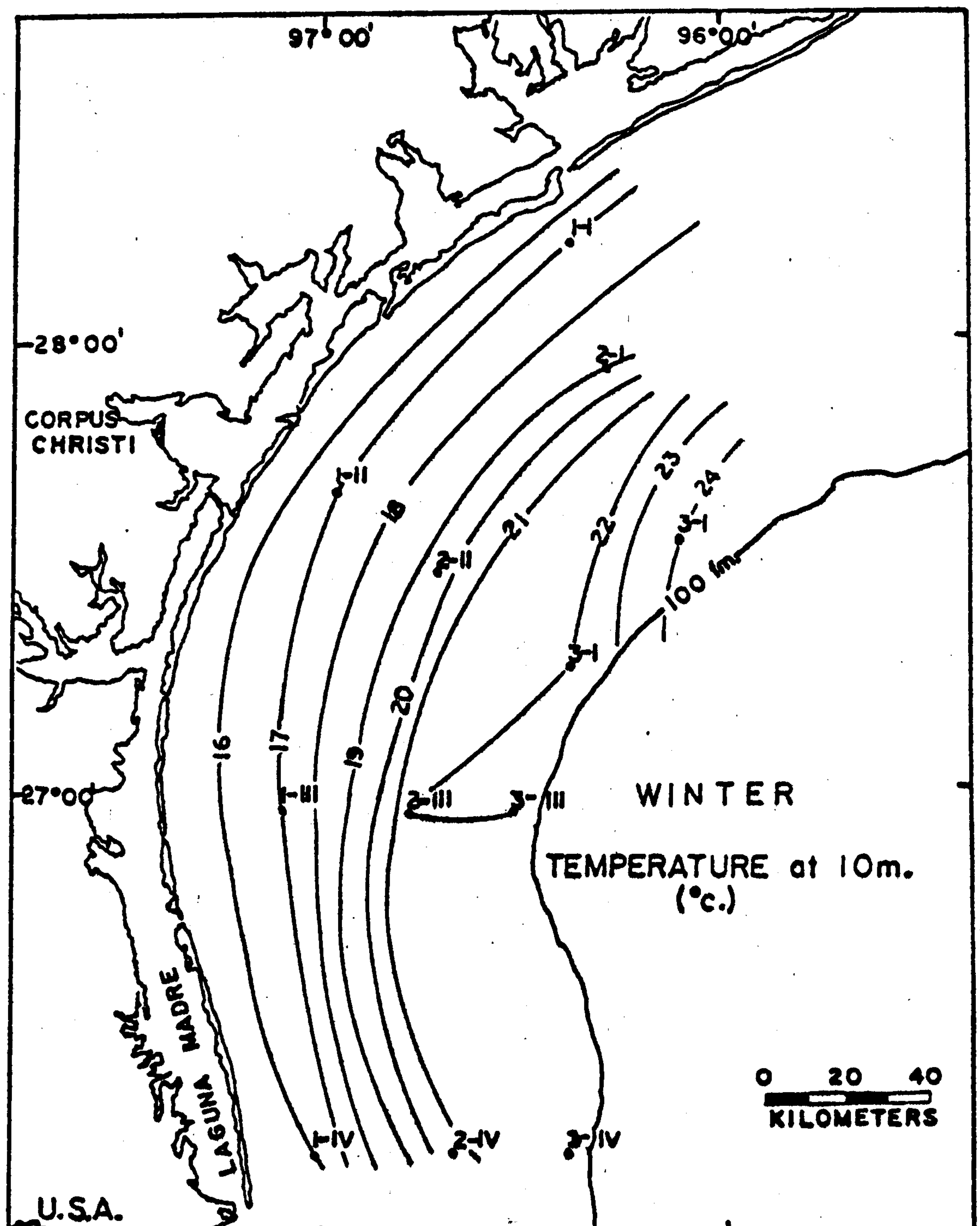


Figure 25. Winter temperature at 10 meters.

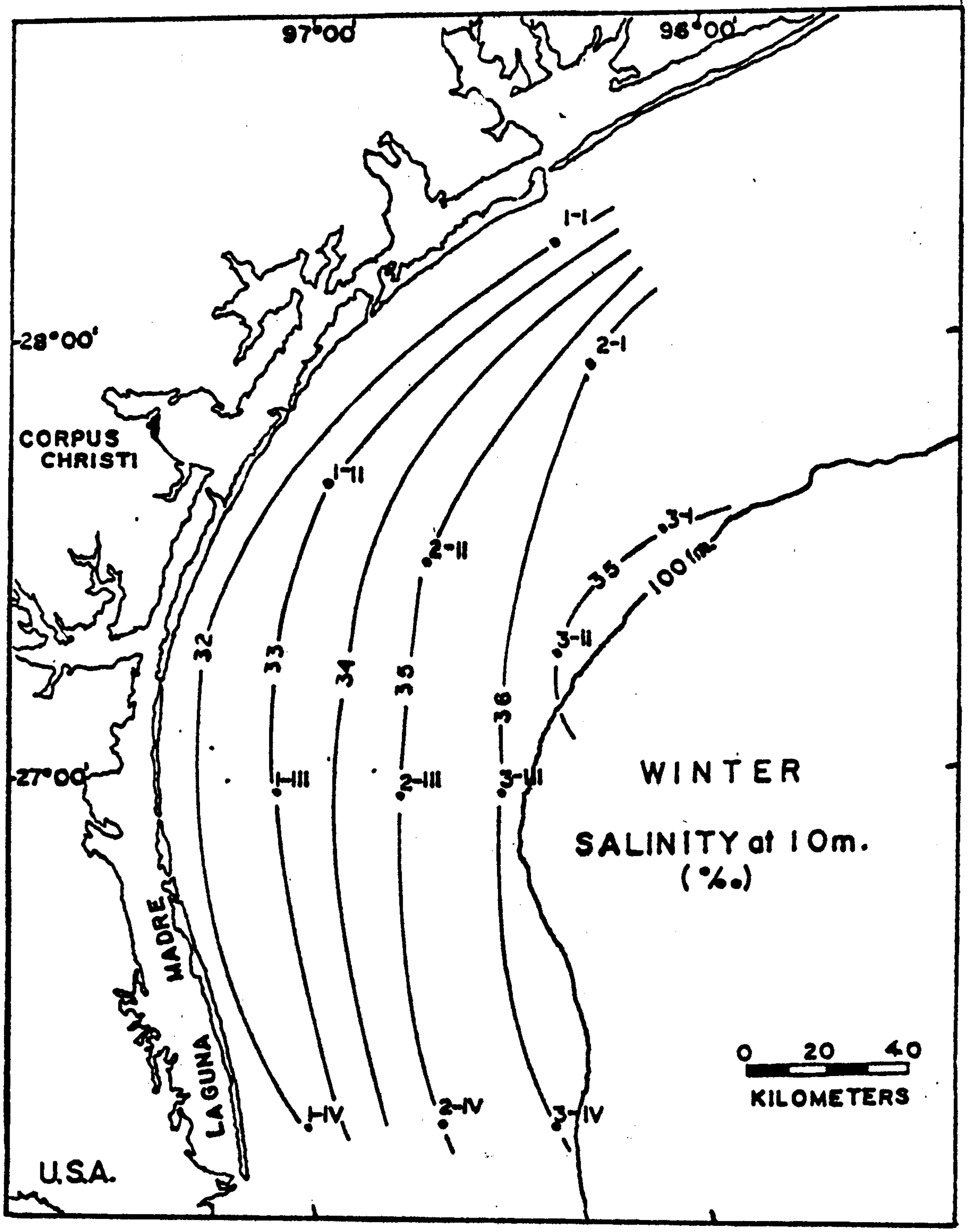


Figure 26. Winter salinities at 10 meters.

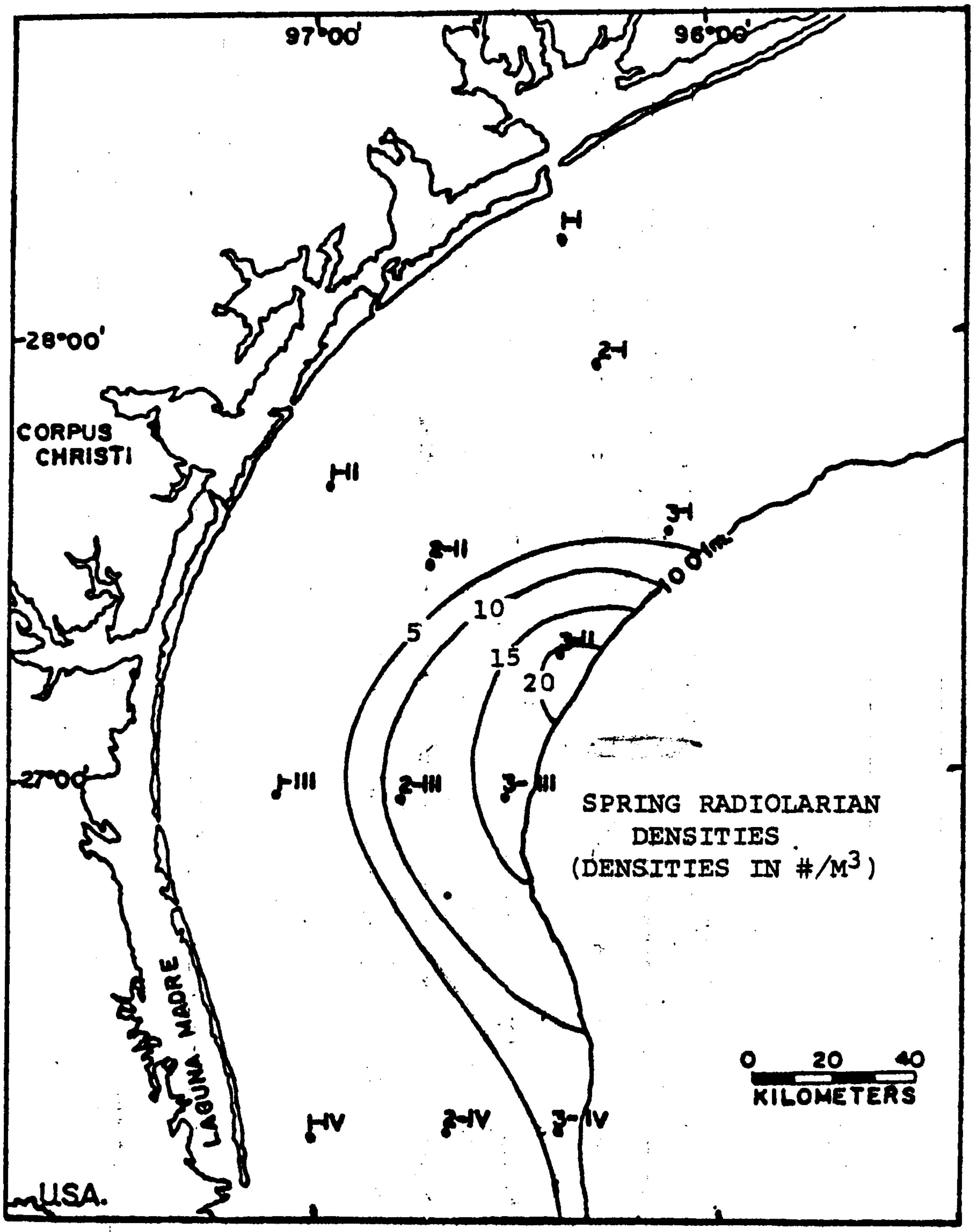
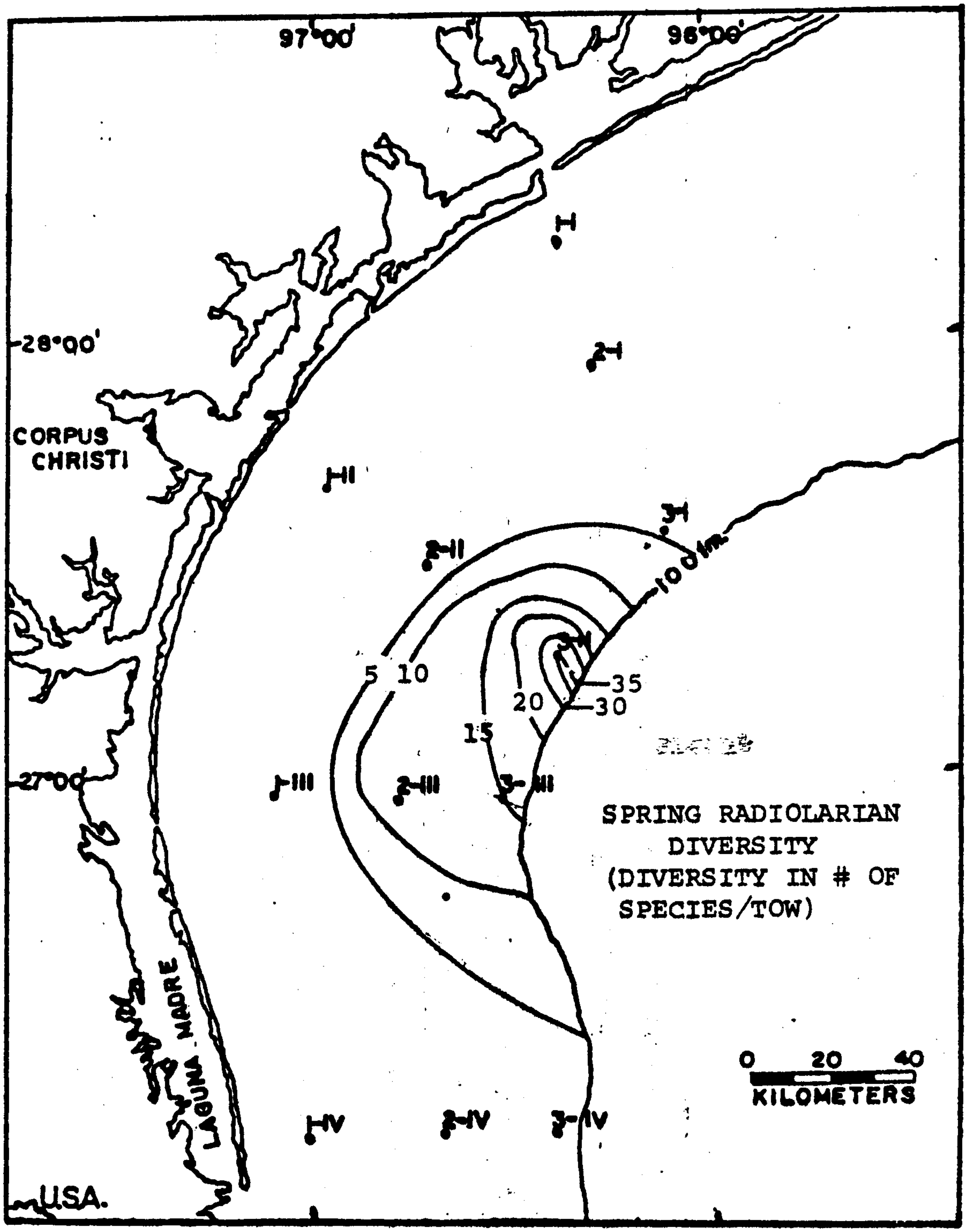


Figure 27. Spring radiolarian densities.



Spring 28. Spring radiolarians diversity.

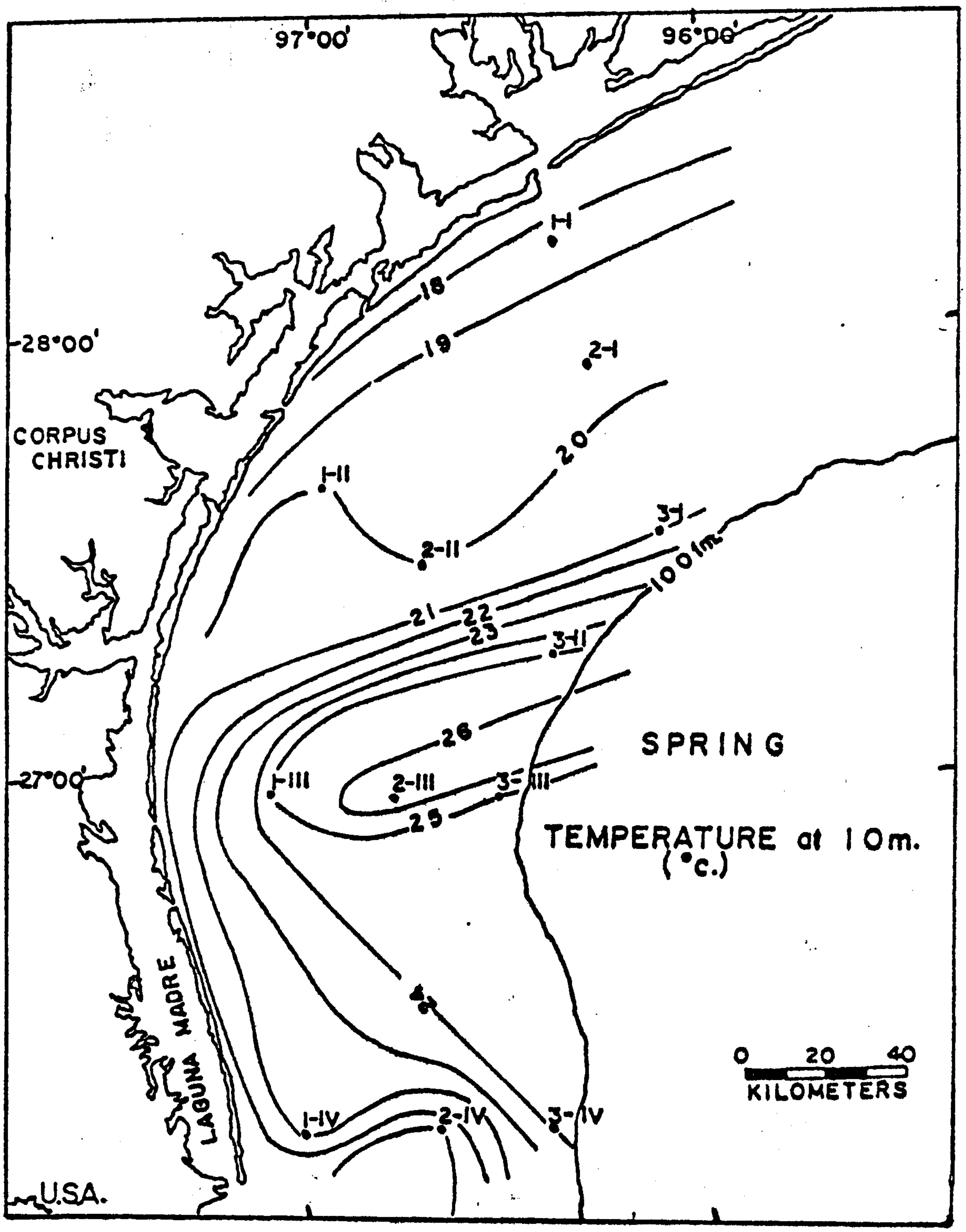


Figure 29. Spring temperatures at 10 meters.

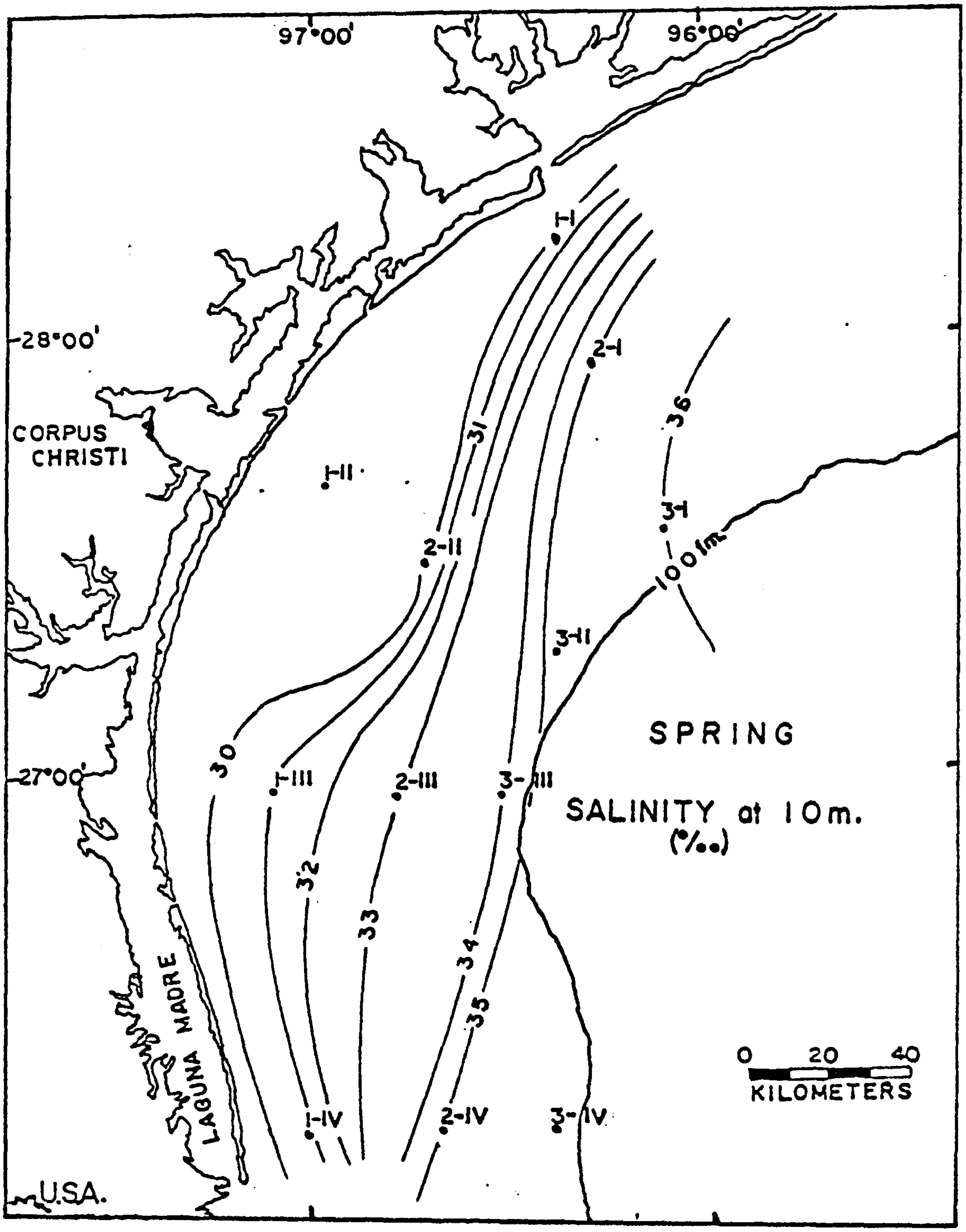


Figure 30. Spring salinities at 10 meters.

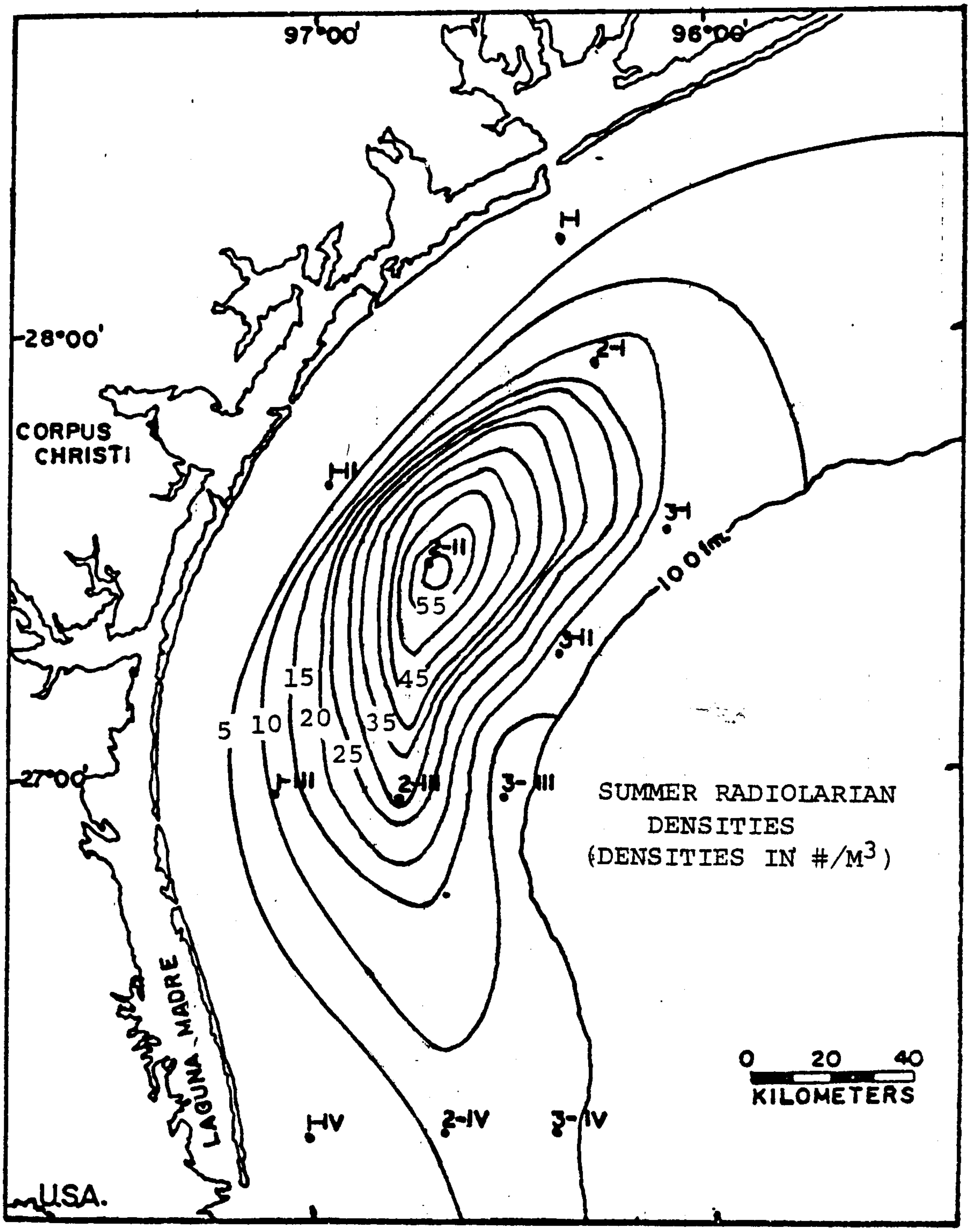


Figure 31. Summer radiolarian densities.

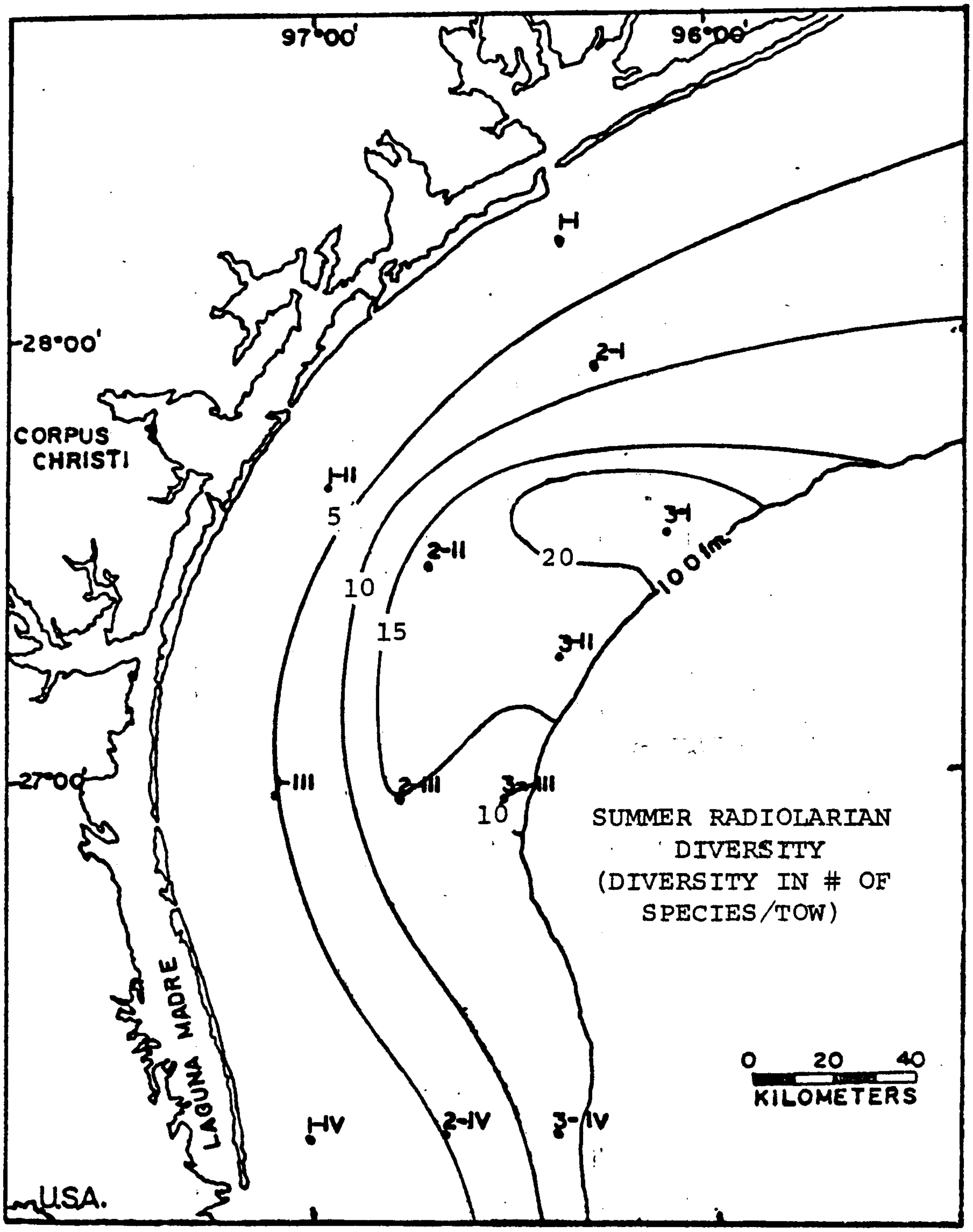


Figure 32. Summer radiolarian diversity.

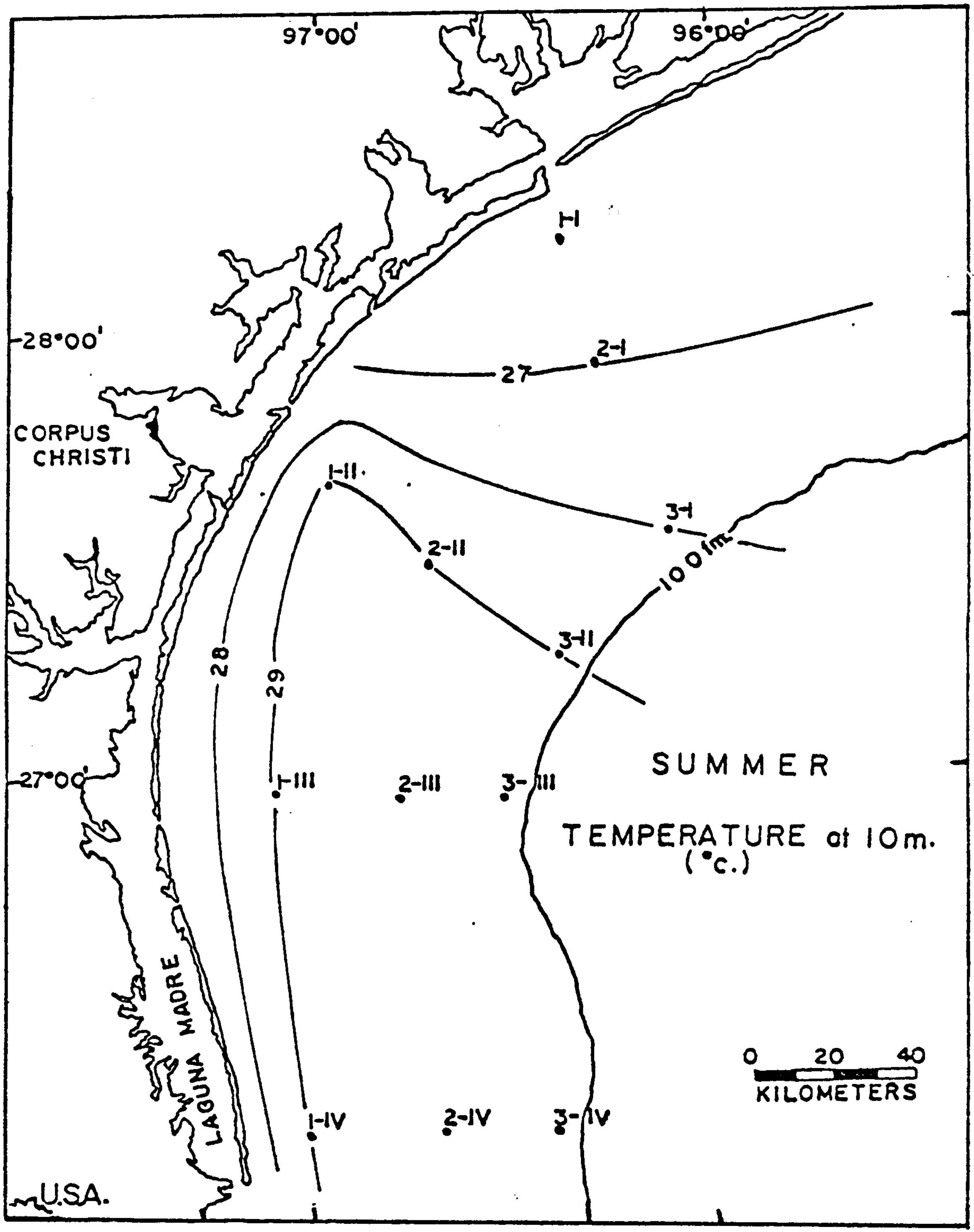


Figure 33. Summer temperatures at 10 meters.

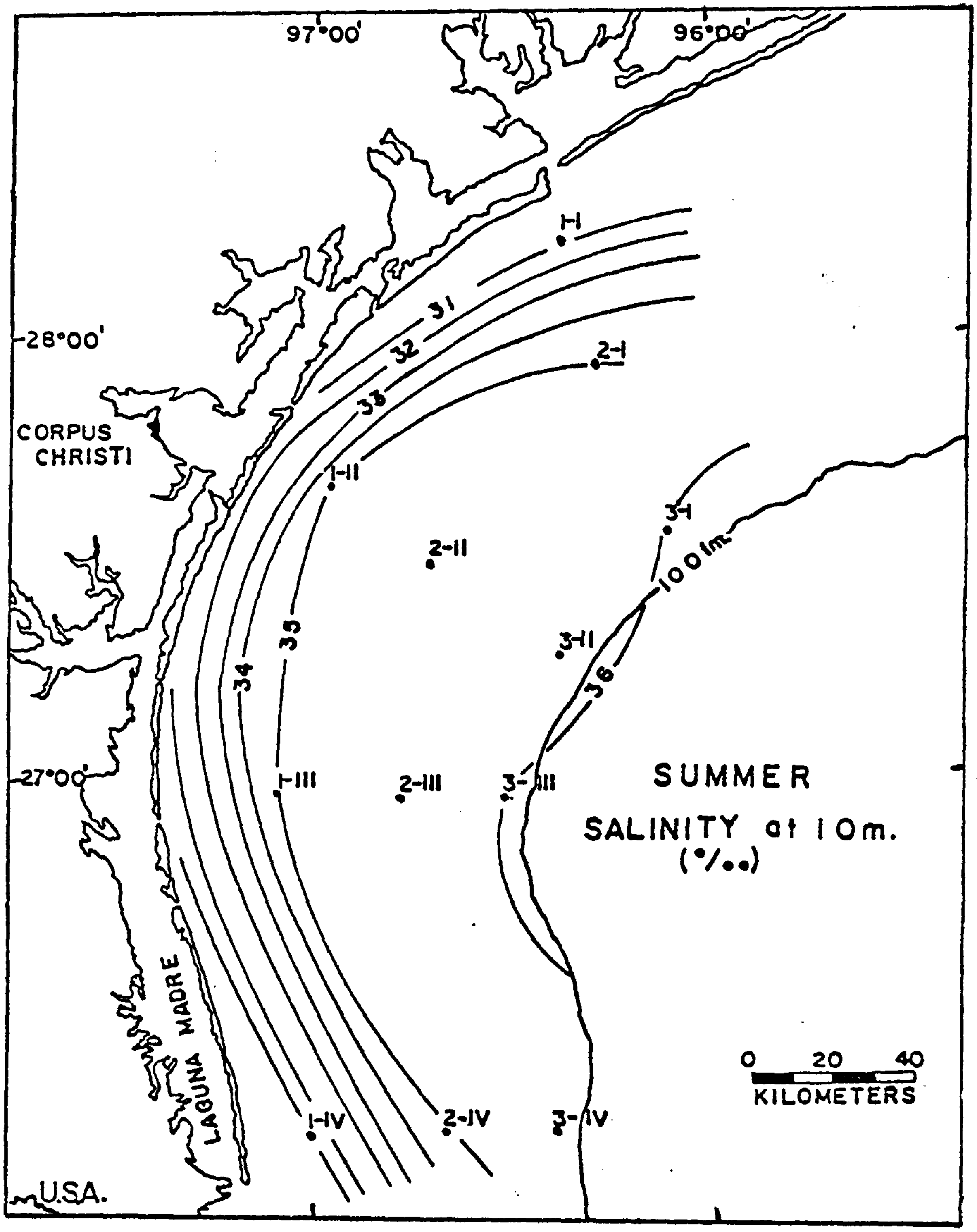


Figure 34. Summer salinities at 10 meters.

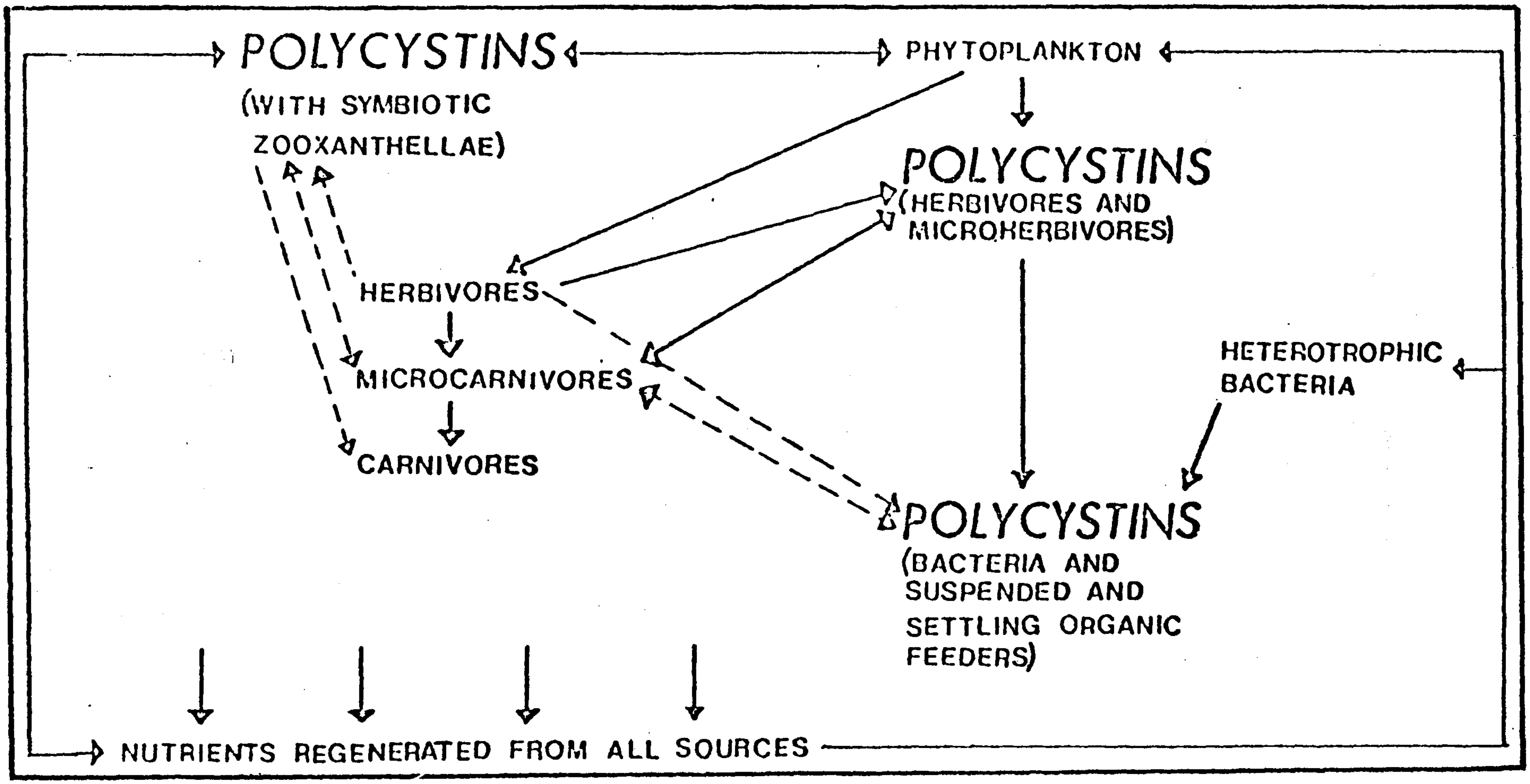


FIGURE 35. Probable niche of polycystin radiolarians. From Casey, in press a.

TABLE 1

OCCURRENCES OF LIVING BENTHONIC

FORAMINIFERA IN THE PLANKTON TOWS

WINTER '74

TRANSECT	I	IV	IV
STATION	3 ACL	2 BFQ	3 BOS
Depth (m)	117	47	91
Ammonia beccarii	0.9		0.8
Bolivina lowmani	1.5	1.4	0.8
Bolivina spinata	0.3		
Bolivina subaenariensis var. *mexicana*	0.6	0.8	
Cassidulina cf. *subglobosa*			0.8
Cassidulina curvata	0.6		
Cibicides concentricus	0.3	0.8	
?Eponides species			0.8
Eponides tumidulus			1.5
Marginulina species	0.3		
Neoeponides antillarum	0.3		
Nonionella basiloba	0.3		
Uvigerina auberiana var. *laevis*	0.3		
Uvigerina hispido-costata	0.6		

TABLE 1 CONT.

	3 ACL	2 BFQ	3 BOS
Uvigerina peregrina	0.8		
Valvulineria cf. araucana	0.3		

SPRING '75

TRANSECT	I	I	II	II	III	III	IV	IV
STATION	1	2	1	2	1	3	2	3
	CCP	CFT	CMD	CPH	CWR	DCF	DIO	DLW
Depth (m)	20	43	22	48	26	106	47	91
Bolivina lowmani	24.8	2.5	1.6	3.7	2.7			
Cassidulina cf. subglobosa		2.5						
Lagena spirata								0.4
Uvigerina peregrina						0.3	0.8	

SUMMER '75

TRANSECT	I	I	II	III	IV	IV	IV
STATION	1	3	2	1	1	2	3
	ECP	EIX	EPI	EWR	FFW	FIY	FMH
Depth (m)	18	42	49	25	27	47	91
Bolivina lowmani	39.3	0.3	9.4	2.8	1.3	4.5	0.8

TABLE 2

SELECTED SHELLED MICROZOOPLANKTONIC AND MICROZOOBENTHONIC INDICATORS OF ENVIRONMENTAL PARAMETERS STOCS

1. NEAR SHORE BENTHONIC ENVIRONMENT =
   (1) Ammonia beccarii and Brizalina lowmani (especially north part of study area).
   (2) Nonionella basiloba and Buliminella spp. (especially of south part of study area).

2. INDICATIVE OF BENTHONIC SEASONALITY =
   (1) Nonionella basiloba and Brizalina lowmani (dominate in winter).
   (2) Brizalina spinata and Buliminella, Cibicides and Fursenkoina (dominate in spring).

3. DEPTH INDICATORS OF BENTHONIC SHELF ENVIRONMENT =
   (1) Brizalina lowmani, Nonionella basiloba, Ammonia beccarii and Buliminella spp. (inner-shelf indices).
   (2) Fursenkoina (possible mid-shelf indices).
   (3) Uvigerina peregrina, Cibicides, Siphonina, Brizalina spinata and other Brizalina except for B. lowmani (outer-shelf indices).

4. UPWELLING INDICATORS IN WATERS OVER AND SHOREWARD OF SHELF BREAK =
   Conchasma sphaerulites, Conchoceras caudatum and Spongotrochus glacialis.

5. INDICATIVE OF SPRING "FRESH WATER" LENS =
   Bolivina (or Brizalina) lowmani and acantharian radiolarians.

6. INDICATIVE OF SEASONALITY IN WATER COLUMN =
   (1) Globigerina falconensis, Globigerina quinqueloba, Theopilium tricostatum, Spirocyrtis scalaris and Pterocanium praetextum eucolpum (winter).
   (2) Globigerina quinqueloba, acantharians and ? Anthocyrtidium ophiurensis (these are possible domianants for the spring).
   (3) Globigerinoides ruber, Globigerina bulloides, Lamprocyclas maritalis, Euchitonia elegans, Euchitonia furcata, Ommatartus tetrathalamus and Pterocanium praetextum praetextum (summer).

7. OFFSHORE INCURSIONS OF GULF WATER =
   High densities and diversities of radiolarians and planktonic foraminiferans.

8. INDICATIVE OF NEARSHORE WATER COLUMN =
   Hymeniastrum profundum, planktonic-benthonic foraminiferans and low radiolarian and planktonic foraminiferan densities and diversities.

TABLE 2 CONT.

9. INDICATIVE OF OFFSHORE WATER COLUMN =
Upwelling forms, high radiolarian and planktonic foraminiferan densities and diversities.

10. INDICATIVE OF CURRENT DIRECTION AND VELOCITY (STRENGTH)=
A bulge of the density or diversity contours of radiolarians or to a lesser extent planktonic foraminiferans (bulge points downcurrent), rapid decline in density or diversity downcurrent equals slow current, little decline in density or diversity downcurrent equals fast current.

11. INDICATIVE OF VOLUME OF UPWELLING =
Greater density of deeper species equals greater volume of upwelling.

12. INDICATIVE OF WATER MASSES =
Q-mode radiolarian and planktonic foraminiferan groups (clusters).

ZOOPLANKTON PROJECT

Texas A&M University
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INTRODUCTION

With little study done previously, or limited knowledge available in the literature on the zooplankton community of the South Texas continental shelf waters, the present study was conducted to gain a general picture of the community in terms of biomass, species composition and their relative abundance. The sampling was carried out by the Marine Science Laboratory of the University of Texas, and the preserved samples were shipped to us for analyses immediately after they were collected. The laboratory analyses involved the measurement of displacement volume, dry weight, and dry organic weight of zooplankton. Each component species was identified and counted.

In view of the primary objectives of the study, that is, the assessment of the overall picture of the zooplankton community, particular emphasis was placed on quantitative sampling of the entire water column in order to obtain representative samples of the whole community.

METHODS

Sampling

The study was based on a total of 144 zooplankton samples collected on the research vessel Longhorn during three seasonal sampling periods (December-January 1974, April-May 1975, and August-September 1975). A total of 12 stations, three on each of four transects, were sampled. Each station was occupied twice, once during the day and once at night, and two replicate samples were taken during each occupation, yielding four samples in each sampling period. The sampling data, which includes the sampling depth, date, and time of tow, are shown in Appendix VII.

Standard one-meter NITEX nets of 233 µm mesh size were used. A digital flowmeter (Model 2030, GENERAL OCEANICS) was mounted centrally in the mouth of the net in order to determine the amount of water filtered in each tow, and a time-depth recorder (Model 1170-250, BENTHOS) was attached close to the net to determine the maximum depth of sampling. The water column was sampled from the surface to near bottom by means of oblique tows of about 15 minutes duration. During the tow the ship speed was maintained constant at about 2.5 knots. As shown in Appendix VII, the amount of water filtered by the net in each tow varied between 87.0 and 1189.4 m^3. After the tow, the net was rinsed down using the deck hose. The contents of the cod-end were drained through a 100 μm NITEX net, transferred to a jar, and preserved with buffered formalin.

Sample Analysis

The samples were split by means of a Folsom plankton splitter to achieve adequate subsamples for archiving and analysis. The subsample size for biomass determination was adjusted to the capacity of the crucible to be used (50 ml). As the samples were variable in size, the subsample used for biomass determination ranged from a 1/64 to 1/4 aliquot depending on the original sample size (Appendix VII).

The displacement volume of each subsample was determined by the method of Yentsch and Hebard (1957). Large organisms, particularly jellyfish and their fragments, were removed before the volume determination, and returned to the subsample for the determination of dry weight and dry organic weight. Vacuum filtration was substituted for Yentsch and Hebard's method of blowing the water through the filter. A constant vacuum pressure of about 15" Hg was generally maintained until water droplets ceased to form on the side of the filtration crucible. After measuring the displacement volume by filling up the filtration crucible with fresh water, the subsample was drained again by vacuum filtration and dried in the same crucible to a constant weight at 55°C in an oven.

After determining the dry weight, the subsample was ashed in a muffle furnace at 550°C to obtain the ash weight of the subsample. The crucibles used were 50 ml PYREX glass crucibles with fritted discs of 40-60 μm pore size.

The size of subsample examined for species and their abundance varied between 1/4096 and 1/64, and the number of zooplankters found in the subsamples varied from 660 to 5405 (Appendix VIII). Each subsample was sorted into major taxonomic components which were placed in separate dishes for further taxonomic and quantitative analysis. The copepods were most intensively studied. They were first separated into the three suborders (Calanoida, Cyclopoida, and Harpacticoida) and then each suborder into adult females, males, and immature forms. All adult female copepods were identified to the species level, and their numbers were recorded for each species.

In addition to the subsamples mentioned above, a large portion of the remaining sample (usually a half of the original sample) was examined in a Bogorov plankton sorting tray for copepod species that were not represented in the subsample.

Species Diversity and Equitability

The species diversity index was calculated for each sample on the basis of adult female copepods according to the Shannon-Weaver function. The coefficient of equitability was calculated for each sample using two different formulas as shown below:

a. $E = \frac{S'}{S}$

Where S = number of species found in the subsample

S' = hypothetical species number for a given species diversity (Lloyd and Ghelardi, 1964).

b. $E = \dfrac{H(S)}{H_{max}(S)}$

Where $H(S)$ = observed species diversity

$H_{max}(S) = \log_2 S$ (Maximum species diversity for a given S)

RESULTS AND DISCUSSION

Biomass

The zooplankton biomass in terms of displacement volume, dry weight, and dry organic weight per m^3 of water filtered varied considerably from station to station and from season to season. Even two replicate samples taken at the same station sometimes differed in quantity to such an extent that the larger was almost twice as much as the smaller (Appendix VII). The displacement volumes of the 48 samples collected in each sampling period, for example, varied from 36.2 to 360.9 $\mu l/m^3$ in December-January, from 34.3 to 702.0 $\mu l/m^3$ in April-May, and from 37.1 to 524.1 $\mu l/m^3$ in August-September. In all transects, biomass per m^3 showed a consistent increase from the deep to shallow stations (Figure 1), and the increase was particularly steep in the spring and summer months when the zooplankton production was high at the shallow stations. Averaged over the three sampling periods, the zooplankton biomass was the highest at Station 1/I and of the four transects, Transect III had the lowest value (Figure 1-4).

Numerical abundance of Zooplankton

The number of zooplankters per m^3 of water filtered was closely proportional to the biomass and varied from 166 to 10840 (Appendix IX). As in the biomass distribution, the numerical abundance of zooplankton showed a marked increase from the deep to shallow stations. The increase was highly pronounced on Transect 1 in the April-May sampling period when the zooplankton concentration at station 1 was extremely high (Figure 2-2).

In all samples the Copepoda were the most abundant group, comprising approximately 70% of the zooplankton by number. The relative abundance of the Copepoda is indicated in Figure 2 by the shaded portion of the circle which represents the total zooplankton. As depicted in the figures, the relative abundance of the Copepoda was slightly lower in the spring and summer months than in the winter, and this decrease was mainly due to the relative increase of larvae of the other invertebrates.

Other than the Copepoda, the more abundant groups were the Ostracoda, Mollusca, Chaetognatha, and Larvacea (Appendices IX & X). Composed mainly of veliger larvae, the Mollusca were most abundant at shallow stations. The Chaetognatha and Larvacea occurred quite regularly throughout the study area in all sampling periods and did not show any conspicuous variations in their spatial and temporal distribution.

The Ostracoda, however, showed a highly regionalized spatial distribution; that is, the highest number was consistently found at stations of intermediate depths, and their highest concentration shifted south as the seasons progressed from winter through to autumn (Figure 4). When all the samples were considered, station 2/IV, had the highest number of ostracods. The species composition of the Ostracoda was also highly characteristic with a single species (Euconchoecia chierchiae) predominating to such an extent as to comprise all ostracods.

Numerical Abundance of Copepods

The number of copepods, including all developmental stages, varied from 156.8 to 9745.2/m^3. When the mean of the four samples from each station is considered, the quantitative distribution of copepods was closely related to that of the total zooplankton or biomass; that is, the number of copepods per m^3 of water decreased consistently from the shallow to deep stations with the highest annual mean at station 1/I, (Figure 3).

The most abundant suborder of copepods was the Calanoida, followed by the Cyclopoida and Harpacticoida (Appendices XI & XII). Except for the Harpacticoida, the developmental stages were abundant throughout the year, comprising nearly 50% in the Calanoida and about 20% in the Cyclopoida. A total of 182 species of copepods were identified which consisted of 118 species of calanoids, 52 species of cyclopoids, and 7 species of harpacticoids (Appendix XIII).

By identifying and counting all adult female copepods in the subsample, the numerical abundance of each copepod species per m^3 was determined (Appendix XIV). Contrary to the trend of numerical abundances, the number of copepod species increased considerably from the shallow to the deep stations (Appendix XV).

The most abundant species were *Paracalanus indicus*, *Paracalanus quasimoto*, and *Clausocalanus furcatus*. As shown in Figures 5 and 6, *Paracalanus indicus* and *P. quasimoto* increased shoreward in their abundance while *Clausocalanus furcatus* increased seaward. *Acartia tonsa*, an estuarine or near shore species, was an important component at the shallow stations. The highest zooplankton concentration observed during the study (station 1/I, in April-May) was mainly due to the increase of *Acartia tonsa*.

Species Diversity

Species diversity indices based on adult female copepods and coefficients of equitability calculated from these diversity indices are presented in Appendix XVI. When the average value of the four samples from each station was considered, the species diversity indices generally increased from the shallow to deep stations in conformity to the number of species (Figure 7). The coefficients of equitability calculated from these species diversity indices, however, did not show such a regular trend.

The coefficient of equitability (E) will have a maximum value of 1.0 when MacArthur's model (MacArthur, 1957) is perfectly obeyed. The values of E obtained in this study are obviously too low to be interpreted as being close to the theoretical model. However, the values seem to indicate that the copepod community in this area is rather unstable and poorly organized, as are those of any neritic waters.

Interrelationship between Zooplankton
and other Biological and Physical Parameters

Data for physical and biological parameters measured at the time of zooplankton collections and presented by other investigators in the final report have been examined for possible relationships to the zooplankton. Of all environmental parameters presented in the final report, the temperature, salinity and chlorophyll a seemed to have readily discernable relationships to the zooplankton. In the discussion below only the surface values of these parameters are considered for simplicity.

When the data for all twelve stations are considered as mean values for the three seasonal sampling periods (Table 1), certain relationships of the zooplankton to the chlorophyll a, salinity and temperature are suggested. The most pronounced change in the parameters under consideration occurred between the winter and spring collections. Notably, a three fold increase in chlorophyll a coincided with a 1.7 fold increase in zooplankton biomass in terms of ash-free dry weight and a 1.4 fold increase in the number of zooplankters. An increase of the copepod Acartia tonsa (an estuarine species) by 27.6 times during the same period was accompanied by a decrease in salinity, and this relation was particularly pronounced when only the shore stations of transect I and II were considered. On the other hand the copepod Clausocalanus furcatus, a typically oceanic species, showed a marked decline. Data reported from the summer samples showed a decrease in chlorophyll a to only 28% of the spring value or to a level 17% below that of the winter samples. Salinity increased to a level just below that of the winter cruise, and the temperature increased to the highest value. Coincident changes in the zooplankton included a 15% decline in the biomass, a 20% decrease in the number of zooplankters, and the almost complete disappearance of Acartia tonsa. The numerical abundance of ostracods, however, showed a steady increase, and Paracalanus parvus group (the most common copepod species) showed a gradual decline with season. The average number of copepod species found in a sample also showed a gradual decline with season. The species diversity indices and the coefficients of equitability showed no obvious seasonal trend.

When the data for all four transects are grouped by station and averaged for the entire year (Table 2), the annual mean value for chlorophyll a was highest at station 1 (3.11 ug/m^3), decreased at station 2 (o.81 ug/m^3) and was lowest at station 3 (0.36 ug/m^3). Conversely, salinity increased from station 1 to 3 with annual means of 30.4, 34.9, and 35.3 respectively, and temperatures increased by increments of 1°C from 22.6°C at station 1 to 24.6°C at station 3. Associated changes in the zooplankton included seaward reduction in biomass and numerical abundance of total zooplankton and copepods, which were almost proportional to the decline in chlorophyll a. The number of copepod species increased by 14 to 16 species per station from station 1 to 3. The copepods, *Acartia tonsa* and *Paracalanus parvus* group, decreased from over 200 per m^3 at station 1 to fewer than 10 per m^3 at station 3. Some measurements of the zooplankton, however, did not show patterns of change on an annual basis which suggest relationships to the physical and biological parameters under study; for instance, the mean number of ostracods, which was greatest at station 2.

When the data are grouped by transect for the entire year (Table 3), some consistent differences are evident among the transects. The values for chlorophyll *a* were more than two times higher on transects I and II than transects III and IV. The zooplankton abundance in terms of biomass and number were highest on transect I and lowest on transect III. However, the temperature and salinity were highest on transect III indicating a strong influence of the oceanic water. This situation was clearly reflected in the copepod distribution; that is, *Clausocalanus furcatus*, a typical oceanic species, was most abundant on this transect. *Acartia tonsa* was most abundant on transect I and the Ostracoda were most abundant on transect IV.

Linear regression of chlorophyll *a* and salinity data against measurements of the zooplankton resulted in coefficients of correlation (Table 4) which support many of the relationships suggested by inspection of the data. Changes in ash-free dry weight, the number of zooplankton and the number of copepods per m^3 correlate better with salinity than chlorophyll *a*. However, these results may be misleading. The greatest fluctuations in salinity occurred at station 1 and were caused by spring time dilutions from nutrient rich land drainage which support phytoplankton blooms and thus provide a base for many food webs in the zooplankton. Regression analysis shows a better fit between the number of copepod species and salinity than between species and chlorophyll a. Changes in the copepods Acartia tonsa and Paracalanus parvus group show a strong relationship with chlorophyll a. Clausocalanus furcatus, an oceanic species, however, does not show such relationship.

SUMMARY

On the basis of 144 samples collected during three seasons, the zooplankton of the South Texas continental shelf waters was investigated to determine its abundance and species composition. The zooplankton abundance in terms of biomass and number showed a consistent decrease seaward, and this decrease was particularly pronounced in the spring and summer months when the zooplankton production was high at the shallow stations. The seasonal change of the zooplankton in both biomass and species composition was progressively extensive from the deep to shallow stations. Copepods were the most abundant group, comprising about 70% of the zooplankton by number. A total of 182 species of copepods were found, of which Paracalanus indicus, Paracalanus quasimoto, and Clausocalanus furcatus were most abundant. The species diversity indices based on adult female copepods showed a consistent increase seaward in conformity to the number of species found. The coefficients of equitability, however, did not show such a regular trend.

TABLE 1

MEAN VALUES OF CERTAIN ZOOPLANKTON

AND OTHER ENVIRONMENTAL DATA

BY SAMPLING PERIOD FOR ENTIRE STUDY AREA

Season	Dec-Jan	Apr-May	Aug-Sep
Chlorophyll *a* (mg/m^3)	0.89	2.68	0.74
Salinity (ppt)	34.7	32.5	33.8
Temperature (C°)	20.2	22.5	28.1
Ash-Free Dry Wt. (mg/m^3)	15.3	25.2	21.3
No. of Zoopl. per m^3	1438.3	2023.8	1613.2
No. of Copepod Species	35.1	30.6	28.3
No. of Copepods per m^3	1163.7	1376.6	971.1
Copepod % of Zoopl.	77.9	65.4	66.1
No. of *Acartia tonsa* ♀♀/m^3	8.5	234.7	1.6
No. of *Paracalanus parvus* ♀♀/m^3	127.5	107.9	62.1
No. of *Clausocalanus furcatus* ♀♀/m^3	99.0	16.5	90.0
No. of Ostracods /m^3	123.0	155.0	259.2
Species Diversity			
Index (H)	3.1872	3.2578	3.1286
$E=\frac{H(S)}{H_{Max}(S)}$	0.6226	0.6777	0.6584

TABLE 2

ANNUAL MEAN VALUES OF CERTAIN ZOOPLANKTON

AND OTHER ENVIRONMENTAL DATA

BY STATION FOR ENTIRE STUDY AREA

Station	1	2	3
Chlorophyll a (mg/m^3)	3.11	0.81	0.36
Salinity (ppt)	30.4	34.9	35.3
Temperature (°C)	22.6	23.6	24.6
Ash-Free Dry Wt. (mg/m^3)	35.1	17.6	9.2
No. of Zoopl. per m^3	2757.3	1558.5	759.6
No. of Copepod Species	17.6	30.1	46.4
No. of Copepods per m^3	2146.3	830.7	534.5
Copepod % of Zoopl.	75.7	63.7	70.0
No. of *Acartia tonsa* ♀♀$/m^3$	236.15	8.3	0.4
No. of *Paracalanus parvus* group ♀♀$/m^3$	228.2	66.8	8.4
No. of *Clausocalanus furcatus* ♀♀ $/m^3$	14.0	104.8	86.7
No. of Ostracods $/m^3$	59.4	392.55	85.2
Species Diversity			
Index (H)	2.5421	3.2497	3.7797
$E=\frac{H(S)}{H_{Max(S)}}$	0.6160	0.6712	0.6715

TABLE 3

ANNUAL MEAN VALUES OF CERTAIN ZOOPLANKTON

AND OTHER ENVIRONMENTAL DATA BY TRANSECT

Transect	I	II	III	IV
Chlorophyll a (mg/m^3)	2.00	2.15	0.80	0.76
Salinity (ppt)	32.9	33.4	34.2	33.7
Temperature (°C)	22.4	23.4	24.7	23.8
Ash-Free Dry Wt. (mg/m^3)	26.1	19.7	16.5	20.2
No. of Zoopl. per m^3	1929.6	1809.0	1412.4	1616.2
No. of Copepod Species	31.3	33.4	31.0	29.7
No. of Copepods per m^3	1493.2	1187.4	1065.0	936.3
Copepod % of Zoopl.	70.7	69.2	73.5	65.2
No. of *Acartia tonsa* ♀♀/m^3	305.9	8.1	8.2	4.3
No. of *Paracalanus parvus* group ♀♀/m^3	77.9	164.0	58.5	103.9
No. of *Clausocalanus furcatus* ♀♀/m^3	37.3	69.9	106.2	60.5
No. of Ostracods /m^3	90.5	157.7	123.3	350.7
Species diversity				
Index (H)	3.1346	3.1140	3.2726	3.2407
$E=\frac{H(S)}{H_{Max}(S)}$	0.6422	0.6123	0.6775	0.6796

TABLE 4

CORRELATION COEFFICIENTS OF LINEAR REGRESSION OF SALINITY AND CHLOROPHYLL *a* DATA AGAINST CERTAIN MEASUREMENTS OF ZOOPLANKTON

	Chlorophyll *a*	Salinity
Ash-Free Dry Wt.	0.6243	0.7628
No. of Zoopl. per m^3	0.7454	0.7586
No. of Copepods per m^3	0.7143	0.7226
No. of Copepod Species	0.4667	0.7114
No. of *Acartia tonsa* ♀♀/m^3	0.6279	-0.5785
No. of *Paracalanus parvus* group ♀♀/m^3	0.6530	-0.5953
No. of *Clausocalanus furcatus* ♀♀/m^3	-0.2897	0.5405
No. of Ostracods /m^3	0.1997	0.2408

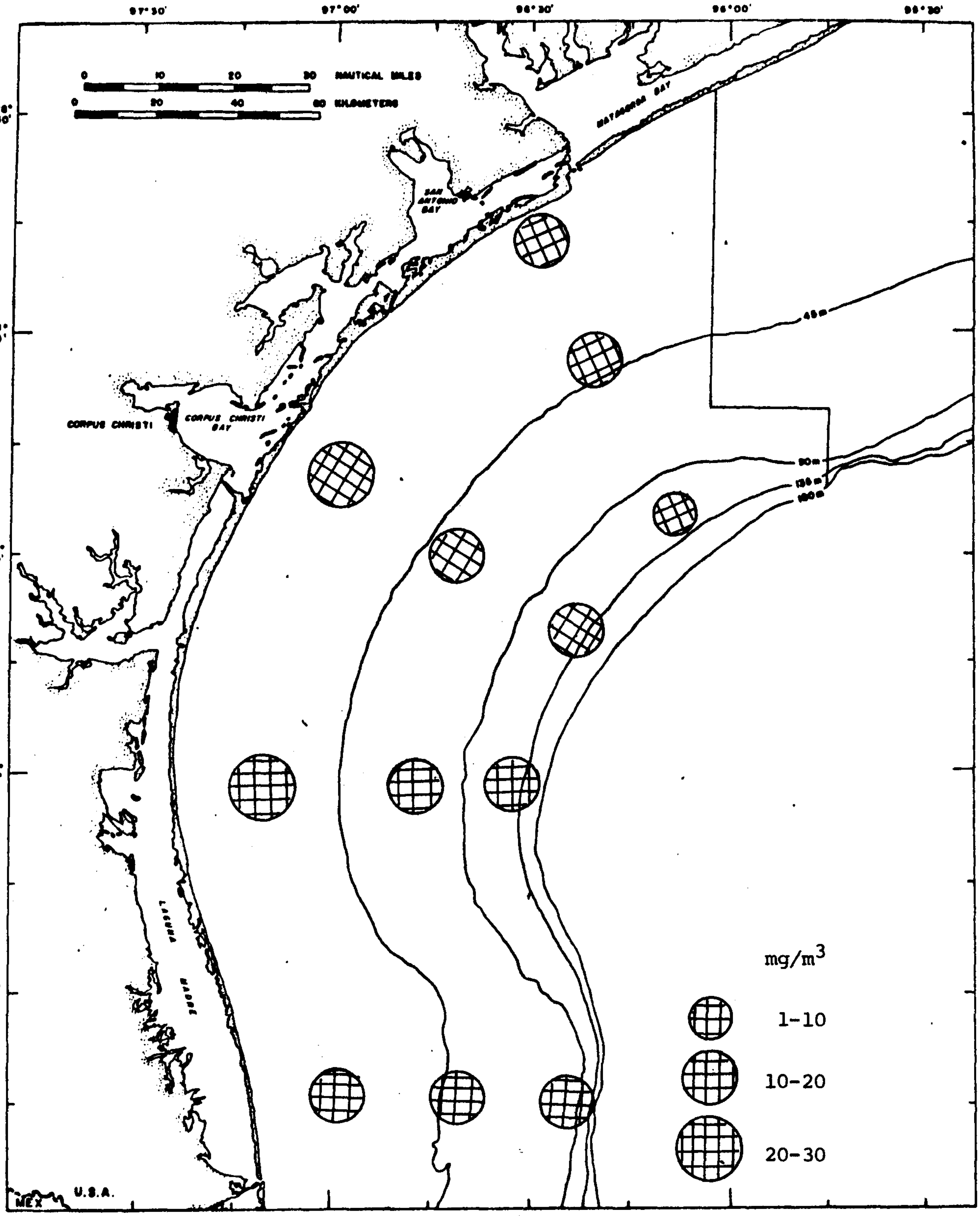

Figure 1-1. Average value of ash-free dry weight at each station, December - January.

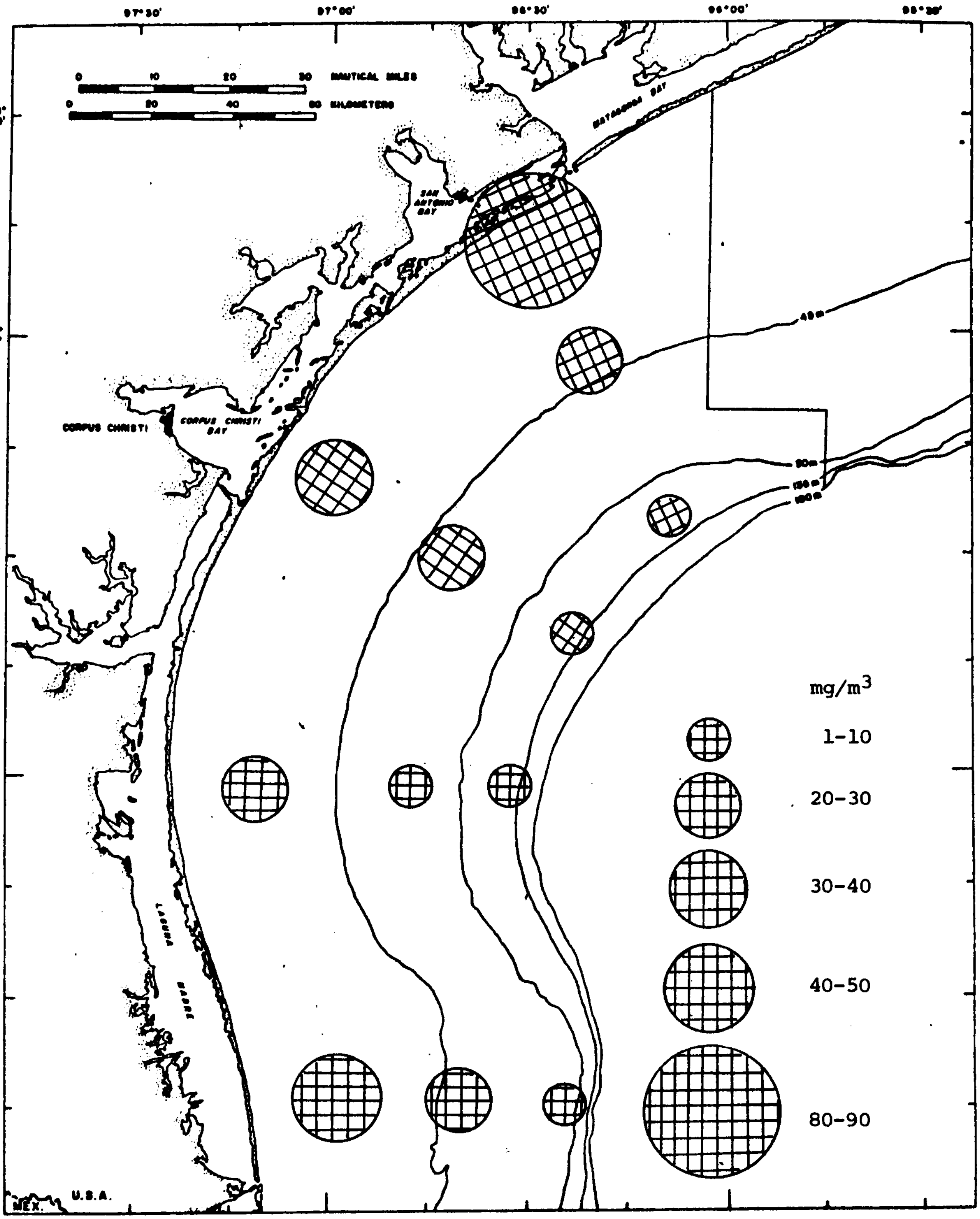

Figure 1-2, Average value of ash-free dry weight at each station, April - May.

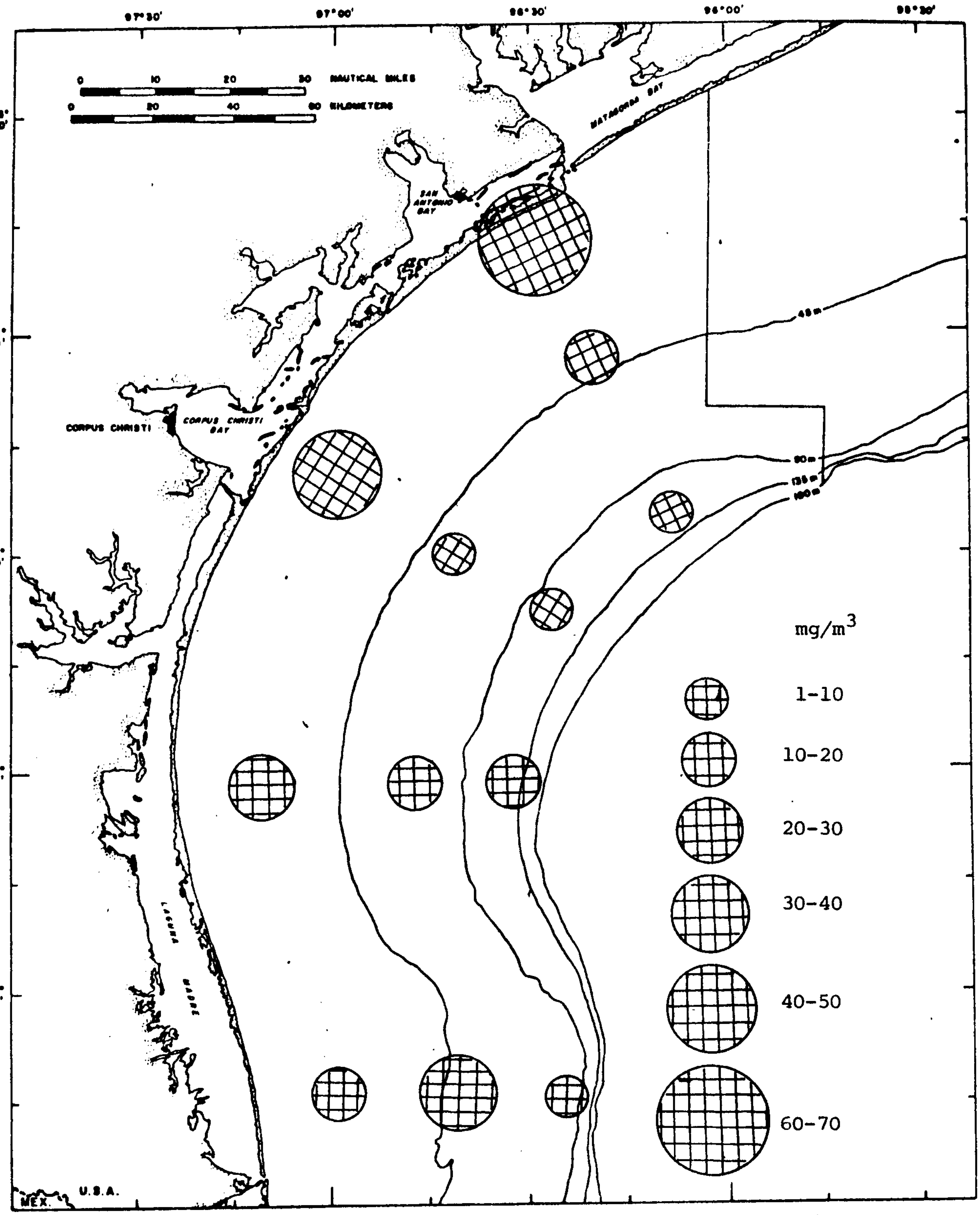

Figure 1-3. Average value of ash-free dry weight at each station, August - September.

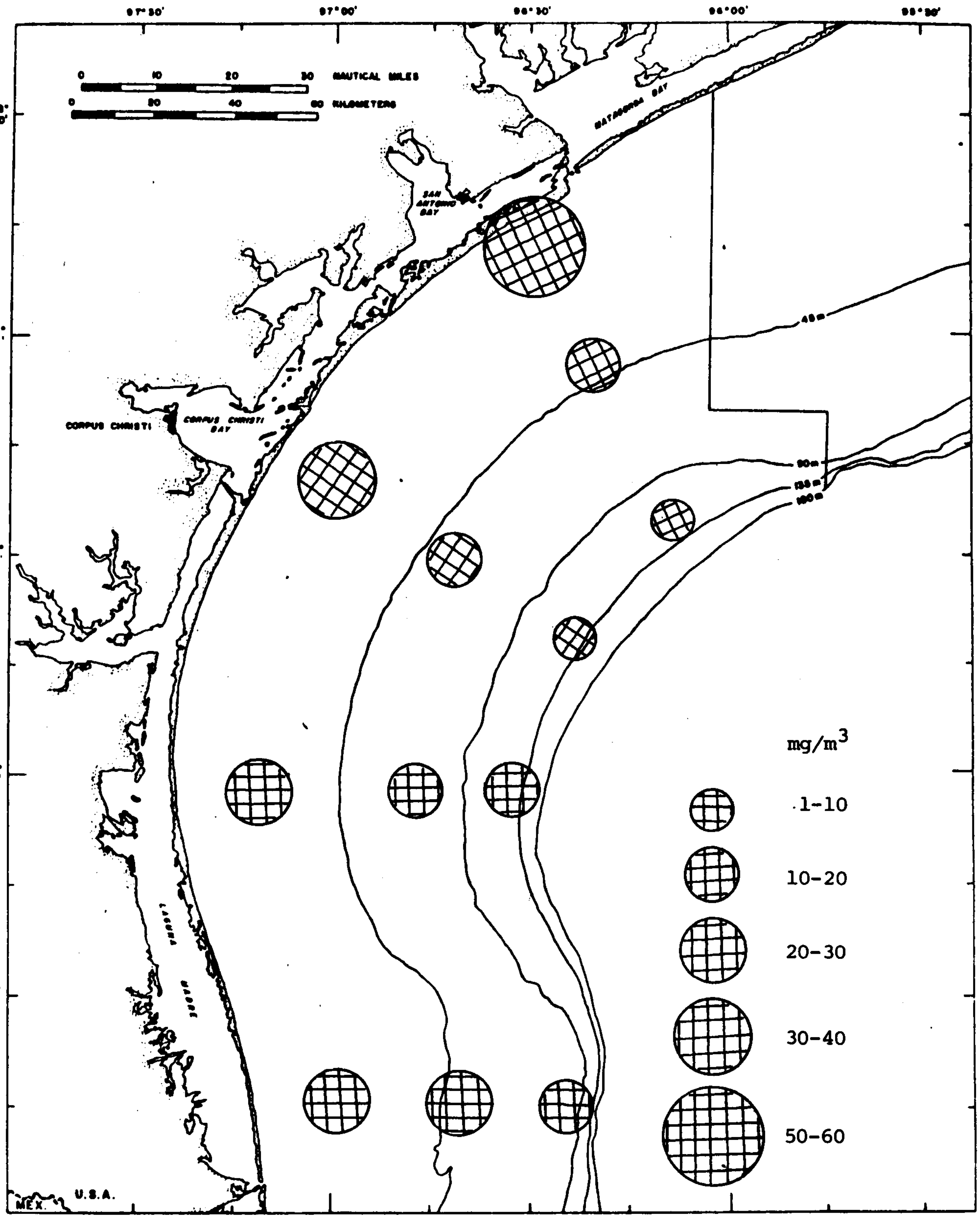

Figure 1-4. Annual mean of ash-free dry weight at each station.

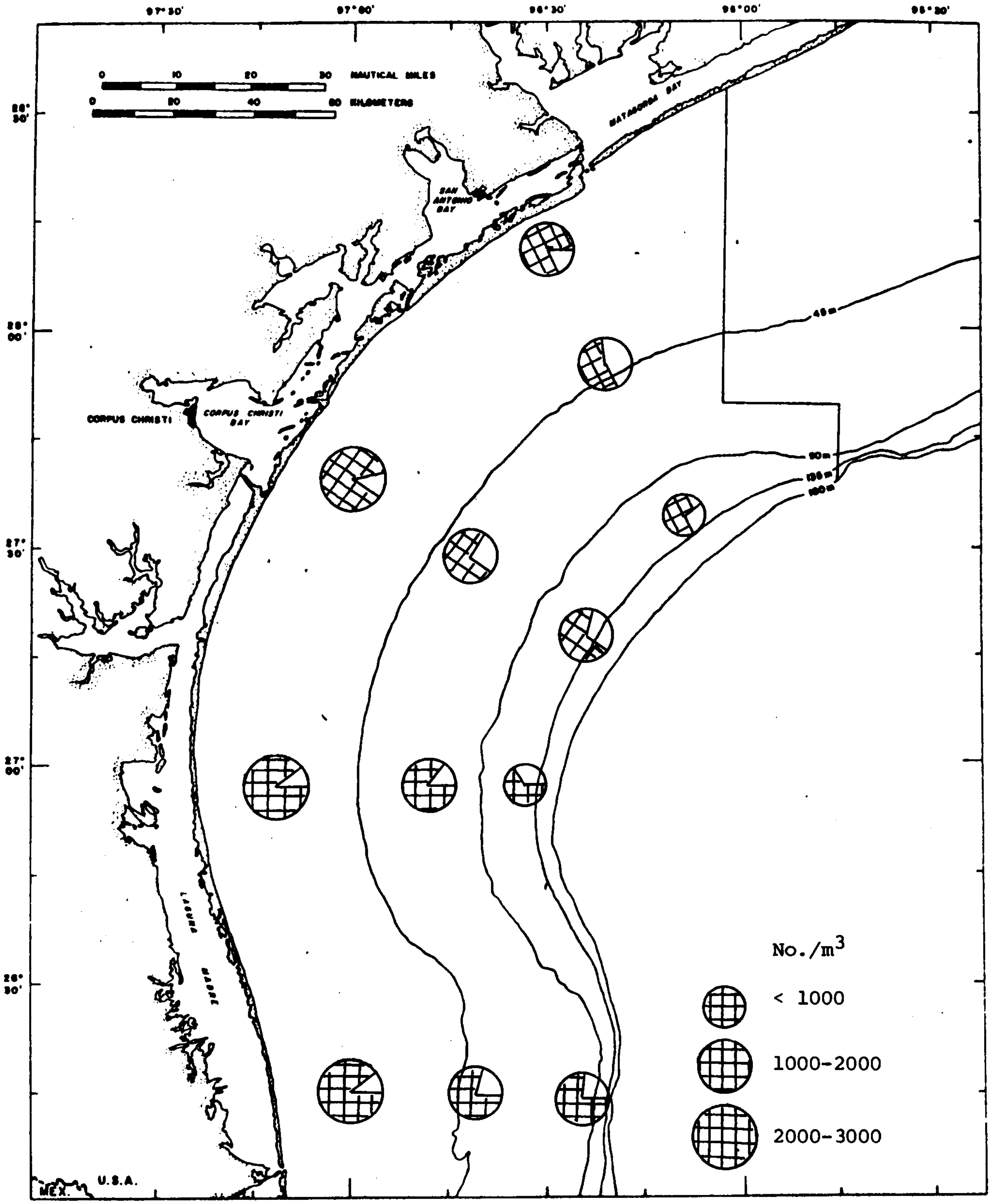

Figure 2-1. Average numerical abundance of zooplankton and proportion of copepods (shaded), December - January.

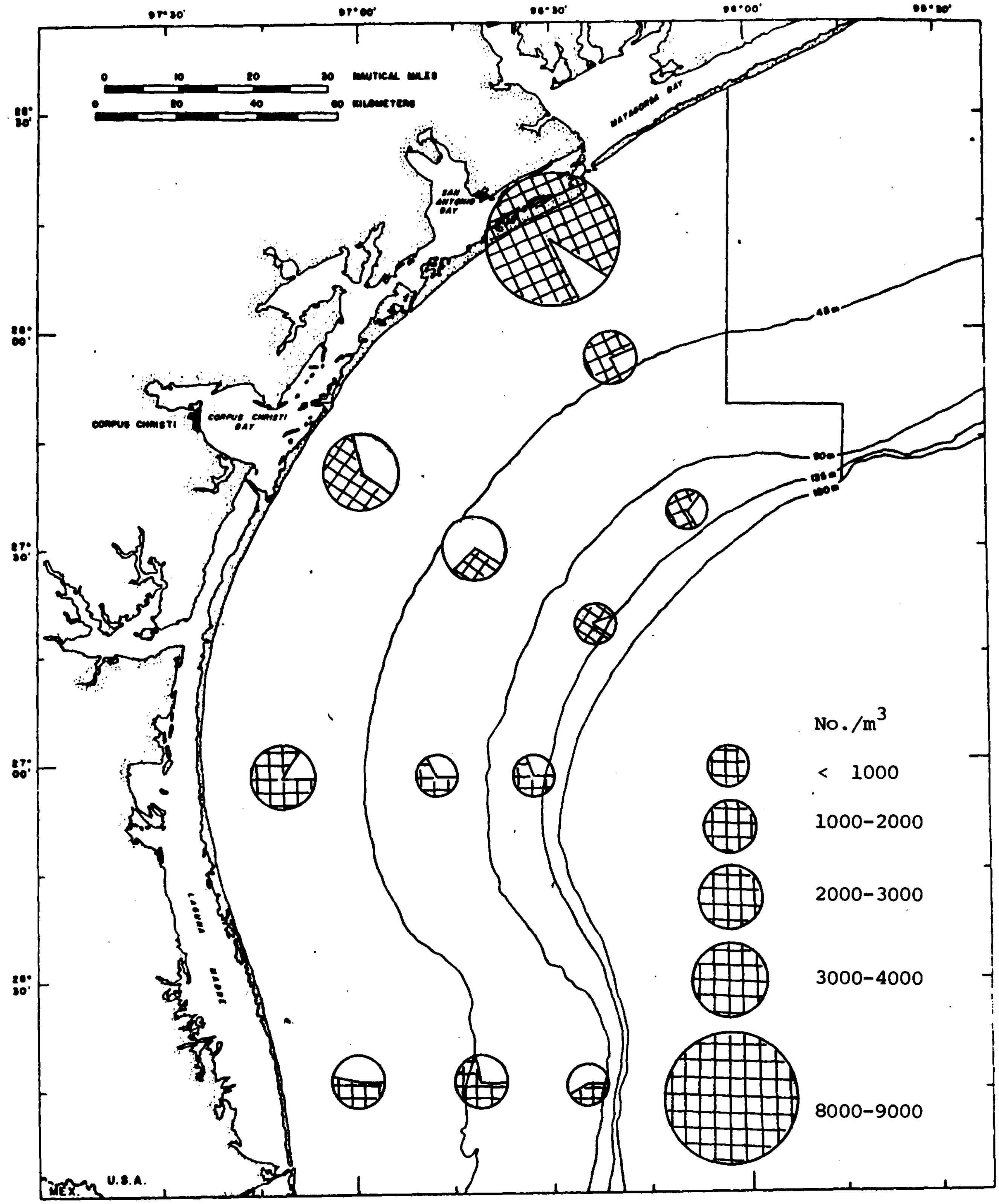

Figure 2-2. Average numerical abundance of zooplankton and proportion of copepods (shaded), April - May.

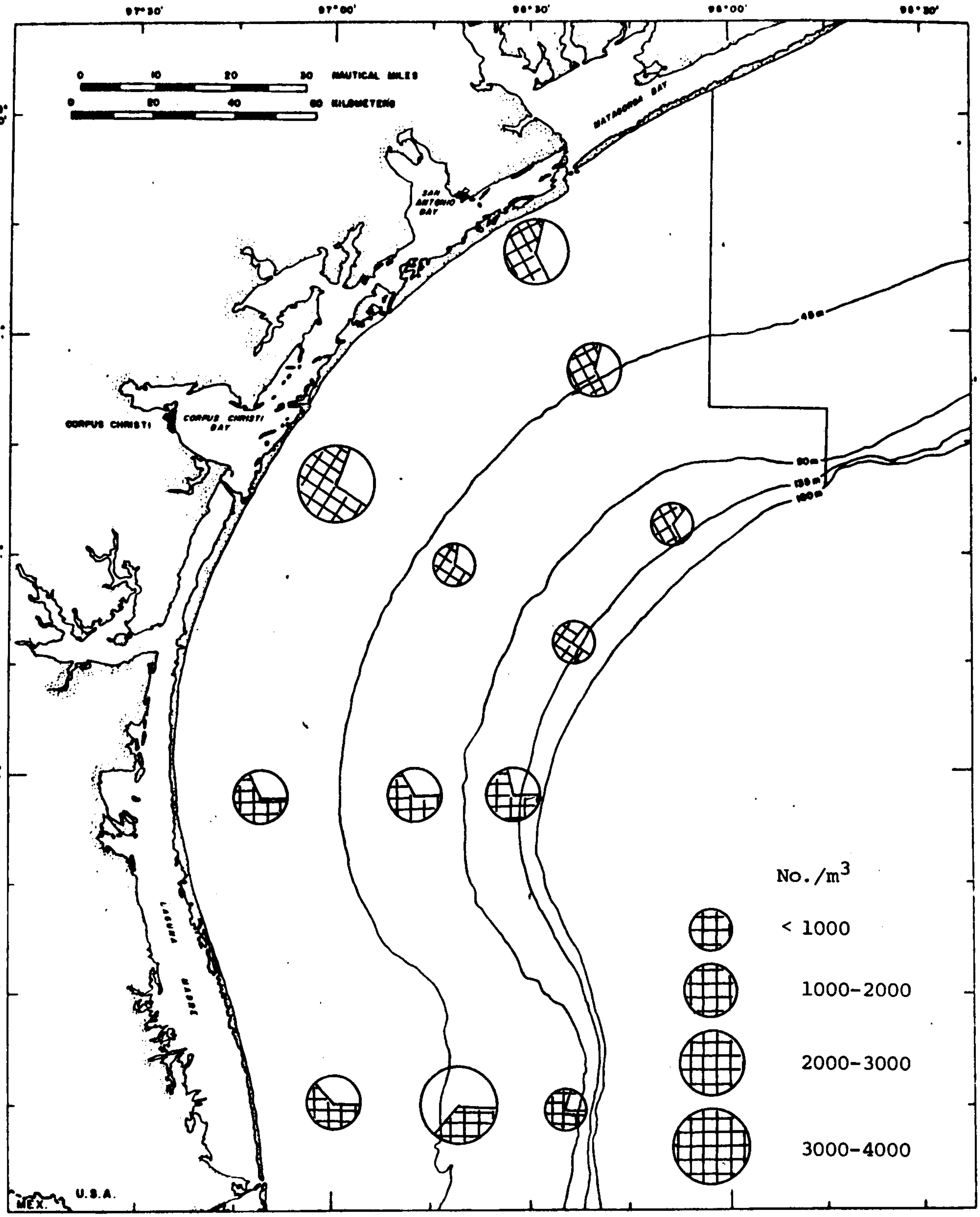

Figure 2-3. Average numerical abundance of zooplankton and proportion of Copepods (shaded), August - September.

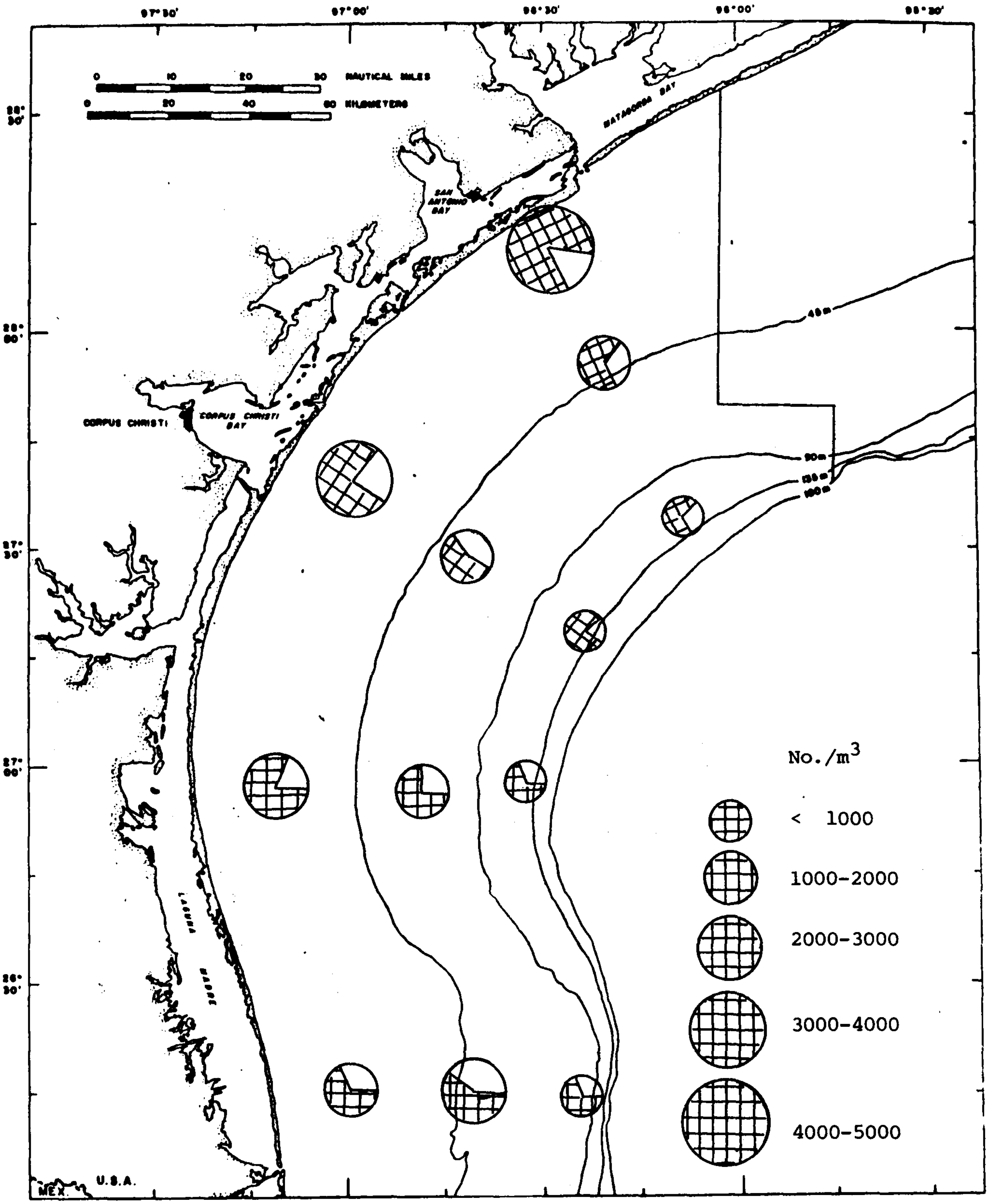

Figure 2-4. Annual mean of numerical abundance of zooplankton and proportion of copepods (shaded).

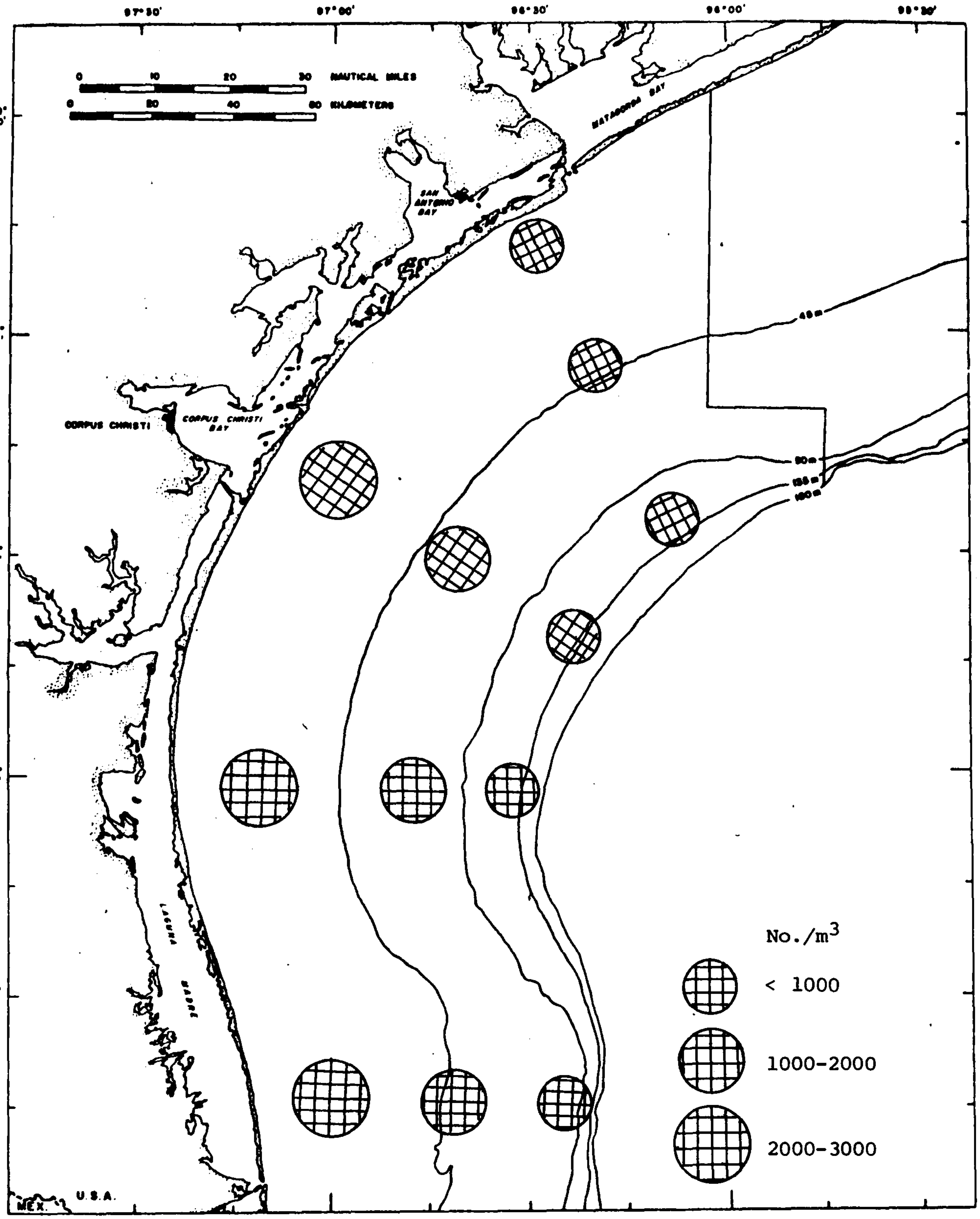

Figure 3-1. Average numerical abundance of copepods at each station, December - January.

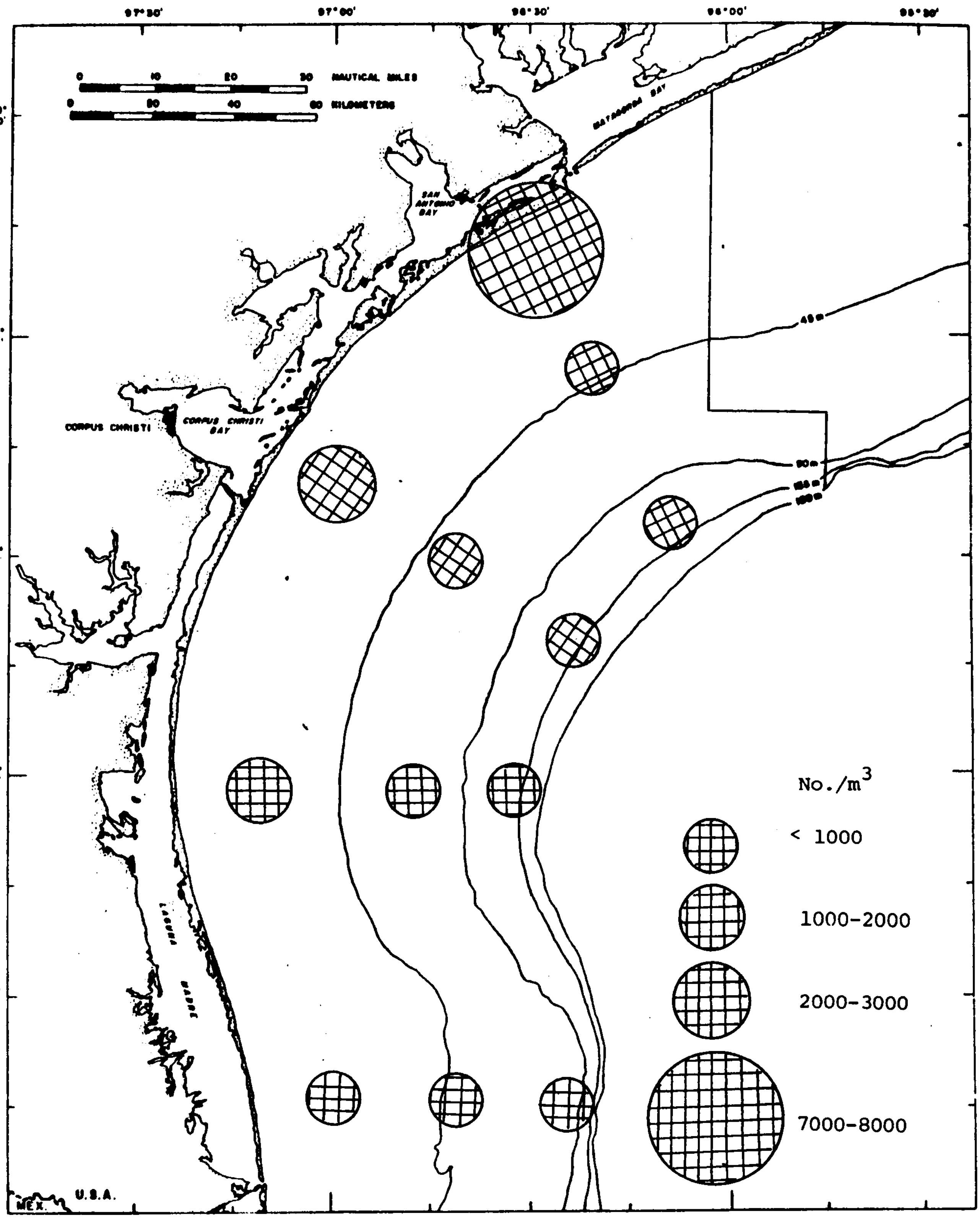

Figure 3-2. Average numerical abundance of copepods at each station, April - May.

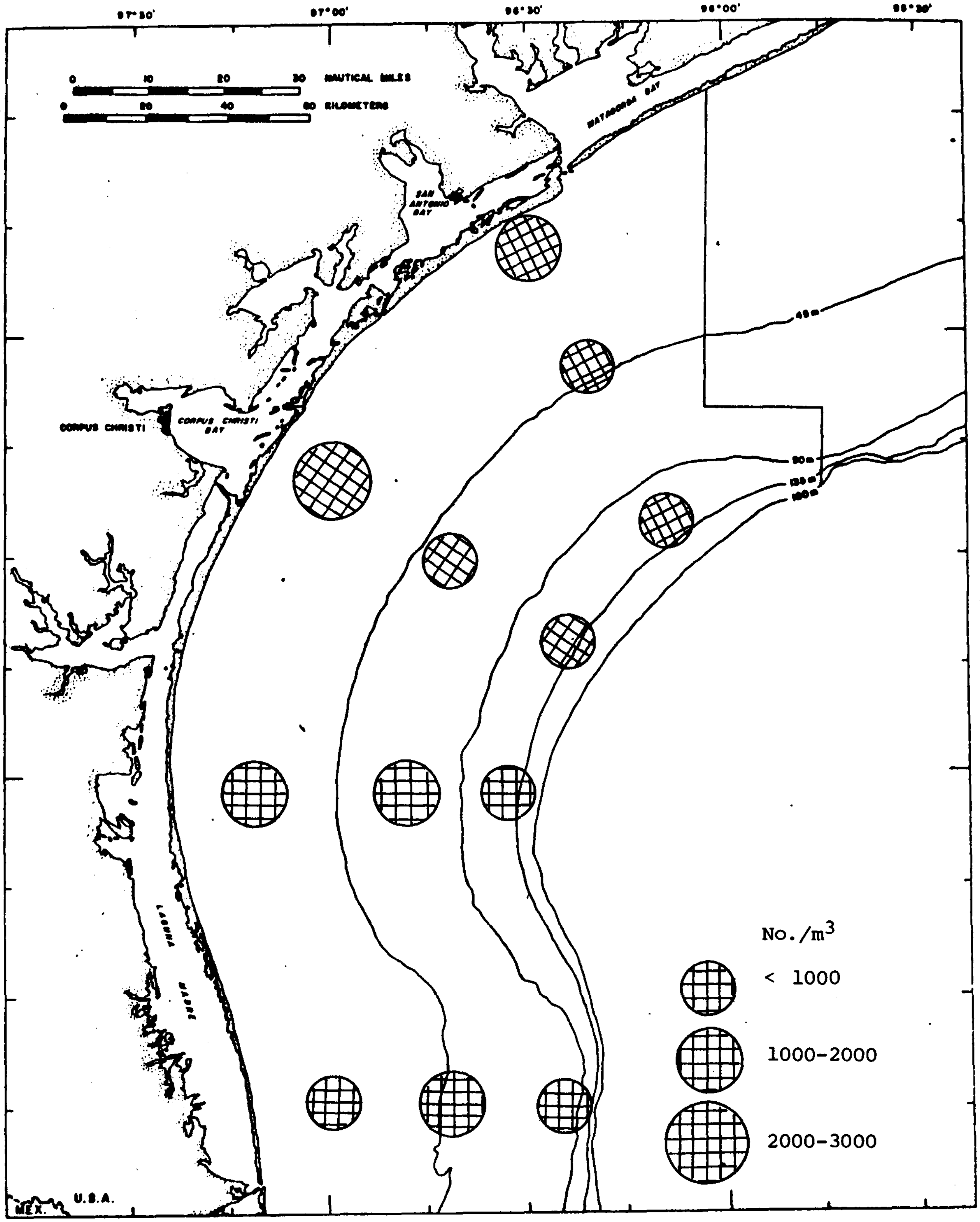

Figure 3-3. Average numerical abundance of copepods at each station, August - September.

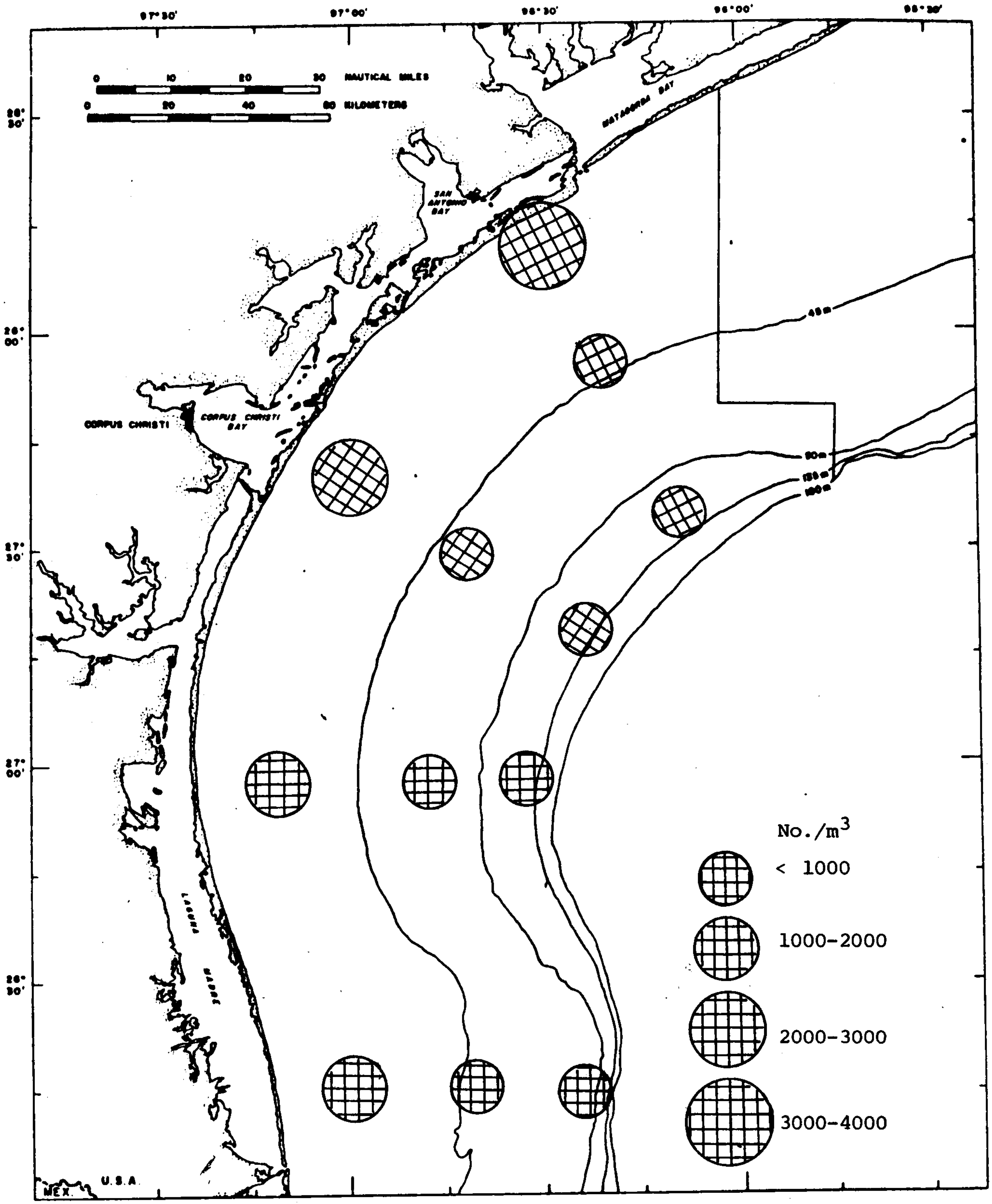

Figure 3-4. Annual mean of numerical abundance of copepods at each station.

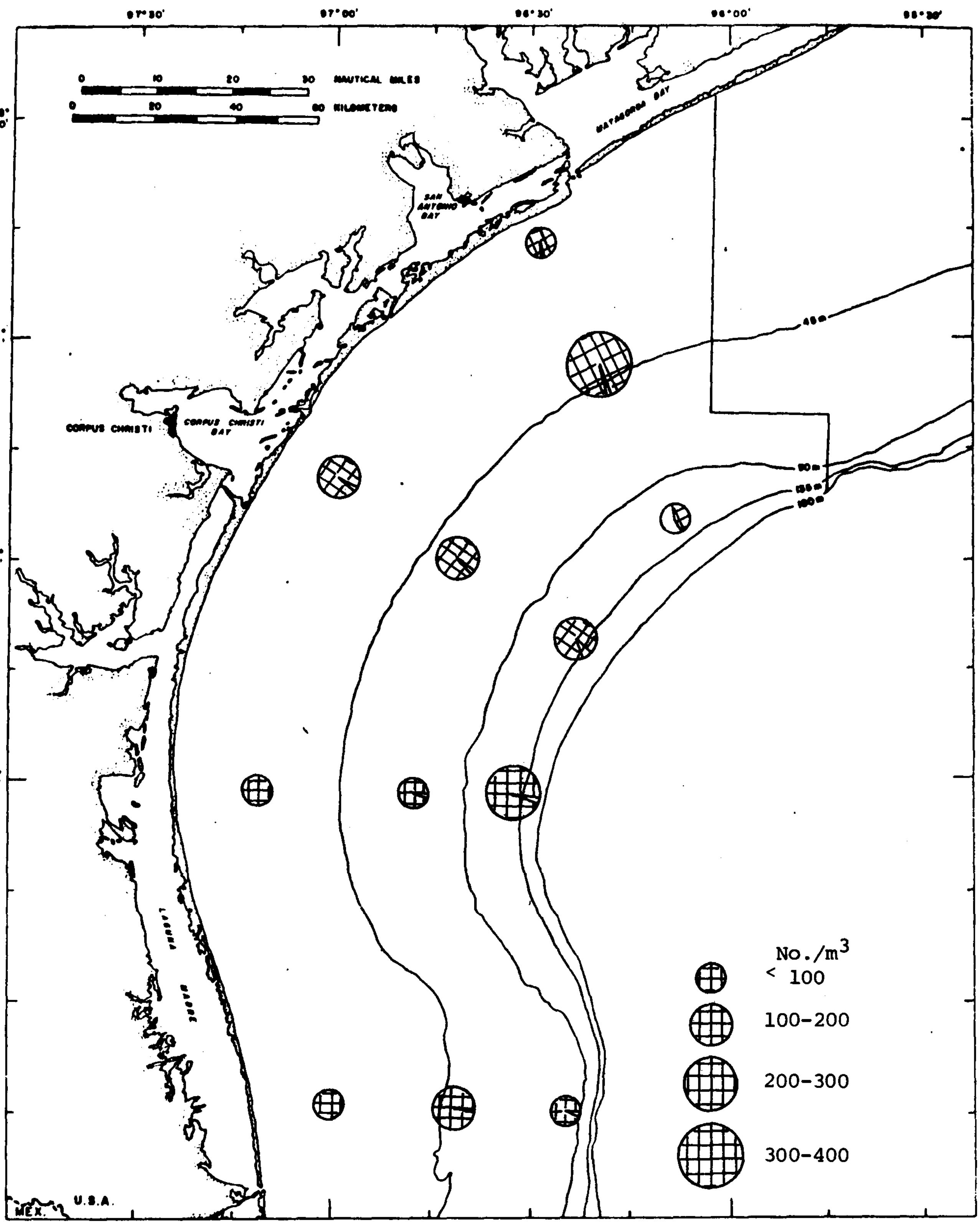

Figure 4-1. Average numerical abundance of ostracods and proportion of Euconchoecia (shaded), December - January.

