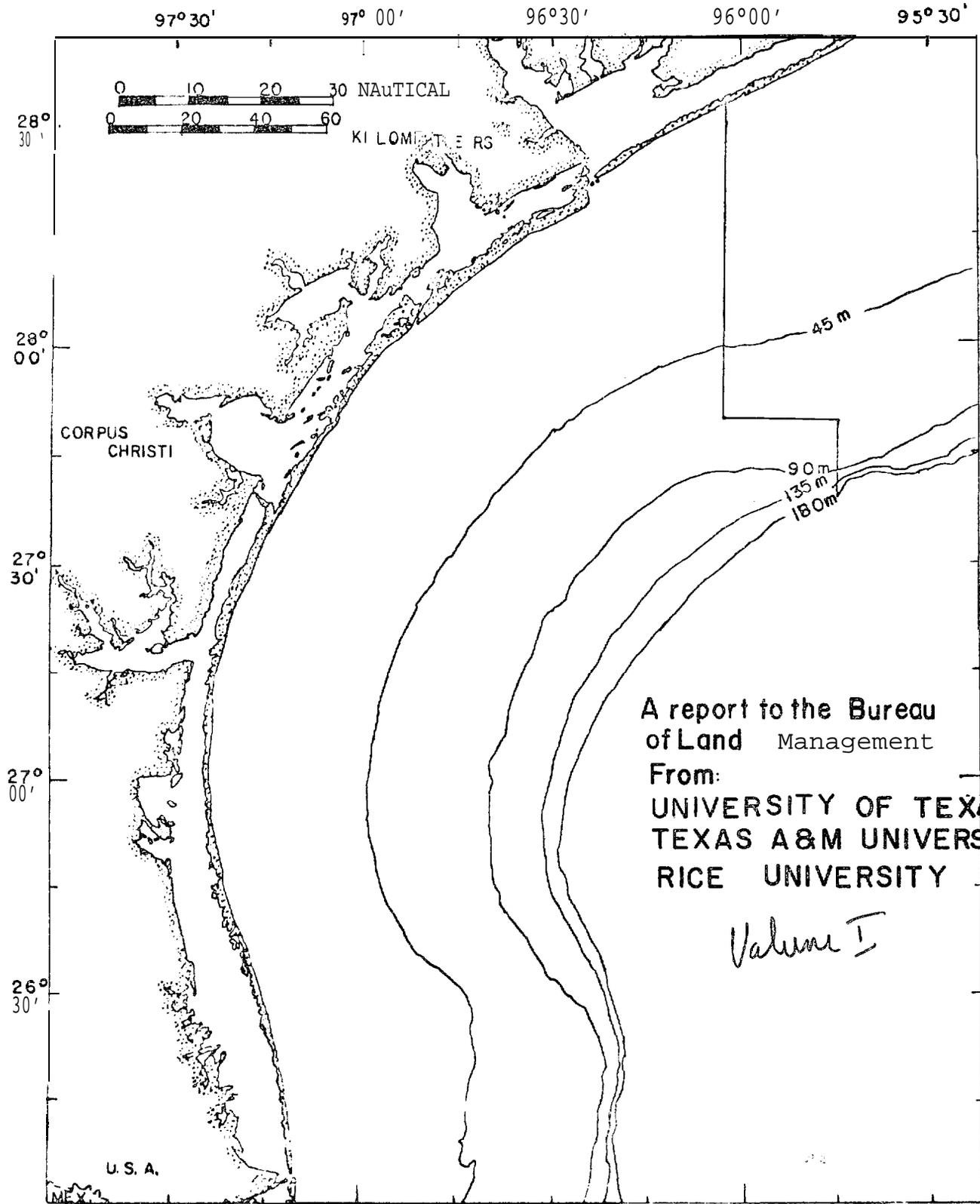


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Tom Ruppel

# ENVIRONMENTAL ASSESSMENT OF THE SOUTH TEXAS OUTER CONTINENTAL SHELF CHEMICAL AND BIOLOGICAL SURVEY COMPONENT

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ENVIRONMENTAL ASSESSMENT OF THE SOUTH TEXAS OUTER CONTINENTAL SHELF  
CHEMICAL AND BIOLOGICAL  
SURVEY COMPONENT

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ENVIRONMENTAL ASSESSMENT OF THE SOUTH TEXAS OUTER CONTINENTAL SHELF

CHEMICAL AND BIOLOGICAL

SURVEY COMPONENT

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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 **individual** chapters of this document.

## Location of Area and **Bathymetry**

The South Texas OCS as described herein corresponds to the area **out-**lined 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.

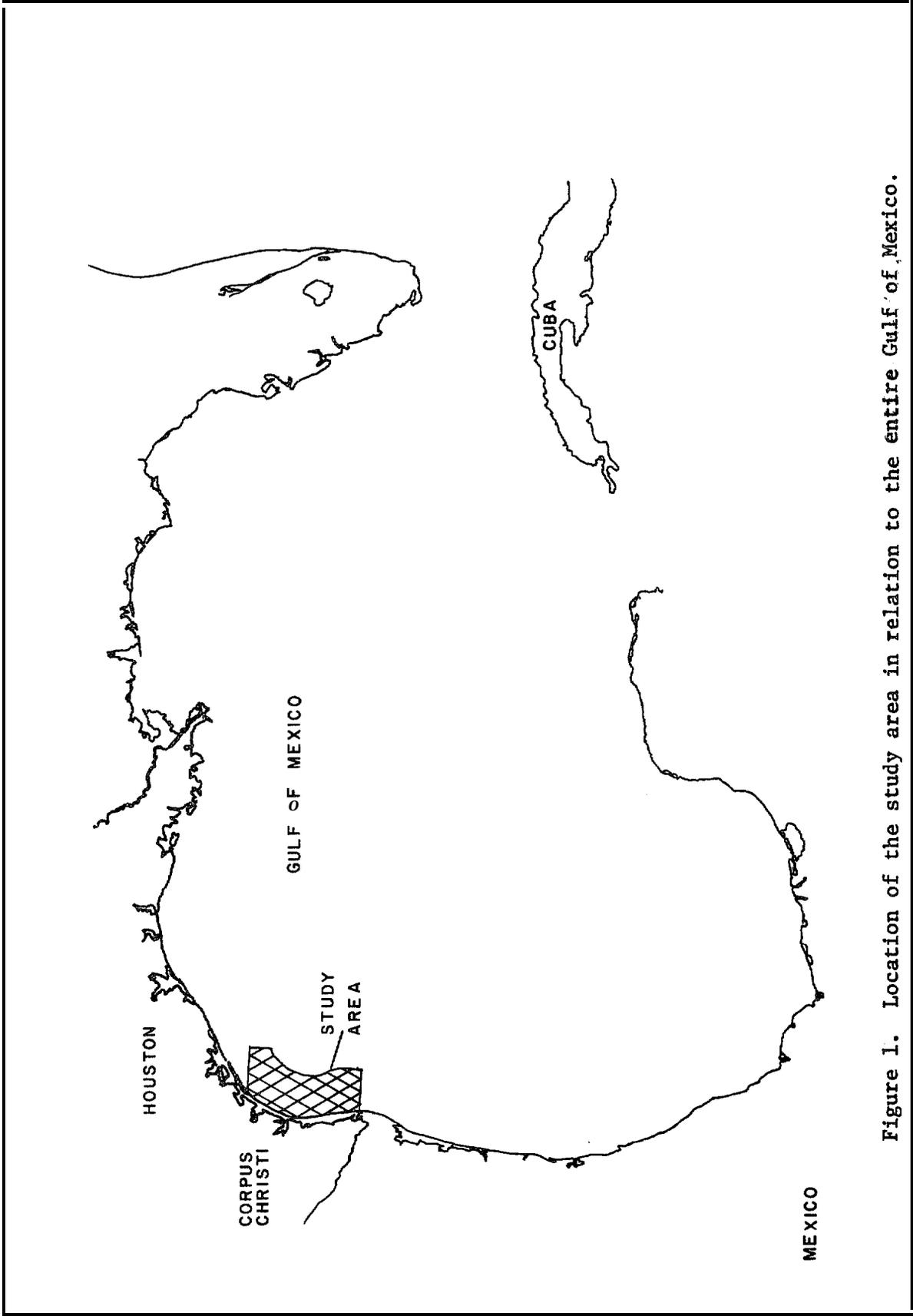


Figure 1. Location of the study area in relation to the entire Gulf of Mexico.

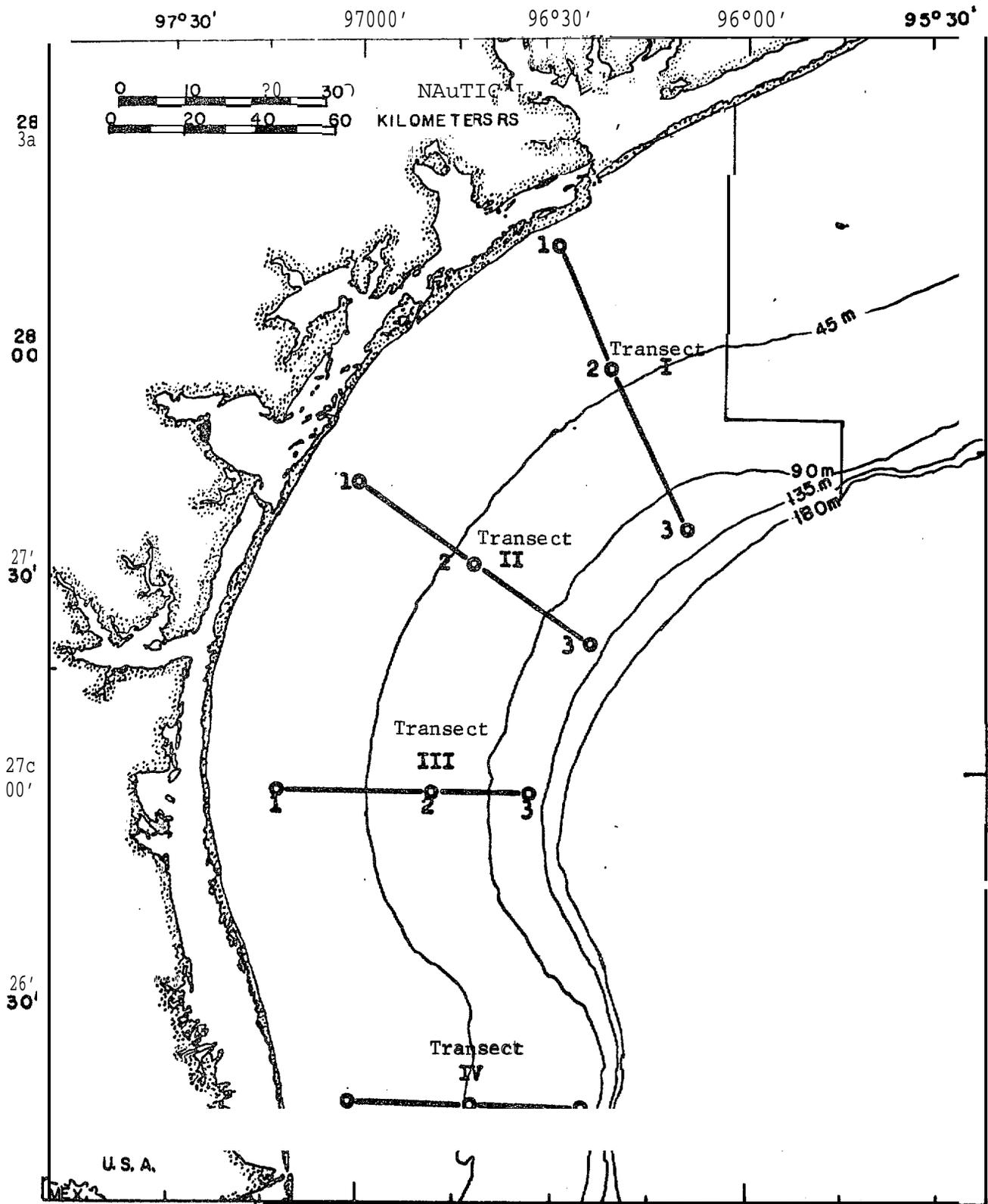


Figure 2. Station locations and bathymetry of the South Texas continental shelf. Depths in meters,

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 (**off-**shore 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 **pro-****files** 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 **micro-****zooplankton** 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'	<b>96°59'</b>	22
	2	27°30'	<b>96°44.5'</b>	49
	3	27°17,5'	96°23'	131
III	1	26°57,5'	97°11'	25
	2	26°S7.5'	96°48'	65
	3	26°57,5'	96°32,5'	106
IV	1	<b>26°10'</b>	<b>97°00.5'</b>	27
	2	26°10'	96°39'	47
	3	<b>26°10'</b>	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<sup>3</sup> 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 **macro-nekton** 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. **Zoo-**plankton 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 **equippéd** 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. **Macronek-**ton was supplied to us by Dr. Bright (Texas **A&M** University, Topographic High project) in accordance with **BLM**. All STOW 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 **investi-**gator,

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

Type	Number
<b>Phytoplankton</b>	72
<b>Zooplankton</b>	<b>144</b>
<b>Neuston</b>	36
Benthos	313
Hydrography	72
Light Hydrocarbon	146
Heavy Hydrocarbon	432
Trace Metal	396
<b>Microzooplankton</b>	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 <sup>was</sup> 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  $-2^{\circ}$  and  $+35^{\circ}\text{C}$  to within  $0.1^{\circ}\text{C}$ , 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 111 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 3/111 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 1/1 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 3/111, 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 **approx-** **imately** 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 111 (Figure 11), obtained between May 14 and 16, 1975. **Cross-** shelf surface temperatures are nearly uniform **at** just above 25°C. A **ther-** **mocline** 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). **Sali-**

nities 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 2/1. 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 **aver 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 1/1 and 2/1. 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** 2/11. Both of the outer two stations show very nearly **isohaline** conditions.

An extremely well developed **halocline** is **seen** at the inner station along Track 111 (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 susceptibility **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.

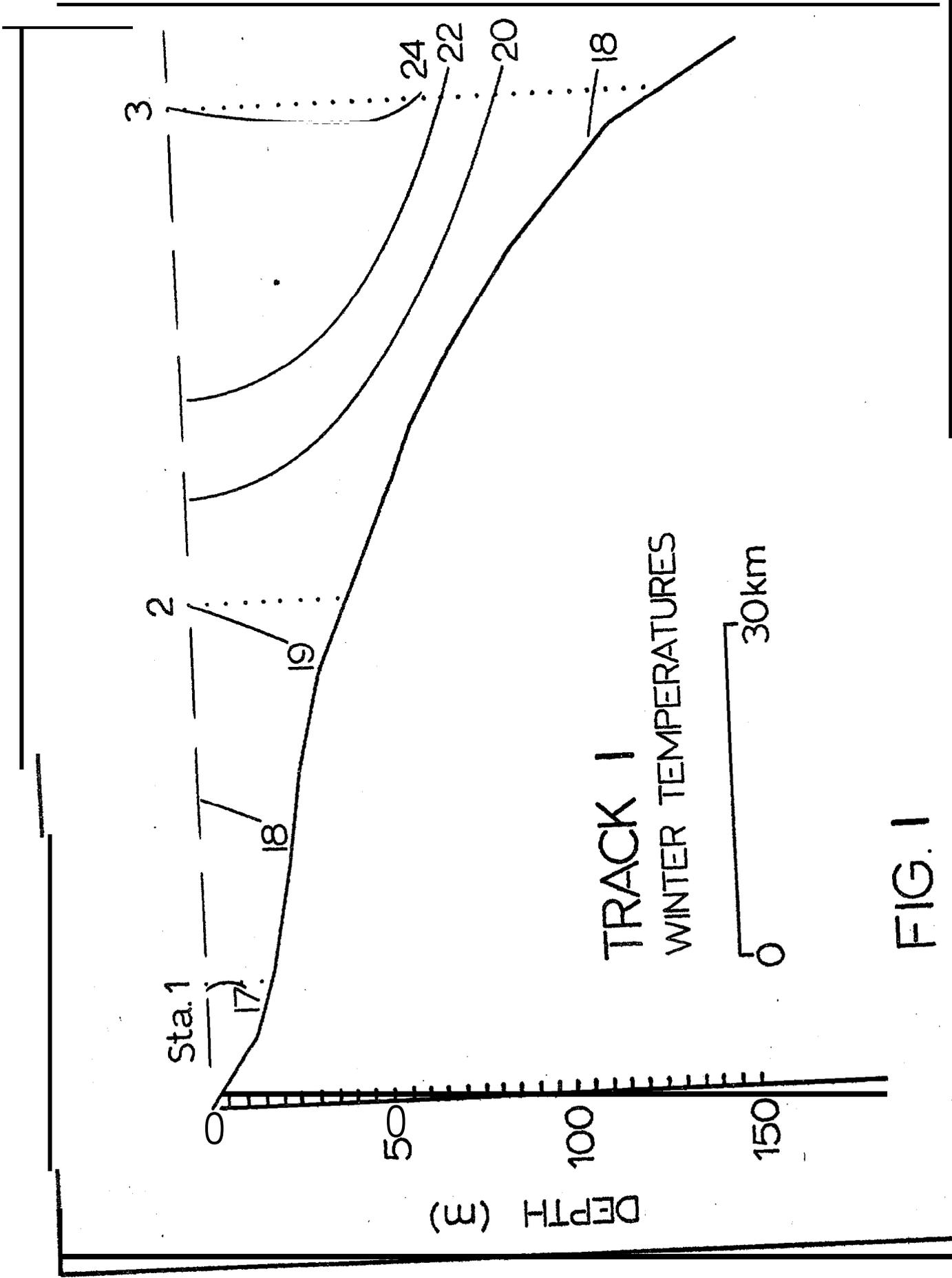


FIG. 1

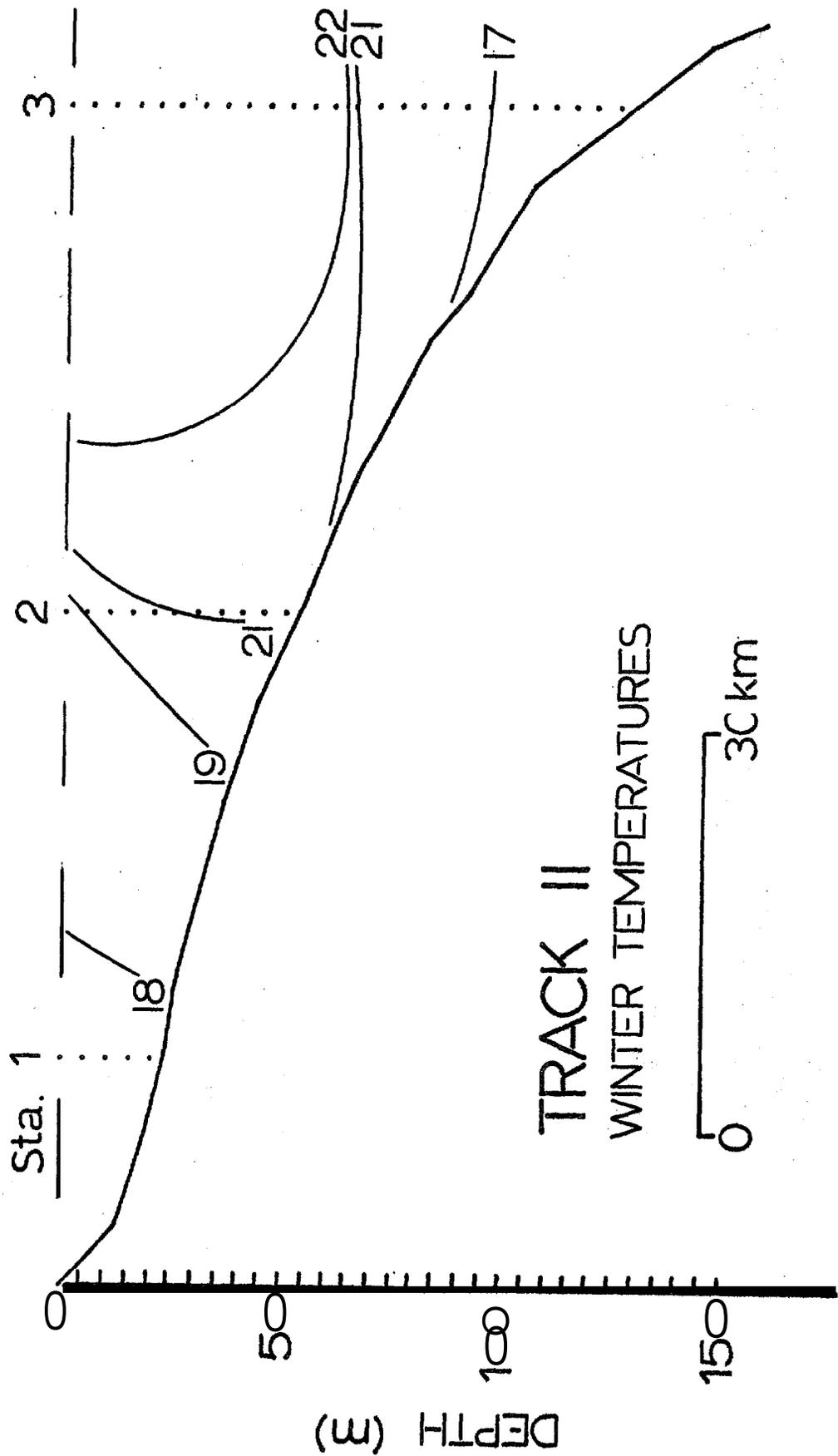


FIG. 2

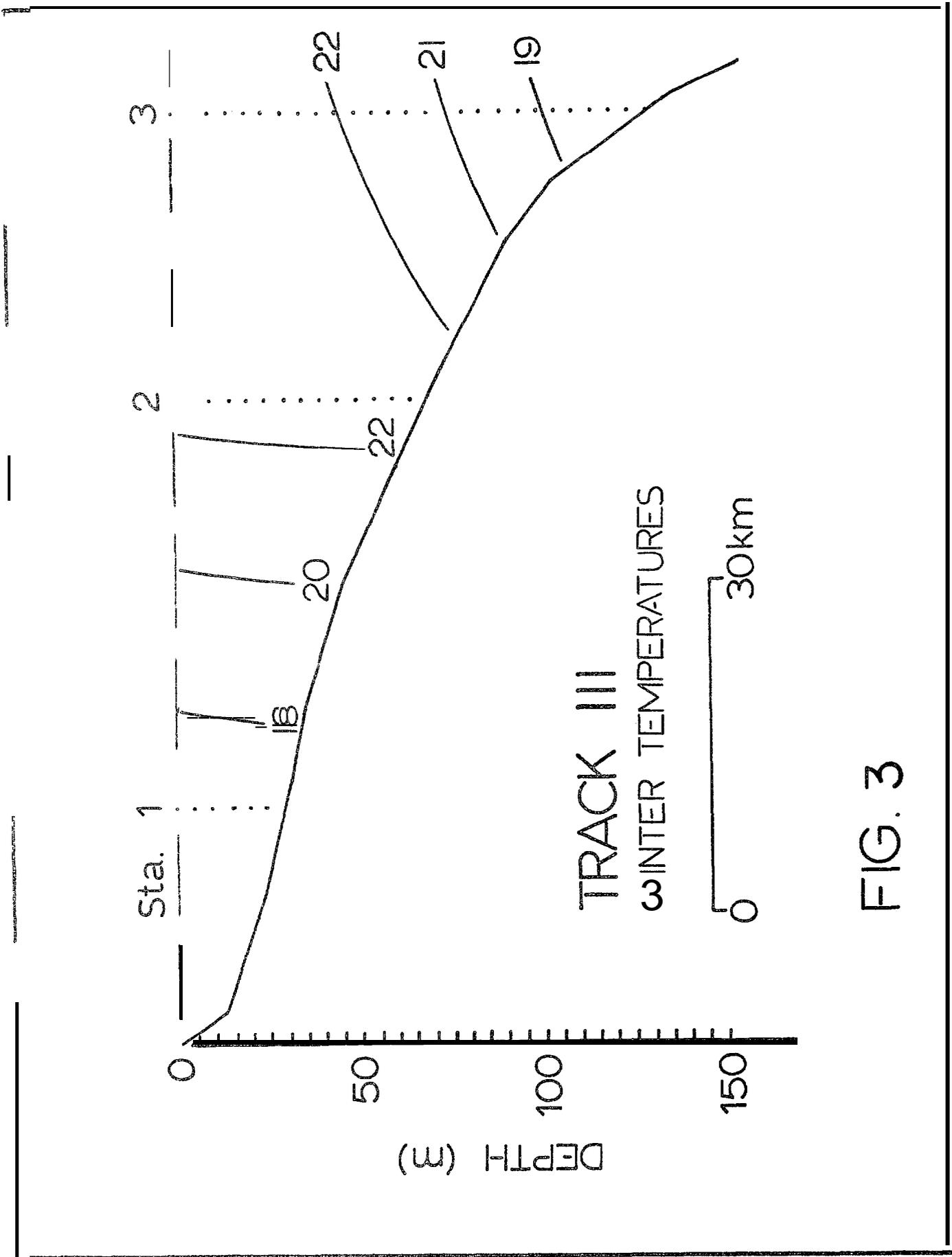
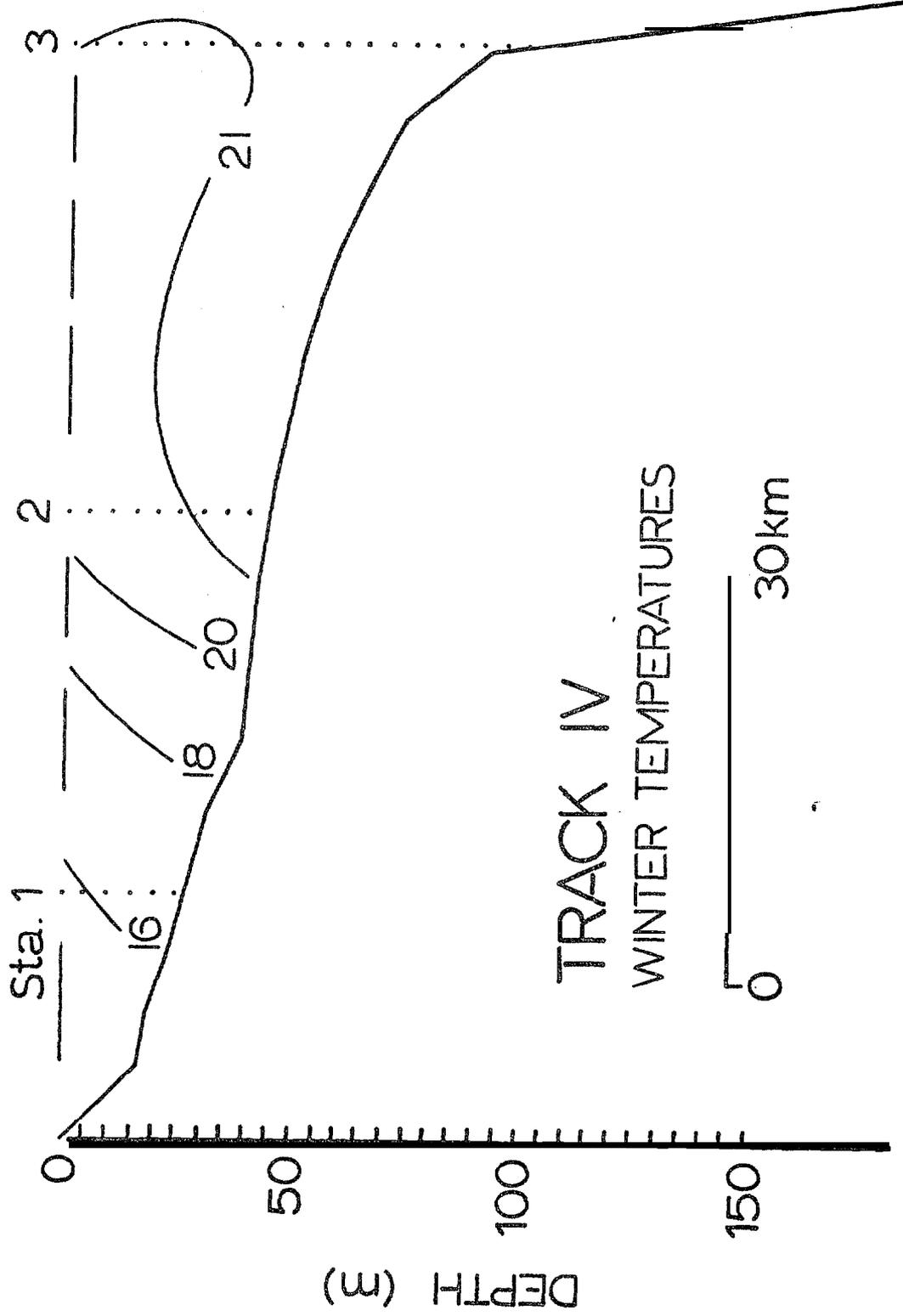


FIG. 3



TRACK IV  
WINTER TEMPERATURES



FIG. <

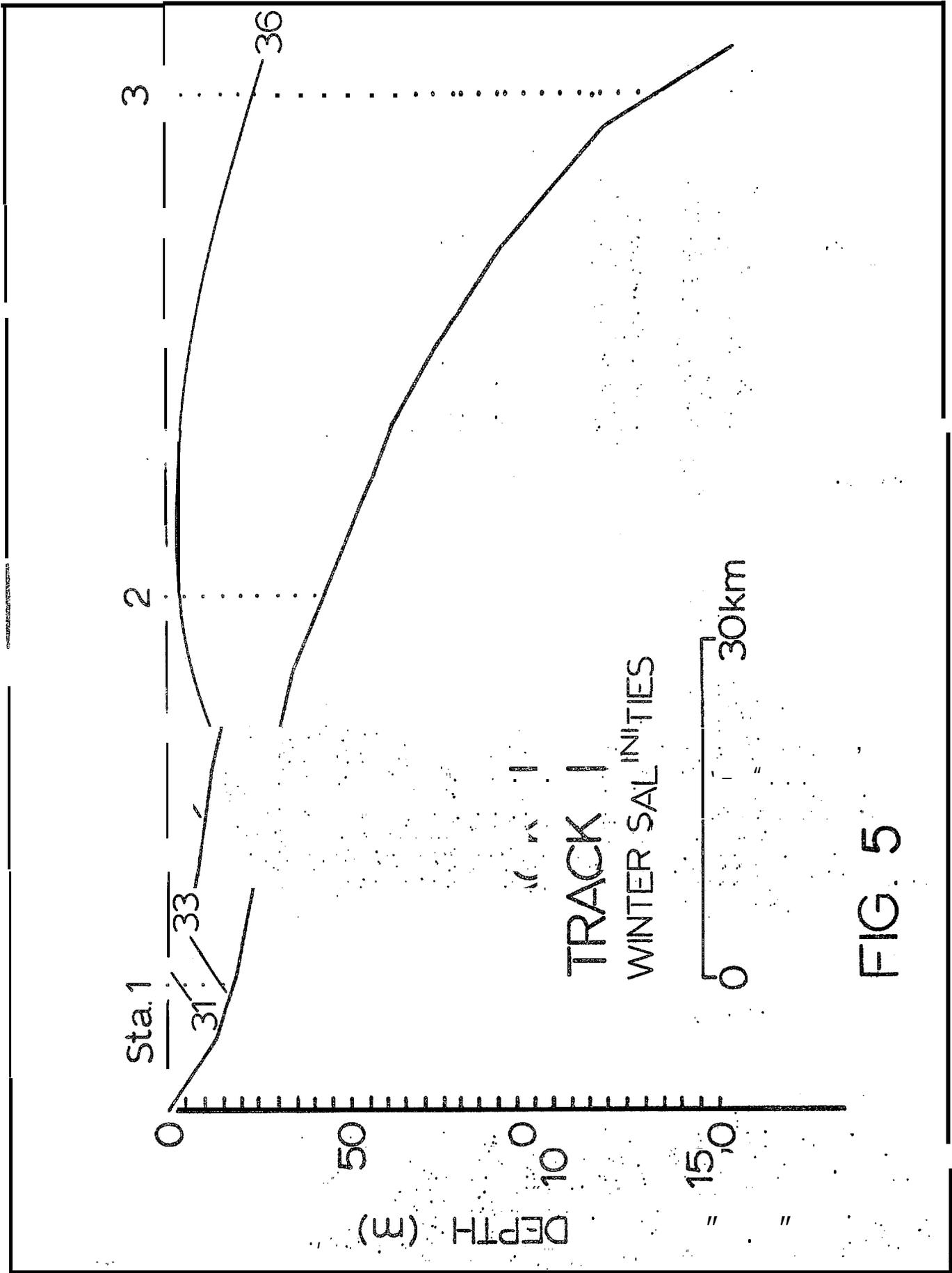


FIG. 5

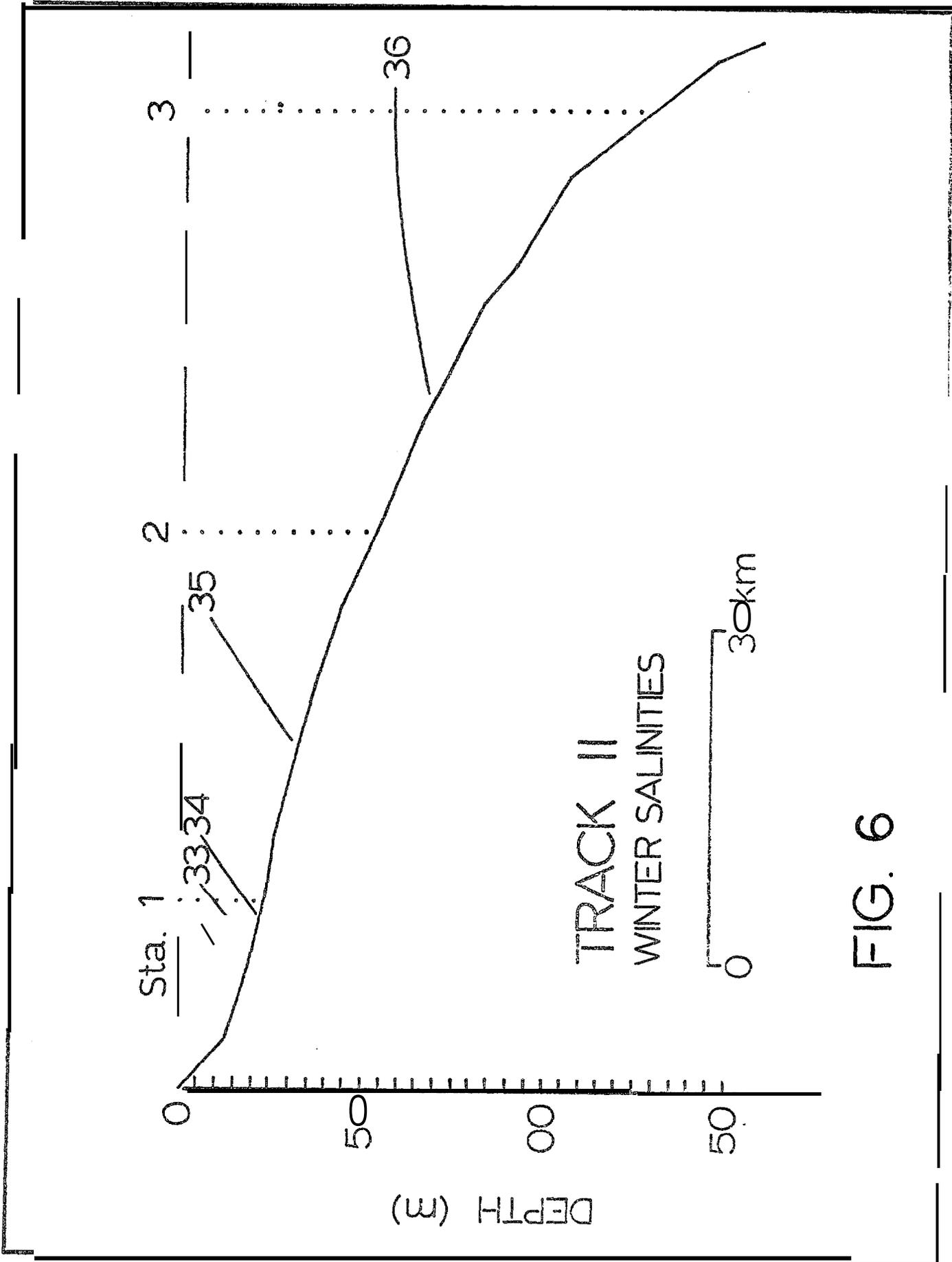


FIG. 6

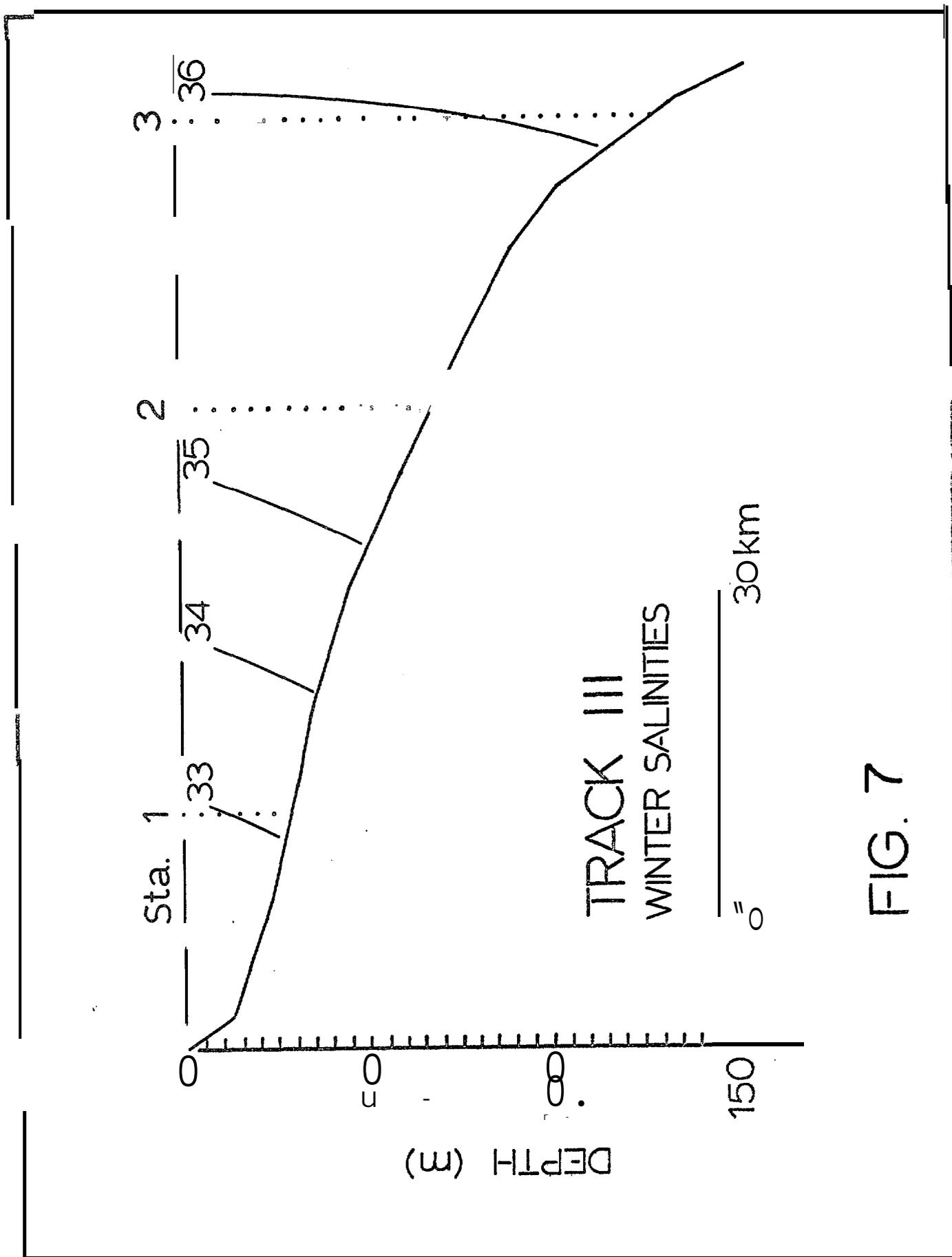
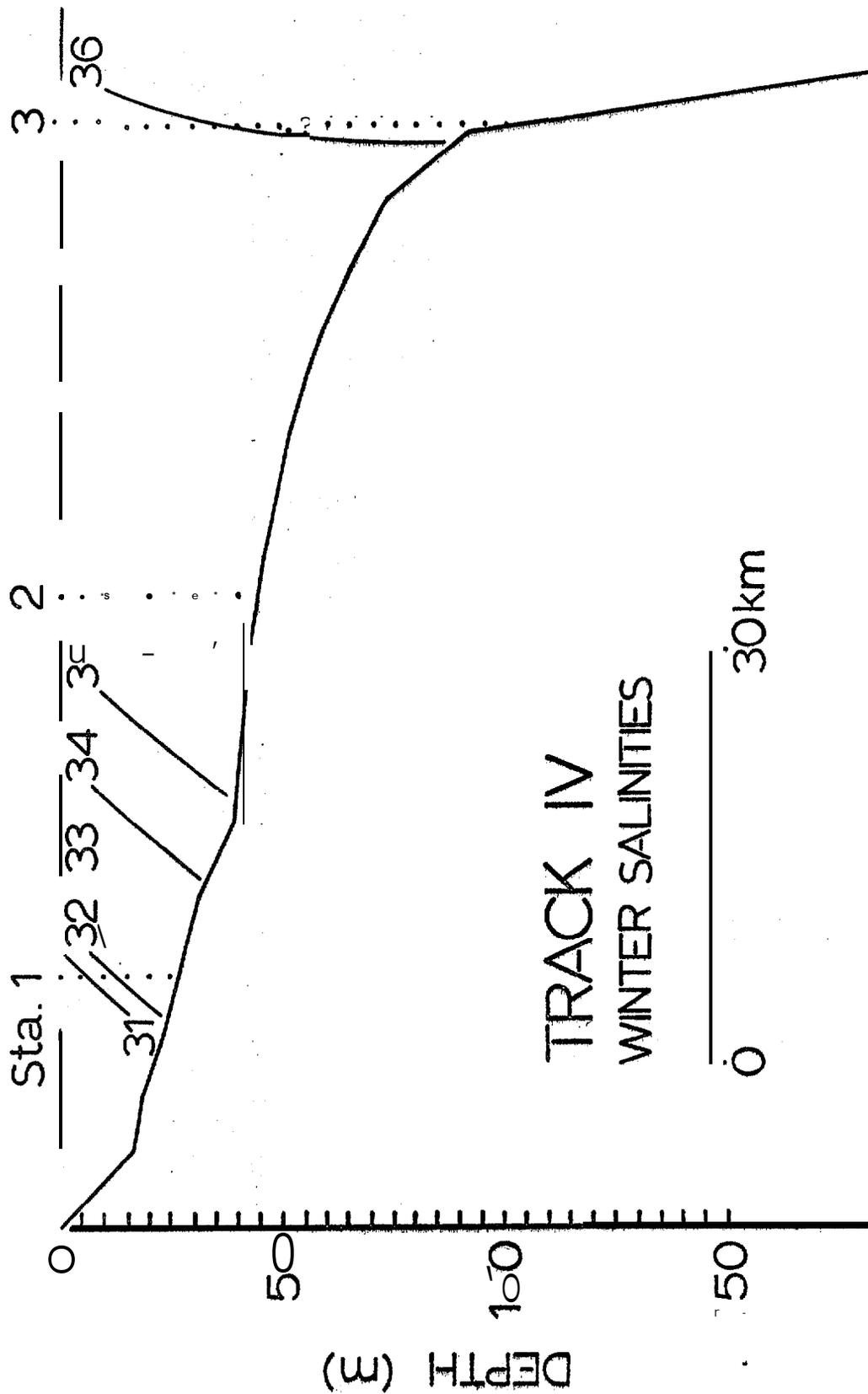


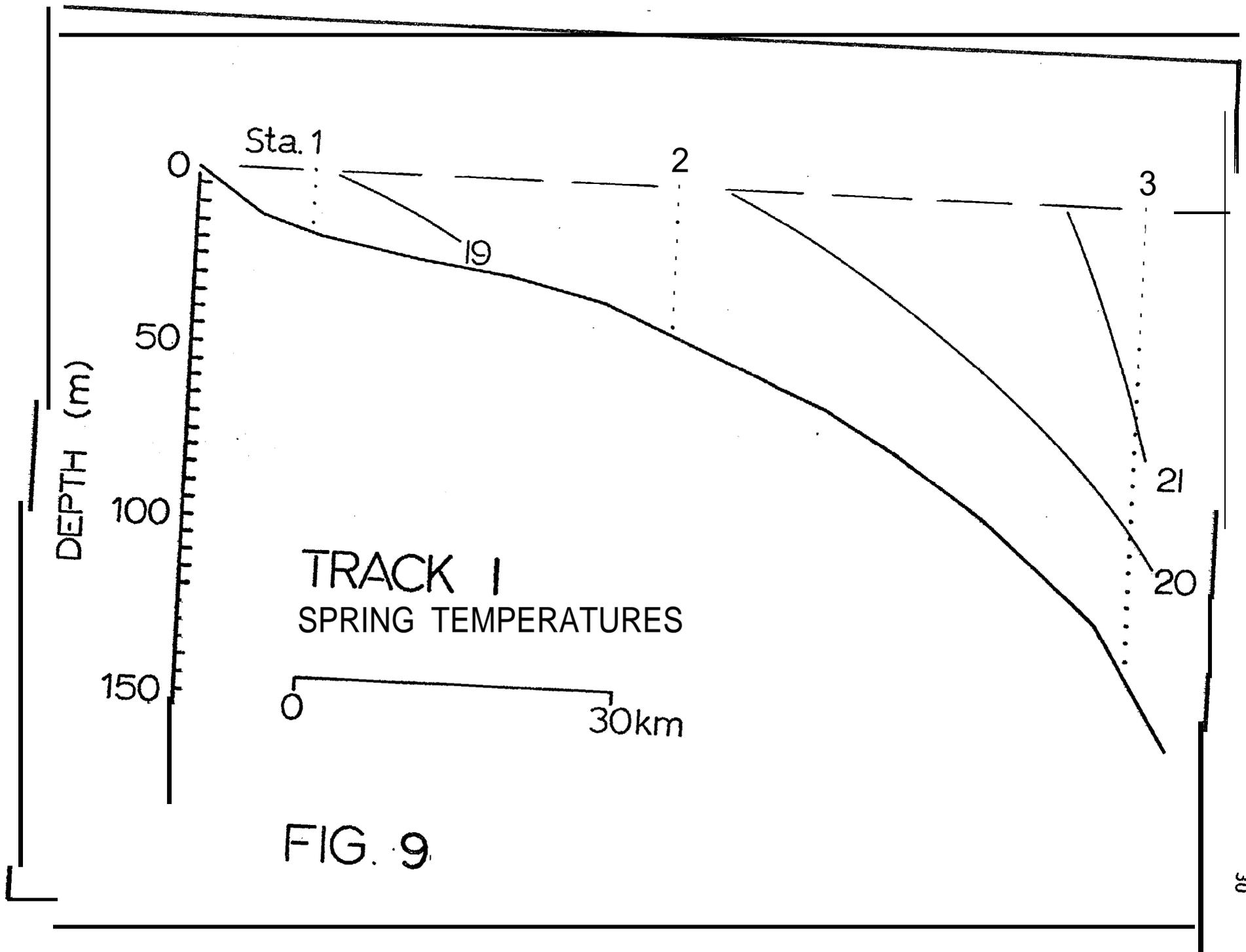
FIG. 7



TRACK IV  
WINTER SALINITIES

0 30km

FIG. 8



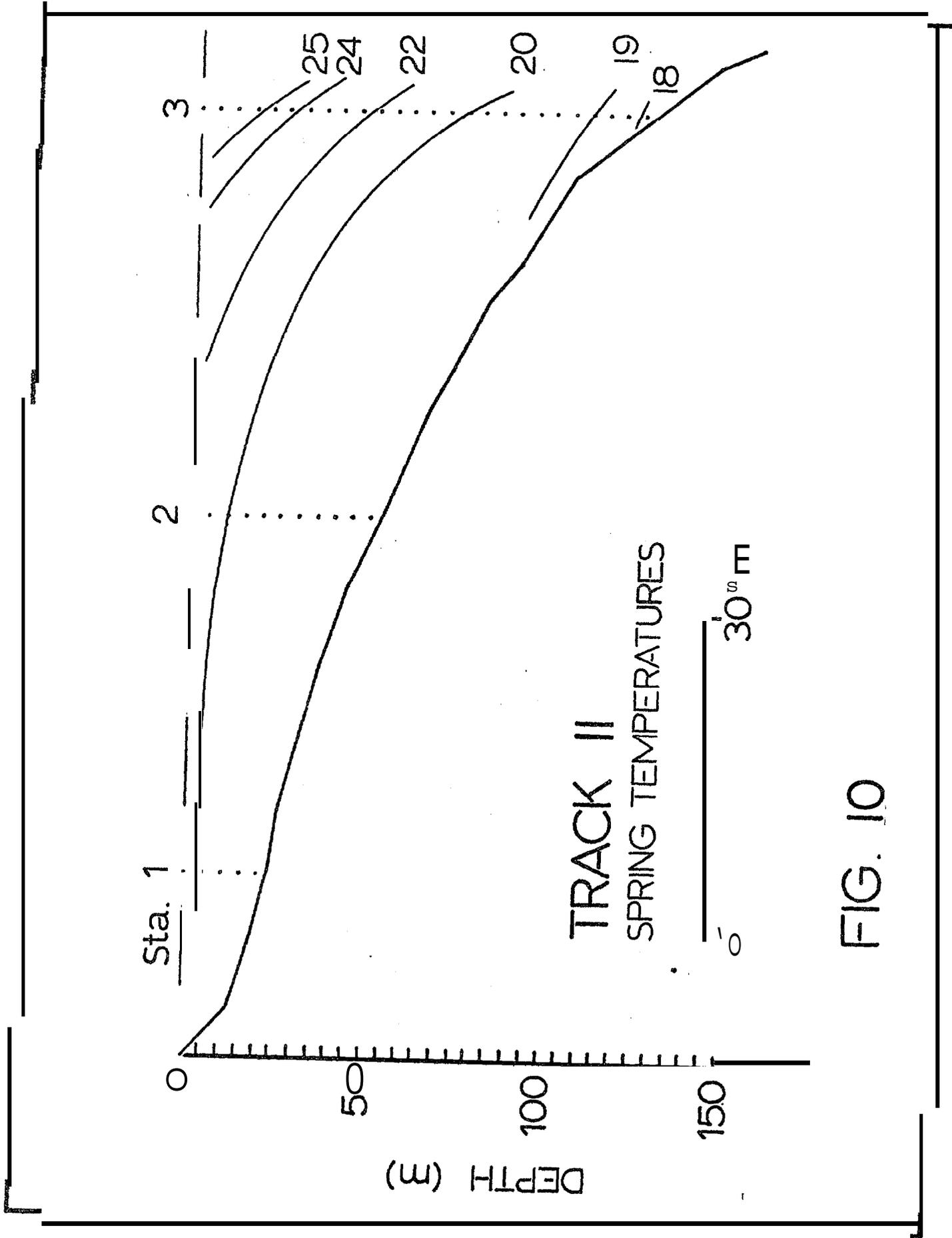


FIG. 10

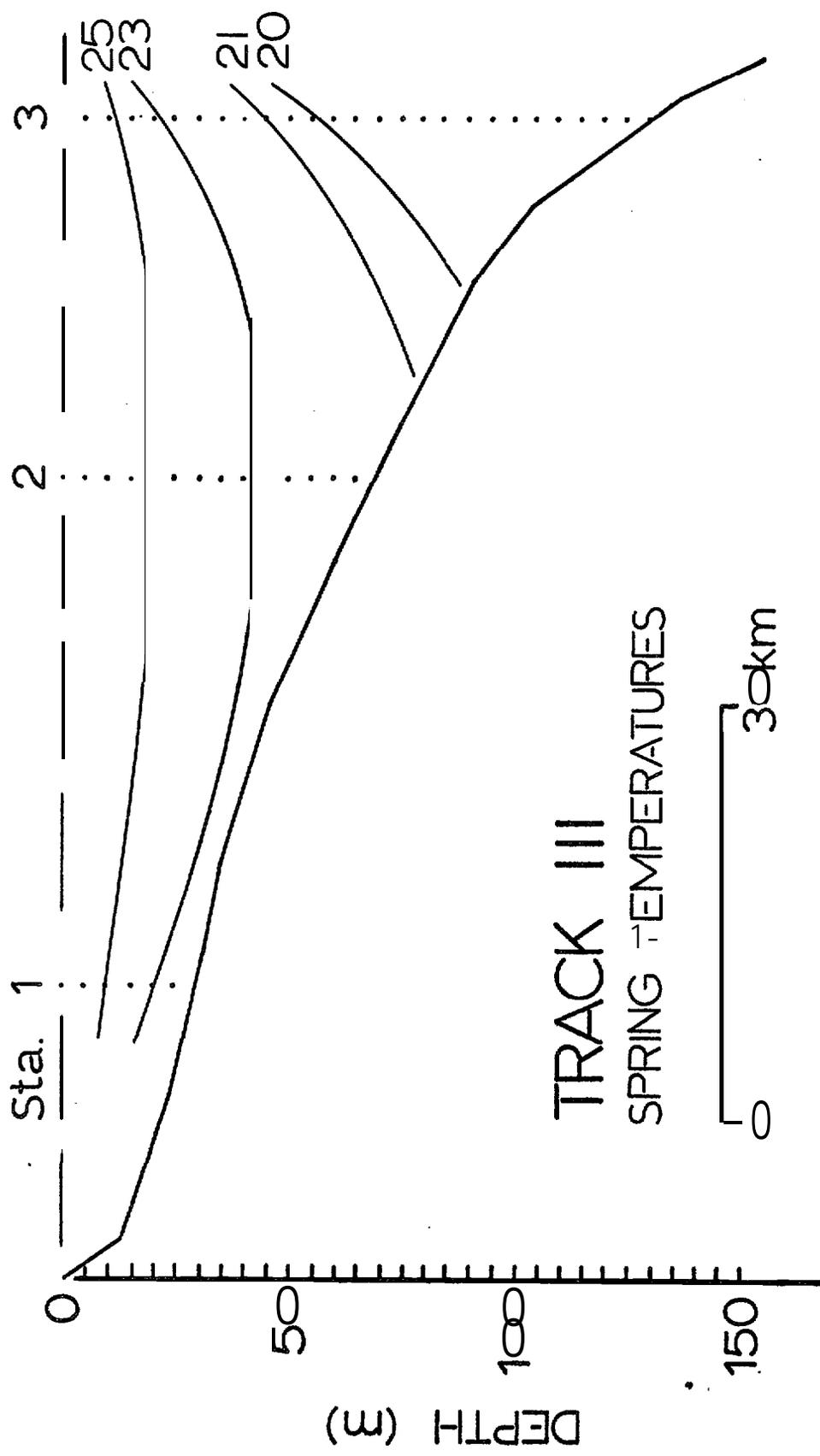
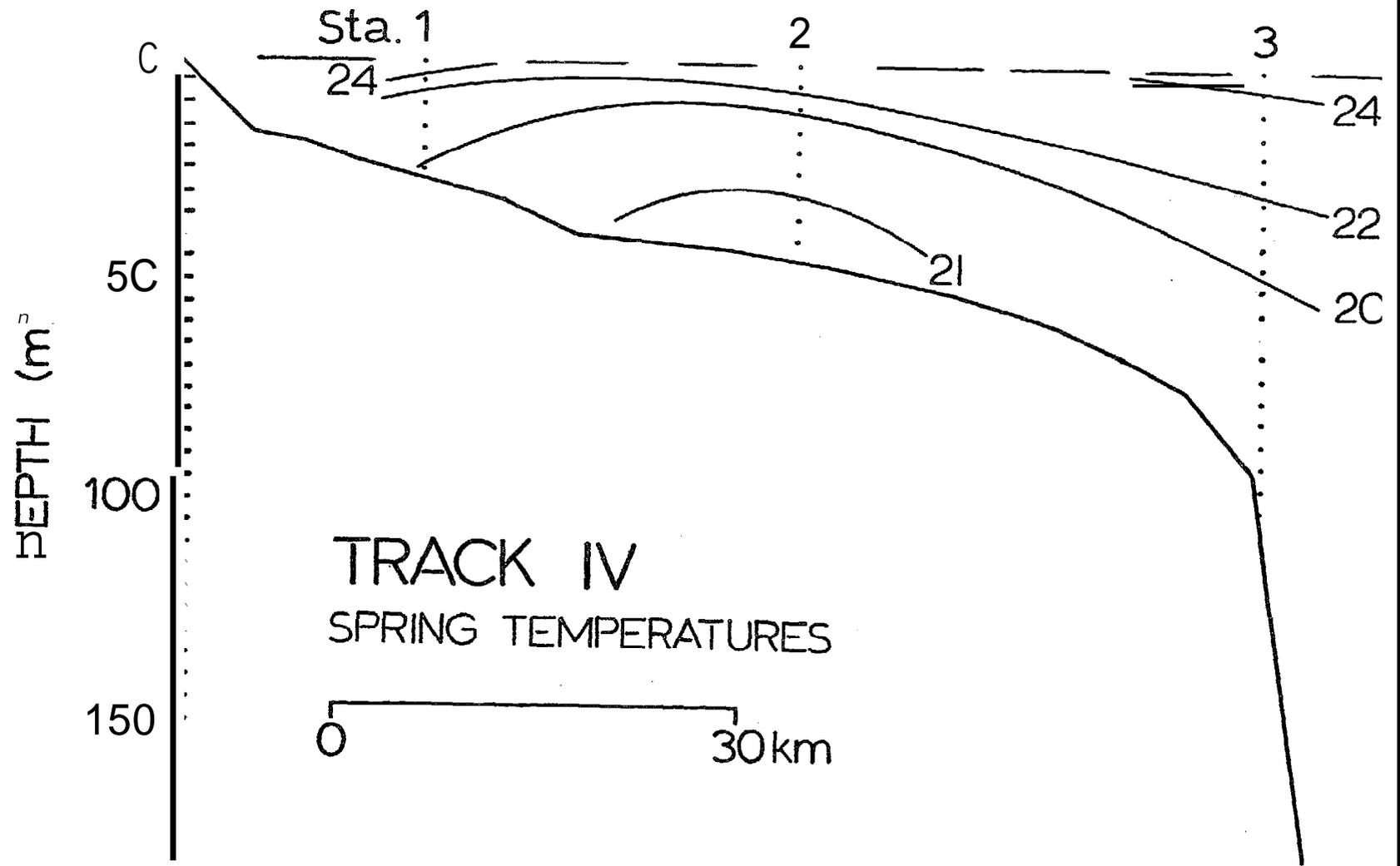