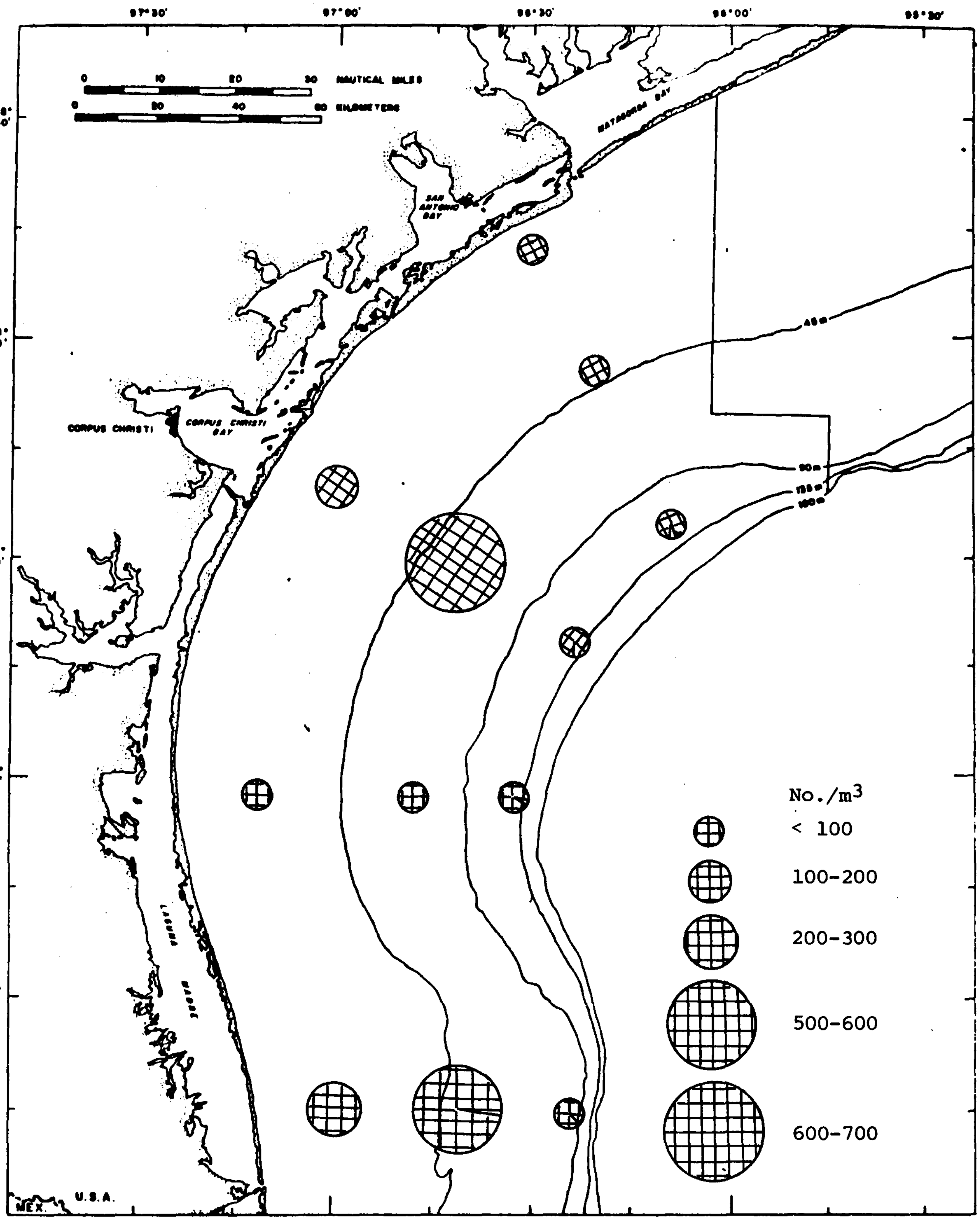

Figure 4-2. Average numerical abundance of ostracods and proportion of <u>Euconchoecia</u> (shaded), April - May.

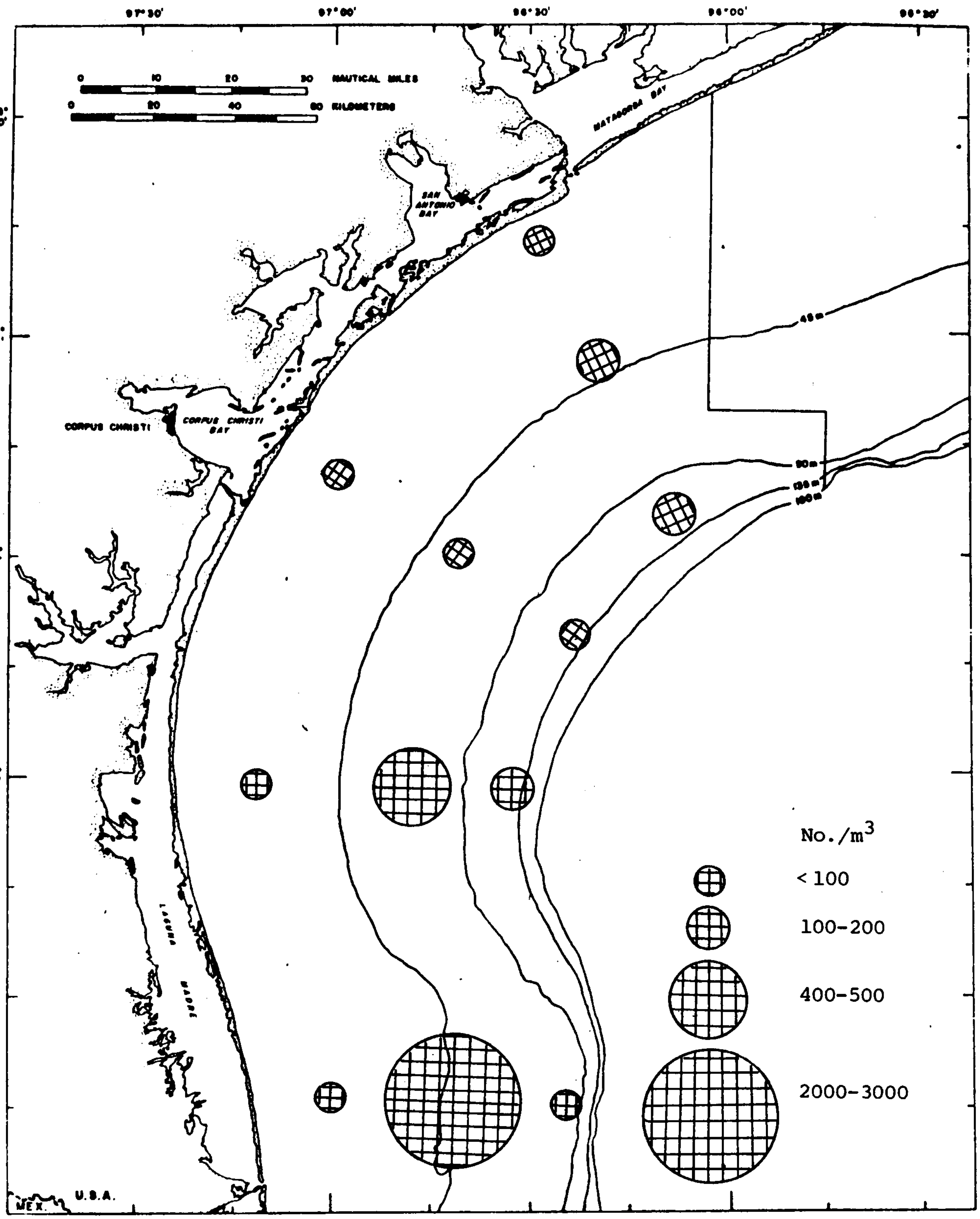

Figure 4-3. Average numerical abundance of ostracods and proportion of Euconchoecia (shaded), August - September.

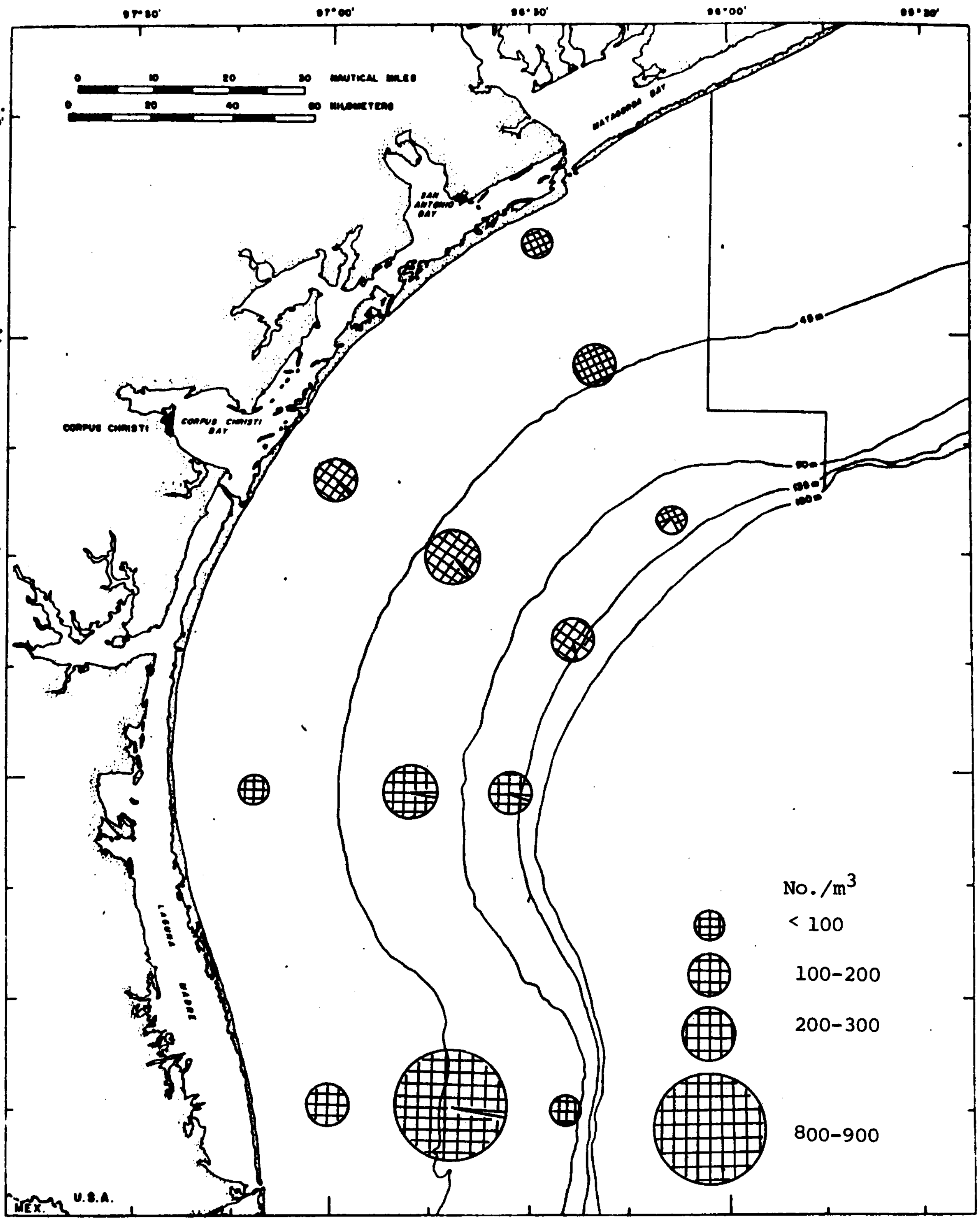

Figure 4-4. Annual mean of numerical abundance of ostracods and proportion of Euconchoecia (shaded).

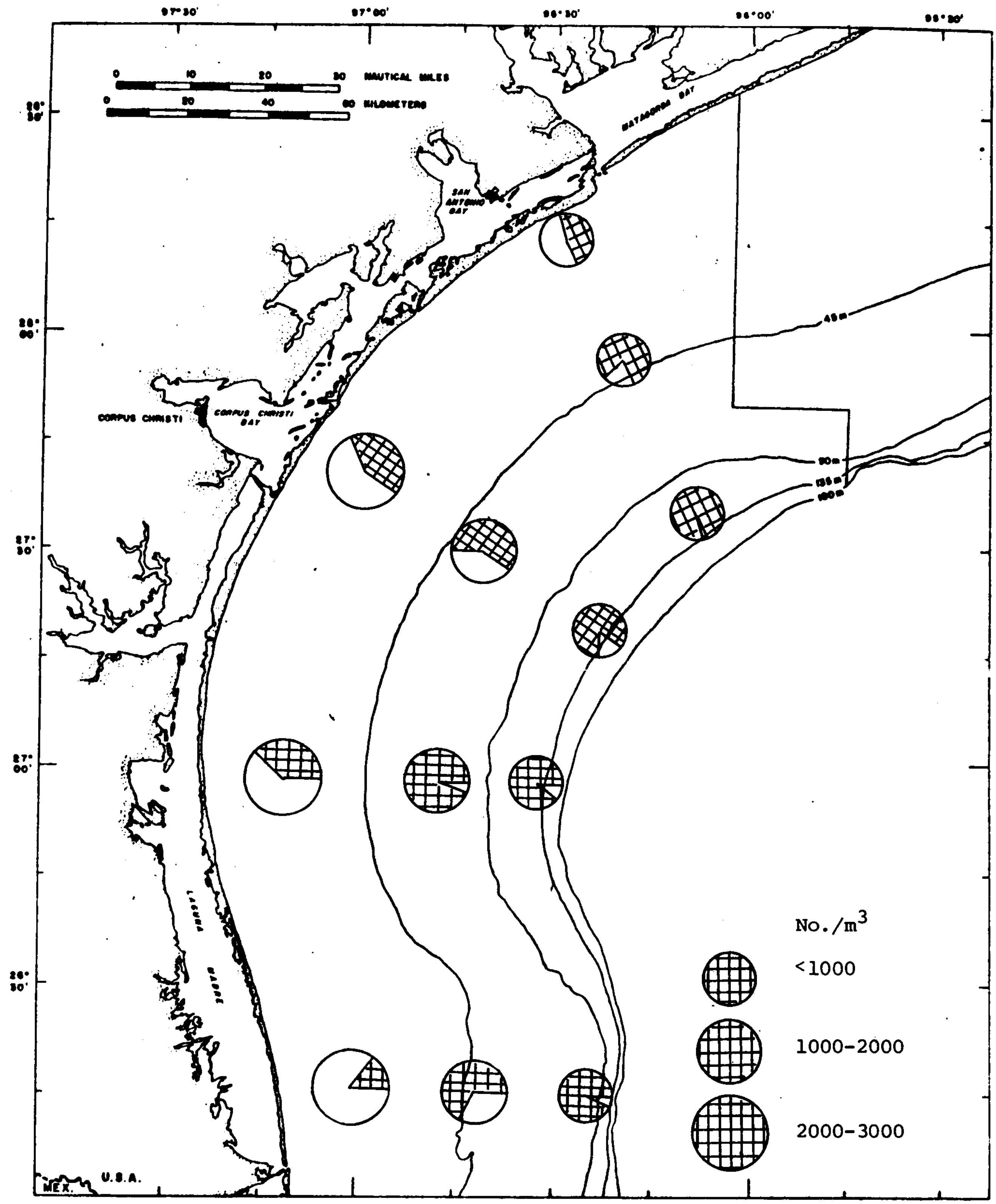

Figure 5-1. Average numerical abundance of adult female copepods and proportion of Paracalanus parvus group (P. indicus and P. quasimoto) (unshaded), December - January.

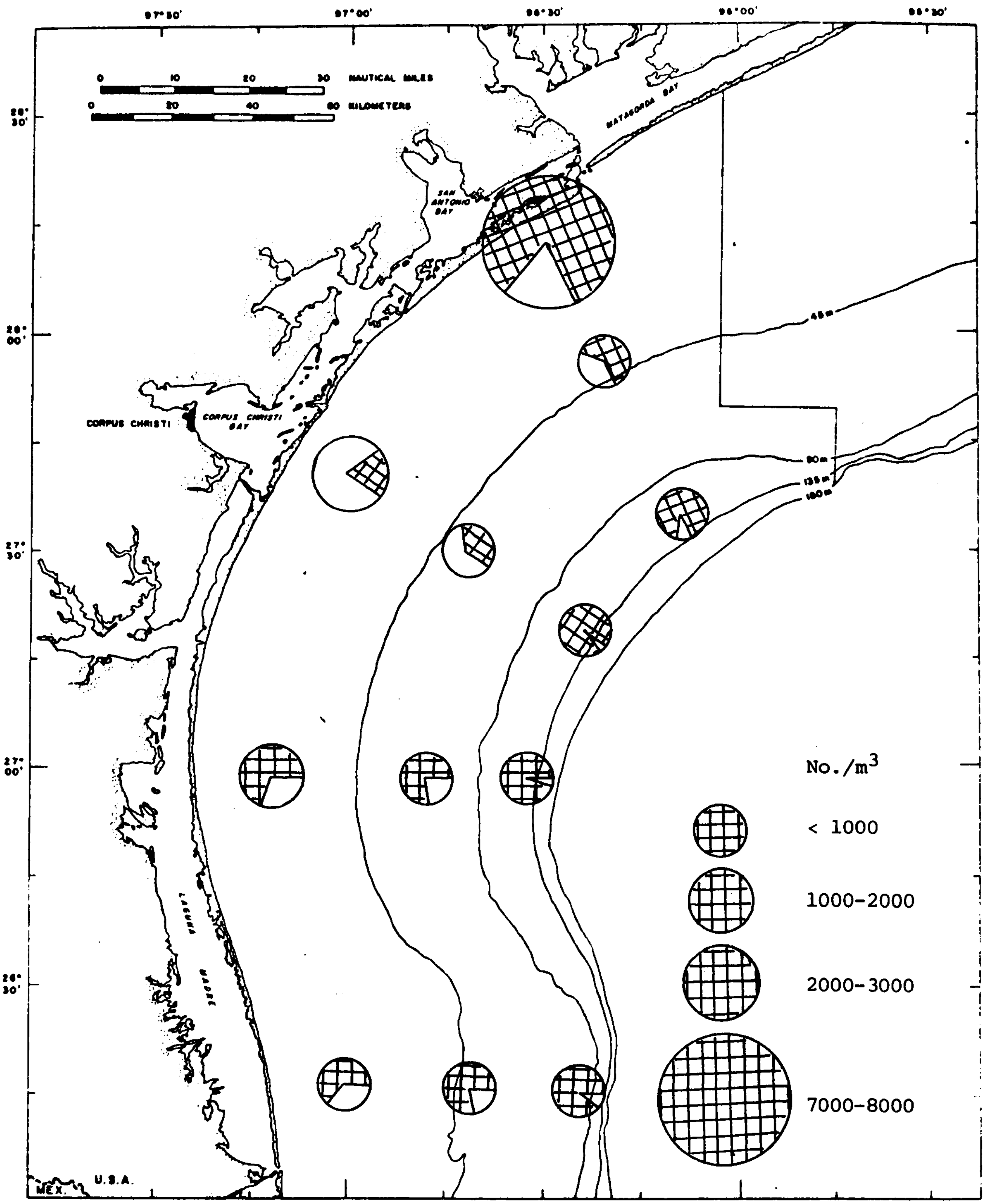

Figure 5-2. Average numerical abundance of adult female copepods and proportion of Paracalanus parvus group (P. indicus and P. quasimoto) (unshaded), April - May.

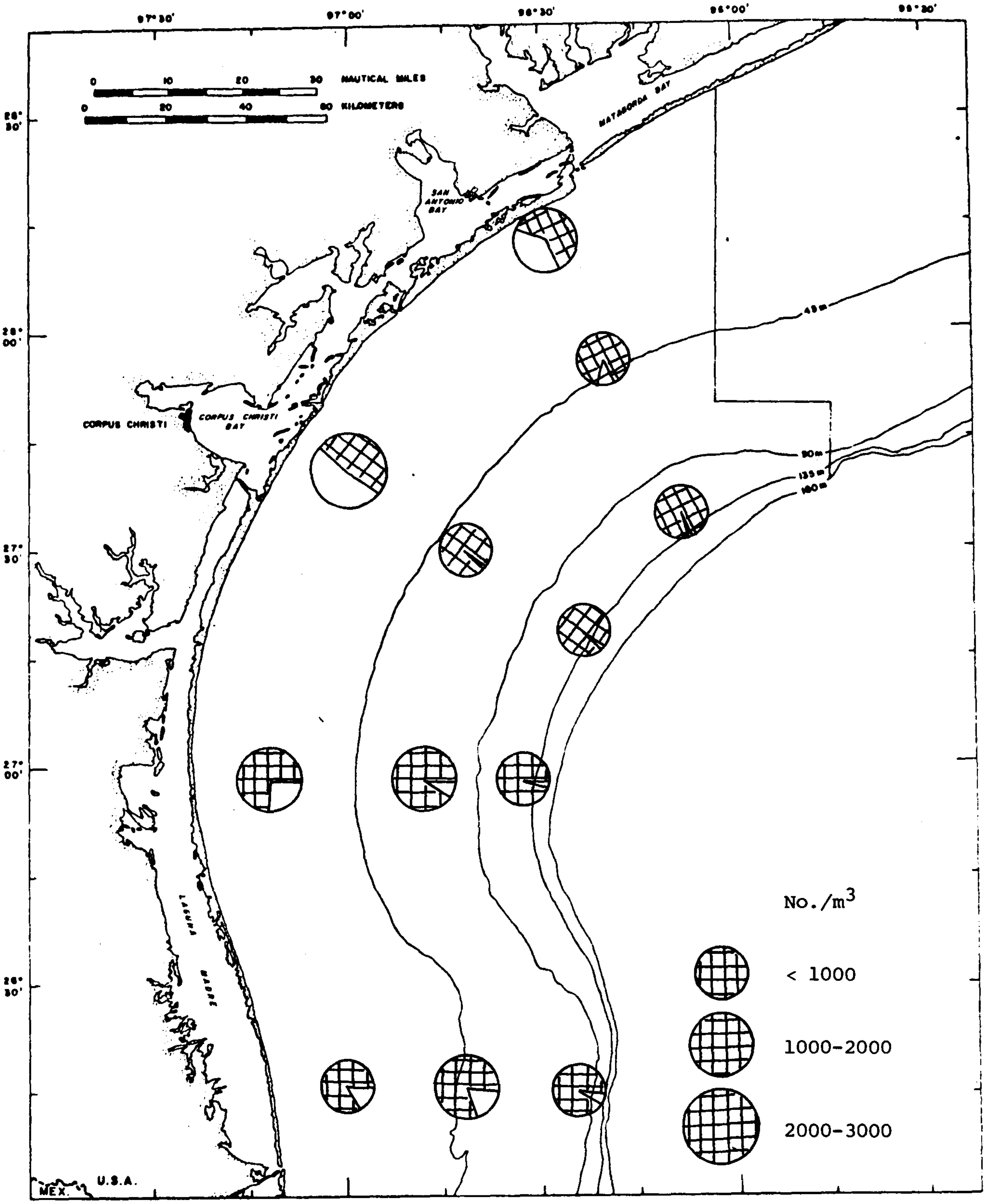

Figure 5-3. Average numerical abundance of adult female copepods and proportion of Paracalanus parvus group (P. indicus and P. quasimoto) (unshaded), August - September.

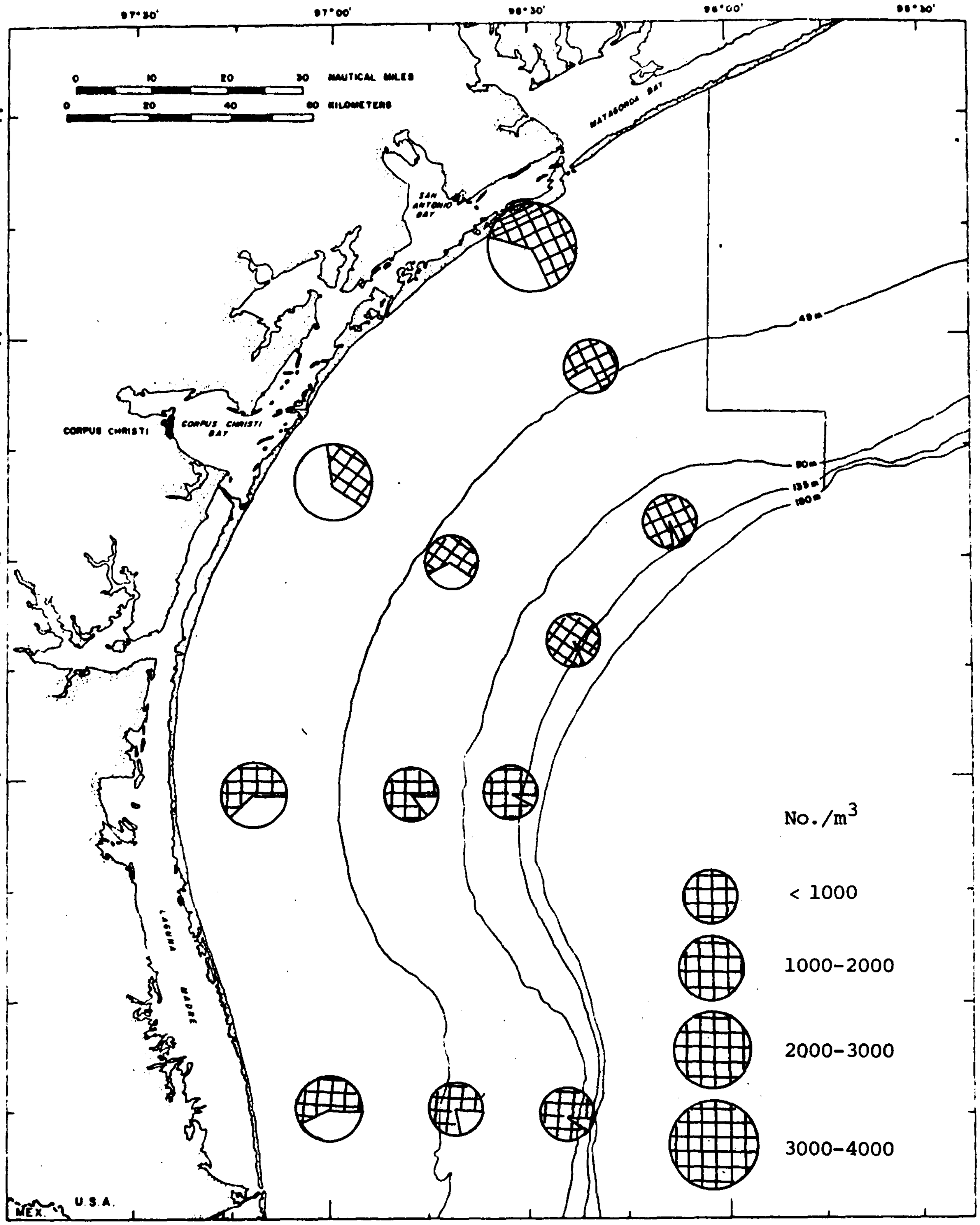

Figure 5-4. Annual mean of numerical abundance of adult female copepods and proportion of *Paracalanus parvus* group (*P. indicus* and *P. quasimoto*) (unshaded).

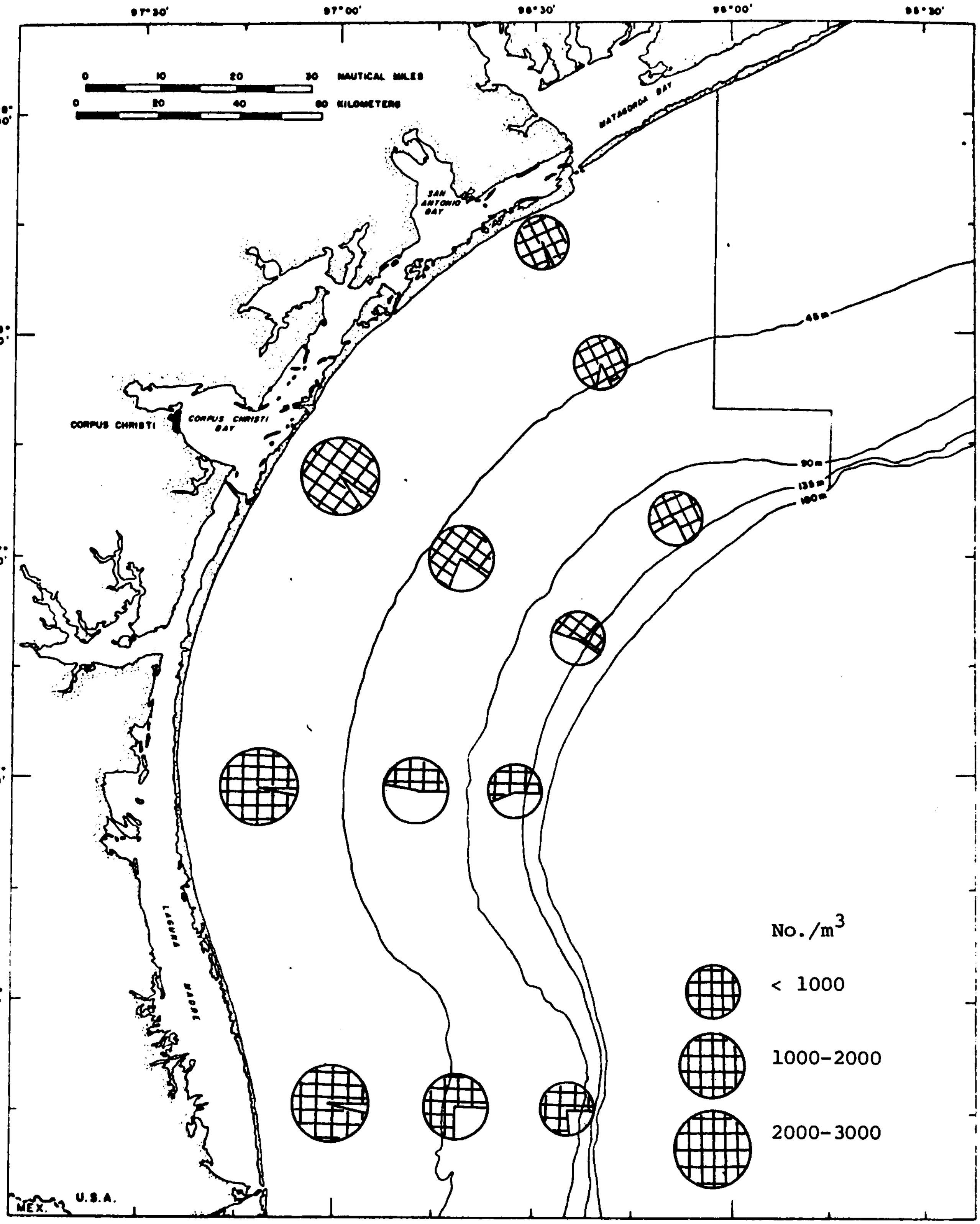

Figure 6-1. Average numerical abundance of adult female copepods and proportion of Clausocalanus furcatus (unshaded), December - January.

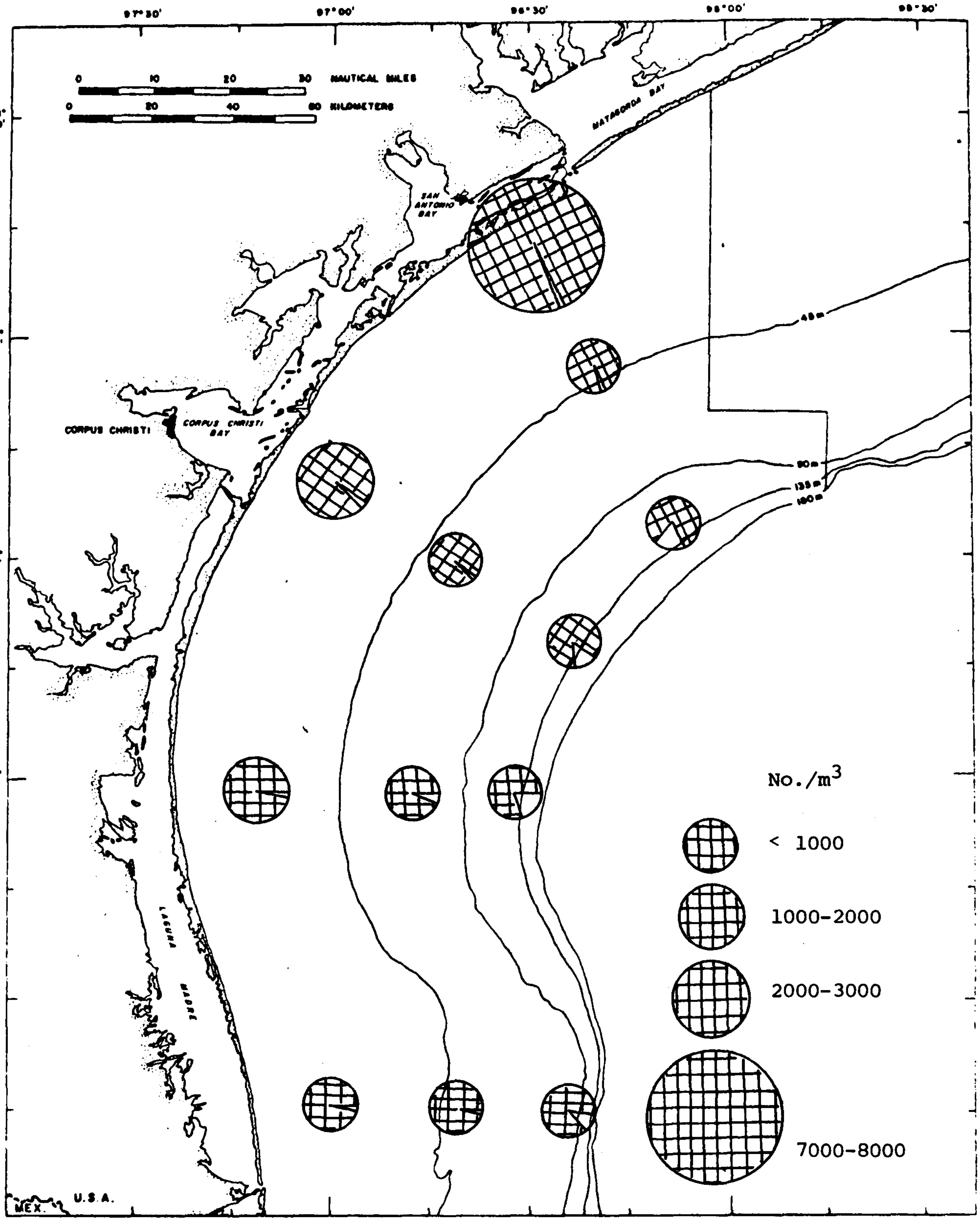

Figure 6-2. Average numerical abundance of adult female copepods and proportion of Clausocalanus furcatus (unshaded), April - May.

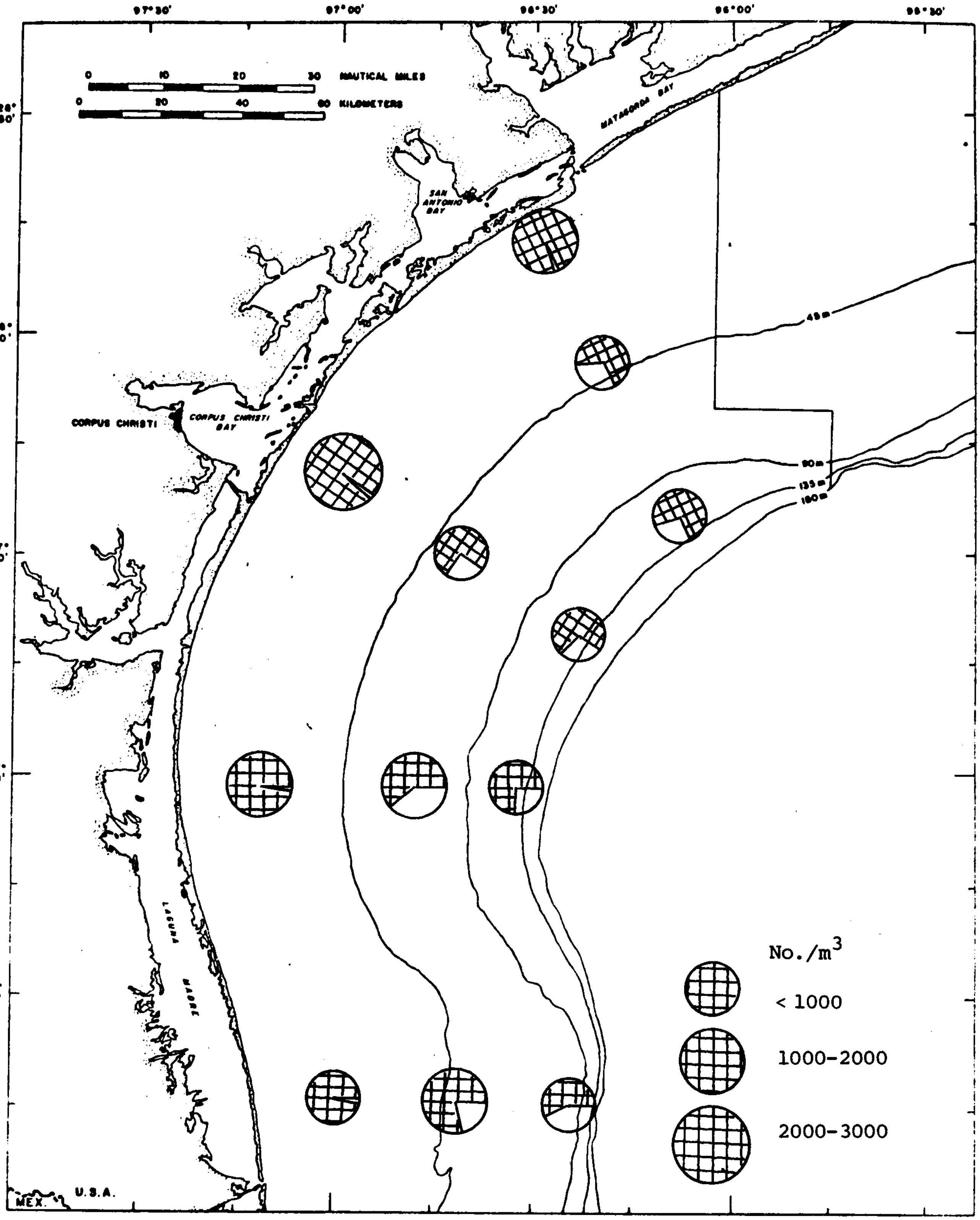

Figure 6-3. Average numerical abundance of adult female copepods and proportion of Clausocalanus furcatus (unshaded), August - September.

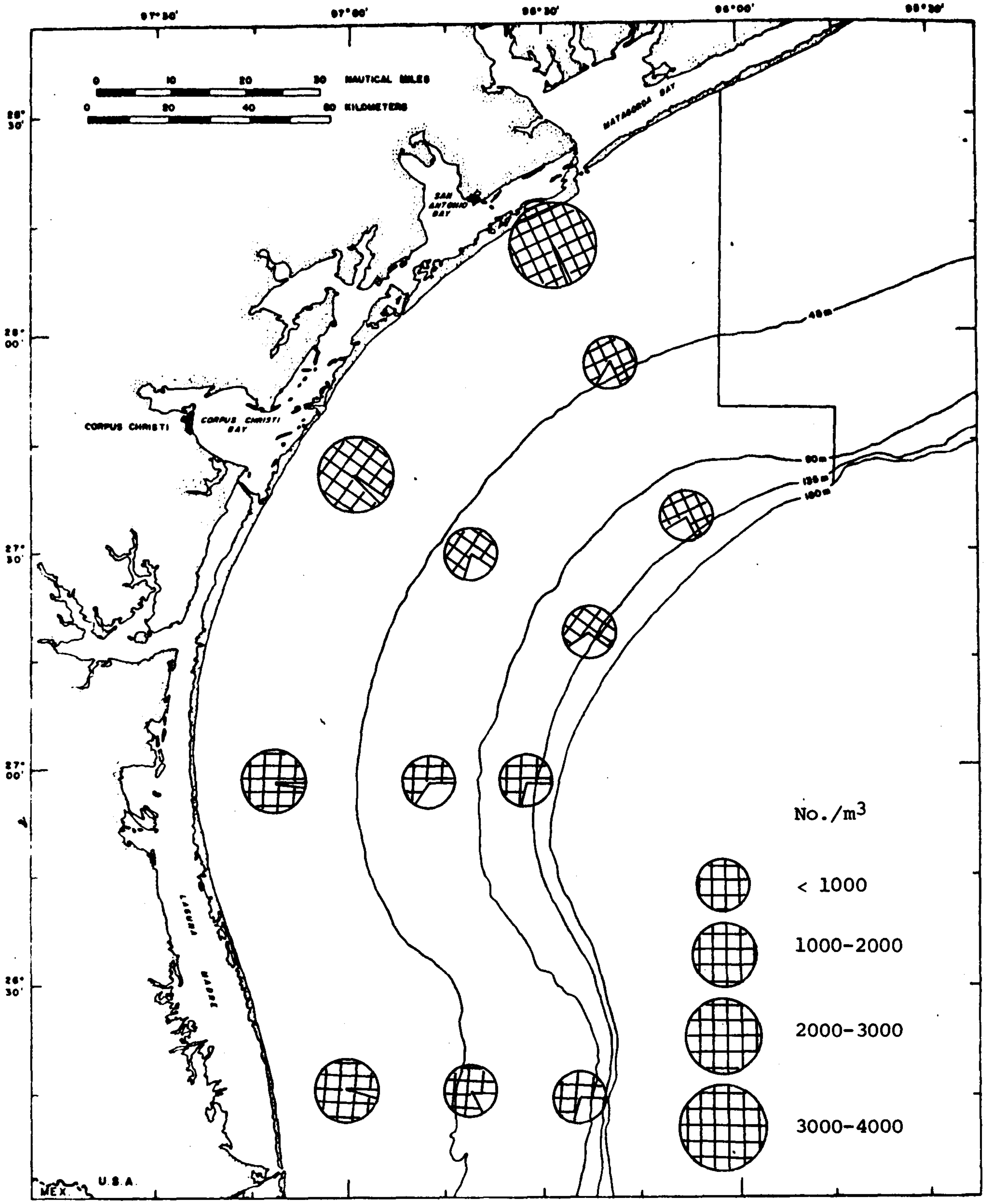

Figure 6-4. Annual mean of numerical abundance of adult female copepods and proportion of Clausocalanus furcatus (unshaded).

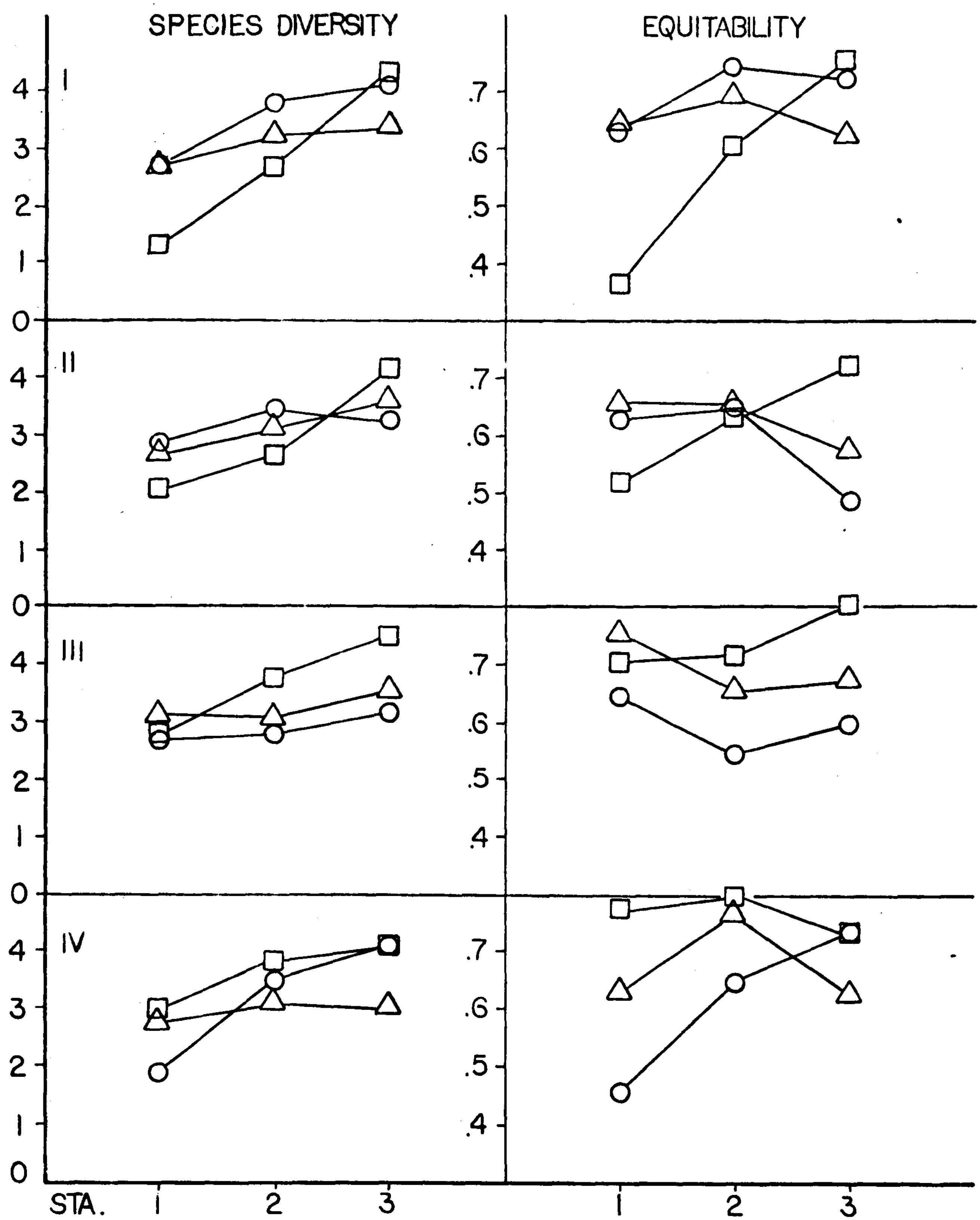

Figure 7. Species indices and coefficients of equitability ($E = \frac{H(S)}{H_{max}(S)}$) shown for each transect (I-IV). ○- December-January, □- April-May, △- August-September.

NEUSTON PROJECT

University of Texas Marine Science Laboratory

Principal Investigator:
J. Selmon Holland

Associate Investigator:
Richard D. Kalke

INTRODUCTION

Neuston is composed of the plants and animals which live on or just beneath the surface film of the water. As such, it may be very vulnerable to surficial pollutants. It could be an important indicator of environmental disorder brought about by petroleum production on the Texas Outer Continental Shelf. Sargassum weed was the most obvious plant found in the neuston samples. Some of the animals collected were those which are dependent on Sargassum for protection and food. The most abundant organisms collected were copepods, mollusc larvae, chaetognaths, sergested shrimps, cladocerans and decapod larvae.

METHODS

Field

Neuston samples were taken by towing a 1/2 meter, 153micrometer mesh NITEX plankton net attached to a fiberglassed plywood sled for approximately 15 minutes. The pontoons on the sled were 15 cm wide by 16.5 cm high. The posterior end of the pontoon was square and the anterior end was made at an angle to keep the anterior end of the sled on the surface of the water while it was being towed. The total length of the top of the pontoon was 90 cm and the length of the botton was 75 cm. A keel 71.5 cm in length was attached to the front left corner of each pontoon and extended to the right rear corner. Each keel tapered from a depth of 4 cm in the front to 13 cm in the rear. When the sled was towed, the keels guided the sled away from the wake of the boat. A 3.6 x 9 x 90 cm board attached to the anterior top and a 1.8 x 9 x 90 cm board attached to the posterior top of the pontoon held them 55 cm apart. The net was tied to the anterior cross bar and to two 9 cm x 20 cm wooden supports located on the inner side of each pontoon. No flowmeter was used so it was impossible to make quantitative neuston counts. Following each tow, samples were transferred to a labelled jar and frozen.

Laboratory

In the laboratory the neuston samples were allowed to thaw and were placed in a graduated beaker where they were diluted from 200 to 800 ml, depending on the concentration of the organisms. From this concentration 1 to 4 ml and 20 ml aliquots were taken using a Hensen-Stempel pipette. Aliquot size ranged from 1/800 to 1/10 and the number of organisms counted in the aliquot ranged from 27 to 523 (Table 1.). Aliquots were placed in a Ward zooplankton counting wheel and counted at 25X with a WILD M-5 dissecting microscope. Organisms which were most abundant were counted in the 1-4 ml aliquot, and organisms which occurred either in very low numbers in the first aliquot or not at all were counted in the 20 ml aliquot. Most of the organisms in the samples were damaged beyond species recognition due to the freezing of the samples; therefore, identifications were made only to major groups of animals and in very few cases to species.

RESULTS

Neuston samples were taken at every station (1, 2 and 3) on each transect (I, II, III and IV) during the Winter 1974-1975, Spring 1975 and Summer 1975. Of the 36 samples collected, 3/II AOY was lost, and 2/II ALV and 2/III AVF were apparently collected by dip net. A listing of major groups of animals collected in order of abundance and total number of individuals in each sample are listed in Tables 1-36 in Appendix XVII. The total number of organisms collected by combining all stations for the Winter, Spring and Summer was 769,293, 581,410 and 229,036 respectively.

Calanoid and cyclopoid copepods made up 66%, 62% and 88% of the total numbers of organisms collected during the Winter, Spring and Summer, respectively. Some of the calanoid species which were seen in the samles but not quantified separately were: *Acartia tonsa*, *A. lilljeborgii*, *Paracalanus* spp., *Centropages velificatus*, *C. hamatus*, *Anomalocera ornata*, *Pontella* spp., *Labidocera aestiva*, *L. scotti*, *Pontellina plumata*, *Paracandacia simplex*, *Pontellopsis villosa* and *Temora stylifera*. The most common cyclopoid copepods were *Oncaea* spp., *Corycaeus* spp., *Oithona* spp., *Farranula* spp. and *Corycella gracilis*. Harpacticoid copepods were the least abundant of the copepods, The most common species collected were *Euterpina acutifrons*, *Macrosetella gracilis* and *Miracia* spp.. Other harpacticoids in the samples were usually associated with *Sargassum*. Other animals which occurred with *Sargassum* were *Latreutes fucorum*, *L. paravulus*, some fish larvae, portunid crabs, amphipods and isopods. Mollusc larvae were in most cases second to copepods in abundance. Cladocerans were noted during the summer months only. They probably occurred during other seasons but during the freezing and thawing of the samples they deteriorated. *Lucifer faxoni* and chaetognaths were some of the larger organisms collected in the samples. They occurred during the Winter, Spring and Summer.

DISCUSSION

Due to the absence of flowmeter data, and to the poor condition of the samples due to freezing it is impossible to make any quantitative comparisons between stations. In general appearance most of the neuston tows were similar to each other with calanoid and cyclopoid copepods and mollusc larvae usually being the most abundant organisms.

Samples which contained Sargassum usually resulted in the occurrence of animals which live within and are dependent on this unique floating habitat.

Table 1. Size of aliquot examined and number of organisms counted in each aliquot at each station by season.

TRANSECT	STATION	SEASON	ALIQUOT SIZE		NUMBER PER EACH ALIQUOT		TOTAL NO. COUNTED
			No. 1	No. 2	No. 1	No. 2	
I	1	Winter	1/125	1/12.5	56	0	56
	2		1/250	1/25	148	19	167
	3		1/50	1/10	118	0	118
II	1		1/800	1/40	269	254	523
	2		1/125	1/12.5	19	8	27
	3		*	*	*	*	*
III	1		1/400	1/40	479	6	485
	2		1/100	1/10	0	30	30
	3		1/100	1/10	54	24	78
IV	1		1/400	1/40	459	20	479
	2		1/125	1/12.5	87	12	99
	3		1/125	1/12.5	143	23	166
I	1	Spring	1/125	1/12.5	106	25	131
	2		1/250	1/25	82	68	150
	3		1/100	1/10	134	68	202
II	1		1/500	1/25	109	7	116
	2		1/600	1/30	755	64	819
	3		1/50	1/10	6	46	52
III	1		1/125	1/12.5	0	255	255
	2		1/100	1/10	23	127	150
	3		1/150	1/15	0	57	57
IV	1		1/300	1/30	0	74	74
	2		1/100	1/10	27	39	66
	3		1/250	1/25	32	23	55
I	1	Summer	1/250	1/25	25	88	113
	2		1/200	1/20	95	92	187
	3		1/150	1/15	66	154	220
II	1		1/250	1/12.5	250	96	346
	2		1/150	1/15	27	134	161
	3		1/100	1/10	0	41	41
III	1		1/125	1/12.5	249	71	320
	2		1/150	1/15	259	16	275
	3		1/100	1/10	47	10	57
IV	1		1/125	1/12.5	148	58	206
	2		1/125	1/12.5	144	97	241
	3		1/125	1/12.5	34	21	55

* Sample missing

BENTHOS PROJECT

Invertebrates

University of Texas, Marine Science Laboratory

Principal Investigator:
J. Selmon Holland

Associate Investigators:
Scott Holt
Michael Carlisle

INTRODUCTION

The ability to assess the environmental impact of any factor is precluded by a lack of knowledge of the communities of organisms endemic to the region. This knowledge must first include a taxonomic survey of the organisms and then their interactions with their environment. The benthic portion of the Texas Outer Continental Shelf study has been primarily aimed at the first of these two basic sets of knowledge. The macrobenthic organisms from this area are now being identified and quantified as the initial phase in understanding the present status of benthic invertebrate communities along the Texas Outer Continental Shelf.

METHODS

Both infaunal and epifaunal macroinvertebrates were collected from the twelve study sites for analysis by our group. Meiofaunal samples and chemical samples were taken as per the proposal and sent to the appropriate investigators.

Epifaunal organisms were sampled both day and night using a 35-ft. (10.7 meter) otter trawl with a 1.25 cm stretched mesh liner. Fifteen minute tows were made at a boat speed of approximately two knots. Epifauna were preserved, sorted, identified, enumerated and numbers per trawl recorded. A total of 72 epifaunal samples were taken and analyzed.

Infaunal samples were taken with a SMITH-MACINTYRE bottom sampler. The volume of each sample was approximately $.0125m^3$. Four replicate samples were taken at each site occupation so that approximately $.05m^3$ of sediment was sampled at each site. Meiofaunal plugs and small sediment samples for particle size analysis were taken from the SMITH-MACINTYRE samples. One hundred and forty-four infaunal samples were collected and analyzed during the first year of the Texas Outer Continental Shelf study. The following chart outlines the handling of each sample type:

Epifauna
↓
Day/Night Samples
(One sample each)
↓
35 ft. otter trawl
(10.69 meter)
(15 minute trawls)
↓
Shipboard Preservation
of all invertebrates

Infauna
↓
One set of four
replicate samples
per station
↓
Smith-MacIntyre Sampler
(volume equal .0125m^3)
(surface area .1088m^2)
↓
Shipboard washing through
.50mm mesh and preservation of all invertebrates

↓

Laboratory sorting, identification and enumeration
of individuals of each species
↓
Cataloguing and final preservation of all specimens
↓
Coding of data for computer input
↓
Data Analysis

RESULTS

A list of species and their occurrence during each sampling period is given in Table 1. A total of 281 species is listed including eight non-invertebrates, primarily fish, collected in the Smith-MacIntyre sampler. The total number of invertebrates occurring in the winter, spring and summer collections are 159, 181 and 166, respectively. Species diversity values (H"), equitability and Hurlbert's probability of interspecific encounter (P.I.E.; Hurlbert, 1971) values for all epifaunal samples are presented in Table 2. The same values for the summed replicate infaunal samples are presented in Table 3. Species diversity values and numbers of species present are given for epifaunal collections (Figures 1-6) and infaunal collections (Figures 7 -9). The species collected and counts (per .0125m^3) in each sample taken are given in Appendix XVIII. Distributional data for selected infaunal species are presented in Table 4 for the winter, spring and summer collections. Distributional data for selected epifaunal species are given in Table 5 for winter, spring and summer collections respectively. Sediment textural data are presented for each transect in Figures 10-13.

The benthic infauna of our study area consists of three groups of organisms based on abundance and distribution. The first group consists of a few species that are very common to nearly ubiquitous. They are found at many sites during most of the year. This group includes the polychaetes Paraprionospio pinnata, Nereis sp. and the amphipod, Ampelisca agassiz. As with infauna in general, this group apparently is most common at the shallower sites and on transects I and IV. Some, particularly P. pinnata, are found frequently even at the deepest stations. A second group including Armandia maculata, Mediomastus californiensis, Tharyx setigera, Cossura delta and Ninoe nigripes are common to uncommon, neither as widespread nor as abundant generally as the first group. The majority of the infaunal species are in the third group which is classified as rare in that they are found infrequently and in very low numbers.

Similar groups for the epifauna can be shown. The first group includes Solenocera vioscai, Penaeus aztecus, Trachypenaeus similis, Sicyonia dorsalis and Callinectes similis. The second group, common to uncommon species, includes Amusium papyraceus, Squilla chydea, Parapenaeus longirostris, Portunus spiniparpus, Astropecten duplicatus and Brissiopsis alta. As in the infauna, a large number of epifaunal species are rare, being collected very infrequently during the study. The number of species in the ubiquitous-common, and the common-uncommon groups is proportionately larger in the epifauna than in the infauna.

The infaunal and epifaunal assemblages are very different in composition. The infauna is dominated numerically and taxonomically by the polychaetous annelids. The epifauna is dominated by crustaceans, especially decapods, at most sites. Molluscs were collected infrequently in the infaunal samples.

More were in the epifaunal samples.

Indications of temporal changes in distribution and abundance were observed with infauna and epifauna. The data indicate an increase in species numbers of molluscs during the winter collection. A similar increase occurs in the echinoids, Brissiopsis alta and Moira atrops. Some of the decapod crustaceans show a dramatic peak in abundance in the spring collections (Table 1, Appendix XVIX). These include Solenocera vioscai, Parapenaeus longirostris, Trachypenaeus similis, Sicyonia dorsalis and Acetes americanus. The latter species, although a dominant organism in both the winter and spring collections was not found in the summer. The amphipods had increased species numbers and abundance during the spring. A large percentage of the species collected (46%) were found only during one seasonal collection. Most of these were found in very small numbers and were considered rare. Several unique seasonal distributions were observed.

The bivalve, Diplodonta sp., was found in large numbers (512) at station 2, transect II during the spring cruise. Numerically, it was the dominant benthic mollusc found during the study but it was found only once. Another species found during only one season was the squid, Rossia tenera, which may be discussed as it is not a member of the neritic Loliginidae, but is a member of the Rossinae (Serpiolidae) which are believed to be exclusively benthonic on continental slopes, margins and shelves. It was collected only during the spring and was found on all four transects at the second site. The number of individuals varied from one to fourteen.

Approximately 29 percent of the species collected were found during all seasons. There were many species of polychaetes and arthropods in this category. A large percentage of two subfamilies of decapod crustacea of particular interest to man (Penaeinae and Sicyoninae) were found in all seasons during the study.

Distribution of the infaunal invertebrates presents a distinct pattern spatially. There is an apparent decrease in species numbers and abundance with distance offshore, and species numbers and abundance are greater on transects I and IV than on II and III. Various infaunal species exhibit apparent spatial limitations (Tables 4 - 5). The polychaete *Paralacydonia paradoxa* is found only at station 3 on each transect. Others including *Magelona* sp., *Nereis* sp. and *Diopatra cuprea* are found only at or primarily at stations 1 and 2.

The epifaunal invertebrates did not exhibit the distinct spatial distribution patterns in terms of species numbers and abundance seen in the infauna. There did not appear to be any consistent pattern of species numbers or abundance with either water depth or latitude. Individual species did, however, evidence possible spatially limited distributions. Some congeneric species such as *Portunus gibbesii* and *P. spinicarpus* apparently have overlapping ranges with *P. gibbesii* being the dominant form at shallow stations and *P. spinicarpus* dominating the deeper sites. Several species including *Amusium papyraceus*, *Solenocera vioscai* and *Parapenaeus longirostris* were absent from station 1 on all transects, being found only in the deeper stations. Others, including *Callinectes similis* and *Portunus gibbesii* are apparently restricted to the shallower two stations along all transects. As previously stated, *Rossia tenera* was limited to the second site along all transects.

Species diversity values (Tables 2 and 3; Figures 1-7) were generally greater in the infauna than in the epifauna. There appears to be a general tendency toward increasing infaunal diversity values with depth. No apparent patterns of diversity values are observed with the epifauna.

Sediment data from most of the samples are presented in Figures 10-13. The percentage of sand generally decreases with water depth with exception of the outer edge of the shelf in the southern sector which has large amounts of sand and shell.

The inshore stations on transects I and IV have greater percentages of sand than inshore stations on transects II or III.

DISCUSSION

The benthic invertebrate fauna of the Texas Outer Continental Shelf is a large, diverse assemblage. A benthic study of such an area has many sources of error. These must be recognized before results are discussed. The sampling program used during the first year of the study had several such sources. Navigation was such that we could not be assured of returning to the "same" location each trip. Evaluation of sampling precision for the second year of the study has indicated (and will be more fully discussed in a later report) that four samples are collecting approximately 84% of the number of non-rare species at a given site. If all species are included, four grabs will be expected to collect only 62% of the total number of species present. Thus a great deal of variability exists between replicate samples at a given site. A large portion of this variability is explained by the inability of a single sample to adequately collect the rare species. Preliminary investigations indicate that a large number (50 or more) of samples at an individual site might be needed to adequately sample the total infaunal population. More information on this topic will be forthcoming in later reports to BLM. A third source of variability in the samples collected involves the epifaunal trawls. At some sites, particularly site 3, transects I and II, the trawls often buried in the soft sediment.
This problem is particularly acute during rough weather which is most often

encountered in the winter. Many trawls have been lost at these stations. The samples retrieved often contain huge quantities of sediment. These samples are quite different from samples in which the trawl rides normally at the sediment-water interface. The increase in molluscan forms during the winter collection is believed to result from the digging in of the trawl at the outer-most sites, particularly on transect I.

The taxonomy of the invertebrates of the Gulf of Mexico has not been studied as well as that of the Atlantic or Pacific coast invertebrates. Separation of our samples to species has often been accomplished using taxonomic literature from other regions. Many of the invertebrates are very widely distributed so that for the majority of our species the identifications are valid. We realize that changes will be made. We have striven for consistency in our identifications. Therefore, if a change is made, it can be carried throughout the data base. All specimens from the first year study are extant and a reference collection has been made so that with new taxonomic information, we can make proper adjustments in the data. The calculations based on present data would not be altered by simple changes in taxonomy unless a change in the number of species was involved.

Several species of invertebrates collected in the infaunal samples (*Centropages velificatus*, *Centropages* sp., *Labidocera aestiva*, *Temora stylifera*) and the epifaunal samples (*Loligo pealei*, *Lolliguncula brevis* and *Rossia tenera*) are listed in the species lists but are not used in the calculations. The former group are pelagic copepods that are believed to either be trapped in the sampler as it descends or, are carried into the sample in the seawater used in washing the sample on-board ship. The latter group are squid which are caught in large numbers by the diurnal epifaunal trawl but are virtually absent from the bottom at night.

The total numbers of species collected during each seasonal sample (159, 181 and 166; winter, spring and summer, respectively) does not necessarily give any indication of seasonality in the invertebrate species composition on the Texas Outer Continental Shelf. If, however, the 23 species of molluscs found only during the winter collection in those samples in which the trawl came up full of mud are deleted from the winter total, the resultant number (136) is far below those of the subsequent seasons. There apparently was a diminished species richness in the "mud bolus" trawl samples if the molluscs were not included. This observation indicates a diminished winter benthic community. There are apparent trends within some groups toward spring peaks in abundance. Several co-investigators observed similar phenomena within their biotic groups. The phytoplankton had greatest average cells/liter at all stations and all depths during the spring. The microzooplankton had lowest diversity but greatest standing crops during the spring collections. Whether or not the seasonal fluctuations in benthos abundance and species richness are chance observations, artifacts due to sampling (station re-location or gear bias) or truly variations in community structure seasonally cannot yet be ascertained. A second year's collection may help in resolving the question.

Spatial distribution of the infaunal invertebrates of the Texas shelf area seems to be primarily influenced by sediment particle size. Our infaunal data and sediment particle size data agrees very well with those presented in the U.S. Geological Survey section of the draft report. Our richest sites (both taxonomically and numerically) are those with the coarsest sediments. The geological report (and our own sediment analyses) indicate a greater percentage of sand along the inner sites and on transects I and IV. According to the U.S.G.S. report this transect effect results from ancient river outflows. [Other researchers (Park) report a decrease in zooplankton away from shore in all seasons, highest biomass (zooplankton) at site 1/I and lowest along transect III. Phytoplankton counts were highest inshore also (Van Baalen)]. We do not mean to imply any cause and effect relationship between phytoplankton and zooplankton abundance and benthic infaunal abundance as there is some question as to whether or not the measured phytoplankton and zooplankton populations reach down to the benthic populations.

The decrease in infaunal species richness offshore as seen in Figures 6 -9 appears well documented. There is a great diversity of sparsely scattered species in the offshore area as indicated by the many species considered rare that are found at the outer shelf sites. It may well be that species richness in that part of the shelf is equal to or greater than the shore area but, due to the sparseness of distribution many more samples would be necessary to show it. This is highly conjectural but may be the basis for further study at the outer-most sites.

Spatial distribution of the epifaunal assemblages did not follow the pattern set forth for the infaunal groups. The number of species of epifauna collected seasonally present no consistent patterns of distribution with depth or latitude (Table 2 ; Figures 1-6). Commercial shrimpers in this portion of the Gulf attest to the fact that the shrimp populations are highly motile and change distribution patterns with disturbing frequency and rapidity. The lack of a consistent pattern in epifaunal distribution may indicate that, as a group, the epifauna wander over the study area with few limitations. We did observe that some species of the epifauna exhibited distinct patterns through the first year's study, i.e. some are found only in deeper sites, some only in shallow. Water depth apparently is a major factor for some epifaunal species as was sediment particle size for the infauna. Latitudinally limited distribution was not observed for the epifauna or the infauna. As with the observed variations in temporal distributions, the observed spatial distributions may be chance occurrence, sampling bias or real spatial limitations.

Diversity indices (Tables 2-3 ; Figures 1-9) indicate generally a greater diversity of infauna than of epifauna. There is, however, generally a greater redundancy (domination of the sample by 1 or more species) in epifaunal collections, particularly at the two deeper sites on each transect, than for the infauna. The increased redundancy is primarily a factor of the schooling of many of the decapods and their numerical domination of the epifaunal samples. The infaunal diversity values were consistently lower at the inshore sites even though species numbers and total abundance was greatest at these sites. Again, this is a function of the higher redundancy caused primarily by the domination of the samples by Paraprionospio pinnata, Nereis sp. or Ampelisca agassiz.

Our diversity data corresponds to that of the U.S.G.S. in some respects but not in others. We, as they, consistently had the greatest diversity values at site 1/IV. This stems from the greatest number of species at that shelly-sandy site and the fact that the equitability of these samples is high. That is, the dominance by the near-ubiquitous group (P. pinnata etc.) is lessened by the greater abundance of the common-uncommon species. Our infaunal diversity figures at transect I, II and III definitely tend to increase seaward which was not found by the U.S.G.S. We consider this difference to be due to the difference in the numbers of samples taken. The U.S. G.S. data is from one SMITH-MACINTYRE sample, ours from four samples. The inshore assemblages are such that with each grab, one gets moderate numbers of one or two ubiquitous species and few individuals of a larger group of uncommon and rare species. One grab will obtain approximately 30% of the species expected to be found at one time at the inshore stations based on Pk values on a suite of 12 samples (Gaufin, et al., 1956). Four grabs will get slightly over 60% of the species. With each grab, the numbers of individuals of the ubiquitous to very common group increase as does the number of common to rare species, whose number of individuals increase at a lower rate than the ubiquitous to very common group. With four grabs, the domination of the sample by the ubiquitous-very common group is much greater, the equitability of the sample is less and diversity is lowered. Thus our onshore sites showed lowered diversities reflecting the dominance (lack of equitability of samples) by a few species. It may also be that as some of the "ubiquitous" species (P. pinnata, Nereis sp. and Ampelisca agassiz) exhibit significantly non-random distribution (Gage and Geekie, 1973) based on data from 1/II. They were not collected by a single sample in numbers corresponding to their abundance.

The difference in environmental stability between the inner-most sites (20 meters) and the outer-most sites (100 meters) may be considerable, but we believe the major factor influencing the species richness and abundance of infauna populations is sediment type.

CONCLUSIONS

1. *Benthic infaunal and epifaunal assemblages on the Texas Outer Continental Shelf exhibit very different taxon composition, diversity and spatial distributions.*

2. *The major factors influencing infauna and epifauna distribution are sediment type (particle size) and water depth respectively.*

3. *Observed distribution patterns may be chance occurrences, biased by sampling or true patterns, particularly in the epifauna.*

Table 1. Species taken during the first year with numbers collected each season.

	WINTER		SPRING		SUMMER		TOTAL
	Inf.	Epi.	Inf.	Epi.	Inf.	Epi.	
PHYLUM PORIFERA							
Demospongiae							
Sponge (Unidentified)		2				3	5
PHYLUM COELENTERATA							
Anthozoa							
Caliactis tricolor		3		1			4
Renilla mulleri		5	1	127		8	141
Anenome sp.			1				1
PHYLUM NEMERTINEA							
Cerebratulus lacteus			4				4
Nemertean (Unidentified)	72		80		109		271
PHYLUM NEMATODA							
Nematode A		2	1		4		7
Nematode B							
PHYLUM ANNELIDA							
Polychaeta							
Polynoidae							
Lepidasthenias sp.			1				1
Polydontidae							
Eupanthalis tubifex	5	6	2				13
Eupanthalis sp.	1						1
Polydontes lupina	2	4					6
Sigalionidae							
Sthenelais boa	2		9		3		14
Sthenelais limicola	1				3		1
Sthenelais sp.					3		3

Table 1. Cont.'d

	WINTER		SPRING		SUMMER		TOTAL
	Inf.	Epi.	Inf.	Epi.	Inf.	Epi.	
Chrysopetalidae							
Paleonotus heteroseta	2		8				10
Amphinomidae							
Amphinome rostrata	5						5
Chleoia viridis	1						1
Pseudoeurythoe sp.	1		5		8		14
Phyllodocidae							
Anaitides longipes						1	1
Phyllodoce cf. *groenlandia*						1	1
Phyllodoce cf. *maculata*		1					1
Phyllodoce mucosa			1				1
Pilargidae							
Ancistrosyllis groenlandica			2		6		8
Ancistrosyllis jonesi			1				1
Ancistrosyllis papillosa	4		2		1		7
Ancistrosyllis sp.	1						1
Sigambra bassi			2				2
Sigambra ocellata			1				1
Sigambra tentaculata	7		14		26		47
Synelmis albini			1				1
Hesionidae							
Gyptis vittata	1		2		1		4
Ophiodromus obscurus			1				
Nereidae							
Ceratonereis cf. *miritabilis*	4						4
Nereis falsa	6						6
Nereis succinea			1				1
Nereis sp.	71		60		75		206
Websterinereis sp.	1						1
Nephtyidae							
Aglaophamus circinata	2		1				3
Micronephtys minuta	2						2

Table 1. Cont.'d

	WINTER		SPRING		SUMMER		TOTAL
	Inf.	Epi.	Inf.	Epi.	Inf.	Epi.	
Nephtys bucera	2		1				3
Nephtys incisa	32		37		11		80
Nephtys picta			3		7		10
Nephtys sp.	1				3		4
Glyceridae							
Glycera americana	9		12		30		51
Glycera capitata	1		1				2
Glycera tessellata	3						3
Goniadidae							
Glycinde solitaria	1				2		3
Goniada maculata	1						1
Onuphidae							
Diopatra cuprea	20	10	28		17		85
Onuphis sp.	14	1	12		30		57
Eunicidae							
Marphysa aransensis					1		1
Marphysa sanguinea					1		1
Lumbrinereidae							
Lumbrineris fragilis	4		1		9		14
Lumbrineris latrelli					1		1
Lumbrineris parvapedata			2				2
Lumbrineris tenuis	2		3		3		8
Lumbrineris tetraura	15		35		15		55
Lumbrineris sp.	1		36		21		58
Ninoe nigripes	16		23		21		60
Arabellidae							
Arabella iricolor	5		4		2		11
Drilonereis magna			3		7		10
Drilonereis longa	1				1		2
Spionidae							
Apoprionospio sp.					1		1

Table 1. Cont.'d

	WINTER		SPRING		SUMMER		TOTAL
	Inf.	Epi.	Inf.	Epi.	Inf.	Epi.	
Malacocerus indicus	5		3		5		13
Malacocerus cf. *vanderhosti*	2						2
Minuspio cf. *cirrifera*					1		1
Minuspio cf. *cirrobranchiata*					1		1
Minuspio cf. *longbranchiata*					1		1
Minuspio polybranchiata					1		1
Minuspio sp.					1		1
Paraprionospio pinnata	206		1146		67		1419
Polydora ligni					1		1
Polydora socialis			2				2
Polydora websteri			5				5
Prionospio cirrifera			2				2
Prionospio cirrobranchiata	1				1		2
Prionospio steenstrupi			25		73		108
Prionospio sp.					1		1
Scolecolepides viridis	1						1
Scolelepis cf. *texana*			1		2		3
Scolelepis sp.	1						1
Spiophanes bombyx	2		5		4		11
Spiophanes longicirus			3				3
Spiophanes sp.			1				1
Megalonidae							
Magelona pettiboneae	9		19		45		73
Magelona phyllisae	7		79		87		173
Magelona sp.	38	3	38		16		105
Cirratulidae							
Chaetozone gayheadia	1				3		4
Tharyx marioni					8		8
Tharyx setigera	15		21		18		54
Cossuridae							
Cossura delta	12		32		34		78
Cossura cf. *soyeri*	2						2

Table 1. Cont.'d

	WINTER		SPRING		SUMMER		TOTAL
	Inf.	Epi.	Inf.	Epi.	Inf.	Epi.	
Orbinidae							
Haploscoloplos foliosus	2		2				4
Paraonidae							
Aedicira albatrossae	2		2				4
Aedicira sp.	3		2		2		7
Aricidea brevicornis	2		2		1		5
Aricidea cf. *cerruti*			1				1
Aricidea fragilis	1				1		2
Aricidea jeffreysi	1		1		10		12
Aricidea longobranchiata	1						1
Aricidea sucecica	3						3
Aricidea taylori	6		3		1		10
Aricidea wassi			1				1
Aricidea sp.	1		1		2		4
Paraonides lyra	1		2				3
Paraonis cf. *fulgens*					1		1
Opheliidae							
Armandia agilis	10		5		18		33
Armandia maculata	1						1
Polyopthalmus picta	4		1		3		8
Capitellidae							
Capitellides teres	1						1
Heteromastus filiformis					1		1
Leiocapitella glabra			1				1
Mediomastus californiensis	3		6		8		17
Notomastus americanus	1		2				3
Notomastus hemipodus	2				1		3
Notomastus latericeus	19		8		11		38
Notomastus sp.	1				1		2
Oweniidae							
Owenia fusiformis			6				6

Table 1. Cont.'d

	WINTER		SPRING		SUMMER		TOTAL
	Inf.	Epi.	Inf.	Epi.	Inf.	Epi.	
Sternaspidae							
Sternaspis scutata			1				1
Pectinariidae							
Pectinaria gouldi			5		1		6
Ampharetidae							
Ampharetid sp.			1				1
Amphicteis gunneri					5		5
Amphicteis cf. *gunneri*					1		1
Isolda pulchella	1						1
Melinnopsis atlantica			5				5
Maldanidae							
Asychis cf. *capensis*			1				1
Asychis carolinae	5		2		8		15
Asychis sp.	6	7					13
Branchioasychis americana			1				1
Clymanella mucosa	2						2
Clymanella torquata	4		5		8		17
Clymanella sp.	1						1
Maldane sarsi	4				9		13
Terebellidae							
Polycirrus eximius	1						1
Terebellides stroemii	6		1		6		13
Sabellidae							
Eupomatus protulicola					19		19
Paralacydonidae							
Paralacydonia paradoxa	4		12		12		28
Flabelligeridae							
Flabelligerid sp.					7		7
Oligochaeta					1		1
Hirudinea			1				1

Table 1. . Cont.'d

	WINTER		SPRING		SUMMER		TOTAL
	Inf.	Epi.	Inf.	Epi.	Inf.	Epi.	
PHYLUM MOLLUSCA							
Pelecypoda							
Nuculanidae							
Nuculana acuta		6					6
Arcidae							
Anadara lienosa floridana			1				1
Anadara notibilis		8				2	10
Pectinidae							
Amusium papyraceus		86		71		29	186
Diplodontidae							
Diplodonta sp.			511				511
Cardiidae							
Microcardium permable		4					4
Trigoniocardium antillarum		8					8
Vereidae							
Chione clenchi		1					1
Pitar cordatus		1		3		2	6
Mactridae							
Mulinia lateralis		5					5
Tellinidae							
Tellina aequistriata		1					1
Tellina sp.		2	2		5	2	11
Corbulidae							
Corbula contracta	1						1
Gastropoda							
Architectonica							
Architictonica nobilis		1				1	2
Clayptraeidae							
Crepidula fornicata		1					1
Naticidae							
Natica marochiensis		1					1

Table 1. Cont.'d

	WINTER		SPRING		SUMMER		TOTAL
	Inf.	Epi.	Inf.	Epi.	Inf.	Epi.	
Cassididae							
Sconscia striata		1		2			3
Cymatiidae							
Distorsio clathrata						1	1
Muricidae							
Centrifuga swansoni		1					1
Murex fulvescens		1		1			2
Nassariidae							
Nassarius vibex	13						13
Buccinidae							
Cantharus cancellaria		20		37			57
Melongenidae							
Busycon contratium		1					1
Fasciolariidae							
Fasciolaria hunteria				1		2	3
Volutidae							
Aurinopsis kieneri		2			1		3
Conidae							
Conus austini					1		1
Conus cf. *clarki*		1					1
Turridae							
Polystira albida		1					1
Columbellidae							
Anachis obesa	1						1
Scaphopoda							
Dentallidae							
Dentalium texasianum		1					1
Cephalopoda							
Loliginidae							
Loligo pealei		250		1151		446	1847
Lolliguncula brevis		1290		292		21	1603
Sepiolidae							
Rossia tenera				27			27

Table 1. Cont.'d

	WINTER Inf.	WINTER Epi.	SPRING Inf.	SPRING Epi.	SUMMER Inf.	SUMMER Epi.	TOTAL
Nudibranch				3			3
PHYLUM ARTHROPODA							
Cirripedia							
Thoracila							
Lepas sp.			1				1
Stomatopoda							
Squilla chydaea		29		95		44	168
Squilla empusa		100		203		30	330
Squilla sp.				3			3
Parasquilla coccinea				1			1
Amphipoda							
Ampelisca aequicornis	5		128		18		151
Ampelisca abdita	4		5		4		13
Ampelisca typica	240		191		101		532
Ampelisca vadorum	41		13		2		56
Ampelisca verrilli	14		5		34		53
Ampelisca sp.	2		7				9
Corophium ascherusicum		6					6
Corophium bonelli		1					1
Corophium insidiosum		4					4
Corophium cf. *insidiosum*		1					1
Corophium volutator			3				3
Corophium sp.	5		2		3		10
Erichthonius rubricornis				4			4
Harpinea apropinque				2			2
Harpinea neglecta	2						2
Hippomedon propinquus			2				2
Hyperiella sp.			6				6
Listriella barnardi			1		2		3
Listriella clymenella			10				10

Table 1. Cont.'d

	WINTER		SPRING		SUMMER		TOTAL
	Inf.	Epi.	Inf.	Epi.	Inf.	Epi.	
Melita dentata					1		1
Melita nitida	2		3				5
Microdeutopas anomalus			1				1
Monoculodes norvecicus					1		1
Photis cf. *dentata*					3		3
Phtisica marina					1		1
Sphyrapus cf. *anomalus*					1		1
Photis macrocoxa			8				8
Unicola serrata			1		2		3
Unicola irrorata					6		6
Isopoda							
Apseudid sp.	5		6		10		21
Aegathoa oculata					1		1
Cymothoa excisa				1			1
Lironeca texana		2		6			8
Xenanthura brevitelson	2						2
Copepoda							
Centropages velificata			2				2
Centropages sp.	2		6				8
Labidocera aestiva	3					10	13
Cumacea							
Eudorella emarginatus			1		3		4
Eudorella hispida	4		1		3		8
Eudorella truncatula			6				6
Decapoda							
Natantia							
Solenocerinae							
Solenocera atlantidis	1					7	8
Solenocera vioscai		48		707		232	987
Penaeinae							
Parapenaeus longirostrus		28		845		11	887

Table 1. Cont.'d

	WINTER		SPRING		SUMMER		TOTAL
	Inf.	Epi.	Inf.	Epi.	Inf.	Epi.	
Penaeus aztecus		409		136		331	776
Penaeus duorarum		6		4		40	50
Penaeus setiferus		86		31			117
Trachypenaeus constrictus				1			1
Trachypenaeus similis	1	348	1	4583		32	4965
Xiphopenaeus kroyeri		1					1
Sicyoninae							
Sicyonia brevirostris		43		16		33	92
Sicyonia dorsalis		516		3516		1041	5073
Sicyonia stimpsoni		2		47		17	66
Sergestidae							
Acetes americanus		2106		4147			6253
Lucifer faxoni	1				1		2
Pasiphaeidae							
Leptochelia serratorbita					1		1
Palaemonidae							
Leander tenuicornis				1			1
Alpheidae							
Alpheus floridanus	3		1	16			20
Alpheus sp.	1		2		1		4
Automate evermanii	7		12		15		34
Automate sp.			1				1
Synalpheus sp.						1	1
Hippolytidae							
Latreutes fucorum			4	1			5
Latreutes parvulus			2				2
Parapandalidae							
Parapandalus cf. *longicauda*	2		5	2		2	11
Pleisonika tenuipes				3			3
Processidae							
Processa hemphilli						1	1

Table 1. Cont.'d

	WINTER		SPRING		SUMMER		TOTAL
	Inf.	Epi.	Inf.	Epi.	Inf.	Epi.	
Reptantia							
Scyllaridae							
Scyllarus chacei				2			2
Callianassidae							
Callianassa latispina			1		2		3
Callinassa cf. *major*			2				2
Axiidae							
Calocaris oxypleura					1		1
Galatheidae							
Munida forceps						1	1
Porcellanidae							
Porcellana sayana				15		2	17
Porcellana sigsbeiana						1	1
Diogenidae							
Dardanus insignis		1		2		1	4
Paguristes cf. *moorei*		9					9
Paguristes triangulatus				1			1
Petrochirus diogenes						1	1
Paguridae							
Pagurus annulipes		2					2
Pagurus bullisi		4				6	10
Pagurus pollicaris						3	3
Raninidae							
Raninoides louisianensis		10		6		1	17
Leucosiidae							
Myropsis quinquespinosa		1		1		1	3
Persephona crinita		1		2			3
Dorippidae							
Ethusa microphthalma		2					2
Calappidae							
Acanthocarpus alexandri		3		3		1	7

Table 1. Cont.'d

	WINTER		SPRING		SUMMER		TOTAL
	Inf.	Epi.	Inf.	Epi.	Inf.	Epi.	
Calappa sulcata				3		1	4
Hepatus epheliticus		1		2		1	4
Hepatus pudibundus				2			2
Cymopolidae							
Cymopolia obesa		1					1
Majidae							
Anasimus latus		4		37		11	52
Collodes trispinosus		1					1
Libinia emarginata				2			2
Stenocionops furcata				1			1
Portunidae							
Callinectes sapidus				3		1	4
Callinectes similis		197		626		1323	2146
Ovalipes quadulpensis				3			3
Portunus gibbesi		6		30		15	51
Portunus spinicarpus		37		20		59	116
Portunus spinimanus				23			23
Xanthidae							
Eurypanopeus depressus		1		3		4	8
Micropanope sculptipes					1	2	3
Neopanope texana	1			2	1		4
Neopanope cf. sp.						1	1
Pilumnus dasypodus						1	1
Parthenopidae							
Leiolambrus nitidus				3		1	4
Goneplacidae							
Chasmocarcinus mississippiensis	2		4		3		9
Speocarcinus lobatus	3		3	1	7	1	15
Pinnotheridae							
Pinnixa cf. *chaetopterana*						1	1
Pinnixa retinens	1		9		6		16

Table 1. Cont.'d

	WINTER		SPRING		SUMMER		TOTAL
	Inf.	Epi.	Inf.	Epi.	Inf.	Epi.	
Pinnixa sayana					1		1
Pinnixa sp.	1						1
Echiurida							
Unknown #1	2		1				3
Echinodermata							
Asteroidea							
Astropecten cingulatus		15		8		12	35
Astropecten duplicatus		34		318		9	361
Astropecten sp.		1				1	2
Luidia clathrata				1			1
Roaster alexandri		6					6
Tethyaster vestitus						4	4
Ophiuroidea							
Unidentified Ophiuroid	4				12		16
Echinoidea							
Brissiopsis alta		93		19		10	132
Clypeaster ravenelii				14		1	15
Clypeaster subdepressus						6	6
Moira atrops	2	68	4	8	1		83
Hemichordata							
Tunicates			1				1
Fish							
Anchoa sp.	1						1
Bregmaceros atlanticus						1	1
Bregmaceros macciellandi	1		5		1		7
Neoconger mucronatus					1		1
Prionotus stearnsi			1				1
Eel larvae					1		1

Table 2. Total number of species, total number of individuals, H", E (equitability) indices and Hurlbert's probability of interspecific encounter (P.I.E.) replicates at each station for the winter, spring and summer epifaunal collections.

WINTER

	Transect	Station	Rep.	Sp.	Ind.	H"	E	P.I.E.
Day	I	1	AHO	12	2177	.2183	.086	.0692
Night	I	1	AFL	13	957	1.2435	.447	.9417
Day	I	2	AFB	8	34	1.6150	.704	.7290
Night	I	2	ACT	11	449	1.2682	.511	.5618
Day	I	3	ABD	21	67	2.6913	.870	.9231
Night	I	3	BHW	21	86	2.5810	.823	.9094
Day	II	1	AJB	2	4	.5623	.510	.4999
Night	II	1	AII	7	86	1.0390	.473	.5778
Day	II	2	AMA	4	29	.8758	.547	.4630
Night	II	2	ALG	3	3	1.0986	.793	1.0000
Day	II	3	APD	4	9	1.2148	.671	.7500
Night	II	3	AOI	9	29	1.6630	.721	.7438
Day	III	1	ASF	3	6	.8675	.541	.6000
Night	III	1	ARL	7	82	1.3290	.605	.6654
Day	III	2	AVK	1	2	N.C.	N.C.	N.C.
Night	III	2	AUO	7	49	1.4729	.707	.7108
Day	III	3	AYH	1	9	N.C.	N.C.	N.C.
Night	III	3	ANX	15	207	1.709	.631	.735
Day	IV	1	BBG	8	18	1.8019	.782	.8431
Night	IV	1	BAL	8	159	1.7058	.778	.7887
Day	IV	2	BEI	5	5	1.609	1.00	1.0000
Night	IV	2	BDL	6	66	1.5452	.797	.7724
Day	IV	3	BPD	0	0	N.C.	N.C.	N.C.

Table 2. Cont.'d

	Transect	Station	Rep.	Sp.	Ind.	H"	E	P.I.E.
Night	IV	3	BGM	6	44	1.3285	.683	.6754
			SPRING					
Day	I	1	CBB	11	1315	1.1691	.456	.6131
Night	I	1	CAH	16	1420	.7922	.279	.3485
Day	I	2	CEB	9	161	.4846	.213	.1771
Night	I	2	CDL	13	681	1.0592	.402	.5062
Day	I	3	CHL	5	7	1.4750	.826	.8571
Night	I	3	CGP	8	33	1.6499	.751	.7821
Day	II	1	CKR	13	4161	.7534	.277	.3554
Night	II	1	CJW	15	1228	.7516	.271	.3148
Day	II	2	CNU	6	878	.3950	.192	.1666
Night	II	2	CMZ	13	1175	1.4797	.561	.7129
Day	II	3	CQW	2	10	.3250	.300	.1999
Night	II	3	CQB	5	54	.6176	.346	.2976
Day	III	1	CUE	6	119	1.2461	.601	.6554
Night	III	1	CTI	11	1029	1.0650	.417	.5820
Day	III	2	CYA	11	79	1.5445	.604	.6325
Night	III	2	CXL	13	318	1.7009	.628	.7540
Day	III	3	DBC	6	48	1.1822	.606	.6318
Night	III	3	DAJ	11	162	1.8401	.767	.7799
Day	IV	1	DEC	8	432	1.4793	.674	.7296
Night	IV	1	DDJ	12	1442	1.200	.483	.642
Day	IV	2	DHB	8	13	1.9512	.887	.9102
Night	IV	2	DGI	16	142	1.9002	.657	.7861
Day	IV	3	DKG	10	27	1.7907	.746	.7777
Night	IV	3	DJK	14	56	2.0727	.764	.8129

Table 2. Cont.'d

SUMMER

	Transect	Station	Rep.	Sp.	Ind.	H"	E	P.I.E.
Day	I	1	EBB	10	90	1.3404	.559	.5782
Night	I	1	EAH	7	183	1.0385	.500	.5769
Day	I	2	EEB	9	495	.6013	.261	.3398
Night	I	2	EDL	10	134	1.5817	.059	.7343
Day	I	3	EHL	10	37	1.9015	.825	.8108
Night	I	3	EGP	10	71	1.1517	.480	.4726
Day	II	1	EKR	1	1	N.C.	N.C.	N.C.
Night	II	1	EJW	6	95	1.6763	.863	.8089
Day	II	2	ENV	10	22	1.8553	.776	.7922
Night	II	2	EMZ	8	37	1.2429	.596	.5660
Day	II	3	EQW	7	17	1.6459	.793	.8088
Night	II	3	EQB	8	21	1.7371	.832	.8095
Day	III	1	EUE	6	79	1.1597	.558	.5556
Night	III	1	ETI	7	159	1.3355	.610	.6774
Day	III	2	EYA	8	56	1.3064	.625	.6506
Night	III	2	EXL	2	147	1.3302	.640	.6594
Day	III	3	FBC	1	5	N.C.	N.C.	N.C.
Night	III	3	FAJ	3	45	2.2459	.873	.8868
Day	IV	1	FEK	4	97	.6636	.410	.3395
Night	IV	1	FDQ	8	95	1.6999	.818	.7726
Day	IV	2	FHL	3	40	.5354	.397	.3038
Night	IV	2	FGQ	11	529	1.2360	.513	.5638
Day	IV	3	FKQ	4	5	1.3321	.826	.9000
Night	IV	3	FJU	11	52	1.7627	.734	.7503

N.C.-Not calculated.

Table 3. Total number of species, total number of individuals, H'', E (equitability) and Hurlbert's probability of interspecific encounter (P.I.E.) for the replicates at each station for the winter, spring and summer infaunal collections.

Winter

Transect	Station	Species	Individuals	H''	E	P.I.E.
I	1	33	265	2.33	.666	.835
I	2	30	96	2.72	.800	0.89
I	3	19	29	2.79	.948	.96
II	1	22	228	1.55	.501	.679
II	2	14	29	2.73	1.03	.913
II	3	7	12	1.82	.935	.893
III	1	13	133	.82	.320	.302
III	2	7	14	1.83	.940	.890
III	3	11	16	2.22	.926	.924
IV	1	44	210	3.34	.883	.946
IV	2	22	36	2.85	.922	.928
IV	3	17	20	2.76	.974	.978

Spring

Transect	Station	Species	Individuals	H''	E	P.I.E.
I	1	42	513	1.71	.458	.609
I	2	30	70	2.96	.870	.933
I	3	13	16	2.42	.943	.949
II	1	43	1481	1.66	.441	.704
II	2	27	66	2.97	.901	.933
II	3	13	18	2.44	.951	.954
III	1	34	301	1.82	.516	.648
III	2	25	53	2.86	.889	.933
III	3	13	21	2.44	.951	.947

Table 3. Cont.'d

Transect	Station	Species	Individuals	H"	E	P.I.E.
IV	1	45	165	3.14	.825	.930
IV	2	17	30	2.71	.957	.958
IV	3	7	12	1.74	.894	.863
			Summer			
I	1	25	144	1.96	.609	.681
I	2	28	58	2.91	.873	.954
I	3	10	14	2.24	.973	.956
II	1	27	116	2.48	.752	.864
II	2	19	33	2.71	.920	.945
II	3	11	15	2.30	.959	.952
III	1	23	116	2.40	.765	.837
III	2	19	30	2.70	.917	.944
III	3	26	65	2.73	.838	.902
IV	1	54	364	3.24	.812	.929
IV	2	28	61	3.25	.975	.768
IV	3	53	147	3.47	.874	.967

Table 4. Distribution of selected species from winter, spring and summer collections. Numbers indicate total number of individuals in all four Smith-MacIntyre grab sample replicates (0.05 m^3) numbers within ( ) indicate number of replicates at which individuals occurred.

Winter

Station	1/I	2/I	3/I	1/II	2/II	3/II	1/III	2/III	3/III	1/IV	2/IV	3/IV
Ampelisca abdita			1(1)			1(1)			1(1)			1(1)
Ampelisca aequicornis										4(3)		1(1)
Ampelisca agassiz (typica)	95(3)	4(3)	1(1)	78(4)	1(1)		103(4)	1(1)		3(2)		1(1)
Armandia maculata	9(3)	1(1)			1(1)							
Aricidea jeffreysi			2(2)									
Automate evermanni		4(2)		1(1)		1(1)					1(1)	
Cossura delta		1(1)			3(1)			1(1)	1(1)	3(2)	3(1)	1(1)
Diopatra cuprea	6(3)	1(1)		1(1)			3(2)			7(4)		
Glycera americana									3(1)	6(4)	3(2)	
Lumbrinereis tetraura				2(1)						13(4)		
Lumbrinereis sp.												
Magelona pettiboneae	2(2)	5(2)								2(1)		
Magelona phyllisae							1(1)			6(3)		
Magelona sp.	2(2)	10(2)		4(3)	3(1)		2(2)	3(1)		7(2)	9(4)	
Mediomastus californiensis		1(1)				1(1)				1(1)		
Minuspio cirrifera												
Nereis sp.	8(3)	15(4)		16(4)	5(3)					26(4)	1(1)	
Nephtys incisa	4(2)	4(2)		8(3)	2(2)		1(1)			2(2)		2(2)
Ninoe nigripes	3(2)	1(1)	2(2)	1(1)	1(1)		6(2)				1(1)	
Notomastus latericeus	11(3)	2(2)	1(1)				1(1)			3(3)		
Onuphis sp.												
Paralacydonia paradoxa			4(2)									1(1)
Paraprionospio pinnata	19(4)	27(4)	1(1)	98(4)	2(2)	2(2)		2(1)	5(4)	33(4)	4(3)	3(1)
Prionospio steenstrupi												
Sigambra tentaculata		1(1)	1(1)	1(1)	1(1)		1(1)		1(1)			1(1)
Speocarcinus lobatus		1(1)								1(1)		
Tharyx setigera		2(1)				2(2)			1(1)	10(3)		

Table 4. Cont.'d

Spring

Station	1/I	2/I	3/I	1/II	2/II	3/II	1/III	2/III	3/III	1/IV	2/IV	3/IV
Ampelisca abdita							1(1)			4(2)		
Ampelisca aequicornis	6(3)	1(1)	24(2)	77(2)			16(1)			5(2)		
Ampelisca agassiz (typica)	7(3)	1(1)	74(2)	44(2)			60(3)			3(2)	1(1)	
Armandia maculata	1(1)							2(1)				
Aricidea jeffreysi												
Automate evermanni		1(1)		1(1)			1(1)	5(1)	1(1)	2(1)	1(1)	
Cossura delta	4(3)	3(2)	3(1)	3(1)	6(3)	1(1)	1(1)	6(3)	3(2)	1(1)	2(2)	
Diopatra cuprea	11(3)	2(2)	1(1)	4(2)			2(2)	1(1)		5(4)	1(1)	
Glycera americana	2(2)	1(1)		2(1)				1(1)		6(3)		
Lumbrinereis tetraura	7(2)		4(1)	13(3)			1(1)			8(3)		
Lumbrinereis sp.	1(1)	2(2)										
Magelona pettiboneae		3(2)					1(1)	11(4)		1(1)	3(3)	
Magelona phyllisae	55(4)		7(1)	22(2)	1(1)		1(1)			2(1)		
Magelona sp.	3(3)	1(1)		16(2)	8(3)		2(2)			9(4)		
Mediomastus californiensis	2(1)	1(1)					2(2)		1(1)			
Minuspio cirrifera												
Nereis sp.	3(3)	9(4)		10(3)	4(2)			1(1)		13(4)	2(1)	
Nephtys incisa	4(3)	5(2)	1(1)	3(2)	12(4)	2(2)	10(3)	2(2)		1(1)	2(1)	
Ninoe nigripes	6(3)	3(2)	1(1)	1(1)			9(4)				2(2)	
Notomastus latericeus	2(2)									6(4)		
Onuphis sp.										1(1)		
Paralacydonia paradoxa			4(2)			1(1)			3(1)			4(3)
Paraprionospio pinnata	314(4)	14(4)	1(1)	603(4)	7(3)		167(4)	5(3)	3(2)	30(3)	1(1)	2(2)
Prionospio steenstrupi										25(3)		
Sigambra tentaculata			2(2)	2(1)	1(1)	3(2)		1(1)		2(2)		
Speocarcinus lobatus				2(1)					1(1)			
Tharyx setigera		3(1)	1(1)		4(3)		2(2)	3(2)	1(1)	5(3)	4(2)	1(1)

Table 4. Cont.'d

Summer

Station	1/I	2/I	3/I	1/II	2/II	3/II	1/III	2/III	3/III	1/IV	2/IV	3/IV
Ampelisca abdita										1(1)		3(3)
Ampelisca aequicornis		2(2)		3(3)			3(3)			4(3)	3(2)	
Ampelisca agassiz (typica)		1(1)		23(4)	1(1)	1(1)	43(4)	1(1)		29(3)		1(1)
Armandia maculata				4(2)			2(1)			11(4)	1(1)	
Aricidea jeffreysi												
Automate evermanni				3(2)		2(2)		5(4)	2(2)	5(3)	5(2)	3(2)
Cossura delta	2(2)	4(2)		3(2)	5(3)	2(2)		3(1)	1(1)	4(3)		1(1)
Diopatra cuprea	4(3)			1(1)			2(2)			15(3)		
Glycera americana	2(2)	1(1)	1(1)						1(1)	11(3)		8(2)
Lumbrinereis tetraura		3(2)					7(4)	1(1)		2(2)		
Lumbrinereis sp.										1(1)	4(2)	
Magelona pettiboneae		9(4)		5(2)	4(1)		2(1)	5(3)		15(2)	4(2)	
Magelona phyllisae	80(4)	1(1)		2(2)						9(3)		
Magelona sp.	1(1)				1(1)		1(1)			9(2)		
Mediomastus californiensis				4(1)								
Minuspio cirrifera		1(1)										
Nereis sp.	7(2)	4(3)		11(4)			3(1)		1(1)	44(4)		
Nephtys incisa	2(1)	4(3)	2(2)	1(1)	5(3)	2(1)	12(4)	2(1)		1(1)	2(1)	
Ninoe nigripes	6(4)		2(2)	1(1)	1(1)	3(2)	2(2)		2(2)			
Notomastus latericeus				2(2)			4(3)			3(2)	2(1)	
Onuphis sp.												1(1)
Paralacydonia paradoxa			2(2)		1(1)				1(1)			6(3)
Paraprionospio pinnata	1(1)	4(3)		29(3)	3(2)	1(1)	4(2)		4(3)	12(3)		4(3)
Prionospio steenstrupi										73(4)	2(1)	1(1)
Sigambra tentaculata	4(2)			3(3)		1(1)	10(4)		6(3)	1(1)	1(1)	
Speocarcinus lobatus	1(1)									5(2)		
Tharyx setigera	1(1)	5(2)			1(1)	1(1)			2(2)	2(1)	2(2)	5(3)

Table 5. Distribution of selected species from winter, spring and summer epifauna collections. Numbers indicate individuals per 15 minute trawl tow, day and night.

Winter

Station	1/I		2/I		3/I		1/II		2/II		3/II		1/III		2/III		3/III		1/IV		2/IV		3/IV	
	D	N	D	N	D	N	D	N	D	N	D	N	D	N	D	N	D	N	D	N	D	N	D	N
Renilla mulleri	1	4																						
Squilla chydea			1	11				1	2	1										5		8		
Squilla empusa	15	55		1				1					1	6						24				
Amusium papyraceus									72			14												
Penaeus aztecus			3	30				35	8	1	1	4	4	40		9	9		4	15	1	22		22
Penaeus duorarum	1													1						4				
Penaeus setiferus	28	58					2																	
Solenocera vioscai				1		4			5			4				7						12		4
Parapenaeus longirostris					9	12			4			2				2								
Trachypenaeus similis	12	122	2	64				44		1	1		1	25					3	55		18		
Sicyonia brevirostris								2						4					1	24	1			12
Sicyonia dorsalis	6	113	17	287					21	1				1		24			6	34		5		
Callinectes similis	3	142	4	16			1	1	17			2		5		7								
Portunus gibbesii		3		2				2											1					
Portunus spinicarpus	5		1		13	8			4														3	
Acanthocarpus alexandri					5	3						1												
Anasimus latus					1	1			1															
Reninoides louisianensis					1	2			2															
Astropecten cingulatus									14							1								
Astropecten duplicatus			3	28	3																			
Brissiopsis alta					3	14			76								15	4						
Clypeaster ravenelli																								

Table 5. Cont.'d

Spring

Station	1/I		2/I		3/I		1/II		2/II		3/II		1/III		2/III		3/III		1/IV		2/IV		3/IV	
	D	N	D	N	D	N	D	N	D	N	D	N	D	N	D	N	D	N	D	N	D	N	D	N
Renilla mulleri		5	4				2	115						1										
Squilla chydea										24		1		3	1	21			22	5		18		2
Squilla empusa	51	65						22		2				14					22	8		1		
Amusium papyraceus						9					9				3	3	21	20			2		1	3
Penaeus aztecus		1	1	17			4	1	1			26	1	20	6	21	1	12	8	10	3	1		2
Penaeus duorarum								1												1				
Penaeus setiferus	19	3						7																
Solenocera vioscai				112		5				265		6				124		24				17		1
Parapenaeus longirostris				2	1	12				11						82	2	14			3	9	1	1
Trachypenaeus similis	674	1135		69			130	1009	22	325		45	9	468	47	45			113	436		56		
Sicyonia brevirostris				1										3					1	1	1	7		2
Sicyonia dorsalis	448	135	146	460			480		45	468			51	22		1			166	697	1	23	2	
Callinectes similis	108	60	2	3			6	23	3				4	41	1		1		97	258			1	
Portunus gibbesii	8	6	4	1			1			3			5							2				
Portunus spinicarpus				6				1		5						6					1	1	1	
Acanthocarpus alexandri					3																			
Anasimus latus					1	1	7								5	4	2	14				1		1
Raninoides louisianensis					1	1						1						3						
Astropecten cingulatus									6			2												
Astropecten duplicatus	1						196		7	2			7	1		5			3	2		1		
Brissiopsis alta																								
Clypeaster ravenelli																							5	9

Table 5. Cont.'d

Summer

Station	1/I D	1/I N	2/I D	2/I N	3/I D	3/I N	1/II D	1/II N	2/II D	2/II N	3/II D	3/II N	1/III D	1/III N	2/III D	2/III N	3/III D	3/III N	1/IV D	1/IV N	2/IV D	2/IV N	3/IV D	3/IV N
Renilla mulleri			1										4											
Squilla chydea		6	1	2				6	1	1				2		11			1			18	1	1
Squilla empusa			1	1		1		6		1			4	7		1						1		
Amusium papyraceus				1		1				1		8					5						1	4
Penaeus aztecus	5	69	2	42	2	3	1	22	1	1	51	2		73	4	12			9		6	19	2	5
Penaeus duorarum		1																		39				
Penaeus setiferus																								
Solenocera vioscai				13		51					1	5				41						110		11
Parapenaeus longirostris											1	1												9
Trachypenaeus similis	5	8		3				19						6								10		
Sicyonia brevirostris																				15		8		10
Sicyonia dorsalis	12	1	391	52				20	10	3			6	21	18	74			78	10	33	330		2
Callinectes similis	57	97		14				22	1	24	5	1	12	49	28	4			9	12		14		
Portunus gibbesii		1											2	1	1					9				
Portunus spinicarpus				2	14			8	2													1		24
Acanthocarpus alexandri					1																			
Anasimus latus					1	3										4								3
Raninoides louisianensis					1																			
Astropecten cingulatus					7										1									4
Astropecten duplicatus	2	4							2										1					
Brissiopsis alta					4						6													
Clypeaster ravenelli																								5

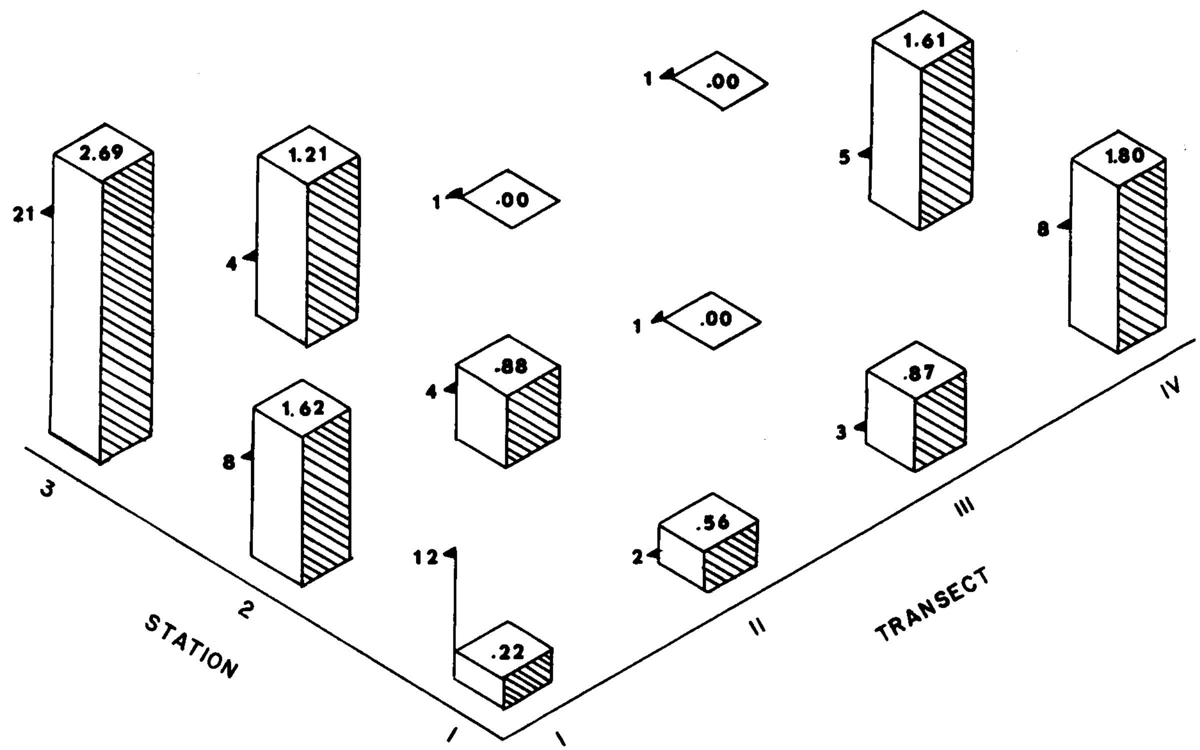

Figure 1. Shannon diversity values - H'' (number on histograms) and number of species (flag on histograms) for the diurnal Winter epifauna samples.

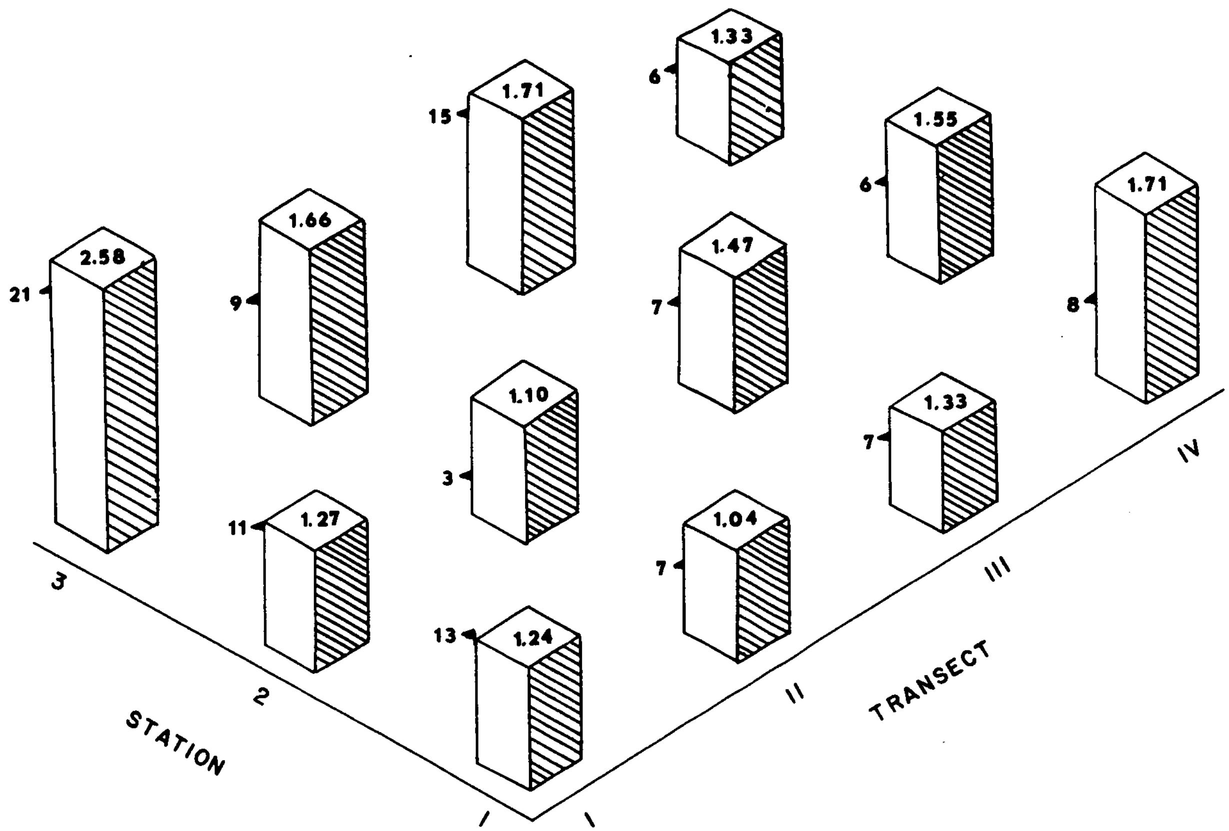

Figure 2. Shannon diversity values - H'' (number on histograms) and number of species (flag on histograms) for the nocturnal Winter epifauna samples.