FIG. II



TRACK IV  
SPRING TEMPERATURES

0 30km

FIG. 12

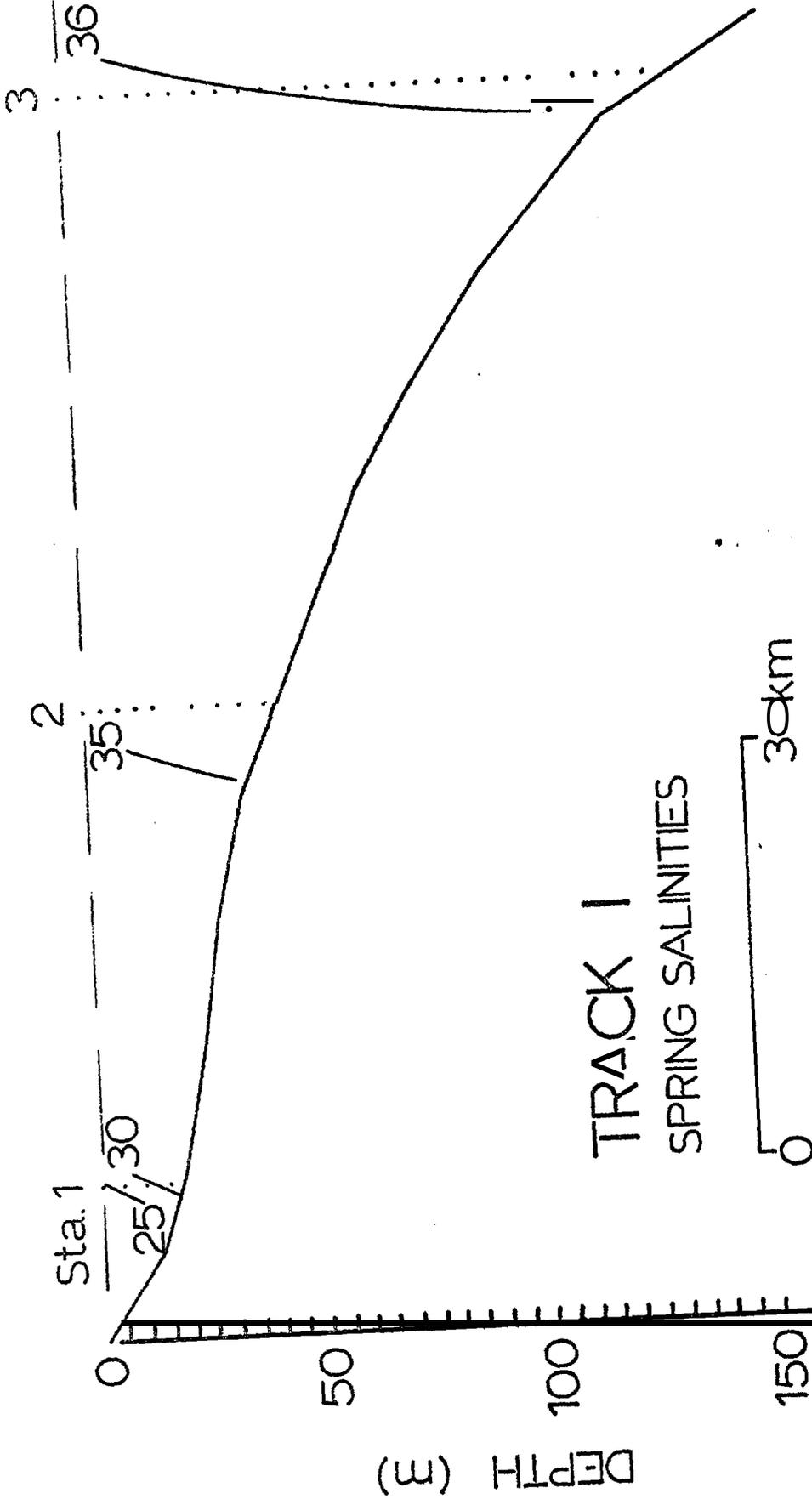


FIG. 13,

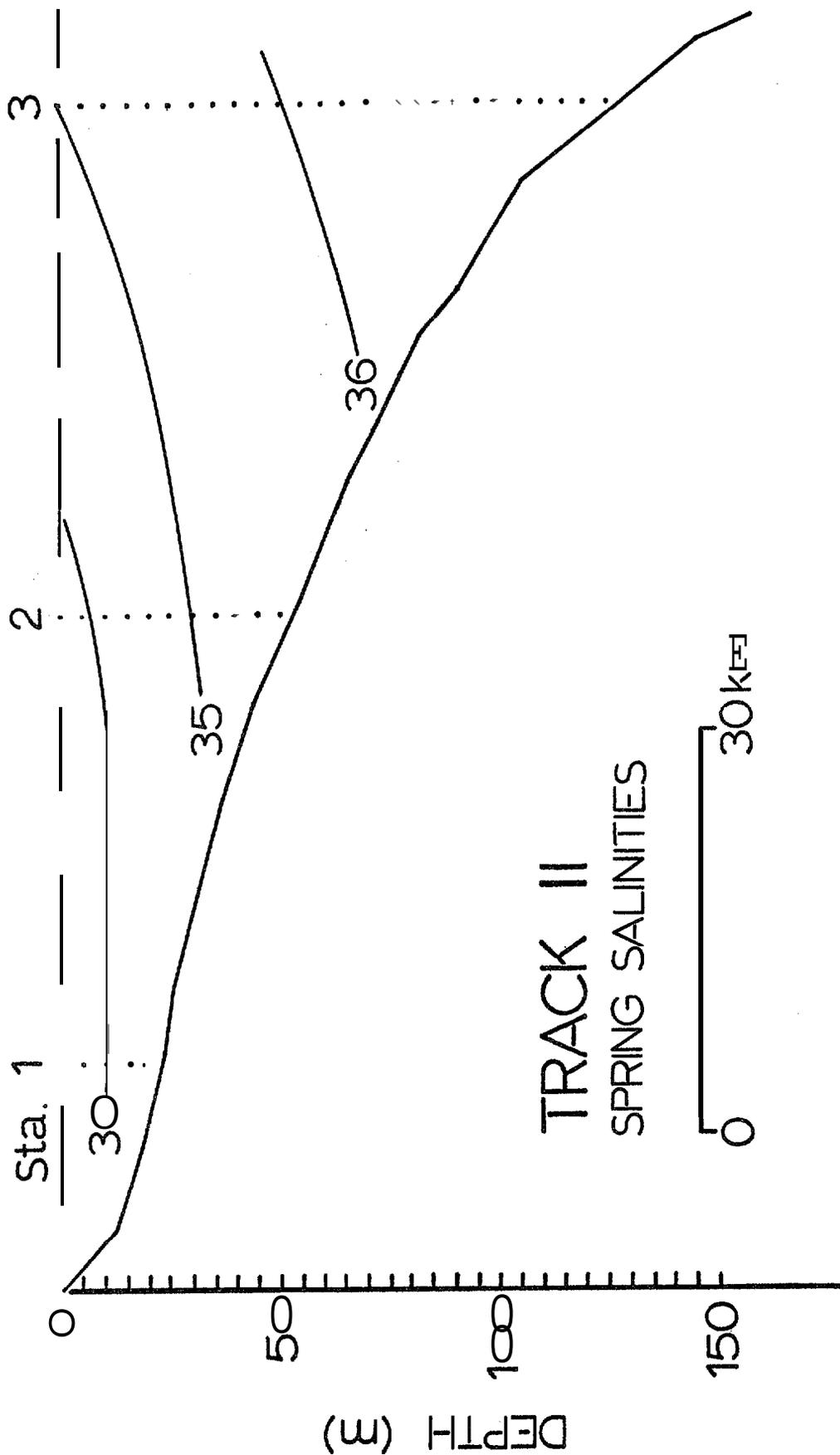


FIG. 14

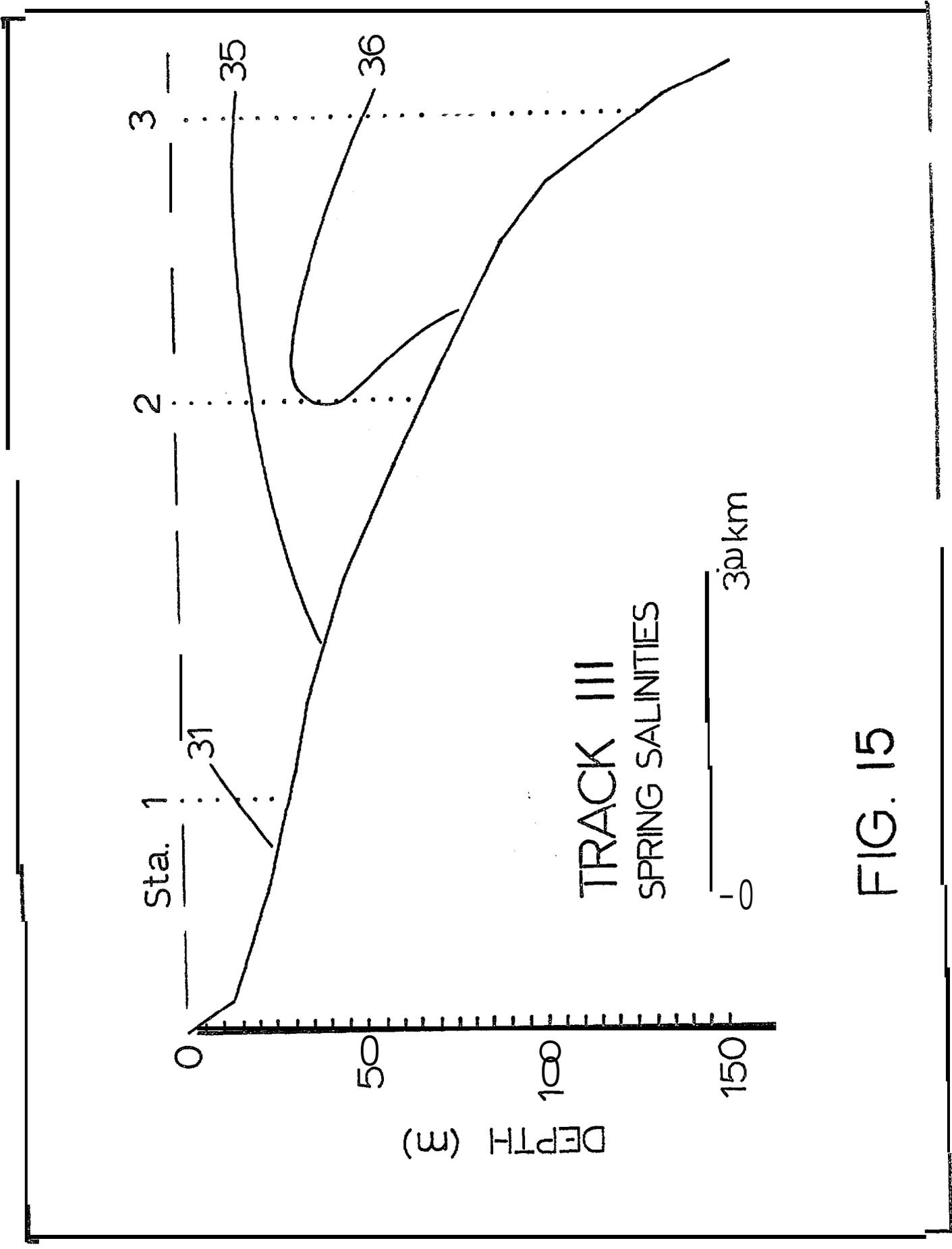


FIG. 15

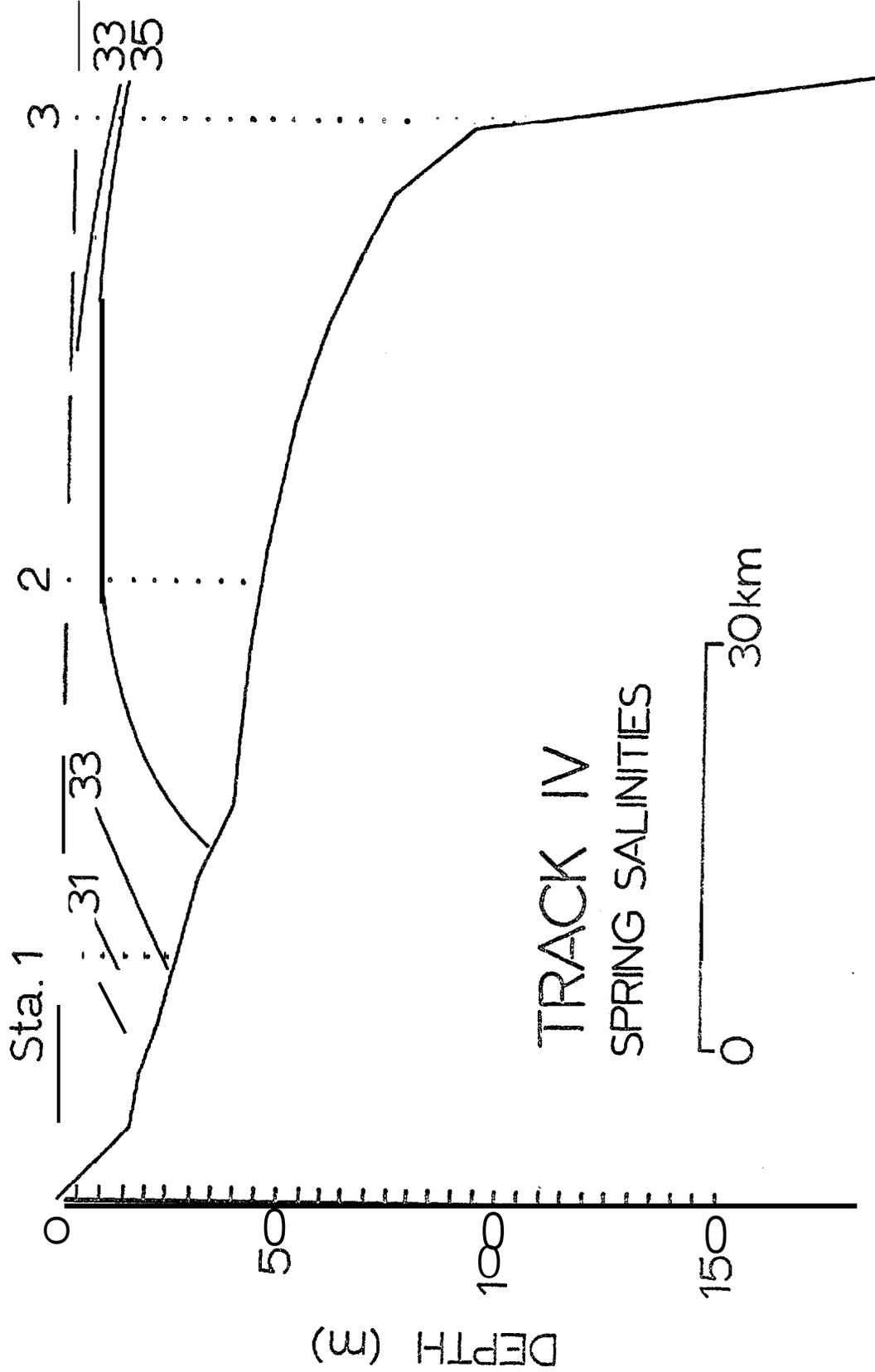
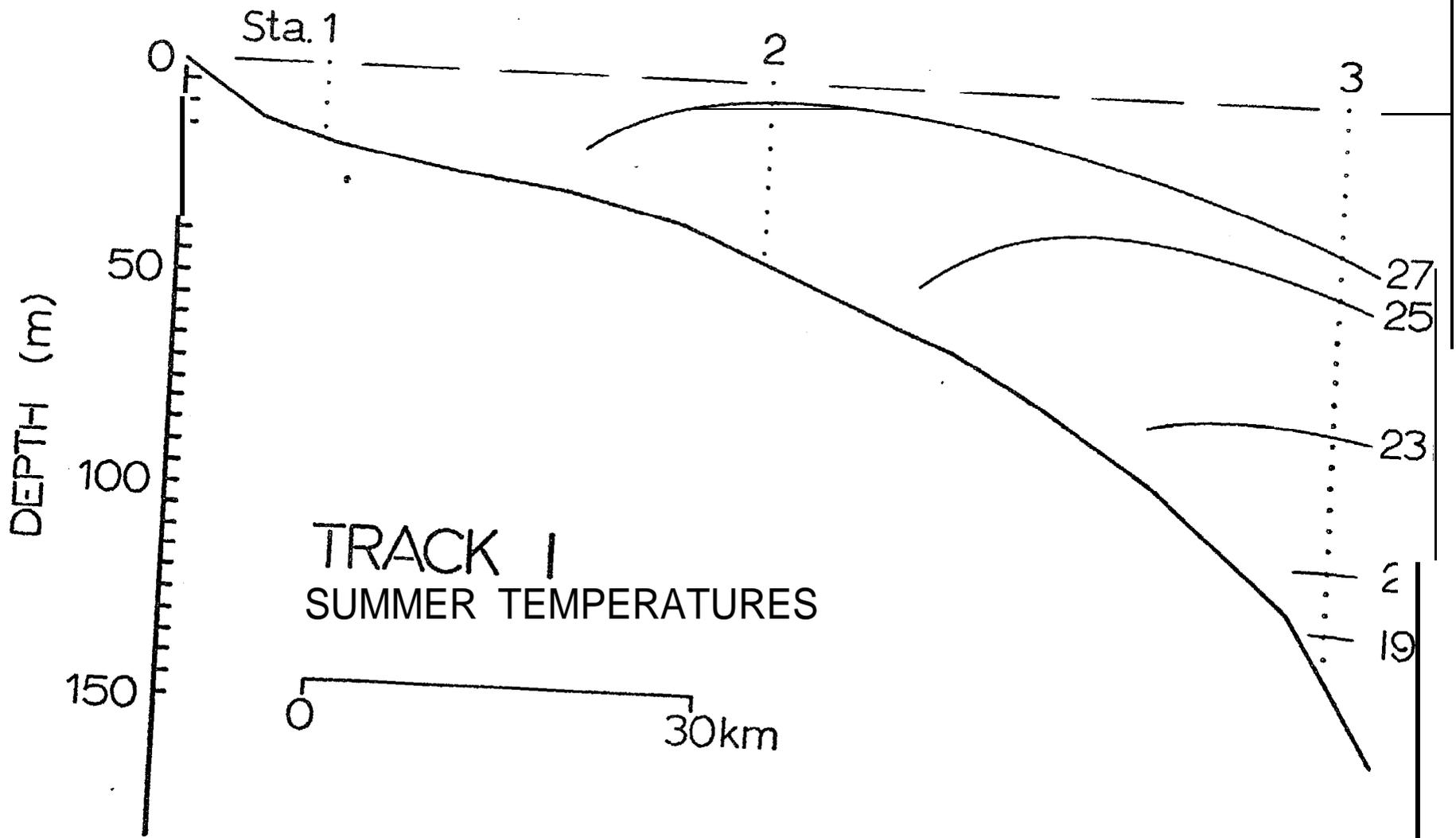


FIG. 16



TRACK I  
SUMMER TEMPERATURES

0 30km

FIG. 17

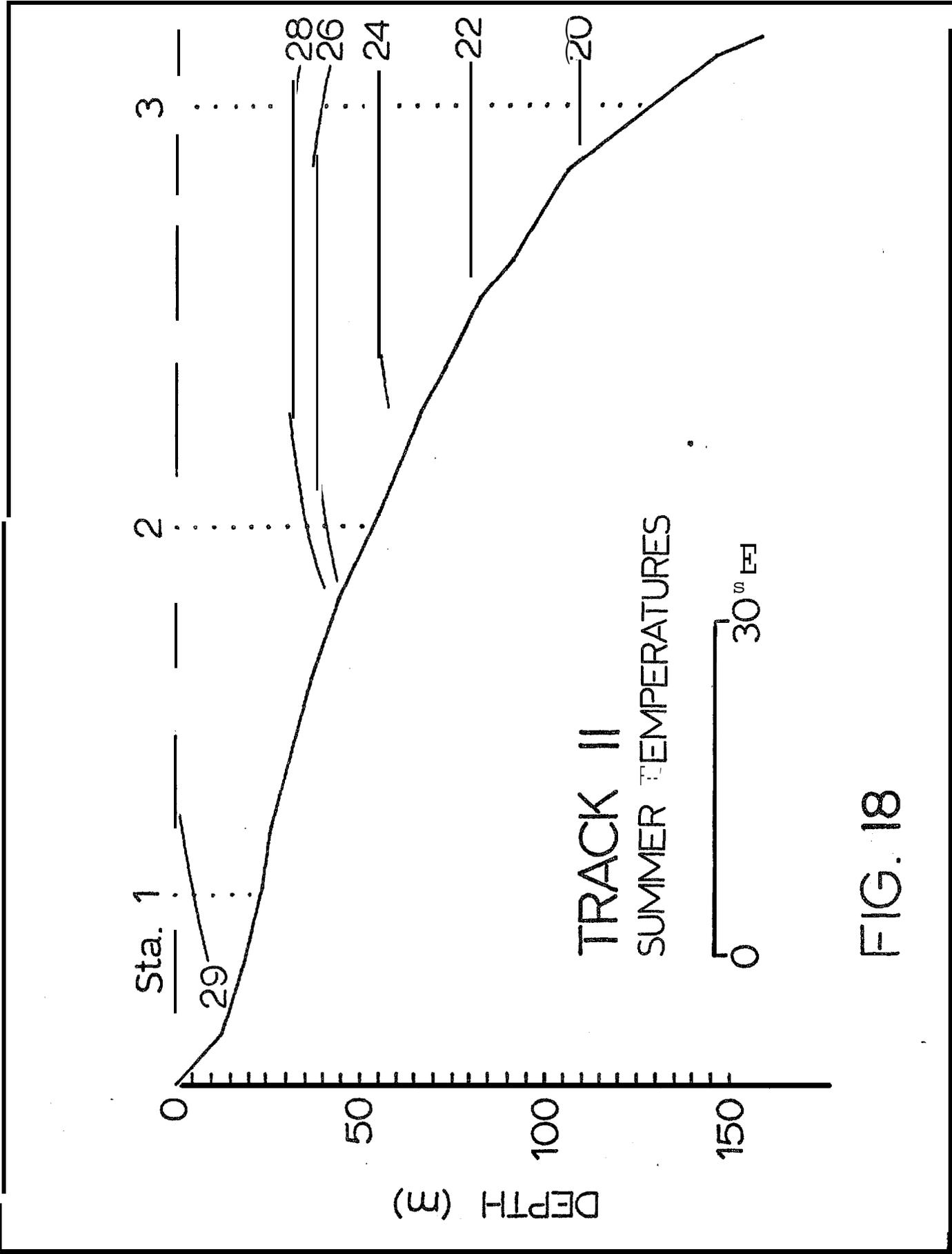
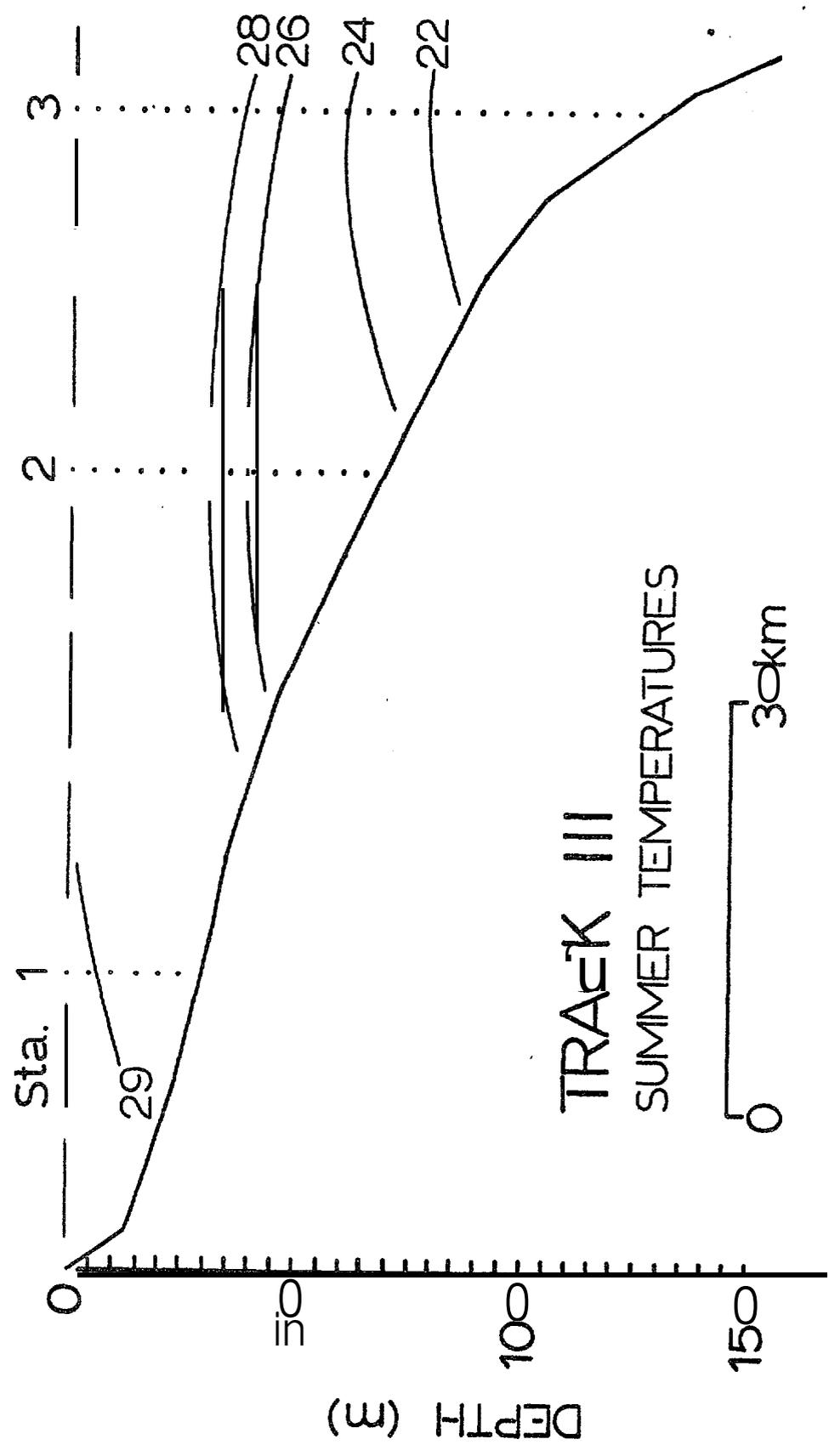


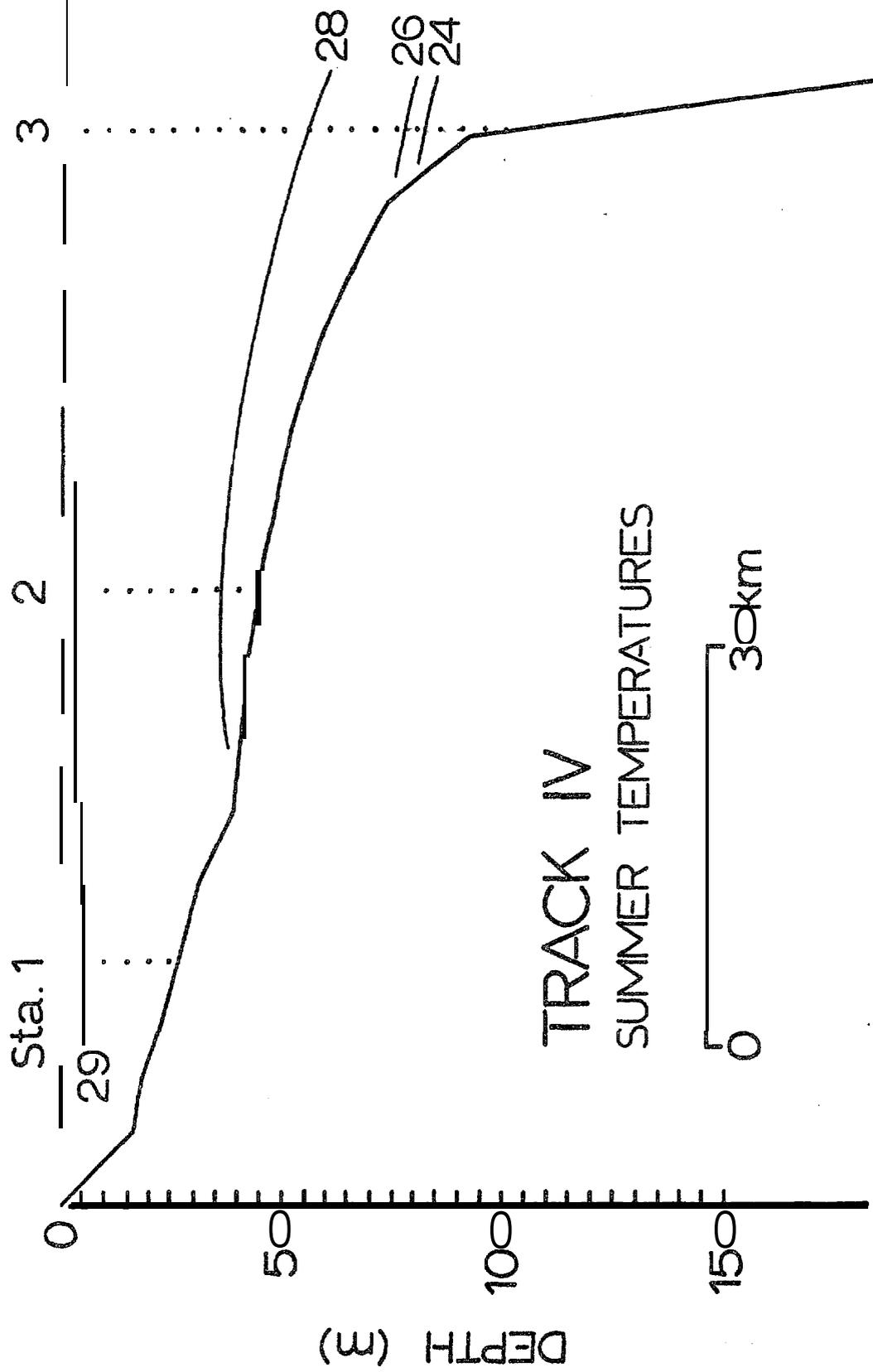
FIG. 18



TRACK III  
SUMMER TEMPERATURES

0 30km

FIG. 19



TRACK IV  
SUMMER TEMPERATURES

0 30km

FIG. 20

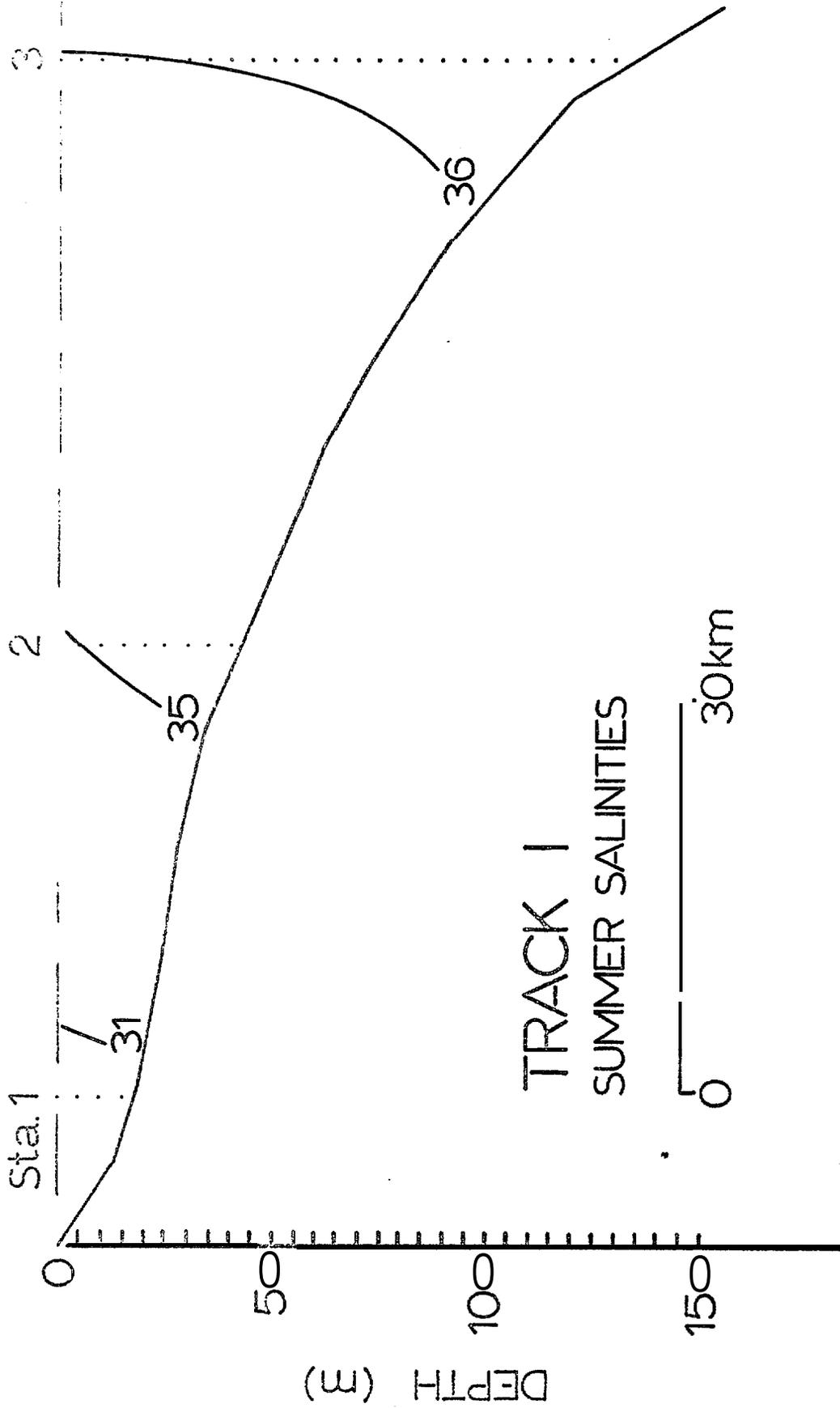


FIG. 21

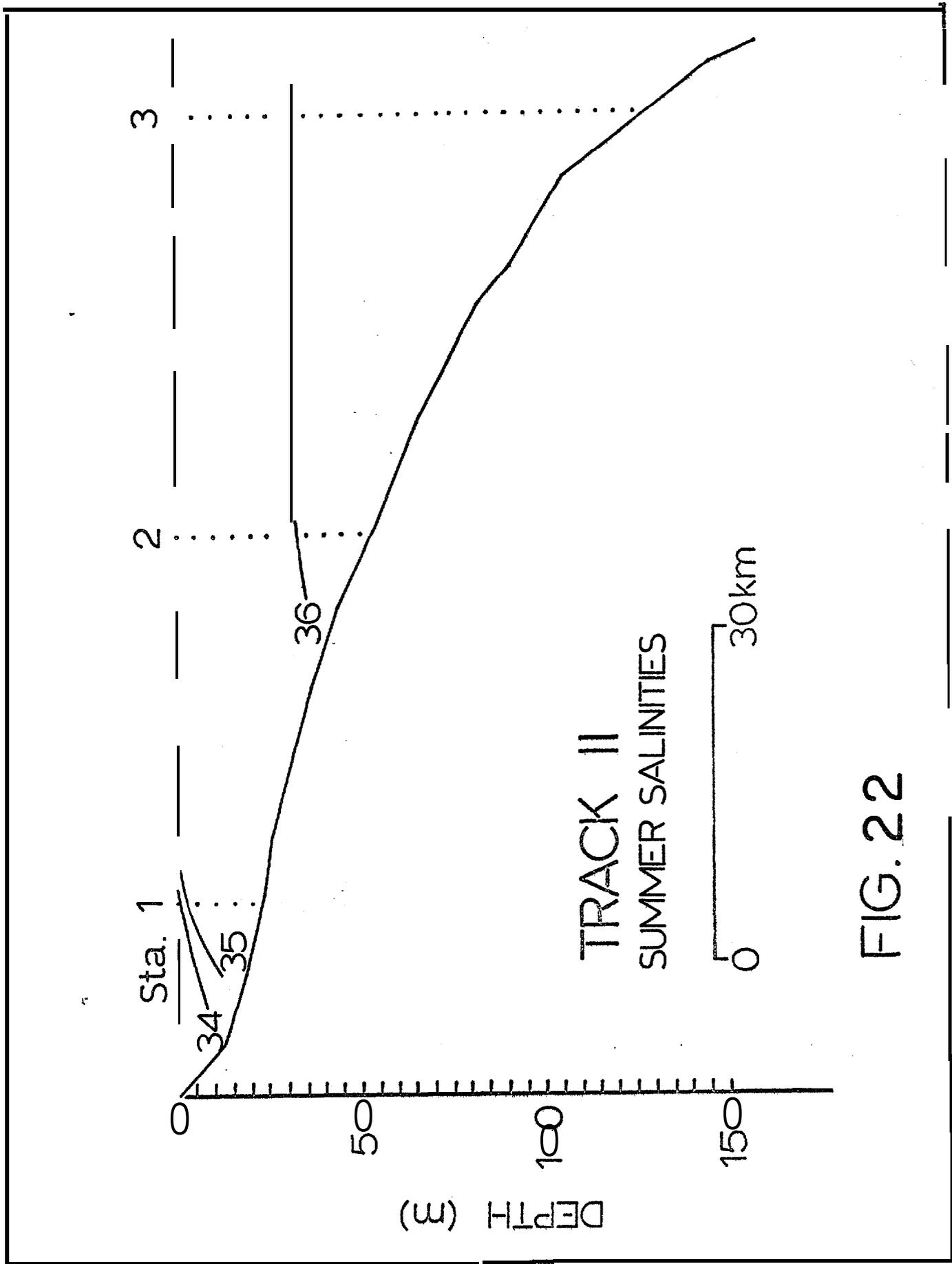
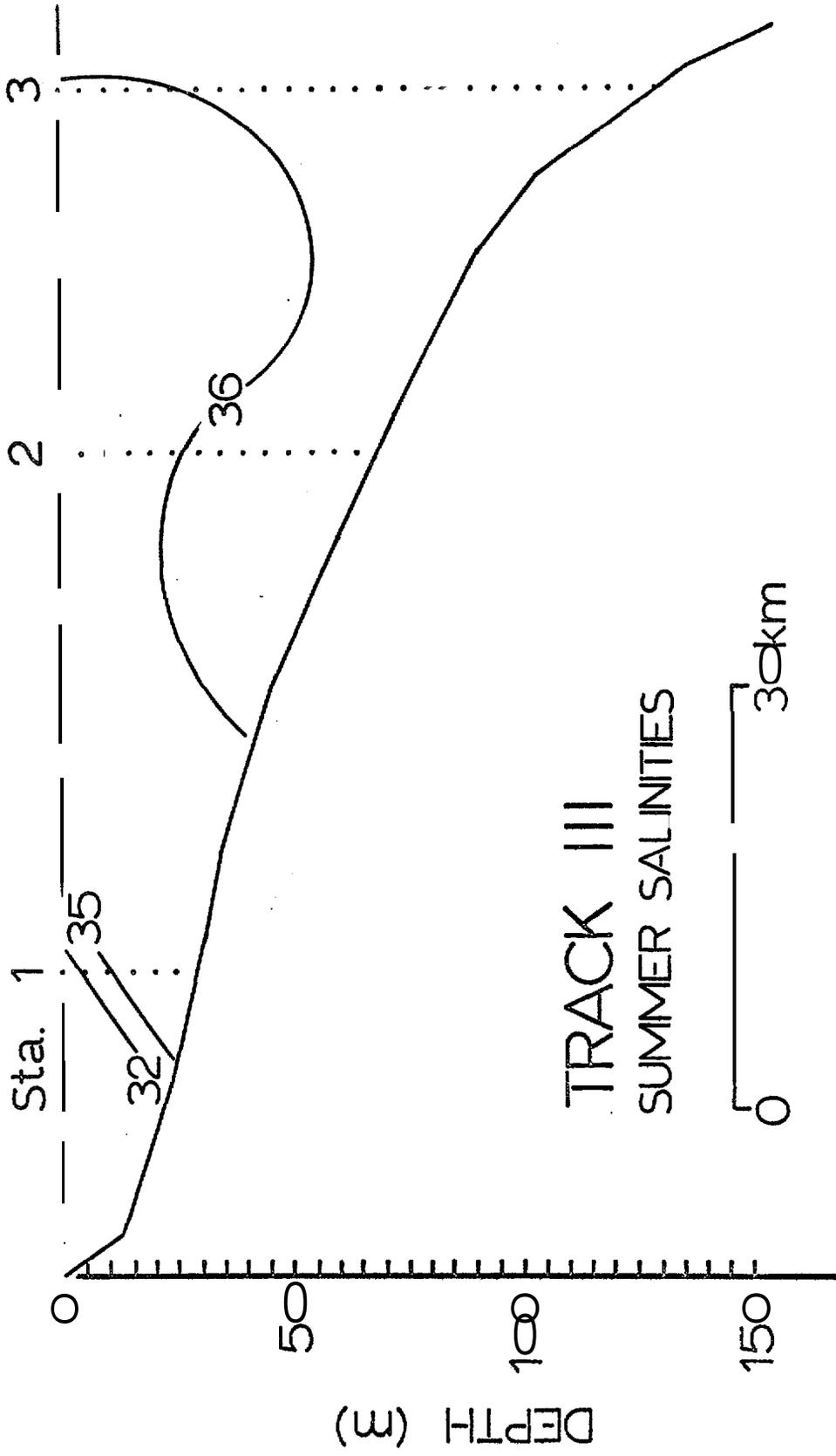


FIG. 22



TRACK III  
SUMMER SALINITIES

0 30km

FIG. 23

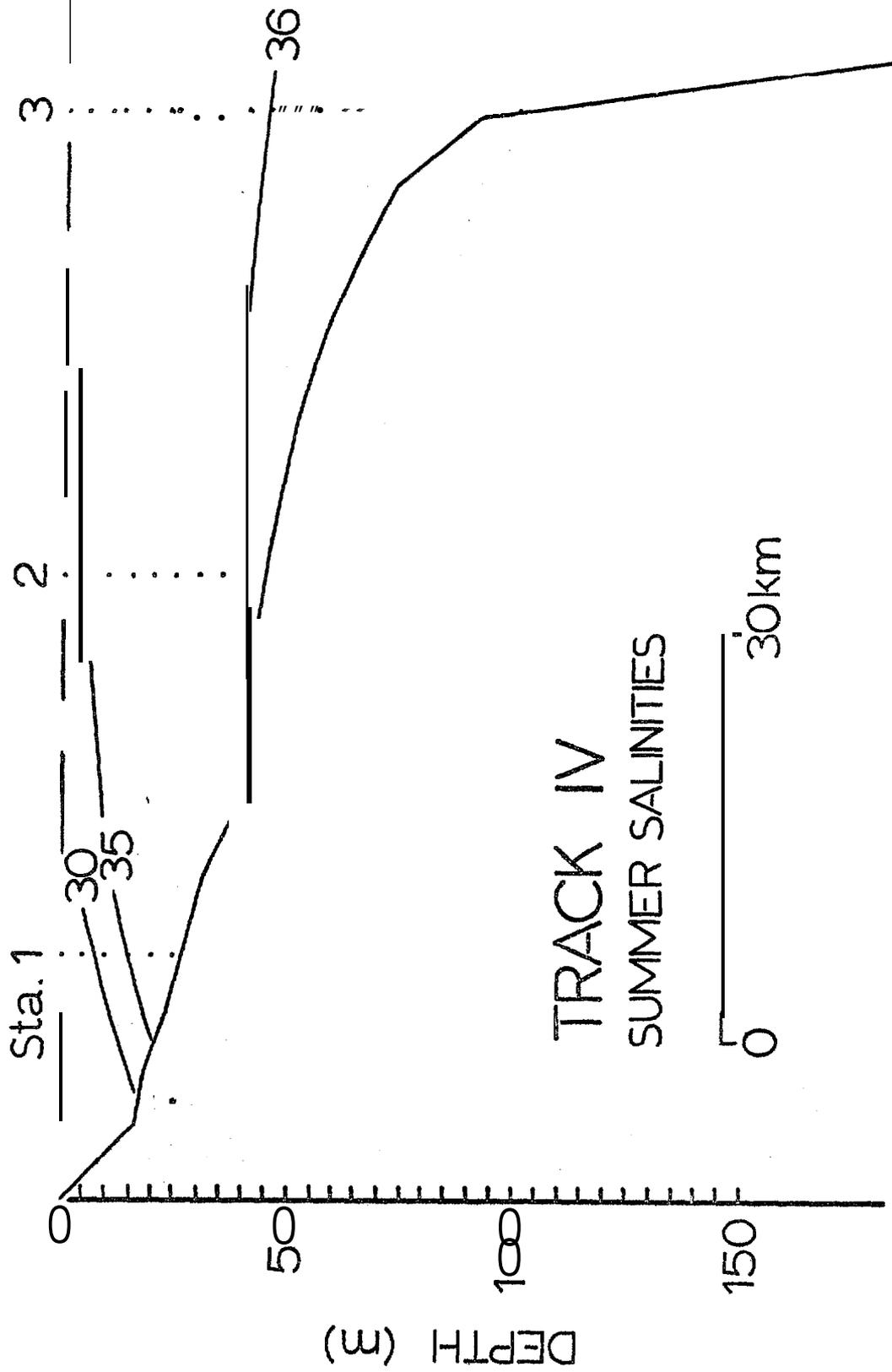


FIG. 24

**PHYTOPLANKTON AND PHYTOPLANKTON BIOMASS**

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Chase Van **Baalen**

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

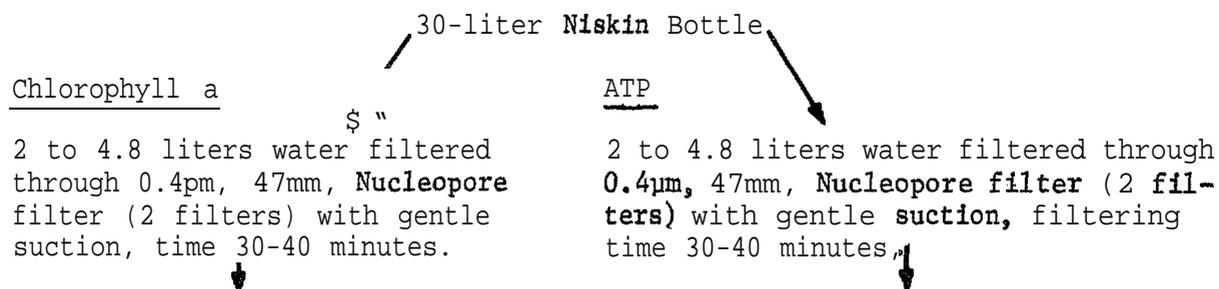
## INTRODUCTION

As part of the Texas Outer Continental Shelf **Study**, Productivity **Section**, estimates of chlorophyll a, ATP (adenosine 5<sup>r</sup>-triphosphate), and **net-plankton** counts, on samples from the water column, have been carried out. Chlorophyll a values (in  $\mu\text{g/liter}$ ) 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.



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

↓  
 Add 4ml of 90% acetone (redistilled) and approx. 1mg NaHCO<sub>3</sub>, 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, 100ox. 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  $\mu\text{g/liter}$ .

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	
<u>Chloro a</u> <sup>2</sup>						
<u>Phaeo a</u>	1.46	1.72	1.51	1.45	1.21	1.49
Sample No.	AGA	AGF	AGK	ADO	ADT	ADY
ATP <sup>3</sup>	0.20	0.29	0.57	0.25	0.14	0.15
		AV= 0.35			AV= 0.18	
Date						
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	
<u>Chloro a</u> <sup>2</sup>						
<u>Phaeo a</u>	1.59	1.57	1.40	1.40	1.46	1.41
Sample No.	CBV	CCA	CCF	CFA	CFF	CFK
ATP <sup>3</sup>	0.15	0.12	0.03	0.07	0.09	0.05
		AV= 0.10			AV= 0.07	
Date						
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. <sup>4</sup>	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	
<u>Chloro a</u> <sup>2</sup>						
<u>Phaeo a</u>	1.48	1.40	1*34		1.17	1.44
Sample No.	EBU	ECA	ECF	EFA	EFF	EFK
ATP <sup>3</sup>	0.15	0.29	0.17	0.05	0.06	0.22
		AV= 0.20			AV= 0.11	

Table 1. Cent.'d

I			II			II		
3			1			2		
1-16-75			12-17-74			1-9-75		
3	42	130	<b>1</b>	9	20	3	15	45
<b>AAV</b>	ABN	ABT	AJW	<b>AKB</b>	AKG	<b>AMV</b>	ANA	ANG
0.58	0.68	<b>N.D.</b>	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			<b>AV= 1.70</b>			AV= 0.64	
	<b>AV= 0.45</b>			AV= 1.36			AV= 0.42	
1.42	1.40		1.51	1.48	1.49	1.40	1.30	1.37
<b>AAV</b>	ABO	ABU	<b>AJX</b>	AKC	AKH	<b>AMW</b>	ANB	ANF
0.11	0.02	.003	0.26	0.34	<b>0.11</b>	0.42	0.26	0.06
	<b>AV= 0.04</b>			AV= 0.24			AV= 0.25	
4-10-75			4-17-75			4-18-75		
<b>1</b>	25	125	<b>1</b>	5	20	<b>1</b>	15	30
CIF	<b>CIK</b>	<b>CIP</b>	CLL	<b>CLQ</b>	CLV	COO	COT	COY
0.19	0.30	<b>N.D.</b>	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			<b>AV=12.07</b>			AV= 2.34	
	<b>AV= 0.14</b>			<b>AV=10.34</b>			AV= 1.82	
1.28	1.28		1.57	1*59	1.46	1.49	1.47	<b>1.46</b>
CIE	CIJ	<b>CIO</b>	<b>CLK</b>	<b>CLP</b>	CLU	CON	Cos	<b>COX</b>
0.06	0.15	0.02	0.15	0.12	0.01	0.18	<b>0.21</b>	<b>0.17</b>
	<b>AV= 0.08</b>			<b>AV= 0.09</b>			AV= 0.19	
8-28-75			9-4-75			9-5-75		
<b>1</b>	25	120	<b>1</b>	<b>11</b>	<b>20</b>	<b>1</b>	25	45
EIF	EIK	EIP	ELL	ELQ	ELV	EOP	EOU	EOZ
<b>N.D.</b>	0.21	0.27	0.66	0.78	<b>1.36</b>	<b>N.D.</b>	0.18	1.14
	0.10	0.11	0.41	0.45	0.88		0.10	0.78
	AV= 0.24			<b>AV= 0.93</b>			AV= 0.66	
	<b>AV= 0.11</b>			<b>AV= 0.58</b>			AV= 0.44	
1.22	1.20		1.34	1.31	<b>1.36</b>		1.26	1.39
EIE	EIJ	EIO	ELK	ELP	ELU	<b>E</b>	EOT	EOV
0.07	0.11	0.02	0.19	0.08	0.26	0.03	0.07	0.56
	<b>AV= 0.07</b>			<b>AV= 0.18</b>			AV= 0.22	

Table 1, Cont. 'd

II			III			III		
3			1			2		
12-12-74			12-15-74			12-14-74		
<b>10</b>	23	105	2.5	<b>10</b>	20	10	25	55
APx	AQC	AQH	ASZ	ATH	ATM	<b>AWB</b>	<b>AWF</b>	AWL
0.53	0.56	<b>N.D.</b>	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	<b>1.32</b>	1.34	1.21	1.32
<b>APY</b>	AQD	<b>AQI</b>	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		
<b>1</b>	23	115	<b>1</b>	7.5	16	<b>1</b>	23	60
CRQ	CRV	CSA	<b>CUY</b>	<b>CWD</b>	<b>CWI</b>	<b>CYY</b>	CZD	<b>CZI</b>
0.20	0.20	<b>N.D.</b>	4*39	<b>2.25</b>	<b>1.38</b>	<b>0.66</b>	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= <b>0.54</b>	
	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	<b>CUX</b>	<b>CWC</b>	<b>CWH</b>	<b>CYX</b>	<b>CZC</b>	CZH
0.07	0.04	0.01	0*12	0.13	0.05	<b>0.08</b>	0.18	0.003
	AV= 0.04			AV= <b>0.10</b>			AV= 0.09	
9-6-75			9-8-75			9-7-75		
<b>1</b>	29	120	<b>1</b>	9	20	<b>1</b>	26	60
ERQ	ERV	ESA	EUY	<b>EWD</b>	EWI	<b>EYY</b>	EZD	EZI
<b>N.D.</b>	0.18	0.25	<b>1.15</b>	<b>0.87</b>	0.80	<b>0.20</b>	0.24	<b>1.69</b>
	0.08	0.10	0.87	0.59	<b>0.53</b>	0.08	<b>0.10</b>	1.50
	AV= 0.22			AV= 0.94			AV= 0.71	
	AV= 0.09			AV= <b>0.66</b>			AV= 0.56	
	<b>1.22</b>	1.18	1.45	1.39	1.36	<b>1.19</b>	1.19	1.38
<b>ERP</b>	ERU	ERZ	EUX	<b>EWC</b>	EWI	<b>EYX</b>	EZC	EZH
0.02	0.02	0.07	0.05	Lost	0.03	0.09	0.05	0.06
	AV= 0.04			AV= <b>0.04</b>			AV= <b>0.07</b>	

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	<b>18</b>	45
<b>AYZ</b>	AZE	AZJ	BBX	<b>BCC</b>	<b>BCH</b>	BEZ	BFE	BFJ
<b>N.D.</b> <sup>4</sup>	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	<b>1.43</b>	1.36	1031
AZA	AZF	AZK	<b>BBY</b>	BCD	<b>BCI</b>	BFA	BFF	BFK
0.01	0.09	0.03	0.11	0.17	0,15	0.19	0.03	<b>0.01</b>
	AV= 0.04			AV= <b>0.14</b>			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	<b>DFB</b>	DFG	DHV	<b>DHZ</b>	DIF
0.27	0.22	<b>N.D.</b>	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= <b>1.10</b>			AV= 1.35	
	AV= 0.15			AV= <b>0.79</b>			AV= 1.11	
1.39	1.22		1.49	<b>1.41</b>	1.40	1.49	1.46	1.42
<b>DCJ</b>	<b>DCO</b>	DMN	<b>DEV</b>	<b>DFA</b>	<b>DEF</b>	<b>DHU</b>	<b>DIA</b>	DIE
0.04	<b>0.11</b>	0.05	0.44	1,08	0,10	0,18	0.40	0.12
	AV= 0.07			AV= <b>0.54</b>			AV= 0,23	
9-7-75			9-12-75			9-12-75		
1	29	100	1	13	22	<b>1</b>	13	40
FCM	FCR	FCW	FFE	FFJ	<b>FFO</b>	<b>FIF</b>	FIK	<b>FIP</b>
0.19	0.21	0.25	0.91	0.95	<b>1.23</b>	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= <b>1.03</b>			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	<b>1.21</b>	1.36
FCL	<b>FCQ</b>	<b>FCV</b>	FFD	<b>FFI</b>	FFN	<b>FIE</b>	FIJ	<b>FIO</b>
0.04	0.02	0.02	0.77	0.51	Lost	0.08	1.45	0.31
	AV= 0,04			AV= 0.64			AV= <b>0.61</b>	

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. <sup>4</sup>	N.D. <sup>4</sup>	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<sub>663</sub> < 0.0015A.

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).

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

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 2/1 and 1/11 are higher (more productive?) than 1/111 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. <sup>1</sup>  
 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. <i>Bacteriastrium hyalinum</i>	2	3	1	2	2	*	3	1	5	2		
	*	4	-	3	4	*	-	-	2	3		
2. <i>Cerataulina bergoni</i>	11	*	*	7	*	1	*	*		2	3	
	56	*	-	10	3	*	1	-	*	*	3	5
3. <i>Chaetoceros curvisetus</i>	-	*	2	1	*	*	-		5			6
		1	*	-	*	5	1		7			
4. <i>C. decipiens</i>	1	10	20			18	-	17	17	*	3	6
		4	11			21	-	-	13	2	s.	2
5. <i>C. lorenzianus</i>	3	7	8	2	4	7	4	2	5	*	4	*
	2	4	-	*	2	5	3	-	11	3	*	*
6. <i>C. pelagicus</i>		*	10		*	1	*	*	2	*	*	1
		1	*		4	-	16	-	2	*		
7. <i>Nitzschia seriata</i>	1	*	3	*	8	1	*	2	3	18	18	-
	*	2	-		6	-	-	-	5	32	11	-
8. <i>Rhizosolenia stolterfothii</i>	1	*	*	22	*	*	*	2	2		*	2
	3	*		13	*	*	*		1			1
9* <i>Skeletonema costatum</i>	7	11	3	*	24"	-	20	*		*		
	2	9	*		10	-	16	-	*		2	2
10. <i>Thalassionema nitzschioides</i>	8	18	5	3	6	12	-	17	8	*	4	*
	1	10	11	2	2	10	18	-	13	6	-	7
11. <i>Thalassiosira rotula</i>	35	14	*	3	-	*	*	*	*	2	4	*
				2	-	*	6	-		2	*	*
12. <i>Thalassiosira subtilis</i>	6	6	-	6	-	-	2	*	9			*
		3	-	24	-	-	2	-	*			*
Total Cells per Liter,	.586	.638	.315	.548	.548	.602	.648	.815	.478	.100	.096	.226
X 10 <sup>4</sup>	.601	.866	.016	.793	.084	.497	.583	lost	.503	.108	.117	.418

Table 2. Cent.'d

Cruise 2 - Spring (April-May 1975)

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

Table 2. Cont.f.d

Cruise 2 - Cent.'d

ORGANISM	Transect I			Transect II			Transect 111			Transect IV		
14. <i>Nitzschia seriata</i>	2	-	4	*	*		1	-		3	*	
	I 3	*	3	1	*			1	*	1	2	
15. <i>Skeletonema costatum</i>	13	16	-	37	50	*	6	6	-	47	6	2
	I 14	14	-	72	58	-				61	T-9	4
16. <i>Thalassionema nitzschioides</i>	12	3	-	*	3	*	4	*	*		3	3
	8	2	*	4	*	*	6	2	2	*	*	?
17. <i>Thalassiosira rotula</i>	3	*		1	2	-					*	
	2	*		4	*		*	*		*	*	
18. <i>Thalassiothrix mediterranea</i>		*		*	*	*	*	1	*		2	
				*	*		*	7	*			
Total Cells per Liter, x 10 <sup>4</sup>	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)

1. <i>Bacteriastrum hyalinum</i>	*	-	-	5	-	*		*		*	.9	-
	4	-	-	6	-	-	4			5	21	7
2. <i>Chaetoceros curvisetus</i>	5	-	-	9	*	10	1	-	-	6	27	*
	8	-	-	4	10	-	13			21	10	6
3. <i>C. decipiens</i>	11	-	-	*				3	-	*	*	2
	4			2							6	
4. <i>C. diversus</i>	32	-	-	9	15	4	*			*	6	*
	3			1	3	-	15	-	-	2	11	*
5. <i>C. gracilis</i>	3	-	-					*			*	
	3	-	-				*			*		
6. <i>C. lacinosus</i>	17	-	-	*			*	15	-	*		
	10	-	-	1	-	-	1	17	7		*	

Table 2. Cent.'d

Cruise 3 - Cent.'d

ORGANISMS	Transect I			Transect II			Transect 111			Transect IV		
	1	2	3	1	2	3	1	2	3	1	2	3
7. <i>Nitzschia delicatissima</i>			-	34	7	8	54	-	-	62	32	27
		5	-	13	-	39	8	-	-	35	4	13
8. <i>N. seriata</i>			-	2	*	-	18	6	18	2	*	
	2	-	*	-	-	-	5	10	14	13	*	-
9. <i>R. alata</i> v. <i>gracillima</i>	*	16	12	-	5	10	-	6	13	*	*	27
	1	7	22	*	9	7	-	13	16	*	*	21
10. <i>Thalassionema nitzschioides</i>	4	12	*	5	-	*	5	-	-	11	4	
	6	14	-	1	-	-	*	-	-	2	1	*
11. <i>Trichodesmium thiebautii</i>	*	9	-	5	3	*	*	8	*	*	5	*
	*	*	*	-	3	-	*	-	*	*	9	*
12. <i>Rhizosolenia hebetata</i> v. <i>semispina</i>	1	7				1	-	6	*	-		
		6	*	-		-	-	4	*	-		
Total Cells per Liter, $\times 10^4$	13.8	.010	.009	.428	.047	.025	.629	.033	.008	2.84	.882	.054
	3.19	.019	.004	3.00	.029	.045	.201	.029	.029	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	<b>6013</b>
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	<b>ABW</b>	3	3.00	52	3154
3	I	12-4-74	ABX	25	3.23	32	157*
1	II	12-17-74	AJQ	<b>1</b>	3.13	56	5478
1	II	12-17-74	AJS	9	2.83	51	7932
2	II	1-9-75	<b>AMM</b>	3	2.53	45	5475
2	11	1-9-75	<b>AMQ</b>	15	3.39	44	281
3	II	12-12-74	APP	10	3.02	60	<b>6018</b>
3	<b>II</b>	12-12-74	<b>APS</b>	23	2.86	51	4974
1	111	12-15-74	ASR	2.5	<b>2.81</b>	52	6483
1	III	12-15-74	ASU	10	2.74	43	5833
2	111	12-14-74	<b>AVV</b>	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	111	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	<b>IV</b>	1-24-75	<b>BEU</b>	18	3.42	52	1172
3	<b>IV</b>	1-25-74	BPR	2	3.21	61	2260

Table 3. Cont. 'd

Station	Transect	Date	Sample Code"	Depth	H <sup>+</sup>	Total Spp.	Total cells/ liter
3	IV	J-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	11	5-16-75	CRF	1	2.54	42	5706
3	11	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	<b>EHU</b>	1 2.14	12	91
3	I	8-28-75	EHY	20 2.31	14	41
1	II	9-4-75	<b>ELE</b>	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	<b>ERF</b>	1 2.80	2 2	249
3	11	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	111	9-7-75	EYN	1 2.53	20	327
2	111	9-7-75	EYR	26 2.59	20	228
3	III	9-12-75	<b>FBN</b>	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. Cent. '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

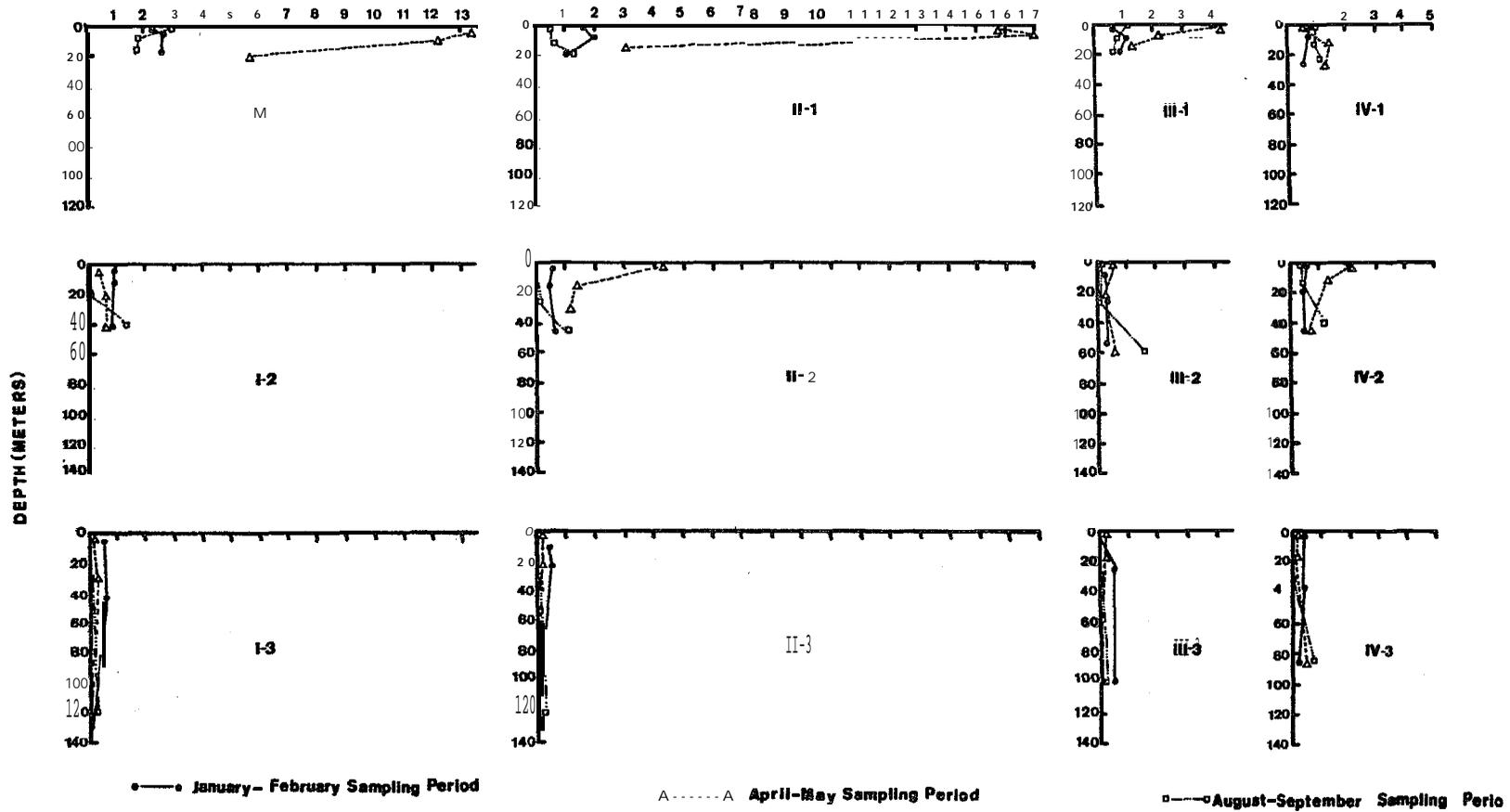


Figure 1. SEASONAL VARIATIONS IN CHLOROPHYLLA µg/liter

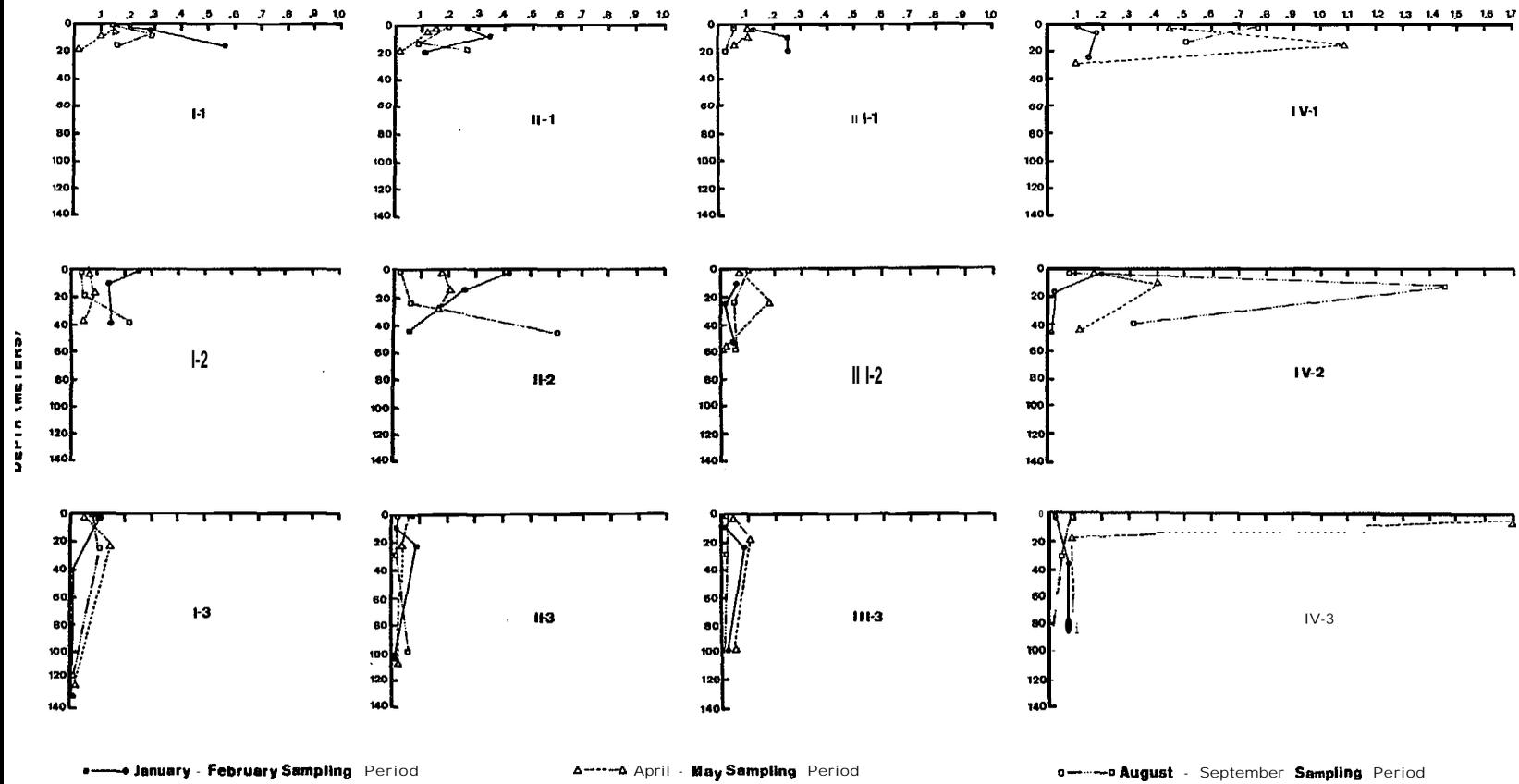


Figure 2, SEASONAL VARIATIONS IN ATP  $\mu\text{g/liter}$

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, phosphates 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  $\pm 0.4$ . 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

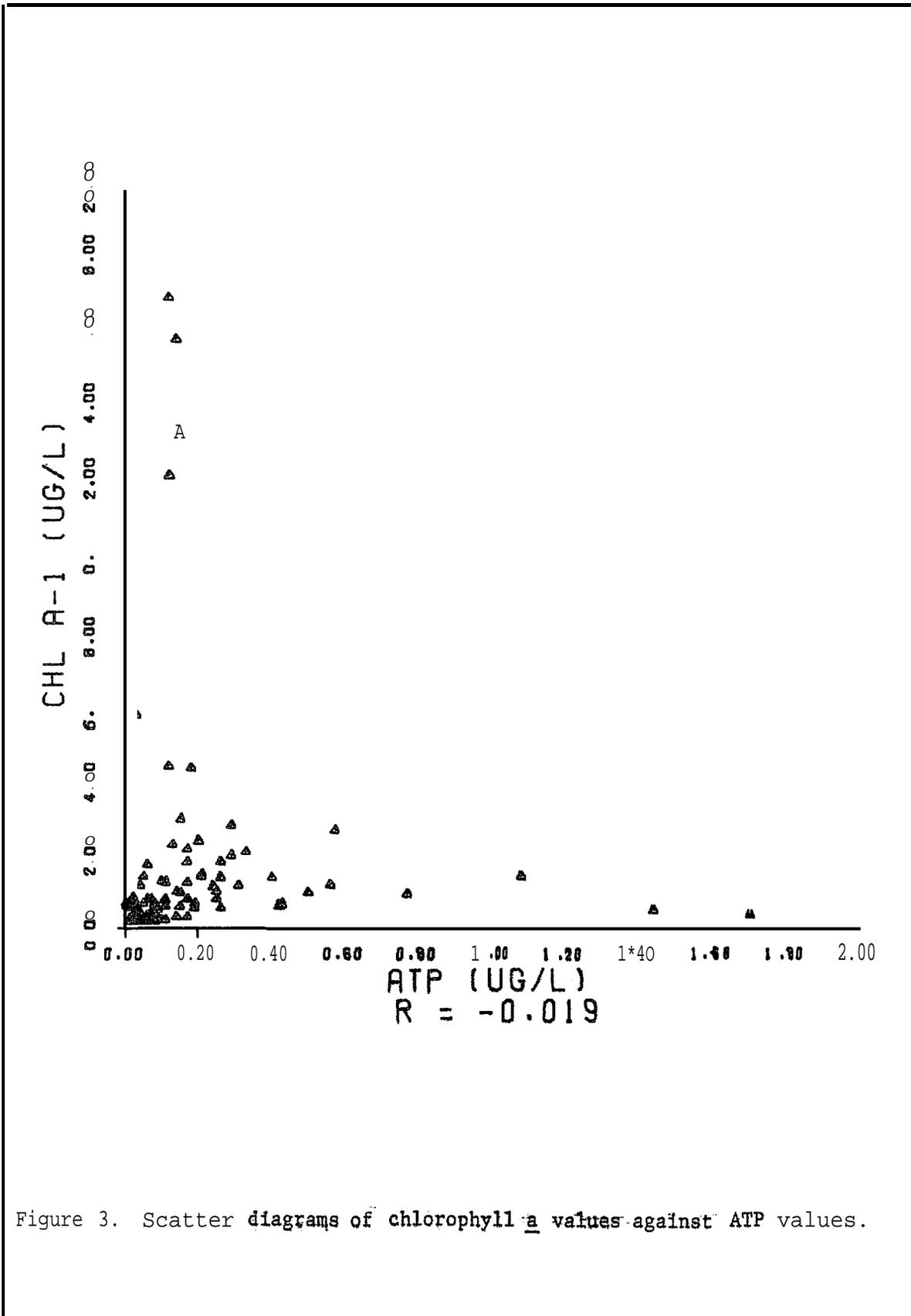


Figure 3. Scatter diagrams of chlorophyll a values against ATP values.

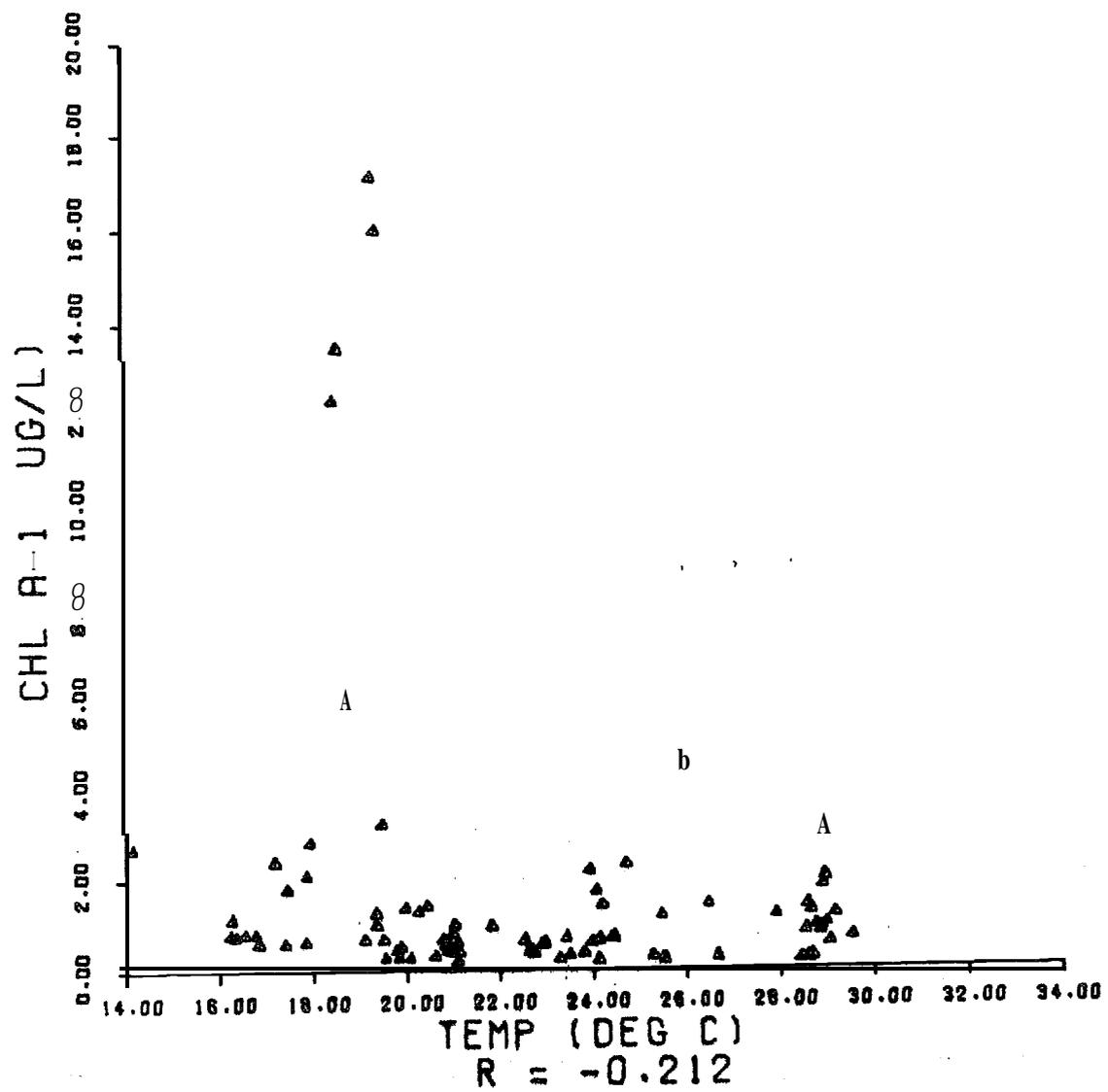


Figure 4. Scatter diagrams of chlorophyll a values against temperature values.

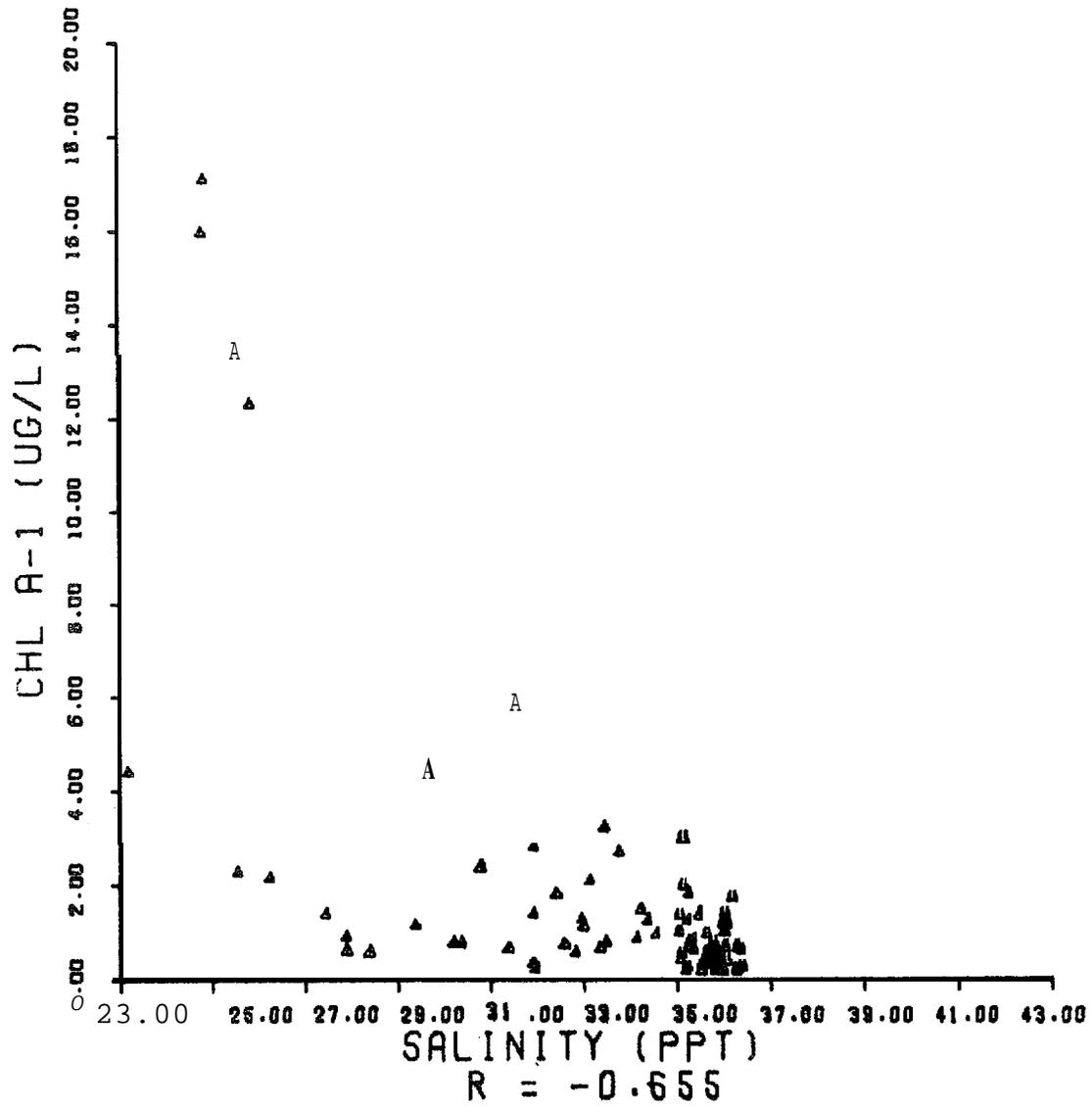
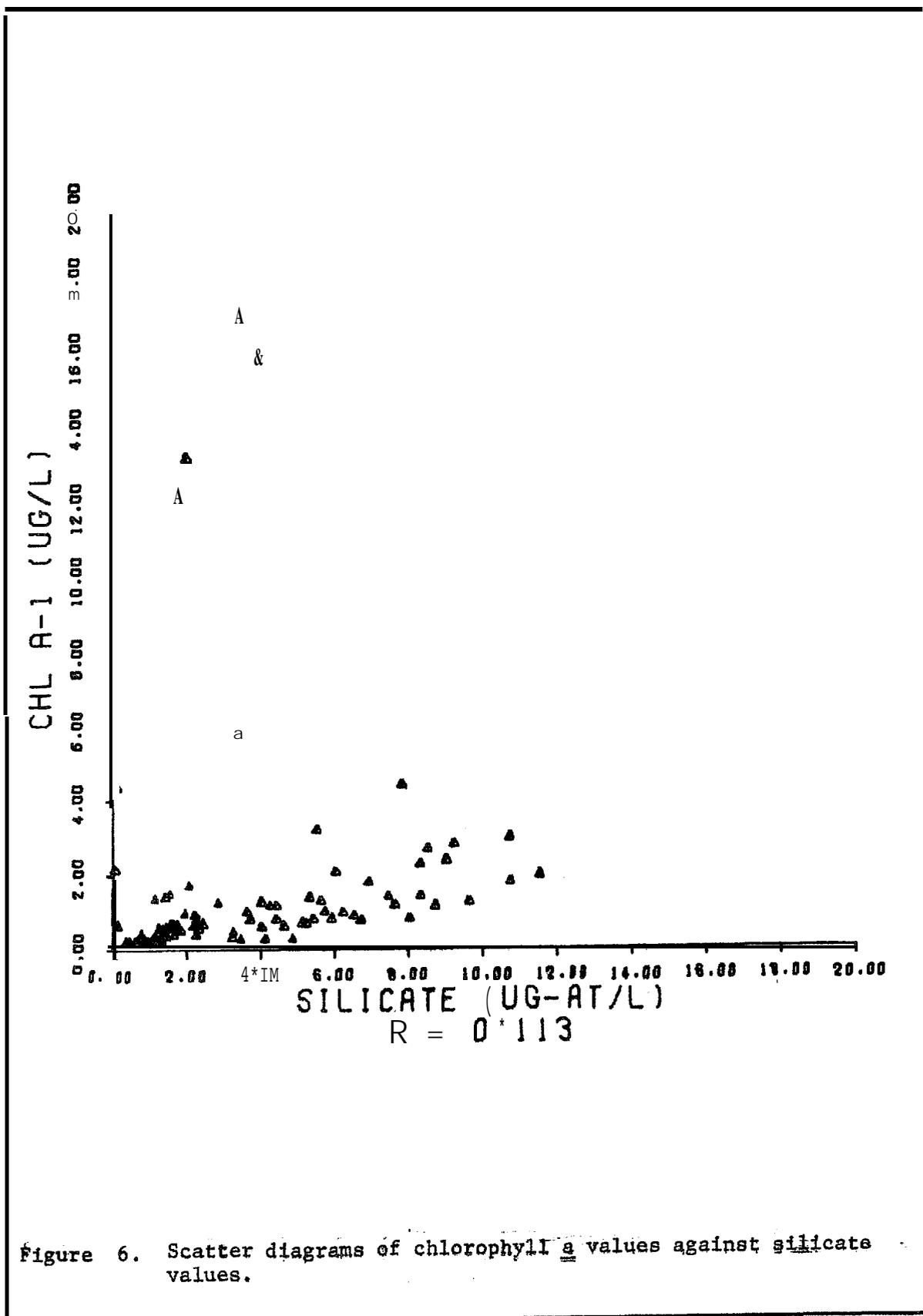


Figure 5. Scatter diagrams of chlorophyll a values against salinity values.



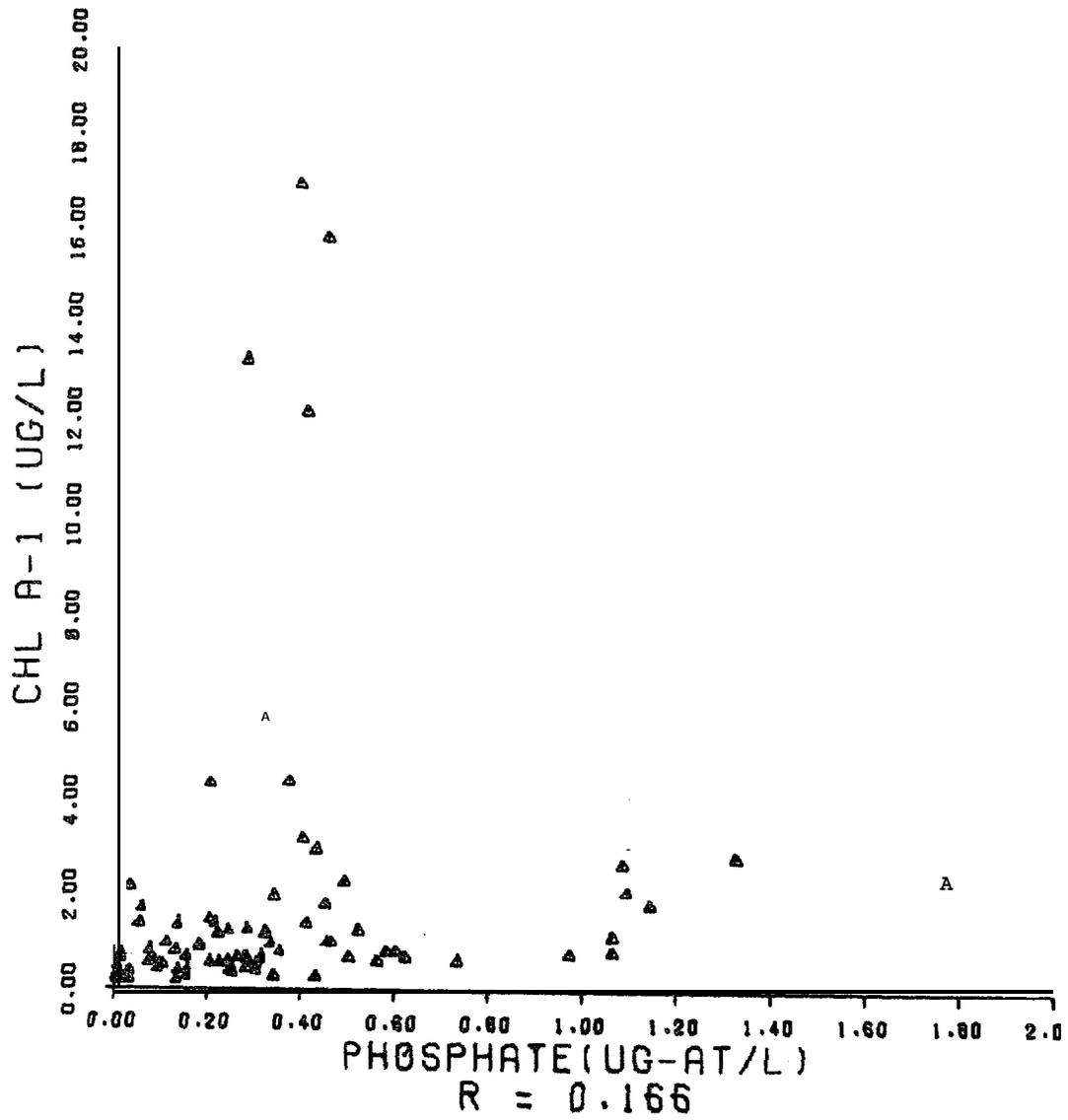


Figure 7. Scatter diagrams of chlorophyll a values against phosphate values.

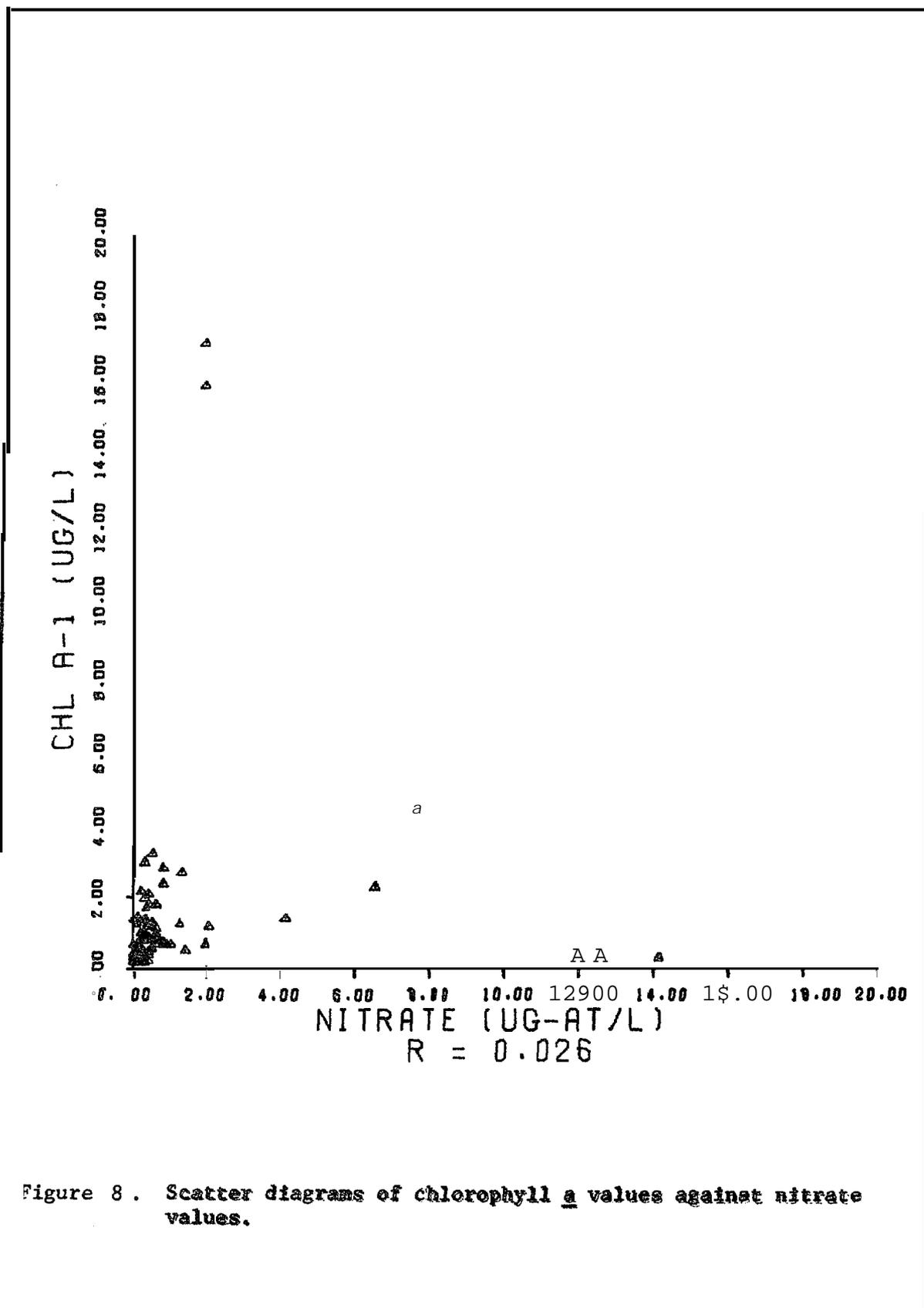


Figure 8 . Scatter diagrams of chlorophyll a values against nitrate values.

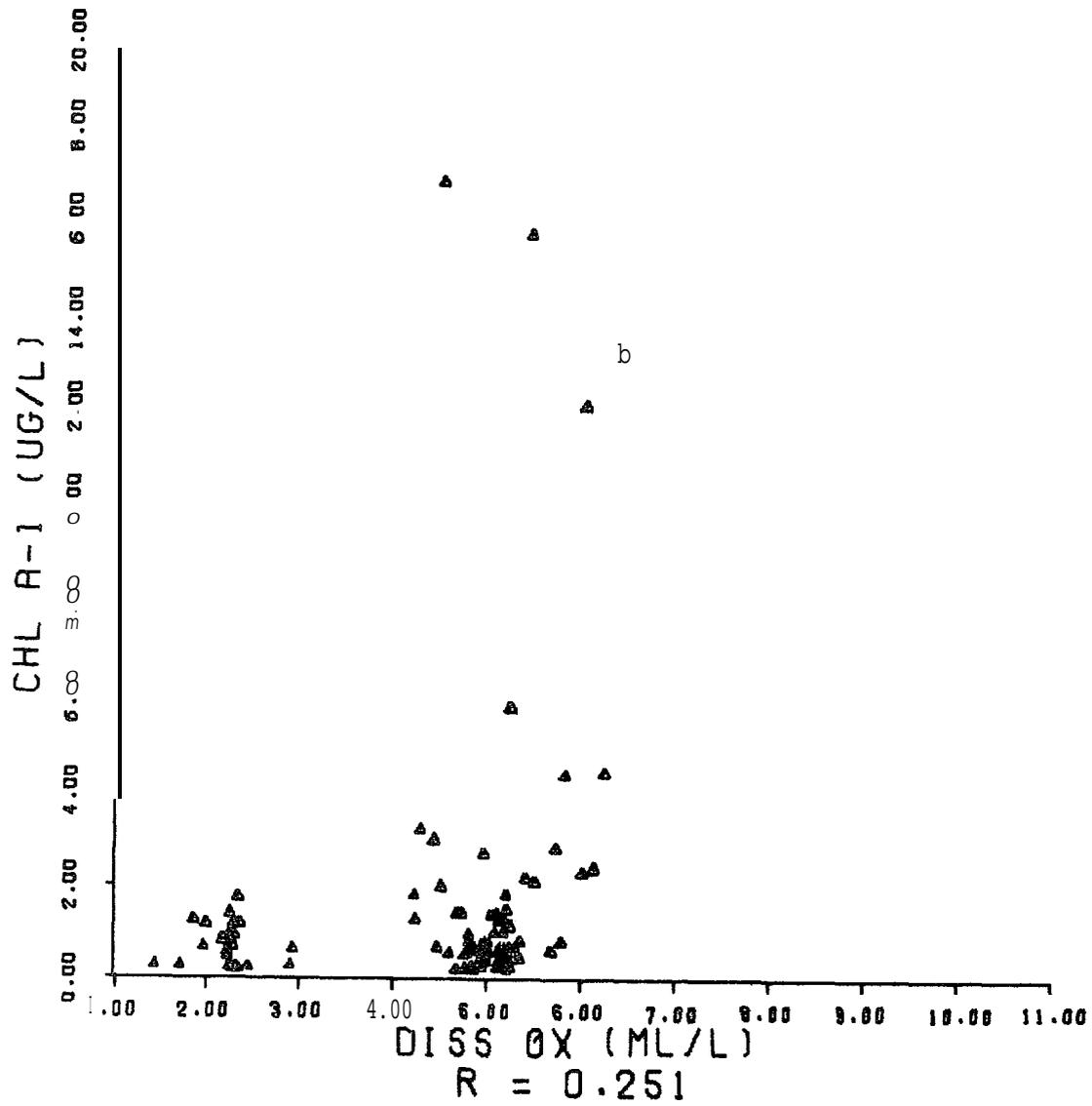


Figure 9. Scatter diagrams of Chlorophyll a values against dissolved oxygen values.

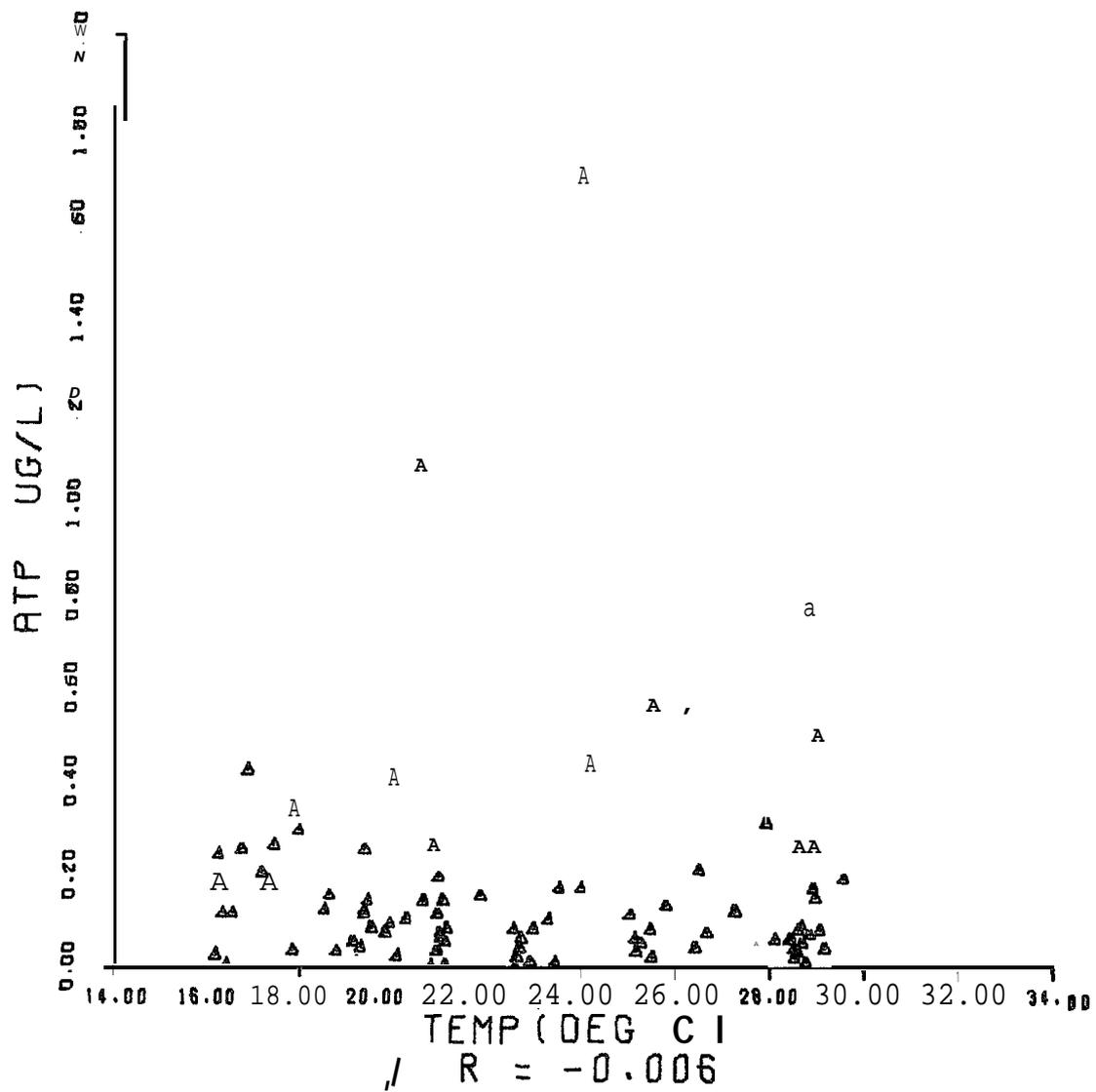


Figure 10. Scatter diagrams of ATP values against temperature values.

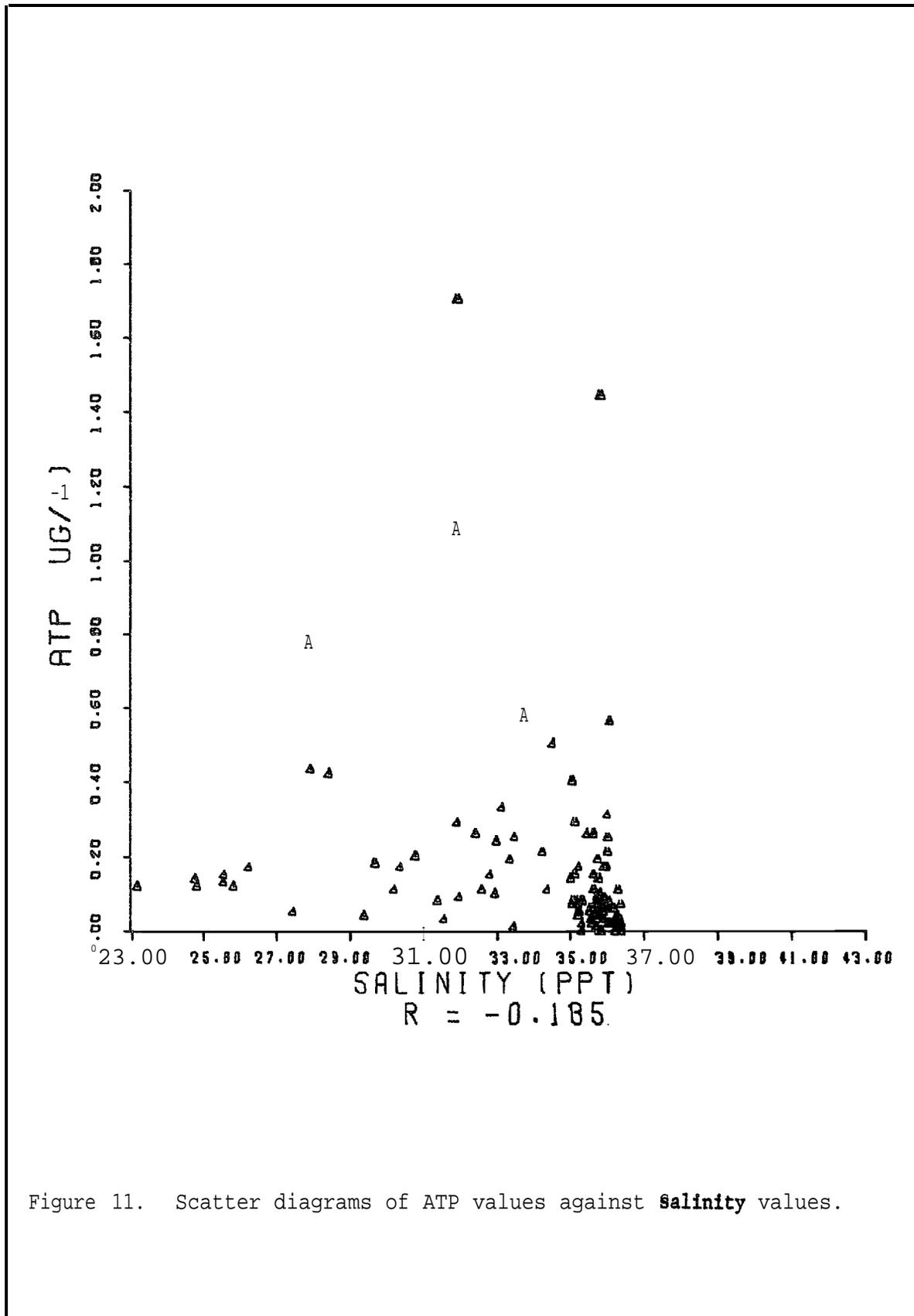


Figure 11. Scatter diagrams of ATP values against **salinity** values.