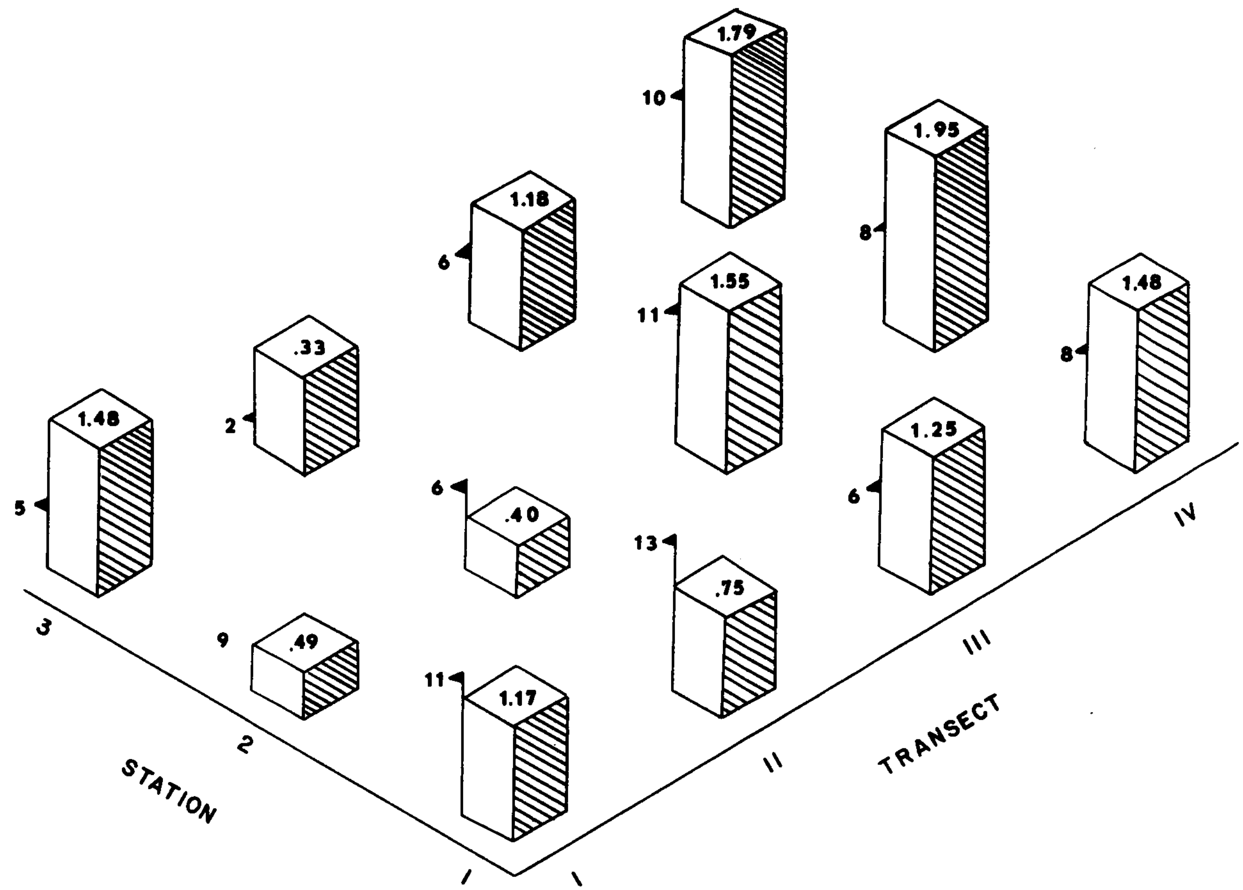

Figure 3. Shannon diversity values - H" (number on histograms) and number of species (flag on histograms) for the diurnal Spring epifauna samples.

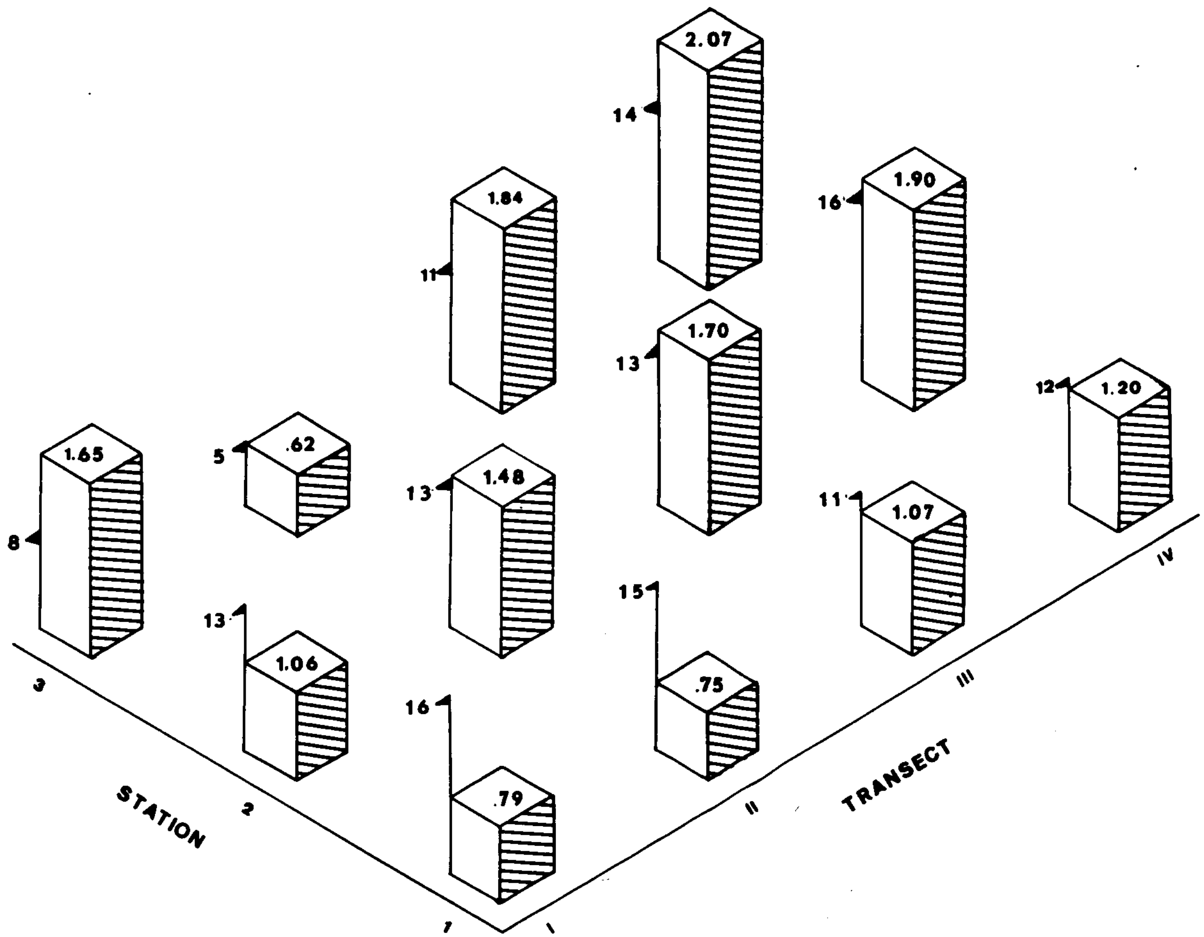

Figure 4. Shannon diversity values - H' (number on histograms) and number of species (flag on histograms) for the nocturnal Spring epifaunal samples.

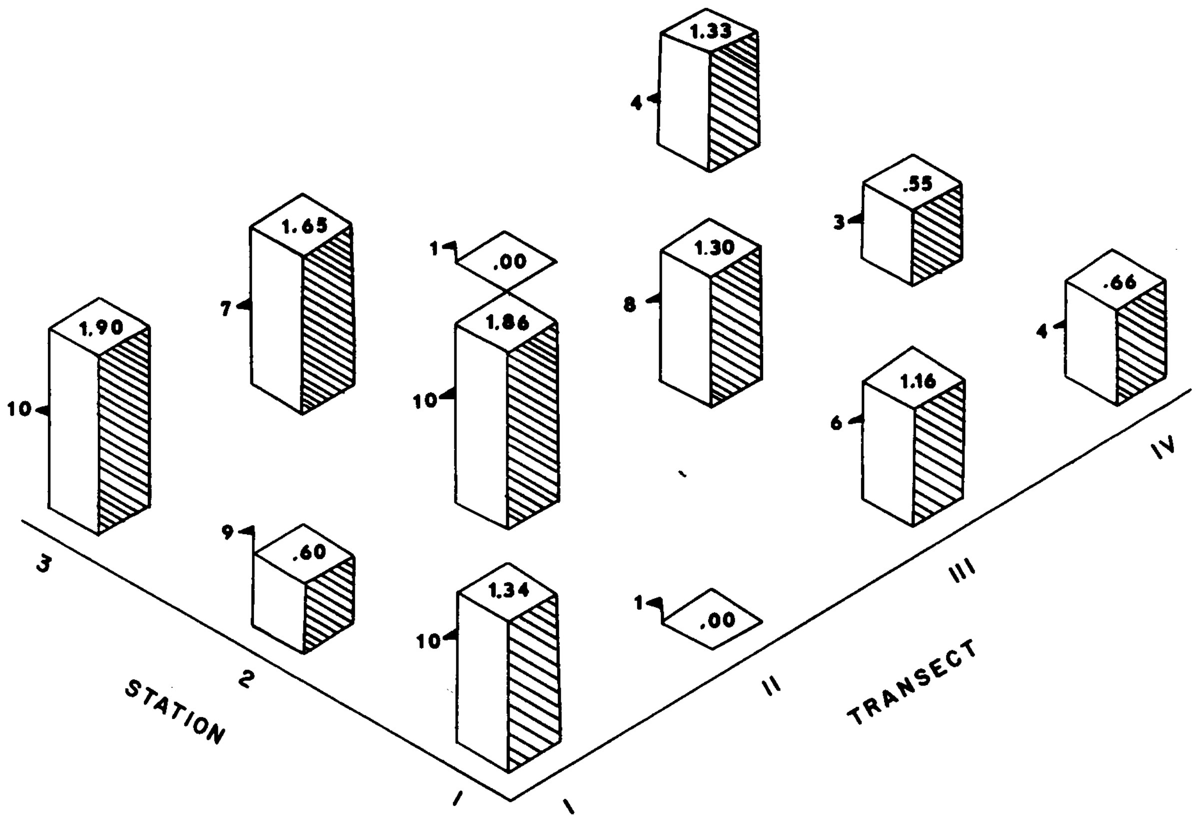

Figure 5. Shannon diversity values - H'' (number on histograms) and number of species (flag on histograms) for the diurnal Summer epifauna samples.

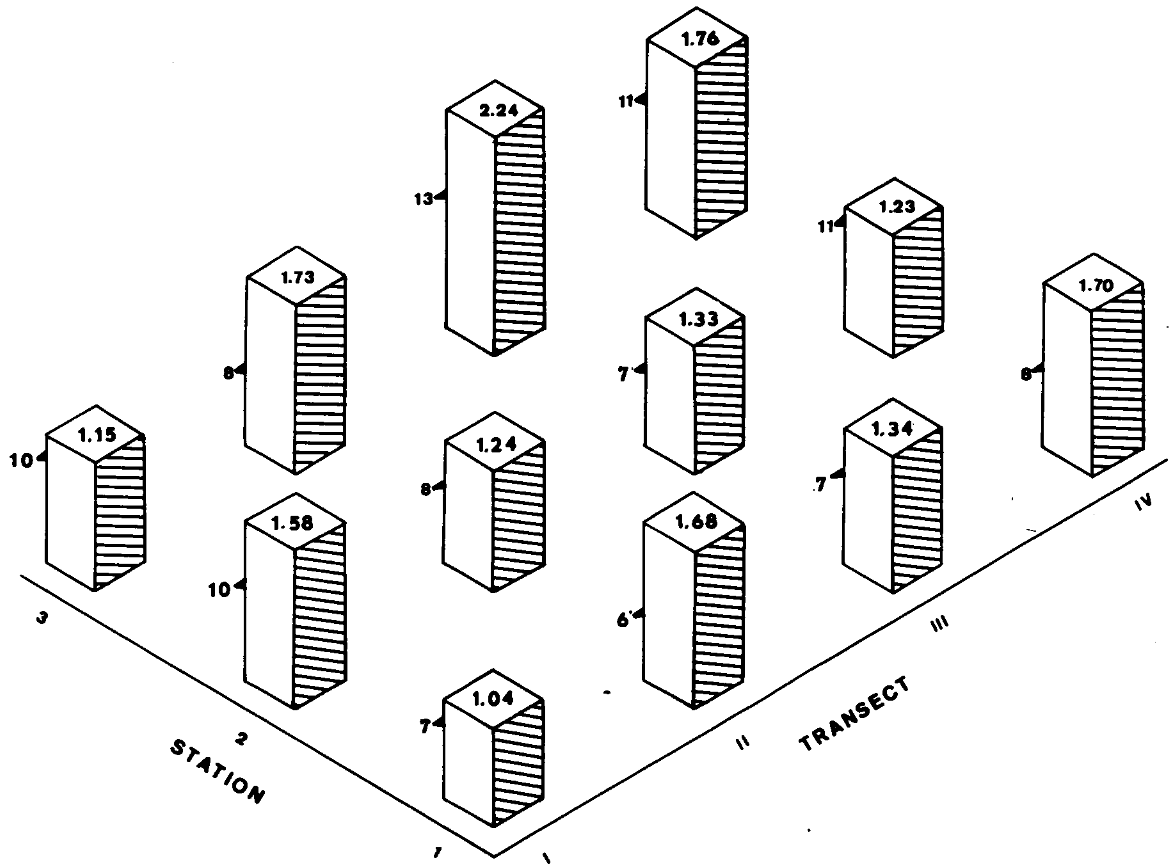

Figure 5. Shannon diversity values - H'' (number on histograms) and number of species (flag on histograms) for the nocturnal Summer epifaunal samples.

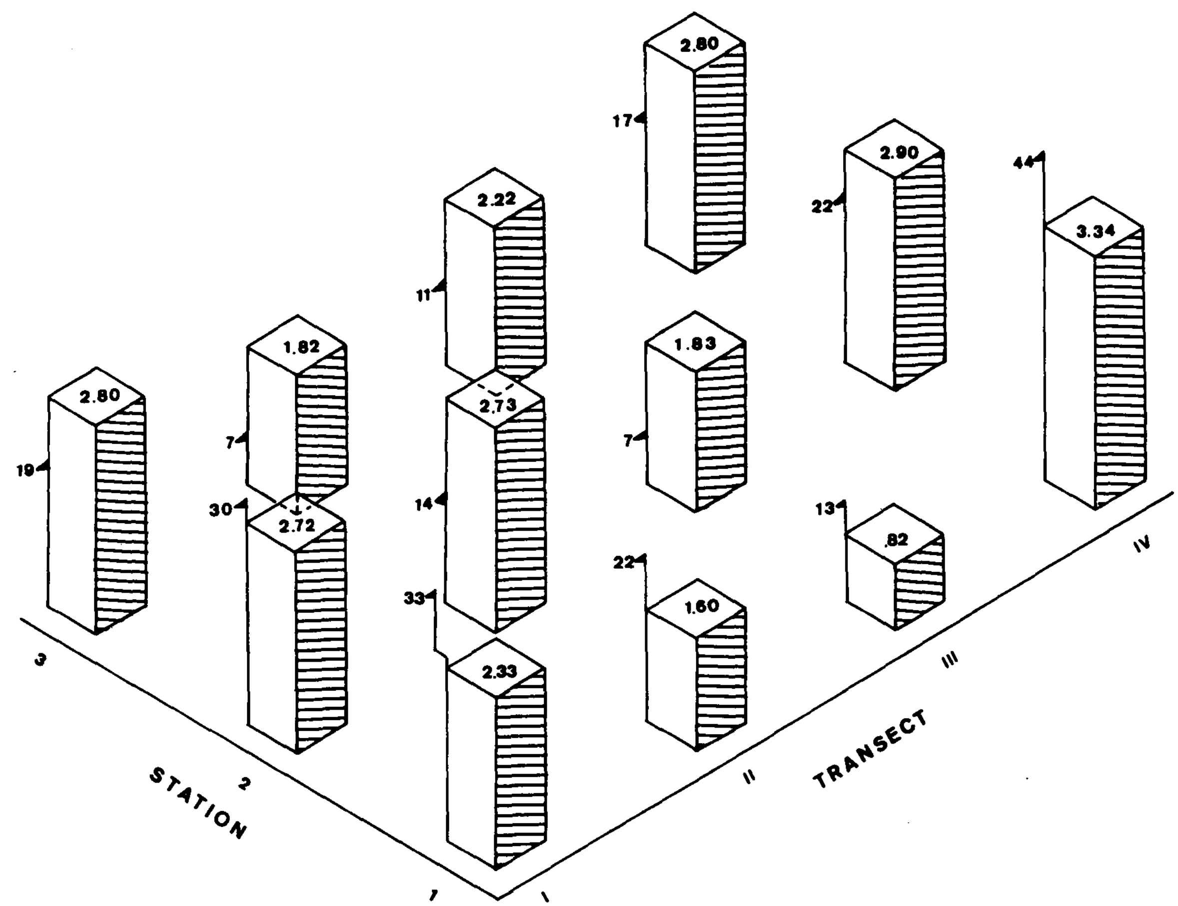

Figure 7. Shannon diversity values - H'' (number on histograms) and number of species (flag on histograms) for the Winter Infauna samples.

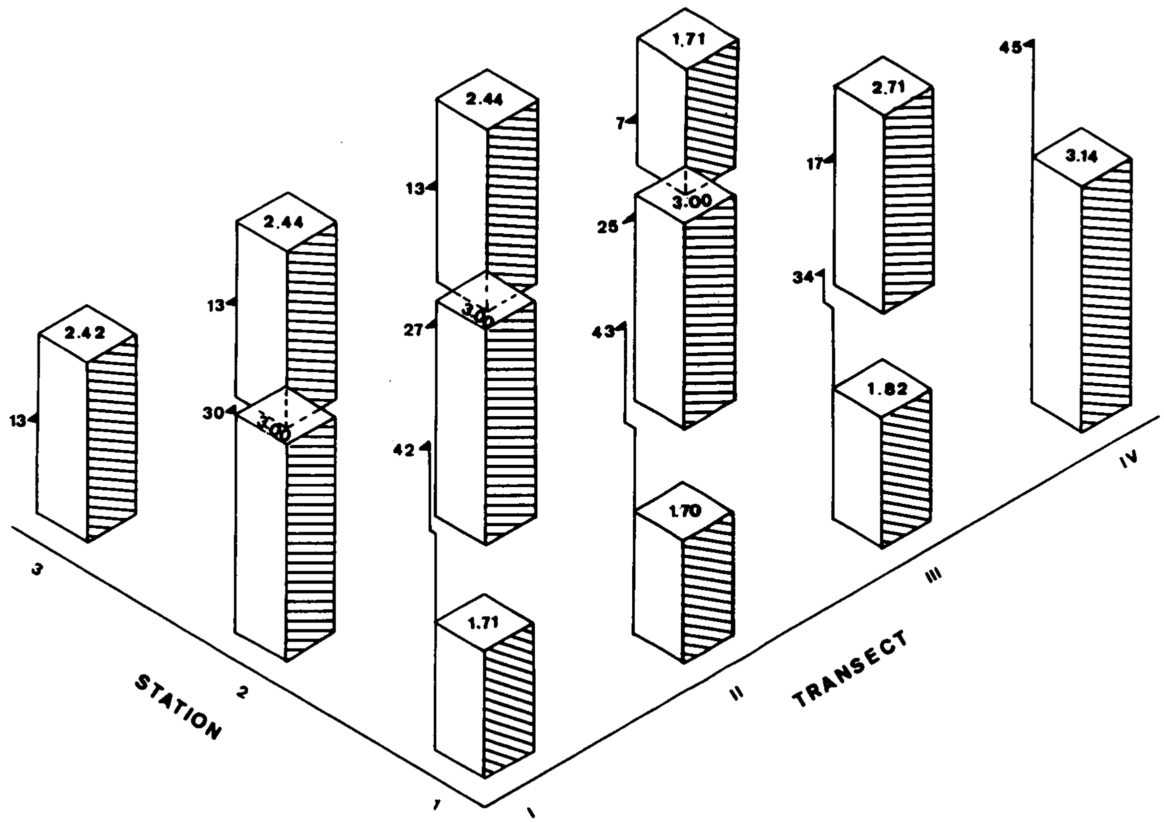

Figure 8. Shannon diversity values - H" (number on histograms) and number of species (flag on histograms) for the Spring Infaunal samples.

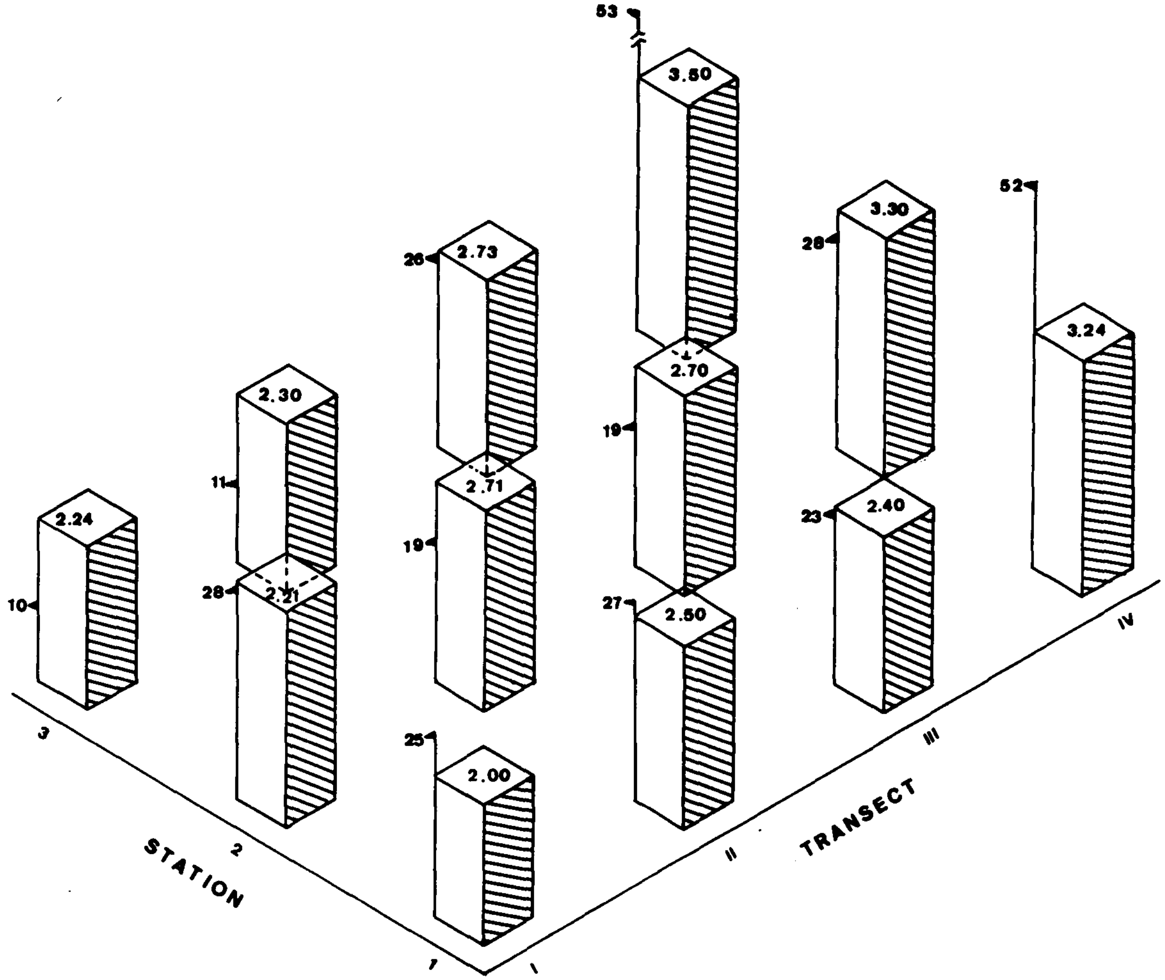

Figure 9. Shannon diversity values - H'' (number on histograms) and number of species (flag on histograms) for the Summer Infaunal samples.

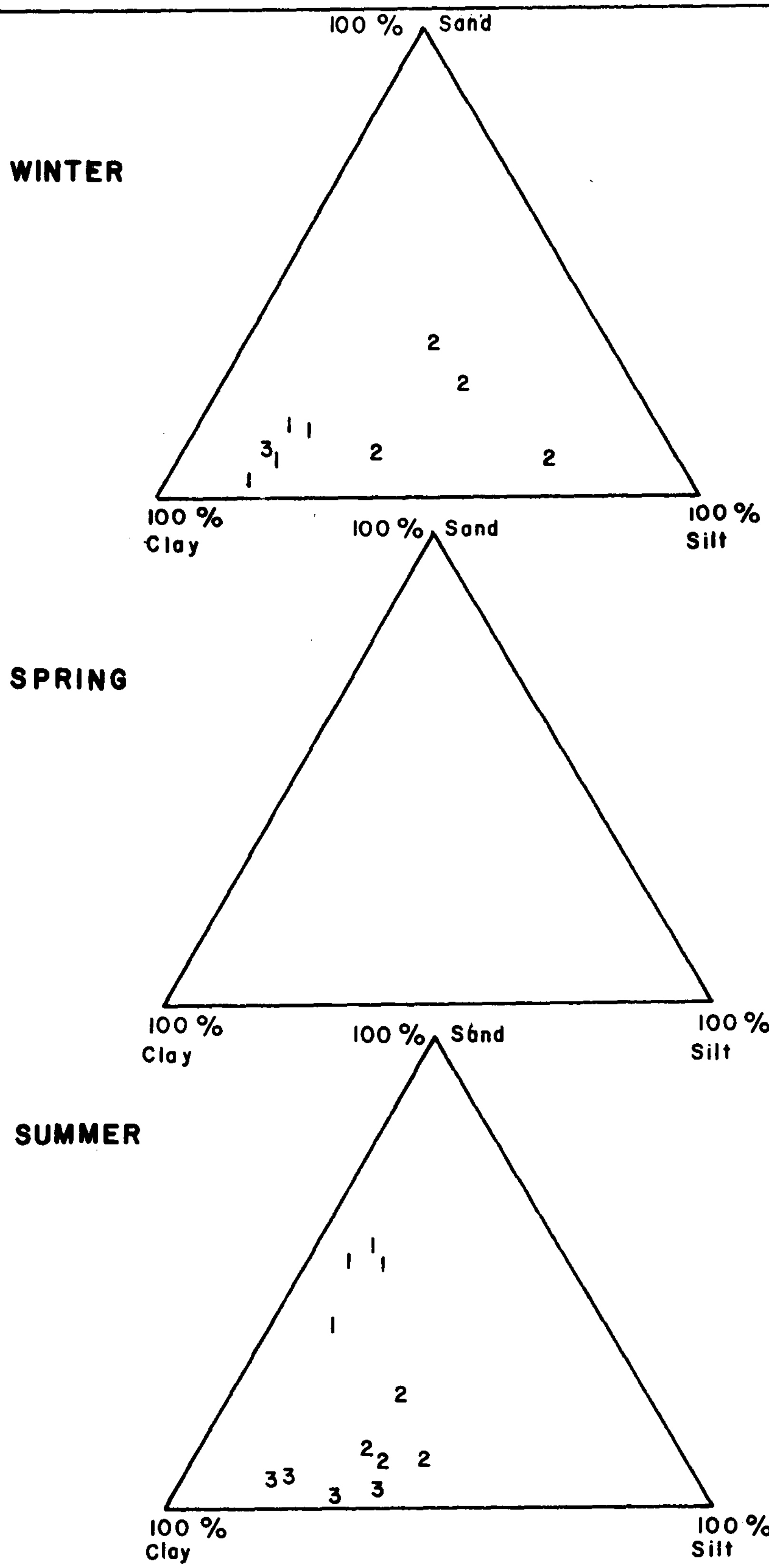

Figure 10. Sediment composition of replicates at each station along Transect I.

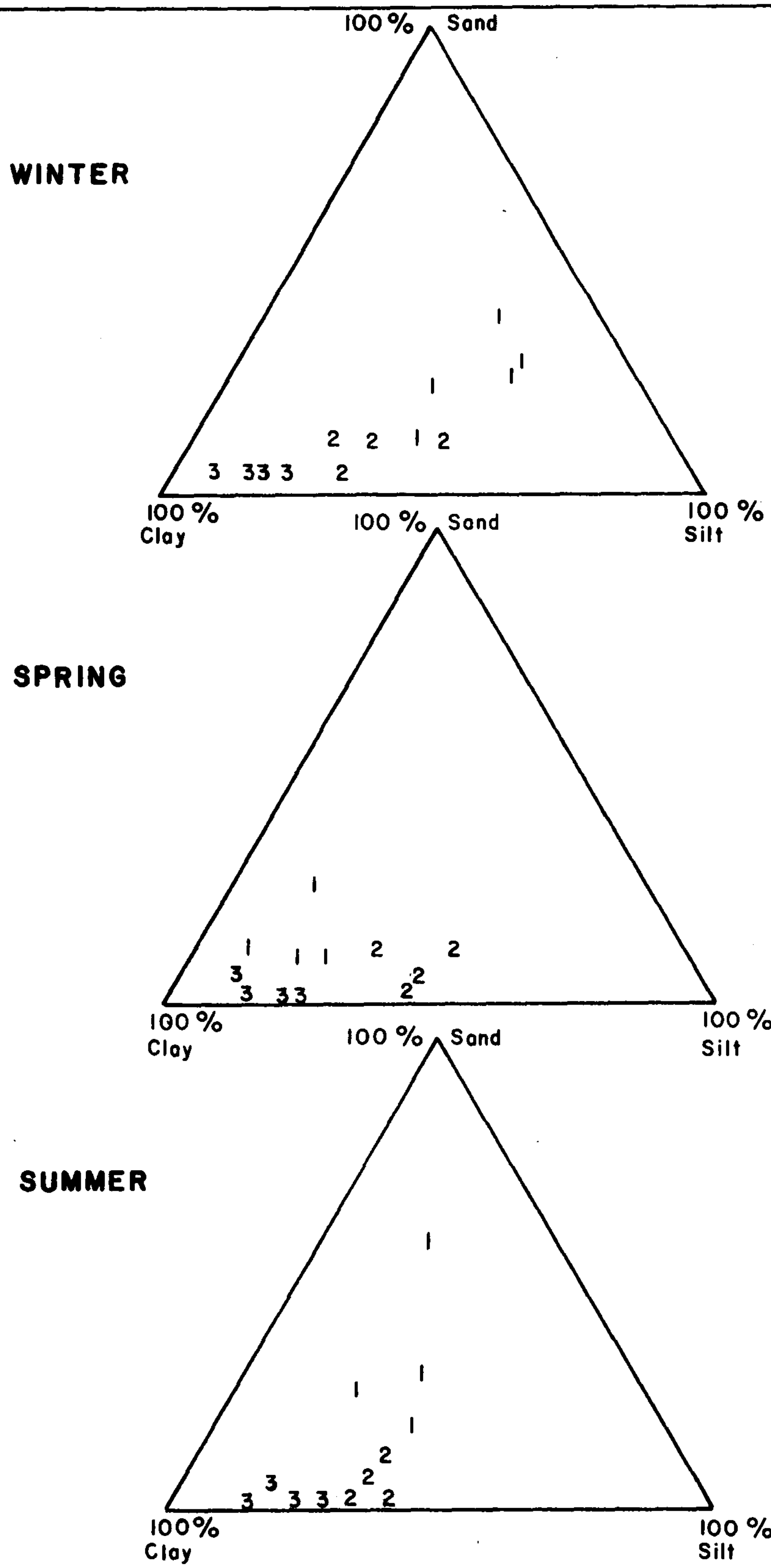

Figure 11. Sediment composition of replicates at each station along Transect II.

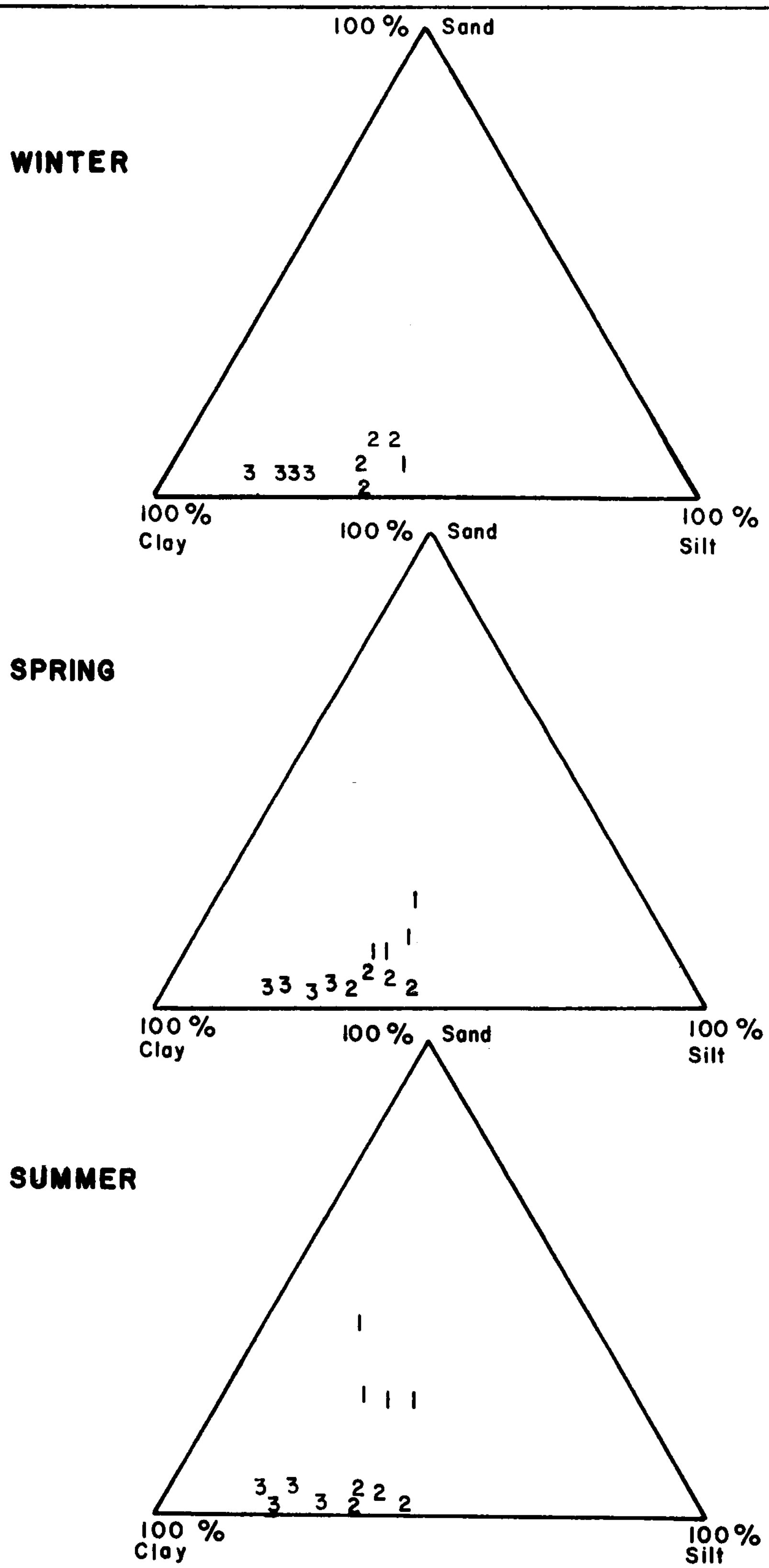

Figure 12. Sediment composition of replicates at each station along Transect III.

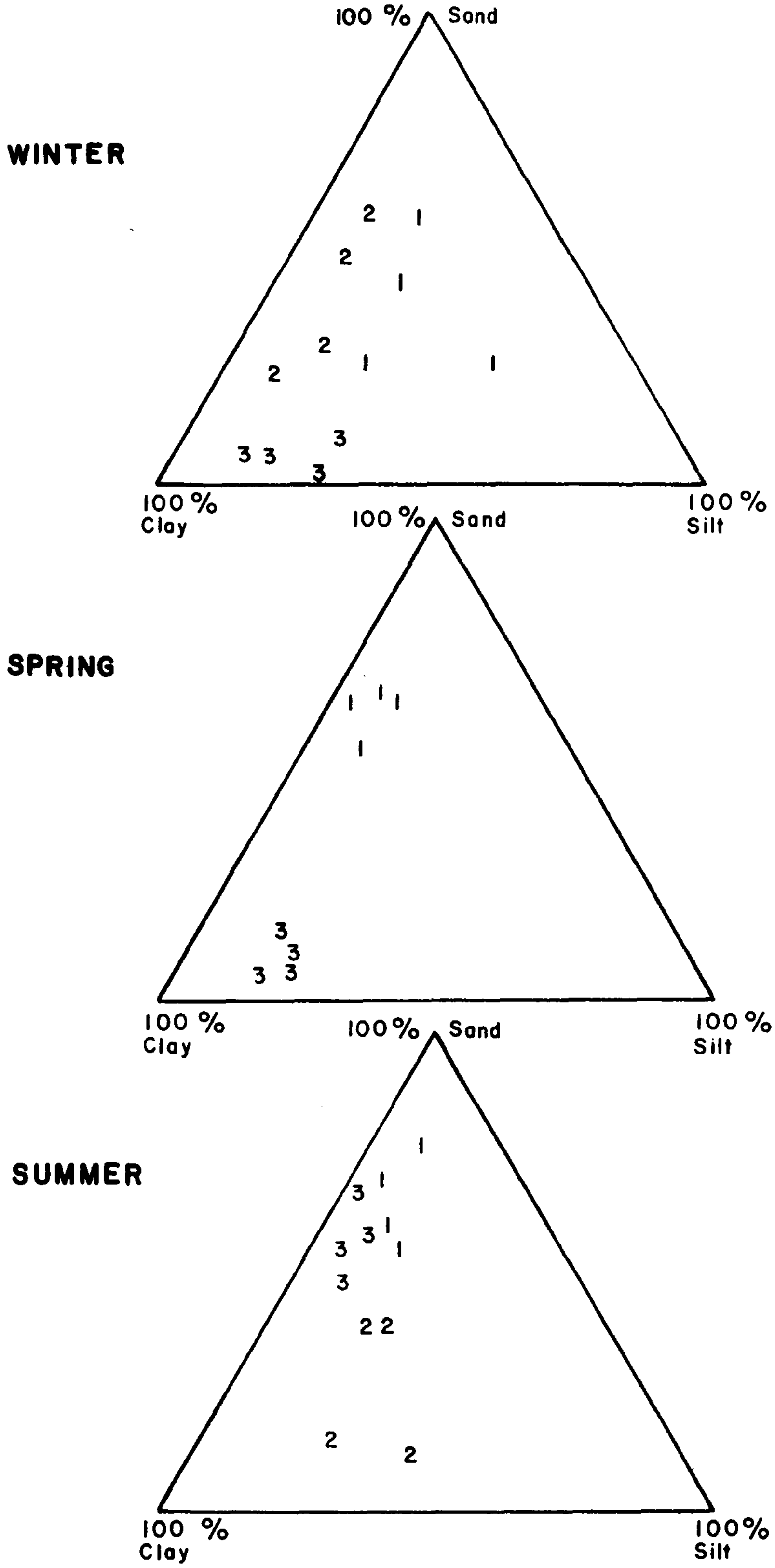

Figure 13. Sediment composition of replicates at each station along Transect IV.

BENTHOS PROJECT

EPIFAUNAL FISHES

University of Texas Marine Science Laboratory

Principal Investigator:
Donald E. Wohlschlag

Associate Investigators:
James F. Cole
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INTRODUCTION

The purpose of this study is to develop a baseline pertinent to both the abundance and the distribution of benthic fishes on the South Texas Outer Continental Shelf (OCS).

The needs for concentrated, standardized and synoptic surveys of organisms in this area are, and have been, obvious for an understanding of both the nature of organisms and the influences of environmental regimes, both natural and man-influenced, on them. The utilization of distributional and abundance information has become increasingly important for the assessment and interpretation of both environmental stability and effects of perturbations, particularly subtle perturbations that cannot be immediately and easily recognized.

The use of fishes for environmental assessment includes ecologically important considerations of theoretical and practical nature. For example:

1. Fishes are widely known to the public at large as commercially and recreationally valuable resources.
2. Fishes in areas like the South Texas OCS are well known taxonomically to biologists to the extent that the species can be readily identified accurately with little confusion expected in the identification of new or rare species.
3. Fishermen and biologists, collectively, usually have an awareness of changes in abundance and distribution of species important to them; usually, based on "native wisdom", they develop adverse reaction rather quickly to acute adversities suffered by fish populations; but they have ordinarily little immediate

awareness of reaction to subtle, chronic adversities that have long term deleterious effects on fishes up to the time that population declines are more or less disastrous.

4. Ecologically, there is a large amount of knowledge of the reactions of fishes to natural and anthropogenic features of the marine environment, although few baselines for comparisons of environmental quality exist to the extent that adequate, quantitative predictivity is yet possible.
5. Fishes as a broad group are widely distributed in all marine environments, whose environmental characteristics and qualities can be related in at least a general, comparative manner to the kinds and numbers of fishes present.
6. Fishes throughout the world tend to have rather similar physiological systems that can be compared among themselves with reference to their adaptational propensities to specific environments; the ubiquitous distribution of marine fishes implies that they can be compared from one type of environmental regime to the next by means of physiological characteristics that relate to their distribution and especially abundance.
7. Fishes in a given environment have an ecological stability that assures their survival over relatively long periods of time compared to most other organisms at relatively stable population numerical and biomass levels. These levels which can naturally vary usually less than one order of magnitude over periods of decades, whereas numerical and biomass levels of smaller short-lived micro-organisms ordinarily found at lower ecotrophic levels can naturally vary ten or more orders of magnitude in

several days in response to natural environmental changes.

Ricker (1975) reviews much of the available quantitative literature that applies to numerical or ponderal assessment of population (or "stock") size for moderate-to long-lived species. If the data available for rates of growth, recruitment, natural mortality, and fishing mortality in these populations are realistic, then it is easy to calculate the increases in mortality-even if recruitment is maintained-that would reduce a population to one-tenth (one order of magnitude). For most all but the shortest-lived populations, reductions would essentially eliminate the older, sexually mature age classes, to the extent that there would eventually be a failure in adequate spawning and recruitment with a resulting population collapse. Murphy (1966, 1967, 1968) has appropriately documented both Pacific sardine (pilchard) data and their interpretations that show the relatively small degree to which population size can fluctuate without collapse.

Well documented examples of large order-of magnitude increases in natural populations of moderate-to long-lived species are unknown to this author, except in cases of introduced species. Cyclic populations of Pacific salmon and some other species are documented to show that year-to-year fluctuations may exceed one order of magnitude. However, these cyclic fluctuations, even when extreme, should be considered as a population function over complete cycles, the averages of which ordinarily cannot be greatly reduced or expanded in natural populations.

8. Because most fishes are at the higher ecotrophic levels and tend to have relatively stable populations, their stabilizing and integrating effects on the overall natural ecosystem are most likely considerable.

These eight considerations taken together comprise a powerful argument for the use of fishes in any general sort of environmental baseline assessment procedure.

Although there is much known in general regarding the kinds of fishes found in the Gulf of Mexico with suitable keys for their identifications (Parker, 1972), there is little published information on the distribution and abundance of the outer continental shelf (OCS) benthic species. Most of these species are presently of little direct economic importance, either commercially or recreationally.

To assess these benthic species as overall representative OCS organisms for a baseline study when details of their life histories are presently not well known, it is essential first to have firm data (a) of which species are present and (b) in what relative numbers. These observational data must further be considered within sampling constraints that will in the future allow for reproducibility.

Sampling constraints first of all involve the nature of temporal and spatial distribution of the fishes. In this Texas OCS Study three stations at inshore, middle and offshore depths at four transects from offshore at Port O'Connor, Port Aransas, Port Mansfield and Port Isabel are the subject of study with winter, spring and late summer collections. With day and night collections by trawling and the spatial and seasonal sampling, a total of 72 samples forms the basis of the study.

The second sampling constraint involves gear selectivity. Within the degree to which any given sample can be repeated, it is possible that the same biases will persist in making the traditional catch-per-unit-of-effort comparisons among the samples in space and time. By utilizing the same gear and identical methods of fishing for each of the OCS stations throughout the yearly period, differential selectivity by the gear is obviated. Compared to most fishery data, the data from this study are such that each trawl sample is a measure of catch-per-unit-of-effort in both numerical and ponderal units without recourse to weighting or scaling of catch measurements. Catch-per-unit-of-effort data are required for calculating and interpreting population dynamics information in modern fishery research methodologies as given in Beverton and Holt (1957), Ricker (1958), or in more recently derived methodologies.

A very important third sampling constraint, measuring the degree of randomness and variability of samples, is not a part of the present study, since replicate collections could not be made at each station. Replicate samples are required to develop the quantitative nature of intrastation variability against which various other stations can be compared. However, this study will permit general seasonal trends to be evaluated at each station, and it will permit seasonal comparisons over the entire South Texas OCS area. Such evaluations and comparisons should in the future permit general collation of data with regard to any overall environmental changes that may take place.

A fourth constraint of the overall comparative value of the sampling operations involves the assumption that the effects of fishing will remain constant so that any future environmental effects on the fishes will not be confounded with any future population changes ascribed to fisheries.

Since the purpose of this study is to develop a baseline pertinent to the distribution and abundance of benthic fishes in the South Texas OCS area, there is an accompanying necessity to present data in forms usable for both theoretical and practical purposes. For practical purposes, simply tabulating the species with counts and biomasses for each of the collections is unduly cumbersome, although a time-honored system. During the past 20 years, there has been an increasing use of various diversity or informational indices, along with many derivatives, that are used to measure environmental stability. Originally these informational or diversity indices presumably had a solid theoretical basis in information and thermodynamic theory. Hence their wide usage for practical data reduction and interpretation was thought not only to provide a convenient method of expressing the variability, or the lack of it, inherent in species abundance tabulations, but to provide a solid link to the theory of environmental stability, species diversity and ecological optimization (evolution). The theoretical basis and usage of these indices both have been rationally criticized recently. Hurlbert (1971) considers the notion of species diversity based on information theory a nonconcept. Goodman (1975) summarizes much of the criticism of the theory of diversity-stability relationships in ecology. He concludes that no simple relationship exists in ecological systems between diversity and stability.

Assuming that the calculation of diversity indices, measures of evenness of species distribution, etc. can be a data reduction system, there can still be some practical utility, however arbitrary, in comparing a like group of samples by the use of such indices if further assumption of empiricism is admitted. By using various indices empirically with actual species lists, counts and biomass, there should be a reasonable amount of intersample distributional and abundance comparability for a single group of organisms like fish over a reasonably restricted geographical range like the shelf area off the South Texas coast. In any case the original data are always fundamentally sound, subject to the usual constraints of sampling.

METHODS

Collections

During winter, spring and late summer trawled fish collections were taken from the outer continental shelf at three stations for each of four transects. The detailed descriptions of these stations are elsewhere in this report. At each of the three seasonal collection periods, separate samples were taken during the day and during the night. The localities, dates and times of the collections are in Appendix XX summaries.

When the benthic fishes and invertebrates were hauled to the deck they were rough sorted, and the fish were placed in polyethylene bags and iced down for subsequent onshore processing. Pertinent notes were recorded and preserved for later use. Each collection was labeled with a three-letter code for general cruise reference. The macrobenthic invertebrates from these samples are considered by Dr. J. Selmon Holland in the preceeding section.

At the same stations, additional hauls were for specimens to be utilized for chemical analysis and for archive specimens, when required.

Gear

All sampling in this study was by means of identical trawl gear, trawled identically at each station.

The trawl is a conventional Gulf coast 35-foot (10.7 m) standard flat trawl. The net has a 40-foot (12.2 m) lead (ground) line and a 30-foot (9.1 m) cork (head) line, each of 1/2-inch (12,7 mm) "steel impregnated" rope. There is a 3-foot (0.9 m) separation between the net wings and the 30-inch (76.2 cm) by 60-inch (152.4 cm) doors (otter boards fitted with steel runners).

The net materials are of untreated white nylon twine. Wings and main body of the net are of 1 3/4-inch (44.5 mm)[nominal 2-inch (50.8 mm)] stretched mesh No. 6 nylon twine. The chafing gear surrounding the net is made up of nominal 2-inch (50.8 mm) stretched mesh 1/8-inch (3.2 mm) poly propylene twine.

At all depths, stations and times, the trawling time-on-bottom was as near 15 minutes as possible. The winch "brake-off" time was increased to about 18 minutes at the greatest depths to allow time for taking up slack, developing tension on the warps and positioning of the boards so that an appropriate 15-minute fishing period would be effected.

Trawls were all from the twin-screwed R/V LONGHORN at 900 rpm, which is equivalent to 3.5 to 4 knots, depending on windage, currents and other uncontrolled variables. With net drag, speed is about 2 knots.

Study Areas

Although detailed description of the general area and the specific sampling stations are described in detail elsewhere in other parts of the STOCS study, for immediate purposes the schedule below gives the geographical coordinates and depths (in parentheses) of the individual stations. Dates of collections are in Appendix XX tables.

Transect Line	Station 1	Station 2	Station 3
I	28°12'N 96°27'W (18 m)	27°54.5'N 96°19.5'W (42 m)	27°33.5'N 96°06.5'W (134 m)
II	27°40'N 96°59'W (22 m)	27°30'N 96°44.5'W (42 m)	27°17.5'N 96°23'W (131 m)
III	26°57.5'N 97°11'W (25 m)	26°57.6'N 96°48'W (65 m)	26°57.5'N 96°32.3'W (106 m)
IV	26°10'N 97°00.5'W (27 m)	26°10'N 96°39'W (47 m)	26°10'N 96°24'W (91 m)

Processing.

Because the fish had to be preserved by freezing for several weeks pending identification, wet weights of the iced collections were made initially. Later, when the frozen fish were thawed, identified and weighed to the nearest 0.1 gram, the total weights were summed up so that a pro rata correction could be made for any dehydration weight losses of individual species due to freezing. (The average weight loss was of the order of 7%, although there was considerable variability associated largely with the degree to which blotting of excess water was possible when the fish were removed from the trawl on deck.)

Fish from each sample were identified individually, individually weighed, and standard, fork and total lengths measured to the nearest millimeter. When a single species was very abundant in a collection, only about 30 of the total were individually weighed and measured, while the remainder were weighed collectively. In all cases the total numbers and weights of each species were determined.

Identification was routine for the most part by means of keys published by Galloway, Parker and Moore (1972) and a number of unpublished detailed keys and descriptions by Drs. H.D. Hoese and R.H. Moore. Dr. R.H. Moore kindly identified some of the more "difficult" specimens. Throughout, the nomenclature is that of The American Fisheries Society's "A List of Common and Scientific Names of Fishes" Third Edition (Bailey, 1970).

Species Diversity Index

To supply some insight, however empirical, into the diversity of the fish species, the species diversity index, estimated from the samples and independent of sample size, is utilized. In this study, the index known as the "Shannon-Wiener" or the "Shannon-Weaver" is computed. This index is from Shannon (1948), Wiener (1948) and Shannon and Weaver (1963), among others. It has been widely used.

Essentially the index H" is estimated by:

$$H'' = -\Sigma(n_i/N)\log_e(n_i/N),$$

where n_i is the number of individuals in the i^{th} species and N is the total number of individuals. Because natural logarithms are used, diversity units for H" are expressed in natural bels per individual (Pielou, 1966b).

The H" diversity index was calculated and tabulated for all 72 samples from each of the 72 stations.

Wilhm (1968) suggested using n_i as the weights (biomasses) of the i^{th} species and N as the weight of individuals in the sample, thus redefining diversity in terms of biomass that would be more closely related to energy distribution among species.

The H" diversity index for biomass in grams was likewise calculated in the same manner and tabulated for all samples.

Probability of Interspecific Encounter (P.I.E.)

From the standpoint that species diversity may be a "nonconcept" (Hurlbert, 1971), the use of the notion of "probability of interspecific encounter" (P.I.E.) has merit. A basic consideration is the proportion of potential interindividual encounters, which is interspecific, assuming that every individual in a collection could encounter all others. From Hurlbert (1971): "Of the $N(N - 1)/2$ potential encounters in a community of N individuals, $\sum_i (N_i)(N - N_i)/2$ encounters involve individuals belonging to different species. Thus

$$\Delta_1 = \sum_{i=1}^{S} \left(\frac{N_i}{N}\right) \left(\frac{N - N_i}{N - 1}\right)$$

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

is the probability of interspecific encounter (P.I.E.) or the proportion of potential encounters that is interspecific, where

N_i = number of individuals of the i^{th} species in the community (or collection),

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

$\pi_i = N_i/N$, and

S = number of species in the community."

The P.I.E. estimated values were calculated and tabulated for all 72 samples from each of the 72 stations.

Equitability

Since there are two components of diversity-heterogeneity indices, viz. the number of species and the distribution of individuals or equitability among those species, an index of equitability was used for all the samples. Lloyd and Ghelardi (1964) base their considerations on MacArthur's "broken-stick" model that can have a theoretical maximum diversity and that can be related to the observed species diversity (H_s in their notation). This relationship is calculated on the basis of the number of hypothetical "equitably distributed" species s' that is required to produce a species diversity equivalent to that observed from the sample.

By using the calculated species diversity and the tabulated values in Lloyd and Ghelardi (1964, Table 1), the value of s' is defined. Equitability, E, is simply the ratio of the hypothetical s' to the observed s.

The E ratios were calculated and tabulated for all 72 samples from each of the 72 stations.

Rarefaction Curve Method

This method is that of Sanders (1968). In order that samples from different times and places and with different numbers of specimens in each can be compared uniformly, the species from each sample are ranked in order of abundance and the percentage composition of each species and the cumulative percentage are plotted. The procedure is to keep the percentage composition of component species constant but reduce the sample size, thereby creating the results that would have occurred had smaller samples with the identical species composition been collected.

In this study, the species numbers and the numbers for each station are combined for the day-night and seasonal collections to gain a graphic insight into a one-year concept of the distribution-abundance characteristics at each station.

The procedure follows Sanders (1968) for the plots of rarefaction curves of the numbers of species (y-axis) against the numbers of individuals (x-axis). Essentially the procedure involves the calculation of hypothetical species-individuals curves for collections of various sizes. For the combined station data, 12 curves are constructed based on smaller-than-observed hypothetical collections of 10, 25, 50, 100, 200, 300 and 500 individuals, and (where appropriate) of 800, 1000, 1500 and 3000 individuals.

Gear Selectivity and Growth of Selected Fishes

To illustrate how spatial distribution and seasonal growth affects sampling and ultimate data interpretation, a series of five tables was prepared to show length-frequency distributions of five different species. A separate distribution was made up for day-night combined catches for each station and for each of the seasonal collections.

The five species were chosen on the basis of their more or less generalized distribution over the entire geographic range of the 12 stations. Their general importance or overall abundance was not considered.

The classical length-frequency, or Petersen, method of growth rate determination is described in various texts, e.g., Royce (1972). The method involved following modal sequences in length (or weight) frequencies over a period of time. It is a particularly useful method for small, rapidly growing species, where single age-classes are separable on a length or weight basis.

The length-frequency distributions chosen for this presentation are for the purposes of showing how size of fish affects the distribution with respect to depth and north-south distribution along the OCS and how fish size and gear selectivity operate over a one-year period. In the latter case, the very smallest and particularly the largest fish are not completely vulnerable to the gear. Further, as fish grow they tend to move from one area to another, a fact which is manifested by the change in average lengths in going from one environmental site to the next. The length-frequency evaluations also permit any distinctions among mass seasonal migrations and highly localized endemism, in addition to more modest movements associated with size.

RESULTS

In Appendix XX are tables for all 72 separate collections, for three times yearly, three stations on each of four transects, and day and night collections at each station. These are the base data with dates and localities along with species identifications, numbers and weights from which all the other data are derived.

Catch per 15-minute standardized trawl for the individual species at each collection are available directly either in numerical or ponderal (gram) units from Appendix XX tabulations.

For the three seasonal combined collections in Winter, Spring and late Summer, the enumeration of number of species, number of individuals, the diversity index (H"), equitability ratio (E) and the probability of interspecific encounter (P.I.E.) are in summary form in Tables 1-3 which include day-night collections over the 4 transects of 3 stations each. The three letter code designations identify the collections so that they may be compared to appropriate collections of physical, chemical, geological and other biological data.

In Tables 4-6 are the same data in terms of weight in grams with the H" values representing "biomass" diversity.

These same data can be plotted for a visual presentation as in Figures 1-12 in pairs having respectively the daytime and nighttime presen-

Table 1. Total number of species, total number of individuals, H" diversity index, equitability (E), and Hurlbert's probability of interspecific encounter (P.I.E.) for each sample in the Winter epifaunal collections.

	Transect	Site No.	Code	Spp.	Ind.	H"	E	P.I.E.
Day	I	1	AHN	23	700	0.583	.086	.186
Night	I	1	AFK	23	754	1.441	.130	.659
Day	I	2	AFC	18	178	2.206	.333	.862
Night	I	2	ACT	21	243	2.147	.285	.807
Day	I	3	AAK	21	488	2.177	.285	.839
Night	I	3	AAE	19	302	1.931	.263	.799
Day	II	1	AJA	5	8	1.494	.800	.857
Night	II	1	AIA	19	83	2.208	.315	.824
Day	II	2	ALZ	15	189	1.923	.333	.778
Night	II	2	ALF	6	9	1.735	.667	.916
Day	II	3	APC	15	535	0.929	.133	.358
Night	II	3	AOH	22	283	1.946	.227	.787
Day	III	1	ASE	12	31	2.189	.500	.881
Night	III	1	ARK	19	97	2.041	.263	.794
Day	III	2	AVJ	11	84	1.357	.272	.570
Night	III	2	AUN	21	215	2.135	.285	.759
Day	III	3	AYG	14	411	1.031	.143	.381
Night	III	3	AXM	26	305	2.335	.269	.853
Day	IV	1	BBF	15	85	2.012	.333	.795
Night	IV	1	BAK	13	124	1.623	.307	.675
Day	IV	2	BEH	14	109	1.782	.285	.764
Night	IV	2	BDK	15	269	1.483	.266	.652
Day	IV	3	BPC	15	186	1.424	.200	.584
Night	IV	3	BGL	20	200	2.361	.350	.873

Table 2. Total number of species, total number of individuals, H" diversity index, equitability (E), and Hurlbert's probability of interspecific encounter (P.I.E.) for each sample in the Spring epifaunal collections.

	Transect	Site No.	Code	Spp.	Ind.	H"	E	P.I.E.
Day	I	1	CBA	20	2,199	1.029	.100	.424
Night	I	1	CAG	21	1,018	1.409	.143	.579
Day	I	2	CEA	24	398	2.062	.250	.788
Night	I	2	CDK	29	216	2.836	.345	.913
Day	I	3	CHK	19	177	2.263	.316	.865
Night	I	3	CGO	18	193	2.071	.333	.824
Day	II	1	CKQ	24	830	1.710	.167	.722
Night	II	1	CJV	16	457	1.302	.187	.548
Day	II	2	CNT	23	508	2.164	.261	.832
Night	II	2	CMY	30	282	2.509	.266	.832
Day	II	3	CQV	11	125	2.075	.545	.858
Night	II	3	CQA	19	69	2.363	.368	.872
Day	III	1	CUD	20	502	2.270	.300	.870
Night	III	1	CTH	19	333	1.573	.210	.677
Day	III	2	CXZ	21	228	2.356	.333	.866
Night	III	2	CXK	30	285	2.282	.233	.779
Day	III	3	DBB	15	144	2.192	.400	.864
Night	III	3	DAI	25	289	2.107	.240	.765
Day	IV	1	DEB	25	405	2.023	.200	.811
Night	IV	1	DDI	24	215	2.279	.291	.825
Day	IV	2	DHA	20	354	2.023	.250	.809
Night	IV	2	DGH	32	114	3.738	.593	.806
Day	IV	3	DKF	25	239	1.615	.160	.552
Night	IV	3	DJJ	23	105	2.747	.391	.930

Table 3. Total number of species, total number of individuals, H" diversity index, equitability (E), and Hurlbert's probability of interspecific encounter (P.I.E.) for each sample in the Summer epifaunal collections.

	Transect	Site No.	Code	Spp.	Ind.	H"	E	P.I.E.
Day	I	1	EBA	20	207	2.447	.350	.891
Night	I	1	EAG	23	648	1.589	.174	.653
Day	I	2	EEA	22	316	1.957	.227	.724
Night	I	2	EDK	13	40	2.266	.461	.894
Day	I	3	EHK	18	86	2.528	.444	.907
Night	I	3	EGO	20	205	1.777	.200	.694
Day	II	1	EKQ	15	147	2.348	.467	.889
Night	II	1	EJV	21	207	2.401	.333	.877
Day	II	2	ENU	17	86	2.391	.412	.886
Night	II	2	EMY	10	15	2.245	.400	.952
Day	II	3	EQV	11	60	1.794	.364	.759
Night	II	3	EQA	15	93	1.728	.267	.722
Day	III	1	EUD	28	776	2.203	.214	.822
Night	III	1	ETH	19	278	1.392	.158	.587
Day	III	2	EXZ	14	28	2.465	.571	.931
Night	III	2	EXK	18	215	1.904	.278	.732
Day	III	3	FBB	15	106	2.154	.400	.850
Night	III	3	FAI	22	170	1.928	.227	.728
Day	IV	1	FEJ	25	275	2.655	.360	.906
Night	IV	1	FDP	34	762	2.316	.206	.829
Day	IV	2	FHK	20	234	2.247	.300	.831
Night	IV	2	FGP	30	514	2.111	.200	.751
Day	IV	3	FKP	19	171	2.196	.316	.837
Night	IV	3	FJT	24	205	2.227	.250	.824

Table 4. Total number of species, total number of individuals, total weight, and H'' (biomass) diversity index for each sample in the Winter epifaunal collections.

	Transect	Site No.	Code	Spp.	Ind.	Weight (g)	H''
Day	I	1	AHN	23	700	6423.6	1.207
Night	I	1	AFK	23	754	4844.9	2.208
Day	I	2	AFC	18	178	2627.1	2.267
Night	I	2	ACT	21	243	3455.7	2.099
Day	I	3	AAK	21	488	12434.3	2.151
Night	I	3	AAE	19	302	15144.0	1.762
Day	II	1	AJA	5	8	572.8	1.162
Night	II	1	AIA	19	83	1194.9	2.146
Day	II	2	ALZ	15	189	4027.1	2.137
Night	II	2	ALF	6	9	308.5	0.961
Day	II	3	APC	15	535	10833.2	1.521
Night	II	3	AOH	22	283	7607.5	2.203
Day	III	1	ASE	12	31	362.5	2.083
Night	III	1	ARK	19	97	1303.2	2.146
Day	III	2	AVJ	11	84	1488.5	1.705
Night	III	2	AUN	21	215	7706.0	2.380
Day	III	3	AYG	14	411	9634.4	1.606
Night	III	3	AXM	26	305	13082.6	2.516
Day	IV	1	BBF	15	85	2203.4	1.864
Night	IV	1	BAK	13	124	1804.2	2.077
Day	IV	2	BEH	14	109	2498.8	1.776
Night	IV	2	BDK	15	269	2778.7	1.954
Day	IV	3	BPC	15	286	9992.2	1.835
Night	IV	3	BGL	20	200	11039.8	2.180

Table 5. Total number of species, total number of individuals, total weight, and H'' (biomass) diversity index for each sample in the Spring epifaunal collections.

	Transect	Site No.	Code	Spp.	Ind.	Weight (g)	H''
Day	I	1	CBA	20	2,199	14365.1	2.002
Night	I	1	CAG	21	1,018	7638.6	1.961
Day	I	2	CEA	24	398	6560.8	2.237
Night	I	2	CDK	29	216	5206.3	2.688
Day	I	3	CHK	19	177	7454.2	1.928
Night	I	3	CGO	18	193	6363.0	1.882
Day	II	1	CKQ	24	830	12725.4	1.816
Night	II	1	CJV	16	457	6126.9	1.316
Day	II	2	CNT	23	508	6844.0	2.159
Night	II	2	CMY	30	282	6004.1	2.462
Day	II	3	CQV	11	125	5402.5	1.808
Night	II	3	CQA	19	69	2452.8	2.293
Day	III	1	CUD	20	502	4218.8	2.191
Night	III	1	CTH	19	333	4237.2	1.950
Day	III	2	CXZ	21	228	6849.5	2.523
Night	III	2	CXK	30	285	5446.0	2.445
Day	III	3	DBB	15	144	7381.1	2.119
Night	III	3	DAI	25	289	11172.6	2.548
Day	IV	1	DEB	25	405	5172.2	2.059
Night	IV	1	DDI	24	215	3065.3	2.058
Day	IV	2	DHA	20	354	3619.4	1.949
Night	IV	2	DGH	32	114	3746.5	2.920
Day	IV	3	DKF	25	239	5738.9	1.763
Night	IV	3	DJJ	23	105	2673.1	2.389

Table 6. Total number of species, total number of individuals, total weight, and H" (biomass) diversity index for each sample in the Summer epifaunal collections.

	Transect	Site No.	Code	Spp.	Ind.	Weight(g)	H"
Day	I	1	EBA	20	207	3684.7	2.378
Night	I	1	EAG	23	648	16849.2	1.339
Day	I	2	EEA	22	316	4175.1	2.256
Night	I	2	EDK	13	40	980.0	2.110
Day	I	3	EHK	18	86	4578.1	2.337
Night	I	3	EGO	20	205	7227.7	1.881
Day	II	1	EKQ	15	147	4895.7	2.132
Night	II	1	EJV	21	207	3106.1	2.380
Day	II	2	ENU	17	86	2182.3	2.216
Night	II	2	EMY	10	15	887.9	1.549
Day	II	3	EQV	11	60	2754.0	1.372
Night	II	3	EQA	15	93	3080.7	1.698
Day	III	1	EUD	28	776	21606.8	2.098
Night	III	1	ETH	19	278	11151.0	1.042
Day	III	2	EXZ	14	28	1060.6	1.955
Night	III	2	EXK	18	215	4832.6	2.040
Day	III	3	FBB	15	106	4876.8	1.856
Night	III	3	FAI	22	170	6028.5	2.043
Day	IV	1	FEJ	25	275	5738.6	2.421
Night	IV	1	FDP	34	762	18616.3	1.523
Day	IV	2	FHK	20	234	6557.4	2.255
Night	IV	2	FGP	30	514	4179.3	2.557
Day	IV	3	FKP	19	171	7409.0	2.096
Night	IV	3	FJT	24	205	5449.5	2.165

tations. Figures 1-6 illustrate by histogram height the relative values of H" and by flag height the number of species taken; these six figures are for collections in terms of time of day and season. Figures 7-12 illustrate by histogram height the biomasses for each day and night sample, while the height of the flags represent the corresponding numbers of individuals; these six figures also are for collections in terms of time of day and season.

The rarefaction curves are from the calculation of expected numbers of species that correspond to various numbers of individuals up to and including the number actually counted from the combined yearly collections at each station. These hypothetical numbers of species are in Table 7 The rarefaction curves are in Figure 13 for the stations in Transect I and II and in Figure 14 for the stations in Transects III and IV.

Length-frequency data for the five fish species are in Tables 8-12 Table 8 is for *Synodus foetens*, the inshore lizardfish; Table 9 is for *Syacium gunteri*, the shoal flounder; Table 10 for *Serranus atrobranchus*, the blackear bass; Table 11 for *Pristipomoides aquilonaris*, the wenchman; and Table 12 for *Cynoscion nothus*, the silver seatrout. (When subsamples for individual stations were used, the subsample size for any station is given in parentheses in all 5 tables.) These data are arranged so that comparisons can be made from station to station, from transect to transect, and from season to season.

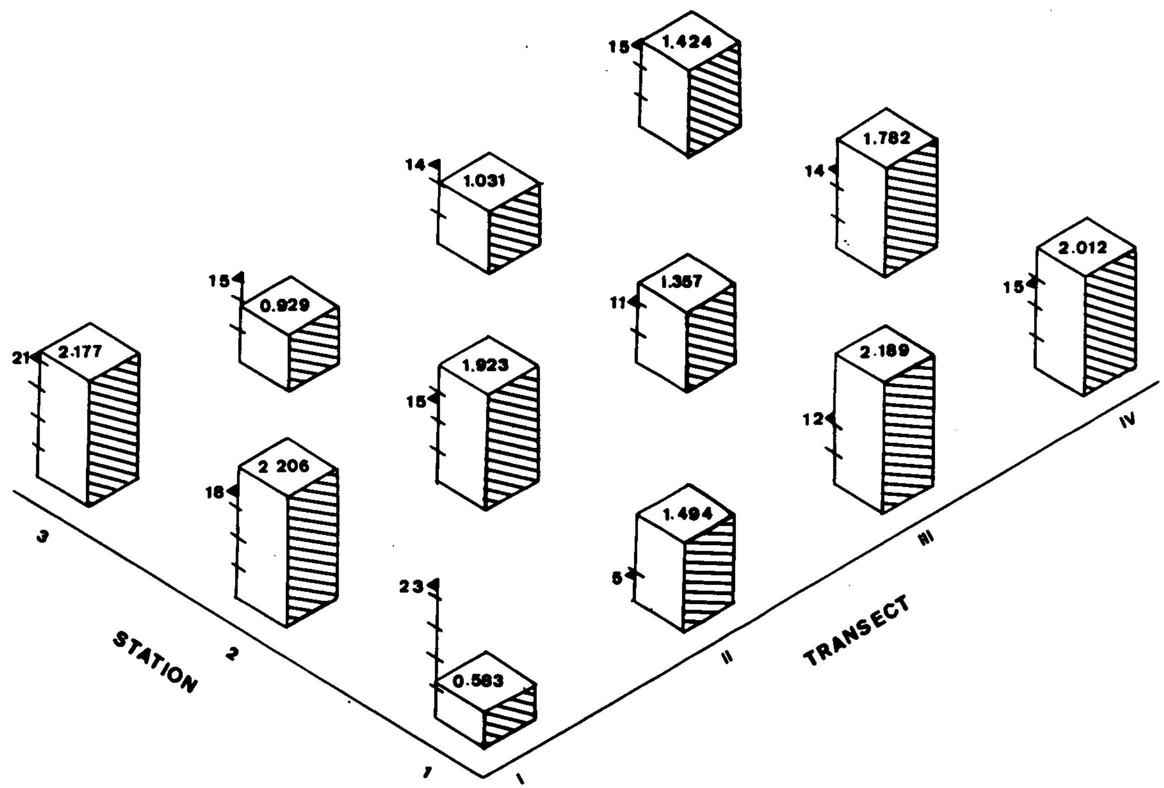

Figure 1. Shannon species diversity index, H" (height of block and number), and number of species (height of flag) for winter, day samples.

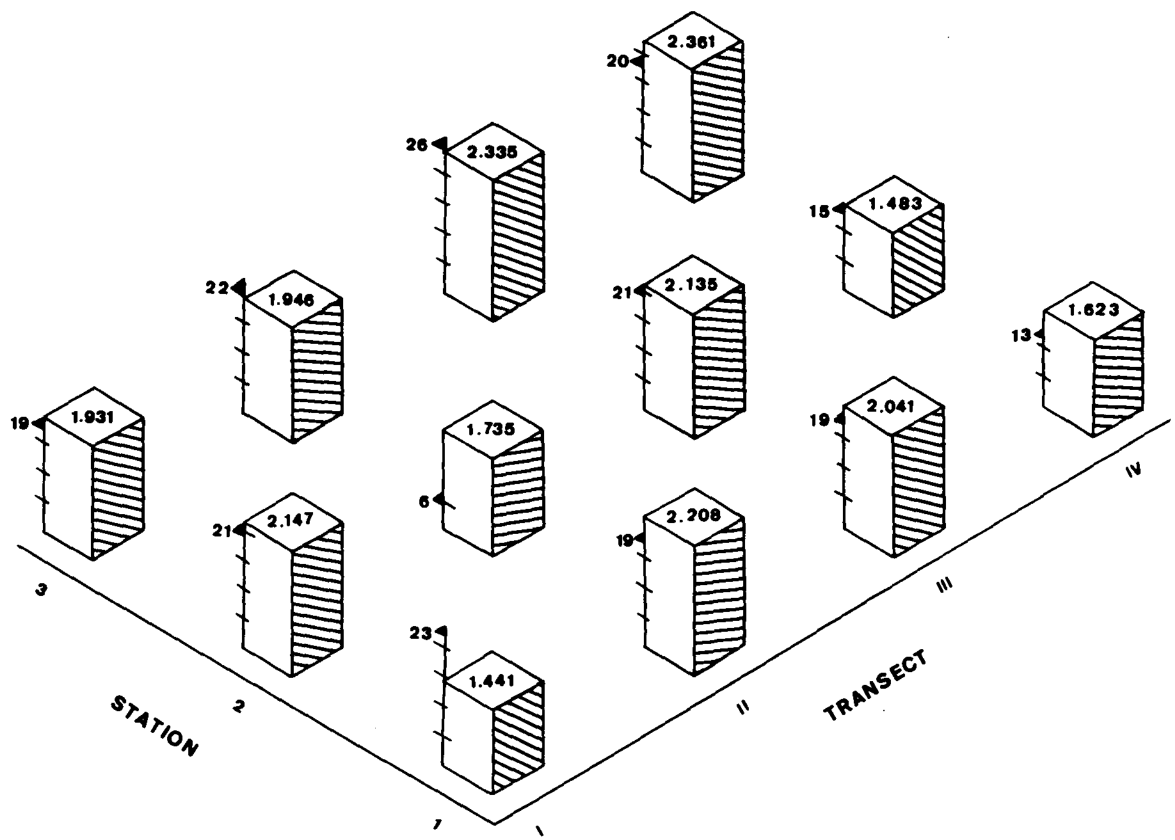

Figure 2. Shannon species diversity index, H" (height of block and number), and number of species (height of flag) for Winter, night samples.

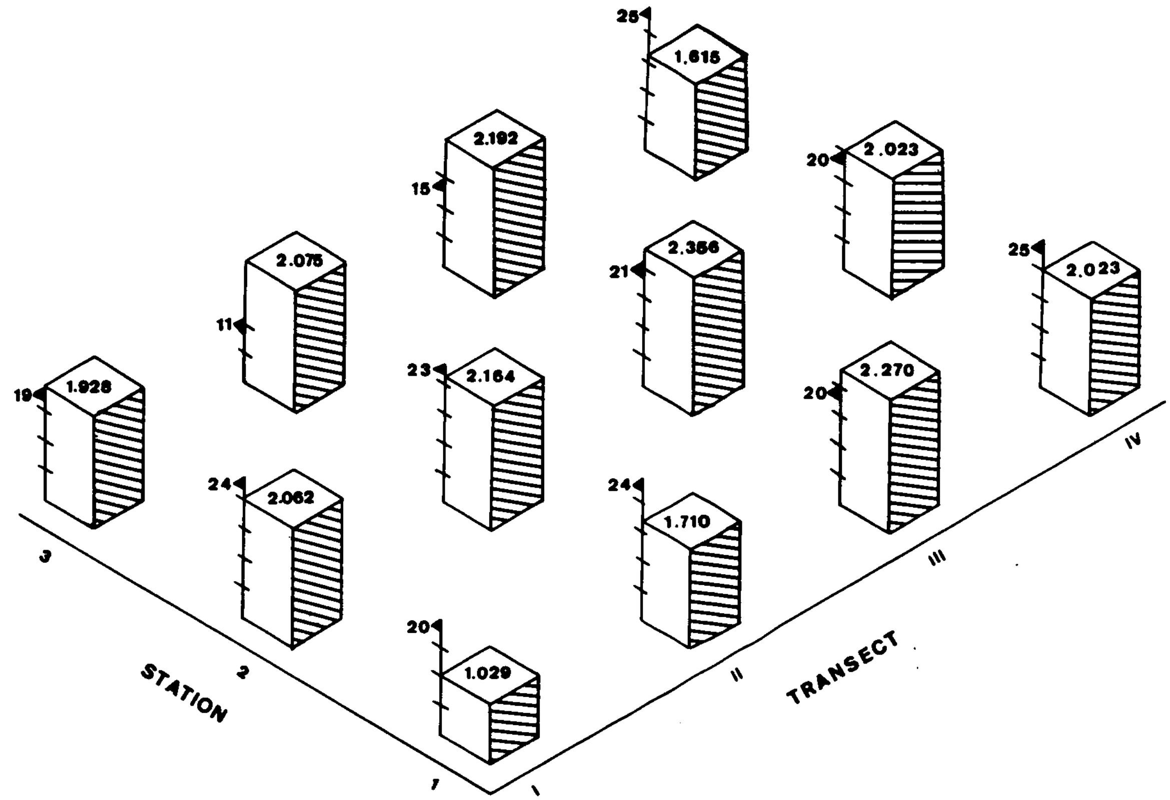

Figure 3. Shannon species diversity index, H" (height of block and number), and number of species (height of flag) for Spring, day samples.

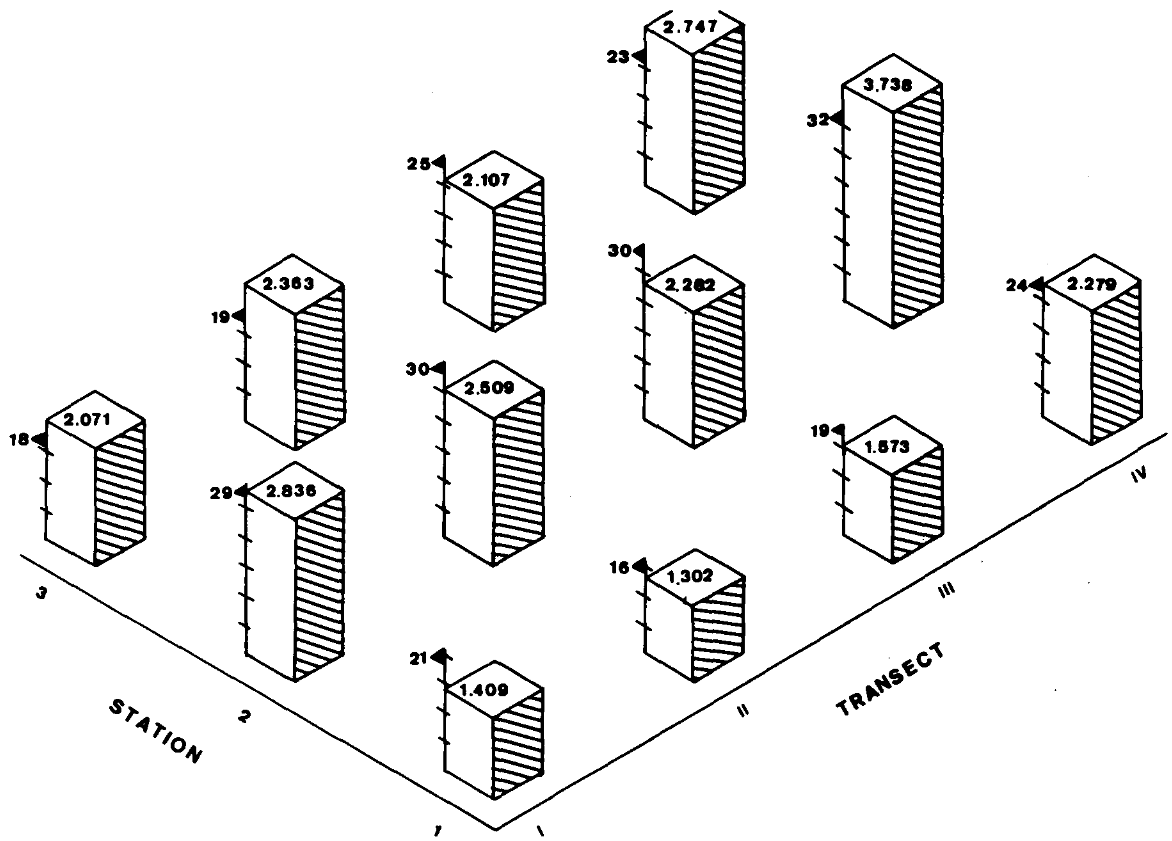

Figure 4. Shannon species diversity index, H" (height of block and number), and number of species (height of flag) for Spring, night samples.

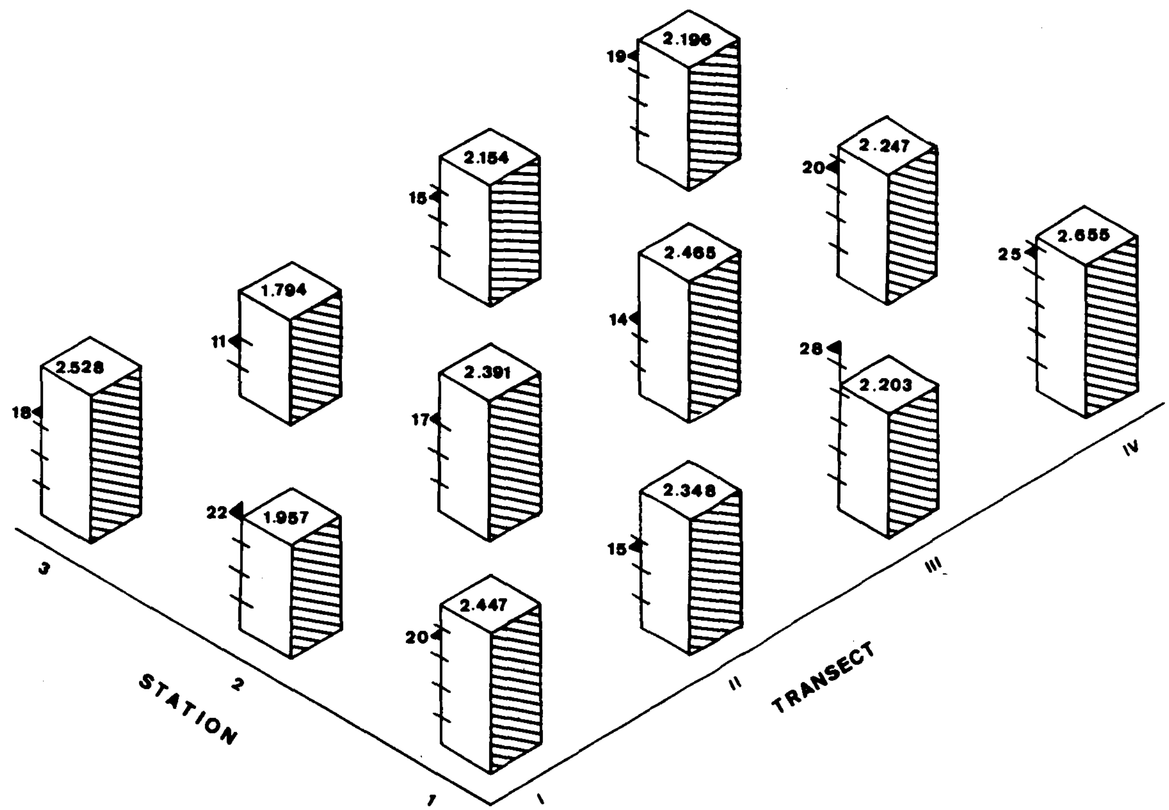

Figure 5. Shannon species diversity index, H" (height of block and number), and number of species (height of flag) for Summer, day samples.

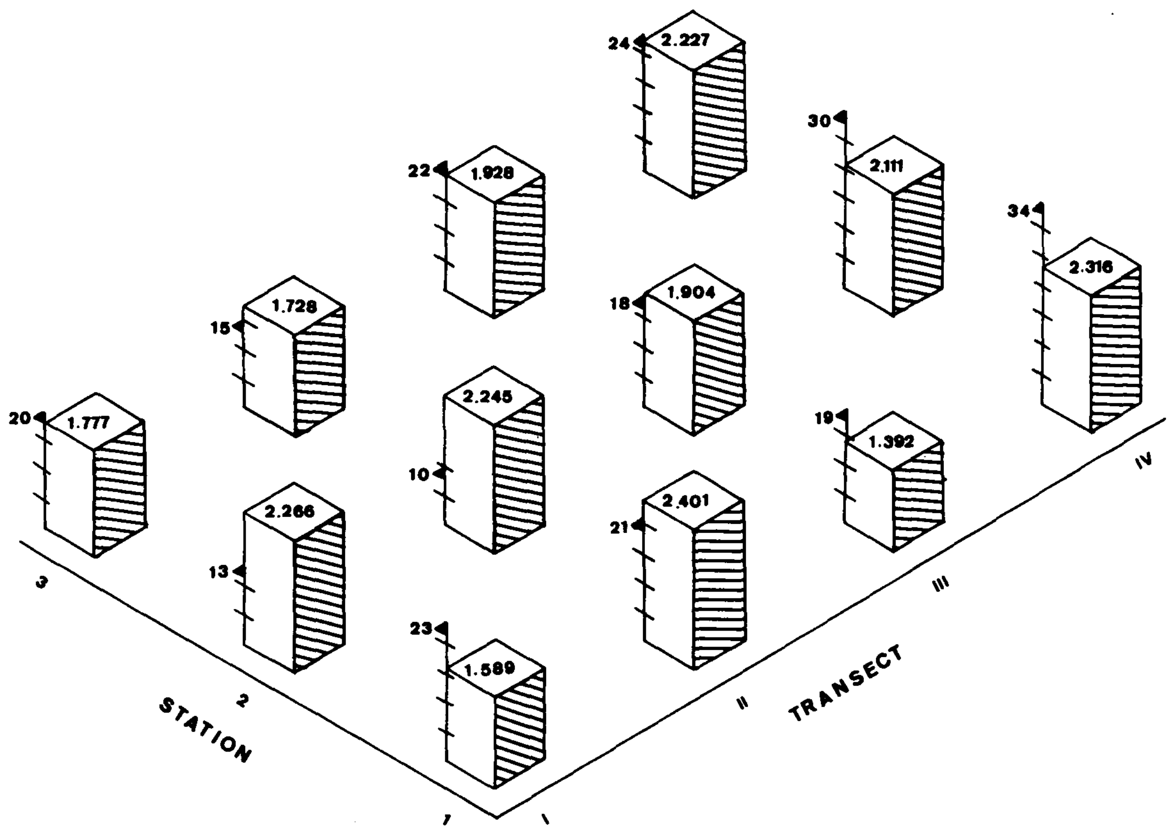

Figure 6. Shannon species diversity index, H'' (height of block and number), and number of species (height of flag) for Summer, night samples.

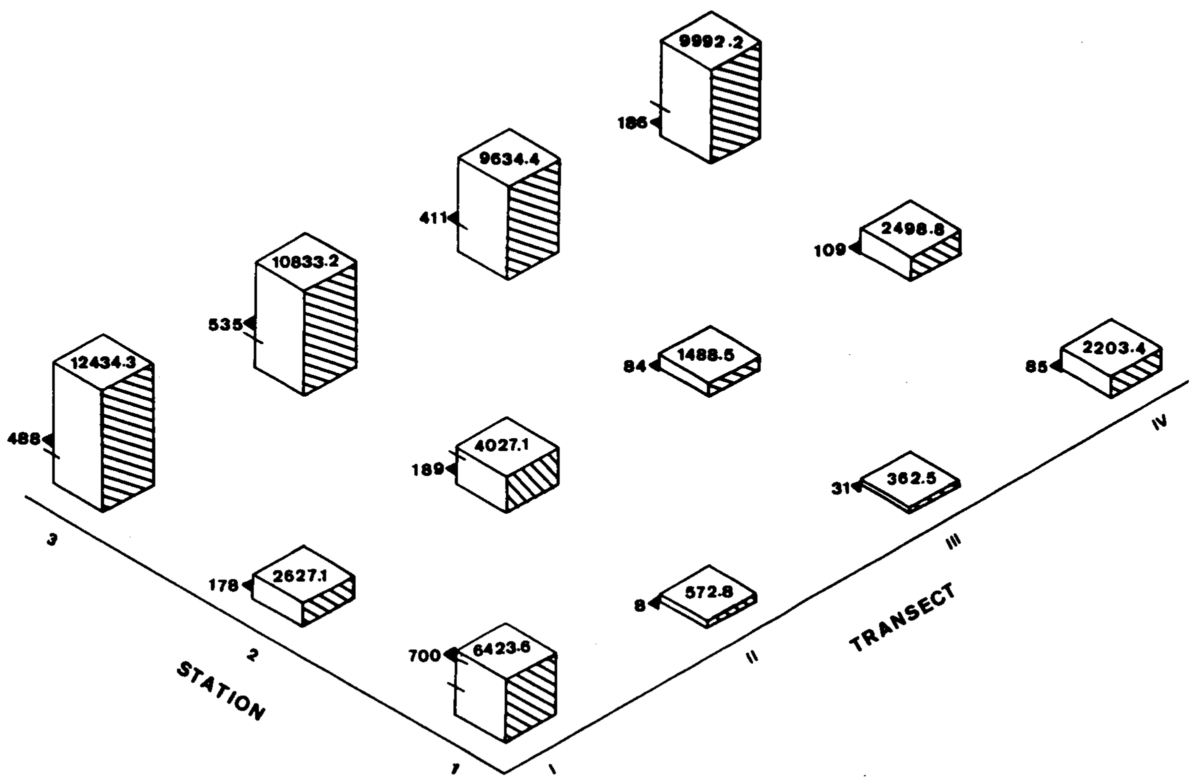

Figure 7. Total biomass in grams (height of blocks and numbers) and number of individuals (height of flags and numbers) for Winter, day samples.

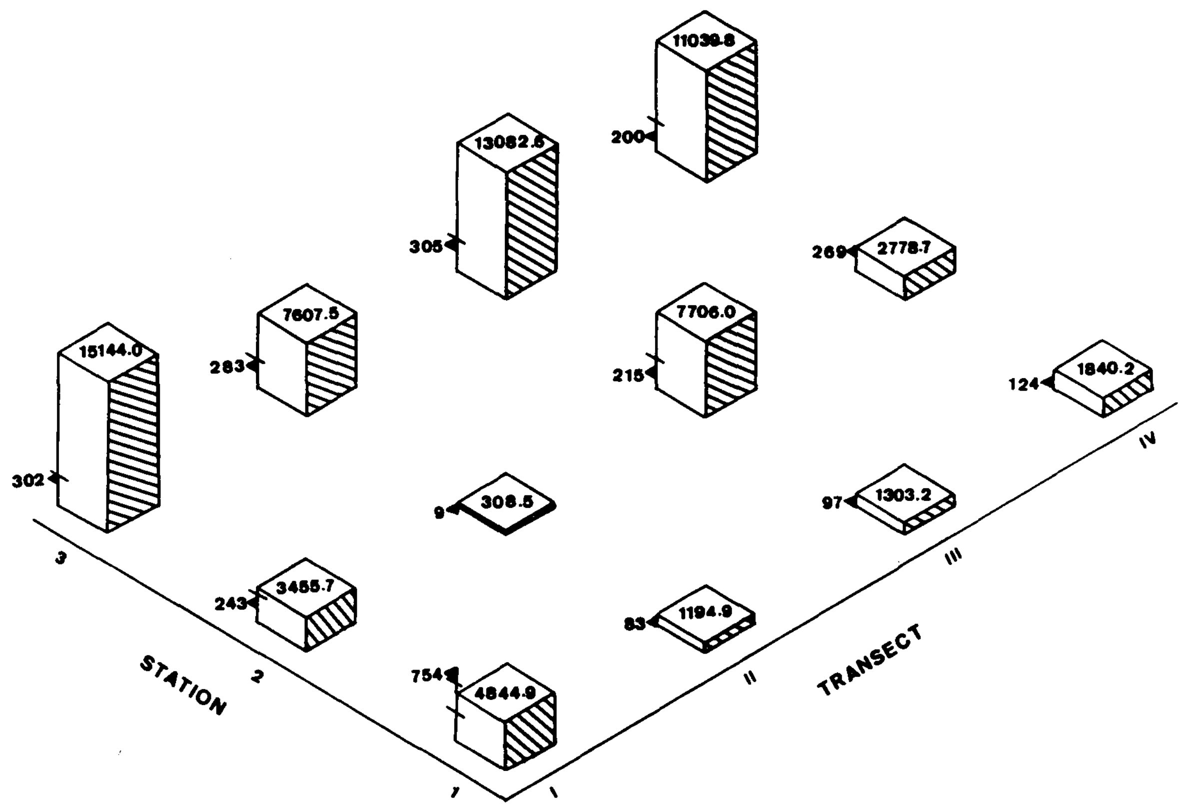

Figure 3. Total biomass in grams (height of blocks and numbers) and number of individuals (height of flags and numbers) for Winter, night samples.

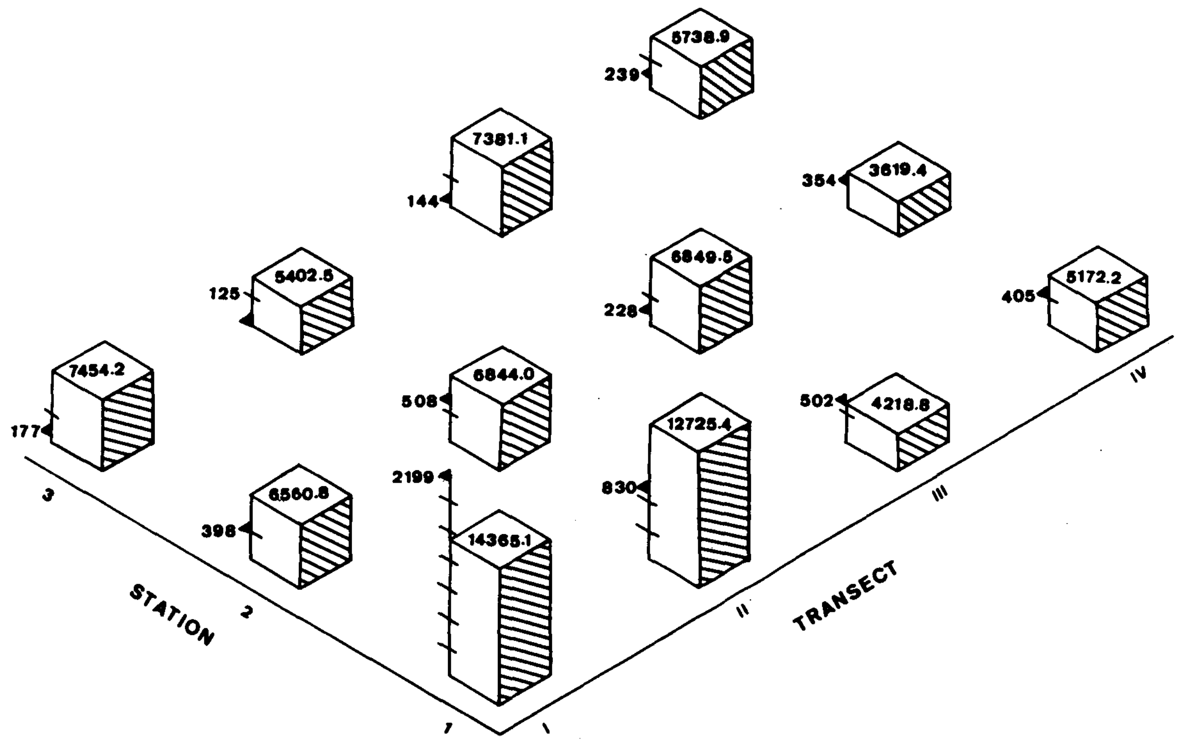

Figure 9. Total biomass in grams (height of blocks and numbers) and number of individuals (height of flags and numbers) for Spring, day samples.

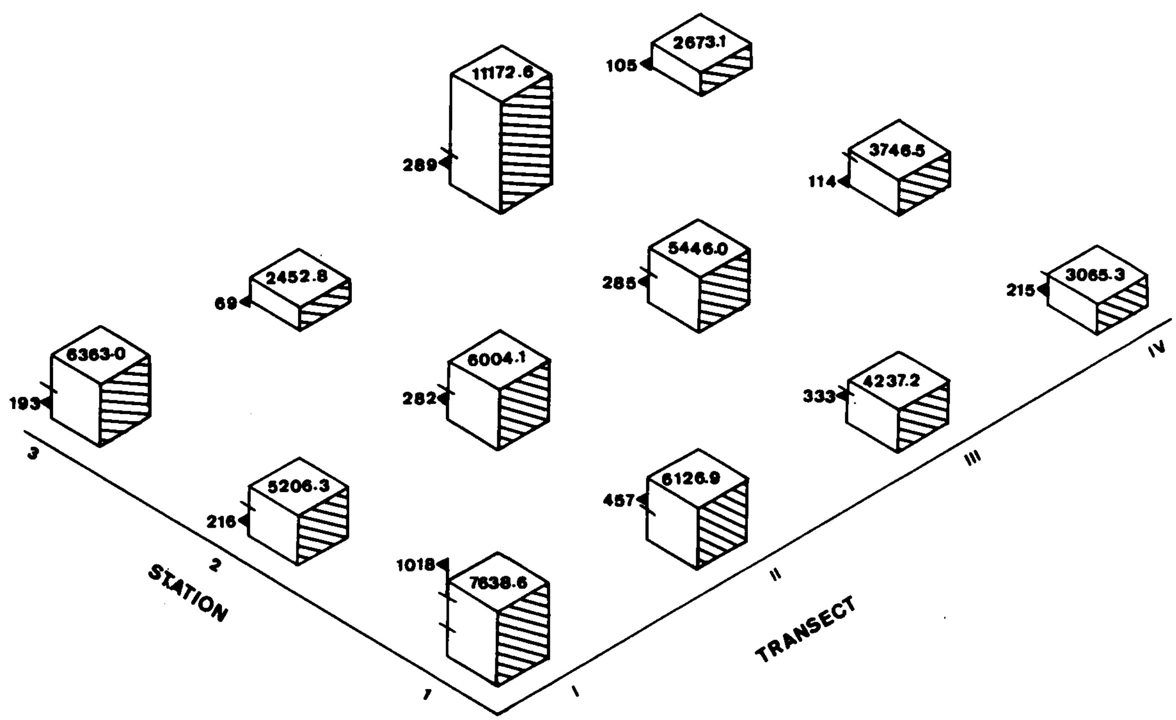

Figure 10. Total biomass in grams (height of blocks and numbers) and number of individuals (height of flags and numbers) for Spring, night samples.

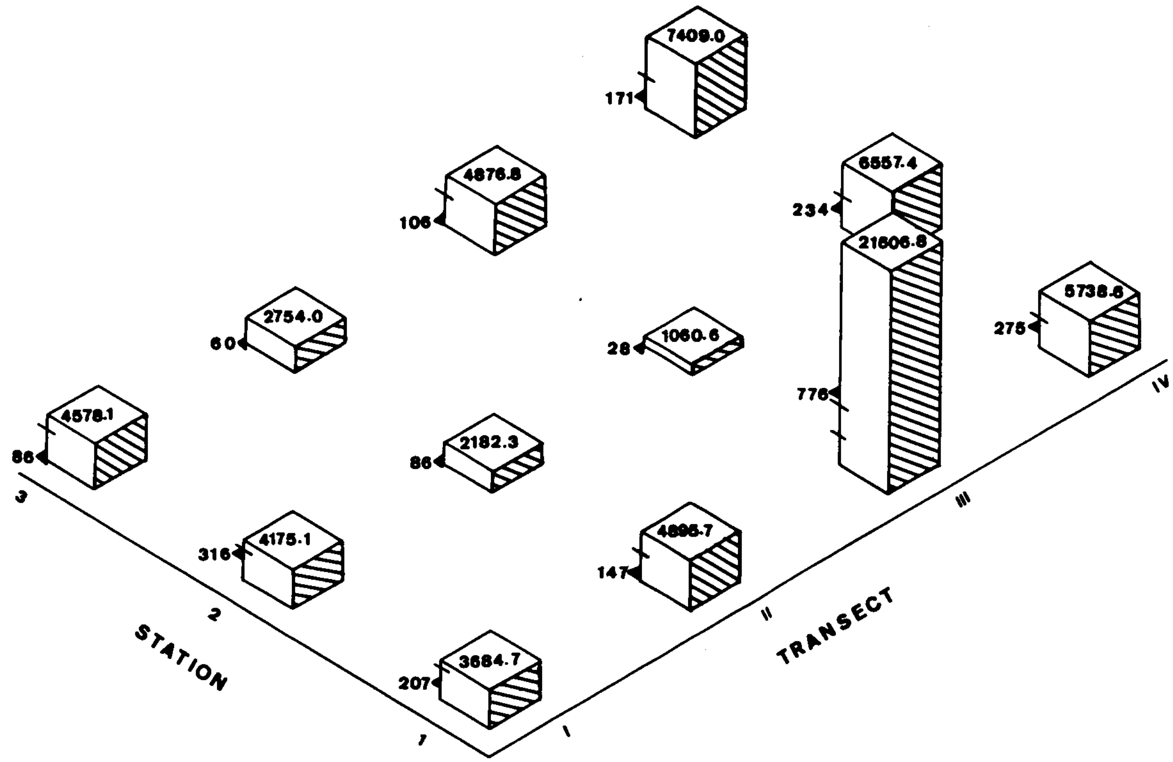

Figure 11. Total biomass in grams (heights of blocks and numbers) and number of individuals (height of flags and numbers) for Summer, day samples.

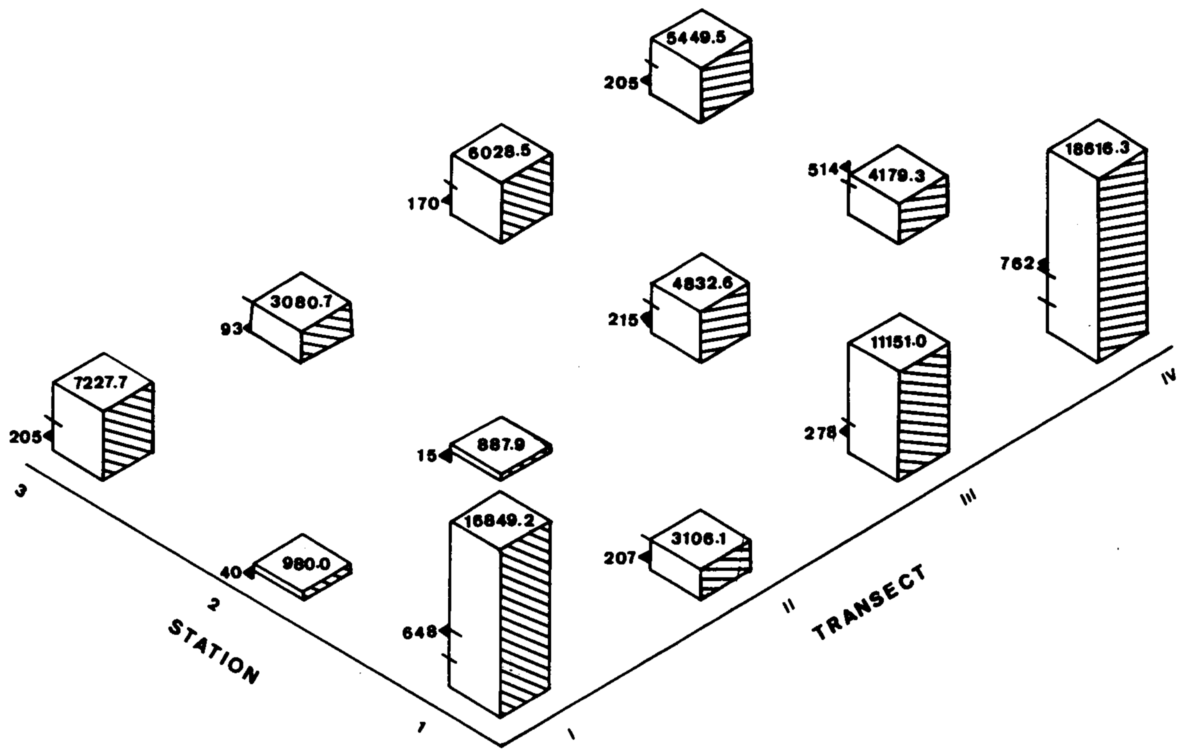

Figure 12. Total biomass in grams (height of blocks and numbers) and number of individuals (height of flags and numbers) for Summer, night samples.

Table 7. Tabulation of numbers of species and individuals for rarefaction curves. Last number in each column corresponds to the observed number of species and the observed number of individuals in the left-hand column.

TRANSECT:	I			II			III		
STATION:	1	2	3	1	2	3	1	2	3
No. of Ind.									
10	4.8	7.6	7.3	6.0	8.6	5.6	9.2	6.7	7.0
25	8.0	13.5	12.3	11.9	14.0	9.0	16.2	14.7	11.9
50	12.5	19.0	14.8	18.1	19.0	12.0	20.5	20.6	16.2
100	19.0	25.0	20.3	23.8	25.3	16.7	26.9	25.3	20.7
200	24.8	31.0	25.8	29.4	32.4	22.6	34.0	30.0	25.6
300	27.5	33.4	29.5	31.8	37.2	25.5	37.4	33.4	29.0
500	34.0	37.0	32.5	35.0	42.5	28.0	42.0	38.5	24.0
761	-	-	-	-	-	-	-	-	-
800	38.0	42.2	33.8	39.4	46.0	30.0	46.0	41.2	39.2
1000	40.0	45.0	34.0	41.0	-	31.0	48.0	43.0	40.0
1054	-	-	-	-	-	-	-	44.0	-
1126	-	-	-	-	49.0	-	-	-	-
1162	-	-	-	-	-	32.0	-	-	-
1386	-	50.0	-	-	-	-	-	-	-
1422	-	-	-	-	-	-	-	-	44.0
1447	-	-	34.0	-	-	-	-	-	-
1500	44.0	-	-	-	-	-	51.1	-	-
1654	-	-	-	-	-	-	-	-	-
1700	-	-	-	-	-	-	-	-	-
1763	-	-	-	47.0	-	-	-	-	-
1799	-	-	-	-	-	-	52.0	-	-
1828	-	-	-	-	-	-	-	-	-
3000	50.0	-	-	-	-	-	-	-	-
4627	53.0	-	-	-	-	-	-	-	-

Table 7. Cont.'d

TRANSECT:	IV		
STATION:	1	2	3
No. of Ind.			
10	9.1	8.0	8.8
25	15.5	11.4	15.7
50	21.4	20.9	21.6
100	27.9	27.9	27.9
200	34.8	34.8	34.6
300	40.6	39.0	37.9
500	45.5	44.0	42.0
761	-	-	47.0
800	52.2	48.0	-
1000	55.0	49.0	-
1054	-	-	-
1126	-	-	-
1162	-	-	-
1386	-	-	-
1422	-	-	-
1477	-	-	-
1500	58.6	50.5	-
1654	-	52.0	-
1700	59.7	-	-
1763	-	-	-
1799	-	-	-
1828	60.0	-	-
3000	-	-	-
4627	-	-	-

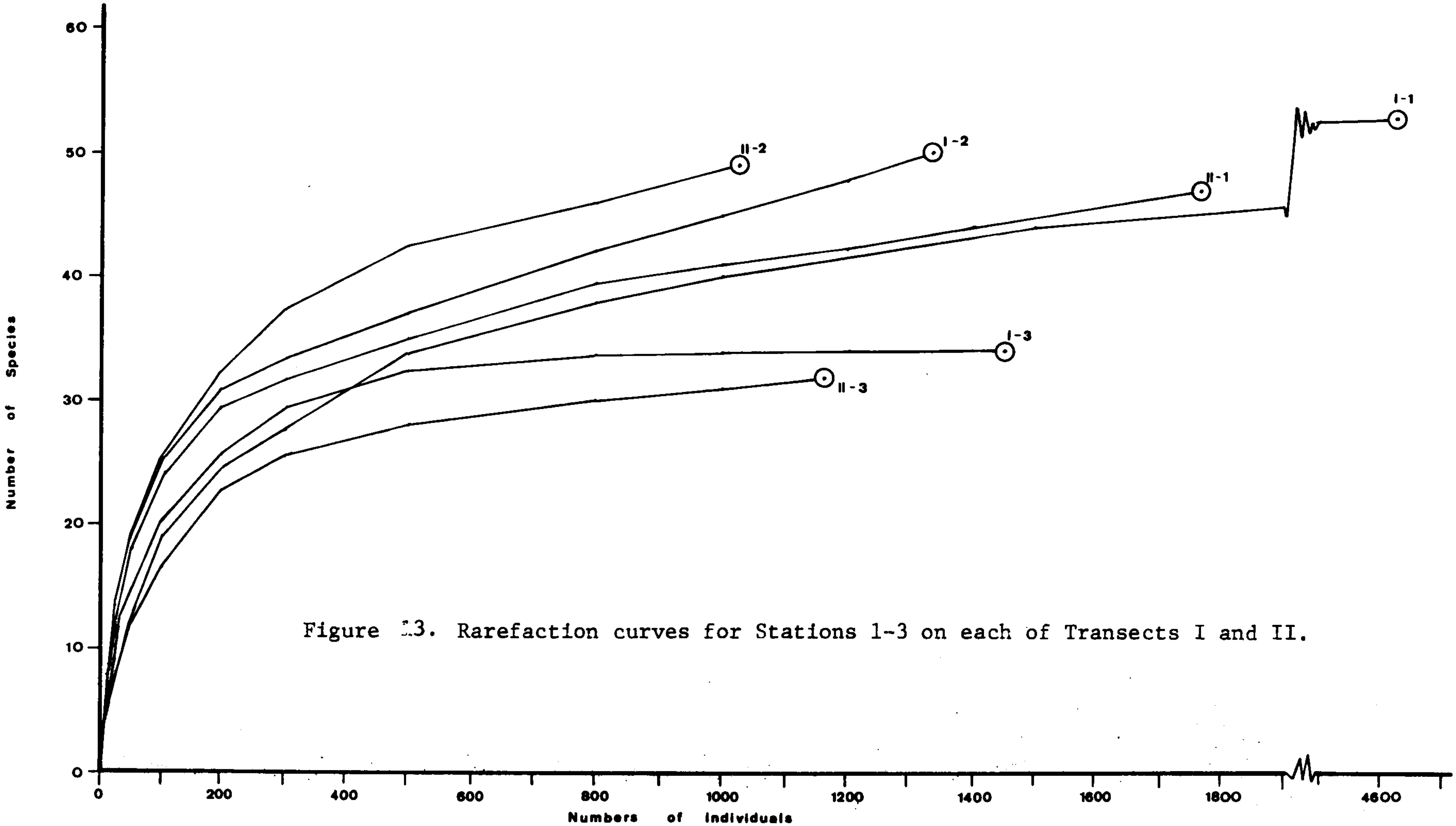

Figure 13. Rarefaction curves for Stations 1-3 on each of Transects I and II.