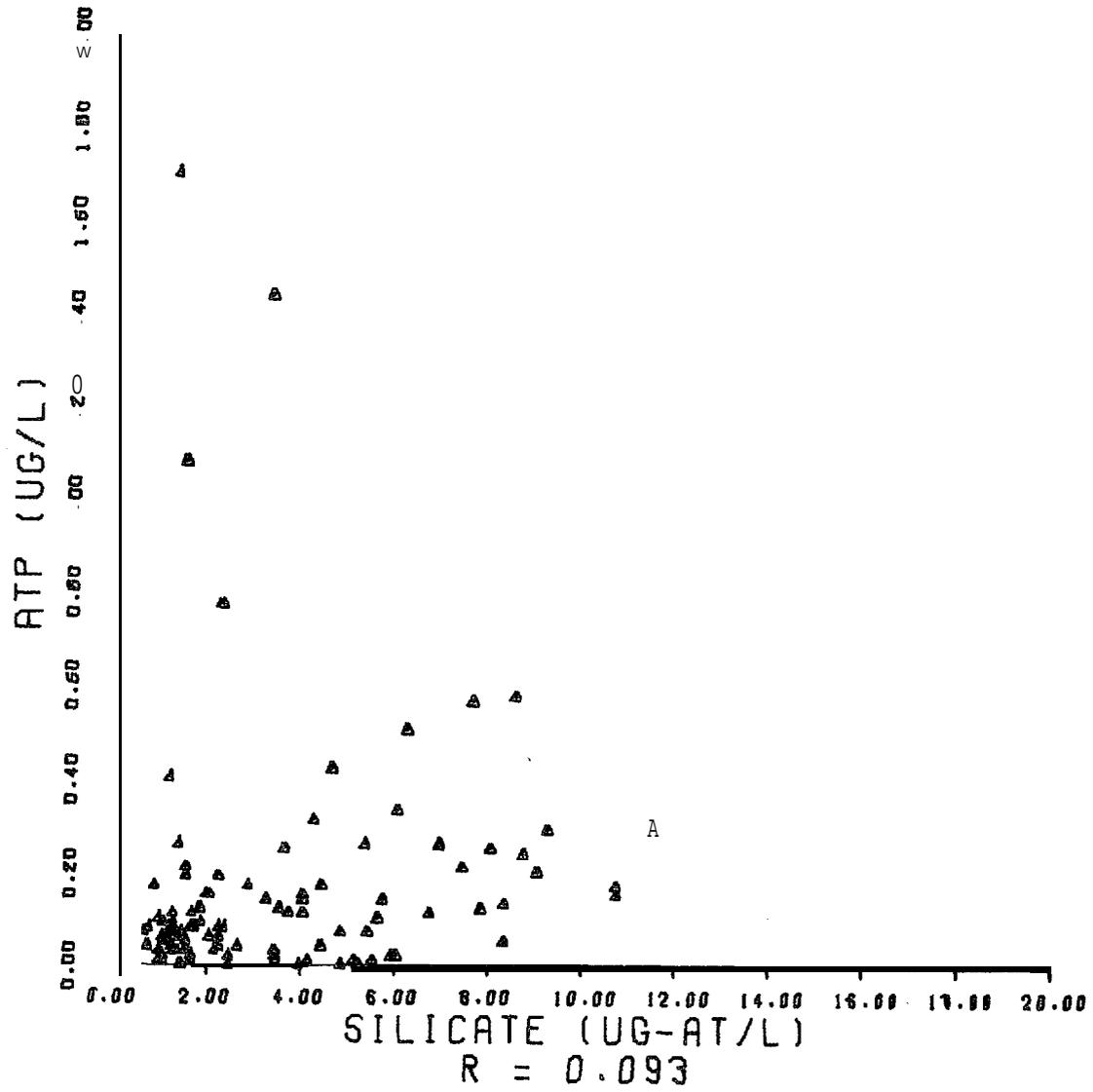


Figure 12. Scatter diagrams of ATP values against silicate values.

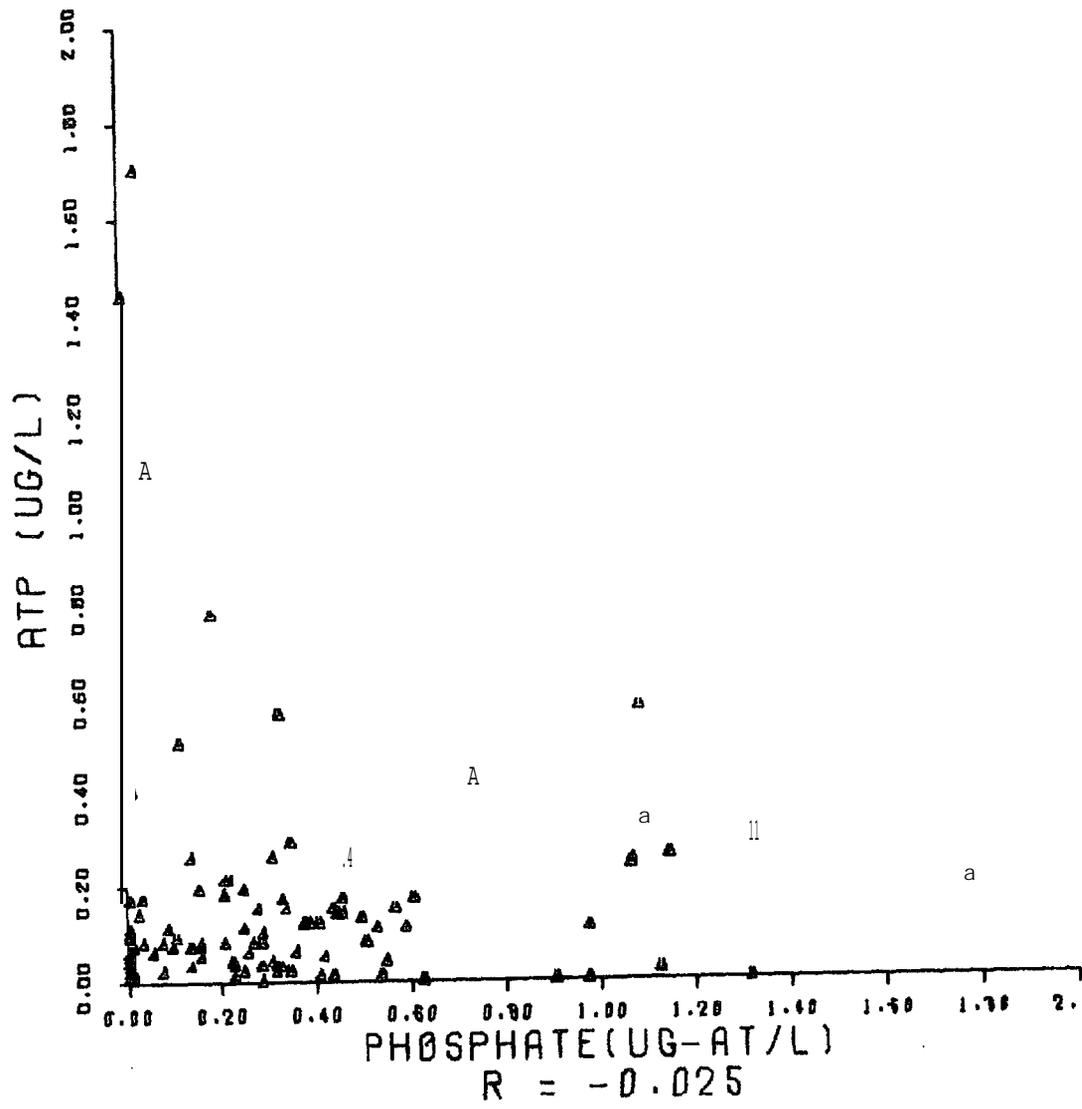


Figure 13. Scatter diagrams of ATP values against phosphate values.

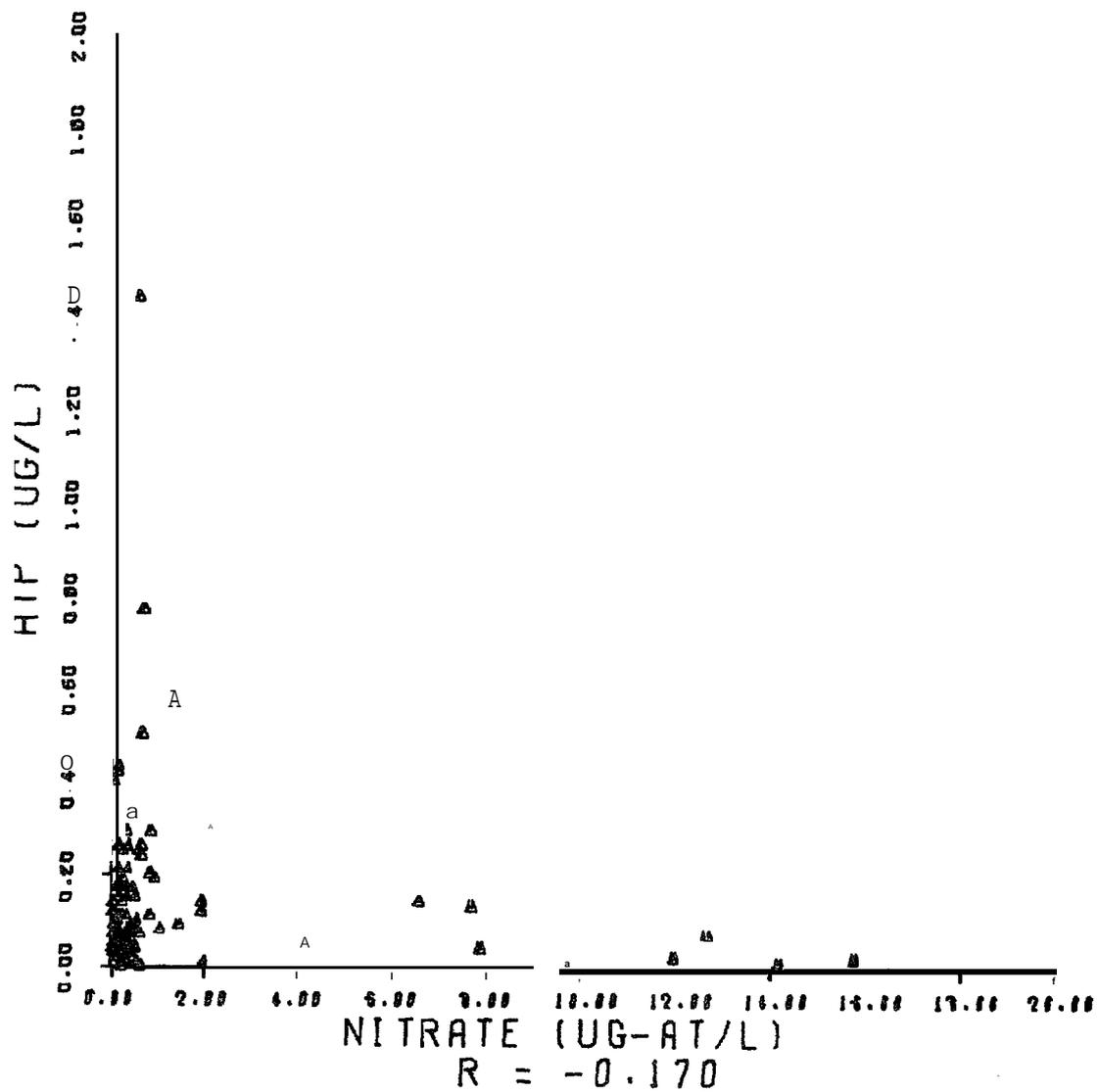


Figure 14. Scatter diagrams of ATP values against nitrate values.

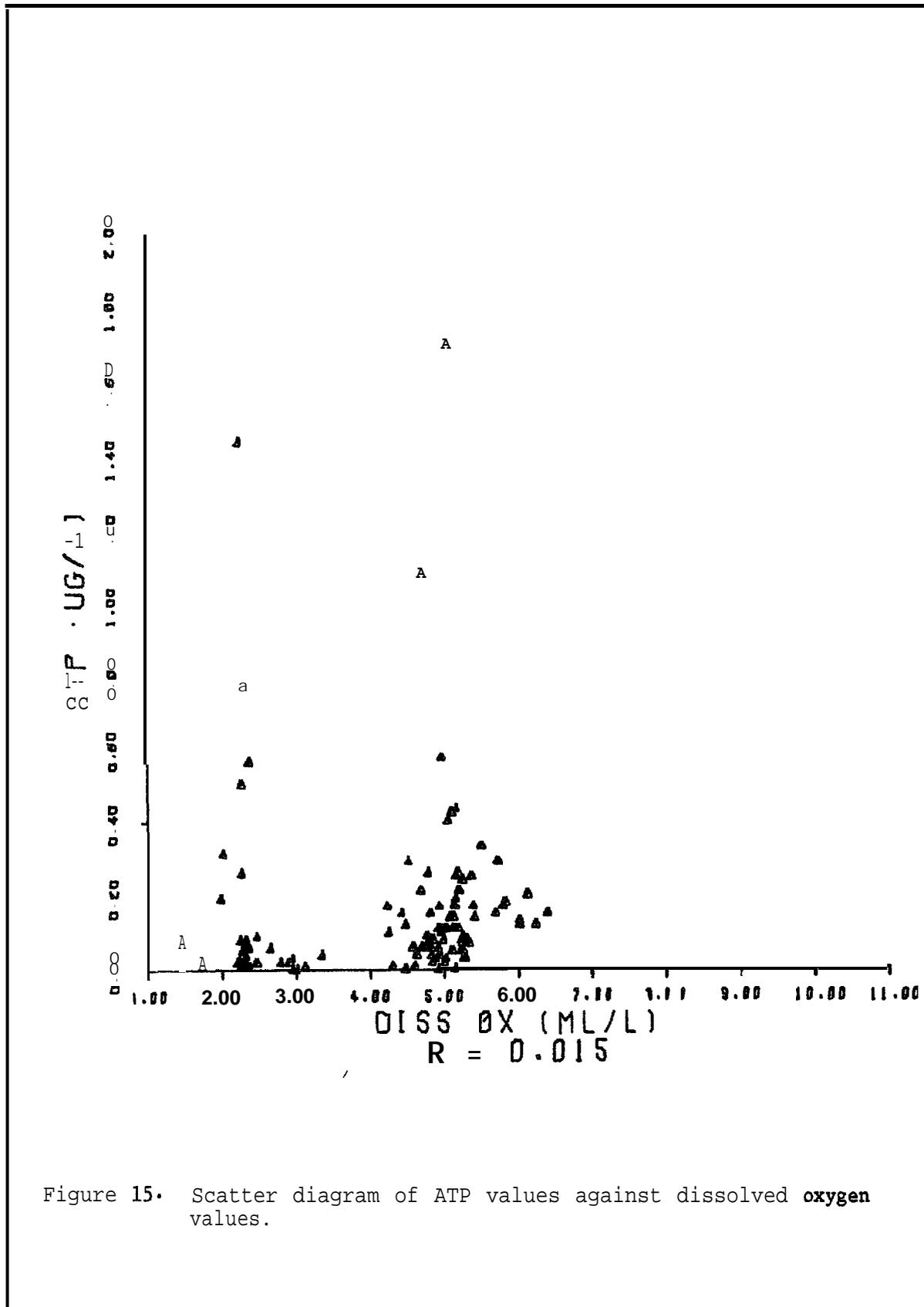


Figure 15. Scatter diagram of ATP values against dissolved oxygen values.

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  $1.1 \times 10^6$  cells per liter at the shore **to**  $8.5 \times 10^3$  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  $1.0 \times 10^6$  cells per liter close to Florida's west coast. Hulburt, et al., (1960) record cell counts of  $1 \times 10^3$  to  $2 \times 10^6$  cells per liter in the Sargasso Sea. The most dominant organism found there, a **coccolithophorid** (*Coccolithithus 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  $4.1 \times 10^5$  cells per liter at the inshore stations,  $7.8 \times 10^4$  at the middle stations, and  $2.6 \times 10^3$  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  $4.7 \times 10^5$  cells per liter. The summer and winter averaged were  $1.1 \times 10^4$  and  $4.9 \times 10^3$ , 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*, *Bacteriastrium 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 ( $1.6 \times 10^6$  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*, *Bacteriastrium 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 **over-**stress 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 38 $\mu$ m 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 m 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 foraminifera 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 spumellarians 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 Theopillium tricostatum-Sprioxyrtis scalaris fauna and the summer by a Lamprocyclus 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 guineoloba 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 pachyderm, 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 ~q'ue'lobs, 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 multivariate 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 **studied**, 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. bassendorf ensis.

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 re-plots 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 multivariate 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 increas-

ing 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 in-shore 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 **trans-ects** 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 the waters 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 easily 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 (intermediate 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 3/11 and 3/III and the offshore " winter fauna (O 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 3/11 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 detennination 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 33. 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 zaquebarica 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 consistent 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 3.6million 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 paleoceanographic 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 paleoceanographic 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 3) 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 pachyderm 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 pachyderm 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 sporadically 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 pachyderm exists today as a cold water form in the tropical and subtropical Gulf. Globigerina pachyderm 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 is associated with Globigerina pachyderm 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 **Micro-**  
benthon 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 phenomena 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 consistency 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, X 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 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.

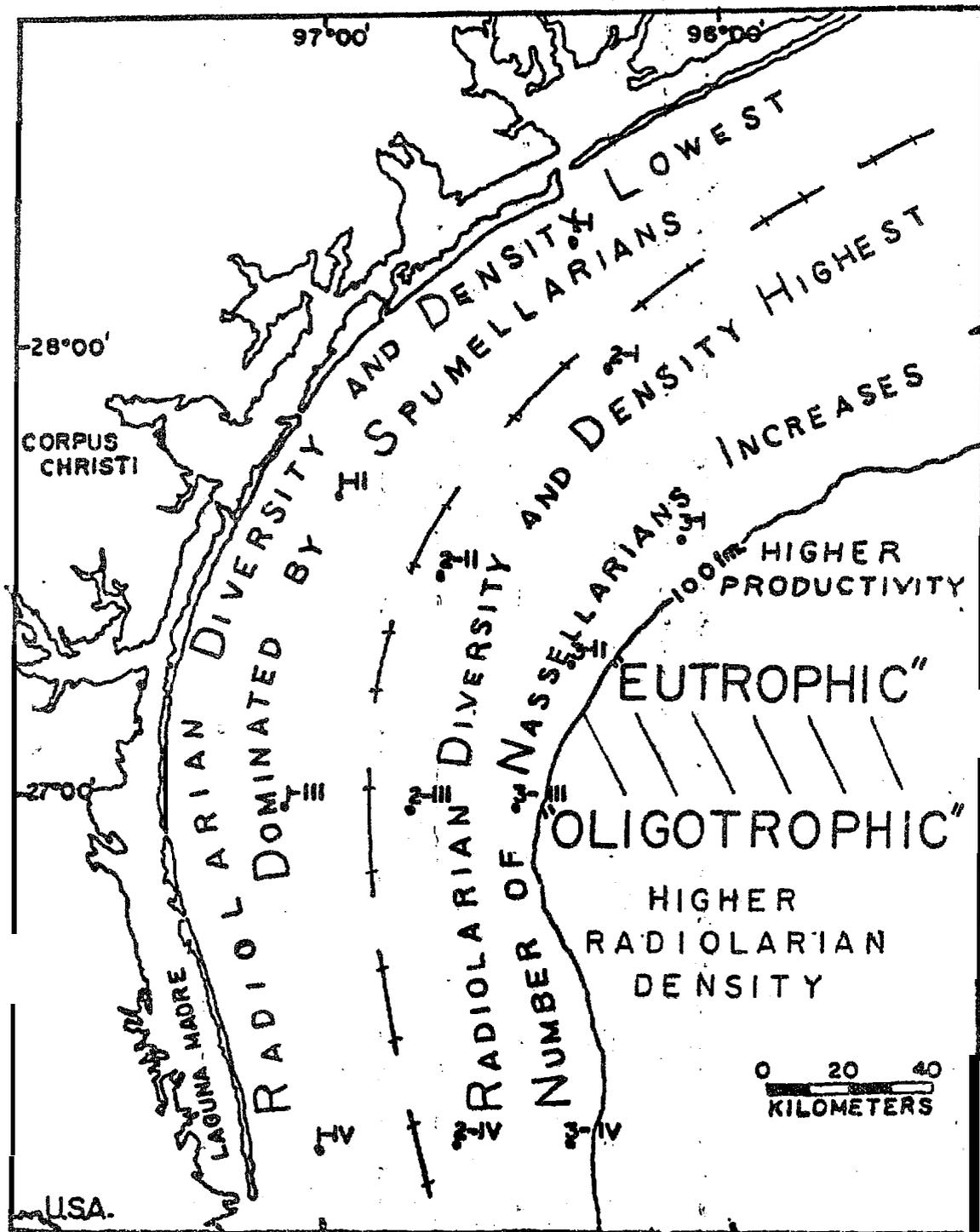
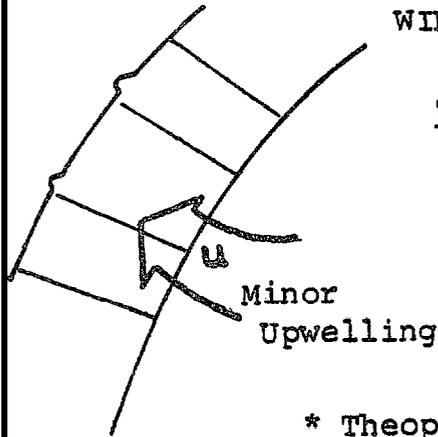


Figure 1. General radiolarian trends.

# SEASONAL TRENDS DERIVED FROM RADIO LARIAN DATA

WINTER 74-75

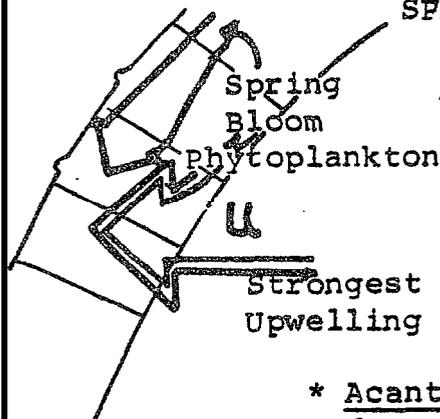


$$\frac{TLN}{TLS} = \frac{1}{3}$$

- I. Almost as high a standing crop as in summer.
- II. Highest Diversity..
- III. Dead population same as in spring

\* Theopilium tricostatum-Spirocyrtis scalaris fauna

SPRING 75

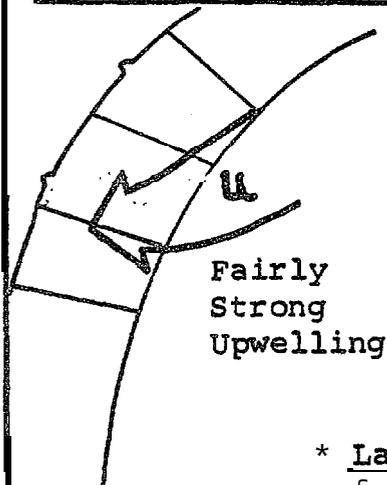


$$\frac{TLN}{TLS} = \frac{1}{1}$$

- I. Lowest standing crop  $\frac{1}{2}$  of winter or summer.
- II. Diversity almost as high as winter.
- III. Deads same as winter

\* Acantharian-?Anthocyrtidium ophiurensis fauna (no real dominants)

SUMMER 75



$$\frac{TLN}{TLS} = \frac{1}{8}$$

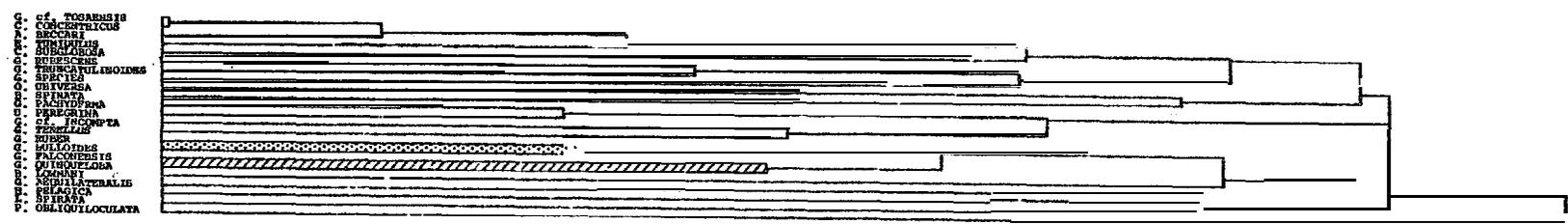
- I. Greatest standing crop.
- II. Lowest' diversity.
- III. Lowest % of deads,  $\frac{1}{5}$  that of winter or spring.

\* Lamprocyclas maritialis-Euchitonia elegans fauna

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



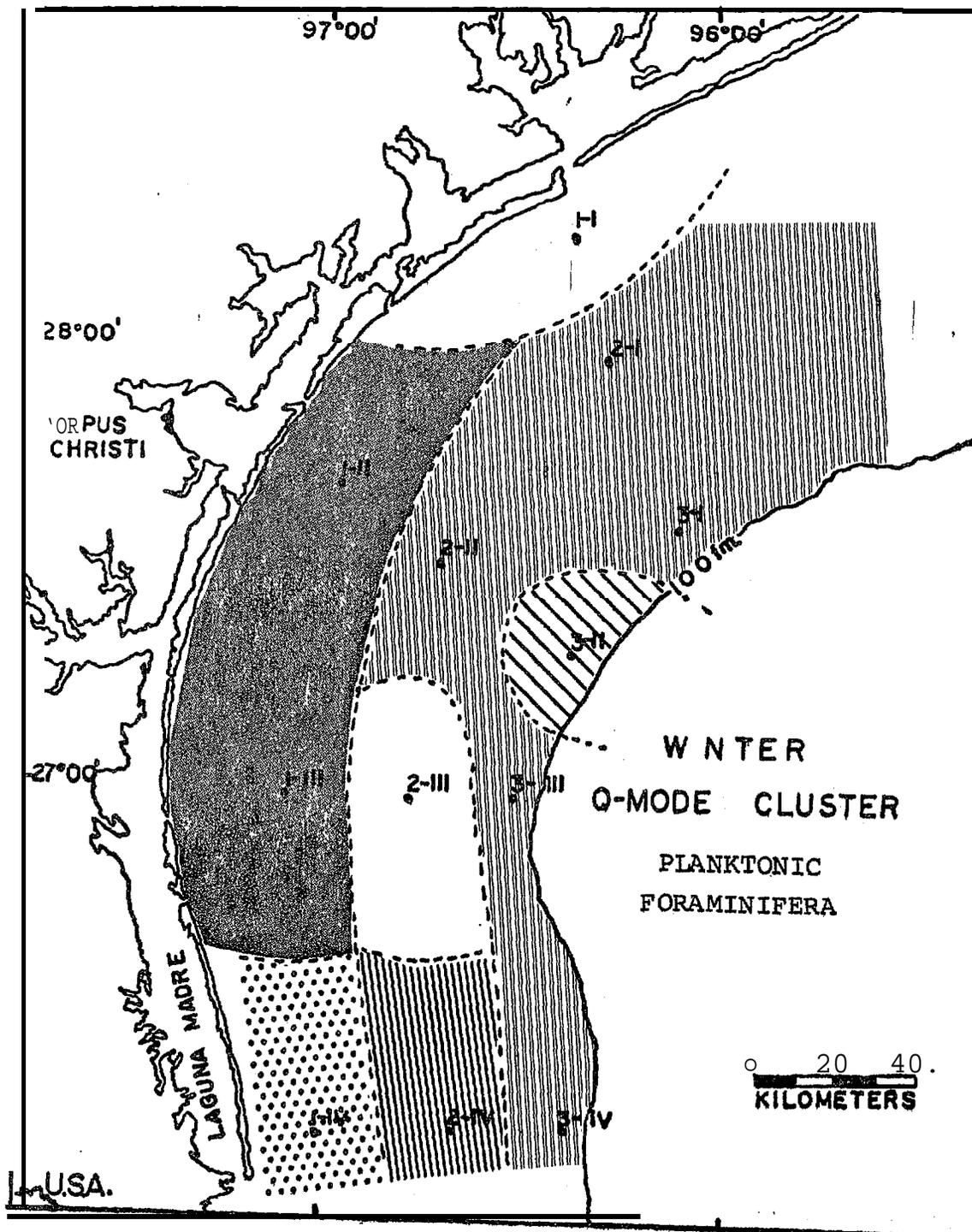


Figure 4. Winter Q-mode cluster for planktonic foraminifera.

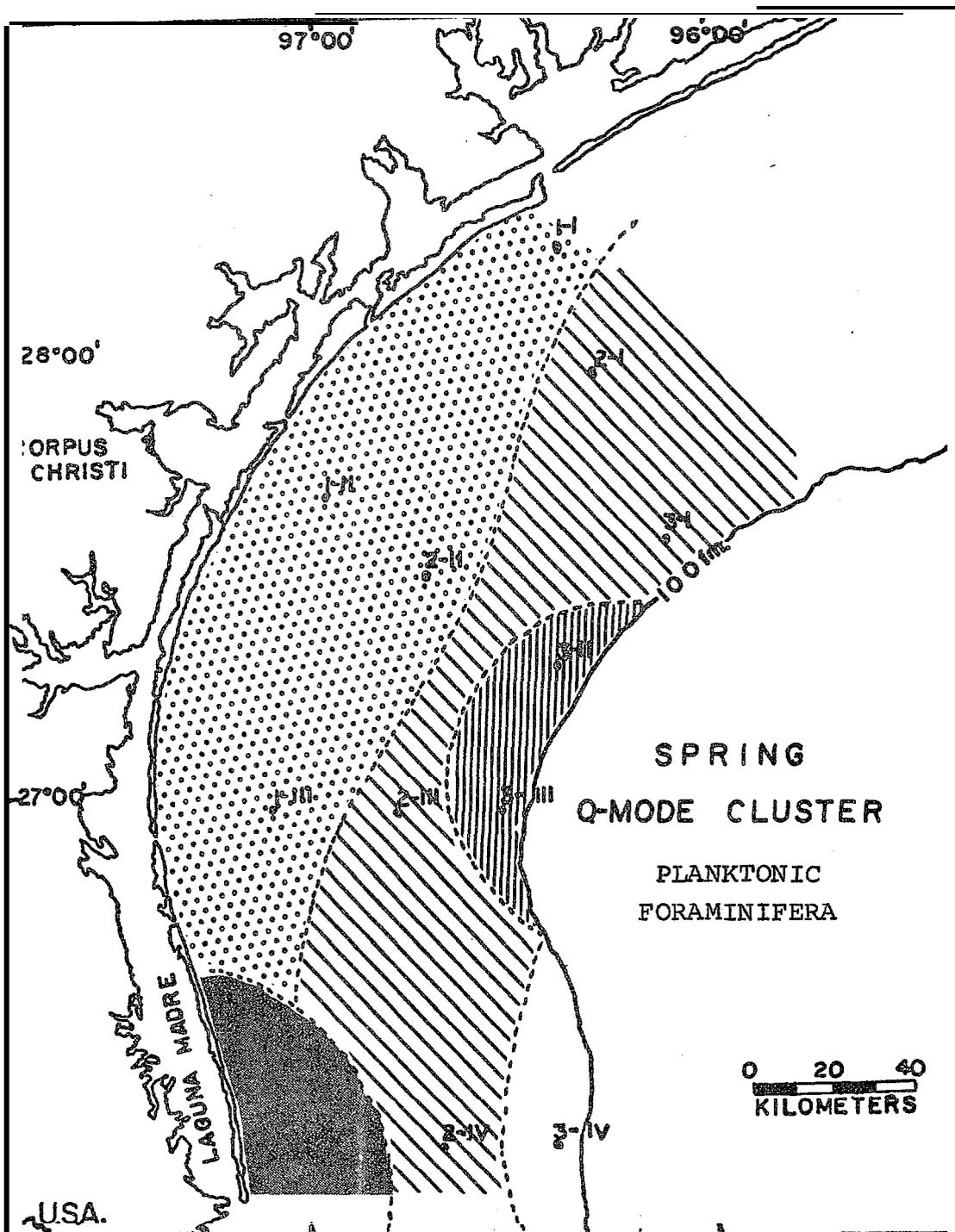
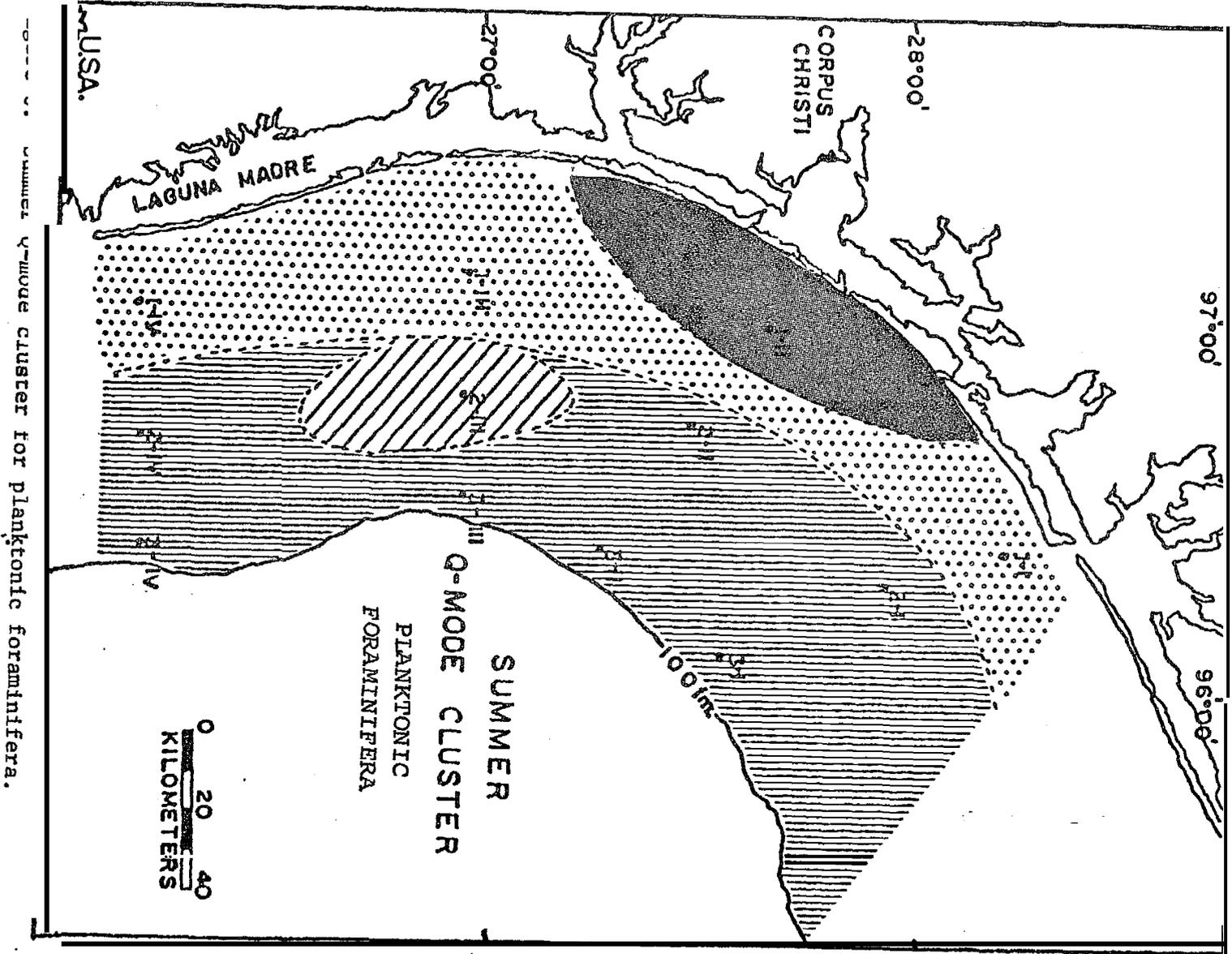


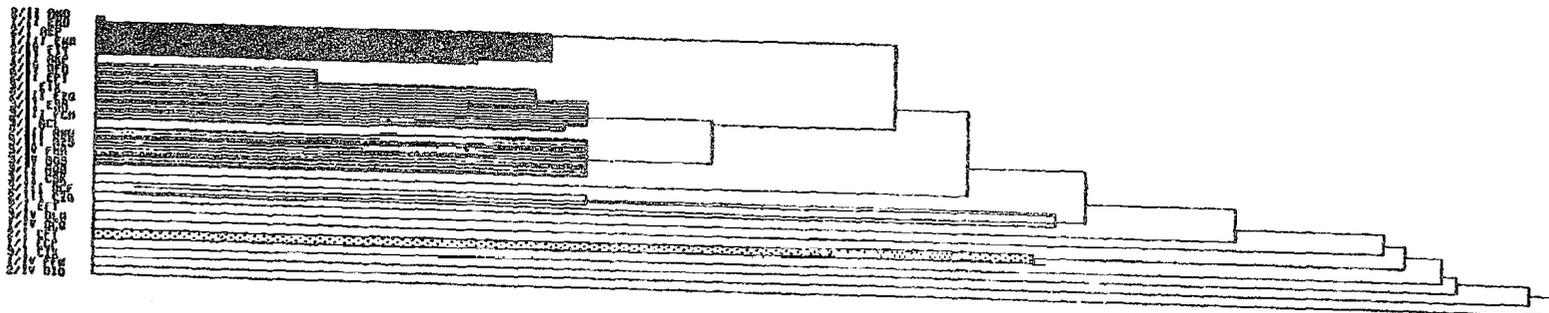
Figure 5. Spring Q-mode cluster for planktonic foraminifera.



Q-MODE CLUSTER FOR PLANKTONIC FORAMINIFERA.

FIGURE 7.

Q-MODE CLUSTER LIVE RADIOLARIANS WINTER-SPRING-SUMMER



LEGEND: Q-MODE CLUSTER

RADIOLARIANS

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



HYMENIASTRUM PROFUNDUM (ADULT AND JUVENILE) CLUSTER

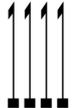


PTEROCANIUM PRAETEXTUM-HYMENIASTRUM PROFUNDUM (JUVENILE)

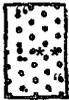


CLUSTER

PTEROCORYS ZANCLEUS--THEOPILIUM TRICOSTATUM CLUSTER



CONCHASMA UPWELLING FAUNA



SPONGOSPHAERA STREPTACANTHA CLUSTER

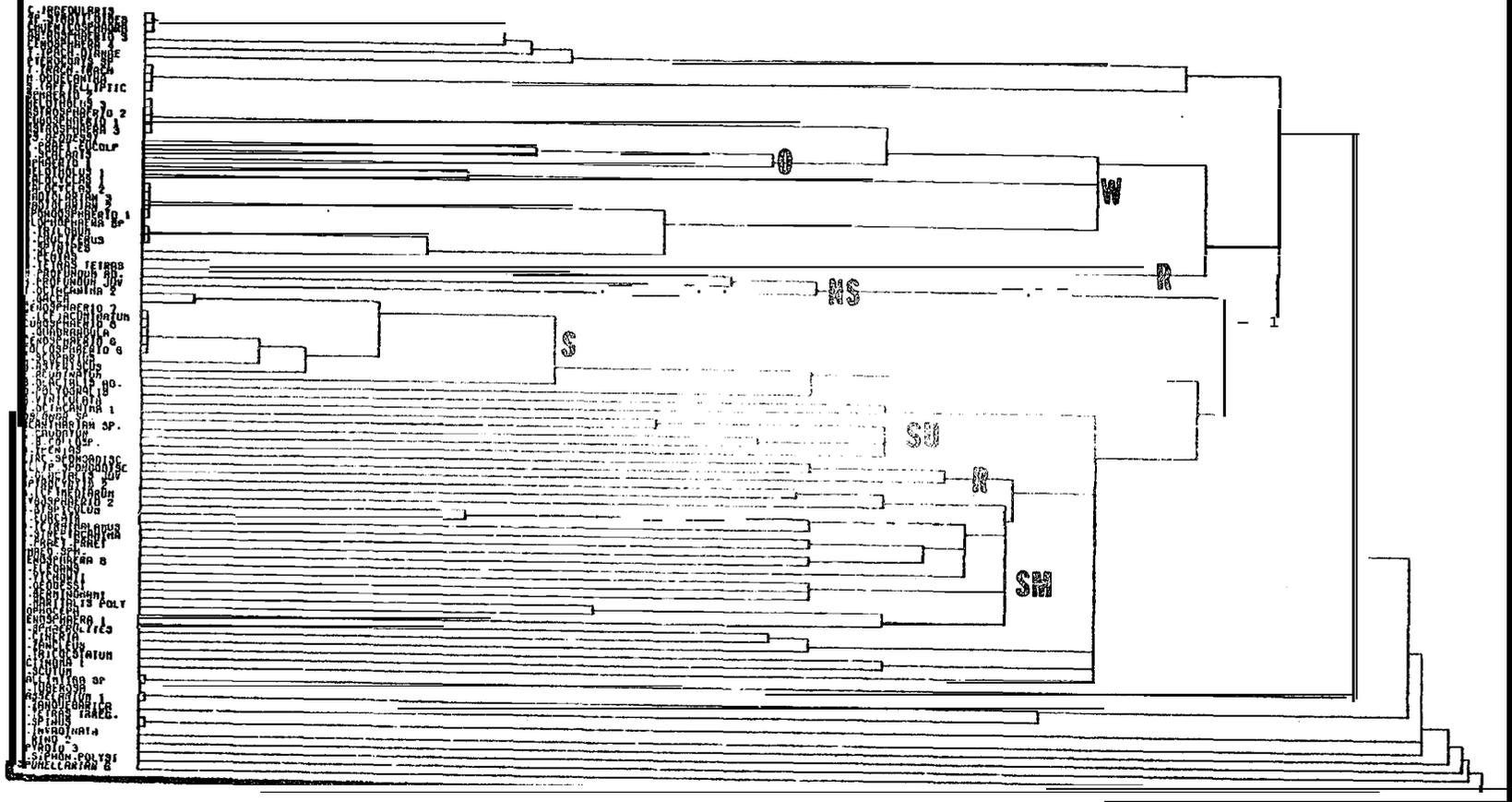


SAMPLES CLUSTERING AT LOW LEVELS



FIGURE 8.

R-MODE CLUSTER LIVE RRD1OLFIRIFII.JS WINTER-SPRING-SUMMER





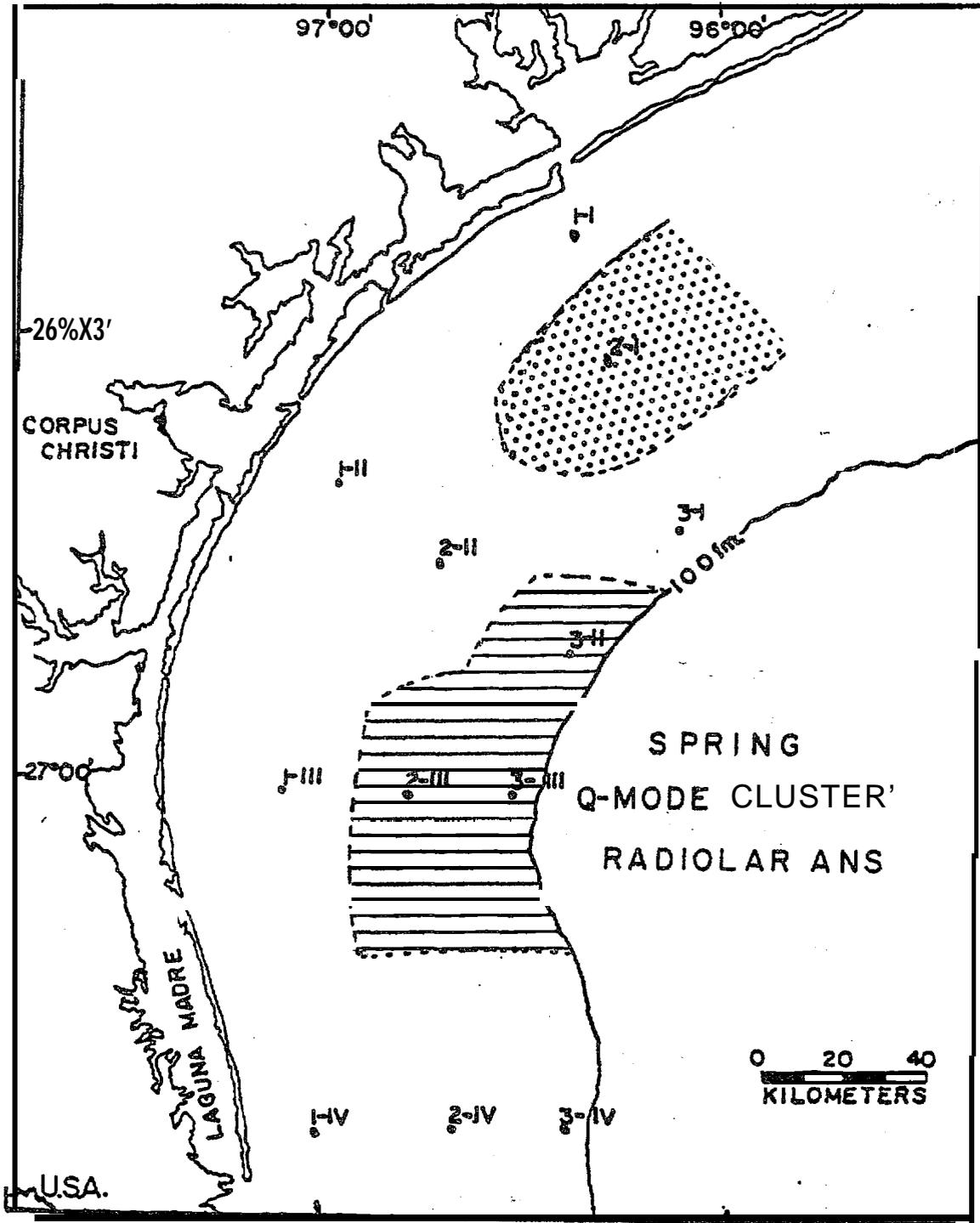


Figure 10. Spring Q-mode cluster for radiolarians.

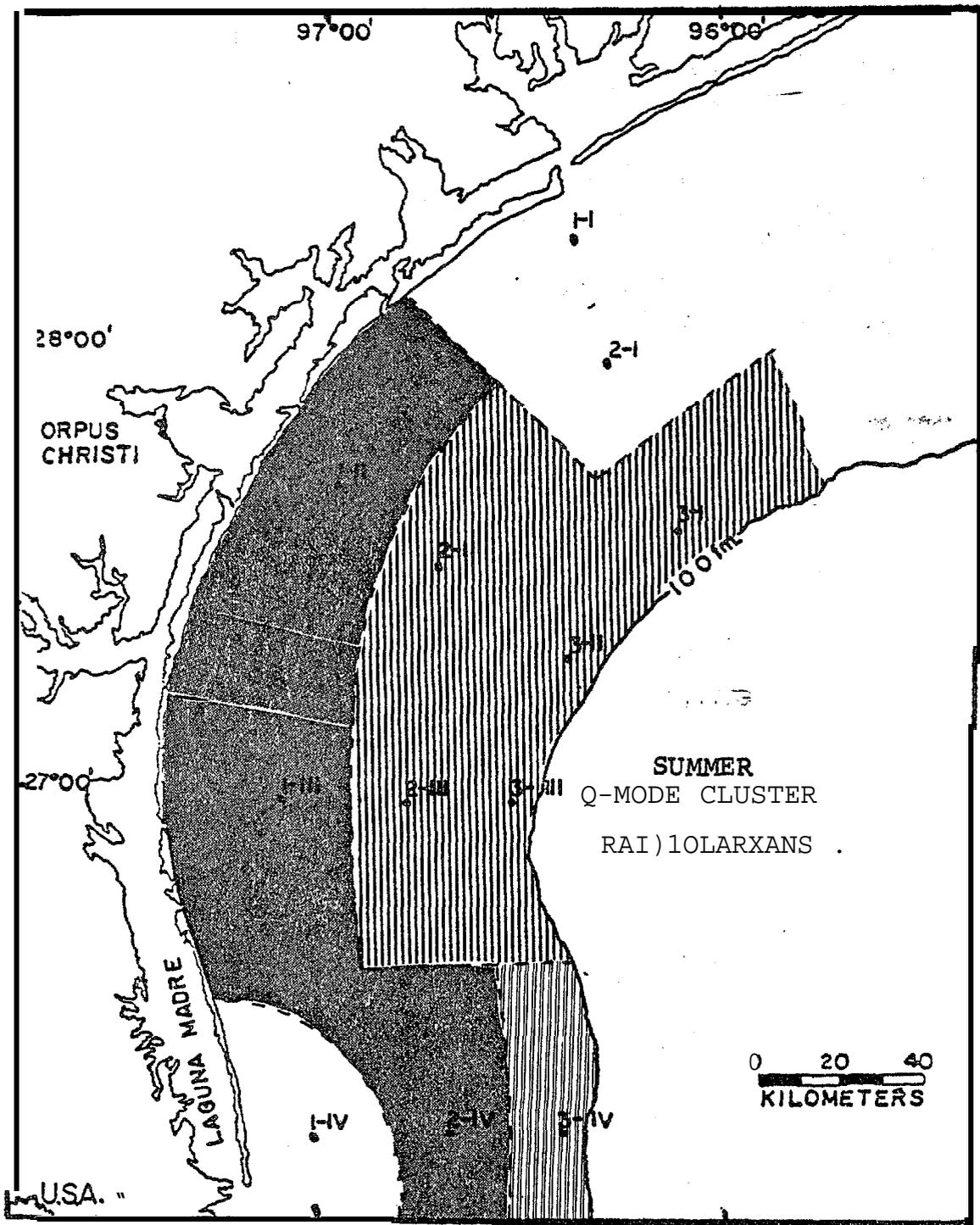


Figure 11. Summer Q-mode cluster for radiolarians.

R-MODE CLUSTER RADIOLARIANS, FORAMINIFERA, AND PTEROPODS

FIGURE 12

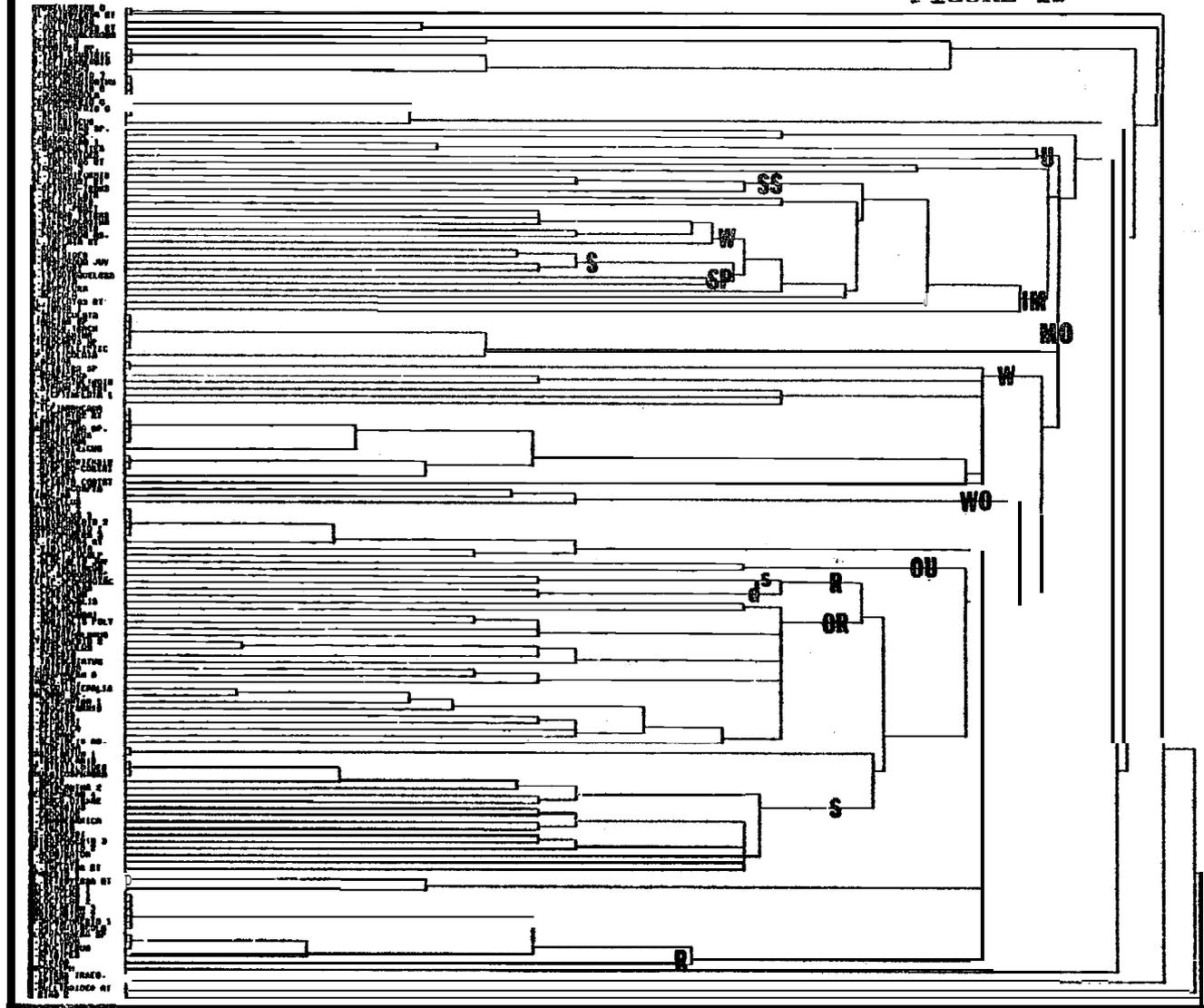
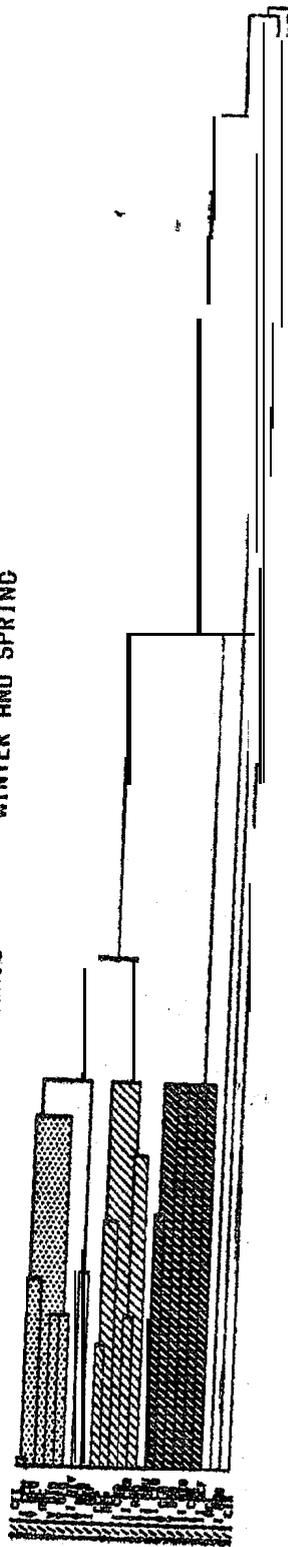


FIGURE 13.

0-NODE CLUSTER LIVE BENTHONIC  
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





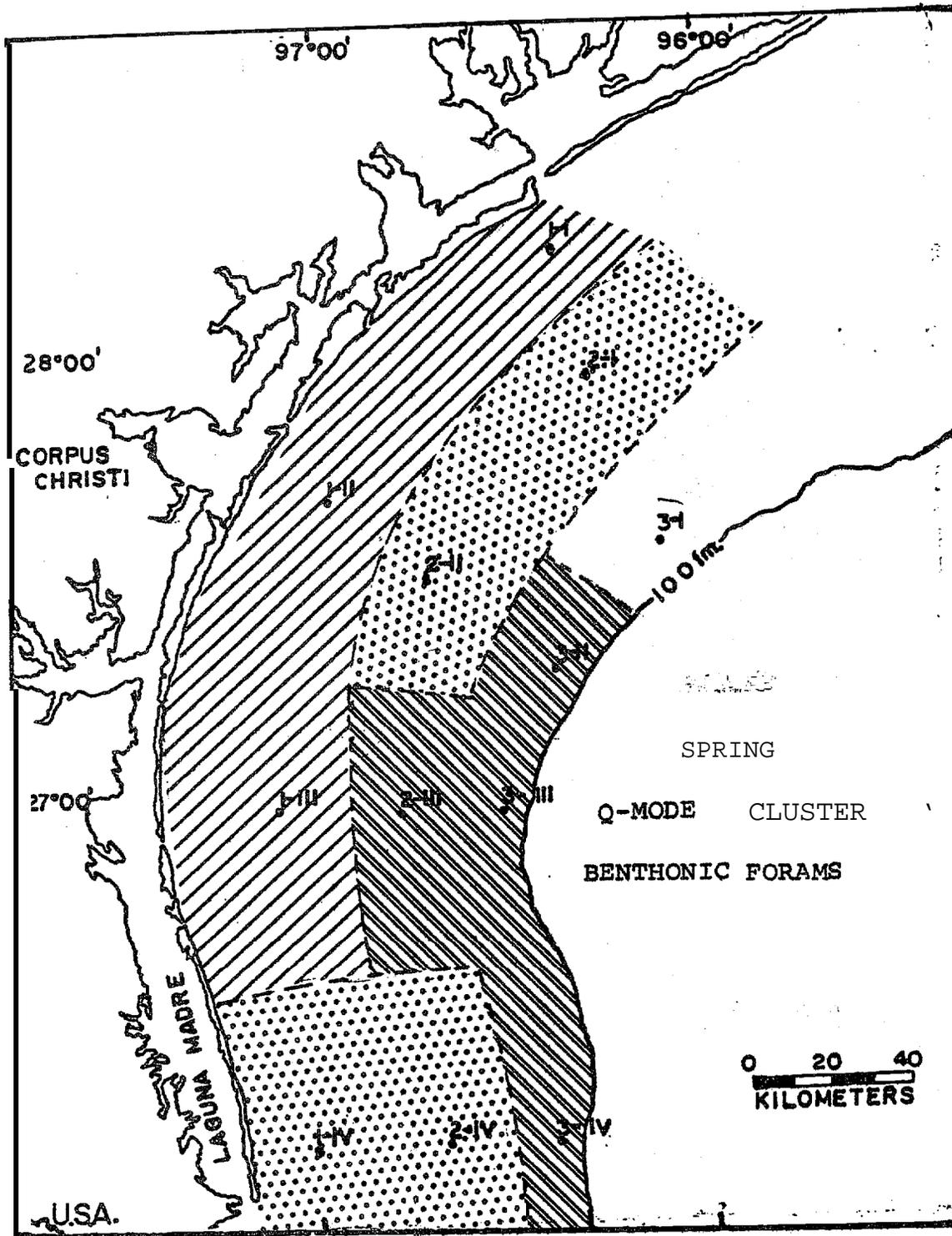


Figure 15. Spring Q-mode cluster for benthonic forams.



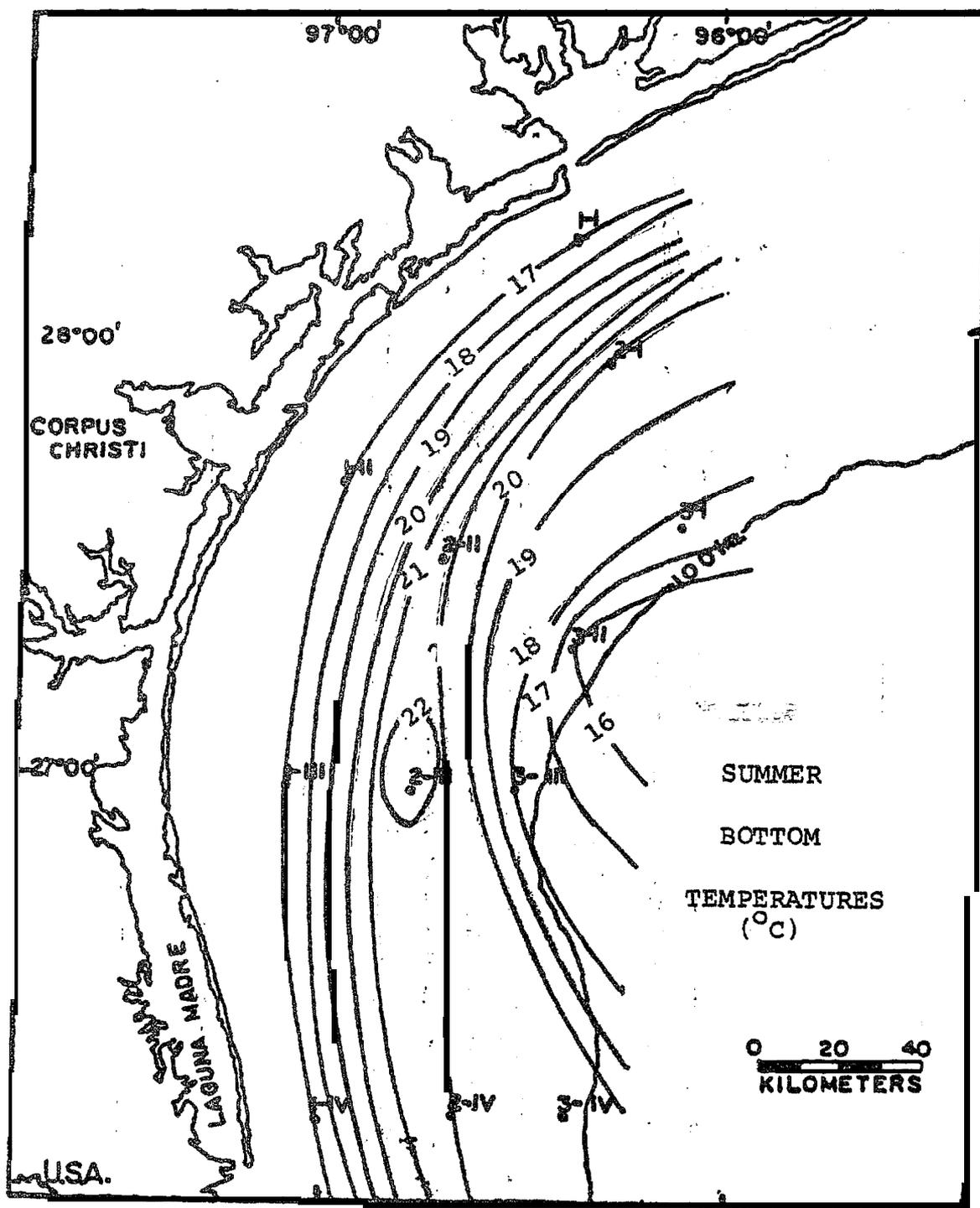


Figure 17. Summer bottom temperatures ( $^{\circ}\text{C}$ ).

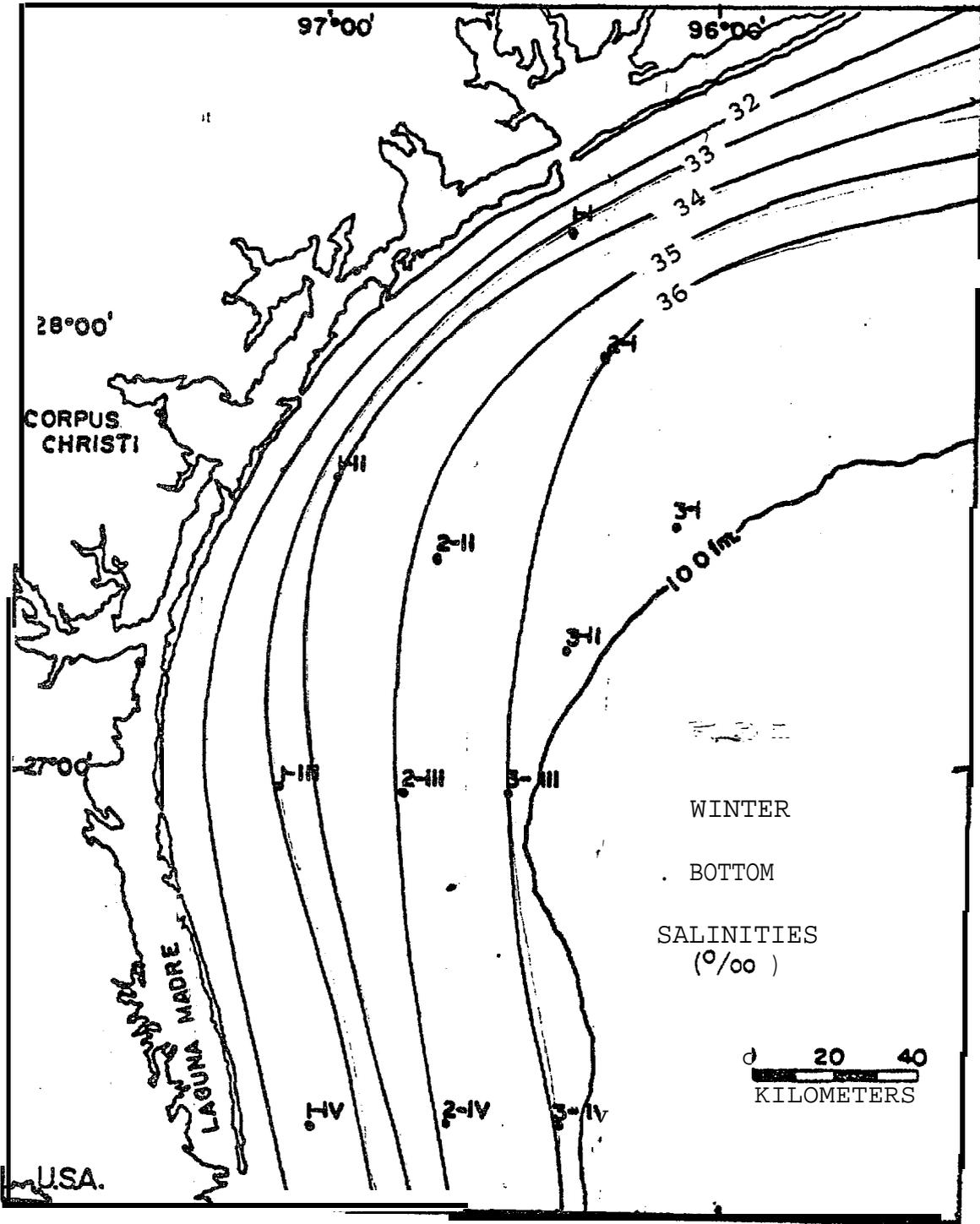


Figure 18. Winter bottom salinities (‰).

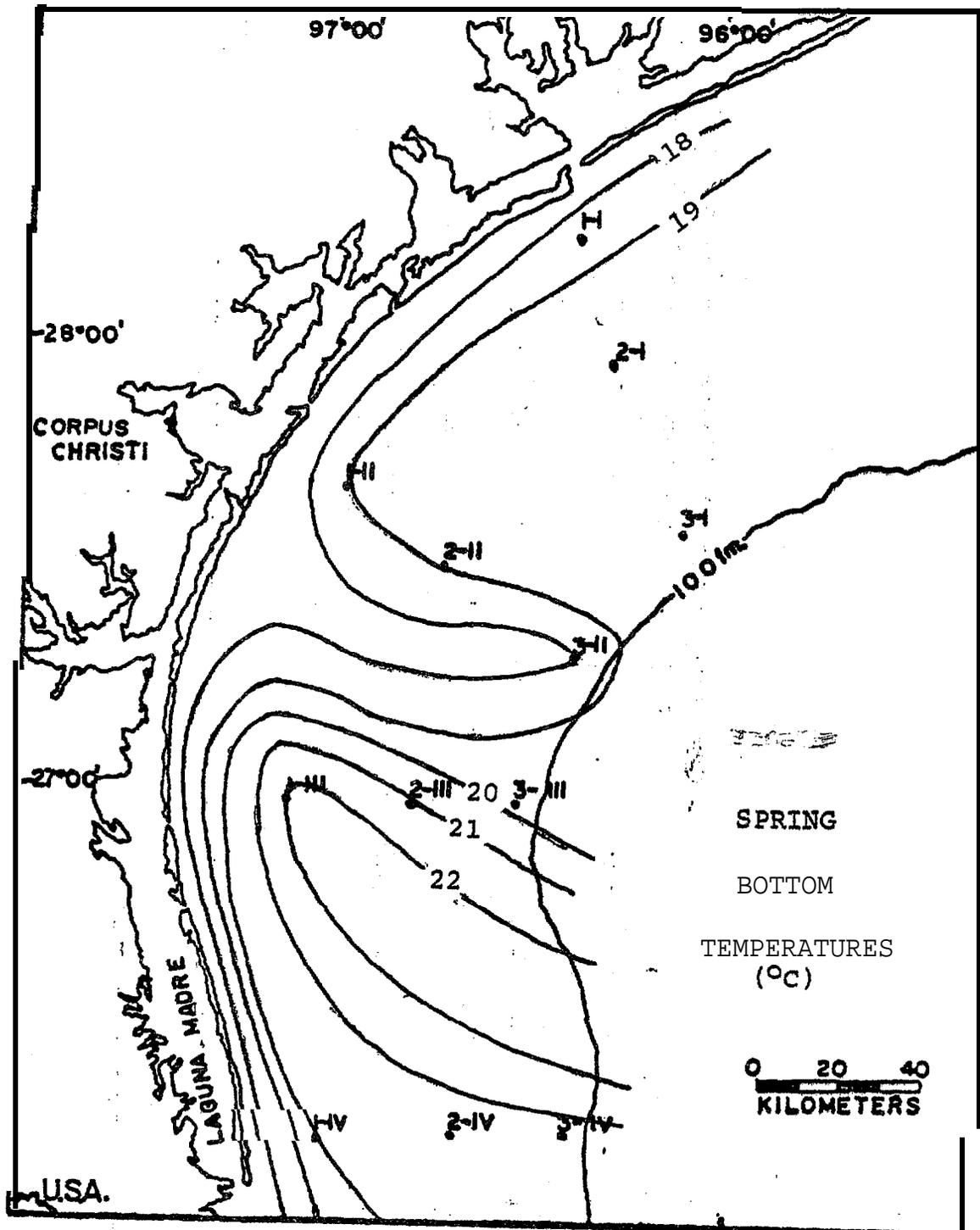


Figure 19. Spring bottom temperatures ( $^{\circ}\text{C}$ ).

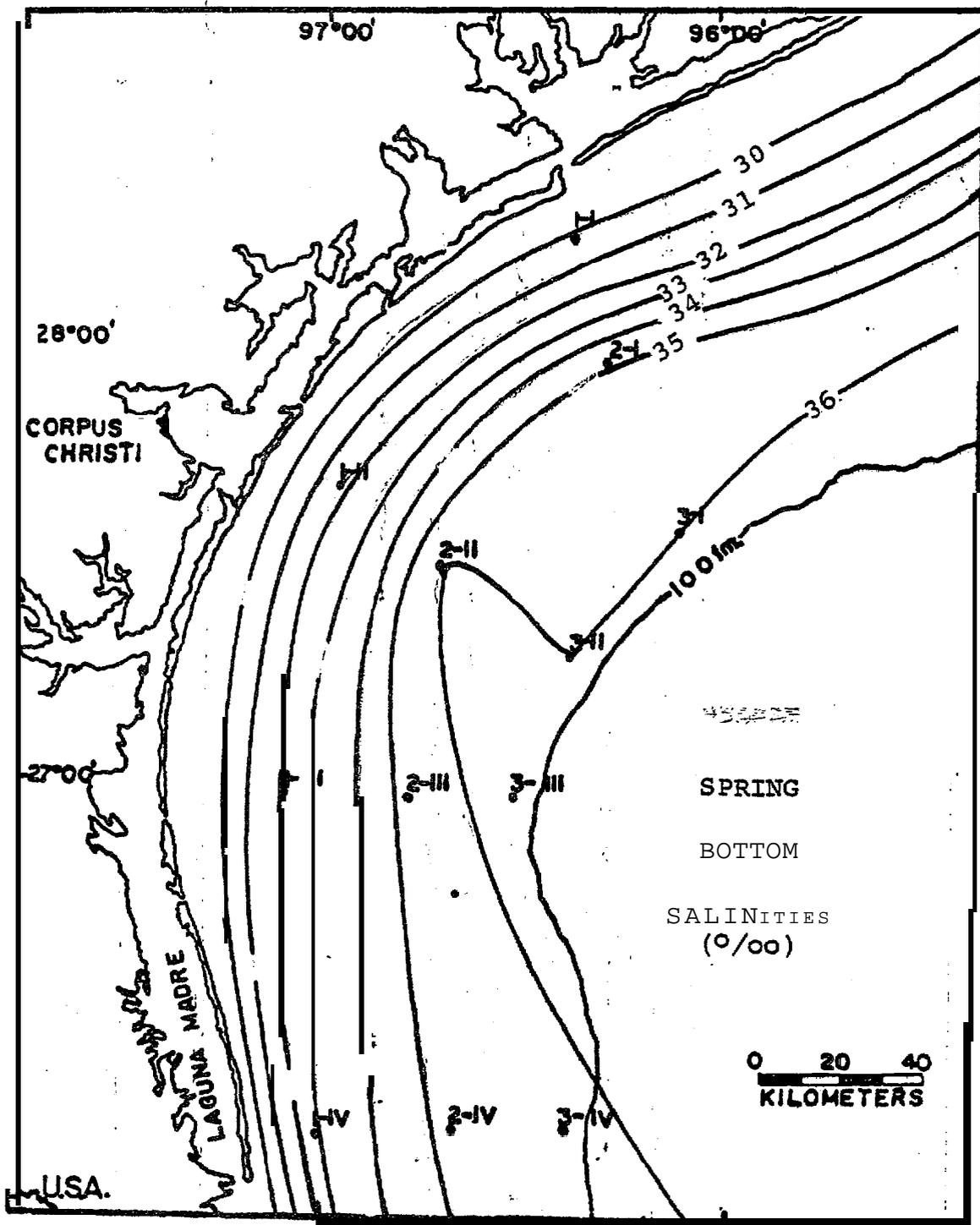
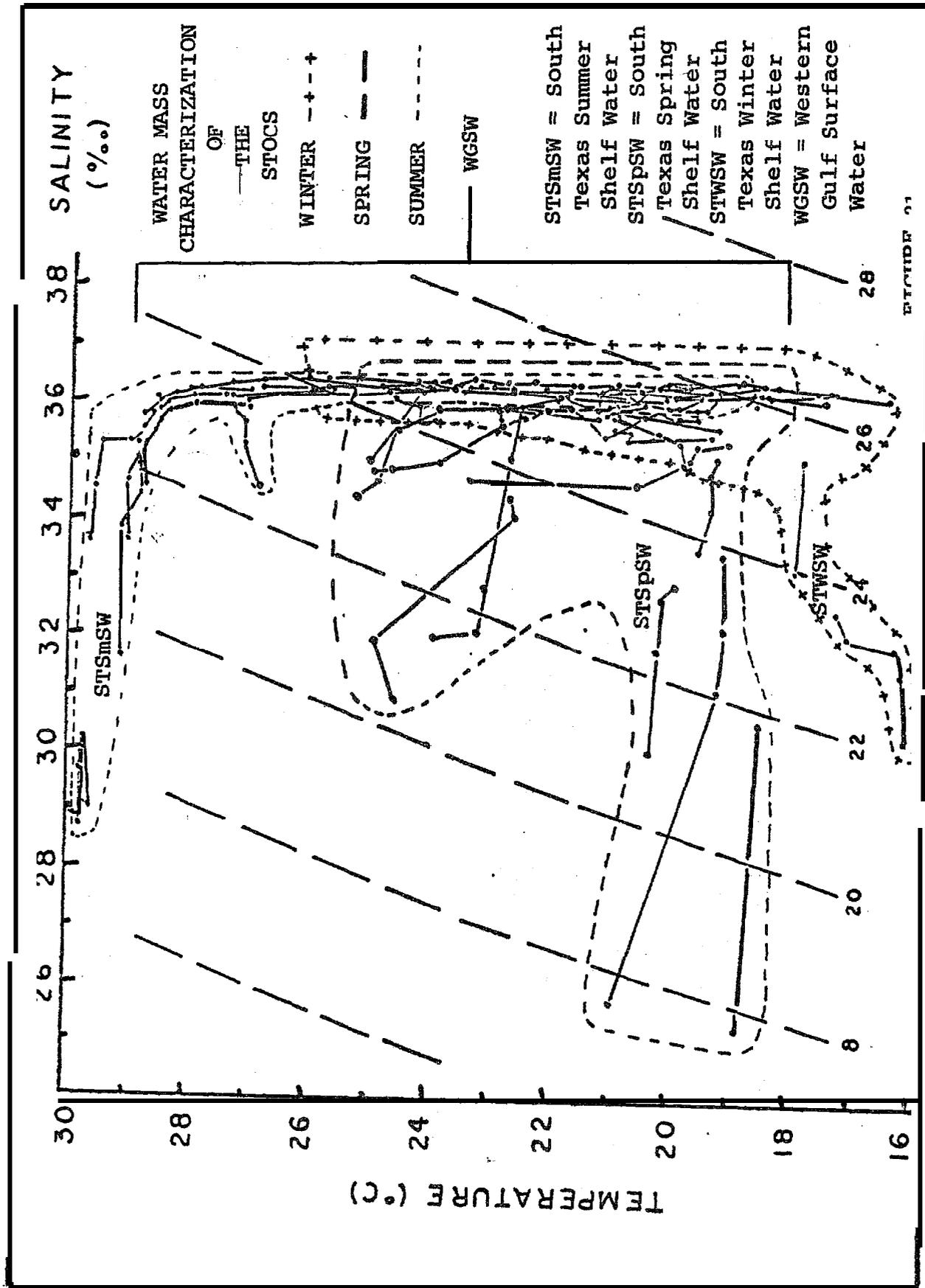
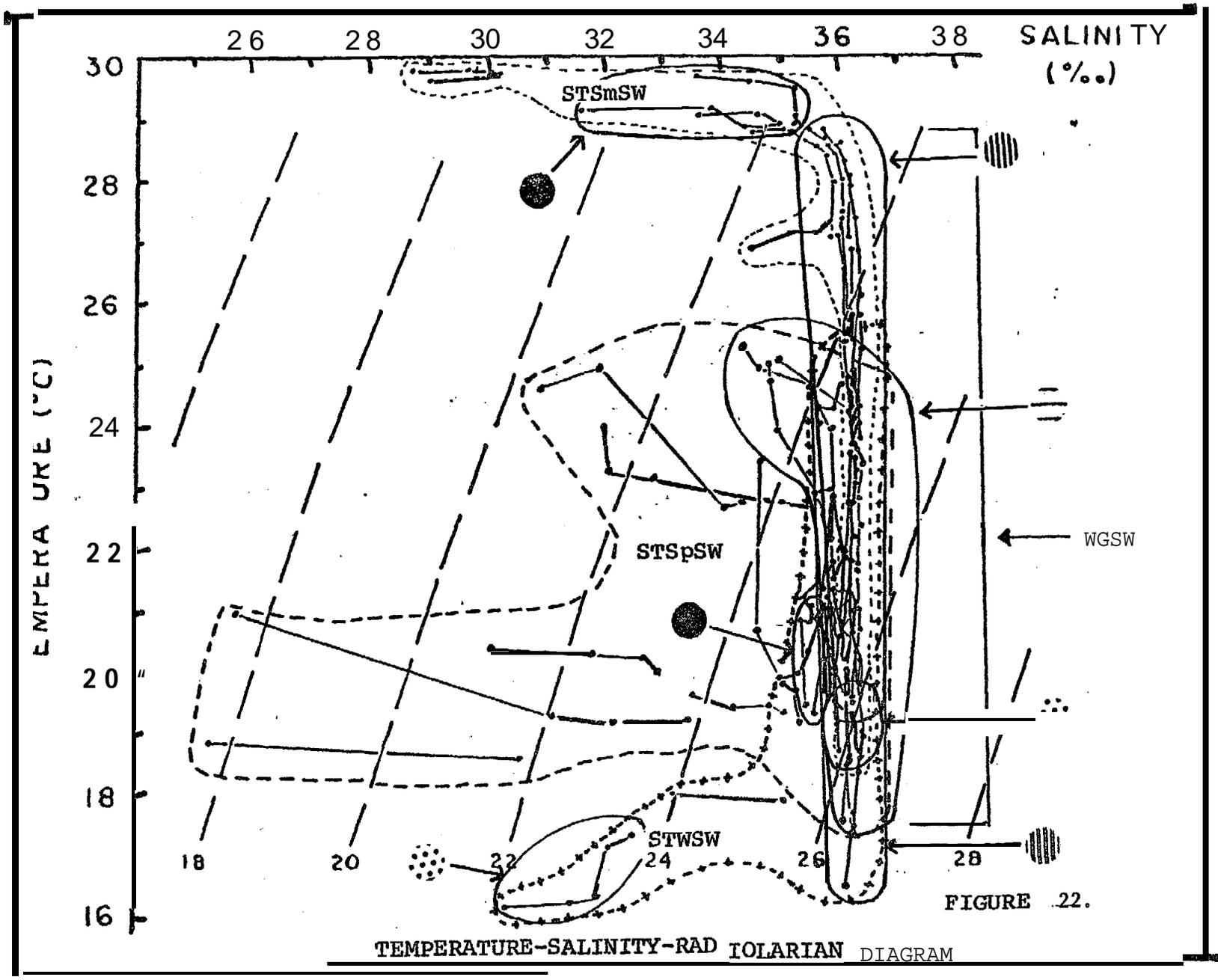


Figure 20. Spring bottom salinities (‰).





TEMPERATURE-SALINITY-RADIOLARIAN DIAGRAM

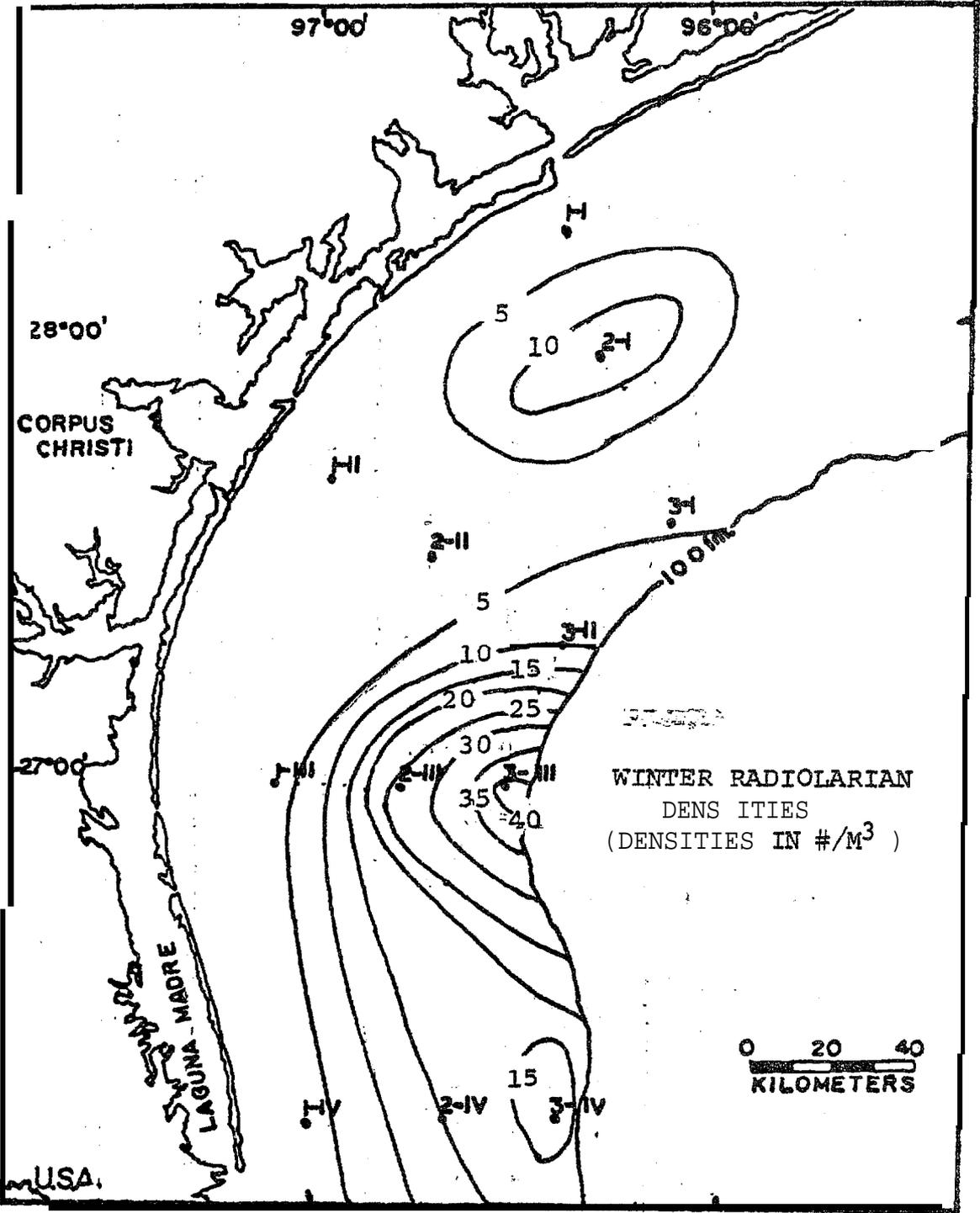
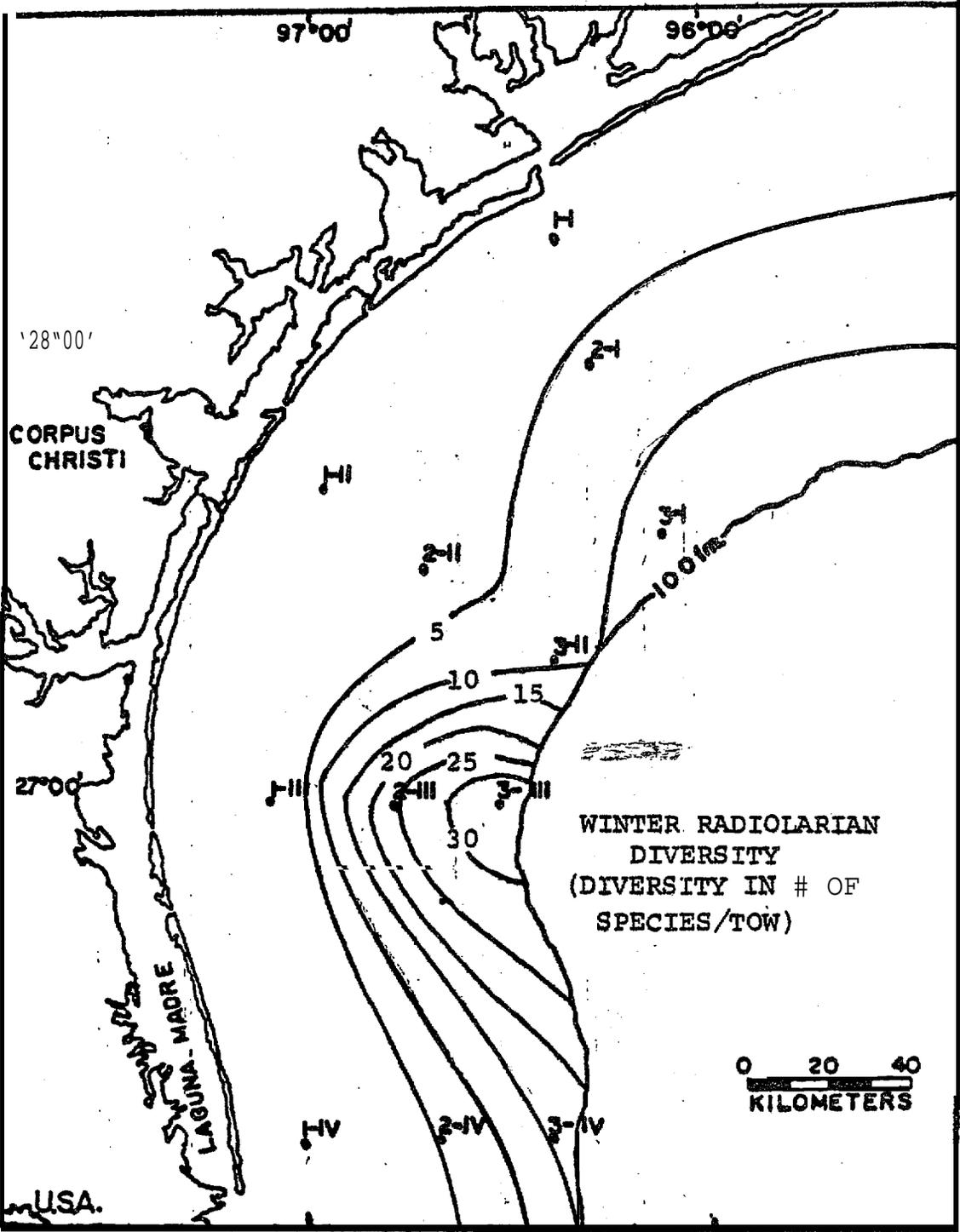


Figure 23. Winter radiolarian densities.



Figure' 24. Winter radiolarian diversity.

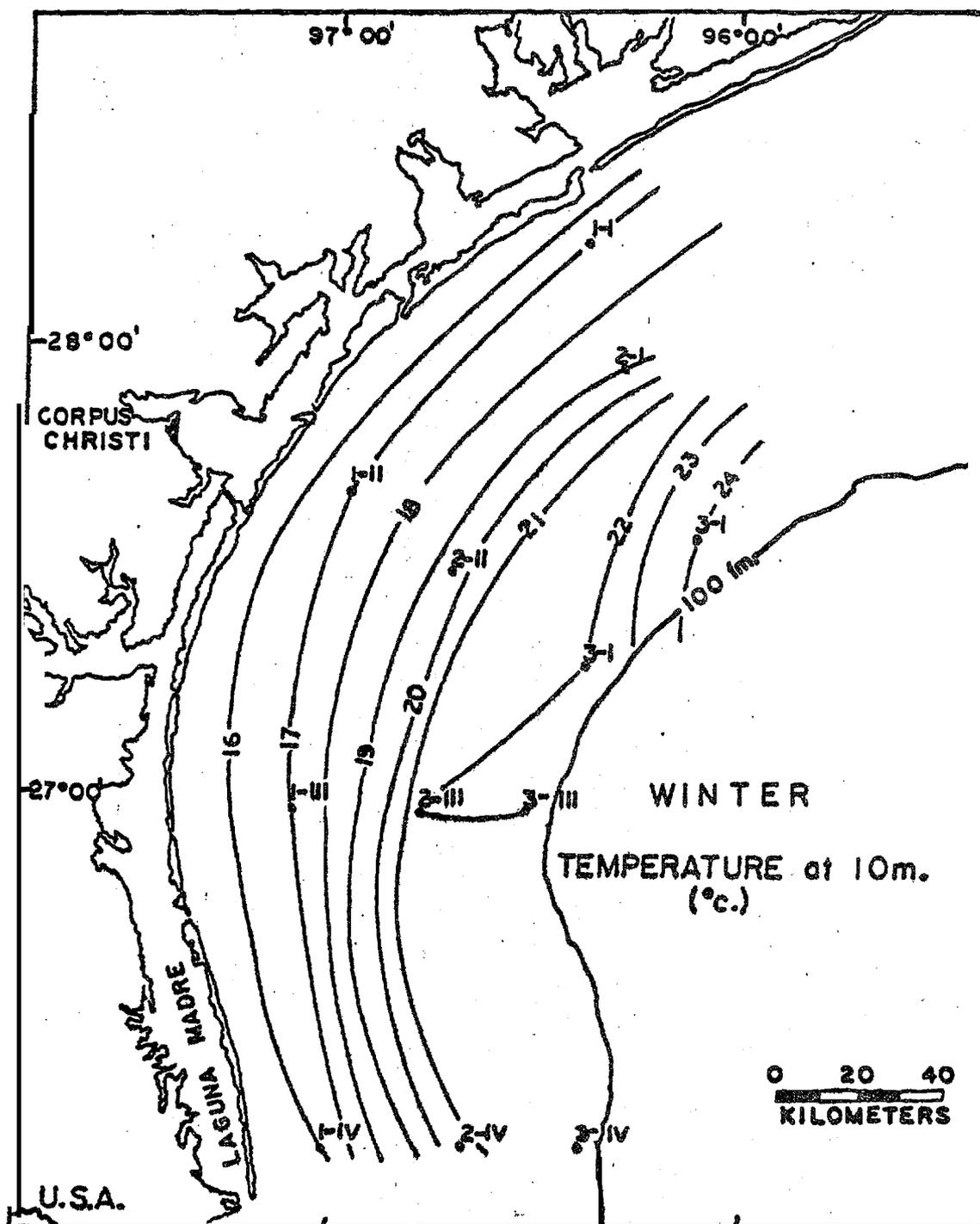


Figure 25. Winter temperature at 10 meters.

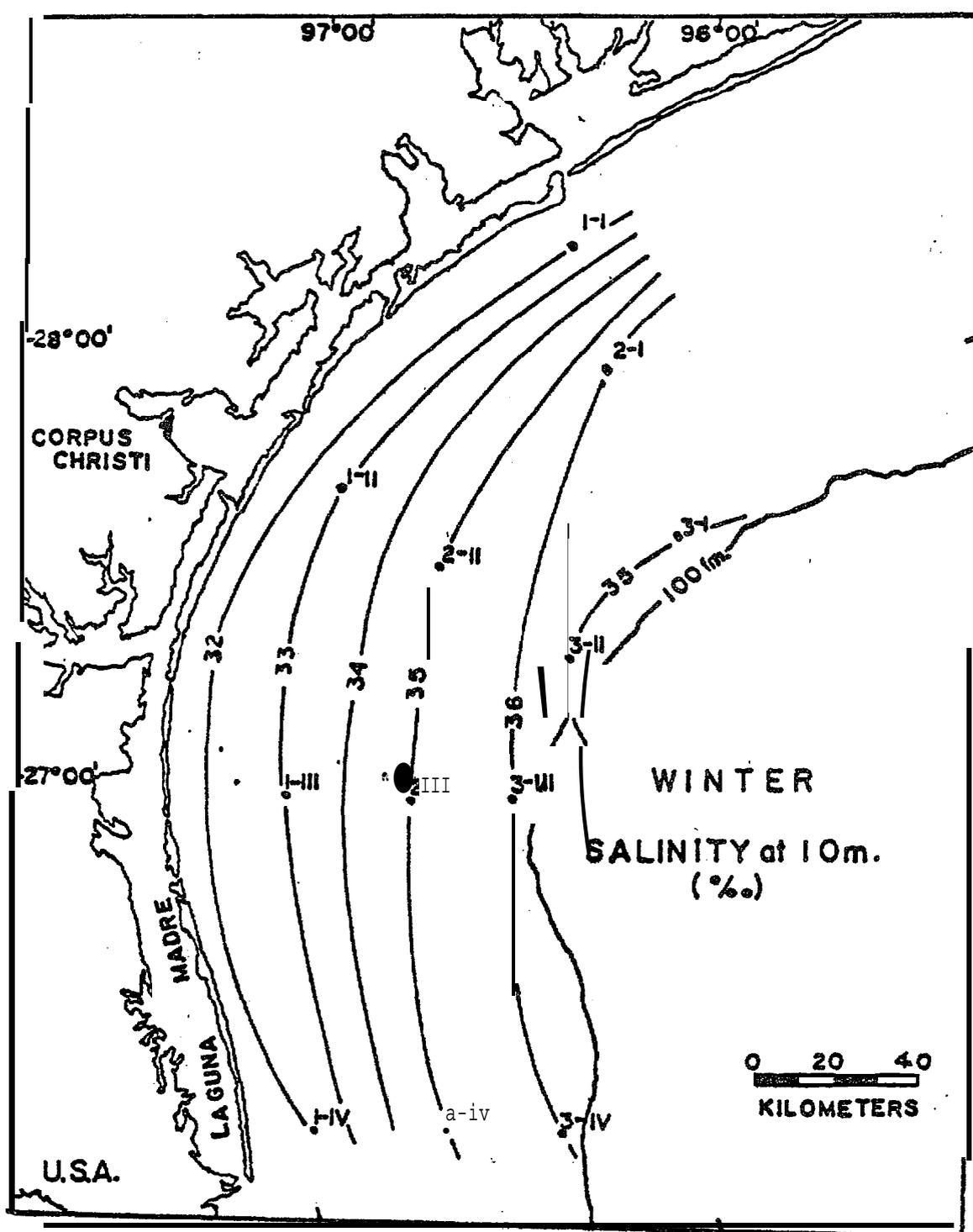


Figure 26. Winter salinities at 10 meters.

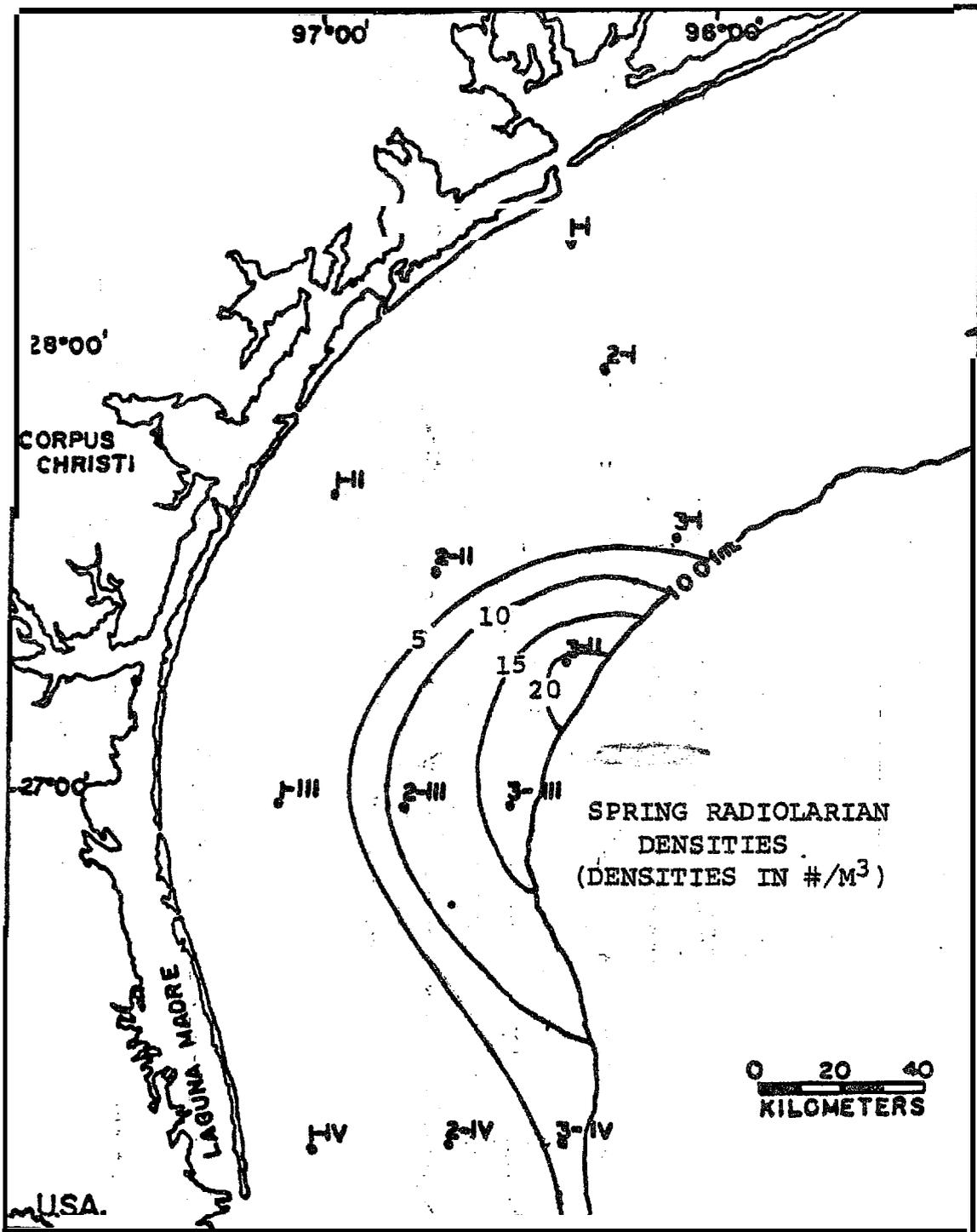
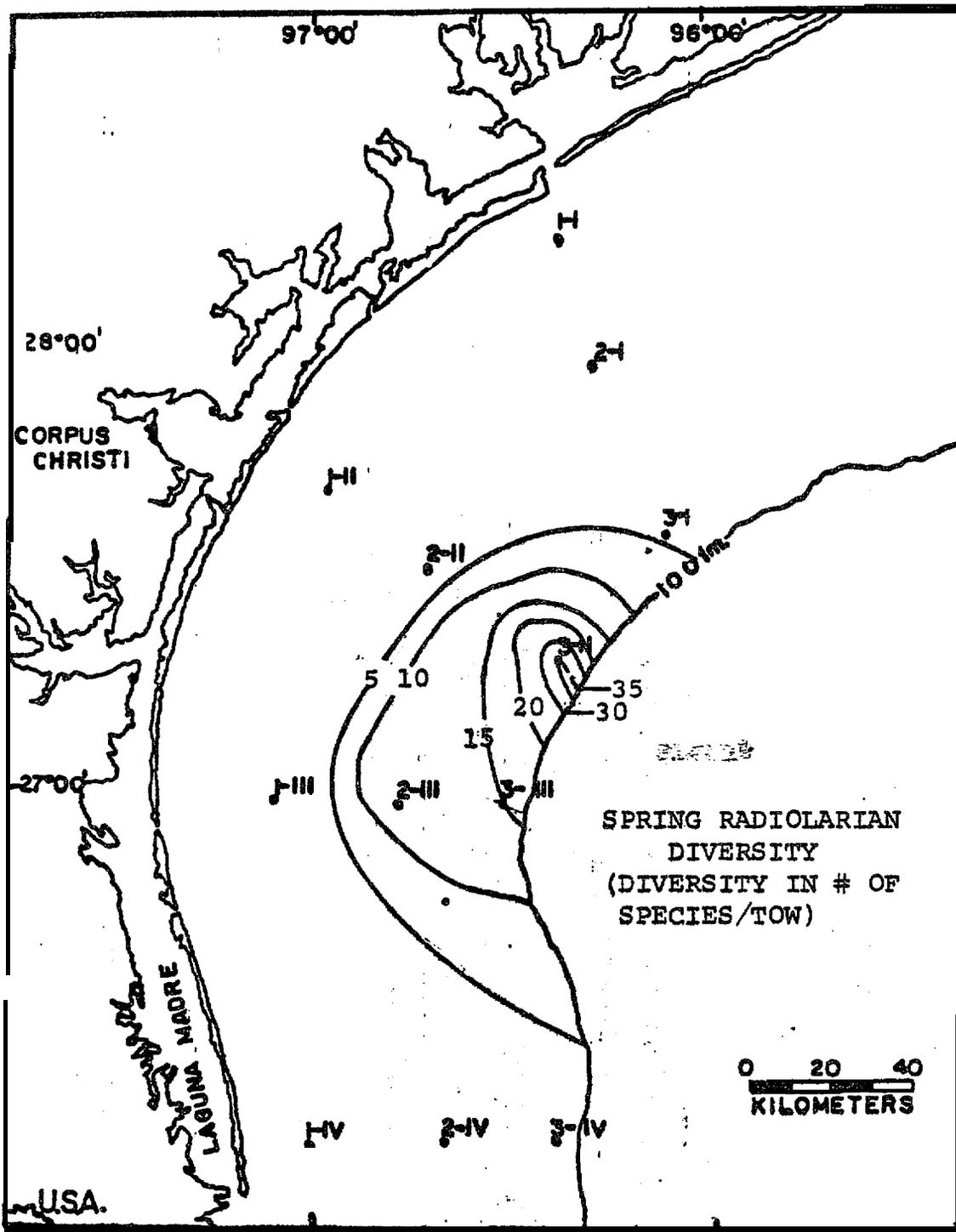


Figure 27. Spring radiolarian densities.



Spring 28. Spring radiolarians diversity.