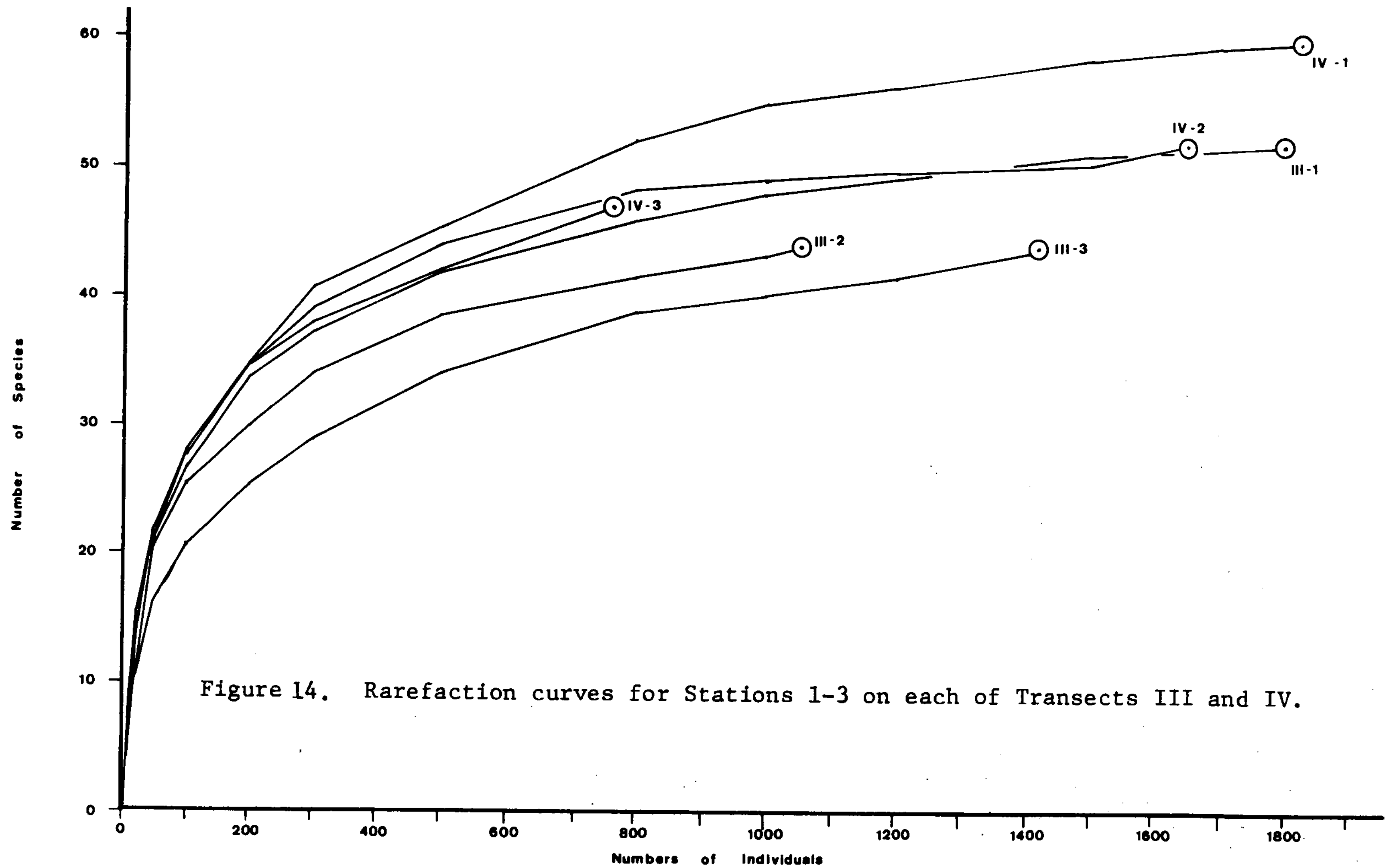

Figure 14. Rarefaction curves for Stations 1-3 on each of Transects III and IV.

Table 8. *Synodus foetens* (inshore lizardfish). Frequency of various length groups of trawled fish. Day-night collections combined. Number in parentheses denotes subsample size.

TRANSECT:	I	I	I	II	II	II	III	III	III	IV	IV	IV
STATION:	1	2	3	1	2	3	1	2	3	1	2	3
cm.					WINTER							
0.1-5	-	-	-	-	-	-	-	-	-	-	-	-
5.1-10	1	-	-	1	-	-	-	-	-	2	-	-
10.1-15	-	1	-	1	-	-	3	-	-	8	-	-
15.1-20	1	11	-	2	5	-	3	7	-	3	2	-
20.1-25	-	-	-	2	3	-	-	3	3	-	5	11
25.1-30	-	2	1	-	2	-	-	1	5	-	-	8
30.1-35	-	-	-	-	-	-	-	1	1	-	-	1
35.1-40	-	-	-	-	-	-	-	-	-	-	-	-
cm.					SPRING							
0.1-5	-	-	-	-	-	-	4	-	-	-	-	-
5.1-10	-	-	-	-	-	-	2	-	-	-	-	-
10.1-15	-	-	-	46	3	-	3	-	-	5	-	-
15.1-20	-	22	-	10	22	-	3	5	-	2	6	-
20.1-25	-	9	1	-	5	4	2	3	4	1	1	4
25.1-30	-	4	-	-	1	2	-	5	8	-	-	2
30.1-35	-	-	-	-	-	1	-	1	2	-	-	1
35.1-40	-	-	-	-	-	-	-	1	-	-	-	-
				(40)								
cm.					SUMMER							
0.1-5	-	-	-	-	-	-	-	-	-	-	-	-
5.1-10	13	-	-	4	-	-	1	-	-	2	-	-
10.1-15	11	1	-	1	-	-	16	-	-	8	-	-
15.1-20	3	2	-	3	4	-	6	1	-	3	1	1
20.1-25	-	6	2	1	-	-	-	8	2	3	7	13
25.1-30	1	3	-	-	2	-	-	3	2	-	2	3
30.1-35	-	-	-	-	1	-	-	1	-	-	-	-
35.1-40	-	-	-	-	-	-	-	-	-	-	-	-

Table 9. *Syacium gunteri* (shoal flounder). Frequency of various length groups of trawled fish. Day-night collections combined. Numbers in parentheses denote subsample sizes.

TRANSECT:	I	I	I	II	II	II	III	III	III	IV	IV	IV
STATION:	1	2	3	1	2	3	1	2	3	1	2	3
cm.						WINTER						
0.1-2	-	-	-	-	-	-	-	-	-	-	-	-
2.1-4	-	3	-	-	-	-	-	-	-	-	-	-
4.1-6	-	17	-	-	-	-	-	-	-	-	1	-
6.1-8	22	36	-	26	4	-	18	-	-	13	-	-
8.1-10	17	44	-	6	2	-	15	-	-	13	3	-
10.1-12	3	15	-	-	1	-	4	2	-	2	-	-
12.1-14	-	-	-	-	-	-	-	-	-	1	-	-
cm.						SPRING						
0.1-2	-	-	-	-	-	-	-	-	-	-	-	-
2.1-4	-	-	-	-	-	-	-	-	-	-	-	-
4.1-6	-	8	-	51	11	-	2	-	-	5	1	5
6.1-8	-	22	-	178	71	-	49	-	-	52	15	4
8.1-10	1	48	-	173	100	-	122	-	-	77	14	2
10.1-12	-	17	-	30	36	-	26	-	-	18	2	-
12.1-14	-	-	-	8	1	-	2	-	-	1	-	-
				(104)	(164)		(123)			(116)		
cm.						SUMMER						
0.1-2	-	-	-	-	-	-	-	-	-	-	-	-
2.1-4	3	-	-	-	-	-	-	-	-	1	-	-
4.1-16	-	-	-	20	-	-	8	-	-	12	1	5
6.1-8	-	10	-	6	-	-	6	-	-	11	2	-
8.1-10	15	18	-	11	-	-	15	-	-	16	5	-
10.1-12	9	3	-	8	2	-	9	-	-	9	-	-
12.1-14	-	2	-	-	-	-	-	-	-	-	-	-

Table 10. *Serranus atrobranchus* (blackear bass). Frequency of various length groups of trawled fish. Day-night collections combined. Numbers in parentheses denote subsample sizes.

TRANSECT:	I	I	I	II	II	II	III	III	III	IV	IV	IV
STATION:	1	2	3	1	2	3	1	2	3	1	2	3
cm.						WINTER						
0.1-1	-	-	-	-	-	-	-	-	-	-	-	-
1.1-2	-	-	-	-	-	-	-	-	-	-	-	-
2.1-3	-	-	-	-	-	-	-	-	-	-	-	-
3.1-4	-	-	-	-	-	-	-	-	-	-	-	-
4.1-5	-	-	-	-	1	-	-	3	-	-	-	-
5.1-6	1	17	-	-	9	-	-	27	-	-	4	-
6.1-7	2	45	-	-	62	-	1	57	-	-	20	38
7.1-8	-	2	19	-	4	24	-	54	37	2	17	23
8.1-9	-	-	75	-	-	99	-	14	60	1	-	-
9.1-10	-	-	5	-	-	6	-	-	9	-	-	-
cm.						SPRING						
0.1-1	-	-	-	-	-	-	-	-	-	-	-	-
1.1-2	-	-	-	-	-	-	-	-	-	-	-	-
2.1-3	-	-	-	-	1	-	12	-	-	-	6	-
3.1-4	-	1	-	-	3	-	4	2	-	-	2	-
4.1-5	-	5	-	-	3	-	5	2	-	-	1	-
5.1-6	-	10	-	-	4	-	-	-	-	-	1	-
6.1-7	-	11	-	-	-	1	-	41	1	-	10	3
7.1-8	-	35	9	-	4	6	-	97	38	-	19	1
8.1-9	-	-	53	-	-	30	-	46	30	-	1	-
9.1-10	-	-	23	-	-	3	-	2	3	-	-	-
								(88)				
cm.						SUMMER						
0.1-1	-	-	-	-	-	-	-	-	-	-	-	-
1.1-2	-	-	-	-	-	-	-	-	-	-	-	-
2.1-3	-	-	-	-	-	-	-	-	-	-	-	-
3.1-4	-	-	-	-	-	-	-	-	-	-	-	-
4.1-5	-	13	-	-	2	-	-	26	-	-	17	-
5.1-6	-	6	-	-	3	-	-	20	-	5	135	3
6.1-7	-	6	3	-	1	-	-	8	-	1	31	1
7.1-8	-	12	3	-	11	8	-	33	13	-	48	4
8.1-9	-	2	93	-	6	36	1	20	84	-	30	12
9.1-10	-	-	19	-	-	10	-	-	12	-	-	-
			(42)					(42)	(56)		(60)	

Table 11. *Pristipomoides aquilonaris* (wenchman). Frequency of various length groups of trawled fish. Day-night collections combined. Numbers in parentheses denote subsample sizes.

TRANSECT:	I	I	I	II	II	II	III	III	III	IV	IV	IV
STATION:	1	2	3	1	2	3	1	2	3	1	2	3
cm.						WINTER						
0.1-5	-	20	-	-	-	3	-	3	2	-	26	-
5.1-10	-	21	125	-	9	52	1	12	4	-	136	4
10.1-15	-	-	59	-	-	24	-	1	26	-	-	21
15.1-20	-	-	35	-	-	13	-	-	14	-	-	18
20.1-25	-	-	1	-	-	-	-	-	-	-	-	-
cm.						SPRING						
0.1-5	-	-	-	-	-	-	-	-	-	-	-	-
5.1-10	-	23	19	-	23	16	21	1	-	-	20	8
10.1-15	-	-	27	-	-	20	-	1	5	-	-	2
15.1-20	-	-	19	-	-	9	-	-	13	-	-	-
20.1-25	-	-	-	-	-	-	-	-	-	-	-	-
cm.						Summer						
0.1-5	-	6	-	-	4	1	-	3	-	-	67	21
5.1-10	-	2	2	-	-	5	-	-	2	-	12	21
10.1-15	-	-	29	-	-	32	-	1	28	-	-	24
15.1-20	-	-	13	-	-	9	-	-	16	-	-	23
20.1-25	-	-	-	-	-	-	-	-	-	-	-	-
											(39)	(60)

Table 12. *Cynoscion nothus* (silver seatrout). Frequency of various length groups of trawled fish. Day-night collections combined. Number in parentheses denote subsample sizes.

TRANSECT:	I	I	I	II	II	II	III	III	III	IV	IV	IV
STATION:	1	2	3	1	2	3	1	2	3	1	2	3
cm.						WINTER						
0.1-2	-	-	-	-	-	-	-	-	-	-	-	-
2.1-4	44	-	-	-	-	-	-	-	-	-	-	-
4.1-6	385	-	-	-	-	-	-	-	-	1	-	-
6.1-8	297	-	-	-	-	-	-	-	-	3	-	-
8.1-10	175	-	-	-	-	-	1	-	-	6	-	-
10.1-12	1	-	-	-	-	-	1	-	-	-	-	-
12.1-14	-	-	-	-	-	-	-	1	-	-	-	-
14.1-16	-	-	-	-	-	-	-	1	-	-	-	-
16.1-18	-	-	-	-	-	-	-	2	-	-	-	-
cm.						SPRING						
0.1-2	-	-	-	-	-	-	-	-	-	-	-	-
2.1-4	-	-	-	-	-	-	-	-	-	-	-	-
4.1-6	-	-	-	-	-	-	-	-	-	-	-	-
6.1-8	100	-	-	112	-	-	-	-	-	-	-	-
8.1-10	223	-	-	348	-	-	1	-	-	-	-	-
10.1-12	46	-	-	31	-	-	2	-	-	2	-	-
12.1-14	-	-	-	-	-	-	4	-	-	-	-	-
14.1-16	-	-	-	-	2	-	-	-	-	-	-	-
16.1-18	-	-	-	-	-	-	2	-	-	-	-	4
	(81)			(79)								
cm.						SUMMER						
0.1-2	-	-	-	-	-	-	-	-	-	-	-	-
2.1-4	-	-	-	-	-	-	-	-	-	-	-	-
4.1-6	-	-	-	1	-	-	-	-	-	-	-	-
6.1-8	-	-	-	-	-	-	2	-	-	-	-	-
8.1-10	-	-	-	1	-	-	6	-	-	2	-	-
10.1-12	-	-	-	-	-	-	7	-	-	2	-	-
12.1-14	2	-	-	1	-	-	8	-	-	2	-	-
14.1-16	2	-	-	6	-	-	41	-	-	1	-	-
16.1-18	-	-	-	1	-	-	3	-	-	-	-	-
							(41)					

DISCUSSIONS AND CONCLUSIONS

Introduction

This section includes (a) a brief evaluation of theory and techniques and (b) a preliminary overview discussion of results. In contrast to studies of other biota, all the fishes in this study have been identified to the species level.

At this point of the ongoing OCS study, individual and composite reports of other concurrent studies are unavailable for comparison, analysis and synthesis. Consequently the data for benthic fishes alone are available for generalized discussion.

Thus far it is preliminarily sufficient to note that none of the benthic fish data yielded any "surprises" in terms of unusual numbers of individuals, numbers of species, "new" or unusual species, or completely unsuspected species associations.

Note: In the following discussions, the conclusions are italicised.

Informational Indices

The species associations and abundance data are in customary form in the 72 Appendix XX tables, which contain the basic available information from this study. Quite obviously, unreduced data in this traditional type of presentation are awkward and hence useful to relatively few ichthyologists and fisheries scientists who have a considerable amount of additional knowledge and expertise on the individual life histories of species, the relationships of species to each other, and the vagaries of sampling.

For approximately two decades, data on distribution and abundance have received much attention in reduced terms, or indices. A number of widely used indices depend upon various aspects of general information and/or thermodynamic theory for their derivation (Patten, 1962). Within the last decade mounting criticism of many informational indices has occurred.

Recently the metaphorical nature of the application of information and thermodynamic theory to biological systems has emerged. Peet (1974) reviews the entire concept of species diversity and notes that no generally accepted definition of diversity has emerged. Hurlbert (1971) considers species diversity a nonconcept as do others more recently. Peet (1975) demonstrates the existence of mathematically undesirable qualities of diversity indices regardless of whether the maximum diversity is defined to be limited by the number of species or by the number of individuals present.

The eristic nature of indices should be rather obvious in a consideration of initial assumptions in their derivations. How a single unit (bit) of information can be unique for the occurrence of a particular species at a particular time and place is a basic premise to be questioned. That occurrence seems more rationally defined by much more "information" than even a few bits. In light of specific knowledge of adaptations or of ecological optimization (evolution) theory a vast amount of "information" must (by definition?) be involved to determine or establish the occurrence of an individual of a given species. For this reason alone it would appear that application of the various informational indices to occurrence and abundance of species and individuals does not represent a universal truth.

However, the dialectic nature of some of these information indices may be reasonable. Their usefulness to provide an empirical methodology of great utility in data reduction can be expected. In the case of empirical usage, the best course to follow would be to retain the original tabulations of numbers of species and numbers of individuals as in the Appendix XX tables, however bulky these tabulations may be.

The interpretation of species diversity in terms of ecological stability is another metaphorical area where apparently the "right" questions can not yet be formalized to lead to universally accepted concepts. In the series of papers on ecological stability and species complexity there are widely divergent points of view (Usher and Williamson, 1974). Quite obviously, there are presently wide differences between the biological reality of existing systems and the mathematical or statistical abstractions of these systems.

Conclusion:

The use of the various theoretically based indices therefore implies that these indices must be used with great caution, should be considered as empirical and somewhat arbitrary, and must be used in conjunction with species abundance tabulations.

Gear Selectivity

Because all the sampling in this study was by identical trawling procedures, data comparisons by use of the various informational indices and other data reduction systems are inherently reasonable regardless of the empiricism involved.

The species-abundance comparisons of one trawl haul to the next are reasonable in several respects. At the trawling stations the bottom sediments ranged from sand to fine mud. At only three stations were rocky bottoms or snags encountered. In these cases replicate trawls within

1/2 mile were possible on finer, more uniform substrates. Quite obviously, the trawling technique could not be used successfully on the rocky "reefs" or topographical highs at about 60 m scattered through parts of the south Texas OCS. In this area there appears to be no successful trawl gear that can effectively "dig" into the mud to a great degree. The trawl net and board arrangement for this study was suitable for avoiding "mud hauls" that result when lead lines and boards are improperly rigged and result in large quantities of packed mud retained in the bag to the extent that adequate sampling of benthos is prevented.

Conclusion:

The trawl gear is highly effective for sampling benthic fishes over the fine sediments that predominate in the South Texas OCS.

Selectivity of the kinds and numbers of fishes taken by any single type of gear has not been quantitatively evaluated, and no detailed studies of intercalibration among various types of trawls or other gear have been made in this area.

Without such studies, the evaluation of trawl type, mesh size, time on bottom, is impossible as related to the abundance of fish. The abundance of fishes in turn depends upon their vulnerability to the gear, which involves their size, diurnal and seasonal occurrence at or near the bottom, migrations, sex, behavior in the presence of gear, swimming behavior to escape the gear, etc. Life history and general behavior studies of the individual species, when available, usually provide insufficient information to evaluate gear selectivity. Cushing (1967) and Royce (1972) describe various aspects and consequences of gear selectivity.

The constraints imposed by single catches without replication are such that the actual distribution of a species cannot be directly assessed. Even if a species is completely vulnerable to the gear, only replicate samples with means and variances can yield information on the degree of aggregation, random distribution or superdispersion that occurs at any time and place.

Conclusion:

Because provisions in this study exist neither for evaluation of gear selection or for assessment of random variability, it is suggested that the catch data be interpreted in conjunction with the appended species lists and with the length-weight data accumulated for the individual samples.

Catch Per Unit of Effort

In fisheries management one of the principal and most useful basic data sources is catch statistics combined with standardized measures of fishing effort. In this study the 15 minute trawls provided a very uniform measure of effort.

Usually there were few exceptionally small or large catches as indicated in Appendix XX, Tables 1-6, and Figures 7-12.

While the weights and numbers in the catches might appear to be rather random over the day-night and seasonal collections, a few generalizations are possible. In Table 13, the day-night tabulations indicate that there is little evidence of any major numerical trends. In many single station and season comparisons the day-night differences are considerable, but these differences are inconsistent through the seasons at any single station. Except for the inshore stations there seem to be few major day-night differences. These differences are quite striking for numbers and biomasses in Figures 7-12. However, there are even more striking day-night differences in species compositions indicated in the

Table 13. Number of individual benthic fish in day (D) and night (N) trawls at each station (Arabic numerals), transect (Roman numerals) and season.

Season	Winter		Spring		Summer	
Time	D	N	D	N	D	N
I-1	700	754	2,199	1,018	207	648
I-2	178	243	398	216	316	40
I-3	488	302	177	193	86	205
II-1	8	83	830	457	147	207
II-2	189	9	508	282	86	15
II-3	535	283	125	69	60	93
III-1	31	97	502	333	776	278
III-2	84	215	228	285	28	215
III-3	411	305	144	289	106	170
IV-1	85	124	405	215	275	762
IV-2	109	269	354	114	234	514
IV-3	186	200	239	105	171	205

Appendix XX species lists. For example, one atlantic midshipman (*Porichthys porosissimus*) as is well known is definitely nocturnal; during day time it buries itself in the substrate (Lane, 1967; Moore, 1970). Many other species are definitely more vulnerable to the sampling at either day or night periods.

The catch statistics in Tables 1-6 and Figures 7-12 also clearly indicate that the weights per fish tend to increase with depth.

The greatest irregularities in catch numbers and weights appear to occur at the inshore stations. These irregularities can best be understood by evaluations of the species compositions and average size of individuals derived from the Appendix tables. Evaluation of the occurrences at inshore stations would involve the degree to which earlier life history stages are associated with the shallower waters or migrations to or from inshore nursery grounds.

Assuming equal sampling (fishing) effort, the most useful way to evaluate erratic numbers or weights at any season is to utilize the species composition data in Appendix XX. Among the inshore stations, Station 1, Transect I appears to be one of the most erratic in both weights and numbers.

Conclusions:

Catch effort by numbers or weights among the 72 collections were not unusually variable. Station 1, Transect I was the most erratic. There were no regular day-night trends of numbers or weights that persisted seasonally, but some individual species were predominately diurnal or nocturnal. It is precarious to make relative abundance comparisons or conclusions without involving comparisons among individual species.

Species Diversity Index

Diversity Index, H", for Species Numbers.

Over the OCS area, there are several Shannon species diversity index trends that are realistic. From Tables 1-3 and Figures 1-6, , the H" values are realistic with respect both to the species abundance data in the Appendix XX tables and general ichthyological knowledge.

The H" values are more irregular and probably smaller for winter than for spring and summer samples. Contributing to the uneveness no doubt is the fact that among several species the juveniles grow rapidly and reach a vulnerable size at the various localities by spring and summer. In winter the young of these species might be absent or would not be as vulnerable. Alternatively, in some cases some species may be sufficiently migratory to occur more frequently in spring and summer.

The extent to which migrations influence H" values would be considerable. It is commonly recognized that many pelagic fishes like billfishes and scombroids migrate into this OCS area during summer and largely disappear in winter. Too little distribution and life history data are presently available for benthic species to permit a complete species-specific assessment at this time. However, a glance at Figures 1-6 and Tables 1-3 reveals that the southern transect IV tends to have more species and greater H" values, especially in spring and summer. The tentative explanation is that there is a greater consistent influence by tropical to subtropical species in the southernmost OCS area.

Possibly the northernmost inshore stations on transects I and II are more influenced by the presence or absence of species at least seasonally. Station 1 transect I is especially interesting in this regard. For this station (I-1) the H" values tend to be low except in summer.

In the winter and spring this station had the lowest H" chiefly because there was a good distribution of species with but a few of each of the summer inshore estuarine species, but with a relative superabundance of predominant marine *Cynoscion nothus* both seasons, and a superabundance of *Micropogon undulatus* in spring, which also occurred superabundantly in the summer night haul. Other low H" values are associated with the predominance of, say, 1-4 species as for examples: winter, day II-3; summer, night III-1.

By contrast, the highest of the H" values occur when there were more uniform apportionments among at least modestly large species complements. The highest H", 3.738, was for the spring IV-2, night sample with 32 species, 114 individuals of which 28 species occurred each with less than 10 individuals.

Diversity Index, H", for Biomass.

In terms of weights of species and individuals, the H" calculated for Tables 4-6 have some interesting properties that relate to the numerical diversity indices with more or less direct correlations and in fairly direct proportion to the number of species sampled as well. Most interesting is the observation that the range of biomass H_w'' (Tables 4-6) is fairly constant among the 24 values for each season, whereas both the range and displacement of the numerical H_n'' (Tables 1-3) changes seasonally.

In terms of regressions of H_w'' for the biomass indices on H_n'' for the numerical indices, the equations with correlation (r) values are:

Winter: $H_w'' = 0.9155 + 0.5639\ H_n''$; N=24; r=0.68;

Spring: $H_w'' = 1.0883 + 0.4994\ H_n''$; N=24; r=0.79; and

Summer: $H_w'' = 0.1741 + 0.8489\ H_n''$; N=24; r=0.69.

(Since both H_w'' and H_n'' contain the same sort of information in common, it is likely that the correlations are to some extent spurious.)

The changes in the seasonal intercept and slope values, however, are largely a reflection of the range and displacement of H_n''. Generally, there is a fairly direct correlation between H_w'' and H_n''. Among the H_w'', there was a reasonably consistent, direct relationship to extreme H_n'' values. Apparently the biomasses of the fishes are not inconsistent either with the numerical species diversity indices.

Since there has been relatively little application of the species diversity index on the basis of biomass in the sense of Wilhm (1968), there are few comparative data for fishes. Bechtel and Copeland (1970) noted that there was a significant difference between Galveston Bay fish weight and number diversity indices and that usually the greatest variability occurred among the weight indices. This contrast to the OCS data might be expected since the inshore areas provide both nursery grounds and adult habitats variously for different species.

Conclusions:

➔ *For the benthic OCS fishes, the Shannon diversity index provides a realistic, but probably arbitrary and empirical, measure of diversity in general agreement with species abundance tabulations.*

➔ *There are few stations with exceptionally low or high diversities that cannot be explained by sampling variations.*

➔ *Seasonal differences do occur. Day-night differences are not generally obvious, even though species lists are different.*

➔ *Diversity indices on a weight basis are less variable and less sensitive than comparable indices on a numerical basis.*

Equitability, E

The E values of Tables 1-3 as calculated from Lloyd and Ghelardi (1964) may be quite useful, although Goodman (1975) notes that this measure of evenness is not wholly independent of species richness and is not altogether unambiguous.

The E values tend to be seasonally different when compared to the Shannon numerical species diversity H" indices. In a seasonal comparison of E with H_n'' the regressions, with correlations r , are:

Winter: $E = 0.1139 + 0.1082\ H_n''$; N=24; r=0.32;

Spring: $E = -0.0693 + 0.1676\ H_n''$; N=24; r=0.79; and

Summer: $E = -0.1595 + 0.2225\ H_n''$; N=24; r=0.64.

Clearly the winter E data are much more dispersed, in reference particularly to Stations II-1 Day, II-2 Night, and III-1 Day. Each of these stations had relatively high E, few species and few individuals. In this sense the equitability is relatively high. By contrast the E were much more closely, and reasonably linearly, related to H_n'' in spring and summer.

Part of the ambiguity in the use of equitability according to Goodman (1975), among others, results from a wide range of ecological variables. However, in a baseline study such as this, these ambiguities, station differences and temporal differences, are of direct interest for further evaluations.

Conclusions:

➔ *Equitability is linearly related to the species diversity indexes, with the greatest irregularities in winter.*

➔ *There are seasonal differences in equitability that presumably are related to spatial and temporal and ecological variables.*

Equitability tends to be high when there are few species and few individuals in the samples.

Probability of Interspecific Encounter (P.I.E.)

The P.I.E. values in Tables 1-3 seem to relate very closely to the corresponding H_n'' values. Simple plots of P.I.E. against H_n'' indicate a high degree of correlation and minimal dispersion. Again it should be noted that there is a certain degree of spuriousness in correlations of this kind because the same numbers are utilized in calculating the H'' and P.I.E.

As in the case of equitability small numbers of individuals and few species in a collection tend to result in larger P.I.E. values. Regression comparisons, with correlation coefficients show pronounced seasonal variations in the P.I.E. - H_n'' regressions.

Winter: P.I.E. = 0.0941 + 0.3529 H_n''; N=24; r=0.90;

Spring: P.I.E. = 0.3992 + 0.1771 H_n''; N=24; r=0.76; and

Summer: P.I.E. = 0.2134 + 0.2800 H_n''; N=24; r=0.93.

Dispersion seems to be much less for the P.I.E. - H_n'' interrelation than for the E - H_n'' interrelation discussed above. Spring variability seems to be the greatest, summer the least.

With few possible exceptions the interpretation of P.I.E. values with respect to individual samples is about the same as for the E values. The relatively high winter P.I.E. values (Table 1) at stations II-1 Day and II-2 Night, for example, are associated with few species and individuals. It would appear reasonable, even if empirical, that P.I.E. allows both for straightforward biological interpretation and for an alternative approach to the measurement of species diversity as proposed by Hurlbert (1971).

Conclusions:

➔ *P.I.E., the probability of interspecific encounter, is closely related to the Shannon diversity index and may be used as an alternative, however empirical P.I.E. calculations may be.*

➔ *Like equitability, P.I.E. tends to be high when there are few species and individuals in a collection.*

➔ *The P.I.E. data indicate that there are pronounced seasonal differences in the distribution and abundance of south Texas OCS benthic fishes.*

Rarefaction Curves

The rarefaction curve method has been applied as a practical, method for comparison of different species abundance combinations by Sanders (1968). The method utilized a mathematical scaling system to reduce all measurements to common sample sizes. Simberloff (1972) noted that Sanders' (1968) method is conceptually incorrect and that "scaled down" subsamples of a given size, when randomly drawn from the entire sample tend to be much lower for the species that rank toward the top in abundance. Simberloff also noted that rarefaction not only consistently overestimated expected species number, but it did so to much greater extent for intermediate size subsamples than for small or large ones.

In this study, the rarefied curve calculations utilized all the data for each station for the entire year (Figures 13-14), so that the total number of species and individuals would be larger than the examples used by Simberloff's evaluation of Sanders' (1968) data. Even so the upward convexity of the left portions of the curves in Figures 13 and 14 would be biased upward.

Inasmuch as these curves are here considered empirical and for their interpretation require value judgments based on the data in Appendix

XX until other enviromental variables can be studied, they can be used only tentatively to describe the yearly species associations at any one of the 12 stations.

Allowing for the possible arbitrariness of the rarefaction curves, it still appears that the lowest diversity occurs at stations I-3 and II-3 and the greatest at IV-1 considering the entire year of accumulated samples at the 12 stations. It should be noted that Stations I-3 and II-3 are the northernmost deepwater stations, while IV-1 is the southernmost and shallowest station. Whether these geographical relationships are involved in an explanation of species abundance and diversity is not entirely clear. Nor is it clear how sampling is influenced by aggregational tendencies at specific sites and times since replicate samples were not taken in this study.

Conclusions:

➔ *The rarefaction curves appear to be arbitrary and biased, but still appear to be tentatively useful when large collections are available.*

➔ *For year around combinations of data at each of the 12 sites, the nature of the curves indicates that there may be an overall diversity gradient from deep northern stations to shallow southern stations.*

Length-Frequency Growth Data

The length-frequency information for the five species in Tables 8-13 are presented to show how such information can be of use in establishing standards of comparisons (baselines) that depend upon growth evaluations especially for smaller fish.

In three cases (Tables 8, 10 and 11), the average sizes increase from inshore to offshore at all seasons. For the shoal flounder (Table 9) it is evident that the deeper stations are not general habitats; the same is true for the silver seatrout (Table 12). In the case of the shoal flounder, the species should be continuously vulnerable to the gear with increased size; in the case of the silver seatrout, it is likely that there would be decreasing vulnerability to the gear as the fish grew.

It is also evident that the length-frequency tabulations show an increase in length from winter through summer as would be expected. In most cases there is some possible indication that the larger faster growing fish are found at the southern transects.

For most of the species taken in this study, there are insufficient specimens to make up detailed, seasonally, and spatially useful length-frequency diagrams. In the case of selected species of importance to fisheries, additional data collecting might be instructive and useful inasmuch as growth rates can be directly influenced by environmental quality. To be of greatest use, growth data should be available over several years to allow for interpretations of year-to-year environmental variability that affects growth rates as well as spawning, larval and juvenile survival, fecundity of adults, and possibly spawning migrations.

Conclusions:

➔ *There is a general trend for the larger fish to be found in deeper waters, except for the strictly shallow water species.*

➔ *There is a tentative indication that a given species grows faster at the southern stations.*

➔ *In general the length-frequency system of evaluating growth can provide highly useful baseline information, providing sufficient numbers are sampled.*

Preliminary Interpretations of STOCS Fish Distribution

It is somewhat premature to draw conclusions concerning assemblages of the various, much beyond the compilations in Appendix XX and from the derived informational indices. At individual stations the separate collections are unreplicated so that a measure of intrastations variability is unavailable. As pointed out in an earlier section, there is little quantitative information on the nature of gear selectivity that determines how many and which species are, or are not, captured.

Between stations both distance and time factors make judgements of geographic and bathymetric extents of distributions rather precarious. Attempts to plot density distributions of several of the common species indicated that the collection grid of 12 stations was too coarse for easy interpretation. The contributions by seasonal migrants from adjacent estuarine regions and other regions outside the sampling area will become clearer with additional collections.

From the summaries of the 36 day-night pairs of collections the immediate conclusion is that there are major differences between day and night species compositions among the 12 stations. Additional collecting with replication will be required to evaluate true diurnal differences from differences associated with random sampling.

To permit the delineation of abundance and distribution, areally and bathymetrically, of the benthic fishes on both numerical and ponderal bases, it is recommended that:

1. *Five or six collections be made on each transect.*

2. *On at least one transect there should be monthly collections to permit a finer assessment of seasonal changes; and*

3. *There should be serious attempts at obtaining as many replicate*

samples as feasible.

Internal Consistency of Informational Indices

The purpose of this section is to investigate the empirical relationship among the indices discussed in earlier sections.

The relationships between the H" numerical index (H_n") and the corresponding index (H_w") for biomass of the individual fish species can be compared by the regression of H_w" on H_n" as in Figures 15, 16, 17 for the respective Winter, Spring and Summer seasonal combined day and night collections. The respective correlation coefficients are r = 0.68, r = 0.79, and r = 0.69. For the winter data the Figure 15 upper arrow denotes Transect II, Station 1, day collection of 8 specimens and 5 species and the lower arrow denotes Transect II, Station 2, night collection of 9 specimens and 6 species. No explanation for the poor diversity and numbers is readily apparent for these two stations. Figure 18 is a summary of the three seasonal regressions; note that the summer regression indicates that there is nearly a one-to-one correspondence between H_w" and H_n".

The H_w" and H_n" plots involve spurious correlations inasmuch as there are common elements in each of the H_w" and H_n" pairs. This means that the dispersion of the indices should be minimal with high correlation values if there is a reasonable correspondence between the ponderal H_w" and the more customary numerical H_n" indices. Quite clearly, calculating and plotting the diversity indices in this manner, however empirical, is a useful way of identifying graphically the more aberrant collections with respect either to numbers or to biomass. The correspondence of H_w" to the H_n" also lends some credence to the utility of Wilhm's (1968) argument for biomass to assess diversity.

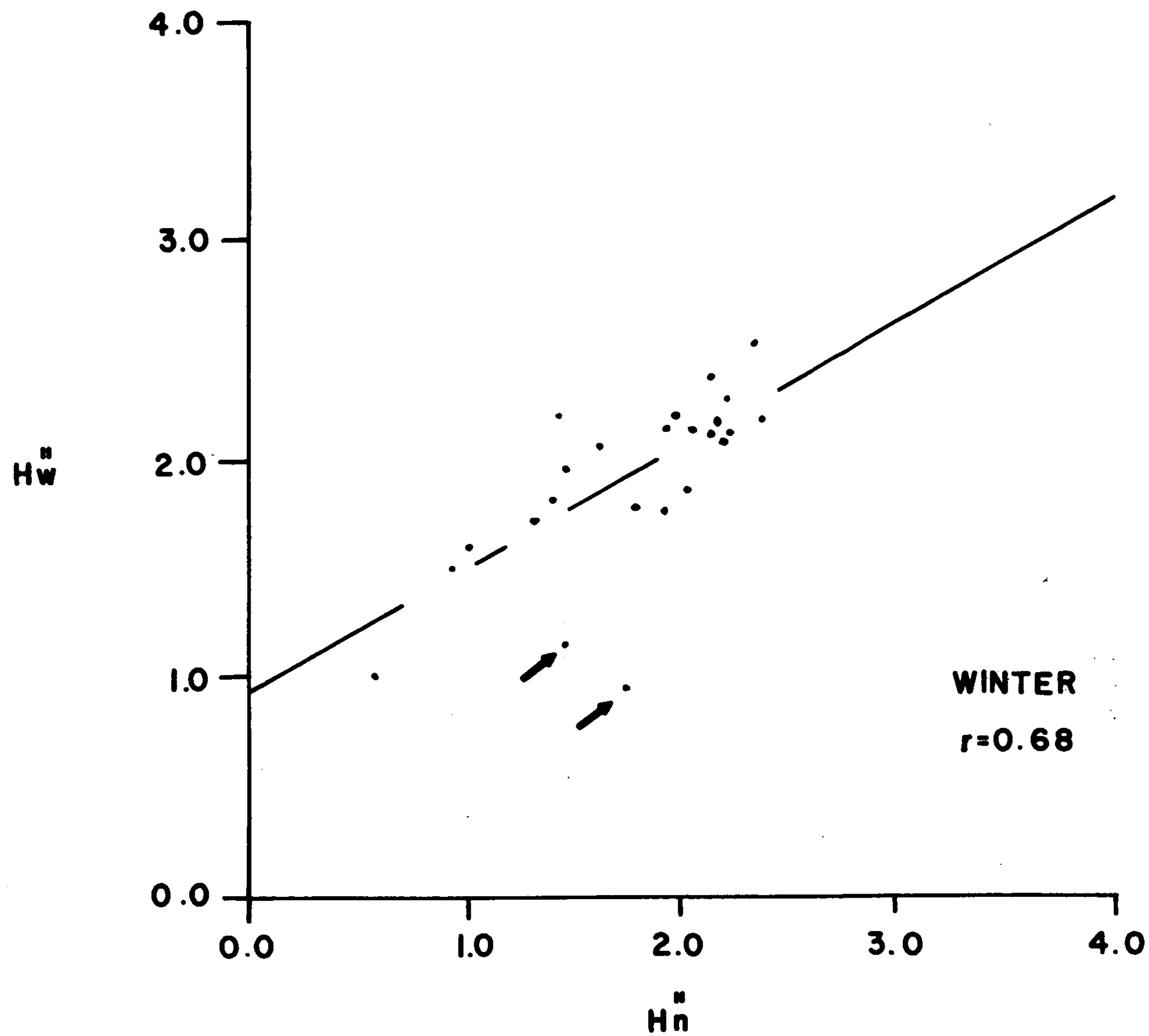

Figure 15. Relationship between fish diversity indices H_w" (biomass) and H_n" (numbers) for winter collections. See text for explanation of arrows.

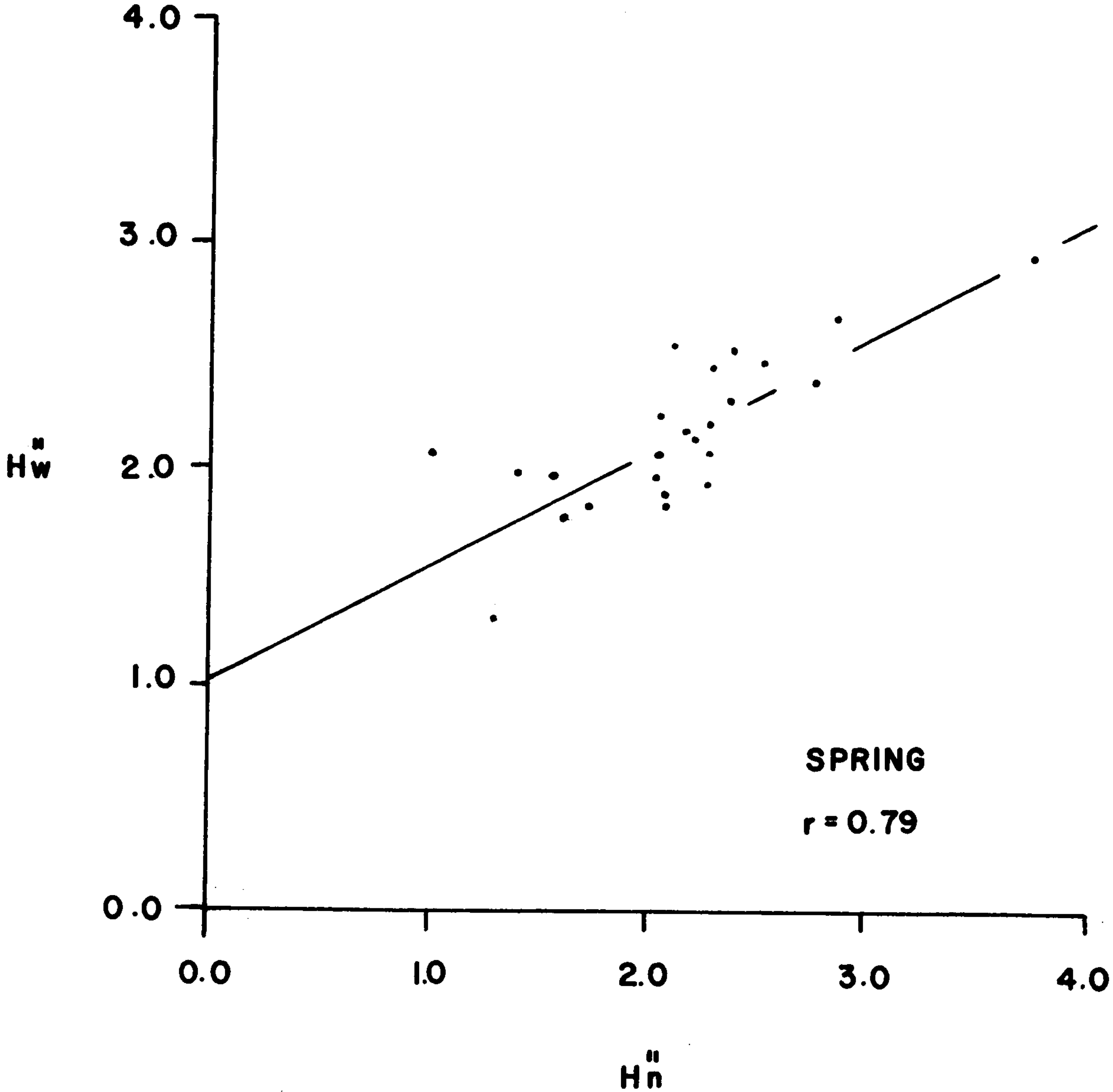

Figure 16. Relationship between fish diversity

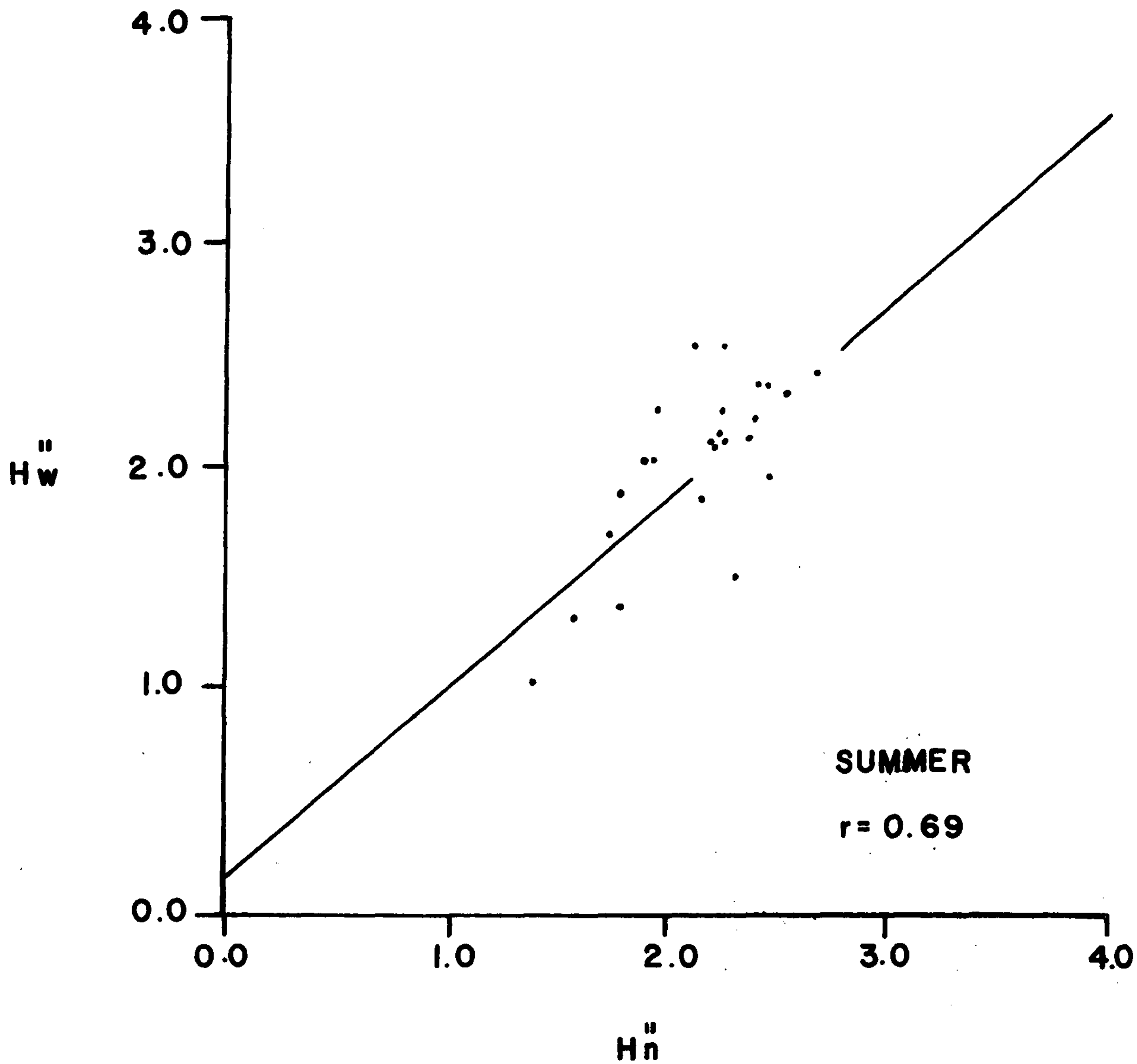

Figure 17. Relationship between fish diversity indices H_w'' (biomass) and H_n'' (numbers) for summer collections.

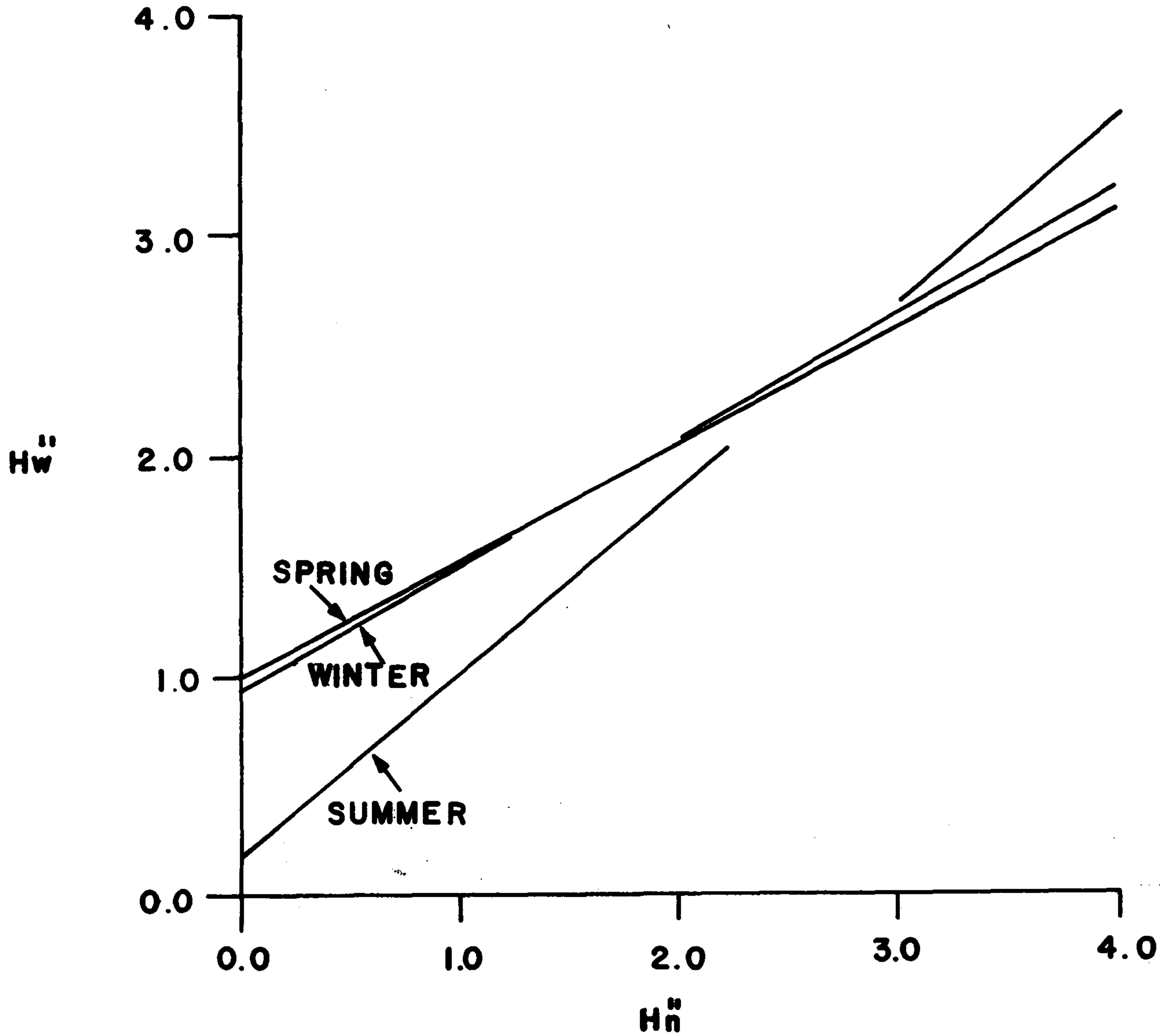

Figure 18. Relationships of seasonal diversity regressions of H_w" on

Comparisons of regressions of equitability, E, with H_n'' are also quite instructive for the 24 day and night catches at each of the seasons. The data, regression lines and correlations are given in Figures 19, 20 and 21 for Winter, Spring and Summer, respectively. The seasonal summary comparisons of regressions (without deleted data pairs) are in Figure 22.

First, it should be noted that the spurious nature of these regressions derives from the relation of E as based on H_n''. This means that the values plotted in the figures should have minimal dispersion if the two variables are closely related. Second, the presence of divergent, outlier, values indicated by arrows in Figures 19 and 20 can alter both the degree of correlation considerably (as indicated by the increase in $\underline{r}$ values when disparate data are omitted) and change the nature of the regression (dashed lines), especially in Figure 19. The disparity, as in Figure 15, shows up in Figure 19 where the uppermost arrow again denotes Transect II, Station 1, Day; the middle arrow, Transect II, Station 2, Night; and the lowest arrow, Transect III, Station 1, Day with 31 fish and 12 species. The arrow in Figure 20 denotes the 15 species among 535 individuals from the Spring Transect II, Station 3, Day collection. This represents a rather aberrant situation with a relatively small number of species for so many individuals, which, however, affects the regression little, but increases the correlation from $r = 0.79$ to $r = 0.90$ upon deletion.

The summer data in Figure 21 show a moderate degree of "clustering" and fairly great dispersion, which results in a relatively low correlation.

All three of the seasonal equitability-diversity index plots represented by the regressions plots of Figure 22 would be quite similar if the plot for the winter had the three winter aberrant values (Figure 19) removed.

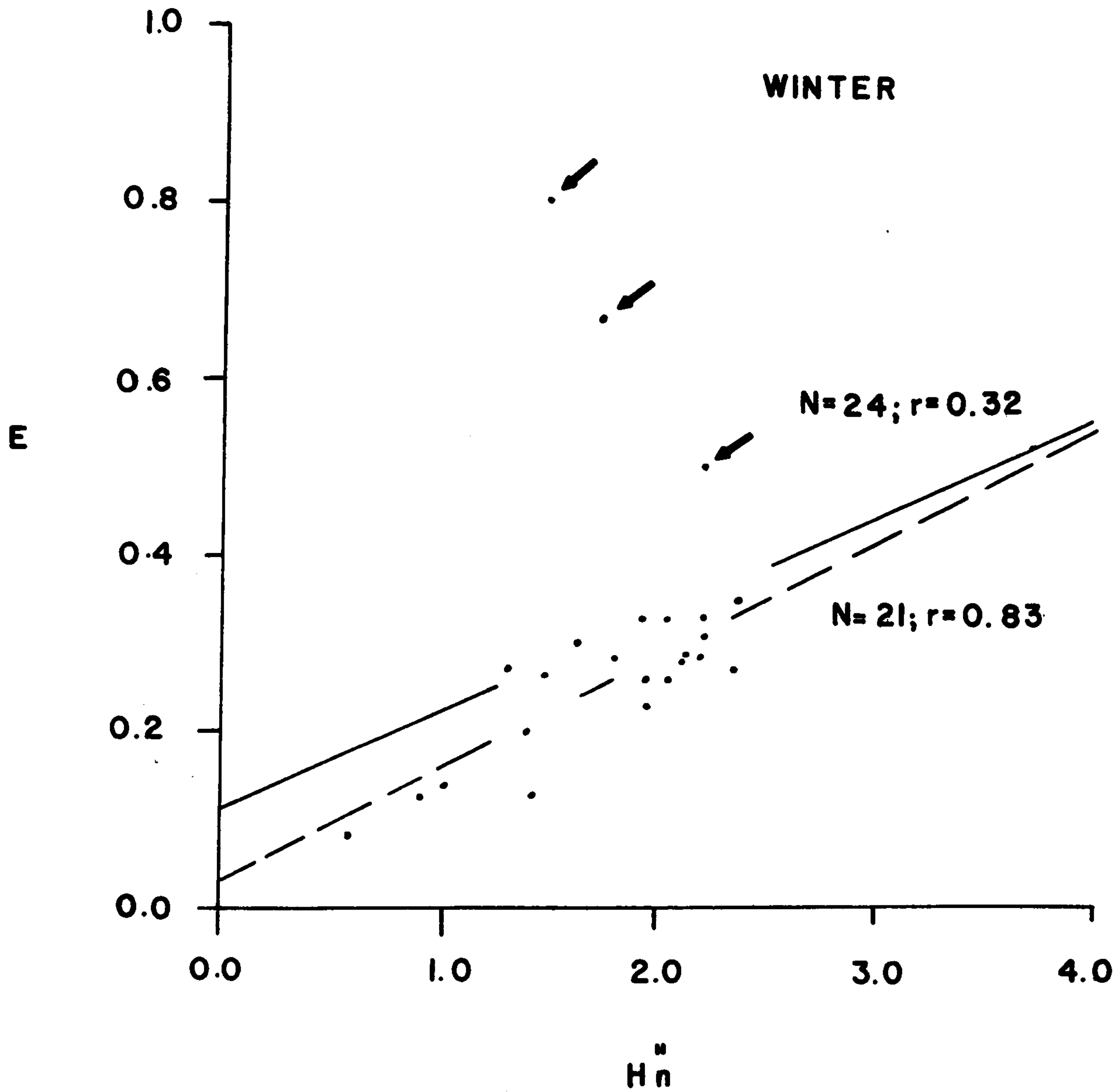

Figure 19. Relationship between

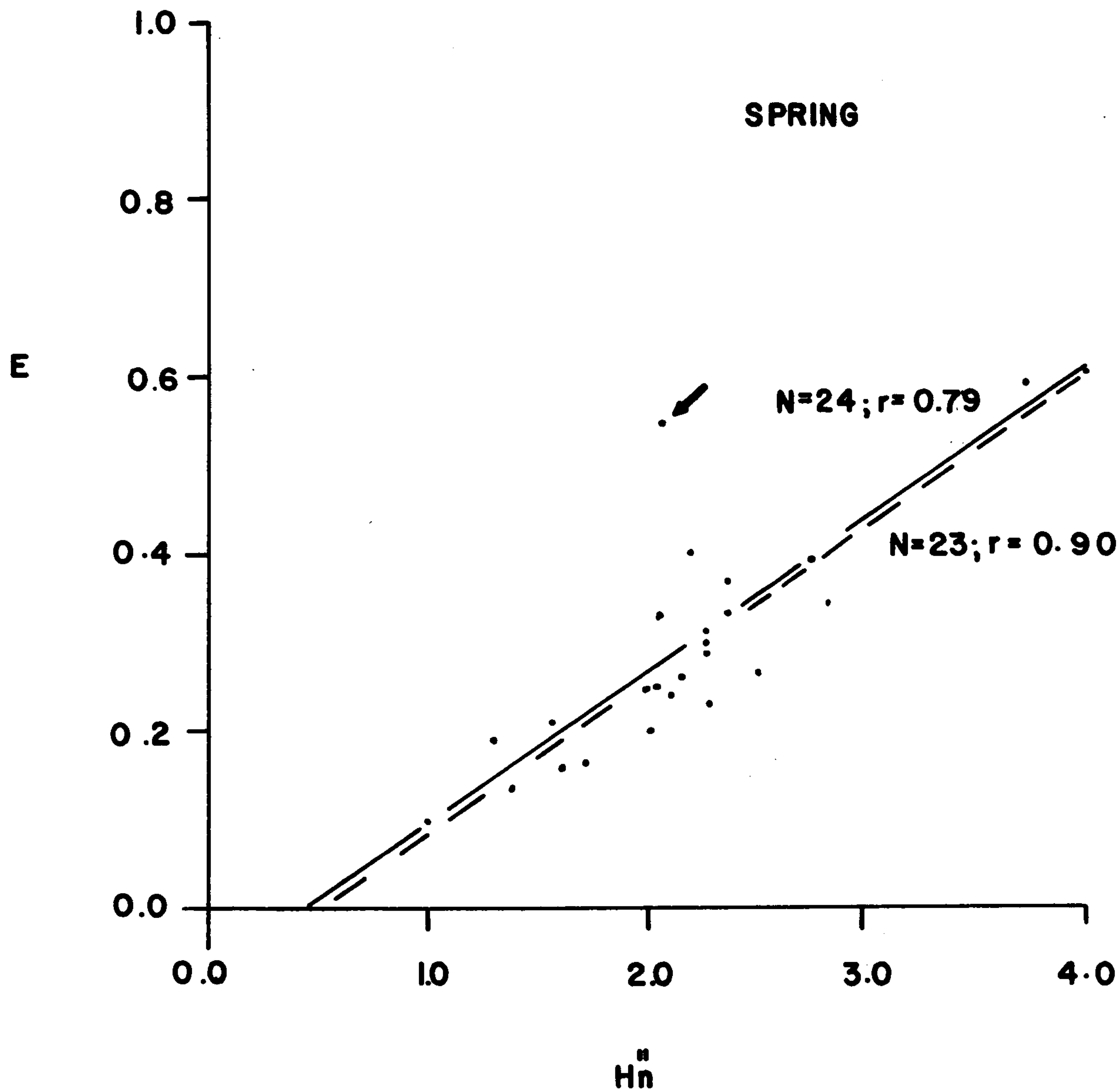

Figure 20. Relationships between equitability, E, and Shannon diversity index, H_n", for spring fish collections. See text for explanation of arrow.

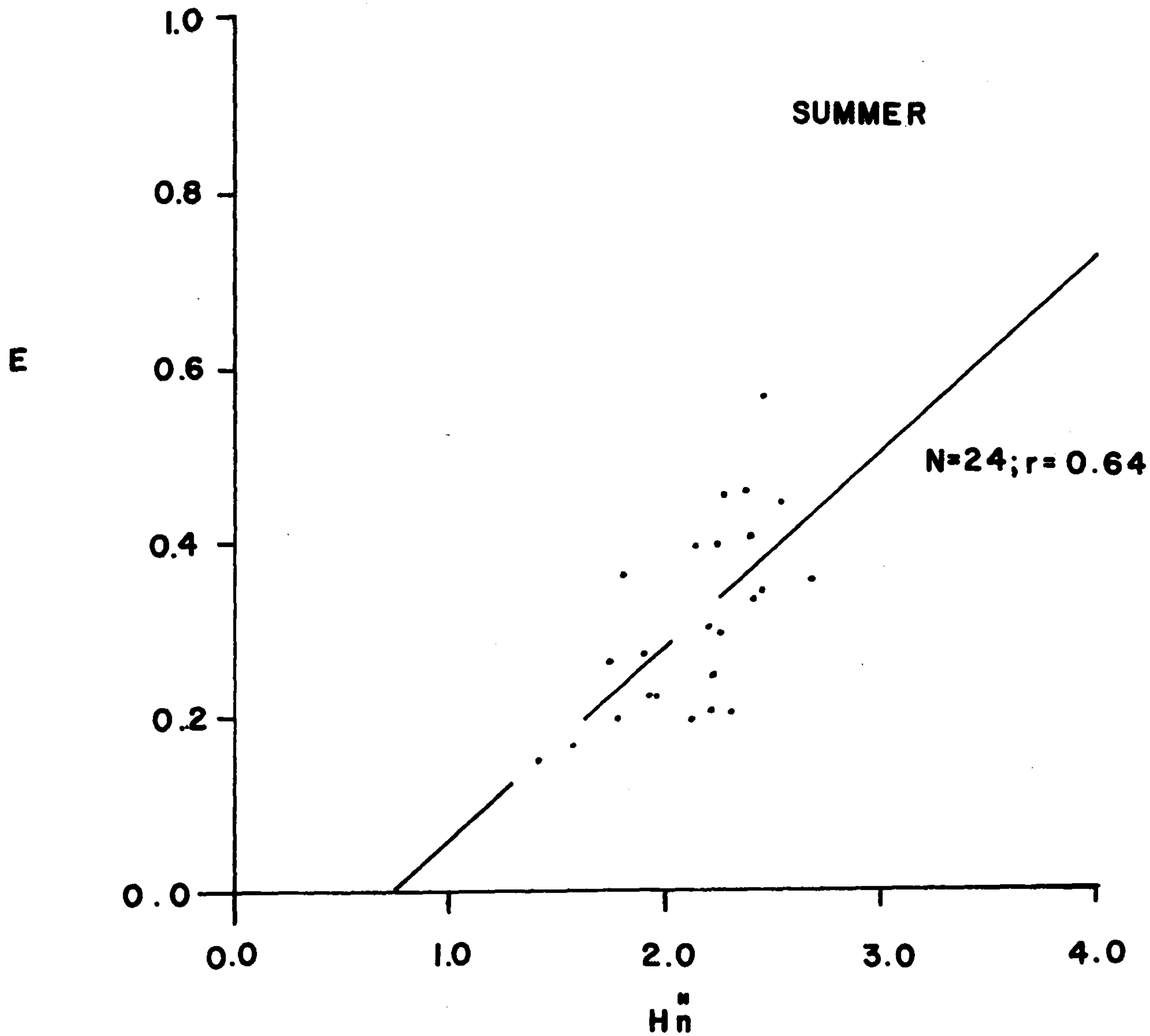

Figure 21. Relationship between equitability, E, and Shannon diversity

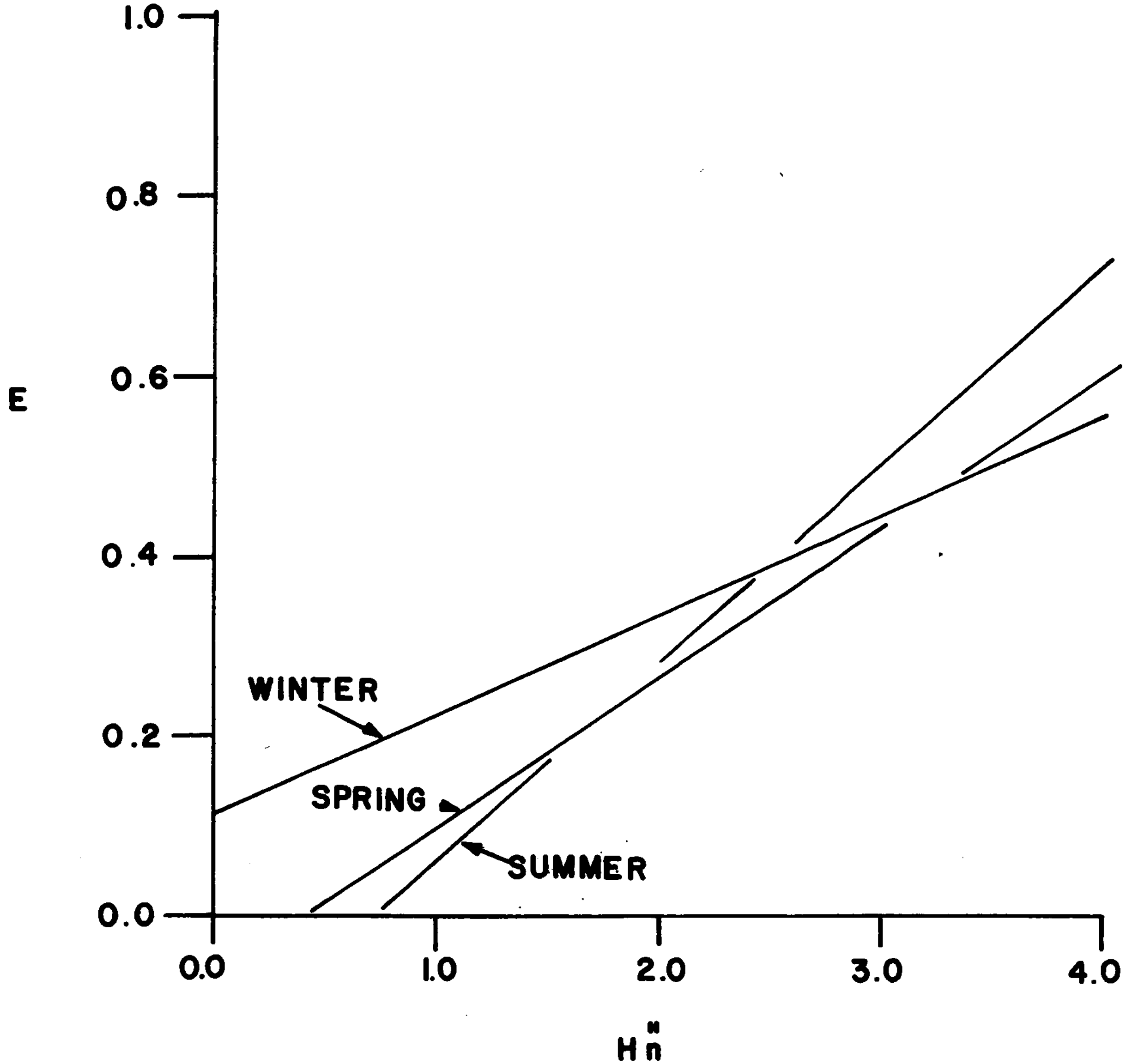

Figure 22. Relationships among equitability-diversity index regressions for 24 samples each season.

Of particular interest is a comparison of the values of Hurlbert's (1971) PIE, the probability of interspecific encounter, that was developed to avoid some of the theoretical inadequacies of the Shannon diversity index, H".

For each of the seasons, the 24 day and night PIE values plotted against H_n" yield the regressions in Figures 23, 24 and 25. In the winter regression (Figure 23) the two topmost left values are again from the Transect II, Stations 1 day and 2 night, but the correlation is high at $r = 0.90$. In the spring, the Figure 24 data show that there is again a high correlation, especially if the value (indicated by arrow) for Transect IV, Station 2, night is deleted. The distribution of fishes from this spring collection comprised 32 species among 114 individuals, but 4 of the species were much more abundant than the remaining 28. The spring data, with this value removed, yield a change in correlation from $r = 0.76$ to $r = 0.95$. The summer PIE-H_n" relationship is quite good with $r = 0.93$.

In the summary comparison of the three seasonal regressions of Figure 26, it should be noted that the spring regression would be very near that for summer but for the one aberrant value indicated by the arrow in Figure 24.

The close agreement of the PIE and H_n" value is based partially on the spuriousness of the regressions inasmuch as the same data, numbers of species and numbers of individuals, are used for calculating both values. Because the correspondence between PIE and H_n" are so close and because the PIE is supposedly better theoretically, PIE would probably be a superior measure as suggested by Hurlbert (1971).

In an overall evaluation of the internal consistencies of the various informational indices, several conclusions may be made:

1. Regression comparisons of Shannon's index H_w'' based on biomass with the same index H_n'' based on numerical data provide a good system for identifying aberrant collections that are displaced from the calculated regression.

2. Regression comparisons of the equitability, E, with the Shannon index H_n'' also provide a system for identifying aberrant values.

3. The PIE index compared by regression to H_n'' indicates a close correspondence for the seasonal collections with few "outliers" from the regression lines. This is interpreted to mean that PIE values may be theoretically sounder than are the Shannon index values.

The regression relationships of H_w'', E, or PIE to H_n'' do not show any striking seasonal differences.

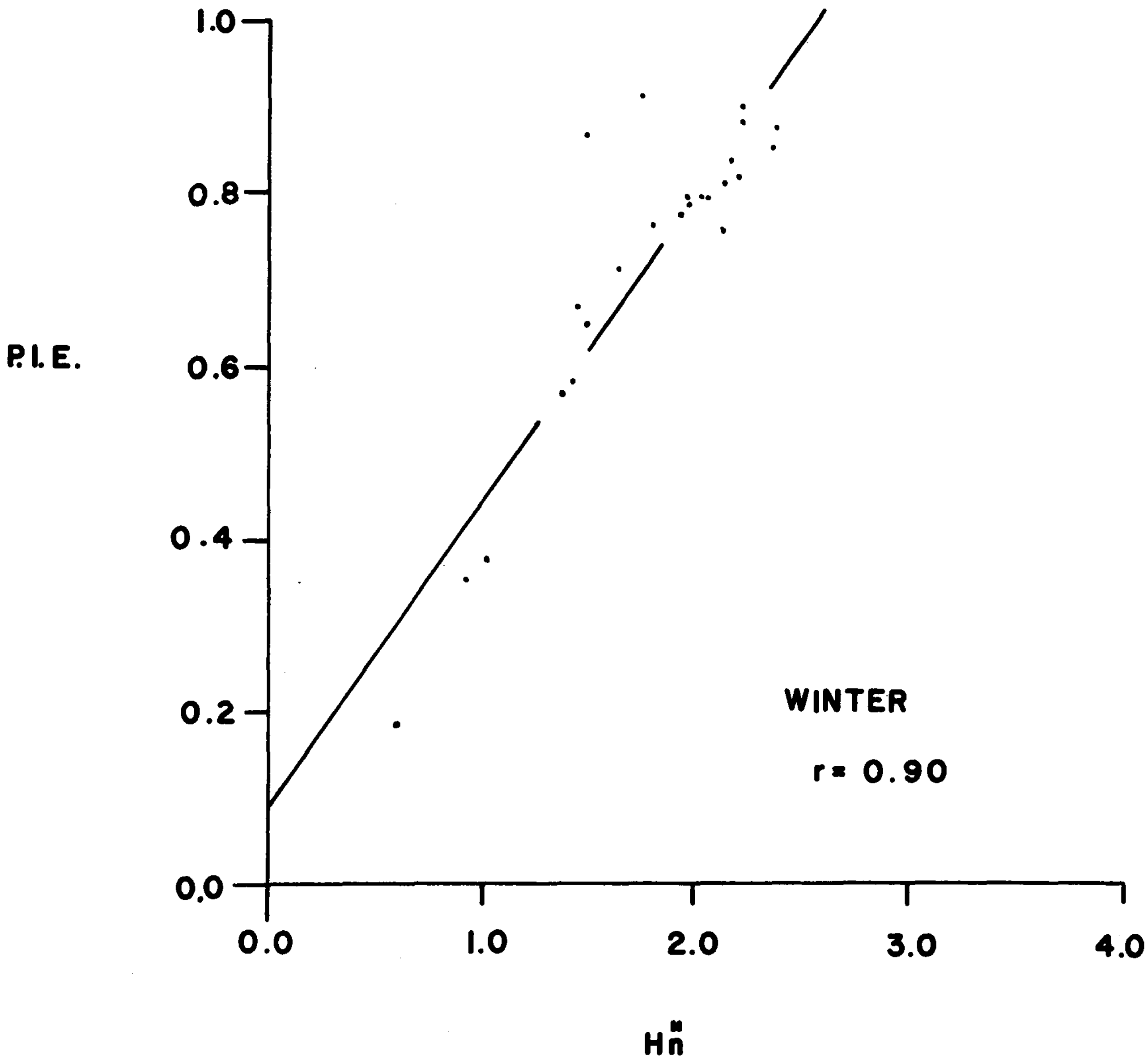

Figure 23. Relationship between the probability of interspecific encounter

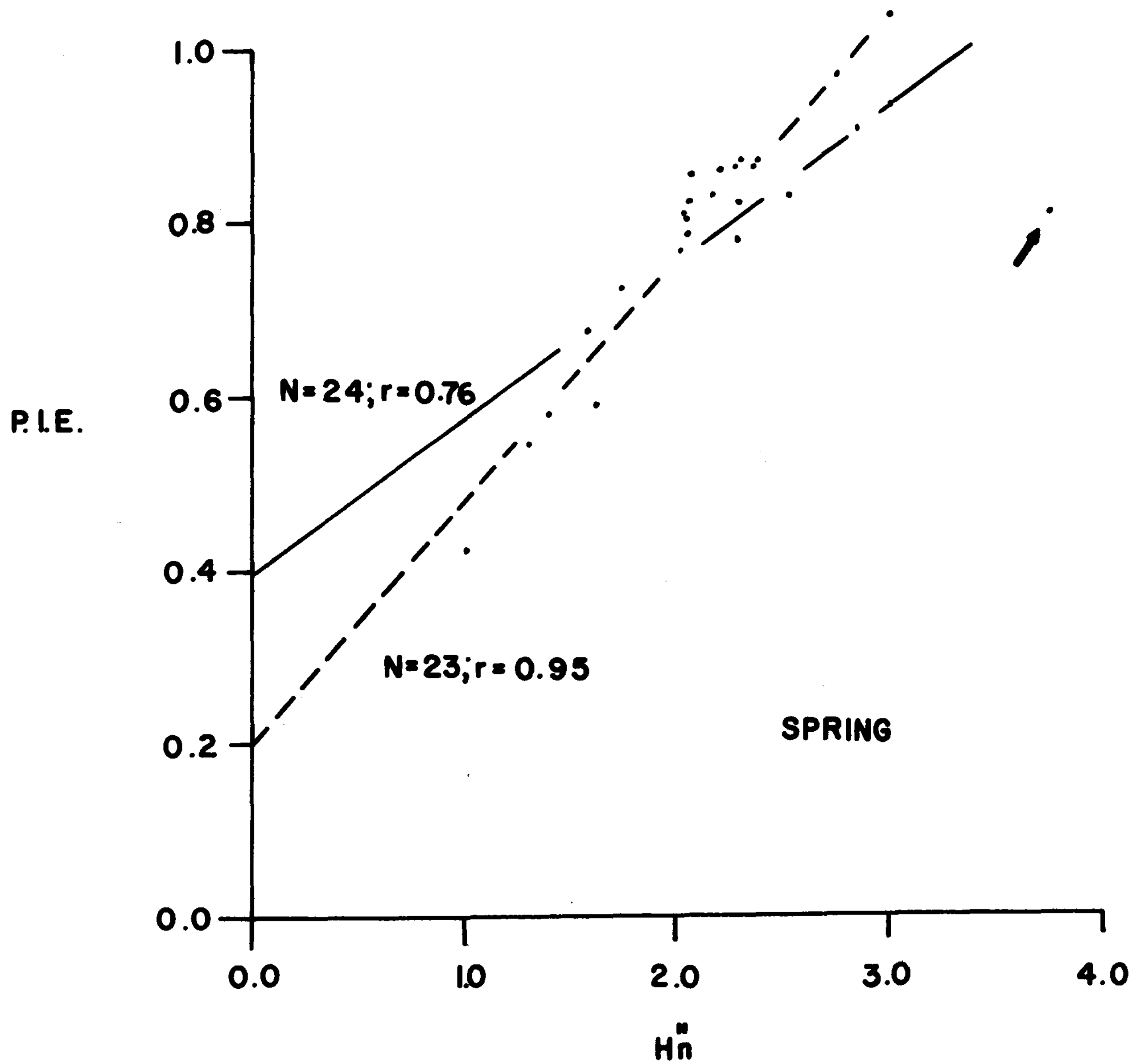

Figure 24. Relationship between PIE and H_n'' for spring collections. Dashed line indicates relationship with deletion of outlying value indicated by arrow.

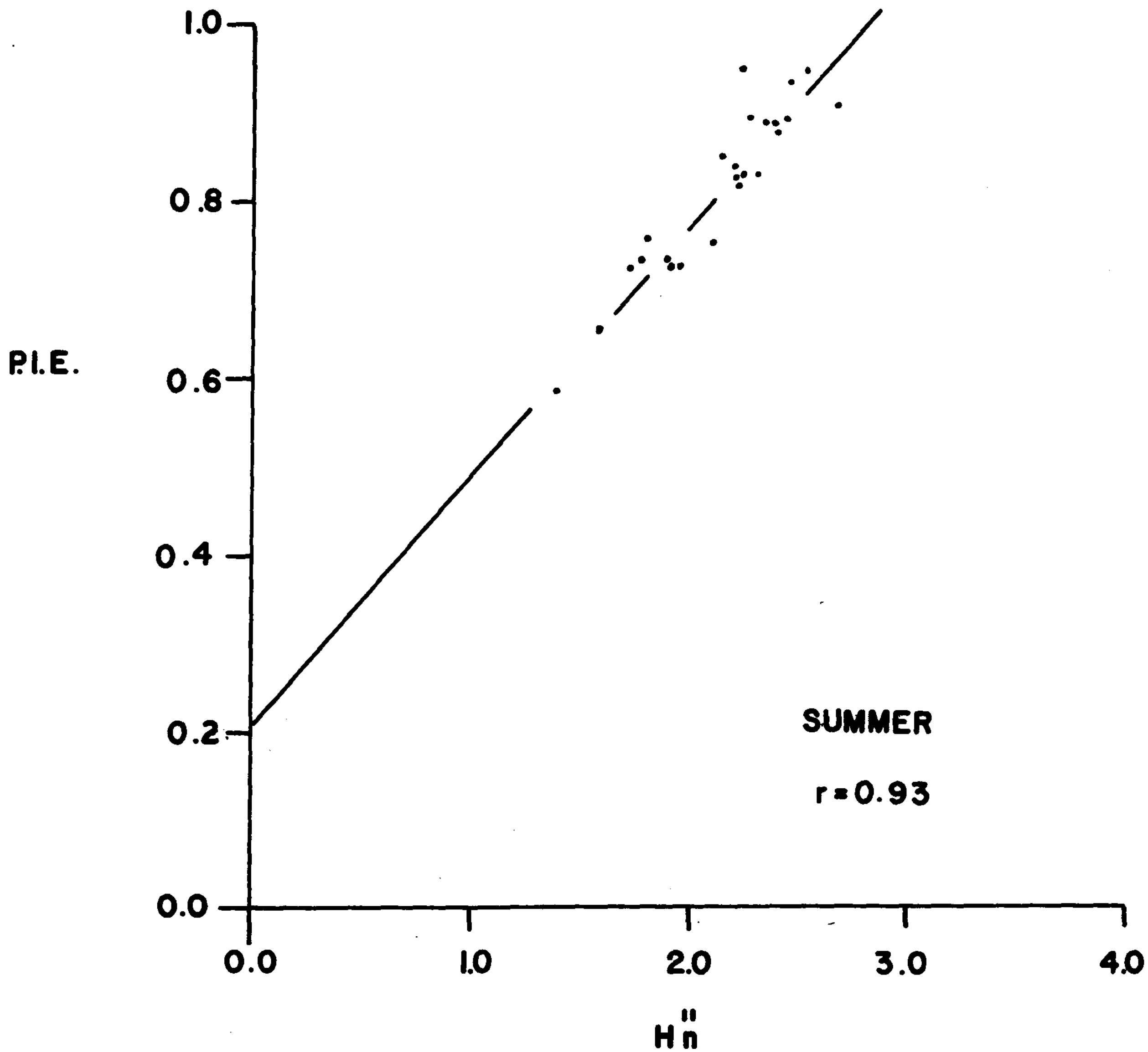

Figure 25. Relationship between PIE and H_n" for summer collections.

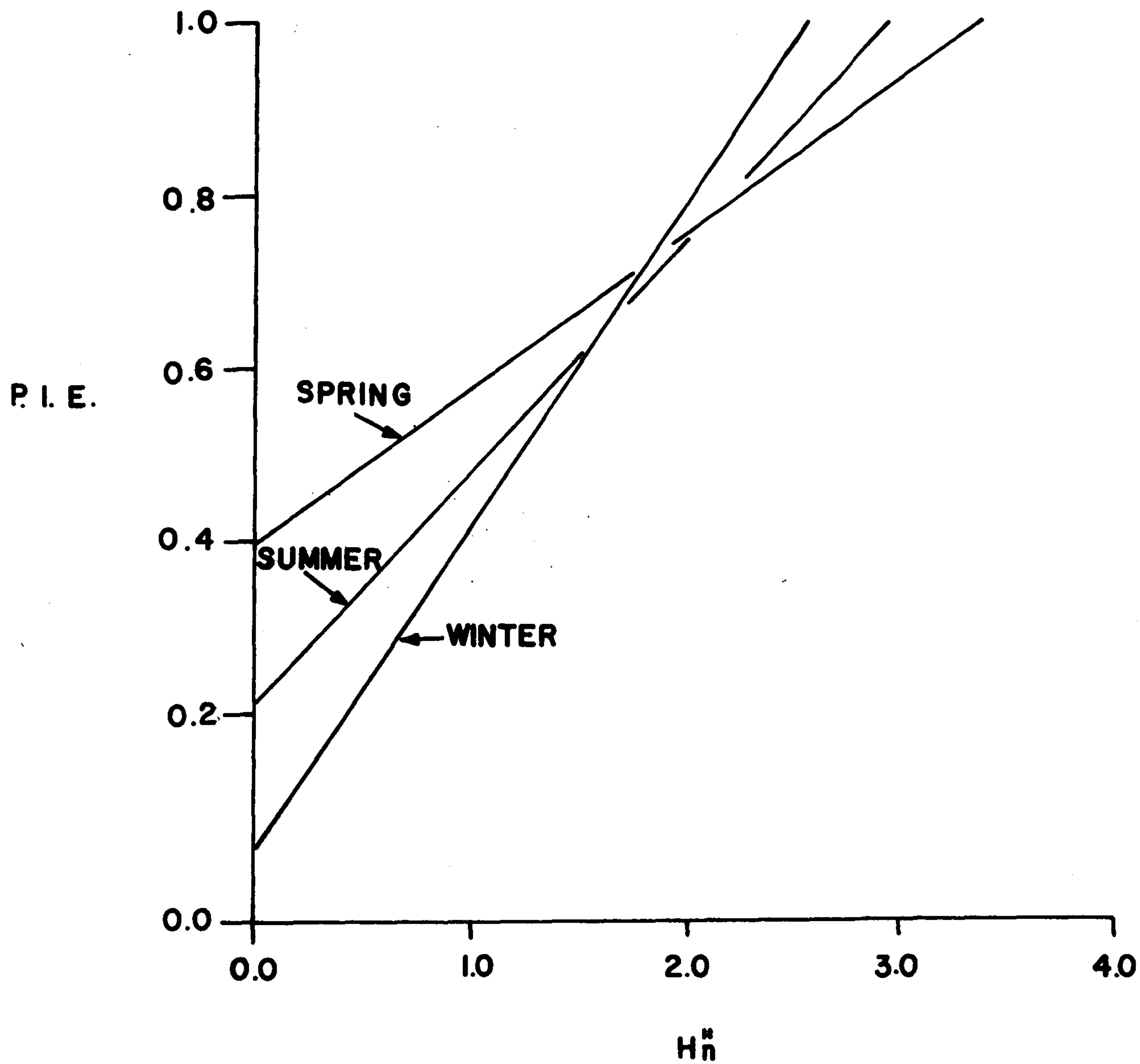

Figure 26. Relationships of seasonal PIE-H_n'' regressions for 24 samples each season.

Comparisons of Epifaunal Fish and Invertebrate Data

In terms of abundance and distribution of the seasonal fish collections compared to the corresponding invertebrate collections (Table 1, pp. 328-331 in the preceding section by Dr. J. S. Holland), one important question is: Does the diversity of benthic fishes have any direct relationship to the diversity of the epifaunal invertebrates?

To examine this question, the Shannon (H'') numerical diversity indices of the two groups of organisms were compared by simple correlation analysis on the assumption that the H'' are normally distributed. For the winter the correlation is $r = 0.23$ ($n = 23$); for spring $r = 0.40$ ($n = 24$); and for summer $r = -0.02$ ($n = 24$). Except possibly for the spring $r = 0.40$ ($P \sim 0.05$), the comparisons are of little interest. Nor is there any particular ecological basis for diversity of one group of organisms to be directly related to another unless there can be established functional intergroup processess.

Numerically there also is little correspondence between fish numbers and numbers of epibenthic invertebrates in comparable collections. This lack of, or poor, correlation functionally can be supposed to be related to the usual great size (biomass) differences between individual species of invertebrates and fishes and to the expected great differences in population turnover rates, which depend on functional differences in rates of birth, growth, death, etc.

However, there are often some interesting interrelationships between standing crop biomasses of invertebrates and those of fishes, many of which forage directly on the invertebrate trophic levels. In the case of the STOCS study are the invertebrate data given in the USGS geological report by Berryhill (1975) and contributors, whose interest and aid in the following interpretations are gratefully acknowledged. Mr. Gary W. Hill's help with the invertebrate data was especially useful.

From the USGS report the various invertebrate collections were matched location by location with the fish collections. Invertebrate collections taken by Smith-McIntyre grab in October - December while the nearest comparable fish collections were taken by trawl in December - January. In Figure 27 the dots indicate the weight comparisons of day plus night fish collections with the invertebrate weights at the same stations. The squares indicate the weights of fishes from either the day or night collection that corresponds to the time of day when the invertebrate grab samples were taken. In Figure 27 the solid line is arbitrary and is used to show the relation, station by station, of the total day plus night fish biomasses to the corresponding invertebrate biomasses; the dashed line indicates the same arbitrary relationship to the biomasses on a day or night basis, depending on the time the invertebrate samples were taken.

The two top points at the left and the top point at the right are all from the deepest (Station 3) stations of Transects I, II and III, but not IV. This distribution might indicate an irregular relationship between benthic invertebrates and fishes in the northern deep stations.

The upper right high points (both dot and square) representing Transect III, Station 3, if omitted would leave the remainder of the points to describe a convex downward (logarithmic) curve. Such a curve would indicate that the smaller the fish biomass, the greater the invertebrate biomass to imply that fish may well crop the invertebrate populations. The high points from III-3, however, change the shape of the curve to indicate a minimal fish - maximum invertebrate of about 4-kg fish to 0.3 or 0.4

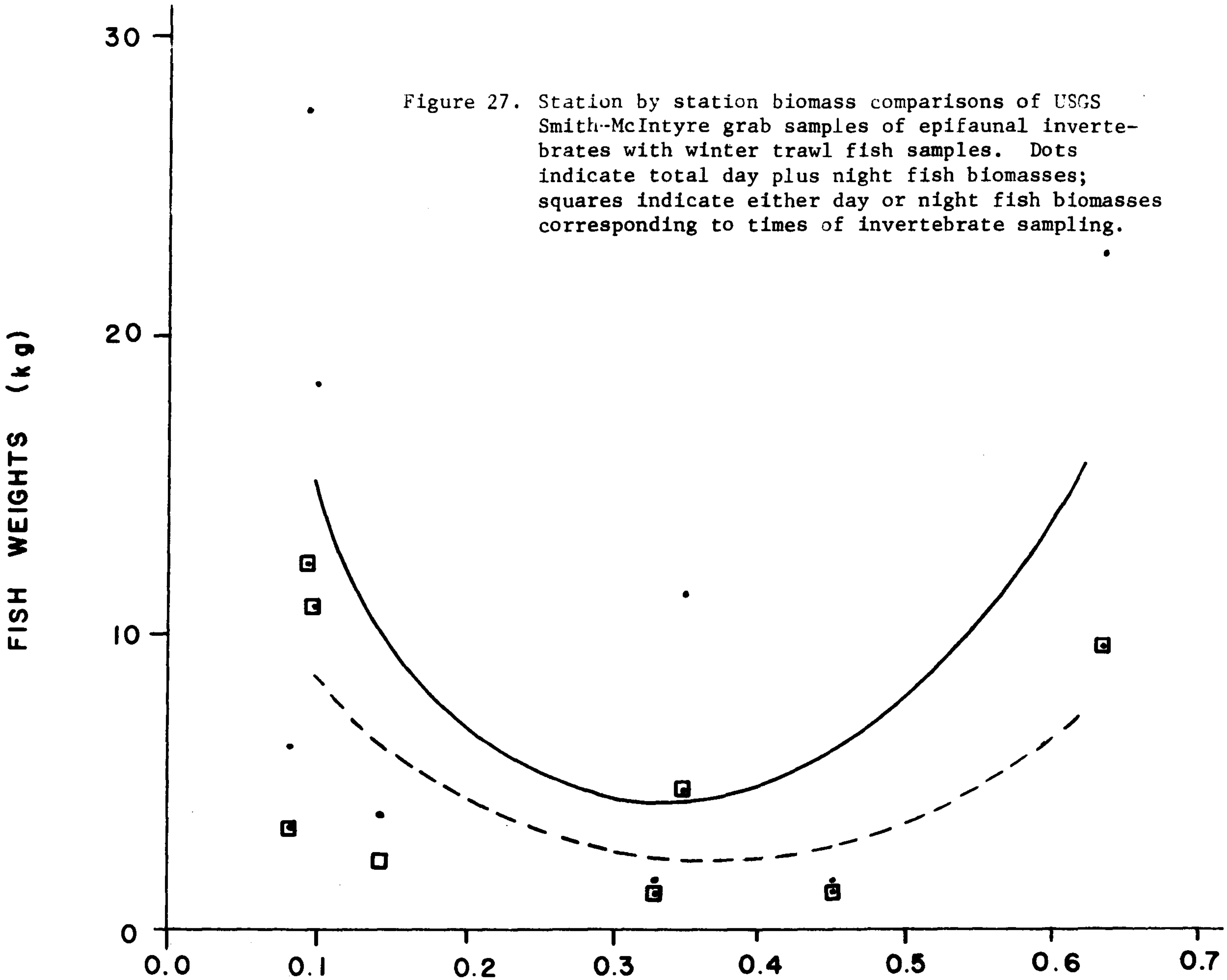

Figure 27. Station by station biomass comparisons of USGS Smith-McIntyre grab samples of epifaunal invertebrates with winter trawl fish samples. Dots indicate total day plus night fish biomasses; squares indicate either day or night fish biomasses corresponding to times of invertebrate sampling.

invertebrates. Without knowing what the quantitative functional relationships between benthic invertebrates and fishes are, it is not possible to make a rational choice between the types of curves.

Perhaps the most interesting feature of Figure 27 is the appearance of a better concordance of fish-invertebrate biomasses when the collections are matched on a day-day or night-night basis (dashed line). Why this is so is not clear unless direct relationships between forage and forager exist on a diel basis. In this case, it would be necessary to consider day and night sampling as was accomplished in the benthic faunal studies.

➔ *In general it may be concluded that numerical relationships between benthic fishes and invertebrates are not direct, but the correspondence on a biomass basis seems much better.*

➔ *There is also an indication that fish-invertebrate biomass comparisons may depend directly on the time during a 24 hour day when samples are taken.*

Comparisons of Epifaunal Fishes with Chemical and Geological Factors

Several attempts were made to relate fish abundance and distribution to various toxic metals, light and heavy hydrocarbon constituents, physical variables of temperature and salinity, and illite and montmorillonite clay fractions. These attempts gave little indications of any direct relationships. Thus it might be concluded that fish abundance and distribution depends on any of the above variables in a very indirect and complex fashion. Such complexities can be unravelled only by elucidating the various processes by which these variables are indirectly related to the fishes.

Since it is known that the type of bottom is associated both with the fish and invertebrate faunas and with the effectiveness of various sampling gear, it is instructive to evaluate sediment characteristics that may affect the abundance and distribution of fishes. From Berryhill (1975) it was noticed that some correspondence exists between sand/clay or silt/clay ratios and the invertebrates.

For the winter fish collections, the relationship between 12 day and 12 night samples to the corresponding silt/clay ratios at these same stations, there is a modest correlation of r = 0.35 in Figure 28 .

It is interesting to observe that the maximum fish biomasses tend to decline rather sharply as the silt/clay ratio increases, although the reasons are not particularly obvious.

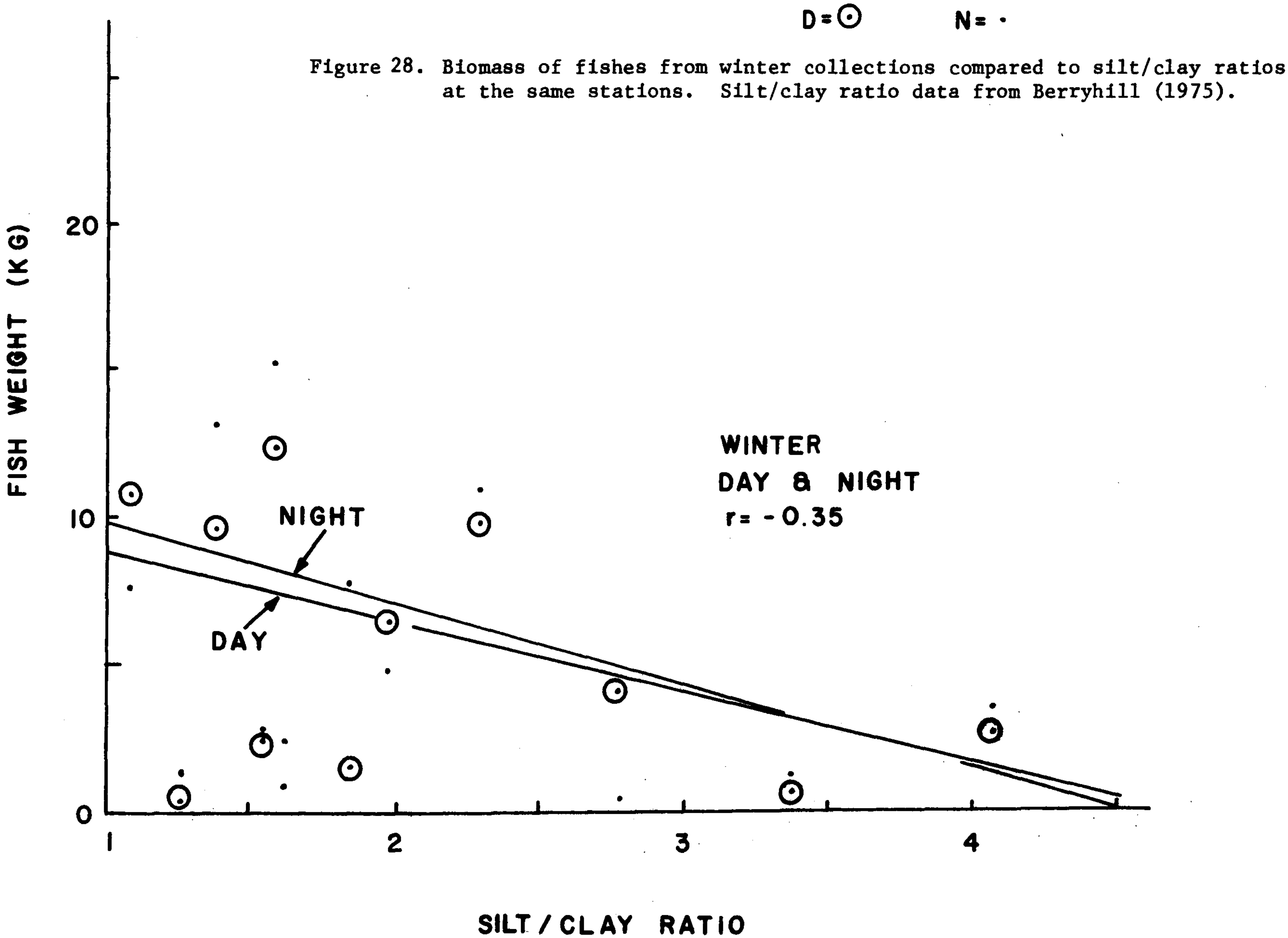

Figure 28. Biomass of fishes from winter collections compared to silt/clay ratios at the same stations. Silt/clay ratio data from Berryhill (1975).

PRODUCTIVITY AND LOW-MOLECULAR-WEIGHT HYDROCARBONS PROJECT

Texas A&M University, College Station

Principal Investigator:
William M. Sackett

Associate Investigator:
James M. Brooks

INTRODUCTION

This report contains a comprehensive tabulation of all the analyses of samples for the BLM-South Texas OCS area during 1975. This includes analyses of (1) methane, (2) ethene, (3) ethane, (4) propene, (5) propane, (6) dissolved oxygen, (7) nitrate, (8) phosphate, (9) silicate, (10) temperature and (11) salinity for three depths at each of the twelve stations during each of the seasonal sampling periods. In addition, this report contains hydrographic and hydrocarbon data obtained in the South Texas OCS region during 1975 that were not taken as part of the South Texas OCS contract. This includes: (1) more sampling depths on the twelve stations during the August-September sampling period; (2) 5 stations with methane, nutrient and hydrographic data; and (3) hydrocarbon "sniffer" data across part of the South Texas OCS area during a cruise in early October.

METHODS

Low-Molecular-Weight Hydrocarbons

Low-Molecular-Weight (LMW) hydrocarbons are analyzed by two methods. Methane is analyzed by McAullife's (1971) method and C_2's and C_3's are analyzed by a modification of the Swinnerton and Linnenbom (1967) method.

Samples for quantitative analysis by the Swinnerton and Linnenbom (1967) method are collected by standard Niskin and Nansen hydrographic casts. After retrieval, the sea water samples are transferred by gravity flow into 1-liter ground glass stoppered bottles. The bottles are stoppered in such a way as to avoid entrapment of gas bubbles. The sample is poisoned with sodium azide to prevent bacterial alteration.

Samples for McAullife's (1971) method are collected in 125-ml narrow mouth bottles with screw-top caps. The bottles are stored upside-down until analysis.

Open ocean levels of C_2 and C_3 hydrocarbons are determined quantitatively by the method of Swinnerton and Linnenbom (1967). This method involves purging one-liter of sea water with a hydrocarbon-free helium stream and collecting the light hydrocarbons in a cold trap. After collection, the trap is heated to inject the absorbed hydrocarbons into the chromatographic stream. The precision of the determination at the lower level of sensitivity (0.05 nl/L) is $\pm$10 percent (standard deviation of replicate determinations). The precision of the determination of methane at 50 nl/L is $\pm$2 percent with sensitivity and precision increasing rapidly with increasing hydrocarbon concentrations.

McAullife's (1971) method of multiple phase equilibrium involves equilibrating 25 ml of purified helium with 25 ml of sample water in a 50 ml syringe with a Luer-Lok stopcock. Since 96+% of the light aliphatic hydrocarbons partition into the gas phase, analysis is performed by injecting 1.76 ml of the equilibrated helium into the chromatographic stream by means of a sample injection valve. For open ocean concentrations of light hydrocarbons this method is only sensitive enough for methane.

Temperature

Temperatures were determined using deep-sea reversing thermometers attached to Nansen bottles. The thermometers are calibrated yearly to $\pm$0.005 degrees Centigrade. Two reversing thermometers are attached to each Nansen bottle, and each thermometer is read in duplicate by two observers. The thermometers readings from each depth are averaged and reported to an accuracy and precision of ±0.01 degrees Centigrade.

Salinity

Samples for salinity measurements were collected after LMW hydrocarbons and oxygen samples. The samples were stored in approximately 500 ml citrate bottles. The samples were determined twice on a PLESSEY 6210 inductive salinometer and averages reported. The accuracy is ±0.001°/₀₀ (ppt).

Dissolved Oxygen

Samples were anlayzed using the Winkler method, as outlined by Strickland and Parsons (1972), "A Practical Handbook of Seawater Analyses". All samples were determined in duplicate and averages reported. The precision of the analysis is somewhat dependent on the technician doing the analysis, but accuracy and precision was generally better than ±0.01 ml/L.

Nutrients

Phosphate, nitrate and silicate samples were taken in separate 6 oz. Whirl-Pak plastic bags and frozen. Samples were analyzed using a single-channel TECHNICON AUTOANALYZER, following the methods of Strickland and Parsons (1972), "A Practical Handbook of Seawater Analysis", and as modified by Atlas et al. (1971), "A Practical Manual for Use of the Technicon Autoanalyzer on Seawater Nutrient Analysis, revised".

RESULTS AND DISCUSSION

The near surface values for the three sampling seasons (winter, spring, and summer) on methane, ethane plus ethene, propane, propene, temperature, salinity, silicate, phosphate, nitrate and dissolved oxygen are shown in Figures 1 through 10, respectively. The vertical distribution of these parameters with depth (except C_2's and C_3's) are shown in Figures 11 through 17. Each figure gives the results of one parameter for each depth at each station in each transect and for each of the three seasonal cruises. Tables 1 and 2 contain a tabulation of all the data. A brief discussion will follow on the spatial and temporal distribution of each parameter and the significance of these distributions in regard to other data.

Hydrocarbons

Methane

According to Henry's Law the equilibrium concentration of a dissolved gas in surface sea water is the product of its solubility coefficient and its partial pressure in the atmosphere. For the low-molecular-weight hydrocarbons, only the partial pressure of methane, 1.4 ppmv for the atmosphere over the entire earth, is known with any degree of certainty. Using this value and reported solubility coefficients, the equilibrium concentrations of methane, in nannoliters per liter (nl/L) as a function of salinity and temperature are as follows:

Temperature	Salinity (°/₀₀)			
°C	30	32	34	36
0	64.7	63.8	62.8	61.9
10	49.8	49.1	48.5	47.8
20	40.2	39.8	39.3	38.8
30	34.0	33.6	33.2	32.8

Comparing the measured methane, salinity and temperatures in the South Texas OCS region with values calculated in the table given above, indicates a 10 to 200% supersaturation of methane in surface water for all profiles. As significant amounts of methane are not known to be biologically produced in the water column, this supersaturation apparently

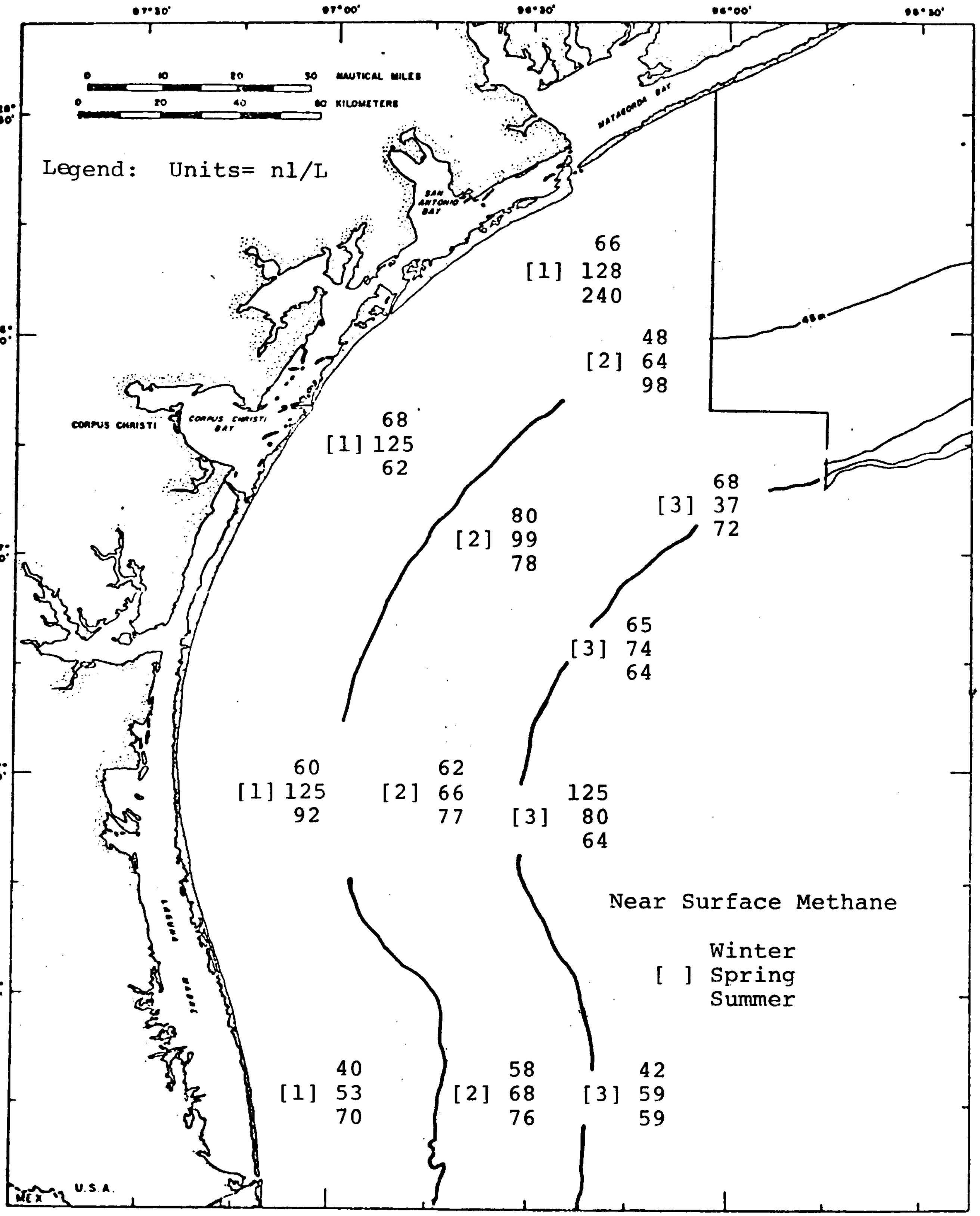

Figure 1. Near Surface Methane Concentrations, 1975.

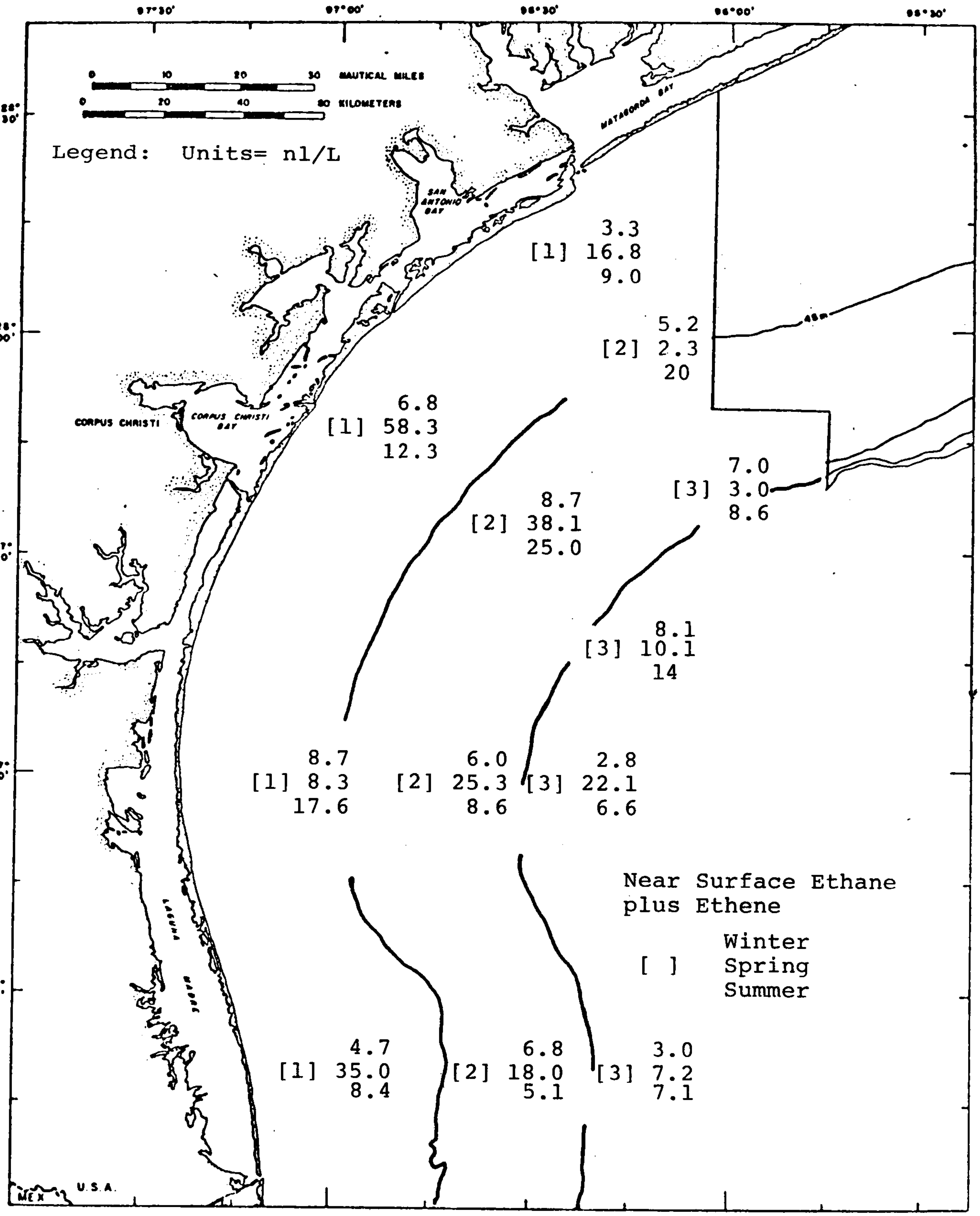

Figure 2. Near Surface Ethane plus Ethene Concentrations, 1975.

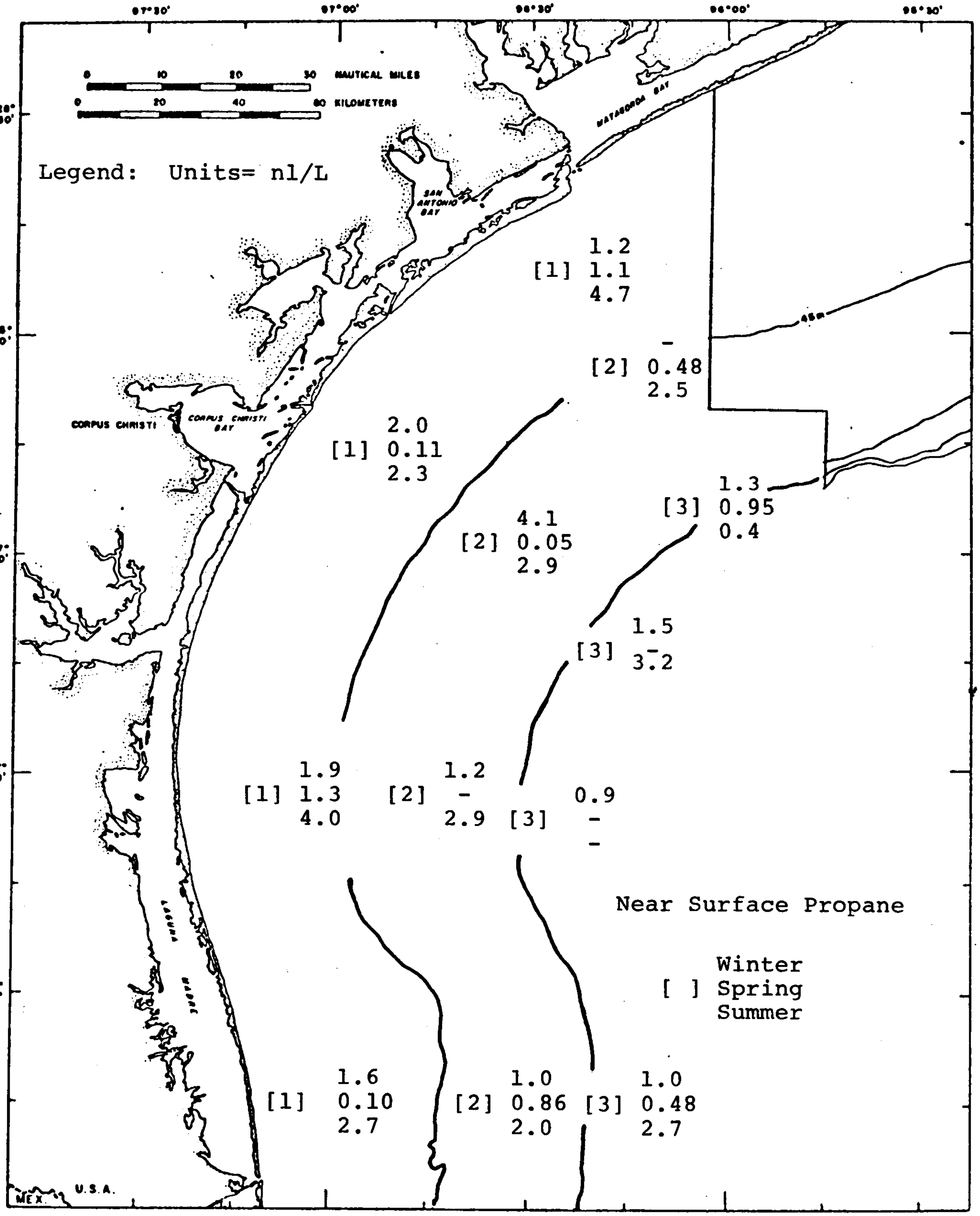

Figure 3. Near Surface Propane Concentrations, 1975.