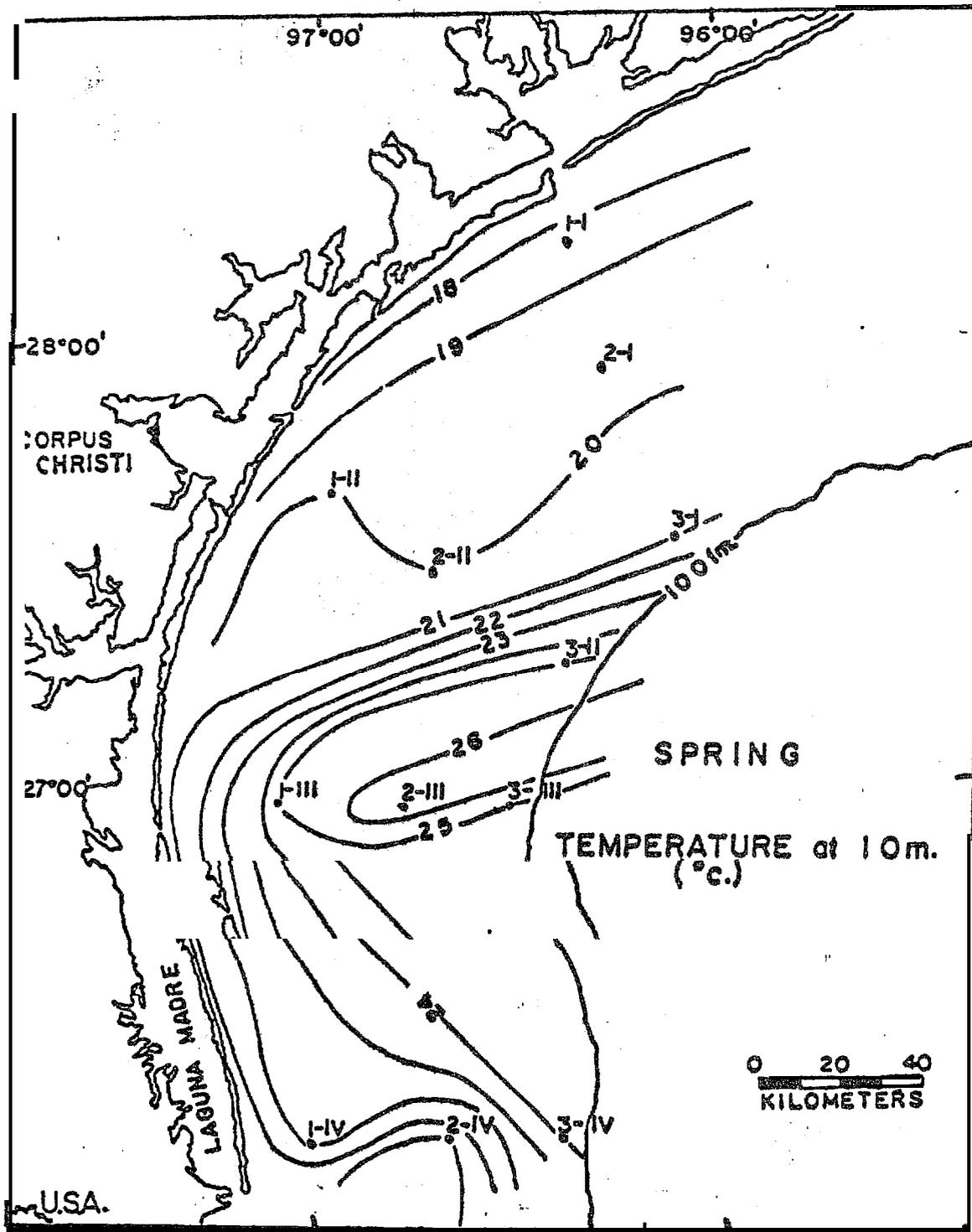


Figure 29. Spring temperatures at 10 meters.

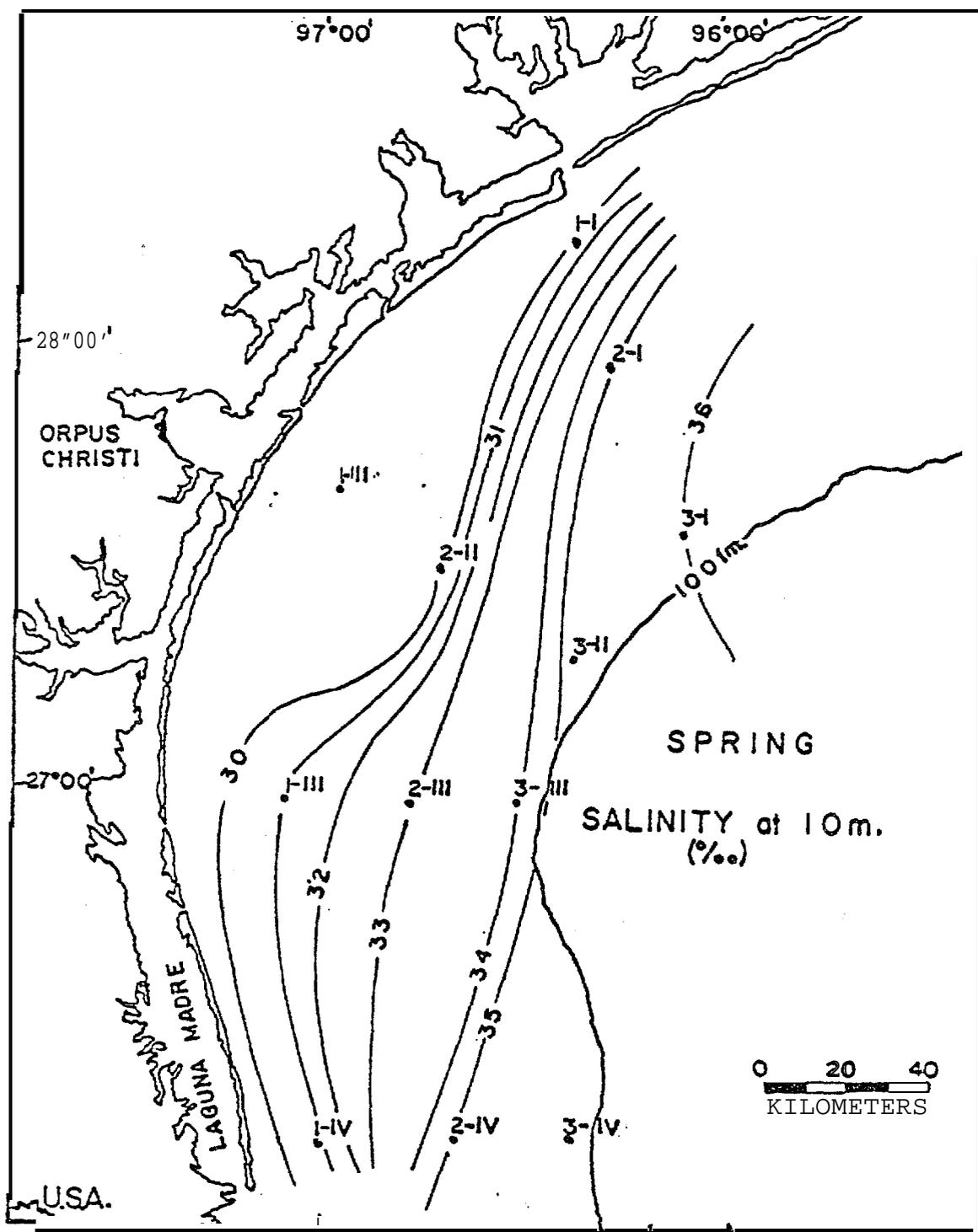


Figure 30. Spring salinities at 10 meters.

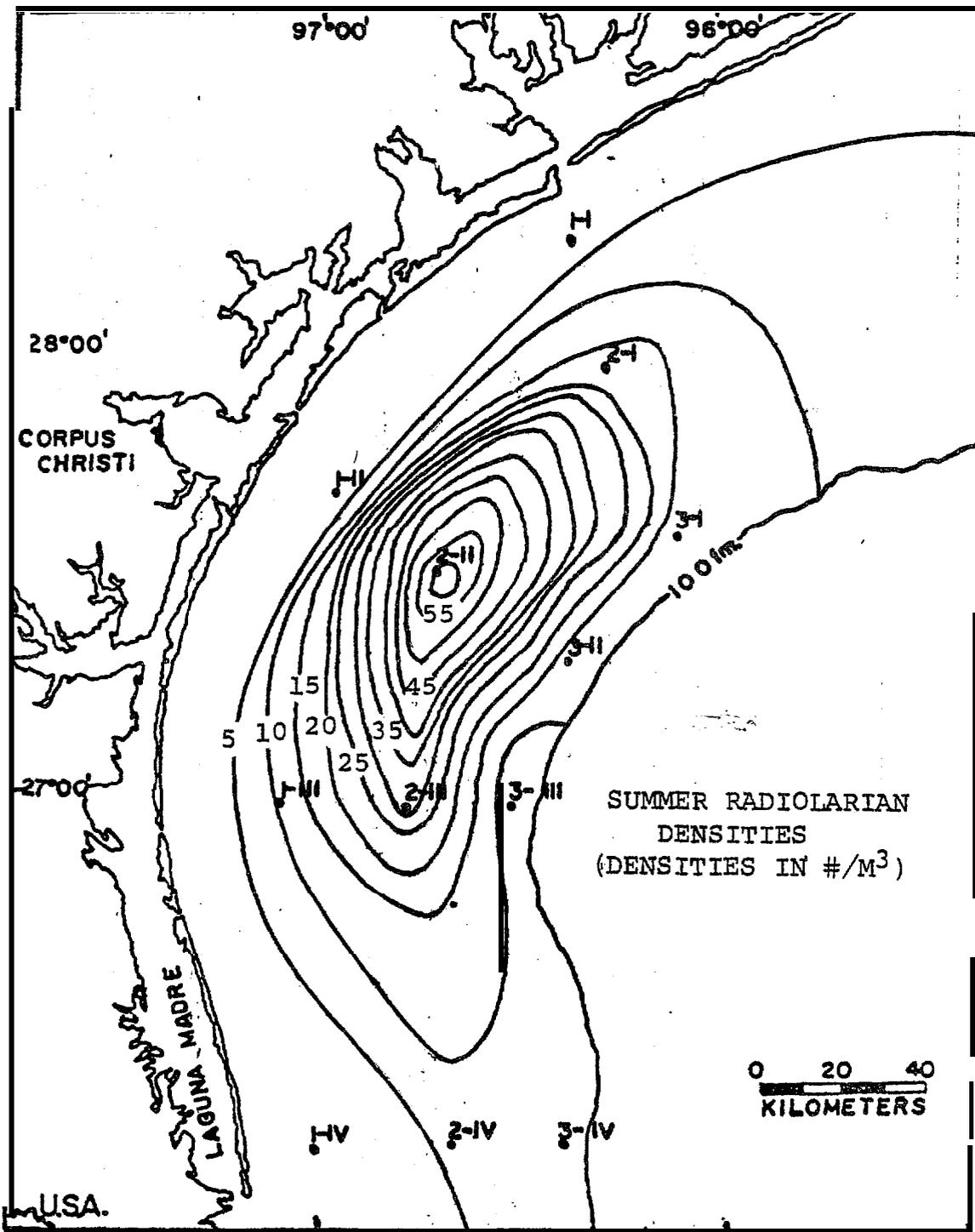


Figure 31. Summer radiolarian densities.

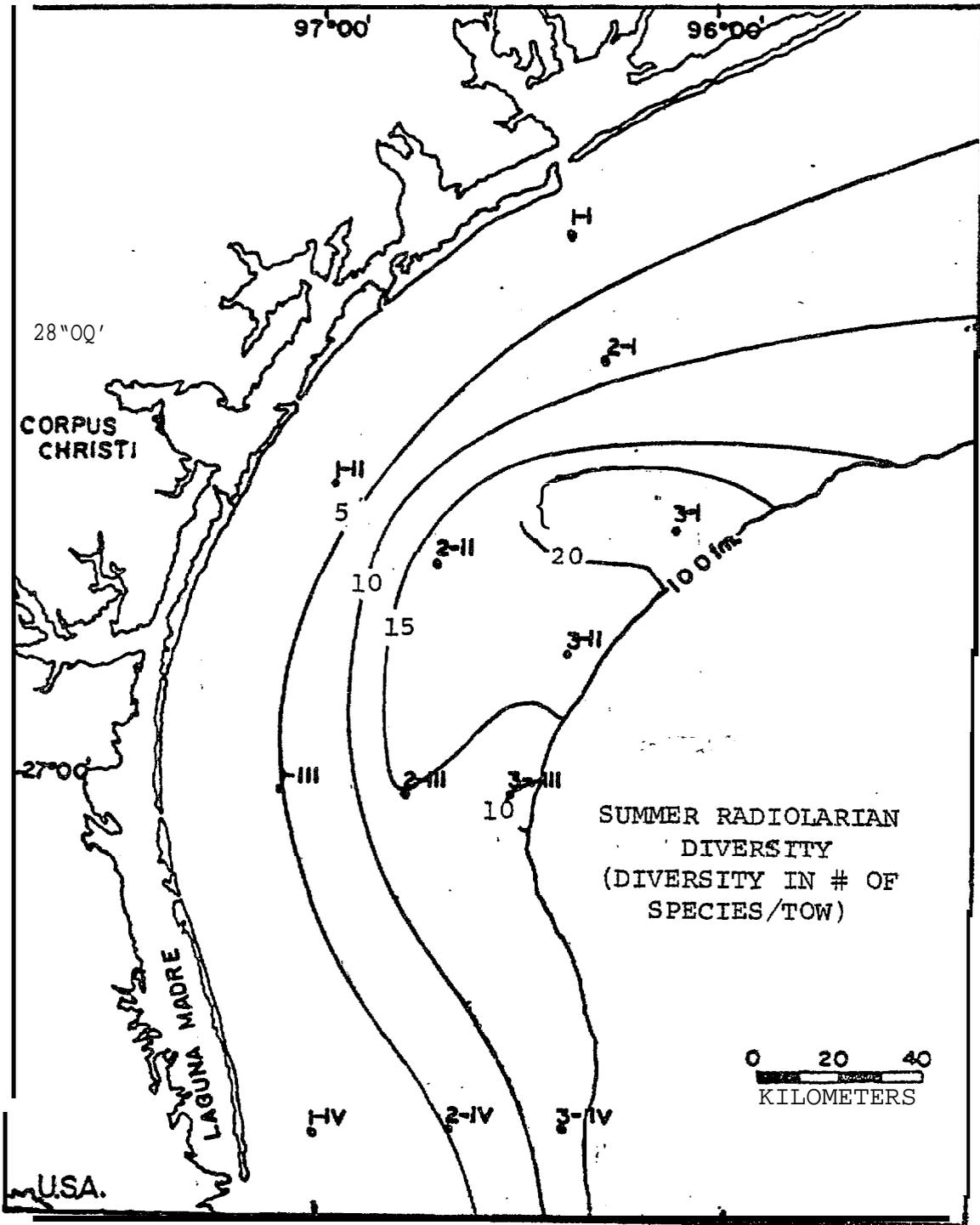


Figure 32. Summer radiolarian diversity.

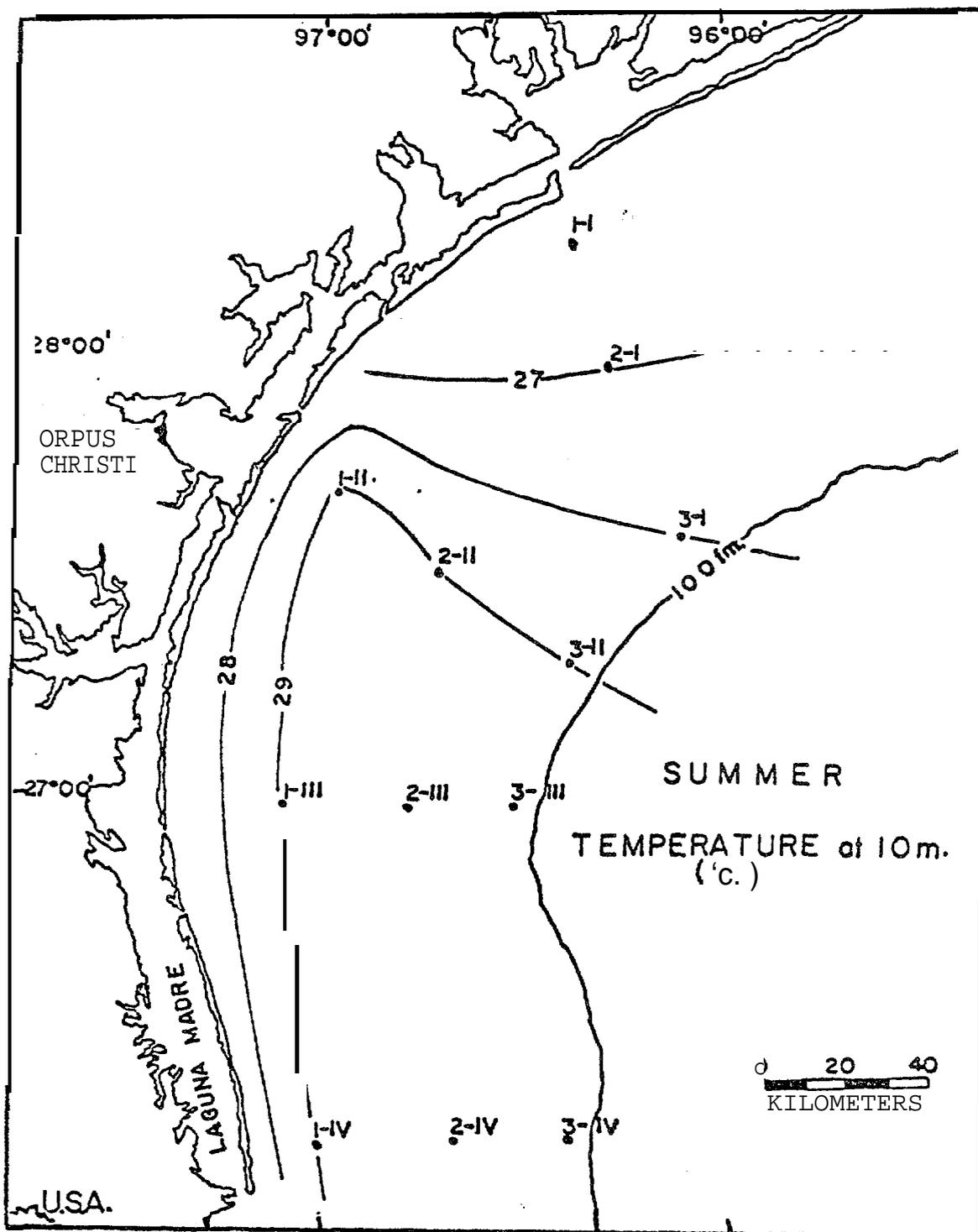


Figure 33. Summer temperatures at 10 meters.

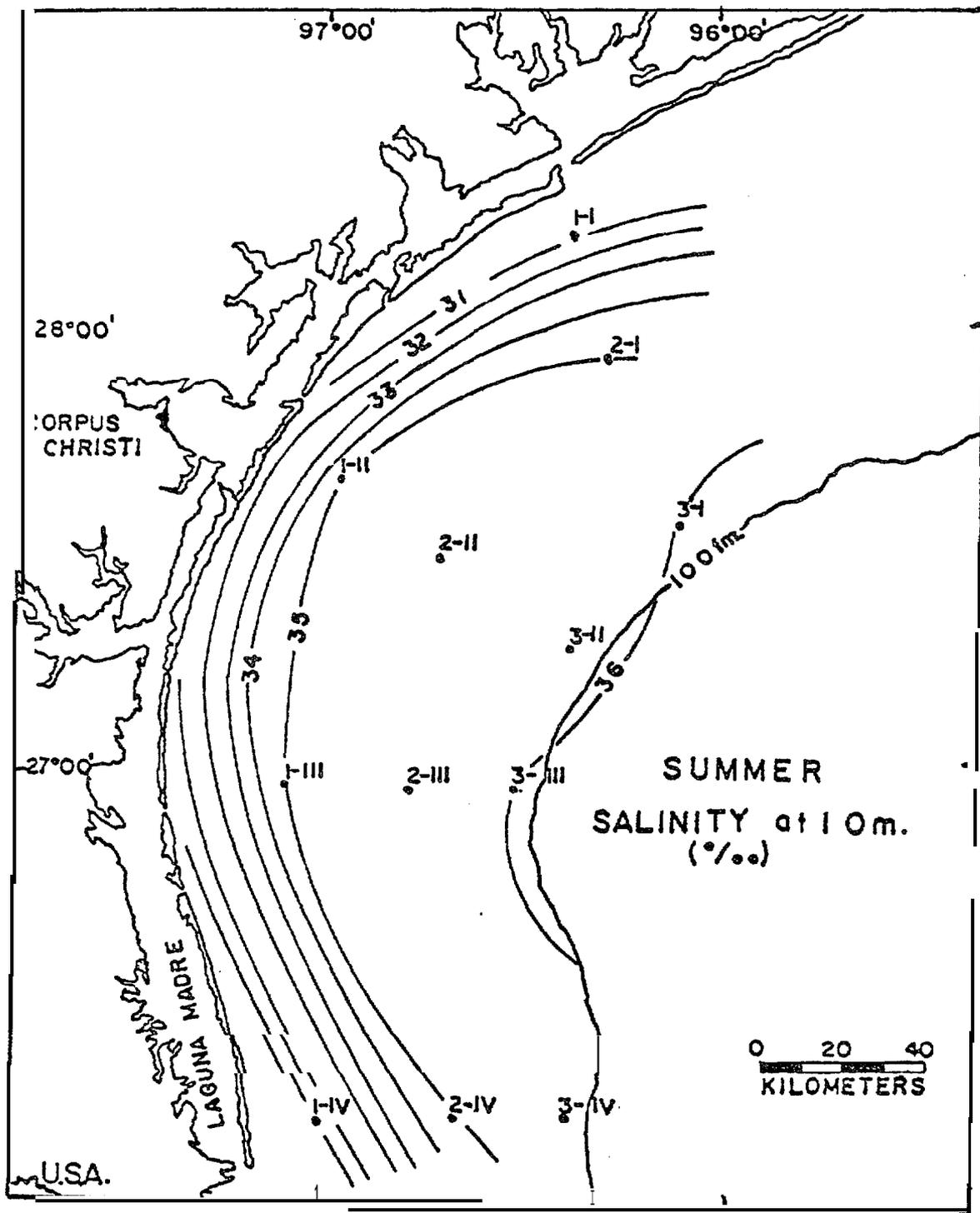


Figure 34. Summer salinities at 10 meters.

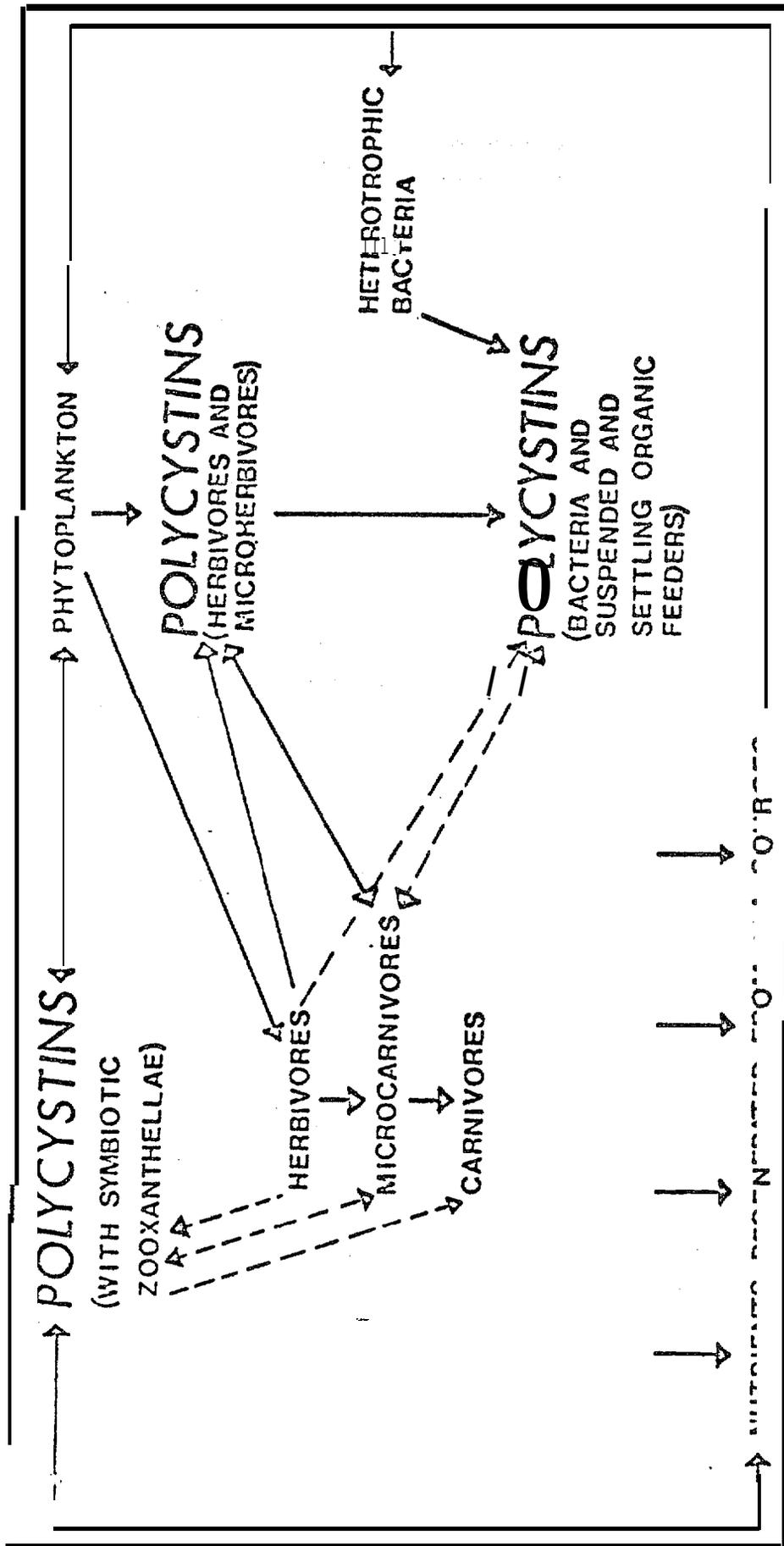


FIGURE 35. Probable niche of polycystin radiolarians. From Casey, in press a.

TABLE 1  
 OCCURRENCES OF LIVING BENTHONIC  
 FORAMINIFERA IN THE PLANKTON TOWS

WINTER '74

TRANSECT	I	IV	IV
	3	2	3
STATION	ACL	BFQ	BOS
Depth (m)	117	47	91
<u>Ammonia</u>			
<u>beccarii</u>	0.9		0.8
<u>Bolivina</u>			
<u>lowmani</u>	1.5	1.4	0.8
<u>Bolivina</u>			
<u>spinata</u>	0.3		
<u>Bolivina sub-</u>			
<u>aenariensis</u>			
var. <u>mexicana</u>			
<u>na</u>	0.6	0.8	
<u>Cassidulina</u> cf.			
<u>subglobosa</u>			0.8
<u>Cassidulina</u>			
<u>curvata</u>	0.6		
<u>Cibicides</u>			
<u>concentricus</u>	0.3	0.8	
? <u>Eponides</u>			
species			0.8
<u>Eponides</u>			
<u>tumidulus</u>			1.5
<u>Marginulina</u>			
species	0.3		
<u>Neoeponides</u>			
<u>antillarum</u>	0.3		
<u>Nonionella</u>			
<u>basiloba</u>	0.3		
<u>Uvigerina au-</u>			
<u>beriana</u> var.			
<u>laevis</u>	0.3		
<u>Uvigerina his-</u>			
<u>pido-costata</u>	0.6		

TABLE 1 CONT.

	3 ACL		2 BFQ		3 BOS			
<u>Uvigerina</u>								
<u>peregrina</u>	0	.8						
<u>Valvulineria</u>								
cf. <u>arau-</u>								
<u>cana</u>	0.3							
SPRING '75								
TRANSECT	I	I	II	II	III	III	IV	IV
	<b>1</b>	2	1	2	1	3	2	3
STATION	CCP	<b>CFT</b>	<b>CMD</b>	<b>CPH</b>	CWR	DCF	DIO	DLW
Depth (m)	20	43	22	<b>48</b>	26	106	47	91
<u>Bolivina</u>								
<u>lowmani</u>	24.8	2.5	1.6	3.7	2.7			
<u>Cassidulina</u>								
cf. <u>sub-</u>								
<u>globosa</u>		2.5						
<u>Lagena</u>								
<u>spirata</u>								0.4
<u>Uvigerina</u>								
<u>peregrina</u>					0.3		0.8	
SUMMER '75								
TRANSECT	<b>I</b>	I	II	III	<b>IV</b>	<b>IV</b>	<b>IV</b>	
	<b>1</b>	3	2	<b>1</b>	1	2	<b>3</b>	
STATION	ECP	E IX	<b>EPI</b>	EWR	FFW	<b>FIY</b>	<b>FMH</b>	
Depth (m)	18	42	49	25	27	47	91	
<u>Bolivina</u>								
<u>lowmani</u>	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 maritatis, 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 foramini.ferans.
8. INDICATIVE OF NEARSHORE WATER COLUMN =
 

Hymeniastrum profundum, planktonic-benthonic foraminif-erans 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  
Moody College of Marine Sciences and Maritime Resources

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**Soshi** Hamaoka  
Philip Turk  
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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  $\mu\text{m}$  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<sup>3</sup>. After the tow, the net was rinsed down using the deck hose. The contents of the cod-end were drained through a 100  $\mu$ m 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  $\mu\text{m}$  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 (AppendixVIII). 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:

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

Where S = number of species found in the subsample

s = hypothetical species number for a given species

diversity (Lloyd and Ghelardi, 1964).

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

Where  $H(S)$  = observed species diversity

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

## 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 1/1 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 chierchiaie) 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<sup>3</sup>. 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 1/1, (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 1/1, 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 pre-

sented 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 ( $3.11 \text{ ug/m}^3$ ), decreased at station 2 ( $0.81 \text{ ug/m}^3$ ) and was lowest at station 3 ( $0.36 \text{ ug/m}^3$ ). 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  $1^\circ\text{C}$  from  $22.6^\circ\text{C}$  at station 1 to  $24.6^\circ\text{C}$  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 <u>a</u> (mg/m <sup>3</sup> )	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 <sup>3</sup> )	15.3	25.2	21.3
No. of Zoopl. per m <sup>3</sup>	1438,3	2023.8	1613.2
No. of Copepod Species	35.5	30.6	28.3
No. of Copepods per m <sup>3</sup>	1163.7	1376.6	971.1 -
Copepod % of Zoopl.	77.9	65.4	66.1
No. of <u>Acartia</u> <del>pp</del> /m <sup>3</sup>	8.5	234.7	1.6
No. of <u>Paracalanus parvus</u> <del>pp</del> /m <sup>3</sup>	127,5	107.9	62.1
No. of <u>Clausocalanus furcatus</u> <del>pp</del> /m <sup>3</sup>	99.0	16.5	90.0
No. of Ostracods /m <sup>3</sup>	123,0	155.0	259.2
Species Diversity			
Index (H)	3.1872	3.2578	3 . 1 2 \$ 6
$E \frac{H(S)}{H_{Max}(S)}$	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 <u>a</u> (mg/m <sup>3</sup> )	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 <sup>3</sup> )	35.1	17.6	9.2
No. of Zoopl. per m <sup>3</sup>	2757.3	1558.5	<b>759.6</b>
No. of Copepod Species	17.6	30.1	46.4
No. of Copepods per m <sup>3</sup>	2146.3	830.7	534.5
Copepod % of Zoopl.	75.7	63.7	70.0
No. of <u>Acartia tonsa</u> ♀♀/m <sup>3</sup>	<b>236.15</b>	8.3	0.4
No. of <u>Paracalanus parvus</u> group ♀♀/m <sup>3</sup>	228.2	66.8	8.4
No. of <u>Clausocalanus furcatus</u> ♀♀/m <sup>3</sup>	14.0	104.8	86.7
No. of Ostracods /m <sup>3</sup>	59,4	392.55	85.2
Species Diversity			
Index (H)	2.5421	3.2497	3.7797
$E = \frac{H(S)}{\text{Max}(S)}$	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 <u>a</u> (mg/m <sup>3</sup> )	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 <sup>3</sup> )	26.1	<b>19.7</b>	16.5	20.2
No. of Zoopl. per m <sup>3</sup>	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 <sup>3</sup>	<b>1493.2</b>	<b>1187.4</b>	1065.0	936.3
Copepod % of Zoopl.	70.7	69.2	73.5	65.2
No. of <u>Acartia tonsa</u> ♀♀/m <sup>3</sup>	305.9	8.1	8.2	4.3
No. of <u>Paracalanus parvus</u> group ♀♀/m <sup>3</sup>	77.9	164.0	58.5	103.9
No. of <u>Clausocalanus furcatus</u> ♀♀/m <sup>3</sup>	37.3	69.9	106.2	60.5
No. of Ostracods /m <sup>3</sup>	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

7\*

**TABLE 4**  
CORRELATION COEFFICIENTS OF LINEAR  
REGRESSION OF SALINITY AND  
CHLOROPHYLL a DATA AGAINST  
CERTAIN MEASUREMENTS OF ZOOPLANKTON

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

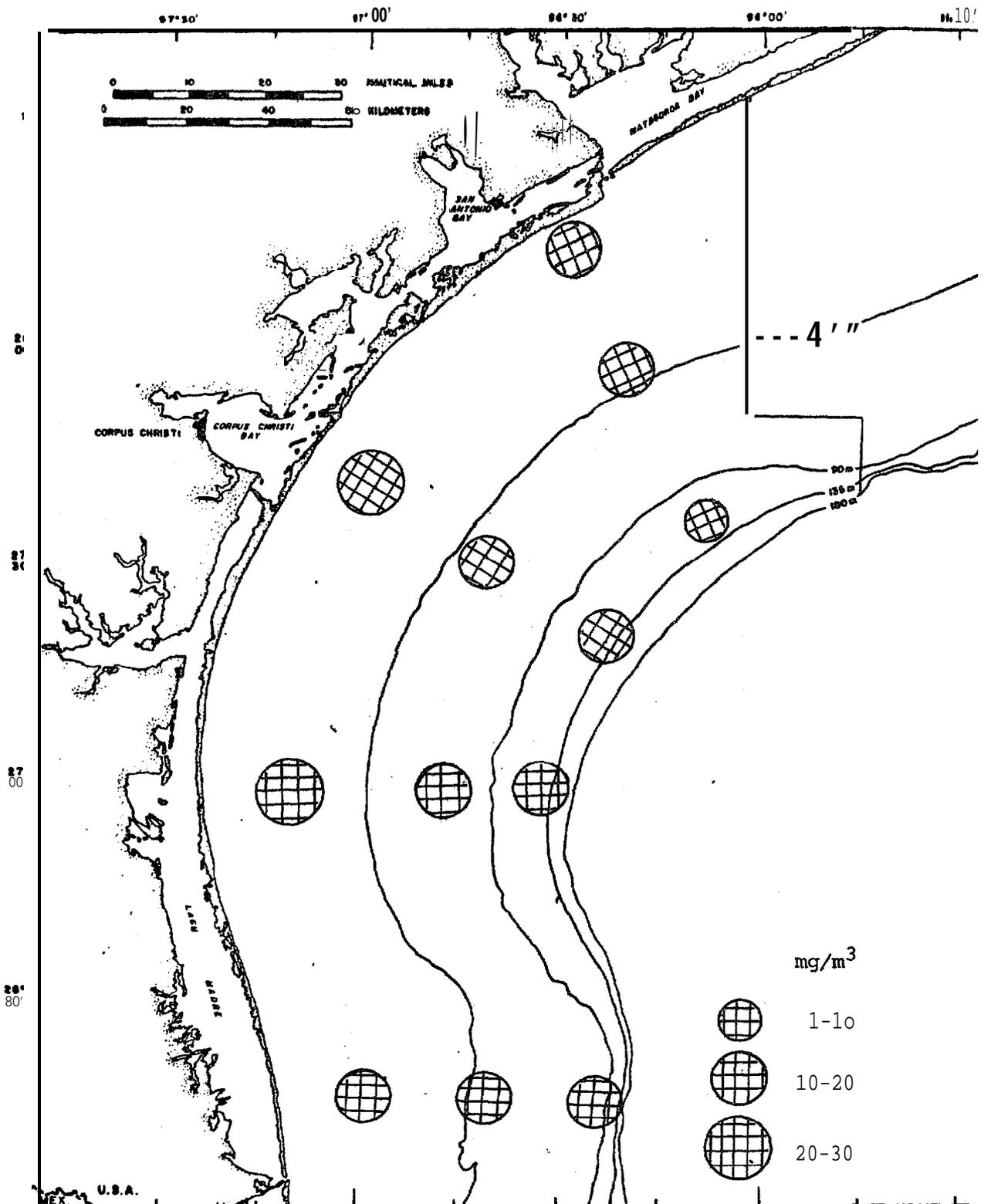


Figure 1-1, Average value of ash-free dry weight at each station, December - January.

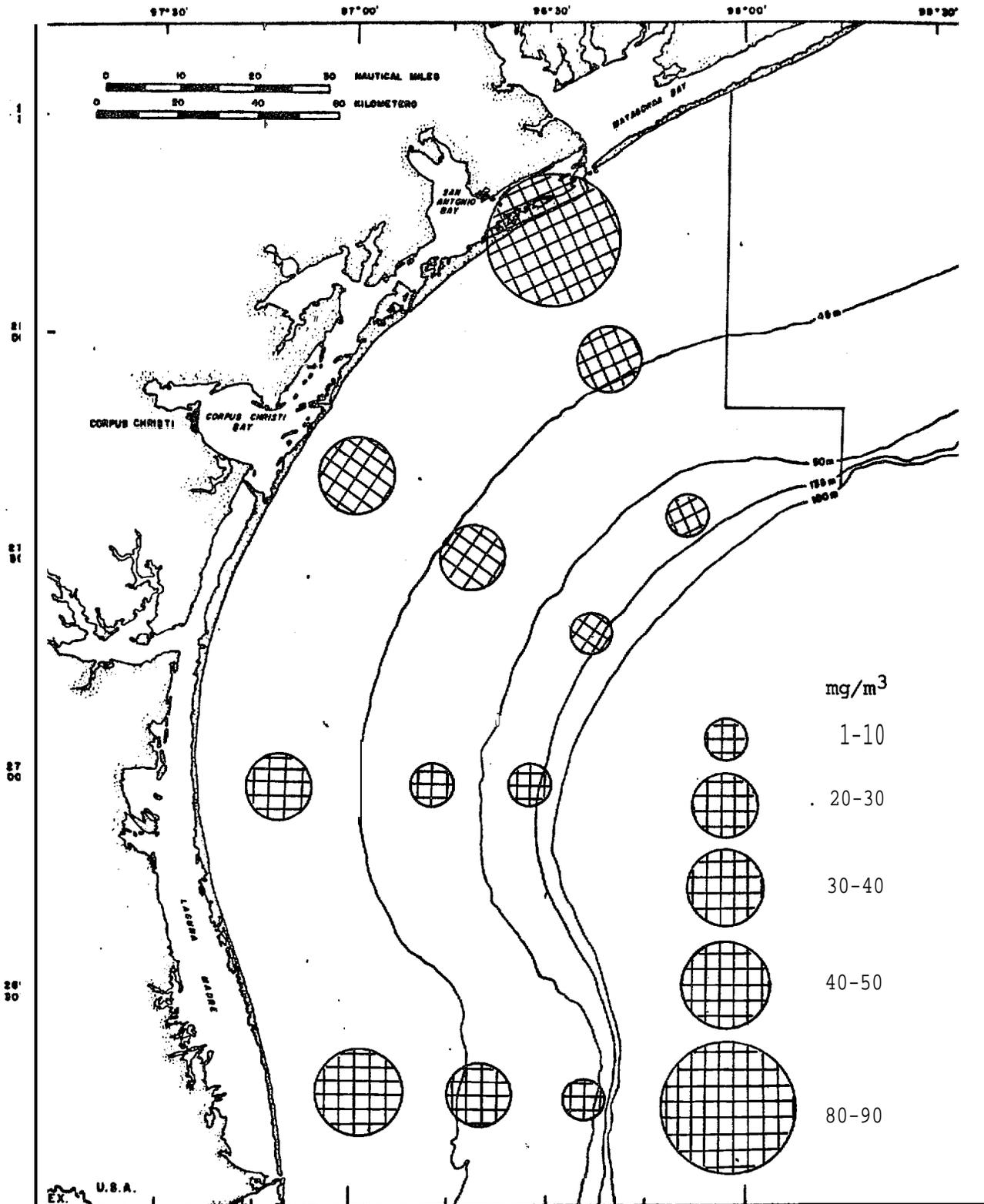


Figure 1-2. Average value of ash-free dry weight at each station, . April - May.

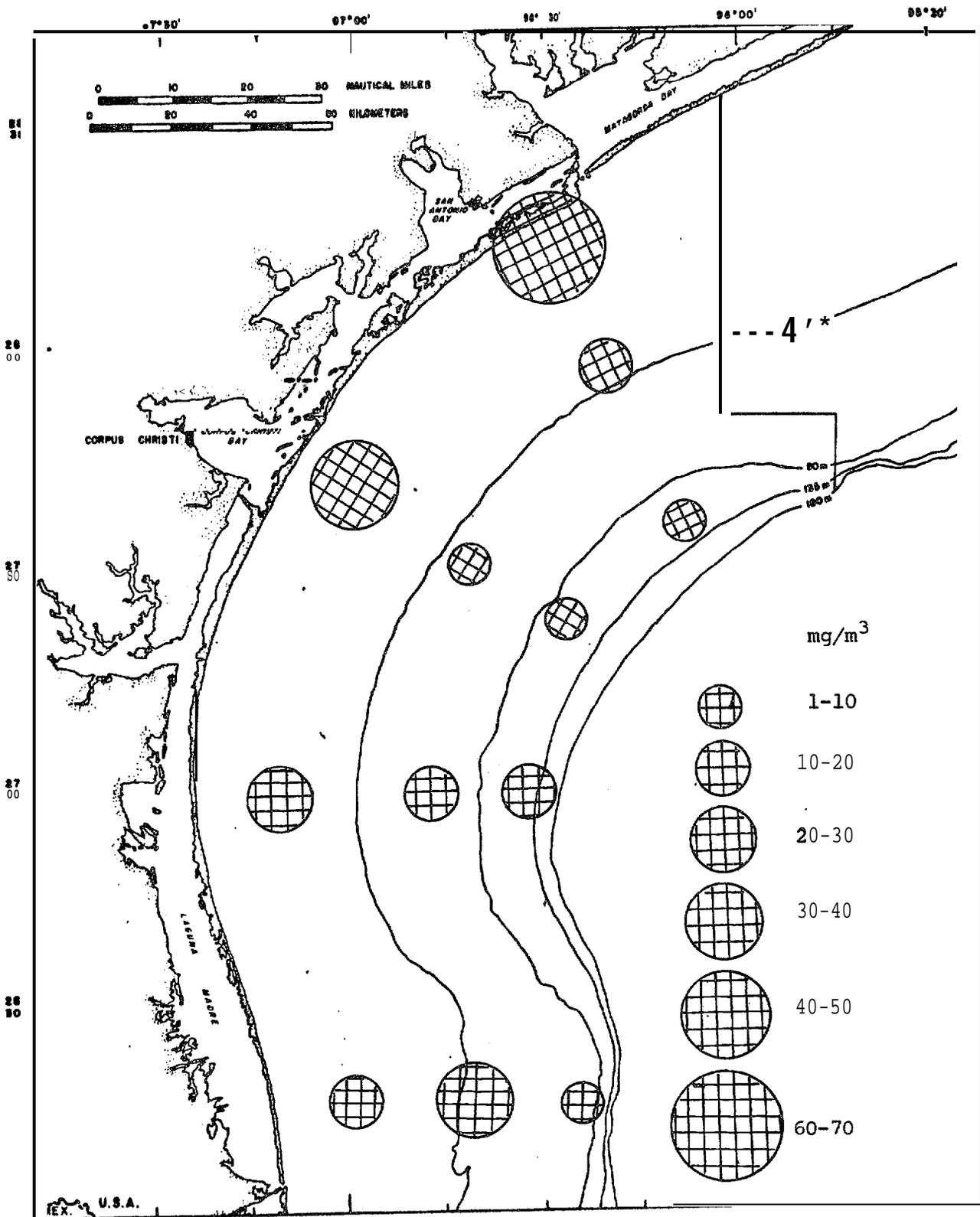


Figure 1-3. Average value of ash-free dry weight at each station, August - September.

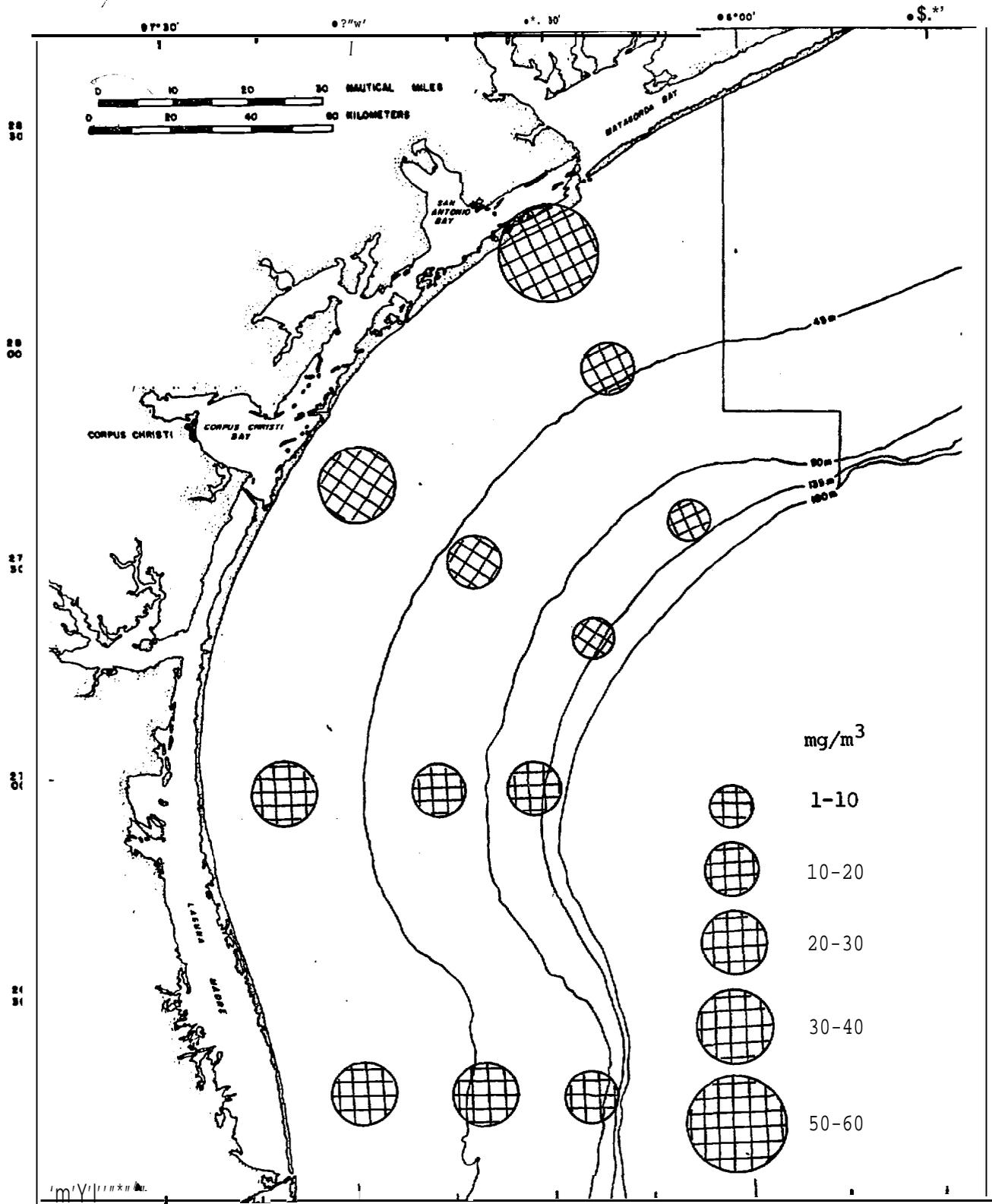


Figure 1-4. Annual mean of ash-free dry weight at each station.

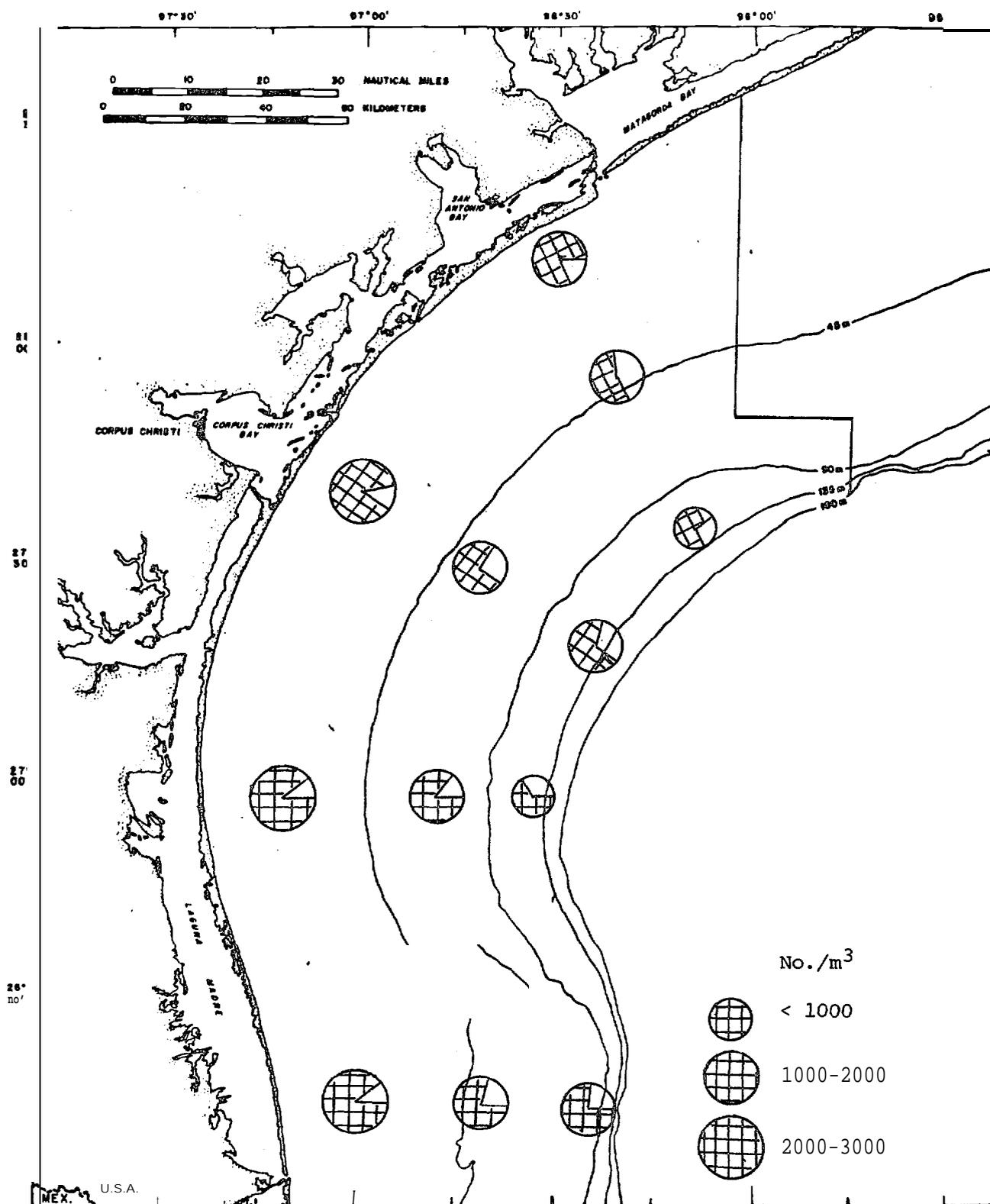


Figure 2-1. Average numerical abundance of zooplankton and proportion of copepods (shaded), December - January.

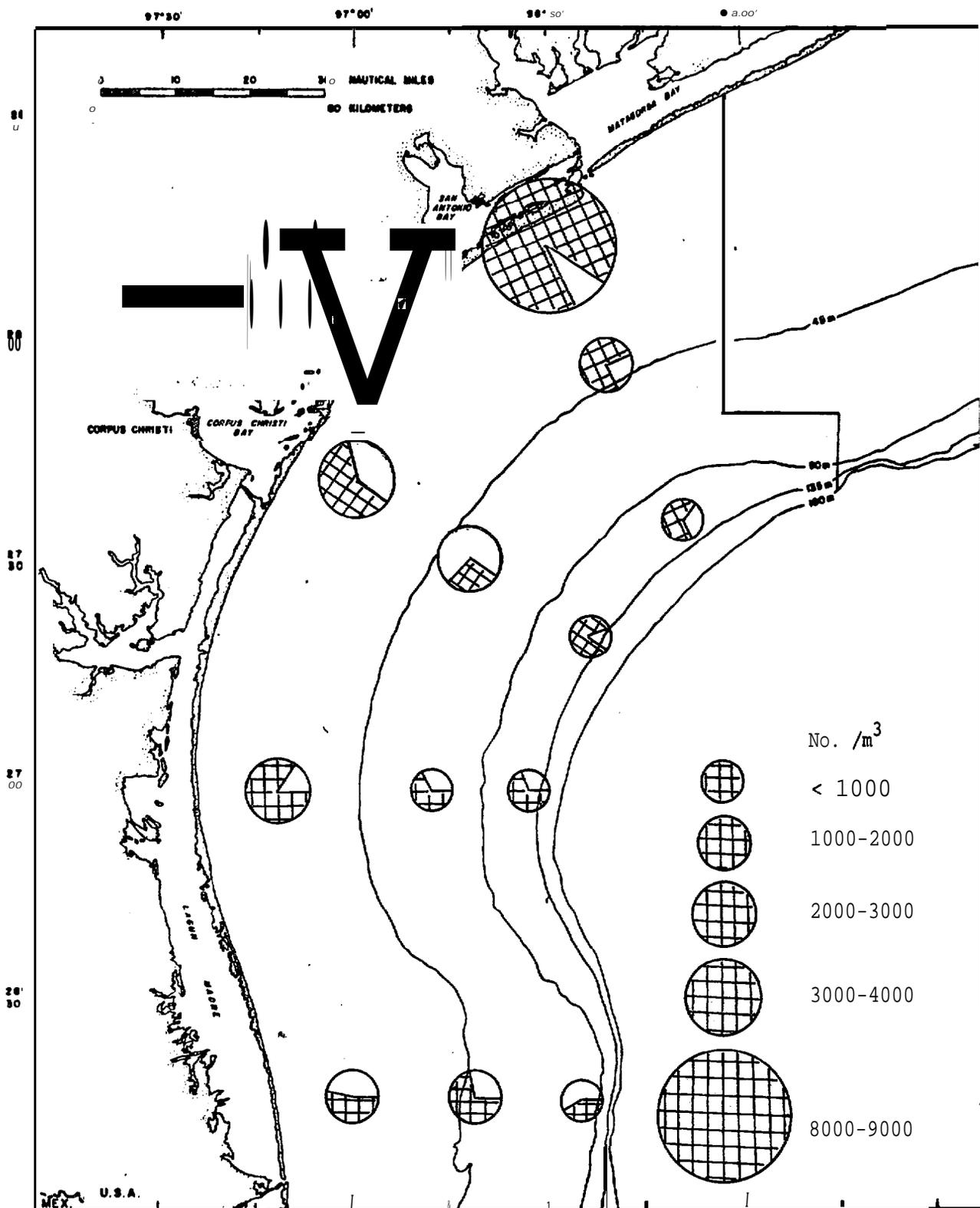


Figure 2-2. Average numerical abundance of zooplankton and proportion of copepods (shaded), April - May.

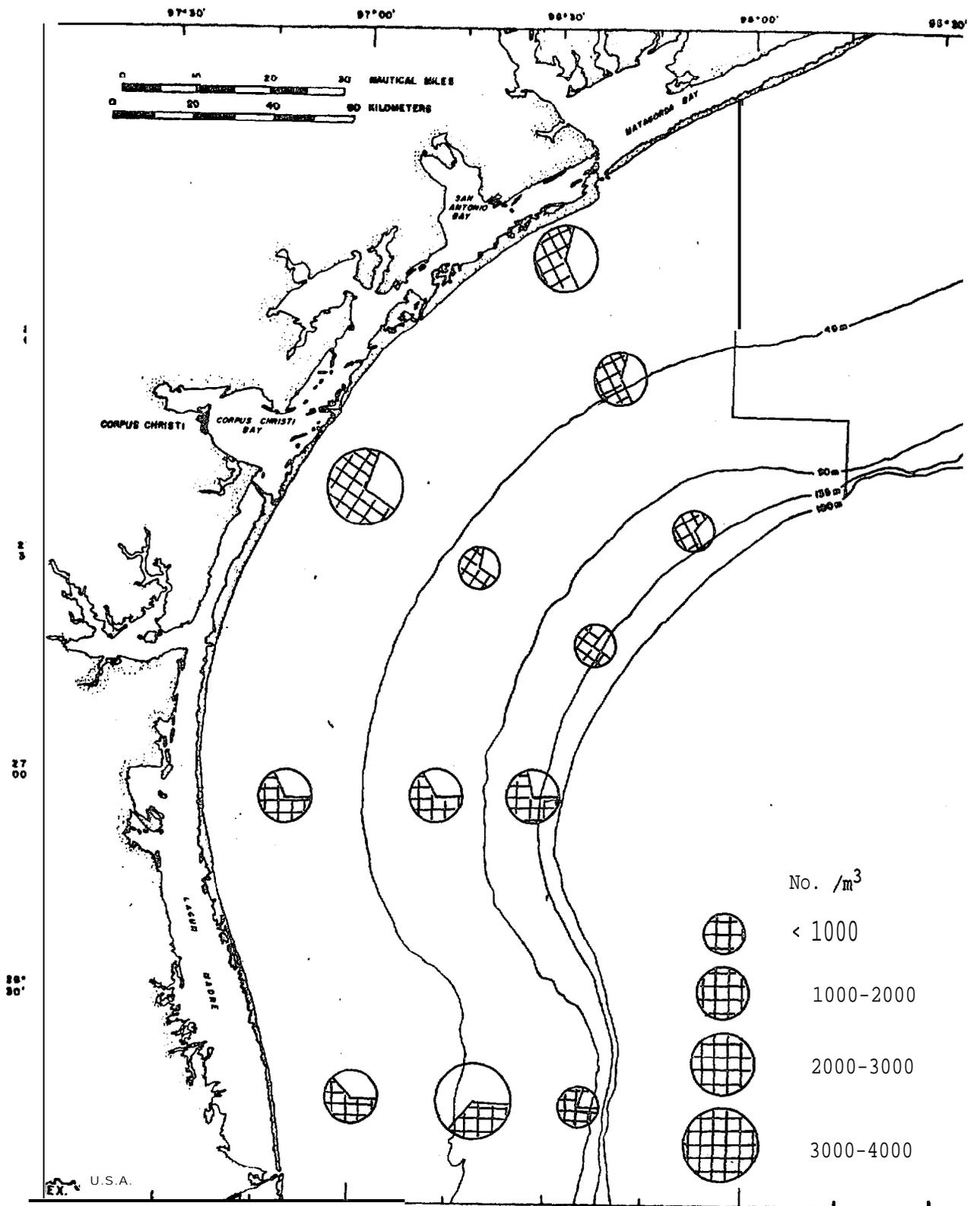


Figure 2-3. Average numerical abundance of zooplankton and proportion of Copepods (shaded), August - September.

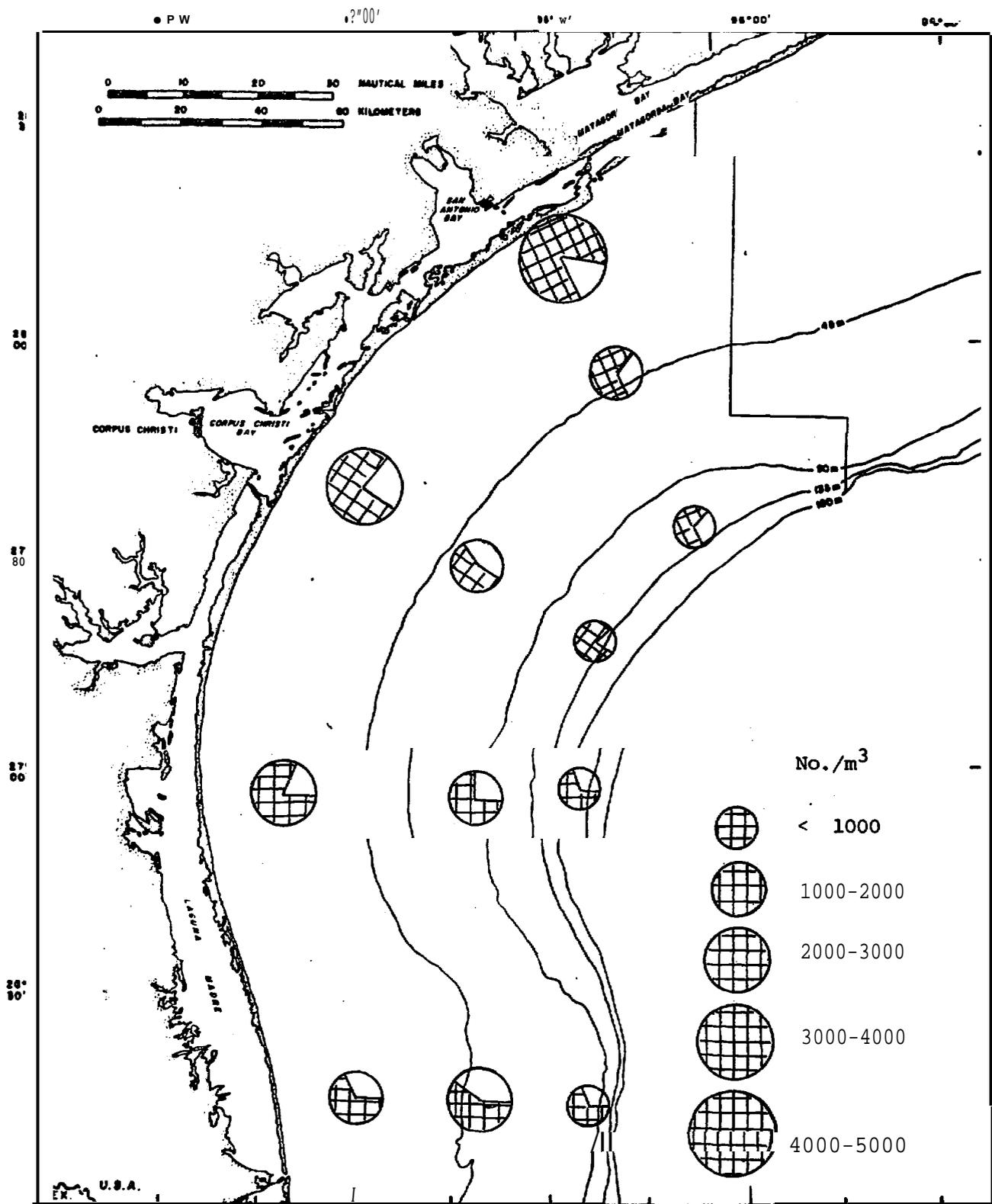


Figure 2-4. Annual mean of numerical abundance of zooplankton and proportion of copepods (shaded).

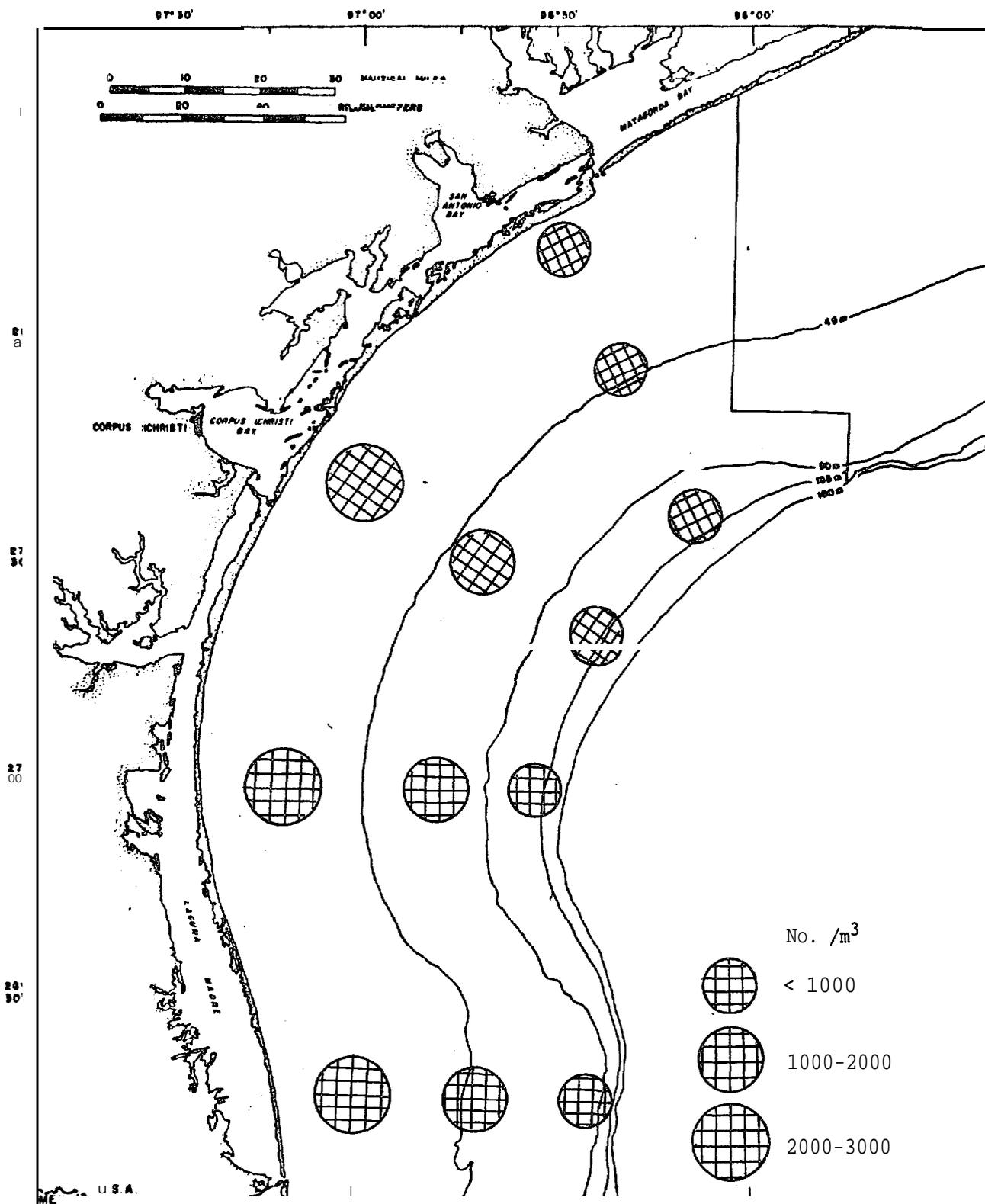
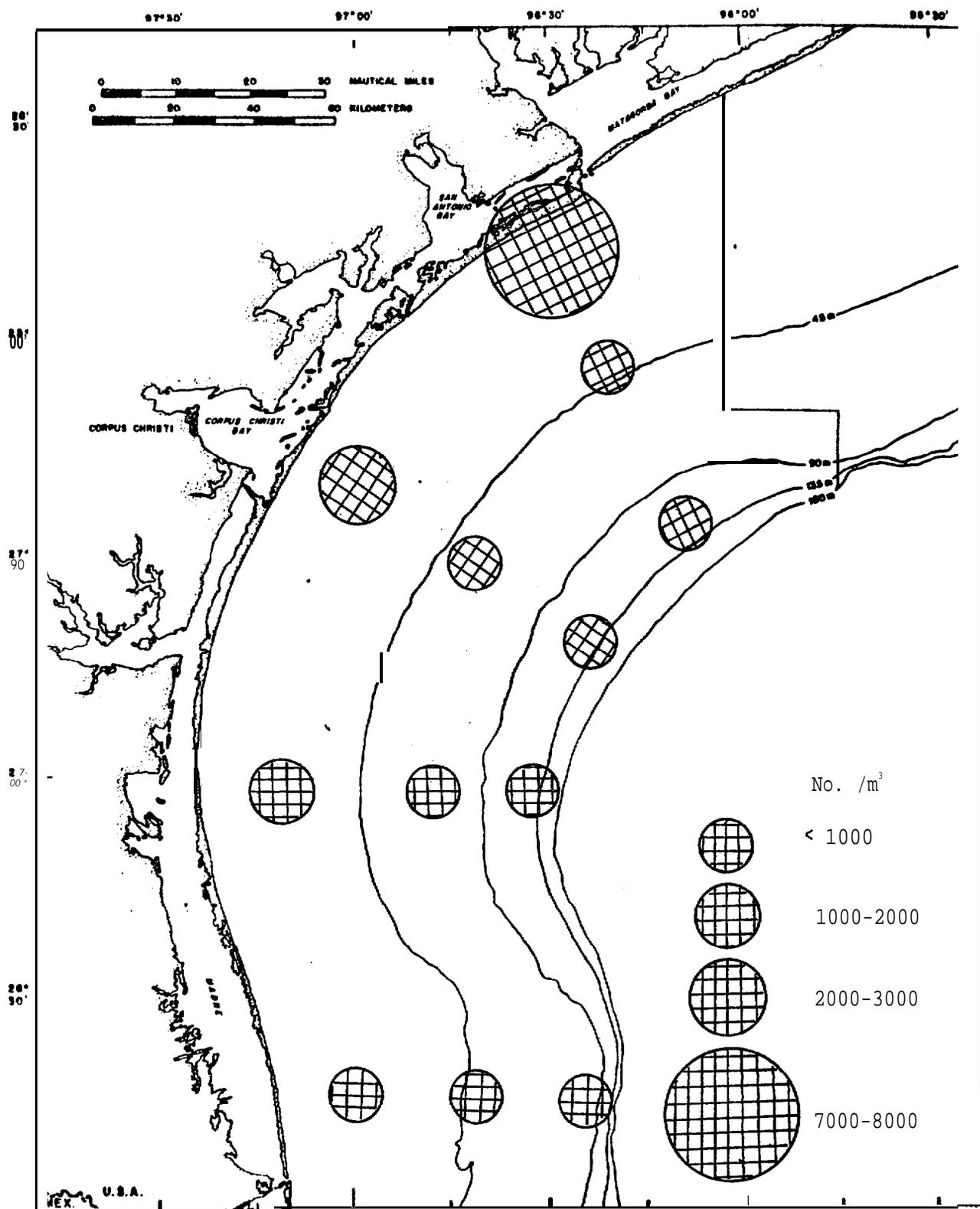


Figure 3-1. Average numerical abundance of copepods at each station, December - January.



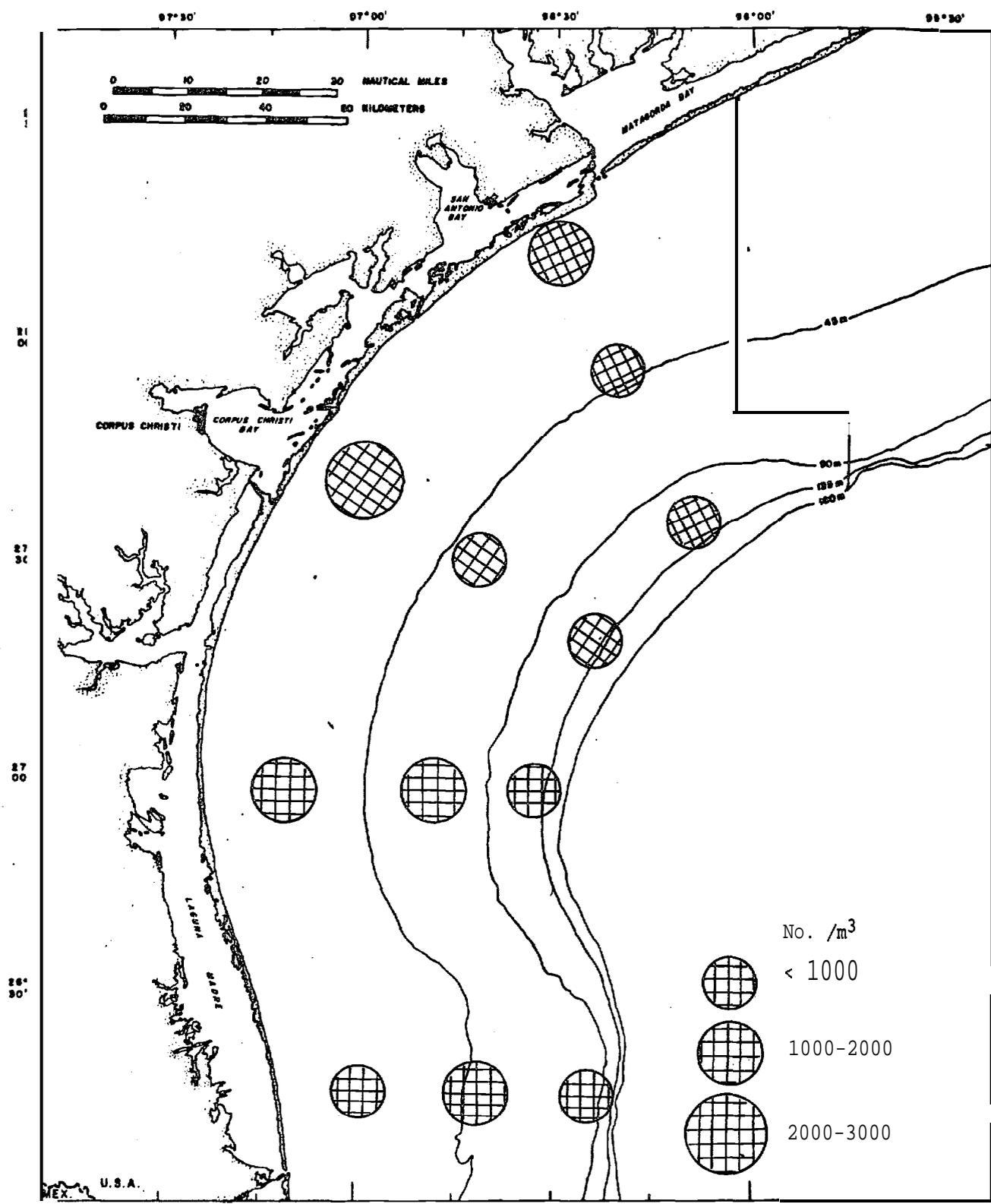


Figure 3-3. Average numerical abundance of copepods at each station, August - September.

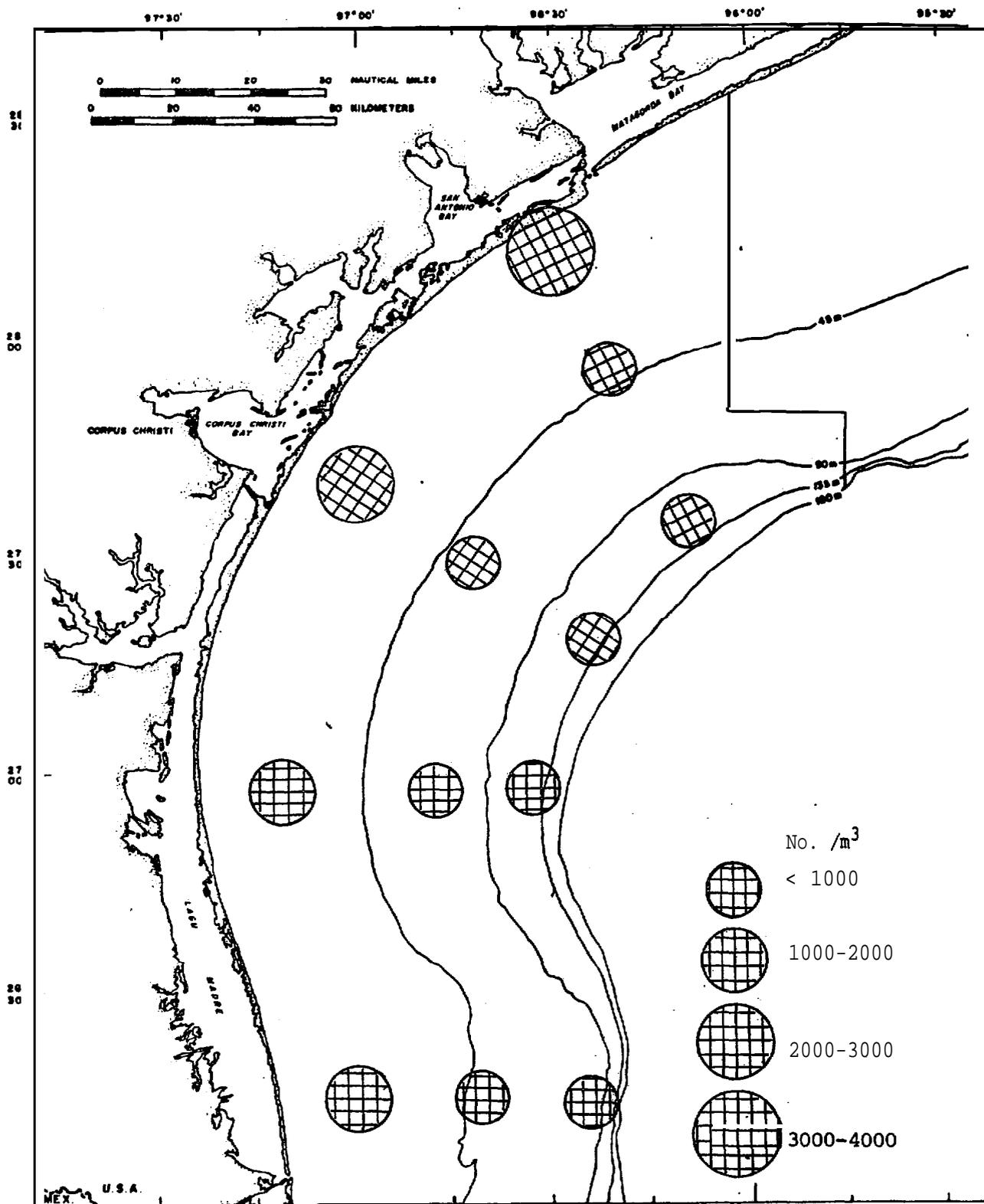


Figure 3-4. Annual mean of numerical abundance of copepods at each station.

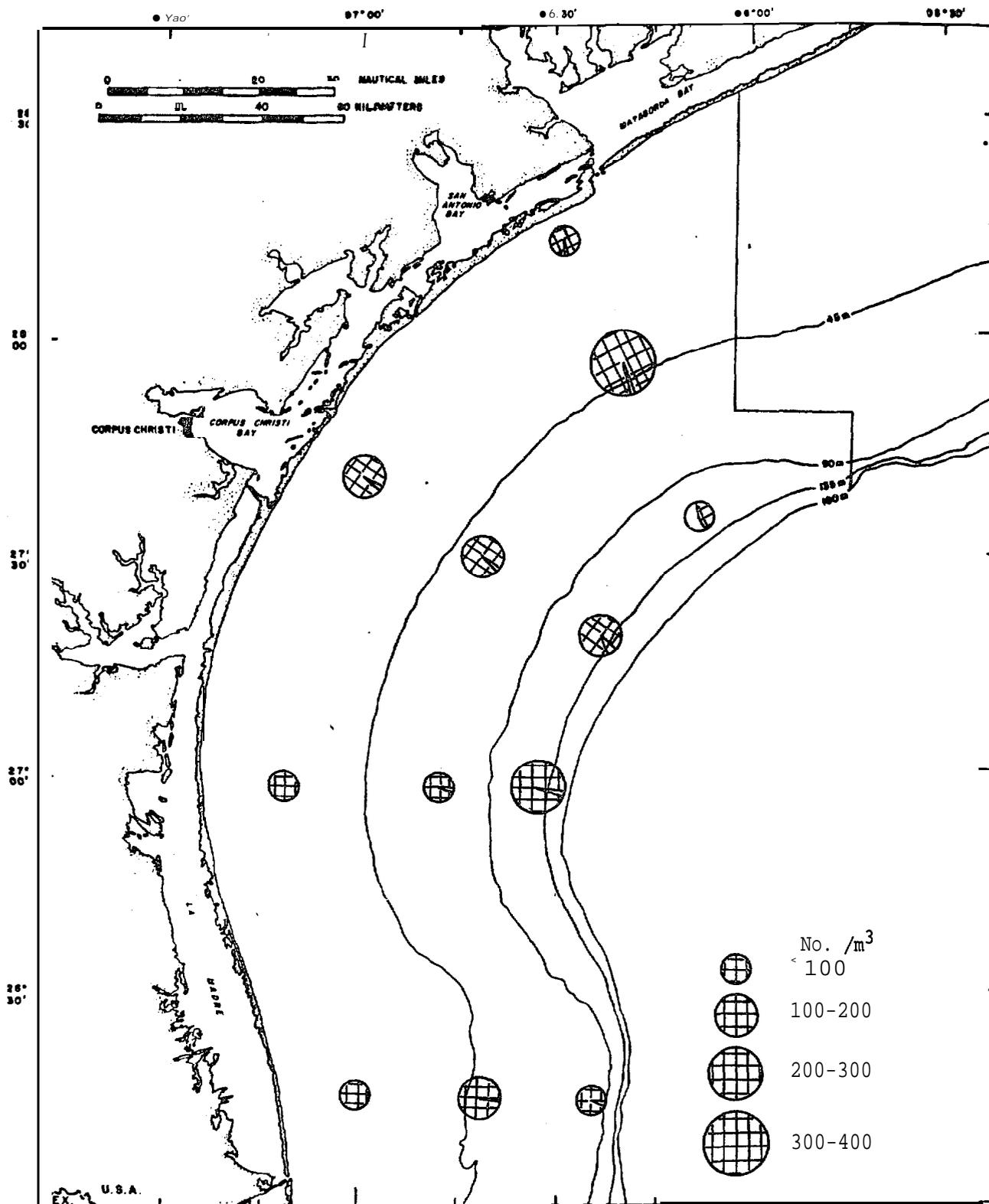


Figure 4-1. Average numerical abundance of ostracods and proportion of *Euconchoecia* (shaded), December - January.

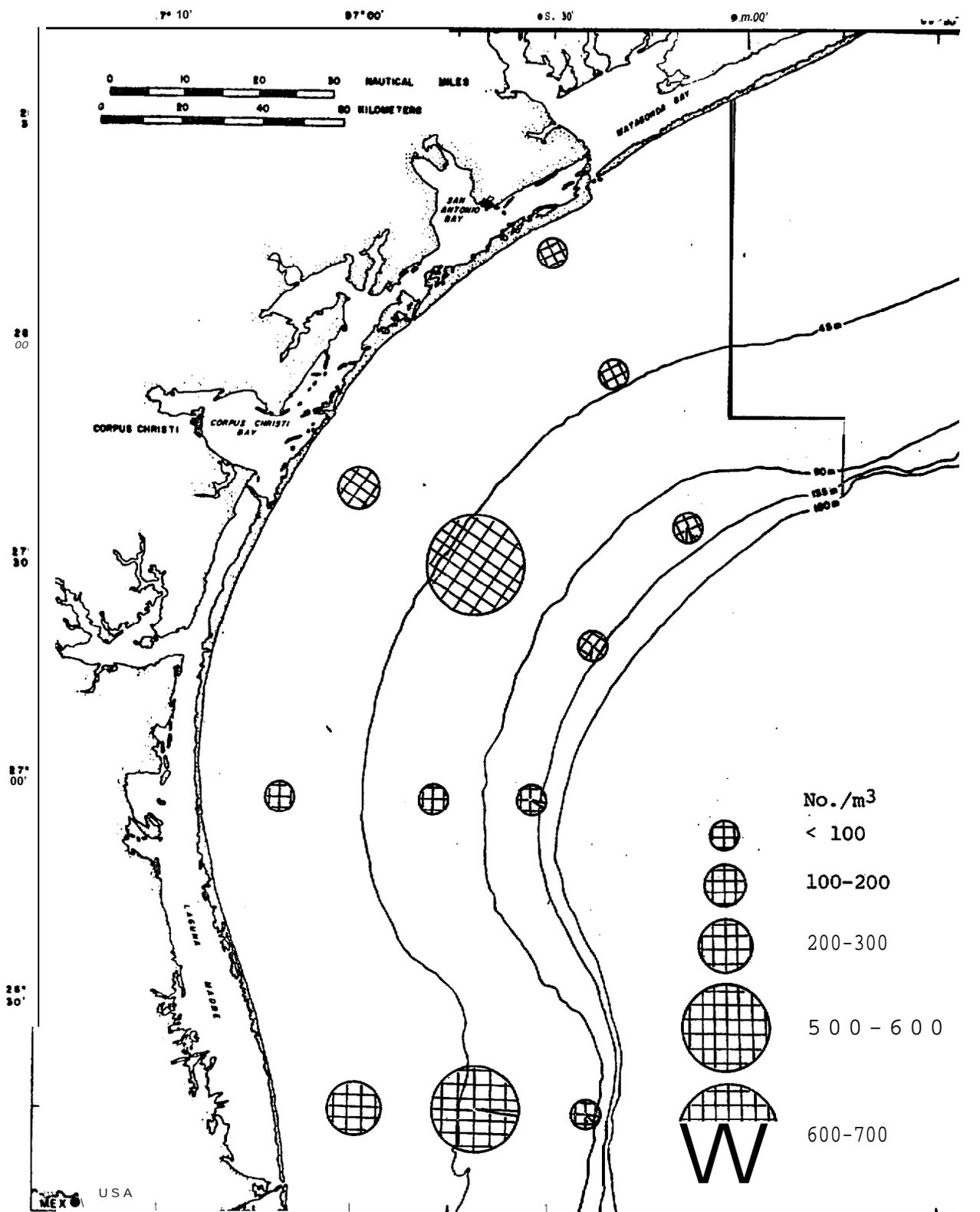


Figure 4-2. Average numerical abundance of ostracods and proportion of Euconchoecia (shaded), April - May.

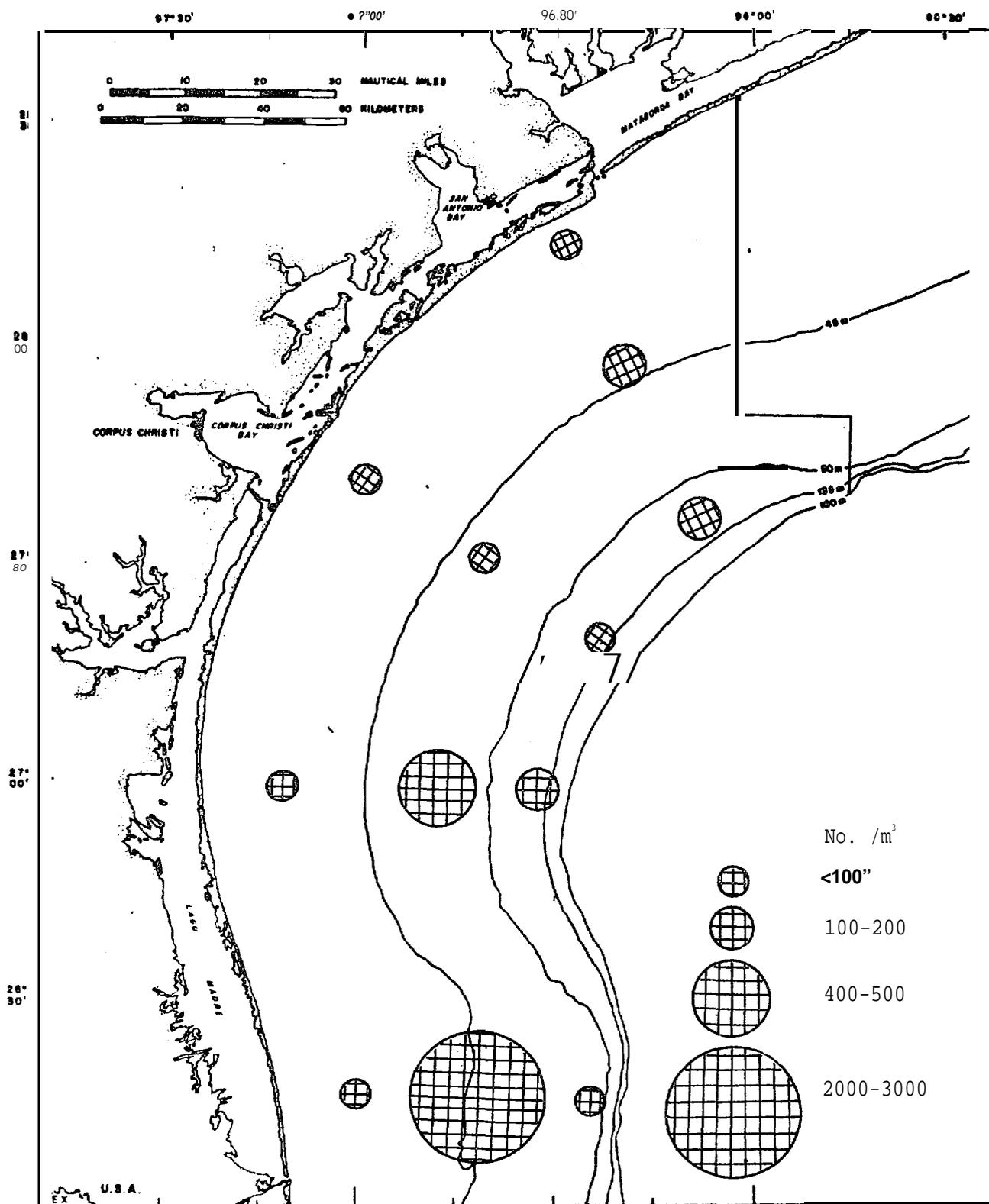


Figure 4-3. Average numerical abundance of ostracods and proportion of Euconchoecia (shaded), August - September.

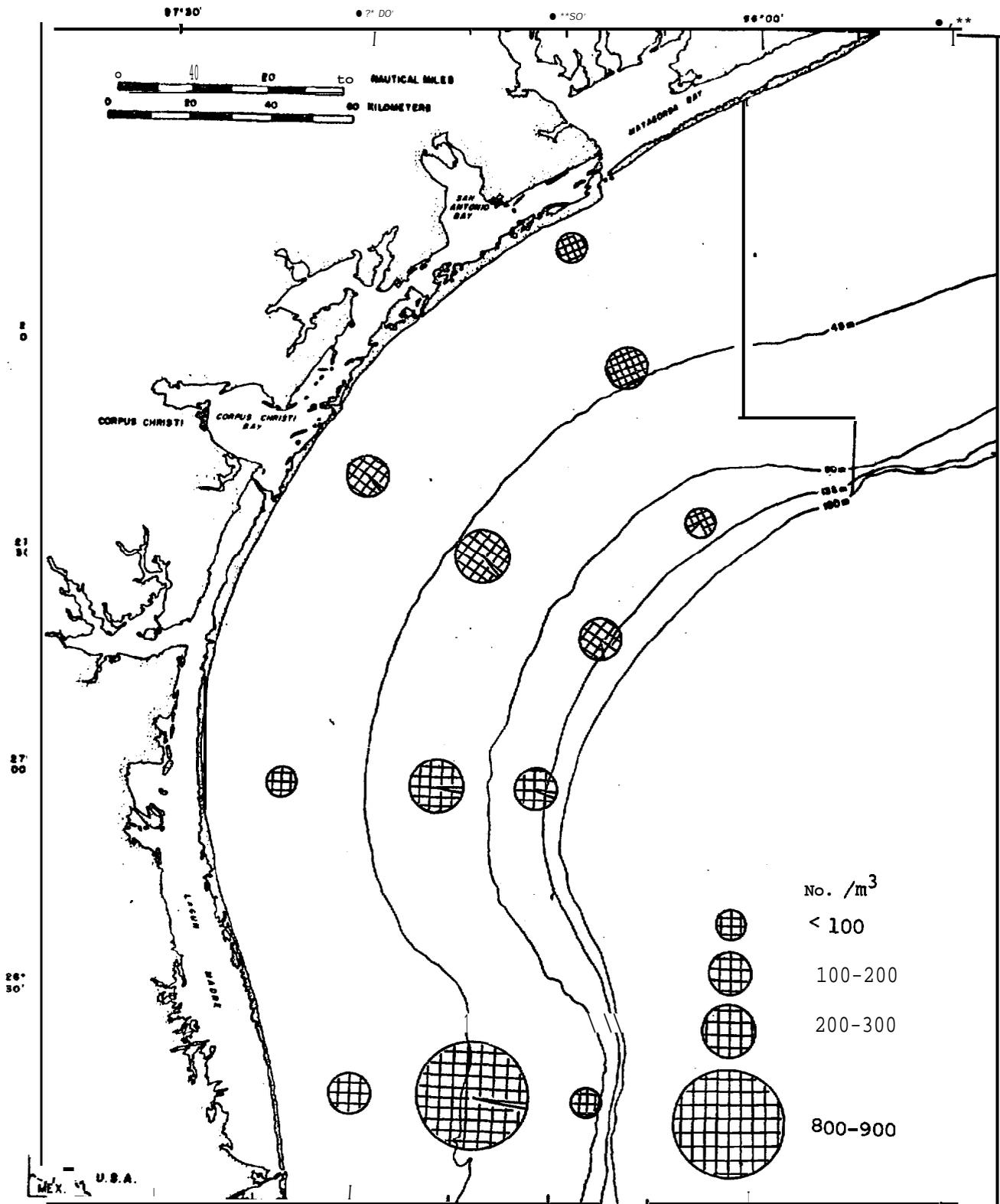


Figure 4-4. Annual mean of numerical abundance of ostracods and proportion of *Euconchoecia* (shaded).

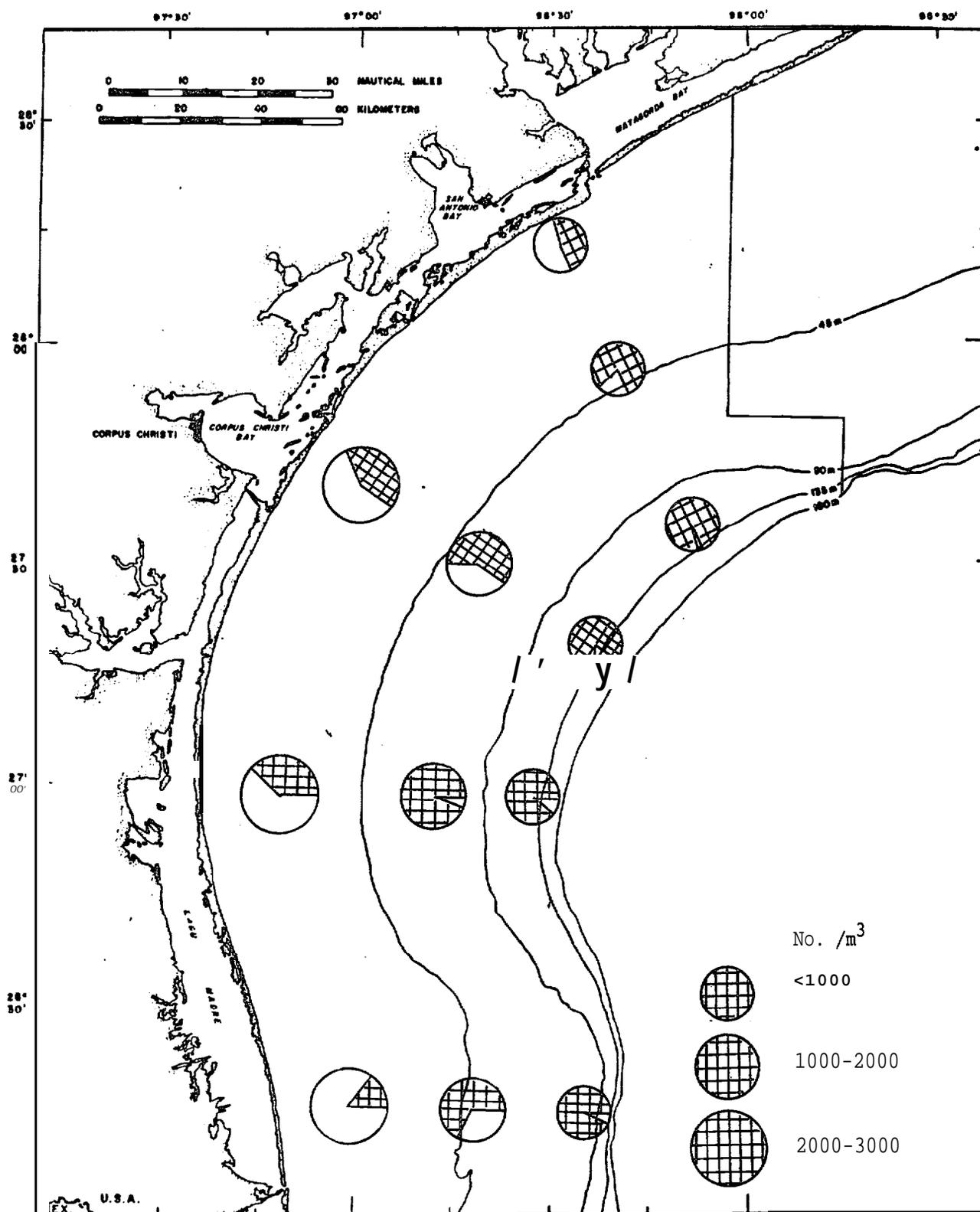


Figure 5-1. Average numerical abundance of adult female copepods and proportion of *Paracalanus parvus* group (*P. indicus* and *P. quasimoto*) (unshaded), December January.

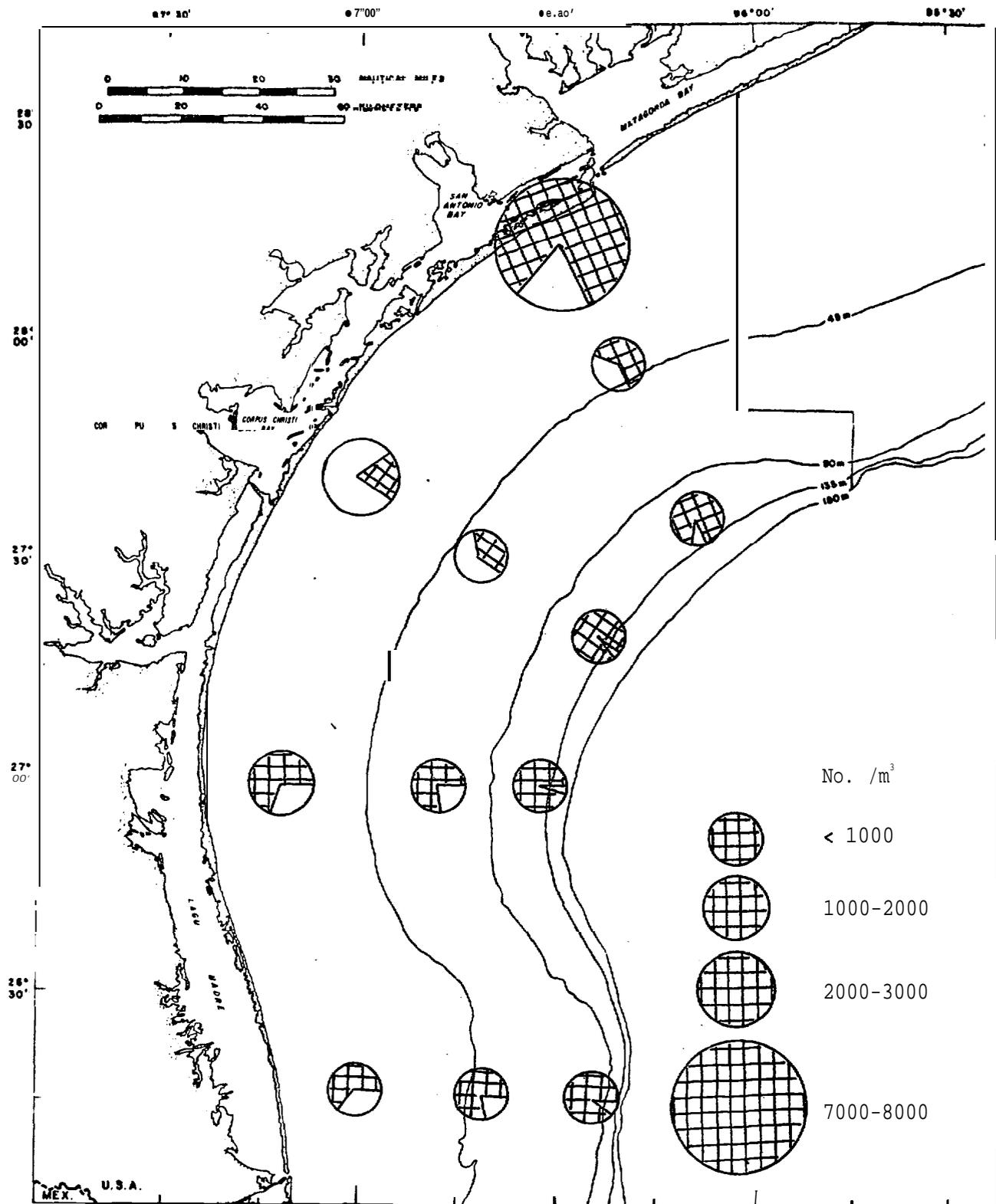


Figure 5-2. Average numerical abundance of adult female copepods and proportion of *Paracalanus parvus* group (*P. indicus* and *P. quasimoto*) (unshaded), April - May.

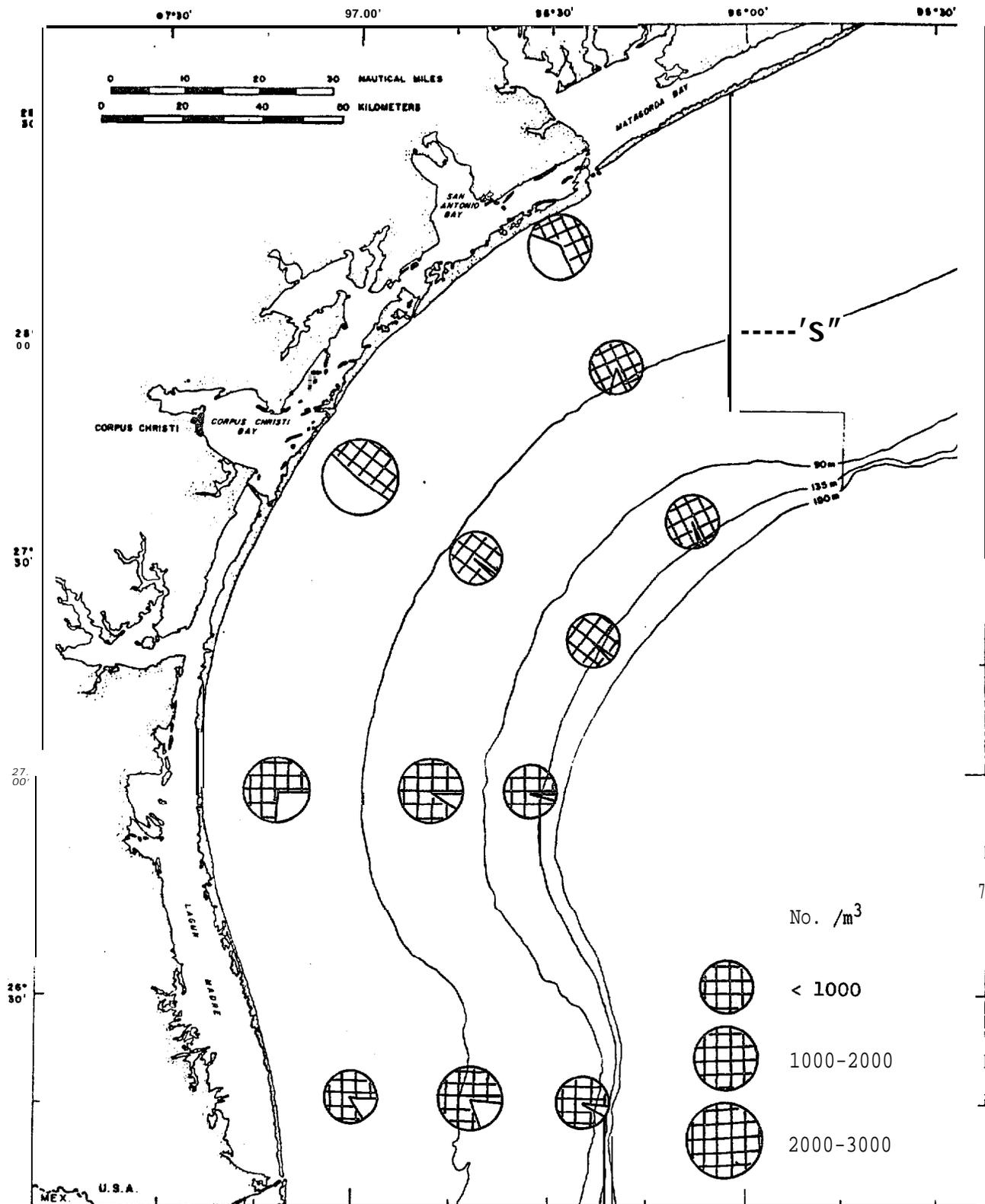


Figure 5-3. Average numerical abundance of adult female copepods and proportion of *Paracalanus parvus* group (*P. indicus* and *P. quasimoto*) (unshaded), August - September.

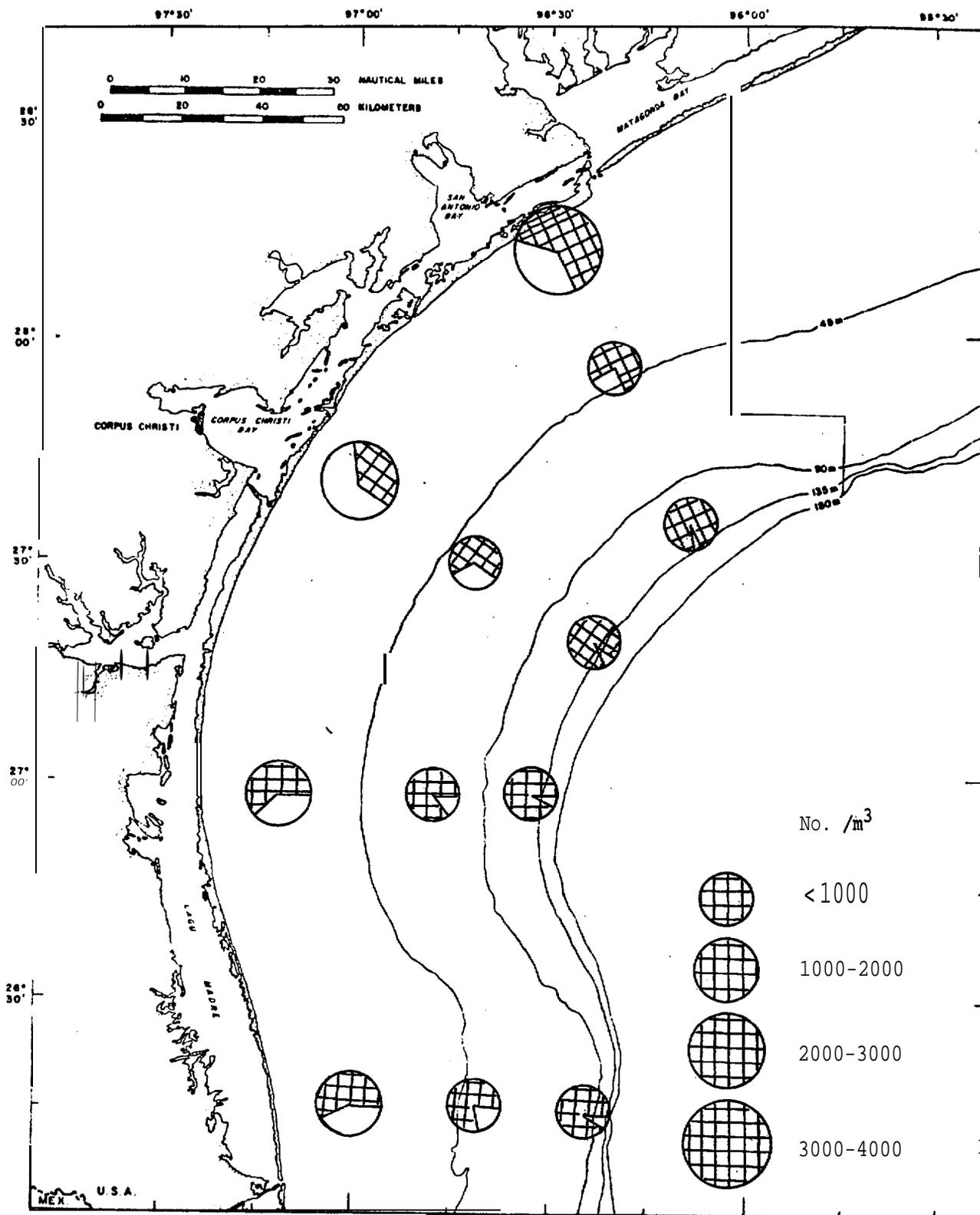


Figure 5-4. Annual mean of numerical abundance of adult female copepods and proportion of *Paracalanus parvus* group (*P. indicus* and *P. quasimoto*) (unshaded).