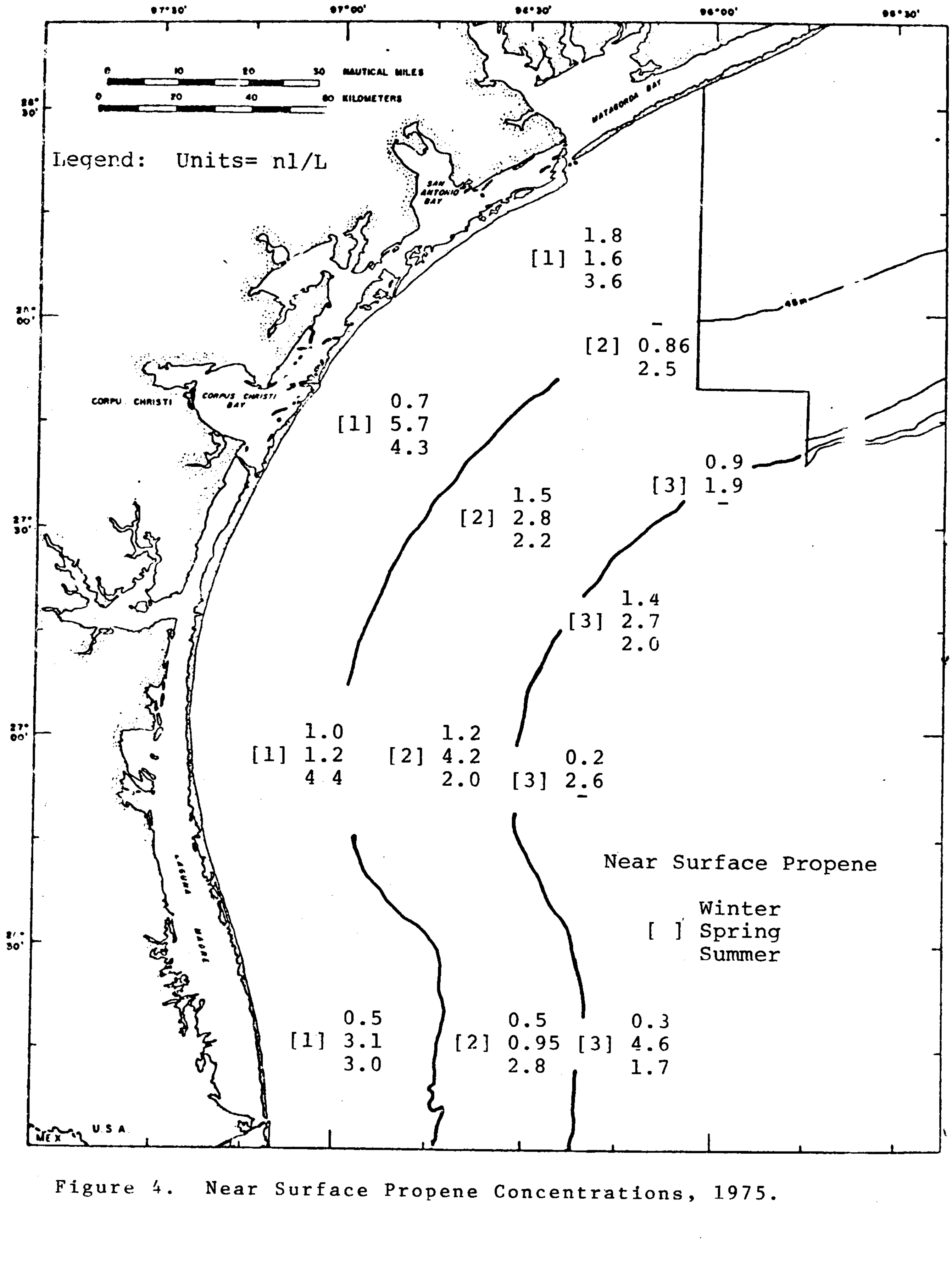

Figure 4. Near Surface Propene Concentrations, 1975.

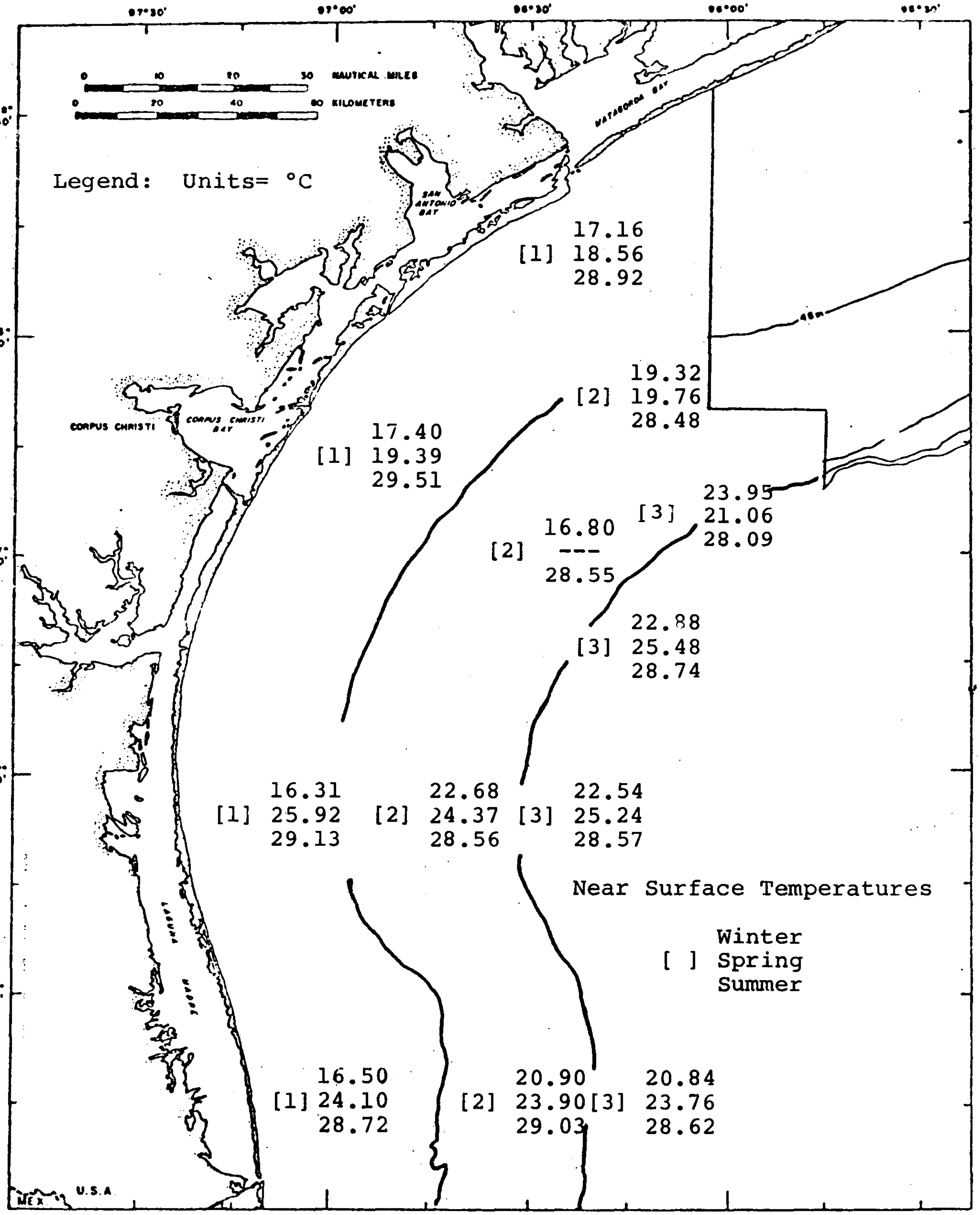

Figure 5. Near Surface Temperature Concentrations, 1975.

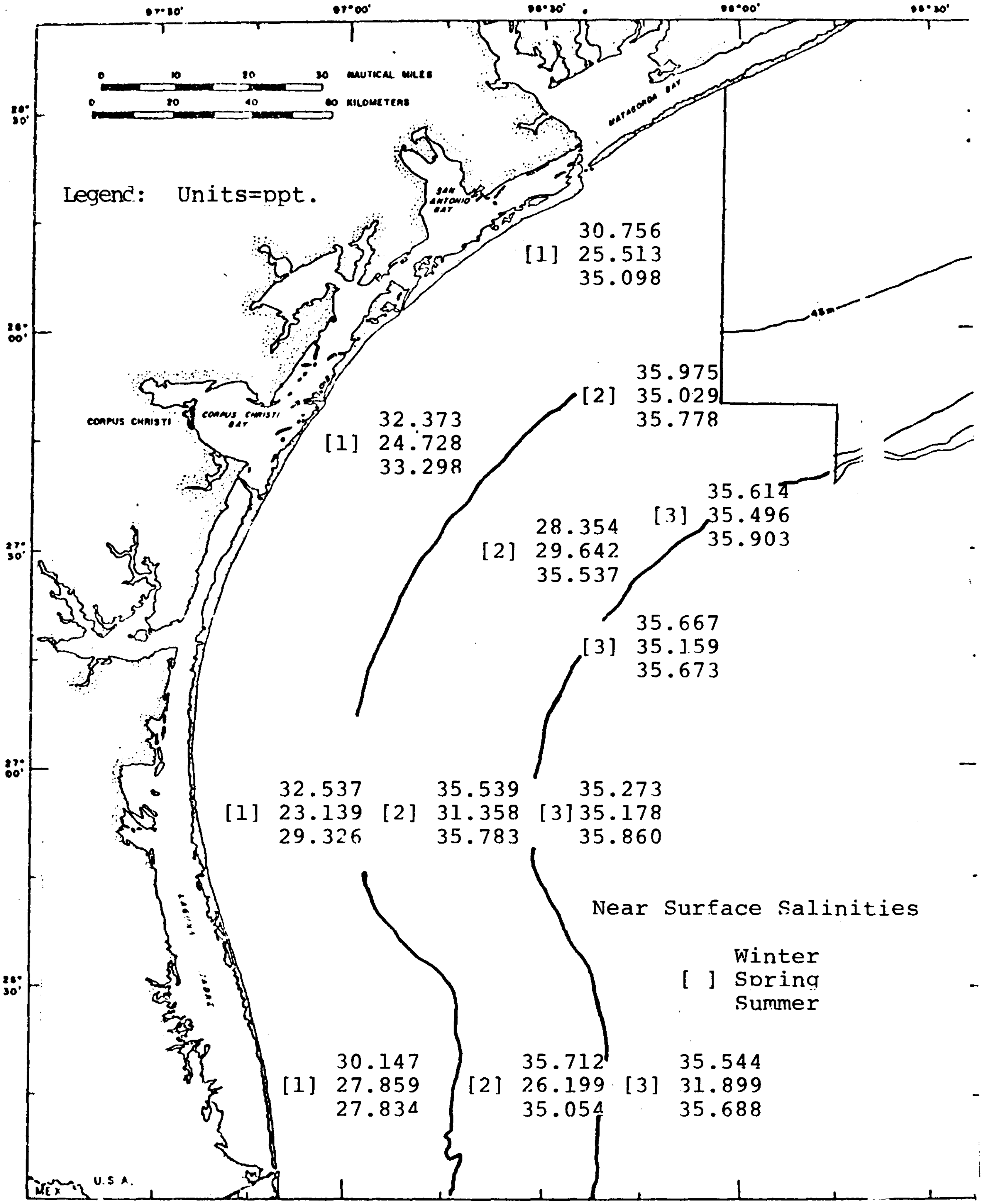

Figure 6. Near Surface Salt Concentrations, 1975.

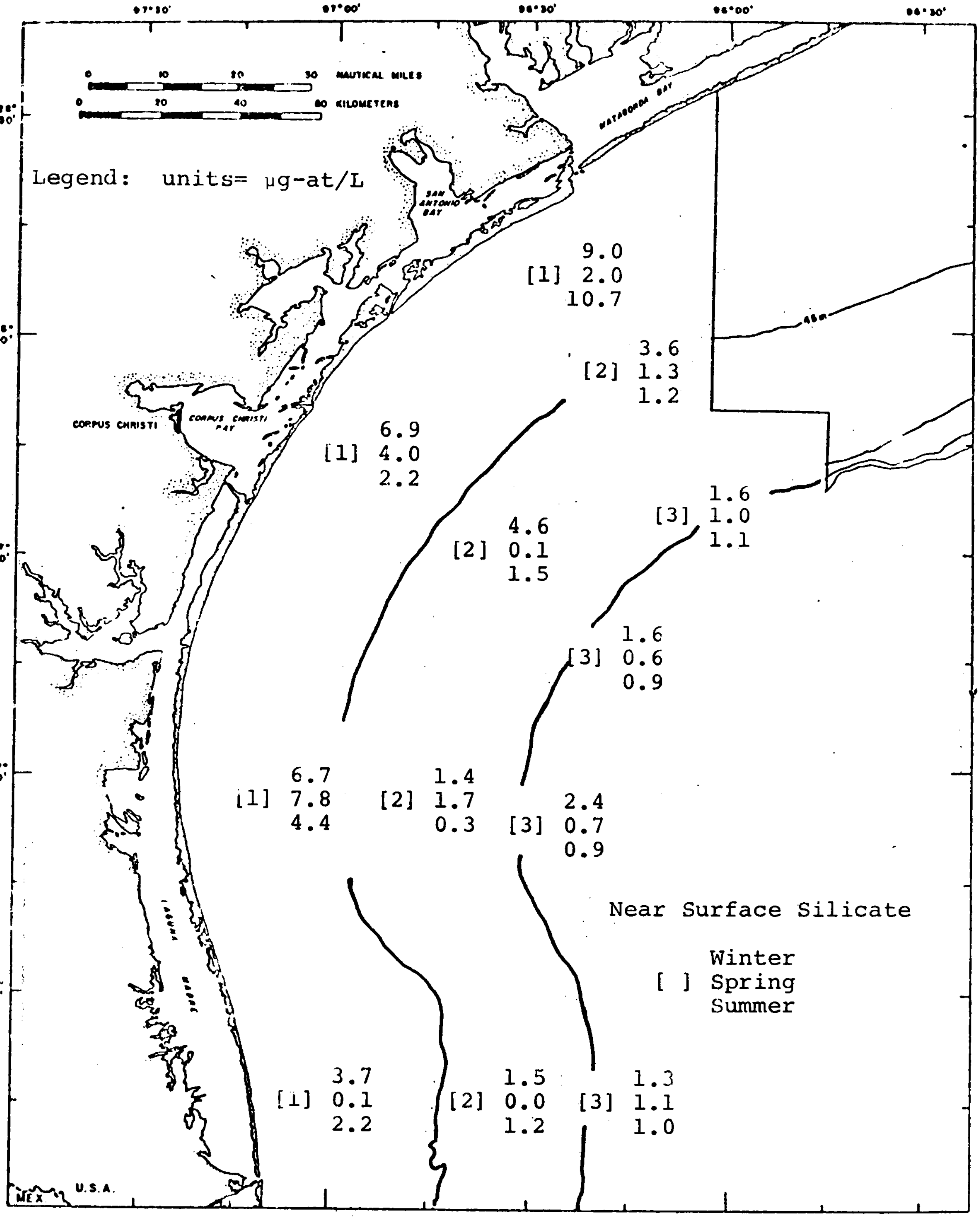

Figure 7 Near Surface Silicate Concentrations, 1975.

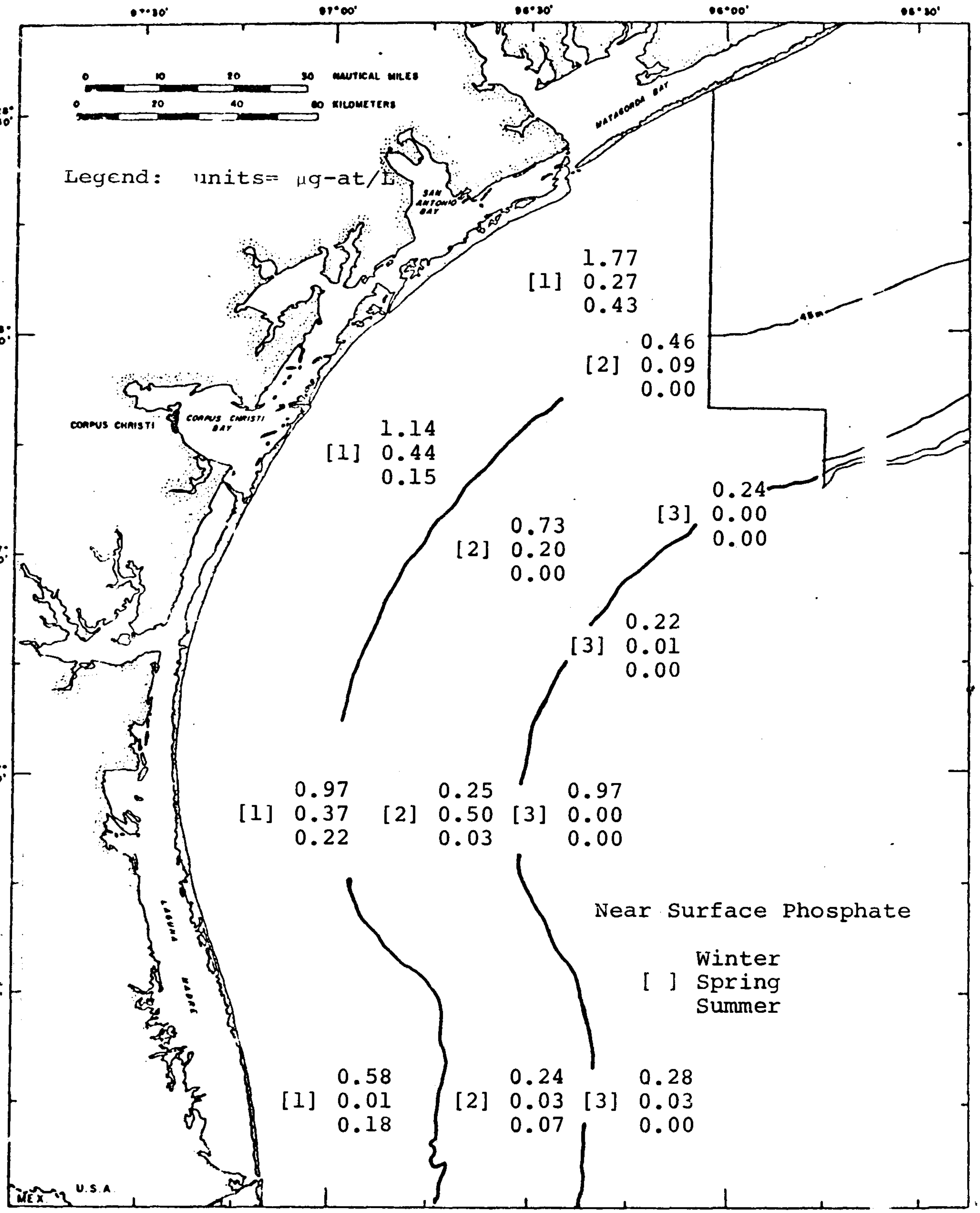

Figure 8. Near Surface Phosphate Concentrations, 1975.

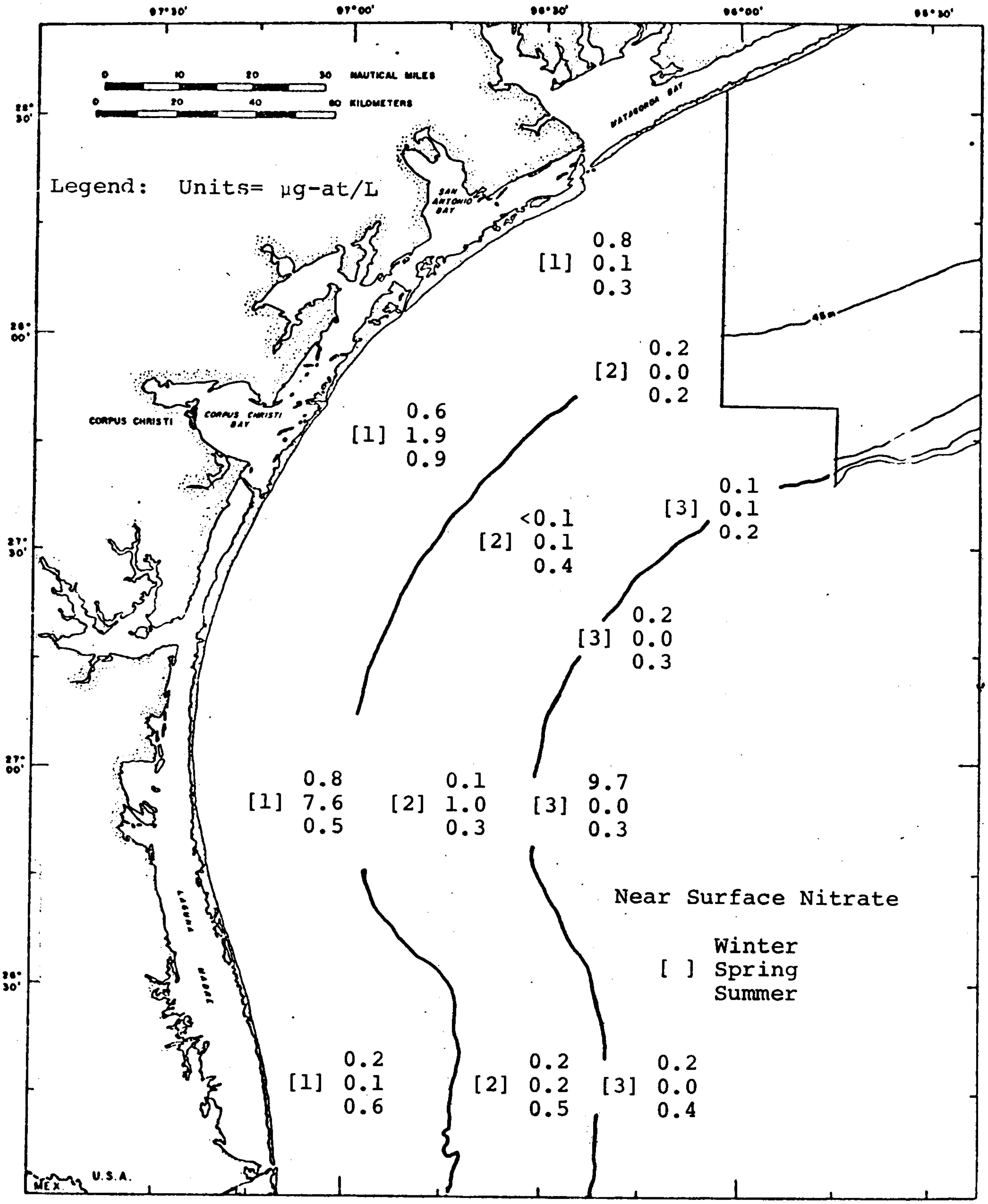

Figure 9. Near Surface Nitrate Concentrations, 1975.

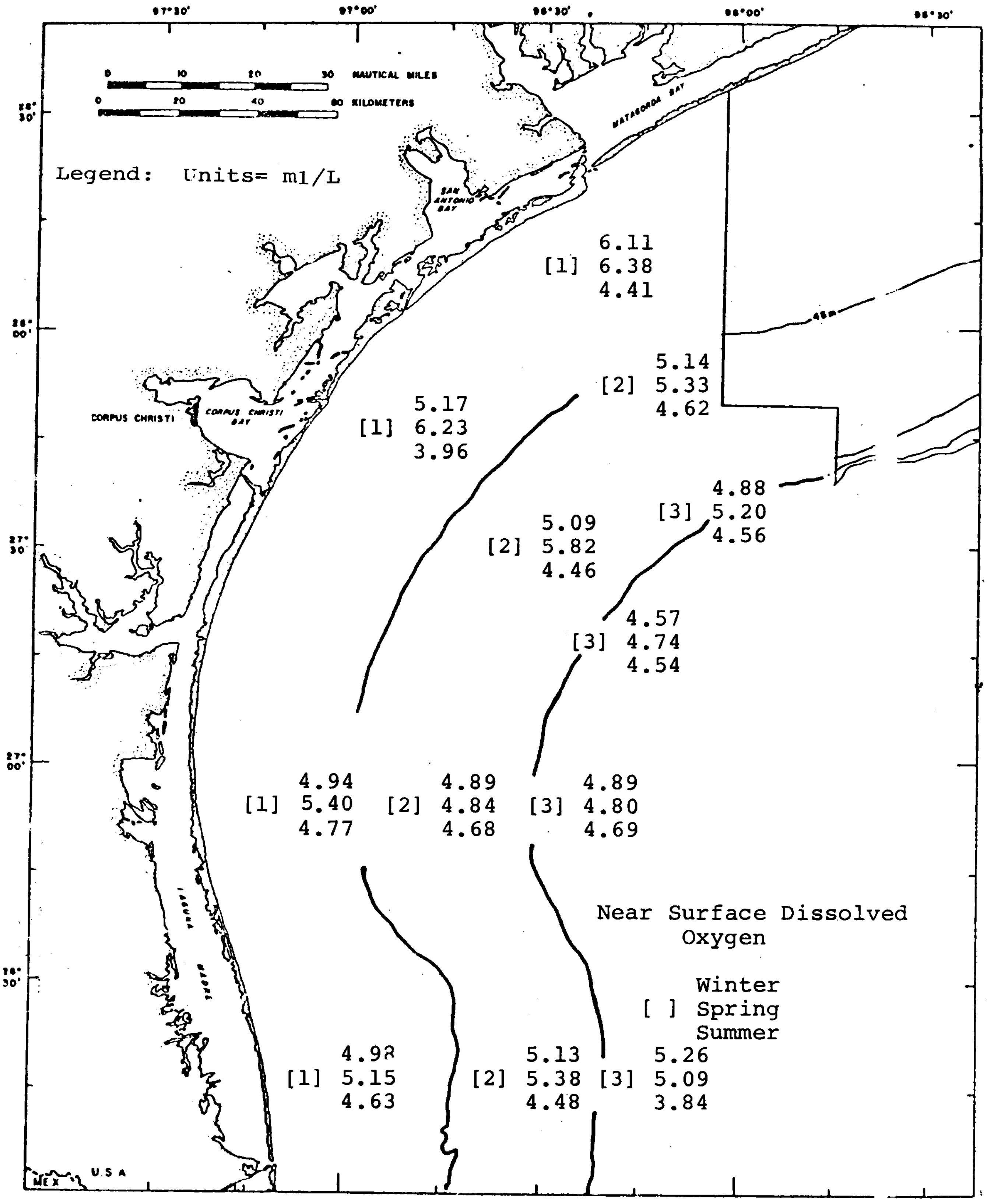

Figure 10. Near Surface Dissolved Oxygen Concentrations, 1975.

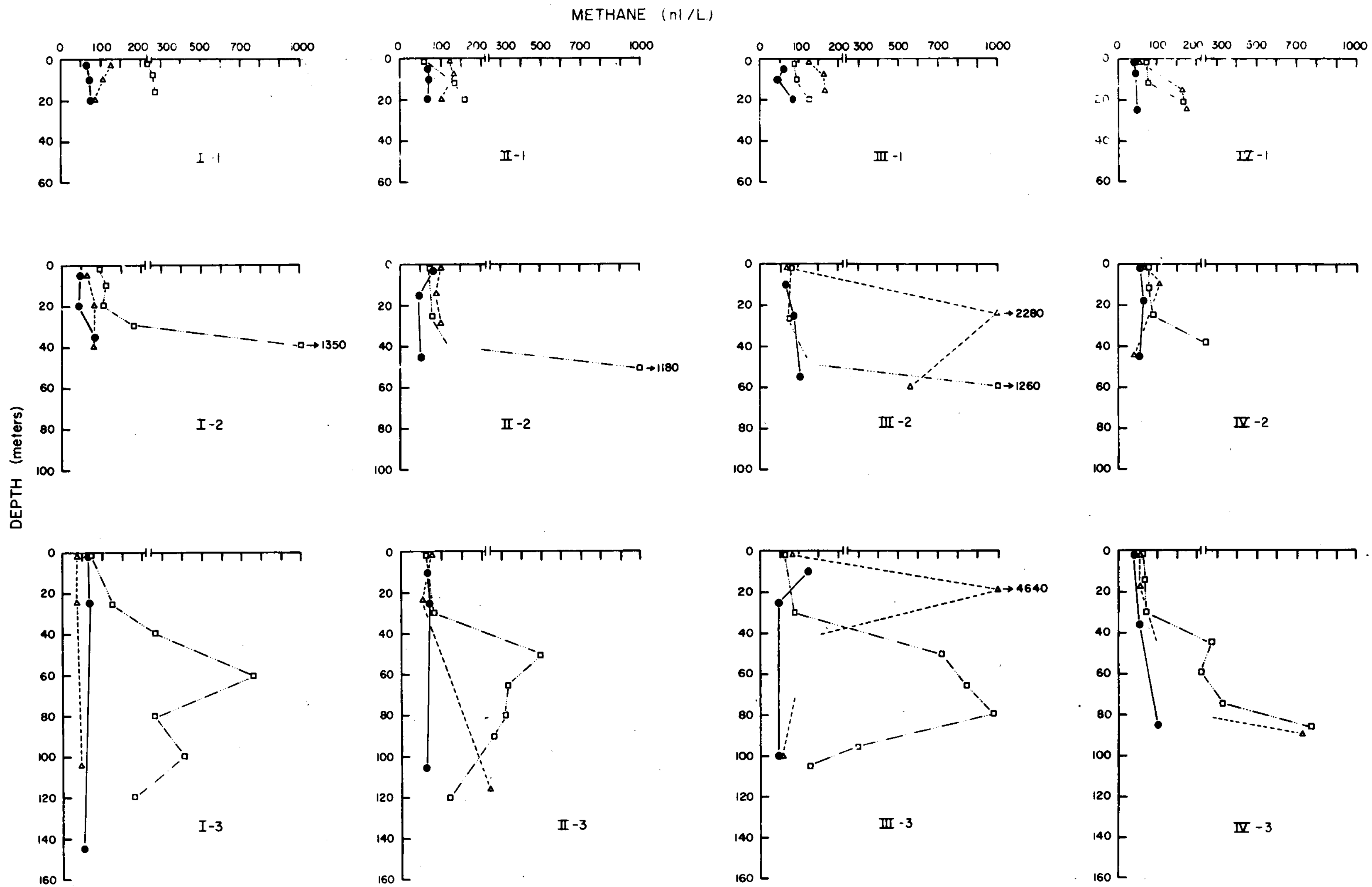

Figure 11. Vertical Methane Profiles for Winter (circles), Spring (triangles), and Summer (squares) Sampling Periods.

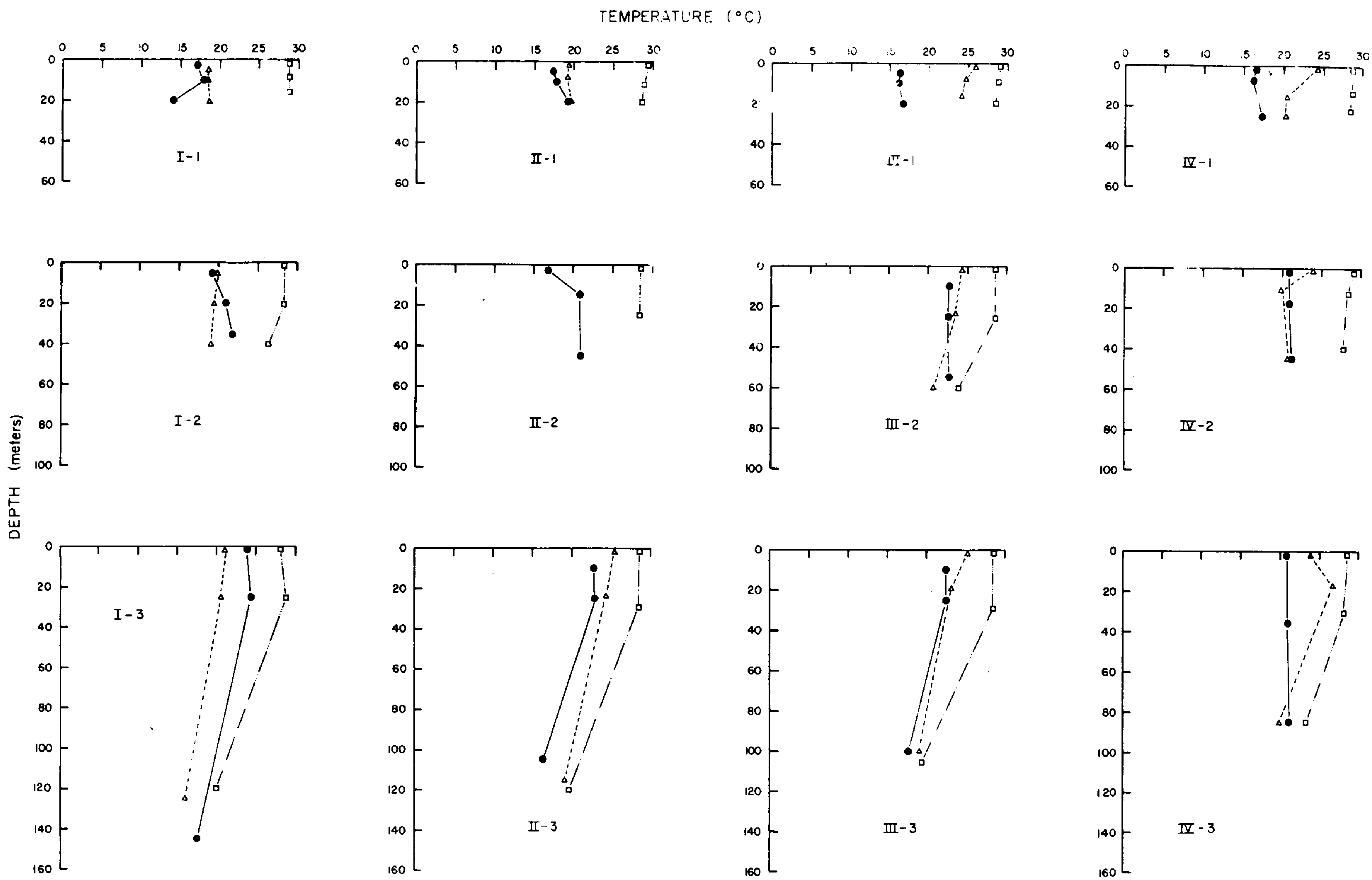

Figure 12. Vertical Temperature Profiles for Winter (circles), Spring (triangles) and Summer (squares) Sampling Periods.

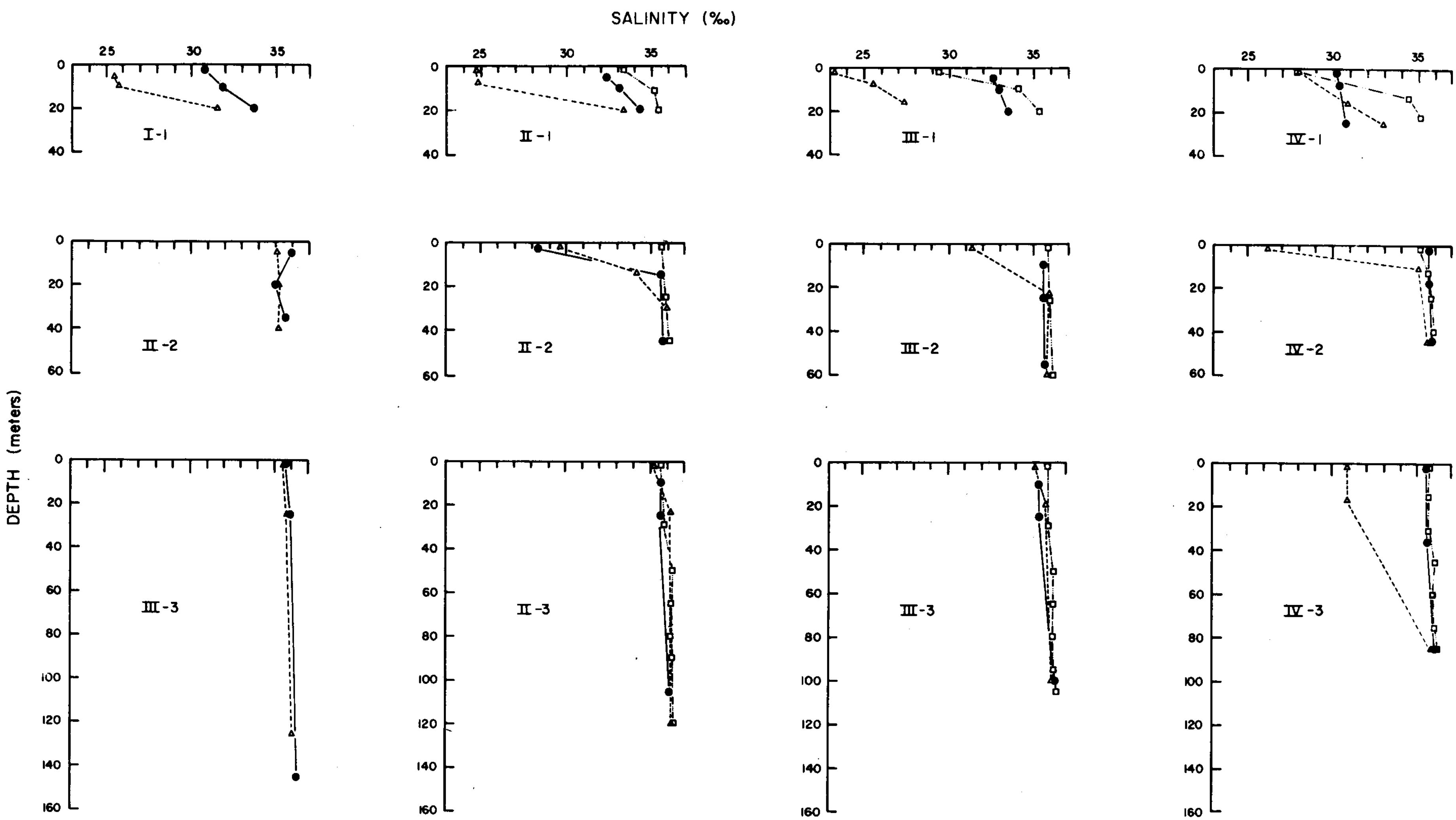

Figure 13. Vertical Salinity Profiles for Winter (circles), Spring (triangles), and Summer (squares) Sampling Periods.

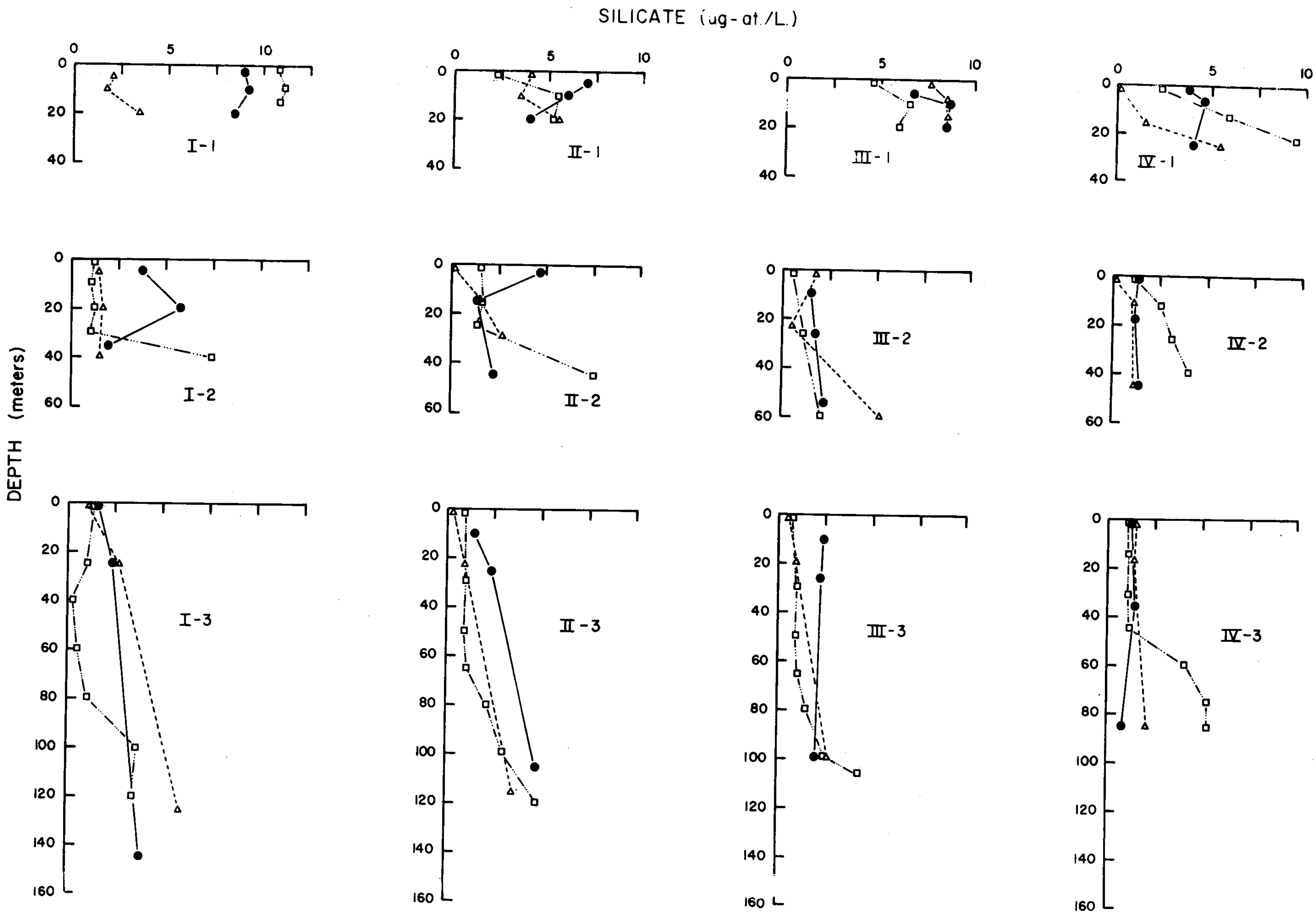

Figure 14. Vertical Silicate Profiles for Winter (circles), Spring (triangles), and Summer (squares) Sampling Periods.

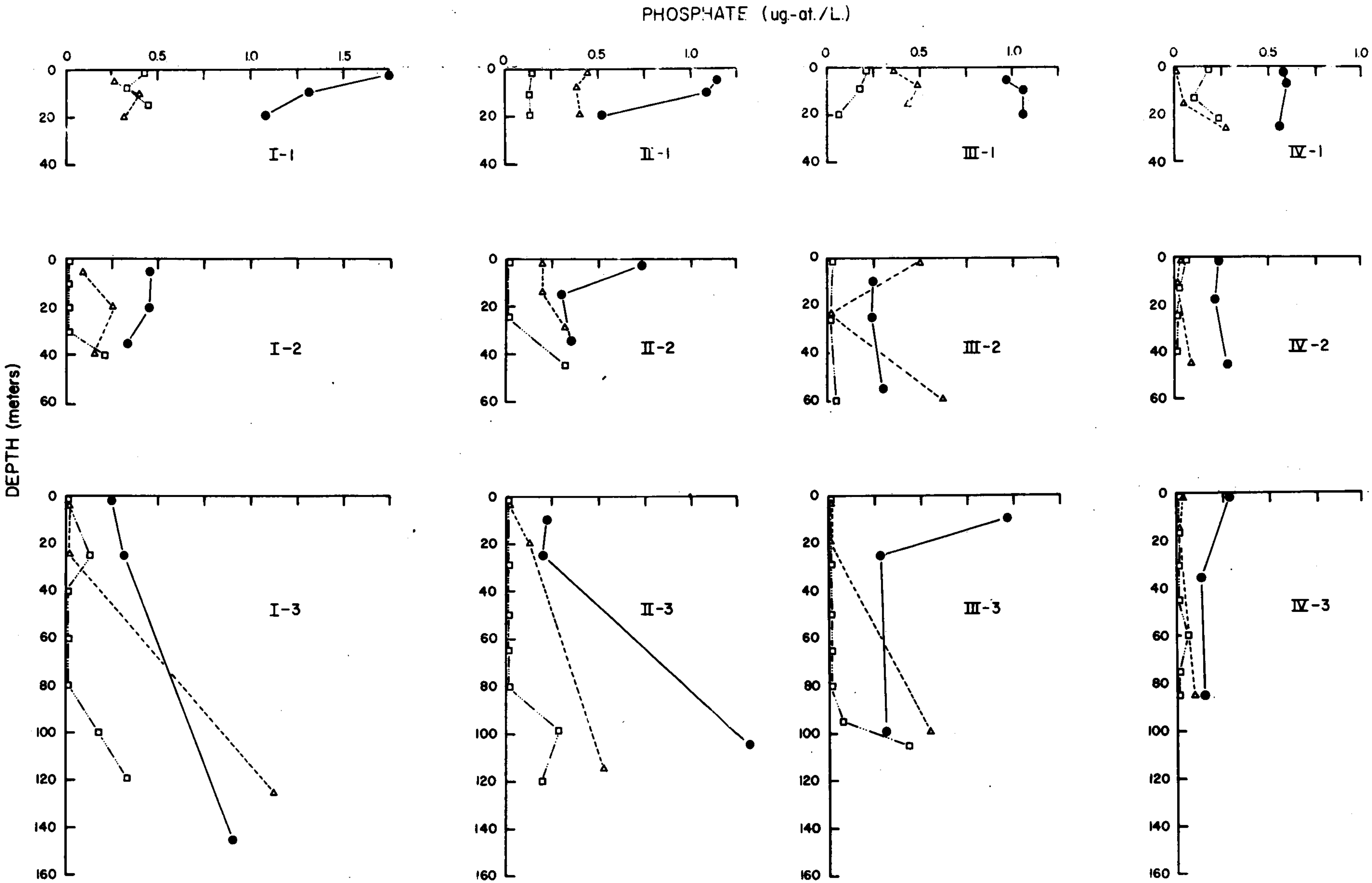

Figure 15. Vertical Phosphate Profiles for Winter (circles), Spring (triangles), and Summer (squares) Sampling Periods.

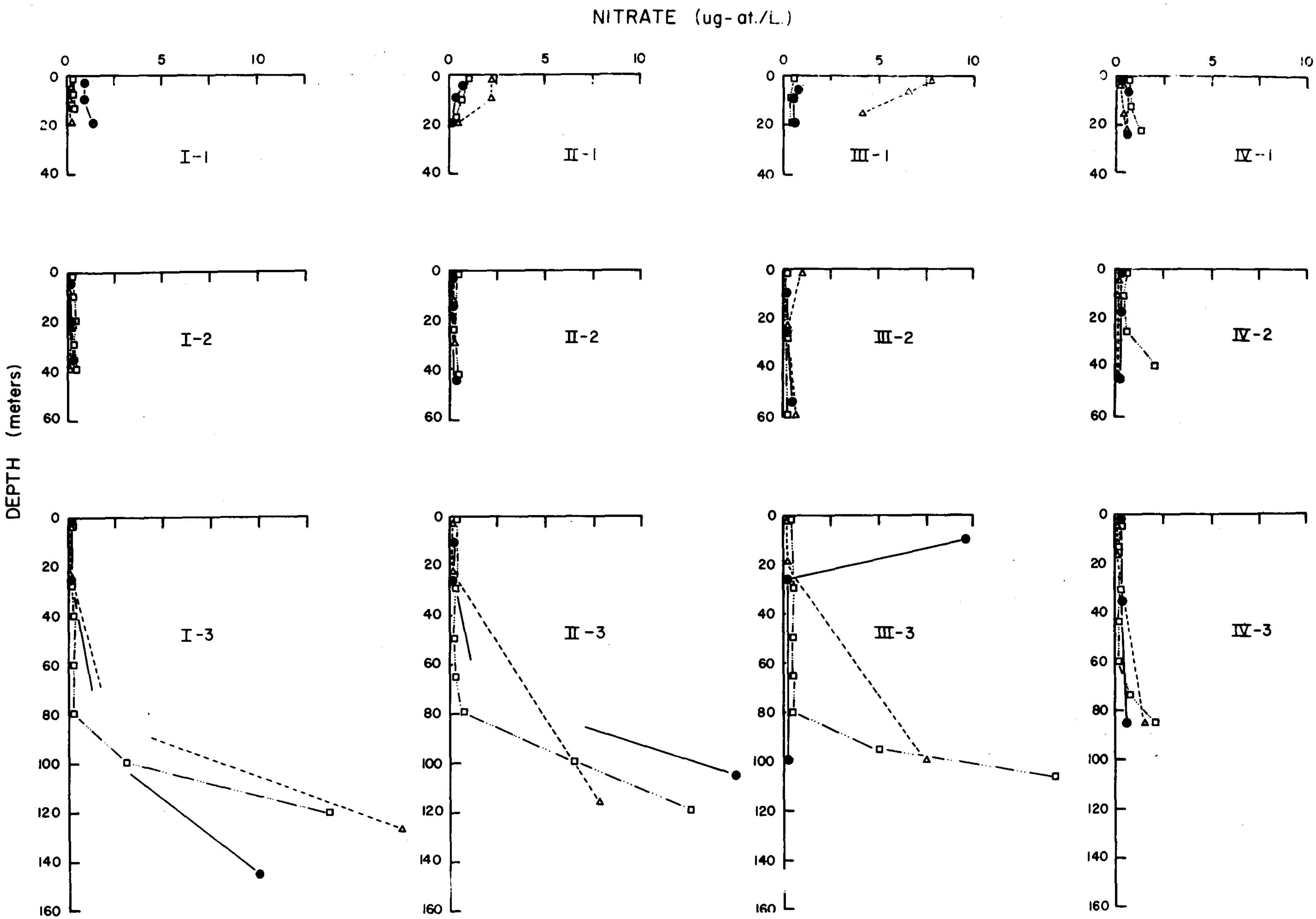

Figure 16. Vertical Nitrate Profiles for Winter (circles), Spring (triangles),

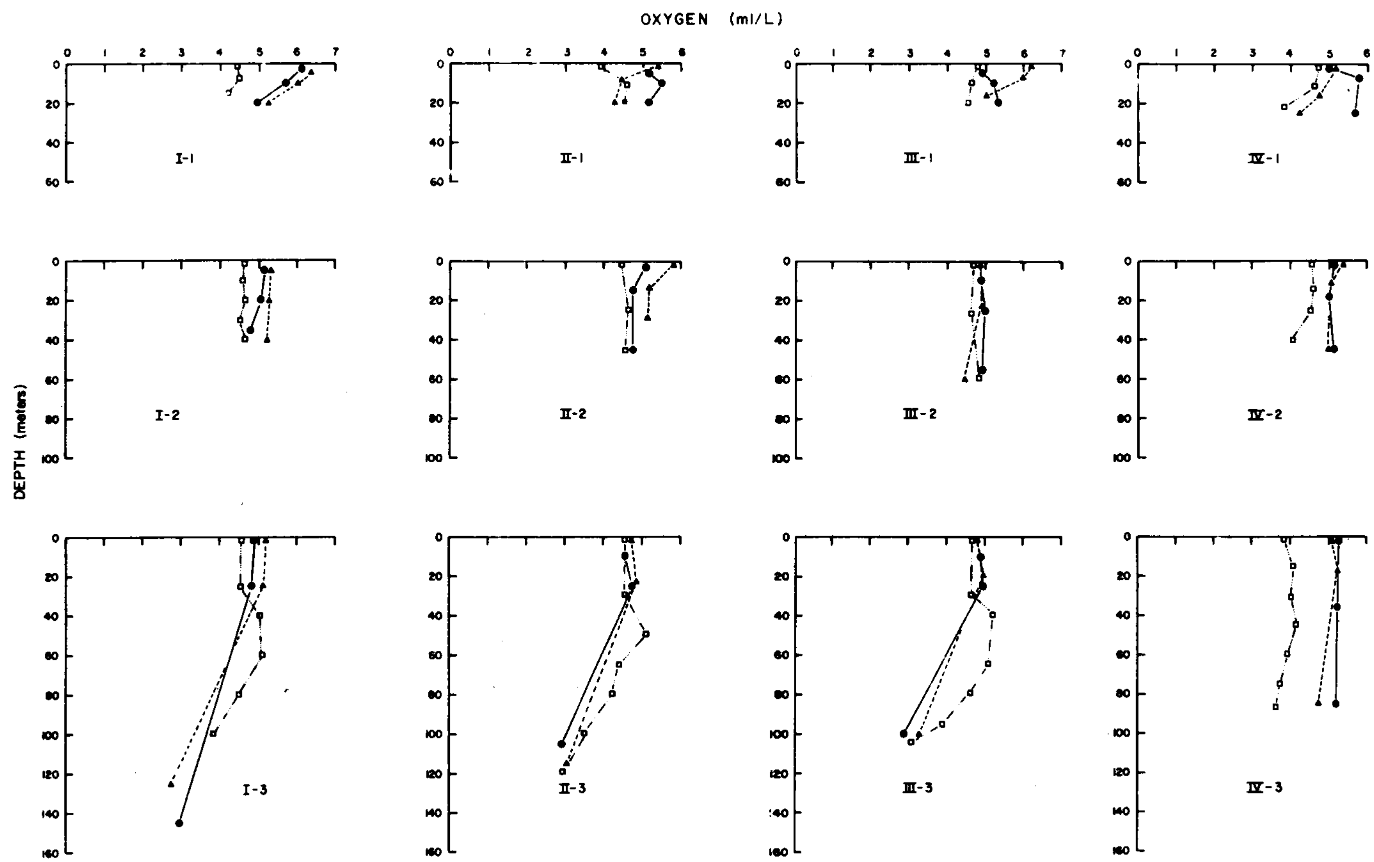

Figure 17. Vertical Oxygen Profiles for Winter (circles), Spring (triangles), and Summer (squares) Sampling Periods.

Table 1. Hydrographic Data for South Texas OCS Area, 1975.

BUREAU OF LAND MANAGEMENT - SOUTH TEXAS (JANUARY - FEBRUARY, 1975)

STATION	DEPTH	TEMPERATURE (DEGREE'S C)	SALINITY ($^{o}/_{oo}$)	SILICATE μg-at/L	PHOSPHATE μg-at/L	NITRATE μg-at/L	OXYGEN mℓ/L
I/1	2.5 m	17.16	30.756	9.0	1.77	0.8	6.11
	10 m	17.91	31.863	9.2	1.32	0.8	5.71
	20 m	14.12	33.698	8.5	1.08	1.3	4.95
I/2	5 m	19.32	35.975	3.6	0.46	0.2	5.14
	20 m	21.00	34.999	5.7	0.45	0.2	5.06
	35 m	21.81	35.583	1.9	0.33	0.3	4.79
I/3	1 m	23.95	35.614	1.6	0.24	0.1	4.88
	25 m	24.24	35.983	2.4	0.31	< 0.1	4.81
	145 m	17.76	36.343	3.9	0.90	10.1	2.97
II/1	5 m	17.40	32.372	6.9	1.14	0.6	5.17
	10 m	17.83	33.066	6.0	1.09	0.4	5.49
	20 m	19.34	34.319	4.0	0.52	0.1	5.16
II/2	3 m	16.80	28.354	4.6	0.73	< 0.1	5.09
	15 m	20.82	35.598	1.3	0.30	0.1	4.76
	45 m	20.98	35.737	2.2	0.35	0.3	4.79
II/3	10 m	22.88	35.667	1.6	0.22	0.2	4.57
	25 m	22.95	35.684	2.3	0.20	0.1	4.78
	105 m	16.40	36.181	4.8	1.31	16.4	2.92
III/1	5 m	16.31	32.537	6.7	0.97	0.8	4.94
	10 m	16.22	32.932	8.7	1.06	0.6	5.23
	20 m	16.74	33.414	8.0	1.06	0.5	5.34
III/2	10 m	22.69	35.539	1.4	0.25	0.1	4.89
	25 m	22.60	35.545	1.6	0.24	0.1	4.98
	55 m	22.66	35.593	2.2	0.30	0.4	4.91

Table 1. Cont'd.

STATION DEPTH	TEMPERATURE (DEGREE'S C)	SALINITY ($^o/_{oo}$)	SILICATE µg-at/L	PHOSPHATE µg-at/L	NITRATE µg-at/L	OXYGEN
III/3 10 m	22.54	35.273	2.4	0.97	9.7	4.69
25 m	22.50	35.283	2.2	0.28	0.1	4.96
100 m	17.62	36.318	2.1	0.31	<0.1	2.91
IV/1 2 m	16.50	30.147	3.7	0.58	0.2	4.98
7 m	16.19	30.309	4.4	0.60	0.3	5.78
25 m	17.37	32.745	4.0	0.56	0.5	5.67
IV/2 2 m	20.90	35.712	1.5	0.24	0.2	5.13
18 m	20.91	35.712	1.2	0.22	0.2	4.99
45 m	21.08	35.808	1.4	0.28	0.2	5.11
IV/3 2 m	20.84	35.544	1.3	0.28	0.2	5.26
36 m	20.92	35.686	1.4	0.13	0.3	5.22
85 m	21.09	36.014	0.7	0.15	0.4	5.20

Table 1. Cont'd.

BUREAU OF LAND MANAGEMENT - SOUTH TEXAS (APRIL-MAY)

STATION DEPTH	TEMPERATURE (DEGREE'S C)	SALINITY (o/oo)	SILICATE µg-at/L	PHOSPHATE µg-at/L	NITRATE µg-at/L	OXYGEN ml/L
I/1 5 m	18.56	25.513	2.0	0.27	0.1	6.382
10 m	18.46	25.779	1.8	0.40	0.0	6.007
20 m	18.74	31.508	3.4	0.32	0.1	5.230
I/2 5 m	19.76	35.029	1.3	0.09	0.0	5.328
20 m	19.49	35.212	1.6	0.26	0.1	5.282
40 m	19.10	35.208	1.5	0.15	0.0	5.226
I/3 1 m	21.06	35.496	1.0	0.00	0.1	5.195
25 m	20.59	35.740	3.2	0.02	0.0	5.116
125 m	16.18	36.095	6.0	1.12	15.7	2.750
II/1 0 m	19.39	24.728	4.0	0.44	1.9	6.226
8 m	19.31	24.761	3.5	0.38	1.9	6.006
20 m	19.48	33.381	5.5	0.40	0.5	5.084
II/2 0 m	-	29.642	0.1	0.20	0.1	5.816
14 m	-	34.197	1.5	0.20	0.1	5.198
29 m	-	35.953	2.8	0.32	0.2	5.128
II/3 1 m	25.48	35.159	0.6	0.01	0.0	4.736
23 m	24.08	36.233	0.9	0.13	0.0	4.860
115 m	19.16	36.243	3.4	0.53	8.2	3.081

Table 1. Cont'd.

BUREAU OF LAND MANAGEMENT - SOUTH TEXAS (APRIL-MAY)

STATION DEPTH	TEMPERATURE (DEGREE'S C)	SALINITY (o/oo)	SILICATE µg-at/L	PHOSPHATE µg-at/L	NITRATE µg-at/L	OXYGEN ml/L
III/1 1 m	25.92	23.139	7.8	0.37	7.6	5.399
7.5 m	24.68	25.496	8.3	0.49	6.5	4.458
16 m	24.18	27.381	8.3	0.41	4.1	4.261
III/2 1 m	24.37	31.358	1.7	0.50	1.0	4.836
23 m	23.47	35.880	0.8	0.00	0.1	4.916
60 m	20.76	35.766	5.2	0.62	0.6	4.459
III/3 1 m	25.24	35.178	0.7	0.00	0.0	4.801
19 m	23.24	35.748	0.9	0.00	0.1	4.941
100 m	19.24	36.230	2.6	0.54	7.8	3.314
IV/1 1 m	24.10	27.859	0.1	0.01	0.1	5.149
16 m	20.41	31.878	1.4	0.05	0.3	4.713
25 m	20.23	32.891	5.6	0.28	0.5	4.217
IV/2 1 m	23.90	26.199	0.0	0.03	0.2	5.384
11 m	19.94	35.018	1.1	0.01	0.0	5.030
45 m	20.90	35.594	1.2	0.08	0.1	5.000
IV/3 1 m	23.76	31.899	1.1	0.03	0.0	5.089
17 m	26.63	31.918	1.2	0.00	0.0	5.237
85 m	19.86	35.870	1.8	0.10	1.4	4.740

Table 1. Cont'd.

BUREAU OF LAND MANAGEMENT - SOUTH TEXAS (AUGUST - SEPTEMBER) 1975

STATION	DEPTH	TEMPERATURE (DEGREE'S C)	SALINITY (o/oo)	SILICATE µg-at/L	PHOSPHATE µg-at/L	NITRATE µg-at/L	OXYGEN ml/L
I/1	0 m	28.92	35.098	10.7	0.43	0.3	4.41
	7.5 m	28.92	35.097	11.5	0.34	0.3	4.49
	15 m	28.87	35.173	10.7	0.45	0.4	4.20
I/2	0 m	28.48	35.778	1.2	0.0	0.2	4.62
	10 m	-	35.952	1.0	0.0	0.3	4.60
	20 m	28.38	35.941	1.3	0.0	0.3	4.66
	30 m	-	35.960	1.0	0.0	0.3	4.52
	40 m	26.41	35.965	7.4	0.21	0.3	4.67
I/3	0 m	28.09	35.903	1.1	0.0	0.2	4.56
	25 m	28.90	35.946	1.1	0.13	0.2	4.54
	40 m	-	36.072	0.1	0.0	0.2	5.02
	60 m	-	36.258	0.4	0.0	0.3	5.10
	80 m	-	36.246	1.0	0.0	0.3	4.50
	100 m	-	36.213	3.6	0.18	3.4	3.84
	120 m	20.03	36.333	3.4	0.34	11.9	2.88
II/1	1 m	29.51	33.298	2.2	0.15	0.9	3.96
	11 m	28.82	35.179	5.4	0.13	0.6	4.56
	20 m	28.56	35.394	5.3	0.13	0.3	4.46
II/2	1 m	28.55	35.537	1.5	0.0	0.4	4.46
	25 m	28.44	35.837	1.2	0.0	0.2	4.56
	45 m	25.42	36.021	7.6	0.32	0.3	4.51
II/3	1 m	28.74	35.673	0.9	0.0	0.3	4.54
	29 m	28.50	35.779	1.0	0.0	0.3	4.67
	50 m	-	36.259	0.8	0.0	0.2	5.09
	65 m	-	36.238	1.0	0.0	0.3	4.78
	80 m	-	36.213	2.0	0.0	0.8	4.20
	95 m	-	36.247	3.0	0.29	6.5	3.50
	120 m	19.78	36.335	4.8	0.15	12.6	2.91

Table 1. Cont'd.

BUREAU OF LAND MANAGEMENT - SOUTH TEXAS (AUGUST - SEPTEMBER)

STATION	DEPTH	TEMPERATURE (DEGREE'S C)	SALINITY (o/oo)	SILICATE µg-at/L	PHOSPHATE µg-at/L	NITRATE µg-at/L	OXYGEN ml/L
III/1	1 m	29.13	2[illegible].326	4.4	0.22	0.5	4.77
	9 m	28.85	34.068	6.5	0.18	0.4	4.63
	20 m	28.51	35.275	5.9	0.07	0.3	4.53
III/2	1 m	28.56	35.783	0.3	0.03	0.3	4.68
	26 m	28.66	35.867	1.1	0.0	0.3	4.61
	60 m	24.03	36.138	2.0	0.05	0.3	4.80
III/3	1 m	28.57	35.860	0.9	0.0	0.3	4.69
	29 m	28.53	35.902	1.0	0.0	0.5	4.65
	50 m	-	36.213	1.0	0.0	0.4	5.17
	65 m	-	36.216	1.0	0.0	0.4	5.03
	80 m	-	36.186	1.6	0.0	0.4	4.59
	95 m	-	36.224	2.6	0.08	5.0	3.76
	105 m	19.50	36.338	4.1	0.43	14.1	3.08
IV/1	1 m	28.72	27.834	2.2	0.18	0.6	4.63
	13 m	28.95	34.464	6.2	0.11	0.6	4.52
	22 m	28.64	35.148	9.6	0.24	1.2	3.75
IV/2	1 m	29.03	35.054	1.2	0.07	0.5	4.48
	13 m	28.48	35.701	2.5	0.03	0.4	4.52
	25 m	-	35.763	3.2	0.0	0.4	4.47
	40 m	27.86	35.922	4.2	0.0	2.0	3.99
IV/3	1 m	28.62	35.688	1.0	0.0	0.4	3.84
	15 m	-	35.704	1.1	0.0	0.4	4.02
	31 m	28.19	35.719	1.1	0.0	0.4	3.96
	45 m	-	36.133	1.0	0.0	0.4	4.12
	60 m	-	35.971	4.2	0.06	0.3	3.87
	75 m	-	36.106	5.2	0.01	0.8	3.69
	85 m	23.40	36.226	5.1	0.01	1.9	3.58

Table 2. Low-Molecular-Weight Hydrocarbon Data for the South Texas OCS Area, 1975.

BUREAU OF LAND MANAGEMENT - SOUTH TEXAS (JANUARY - FEBRUARY, 1975)

STATION DEPTH	METHANE (nl/L)	ETHENE (nl/L)	ETHANE (nl/L)	PROPENE (nl/L)	PROPANE (nl/L)
I/1 2.5 m	66	2.3	1.0	1.8	1.2
10	71	4.0	1.8	4.1	4.7
20	76	3.6	1.5	-	1.1
I/2 5 m	48	3.0	2.2	-	-
20	45	3.5	1.3	-	0.8
35	85	4.7	1.3	-	0.9
I/3 1 m	68	5.5	1.5	0.9	1.3
25	70	11.8	3.0	0.9	1.3
145	52	1.5	1.5	0.2	0.8
II/1 5 m	68	5.0	1.8	0.7	2.0
10	70	3.5	1.8	0.2	2.0
20	68	3.8	1.5	0.5	1.5
II/2 3 m	80	5.2	3.5	1.5	4.1
15	45	4.2	1.8	0.7	1.5
45	50	3.0	2.0	0.7	1.3
II/3 10 m	65	6.3	1.8	1.4	1.5
25	70	5.7	1.5	1.1	1.3
105	62	2.7	1.5	5.9	3.5

Table 2. Cont'd.

BUREAU OF LAND MANAGEMENT - SOUTH TEXAS (JANUARY - FEBRUARY, 1975)

STATION	DEPTH	METHANE (nl/L)	ETHENE (nl/L)	ETHANE (nl/L)	PROPENE (nl/L)	PROPANE (nl/L)
III/1	5 m	60	6.5	2.2	1.0	1.5
	10	45	3.0	1.5	0.7	1.4
	20	84	2.7	1.5	0.7	1.3
III/2	10 m	62	4.5	1.5	1.2	1.2
	25	87	4.8	1.5	0.9	1.1
	55	105	4.2	1.3	<0.2	1.6
III/3	10 m	125	1.5	1.3	0.2	0.9
	25	46	3.8	1.5	3.7	2.1
	100	45	3.3	1.3	0.5	1.4
IV/1	2 m	40	3.0	1.7	0.5	1.6
	7	42	2.0	1.7	0.6	1.6
	25	49	2.3	1.5	0.5	1.3
IV/2	2 m	58	5.3	1.5	0.5	1.0
	18	66	6.0	1.5	0.4	1.0
	45	52	3.3	1.5	0.4	1.0
IV/3	2 m	42	1.5	1.5	0.3	1.0
	36	57	1.3	1.3	0.2	1.0
	85	100	3.0	1.3	0.2	1.0

Table 2 Cont'd.

BUREAU OF LAND MANAGEMENT - SOUTH TEXAS (APRIL-MAY)

STATION	DEPTH	METHANE (nl/L)	ETHANE + ETHENE (n/L)	PROPENE (nl/L)	PROPANE (nl/L)
I/1	5 m	128	16.8	1.6	1.1
	10 m	107	12.1	1.9	1.0
	20 m	85	55	1.9	0.86
I/2	5 m	64	2.3	0.86	0.48
	20 m	82	13.8	1.1	0.67
	40 m	80	4.0	2.1	1.2
I/3	1 m	37	3.3	1.9	0.95
	25 m	37	3.0	1.6	1.3
	125 m	46	0.5	0.95	0.61
II/1	0 m	125	58.3	5.7	0.11
	8 m	134	14.0	4.9	0.23
	20 m	106	4.3	2.7	0.10
II/2	0 m	99	38.1	2.8	0.05
	14 m	88	5.8	2.3	0.24
	29 m	99	4.5	2.2	t
II/3	1 m	74	10.1	2.7	---
	23 m	53	6.3	0.3	---
	115 m	265	1.2	0.3	---
III/1	1 m	125	8.3	1.2	1.3
	75 m	162	13.3	3.5	t
	16 m	165	11.3	3.5	t
III/2	1 m	66	25.3	4.2	---
	23 m	2280	22.2	2.0	---
	60 m	456	3.0	1.2	---

Table 2. Cont'd.

BUREAU OF LAND MANAGEMENT - SOUTH TEXAS (APRIL-MAY)

STATION	DEPTH	METHANE (nl/L)	ETHENE + ETHANE (n/L)	PROPENE (nl/L)	PROPANE (nl/L)
III/3	1 m	80	22.1	2.6	---
	19 m	4640	10.6	1.3	---
	100 m	55	1.6	1.9	---
IV/1	1 m	53	35.0	3.1	0.10
	16 m	164	10.5	2.7	0.19
	25 m	176	5.6	4.7	0.48
IV/2	1 m	68	18.0	0.95	0.86
	11 m	105	4.6	---	0.81
	45 m	46	4.6	---	1.1
IV/3	1 m	59	7.2	4.6	0.48
	17 m	57	15.9	1.7	t
	85 m	722	3.8	2.1	0.47

Table 2. Cont'd.

BUREAU OF LAND MANAGEMENT - SOUTH TEXAS (AUGUST - SEPTEMBER)

STATION	DEPTH	METHANE (nl/L)	ETHENE (nl/L)	ETHANE (nl/L)	PROPENE (nl/L)	PROPANE (nl/L)
I/1	0 m	240	7.8	1.2	3.6	4.7
	7 m	260	7.8	t	1.7	3.7
	15 m	280	8.3	t	1.7	4.0
I/2	0 m	98	20	t	2.5	2.5
	10 m	110	-	-	-	-
	20 m	110	4.2	1.3	t	3.1
	30 m	180	-	-	-	-
	40 m	1,350	20	t	1.3	4.9
I/3	0 m	72	8.6	t	-	0.4
	25 m	120	13	t	2.0	2.5
	40 m	260	-	-	-	-
	60 m	750	-	-	-	-
	80 m	250	-	-	-	-
	100 m	400	-	-	-	-
	120 m	180	2.8	0.8	t	2.7
II/1	1 m	62	11	1.3	4.3	2.3
	11 m	130	5.8	2.0	1.9	2.5
	20 m	160	7.6	1.3	2.0	3.7
II/2	1 m	78	25	t	2.2	2.9
	25 m	76	30	t	3.2	1.9
	40 m	1,180	14	0.8	0.7	7.1
II/3	1 m	64	14	0.8	2.0	3.2
	29 m	78	20	0.8	2.0	4.2
	50 m	490	-	-	-	-
	65 m	330	-	-	-	-
	80 m	320	-	-	-	-
	90 m	260	-			-
	120 m	120	0.8	1.3	t	1.9

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Table 2. Cont'd.

BUREAU OF LAND MANAGEMENT - SOUTH TEXAS (AUGUST - SEPTEMBER)

STATION	DEPTH	METHANE (nl/L)	ETHENE (nl/L)	ETHANE (nl/L)	PROPENE (nl/L)	PROPANE (nl/L)
III/1	1 m	92	16	1.6	4.4	4.0
	9 m	97	3.5	2.2	0.7	3.7
	20 m	130	5.6	0.8	1.6	2.9
III/2	1 m	77	8.6	t	2.0	2.9
	26 m	67	25	t	2.0	3.7
	50 m	1,260	11	1.6	1.3	5.2
III/3	1 m	64	6.6	t	-	-
	29 m	87	7.1	2.2	3.6	4.0
	50 m	710	-	-	-	-
	65 m	840	-	-	-	-
	80 m	990	-	-	-	-
	95 m	290	-	-	-	-
	105 m	140	0.7	0.8	1.7	1.3
IV/1	1 m	70	8.4	t	3.0	2.7
	13 m	79	3.5	t	3.0	3.5
	22 m	160	4.0	t	2.5	2.5
IV/2	1 m	76	5.1	t	2.8	2.0
	13 m	76	6.7	0.4	1.7	2.7
	25 m	90	-	-	-	-
	40 m	240	4.4	0.3	2.2	2.3
IV/3	1 m	59	7.1	t	1.7	2.7
	15 m	68	-	-	-	-
	31 m	69	11	t	1.3	2.3
	45 m	290	-	-	-	-
	60 m	230	-	-	-	-
	75 m	310	-	-	-	-
	85 m	760	2.6	1.3	1.3	2.2

is due to the methane generated below the sediment-water interface either by bacterial or thermo-catalytic (petroleum forming) processes. Indeed, numerous instances of gas seepage from the bottom in our study area have been reported by Berryhill and co-workers (personal communications). Because greatest solution occurs at depth as a result of lower temperatures and increased partial pressures within the bubble, this phenomenon is thought to be responsible for the near bottom methane highs observed at stations 3/IV and 3/II. Although these high near-bottom methane anomalies are almost certainly due to gas seepage in the South Texas OCS study area, it is difficult to ascertain the origin of these hydrocarbons without chemical and isotopic analyses of the gas bubbles at various locations.

There were very large mid-depth maxima observed at stations 2/II and 3/III during the spring sampling period. One of these maxima, in excess of 4,000 nl/L is higher than found on parts of the heavily LMW hydrocarbon-contaminated Louisiana shelf. Because of this observation, several additional mid-depth stations were taken during the summer sampling period. These profiles showed a very pronounced mid-depth maximum between 50 and 80 meters at stations 3/I, 3/II, 3/III and 3/IV during the summer sampling. This same increase at 40 to 50 meters was observed also at stations 2/I, 2/II, 2/III and 2/IV. Thus, there is a very large mid-depth LMW hydrocarbon maxima during the spring and summer months in the South Texas OCS area.

The origin of the mid-depth maximum is unknown. It could originate from (1) gas seepage from 50 to 80 meters on the shelf spreading laterally to deeper waters, (2) seasonal variations in current patterns with higher LMW hydrocarbon concentration water sweeping onto the lower Texas shelf during the spring and summer, and/or (3) stratification of the water column during the summer allowing the "in situ" production of methane at mid-depths to be accumulated. We have some information from the Louisiana shelf region that indicates there may be mid-depth production of methane in the water column, but whether this process can account for the very large mid-depth maxima on the South Texas shelf is unknown.

Other Saturated LMW Hydrocarbons

Without knowledge of either the global partial pressures of ethane, propane and higher hydrocarbons or their solubility coefficients, it is not possible to calculate their equilibrium concentrations in oceanic surface waters. However, on the basis of considerable amount of work by us and Swinnerton and co-workers at the Naval Research Laboratory, measured concentrations, which are probably near equilibrium values, are approximately 2 nl/L for ethane and 1 nl/L for propane. These low concentrations are extremely difficult to measure. Poor performance of our gas chromatograph during the spring sampling did not allow separation and detection of ethane and ethene separately.

The surface values for ethane and propane (Figures 2 and 3, and Table 2) are close to the open ocean values reported by Brooks (1975) and Sackett and Brooks (1975). The highest surface propane concentrations were generally observed during the summer sampling with the lowest concentrations during the spring sampling. There was no systematic decrease in either of these hydrocarbons with depth. There was also little correlation of the C_2 and C_3 saturated LMW hydrocarbons with the high methane concentrations observed on the South Texas shelf. One significant feature is that the average propane concentration for 35 samples is 3.1 nannoliters per liter, a factor of three higher than apparent equilibrium levels, and paralleling high methane levels found at the same time.

Unsaturated Higher Hydrocarbons

Biologically derived ethene and propene were detected and measured in most water samples. Generally ethene is 2 to 3 times ethane, its saturated analog, and propene about the same as propane. However there are several exceptions to this generalization. The highest ethene concentrations appear to be found during the spring sampling. The outer stations usually have the lowest ethene and propene concentrations (Figures 3 and 4). Ethene and propene decrease with depth at the mid and outer sampling stations of the transects (stations 2 and 3).

Temperature

Temperatures were not obtained for station 2/II for the spring period because samples were taken using Niskin bottles not having reversing thermometers.

Except for station 3/I, surface water shows the expected warming from winter, spring, to summer sampling periods. In addition there is a warming of surface water away from the coast during just the winter sampling period. The spread in temperatures for any given level for any station generally decreases with increasing depth. The only anomalous observations seems to be the inversion between winter and spring temperatures at station 2/I (Figures 5 and 12). This inversion seems to be due to the intrusion of abnormally cold water at the surface during the spring and the intrusion of warm water at depth in the winter at this location.

Salinity

The most striking feature of these data is the appearance of low salinities in surface water during the spring sampling period for stations 1/I, 1/II, 1/III, 2/III, 1/IV, 2/IV and 3/IV (Figures 6 and 13). This suggests a wedge of low salinity water moving southwest down the coast at this period of time. During all sampling seasons the inshore stations generally had lower salinities with salinities increasing seaward and with depth.

Nitrate

Low surface values are typical for the Gulf of Mexico. High values for the deepest samples for stations 3/I, 3/II and 3/III (Figures 9 and 16) are indicative of 200 to 300 meter open Gulf water moving up on to the shelf. Surface and deep samples for the winter profile of 3/III have probably been inadvertently interchanged aboard ship (also phosphate samples).

Phosphate

Systematic decreases in concentrations from winter to summer (Figures 8 and 15), apparently due to utilization by phytoplankton, are seen for most stations. The 200 to 300 meter open Gulf water is seen again in bottom water samples of stations 3/I, 3/II and 3/III.

Silicate

The 200 to 300 meter open Gulf water is seen again in bottom samples of 3/I and 3/IV (Figure 14). Near surface samples (Figure 7) are generally higher than open Gulf water. This is probably due to high silicate concentrations in the continental runoff component.

Dissolved Oxygen

The most striking feature of these data is the appearance of low-oxygen water at stations 1/II and 3/IV during the summer period (Figures 10 and 17). The highest dissolved oxygen concentrations during the winter and spring were found at the inshore stations, while the opposite trend is seen during some of the summer transects. This can be correlated in most cases to changes in solubility with different salinities and temperatures.

Integration With Other Parameters

An attempt was made to correlate our LMW hydrocarbons with different biological and chemical parameters of other investigators. We found no significant correlation between methane and ATP, propane and ATP, ethene and ATP, and propene and ATP for duplicate samples taken in the STOCS region. Chlorophyll also showed little correlation with methane, propane, ethene and propene. The LMW hydrocarbons do not appear to correlate with these biological parameters.

An attempt was also made to correlate LMW hydrocarbons with the n-paraffins in seawater and particulate material filtered from sea water. There was little correlation (coefficient of correlation = <0.4) between methane and average total n-paraffin hydrocarbon concentrations in near surface seawater. The best correlation was observed between methane and average total n-paraffin concentrations in particulate matter, August 1975 (coefficient of correlation = 0.63). In only the summer sampling were n-paraffin concentrations in particulate matter reported. This correlation between methane and particulate-bound paraffins may or may not be significant. It should be noted that these near-surface samples for methane and heavy hydrocarbons were taken several meters apart in many instances. The precision of the heavy hydrocarbon analysis for total n-paraffins is considerably less than the LMW hydrocarbon analysis. Propane showed little correlation (coefficient of correlation = <0.4) with either dissolved or particulate average total n-paraffins.

CONCLUSIONS AND RECOMMENDATIONS

Since light hydrocarbons are the most mobile fraction of petroleum, they can be spread widely by diffusive processes and turbulent mixing of water masses. These processes are occurring on the Louisiana shelf where LMW hydrocarbons are widely distributed and show dramatic concentration gradients which in most instances can be correlated to proximity to production platforms. In regions close to production platforms LMW hydrocarbons can climb as high as 1 or 2 mls. LMW hydrocarbons per liter of sea water. Increases in LMW hydrocarbon levels due to oil and gas production may be one of the few biological and chemical paraments measured in this STOCS monitoring program that will change in the future.

There are two major sources of LMW hydrocarbon contamination from oil and gas producing platforms. Both of these sources may produce their greatest LMW hydrocarbon contamination at mid-depths in the water column. The underwater venting of low pressure gas at near-bottom depths near the platform is the major source of LMW hydrocarbons from production platforms in many areas of the Louisiana shelf. This underwater venting involves much greater hydrocarbon inputs at depth because of greater solution of the gas bubbles due to hydrostatic pressure. The disposal of produced brines is also a major source of hydrocarbons from producing platforms. These brines are usually highly saline and will therefore sink to some subsurface depth because of their high density. Thus, the two major sources of hydrocarbon contamination from producing platforms have their greatest effect at subsurface depths in the water column. A third source of LMW hydrocarbon contamination is oil spillage which is a surface input. The current BLM STOCS is <u>not</u> providing an adequate baseline for the area of the shelf where potential future inputs are greatest.

The first year of the program showed that there were extremely large methane anomalies at mid-depths in the South Texas OCS region. Concentrations as high as 4000 nl/L were observed at mid-depths during the spring sampling of transect III. Because of this observation, samples were taken at several subsurface levels during the summer sampling in order to define any subsurface maxima. The summer sampling showed very large subsurface maxima between 50 and 80 meters at all transects. Thus, there appears to be a very large seasonal subsurface maximum in the STOCS region. The source and seasonality of these maxima are largely unknown. The second years effort has only called for LMW hydrocarbon samples taken from surface and near-bottom depths. Thus, no effort is being made by BLM to establish an adequate baseline for LMW hydrocarbons at subsurface levels where there will be LMW hydrocarbon contamination when large scale production begins in the STOCS region.

One importance of LMW hydrocarbons is that their petrogenic sources also contain quantities of the C_5 to C_{10} aliphatic and aromatic hydrocarbons. Recent deliberations of the NSF (I.D.O.E.), "Effects of Pollutants on Marine Organisms", indicated that the C_5 to C_{10} hydrocarbons are the most toxic component of petroleum. Since LMW hydrocarbons are more easily measured in sea water than the light liquid hydrocarbons, they are an important tracer of heavier hydrocarbon contamination. Both underwater venting and brine discharges which can be traced with LMW hydrocarbons contain significant amounts of the light liquid hydrocarbons. It is therefore important to establish a reliable LMW hydrocarbon baseline in the STOCS region so that LMW hydrocarbons will be an effective tracer for the more toxic components of petroleum.

Since methane can originate from both biogenic and petrogenic sources, it becomes important to be able to differentiate between its two possible origins. The first years' data suggested a way in which this might be accomplished since concentrations of LMW hydrocarbons in the water column are so low in most cases as to eliminate carbon isotopic analyses as a viable method.

The first years' data showed a rough correlation between methane and paraffinic hydrocarbons in the suspended material. If this relationship does exist, it could indicate a method for estimating the biogenic component by means of particulate hydrocarbons. Since these total paraffinic hydrocarbon concentrations require costly and difficult methods, the relationship between particulate organic carbon (POC) and LMW hydrocarbons should be examined. POC analysis is a standard procedure that can be accomplished easily on-board the research vessel. If a correlation between POC and LMW hydrocarbons exists, it could allow methane and other hydrocarbons to be a more effective tracer of higher hydrocarbon pollution, since a correction could be made for biogenic "in situ" produced LMW hydrocarbons.

There are many areas in the STOCS region where large bottom gas seepage is occurring. These seep areas have been identified by seismic reflection (Berryhill and co-workers, personal communications) and also by near-bottom hydrocarbon anomalies. Since methane saturation is known to destabilize sediments, the LMW hydrocarbon saturation in these seep areas need to be identified. Methane and other LMW hydrocarbons saturation can be determined on these sediments from piston core sections and if concentrations are high enough isotopic analysis of the methane can indicate its origin. Tightly spaced water samples above the sediment interface would be useful in estimating LMW hydrocarbon contributions to the water column in the STOCS region

A continued seasonal study along the four transects of the STOCS region should be continued to establish an adequate seasonal and temporal baseline for LMW hydrocarbons. Since on the Louisiana shelf topographic highs are a continual source of gas seepage, this same phenomenon should be investigated during the STOCS topographic features study. The object would be to determine the extent of hydrocarbon additions from the banks and also their origin. Seep gas origin can be most easily determined by actual collection of the seep gas, but hydrocarbon profiles in seep regions are also indicative.

The following recommendations are suggested for the STOCS Monitoring Study during the coming year(s):

(1) Continue seasonal and monthly sampling along the STOCS transects.

(2) Sample every 10-meters of the water column at stations 2 & 3 of the transects.

(3) Determine POC concentrations on all LMW hydrocarbon samples.

(4) Determine LMW hydrocarbon profiles, and collect gas if possible over topographic highs.

(5) Determine LMW hydrocarbon saturation on piston cores taken near seep areas of the OCS region.

(6) Analyze near bottom profiles for LMW hydrocarbons in seep regions of the STOCS region.

(7) Perform "sniffing" surveys around drilling and production platforms.

(8) Establish a C_5 to C_{10} hydrocarbon baseline in the STOCS region.

HEAVY HYDROCARBON PROJECT

Benthos

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INTRODUCTION

Since petroleum hydrocarbons are generally taken up relatively rapidly by marine organisms (Anderson, et. al., 1974), the presence of oil pollution in an area should be reflected by changes in the hydrocarbon distribution of the area's benthic organisms. Thus, the baseline composition of the aliphatic hydrocarbons of the benthic epifauna provides an important data base for assessing changes due to oil-related activities.

To provide this baseline data for the proposed oil exploration area of the South Texas Outer Continental Shelf, the determination of the heavy hydrocarbon content of the benthic epifauna of the South Texas Outer Continental Shelf was undertaken at Texas A&M University under the direction of Dr. C.S. Giam. These analyses were based on accepted procedures including isolation of compounds by column chromatography, quantitation by gas chromatography using a flame ionization detector, and characterization by gas chromatography-mass spectrometry (Giam, et. al., 1976). The procedure used in our labs is outlined in Figure 1 and details are given in the Methods sections. The organisms for these analyses were chosen from samples provided to us by Dr. Parker and the selection was based on availability of samples, phyla, frequency, size and commercial importance; they are apparently representative of the epifauna of the South Texas OCS (during the sampling periods).

METHODS

Materials

Solvents used in the procedure were MALLINSKRODT NANOGRADE and were used as received or re-distilled when required. Silica gel (WOELM, 70-

230 mesh) was SOXHLET extracted with hexane and activated at 150° for at least 24 hours before use. Hydrocarbon standards were obtained from Analabs, Inc.

Instrumentation

A HEWLETT-PACKARD 5830 GC equipped with dual flame ionization detectors and a programmable integrator was used for analyses. It was equipped with 6' X 1/8" stainless steel columns of 5% FFAP or 3% SE-30 on GAS CHROM Q 100/120. The injector was at 270° and the detector at 350°. The column oven was temperature programmed from 100° to 260° at 6°/minutes.

Procedure

Background Reduction.

The procedure for analysis is outlined in Figure 1. Prior to actual sample analyses, procedure blanks and recovery studies were performed. All solvents to be used in the procedure were concentrated to the extent required by the procedure and analyzed by gas chromatography. Any solvent exhibiting any impurities in the hydrocarbon region of the spectrum was rejected or redistilled in an all glass system. Solid reagents were purified by heating in a 325° oven for at least 24 hours; concentrate of solvent rinses of these materials were inspected by gas chromatography as for solvents. Glassware and equipment were washed with MICRO cleaning solution (International Products Corp.) and distilled water, rinsed with acetone and methanol, and heated overnight at 325°C. After heating, they were rinsed with two portions of methanol and two of hexane. The final hexane rinse was concentrated and checked by gas chromatography. If any impurities were present, rinsing was repeated as needed to obtain an acceptable blank. Glassware checks accompanied each sample run and proce-

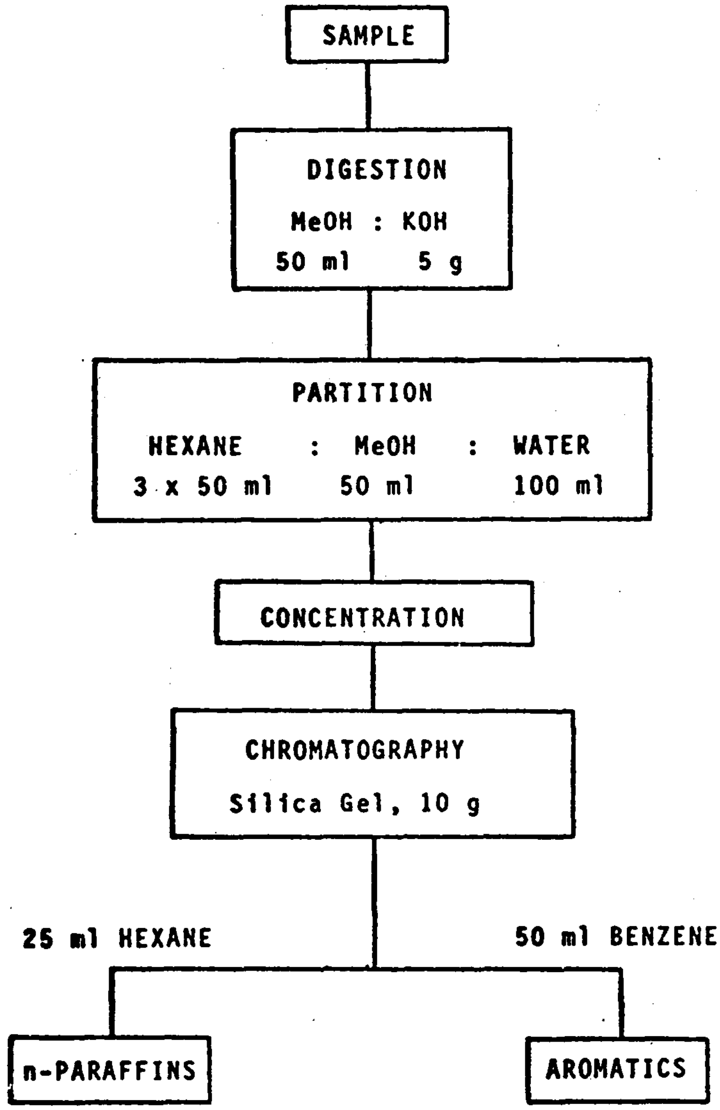

Figure 1. Analysis Scheme for n-Paraffins in Selected Benthic Organisms.

dure blanks were performed at frequent intervals.

Sample Preparation.

The samples, after defrosting for a short period (1-2 hours) were transferred to tared 250 ml round-bottom flasks. Small samples were used whole, while larger samples were cut into smaller pieces as needed for transfer into the flasks. After weighing, the samples were treated with potassium hydroxide (0.05 g/g tissue) and 50 ml of methanol. The samples were then heated under reflux for 2 hours. At the end of this period, the contents were inspected and if the digestion of the tissue was not complete, heating was continued until no tissue remained.

The methanolic hydrolysate was then transferred to a 250 ml separatory funnel. The extraction flask was rinsed with 50 ml of hexane which was transferred to the separatory funnel. Approximately 100 ml of 5% NaCl in water was added to the funnel and the mixture shaken. After allowing for the separation of the hexane layer, the aqueous layer was drawn off and the hexane was transferred to a Kuderna-Danish concentrator. The aqueous layer was extracted with two more 50 ml portions of hexane. The combined hexane extracts were then washed with salt water to remove methanol and concentrated to <u>ca</u> 5 ml with steam.

Column Chromatography.

Silica gel (WOELM, 70-230 mesh) was Soxhlet-washed with hexane and activated at 150°C for at least 24 hours before use. Ten gm of the Silica gel followed by 1 g anhydrous sodium sulfate were placed in a glass column (1.1 X 22 cm) containing hexane. The column was washed with 50 ml of hexane; care was taken to ensure sufficient solvent to just cover the solid absorbants.

The hexane extract was then placed on the column and elution started. When the solvent miniscus reached the top of the column, the vial was rinsed with 5 ml of hexane which was transferred subsequently to the column. The first 2 ml of eluate was discarded and a 23 ml hexane fraction was collected. A third fraction, containing the aromatic compounds, was collected using 50 ml of benzene. The column eluates were then concentrated as needed for gas chromatography using a stream of nitrogen.

Gas Chromatography.

Columns of 1% SE-30 (6' X 1/8") and 5% FFAP (5' X 1/8") were used for the qualitative identification and quantitation of the heavy normal hydrocarbons. Quantitation was performed with the aid of electronic integration and calibration curves established with standards made from n-C_{18}, n-C_{27}, n-C_{32} and n-C_{34} hydrocarbons obtained from Analabs.

RESULTS AND DISCUSSION

Prior to actual sample analyses, procedure blanks and recovery studies were performed. By the use of prechecked reagents and solvents and careful cleaning of all glassware and equipment, good procedural blanks containing negligible quantities of hydrocarbons were obtained; (for a more detailed discussion on general decontamination procedures for the trace analyses of organic compounds in marine samples, see Giam and Wong 1972, and Giam, et. al., 1975). Examples of the gas chromatograms of the sample and procedure blanks are shown in Figures 2 through 9. Recovery studies were performed by adding known amounts of hydrocarbons to previously analyzed tissues; routine recoveries of 90 to 100% were attained.

During the establishment of procedures, several modifications of

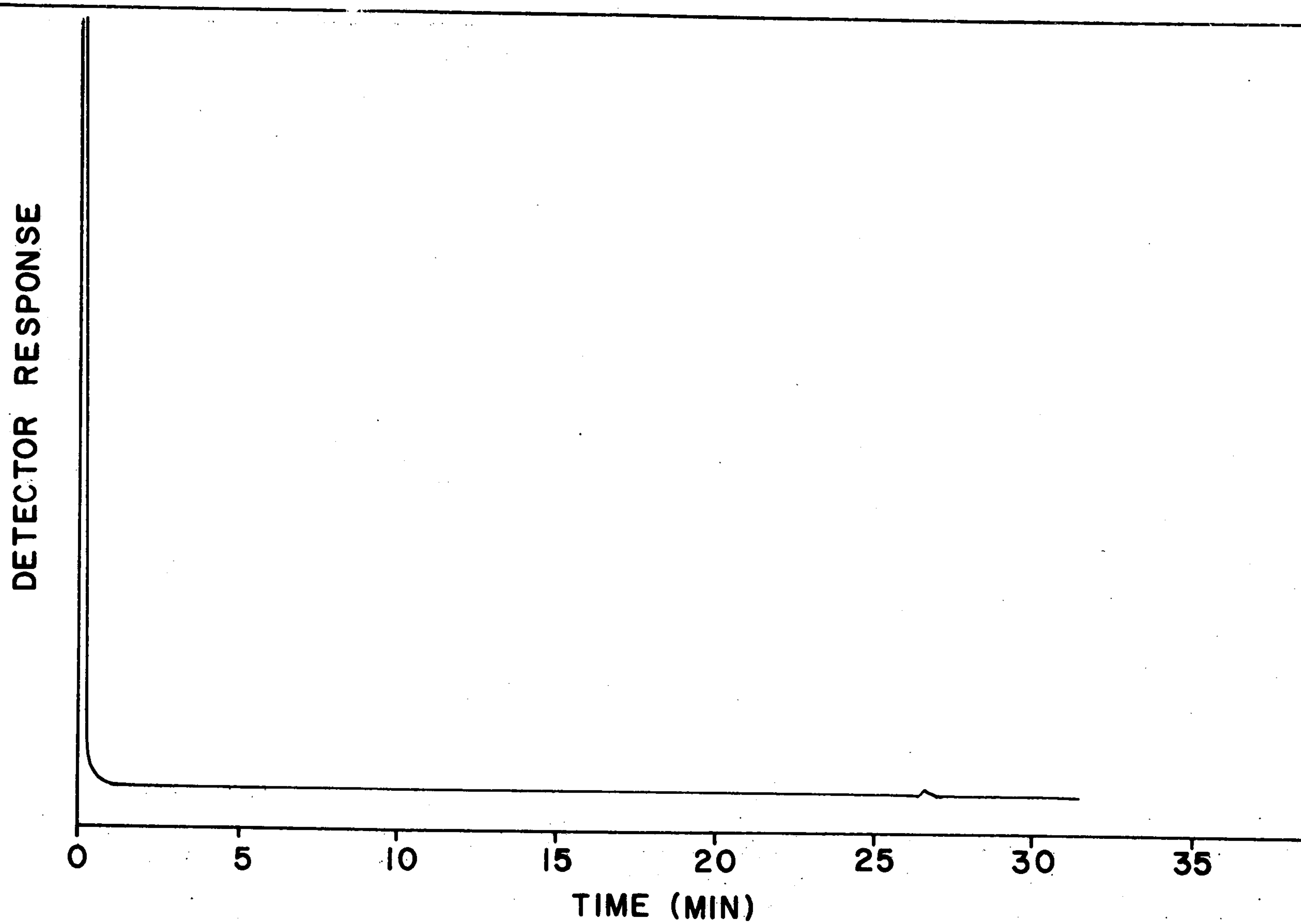

Figure 2. Procedure Blank.

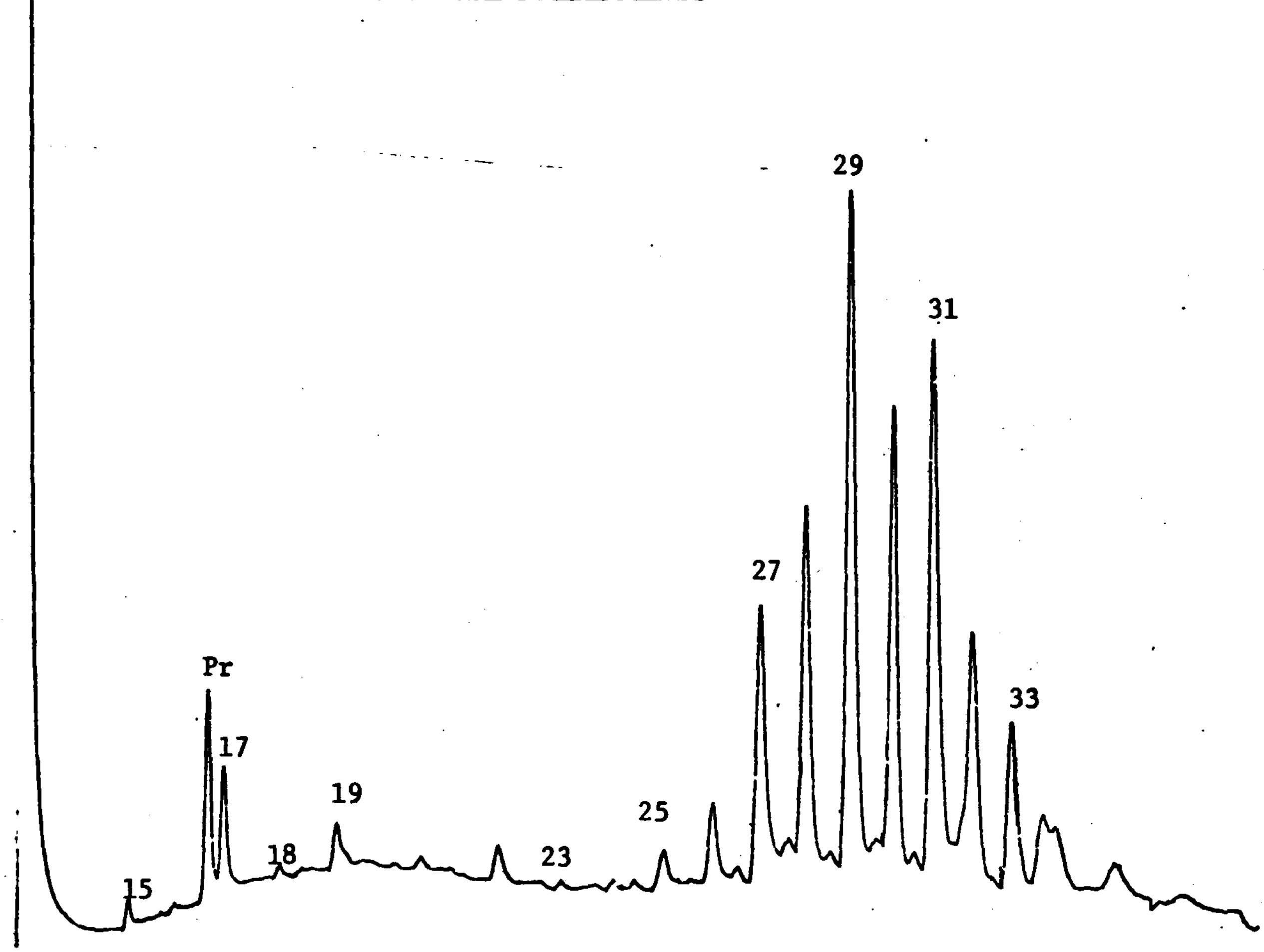

Figure 3. Gas Chromatogram of Hexane Eluate of Gulf Kingfish (*Menticirrhus americanus*) Extract on 5% FFAP.

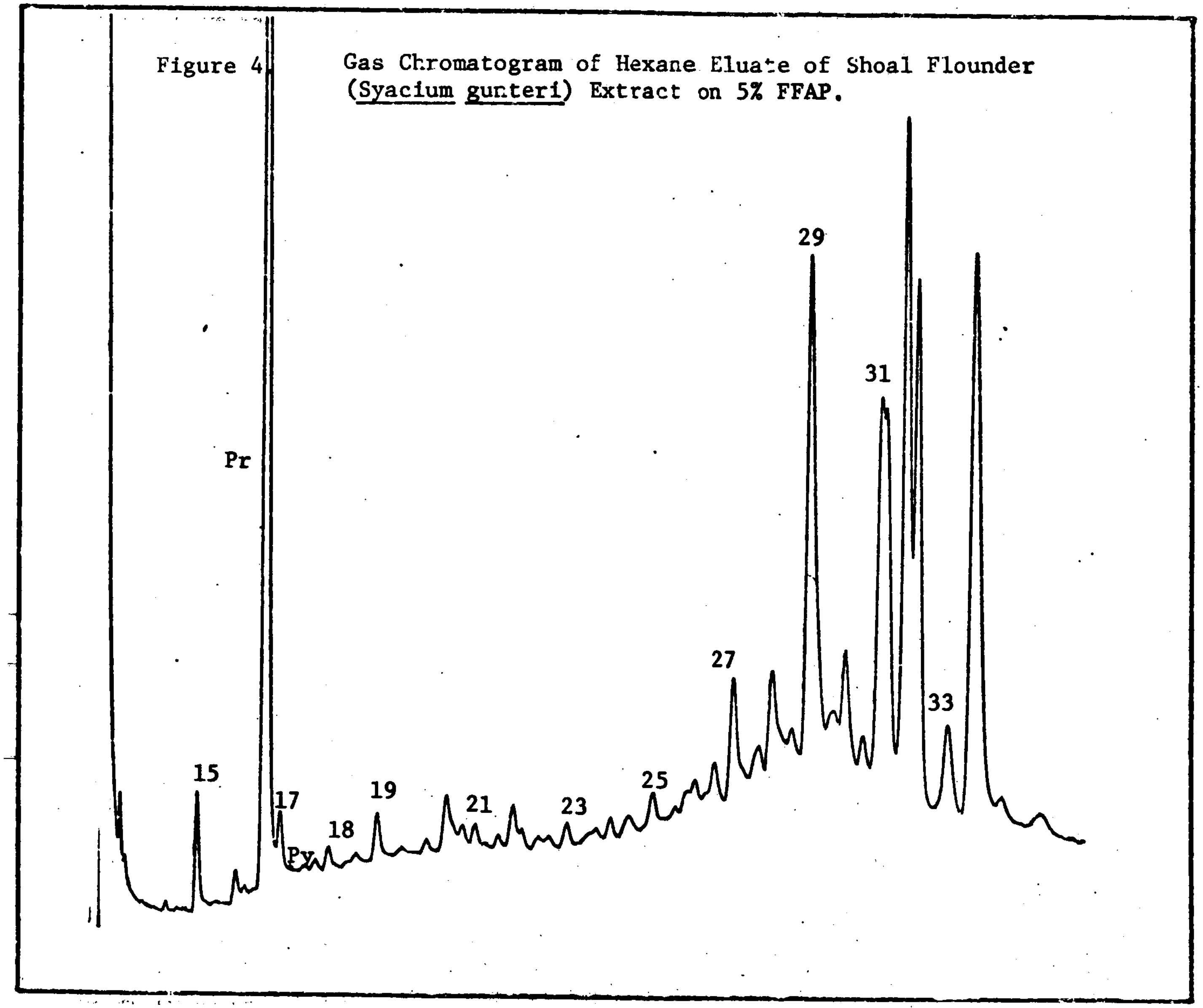

Figure 4. Gas Chromatogram of Hexane Eluate of Shoal Flounder (*Syacium gunteri*) Extract on 5% FFAP.

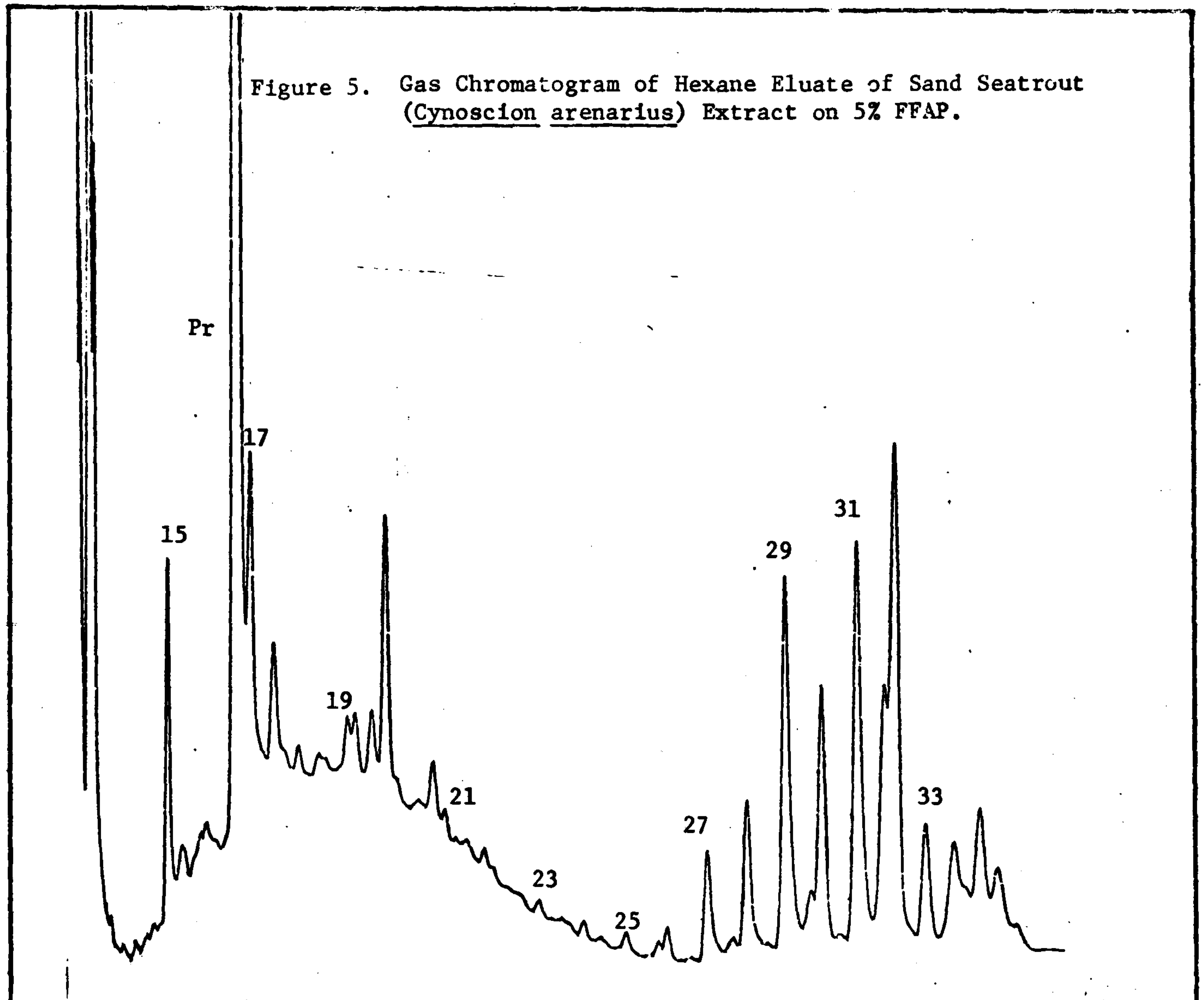

Figure 5. Gas Chromatogram of Hexane Eluate of Sand Seatrout (*Cynoscion arenarius*) Extract on 5% FFAP.

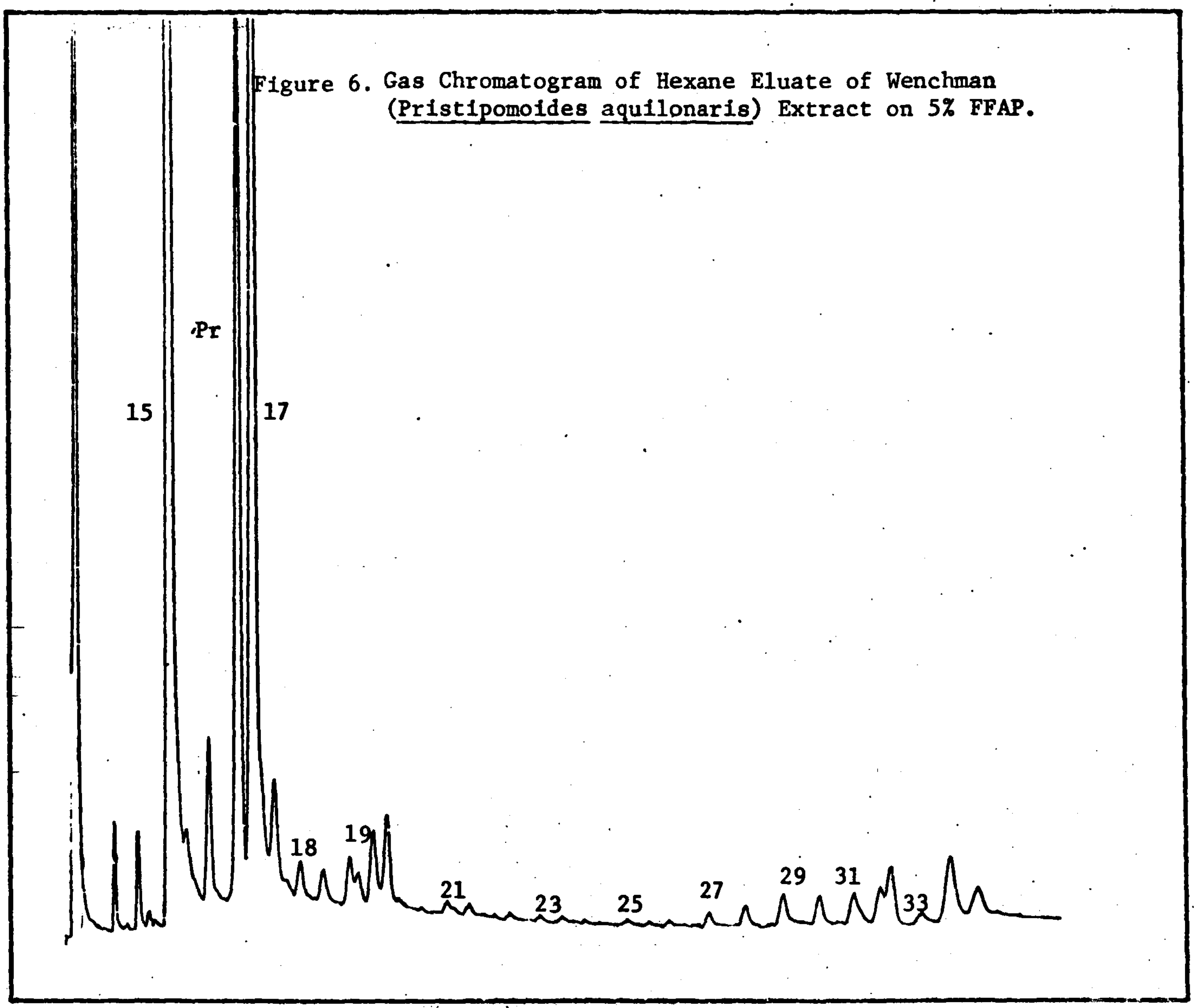

Figure 6. Gas Chromatogram of Hexane Eluate of Wenchman (Pristipomoides aquilonaris) Extract on 5% FFAP.

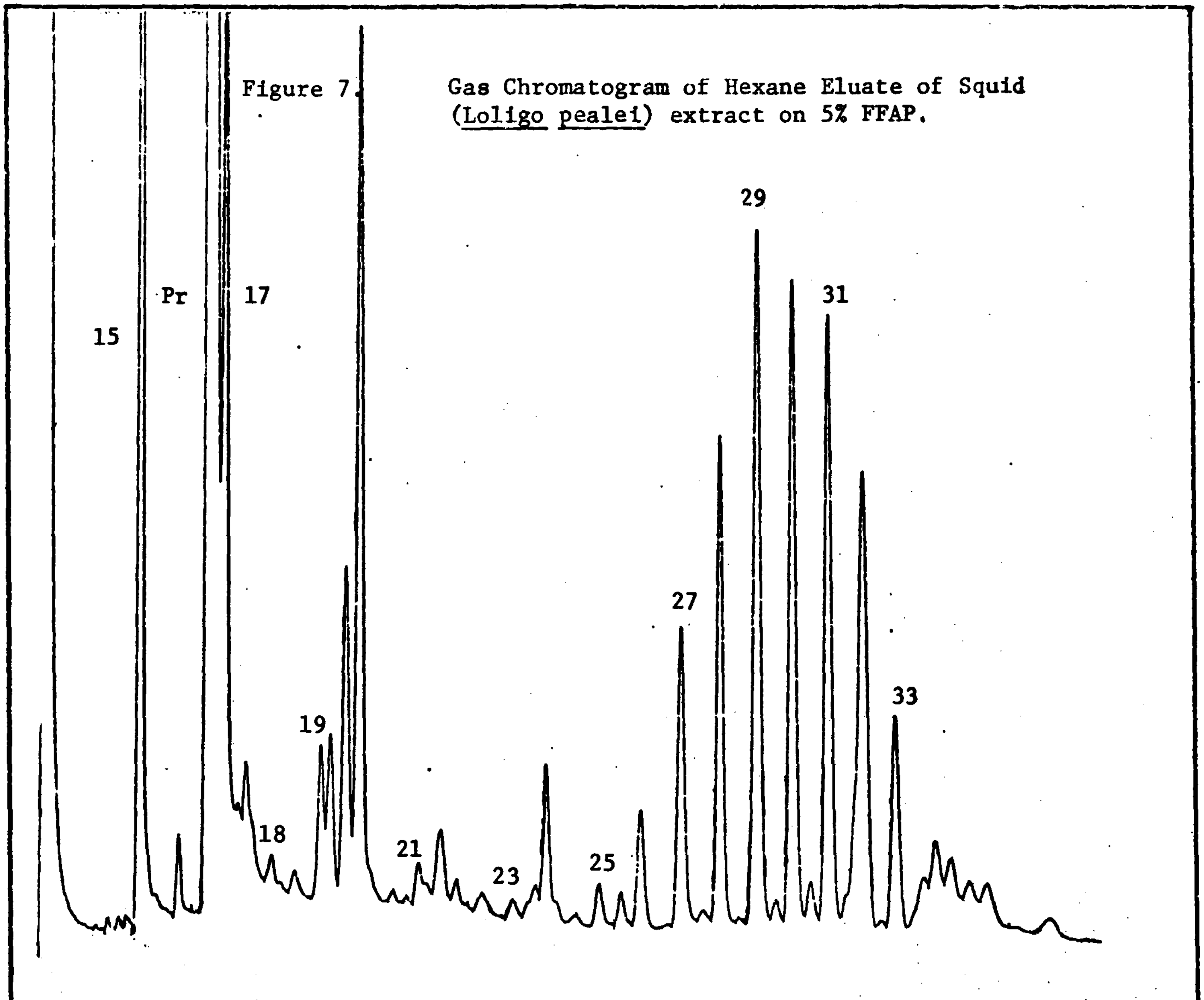

Figure 7. Gas Chromatogram of Hexane Eluate of Squid (*Loligo pealei*) extract on 5% FFAP.

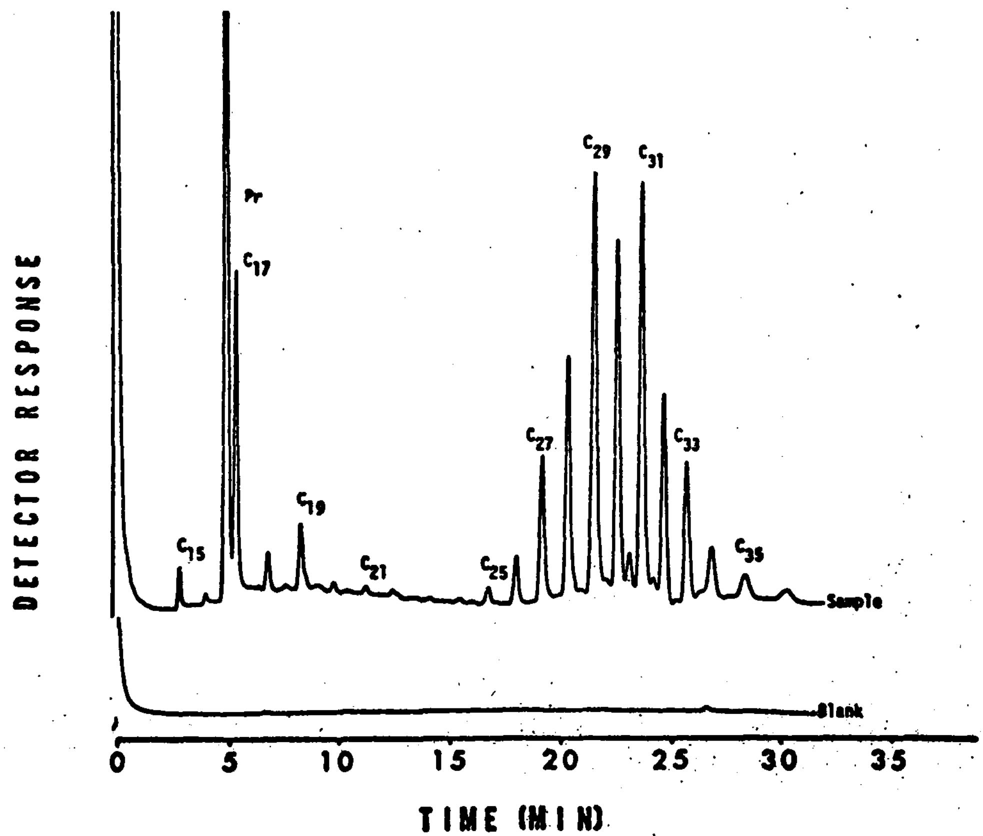

Figure 8. Gas Chromatogram of Hexane eluate of Sand Trout (B38C) extract (n-paraffins) on 5% FFAP.

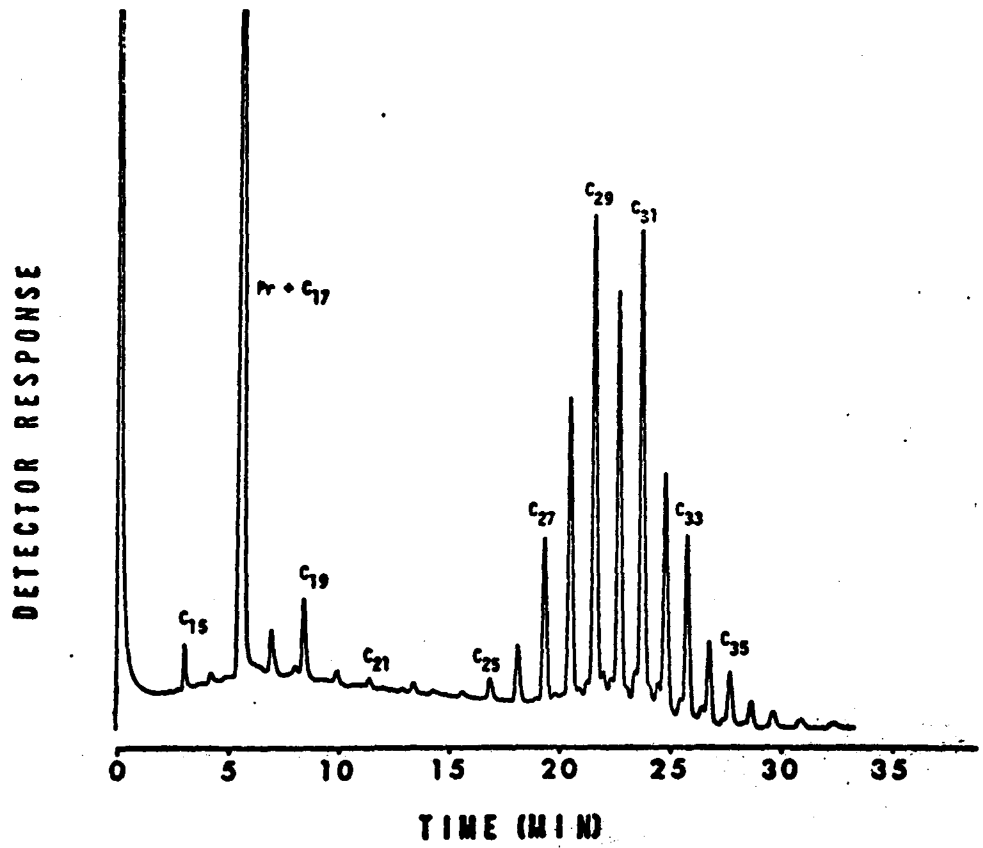

Figure 9. Gas Chromatogram of Hexane eluate of Sand Trout (B38C) extract (n-paraffin) on 3% SE-30.

the proposed procedure were made in accordance with findings reported after the initiation of the project. Originally, an extraction method utilizing a Soxhlet apparatus was used; it was to be followed by alkaline hydrolysis. However, a report that digestion of tissue samples with alcoholic potassium hydroxide produced hydrocarbon recoveries comparable to the Soxhlet-hydrolysis method led us to evaluate that method (Farrington and Medeiros, 1975). The use of methanolic potassium hydroxide in our labs was found to be as efficient and much less time consuming and was thus adopted for these analyses. Also, column chromatography using a combined deactivated silica gel-alumina column was initially proposed. However, a column of only activated silica gel was reported to yield adequate resolution of aliphatic from aromatic and olefinic compounds (Warner, 1975). This column material was found by us to have the desired properties and was used in the analyses.

Gas chromatography was used to quantitate the hydrocarbons present. Using the conditions described, the calibration curve shown in Figure 10. was determined. As opposed to a previous report (Clark, 1974), a decline in sensitivity with increasing molecular weight of the hydrocarbons was not observed. However, this decreasing sensitivity was noted if the detector was allowed to become contaminated. The use of both FFAP and SE-30 columns not only provided confirmation of the compounds; SE-30 provided better quantitation of the higher n-paraffins while FFAP yielded a quantitatable separation of the n-C_{17} hydrocarbon and pristane (Compare Figures 2 - 9). (In addition, 10% of the samples were submitted to Dr. Parker for further confirmation using gas chromatography-mass spectrometry.)

The results of our analyses are tabulated in Tables 1-9. The

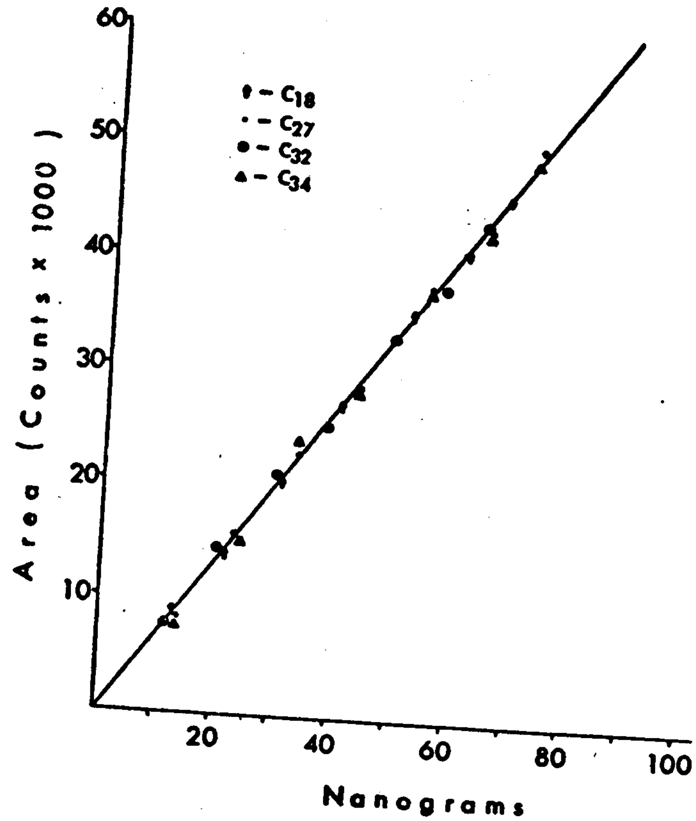

Figure 10. Calibration Curve

species available varied considerably between stations and sampling periods and statistical analysis of the data could not be performed. However, inspection of the data allowed several conclusions to be drawn. No trends in hydrocarbon concentrations between stations were noted. Also, no evidence of petroleum contamination of the organisms was noted; samples had odd/even ratios characteristic of biogenic hydrocarbons and very little phytane. Pristane was present in all samples in relatively high concentrations.

Although the data obtained did not indicate differences between sampling sites, valuable data on the heavy hydrocarbon composition of several species of benthic epifauna was observed. All of the organisms studied had relatively high concentrations of the C_{15} and C_{17} n-paraffins or of the C_{31} compound or both. (Pristane was present in all samples in high concentrations and was not included in these results.) Shrimp were unique with respect to the C_{15} and C_{17} paraffins; these were the hydrocarbons which were absent or in very low concentrations in shrimp but were present in the highest amounts in the other species studied. In squid, C_{17} was generally found in higher concentrations than the C_{15} n-paraffin while C_{15} dominated in fish; however, these ratios did vary or invert for some individual samples and at present, the reasons for these variations (seasonal, physiological, etc.) are not available. In contrast, all samples of wenchman exhibited a higher percentage of C_{15} than C_{17}.

The results of some of the analyses are plotted in Figure 11 as carbon number versus percent composition. The values plotted represent the highest and lowest % concentrations of the reported hydrocarbons (C_{14} -C_{34}) found in individual members of the species. By inspection of

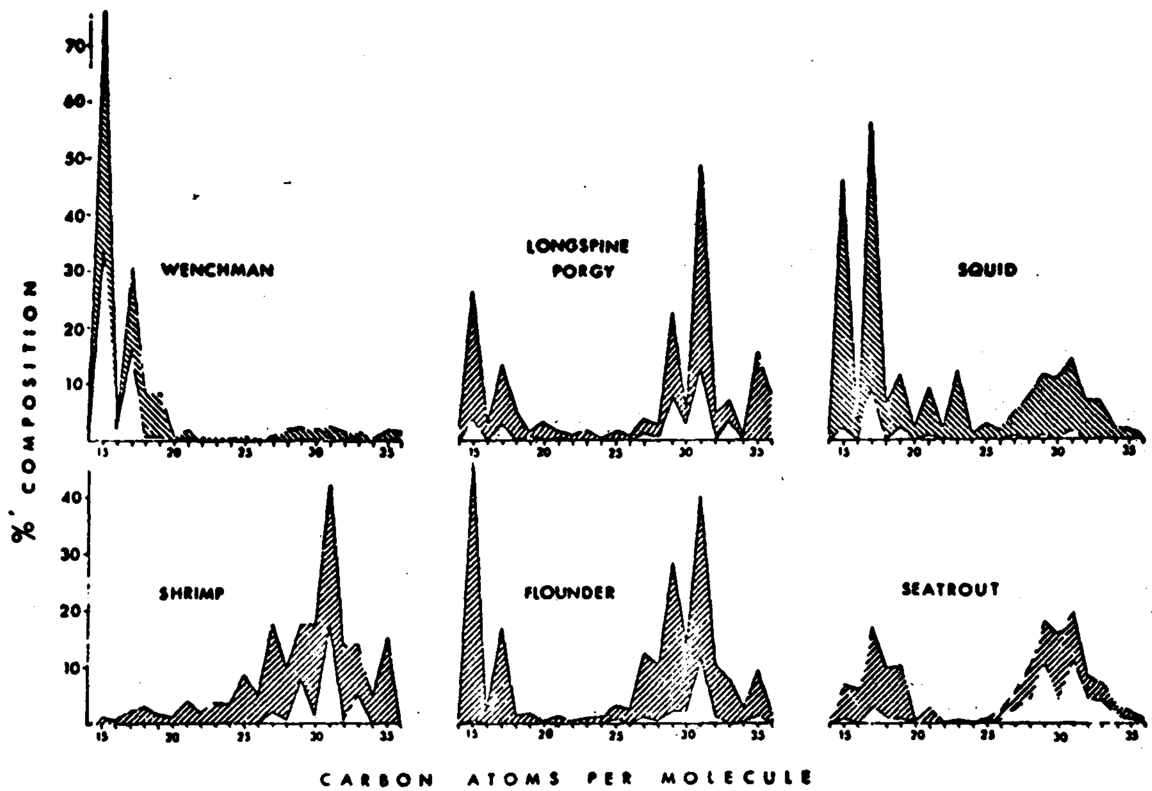

Figure 11. Hydrocarbon Distribution in Selected Benthic Organisms.

these figures, it can be seen that shrimp and wenchman samples had less variance in their hydrocarbon composition than did other species. These species thus provide the most promise as monitoring organisms as the baseline profiles could most readily be subtracted from future profiles to detect trace amounts of petroleum hydrocarbons.

SUMMARY

The analysis of 144 samples of benthic epifauna from the South Texas OCS for heavy hydrocarbons has been performed. The techniques used were based on gas chromatography and data was obtained on the percent distribution of the *n*-alkanes as well as on the total hydrocarbon concentration. The odd/even "carbon-ratios" of the hydrocarbon profiles, suggest that the hydrocarbons present in the benthic organisms were mainly of biogenic origin. Inspection of the data did indicate several features of the hydrocarbon distribution that are of importance to future studies. For example, the heavy aliphatic hydrocarbons appear to have distinct distributions or profiles within species. Although the ratios of various individual hydrocarbons may vary extensively between specimens, the profiles are relatively consistent and may be used as baseline profiles for the detection of petroleum contamination in future samples. Also, certain species, namely shrimp and wenchman, were found to have more consistent patterns than the other species analyzed.

CONCLUSIONS

Heavy petroleum hydrocarbons of anthropogenic origins were not indicated in 1974-75 samples of benthic epifauna from the South Texas OCS. However, the hydrocarbon composition obtained from the analyses of the various species has provided characteristic "baseline" profiles of hydrocarbon distribution for 1974-75. The profiles of several species, notably shrimp and wenchman, were subject to less intraspecies variation relative to the other species analyzed. Thus, the analysis of shrimp and wenchman samples would be emphasized in future studies to determine if the baseline profiles of petroleum hydrocarbons in benthic epifauna have changed.

The data in Tables 1 - 9 can be summarized as follows:

1. The 151 samples analyzed consisted of 39 shrimp, 16 wenchman, 23 squid, 12 flounder, 10 rough scad, 8 longspine porgy, 8 sea robin, 6 bass, 6 seatrout, 4 goatfish, 4 flatfish, 4 lizard fish and 11 miscellaneous of less than 3 specimens per species.

2. The levels of heavy aliphatic hydrocarbons vary from an average of 0.066 ppm for shrimp to 2.640 ppm for lizard fish.

3. Pristane/C_{17} ratios vary from an average of 0.4 in lizard fish to 32.5 in rough scad.

4. Phytane was found in only 11 of the 151 samples analyzed to concentrations of 0.001 to 0.196 ppm.

Table 1

WEIGHTS OF SPECIMENS ANALYZED AND DRY WEIGHT/WET WEIGHT CONVERSION FACTORS

First Sampling

STATION	CODE	SAMPLE NAME	Sample Weight (wet)	dry weight / wet weight Conversion factor
1/I	AFM-EPI	*Cynoscion nothus* Silver sea trout	21.0	0.24
	AFM-EPI	*Stellifer lanceolatus* Star drum	7.0	0.26
	AHP-EPI	*Penaeus aztecus* Brown shrimp	17.2	0.24
	AHP-EPI	*Cynoscion nothus* Silver sea trout	34.0	0.24
2/I	ACV-EPI	*Syacium sp.* Flatfish	29.3	0.25
	ACV-EPI	*Penaeus aztecus* Brown shrimp	20.0	0.24
	AFE-EPI	*Lutjanus campechanus* Carribbean red snapper	16.5	0.28
	AFE-EPI	*Loligo pealei* Squid	10.5	0.28
3/I	AAF-EPI	*Solenocera vioscі* Broken-back shrimp	5.0	0.24
	AAF-EPI	*Syacium sp.* Flatfish	22.5	0.25
	AAF-EPI	*Pristipomoides aquilonaris* Wenchman	46.3	0.22
	AAL-EPI	*Prionotus paralatus* Mexican sea robin	40.0	0.26
1/II	AIK-EPI	*Penaeus aztecus* Brown shrimp	12.0	0.24
	AIK-EPI	*Centropristis philadelphicus* Rock sea bass	24.5	0.26
	AJD-EPI	*Loligo pealei* Squid	26.6	0.28
	AJD-EPI	*Penaeus setiferus* White shrimp	18.0	0.25

Table 1. Cont.'d

STATION	CODE	SAMPLE NAME	Sample Weight (wet)	dry weight / wet weight Conversion factor
2/II	ALH-EPI	Loligo pealei Squid	22.8	0.28
	AME-EPI	Syacium sp. Flatfish	50.0	0.25
	AME-EPI	Squilla sp. Mantis shrimp	15.2	0.23
	AME-EPI	Penaeus aztecus Brown shrimp	44.0	0.24
3/II	AOK-EPI	Prionotus sp Sea robin	50.5	0.26
	APF-EPI	Trachurus lathami Rough scad	58.5	0.22
	APF-EPI	Pristipomoides aquilonaris Wenchman	50.8	0.26
	APF-EPI	Lopholalitus chameleonticeps Tile fish	63.5	0.26
1/III	ARN-EPI	Penaeus aztecus Brown shrimp	6.0	0.24
	ARN-EPI	Loligo pealei Squid	14.7	0.28
	ASH-EPI	Trachurus lathami Rough Scad	18.9	0.22
	ASH-EPI	Syacium sp. Flatfish	12.0	0.25
2/III	AUQ-EPI	Prionotus rubio Black-finned sea robin	41.5	0.26
	AUQ-EPI	Sicyonia dorsalis Rock shrimp	4.5	0.24
	AVM-EPI	Pristipomoides aquilonaris Wenchman	9.0	0.22
	AVM-EPI	Loligo pealei Squid	19.8	0.28
3/III	AXP-EPI	Prionotus paralatus Mexican sea robin	31.7	0.26

Table 1. Cont.'d

STATION	CODE	SAMPLE NAME	Sample Weight (wet)	dry weight / wet weight Conversion factor
3/III	AYJ-EPI	Pristipomoides aquilonaris Wenchman	67.8	0.22
	AYJ-EPI	Loligo pealei Squid	77.2	0.28
	AYJ-EPI	Trachurus lathami Rough scad	33.0	0.22
1/IV	BAN-EPI	Sicyonia brevirostrus Rock shrimp	19.6	0.24
	BBI-EPI	Penaeus aztecus Brown shrimp	29.6	0.24
	BBI-EPI	Trachurus lathami Rough scad	40.8	0.22
	BBI-EPI	Syacium papilosa Dusky flounder	55.5	0.26
2/IV	BDN-EPI	Penaeus aztecus Brown shrimp	32.2	0.24
	BDN-EPI	Centropristis philadelphicus Rock sea bass	68.8	0.24
	BEK-EPI	Loligo pealei Squid	74.1	0.28
	BEK-EPI	Trachurus lathami Rough scad	45.0	0.22
3/IV	BGO-EPI	Penaeus aztecus Brown shrimp	45.6	0.24
	BGO-EPI	Sicyonia brevirostrus Rock shrimp	34.5	0.26
	BPF-EPI	Upeneus parvus Dwarf goatfish	55.5	0.30
	BPF-EPI	Prionotus paralatus Mexican sea robin	50.5	0.26

Table 1. Cont.'d

Second Sampling

STATION	CODE	SAMPLE NAME	Sample Weight (wet)	dry weight / wet weight Conversion factor
1/I	CBC-EPI	*Penaeus setiferus* White shrimp	33.5	0.25
	CBC-EPI	*Cynoscion arenarius* Sand Seatrout	51.3	0.24
	CBC-EPI	*Urophyscis floridanus* Gulf Hake	53.5	0.26
	CAI-EPI	*Cynoscion arenarius* Sand Seatrout	59.5	0.24
	CAI-EPI	*Menticirrhus americanus* Gulf Kingfish	55.5	0.26
2/I	CEC-EPI	*Loligo pealei* Squid	68.0	0.28
	CEC-EPI	*Penaeus aztecus* Brown shrimp	29.0	0.24
	CDM-EPI	*Prionotus rubio* Black-finned sea robin	50.0	0.26
	CDM-EPI	*Syacium gunteri* Shoal flounder	52.0	0.25
3/I	CHM-EPI	*Pristipomoides aquilonaris* Wenchman	164.0	0.22
	CHM-EPI	*Prionotus paralatus* Mexican sea robin	52.0	0.26
	CGO-EPI	*Stenotomus caprinus* Longspine porgy	91.5	0.30
	CGO-EPI	*Penaeus aztecus* Brown shrimp	57.0	0.24
1/II	CKS-EPI	*Loligo pealei* Squid	56.0	0.28
	CJX-EPI	*Syacium gunteri* Shoal Flounder	48.0	0.25
	CJX-EPI	*Penaeus setiferus* White shrimp	40.0	0.25
	CJX-EPI	*Cynoscion arenarius* Sand seatrout	47.5	0.24
2/II	CNV-EPI	*Pristipomoides aquilonaris* Wenchman	52.5	0.22

Table 1. Cont.'d

STATION	CODE	SAMPLE NAME	Sample Weight (wet)	dry weight / wet weight Conversion factor
2/II	CNV-EPI	Loligo pealei Squid	61.0	0.28
	CNA-EPI	Penaeus aztecus Brown shrimp	44.0	0.24
	CNA-EPI	Syacium gunteri Shoal flounder	54.0	0.25
3/II	COX-EPI	Pristipomoides aquilonaris Wenchman	51.5	0.22
	COX-EPI	Loligo pealei Squid	50.0	0.28
	COC-EPI	Stenotomus caprinus Longspine porgy	51.0	0.30
	COC-EPI	Penaeus aztecus Brown shrimp	53.0	0.24
1/III	CUF-EPI	Syacium gunteri Shoal flounder	70.5	0.25
	CTJ-EPI	Penaeus aztecus Brown shrimp	42.6	0.24
	CTJ-EPI	Syacium gunteri Shoal Flounder	50.0	0.25
	CTJ-EPI	Squilla empusa Mantis shrimp	51.0	0.23
2/III	CYB-EPI	Stenotomus caprinus Longspine Porgy	54.5	0.30
	CYB-EPI	Loligo pealei Squid	57.0	0.28
	CXM-EPI	Penaeus aztecus Brown shrimp	35.5	0.24
	CXM-EPI	Penaeus aztecus Brown shrimp	20.6	0.24
3/III	DBD-EPI	Lagodon rhomboides Pinfish	50.0	0.26
	DBD-EPI	Stenotomus caprinus Longspine porgy	52.5	0.30
	DAK-EPI	Penaeus aztecus Brown shrimp	50.0	0.24

Table 1. Cont.'d

STATION	CODE	SAMPLE NAME	Sample Weight (wet)	dry weight / wet weight Conversion factor
3/III	DAK-EPI	*Pristipomoides aquilonaris* Wenchman	91.0	0.22
1/IV	DED-EPI	*Loligo pealei* Squid	62.0	0.28
	DED-EPI	*Trachurus lathami* Rough scad	60.5	0.22
	DDK-EPI	*Syacium gunteri* Shoal flounder	55.0	0.25
	DDK-EPI	*Sicyonia dorsalis* Rock shrimp	50.0	0.24
2/IV	DHC-EPI	*Syacium gunteri* Shoal flounder	61.0	0.25
	DGJ-EPI	*Penaeus aztecus* Brown shrimp	37.0	0.24
	DGJ-EPI	*Pristipomoides aquilonaris* Wenchman	50.0	0.22
	DGJ-EPI	*Loligo pealei* Squid	20.0	0.28
3/IV	DKH-EPI	*Syacium gunteri* Shoal flounder	50.0	0.25
	DKH-EPI	*Pristipomoides aquilonaris* Wenchman	46.9	0.22
	DJL-EPI	*Stenotomus caprinus* Longspine Porgy	51.3	0.30
	DJL-EPI	*Penaeus aztecus* Brown shrimp	35.0	0.24

Table 1. Cont.'d

Third Sampling

STATION	CODE	SAMPLE NAME	Sample Weight (wet)	dry weight / wet weight Conversion factor
1/I	EAI-EPI	_Leiostomus xanthurus_ Spot	47.2	0.26
	EAI-EPI	_Penaeus aztecus_ Brown shrimp	42.7	0.24
	EBC-EPI	_Loligo pealei_ Squid	51.1	0.28
	EBC-EPI	_Synodus foetens_ Lizard fish	55.0	0.27
2/I	EDM-EPI	_Solenocera vioscai_ Broken-back shrimp	38.6	0.26
	EDM-EPI	_Trachurus lathami_ Rough scad	46.0	0.22
	EDM-EPI	_Synodus foetens_ Inshore lizard fish	50.4	0.27
	EEC-EPI	_Sicyonia dorsalis_ Rock shrimp	48.7	0.24
	EEC-EPI	_Centropristis philadelphicus_ Rock sea bass	50.2	0.26
3/I	EGQ-EPI	_Pristipomoides aquilonaris_ Wenchman	51.0	0.22
	EGQ-EPI	_Serranus atrobranchus_ Black ear bass	48.3	0.26
	EGQ-EPI	_Stenotomus caprinus_ Longspine porgy	58.3	0.30
	EHM-EPI	_Syacium gunteri_ Shoal flounder	49.7	0.25
	EHM-EPI	_Pristipomoides aquilonaris_ Wenchman	50.4	0.22
	EHM-EPI	_Prionotus paralatus_ Mexican sea robin	37.6	0.26
1/II	EKS-EPI	_Chloroscombrus chrysurus_ Atlantic bumper	54.6	0.26
	EKS-EPI	_Lutjanus campechanus_ Red Snapper	37.9	0.28
	EKS-EPI	_Loligo pealei_ Squid	57.5	0.28

Table 1. Cont.'d

STATION	CODE	SAMPLE NAME	Sample Weight (wet)	dry weight / wet weight Conversion factor
	EKS-EPI	Cynoscion nothus Silver sea trout	58.0	0.24
2/II	ENA-EPI	Squilla chydaea Mantis shrimp	13.0	0.23
	ENA-EPI	Sicyonia dorsalis Rock shrimp	15.9	0.24
	ENW-EPI	Synodus foetens Inshore lizard fish	68.5	0.27
	ENW-EPI	Loligo pealei Squid	51.0	0.28
3/II	EQC-EPI	Stenotomus caprinus Longspine porgy	52.9	0.30
	EQX-EPI	Pristipomoides aquilonaris Wenchman	50.0	0.22
	EQX-EPI	Loligo pealei Squid	50.2	0.28
	EQX-EPI	Upeneus parvus Dwarf goat fish	50.6	0.30
1/III	ETJ-EPI	Syacium gunteri Shoal flounder	62.1	0.25
	EUF-EPI	Stellifer lanceolatus Star drum	55.0	0.27
	EUF-EPI	Loligo pealei Squid	50.3	0.28
	EUF-EPI	Penaeus aztecus Brown shrimp	50.0	0.24
2/III	EXM-EPI	Centropristis philadelphicus Rock sea bass	29.3	0.27
	EXM-EPI	Penaeus aztecus Brown shrimp	65.0	0.24
	EXM-EPI	Synodus foetens Inshore lizard fish	65.3	0.27
	EYB-EPI	Centropristis philadelphicus Rock sea bass	100.0	0.26

Table 1.- Cont.'d

STATION	CODE	SAMPLE NAME	Sample Weight (wet)	dry weight / wet weight Conversion factor
	EYB-EPI	Upeneus parvus Dwarf goat fish	51.5	0.29
3/III	FAK-EPI	Pristipomoides aquilonaris Wenchman	57.5	0.22
	FAK-EPI	Stenotomus caprinus Longspine porgy	109.5	0.30
	FAK-EPI	Penaeus aztecus Brown shrimp	70.0	0.24
	FBD-EPI	Pristipomoides aquilonaris Wenchman	61.8	0.22
	FBD-EPI	Loligo pealei Squid	78.3	0.28
1/IV	FDR-EPI	Penaeus duorarum Pink shrimp	85.0	0.25
	FDR-EPI	Syacium gunteri Shoal flounder	50.0	0.25
	FEL-EPI	Loligo pealei Squid	80.5	0.28
	FEL-EPI	Peprilus burti Butterfish	62.0	0.26
	FEL-EPI	Trachurus lathami Rough scad	49.0	0.22
2/IV	FGR-EPI	Penaeus aztecus Brown shrimp	63.0	0.24
	FHM-EPI	Upeneus parvus Dwarf goatfish	49.5	0.29
	FHM-EPI	Loligo pealei Squid	102.5	0.28
	FHM-EPI	Trachurus lathami Rough scad	50.0	0.22
3/IV	FJV-EPI	Penaeus aztecus Brown shrimp	70.0	0.24
	FJV-EPI	Loligo pealei Squid	72.8	0.28

Table 1. Cont.'d

STATION	CODE	SAMPLE NAME	Sample Weight (wet)	dry weight / wet weight Conversion factor
3/IV	FKR-EPI	Pristipomoides aquilonaris Wenchman	51.4	0.22
	FKR-EPI	Trachurus lathami Rough scad	53.8	0.22

Table 2

CONCENTRATIONS OF HEAVY HYDROCARBONS IN BENTHIC ORGANISMS FROM THE SOUTH TEXAS OCS

First Sampling

STATION	CODE	SAMPLE NAME	n-Alkane % composition x 10^{-5}	Aromatic Fraction wt % composition x 10^{-2}
1/I	AFM-EPI	*Cynoscion nothus* Silver sea trout	0.054	1.09
	AFM-EPI	*Stellifer lanceolatus* Star drum	≈0.015[b]	<0.10
	AHP-EPI	*Penaeus aztecus* Brown shrimp	0[a]	<0.06
	AHP-EPI	*Cynoscion nothus* Silver sea trout	1.070	0.53
2/I	ACV-EPI	*Syacium sp.* Flatfish	0.103	0.20
	ACV-EPI	*Penaeus aztecus* Brown shrimp	0.030	0.85
	AFE-EPI	*Lutjanus campechanus* Carribbean red snapper	0.175	15.88
	AFE-EPI	*Loligo pealei* Squid	0.226	38.95
3/I	AAF-EPI	*Solenocera viosci* Broken-back shrimp	≈0.060	<0.20
	AAF-EPI	*Syacium sp.* Flatfish	0.088	0.40
	AAF-EPI	*Pristipomoides aquilonaris* Wenchman	0.097	0.32
	AAL-EPI	*Prionotus paralatus* Mexican sea robin	1.315	0.40
1/II	AIK-EPI	*Penaeus aztecus* Brown shrimp	≈0.001	<0.08
	AIK-EPI	*Centropristis philadelphicus* Rock sea bass	0.228	0.20
	AJD-EPI	*Loligo pealei* Squid	0.108	0.22
	AJD-EPI	*Penaeus setiferus* White shrimp	0.0	<0.06

Table 2. Cont.'d

STATION	CODE	SAMPLE NAME	n-Alkane % composition x 10^{-5}	Aromatic Fractio wt % composition x 10^{-2}
2/II	ALH-EPI	Loligo pealei Squid	0.027	0.09
	AME-EPI	Syacium sp. Flatfish	0.115	0.08
	AME-EPI	Squilla sp. Mantis shrimp	≃0.010	<0.07
	AME-EPI	Penaeus aztecus Brown shrimp	≃0.008	<0.02
3/II	AOK-EPI	Prionotus sp. Sea robin	0.252	0.36
	APF-EPI	Trachurus lathami Rough scad	0.083	0.07
	APF-EPI	Pristipomoides aquilonaris Wenchman	0.622	0.29
	APF-EPI	Lopholatilus chameleonticeps Tile fish	0.045	0.30
1/III	ARN-EPI	Penaeus aztecus Brown shrimp	≃0.013	<0.17
	ARN-EPI	Loligo pealei Squid	0.295	0.95
	ASH-EPI	Trachurus lathami Rough Scad	0.048	0.16
	ASH-EPI	Syacium sp. Flatfish	≃0.010	<0.08
2/III	AUQ-EPI	Prionotus rubio Black-finned sea robin	0.097	0.89
	AUQ-EPI	Sicyonia dorsalis Rock shrimp	≃0.005	<0.22
	AVM-EPI	Pristipomoides aquilonaris Wenchman	0.632	1.78
	AVM-EPI	Loligo pealei Squid	0.028	0.51
3/III	AXP-EPI	Prionotus paralatus Mexican sea robin	0.350	0.22

Table 2. Cont.'d

STATION	CODE	SAMPLE NAME	n-Alkane % composition x 10^{-5}	Aromatic Fraction wt % composition x 10^{-2}
3/III	AYJ-EPI	Pristipomoides aquilonaris Wenchman	0.429	1.09
	AYJ-EPI	Loligo pealei Squid	0.144	0.13
	AYJ-EPI	Trachurus lathami Rough scad	0.243	0.03
1/IV	BAN-EPI	Sicyonia brevirostrus Rock shrimp	0.0	<0.05
	BBI-EPI	Penaeus aztecus Brown shrimp	0	<0.03
	BBI-EPI	Trachurus lathami Rough scad	0.246	0.20
	BBI-EPI	Syacium papilosa Dusky flounder	0.090	0.23
2/IV	BDN-EPI	Penaeus aztecus Brown shrimp	0.065	0.09
	BDN-EPI	Centropristis philadelphicus Rock sea bass	0.122	0.19
	BEK-EPI	Loligo pealei Squid	0.636	0.36
	BEK-EPI	Trachurus lathami Rough scad	0.407	0.18
3/IV	BGO-EPI	Penaeus aztecus Brown shrimp	0	<0.02
	BGO-EPI	Sicyonia brevirostrus Rock shrimp	0.656	1.28
	BPF-EPI	Upeneus parvus Dwarf goatfish	0.121	0.05
	BPF-EPI	Prionotus paralatus Mexican sea robin	1.075	0.46

(a) 0 indicates samples where hydrocarbons were not detected; the limit of detection was 0.5 ng. (i.e. $\leq$ 0.02 ppb, for a 30 gm sample).

(b) ≈ represents estimates because of the small quantities of sample available.

Table 2. Cont.'d

Second Sampling

STATION	CODE	SAMPLE NAME	n-Alkane % composition x 10^{-5}	Aromatic Fraction wt % composition x 10^{-2}
1/I	CBC-EPI	*Penaeus setiferus* White shrimp	0.072	1.10
	CBC-EPI	*Cynoscion arenarius* Sand Seatrout	0.449	24.09
	CBC-EPI	*Urophyscis floridanus* Gulf Hake	0.122	0.69
	CAI-EPI	*Cynoscion arenarius* Sand Seatrout	0.243	0.10
	CAI-EPI	*Menticirrhus americanus* Gulf Kingfish	0.426	0.14
2/I	CEC-EPI	*Loligo pealei* Squid	0.599	0.22
	CEC-EPI	*Penaeus aztecus* Brown shrimp	0.056	0.38
	CDM-EPI	*Prionotus rubio* Black-finned sea robin	0.137	26.94
	CDM-EPI	*Syacium gunteri* Shoal flounder	0.202	0.37
3/I	CHM-EPI	*Pristipomoides aquilonaris* Wenchman	2.863	0.09
	CHM-EPI	*Prionotus paralatus* Mexican sea robin	0.233	0.02
	CGO-EPI	*Stenotomus caprinus* Longspine porgy	0.197	0.33
	CGO-EPI	*Penaeus aztecus* Brown shrimp	0.164	0.37
1/II	CKS-EPI	*Loligo pealei* Squid	0.052	0.73
	CJX-EPI	*Syacium gunteri* Shoal Flounder	0.383	0.38
	CJX-EPI	*Penaeus setiferus* White shrimp	0.067	0.25
	CJX-EPI	*Cynoscion arenarius* Sand seatrout	0.657	0.55
2/II	CNV-EPI	*Pristipomoides aquilonaris* Wenchman	0.447	0.36

Table 2. Cont.'d

STATION	CODE	SAMPLE NAME	n-Alkane % composition x 10^{-5}	Aromatic Fraction wt % composition x 10^{-2}
2/II	CNV-EPI	Loligo pealei Squid	0.202	0.26
	CNA-EPI	Penaeus aztecus Brown shrimp	0.077	1.16
	CNA-EPI	Syacium gunteri Shoal flounder	0.400	0.07
3/II	COX-EPI	Pristipomoides aquilonaris Wenchman	2.488	9.61
	COX-EPI	Loligo pealei Squid	0.212	0.08
	COC-EPI	Stenotomus caprinus Longspine porgy	0.055	2.02
	COC-EPI	Penaeus aztecus Brown shrimp	0.050	0.02
1/III	CUF-EPI	Syacium gunteri Shoal flounder	0.246	0.01
	CTJ-EPI	Penaeus aztecus Brown shrimp	0.020	0.21
	CTJ-EPI	Syacium gunteri Shoal Flounder	0.219	0.02
	CTJ-EPI	Squilla empusa Mantis shrimp	0.069	0.10
2/III	CYB-EPI	Stenotomus caprinus Longspine Porgy	0.185	0.02
	CYB-EPI	Loligo pealei Squid	0.177	0.11
	CXM-EPI	Penaeus aztecus Brown shrimp	0.032	0.11
	CXM-EPI	Penaeus aztecus Brown shrimp	0.749	3.50
3/III	DBD-EPI	Lagodon rhomboides Pinfish	0.166	0.76
	DBD-EPI	Stenotomus caprinus Longspine porgy	0.565	0.69
	DAK-EPI	Penaeus aztecus Brown shrimp	0.022	0.60

Table 2. Cont.'d

STATION	CODE	SAMPLE NAME	n-Alkane % composition $\times 10^{-5}$	Aromatic Fraction wt % composition $\times 10^{-2}$
3/III	DAK-EPI	Pristipomoides aquilonaris Wenchman	1.126	0.03
1/IV	DED-EPI	Loligo pealei Squid	0.453	0.16
	DED-EPI	Trachurus lathami Rough scad	1.371	0.63
	DDK-EPI	Syacium gunteri Shoal flounder	0.456	0.38
	DDK-EPI	Sicyonia dorsalis Rock shrimp	0.055	7.82
2/IV	DHC-EPI	Syacium gunteri Shoal flounder	0.450	0.05
	DGJ-EPI	Penaeus aztecus Brown shrimp	0.022	0.24
	DGJ-EPI	Pristipomoides aquilonaris Wenchman	0.470	0.42
	DGJ-EPI	Loligo pealei Squid	0.035	0.25
3/IV	DKH-EPI	Syacium gunteri Shoal flounder	0.078	3.12
	DKH-EPI	Pristipomoides aquilonaris Wenchman	2.875	1.56
	DJL-EPI	Stenotomus caprinus Longspine Porgy	0.391	0.16
	DJL-EPI	Penaeus aztecus Brown shrimp	0.051	0.23

Table 2. Cont.'d

Third Sampling

STATION	CODE	SAMPLE NAME	n-Alkane % composition x 10^{-5}	Aromatic Fraction wt % composition x 10^{-2}
1/I	EAI-EPI	Leiostomus xanthurus Spot	0.1135	<0.02
	EAI-EPI	Penaeus aztecus Brown shrimp	0.0242	0.30
	EBC-EPI	Loligo pealei Squid	0.6513	0.10
	EBC-EPI	Synodus foetens Lizard fish	3.5210	<0.02
2/I	EDM-EPI	Solenocera vioscai Broken-back shrimp	0.1165	<0.03
	EDM-EPI	Trachurus lathami Rough scad	0.2674	<0.02
	EDM-EPI	Synodus foetens Inshore lizard fish	0.0563	<0.02
	EEC-EPI	Sicyonia dorsalis Rock shrimp	0.0528	<0.02
	EEC-EPI	Centropristis philadelphicus Rock sea bass	0.0637	<0.02
3/I	EGQ-EPI	Pristipomoides aquilonaris Wenchman	0.0699	0.31
	EGQ-EPI	Serranus atrobranchus Black ear bass	0.1030	0.25
	EGQ-EPI	Stenotomus caprinus Longspine porgy	0.524	0.15
	EHM-EPI	Syacium gunteri Shoal flounder	0.1764	0.12
	EHM-EPI	Pristipomoides aquilonaris Wenchman	0.3862	0.02
	EHM-EPI	Prionotus paralatus Mexican sea robin	0.0349	0.05
1/II	EKS-EPI	Chloroscombrus chrysurus Atlantic bumper	3.3090	0.04
	EKS-EPI	Lutjanus campechanus Red Snapper	0.5419	0.16
	EKS-EPI	Loligo pealei Squid	2.0860	<0.02

Table 2. Cont.'d

STATION	CODE	SAMPLE NAME	n-Alkane % composition $\times 10^{-5}$	Aromatic Fraction wt % composition $\times 10^{-2}$
	EKS-EPI	*Cynoscion nothus* Silver sea trout	0.8409	0.10
2/II	ENA-EPI	*Squilla chydaea* Mantis shrimp	0.0440	0.54
	ENA-EPI	*Sicyonia dorsalis* Rock shrimp	0.0181	<0.06
	ENW-EPI	*Synodus foetens* Inshore lizard fish	0.4859	0.01
	ENW-EPI	*Loligo pealei* Squid	0.9380	0.04
3/II	EQC-EPI	*Stenotomus caprinus* Longspine porgy	0.1140	0.02
	EQX-EPI	*Pristipomoides aquilonaris* Wenchman	0.8857	<0.02
	EQX-EPI	*Loligo pealei* Squid	0.1308	0.04
	EQX-EPI	*Upeneus parvus* Dwarf goat fish	0.4335	<0.02
1/III	ETJ-EPI	*Syacium gunteri* Shoal flounder	0.2587	0.16
	EUF-EPI	*Stellifer lanceolatus* Star drum	0.0602	<0.02
	EUF-EPI	*Loligo pealei* Squid	1.1207	0.08
	EUF-EPI	*Penaeus aztecus* Brown shrimp	0.0065	<0.02
2/III	EXM-EPI	*Centropristis philadelphicus* Rock sea bass	0.0173	0.20
	EXM-EPI	*Penaeus aztecus* Brown shrimp	0.0255	0.20
	EXM-EPI	*Synodus foetens* Inshore lizard fish	6.5023	0.02
	EYB-EPI	*Centropristis philadelphicus* Rock sea bass	0.0170	0.01

Table 2. Cont.'d

STATION	CODE	SAMPLE NAME	n-Alkane % composition x 10^{-5}	Aromatic Fraction wt % composition x 10^{-2}
	EYB-EPI	Upeneus parvus Dwarf goat fish	0.0572	<0.02
3/III	FAK-EPI	Pristipomoides aquilonaris Wenchman	0.0416	0.16
	FAK-EPI	Stenotomus caprinus Longspine porgy	0.1867	0.26
	FAK-EPI	Penaeus aztecus Brown shrimp	0.0260	0.76
	FBD-EPI	Pristipomoides aquilonaris Wenchman	0.1452	0.10
	FBD-EPI	Loligo pealei Squid	0.0201	0.01
1/IV	FDR-EPI	Penaeus duorarum Pink shrimp	0.0215	0.11
	FDR-EPI	Syacium gunteri Shoal flounder	0.3686	0.18
	FEL-EPI	Loligo pealei Squid	0.3052	<0.01
	FEL-EPI	Peprilus burti Butterfish	0.2132	0.06
	FEL-EPI	Trachurus lathami Rough scad	0.2460	0.35
2/IV	FGR-EPI	Penaeus aztecus Brown shrimp	<0.0100	0.14
	FHM-EPI	Upeneus parvus Dwarf goatfish	0.6472	0.53
	FHM-EPI	Loligo pealei Squid	0.2970	0.29
	FHM-EPI	Trachurus lathami Rough scad	0.2396	0.04
3/IV	FJV-EPI	Penaeus aztecus Brown shrimp	0.0287	0.14
	FJV-EPI	Loligo pealei Squid	0.0551	<0.01

Table 2. Cont.'d

STATION	CODE	SAMPLE NAME	n-Alkane % composition $\times 10^{-5}$	Aromatic Fraction wt % composition $\times 10^{-2}$
3/IV	FKR-EPI	<u>Pristipomoides aquilonaris</u> Wenchman	1.0090	0.16
	FKR-EPI	<u>Trachurus lathami</u> Rough scad	0.7284	3.14

Table 3.

Odd-Even Ratio Evaluations based on CPI* Values
(Carbon Preference Index)

CPI_{14-20} or CPI_{20-36} range	% Samples with CPI_{14-20}	% Samples with CPI_{20-36}
1 - 1.9	3.0	5.0
2 - 10	66.0	22.0
>10	31.0	73.0

*R. C. Clark, Jr. and J. S. Finley, Conference on Prevention and Control of Oil Pollution, 1973.

None of the above samples have both CPI_{14-20} and CPI_{20-36} in the low range of 1-1.9; suggesting that the hydrocarbons are probably biogenic. A small percentage (<5%) have either low CPI_{14-20} or CPI_{20-36}; this may be characteristic of the species. We hope to check this in later studies.

Table .4.

PERCENT DISTRIBUTION OF n-ALKANES IN BENTHIC ORGANISMS FROM THE SOUTH TEXAS OCS

FIRST SAMPLING

n-Hydrocarbons	Samples*						
	B1C	B2C	B4B	B4D	B5B	B5D	B7C
C-15					17.5		
C-16							
C-18							
C-19	10.9						
C-20						1.5	
C-21						1.0	4.2
C-22	1.9				1.7	1.7	
C-23	3.6	0.7	2.9		2.7	5.0	2.2
C-24	3.5		2.7		3.3	2.1	1.4
C-25	7.2		3.7		3.7	2.1	2.0
C-26	7.2		3.7		3.7	2.8	1.5
C-27	7.9	0.1	7.4	12.5	4.6	3.0	2.1
C-28	5.4	0.6	8.1	36.8	1.0		4.3
C-29	12.7	1.4	21.4	4.5	1.3	11.1	9.0
C-30	2.8		5.7			8.8	1.6
C-31	36.9	97.2	44.4	11.8	8.5	53.9	70.0
C-32						2.7	1.7
C-33				34.4	52.0	2.7	
C-34							
C-35						1.6	
TOTAL ppm	(0.054)	(1.07)	(0.103)	(0.030)	(0.175)	(0.226)	(0.088)

Table 4. Cont.'d

n-Hydrocarbons	Samples						
	B7D	B8B	B10D	B11A	B13D	B14B	B16C
C-15	21.7	0.4					
C-16	1.0	0.2					
C-18		0.2					
C-19		0.1	0.5		0.1		
C-20		0.1	0.4	3.3	1.1		
C-21		0.7	2.9	4.0	1.6	1.6	2.2
C-22	1.6	0.1	0.8	1.7	1.2		0.3
C-23	7.5	1.1	7.8	46.1	21.2		11.7
C-24		0.2	2.8	4.1	1.7		2.6
C-25		0.5	3.8	4.5	2.5	0.7	2.7
C-26		0.2	4.8	3.8	3.3	0.4	0.7
C-27		0.3	6.8	4.9	5.8	3.4	1.3
C-28		1.8	8.8	5.3	8.2	4.3	0.9
C-29		2.0	11.4	6.2	11.4	20.5	2.7
C-30		0.6	11.2	2.8	11.1	5.7	1.4
C-31	10.4	19.0	19.3	10.4	14.2	62.8	73.5
C-32		0.3	3.7	2.1	5.1	0.6	
C-33	57.8	72.2	15.0	0.8	6.5		
C-34					2.3		
C-35					2.5		
TOTAL ppm	(0.097)	(1.315)	(0.228)	(0.108)	(0.027)	(0.115)	(0.252)

Table 4. Cont.'d

n-Hydrocarbons	Samples						
	B17A	B17B	B17C	B19C	B20C	B22B	B23B
C-15		87.8					
C-16							
C-18	1.8						
C-19		2.0					
C-20	0.7					1.0	
C-21	11.6	0.8	3.9			33.6	1.5
C-22	2.5				1.8	1.6	0.6
C-23		3.0	13.6		19.1	6.8	5.2
C-24	4.0		2.1		3.4	4.7	1.8
C-25	9.4	0.1	1.1		5.2	6.0	2.3
C-26	3.2			3.2	4.4	6.2	1.9
C-27	3.6			9.1	6.9	5.3	1.9
C-28	3.1			16.2	1.5	7.4	1.1
C-29	3.4		1.2	26.1	1.6	6.2	1.1
C-30	2.3			15.3		6.4	1.2
C-31	41.7	0.2	10.3	17.8	12.8	11.1	9.5
C-32	2.2			8.1		3.7	0.3
C-33		6.1	28.8	4.2	43.3		70.3
C-34							
C-35	10.5		39.0				1.3
TOTAL ppm	(0.083)	(0.622)	(0.045)	(0.295)	(0.048)	(0.097)	(0.632)

Table 4. Cont.'d

n-Hydrocarbons	Samples							
	B23D	B25A	B26A	B26B	B26C	B29C	B29D	B31A
C-15		14.3	1.5	34.3		15.8		
C-16				2.2				
C-18				1.4				
C-19		0.2	1.8	3.5		0.3		
C-20				1.8				
C-21		0.9	0.9	6.8	7.1			2.0
C-22		0.2		4.0	0.3	0.2		0.6
C-23	25.4	21.9		18.5	24.5	24.1	1.4	2.2
C-24	7.2	0.8		0.3	0.7	0.9	1.5	2.2
C-25	8.3	0.9	0.2	12.1	4.2	1.0	2.1	2.9
C-26	5.8	0.5	0.1	0.8	1.0	0.5	4.2	1.2
C-27	6.6	1.1	0.2		1.6	1.2	8.2	3.9
C-28	3.4	0.4	1.1		0.7	0.5	14.0	2.3
C-29		1.9	1.2		5.2	2.1	21.2	3.9
C-30		0.7			0.8	0.8	18.4	1.2
C-31	43.3	56.2	93.0	5.1	53.5	52.6	16.9	20.8
C-32					0.3		5.8	
C-33				9.2			6.3	20.2
C-34								
C-35								36.6
TOTAL ppm	(0.028)	(0.350)	(0.429)	(0.144)	(0.243)	(0.246)	(0.090)	(0.065)

Table 4. Cont.'d

n-Hydrocarbons	Samples					
	B31B	B32C	B32D	B34C	B35C	B35D
C-15		57.9	44.4			
C-16						
C-18						
C-19		5.6			2.1	0.7
C-20						
C-21		1.1	5.5	0.7	2.0	0.2
C-22			0.2			0.1
C-23	21.6	6.9	14.3		6.2	0.5
C-24	1.5		0.7		0.8	0.1
C-25	2.8	0.6	1.8		2.6	0.2
C-26	2.3	1.4	0.6		3.4	0.4
C-27	5.4	2.8	2.2		6.1	0.9
C-28	7.9	5.0	2.6		9.0	1.3
C-29	9.6	5.3	4.2		11.7	2.3
C-30	7.9	4.2	2.9		9.8	1.8
C-31	37.8	0.9	19.0	99.3	16.5	90.9
C-32	3.2	6.1	1.6		4.3	0.6
C-33		1.4			25.5	
C-34		0.8				
C-35						
TOTAL ppm	(0.122)	(0.636)	(0.407)	(0.656)	(0.121)	(1.075)

*Listed according to TAMU Code; all numbers preceded by AMG, e.g. B1C is AMG B1C.

Table 5.

PERCENT DISTRIBUTION OF n-ALKANES IN BENTHIC ORGANISMS FROM THE SOUTH TEXAS OCS

SECOND SAMPLING

n-Hydrocarbons[1]	Samples*						
	B37A[2]	B37C	B37D	B38C	B38D	B39B	B39C
C-14						0.2	
C-15		1.8	0.3	0.8	0.5	19.5	
C-16		0.2	0.1	0.2	0.1	1.0	
C-17		2.7	1.6	9.1	6.8	14.0	
C-18	1.4	1.8	0.1	1.2	0.5	1.7	
C-19		0.5		2.1	0.9	2.5	
C-20				0.2		0.3	
C-21	1.4			0.1	0.2	1.0	
C-22						0.2	
C-23		0.5	0.4		0.1	0.5	
C-24	1.4	0.2			0.2	0.2	
C-25	2.8	0.9	0.8	0.4	1.4	0.6	
C-26	1.4	2.5	2.5	1.6	2.6	1.8	1.8
C-27	9.7	5.8	5.7	5.3	7.3	4.7	5.4
C-28	9.7	11.0	11.3	9.7	11.0	7.7	7.1
C-29	13.9	17.8	21.9	17.4	20.0	10.9	8.9
C-30	8.3	15.8	13.8	14.2	13.6	10.2	17.8
C-31	20.8	19.4	17.0	17.2	16.2	9.8	33.9
C-32	13.9	8.4	9.7	8.1	7.3	5.7	3.6
C-33	13.9	7.1	6.6	6.2	5.6	3.7	5.4
C-34		2.5	4.1	3.3	2.4	2.0	1.8
C-35	1.4	1.1	3.3	2.1	2.6	1.3	14.3
C-36			0.8	0.8	0.7	0.5	
TOTAL ppm	(0.072)	(0.449)	(0.122)	(0.243)	(0.426)	(0.599)	(0.056)

[1]Percentage Distribution; [2]AMG-Code

Table 5. Cont.'d

n-Hydrocarbons	Samples						
	B40B	B40C	B41A	B41B	B42B	B42C	B43B
C-14		0.1	0.4		1.0		
C-15	2.2	3.0	58.3	2.2	26.4		13.4
C-16	1.5	0.1	4.3	0.4	2.0	0.6	1.0
C-17	2.9		28.3	1.8	13.2		55.8
C-18	0.7		2.6	0.4	0.5	2.4	1.7
C-19	0.7	0.5	1.6	0.2	1.0	1.8	11.5
C-20			0.3		0.5	1.2	0.2
C-21	4.4	0.5	0.3	0.4	1.5	3.7	0.6
C-22		0.1	0.1	0.4	1.0		
C-23	0.7	0.1	0.1	0.4	1.0	3.7	
C-24	0.7	0.2	0.1	0.4	0.5	3.0	
C-25	2.2	2.0	0.1	0.9	1.5	4.3	
C-26		1.0	0.1	1.3		1.2	
C-27	5.8	1.0	0.2	4.0	1.5	9.8	1.2
C-28	6.6	0.5	0.3	4.0	1.0	3.0	1.2
C-29	12.4	26.0	0.8	14.8	7.6	16.5	3.8
C-30	10.2	11.6	0.5	8.0	3.6	2.4	3.8
C-31	33.0	31.0	0.7	45.4	23.5	39.1	5.8
C-32		4.5	0.4	4.0	4.6		
C-33	16.0	6.4	0.2	9.3	7.1	7.3	
C-34		2.0	0.2	1.3	1.0		
C-35		9.4	0.1	0.4			
C-36							
TOTAL ppm	(0.137)	(0.202)	(2.863)	(0.225)	(0.197)	(0.0164)	(0.052)

Table 5. Cont.'d

n-Hydrocarbons	Samples						
	B44A	B44B	B44D	B45A	B45B	B46C	B46D
C-14			0.3	0.4	0.5		
C-15	0.5	0.1	6.7	33.6	28.7	1.0	2.3
C-16	0.3		5.9	4.0	3.0	0.1	0.7
C-17			16.7	30.3	25.6		1.7
C-18	0.3	0.1	9.7	8.3	6.4	1.3	0.3
C-19	0.3	0.4	10.0	8.5	8.9		0.5
C-20	0.0	0.3		0.9	1.5		0.3
C-21	0.3	1.9	3.0	0.9	3.0	3.2	0.5
C-22	0.3	1.6		0.4	0.5	0.3	0.5
C-23	0.5	1.8	0.2	0.7	1.5	0.3	0.7
C-24	0.3	2.8	0.3	0.4	1.0	0.4	1.3
C-25	1.0	4.6	0.3	0.7	1.5	1.0	3.0
C-26	1.6	5.2	0.6	0.4		2.5	2.5
C-27	6.8	7.3	2.7	1.1	2.5	4.0	9.3
C-28	8.1	6.6	4.1	0.7	2.5	6.5	10.5
C-29	21.1	11.2	10.2	1.8	3.5	8.6	28.2
C-30	14.1	7.9	6.8	1.3	3.0	1.8	6.8
C-31	19.5	24.4	11.6	2.5	5.4	42.4	15.5
C-32	10.4	3.9	4.3	0.7		0.6	2.0
C-33	7.6	9.8	4.0	0.4	1.0	8.2	7.8
C-34	2.6	2.2	1.2	0.2		0.4	0.5
C-35	3.1	7.9	0.9	1.8		17.4	4.8
C-36	1.3		0.5				0.3
TOTAL ppm	(0.383)	(0.067)	(0.657)	(0.447)	(0.202)	(0.077)	(0.400)

Table 5. Cont.'d

n-Hydrocarbons	Samples							
	B47A	B47C	B48B	B48C	B49A	B50A	B50C	B50D
C-14	0.3							
C-15	64.5	12.4	3.6	0.4	27.7		3.2	
C-16	3.7	0.5		0.8	0.8		0.4	
C-17	22.0	9.4	7.2	1.0	16.6		0.1	1.5
C-18	2.3	0.9		1.0	0.4		0.9	
C-19	2.0	2.4	1.4	0.8	0.4		0.4	
C-20	0.4	0.5		0.6				
C-21	0.5	1.9	0.4	1.2				1.5
C-22	0.1	0.9		1.0				
C-23	0.3	2.8		1.0	0.4		0.9	1.5
C-24	0.2	0.9		0.8	0.4		1.4	1.5
C-25	0.2	1.9	0.7	1.4	0.8	5.0	3.2	8.6
C-26	0.1	1.9		0.4		5.0	2.3	2.8
C-27	0.3	4.2	3.6	2.0	4.1	10.0	12.3	17.4
C-28	0.3	7.0	0.5	2.0	3.7	5.0	9.1	10.2
C-29	0.6	11.4	22.5	8.8	13.4	15.0	25.6	17.5
C-30	0.5	10.8	2.9	5.6	8.1	5.0	8.7	2.8
C-31	1.0	12.4	48.6	23.4	11.4	25.0	21.5	17.5
C-32	0.1	7.0		4.2	3.7	15.0	2.7	2.8
C-33	0.4	6.1	5.0	11.8	4.9	5.0	3.2	11.5
C-34	0.1	2.4		1.4	1.2	5.0	0.9	1.4
C-35	0.1	1.4	3.6	15.2	2.0	5.0	3.2	1.5
C-36		0.9		15.2				
TOTAL ppm	(2.488)	(0.212)	(0.0555)	(0.050)	(0.246)	(0.020)	(0.219)	(0.069)

Table 5. Cont.'d

n-Hydrocarbons	Samples							
	B51A	B51C	B52A	B52AW	B53A	B53B	B54A	B54B
C-14	5.4				0.1	1.2		1.1
C-15	2.7	2.2	1.2	1.2	1.8	5.3	1.4	54.6
C-16	2.7	0.2		0.3	1.2	3.0	0.4	3.0
C-17	13.5	11.2		1.3	61.7	12.2		26.5
C-18	1.6	1.1	0.6	0.7	1.2	5.3	0.9	1.8
C-19	1.6	2.2		0.3	0.6	1.1	0.9	2.4
C-20	3.2	1.7		0.1	0.1	0.4		0.1
C-21	1.6	9.1		1.5	1.8	0.9	3.2	1.2
C-22		1.7			0.4	0.7	1.8	0.1
C-23	1.6	11.2		0.7	1.2	0.9	4.1	0.2
C-24		1.1		0.4	0.3	0.4	3.6	0.0
C-25	0.5	2.8		0.1	1.2	0.5	4.5	0.2
C-26		1.7			0.6		2.3	0.1
C-27	3.8	4.0	9.5	6.7	1.8	1.2	9.1	0.4
C-28	1.1	6.8	3.2	4.5	1.2	0.7	9.1	0.3
C-29	16.8	9.5	22.1	14.8	2.4	10.3	13.6	1.1
C-30	4.9	8.6	6.3	7.0	1.8	2.8	9.1	0.6
C-31	27.1	9.3	28.7	17.9	9.7	21.1	22.4	1.6
C-32	1.1	5.2	18.9	4.0		2.3		0.4
C-33	3.2	6.9	9.5	6.7	10.9	6.4	13.6	0.5
C-34		1.7		2.4		0.7		0.2
C-35	7.6	1.7		26.5		15.9		1.8
C-36				2.9		6.7		1.8
TOTAL ppm	(0.185)	(0.177)	(0.032)	(0.749)	(0.166)	(0.565)	(0.022)	(1.126)

Table 5. Cont.'d

n-Hydrocarbons	Samples							
	B55A	B55D	B56C	B56D	B57C	B58A	B58B	B58C
C-14	0.2	2.3	0.4		0.1		0.6	
C-15	45.8	64.2	46.6	0.5	20.0		47.6	20.0
C-16	2.0	3.5	2.2	0.4	0.9		1.9	
C-17	28.7	23.5	13.8	2.2	9.8		22.6	48.4
C-18	5.1		1.3	0.4	1.1		2.1	
C-19	6.4		1.8	0.4	1.8		4.5	2.9
C-20	0.7		0.4		0.2		0.4	
C-21	2.9		1.3	1.8	0.7		1.7	2.9
C-22	0.4		0.4	0.9			0.2	
C-23	1.1		0.7	2.0	0.4		0.6	
C-24	0.2	0.3	0.4	0.4	0.2		0.2	
C-25	0.4	0.3	0.9	1.8	0.9		0.6	
C-26	0.4	0.3	1.1		1.1	0.9	0.4	
C-27	0.7	0.5	1.5	6.0	5.3	6.5	0.9	2.9
C-28	0.7	0.6	1.3	4.4	4.9	0.9	2.1	
C-29	0.9	1.1	4.6	12.9	17.3	10.1	2.3	5.7
C-30	0.7	0.8	2.0	5.8	6.7	1.4	2.1	
C-31	1.6	1.5	13.8	32.4	20.5	65.9	4.3	14.3
C-32	0.7	0.5	1.1	5.5	2.2	8.3	1.5	
C-33	0.4	0.3		11.3	3.3	6.0	1.5	2.9
C-34		0.1	0.2	1.8	0.4		0.4	
C-35		0.2	2.9	9.1	2.2		1.5	
C-36			1.3					
TOTAL ppm	(0.453)	(1.371)	(0.456)	(0.055)	(0.450)	(0.022)	(0.470)	(0.035)

Table 5. Cont.'d

n-Hydrocarbons	Samples			
	B59A	B59B	B60A	B60D
C-14			2.8	
C-15	21.6	76.2	22.2	2.0
C-16	1.3	3.7	1.3	
C-17	0.0	16.2	8.2	
C-18		0.8	0.5	
C-19		0.8	0.8	
C-20		0.2	0.3	
C-21	0.5	0.6	1.5	
C-22			0.3	
C-23		0.2	0.8	
C-24			0.3	
C-25	1.3	0.1	0.5	
C-26			0.8	
C-27	2.6	0.1	1.8	3.9
C-28	2.6	0.1	2.6	5.9
C-29	12.8	0.2	8.4	7.8
C-30	9.0	0.1	5.4	11.8
C-31	39.0	0.5	12.7	39.2
C-32	2.6	0.1	3.6	23.5
C-33	5.1	0.1	3.6	5.9
C-34	0.3		1.0	
C-35	1.3		12.9	
C-36			7.7	
TOTAL ppm	(0.078)	(2.875)	(0.391)	(0.051)

Table 6.

PERCENT DISTRIBUTION OF n-ALKANES IN BENTHIC ORGANISMS FROM THE SOUTH TEXAS OCS

THIRD SAMPLING

n-Hydrocarbons	Samples							
	B61B	B61C	B62C	B62D	B63B	B63C	B63D	B64B
C-14			0.2	0.3		0.1	0.4	
C-15	1.8	8.3	36.2	57.0	1.7	61.0	51.4	3.8
C-16			2.8	3.0		5.2		
C-17	1.8	4.1	51.0	34.6	0.9		35.5	3.7
C-18	0.4	0.4	1.8	1.7			0.7	9.4
C-19	0.2		2.9	2.6		7.5	3.6	
C-20	0.1	0.8	0.7	0.3			0.2	
C-21	0.9	2.1	1.1		0.6	4.9	0.7	1.5
C-22		0.4	0.2					1.0
C-23	0.9		0.6		0.5	1.5	0.4	2.0
C-24	0.6		0.1		0.3		0.2	2.0
C-25			0.1		0.7	0.4	0.2	1.7
C-26	0.1			0.1				1.3
C-27	0.9	0.8	0.1	0.1	5.2	0.4		3.7
C-28	0.9	0.4	0.2		2.6	0.4	1.4	1.3
C-29	10.5	24.8	0.3		12.0	3.7	5.3	2.0
C-30	18.4	12.4	0.2		6.0	2.6		0.4
C-31	62.5	45.5			31.8	12.3		2.0
C-32								22.6
C-33			1.5	0.3	37.7			41.6
C-34								
C-35								
TOTAL ppm	(.1135)	(.0242)	(.6513)	(3.521)	(.1165)	(.2674)	(.0563)	(.0528)

Table 6. Cont.'d

n-Hydrocarbons	Samples							
	B64D	B65A	B65C	B65D	B66A	B66B	B66C	B68A
C-14						0.3		0.2
C-15	4.7	4.3	1.9	13.4	2.8	34.7	1.7	48.9
C-16	1.1	0.9		1.9	0.2	3.9		3.5
C-17	21.9	33.0	1.9		2.3	51.0	2.9	36.2
C-18	1.6	1.4	0.1	0.6	0.1	5.2		2.0
C-19	1.4	4.3	0.2		0.2	3.9		3.5
C-20								
C-21	0.6	1.4	0.2	1.7	0.6	0.5		1.1
C-22		0.7						0.6
C-23	1.3	1.4	0.6	5.7	1.1	0.5		0.7
C-24	0.3	1.0	0.6		0.3			0.1
C-25	0.5	1.1	0.5	1.1	0.6			0.1
C-26	0.5	0.9	0.8		0.1		2.0	0.1
C-27	0.5	1.0	1.0	1.9	1.7		5.7	0.2
C-28	1.3	1.4	7.8		2.8		1.7	0.1
C-29	7.9	8.6	12.6	17.2	19.8		5.7	0.5
C-30	9.4	14.3	9.7	0.6	12.5			0.2
C-31	47.0	24.3	34.9	45.8	54.9		22.9	1.0
C-32				0.6			57.4	
C-33			27.2	9.5				1.0
C-34								
C-35								
TOTAL ppm	(.0637)	(.0699)	(.1030)	(.0524)	(.1764)	(.3862)	(.0349)	(3.3090)

Table 6. Cont.'d

n-Hydrocarbons	Samples						
	B68B	B68C	B68D	B69B	B69D	B70A	B70C
C-14	0.2	0.2					0.4
C-15	28.0	41.3	31.3	13.6	22.0	10.2	58.8
C-16	1.1	2.9	3.0			1.9	3.6
C-17	21.3	35.1	42.9	9.1	16.6	64.9	19.1
C-18	0.9	3.5	4.9			4.5	1.8
C-19	1.3	5.8	6.4			10.5	1.6
C-20		1.7	1.4			1.9	
C-21	0.4	2.5	0.7			1.9	1.4
C-22		0.3					0.2
C-23		1.0	1.0		1.7	0.6	1.1
C-24							0.1
C-25	0.2	0.1	0.1			0.1	0.3
C-26					2.8		0.2
C-27	1.3	0.3	0.6	6.8	5.5	0.2	0.2
C-28	1.9	0.7	0.5	2.3	1.7		0.4
C-29	6.3	1.0	2.5	18.2	16.6		0.5
C-30	12.9	1.6	1.0	50.0	5.5	0.2	
C-31	10.5	1.0	2.4		11.1	0.8	10.3
C-32	5.0	0.1	1.3				
C-33	8.7	0.9			16.5	2.3	
C-34							
C-35							
TOTAL ppm	(.5419)	(1.043)	(0.8409)	(.0440)	(.0181)	(0.4859)	(.9380)

Table 6. Cont.'d

n-Hydrocarbons	Samples							
	B71D	B72A	B72C	B72D	B73C	B74B	B74C	B74D
C-14		0.1	0.5			5.0	0.3	
C-15	7.0	38.6	53.6	27.6	0.4		48.7	30.8
C-16	0.8		2.3	1.2	0.1	0.3	2.9	
C-17	17.5	53.3	23.8	14.1	0.8	15.0	37.2	30.8
C-18		3.4	1.5	0.7		0.3	2.0	
C-19	2.6	4.1	1.5			3.3	5.4	
C-20							0.9	
C-21	0.9	0.3	3.1	1.2		0.2	1.5	
C-22			0.5			1.0	0.2	
C-23	0.9	0.2	3.1	3.2		0.7	0.8	
C-24			0.6	0.1		0.2		
C-25	0.4			0.9	0.2			1.5
C-26			0.6	0.2	2.3	0.2		
C-27	1.8		1.5	1.4	6.2	0.3	0.1	6.2
C-28	0.6		0.6	0.5	10.4	1.2		
C-29	6.1		5.3	3.0	27.1	8.3		30.7
C-30	1.8			1.2	17.4	1.0		
C-31	18.4		1.5	8.5	16.2	34.8		
C-32	26.3			27.2	14.3			
C-33	14.9			9.0	4.6	28.2		
C-34								
C-35								
TOTAL ppm	(0.1140)	(0.8857)	(.1308)	(.4335)	(0.2587)	(.0602)	(1.1207)	(.0065)

Table 6. Cont.'d

n-Hydrocarbons	Samples							
	B75A	B75C	B75D	B76C	B76D	B77A	B77B	B77C
C-14			0.5				0.1	
C-15	11.6	3.9	65.3	29.4	33.1	9.6	3.8	3.9
C-16			2.7	4.7	1.8	1.7	0.3	
C-17	17.3	3.1	26.3	29.3	19.1	62.6	8.6	3.9
C-18			0.9	2.4	1.1	2.4	3.2	
C-19			3.0	2.4	1.8	7.2	4.8	
C-20			0.5		0.7			
C-21			0.5	1.2	1.8	0.5	8.6	
C-22								
C-23	1.7	1.6	0.2	1.8	1.8	0.5	8.0	
C-24	0.6	1.2		0.6	0.2	0.2		0.4
C-25	1.2	1.2		1.8	0.5	0.2	3.8	1.2
C-26	1.7					0.2		
C-27	3.5	2.8			0.7	1.0	2.7	1.9
C-28	0.6				0.7	0.2		0.8
C-29	11.6	11.8	0.1		0.2	1.2	16.0	61.4
C-30				2.9	1.6	0.5	4.8	
C-31	4.1	27.4		23.5	34.9	12.0	35.3	
C-32	28.8							3.5
C-33	17.3	47.0						23.0
C-34								
C-35								
TOTAL ppm	(.0173)	(.0255)	(6.5023)	(.0170)	(.0572)	(.0416)	(.1867)	(.0260)

Table 6. Cont.'d

n-Hydrocarbons	Samples							
	B78A	B78C	B79C	B79D	B80B	B80C	B80D	B81A
C-14	17.2				0.1	0.2	0.2	
C-15		4.5	4.7	1.9	41.0	41.7	57.7	
C-16	2.1	0.5		0.2		2.4	3.3	
C-17	55.8	24.8	4.7	2.4	38.3	37.1	30.1	
C-18	3.4	1.5	0.9		2.6	1.9	1.6	
C-19	4.8	4.0	0.9	0.5	5.2	10.8	4.1	
C-20					3.0	0.9		
C-21	0.5	5.0	2.8	1.1	5.9		0.8	for all <.0005 ppm
C-22		1.0			1.3		0.2	
C-23	0.5	5.0	1.4	1.1	2.0		1.6	
C-24	0.1	1.5	1.4		0.3			
C-25	0.3	2.5	1.9	1.4	0.3		0.4	
C-26	0.2	2.0	1.4	3.0				
C-27	0.5	4.5	4.2	10.0		0.4		
C-28	0.6	3.5	2.3	12.2		0.1		
C-29	0.2	4.0	14.0	29.4		1.4		
C-30	1.4	1.0	3.7	12.7		0.3		
C-31	12.4	34.7	23.2	11.9		0.9		
C-32			32.5	9.2		1.9		
C-33				3.0				
C-34								
C-35								
TOTAL ppm	(.1452)	(.0201)	(.0215)	(0.3686)	(.3052)	(0.2132)	(.2460)	(<.010)

Table 6. Cont.'d

n-Hydrocarbons	Samples						
	B82B	B82C	B82D	B83C	B83D	B84A	B84C
C-14	0.5		0.3			0.5	1.2
C-15	41.8	8.4	8.8	3.1	3.6	54.3	63.9
C-16	2.9	0.7	2.5		0.7	3.1	3.4
C-17	13.0	26.9	62.2	2.1	52.7	32.1	22.0
C-18	6.8	1.0	0.8		1.8	2.3	
C-19	9.7	5.4	7.5		14.5	3.9	1.9
C-20	18.7	0.7			0.2		
C-21			2.1		1.6	0.4	0.6
C-22							0.1
C-23	1.1	0.3	3.8	0.7	12.7	0.1	0.7
C-24		0.3		0.7			
C-25		0.3	0.8	0.7			0.1
C-26		0.7		0.7	0.4		0.1
C-27		3.7	0.4	3.5	7.3	0.2	0.3
C-28		0.7		1.4	0.7	0.2	0.1
C-29	1.1	0.7	0.4	7.0	3.6	0.4	1.2
C-30	0.7	1.7	0.4		0.2	1.3	1.1
C-31	1.1	10.4	2.9	27.9		0.6	
C-32	0.9	27.7	3.3			0.6	
C-33	1.7	10.4	3.8	52.2			3.3
C-34							
C-35							
TOTAL ppm	(0.6472)	(.2970)	(0.2396)	(.0287)	(.0551)	(1.0090)	(.7284)

Table 7.

CONCENTRATIONS OF HEAVY HYDROCARBONS IN BENTHIC ORGANISMS FROM THE SOUTH TEXAS OCS

FIRST SAMPLING

Location	Sample Number UTMSI Code	Sample Number TAMU Code	Sample Name	Hydrocarbon Concentration in ppm, wet weight
I-1	AFM-EPI	AMG B1C	Silver sea trout	0.054
	AFM-EPI	AMG B1D	Star drum	≈0.015[b]
	AHP-EPI	AMG B2A	Brown shrimp	0[a]
	AHP-EPI	AMG B2C	Silver sea trout	1.070
I-2	ACV-EPI	AMG B4B	Flatfish	0.103
	ACV-EPI	AMG B4D	Brown shrimp	0.030
	AFE-EPI	AMG B5B	Carribbean red snapper	0.175
	AFE-EPI	AMG B5D	Squid	0.226
I-3	AAF-EPI	AMG B7A	Broken-back shrimp	≈0.060
	AAF-EPI	AMG B7C	Flatfish	0.088
	AAF-EPI	AMG B7D	Wenchman	0.097
	AAL-EPI	AMG B8B	Mexican sea robin	1.315
II-1	AIK-EPI	AMG B10A	Brown shrimp	≈0.001
	AIK-EPI	AMG B10D	Rock sea bass	0.228
	AJD-EPI	AMG B11A	Squid	0.108
	AJD-EPI	AMG B11C	White Shrimp	0
II-2	ALH-EPI	AMG B13D	Squid	0.027
	AME-EPI	AMG B14B	Flatfish	0.115
	AME-EPI	AMG B14C	Mantis shrimp	≈0.010
	AME-EPI	AMG B14D	Brown shrimp	≈0.008

Table 7. Cont.'d

Location	Sample Number UTMSI Code	Sample Number TAMU Code	Sample Name	Hydrocarbon Concentration in ppm, wet weight
II-3	AOK-EPI	AMG B16C	Sea robin	0.252
	APF-EPI	AMG B17A	Rough scad	0.083
	APF-EPI	AMG B17B	Wenchman	0.622
	APF-EPI	AMG B17C	Tile fish	0.045
III-1	ARN-EPI	AMG B19B	Brown shrimp	≈0.013
	ARN-EPI	AMG B19C	Squid	0.295
	ASH-EPI	AMG B20C	Rough scad	0.048
	ASH-EPI	AMG B20D	Flatfish	≈0.010
III-2	AUQ-EPI	AMG B22B	Black-finned sea robin	0.097
	AUQ-EPI	AMG B22D	Rock shrimp	≈0.005
	AVM-EPI	AMG B23B	Wenchman	0.632
	AVM-EPI	AMG B23D	Squid	0.028
III-3	AXP-EPI	AMG B25A	Mexican sea robin	0.350
	AYJ-EPI	AMG B26A	Wenchman	0.429
	AYJ-EPI	AMG B26B	Squid	0.144
	AYJ-EPI	AMG B26C	Rough scad	0.243
IV-1	BAN-EPI	AMG B28A	Rock shrimp	0
	BBI-EPI	AMG B29B	Brown shrimp	0
	BBI-EPI	AMG B29C	Rough scad	0.246
	BBI-EPI	AMG B29D	Dusky flounder	0.090
IV-2	BDN-EPI	AMG B31A	Brown shrimp	0.065
	BDN-EPI	AMG B31B	Rock sea bass	0.122

Table 7. Cont.'d

Location	Sample Number UTMSI Code	TAMU Code	Sample Name	Hydrocarbon Concentration in ppm, wet weight
	BEK-EPI	AMG B32C	Squid	0.636
	BEK-EPI	AMG B32D	Rough scad	0.407
IV-3	BGO-EPI	AMG B34B	Brown shrimp	0
	BGO-EPI	AMG B34C	Rock shrimp	0.656
	BPF-EPI	AMG B35C	Dwarf goatfish	0.121
	BPF-EPI	AMG B35D	Mexican sea robin	1.075

(a) 0 indicates samples where hydrocarbons were not detected; the limit of detection was 0.5 ng. (i.e. $\leq$ 0.02 ppb, for a 30 gm samples).

(b) ≈ represents estimates because of the small quantities of sample available.

Table 8.

CONCENTRATIONS OF HEAVY HYDROCARBONS IN BENTHIC ORGANISMS FROM THE SOUTH TEXAS OCS

SECOND SAMPLING

Location	Sample Number UTMSI Code	Sample Number TAMU Code	Sample Name	Hydrocarbon Concentration in ppm, wet weight
I-1	CBC	AMG B37A	White shrimp	0.072
	CBC	AMG B37C	Sand Seatrout	0.449
	CBC	AMG B37D	Gulf Hoke	0.122
	CAI	AMG B38C	Sand Seatrout	0.243
	CAI	AMG B38D	Gulf Kingfish	0.426
I-2	CEC	AMG B39B	Squid	0.599
	CEC	AMG B39C	Brown shrimp	0.056
	CDM	AMG B40B	Black-finned sea robin	0.137
	CDM	AMG B40C	Shoal Flounder	0.202
I-3	CHM	AMG B41A	Wenchman	2.863
	CHM	AMG B41B	Mexican sea robin	0.233
	CGO	AMG B42B	Longspine Porgy	0.197
	CGO	AMG B42C	Brown shrimp	0.164
II-1	CKS	AMG B43B	Squid	0.052
	CJX	AMG B44A	Shoal Flounder	0.383
	CJX	AMG B44B	White shrimp	0.067
	CJX	AMG B44D	Sand Seatrout	0.657
II-2	CNV	AMG B45A	Wenchman	0.447
	CNV	AMG B45B	Squid	0.202
	CNA	AMG B46C	Brown shrimp	0.077

Table 8. Cont.'d

Location	Sample Number UTMSI Code	TAMU Code	Sample Name	Hydrocarbon Concentration in ppm, wet weight
	CNA	AMG B46D	Shoal Flounder	0.400
II-3	COX	AMG B47A	Wenchman	2.488
	COX	AMG B47C	Squid	0.212
	COC	AMG B48B	Longspine Porgy	0.0555
	COC	AMG B48C	Brown shrimp	0.050
III-1	CUF	AMG B49A	Shoal Flounder	0.246
	CTJ	AMG B50A	Brown shrimp	0.020
	CTJ	AMG B50C	Shoal Flounder	0.219
	CTJ	AMG B50D	Mantis shrimp	0.069
III-2	CYB	AMG B51A	Longspine Porgy	0.185
	CYB	AMG B51C	Squid	0.177
	CXM	AMG B52A	Brown shrimp	0.032
	CXM	AMG B52AW	Brown shrimp	0.749
III-3	DBD	AMG B53A	Pinfish	0.166
	DBD	AMG B53B	Longspine Porgy	0.565
	DAK	AMG B54A	Brown shrimp	0.022
	DAK	AMG B54B	Wenchman	1.126
IV-1	DED	AMG B55A	Squid	0.453
	DED	AMG B55D	Rough Scad	1.371
	DDK	AMG B56C	Shoal Flounder	0.456
	DDK	AMG B56D	Rock shrimp	0.055
IV-2	DHC	AMG B57C	Shoal Flounder	0.450

Table 8. Cont.'d

Location	Sample Number UTMSI Code	TAMU Code	Sample Name	Hydrocarbon Concentration in ppm, wet weight
	DGJ	AMG B58A	Brown shrimp	0.022
	DGJ	AMG B58B	Wenchman	0.470
	DGJ	AMG B58C	Squid	0.035
IV-3	DKH	AMG B59A	Shoal Flounder	0.078
	DKH	AMG B59B	Wenchman	2.875
	DJL	AMG B60A	Longspine Porgy	0.391
	DJL	AMG B60D	Brown shrimp	0.051

Table 9.

CONCENTRATIONS OF HEAVY HYDROCARBONS IN BENTHIC ORGANISMS FROM THE SOUTH TEXAS OCS

THIRD SAMPLING

Location	Sample Number UTMSI Code	Sample Number TAMU Code	Sample Name	Hydrocarbon Concentration in ppm, wet weight
I-1	EAI-EPI	AMG-B61B	Spot	0.1135
	EAI-EPI	AMG-B61C	Brown shrimp	0.0242
	EBC-EPI	AMG-B62C	Squid	0.6513
	EBC-EPI	AMG-B62D	Lizard fish	3.5210
I-2	EDM-EPI	AMG-B63B	Broken-back shrimp	0.1165
	EDM-EPI	AMG-B63C	Rough scad	0.2674
	EDM-EPI	AMG-B63D	Inshore lizard fish	0.0563
	EEC-EPI	AMG-B64B	Rock shrimp	0.0528
	EEC-EPI	AMG-B64D	Rock sea bass	0.0637
I-3	EGQ-EPI	AMG-B65A	Wenchman	0.0699
	EGQ-EPI	AMG-B65C	Black ear bass	0.1030
	EGQ-EPI	AMG-B65D	Longspine porgy	0.0524
	EHM-EPI	AMG-B66A	Shoal flounder	0.1764
	EHM-EPI	AMG-B66B	Wenchman	0.3862
	EHM-EPI	AMG-B66C	Mexican sea robin	0.0349
II-1	EKS-EPI	AMG-B68A	Atlantic bumper	3.3090
	EKS-EPI	AMG B68B	Red Snapper	0.5419
	EKS-EPI	AMG-B68C	Squid	2.0860

Table 9. Cont.'d

Location	Sample Number UTMSI Code	TAMU Code	Sample Name	Hydrocarbon Concentration in ppm, wet weight
II-1	EKS-EPI	AMG-B68D	Silver sea trout	0.8409
II-2	ENA-EPI	AMG-B69B	Mantis shrimp	0.0440
	ENA-EPI	AMG-B69C	Rock shrimp	0.0181
	ENW-EPI	AMG-B70A	Inshore lizard fish	0.4859
	ENW-EPI	AMG-B70C	Squid	0.9380
II-3	EQC-EPI	AMG-B71D	Longspine porgy	0.1140
	EQX-EPI	AMG-B72A	Wenchman	0.8857
	EQX-EPI	AMG-B72C	Squid	0.1308
	EQX-EPI	AMG-B72D	Dwarf goat fish	0.4335
III-1	ETJ-EPI	AMG-B73C	Shoal flounder	0.2587
	EUF-EPI	AMG-B74B	Star drum	0.0602
	EUF-EPI	AMG-B74C	Squid	1.1207
	EUF-EPI	AMG-B74D	Brown shrimp	0.0065
III-2	EXM-EPI	AMG-B75A	Rock sea bass	0.0173
	EXM-EPI	AMG-B75C	Brown shrimp	0.0255
	EXM-EPI	AMG-B75D	Inshore lizard fish	6.5023
	EYB-EPI	AMG-B76C	Rock sea bass	0.0170
	EYB-EPI	AMG-B76D	Dwarf goat fish	0.0572
III-3	FAK-EPI	AMG-B77A	Wenchman	0.0416
	FAK-EPI	AMG-B77B	Longspine porgy	0.1867
	FAK-EPI	AMG-B77C	Brown shrimp	0.0260
	FBD-EPI	AMG-B78A	Wenchman	0.1452

Table 9. Cont.'d

Location	Sample Number UTMSI Code	Sample Number TAMU Code	Sample Name	Hydrocarbon Concentration in ppm, wet weight
	FBD-EPI	AMG-B78C	Squid	0.0201
IV-1	FDR-EPI	AMG-B79C	Pink shrimp	0.0215
	FDR-EPI	AMG-B79D	Shoal flounder	0.3686
	FEL-EPI	AMG-B80B	Squid	0.3052
	FEL-EPI	AMG-B80C	Butterfish	0.2132
	FEL-EPI	AMG-B80D	Rough scad	0.2460
IV-2	FGR-EPI	AMG-B81A	Brown shrimp	<0.0100
	FHM-EPI	AMG-B82B	Dwarf goatfish	0.6472
	FHM-EPI	AMG-B82C	Squid	0.2970
	FHM-EPI	AMG-B82D	Rough scad	0.2396
IV-3	FJV-EPI	AMG-B83C	Brown shrimp	0.0287
	FJV-EPI	AMG-B83D	Squid	0.0551
	FKR-EPI	AMG-B84A	Wenchman	1.0090
	FKR-EPI	AMG-B84C	Rough scad	0.7284

HEAVY HYDROCARBON PROJECT

Water, Zooplankton, Neuston and Sediment

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INTRODUCTION

Analyses have been completed for all samples taken for heavy hydrocarbon determination. These include seawater, neuston, zooplankton, sediment and macronekton taken from the topographic highs of the area. The chemical analyses in this first study have been focused on normal alkanes and isoprenoid hydrocarbons. Non-saturated hydrocarbons were present in some samples, especially zooplankton, but were natural products rather than aromatic from petroleum.

The striking thing about the study is the very low level of petroleum type hydrocarbon present in the various samples from the study area. This is useful information for two reasons; first the collections are clean and uncontaminated and second the study area is virgin and suitable for future studies designed to measure the impact of oil drilling and production.

The odd/even preference of normal alkanes as expressed by the OEP method (see following) has been found to be useful in the few cases where petroleum presence is suspected. Nevertheless, this type of study remains difficult and not suited to routine treatment; in a sense each sample is different.

Detailed presentations of methods, results and discussions are given in the following sections.

ANALYTICAL INSTRUMENTATION

Gas chromatography of heavy hydrocarbon samples utilized either a PERKIN-ELMER model 900 or a HEWLETT-PACKARD model 7620A chromatograph. Both instruments are equipped for a dual column operation with flame ionization detectors and electronic integrators. Routine analyses were conducted on 1/8" x 6' stainless steel columns of 5% FFAP on 80/100 mesh GAS CHROM Q (3% APIEZON L was used for a few early water samples). Oven temperature was programmed from 80° to 270°C at 6° per minute. Combined gas chromatography-mass spectrometry (GC-MS) was carried out with a VARIAN 2700 chromatograph interfaced to a DUPONT 21-491 mass spectrometer. The column and conditions used during GC-MS analysis were similar to those described for GC analysis. GC-MS analysis for identification and/or confirmation was undertaken on more than 10% of the samples. Mass spectra obtained from the samples were compared with spectra published in the Registry of Mass Spectral Data (1974) and with mass spectra taken of authentic, known compounds. Some spectra were processed through the Mass Spectral Data Base, MSSS, of the Environmental Protection Agency and the National Institutes of Health maintained on the "Cybernetics" time-sharing computer.

Table 1 lists samples processed by GC-MS along with components confirmed or identified using this procedure. A few representative gas chromatograms and mass spectra are included as Figures 1 - 6.

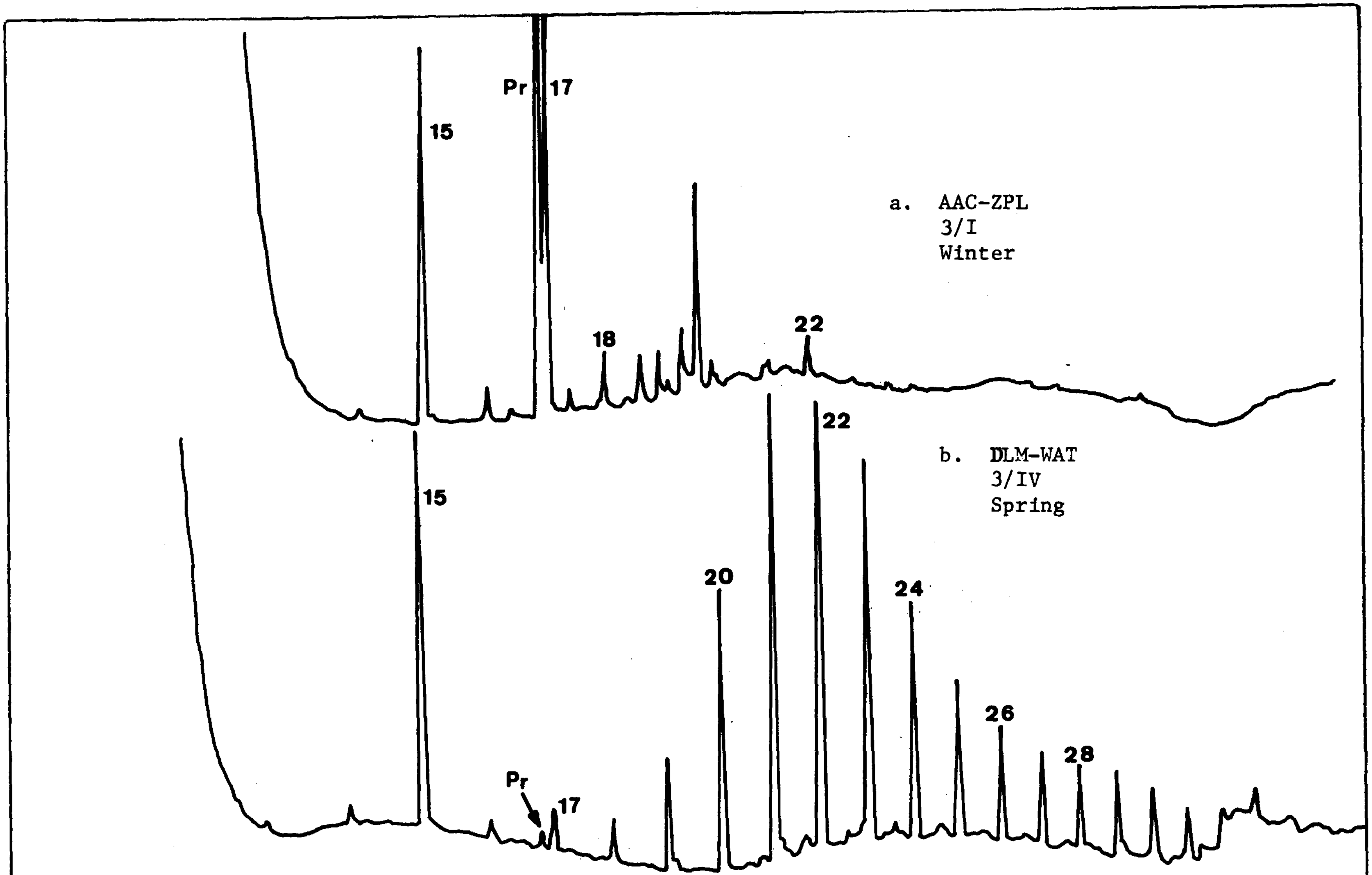

Figure 1. Gas chromatograms, hexane fraction, a. zooplankton, b. water.

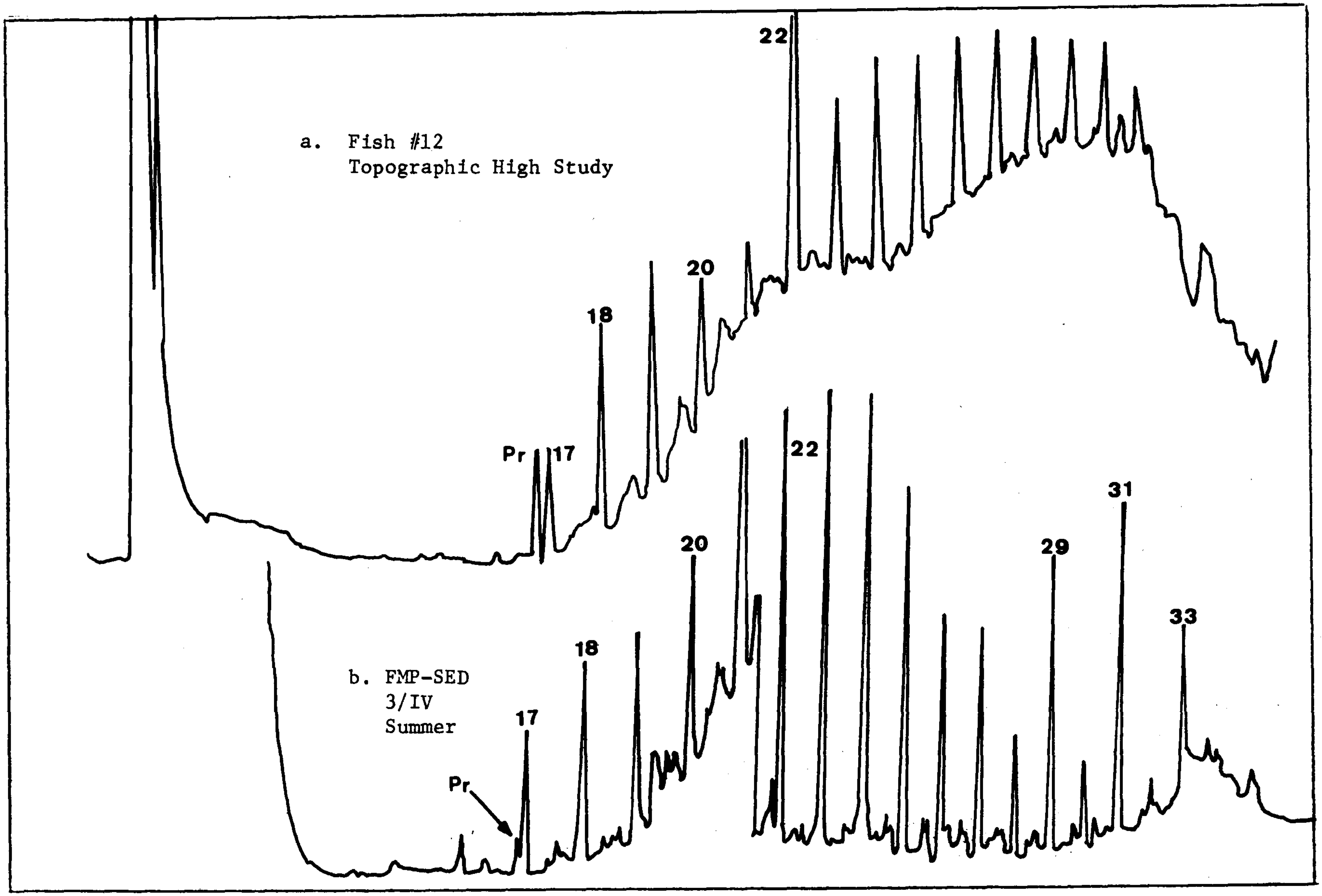

Figure 2. Gas chromatograms, hexane fraction, a. fish, b. sediment.

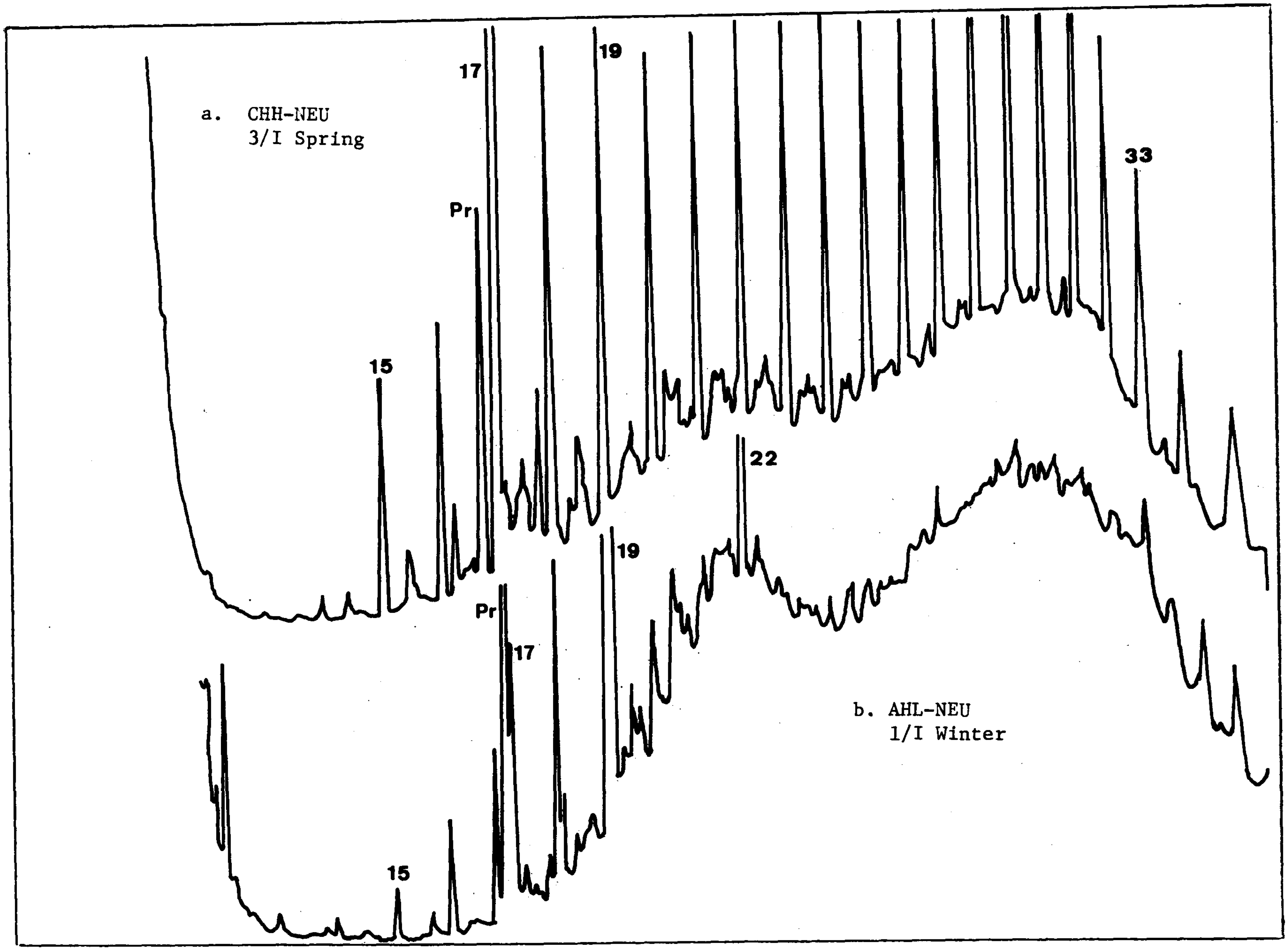

Figure 3. Gas chromatograms, hexane fraction, neuston.

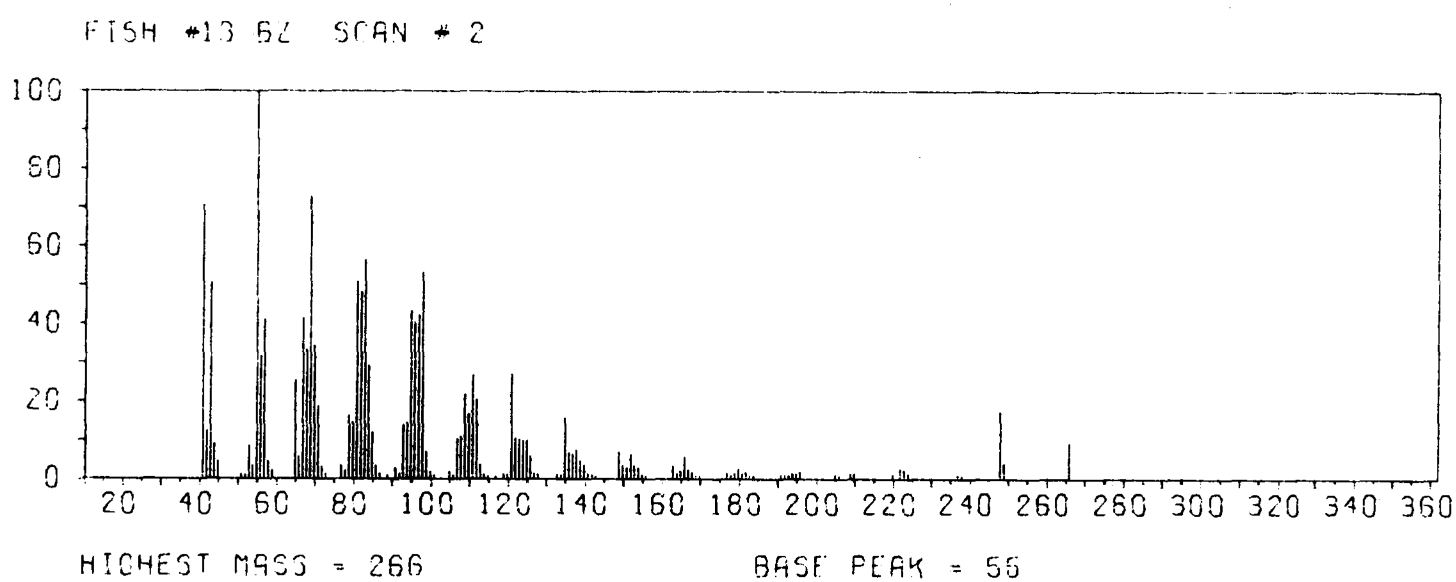

Figure 4. Mass Spectra of $C_{19:1}$, Benzene Fraction Component, Fish #13, Topographic High Study.

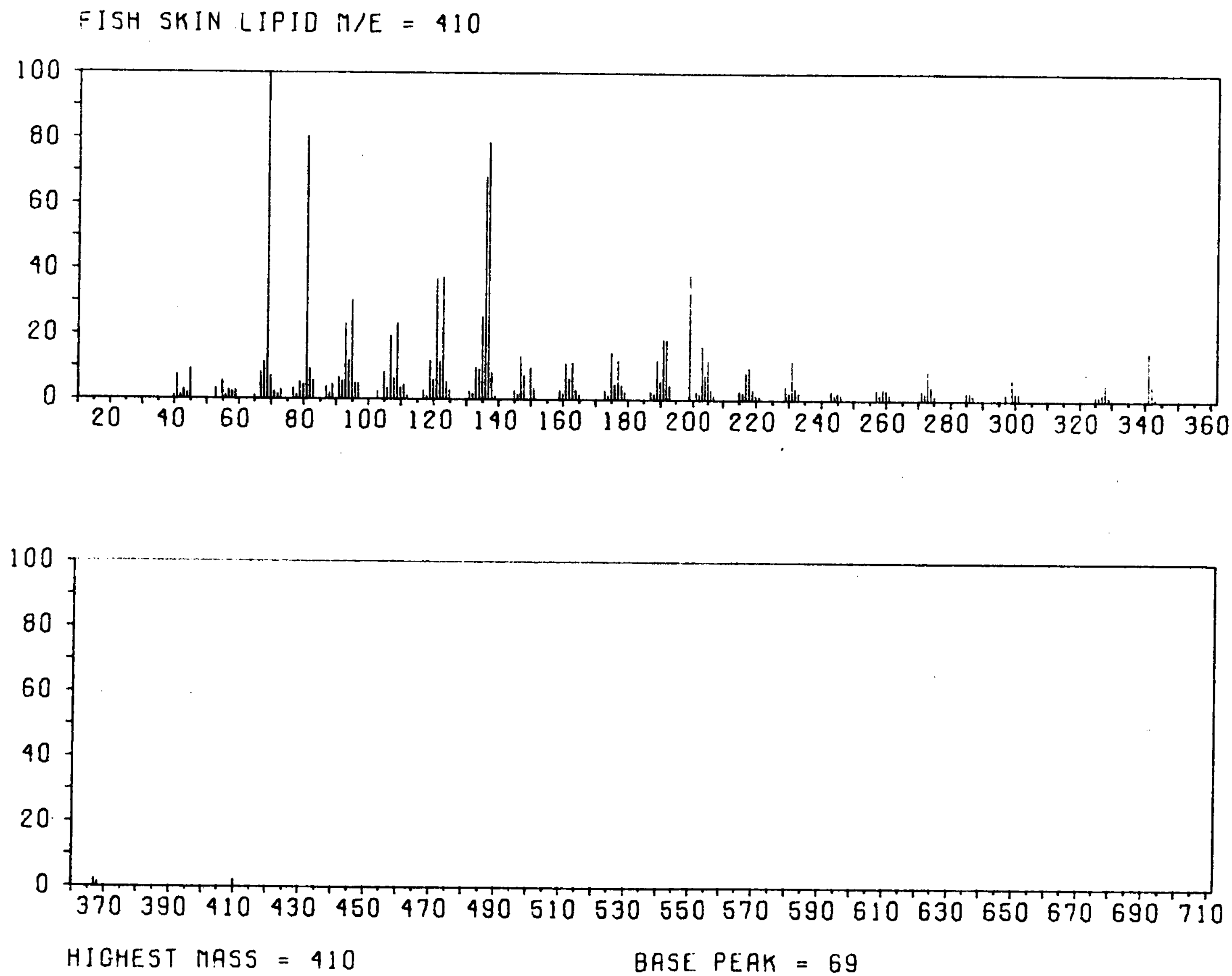

Figure 5. Mass Spectra of Squalene, Benzene Fraction, Fish, Topographic High Study.

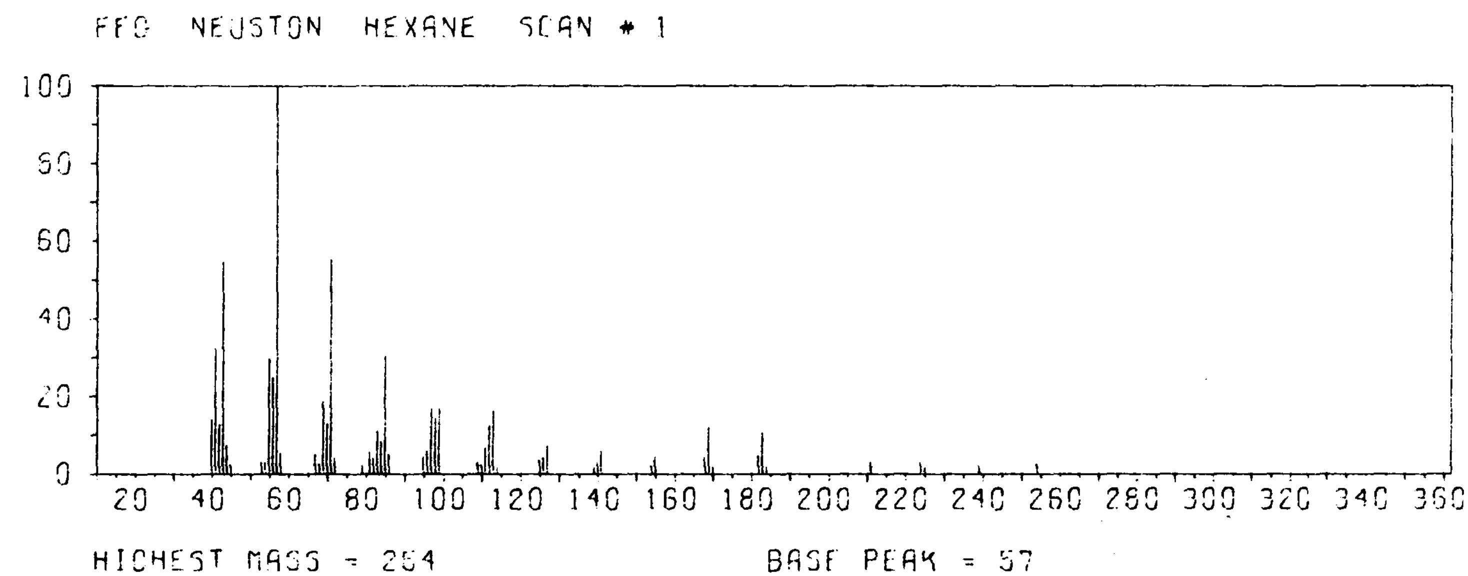

Figure 6. Mass Spectra of a Branched C_{18} Paraffin from Neuston Sample FEG.

WATER

MATERIALS AND METHODS

Water samples were collected at a depth of about 10 m in 19-liter glass carboys. The carboy was held in a weighted stainless steel cage fitted with a tapered TEFLON plunger which sealed the mouth of the carboy. The carboy was lowered to proper depth with a nylon rope and the plunger then partially removed by means of an accessory rope. After the bottle had filled, tension on the accessory rope was relaxed and the carboy was again sealed by the plunger. The carboy was then brought aboard, removed from the cage, and sealed with a TEFLON-lined screw cap.

Samples to be filtered were processed soon after collection in the wet lab of the R/V LONGHORN. GELMAN Type A glass fiber filters which had previously been extracted in boiling benzene were used. The water was transferred through glass tubing and an all glass filter into another 19-liter carboy in which the pressure ahd been reduced by means of an aspirator. The filters required for a given sample were placed in a 125-ml flask and frozen.

The carboys, which had been poisoned with about 15 g of mercuric chloride, were stored in dim light at room temperature until extraction. Samples were processed in completely random order except for August-September samples.

Extraction of hydrocarbons from seawater was carried out in all glass, continuous, liquid-liquid extractors using benzene as the solvent. Approximately 250 ml of benzene was used per sample. Extraction was carried out for 24-36 hours. The extract was reduced to near dryness (.1-.2 ml) in a KUDERNA-DANISH Concentrator on a steam bath. The sample was transferred in a total volume of about 1 ml of hexane to a micro-silica gel (WOELM, A

Activity I) column which had been packed in hexane. This column was eluted with 2 ml of hexane to remove saturates, then 2 ml of benzene to remove more polar compounds including aromatics. These fractions were concentrated to 50-100 μl with air filtered through silica gel. The samples were kept warm, about 40°C, on a hot plate during evaporation.

Hydrocarbons in particulate matter from seawater were extracted from filter pads on a hot plate with methanol (25 ml) and then benzene (25 ml). The two extracts were combined in a separatory funnel. About 5 ml of water was added, the mixture shaken and allowed to separate. The benzene layer was removed, evaporated to 1-2 ml and saponified for at least 2 hours with 10 ml of KOH in methanol (15 g; 500 ml). After addition of 5 ml of water to the mixture was extracted three times with benzene. The benzene extract was concentrated and fractionated on micro columns of silica gel as described for water samples.

Several experiments were carried out as checks of the experimental procedure. A check of extraction efficiency was carried out by extracting two water samples for a second 24 hour period with a second 250-ml portion of benzene. Analyses of these second extracts yielded .002 and .003 μg/l. The distribution of paraffins in these extracts was basically the same as the original extracts. These results coupled with previous extraction efficiency tests with similar extractors (Parker, Winters and Morgan, 1971) appear to indicate an adequate extraction with a low blank.

Results of an experiment to check losses during concentration in the KUDERNA-DANISH Concentrators are given below:

Compound	Sample Weight (μg)	Recovery #1	Recovery #2	Average Recovery (%)
Biphenyl	80.8	78.7	92.3	85.5
Methylbiphenyl	45.9	81.1	93.4	87.2

Compound	Sample Weight (μg)	Recovery #1	Recovery #2	Average Recovery (%)
Methylflourene	14.8	82.3	92.3	87.3
nC_{18}	23.0	90.9	95.7	93.3
nC_{20}	32.7	93.8	100.4	97.1
nC_{21}	26.5	98.4	103.7	101.0

The losses which resulted during the test conditions should be considered maximum. The rate of solvent removal during these tests was considerably faster than the rate normally employed with samples. Evaporation of 250 ml of benzene to dryness under a stream of nitrogen would probably result in an even greater loss of the aromatics.

RESULTS

Tables 2, 3 and 4 contain n-paraffin and isoprenoid hydrocarbon data obtained from winter, spring and summer cruises, respectively. Tables 5 and 6 contain similar data for particulate matter filtered from water samples during spring and summer, respectively.

Values in Table 2 were determined on APIEZON L columns; all other values were obtained with FFAP. These APIEZON L columns did not resolve phytane from C_{18}. After duplicate analyses on APIEZON L, quantation of the small remaining amount of sample on FFAP was not feasible.

The variation in concentration of total n-paraffins between replicate water samples (Tables 2 - 4) has been the subject of no little concern. Differences in winter samples were attributed variously to new personnel, delays while extraction equipment was set up and contamination. Midway through the second set of samples (spring) it was thought that variations in the particulate matter could be responsible and a few of the remaining spring samples were filtered. All summer samples were filtered shortly after collection, replicates run as pairs and samples extracted in order

(1/I and 3/IV); yet variation between replicates was as great as previous samples. Regardless of whether the variation among replicates is real or a procedural artifact, the average value is probably more meaningful than any single value for a given sample.

Total concentration values from each sample period have been averaged and are presented in Figure 7. The three seasonal values at each station were also averaged to yield a yearly value. The data of Figure 7 appear to indicate three general trends: 1) a decrease in concentration with increase in distance offshore, 2) an increased concentration during the spring (April-May) and 3) similar concentrations for the four transects.

The average concentration of n-paraffins in summer particulate matter (Table 6) are presented in Figure 8. These data also appear to show a decrease in concentration offshore and no consistent variation between transects.

In Figure 9 the total n-paraffin concentration of particulate matter are compared with the concentration of "dissolved" hydrocarbons at each station during the summer. At 9 of the 12 stations "dissolved" hydrocarbons were present at a concentration similar to or greater than that of the particulate hydrocarbons. Concentration of hydrocarbons in spring particulate matter (Table 5) are, however, greater than the corresponding concentrations of "dissolved" hydrocarbons (Table 3).

The percentage composition of n-paraffins generally did not show as great a variation between replicate samples as did total concentration. In a few samples, however, large differences in total concentration of paraffins between replicates was coupled with large differences in percentage composition, i.e. 1/III Table 3 and 2/I Table 4.

There was no apparent consistent change in percentage composition with

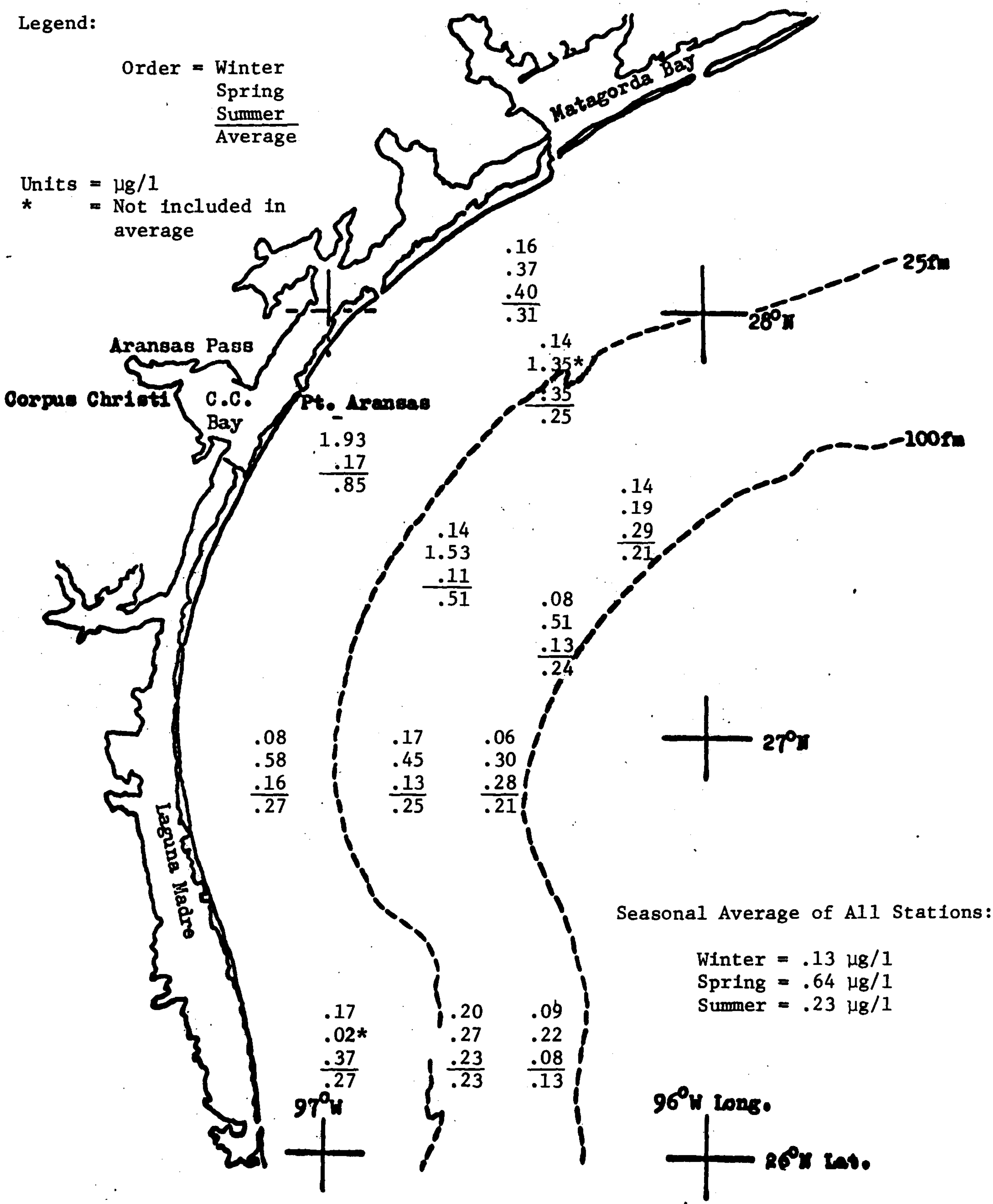

Figure 7. Average Total n-Paraffin Concentration in Seawater.

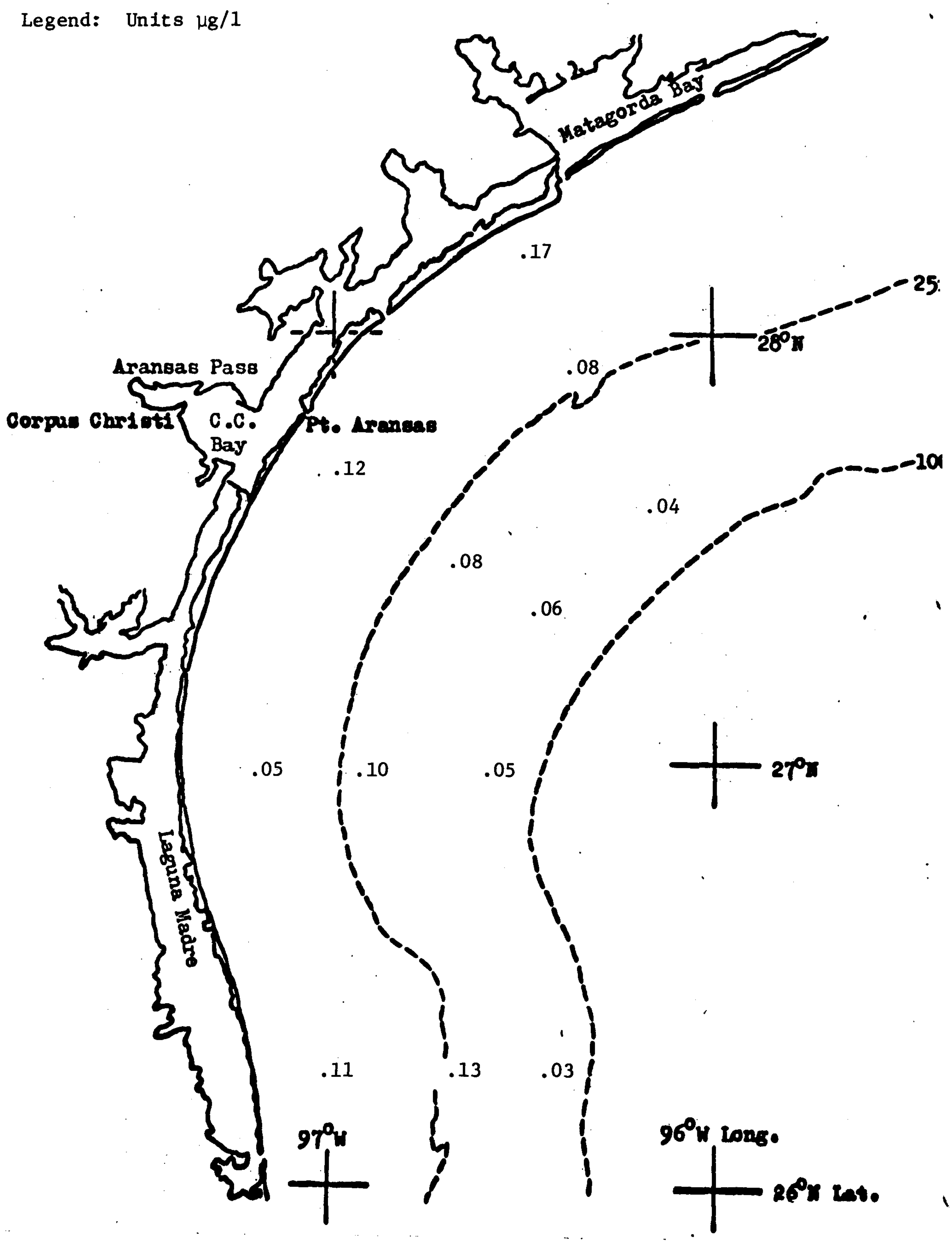

Figure 8. Average Total n-Paraffin Concentration in Particulate Matter from Seawater, August 1975.

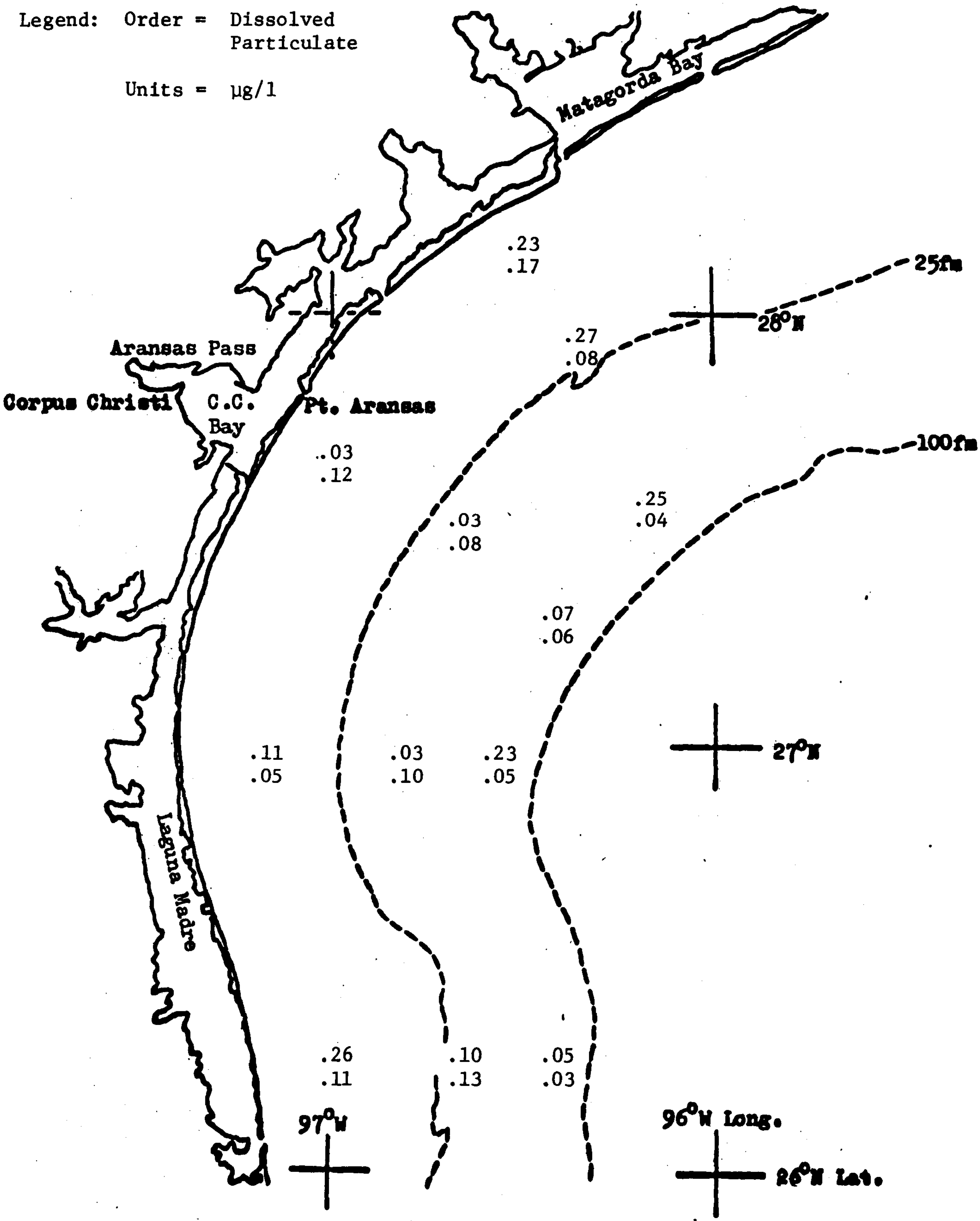

Figure 9. Average Total n-Paraffin Concentration in "Dissolved" and Particulate Organics from Seawater, August 1975.

Table 1. Components in samples from STOCS studies confirmed by combined Gas Chromatography-Mass Spectrometry.

Sample Code	Sample Type	Component Code [1]
AAT	Zooplankton	9
ACA	Zooplankton	5,11,12,17,24,26
AIW	Zooplankton	15,17,19,22,26,28,29
AOD	Zooplankton	5,6,11,12,14,20
BAY	Zooplankton	5,10,11
BHS	Zooplankton	24
CAE	Zooplankton	2,4,5,11,20,24
CMU	Zooplankton	2,5,11,14
DJF	Zooplankton	2,5,11
ALW	Neuston	7,14,17,26
BEG	Neuston	25
BPJ	Neuston	1,2,4,5,20
CAX	Neuston	24,25
CEI	Neuston	1,2,3,4,5,6,12,16,20
FEG	Neuston	4,6
AEF	Sediment	13,21,24
AGU	Sediment	13,26,30
AQX	Sediment	5,6,12,26,30
CCX	Sediment	23,26,27,30
CGB	Sediment	13,21
AHD	Water (dissolved)	25
CCJ	Water (dissolved)	25
ECJ	Water (particulate)	8,9
EIR	Water (dissolved)	25
FIR	Water (particulate)	5,6,11,15
AFM-C	Epifauna	13
AIK-D	Epifauna	13
BEK-C	Epifauna	2,11
BEK-D	Epifauna	2,11,26
Other Epifauna	samples[2]	
Fish 11	Reef fishes	26
Fish 12	Reef fishes	26
Fish 13	Reef fishes	10
Fish 22	Reef fishes	10

[1]Key to component code

Key	Mass	Component
1	210	$C_{15}H_{30}$ (C_{15}:1)
2	212	$C_{15}H_{32}$ (nC_{15})
3	226	$C_{16}H_{34}$ (nC_{16})
4	238	$C_{17}H_{34}$ (C_{17}:1)
5	240	$C_{17}H_{36}$ (nC_{17})
6	254	$C_{18}H_{38}$ (nC_{18})
7	258	$C_{19}H_{30}$ (C_{19}:5)
8	262	$C_{19}H_{34}$ (C_{19}:3)
9	264	$C_{19}H_{36}$ (n_{19}:2)

Table 1. Cont.'d

Key	Mass	Component
10	266	$C_{19}H_{38}$ (C_{19}:1)
11	268	$C_{19}H_{40}$ (Pristane)
12	268	$C_{19}H_{40}$ (nC_{19})
13	270	$C_{17}H_{34}O_2$ (methyl palmitate)
14	278	$C_{20}H_{38}$ (Phytadiene)
15	282	$C_{20}H_{42}$ (Phytane)
16	282	$C_{20}H_{42}$ (nC20)
17	285	$C_{21}H_{32}$ (C21:6)
18	288	$C_{21}H_{34}$ (C21:4)
19	296	$C_{21}H_{44}$ (?, not nC_{21})
20	310	$C_{22}H_{46}$ (nC22)
21	340	$C_{22}H_{44}O_2$ (methyester of C_{21}FA)
22	340	$C_{23}H_{48}O$?
23	346	$C_{25}H_{44}$ (C25:4)
24	370	$C_{27}H_{46}$ (not cholestene but very close)
25	390	$C_{24}H_{38}O_4$ (di-C_8-Phthalate)
26	410	$C_{30}H_{50}$ (Squalene)
27	410	$C_{30}H_{50}$ (Squalene isomer ?)
28	414	$C_{30}H_{54}$ (C30:4 ?)
29	422	$C_{30}H_{62}$ (Squalane)
30	442	$C_{30}H_{50}O_2$ (Betulin)

[2] GC-MS analysis attempts on ten other epifauna samples were not successful due to an inadequate amount of material. These samples were AAF-C, AJD-A, ASH-C, AUQ-B, AVM-D, BBI-C, BBI-D, BDN-B, BPF-C, and BPF-D.

Table 2. Percent Composition of n-Paraffins in Seawater from Texas OCS, January 1975.

Station	I-1	I-1	I-2	I-3	I-3	II-2	II-2	II-3	III-1
Sample Code	AHD	AHE	AEJ	ACH	ACG	ANI	ANJ	AQK	ATP
Carbon No.									
15	9.1	1.2	Tr	.6	2.2	15.5	21.4	Tr	Tr
16	1.5	Tr	Tr	Tr	Tr	1.4	5.9	Tr	Tr
Pristane	4.2	3.4	1.9	1.3	5.0	2.4	9.1	4.1	3.5
17	4.4	2.5	.7	.8	1.0	25.3	20.5	1.3	2.0
18+Phytane	2.1	1.4	Tr	.8	1.1	2.6	1.1	Tr	Tr
19	4.1	3.7	1.2	3.3	2.7	5.3	4.5	2.7	5.2
20	5.4	6.6	3.1	5.3	4.4	3.4	Tr	4.1	5.0
21	8.5	11.1	7.3	9.1	8.1	4.6	Tr	8.9	9.0
22	19.4	17.7	14.4	24.3	25.0	7.5	Tr	16.5	15.3
23	10.1	14.9	14.4	12.8	12.5	6.5	Tr	15.8	11.5
24	7.9	12.0	12.9	10.4	10.5	4.8	Tr	13.7	11.4
25	6.2	8.4	10.4	8.3	8.3	4.6	Tr	8.2	12.2
26	4.4	5.5	7.7	6.0	5.8	3.6	5.0	5.8	13.0
27	3.6	3.7	6.2	4.6	4.4	3.1	5.9	4.8	12.9
28	2.7	2.5	5.0	3.2	3.0	2.4	5.4	4.1	11.8
29	2.4	2.5	4.6	3.5	2.8	2.5	6.8	5.5	11.0
30	1.3	.8	2.3	2.2	1.6	1.2	3.8	.5	4.8
31	2.0	1.2	3.7	2.6	2.4	1.4	4.7	3.4	6.2
32	Tr	Tr	1.8	Tr	1.5	.9	3.6	Tr	4.2
33	Tr	Tr	1.5	Tr	1.3	Tr	1.8	Tr	4.0
Total n-paraffins (μg/l)	.18	.13	.14	.12	.16	.11	.17	.08	.08
C.P.I. C_{15}-C_{20}*	1.9	.9	.6	.8	.7	6.2	6.6	1.0	1.4
C.P.I. C_{25}-C_{38}	1.7	1.8	1.6	1.7	1.6	1.4	1.1	2.1	1.4
Pristane/Phytane									

Table 2. Cont.'d

Station	III-2	III-2	III-3	IV-1	IV-1	IV-2	IV-3
Sample Code	AWO	AWP	AZM	BCK	BCL	BFR	BOM
Carbon No.							
15	2.6	27.6	1.5	Tr	3.9	8.3	17.9
16	1.1	10.2	Tr	3.7	1.3	6.2	4.3
Pristane	22.3	7.5	Tr	6.1	1.9	10.6	4.6
17	10.2	7.5	3.1	10.1	2.5	7.0	4.8
18+Phytane	4.2	1.5	Tr	8.0	2.1	14.6	9.5
19	4.0	1.9	5.1	12.6	3.2	6.9	8.5
20	2.8	Tr	4.6	10.7	7.1	7.0	13.2
21	3.8	Tr	8.6	12.3	9.5	5.5	7.5
22	6.1	Tr	14.6	13.5	12.5	11.7	7.8
23	6.5	Tr	15.5	4.6	13.4	.6	1.3
24	7.3	Tr	10.3	2.7	12.3	.6	1.5
25	7.2	Tr	8.8	2.3	9.4	.5	1.2
26	6.4	Tr	6.2	2.1	6.3	3.9	2.2
27	4.9	Tr	6.4	3.0	4.7	4.7	2.8
28	3.4	Tr	7.2	2.4	2.3	2.9	2.3
29	2.8	Tr	4.6	2.4	2.9	2.4	4.1
30	1.7	9.4	2.0	1.5	1.7	2.0	2.6
31	1.9	7.9	Tr	1.2	1.9	1.7	2.3
32	Tr	7.1	Tr	Tr	Tr	1.3	1.3
33	Tr	4.7	Tr	Tr	Tr	1.0	.6
Total n-paraffins (µg/l)	.22	.13	.06	.09	.25	.20	.09
C.P.I. C_{15}-C_{20} *	2.0	3.2	2.0	1.0	.9	.8	1.6
C.P.I. C_{25}-C_{38}	1.5	.8	1.3	1.5	1.8	1.0	1.3
Pristane/Phytane							

* Carbon Preference Index $\text{C.P.I. } C_{15} - C_{20} = \dfrac{C_{15} + C_{17} + C_{19}}{C_{16} + C_{18} + C_{20}}$

Table 3. Percentage Composition of n-Paraffins in Seawater, April-May, 1975.

Station	I-1	I-1	I-2	I-3	II-1	II-2	II-2	II-3	II-3
Sample Code	CCI	CCJ	CFN	CIR	CLX	CPA	CPB	CSM	CSN
Carbon No.									
15		2.9		Tr		4.2		.1	
16		.7		Tr		5.6		.1	
Pristane		.3		.1	Tr	1.4		.2	
17		1.8		.2	Tr	5.6		.7	
Phytane	Tr	.1		.1	Tr	1.0		.1	
18	Tr	.5		.2	2.2	5.9		1.6	.4
19	.4	.7		.8	6.8	8.7	1.8	6.8	3.3
20	1.3	.8		1.9	16.5	12.9	11.2	17.0	8.8
21	3.1	1.0		6.3	23.3	17.7	21.6	25.3	14.0
22	3.0	1.4	.3	8.6	17.5	12.7	21.2	16.8	10.5
23	8.4	4.2	.2	8.9	8.7	7.2	9.2	8.0	7.6
24	12.8	7.0	.3	10.3	6.0	4.5	7.3	4.0	6.5
25	14.4	11.3	.4	11.0	3.7	2.5	2.8	2.6	4.5
26	13.2	10.6	.4	10.7	1.8	2.0	2.5	1.6	4.0
27	12.0	10.5	1.3	10.1	1.1	2.0	2.6	1.2	3.0
28	9.2	9.9	4.0	8.2	2.0	1.2	2.0	1.1	3.2
29	8.3	9.2	9.5	7.0	3.5	1.9	3.0	1.9	4.5
30	4.7	7.8	13.2	5.8	.4	1.1	2.5	1.9	5.5
31	3.7	6.8	17.8	4.7	.8	.4	1.2	2.3	6.4
32	2.9	5.1	15.0	2.5	.9	.5	.6	2.3	6.4
33	1.2	4.8	12.4	1.6			1.2	1.5	4.8
34	.2	2.1	7.8	.6			Tr	.7	2.4
35	.2	.6	5.6	.3				.7	2.3
36			3.5					.3	.5
37			3.5						.4
38									
Total n-paraffins (μg/l)	.23	.52	1.35	.19	.07	.22	.06	.72	.30
C.P.I. C_{15}-C_{20}*	.3	2.7		.5	.4	.8	.2	.4	.4
C.P.I. C_{25}-C_{38}	1.3	1.2	1.0	1.3	1.8	1.4	1.4	1.3	1.2
Pristane/Phytane		3.0		1.0	1.0	1.4		2.0	

Table 3. Cont.'d

Station	III-1	III-1	III-2	III-3	III-3	IV-1	IV-2	IV-2
Sample Code	CWK	CWL	CZK	DBV	DBW	DFI	DIH	DII
Carbon No.								
15		.3	3.1		.3		2.5	
16		.2	.8		.3		.1	
Pristane	Tr	.1	.3		.3		.2	
17	.3	.3	1.6		1.3		.3	
Phytane	Tr	.1	.1	Tr	.2		.1	
18	.6	.3	1.6	1.1	1.7		.7	Tr
19	2.1	.5	3.3	5.4	5.0	1.5	2.7	1.0
20	2.0	.6	7.1	16.1	13.9	6.5	5.4	9.2
21	3.0	1.0	10.3	26.1	20.8	15.2	8.4	21.0
22	5.7	.5	8.4	18.5	15.7	34.2	8.5	18.2
23	11.9	.2	6.7	9.3	9.0	11.7	8.6	10.7
24	12.4	.2	6.2	4.9	6.8	7.1	10.2	8.6
25	12.6	.2	4.4	3.8	5.7	4.1	10.5	4.1
26	9.6	.6	2.8	2.2	4.3	4.4	9.9	4.3
27	6.7	1.6	4.0	1.8	3.8	2.6	8.3	3.6
28	6.8	3.8	6.6	1.7	2.6	3.2	6.9	3.9
29	6.5	9.1	6.0	1.9	3.7	3.1	5.9	5.3
30	5.6	12.8	5.6	1.7	1.7	2.8	4.1	2.7
31	5.5	17.2	6.1	2.0	1.7	1.3	2.7	3.4
32	4.9	14.5	4.9	1.7	1.2	Tr	2.2	2.2
33	1.9	11.9	4.0	.7	.4		.7	1.1
34	1.4	7.8	2.2	.3			.3	
35	1.0	5.8	1.7	Tr				
36		3.6	.9					
37		2.6	.7					
Total n-paraffins (μg/l)	.08	1.09	.45	.42	.19	.02	.50	.05
C.P.I. C_{15}-C_{20}*	.9	1.0	.8	3.2	.4	.23	.9	.1
C.P.I. C_{25}-C_{38}	1.2	1.0	1.1	1.4	1.6	1.0	1.2	1.3
Pristane/Phytane	1.0	1.0	3.0		1.5		2.0	

Table 3. Cont.'d

Station	IV-3	IV-3
Sample Code	DLM	DLN
Carbon No.		
15	12.1	
16	.6	
Pristane	.4	
17	.7	Tr
Phytane	Tr	
18	1.0	Tr
19	2.7	2.6
20	7.4	2.4
21	17.1	14.9
22	22.2	21.4
23	10.3	15.8
24	6.1	10.4
25	4.2	6.0
26	2.9	4.5
27	3.0	3.6
28	2.0	3.2
29	2.0	4.9
30	1.5	3.2
31	1.1	3.0
32	.6	2.7
33	.4	.8
34		
35		
36		
37		
Total n-paraffins (μg/1)	.28	.15
C.P.I. C_{15}-C_{20}*	1.7	1.0
C.P.I. C_{25}-C_{38}	1.5	1.3
Pristane/Phytane	8.0	

* Carbon Preference Index $\text{C.P.I. } C_{15} - C_{20} = \dfrac{C_{15} + C_{17} + C_{19}}{C_{16} + C_{18} + C_{20}}$

Table 4. Percentage Composition of n-Paraffins in Seawater, August-September, 1975.

Station	I-1	I-1	I-2	I-2	I-3	I-3	II-1	II-1	II-2
Sample Code	ECI	ECJ	EFN	EFO	EIR	EIS	ELX	ELY	EPB
Carbon No.									
15	1.2			.7					
16	.9								
Pristane	1.1		Tr	Tr			Tr		
17	1.8		Tr	Tr			1.9		
Phytane	Tr		Tr	Tr			Tr		
18	.4	Tr		.2			4.2	.4	4.1
19	2.7	Tr		.8	.5		7.1	3.6	7.6
20	6.6	6.7	.7	1.1	.7	1.0	8.3	5.8	5.9
21	6.5	8.3	4.6	1.3	1.9	1.2	10.1	7.1	6.0
22	8.5	20.3	11.6	2.7	5.4	2.0	9.5	7.7	12.5
23	5.2	10.7	20.1	4.2	5.9	1.5	5.2	6.3	7.2
24	4.9	7.7	18.2	15.0	6.7	6.6	4.6	5.3	6.4
25	4.9	5.6	13.2	7.0	9.0	6.5	4.7	4.8	2.8
26	5.6	3.5	8.2	7.4	8.0	9.8	6.9	6.6	3.2
27	6.1	2.9	5.8	7.6	9.7	11.5	8.4	7.4	3.5
28	5.6	4.8	3.6	9.2	8.7	12.1	6.4	7.7	4.4
29	7.1	4.1	4.1	9.4	9.1	11.8	8.7	7.9	7.9
30	5.6	5.5	4.2	8.4	7.9	9.9	7.2	7.2	7.5
31	8.0	9.3	1.5	10.5	10.4	11.0	3.7	7.9	8.8
32	5.2	3.8	2.4	8.4	5.7	7.1	2.4	5.2	6.2
33	4.9	2.0	1.1	8.0	4.9	4.9	Tr	4.9	4.2
34	2.6	2.1		4.7	1.6	1.4		3.3	.8
35	3.3	2.0		2.8	1.7	.9			Tr
36	1.1	Tr		.8	1.5				
37	Tr			.2	Tr				
38									
Total n-paraffins (μg/l)	.41	.05	.10	.45	.35	.16	.02	.03	.03
C.P.I. C_{15}-C_{20}*	.7			1.2	.7		.4	.6	.7
C.P.I. C_{25}-C_{38}	1.3	1.3	1.4	1.2	1.3	1.2	1.1	1.1	1.2
Pristane/Phytane	22.0		1.0	1.0					

Table 4. Cont.'d

Station	II-2	II-3	II-3	III-1	III-1	III-2	III-2	III-3
Sample Code	EPC	ESO	ESP	EWK	EWL	EZK	EZL	FBV
Carbon No.								
15								
16								
Pristane		Tr			Tr			
17	Tr	1.2			3.0	2.8		
Phytane		1.1			Tr			
18		3.0			1.0	2.3		
19	.8	7.9	5.8	Tr	3.2	3.3	6.1	10.5
20	5.6	10.0	9.2	4.7	5.3	4.2	8.7	1.2
21	6.8	7.6	2.4	6.1	6.3	2.3	10.5	1.3
22	10.5	26.3	4.5	31.6	23.6	16.9	11.4	1.5
23	8.3	6.2	3.6	6.4	6.5	6.1	5.7	2.7
24	8.7	7.4	1.5	6.7	5.7	5.6	5.9	2.9
25	8.9	3.4	1.3	4.8	6.1	5.6	4.3	4.4
26	9.2	2.9	3.9	2.2	4.1	6.1	5.2	6.2
27	10.5	3.2	11.0	5.3	5.3	7.5	6.1	8.2
28	9.7	2.2	10.2	13.7	9.4	7.0	6.6	9.1
29	8.2	3.2	14.8	5.0	4.9	8.4	7.0	10.1
30	5.1	2.9	11.1	4.2	4.5	7.0	4.7	13.0
31	4.5	3.9	13.5	4.6	4.3	7.5	6.5	12.2
32	1.2	2.6	2.9	1.3	2.8	2.8	5.0	7.9
33	1.2	2.3	3.5	2.7	3.2	3.7	5.4	4.4
34	Tr	1.1	Tr	Tr	Tr	Tr		1.0
35	Tr	1.6	Tr	Tr	Tr	Tr		1.1
36								.8
37								.5
38								
Total n-paraffins (µg/l)	.02	.11	.04	.04	.18	.03	.02	.09
C.P.I. C_{15}-C_{20}*	.1	.7	.6		.98	.9	.7	8.7
C.P.I. C_{25}-C_{38}	1.3	1.5	1.6	1.0	1.1	1.4	1.4	1.1
Pristane/Phytane					1.0			

Table 4. Cont.'d

Station	III-3	IV-1	IV-1	IV-2	IV-3	IV-3
Sample Code	FBW	FFQ	FFR	FIR	FLV	FLW
Carbon No.						
15						
16						
Pristane			4.5			1.0
17			5.2			6.1
Phytane			5.1			.6
18			6.4		Tr	5.4
19	Tr		5.9		3.2	4.7
20	Tr		5.3		2.5	6.8
21	Tr	1.3	8.0	1.4	2.1	4.7
22	1.3	1.0	2.5	2.3	2.4	5.7
23	3.2	2.5	5.2	2.5	2.7	9.5
24	4.5	5.1	2.9	5.0	3.4	4.2
25	6.3	8.0	2.4	7.2	5.1	3.8
26	7.7	8.5	4.9	7.3	7.1	4.2
27	8.8	9.8	6.4	8.9	7.8	5.4
28	9.0	10.0	6.2	9.7	8.6	6.1
29	9.2	9.6	8.5	11.1	9.8	6.3
30	9.1	9.1	6.3	9.4	10.4	6.1
31	11.5	12.4	6.9	11.8	11.9	8.0
32	8.8	8.9	2.0	8.9	8.3	4.0
33	9.1	8.1	3.2	7.8	6.0	4.2
34	4.2	2.6	.8	2.9	3.3	2.1
35	2.8	1.6	.1	1.4	3.0	
36	1.2	.8		1.3	1.4	
37	1.1	.7		.6	Tr	
38		.4				
Total n-paraffins (μg/l)	.37	.52	.01	.10	.07	.03
C.P.I. C_{15}-C_{20}*	1.0		.9		1.2	.9
C.P.I. C_{25}-C_{38}	1.2	1.3	1.4	.7	1.1	1.2
Pristane/Phytane			.8			1.6

* Carbon Preference Index C.P.I. $C_{15} - C_{20} = \frac{C_{15} + C_{17} + C_{19}}{C_{16} + C_{18} + C_{20}}$

Table 5. Percentage Composition of n-Paraffins in Particulate Matter from Seawater, April-May 1975.

Station	II-1	II-1	II-2	II-2
Sample Code	CLX	CLY	CPA	CPB
Carbon No.				
15	.1	.1	.3	.5
16	Tr	.1	Tr	Tr
Pristane	.5	.8	.5	.4
17	.7	.6	.6	.4
Phytane	.1	.2	.2	.1
18	1.7	2.5	2.5	1.8
19	6.3	8.7	9.3	7.8
20	14.9	19.2	19.9	18.7
21	22.6	27.0	27.0	27.2
22	16.9	18.3	17.7	19.1
23	9.1	8.8	8.4	9.3
24	5.1	4.3	4.3	4.7
25	3.7	2.7	2.5	2.7
26	3.5	1.8	1.6	1.8
27	3.3	1.2	1.0	1.2
28	2.9	.8	.9	.9
29	2.9	.9	.8	.9
30	1.8	.5	.3	.7
31	1.7	.3	.2	.5
32	.9	.3	.2	.5
33	.5	.1	.1	.2
34	.1			
Total n-paraffins (μg/1)	1.79	1.94	1.54	1.24
C.P.I. C_{15}-C_{20}*	.4	.4	.5	.4
C.P.I. C_{25}-C_{38}	1.3	1.5	1.5	1.4
Pristane/Phytane	5.0	4.0	2.5	4.0

* Carbon Preference Index $\text{C.P.I. } C_{15} - C_{20} = \dfrac{C_{15} + C_{17} + C_{19}}{C_{16} + C_{18} + C_{20}}$

Table 6. Percentage Composition of n-Paraffins in Particulate Matter from Seawater, August-September, 1975.

Station	I-1	I-1	I-2	I-2	I-3	I-3	II-1	II-1	II-2
Sample Code	ECI	ECJ	EFN	EFO	EIR	EIS	ELX	ELY	EPB
Carbon No.									
15									
16									
Pristane									
17									
Phytane									
18									
19					2.8	2.0	2.5	.3	2.5
20			.7		3.2	2.9	1.6	.3	1.8
21			.8		4.2	1.1	2.3	.8	3.0
22	1.5	.4	.9		4.6	.8	2.4	.8	3.1
23	4.5	.8	1.6		3.4	1.3	2.0	.4	3.6
24	6.9	1.4	1.6		4.0	1.3	.8	.4	2.3
25	7.6	1.8	1.7	.6	3.0	1.6	1.2	1.0	1.9
26	9.2	4.0	1.8	1.5	3.4	2.2	1.1	.7	2.1
27	9.3	4.7	2.1	4.6	5.1	4.5	3.9	2.4	7.0
28	7.6	5.8	4.1	5.7	6.9	7.1	3.0	3.7	5.7
29	10.5	9.6	8.5	9.0	11.5	8.9	6.4	8.0	8.1
30	11.3	13.0	11.3	12.6	11.2	11.3	9.8	12.4	9.2
31	13.4	18.7	17.9	19.2	14.9	19.0	15.8	17.1	13.2
32	8.4	12.9	13.8	14.2	7.9	9.3	12.3	13.1	7.6
33	1.0	12.8	13.0	14.2	10.8	13.4	12.7	13.6	13.0
34	3.6	5.1	9.0	8.3	1.0	6.0	5.3	6.7	4.7
35	2.4	3.6	3.8	5.7	1.3	2.5	5.8	5.8	4.7
36	1.8	3.0	3.3	2.8		2.2	5.5	3.9	3.0
37		1.6	3.2	1.0		1.8	4.6	5.9	2.3
38								1.7	
Total n-paraffins (μg/1)	.10	.25	.09	.07	.02	.06	.09	.16	.05
C.P.I. C_{15}-C_{20}*					.9	.7	1.6	1.0	1.4
C.P.I. C_{25}-C_{38}	1.0	1.2	1.2	1.2	1.5	1.4	1.4	1.3	1.6
Pristane/Phytane									

Table 6. Cont.'d

Station	II-2	II-3	II-3	III-1	III-1	III-2	III-2	III-3
Sample Code	EPC	ESO	ESP	EWK	EWL	EZK	EZL	FBV
Carbon No.								
15								
16								
Pristane								
17								
Phytane								
18								
19	2.8	5.4	1.4	2.6	1.9		5.6	10.1
20	3.5	3.5	.7	1.3	1.1		.8	5.0
21	3.6	2.7	.8	1.5	.6		1.1	5.9
22	2.8	3.3	.9	1.3	.7		2.9	5.4
23	2.5	1.8	.7	.5	1.4		3.8	3.4
24	1.8	2.9	.7	.9	.8		4.7	2.0
25	2.3	1.3	1.2	.6	1.3	.2	8.5	3.2
26	2.3	2.0	.7	.3	1.1	.5	13.2	1.9
27	3.5	3.4	4.2	2.6	1.9	2.6	6.5	3.7
28	4.8	5.7	6.1	4.1	4.9	5.4	5.9	8.5
29	7.7	9.2	10.1	7.6	8.3	7.9	7.1	5.9
30	10.7	10.8	13.1	14.6	10.8	11.1	7.3	8.0
31	13.4	17.3	19.7	16.7	17.4	17.4	8.2	15.2
32	10.3	12.1	12.3	14.1	15.5	14.9	6.1	6.3
33	10.2	12.3	11.7	15.4	15.4	15.7	5.0	9.9
34	4.7	3.2	4.4	4.9	4.4	7.1	3.8	2.0
35	4.3	1.5	4.5	4.3	3.9	4.9	2.9	2.2
36	2.8	.6	4.2	2.9	5.5	5.2	2.6	.5
37	3.5		1.7	2.6	2.3	4.6	3.2	
38	1.2					1.9		
Total n-paraffins (μg/1)	.11	.04	.09	.06	.03	.10	.57	.03
C.P.I. C_{15}-C_{20}*	.8	1.5	2.0	2.0	1.7		7.0	2.0
C.P.E. C_{25}-C_{38}	1.2	1.3	1.3	1.2	1.2	1.2	1.0	1.5
Pristane/Phytane								

Table 6. Cont.'d

Station	III-3	IV-1	IV-1	IV-2	IV-2	IV-3	IV-3
Sample Code	FBW	FFQ	FFR	FIR	FIS	FLV	FLW
Carbon No.							
15							
16							
Pristane				1.3			
17			4.2	1.5			
Phytane				.1			
18			2.1	1.0			
19	1.6	.7	4.2	12.6	.5	1.7	5.1
20	Tr	Tr	1.2	.6	.6	1.1	5.3
21	.3	Tr	.4	.5	.7	2.1	2.2
22	.8	.6	Tr	1.6	.5	6.5	2.8
23	1.7	1.2	Tr	2.0	1.1	6.3	2.1
24	1.9	.1	.1	2.9	.4	5.9	1.6
25	2.1	.3	.6	4.6	.3	6.9	1.5
26	2.4	.8	1.5	7.3	.4	7.7	1.0
27	2.6	3.8	2.4	6.2	.9	12.2	2.8
28	5.5	5.2	4.0	7.1	3.3	10.3	4.9
29	9.0	10.0	7.0	8.6	6.4	12.1	6.9
30	12.1	15.1	10.6	7.6	10.7	7.7	11.8
31	17.0	21.9	15.0	8.7	17.4	10.7	15.4
32	11.5	Tr	12.4	6.5	14.9	3.6	8.9
33	11.9	18.2	15.3	5.4	14.3	4.6	14.5
34	5.8	7.9	5.6	3.6	8.1		5.1
35	5.6	5.6	3.8	3.3	6.8		4.0
36	4.4	4.6	3.9	2.9	5.4		2.5
37	2.9	3.1	3.8	2.8	6.3		.8
38			1.0				
Total n-paraffins (μg/l)	.08	.09	.12	.19	.07	.02	.05
C.P.I. C_{15}-C_{20}*	32.0	14.0	2.5	8.8	.8	1.5	.9
C.P.I. C_{25}-C_{38}	1.2	1.9	1.9	1.1	1.2	1.6	1.3
Pristane/Phytane				13.0			

* Carbon Preference Index $\text{C.P.I. } C_{15} - C_{20} = \dfrac{C_{15} + C_{17} + C_{19}}{C_{16} + C_{18} + C_{20}}$

either distance offshore or between transects.

Percentage composition did appear to demonstrate slight differences with season. Winter samples appear to contain a higher percentage of hydrocarbons in the C_{15} - C_{20} range and less in the C_{30} - C_{35} range than spring and summer samples. The most abundant n-paraffin in spring particulate samples was C_{22}; in summer C_{31} was generally the most abundant.

One objective for characterizing the n-alkanes distribution within a sample is to be able to distinguish between n-alkanes which arise from contamination by petroleum-like organic matter and those which are indigenous to the sample. N-alkanes contained in petroleum having odd numbers of carbon atoms in their chain lengths have little or no predominance over those having even numbers (Bray and Evans, 1961). N-alkanes indigenous to most organisms and contained in recent sediments have a large excess of odd numbered chain lengths. This makes possible a semi-quantitative estimate of the extent of petroleum contamination by measuring the odd to even ratio of n-alkanes.

One useful method of presenting the odd to even ratio is given by Scalan and Smith (1970). The odd-even-predominance (OEP) is plotted as a function of the number of carbons in the n-alkanes. For many petroleums, this "running ratio" provides a "fingerprint" characteristic of the origin of the oil. By scanning the OEP curves it is possible to quickly distinguish those samples for which the curve lies close to the unity base line (petroleum-like) from those whose curve departs from unity.

Some organisms may have n-alkane distributions which have no odd predominance, for example bacteria and corals. This may be the case for water samples which show little OEP character. OEP curves for most samples are given in the Appendix.

A supplementary odd/even ratio has been calculated for two molecular-weight ranges, C_{15} - C_{20} and C_{25} - C_{38} and the value included in Tables 2 - 6. Over the C_{15} - C_{20} range the OEP is greatly influences by the C_{15}/C_{16} and C_{17}/C_{18} ratios. Samples with a relatively large C_{15} and C_{17} contribution, presumably from phytoplankton and zooplankton, have large OEP values in this range, which differ greatly from samples in which little if any C_{15} or C_{17} is present. Over the C_{25} - C_{38} range the presence or absence of a few individual paraffins does not greatly effect the OEP value. Spring and summer samples have also had the odd/even ratio plotted vs. carbon number by the method of Scalan and Smith (1970). These curves are in the Appendix.

Analyses of benzene fractions from water and particulate matter samples did not disclose the presence of representative petroleum derived aromatic compounds such as naphthalenes or alkyl phenols. The most abundant compound in many samples has been identified by combined gas chromatography-mass spectroscopy as diethylhexyl phthalate. The origin of most of this phthalate was probably short lengths of TYGON tubing used to give flexibility to otherwise all-glass filtration and extraction apparatus.

DISCUSSION

The concentrations of n-paraffins in seawater found during the period of this study (generally .1-.1 μg/l) were similar to concentrations reported in an earlier study on the Texas and Louisiana coasts (Parker, Winters and Morgan, 1971). The values are also similar to values reported for the Florida Straits (Calder, 1975). Higher concentrations found during the spring apparently result from the higher productivity during this season. Likewise, the trend toward higher concentrations at inshore stations in all seasons presumably is a reflection of the abundance of phytoplankton and zooplankton inshore.

The percentage composition of n-paraffins in seawater did not show a significant systematic change with distance offshore and only slight changes with season. Percent composition in many samples reached a maximum at or near C_{22}. This hydrocarbon, C_{22}, is also a major constituent in many marine samples such as zooplankton, fish and sediment. Seawater often demonstrates a bimodal distribution of n-paraffins with other maxima at odd carbon numbers between C_{15} and C_{20} (winter samples) or between C_{25} and C_{35} (summer samples). Over each of these ranges of carbon number a slight odd carbon preference is indicated.

The odd/even ratio of n-paraffins in a sample has been suggested as a parameter to distinguish between recently biosynthesized "natural" hydrocarbon and petroleum derived "pollutant" hydrocarbon sources. The large predominance of odd carbon number and high pristane/phytane ratios usually associated with natural unpolluted samples may not, however, be exhibited in hydrocarbons produced by bacteria. Indeed there is some evidence to the contrary (Sever, 1970). Interpretation of the odd/even ratio of paraffins in seawater is therefore difficult. Concentration and percentage composition of hydrocarbons in particulate matter did show significant changes between spring and summer samples. The four samples taken in the spring (Table 5) were high in concentration (av. 1.63 μg/l) with a maximum at C_{21} while summer samples averaged .09 μg/l with a maximum at C_{31}. The higher concentration in spring is consistent with a higher concentration of phyto- and zooplankton during this period. The distribution of hydrocarbons in particulate matter (C_{21} maximum) is reflected in the "dissolved" hydrocarbons at these stations. Lower concentrations in summer could result from a decrease in phytoplankton in the water column at this time. Hydrocarbon distribution in particulate matter during the summer (maximum at C_{31}) was often significantly different from the distribution of "dissolved" hydrocarbons (maximum at C_{22}). Odd carbon preference between C_{25} and C_{35} in summer particulate hydrocarbons appears to be somewhat greater than that found in summer "dissolved" hydrocarbons.

Further speculation with regard to the interrelationship of phytoplankton, zooplankton and "dissolved" or particulate hydrocarbons will be reserved until the integrated report.

ZOOPLANKTON

MATERIALS AND METHODS

Zooplankton samples were collected for heavy hydrocarbon analysis in a manner similar to that used for taxonomic samples. An oblique tow of a 1-meter net for 15 minutes duration generally provided adequate material for analysis.

The net used was that also used for trace-metals sampling. A standard 1 meter NITEX net of 233 μm mesh size was mounted on a square hoop constructed of polyvinyl chloride. The usual brass eyelets of the nets had been replaced with plastic eyelets. Because the digital flow meter used for taxonomy studies was oil filled, it was not used for hydrocarbon sampling. The net was protected between sampling by placing it within a clean plastic bag. Care was used to avoid contact of the net with the ship or its rigging. Samples were not "washed down" the net into the cod-end so as to avoid contamination from the pumped water and the hose connections.

Samples from the net were placed in specially precleaned jars and were frozen. The samples were maintained frozen until immediately before start of analysis at which time they were quickly thawed by immersion of the sample container in warm water. The particulate matter (zooplankton) was separated from the liquid (seawater) by direct filtration into a precleaned cellulose extraction thimble.

The samples were extracted with methanol in a SOXHLET extractor for at least 8 hours. This preliminary extraction removed water and part of the hydrocarbons. The remaining hydrocarbons were then extracted from the sample using benzene for at least 8 hours. This extraction technique was tested using re-extraction and was found to remove essentially all of the hydrocarbons. A test sample was extracted in the manner described above. A chromatogram of the recovered saturate hydrocarbons is given in curve A of Figure 10. The same sample was then re-extracted with benzene and the chromatogram of curve B was obtained. Based on the areas beneath the known peaks no more than an additional 2% of these materials were removed by the second extraction. The extracts also contained many non-hydrocarbons.

The extracts were recovered from the solvents by evaporation under partial vacuum on a flash-evaporator (BUCHLER Instruments) at 45°C. Approximately 50 ml of a solution of potassium hydroxide in methanol (30 g KOH per liter CH_3OH) were added for saponification. The mixture was refluxed on a steam-bath for 4 to 15 hours.

Distilled-deionized water was added to the saponified mixture and the non-saponifiable hydrocarbons were extracted into hexane using a separatory funnel with gentle mixing to avoid emulsion formation. The hexane was evaporated from the hydrocarbons under a nitrogen "blanket" at 40°C and the "total hydrocarbon" was recovered and weighed.

The "total hydrocarbon" sample is separated by column chromatography into two fractions. A column 20 cm long by 1 cm in diameter was packed with silica gel (WOELM, Activity I, ICN Pharmaceuticals*) and prewashed with purified hexane. The total nonsaponifiable organic extract was washed onto the column with a small portion (~ 1 ml) of hexane and the "saturate" hydrocarbons were eluted from the column with 50 ml of hexane (3-4 column volumes) Hexane insoluble material not previously added to the column was washed onto the column with a small portion (~ 1 ml) benzene and the column was eluted of "non-saturate" hydrocarbons with 50 ml of benzene.

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* The specific manufacturer is given for reference only and does not constitute an endorsement of product.

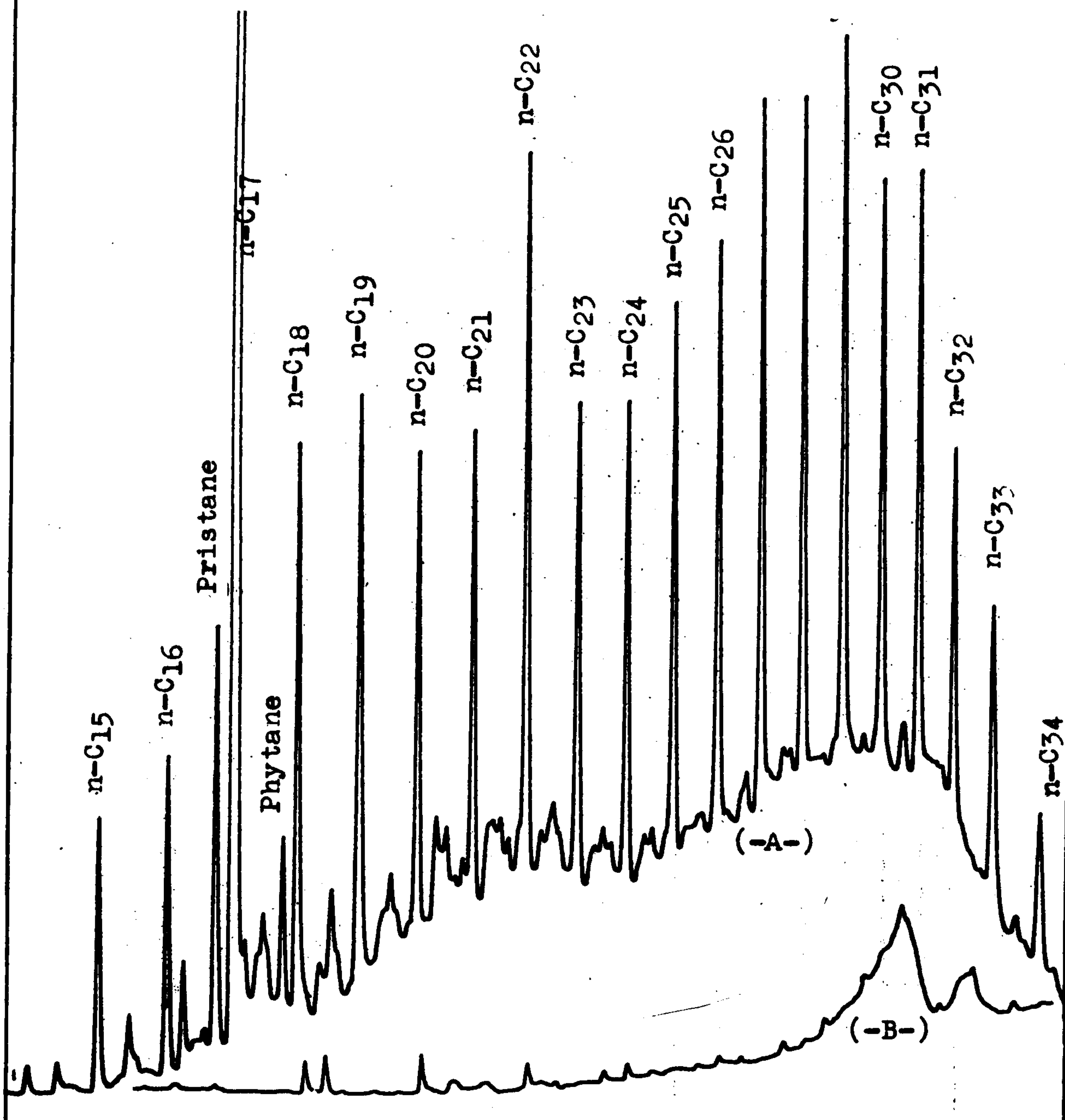

Figure 10. Comparison of initial extract (-A-) with second extract (-B-) of a test neuston sample.

The eluting solvents were evaporated from the saturate and non-saturate hydrocarbons with a nitrogen stream at ~40°C. The two fractions were weighed and diluted with 0.2 ml of hexane for gas chromatographic analysis.

Gas chromatographic analysis of saturate and non-saturate fractions was identical for all samples to that outlined for the water heavy hydrocarbons analysis.

RESULTS AND DISCUSSION

The results of hydrocarbons analyses of zooplankton samples are given in Tables 7 through 12. Some general conclusions can be drawn from these results and from the nature of the chromatograms themselves.

Pristane, a nineteen carbon isoprenoid, and n-heptadecane are the two most predominant hydrocarbons in zooplankton samples. Other hydrocarbons frequently observed in zooplankton are: nC_{15}, nC_{19}, nC_{22}, a phytadiene and singly unsaturated C_{19}.

Gas chromatograms of the saturate and non-saturate hydrocarbons generally are not complex. That is, a relatively few prominant hydrocarbon peaks are observed with a low background of unresolved hydrocarbons. Of 72 samples, one was found to contain no hydrocarbons, three samples were taken but not delivered to the analysi and thus were not available for analysis; nine were found to have a "hump" or unresolved hydrocarbons and 59 had no "hump" or only a small one.

For only six zooplankton samples did the distribution of n-alkanes extend appreciably beyond nC_{22} and even these samples did not contain a "full suite" of n-alkanes from nC_{15} to nC_{35} usually associated with petroleum contamination. Table 13 gives the relative weight pereentages of n-alkanes in these samples. The alkanes nC_{15}, nC_{17} and nC_{22} are predominant ones in these samples as they are in order in other zooplankton samples.

Table 7. Analysis of Prominant Hydrocarbons in Zooplankton Samples of Winter Collections, 1974-1975. Micrograms hydrocarbon per gram dry extracted material. (Same as percent times 1000)

				nC_{15}	nC_{16}	nC_{17}	nC_{18}	nC_{19}	nC_{22}
ACA	1	I	D	3.6	1.7	92.4	0.2		
BHS	1	I	N			7.9	1.7		
AEV	2	I	D	0.9	0.2	3.8	0.9	1.5	1.0
ACR	2	I	N	0.3	0.6	2.8	2.1	3.2	2.8
AAT	3	I	D	0.5	0.4	1.9	1.6	2.3	3.7
AAC	3	I	N	12.5	0.7	14.4	1.2	1.3	1.4
AIW	1	II	D	13.5	1.5	6.9	3.8		4.0
AHW	1	II	N	17.6	3.7	19.5	12.0	1.9	32.5
ALT	2	II	D			1.3	1.8		11.6
AMD	2	II	N	433.7		8.3	607.3	44.0	
AØW	3	II	D			0.2	0.3	0.2	0.2
AØD	3	II	N	1.9	3.2	37.2	17.3	23.6	19.6
ARY	1	III	D						
ARG	1	III	N	0.4	0.5	4.2	1.3	3.0	2.6
AVD	2	III	D						
AUL	2	III	N						
AYA	3	III	D	2.2	0.7	41.5	7.3		53.1
AXK	3	III	N	2.0	1.4	40.2	7.4	1.1	9.5
BAY	1	IV	D	0.8	3.2	64.2	8.5	13.1	7.6
BAI	1	IV	N			0.8	0.7	4.1	7.8
BEA	2	IV	D	0.1	0.04	3.9	0.6	2.2	2.0
BDI	2	IV	N	6.4	1.3	18.0	1.7	0.1	1.9
BPA	3	IV	D			1.9	0.3	3.0	1.0
BGJ	3	IV	N	0.7	0.1	7.2	0.6		

Table 7. Cont.'d

				Prist	Phyt	$Phyt_{:2}$	nC_{20}	$nC_{21}+$	$C_{19:1}$	$C_{21:2}$
ACA	1	I	D	177.2	7.8				63.9	
BHS	1	I	N	48.1			1.8			
AEV	2	I	D	18.9		0.3	0.5	0.2		
ACR	2	I	N	17.0	0.7	5.6	2.8	2.5		
AAT	3	I	D	8.6	0.03	1.0	1.0			
AAC	3	I	N	42.2	0.06	5.8	1.0			
AIW	1	II	D	63.6	0.04	12.3				469.9
AHW	1	II	N	494.3	1.6	10.7	9.3		15.6	
ALT	2	II	D	18.5						
AMD	2	II	N	50.4	86.5					
AØW	3	II	D	0.07						
AØD	3	II	N	70.1		11.3	12.8			
ARY	1	III	D							
ARG	1	III	N	23.6	0.4	3.6	2.0	2.3		
AVD	2	III	D							
AUL	2	III	N							
AYA	3	III	D	101.5						
AXK	3	III	N	117.3	1.8	13.9	4.6	3.5	7.3	
BAY	1	IV	D	178.0	1.4	14.4	4.5	5.4	73.8	
BAI	1	IV	N	3.8					8.6	
BEA	2	IV	D	16.6	0.01	3.2				
BDI	2	IV	N	56.8		8.9	0.3	0.6	7.0	
BPA	3	IV	D	6.1		2.4				
BGJ	3	IV	N	16.3						

Table 8. Analysis of Prominant Hydrocarbon in Zooplankton Samples of Spring Collection, 1975. Micrograms hydrocarbon per gram dry extracted material. (Same as percent times 1000)

				nC_{15}	nC_{16}	nC_{17}	nC_{18}	nC_{19}	nC_{22}
CAU	1	I	D	0.9	1.0	1.9	1.5	1.7	1.8
CAE	1	I	N	1.6	0.1	1.4	0.5	0.7	0.7
CDY	2	I	D	2.7	0.7	41.0	1.5	0.2	2.6
CDG	2	I	N	28.0	2.0	49.0	2.5	3.1	2.1
CHE	3	I	D	8.2	0.6	17.5	3.3	3.4	7.0
CGK	3	I	N	22.6	2.2	80.3	2.0	1.7	2.2
CKK	1	II	D			0.4			
CJT	1	II	N	1.8	0.5	6.2	1.4	1.6	3.3
CNN	2	II	D	4.3	0.2	6.3	1.0	0.6	
CMU	2	II	N	26.3	1.2	15.6	2.6	2.6	
CQP	3	II	D			43.4	2.5	4.5	5.6
CPY	3	II	N						1.1
CTX	1	III	D	2.4	0.3	4.1	2.5	2.1	3.9
CTD	1	III	N	3.0	0.01	1.4	0.2		
CXX	2	III	D	3.1	1.8	196.9	2.3	1.9	4.2
CXI	2	III	N	8.1	0.7	64.9	1.3	1.2	0.8
DGB	3	III	D	5.5	3.8	328.1	6.4	6.6	9.0
DAG	3	III	N	7.2	0.4	28.5	0.5	0.4	2.2
DDV	1	IV	D	0.7		1.4	0.3	0.3	1.2
DDG	1	IV	N	5.1	0.5	2.4	3.9	3.4	7.2
DMJ	2	IV	D	0.9		7.3	0.9	1.3	1.1
DGF	2	IV	N	3.6	0.09	3.9	2.7		3.3
DJZ	3	IV	D	4.5	0.7	10.5	3.1	3.6	6.5
DJF	3	IV	N	3.5	1.8	35.0	4.1	6.1	6.8

Table 8. Cont.'d

			Prist	Phyt	Phyt:2	nC_{20}	$nC_{21}+$
CAU	1	I	D	26.4	0.20	1.2	1.0	1.2
CAE	1	I	N	12.5	0.05	0.2	0.3	
CDY	2	I	D	9.8	0.01	1.8	0.7	0.8
CDG	2	I	N	56.7		2.9	1.7	1.5
CHE	3	I	D	13.8			0.9	0.4
CGK	3	I	N	29.0	0.6	5.8	1.0	0.9
CKK	1	II	D	3.2				
CJT	1	II	N	187.4	0.07		0.9	
CNN	2	II	D	105.9				
CMU	2	II	N	159.9	0.05	7.6	0.8	
CQP	3	II	D	9.6				
CPY	3	II	N					
CTX	1	III	D	81.9		1.8	0.7	
CTD	1	III	N	186.5				
CXX	2	III	D				3.8	
CXI	2	III	N	34.4			0.3	2.1
DGB	3	III	D	41.7			4.2	3.0
DAG	3	III	N	11.6		0.7		
DDV	1	IV	D	5.6				
DDG	1	IV	N	91.9	0.6	1.3	3.0	1.2
DMJ	2	IV	D	11.8	0.5		0.6	1.8
DGF	2	IV	N	36.6			1.4	1.3
DJZ	3	IV	D	13.4	0.3	0.9	1.9	1.1
DJF	3	IV	N	49.2			6.5	

Table 9. Analysis of Prominant Hydrocarbon in Zooplankton Samples of Summer Collections, 1975. Micrograms hydrocarbon per gram dry extracted material. (Same as percent times 1000)

				nC_{15}	nC_{16}	nC_{17}	nC_{18}	nC_{19}	nC_{22}
EAU	1	I	D	2.1		7.1	0.4	0.9	0.7
EAE	1	I	N	6.5	0.09	11.4	0.7	0.7	1.2
EDY	2	I	D	2.5	0.5	14.0	0.7	7.1	1.3
EDG	2	I	N						4.8
EHE	3	I	D						1.0
EGK	3	I	N	2.4		29.0	1.0	0.9	2.9
EKK	1	II	D	1.4	1.6	5.0	5.3	4.6	19.6
EJT	1	II	N				0.04	0.3	3.3
ENØ	2	II	D			14.1	0.9	1.4	7.8
EMU	2	II	N	7.5	0.5	9.2	1.2	1.4	6.8
EQP	3	II	D			10.2	0.7		1.2
EPY	3	II	N	2.0	0.6	33.9	4.8	5.6	8.0
ETX	1	III	D	4.6	0.6	13.5	1.9	2.9	4.2
ETD	1	III	N						
EXX	2	III	D	1.5	0.2	16.4	1.4	1.6	2.3
EXI	2	III	N	2.1	0.1	10.1	2.6	2.9	4.1
FBG	3	III	D			1.4	0.9	1.6	4.5
FAG	3	III	N	0.3		1.8			
FED	1	IV	D	3.4	0.3	3.0	1.5	1.3	
FDN	1	IV	N	4.4	0.3	8.3	0.8	1.7	1.4
FHE	2	IV	D			0.2	0.1	0.5	1.2
FGN	2	IV	N	3.3	0.5	4.2	1.4	1.8	2.5
FKJ	3	IV	D			7.5	0.4		
FJP	3	IV	N			11.0			

Table 9. Cont.'d

			Prist	Phyt	$Phyt_{12}$	nC_{20}	nC_{21}^+
EAU	1	I D	17.4		1.0		
EAE	1	I N	13.9		1.1		
EDY	2	I D	17.9	0.003	3.2	0.5	1.0
EDG	2	I N					
EHE	3	I D				0.03	0.8
EGK	3	I N	38.2		3.0	0.7	
EKK	1	II D	18.1	0.5		3.2	12.5
EJT	1	II N	6.8			0.2	2.5
ENØ	2	II D	16.1	0.04	2.6	1.5	4.1
EMU	2	II N	32.1	0.05	4.3	1.6	3.2
EQP	3	II D	4.4				1.7
EPY	3	II N	41.9	0.1	4.7	2.4	
ETX	1	III D	20.3		1.0		
ETD	1	III N					
EXX	2	III D	27.5		5.3	0.8	0.9
EXI	2	III N	17.5	0.6		2.8	5.2
FBG	3	III D	7.3		1.8	0.5	
FAG	3	III N	6.3		0.9		
FED	1	IV D	59.6				
FDN	1	IV N	41.1		2.3	0.2	
FHE	2	IV D	0.9				
FGN	2	IV N	30.0		1.3	0.8	
FKJ	3	IV D	6.0				
FJP	3	IV N	3.4				

Table 10. Analysis of Zooplankton Samples of Winter Collections 1974-75.

Sample Code			Total HC(%)	Sat. (%)	Non-Sat. (%)	$\frac{Pr}{Ph}$	$\frac{Pr}{C_{17}}$	$\frac{C_{17}}{C_{18}}$	$\frac{Sat.}{Non\text{-}Sat.}$	Sample Wt.(g)
ACA	1 I	D	0.54	0.02	0.03	22.6	1.92	523.	3.82	(a)
BHS	1 I	N	10.1	0.17	0.78	-	6.05	4.68	0.22	1.13
AEV	2 I	D	0.90	0.02	0.007	-	4.99	4.29	3.00	2.01
ACR	2 I	N	2.52	0.17	0.31	24.5	6.15	1.33	0.55	2.60
AAT	3 I	D	-	-	-	295.	4.49	1.24	0.56	(a)
AAC	3 I	N	-	-	-	704.	2.94	12.0	0.06	(a)
AIW	1 II	D	5.34	0.37	0.12	1510.	9.21	1.82	3.38	1.94
AHW	1 II	N	5.10	0.30	0.57	308.	25.3	1.63	0.58	3.09
ALT	2 II	D	12.8	0.31	0.27	-	14.0	0.73	1.13	0.75
AMD	2 II	N	7.79	0.71	1.33	0.58	6.07	0.14	0.53	1.14
AOW	3 II	D	0.17	0.02	0.005	-	0.34	0.80	4.20	3.00
AOD	3 II	N	5.22	0.42	0.08	-	1.89	2.15	5.08	0.88
ARY	1 III	D	Sample Lost							
ARG	1 III	N	-	-	-	52.4	5.59	3.30	-	2.60
AVD	2 III	D	Sample Lost							
AUL	2 III	N	Sample Lost							
AYA	3 III	D	7.19	0.02	0.36	-	2.45	5.17	0.56	0.41
AXK	3 III	N	3.59	0.13	-	66.3	2.92	5.41	-	0.44
BAY	1 IV	D	3.88	0.61	0.15	130.	2.77	7.53	4.08	4.01
BAI	1 IV	N	9.58	0.14	0.06	-	4.48	1.17	2.26	0.85
BEA	2 IV	D	2.07	0.07	0.03	1300.	4.26	6.93	2.53	1.21
BDI	2 IV	N	8.97	0.08	0.38	-	3.15	10.3	0.21	2.06
BPA	3 IV	D	6.05	0.04	0.07	-	3.23	6.43	0.57	0.79
BGJ	3 IV	N	0.54	0.02	0.03	-	2.28	11.5	7.80	1.90

(a) Sample was not brought to constant weight due to operator error. Weight is assumed to be 1.3g, average of all samples.

Table 11. Analysis of Zooplankton Samples of Spring Collections, 1975.

Sample Code			Total HC(%)	Sat. (%)	Non-Sat. (%)	$\frac{Pr}{Ph}$	$\frac{Pr}{C_{17}}$	$\frac{C_{17}}{C_{18}}$	$\frac{Sat.}{Non\text{-}Sat.}$	$\frac{Sample}{Wt.(g)}$
CAU	1 I	D	0.58	0.10	0.03	133.	14.1	1.25	2.79	6.23
CAB	1 I	N	2.37	0.05	0.66	276.	8.75	2.73	0.08	2.69
CDY	2 I	D	48.8	-	6.92	1052.	0.24	27.6	-	2.41
CDG	2 I	N	4.83	0.08	0.03	-	1.16	19.3	0.23	1.35
CHE	3 I	D	12.6	0.21	0.06	-	0.78	5.36	3.50	0.46
CGK	3 I	N	33.6	0.12	1.57	46.5	0.36	40.9	0.08	0.84
CKK	1 II	D	-	-	-	-	7.56	-	0.02	1.19
CJT	1 II	N	3.54	0.06	0.16	2800.	30.4	4.43	0.33	1.73
CNN	2 II	D	12.6	0.05	0.13	-	16.7	6.25	0.41	1.53
CMU	2 II	N	7.44	0.10	0.33	3100.	10.2	6.05	0.33	1.24
CQP	3 II	D	3.20	0.09	0.05	-	0.22	17.1	1.77	0.57
CPY	3 II	N	1.83	0.05	0.01	1050.	0.24	27.6	3.57	2.03
CTX	1 III	D	2.93	0.08	0.03	-	20.2	1.60	2.91	1.22
CTD	1 III	N	21.6	0.008	0.06	-	13.1	6.67	0.15	1.10
CXX	2 III	D	3.05	0.06	0.02	-	0.28	84.9	3.0	0.99
CXI	2 III	N	8.59	0.08	0.04	-	0.53	46.9	2.14	1.10
DGB	3 III	D	3.43	0.15	0.04	-	0.13	51.0	3.60	0.71
DAG	3 III	N	3.30	0.03	0.03	-	0.40	56.7	1.12	0.88
DDV	1 IV	D	5.24	0.05	0.002	-	3.98	4.57	22.0	(a)
DDG	1 IV	N	5.14	0.16	0.05	149.	38.8	0.61	3.07	0.57
DMJ	2 IV	D	2.79	0.04	0.001	23.5	1.61	8.10	37.0	0.98
DGF	2 IV	N	7.43	0.06	0.10	-	9.30	1.44	0.55	0.80
DJZ	3 IV	D	4.94	0.09	0.03	47.1	1.27	3.40	0.30	0.98
DJF	3 IV	N	3.79	0.11	0.02	-	1.41	8.46	5.42	0.61

(a) See footnote Table 10.

Table 12. Analysis of Zooplankton Samples of Summer Collections, 1975.

Sample Code			Total HC(%)	Sat. (%)	Non-Sat. (%)	$\frac{Pr}{Ph}$	$\frac{Pr}{C_{17}}$	$\frac{C_{17}}{C_{18}}$	$\frac{Sat.}{Non\text{-}Sat.}$	Sample Wt.(g)
EAU	1 I	D	1.29	0.02	0.02	-	2.46	20.1	0.90	1.64
EAE	1 I	N	1.74	0.02	0.03	-	1.22	0.17	0.83	1.82
ADY	2 I	D	1.08	0.03	0.03	5180.	1.28	21.0	1.05	1.56
EDG	2 I	N	1.95	0.05	0.04	-	-	-	1.35	0.51
EHE	3 I	D	1.02	0.03	0.03	-	-	-	8.33	0.92
EGK	3 I	N	3.55	0.05	0.06	-	1.32	30.2	0.89	0.79
EKK	1 II	D	2.62	0.16	0.03	37.9	3.58	0.96	5.38	0.44
EJT	1 II	N	0.66	0.03	0.01	-	-	-	2.11	0.68
ENO	2 II	D	1.79	0.04	0.03	365.	1.14	14.7	1.11	1.06
EMU	2 II	N	3.85	0.06	0.08	595.	3.49	7.45	0.08	1.11
EQP	3 II	D	0.64	0.04	0.04	-	0.43	14.0	1.07	0.35
EPY	3 II	N	2.54	0.12	0.21	321.	1.24	7.06	0.57	0.37
ETX	1 III	D	2.23	0.04	0.07	-	1.31	8.23	0.64	1.22
ETD	1 III	N	0.20	0.03	0.03	-	-	-	0.94	0.56
EXX	2 III	D	2.14	0.06	0.02	-	1.68	0.12	3.35	0.93
EXI	2 III	N	5.05	0.09	0.12	28.6	1.73	3.82	0.72	1.19
FBG	3 III	D	3.19	0.03	0.03	-	5.08	1.58	1.07	0.50
FAG	3 III	N	1.29	0.007	0.007	-	3.50	-	1.00	1.39
FED	1 IV	D	2.55	0.04	0.002	-	19.7	2.08	26.0	0.64
FDN	1 IV	N	2.43	0.03	0.03	-	4.94	11.0	1.03	1.09
FHE	2 IV	D	0.75	0.008	0.001	-	4.83	1.43	7.00	0.82
FGN	2 IV	N	4.06	0.04	0.03	-	7.14	2.96	1.24	1.27
FKJ	3 IV	D	0.56	0.02	0.01	-	0.80	16.9	1.30	0.71
FJP	3 IV	N	2.40	0.02	0.01	-	0.30	-	1.80	0.96

Table 13. Relative Weight Percentages of N-Alkanes in Zooplankton Samples having Alkanes of Molecular Size Greater than C_{22}.

No. of Carbon Atoms	Sample	CAU	EJT	EKK	EMU	ENØ	EXI
14		1.5					
15		5.9		1.6	16.6		5.6
16		6.8		1.9	1.2		0.3
17		12.7		5.8	20.5	30.5	27.5
18		10.1	0.3	6.1	2.8	2.1	7.2
19		11.3	2.2	5.4	3.1	3.1	8.0
20		7.0	1.5	3.7	3.6	3.2	7.7
21		7.8	17.5	14.4	7.2	8.8	14.1
22		12.6	23.4	22.7	15.1	17.2	11.3
23		8.2	21.3	14.1	12.0	12.3	4.6
24		7.3	14.4	11.5	8.9	8.4	2.8
25		4.9	10.4	8.9	7.3	7.7	2.0
26		2.4	9.0	3.9	1.7	3.5	2.5
27		1.5				2.7	2.0
28						0.5	0.8
29							1.2
30							1.3
31							0.5
32							0.5
Season		Spring	Summer	Summer	Summer	Summer	Summer
Line		I	II	II	II	II	III
Station		1 Day	1 Night	1 Day	2 Night	2 Day	2 Night

The ratio of n-alkanes having odd numbers of carbon atoms to those having even numbers of carbons in the range of C_{25} to C_{35} is frequently cited as a measure of petroleum-like character of saturated hydrocarbons (Bray and Evans, 1961). An extension of this concept to show the local odd/even ratio as a function of carbon number is given by Scalan and Smith (1970). [Such plots (OEP curves) are given as Figures 44 - 49 in Appendix _ for the above six zooplankton samples.] Each of these curves shows a minimum at C_{22} and a maximum or upward trend at C_{17} indicative of the predominance of these two hydrocarbons in the n-alkanes distribution. For these zooplankton, the OEP curves fail as indicators of petroleum contamination since they do not cover the range of petroleum alkanes C_{15} to C_{35}. They do show the general character of OEP curves which may be attributed to "zooplankton character". It is perhaps significant that five of these six samples were from the summer sampling season and were from the innermost sampling stations.

The twenty carbon isoprenoid, phytane, is not a prominant one in zooplankton. It was observed in 26 of the samples. The pristane/phytane ratio may be a useful parameter for indication of petroleum contamination, values close to unity being indicative of presence of petroleum-like hydrocarbons. These ratios are given in Table 12 along with other analytical data. In only one instance was this ratio less than or even close to unity. This particular sample, AMD, was unusual in that the most predominant hydrocarbons were lower molecular size ($< C_{17}$) unsaturated compounds. Apparently this sample was not contaminated with petroleum-like hydrocarbons. This suggests that the pristane/phytane ratio alone is not a sufficient indicator of petroleum contamination.

There is no significant difference in the average of total non-saponifiable organic matter content between winter and spring collections of zooplankton. There is a significant (> 99.9% confidence level) greater average quality of total non-saponifiable material in the winter and spring samples than in the fall sampling. This is in agreement with previous studies (Sackett, W.M. et. al., 1965) that zooplankton in colder waters tend to be more lipid-rich.

Comparisons other than the seasonal show no significant variations in average hydrocarbon content; e.g. Day-Night, North-South, inshore-offshore, etc.

Winter samples may differ from spring and fall samples in having a significantly larger quantity of saturated hydrocarbons though there is no significant difference between spring and fall samples in this regard. Non-saturate hydrocarbons may differ significantly between all three seasons.

NEUSTON

MATERIALS AND METHODS

Neuston samples were collected using a neuston "sled" holding a 1/2 meter plankton net so as to skim the upper 10 cm of the air-water interface. Most samples were of a zooplankton or ichthyoplankton type, but some contained larger materials such as sargassum.

Neuston samples were handled in a manner identical with that for zooplankton samples except that in some neuston samples visible "tar-ball" contaminants were removed. No attempt was made to remove microscopic sized tar-balls. Extraction, saponification, separation and analysis techniques were the same as those used for zooplankton samples.

RESULTS AND DISCUSSION

Results of n-alkanes and isoprenoid analyses of neuston samples are contained in Tables 14 - 16. There are two main types of saturate hydrocarbon distributions in neuston samples: (a) those which resemble zooplankton in having major peaks at nC_{17} and pristane, and to a lesser extent, peaks at nC_{15}, nC_{19} and nC_{22}; and (b) those which are apparently contaminated with petroleum-like alkanes having a full suite of n-alkanes from nC_{15} to nC_{35}. Twenty samples were of the former type and twelve of the latter. Two samples had saturates with no identifiable peaks, and two samples were not delivered to the analyst. These samples were collected but apparently misrouted prior to analysis.

Of those neuston saturate analyses which resembled zooplankton only two did not have a "hump" of unresolved hydrocarbons in the gas chromatograms; so in this respect the chromatograms are somewhat more complex than those for zooplankton. Most of the samples having a petroleum-like distri-

Table 14. Analyses of Neuston Hydrocarbons of Winter Collection, 1974-1975.

Component concentration (micrograms/gram extracted dry sample)

Sample / Component	AHL	AEY	ATE	AJI*	ALW	AOZ	ASC	AVH	AYE	BBD	BEG	BPJ
nC_{14}		sample not available for analysis							n-alkanes and isoprenoids were not detected	0.58		
nC_{15}	1.4			7.3	0.59	0.03	3.6			6.4		
nC_{16}	3.8			0.76	0.57	0.08	1.0			3.6	1.3	
nC_{17}	10.8		0.75	4.2	5.5	6.5	4.9	1.4		83.1	7.8	
nC_{18}	0.42		2.4	1.3	2.6	0.87	3.1	0.48		20.2	8.5	
nC_{19}	13.2		2.2	1.7	3.3	1.5	3.9	0.72		27.1	12.2	
nC_{20}	7.4		1.7	1.9	2.5	1.2	2.2	0.30		30.6	16.6	
nC_{21}	0.14		0.47	0.20	1.5	0.71	0.92	0.02		59.7	25.6	
nC_{22}	12.9		9.0	2.2	6.1	2.6	4.0	1.7		109.6	29.4	
nC_{23}										173.5	35.4	
nC_{24}										218.3	41.1	
nC_{25}										221.2	51.4	
nC_{26}										177.7	57.0	
nC_{27}										120.9	66.5	

Table 14 (cont.)

Sample	AHL	AEY	ATE	AJI*	ALW	AOZ	ASC	AVH	AYE	BBD	BEG	BPJ
Component												
nC_{28}										81.1	59.4	
nC_{29}										89.9	59.2	
nC_{30}										80.1	54.9	
nC_{31}										167.1	58.8	
nC_{32}										56.8	26.4	
nC_{33}										48.3	26.1	
nC_{34}										34.5	14.8	
nC_{35}										22.0	10.8	
nC_{36}										8.4		
nC_{37}										20.3		
nC_{38}										20.6		
nC_{39}										27.2		
nC_{40}										20.9		
Pristane	81.2			181.5	0.09	0.21	34.1			138.0	4.0	
Phytane	11.6			0.12	0.12	0.01	0.53			7.3	1.3	

Table 14 (cont.)

Sample	AHL	AEY	ATE	AJI*	ALW	AOZ	ASC	AVH	AYE	BBD	BEG	BPJ
Ratios												
nC_{17}/nC_{18}	25.4		0.31	3.2	2.1	7.5	1.6	2.9		4.1	0.92	
$Pris/nC_{17}$	7.5			43.6	0.02	0.03	7.0			1.7	0.51	
Pris/Phyt	7.0			1512.	0.75	21.0	64.3			18.9	3.1	
Line/Station	I/1	I/2	I/3	II/1	II/2	II/3	III/1	III/2	III/3	IV/1	IV/2	IV/3
Sample Wt.(g)	1.20	-	0.63	8.08	2.85	3.31	2.75	3.71	3.54	1.85	2.88	3.50
Total H.C.(%)	1.74	-	0.34	1.24	0.41	0.62	1.30	0.85	1.72	0.96	6.27	0.21

*This sample was known to be contaminated by shipboard lubricant.

Table 15. Analyses of Neuston Hydrocarbons of Spring Collection, 1975

Component concentration (micrograms/gram extracted dry sample)

Sample Component	CAX	CEI	CHH	CKN	CNQ	CQS	CUA	CYF	DAY	DDY	DGX	DKC
nC_{15}	2.9	5.0	4.8	sample not available for analysis	2.3	7.5	1.3	3.7	1.2	1.4	4.0	3.5
nC_{16}	0.25	0.49	5.2		0.03	0.98	0.02	0.39	0.46	0.19	0.26	0.26
nC_{17}	4.3	5.0	75.4		2.3	18.6	3.1	10.0	5.8	9.2	10.5	6.3
nC_{18}	1.0	1.7	9.5		0.78	2.6	0.14	1.5	3.7	1.1	0.57	1.1
nC_{19}	1.1	1.4	11.1		1.4	3.1	0.33	1.6	3.7	1.6	0.84	1.3
nC_{20}	0.49	0.86	8.0		0.24	1.8	1.8	0.82	1.6	0.66	0.51	0.26
nC_{21}	0.37	0.03	7.1		0.05	1.3	0.04	0.34	0.66	0.89	0.03	0.19
nC_{22}	3.5	2.8	12.4		2.0	8.2	1.6	3.6	8.6	3.0	1.8	1.9
nC_{23}			7.8									
nC_{24}			7.8									
nC_{25}			9.7									
nC_{26}			10.4									
nC_{27}			12.4									
nC_{28}			11.0									

Table 15 (cont.)

Sample	CAX	CEI	CHH	CKN	CNQ	CQS	CUA	CYF	DAY	DDY	DGX	DKC
Component												
nC_{29}			13.2									
nC_{30}			9.7									
nC_{31}			10.2									
nC_{32}			5.4									
nC_{33}			5.3									
nC_{34}			3.2									
nC_{35}			4.4									
Pristane	0.68		7.3									
Phytane	0.02		2.6									
Ratios												
nC_{17}/nC_{18}	4.3	2.9	7.9		2.9	7.1	22.1	6.7	1.6	8.4	18.4	
Pris/nC_{17}	0.16		0.10									
Pris/Phyt	34.0		2.8									
Station/Line	1/I	2/I	3/I	1/II	2/II	3/II	1/III	2/III	3/III	1/IV	2/IV	3/IV
Sample Wt.(g)	2.26	2.57	2.15	-	1.94	2.43	2.93	2.94	1.50	2.58	3.26	3.28
Total H.C.(%)	0.36	0.39	0.61	-	0.60	0.39	-	0.36	0.74	6.49	0.43	0.41

Table 16. Analyses of Neuston Hydrocarbons of Summer Collection, 1975.

Component concentration (micrograms/gram extracted dry samples)

Sample Component	EAX	EEI	EHH	EKN	ENR	EQS	EUA	EYF	FAY	FEG	FHH	FKM
nC_{14}	0.14											
nC_{15}	3.0			2.4		83.6		1.2	2.4	7.4		
nC_{16}	1.2			0.28		304.6		0.22	1.7	4.7		
nC_{17}	4.4	4.3	0.92	5.8	13.9	709.2	218.5	2.7	11.2	15.0	31.8	19.1
nC_{18}	1.8	1.2	0.26	0.51	1.8	991.9	178.9	1.1	6.9	8.2	32.7	6.3
nC_{19}	1.7	1.3	0.43	2.1	3.3	1135.	197.0	1.5	7.3	8.1	39.7	9.8
nC_{20}	1.4	0.87	0.33		1.7	1158.	188.9	1.4	6.7	6.6	46.0	9.8
nC_{21}	1.3	0.98	0.41		1.3	1171.	181.1	1.6	3.1	6.2	34.4	9.4
nC_{22}	1.6	1.7	0.60		3.2	1141.	191.7	2.4	11.8	6.4	44.1	10.1
nC_{23}	0.92	1.3			0.96	1211.	185.7	0.65		4.4	50.6	9.1
nC_{24}	0.90	1.3			0.68	1280.	178.0	1.8		4.2	54.2	8.1
nC_{25}	0.65	1.2			1.9	1472	182.9	2.3		4.6	61.2	7.5
nC_{26}	0.94	1.1			1.4	1596.	213.1	2.5		4.0	80.3	6.2
nC_{27}	0.87	1.3			1.7	1793.	259.0	3.0		4.0	99.3	5.7

Table 16 (cont.)

Sample	EAX	EEI	EHH	EKN	ENR	EQS	EUA	EYF	FAY	FEG	FHH	FKM
Component												
nC_{28}	1.4	1.3			1.3	1616.	266.0	3.3		5.1	103.0	4.1
nC_{29}	1.0	1.1			1.7	1624.	270.4	3.0		5.2	103.4	4.1
nC_{30}	0.84	1.3			0.96	1345.	224.3	2.3		4.5	92.4	3.0
nC_{31}	0.70	1.5				1139.	262.3	1.9		3.7	103.4	4.1
nC_{32}	0.67	1.7				743.4	219.7	1.1		3.2	79.1	2.3
nC_{33}		1.8				650.0	210.5	1.6			79.2	2.6
nC_{34}		2.8				520.5	161.5	0.75			58.8	2.0
nC_{35}		1.8				417.8	165.9				56.1	1.3
nC_{36}		2.2				388.6	108.7				35.3	
nC_{37}		1.8				381.4	84.3				9.8	
nC_{38}							90.0				8.6	
nC_{39}							75.9				10.7	
nC_{40}							72.0				10.1	
nC_{41}							51.6					
Pristane	1.0			66.6	2.5		158.2		2.2	4.8		7.8
Phytane	0.67				0.18		77.6		0.78	2.8		1.2

Table 16 (cont.)

Sample	EAX	EEI	EHH	EKN	ENR	EQS	EUA	EYF	FAY	FEG	FHH	FKM
Ratios												
nC_{17}/nC_{18}	2.4	3.6	3.5	11.4	7.7	0.71	1.2	2.4	1.6	1.8	0.97	3.0
$Pris/nC_{17}$	0.23			11.5	0.18		0.72		0.20	0.32		0.41
Pris/Phyt	1.5				13.9		2.0		2.8	1.7		6.5
Sample Wt.(g)	5.91	2.16	5.14	0.34	3.42	0.42	1.05	4.72	0.86	3.41	4.40	3.57
Total H.C.(%)	0.33	0.21	0.31	1.92	0.64	18.08	1.86	0.37	0.57	0.48	0.65	0.55
	1/I	2/I	3/I	1/II	2/II	3/II	1/III	2/III	3/III	1/IV	2/IV	3/IV

bution of n-alkanes, also had a "hump" of unresolved peaks. Many of these "petroleum-like" saturates still show some of the "zooplankton" characteristics of having relatively higher nC_{17}, pristane and nC_{22}. This suggests possible contamination of "zooplankton" type samples with petroleum-like organic matter, probably tar-balls of unknown origin.

OEP curves for the twelve samples having n-alkanes of higher molecular size are shown in Figures 50 - 62 of the Appendix. Six samples shown in Figures 50 - 55 (of the Appendix) and possibly the sample of Figure 56 (of the Appendix) show some "zooplankton" character in the OEP curves, that is, minima at C_{22} and maxima at C_{17}. The remaining samples of Figures 57 - 61 (of the Appendix) have rather flat OEP curves with values near unity resembling petroleum. Figure 62 (of the Appendix) is representative of the OEP curves for a "zooplankton" type neuston saturate.

Figure 11 shows the distribution of the "type" of samples seasonally. The "petroleum-like" saturates are more prevalent in summer samples and perhaps more in the southern region of the study area. The spring samples are almost exclusively of the "zooplankton" type. Other parameters, viz. Pristane/Phytane ratio, Pristane/C_{17} ratio, C_{17}/C_{18} ratio are shown in Figures 12, 13 and 14. There are no obvious areal trends among these distributions.

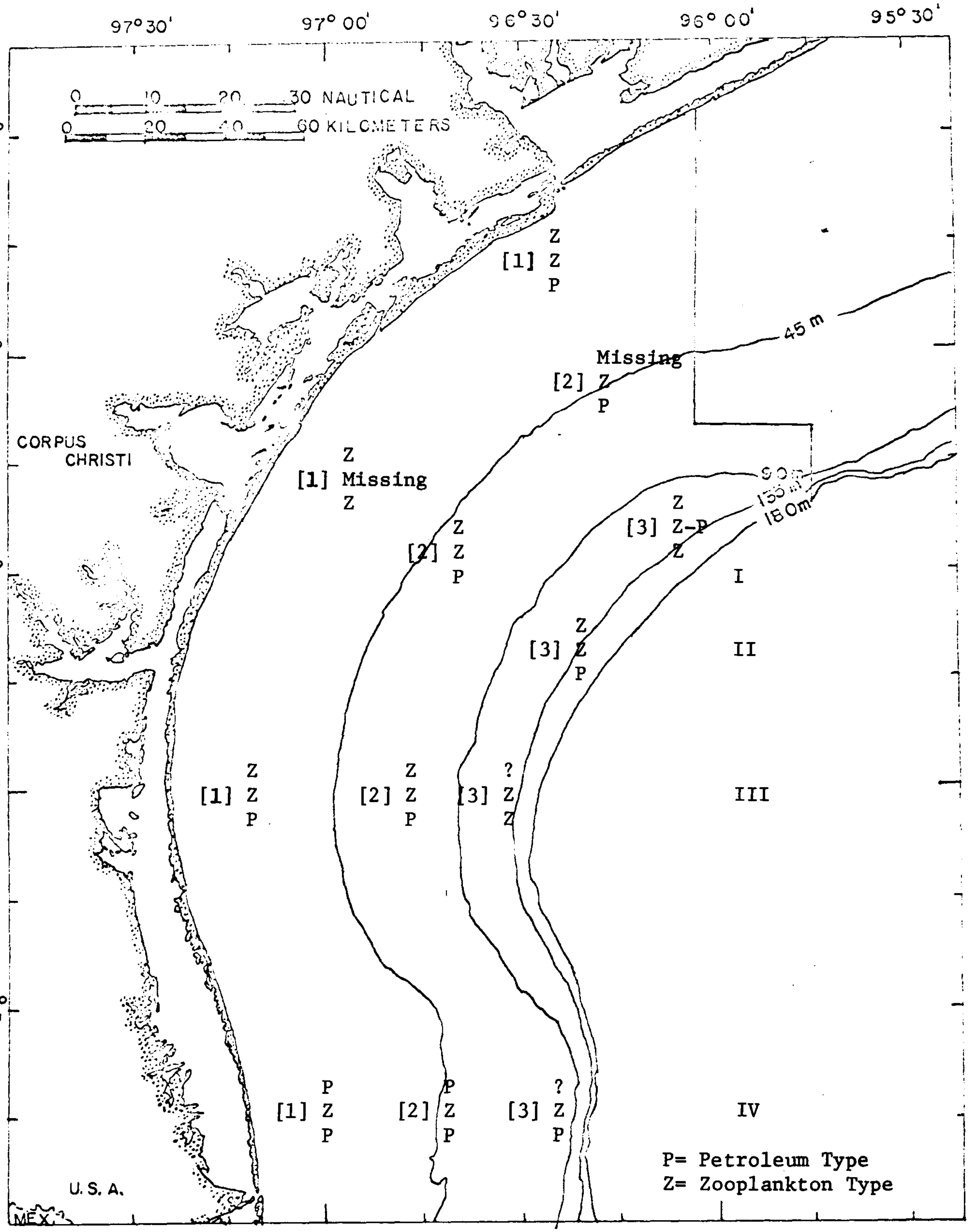

Figure 11. Distribution of the Character of Neuston Saturates.

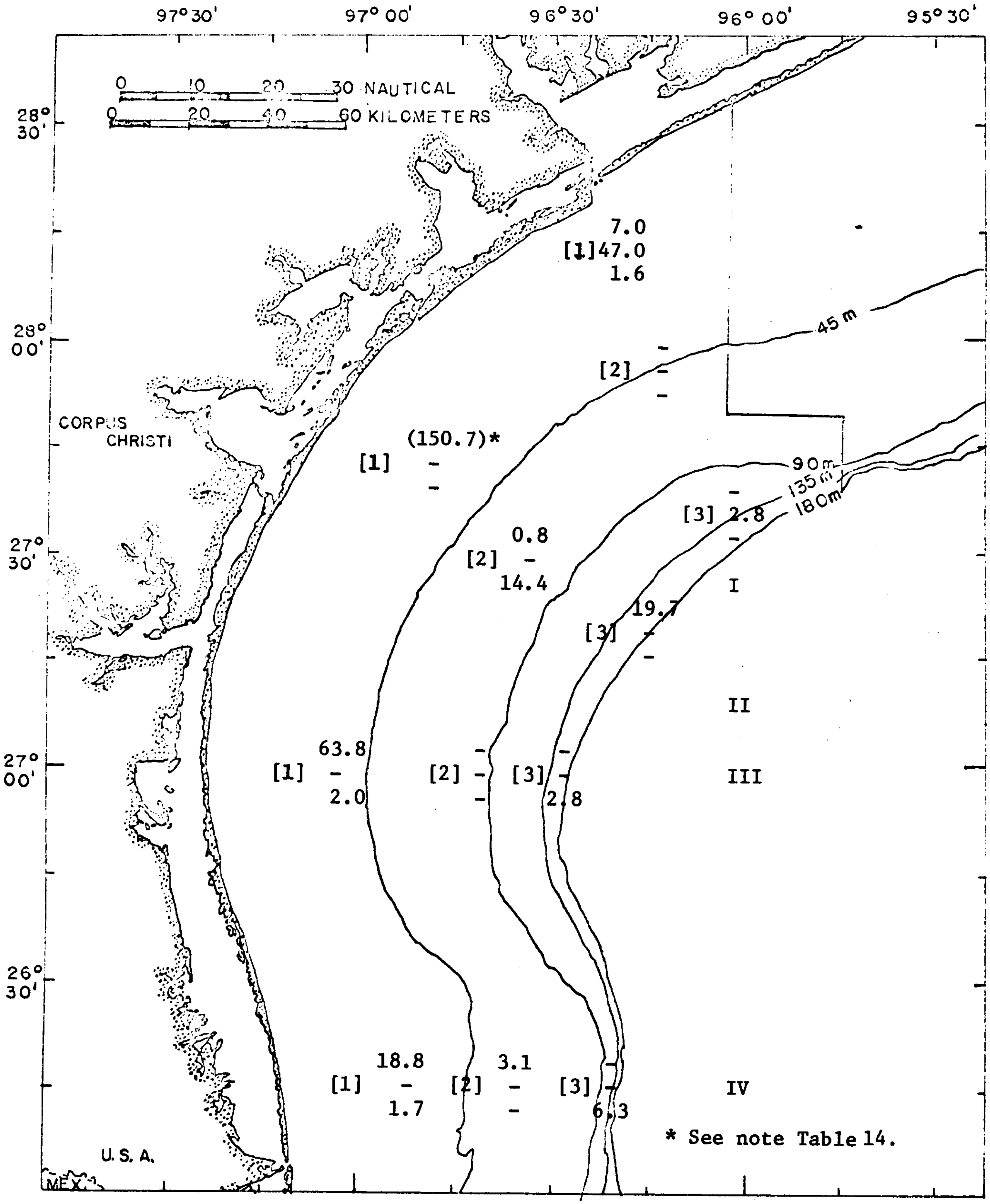

Figure 12. The Ratio Pristane/Phytane in Neuston Samples.

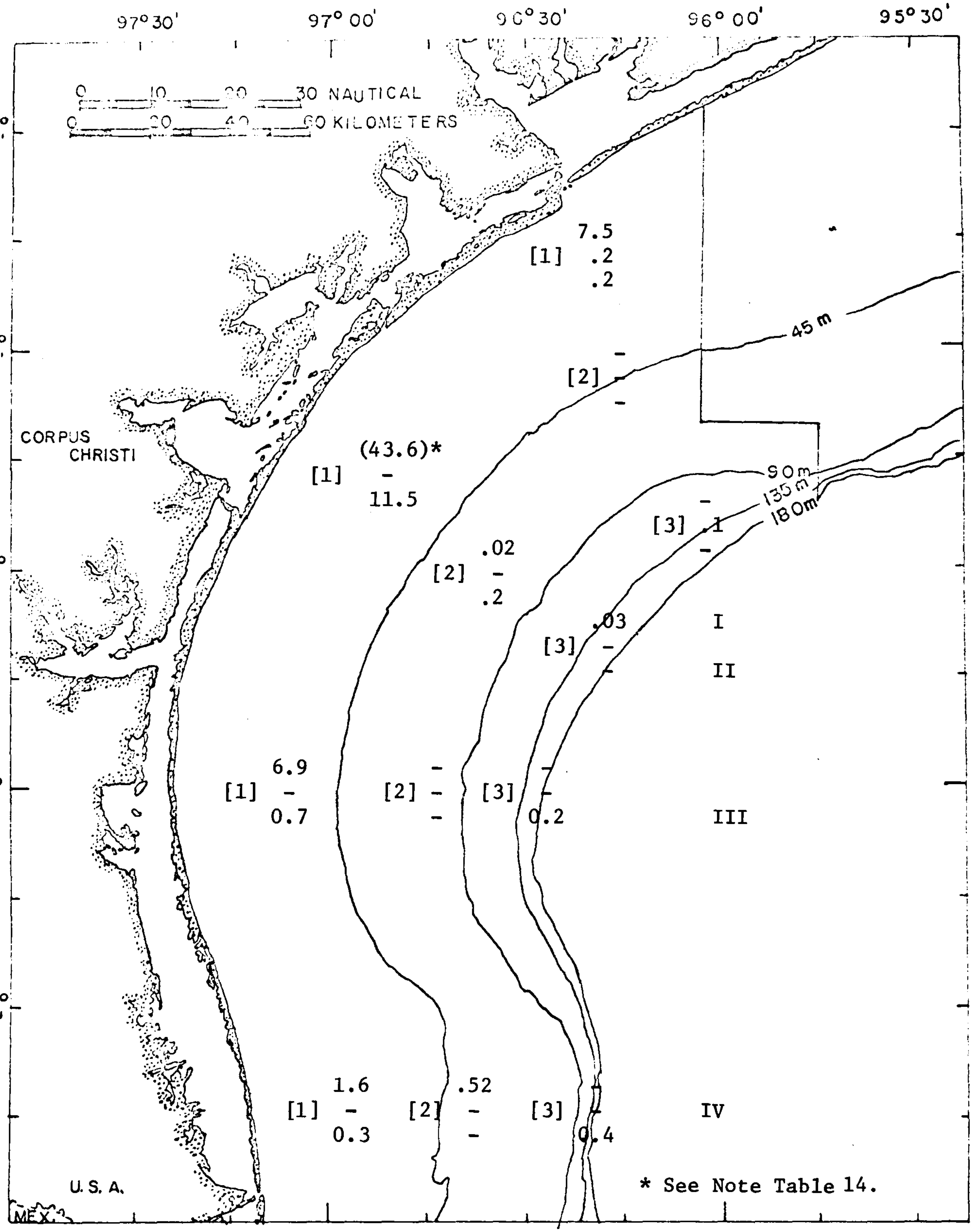

Figure 13. The Ratio Pristane/C_{17} in Neuston Samples.

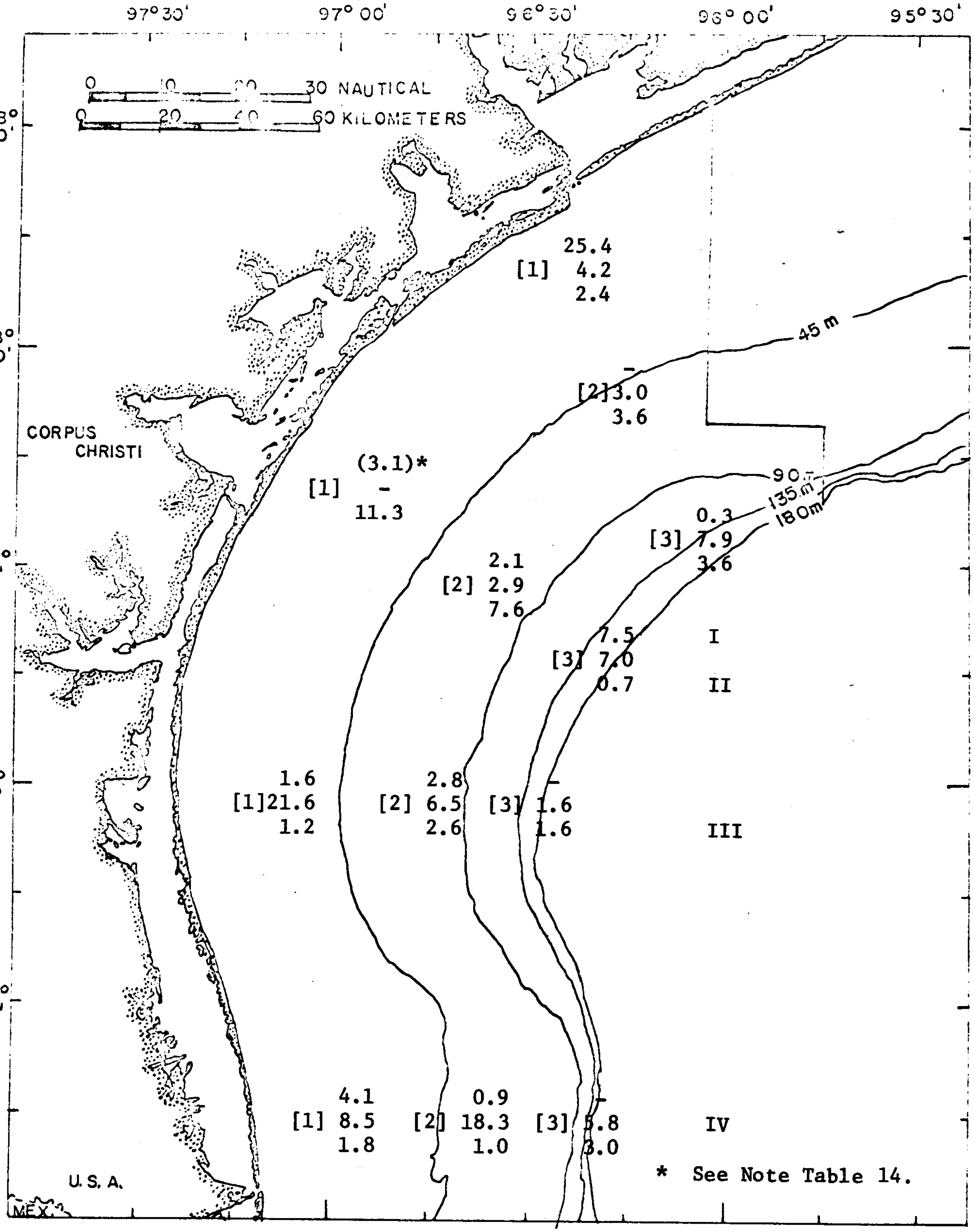

Figure 14. The Ratio C_{17}/C_{18} in Neuston Samples.

SEDIMENTS

MATERIALS AND METHODS

Sediment samples were obtained from each sampling site using a Smith-MacIntyre grab. A portion of about 2 liters size of each grab was removed from the top 10 cm of the whole sample and was placed in a 4-liter glass jar especially cleaned free of hydrocarbons. The sample was maintained frozen or refrigerated until analysis.

Two basic techniques were used for extraction of hydrocarbons from sediments: SOXHLET extraction and ultrasonic dispersion. In both cases the samples were treated first with methanol to remove water and then with benzene to complete the hydrocarbon extraction. In the case of SOXHLET extraction, each solvent was used for a minimum of 24 hours. For ultrasonic extraction the thawed sample was mixed with 3 sample volumes of solvent and sonicated for 10 minutes with a BRANSON MODEL S-125 ultrasonic generator. The sample was filtered under partial vacuum onto prewashed filter paper (WHATMAN #541) and re-extracted 2 more times with each solvent. All extraction solvents were combined, reduced in volume, saponified, separated and analyzed as indicated for zooplankton.

RESULTS AND DISCUSSION

Hydrocarbons were extracted from sediments of each of the twelve stations, three seasons of the year. The average nonsaponifiable extract is 0.02 percent. Analysis of n-alkanes was successful for 34 of the samples. Two samples contained few or no n-alkanes, which could be resolved from a background "hump" of hydrocarbons.

Relative percentages of n-alkanes are given in Tables 17 - 19 for the sediment samples. There are no obvious trends in these data, either areally or seasonally. The n-alkanes distributions show a predominance of alkanes

Table 17. Relative Abundances of N-Alkanes in Station 1 Samples.

Carbon Number	Winter Lines				Spring Lines				Summer Lines			
	I	II	III	IV	I	II	III	IV	I	II	III	IV
Sample	AGU	AKW	AUC	BCX	CCX	CML	CWZ	DFW	ECX	EML	EWZ	FGE
15											1.96	0.34
16						sample contained no n-alkanes			0.70	1.54	3.24	1.51
17	0.19	0.14	5.10				2.44		0.36	9.58	7.40	48.95
18	0.91	0.70	9.51		0.75		6.71	11.83	0.78	12.60	6.40	4.06
19	2.32	1.51	7.98	2.18	0.49		7.86	2.43	1.27	9.83	5.01	4.96
20	1.78	1.41	5.30	0.09	2.84		6.37	4.96	1.53	5.89	3.39	4.54
21	1.73	2.20	2.19	7.32	3.68		7.00	7.74	8.45	1.28	1.16	4.40
22	4.80	3.62	1.02	7.47	5.79		12.97	14.56	6.36	4.30	7.21	4.09
23	1.80	2.68	2.55	4.83	6.88		5.51	5.87	7.38	1.54	1.85	3.77
24	0.86	1.64	3.27	5.95	6.44		3.49	13.00	6.86	1.54	1.31	3.48
25	3.38	4.42	6.20	5.06	7.50		3.98	5.14	6.88	3.58	3.53	3.15
26	2.10	2.45	1.85	5.58	4.13		1.04	1.97	4.99	1.79	2.37	2.97
27	8.02	9.06	9.63	8.64	8.03		5.86	7.07	7.45	8.30	10.82	2.81
28	4.08	3.68	2.97	7.66	3.89		3.60	8.05	3.77	1.33	2.88	2.30

Table 17 (cont.)

Carbon Number	Winter Lines				Spring Lines				Summer Lines			
	I	II	III	IV	I	II	III	IV	I	II	III	IV
Sample	AGU	AKW	AUC	BCX	CCX	CML	CWZ	DFW	ECX	EML	EWZ	FGE
29	19.06	19.08	17.31	12.81	17.88		14.70	10.47	12.62	16.28	20.17	2.38
30	3.13	3.23	1.82	5.19	3.36		0.91	1.04	2.50	1.79	2.50	2.81
31	24.71	24.60	19.40	11.64	18.09		15.14	5.83	12.22	18.84	18.82	3.48
32	3.20	2.78	0.90	4.73	3.37		0.46		2.22			
33	12.63	11.81	3.01	10.85	6.86		1.95		13.67			
34	1.44	1.11										
35	3.86	3.87										
Average OEP	4.7	5.0	6.4	1.6	3.4		7.1	1.4	3.0	6.0	4.4	1.0
Total hydrocarbons (%)	0.02	0.02	0.03	0.0009	0.004	0.02	0.006	0.001	0.0002	0.0009	0.01	0.0001
Sample Wt.	195.0	451.0	33.1	182.4	1653.9	675.5	228.3	930.5	448.0	389.2	352.3	583.0
Ratio Saturate / nonSat.	0.66	1.6	1.1	1.7	3.8	3.7	2.8	0.40	*	0.88	0.82	**

*No non-saturate hydrocarbons were recovered from this sample.

**Part of saturate fraction lost before weighing.

Table 18. Relative Abundances of N-Alkanes in Station 2 Samples.

Carbon Number	Winter Lines				Spring Lines				Summer Lines			
	I	II	III	IV	I	II	III	IV	I	II	III	IV
Sample	AEF	ANV	AXB	BGA	CGB	CPP	CZY	DIW	EGB	EPP	EZY	FJG
15												1.05
16	1.26	0.58									0.98	3.19
17	3.72	2.82	2.65		0.23	1.02	1.05	4.03	0.47		6.91	5.68
18	5.83	5.47	5.78		1.28	4.02	1.59	4.47	2.78	3.49	8.10	6.00
19	5.25	9.84	7.66		2.14	5.27	2.62	6.05	5.15	3.72	11.47	5.59
20	2.52	3.93	2.86		1.80	6.23	2.10	3.64	3.81	5.93	8.44	4.83
21	3.25	3.16	2.83	2.25	4.70	5.03	3.28	4.16	3.43	8.02	5.54	2.42
22	13.63	38.12	22.60	6.92	5.54	8.50	5.43	13.18	10.61	15.70	11.13	7.88
23	1.56	0.74	3.49	17.50	4.89	7.13	4.86	4.94	1.56	8.14	4.48	2.59
24	2.67	1.30	3.06	18.79	2.09	6.79	3.08	1.96	3.18	5.58	2.47	1.84
25	5.44	5.79	2.38	21.75	5.36	8.29	5.77	1.81	3.43	5.81	2.26	4.55
26	1.97	2.21	1.65	17.27	2.98	4.80	4.47	2.04	1.75	5.35	2.13	2.99
27	7.50	9.87	5.83	11.03	8.82	14.63	9.64	5.36	6.86	10.23	7.85	10.41
28	2.23	1.40	1.31	3.28	3.36	3.06	3.66	1.66	3.12	4.42	1.62	2.70

Table 18 (cont.)

Carbon Number	Winter Lines I	II	III	IV	Spring Lines I	II	III	IV	Summer Lines I	II	III	IV
Sample	AEF	ANV	AXB	BGA	CGB	CPP	CZY	DIW	EGB	EPP	EZY	FJG
29	16.09	14.75	13.32	0.81	18.42	14.90	17.94	13.28	16.85	16.28	12.79	20.19
30	1.69		1.03		4.23	0.46	4.39	3.24	6.52	2.09	1.36	1.84
31	17.48		17.56		19.29	9.46	17.98	12.33	18.41	5.23	12.45	16.22
32	0.79		0.44		2.93		1.28	6.99	2.93			
33	6.32		5.54		11.94		10.82	5.12	9.14			
34	0.79							5.75				
35												
Average OEP	7.3	4.2	8.9	1.1	3.7	4.1	3.5	2.9	2.9	2.5	4.5	4.5
Total hydrocarbons (%)	0.06	0.009	*	0.0009	0.02	0.02	0.09	0.01	0.004	0.0001	0.01	0.01
Sample Wt.	144.0	113.5	*	604.9	313.7	271.0	196.0	97.3	198.8	470.5	390.3	388.0
Ratio $\frac{\text{Saturate}}{\text{nonSat.}}$	1.5	1.4	3.5	0.95	0.65	1.4	1.2	2.5	2.4	0.50	0.66	0.56

*Analyst failed to record sample weight.

Table 19 Relative Abundances of N-Alkanes in Station 3 Samples.

Carbon Number	Winter Lines				Spring Lines				Summer Lines			
	I	II	III	IV	I	II	III	IV	I	II	III	IV
Sample	ABH	AQX	AZZ	BOZ	CJF	CSV	DCX	DME	EJF	ESW	FDE	FMP
15												
16								Sample contained no n-alkanes		0.21	4.32	0.35
17	6.07	3.25		3.45			1.36			1.75	12.06	1.19
18	7.20	5.99		4.84			4.01			5.81	13.23	2.57
19	7.57	7.43	1.28	4.45			6.42		2.30	5.83	11.33	3.26
20	2.73	5.64	2.42	2.30	3.04	0.76	4.18		2.94	2.26	6.05	3.02
21	4.33	6.13	5.87	2.73	16.03	0.87	2.67		14.54	0.84	1.99	9.90
22	29.59	13.56	4.14	13.14	23.36	10.83	18.25		19.04	8.42	10.38	12.83
23	3.40	3.94	5.35	2.00	16.14	2.03	1.53		5.89	2.26	2.49	11.75
24	8.09	2.09	5.83	1.36	8.36	3.06	2.65		5.98	2.74	1.90	11.07
25	4.62	4.35	7.35	3.30	2.93	5.50	3.87		7.73	4.28	2.77	8.06
26	1.20	1.82	5.69	1.86	1.34	2.25	1.88		6.26	2.68	1.47	6.22
27	3.57	6.64	10.42	7.22	4.21	14.46	9.45		8.28	8.44	5.19	5.04
28	0.59	2.66	5.07	2.21	0.67	5.20	4.59		5.06	3.56	3.46	2.70

Table 19 (cont.)

Carbon Number	Winter Lines I	Winter Lines II	Winter Lines III	Winter Lines IV	Spring Lines I	Spring Lines II	Spring Lines III	Spring Lines IV	Summer Lines I	Summer Lines II	Summer Lines III	Summer Lines IV
Sample	ABH	AOX	AZZ	BOZ	CJF	CSV	DCX	DME	EJF	ESW	FDE	FMP
29	3.74	13.90	16.38	16.85	8.17	27.02	16.77		8.46	17.30	12.28	6.37
30	0.47	1.95	3.51	1.88	4.18	1.62	0.83		6.07	2.68	1.04	1.76
31	16.84	14.21	15.71	21.93	11.59	21.95	16.11		7.45	18.04	10.03	7.75
32		1.93	2.95	2.21		0.58	0.82			3.44		1.11
33		4.50	8.05	7.58		3.88	4.62			9.47		5.05
34												
35												
Average OEP	4.6	4.5	2.9	6.0	3.1	7.6	6.8	--	1.4	3.9	2.5	2.5
Total Hydrocarbons (%)	0.04	0.17	0.03	0.03	0.02	0.007	0.05	0.001	*	0.0008	0.004	0.0002
Ratio Saturate/NonSat.	1.3	1.0	1.0	2.4	1.2	1.4	2.0	2.2	0.11	9.6	2.8	0.92
Sample Wt.	86.0	116.2	302.5	108.8	597.1	79.4	111.5	186.0	238.6	277.4	255.5	541.0

but one sample measured. This odd predominance is readily observed as generally higher values of OEP in the plots of OEP versus carbon number given in Figures 63 - 96 of the Appendix.

The OEP curves may be readily scanned to pick out those which have little or no odd predominance in the C_{25} to C_{35} region. Only two such samples are found, FGE in Figure 73 (of the Appendix) and BGA in Figure 77 (of the Appendix). Sample FGE is from Station 1, Line IV of the summer season and GBA is from Station 2, Live IV of the spring season. Sample FGE is unusual in that nC_{17} comprises almost 49% of all n-alkanes. In this respect it resembles some zooplankton n-alkanes distributions. Sample BGA is also unusual in that it has only a very limited range of n-alkanes. Both samples amy have been contaminated with petroleum-like hydrocarbons.

The average of OEP values from C_{25} to C_{35} for a sample gives in indication of the total odd carbon number predominance for the sample. Such average values are given for each sample in Tables 17 - 19 and are illustrated in Figure 15. There is no apparent trend in these values except a possible consistent low value for Station 1, Line IV. This may represent an area of sediments contaminated with petroleum-like hydrocarbons, possibly from seeps or a spill.

In an effort to find a trend in these n-alkanes data, the data for all samples of Station 1 designation, i.e. innermost samples of each line and season, were averaged and then a smoothing factor* was applied as a function of carbon number. The result is a general distribution envelop of n-alkanes

* A five point smoothing of the averaged distributions was achieved by applying:

$$C^*_n = \frac{C_{n-2}+4\cdot C_{n-1}+6\cdot C_n+4\cdot C_{n+1}+C_{n+2}}{16}$$

Where: C^*_n is the smoothed percentage at carbon number n for the five values Cn-2 through Cn+2.

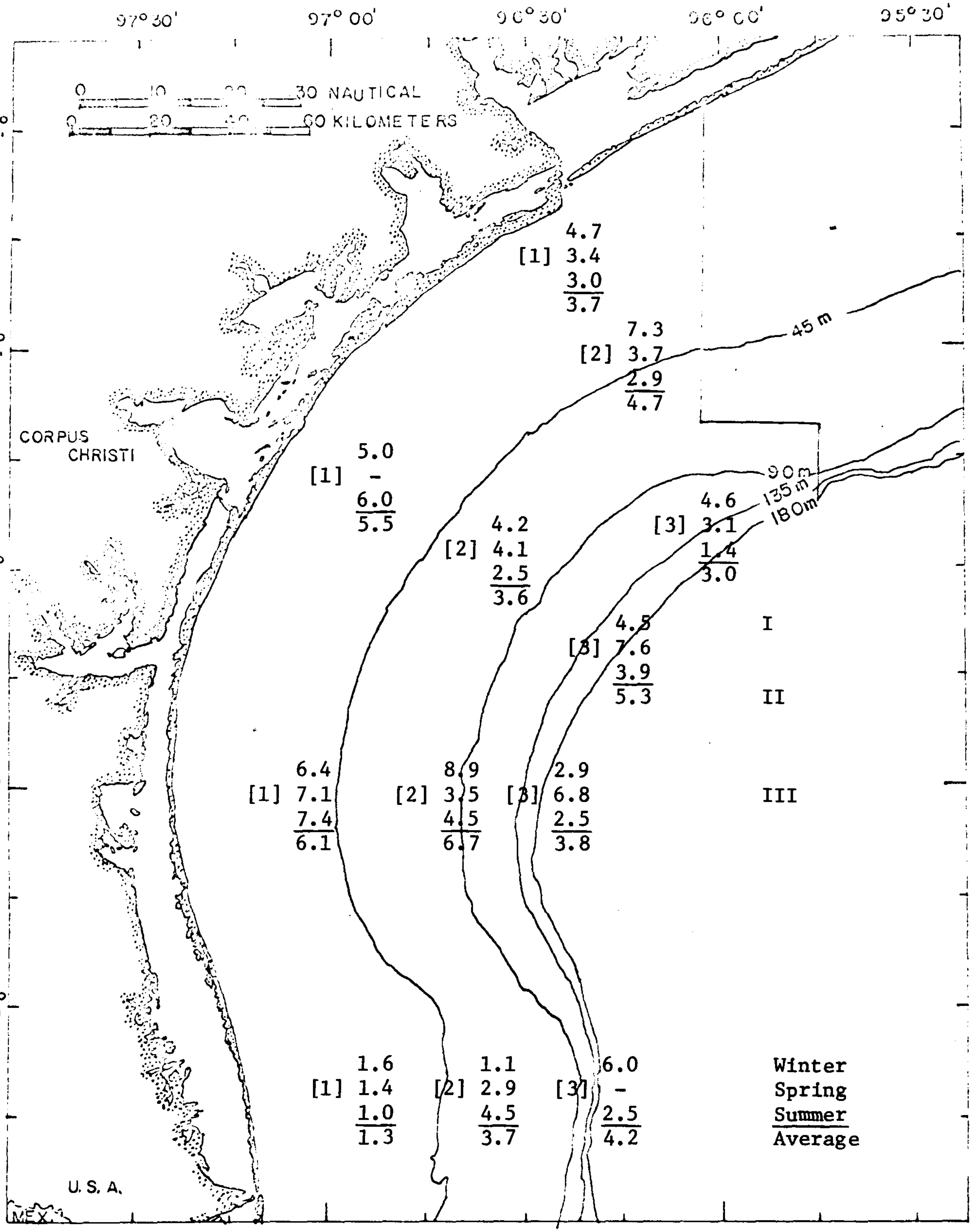

Figure 15. Average OEP values of Sediment n-Alkanes.

with the usual odd-predominance filtered out. Similar smoothed weight percentages were calculated for the averages of other stations and lines. These results are given in Table 20. The smoothed envelopes for the three stations are shown in Figure 16. The outermost samples, Stations 3, appear to have higher relative concentrations of the lower molecular size (C_{20} to C_{24}) n-alkanes. This might be a result of the lower n-alkanes being contributed by more marine-like organisms while the higher n-alkanes are contributed from a more terrestrial source. No such apparent trends were observed for the data when averaged by lines.

Table 20. Smoothed Relative Percentages of Averages of n-Alkanes Analysis of South Texas OCS Sediment Samples.

Number of Carbons in Molecule	Smoothed Relative Percentage n-Alkanes						
	Stations			Lines			
	1	2	3	I	II	III	IV
17	4.20	2.38	3.49	1.25	2.50		
18	4.84	3.74	4.02	2.02	4.01	5.46	4.62
19	4.36	4.40	5.00	2.77	4.60	5.75	3.90
20	4.14	4.88	7.35	4.31	4.84	5.37	4.12
21	4.64	6.45	8.84	6.95	6.10	5.75	5.73
22	5.04	7.81	7.54	8.44	7.06	6.16	7.26
23	4.83	7.00	5.46	7.32	5.90	5.18	7.47
24	4.43	5.55	4.61	5.54	4.37	3.89	6.90
25	4.30	5.29	4.75	4.72	4.32	3.72	6.36
26	4.68	5.74	5.53	4.65	5.24	4.47	6.00
27	5.83	6.35	6.79	5.26	6.60	5.81	5.94
28	7.50	7.30	7.87	6.62	8.29	7.52	6.23
29	8.68	8.04	8.27	8.12	9.28	8.73	6.49
30	8.96	7.80	7.53	9.04	8.81	8.91	6.54
31	8.22	6.63		8.65	7.32	7.88	6.07
32	6.10	4.72		6.61	4.98		4.56
33	3.56			4.05	2.62		

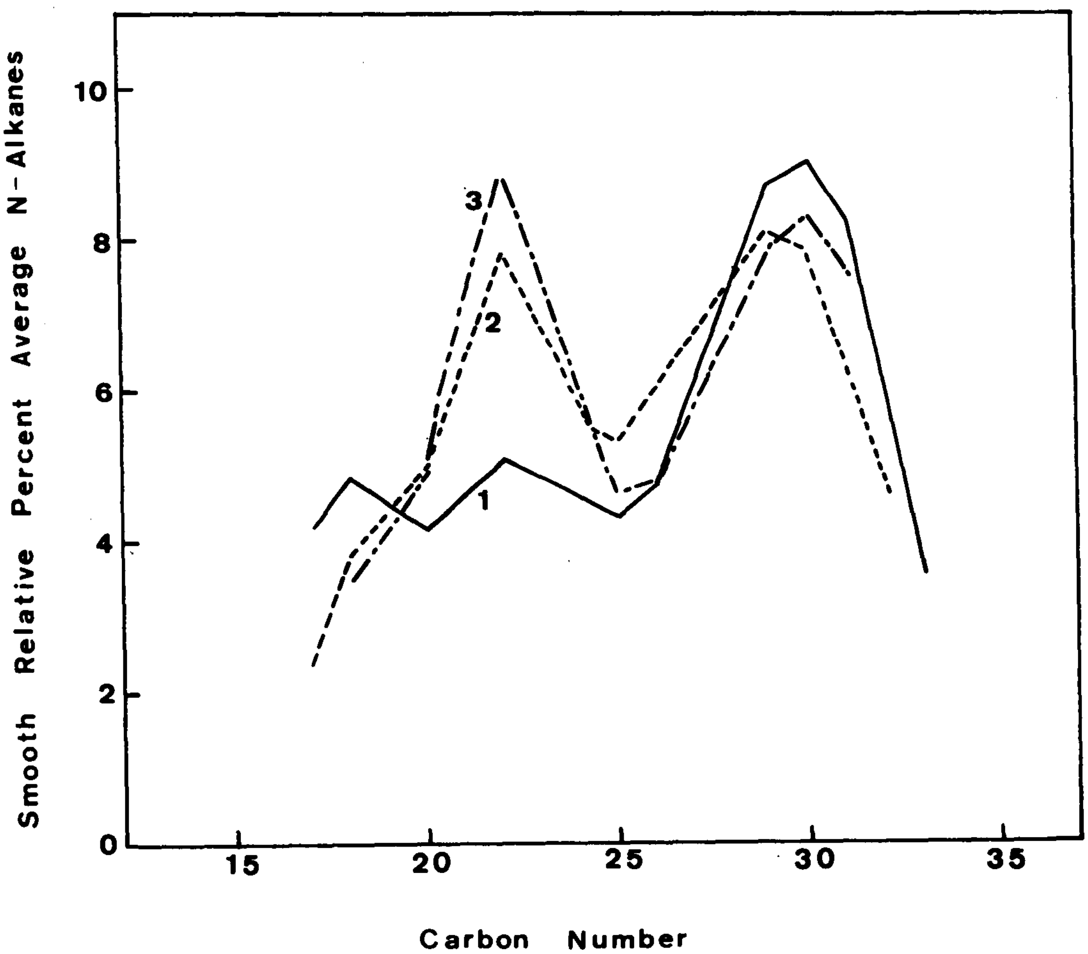

Figure 16. Smoothed n-Alkanes Distributions for Averages of Stations 1, 2 and 3.

MACRONEKTON

MATERIALS AND METHODS

Thirty-seven fish samples of separate collections from the Topographic High Program were submitted by Texas A&M University for heavy hydrocarbon analysis. These fish were sampled by hook-and-line methods, were placed in polyethylene bags and were frozen prior to delivery to the analyst. Two types of samples were made available; twenty-six whole fish which were subsequently to serve as samples for trace metals analysis, and eleven cross-secioned pieces of fish intended solely for heavy hydrocarbons analysis. There were no special precautions taken to preserve the samples against hydrocarbon contamination that were made known to the analyst.

At the request of the trace-metals analyst, the whole-fish samples were to be handled as little as possible, preferably in a metal-free system. Essentially, this precluded any subdivision of what were already relatively small samples. An extraction technique was desired which would not jeopardize the samples for later analysis. It was decided to investigate the hydrocarbons in fish-skin lipids. Functions and structures of mammalian-skin lipids have been discussed by Nicolaides (1974).

Isolation of fish-skin lipids required only partial and rapid thawing of the whole-fish. Lipids materials were rinsed from the fish surface using, first methanol and then benzene. The frozen fish was allowed to thaw in a clean PYREX dish. The skin was then swabbed with quartz or glass wool wads using PYREX stirring rods as "chop-sticks" with 200 ml of solvent. Two such rinses were made for each solvent. All rinsings were combined and the organic extracts were reduced in volume, saponified, separated and analyzed in a manner analogous to that of zooplankton extracts. The fish were re-frozen and submitted for trace-metals analysis.

The eleven sectional samples consisted of 40 to 50 grams of the tail section containing mostly flesh with some vertebrae and skin. The flesh portion was filleted with a clean knife, diced, and macerated in a clean blender prior to digestion. Samples were refluxed with an equal volume mixture of approximately 0.5 N KOH in methanol and benzene. This treatment served to saponify and extract the sample at the same time. Because of the small sample size, it was felt that the possibility of contamination by this total digestion procedure was less than that of SOXHLET extraction. This procedure eliminated multiple sample handling and transfers encountered in a separate saponification step.

RESULTS AND DISCUSSION

Both methods of extraction used for fish samples prevent an accurate determination of the original sample size (area of surface or dry weight of flesh) and thus relative than absolute abundance of alkanes and isoprenoids were determined. For the first twenty-six samples the catch-weights of the fish are reported in Table 21, however, these cannot be used to quantify the data since handling and packaging of the fish prior to analysis could easily have removed mucoid material from the fish.

Relative weight percentages of hydrocarbons are reported for the first 26 fish samples in Table 22. Only four of these samples had n-alkanes of molecular size greater than C_{22}. The OEP curves for these samples are given in Figures 97 - 100 of the Appendix. In general, the fish show OEP values close to unity above C_{25} except for Fish #20 which has an unusually large concentration of nC_{28}. This suggests a possible contamination of the fish with petroleum-like hydrocarbons.

Saturate to non-saturate ratios for the remaining eleven fish samples are given in Table 23. Of these eleven samples only seven had sufficient saturate samples for n-alkanes analysis. The relative analyses for these samples are given in Table 24. The OEP curves for these samples are given in Figures 101 - 107 of the Appendix. All curves show the pronounced minimum at C_{22} due to the predominance of this alkane which seems to be prevalent in most marine samples. The curves also show a predominance of odd carbon alkanes above C_{25} which precludes petroleum contamination.

Latitude and longitude are given in Table 25 for the bank stations.

Table 21. Saturate/Non-Saturate Ratios of Fish Skin Lipids.

Fish	Species	Location	Weight (grams)	Saturate/Non-Saturate
1	*Rhomboplites aurorubens*		110	1.4
2	*Rhomboplites aurorubens*		170	*
3	*Rhomboplites aurorubens*	Baker Bank	370	8.1
4	*Lutjanus campechanus*	South Baker	1420	3.6
5	*Lutjanus campechanus*	Adam Bank	450	10.0
6	*Rhomboplites aurorubens*	Baker Bank	450	1.2
7	*Rhomboplites aurorubens*	Baker Bank	340	0.7
8	*Lutjanus campechanus*	Baker Bank	400	50.0
9	*Rhomboplites aurorubens*	Dream Bank	480	*
10	*Lutjanus campechanus*	Baker Bank	570	6.0
11	*Lutjanus campechanus*	Baker Bank	450	0.2
12	*Lutjanus campechanus*	Big Adam Bank	510	1.4
13	*Rhomboplites aurorubens*	Dream Bank	710	0.7
14	*Rhomboplites aurorubens*	South Baker	230	2.0
15	*Rhomboplites aurorubens*	South Baker	450	6.2
16	*Lutjanus campechanus*	South Baker	600	1.8

Table 21. (cont.)

Fish	Species	Location	Weight (grams)	Saturate/Non-Saturate
17	*Lutjanus campechanus*	South Baker	680	1.8
18	*Lutjanus campechanus*	Big Adams Bank	510	*
19	*Rhomboplites aurorubens*	Big Adams Bank	280	2.2
20	*Lutjanus campechanus*	Baker Bank	450	1.0
21	*Lutjanus campechanus*	Baker Bank	790	5.5
22	*Lutjanus campechanus*	Big Adam Bank	620	1.4
23	*Lutjanus campechanus*	Big Adam Bank	570	8.0
24	*Lutjanus campechanus*	Hospital Bank	2950	8.0
25	*Mycteroperia* sp.	Southern Bank	1590	4.6
26	Grouper	North Hospital	1280	6.0

* Quantity of non-saturates was too small to measure.

Table 22. Relative Weight Percentages of Saturates from Fish Skin Lipids.

Component	Relative Weight Percentage for Fish No.													
	1	2	3	4	5	6	7	8	9	10	11	12	13	14
nC_{15}			4.7							No peaks resolved from large background "hump".	No other peaks resolved.			9.2
nC_{16}			9.1		1.3							0.6		1.8
nC_{17}	7.2	4.0	18.2	1.3	15.2		5.3	6.9	0.9			3.9		8.6
nC_{18}	16.7	11.2	18.6	0.2	23.0	5.3	9.3	12.5	10.9			7.4	1.0	11.7
nC_{19}	20.2	16.8	11.1	2.9	24.4	8.2	13.8	15.7	22.7			8.0	3.9	11.6
nC_{20}	14.0	14.4	6.7	2.4	9.4	7.7	12.0	10.8	14.7			4.9	4.1	6.7
nC_{21}	6.3	9.5	3.5	2.3	3.5	13.9	9.2	5.5	5.2			2.5	3.1	2.4
nC_{22}	23.8	44.2	17.4	9.9	21.6	30.6	33.0	39.7	44.1			18.9	17.9	16.3
nC_{23}				8.4								6.6	5.2	
nC_{24}				10.6								7.5	12.1	
nC_{25}				10.6								6.8	7.3	
nC_{26}				9.9								6.1	7.6	
nC_{27}				8.2								5.4	7.3	
nC_{28}				6.8								4.5	7.4	
nC_{29}				5.6								4.1	7.6	

Table 22. (cont.)

Relative Weight Percentage for Fish No.

Component	1	2	3	4	5	6	7	8	9	10	11	12	13	14
nC_{30}				4.5								3.9	7.7	
nC_{31}				4.3								3.1	5.3	
Pristane	0.9	+	7.6	1.3	1.5		16.4	8.9	0.9			3.8		8.5
Phytane	0.8	+	3.0	2.7	+		0.9		0.5			0.1		0.5
"3050"	10.0	+		8.1		34.2					100.	1.6	2.4	
% of Total Saturates	2.75	2.11	2.99	6.93	2.79	0.74	0.46	2.37	2.08		2.44	7.31	6.02	6.15
Ratios Pris/Phyt	1.1		2.5	0.48			18.1		1.8			38.0		17.0
Pris/nC_{17}	0.12		0.42	5.3	0.10		3.1	1.3	1.0			0.97		0.99
nC_{17}/nC_{18}	0.43	0.36	0.98	6.5	0.66		0.57	0.55	0.08			0.53		0.74

Table 22. (cont.)

Relative Weight Percentage for Fish No.

Component	15	16	17	18	19	20	21	22	23	24	25	26
nC_{15}	2.1				12.1	5.6	6.0	5.9		0.42	0.17	0.93
nC_{16}	3.5				10.5	3.5	5.6	7.3		1.1	0.82	3.8
nC_{17}	13.7	5.5	9.4		16.4	10.9	9.9	15.3	7.5	4.5	3.1	14.3
nC_{18}	15.2	8.3	16.0		11.6	7.3	9.6	12.8	15.4	7.0	4.9	10.5
nC_{19}	13.7	14.5	17.4		8.0	8.3	7.9	10.1	19.9	10.9	7.0	14.87
nC_{20}	8.0	9.7	9.2		6.1	5.0	4.7	7.1	11.9	9.2	5.1	8.2
nC_{21}	3.6	4.5	5.1		4.5	4.8	2.0	2.8	3.4	4.6	1.2	5.6
nC_{22}	25.7	34.2	35.6	100.	8.8	8.7	45.2	9.5	31.6	28.9	15.8	39.3
nC_{23}						1.6						
nC_{24}						2.3		6.2	4.2	2.5	0.95	1.8
nC_{25}						2.4			0.55	1.0	0.45	0.65
nC_{26}						2.4		6.6	5.5	29.85	60.6	
nC_{27}						2.4						
nC_{28}		18.0				11.2		6.2	*	*	*	*
nC_{29}						3.6						

Table 22. (cont.)

Relative Weight Percentage for Fish No.

Component	15	16	17	18	19	20	21	22	23	24	25	26
nC_{30}						3.2						
nC_{31}												
Pristane	13.3	4.4	7.2		18.8	14.2	9.0	9.1	4.2	2.5	0.95	1.8
Phytane	1.2	0.8	+		3.3	+	+	+	0.55	1.0	0.45	0.65
"3050"						2.5			5.5	29.85	60.6	
% of Total Saturates	3.32	2.33	3.53	0.79	5.44	10.11	*	3.73	*	*	*	*
Pris/Phyt	11.1	5.5			5.7				7.6	2.5	2.1	2.8
Pris/nC_{17}	0.97	0.8	0.77		1.1	1.3	0.91	0.59	0.56	0.56	0.31	0.13
nC_{17}/nC_{18}	0.90	0.66	0.59		1.4	1.5	1.0	1.2	0.49	0.64	0.63	1.36

* Reported saturates are less than 10% of total saturates.

Table 23. Saturate/Non-Saturate Ratios of Fish Flesh Samples.

Fish	Species	Location	Sat./Non-Sat.
27	*Rhomboplites aurorubens*	Southern Bank	8.3
28	*Lutjanus campechanus*	Big Adam Bank	2.5
29	*Lutjanus campechanus*	Southern Bank	3.8
30	*Rhomboplites aurorubens*	North Hospital	2.2
31	*Lutjanus campechanus*	Southern Bank	2.4
32	*Lutjanus campechanus*	Southern Bank	4.6
33	*Rhomboplites aurorubens*	Southern Bank	7.0
34	*Rhomboplites aurorubens*	Southern Bank	1.8
35	*Rhomboplites aurorubens*	Southern Bank	2.0
36	*Rhomboplites aurorubens*	Southern Bank	2.9
37	*Rhomboplites aurorubens*	Southern Bank	*

* Non-Saturate weight known to be in error.

Table 24. Relative Weight Percentages of n-Alkanes in Fish Flesh.

Fish	27	30	31	32	33	35	37
Component							
nC_{15}				7.0		6.2	3.2
nC_{16}				0.9		1.8	0.9
nC_{17}	4.9	5.8	7.7	2.8	3.2	5.7	7.5
nC_{18}	8.9	3.1	8.4	3.2	10.3	6.6	9.5
nC_{19}	12.4	5.4	14.1	3.9	15.5	7.6	11.4
nC_{20}	8.2	6.8	9.4	3.6	8.0	6.5	11.5
nC_{21}	4.7	4.0	5.1	3.4	3.5	3.9	3.9
nC_{22}	22.8	20.8	22.8	13.4	34.3	28.8	40.6
nC_{23}	2.4	2.9	1.8	3.3	0.5	1.9	1.8
nC_{24}	3.0	6.1	2.3	3.9	1.6	5.0	1.8
nC_{25}	2.6	4.1	1.3	7.1	0.8	5.4	0.6
nC_{26}	2.3	3.4	0.8	5.8	0.9	4.6	1.4
nC_{27}	2.7	5.4	3.4	7.4	2.1	6.8	0.9
nC_{28}	3.1	4.3	0.6	3.3	0.2	1.6	0.8
nC_{29}	3.4	6.2	2.7	17.9	4.3	5.3	2.2
nC_{30}	2.0	3.6	0.9	5.9	1.5	1.3	1.3
nC_{31}	3.0	5.4	3.3	7.0	2.7	1.0	0.6
nC_{32}	1.7	4.5	5.7		1.0		
nC_{33}	2.2	8.1	9.6		1.3		
nC_{34}	4.9				1.1		
nC_{35}	4.7				2.7		
nC_{36}					4.4		

Table 25. Location of Bank Stations.

	Latitude	Longitude
Southern Bank	27°26'N	96°31'W
South Baker	27°41'N	96°16'W
Big Adam	26°57'N	96°49'W
North Hospital	27°34'N	96°29'W
Hospital	27°33'N	96°28'W
Baker Bank	27°45'N	96°14'W
Dream	27°03'N	96°42'W
Hospital Rock	27°33'N	96°29'W

TRACE METAL PROJECT

Texas A&M University, College Station

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Bobby J. Presley

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Arthur Horowitz
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INTRODUCTION

In order to provide baseline data on the concentration of trace metals in the biota of the South Texas Outer Continental Shelf, various organisms have been analyzed. Zooplankton, neuston and benthos were collected by personnel of the University of Texas Marine Science Laboratory. These samples came from 4 transects across the shelf, each consisting of 3 stations. All stations were sampled 3 times during the year to take into consideration seasonal effects, and zooplankton were collected during both day and night to account for diurnal effects. Fish samples were collected from topographic highs in the area by Dr. Tom Bright of Texas A&M University.

All collections were made specifically for trace metal analysis, and thus every reasonable precaution was taken in order to avoid contamination during sampling. Only those organisms which are typical of the area were collected. The number of species of benthic organisms collected was deliberately kept as small as possible, according to availability, in order to make comparisons easier as the monitoring phase of the program proceeds.

A total of 348 biological samples were analyzed for selected trace metals in this study. The types of samples analyzed were zooplankton (72 samples), neuston (35), invertebrate epifauna (68), dermersal fish (82), and macronekton (fish) samples from the topographic high study (91). This report gives a complete listing of concentrations of Cu, Zn, Cd, Pb, Cr and Ni for all samples supplied by both sampling groups. These data were obtained by atomic absorption spectrophotometry (AAS), as is detailed in the methods section of this report. Many of the samples were also analyed for Fe and Mn by

AAS and these values are given for Dr. Bright's samples. Vanadium concentration was determined on all samples by instrumental neutron activiation analysis (INAA) and is given in the tables. Barium was determined on ½ of the benthic samples, either by INAA or x-ray fluorescence analysis. These methods are more sensitive and less prone to interferences than AAS methods for V and Ba, but even these methods proved not to be completely satisfactory for Ba analaysis due to the low levels encountered.

METHODS

Sample Preparation

All samples arrived in a frozen state and were stored in a freezer until analysis began. The zooplankton samples were thawed and poured onto a 200 micrometer NITEX nylon screen which had been laid over a series of paper towels. The samples were then gently squeezed with the flat side of a stainless steel spatula, in order to remove as much excess moisture as possible. When the neuston samples consisted solely of sargassum, they were simply dried with paper toweling. However, when they were composed of either surface plankton, or sargassum and surface plankton, they were handled in the same way as the zooplankton. The benthic samples fall into three main categories: shrimp, squid and fish. The shrimp were shelled, and the head and internal organs removed. The back vein was also cut out, and only the the flesh was sampled. Flesh samples from the squid were generally taken from the mantle after it had been slit and the chitinous 'pen' and internal organs removed. The heads, fins and internal organs of all the fish samples were removed prior to sampling. Where there was sufficient material, the skin was also removed, and the flesh sample was separated from the bones. (In those few cases where there was insufficient flesh, the entire fish was analyzed and these samples included scales, skin, flesh and bones but not the head, internal organs or fins.)

The wet samples were placed in pre-weighed polypropylene beakers and weighed to determine the wet sample weight. They were then placed in a freeze drier for periods of from 24 to 96 hours to remove all moisture. After removal from the freeze drier, the samples were reweighed to determine the weight loss, and the percentage of moisture in each sample was calculated. The samples were then ground to a fine powder by a combination of an initial grinding and homogenization with 2 porcelain beads in a porcelain container placed in a SPEX mixer-mill. The dried and homogenized samples were then stored in plastic vials inside a desiccator until they could be analyzed.

Atomic Absorption Procedures

Sample aliquots, usually 1 gm of zooplankton and 2 gms of the other materials, were weighed into 200 ml "tall-form" beakers and placed on a hot plate. 10 mls of a 3:1 concentrated HNO_3:$HClO_4$ mixture per gram of sample was added by automatic pipette, and a watch glass was placed on top of the beaker. The beakers were heated at moderate temperatures, and the solutions were allowed to reflux until near-dryness was achieved. This generally took from 2 to 3 hours. The residues in the beakers were then washed into sample containers through WHATMAN number 40 filter paper with two or more 2 ml aliquots of water. The solutions were then brought up to 10 mls with water. Blanks were prepared for each set of samples digested by adding 20 mls of the

3:1 HNO_3:$HClO_4$ mixture to "tall-form" beakers and following the same procedure as was employed with the samples.

The solutions were all run on a JARRELL-ASH 810 atomic absorption spectrophotometer. Mixed standard metal solutions were prepared by diluting concentrated FISHER atomic absorption or TITRASOL standards. Analyses were carried out following the procedures outlined in the JARRELL-ASH handbook. Due to the large quantities of interfering elements (notably Ca and Na) in the samples, background corrections were necessary to provide accurate results. This was accomplished by using a non-absorbing line for each of the sought metals. The accuracy of this method seems quite good as evidenced by the similar results obtained on replicate sample aliquots which had undergone liquid-liquid extraction to remove the major cations (Table 1). In addition, the results obtained on two N.B.S. biological standards (Bovine Liver and Orchard Leaves) also indicate that the method is acceptable. Analytical accuracy and precision was determined on these standards with each set of samples analyzed and is given in Table 16.

Neutron Activation and X Ray Procedures

Instrumental neutron activation analysis was found to be more suitable than atomic absorption spectroscopy for vanadium and barium determination. Initial preparation for neutron activation involved accurately weighing about 0.5 gm of dry powdered sample into a small 1 gm capacity polyethylene vial. The vial was heat-sealed to prevent any loss of sample during the analysis. The marked, encapsulated samples were irradiated by the 1 MW TRIGA Reactor at the Texas A&M University Nuclear Science Center.

For vanadium analysis, each sample was irradiated separately for five minutes. This process was facilitated by a pneumatic transport system which can rapidly transfer samples in and out of the reactor core. The sample vial was placed in a secondary poly vial, together with an aluminum flux monitor, and transported to the core for the 5 minute time period.

After return of the sample and and 1 minute delay, the aluminum flux monitor was counted by a multichanneled pulse height analyzer. After an appropriate delay period (usually 3-5 minutes, so that the dead time was < 30%) the irradiated sample was placed on an ORTEC GE (Li) detector and counted using a separate GEOS Quanta 4096 channel multichannel pulse height analyzer. After a five minute counting period, the spectrum was stored on magnetic tape.

Data reduction was done using the program HEVESY (Schlueter 1972). The program calculates peak intensities and converts these to concentration by comparison with appropriate standards. Corrections are made for varying delay times, dead times and neutron fluxes.

For barium analysis, the samples were irradiated for a 14 hour period. The samples were placed in aluminum SWAGELOK tubes along with standards and blanks and set in a rotisserie in the reactor core. After irradiation the samples were allowed to "cool" for 1 to 2 weeks.

The irradiated samples were counted for two hours using an ORTEC GE (Li) detector and a CANBERRA model 8700, 1024 channel multichannel pulse height analyzer. After the two hour counting period, the spectrum was stored on magnetic tape. As an alternate procedure, which proved to be more sensitive, the samples were counted for 4 hours while exposed to a radioactive source which excited them to emit characteristic X rays.

Appropriate standards were used with both procedures to insure accurate results.

RESULTS AND DISCUSSION

The trace metal concentrations in the organisms from the South Texas Outer Continental Shelf proved to be quite variable, as has been found in other studies (Goldberg 1972). This fact is especially true for the zooplankton and neuston but applies to other groups to some extent. Despite the variability, the concentrations found are generally in the range of those found in other studies.

There are a number of factors which can account for the observed variability, and this situation makes any interpretation of the data difficult. Much of the variability may be simply that naturally found in organisms from any one place. We do not have enough data at the present time to verify this hypothesis, and one benefit of programs such as this one will be to add to our data base. In this program, and in all previous ones, a relatively small number of individuals of any given species has been analyzed. The situation makes any statistical treatment of the data difficult, especially in view of the other factors which can cause variability.

In this study a considerable geographic area was covered, as was a considerable range of water depths. As more data are accumulated on metal contents of various species it may be possible to see some subtle, but statistically significant, trends in metal content with depth or location. Such trends were sought by "eyeballing" the data reported here, but few were found. It will be necessary to apply computer techniques to unravel the variables as more data accumulates.

A modest attempt toward this was made with this data, but time and money did not permit the more sophisticated data treatment needed. In a more sophisticated treatment such things as the sample make-up and the amount of included silicate (clay) material would be considered along with depth and location for the plankton and neuston samples. These same things and sample size might be considered for benthos. Always consideration has to be given to how the sample was collected and the possibility that it was contaminated at some point.

The factors given above discourage one from making generalizations about the data presented, nevertheless, some generalizations are given below. These are certainly subject to revision as more data is collected and better data treatment methods are devised.

Chemical Composition of Zooplankton

The zooplankton are generally more variable in composition than the other sample types as shown by the data presented in the tables according to the season in which the sample was collected. This may be a simple fact of life, but it seems more likely that it can be explained by the following factors: (1) greatly variable species composition among zooplankton samples; (2) contamination of samples by natural silicate material or man-made debris. First, Dr. Park's analysis of replicate zooplankton samples

shows clearly the large number of zooplankton species in greatly varying proportions which make up these samples. We attempted to take this into consideration for the winter set of samples (see Horowitz and Presley, 1976), but have not had time or money to do so for the other two data sets. Second, the zooplankton always have some silicate material, mostly clay, associated with them, and since this certainly varies it adds a factor that should be considered. We have obtained Al values for most of the samples, and this should be an indication of silicate contamination, but we have not had time, or money, to manipulate the data to consider this factor. Finally, the zooplankton and neuston are more prone to contamination from man-made debris during sampling than the other groups. The large net being pulled through the water sometimes picks up paint flakes and other objects, as a microscopic examination of the sample shows. An extreme example of how this occurrence can affect a sample is shown by sample AAU (Table 2) which contained 474 ppm Pb, when the other samples overaged only 8 ppm. When such examples of gross contamination are evident, there are almost certainly more subtle examples, and these may create or destroy real trends in the data. These contamination effects should tend to cancel out as more data is collected.

Keeping in mind the precautions given above, a few generalizations on zooplankton metal content seem warranted.

The copper content found here averages almost exactly the same as that found in the most comprehensive previous study, that of Martin and Knauer (1973). However, the winter and spring samples seem to show a wider range of values than those found by Martin and Knauer. There is much less variation in the summer samples, although the average value is similar. Perhaps the summer samples were more constant in species composition, but there is no clear indication of the situation in the zooplankton section of this report.

It is interesting that the samples which seem to be contaminated due to their high Pb values are not generally enriched in Cu, thus this element may be relatively free of contamination effects.

Zinc concentrations too are similar to those found in previous studies. They are considerabley less variable than the copper results, especially in the spring and summer. Some of the variability in the winter samples may be due to contamination, as in some cases unusually high values correlate with seemingly impossibly high Pb values. There is a trend towards higher values in the summer (see Table 16 for comparisons), and this would have been even stronger if a few high values had not brought the winter average up.

Cadmium concentrations seem to be typical of uncontaminated samples from other places with only a few values over 5 ppm. Furthermore, the samples from all 3 seasons were similar, all lying in a fairly narrow range. The samples with very high Pb values are not enriched in Cd which suggest that cadmium is not prone to contamination in spite of its low concentration. In one of the only geographic trends that holds for all 3 sampling periods, a small but definite increase in cadmium away from shore can be seen. This increase correlates with the decrease in zooplankton biomass observed in mixing from inshore to more offshore stations.
This correlation suggests a kind of dilution phenomenon where as the zooplankton biomass increases the amount of cadmium taken up per unit biomass decreases.

The lead values vary widely, as has been found in previous studies, but the averages given here are typical of those found elsewhere. As has been mentioned above, some of the variability seems to be due to contamination, but it is not obvious how much can be thus explained.

The chromium values given here seem somewhat higher than the few data found in the literature, but it is not clear why this is so. It is also interesting to note that very high values are found for some of the high Pb concentration samples. There seems to be a tendency for decreasing Cr concentration from winter samples.

Nickel values are similar to those found in previous studies, and with a few exceptions, mostly on the high side, are fairly constant throughout the area and year.

Chemical Composition of Neuston

The neuston samples were, as might be expected, somewhat of a grab-bag of various near surface organisms. In the winter and spring collections many samples proved to be almost pure sargassum these were, not surprisingly, fairly constant in chemical composition. The sargassum is much lower in Zn concentration, 30 to 40 ppm, than the samples of sargassum mixed with zooplankton which had 100 to 150 ppm Zn. The sargassum is also somewhat lower in Pb and Cu concentration. An interesting sample from the spring collection has 108 ppm Ni, compared to an average of 9.1 ppm for the other samples and no indication of contamination in the other metals. In the summer collection, one sample gave 321 ppm Ni, compared to an average of 12.5 ppm for the other samples. This sample had a Zn concentration about twice the average, but no other unusual metal values. We can offer no explanation for these "flyers" or assess their significance.

Chemical Composition of Squid

The metal concentrations in squid seem to be similar to those found by other workers. In making such comparisons one must be careful to note if the analysis was done with or without the skin, according to our preliminary work on the winter samples (Table 4). It can be seen that the skin is highly enriched in Cu and Zn, leading to high values for these elements in un-skinned samples. Otherwise, the squid seem to be fairly constant from area to area and with the seasons, except for an apparent Cu enrichment in the winter samples (one high value in the spring brings that average up), and a decided Ni enrichment in the summer samples where 4 out of 9 samples were highly enriched in Ni. We can offer no explanation for this phenomenon.

Chemical Composition of Shrimp

The shrimp probably show less chemical variability than any other group. Even the different species are similar in metal content, although the deep water rock shrimp is surprisingly slightly enriched in metals relative to the brown shrimp who spends at least part of its life near shore. Only one really unusual value was recorded from all the analyses. That was a very high Ni value from one of the 10 summer samples. Otherwise, the values were similar to those found elsewhere and showed no trends with location or season.

Chemical Composition of Fish

A number of different species of fish were collected during the bottom trawling efforts. We kept the number of species analyzed as small as possible, but in order to get enough individuals, at least 7 different species were used each season. It was not possible to use the same species for all seasons in all cases, adding to the complication in interpretating the data. Even though a number of species was used the metal concentrations, with few exceptions were fairly constant throughout the study. The exceptions that show up in the averages (Table 16), such as the high Ni and Cr in the winter flatfish samples, are due to 1 or 2 exceptionally high values and thus may be due to contamination, or to rare individuals. It thus seems fair to say that no obvious trends with location or season are apparent. More samples of the various species will have to be analyzed before subtle trends are sought. The fact that the metal concentrations are low and rather uniform should make any increase due to future activities by man in the area rather easy to detect. These same statements apply to the fish taken from topographic highs in the area by Dr. Bright. Despite the difference in sampling method and the different species involved, the metal concentrations (Table 15) are similar to those in the samples taken by trawling. All values are also similar to those reported in earlier studies (Chow 1972, Goldberg, 1972).

Summary

1. A total of 348 biological samples from 12 stations (4 transects x 3 stations each) on the South Texas Outer Continental Shelf (STOCS) were analyzed for Cd, Cu, Cr, Ni, Pb, V and Zn. Sixty-two of the benthic samples were also analyzed for Ba and 91 for Fe and Mn. The total sample number was divided into the following sample types:

Zooplankton	72 samples
Neuston	35 samples
Invertebrate epifauna	68 samples
Demersal Fish	82 samples
Macronekton (Fish from topographic highs)	91 samples

2. All samples except macronekton were collected seasonally with one-third of each type being sampled in winter (December 1974-January 1975), spring (April-May 1975) and summer (August-September 1975). The topographic high fish samples were collected in summer 1975.

3. Almost all apparent seasonal effects (Table 16) are due to differences in the species composition of the samples or to 1 or 2 high individual values. More sampling and analyses are needed to reveal any subtle seasonal effects.

4. Except for a few high values, which could be due to contamination during sample collection or analyses, the concentrations of the metals in all samples were similar to or lower than literature values for comparable samples from other areas.

5. Zooplankton (predominantly copepods) were more variable in metal content than other sample types. This is probably due to variable species composition and sampling contamination by clay or man-made debris. A definite increase in the cadmium concentration of zooplankton with increasing distance from shore was observed.

6. The trace metal concentrations in neuston were strongly affected by sample species composition. For example, those samples consisting mostly of sargassum were uniform and low in trace metal content.

7. Except for Cu and Ni enrichment in certain seasonal samples, squid (virtually all Loligo pealei) trace metal concentrations were fairly constant for all stations and seasons. Squid skin in greatly enriched in Cu and Zn as compared to muscle tissue.

8. Shrimp (7 species) were fairly uniform in trace metal concentration regardless of species station or season. Deep water forms were similar to sub-littoral ones.

9. At least 15 different species of demersal fish were analyzed and the trace metal content for all was low and uniform. Three (3) species of fish (macronekton) from 8 topographic highs in the STOCS were analyzed and had trace metal concentrations very similar to those of the demersal fish.

Table 1. Comparison of Extraction vs. Direct Determination of Trace Metals in Marine Organisms and N.B.S. Standards.

Sample	(a)	Cu	(b)	(a)	Zn	(b)
Sargassum Weed	7.5		7.3	50.0		48.0
Deveined Shrimp	11.3		11.4	62.5		60.0
Squid	21.3		20.6	75.0		75.0
Jackfish Muscle	8.8		8.2	25.0		28.5
Oyster	125.0		130.0	5000.0		4700.0
Bovine Liver	171.0	(193)*	179.0	125.0	(130)	131.0
Orchard Leaves	11.6	(12)	10.9	28.0	(25)	30.0

Sample	(a)	Cd	(b)	(a)	Pb	(b)
Sargassum Weed	2.44		2.40	4.8		5.0
Shrimp	0.06		0.07	1.0		0.9
Squid	0.33		0.30	4.4		5.7
Jackfish	0.06		0.05	1.1		0.9
Oyster	9.75		8.90	1.6		1.4
Bovine Liver	0.31	(0.27)	0.35	0.4	(0.34)	0.5
Orchard Leaves	0.24	(0.11)	0.28	44.4	(45.00)	45.0

Table 1. Cont'd.

Sample	(a)	Ni	(b)
Sargassum Weed	13.8		12.0
Deveined Shrimp	0.06		0.07
Squid	0.10		0.13
Jackfish	1.80		2.10
Oyster	4.00		3.60
Bovine Liver	2.80	(2.6)	2.30
Orchard Leaves	2.00	(1.3)	1.80

* - Values in parenthesis are either the N.B.S. reported values where available or from the mean value of the I.D.O.E. Baseline Study edited by E. Goldberg (1972).

(a) - Values in column are from a direct determination after a 3:1 HNO_3-$HClO_4$ digestion.

(b) - Values in column are from a determination after a 3:1 HNO_3-$HClO_4$ digestion and and APDC - Chloroform extraction with a back extraction into 1N HNO_3.

Table 2. Chemical Composition of Zooplankton from the South Texas OCS Winter Sampling (ppm dry weight)

Station		Sample #	Dry wt. (gms)	Cu	Zn	Cd	Pb	Ni	Cr	% Water	V
1/I	D	ADB *	1.0	6.4	143	.86	34.1	9.6	26.5	86.1	23
1/I	N	BHT	1.0	8.0	149.5	1.1	4.5	5.7	5.5	85.7	18
2/I	D	AEW	1.0	6.0	85.5	1.61	13.9	5.7	7.2	86.1	12
2/I	N	ACS	1.0	11.0	110	2.40	15.1	4.1	3.0	86.6	7.2
3/I	D	AAU *	0.5	38.0	560	4.60	474	10.2	82.0	92.3	6.8
3/I	N	AAD *	1.0	26.0	248	4.30	215	8.1	36.0	90.8	< 9.1
1/II	D	AIX	1.0	2.7	26.5	.93	3.4	3.1	2.4	79.2	5.8
1/II	N	AHY	1.0	4.4	62.5	1.36	1.8	2.8	1.9	88.3	5.2
2/II	D	ALU	1.0	46.0	170	2.38	14.6	7.0	7.6	86.8	9.2
2/II	N	AMC	1.0	11.6	81.5	4.24	5.3	5.8	5.00	85.3	4.2
3/II	D	AOX	1.0	8.2	83.8	3.55	9.6	5.1	2.70	87.3	< 9.0
3/II	N	AOF	1.0	7.0	72.0	3.49	18.8	5.75	3.0	85.6	6.8
1/III	D	ARZ *	1.0	13.0	235	2.25	85.0	7.50	32.3	88.8	< 9.7

Table 2. Cont'd.

Station	Sample #	Dry wt. (gms)	Cu	Zn	Cd	Pb	Ni	Cr	% Water	V
1/III N	ARI	1.0	9.5	151.5	2.60	6.25	5.38	7:3	85.4	< 9.9
2/III D	AVE	1.0	13.2	112	4.20	14.0	8.00	10.1	72.2	< 15
2/III N	AUM	1.0	15.5	96.0	5.25	3.1	5.88	3.2	87.5	< 11
3/III D	AYB	1.0	6.8	86.0	4.40	6.8	6.5	7.1	87.4	< 14
3/III N	AXL *	1.0	5.8	76.0	3.35	25.0	4.25	6.3	83.2	< 14
1/IV D	BAZ	1.0	8.5	150.0	2.67	1.85	5.15	2.55	90.0	13
1/IV N	BAJ	1.0	6.8	160.0	2.36	2.70	6.3	4.2	87.9	13
2/IV D	BEC	1.0	61.0	78.0	3.18	7.5	6.1	6.3	88.1	5.9
2/IV N	BDJ	1.0	10.0	87.0	3.41	9.3	6.8	1.8	88.3	9.3
3/IV D	BPB *	1.0	7.6	97.0	4.21	40.6	5.4	6.3	87.3	9.3
3/IV N	BGK	1.0	8.0	95.0	4.03	5.1	5.0	3.0	85.8	7.2

* possibly contaminated with metal and/or paint chips

Table 3. Chemical Composition of Neuston Samples from the South Texas OCS Winter Sampling (ppm dry weight).

Station	Sample #	Dry wt. (gms)	Cu	Zn	Cd	Pb	Ni	Cr	% Water	V
1/I	BIM +	1.0	5.20	42.0	.46	24.0	3.60	3.6	84.5	18
2/I	AEZ +	2.0	9.00	152.5	2.10	13.7	5.90	9.2	82.3	< 12
3/I	AAR +	0.5	9.00	156.0	2.76	7.0	7.50	6.2	87.8	17
1/II	AJJ +	2.0	8.00	130.0	3.0	2.8	2.15	2.6	85.8	< 6.3
2/II	ALX *	2.0	7.00	41.0	1.25	3.85	7.05	2.6	89.2	18
3/II	APA	Sample not available from UT/MSI								
1/III	ASD +	2.0	9.50	118.0	.80	23.5	4.15	5.5	82.8	18
2/III	AVI *	2.0	4.10	35.0	2.04	4.65	4.30	1.5	79.0	< 4.2
3/III	AYF *	2.0	3.35	34.0	1.96	4.4	2.65	1.2	81.8	< 5.1
1/IV	BBE +	2.0	8.0	127.5	2.35	1.55	3.35	3.0	87.3	< 11
2/IV	BEF *	2.0	3.3	36.0	1.45	4.1	2.20	1.5	77.1	10
3/IV	PBK *	2.0	2.80	34.1	2.38	6.5	9.90	1.2	76.9	28

* sargassum
\+ surface plankton + sargassum

Table 4. Chemical Composition of Mantle Muscle Tissue of Squid Samples from the South Texas OCS Winter Sampling (ppm dry weight).

Station		Sample #	Dry wt. (gms)	Cu	Zn	Cd	Pb	Ni	Cr	% Water	V	Ba
1/I	D	AQH * #2	1.0	67.0	290	1.18	2.7	2.3	3.0	73.1	< 3.3	< 6.3
2/I	D	AFF + #3	1.0	8.5	56.0	2.56	1.6	4.3	7.6	76.7	< 5.5	< 7.0
1/II	D	AJF * #2	1.0	61.0	94.0	1.00	1.3	2.1	5.1	77.4	< 1.8	<16.4
1/III	D	ASJ * #1	2.0	69.0	50.0	0.91	2.0	2.5	6.1	74.5	3.7	
2/III	D	AVO + #1	2.0	15.5	41.0	1.30	1.8	3.2	7.3	69.1	< 0.8	< 6.8
3/III	D	AYK + #4	2.0	12.5	52.5	0.23	0.4	1.0	2.2	73.3	< 1.6	< 2.0
1/IV	D	BBJ + #1	2.0	21.5	41.5	0.05	1.4	1.5	0.4	76.3	< 2.2	< 4.7
2/IV	D	BEI + #3	2.0	18.0	42.5	0.29	1.3	4.3	11.0	76.3	< 2.4	< 4.5
3/IV	D	BPG + #2	2.0	14.0	50.7	0.17	1.1	1.6	3.8	74.7	< 2.4	< 2.9
Average w/o skin				15	47.4	0.77	1.3	2.7	5.4		-	-
Average w/skin				65.7	144	1.03	2.0	2.5	4.7		-	-

* with skin

\+ without skin

All samples were identified as Cephalopoda:Loliginidae except BPG #2 which was identified as *Loligo pealei*.

Table 5. Chemical composition of Abdominal Muscle Tissue of Shrimp Samples from the South Texas OCS Winter Sampling (ppm dry weight).

Station	Sample #	Dry wt. (gms)	Cu	Zn	Cd	Pb	Ni	Cr	% Water	V	Ba
Penaeus aztecus (brown shrimp)											
1/I N	AFN #1	2.0	20.5	20.5	0.20	1.38	1.9	2.1	75.8	4.1	< 15.6
2/I N	ACW #4	2.0	27.0	48.0	0.11	1.3	1.4	2.6	81.9	< 1.7	< 2.9
1/II N	AIL #4	2.0	28.5	51.5	0.11	1.8	1.6	0.4	72.8	< 1.9	< 4.6
2/II N	ALI #1	2.0	24.0	57.5	0.19	1.65	2.2	2.1	74.8	0.8	< 15.6
1/III N	ARO #3	1.0	26.0	55.0	0.11	0.8	0.9	2.1	73.7	< 1.8	< 2.9
3/III D	AYK #3	2.0	22.5	53.0	0.33	0.7	1.9	3.8	74.0	2.6	< 2.7
1/IV N	BAD #4	2.0	25.0	46.0	0.05	0.6	1.4	2.6	74.1	77	< 4.5
2/IV N	BPD #3	2.0	18.5	47.0	0.10	1.4	0.6	1.5	73.6	< 1.1	< 3.8
3/IV N	BGP #2	2.0	26.5	50.8	0.22	0.5	0.3	1.7	75.0	< 1.3	< 3.2
Average			24.2	47.7	.16	1.1	1.4	2.1		-	-

Table 5. Cont'd.

Station	Sample #	Dry wt. (gms)	Cu	Zn	Cd	Pb	Ni	Cr	% Water	V	Ba
<u>Sicyonia</u> <u>spp</u>. (rock shrimp)											
2/I N	ACW #3	1.0	26.0	62.0	0.23	2.0	3.3	4.2	73.6	< 6.5	< 15.5
1/III N	ARO #2	1.0	23.0	57.0	0.10	1.1	0.8	2.2	74.3	NA	< 15.6
2/III D	AVO #2	2.0	38.5	52.5	0.25	1.6	1.3	2.1	76.4	NA	< 3.0
3/IV N	BGP #3	2.0	37.0	53.5	0.41	1.6	1.1	2.6	76.1	< 2.0	< 4.7
Average			31.1	56.3	.25	1.6	1.6	2.8		-	-
<u>Penaeus</u> <u>setiferus</u> (white shrimp)											
1/II D	AJF #3	2.0	20.5	52.5	0.08	0.8	1.9	3.2	72.0	1.1	< 20.6

Rock shrimp identifications were as follows: ACW #3 <u>Sicyonia sp.</u>
ARO #2 <u>Sicyonia dorsalis</u>
BGP #3 <u>Sicyonia brevirostris</u>

Table 6. Chemical Composition of Muscle Tissue (Except as Noted) of Fish Samples from the South Texas OCS Winter Sampling (ppm dry weight).

Station	Sample #	Dry wt. (gms)	Cu	Zn	Cd	Pb	Ni	Cr	% Water	V
<u>Syacium</u> <u>spp</u>. (flatfish)										
3/I * N	AAG #4	1.0	1.1	16.0	0.19	1.6	1.0	3.0	77.5	< 3.8
2/I N	ACW #2	2.0	1.2	18.5	0.14	1.3	7.4	13.3	76.5	< 2.5
1/I D	AHQ #4	1.0	1.5	17.0	0.07	.04	1.1	3.1	76.3	< 3.7
1/II N	AIL #2	2.0	0.6	14.0	0.10	0.5	0.6	0.8	76.9	< 2.0
1/III D/N	ASJ/ARO #4	1.0	1.0	20.0	0.20	1.1	1.6	4.2	76.5	< 3.4
1/IV D	BBJ #4	2.0	1.2	14.5	0.11	1.2	6.6	11.8	78.3	< 0.9
Average			1.1	16.7	0.14	0.9	3.1	6.0		
<u>Stenotomus</u> <u>caprinus</u> (long-spined porgy)										
2/II D	AMF #2	2.0	1.7	13.0	0.11	0.8	2.0	2.6	77.7	2.3
3/II D/N	APG/AOL #3 #2	2.0	1.4	23.0	0.11	0.9	0.6	0.9	77.0	< 1.3
3/III N	AXQ #3	2.0	1.0	17.5	0.16	1.4	0.6	2.6	76.1	< 1.8

Table 6. Cont'd.

Station	Sample #	Dry wt. (gms)	Cu	Zn	Cd	Pb	Ni	Cr	% Water	V
Stenotomus caprinus (long-spined porgy) continued										
2/IV N	BPD #2	2.0	1.5	15.0	0.09	0.8	0.5	0.9	78.6	< 1.2
3/IV D	BPG #4	2.0	1.1	13.0	0.05	0.6	1.1	3.2	79.1	< 1.6
Average			1.3	16.3	.10	0.9	1.0	2.0		
Trachurus lathami (rough scad)										
1/II D	AJF #4	2.0	2.5	34.0	0.21	1.0	0.8	3.2	76.5	< 1.5
3/II D	APG #2	2.0	2.4	35.0	0.25	0.9	0.8	3.2	77.4	< 1.4
1/III D	ASJ #2	0.5	3.6	24.0	0.28	3.2	2.4	16.4	78.4	< 3.3
3/III D	AYK #1	2.0	2.4	38.0	0.26	0.8	1.2	2.1	77.9	< 2.1
1/IV D	BBJ #2	2.0	2.6	26.5	0.08	0.7	1.1	5.0	78.2	< 2.0
Average			2.7	31.5	0.22	1.5	1.3	6.0		

Table 6. Cont'd.

Station	Sample #	Dry wt. (gms)	Cu	Zn	Cd	Pb	Ni	Cr	% Water	V
<u>Prionotus spp</u>. (sea robins)										
3/I D	AAM #1	2.0	1.1	15.5	0.05	0.7	1.2	3.9	77.4	< 1.8
3/II N	AOL #3	2.0	0.8	16.5	0.11	1.5	0.8	2.6	77.3	< 1.6
3/III N	AXQ #2	2.0	1.0	18.5	0.16	0.7	0.6	2.4	76.0	< 1.6
3/IV N	BGP #4	2.0	0.8	17.5	0.04	0.7	0.5	0.9	78.2	< 2.0
Average			0.9	17.0	0.09	0.9	0.8	2.5		
<u>Serranus atrobranchus</u> (black-ear bass)										
2/I * D/N	AFF/ACW #1 #1	2.0	2.1	23.0	0.19	1.9	2.1	3.2	76.7	< 2.2
2/II * D/N	AMF/ALI #1 #2	2.0	1.3	23.0	0.25	3.1	1.5	0.8	73.7	2.7
3/II * D	APG #4	2.0	0.9	26.5	0.10	2.2	1.4	4.4	74.1	NA
2/III D	AVO #3	0.5	3.4	17.0	0.14	0.3	1.5	7.2	73.4	< 4.5
Average			2.2	22.1	.17	1.9	1.6	3.9		

Table 6. Cont'd.

Station	Sample #	Dry wt. (gms)	Cu	Zn	Cd	Pb	Ni	Cr	% Water	V
Pristipomoides aquilonaris (wenchman)										
3/I D/N	AAM/AAG #3 #1	2.0	1.0	15.5	0.08	0.4	0.6	2.4	78.9	< 1.1
2/III* N/D	AUS/AVO #2 #4	2.0	1.5	28.5	0.16	0.5	1.7	4.4	72.3	< 4.4
2/IV D/N	BEI/BPD #2 #4	2.0	1.5	15.0	0.09	0.8	0.5	0.9	78.6	2.0
Average			1.3	19.7	.12	0.6	0.9	2.5		
Cynoscion spp. (sea trout)										
1/I D/N	AHQ/AFN #3 #3	2.0	1.8	22.0	0.10	1.5	2.8	5.5	76.5	< 2.4
1/III N	ARO #1	1.0	1.8	23.0	0.10	1.1	1.1	0.8	76.3	< 4.2
3/IV N	BGP #1	2.0	1.5	15.5	0.11	0.6	5.1	8.3	78.7	< 0.7
Average			1.7	20.2	0.10	1.1	3.0	4.9		

Table 6. Cont'd

Station	Sample	Dry wt. (gms)	Cu	Zn	Cd	Pb	Ni	Cr	% Water	V
<u>Micropogon undulatus</u> (Atlantic croaker)										
2/II N	AL1 #4	2.0	1.7	17.5	0.10	0.8	2.7	7.3	78.8	< 3.3

* composite of flesh, bones, and skin

All flatfish were identified as <u>Syacium sp</u>. except AIL #2 as <u>Syacium gunteri</u> and BBJ #4 as <u>Syacium papilosa</u>.

All sea robins were identified as <u>Prionotus paralatus</u> except AXQ #2 as <u>Prionotus sp</u>.

All sea trout were identified as <u>Cynoscion arenarius</u> except BGP #1 as <u>Cynoscion nothus</u>.

Table 7. Chemical Composition of Zooplankton from the South Texas OCS Spring Sampling (ppm dry weight).

Station		Sample #	Dry wt. (gms)	Cu	Zn	Cd	Pb	Cr	Ni	V	% Water
Zooplankton											
1/I	D	CAV	1.0	26.6	65.7	1.31	6.6	6.8	21.7	29	85.7
1/I	N	CAF	1.0	10.4	74.9	1.14	5.6	4.8	13.9	43	80.7
2/I	D	CDZ	1.0	8.6	130	2.86	3.5	4.1	11.0	10	84.4
2/I	N	CDI	1.0	9.8	205	2.81	12.4	7.5	11.4	15	84.6
3/I	D	CHF	0.5	9.5	129	6.30	4.2	6.0	12.6	< 44	87.1
3/I	N *	CGM	1.0	12.9	93.6	3.83	107.4	5.9	10.9	4.2	86.8
1/II	D	CKL	1.0	75.8	102	1.42	17.8	7.5	9.8	15	82.8
1/II	N	CJU	1.0	12.8	96.9	1.66	8.0	9.9	9.1	72	86.2
2/II	D	CNO	1.0	8.7	133	2.16	9.4	3.5	7.1	63	81.7
2/II	N	CMW	1.0	9.8	161	2.03	7.0	3.8	7.4	26	79.6
3/II	D	CQQ	0.4	11.0	104	4.62	8.1	7.3	5.0	< 16	86.6
3/II	N	CPZ	1.0	16.1	80.6	6.05	5.4	1.6	6.0	< 4.9	85.4
1/III	D	CYT	1.0	10.1	104	2.00	15.9	7.4	10.6	16	83.4

Table 7. Cont'd.

Station	Sample #	Dry wt. (gms)	Cu	Zn	Cd	Pb	Cr	Ni	V	% Water
Zooplankton (continued)										
1/III N	CTF	1.0	7.2	126	2.35	15.5	3.9	2.8	13	88.0
2/III D	CXY	1.0	9.1	87.4	4.48	3.4	4.3	5.4	13	88.3
2/III N	CXJ	1.0	10.2	104	4.31	7.6	2.8	4.8	13	84.3
3/III D	DBH	1.0	13.2	100	5.78	2.1	3.0	6.1	6.0	87.1
3/III N	DAH	1.0	10.9	111	4.16	3.3	3.5	6.6	4.1	84.7
1/IV D	DDW	1.0	5.8	74.6	3.43	4.4	1.7	5.5	38	92.0
1/IV N	DDH	1.0	8.1	95.8	4.07	12.5	2.5	10.6	52	88.9
2/IV D	DMK	1.0	9.5	80.0	3.41	4.0	5.9	4.5	37	87.6
2/IV N	DGG	1.0	7.9	109	2.80	8.8	2.7	6.0	83	87.1
3/IV D *	DKA	1.0	30.2	108	3.45	49.5	10.3	4.4	24	88.3
3/IV N	DJH	1.0	11.0	90.7	4.37	15.6	1.9	7.3	19	85.0
Average			13.7	108	3.37	8.2	4.7	8.4		

* apparent sample contamination

Table 8. Chemical Composition of Neuston Samples from the South Texas OCS Spring Sampling (ppm dry weight)

Station	Sample #	Dry wt. (gms)	Cu	Zn	Cd	Pb	Cr	Ni	V	% Water
Neuston and Sargassum										
1/I	CAY	1.0	8.5	377 **	1.47	2.3	2.3	12.0	96	89.2
2/I	CEJ	2.0	5.8	60.0	1.97	1.7	1.9	19.0	2.2	79.0
3/I	CHI	0.2	8.4	27.7	1.72	2.5	7.4	108 **	19	87.4
1/II	CKO	2.0	8.5	60.5	1.10	4.0	7.4	8.5	< 29	86.6
2/II	CNR	2.0	6.9	66.9	1.86	5.9	1.7	8.0	8.3	81.2
3/II	CQT	1.0	3.8	39.1	1.55	6.5	2.0	5.4	< 7.6	83.2
1/III	CUB	2.0	3.9	32.5	1.70	2.8	1.2	7.5	9.6	84.1
2/III	CYG	2.0	3.8	29.3	1.95	4.5	.4	8.5	3.3	85.6
3/III	DAZ	2.0	4.0	24.9	1.53	4.5	.7	5.6	2.0	82.2
1/IV *	DDZ	0.25	6.3	42.8	2.44	10.3	3.8	11.8	11	87.7
2/IV	DGZ	2.0	5.3	38.8	2.72	4.4	2.4	7.3	3.2	84.8
3/IV *	DKD	2.0	3.3	23.1	2.26	7.0	.7	7.0	< 4.6	83.1
Average			5.7	40.5	1.86	4.7	2.2	9.1		

Table 8. Cont'd.

Station	Sample #	Dry wt. (gms)	Cu	Zn	Cd	Pb	Cr	Ni	V	% Water
Tar Ball (DKD)			13.6	43.8	.17	3.6	4.7	11.6		31.0
Tar Ball (DDZ)			122.4	447	.64	17.6	25.5	22.6		45.6

* samples include tar balls

** average does not include these values

Table 9. Chemical Composition of Muscle Tissue of Invertebrates from the South Texas OCS Spring Sampling (ppm dry weight)

Station		Sample #	Dry wt. (gms)	Cu	Zn	Cd	Pb	Cr	Ni	V	Ba	% Water
Loligo pealei (common squid)												
2/I	D	CEE #1	2.0	6.5	31.7	.23	.8	2.0	2.8	< 2.0	< 4.1	74.6
3/I	D	CHN #4	2.0	8.4	40.1	.13	.8	4.4	2.4	< 2.7	< 4.8	73.7
1/II	D	CKT #2	2.0	63.7**	41.7	.66	2.4	1.8	.5	< 2.8	< 3.6	74.5
2/II	D	CNW #2	2.0	15.2	45.4	.16	2.1	2.5	1.0	< 2.3	< 7.7	74.1
3/II	D	CQY #2	2.0	5.2	30.8	.24	1.2	1.5	.4	< 2.6	< 4.2	75.8
1/III	D	CUG #1	2.0	8.1	47.0	.16	1.2	2.1	.5	< 2.2	< 4.5	75.4
2/III	D	CYC #1	2.0	8.1	35.3	.22	1.0	2.0	.6	< 2.1	< 4.0	74.7
3/III	D	DBE #1	2.0	7.2	32.6	.17	1.3	1.5	.9	< 2.7	< 7.2	75.7
1/IV	D	DEE #2	2.0	6.9	40.3	.12	.5	1.9	.9	< 2.3	< 4.1	75.6
2/IV	N	DGK #2	2.0	7.1	52.1	.19	1.8	1.1	.6	< 3.1	< 4.9	77.4
Average				8.0	39.7	.23	1.3	2.1	1.1			

** Average does not include this number.

Table 9. Cont'd.

Station	Sample #	Dry wt. (gms)	Cu	Zn	Cd	Pb	Cr	Ni	V	Ba	% Water
***Penaeus setiferus* (white shrimp)**											
1/I N/D	CAJ/CBD #1 #1	2.0	19.2	46.1	.10	.9	1.7	.9	< 1.8	< 4.9	74.5
1/II D	CKT #1	2.0	25.6	61.4	.12	1.8	1.9	.4	< 1.7		74.5
White average			22.4	53.8	.11	1.4	1.8	.7			
***Penaeus duorarum* (pink shrimp)**											
1/III N	CTL #1	2.0	31.0	65.2	.21	1.4	1.8	.7	< 1.8		74.5
***Penaeus aztecus* (brown shrimp)**											
2/I D/N	CEE/CDN #3 #1	2.0	26.2	46.2	.11	.8	3.4	3.0	< 1.8	< 4.2	75.1
3/I N	CGS #4	2.0	20.3	42.5	.17	1.0	2.6	.4	< 2.2		75.2
2/II N	CNC #1	2.0	23.1	56.4	.24	2.1	1.5	1.0	< 2.2		75.1
2/III N	CXN #1	2.0	19.4	61.3	.13	1.1	1.4	.4	< 2.0		74.5
3/III N	DAL #4	2.0	18.5	47.6	.08	1.0	1.9	.7	< 2.0		76.0

Table 9 Cont'd.

Station	Sample #	Dry wt. (gms)	Cu	Zn	Cd	Pb	Cr	Ni	V	Ba	% Water
<u>Penaeus</u> <u>aztecus</u> (brown shrimp)											
1/IV D	DEE #3	2.0	24.3	51.2	.16	.4	1.7	.3	< 2.2	< 4.2	74.9
2/IV D/N	DHD DGK	2.0		45.0	.13	.7	2.2	.3	< 2.5	< 4.3	75.8
3/IV N	DJN #1	2.0	22.5	42.8	.17	.8	1.3	1.6	< 1.9	< 3.9	75.1
Average			22.8	49.1	.15	1.0	2.0	1.0			
Shrimp Gills (pooled)		0.5	181	110	.69	3.1	9.5	26.7			72.3
<u>Sicyonia</u> <u>dorsalis</u> (rock shrimp)											
2/I N	CDN #4	2.0	31.3	51.5	.22	1.5	2.2	2.4	< 2.4	< 2.6	76.7
1/IV N	DDL #2	2.0	18.4	57.1	.17	1.5	1.7	1.7	2.2		79.1
Average			24.9	54.3	.20	1.5	2.0	2.1			

Table 9.

Station	Sample #	Dry wt. (gms)	Cu	Zn	Cd	Pb	Cr	Ni	V	Ba	% Water
Callinectes similis (blue crab)											
1/I N/D	CAJ/CBD #2 #4	2.0	49.0	190	.52	1.8	3.3	2.8	NA		75.8
crab gills	pooled	0.5	335	96	1.92	1.9	5.8	4.3			80.4

Table 10. Chemical Composition of Muscle Tissue of Fish from the South Texas OCS Spring Sampling (ppm dry weight)

Station	Sample #	Dry wt. (gms)	Cu	Zn	Cd	Pb	Cr	Ni	V	% Water
Stenotomus caprinus (longspine porgy)										
3/I D	CHN #3	2.0	1.2	16.9	.12	.7	3.2	.6	< 1.5	79.5
3/I N	CGS #1	2.0	.7	12.1	.10	1.5	1.6	1.9	< 1.7	78.5
3/II D	CQY #3	2.0	1.0	13.9	.08	1.1	1.4	.5	< 1.4	78.6
2/III D	CYC #2	2.0	.9	14.6	.15	1.4	1.8	.5	< 1.2	77.2
3/III N	DAL #2	2.0	1.0	12.3	.06	1.0	1.3	.6	< 1.3	78.0
3/IV D	DKI #2	2.0	1.0	12.7	.07	.4	1.3	.8	< 1.5	80.0
Average			1.0	13.8	.10	1.0	1.8	.8		
Syacium gunteri (shoal flounder)										
2/I D	CEE #4	2.0	.7	27.2	.15	.7	2.4	2.6	1.0	79.5
1/II D	CKT #4	2.0	.9	12.7	.12	1.3	1.1	.4	< 1.5	78.8
2/II D	CNW #3	2.0	.7	20.0	.13	1.0	1.8	.5	1.1	79.0

Table 10. Cont'd.

Station	Sample #	Dry wt. (gms)	Cu	Zn	Cd	Pb	Cr	Ni	V	% Water
<u>Syacium</u> <u>gunteri</u> (shoal flounder) (continued)										
3/II N	CQD #1	2.0	.5	15.6	.10	.9	1.5	.4	< 1.6	79.9
1/III D	CUG #2	2.0	1.1	13.9	.06	.4	1.3	1.2	< 1.3	79.2
1/IV N	DDL #1	2.0	.7	15.9	.11	.3	1.8	.9	< 14	80.0
2/IV N	DGK #4	2.0	.6	19.5	.17	.3	1.5	.9	1.4	80.0
3/IV N	DJN #2	2.0	.3	18.5	.11	.4	1.5	.7	< 2.2	79.7
Average			.7	17.9	.12	.7	1.6	1.0		
<u>Trachurus</u> <u>lathami</u> (rough scad)										
1/II D	CKT #3	2.0	2.4	22.7	.07	1.4	1.3	.4	< 1.4	75.2
2/II D	CNW #4	2.0	2.1	27.1	.16	1.2	1.4	.5	< 1.7	76.3
2/III D	CYC #4	2.0	1.9	16.4	.17	1.6	1.1	.3	< 1.2	75.7
Average			2.1	22.1	.13	1.4	1.3	.4		

Table 10 Cont'd.

Station	Sample #	Dry wt. (gms)	Cu	Zn	Cd	Pb	Cr	Ni	V	% Water
<u>Pristipomoides</u> <u>aquilonaris</u> (wenchman)										
3/II N	CQD #2	2.0	1.0	17.0	.10	1.1	1.2	.6	< 4.4	78.2
3/III N	DAL #1	2.0	.9	11.1	.07	.9	1.4	.9	< 4.5	78.5
3/IV D	DKI #4	2.0	.8	21.2	.07	1.5	1.3	.5	< 4.4	79.2
Average			.9	16.4	.08	1.2	1.3	.7		
<u>Cynoscion</u> <u>nothus</u> (silver seatrout)										
1/III N	CTL #2	2.0	1.0	18.9	.10	1.0	1.4	.5	< 1.3	79.2
<u>Cynoscion</u> <u>arenarius</u> (sand seatrout)										
1/I N	CAJ #4	2.0	1.3	17.6	.10	1.1	2.4	.6	< 1.8	78.7

Table 10. Cont'd.

Station	Sample #	Dry wt. (gms).	Cu	Zn	Cd	Pb	Cr	Ni	V	% Water
<u>Lagodon</u> <u>rhomboides</u> (pinfish)										
2/IV D	DHD #4	2.0	1.7	33.0	.11	.5	1.2	.6	< 1.5	78.1

Table 11. Chemical Composition of Zooplankton Samples from the South Texas OCS Summer Sampling (ppm dry weight).

Station	Sample #	Dry wt. (gms)	Cu	Zn	Cd	Pb	Cr	Ni	V	% Water
Zooplankton										
1/I D	EAV	1.0	18.2	216	2.5	22.7	7.23	19.1	38	88.4
1/I N	EAF	1.0	9.0	83.5	1.92	6.03	7.93	7.32	17	81.3
2/I D	EDZ	1.0	15.5	162	4.57	6.64	2.54	10.1	< 9.0	82.3
2/I N	EDI	1.0	25.3	139	4.68	9.83	4.03	8.37	< 7.4	81.6
3/I D	EHF	0.9	11.8	120	4.72	10.2	2.54	8.17	< 11	85.1
3/I N	EGM	1.0	20.3	135	6.04	12.9	3.30	8.00	5.7	82.0
1/II D	EXL	0.54	9.5	88.1	5.48	9.69	2.17	3.16	< 12	89.1
1/II N	EJU	1.0	8.3	120	1.42	4.60	3.10	3.59	< 13	86.6
2/II D	ENP*	1.0	13.9	144	5.35	8.58	2.29	8.47	< 19	83.6
2/II N	EMW	1.0	18.5	114	4.74	5.15	1.89	7.01	7.1	82.1
3/II D	EQQ	0.8	21.6	93.5	6.47	3.81	1.10	6.28	< 13	83.7
3/II N	EPZ	0.39	14.0	94.4	6.95	17.9	4.55	4.55	NA	86.1
1/III D	ETY	1.0	5.4	93.8	1.38	8.27	0.74	0.93	< 14	90.1

Table 11. Cont'd.

Station	Sample #	Dry wt. (gms)	Cu	Zn	Cd	Pb	Cr	Ni	V	% Water
Zooplankton (continued)										
1/III N	ETF	0.5	11.1	108	2.07	7.47	1.81	2.28	< 14	91.2
2/III D	EXY	0.6	18.0	81.2	4.88	3.82	1.28	5.00	< 12	86.1
2/III N	EXJ	1.0	21.3	92.0	4.16	5.34	0.30	4.31	< 8.8	86.8
3/III D	FBH	0.67	28.3	119	5.67	5.99	0.73	9.45	< 16	83.9
3/III N	FAH	0.8	18.8	138	4.69	7.10	2.08	9.62	< 9.7	84.9
1/IV D	FEE	1.0	7.5	109	2.47	4.65	1.60	8.12	18	91.6
1/IV N	FDO	0.4	12.9	102	2.32	2.41	5.77	2.78	< 15	86.4
2/IV D	FHF	1.0	8.7	271	2.30	12.8	2.67	23.2	< 11	86.9
2/IV N	FGO*	1.0	12.4	160	3.99	16.4	6.95	38.6	16	85.1
3/IV D	FKK	1.0	13.6	135	4.21	33.3	7.49	7.72	11	83.0
3/IV N	FJR	0.22	22.6	137	3.01	25.0	10.9	8.03	< 26	87.8
Average			15.3	127	4.0	10.4	3.54	8.92		

* Value is mean of duplicate run.

Table 12. Chemical Composition of Neuston from the South Texas OCS Summer Sampling (ppm dry weight).

Station		Sample #	Dry wt. (gms)	Cu	Zn	Cd	Pb	Cr	Ni	V	% Water
Neuston											
1/I	D	EAY	2.0	6.12	102	3.60	1.73	2.10	4.39	< 6.9	82.4
2/I	D	EEJ	0.4	9.90	159	2.97	2.46	2.82	2.84	< 12	85.0
3/I	D	EHI	0.25	5.38	24.1	1.26	1.51	< .50	29.0	< 13	83.7
1/II	D	EKO	0.32	11.9	130	1.88	8.05	4.15	37.3	NA	83.5
2/II	D	ENS	1.22	9.94	77.7	2.40	1.35	1.31	7.03	NA	84.8
3/II	D	EQT	0.33	18.7	176	0.96	48.4	9.83	8.67	NA	83.8
1/III	D	EUB	0.35	13.2	164	10.0	14.7	4.85	13.7	NA	86.1
2/III	D	EYG	0.5	7.21	56.7	1.51	15.5	4.26	5.57	NA	83.3
3/III	D	FAZ*	0.03	43.1	787	5.78	856.6	62.8	49.7	NA	83.3
1/IV	D	FEH	0.1	15.5	137	2.99	5.64	4.08	13.3	NA	85.1
2/IV	D	FHI	0.82	7.36	51.5	2.14	3.32	0.62	4.57	16	82.6
3/IV	D	FKN	1.0	11.7	351	1.57	11.4	9.56	321.3**	9.6	80.9
Average				10.6	130	2.84	10.4	4.01	12.5		

* Less than 0.3 grams of this sample received for analyses. Values not included in average as a result of high dilution involved.

** Average does not include this value.

Table 13. Chemical Composition of Muscle Tissue of Invertebrates from the South Texas OCS Summer Sampling (ppm dry weight).

Station		Sample #	Dry wt. (gms)	Cu	Zn	Cd	Pb	Cr	Ni	V	Ba	% Water
<u>Loligo</u> <u>pealei</u> (common squid)												
1/I	D	EBD #3	2.0	6.01	48.7	0.11	0.40	1.60	33.9	< 2.9		74.5
2/I	D	EEE #1	2.0	7.14	43.2	0.30	0.63	1.33	16.7	< 2.9		74.1
1/II	D	EKT #2	2.0	7.58	52.7	0.09	0.68	1.22	0.23	< 2.8	< 10	74.7
2/II	D	ENX #3	2.0	6.67	44.[illegible]	0.35	0.54	1.47	13.5	< 2.6	< 7.2	75.5
3/II	D	EQY #3	2.0	7.65	45.4	0.29	0.51	1.33	1.72	< 3.6	< 10	75.6
1/III	D	EUG #4	2.0	6.39	47.8	0.05	0.33	1.37	0.24	< 2.8		74.6
3/III	D	FBE #4	2.0	10.3	50.9	0.40	0.48	1.47	0.08	< 2.7	< 7.2	76.1
1/IV	D	FEM #1	2.0	9.72	51.2	0.90	0.67	1.26	37.5	< 3.0		74.6
Average				7.68	48.0	0.31	0.53	1.38	13.0			
<u>Penaeus</u> <u>aztecus</u> (brown shrimp)												
1/I	N	EAJ #3	2.0	32.0	58.4	0.18	0.36	0.93	0.42	< 2.2	< 7.6	74.5
2/I	N	EDN #1	2.0	32.7	54.5	0.21	[illegible]	[illegible]	[illegible].35	< 2.5	< 9.8	75.6

Table 13. Cont'd.

Station	Sample #	Dry wt. (gms)	Cu	Zn	Cd	Pb	Cr	Ni	V	Ba	% Water
<u>Penaeus</u> <u>aztecus</u> (brown shrimp) (continued)											
3/I N	EGS #2	2.0	29.3	65.6	0.13	0.40	1.10	0.44	< 2.6		75.8
1/II N	EJY* #1	2.0	24.2	67.4	0.12	0.44	0.98	0.26	< 2.7		74.3
2/II N	ENC #2	1.4	22.2	38.4	0.13	0.70	1.48	1.09	< 4.9		76.6
1/III D	EUG #3	2.0	24.7	65.8	0.08	0.51	1.41	1.84	< 3.2		74.6
2/III D	EYC #1	2.0	26.5	52.9	0.26	0.46	1.00	0.13	< 2.4	< 9.4	74.9
3/III D	FBE #3	2.0	33.2	53.7	0.23	0.43	1.20	0.16	< 2.4	< 9.7	75.0
2/IV N	FGS #4	2.0	20.5	52.3	0.07	0.43	1.64	0.22	< 2.6		74.9
3/IV N	FJX #2	2.0	27.7	51.9	0.24	0.38	1.39	35.4*	< 2.3	< 8.3	75.4
Average			27.3	36.1	0.16	0.43	1.24	0.66			
<u>Solenocera</u> <u>vioscai</u> (broken back shrimp)											
2/III N	EXN #4	2.0	20.9	55.4	0.31	0.54	2.4	0.78	< 3.5		76.9
2/IV N	FGS #3	2.0	15.5	59.8	0.19	0.42	1.16	0.35	2.3		77.0
Average			18.2	57.6	0.25	0.48	1.78	0.56			

* Average does not include this value.

Table 13. Cont'd.

Station	Sample #	Dry wt. (gms)	Cu	Zn	Cd	Pb	Cr	Ni	V	Ba	% Water
<u>Penaeus</u> <u>duorarum</u> (pink shrimp)											
1/IV N	FDS #3	2.0	20.8	62.7	0.09	0.27	0.83	0.30	< 2.2	< 9.0	74.9

Table 14 Chemical Composition of Muscle Tissue of Fish from the South Texas OCS Summer Sampling (ppm dry weight).

Station		Sample #	Dry wt. (gms)	Cu	Zn	Cd	Pb	Cr	Ni	V	Ba	% Water
<u>Micropogon</u> <u>undulatus</u> (Atlantic croaker)												
1/I	N	EAJ #1	2.10	1.03	18.5	0.006	0.32	1.47	0.071	< 2.9	< 10	79.2
1/II	N	EJY #2	2.03	1.12	9.7	0.04	0.30	0.78	0.14	NA		79.6
1/III	D	EUG #1	2.12	1.41	25.2	0.06	0.23	1.33	0.17	NA		78.4
1/IV	N	FDS #1	2.21	1.61	18.9	0.02	0.33	1.38	0.17	NA	< 8.8	79.2
2/IV	N	FGS #2	2.15	1.35	18.2	0.05	0.32	1.10	0.10	< 3.2	< 9.2	78.7
Average				1.30	20.1	0.04	0.30	1.21	0.13			
<u>Pristipomoides</u> <u>aquilonaris</u> (wenchman)												
3/I	N	EGS #3	2.15	0.95	11.7	0.04	0.18	1.05	0.088	< 2.0	< 7.8	78.3
3/II	D	EQY* #1	2.27	1.04	34.0	0.05	0.30	0.92	0.074	< 3.0		78.7
3/III	D	FBE #1	2.23	1.12	13.5	0.05	0.34	1.09	0.17	< 1.8	< 7.7	78.1
3/IV	D	FKS #2	2.59	1.07	13.8	0.07	0.33	1.07	0.28	< 3.3		75.5
Average				1.04	18.2	0.05	0.29	1.03	0.15			

* Value is mean of duplicate run.

Table 14. Cont'd.

Station		Sample #	Dry wt. (gms)	Cu	Zn	Cd	Pb	Cr	Ni	V	Ba	% Water
<u>Upeneus</u> <u>parvus</u> (dwarf goatfish)												
3/I	D	EHN #3	2.30	1.71	16.9	0.06	0.37	0.83	0.19	< 3.6	< 9.0	76.7
3/II	D	EQY #4	2.50	1.77	15.0	0.06	0.23	1.11	0.17	< 3.6		75.2
2/IV	D	FHN #1	2.40	1.57	15.9	0.07	0.36	1.56	0.30	NA		76.4
3/IV	D	FKS #3	2.31	1.43	23.1	0.06	0.41	0.80	0.12	< 2.8	< 9.4	77.0
Average				1.62	17.7	0.06	0.34	1.08	0.20			
<u>Serranus</u> <u>atrobranchus</u> (black ear bass)												
2/II	D	EXN #2	2.39	2.05	14.5	0.14	0.97	1.54	0.19	NA		76.9
3/II	N	EQD #2	2.09	0.81	14.2	0.05	0.42	1.47	0.62	NA		78.5
2/III	N	EXN #2	2.10	1.00	14.3	NA	0.46	0.77	0.081	NA		78.6
Average				1.29	14.3	0.10	0.62	1.26	0.30			

Table 14. Cont'd.

Station	Sample #	Dry wt. (gms)	Cu	Zn	Cd	Pb	Cr	Ni	V	Ba	% Water
Lutjanus campechanus (red snapper)											
1/I D	EBD #1	2.18	1.74	18.4	0.10	0.38	1.31	0.11	< 10		76.4
1/II D	EKT #4	2.45	2.31	15.2	0.04	0.15	1.07	.073	NA		78.4
Average			2.03	16.8	0.07	0.26	1.19	0.09			
Centropristes philadelphicus (rock sea bass)											
3/III N	FAL #3	2.28	0.61	14.8	0.007	0.18	1.07	<.08	< 2.3	< 9.4	77.5
2/I N	EDN #3	2.29	1.08	16.4	0.02	0.19	1.17	.093	< 3.2	< 9.3	77.6
Average			0.84	15.6	.014	0.18	1.12	<.09			
Stenotomus caprinus (longspine porgy)											
3/III D	FBE #2	2.49	0.89	13.3	0.04	0.17	0.95	0.82	< 2.3		76.8
3/I N	EGS #4	2.37	1.10	15.2	0.04	0.46	1.12	0.19	< 2.2	< 7.9	77.4
Average			1.00	14.2	0.04	0.32	1.03	0.14			

Table 14. Cont'd.

Station	Sample #	Dry wt. (gms)	Cu	Zn	Cd	Pb	Cr	Ni	V	Ba	% Water
<u>Syacium</u> <u>gunteri</u> (shoal flounder)											
1/III N	ETL #3	2.04	0.80	15.4	0.04	0.28	1.42	0.20	3.2		79.2
1/IV N	FDS #4	2.29	0.94	15.6	0.02	0.31	1.07		NA		78.3
Average			0.87	15.5	0.03	0.30	1.25	0.21			
<u>Synodus</u> <u>foetens</u> (inshore lizard fish)											
2/I N	EDN #2	2.24	1.09	18.2	0.10	0.30	1.32	0.74	< 1.8	< 7.8	78.3
2/II D	ENX #1	2.44	0.92	14.0	0.34	0.18	1.06	.021	< 2.4	< 8.5	75.8
2/III D	EYC #3	2.46	0.55	12.7	0.05	0.32	0.64	0.10	< 1.6	< 5.4	75.1
3/IV D	FKS**	2.36	1.04 ± .11	19.1 ± 2	0.10 ± .06	0.34 ± .13	1.10 ± .09	.08 ± .01	< 1.5	< 6.4	77.2
Average			0.90	16.0	0.15	0.28	1.05	0.24			

** Mean and standard deviation based on four replicates of this sample, except for V and Ba.

Table 15. Chemical Composition of Various Tissues of the Fish Samples from the South Texas OCS Topographic Highs (ppm dry weight).

Sample	Site	Dry wt. (gms)	Zn	Cu	Cd	Pb	Cr	Ni	Fe	Mn	V	% Water
<u>Rhomboplites</u> <u>aurorubens</u> (vermillion snapper)												
Flesh[1]	SB	2.0	9.4	0.7	0.11	1.4	1.3	0.8	4.9	0.2	< .58****	77.2
Fins[1]	"	2.0	52.4	0.1	1.34	10.8	3.2	4.8	26.8	6.5	< .72**	57.1
Scales[1]	"	2.0	48.5	0.1	0.95	9.8	3.0	2.9	21.5	4.7	.64	41.1
Skin[1]	"	1.72	21.8	2.2	0.53	2.1	2.8	3.1	23.0	0.4	NA	61.6
Gills[1]	"	2.0	71.4	1.5	1.06	5.9	3.9	4.3	110.0	7.5	1.2	72.7
Stomach[1]	"	1.46	74.8	2.7	1.60	4.7	2.3	3.2	69.4	1.9	NA	79.7
Liver[1]	"	0.5	268.0	13.4	5.51	1.8	2.2	0.9	827.0	3.3	NA	72.9
Heart[1]	"	0.27	52.9	7.5	0.29	2.9	1.4	1.0	925.0	1.2	NA	80.4
Intestine[1]	"	1.33	97.5	11.3	3.75	4.3	2.5	4.2	131.0	6.5	NA	82.3
Flesh	"	2.0	11.9	1.7	0.26	1.9	1.1	0.7	5.9	0.5	< .6***	77.5
Flesh	"	2.0	12.2	1.3	0.07	1.5	1.4	1.4	11.9	0.3	.44	76.8
Flesh	"	2.0	11.1	0.9	0.07	1.0	1.4	1.0	16.4	0.3	< .78**	77.4
Flesh	"	2.0	12.2	1.5	0.33	1.7	1.0	0.8	10.8	0.4	< .69	77.5
Flesh	"	2.0	11.7	1.9	0.19	2.8	1.2	1.1	9.4	0.3	< .82	77.7

Table 15. Cont'd.

Sample	Site	Dry wt. (gms)	Zn	Cu	Cd	Pb	Cr	Ni	Fe	Mn	V	% Water
Lutjanus campechanus (red snapper)												
Flesh	SB	2.0	10.3	0.7	0.20	2.0	1.0	1.1	6.2	0.5	< .47**	76.4
Flesh	"	2.0	11.7	0.9	0.21	1.5	1.2	0.9	5.8	0.5	.54	77.8
Flesh	"	2.0	12.0	0.6	0.20	2.9	1.1	1.0	8.0	0.5	< .66	76.5
Mycteroperca sp. (grouper)												
Flesh	SB	2.0	10.6	0.7	0.09	0.7	1.0	1.1	3.6	0.1	< .82**	78.6
Lutjanus campechanus (red snapper)												
Flesh	S.Baker	2.0	8.5	0.7	0.06	0.9	2.0	2.4	20.1	0.2	< .51	76.3
Flesh	"	2.0	0.6	0.6	0.07	0.4	1.2	0.9	4.8	0.1	< .57	74.5
Flesh	"	2.0	13.2	0.6	0.06	2.3	1.6	1.6	10.4	0.1	< .70**	73.6

Table 15. Cont'd.

Sample	Site	Dry wt. (gms)	Zn	Cu	Cd	Pb	Cr	Ni	Fe	Mn	V	% Water
Rhomoboplites _aurorubens_ (vermillion snapper)												
Flesh	S.Baker	2.0	11.0	0.7	0.07	0.6	1.1	1.0	4.6	0.1	< .7**	73.6
Flesh	"	2.0	12.4	0.9	0.12	2.2	1.8	1.9	17.0	0.2	< .64**	74.3
Flesh	"	2.0	8.5	0.6	0.12	1.0	1.2	0.9	4.8	0.1	< .57*****	74.4
Fins[2]	"	0.86	55.0	0.6	0.90	12.6	3.5	5.4	37.0	7.3	NA	39.4
Scales[2]	"	1.5	37.5	0.1	0.90	8.6	2.9	3.9	27.8	5.7	1.1	42.2
Skin[2]	"	1.7	30.6	1.7	0.36	5.4	2.7	4.1	108.0	3.6	5.4	59
Gills[2]	"	0.94	72.2	0.8	0.48	5.6	3.6	4.0	130.0	9.6	NA	64.8
Gonads[2]	"	0.83	302.0	3.0	0.13	1.3	1.1	1.0	40.3	1.6	NA	69.6
Stomach[2]	"	0.5	63.4	7.2	0.74	3.4	2.5	3.9	166.0	4.6	NA	78
Intestine[2]	"	0.33	114.0	11.6	3.87	1.8	2.9	4.6	274.0	6.5	9.4	75.5
Liver[2]	"	1.0	183.0	15.0	2.87	1.0	2.5	0.7	410.0	3.0	2.0	65.5
Heart[2]	"	0.25	59.9	4.5	0.26	0.4	1.1	0.9	947.0	1.0	NA	70.1

Table 15. Cont'd.

Sample	Site	Dry wt. (gms)	Zn	Cu	Cd	Pb	Cr	Ni	Fe	Mn	V	% Water
Lutjanus campechanus (red snapper)												
Flesh	BA	2.0	11.7	0.8	0.15	0.4	1.4	1.2	6.8	0.2	< .55**	77.9
Flesh	"	2.0	10.4	0.5	0.10	0.9	1.5	1.5	6.5	0.1	.66**	77
Flesh	"	2.0	11.1	0.5	0.05	1.3	1.1	0.8	4.5	0.1	< .58	75.1
Flesh	"	2.0	9.5	0.9	0.10	0.3	1.3	1.2	6.7	0.2	< .39**	74.9
Rhomboplites aurorubens (vermillion snapper)												
Flesh	BA	2.0	11.4	0.9	0.08	1.3	1.8	1.8	9.8	0.2	.48	77.3
Flesh[3]	"	2.0	10.2	0.7	0.09	2.5	1.1	1.2	6.7	0.3	< .6****	78.1
Fins[3]	"	0.62	54.5	0.9	1.02	18.1	3.2	4.8	37.0	8.5	NA	55.0
Scales[3]	"	0.96	41.4	0.2	0.84	12.7	3.3	3.9	22.7	6.3	NA	40.7
Skin[3]	"	0.58	25.1	1.2	0.35	4.4	2.8	3.4	17.8	0.8	NA	69.9
Gills[3]	"	0.76	64.4	0.7	0.64	10.1	4.0	4.8	108.0	10.8	NA	75.5
Gonads[3]	"	0.10	67.8	3.1	2.19	2.6	0.9	0.8	35.7	2.0	NA	80.0
Liver[3]	"	0.37	100.0	9.3	6.13	2.2	2.2	0.9	555.0	3.8	NA	76.9

Table 15. Cont'd.

Sample	Site	Dry wt. (gms)	Zn	Cu	Cd	Pb	Cr	Ni	Fe	Mn	V	% Water
Stomach[3]	BA	0.50	69.3	4.8	1.60	2.5	3.0	2.4	79.4	3.0	NA	77.8
Intestine[3]	"	0.43	154.0	7.5	6.42	7.9	3.4	3.0	535.0	18.0	NA	83.5
Heart[3]	"	0.1	45.0	10.0	0.07	1.5	1.1	1.2	490.0	1.0	NA	80.9
Flesh	"	2.0	10.4	1.2	0.14	1.7	1.6	1.5	8.0	0.4	.52	77.3
Flesh[4]	NH	2.0	10.8	1.0	0.06	1.8	1.3	0.9	0.9	0.6	< .56****	77.1
Fins[4]	"	1.46	42.4	2.6	0.92	9.5	3.1	5.1	34.7	6.7	NA	52.3
Scales[4]	"	1.5	45.0	2.0	0.77	11.3	3.4	3.5	33.8	6.5	1.0	42.5
Skin[4]	"	0.99	17.6	4.0	0.19	3.1	3.0	3.7	27.4	1.6	NA	65.7
Gills[4]	"	0.64	54.9	1.2	0.37	8.2	3.7	4.9	104.0	10.0	NA	68.7
Heart[4]	"	0.17	58.9	7.1	0.33	6.1	1.3	1.0	942.0	1.2	NA	76.3
Liver[4]	"	0.16	105.0	9.0	3.70	7.6	2.1	1.0	533.0	3.1	NA	68.4
Testes[4]	"	0.25	69.5	3.9	1.25	0.8	0.9	0.7	49.2	0.8	NA	77.4
Intestine[4]	"	0.65	121.0	6.3	1.98	3.8	2.7	4.5	233.0	5.2	NA	80.3
Stomach[4]	"	0.6	102.0	5.7	0.89	4.5	2.6	4.2	209.0	2.8	NA	76.4

Table 15. Cont'd.

Sample	Site	Dry wt. (gms)	Zn	Cu	Cd	Pb	Cr	Ni	Fe	Mn	V	% Water
Rhomboplites aurorubens (vermillion snapper) (continued)												
Flesh	NH	2.0	13.8	1.1	0.26	2.3	1.1	0.9	10.4	0.8	< .62***	76.3
Flesh	"	2.0	12.0	1.4	0.37	1.5	1.3	1.3	9.9	0.5	.6**	76.9
Grouper (no genus or species identification given)												
Flesh	H	2.0	12.4	0.8	0.13	1.1	1.9	2.1	12.1	0.3	< .55	79
Rhomboplites aurorubens (vermillion snapper)												
Flesh[5]	BB	2.0	11.7	0.9	0.13	0.9	1.0	1.1	4.4	0.1	< .38****	77.1
Fins[5]	"	0.7	65.5	0.3	0.96	9.8	3.8	5.0	41.9	7.2	1.4	50.6
Scales[5]	"	1.23	70.0	0.1	0.83	9.6	3.6	4.2	43.0	5.0	NA	39.2
Skin[5]	"	1.0	36.3	1.6	0.49	4.2	3.0	3.2	35.6	1.2	< 3.1	66.5
Gills[5]	"	0.5	63.2	1.1	0.86	8.6	3.5	5.0	123.0	10.0	1.7	75.2
Gonads[5]	"	0.45	439.0	3.6	0.24	1.2	1.3	1.1	60.0	1.0	NA	79.5
Spleen and Intestine[5]	"	0.5	96.6	9.2	5.96	3.4	3.2	2.1	188.0	25.1	NA	86.1

Table 15. Cont'd.

Sample	Site	Dry wt. (gms)	Zn	Cu	Cd	Pb	Cr	Ni	Fe	Mn	V	% Water
Stomach[5]	BB	1.0	45.0	5.2	1.23	1.3	2.8	3.4	410.0	5.6	NA	79.7
Liver[5]	"	1.0	180.0	14.0	5.70	2.3	2.0	0.9	700.0	4.7	3.6	76.8
Heart[5]	"	0.09	67.8	10.2	0.69	6.8	1.2	1.1	319.0	2.7	NA	80.8
Flesh	"	2.0	9.6	0.6	0.13	1.9	1.8	1.9	11.6	0.2	< .65***	75.3
Flesh	"	2.0	9.8	0.6	0.18	3.7	1.7	1.7	11.3	0.2	< .62**	73.1
Flesh	"	2.0	11.2	0.8	0.07	1.1	1.2	0.8	7.0	0.2	< .51**	74.3
Lutjanus campechanus (red snapper)												
Flesh	BB	2.0	13.1	0.6	0.10	0.7	1.9	1.3	15.1	0.1	< .66	75.0
Flesh	"	2.0	9.8	0.7	0.11	1.1	1.1	1.1	6.4	0.2	< .61	75.9

Table 15. Cont'd.

Sample	Site	Dry wt. (gms)	Zn	Cu	Cd	Pb	Cr	Ni	Fe	Mn	V	% Water
Rhomboplites auroubens (vermillion snapper)												
Flesh[6]	D	2.0	10.3	0.9	0.05	1.3	1.3	1.1	6.5	0.4	< .47****	70.6
Fins[6]	"	1.5	46.9	0.1	0.96	13.1	3.4	5.7	18.8	6.4	1.9	47.7
Scales[6]	"	2.0	32.4	0.1	0.79	11.6	3.8	4.8	18.4	4.5	1.1****	38.3
Skin[6]	"	2.0	14.6	1.4	0.10	3.0	3.2	3.6	29.6	1.1	5.9**	56.8
Gills[6]	"	1.5	58.8	0.5	0.59	9.2	3.8	4.6	121.0	9.4	1.4***	70.6
Gonads[6]	"	1.18	52.1	1.4	0.51	5.8	1.1	0.8	24.5	1.2	NA	77.3
Liver[6]	"	1.8	103.0	12.6	3.30	2.0	2.2	0.8	360.0	2.4	NA	67.5
Stomach[6]	"	1.0	62.7	7.3	0.83	1.5	2.6	3.1	69.5	1.7	.78	78.4
Intestine[6]	"	1.2	92.0	6.6	5.36	8.6	2.8	4.3	136.0	17.6	94	82.1
Heart[6]	"	0.43	50.0	6.3	0.61	1.9	1.4	0.9	986.0	1.5	NA	76.5
Flesh	"	2.0	11.9	1.9	0.27	2.6	2.1	2.0	19.5	0.6	< .84**	73.9
Flesh	"	2.0	9.7	0.7	0.07	2.1	1.6	1.3	11.4	0.1	< .72	73.4

Table 15. Cont'd.

Sample	Site	Dry wt. (gms)	Zn	Cu	Cd	Pb	Cr	Ni	Fe	Mn	V	% Water
Lutjanus campechanus (red snapper)												
Flesh	D	2.0	11.5	0.9	0.07	0.7	1.6	1.4	11.9	0.1	< .77**	75.7
Flesh	HR	2.0	9.8	0.7	0.08	1.0	1.5	1.0	3.7	0.2	.7	76.1

1-6 - Organs from same samples.

* - Indicates average value for indicated number of replicates analyzed. The coefficients of variation was 5% to 30%.

SB - Southern Bank 27°26'N 96°31'W

S. Baker - South Baker 27°41'N 96°16'W

BA - Big Adam 26°57'N 96°49'W

NH - North Hospital 27°34'N 96°29'W

H - Hospital 27°33'N 96°28'W

BB - Baker Bank 27°45'N 96°14'W

D - Dream 27°03'N 96°42'W

HR - Hospital Rock 27°33'N 96°29'W

Table 16.

Seasonal Chemical Variations by Mean Values (ppm dry weight)

Sample	Cu	Zn	Cd	Pb	Cr	Ni
Zooplankton						
Winter	13.4	103	2.95	8.0	5.6	6.0
Spring	13.7	108	3.37	8.2	4.7	8.4
Summer	15.3	127	3.99	10.4	3.5	8.9
Sargassum + Neuston						
Winter	4.1	36.0	1.82	4.7	1.6	5.2
Spring	5.7	40.5	1.86	4.7	2.2	9.1
Summer	10.6	130	2.84	10.4	4.0	12.5
Squid (probably all _Loligo pealei_)						
Winter	15.0	47.4	0.77	1.3	4.7	2.5
Spring	8.0	39.7	0.23	1.3	2.1	1.1
Summer	7.7	48.0	0.31	0.5	1.4	13.0
Brown Shrimp (_Penaeus aztecus_)						
Winter	24.2	47.7	0.16	1.1	2.1	1.4
Spring	22.8	49.1	0.15	1.0	2.0	1.0
Summer	27.3	36.1	0.16	0.4	1.2	0.66
Rock Shrimp (_Sicyonia spp._)						
Winter	31.1	56.3	0.25	1.6	2.8	1.6
Spring	24.9	54.3	0.20	1.5	2.0	2.1
Flatfish (_Syacium spp._)						
Winter	1.1	16.0	0.12	0.9	6.4	3.3
Spring	0.8	17.9	0.12	0.7	1.6	1.0
Summer	0.9	15.5	0.03	0.3	1.2	0.2
Porgy (_Stenotomus caprinus_)						
Winter	1.3	16.0	0.10	0.9	2.0	1.0
Spring	1.0	13.8	0.10	1.0	1.8	0.8
Summer	1.0	14.2	0.04	0.3	1.0	0.1
Rough Scad (_Trachurus lathami_)						
Winter	2.5	31.8	0.15	0.8	3.9	0.9
Spring	2.1	22.1	0.13	1.4	1.3	0.5

Table 17.

Accuracy and Precision of the Atomic Absorption Analyses (ppm dry weight)

Sample	Cu	Zn	Cd	Pb	Cr	Ni
Bovine Liver						
Winter (8)	176 $\pm$ 2	128 $\pm$ 2	0.22 $\pm$ .04	0.5 $\pm$ .1	0.4 $\pm$ 0	0.3 $\pm$ .1
Spring (4)	170 $\pm$ 4	119 $\pm$ 1	0.30 $\pm$ .03	0.3 $\pm$ .05	0.3 $\pm$ 0	0.3 $\pm$ .1
Summer (4)	163 $\pm$ 5	122 $\pm$ 2	0.23 $\pm$ .03	0.36 $\pm$ .13	-	0.9 $\pm$ .5
N.B.S. Values	193 $\pm$ 10	130 $\pm$ 10	0.27 $\pm$ .02	0.34 $\pm$ .08	NA	NA
Orchard Leaves						
Winter (8)	11.5 $\pm$ .5	24.7 $\pm$ 2.6	0.20 $\pm$ .04	43.9 $\pm$ 3	2.5 $\pm$ .2	1.5 $\pm$ .1
Spring (4)	11.4 $\pm$ .4	24.4 $\pm$ 0.7	0.22 $\pm$ .01	42.5 $\pm$ 3	2.5 $\pm$ .2	1.4 $\pm$ .1
Summer (4)	10.7 $\pm$ .5	24.6 $\pm$ 1.4	0.11 $\pm$ .02	39.6 $\pm$ 3	2.9 $\pm$ .1	1.9 $\pm$ .5
N.B.S. Values	12 $\pm$ 1	25 $\pm$ 3	0.11 $\pm$ .02	45 $\pm$ 3	2.6 $\pm$ .2	1.3 $\pm$ .2

(The $\pm$ values are 1 standard deviation, determined from the number of replicates indicated.)

The precision based on 20 pairs of duplicate samples is as follows:

	Cu	Zn	Cd	Pb	Cr	Ni
	4%	4%	11%	9%	7%	7%

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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.