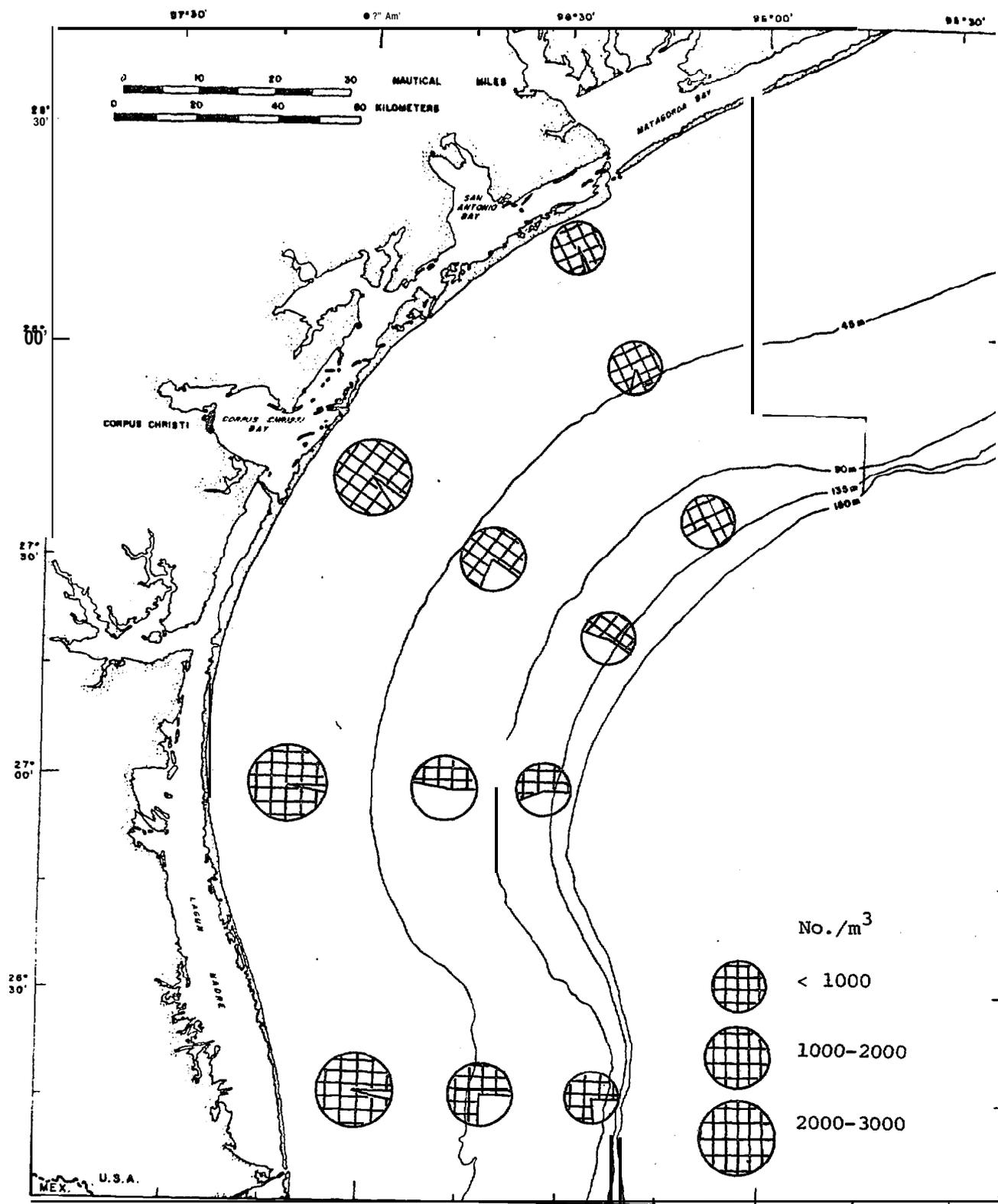


Figure 6-1. Average numerical abundance of adult female copepods and proportion of *Clausocalanus furcatus* (unshaded), December - January.

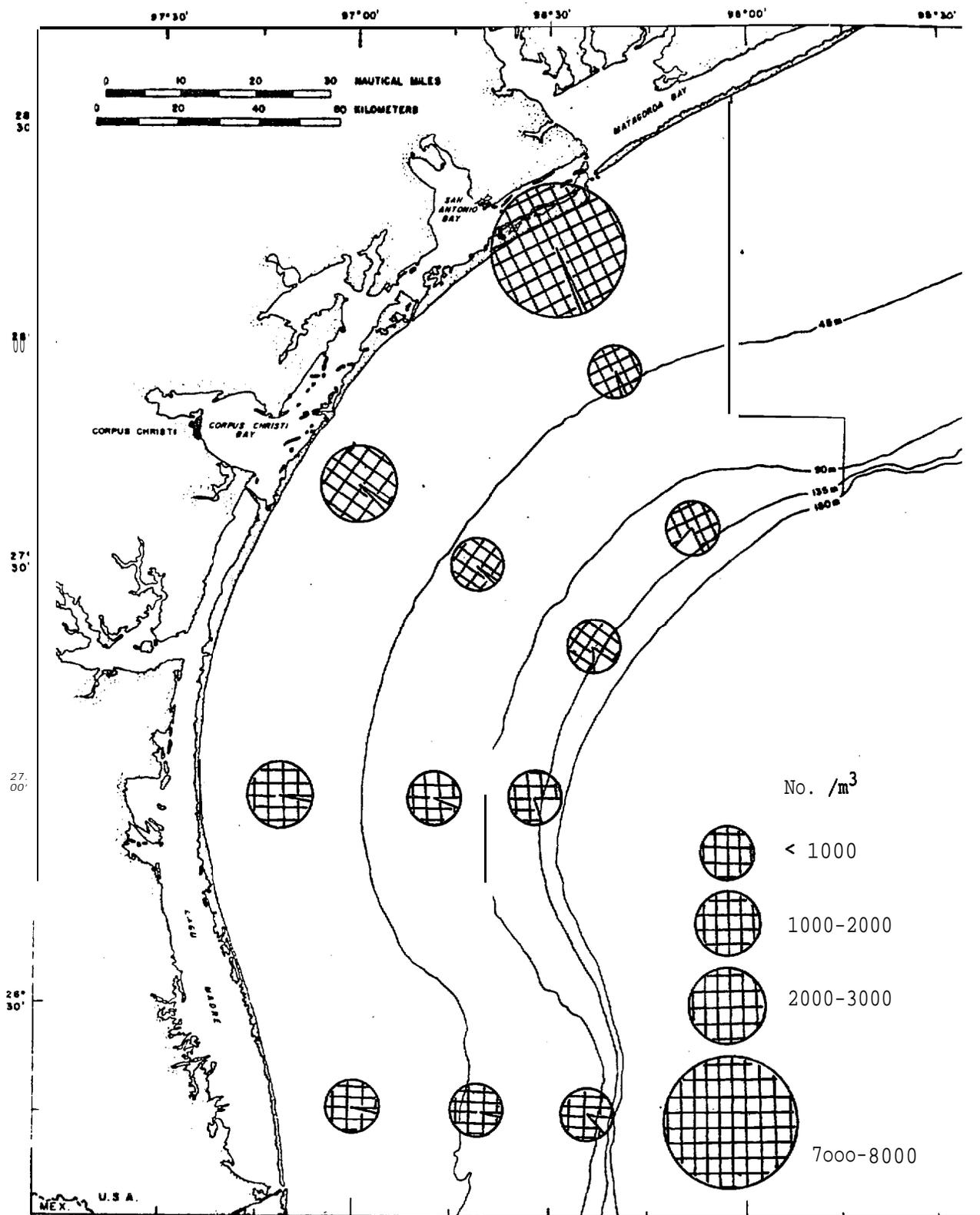


Figure 6-2. Average numerical abundance of adult female copepods and proportion of *Clausocalanus furcatus* (unshaded), April - May.

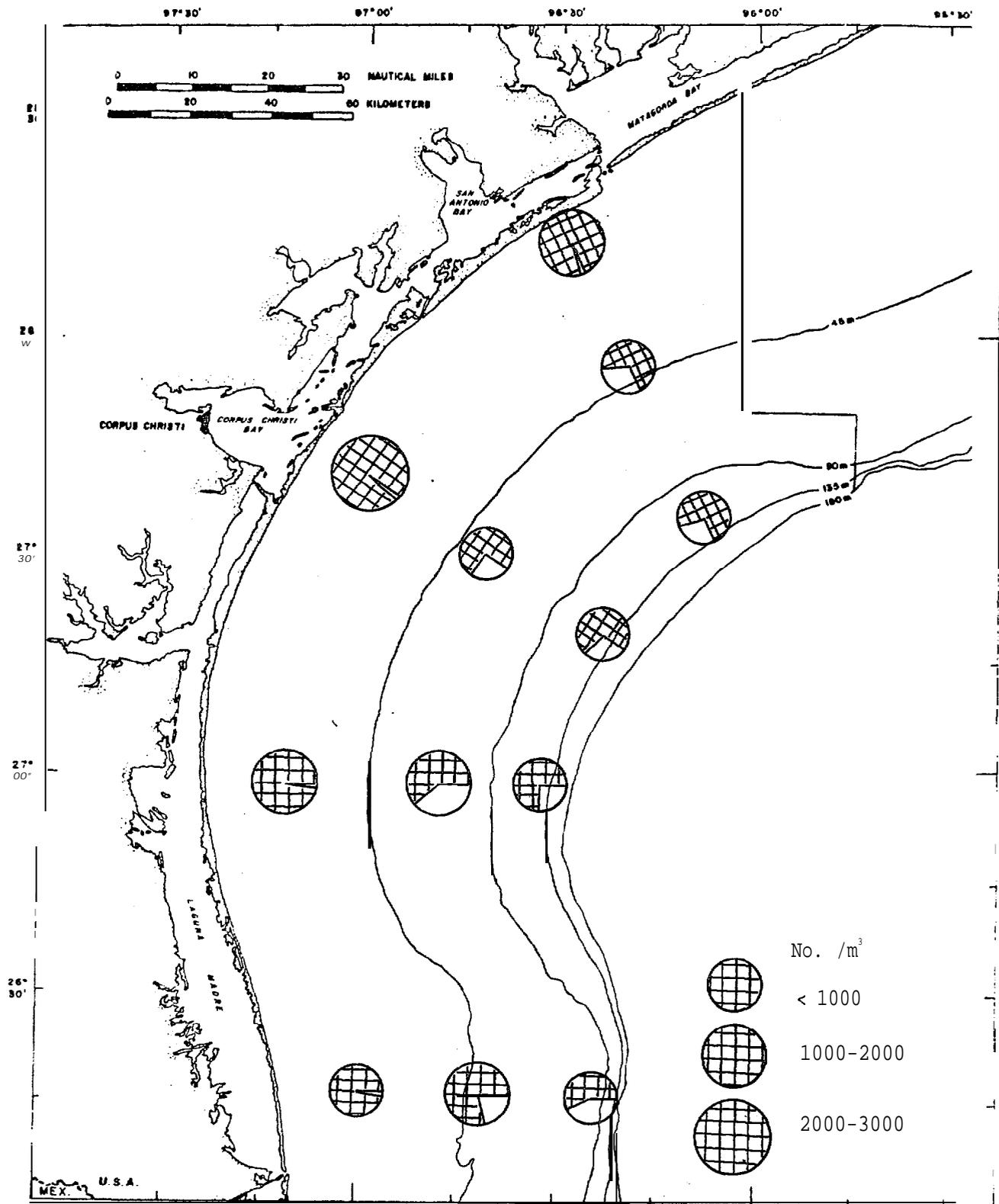


Figure 6-3. Average numerical abundance of adult female copepods and proportion of *Clausocalanus furcatus* (unshaded), August - September.

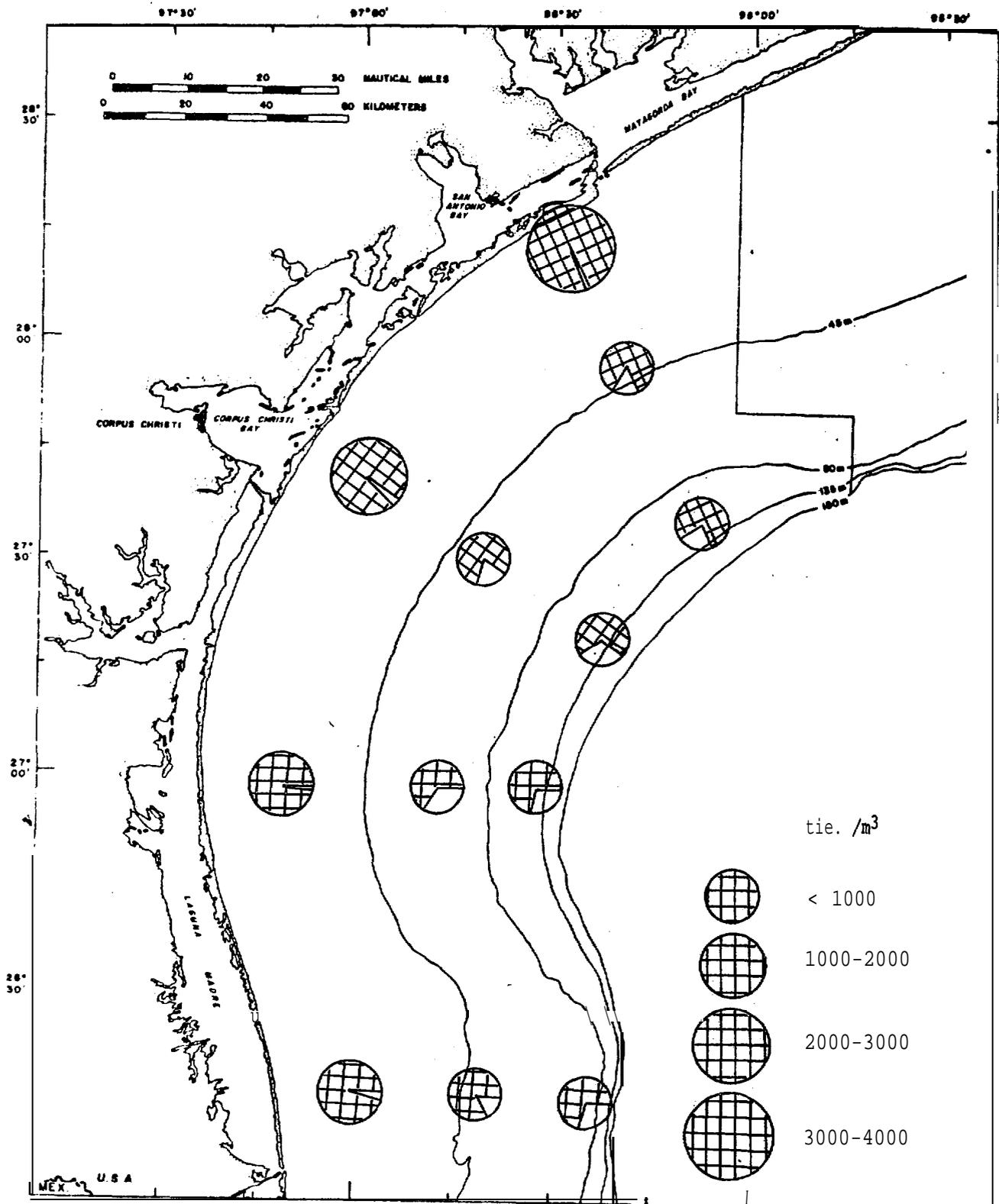


Figure 6-4. Annual mean of numerical abundance of adult female copepods and proportion of *Clausocalanus furcatus* (unshaded).

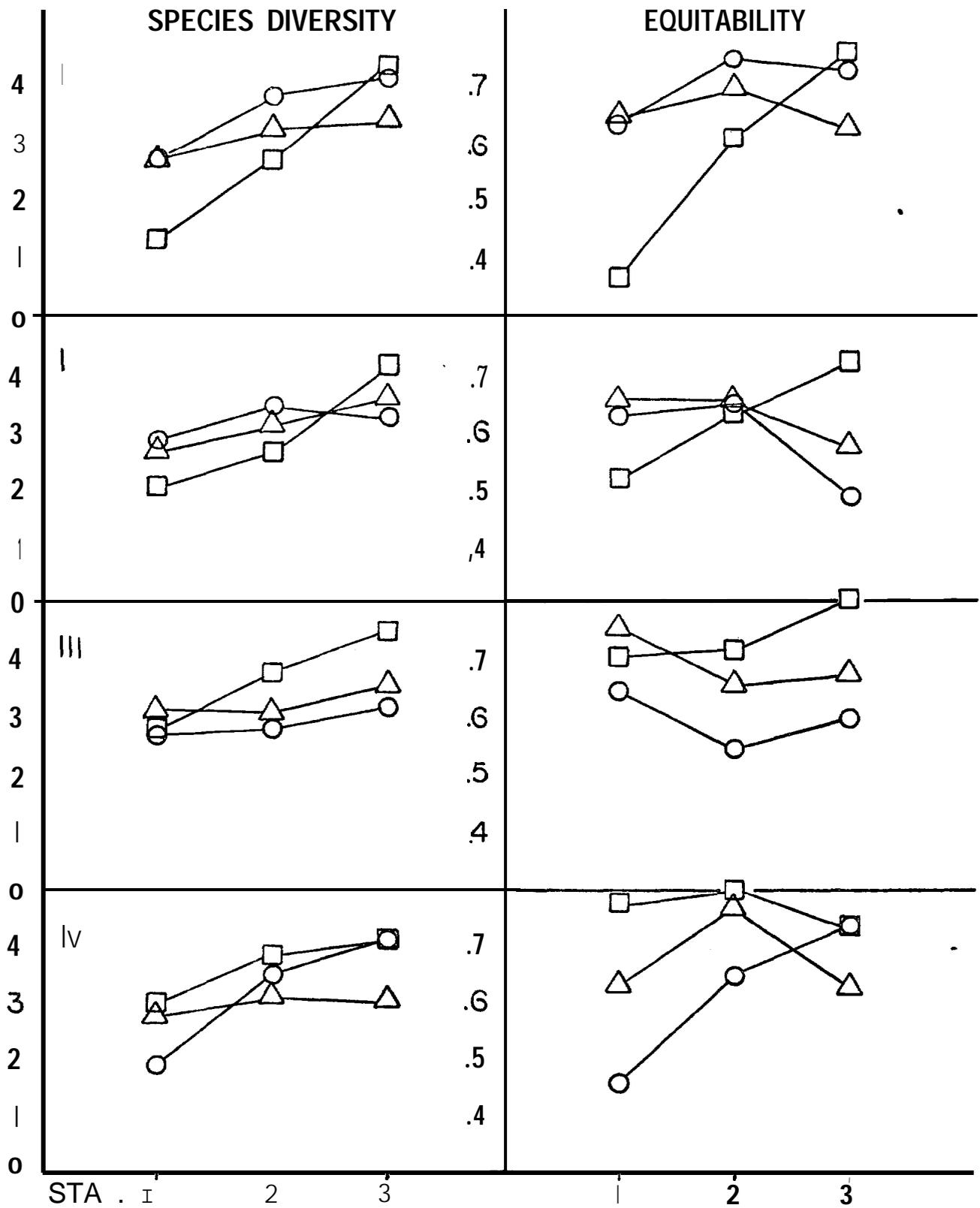


Figure 7. Species indices and coefficients of equitability ( $E = \frac{H(S)}{H_{\max}(S)}$ ), shown for each transect (I-IV). ○ - December-January, □ - April-May, △ - August-September.

**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. **Fol-**lowing 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, 3/11 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 samples 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.

<u>TRANSECT</u>	<u>STATION</u>	<u>SEASON</u>	<u>ALIQUOT SIZE</u>		<u>NUMBER PER EACH ALIQUOT</u>		<u>TOTAL NO. COUNTED</u>
			<u>No. 1</u>	<u>No. 2</u>	<u>No. 1</u>	<u>No. 2</u>	
I	<b>1</b>	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	<b>1</b>		1/800	1/40	269	254	523
	2		1/125	1/12.5	19	8	27
	3		*	*	*	*	*
III	<b>1</b>		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	<b>1</b>	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	<b>1</b>		1/250	1/12.5	250	96	346
	2		1/150	<b>1/15</b>	27	134	161
	3		1/100	1/10	0	41	41
111	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	<b>1</b>		1/125	1/12.5	148	58	206
	2		1/125	1/12.5	144	97	241
	3		1/125	<b>1/12.5</b>	34	21	55

\* Sample missing

BENTHOS PROJECT

Invertebrates

University of Texas, **Marine** Science Laboratory

Principal Investigator:  
J. **Selman** 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.

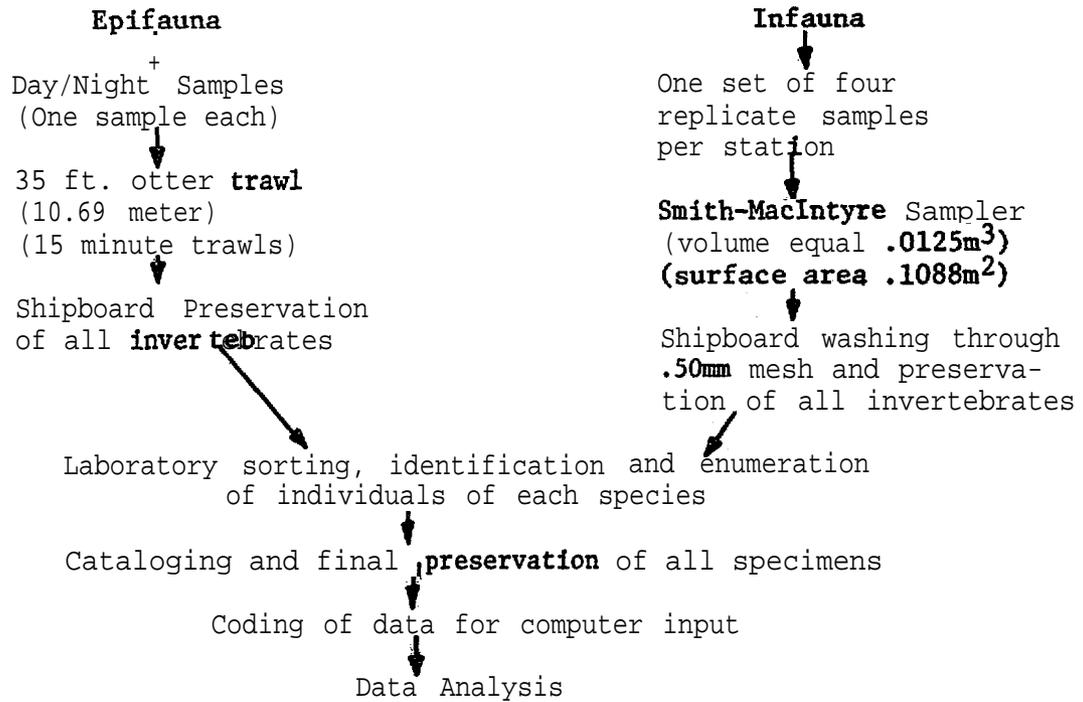
## METHODS

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  $.0125\text{m}^3$ . Four replicate samples were taken at each site occupation so that approximately  $.05\text{m}^3$  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:



## 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, **Dis-**  
**tributional** 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 spinicarpus**, **Astropecten duplicates** 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-commons 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 **Mojra strops**. 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 styli-fera) 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 **out-**

f lows. [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 111. **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 **epi-**fauna or the infauna. As with the observed variations in temporal **distri-**butions, 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 (Gauvin, 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 1/11. 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 samp Zing 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.	
<b>PHYLUM PORIFERA</b>							
<b>Demospongiae</b>							
Sponge (Unidentified)		2				3	5
<b>PHYLUM COELENTERATA</b>							
<b>Anthozoa</b>							
<i>Caliactis tricolor</i>		3		1			4
<i>Renilla mulleri</i>		5	1	127		8	141
Anenome sp.			1				1
<b>PHYLUM NEMERTINEA</b>							
<i>Cerebratulus lacteus</i>				4			4
Nemertean (Unidentified)	72		80		109		271
<b>PHYLUM NEMATODA</b>							
Nematode A		2	1		4		7
Nematode B							
<b>PHYLUM ANNELIDA</b>							
<b>Polychaeta</b>							
<b>Polynoidae</b>							
<i>Lepidasthenias</i> sp.				1			1
<b>Polydontidae</b>							
<i>Eupanthalis tubifex</i>	5	6	2				13
<i>Eupanthalis</i> sp.	1						1
<i>Polydontes lupina</i>	2	4					6
<b>Sigalionidae</b>							
<i>Sthenelais boa</i>	2		9				14
<i>Sthenelais limicola</i>	1						1
<i>Sthenelais</i> sp.							3

Table 1. Cont. ' d

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

Table 1. Cont. 'd

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

Table 1. Cent. 'd

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

Table 1. Cent. ' d

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

Table 1. Cont. 'd

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

Table 1. . Cent.'d

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

Table 1. Cont. 'd

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

Table 1. Cent. 'd

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

Table 1. Cont'd

	WINTER		SPRING		SUMMER		TOTAL
	Inf.	Epi.	Inf.	Epi.	Inf.	Epi.	
<i>Melita dentata</i>					1		1
<i>Melita nitida</i>	2		3				5
<i>Microdeutopus anomalous</i>			1				1
<i>Monoculodes norveicus</i>					1		1
<i>Photis cf. dentata</i>					3		3
<i>Phthisica marina</i>					1		1
<i>Sphyrapus cf. anomalous</i>					1		1
<i>Photis macrocoxa</i>			8				8
<i>Unicola serrata</i>			1		2		3
<i>Unicola irrorata</i>					6		6
<b>Isopoda</b>							
<i>Apseudid</i> sp.	5		6		10		21
<i>Aegathoa oculata</i>					1		1
<i>Cymothoa excisa</i>				1			1
<i>Lironeca texana</i>		2		6			8
<i>Xenanthura brevitelson</i>	2						2
<b>Copepoda</b>							
<i>Centropages velificata</i>			2				2
<i>Centropages</i> sp.	2		6				8
<i>Labidocera aestiva</i>	3					10	13
<b>Cumacea</b>							
<i>Eudorella emarginatus</i>			1		3		4
<i>Eudorella hispidata</i>	4		1		3		8
<i>Eudorella truncatula</i>			6				6
<b>Decapoda</b>							
<b>Natantia</b>							
<b>Solenocerinae</b>							
<i>Solenocera atlantidis</i>	1					7	8
<i>Solenocera vioscai</i>						232	987
<b>Penaeinae</b>							
<i>Parapenaeus longirostris</i>		28		845		11	887

Table 1. Cent. 'd

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

Table 1. Cent. 'd

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

Table 1. Cent. ' d

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

Table 1. Cont. 'd

	WINTER		SPRING		SUMMER		TOTAL
	Inf.	Epi.	Inf.	Epi.	Inf.	Epi.	
<i>Pinnixa sayana</i>					1		<b>1</b>
<i>Pinnixa</i> sp.	1						<b>1</b>
<b>Echiurida</b>							
Unknown #1	2		1				3
<b>Echinodermata</b>							
<b>Asteroidea</b>							
<i>Astropecten cingulatus</i>		15		8		12	35
<i>Astropecten duplicates</i>		34		318		9	361
<i>Astropecten</i> sp.		<b>1</b>				1	2
<i>Luidia clathrata</i>				<b>1</b>			1
<i>Roaster alexandri</i>		6					6
<i>Tethyaster vestitus</i>						4	4
<b>Ophiuroidea</b>							
Unidentified Ophiuroid	4				12		16
<b>Echinoidea</b>							
<i>Brissiopsis alta</i>		93		19		10	132
<i>Clypeaster ravenelii</i>				14		<b>1</b>	15
<i>Clypeaster subdepressus</i>						6	6
<i>Moira atrops</i>	2	68	<b>4</b>	8	1		83
<b>Hemichordata</b>							
<b>Tunicates</b>							
			1				<b>1</b>
<b>Fish</b>							
<i>Anchoa</i> sp.	1						<b>1</b>
<i>Bregmaceros atlanticus</i>						1	<b>1</b>
<i>Bregmaceros macciellandi</i>	1						7
<i>Neconger mucronatus</i>					1		1
<i>Prionotus stearnsi</i>							1
Eel larvae					<b>1</b>		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	<b>1</b>	AHo	12	2177	.2183	.086	.0692
Night	<b>I</b>	<b>1</b>	AFL	13	957	1.2435	.447	.9417
Day	I	2	APB	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	<b>AJB</b>	2	4	.5623	.510	.4999
Night	II	1	<b>AIJ</b>	7	86	1.0390	.473	.5778
Day	II	2	<b>AMA</b>	4	29	.8758	.547	.4630
Night	II	2	ALG	3	3	1.0986	.793	1.0000
Day	II	3	APD	<b>4</b>	9	1.2148	.671	.7500
Night	II	3	AOI	9	29	<b>1.6630</b>	.721	.7438
Day	III	1	<b>ASF</b>	3	6	.8675	.541	.6000
Night	III	1	<b>ARL</b>	7	82	1.3290	.605	.6654
Day	<b>III</b>	2	<b>AVK</b>	<b>1</b>	2	<b>N.C.</b>	<b>N.C.</b>	<b>N.C.</b>
Night	III	2	AUO	7	49	1.4729	.707	.7108
Day	III	3	AYH	<b>1</b>	9	<b>N.C.</b>	<b>N.C.</b>	<b>N.C.</b>
Night	III	3	<b>ANX</b>	15	207	1.709	.631	.735
Day	IV	1	BBG	8	18	1.8019	.782	.8431
Night	<b>IV</b>	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	<b>IV</b>	3	BPD	0	0	<b>N.C.</b>	<b>N.C.</b>	<b>N.C.</b>

Table 2. Cent. 'd

	Transect	Station	Rep.	Sp.	Ind.	H''	E	P.I.E.
Night	<b>IV</b>	3	BGM	6	44	<b>1.3285</b>	.683	.6754
SPRING								
Day	I	1	CBB	11	1315	1.1691	.456	.6131
Night	I	1	<b>CAH</b>	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	<b>II</b>	1	CKR	13	<b>4161</b>	.7534	.277	.3554
Night	II	1	<b>CJW</b>	15	1228	.7516	.271	.3148
Day	11	2	CNU	6	878	.3950	.192	.1666
Night	<b>II</b>	2	<b>CMZ</b>	13	1175	1.4797	.561	.7129
Day	11	3	CQW	2	10	.3250	.300	.1999
Night	11	3	CQB	5	54	.6176	.346	.2976
Day	<b>III</b>	1	CUE	6	119	1.2461	.601	.6554
<b>Night</b>	<b>III</b>	1	CTI	<b>11</b>	1029	1.0650	.417	.5820
Day	III	2	<b>CYA</b>	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	<b>III</b>	3	DAJ	11	162	1.8401	.767	.7799
Day	<b>IV</b>	<b>1</b>	DEC	8	432	1.4793	.674	.7296
Night	<b>IV</b>	<b>1</b>	DDJ	<b>12</b>	1442	<b>1.200</b>	.483	.642
Day	<b>IV</b>	2	DHB	8	13	1.9512	.887	.9102
Night	IV	2	<b>DGI</b>	16	142	1.9002	.657	.7861
Day	<b>IV</b>	3	DKG	10	27	1.7907	.746	.7777
Night	IV	3	DJK	14	<b>56</b>	2.0727	.764	.8129

Table 2. Cent. '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	.60i3	.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	<b>N.C.</b>	<b>N.C.</b>	<b>N.C.</b>
Night	II	1	EJW	6	95	1.6763	.863	.8089
Day	II	2	ENV	10	22	1.8553	.776	.7922
Night	11	2	<b>EMZ</b>	8	37	1.2429	.596	.5660
Day	11	3	EQW	7	17	1.6459	.793	.8088
Night	11	3	EQB	8	21	1.7371	.832	.8095
Day	<b>III</b>	<b>1</b>	EUE	6	79	1.1597	.558	.5556
Night	111	<b>1</b>	ETI	7	159	1.3355	.610	.6774
Day	111	2	EYA	8	56	1.3064	.625	.6506
Night	111	2	<b>EXL</b>	2	147	1.3302	.640	.6594
Day	III	3	FBC	<b>1</b>	5	<b>N.C.</b>	<b>N.C.</b>	<b>N.C.</b>
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	<b>40</b>	.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.

Transect	Station	Species	Winter			
			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	<b>19</b>	29	2.79	.948	.96
II	1	22	228	1.55	.501	.679
II	2	14	29	2.73	1.03	.913
II	3	<b>7</b>	12	1.82	.935	.893
111	<b>1</b>	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
<b>IV</b>	3	17	20	2.76	.974	.978
Spring						
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	<b>18</b>	2.44	.951	.954
III	1	34	301	<b>1.82</b>	.516	.648
III	2	25	53	2.86	.889	.933
III	3	13	21	2.44	.951	.947

Table 3. Cent. ' d

Transect	Station	Species	Individuals	H''	E	P.I.E.
IV	1	45	165	3.14	.825	.930
<b>IV</b>	2	17	30	2.71	.957	.958
<b>IV</b>	3	<b>7</b>	12	1.74	.894	.863
Summer						
I	<b>1</b>	25	144	1.96	.609	.681
I	2	28	58	2.91	.873	.954
I	3	10	14	2.24	.973	.956
11	1	27	116	2.48	.752	.864
II	2	19	33	2.71	.920	.945
II	3	11	15	2.30	.959	.952
III	<b>1</b>	23	116	2.40	.765	.837
III	2	19	30	2.70	<b>.917</b>	.944
<b>III</b>	3	26	65	2.73	.838	.902
<b>IV</b>	<b>1</b>	54	364	3.24	.812	.929
<b>IV</b>	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<sup>3</sup>) numbers within ( ) indicate number of replicates at which individuals occurred.

Station	Winter											
	1/1	2/1	3/1	1/11	2/11	3/11	1/III	2/111	3/111	1/IV	2/IV	3/IV
<i>Ampe lisca abdita</i>			1(1)			1(1)			1(1)			1(1)
<i>Ampelisca aequicornis</i>										4(3)		1(1)
<i>Ampelisca agassiz (typica)</i>	95(3)	4(3)	1(1)	78(4)	1(1)		103(4)	1(1)		3(2)		1(1)
<i>Armandia maculata</i>	<b>9(3)</b>	1(1)			1(1)							
<i>Aricidea jeffreysi</i>			2(2)									
<i>Automate evermanni</i>		4(2)		<b>1(1)</b>		1(1)					1(1)	
<i>Cossura delta</i>		1(1)			3(1)			1(1)	<b>1(1)</b>	3(2)	3(1)	1(1)
<i>Diopatra cuprea</i>	6(3)	1(1)		<b>1(1)</b>			3(2)			7(4)		
<i>Glycera americana</i>									3(1)	6(4)	3(2)	
<i>Lumbrinereis tetraura</i>				2(1)						13(4)		
<i>Lumbrinereis sp.</i>												
<i>Magelona pettiboneae</i>	2(2)	5(2)								2(1)		
<i>Magelona phyllisae</i>							1(1)			6(3)		
<i>Magelona sp.</i>	2(2)	10(2)		4(3)	3(1)		2(2)	3(1)		7(2)	9(4)	
<i>Mediomastus cali forniensis</i>		1(1)				1(1)				<b>1(1)</b>		
<i>Minuspio cirrifera</i>												
<i>Nereis sp.</i>	8(3)	15(4)		16(4)	5(3)					<b>26(4)</b>	1(1)	
<i>Nephtys incisa</i>	4(2)	4(2)		8(3)	2(2)		1(1)			2(2)		2(2)
<i>Ninoe nigripes</i>	3(2)	1(1)	2(2)	1(1)	1(1)		6(2)				1(1)	
<i>Notomastus latericeus</i>	11(3)	2(2)	1(1)				1(1)			3(3)		
<i>Onuphis sp.</i>												
<i>Paralacydonia paradoxa</i>			4(2)									1(1)
<i>Paraprionospio pinnata</i>	19(4)	27(4)	1(1)	98(4)	2(2)	2(2)		2(1)	5(4)	33(4)	4(3)	3(1)
<i>Prionospio steenstrupi</i>												
<i>Sigambra tentaculata</i>		<b>1(1)</b>	<b>1(1)</b>	1(1)	<b>1(1)</b>		1(1)		1(1)			1(1)
<i>Specocarcinus lobatus</i>		<b>1(1)</b>								1(1)		
<i>Tharyx setigera</i>		2(1)				2(2)			1(1)	10(3)		

Table 4. Cont. 'd

Station	Spring											
	1/1	2/1	3/1	1/11	2/11	3/11	1/111	2/111	3/111	1/IV	2/IV	3/IV
<i>Ampe lisca abdita</i>							1(1)				4(2)	
<i>Ampe lisca aequicornis</i>	6(3)	1(1)	24(2)	77(2)			16(1)				5(2)	
<i>Ampe lisca agassiz (typica)</i>	7(3)	1(1)	74(2)	44(2)			60(3)				3(2)	1(1)
<i>Armandia maculata</i>	1(1)							2(1)				
<i>Aricidea jeffreysi</i>												
<i>Automate evermanni</i>		1(1)		1(1)			1(1)	5(1)	1(1)	2(1)	1(1)	
<i>Cossura de lta</i>	4(3)	3(2)	3(1)	3(1)	6(3)	1(1)	1(1)	6(3)	3(2)	1(1)	2(2)	
<i>Diopatra cuprea</i>	11(3)	2(2)	1(1)	4(2)			2(2)	1(1)		5(4)	1(1)	
<i>Glycera americana</i>	2(2)	1(1)		2(1)				1(1)		6(3)		
<i>Lumbrinereis te traura</i>	7(2)		4(1)	13(3)			1(1)			8(3)		
<i>Lumbrinereis sp.</i>	1(1)	2(2)										
<i>Magelona pettiboneae</i>		3(2)					1(1)	11(4)		1(1)	3(3)	
<i>Magelona phyllisae</i>	55(4)		7(1)	22(2)	1(1)		1(1)			2(1)		
<i>Magelona sp.</i>	3(3)	1(1)		16(2)	8(3)		2(2)			9(4)		
<i>Mediomastus californiensis</i>	2(1)	1(1)					2(2)		1(1)			
<i>Minuspio cirrifera</i>												
<i>Nereis sp.</i>	3(3)	9(4)		10(3)	4(2)			1(1)		13(4)	2(1)	
<i>Nephtys incisa</i>	4(3)	5(2)	1(1)	3(2)	12(4)	2(2)	10(3)	2(2)		1(1)	2(1)	
<i>Ninoe nigripes</i>	6(3)	3(2)	1(1)	1(1)			9(4)				2(2)	
<i>Notomastus latericeus</i>	2(2)									6(4)		
<i>Onuphis sp.</i>										1(1)		
<i>Paralacydonia paradoxa</i>			4(2)									4(3)
<i>Paraprionospio pinnata</i>	314(4)	14(4)	1(1)	603(4)	7(3)	1(1)	167(4)	5(3)	3(2)	30(3)	1(1)	2(2)
<i>Prionospio steenstrupi</i>										25(3)		
<i>Sigambra tentaculata</i>			2(2)	2(1)	1(1)	3(2)		1(1)		2(2)		
<i>Speocarcinus lobatus</i>				2(1)					1(1)			
<i>Tharyx setigera</i>		3(1)	1(1)		4(3)		2(2)	3(2)	1(1)	5(3)	4(2)	1(1)

Table 4. Cont. 'd

Station	Summer											
	1/1	2/I	3/1	1/11	2/11	3/11	1/111	2/111	3/111	1/IV	2/IV	3/IV
<i>Ampe lisca abdita</i>										1(1)		3(3)
<i>Ampe lisca aequicornis</i>		<b>2(2)</b>		3(3)			3(3)			4(3)	3(2)	
<i>Ampe lisca agassiz (typica)</i>		1(1)		23(4)	1(1)	1(1)	43(4)	1(1)		29(3)		1(1)
<i>Armandia maculata</i>				4(2)			2(1)			11(4)	1(1)	
<i>Aricidea jeffreysi</i>												
<i>Automate evermanni</i>				3(2)		2(2)			5(4)	2(2)	5(3)	3(2)
<i>Cossura delata</i>	2(2)	4(2)		3(2)	5(3)	2(2)		3(1)	1(1)	1(1)	4(3)	1(1)
<i>Diopatra cuprea</i>	4(3)			1(1)			2(2)				15(3)	
<i>Glycera americana</i>	2(2)	1(1)	1(1)						1(1)		11(3)	8(2)
<i>Lumbrinereis tetraura</i>		3(2)					7(4)	1(1)			2(2)	
<i>Lumbrinereis sp.</i>											1(1)	4(2)
<i>Mage lona pettiboneae</i>		9(4)		5(2)	4(1)		2(1)	5(3)			15(2)	4(2)
<i>Mage lona phyllisae</i>	80(4)	1(1)		2(2)							9(3)	
<i>Mage lona ep.</i>	1(1)				1(1)		1(1)				9(2)	
<i>Mediomastus cali formiensis</i>				4(1)								
<i>Minuspio cirrifera</i>		1(1)										
<i>Nereis ep.</i>	7(2)	4(3)		11(4)			3(1)		1(1)	44(4)		
<i>Nephtys incisa</i>	2(1)	4(3)	2(2)	1(1)	5(3)	2(1)	12(4)	2(1)		1(1)	2(1)	
<i>Ninoe nigripes</i>	6(4)		2(2)	1(1)	1(1)	3(2)	2(2)		2(2)			
<i>Notomastus latericeus</i>				2(2)			4(3)			3(2)	2(1)	
<i>Onuphis sp.</i>												1(1)
<i>Paralacydonia paradoxa</i>			2(2)		1(1)				1(1)			6(3)
<i>Paraprionospio pinnata</i>	1(1)	4(3)		29(3)	3(2)	1(1)	4(2)		4(3)			4(3)
<i>Prionospio steenstrupi</i>										73(4)	2(1)	1(1)
<i>Sigambra tentaculata</i>	4(2)			3(3)		1(1)	10(4)		6(3)	1(1)	1(1)	
<i>Speocarcinus lobatus</i>	1(1)									5(2)		
<i>Tharyx setigera</i>	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 <sup>summer</sup> epifauna collections. Numbers indicate individuals per 15 minute trawl tow, day and night.

Station	Winter																								
	1/1		2/1		3/1		1/II		2/11		3/11		1/111		2/111		3/111		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	
<i>Renilla mulleri</i>	1	4																							
<i>Squilla chydea</i>			1	11			1	2	1										5		8				
<i>Squilla empusa</i>	15	55		1			1						1	6					24						
<i>Amusium papyraceus</i>								72			14														
<i>Penaeus aztecus</i>			3	30			35	8	1	1	4	4	40	9	9			4	15	1	22			22	
<i>Penaeus duorarum</i>	1												1						4						
<i>Penaeus setiferus</i>	28	58					2																		
<i>Solenocera vioscai</i>				1		4			5		4					7						12		4	
<i>Parapenaeus longirostris</i>					9	12			4		2					2									
<i>Trachypenaeus similis</i>	12	122	2	64			44		1	1		1	25					3	55		18				
<i>Sicyonia brevirostris</i>							2						4					1	24	1				12	
<i>Sicyonia dorsalis</i>	6	113	17	287				21	1				1		24			6	34		5				
<i>Callinectes similis</i>	3	142	4	16			1	1	17		2		5		7										
<i>Portunus gibbesii</i>		3		2				2											1						
<i>Portunus spinicarpus</i>	5		1		13	8			4															3	
<i>Acanthocarpus alexandri</i>					5	3					1														
<i>Anasimus latus</i>					1	1			1																
<i>Reninoides louisianensis</i>					1	2			2																
<i>Astropecten cingulatus</i>									14						1										
<i>Astropecten duplicatus</i>			3	28	3																				
<i>Brissiopsis alta</i>					3	14			76								15	4							
<i>Clypeaster ravenelli</i>																									

Table 5. Cent. 'd

spring

Station	1/1		2/I		3/1		1/II		2/11		3/11		1/111		2/111		3/111		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	
<i>Renilla mulleri</i>		5	4				2	115						1											
<i>Squilla chydea</i>										24	1		3	1	21			22	5		18			2	
<i>Squilla empusa</i>	51	65					22		2				14					22	8		1				
<i>Amusium papyraceus</i>					9						9			3	3	21	20				2		1	3	
<i>Penaeus aztecus</i>		1	1	17			4	1	1		26	1	20	6	21	1	12	8	10		3	1		2	
<i>Penaeus duorarum</i>								1																	
<i>Penaeus setiferus</i>	19	3						7													1				
<i>Solenocera vioscai</i>				112		5				265	6			124			24					17		1	
<i>Parapenaeus longirostris</i>				2	1	12				11				82		2	14				3	9	1	1	
<i>Trachypenaeus similis</i>	674	1135		69			130	1009	22	325	45	9468	47	45				113	436			56			
<i>Sicyonia brevirostris</i>				1									3					1	1		1	7		2	
<i>Sicyonia dorsalis</i>	448	135	146	460			480		45	468		51	22		1			166	697		1	23	2		
<i>Callinectes similis</i>	108	60	2	3			6	23	3			4	41	1			1	97	258				1		
<i>Portunus gibbesii</i>	8	6	4	1			1			3		5													
<i>Portunus spinicarpus</i>				6				1		5											1	1		1	
<i>Acanthocarpus alexandri</i>					3																				
<i>Anasimus latus</i>					1	1	7							5	4	2	14					1		1	
<i>Raninoides louisianensis</i>					1	1					1						3								
<i>Astropecten cingulatus</i>									6		2														
<i>Astropecten duplicatus</i>	1						196		7	2		7	1		5			3	2			1			
<i>Brisiopsis alta</i>																									
<i>Clypeaster ravens lli</i>																							5	9	

Table 5. Cent. 'd

Station	Summer																								
	1/1		2/I		3/1		1/11		2/11		3/11		1/111		2/111		3/111		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	
<i>Renilla mulleri</i>			1										4												
<i>Squilla chrysea</i>	6		1	2			6	1	1				2		11			1				18	1	1	
<i>Squilla empusa</i>			1	1		1	6		1				4	7	1							1			
<i>Amisium papyraceus</i>				1		1			1		8						5						1	4	
<i>Penaeus aztecus</i>	5	69	2	42	2	3	1	22	1	1	51	2		73	4	12			9		6	19	2	5	
<i>Penaeus duorarum</i>			1																39						
<i>Penaeus setiferus</i>																									
<i>SO lenocera vioscai</i>				13		51					1	5			41							110		11	
<i>Parapenaeus longirostris</i>										1	1													9	
<i>Trachypenaeus similis</i>	5	8		3				19						6								10			
<i>Sicyonia brevirostris</i>																						8		10	
<i>Sicyonia dorsalis</i>	12	1	391	52			20	10	3				6	21	18	74			15		78	10	33	330	2
<i>Callinectes similis</i>	57	97		14			22	1	24	5	1		12	49	28	4			9	12		14			
<i>Portunus gibbesii</i>		1											2	1	1					9					
<i>Portunus spinicarpus</i>				2	14		8	2														1		24	
<i>Acanthocarpus alexandri</i>					1																				
<i>Anasimus latus</i>					1	3									4									3	
<i>Raninoides louisianensis</i>					1																				
<i>Astropecten cingulatus</i>					7										1									4	
<i>Astropecten duplicatus</i>	2	4						2											1						
<i>Brissopsis alta</i>					4						6														
<i>Clypeaster ravene lli</i>																									5

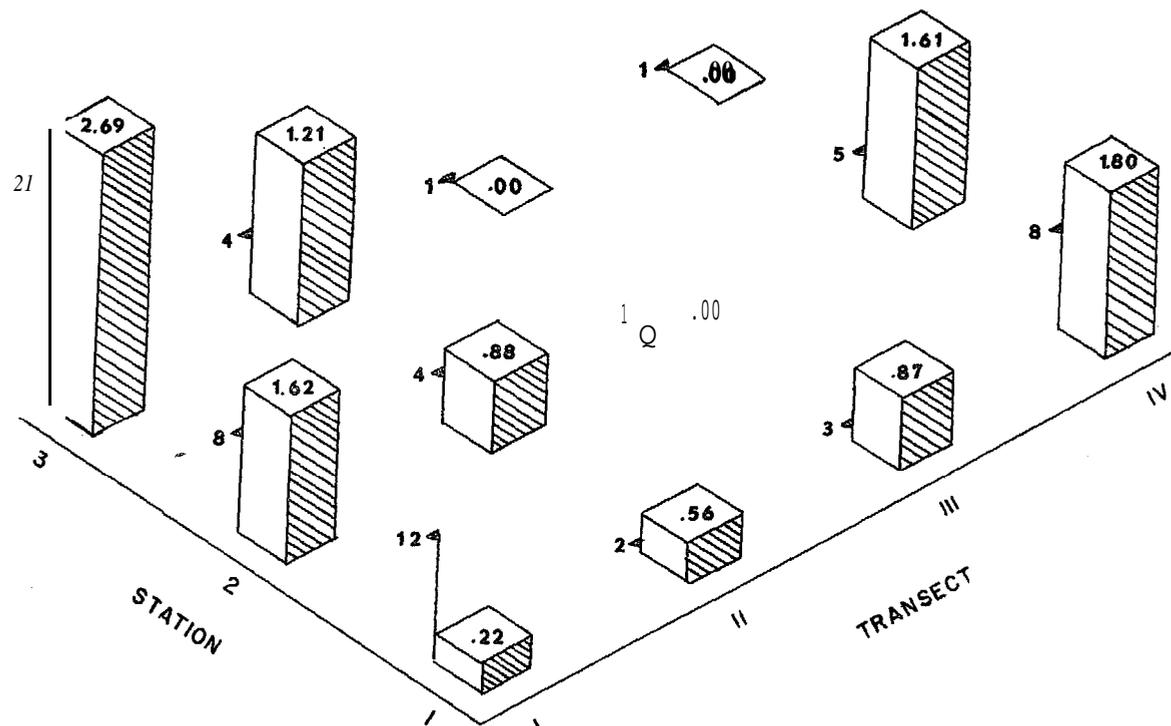


Figure 1. . Shannon diversity values -  $H'$  (number on histograms) and number of species (flag on histograms) for the diurnal winter epifauna samples.

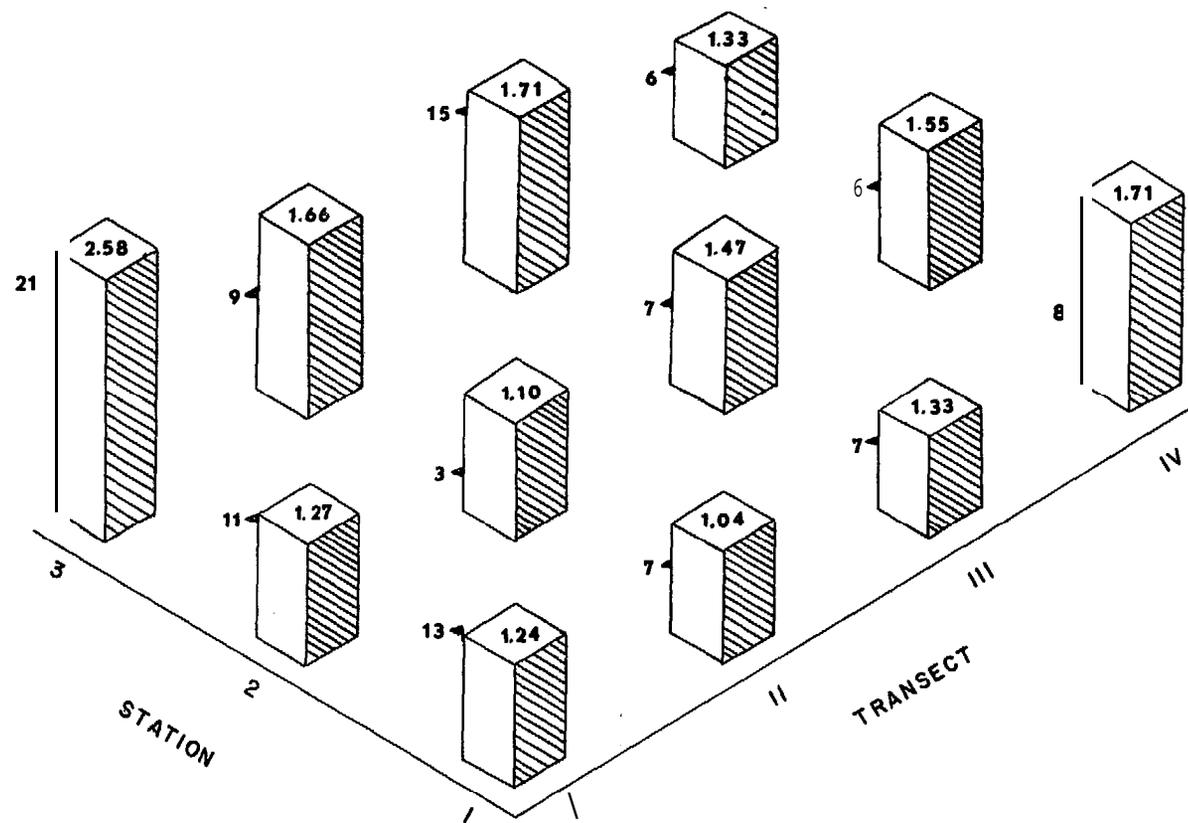


Figure 2. Shannon diversity values -  $H'$  (number on histograms) and number of species (flag on histograms) for the nocturnal Winter epifauna samples.

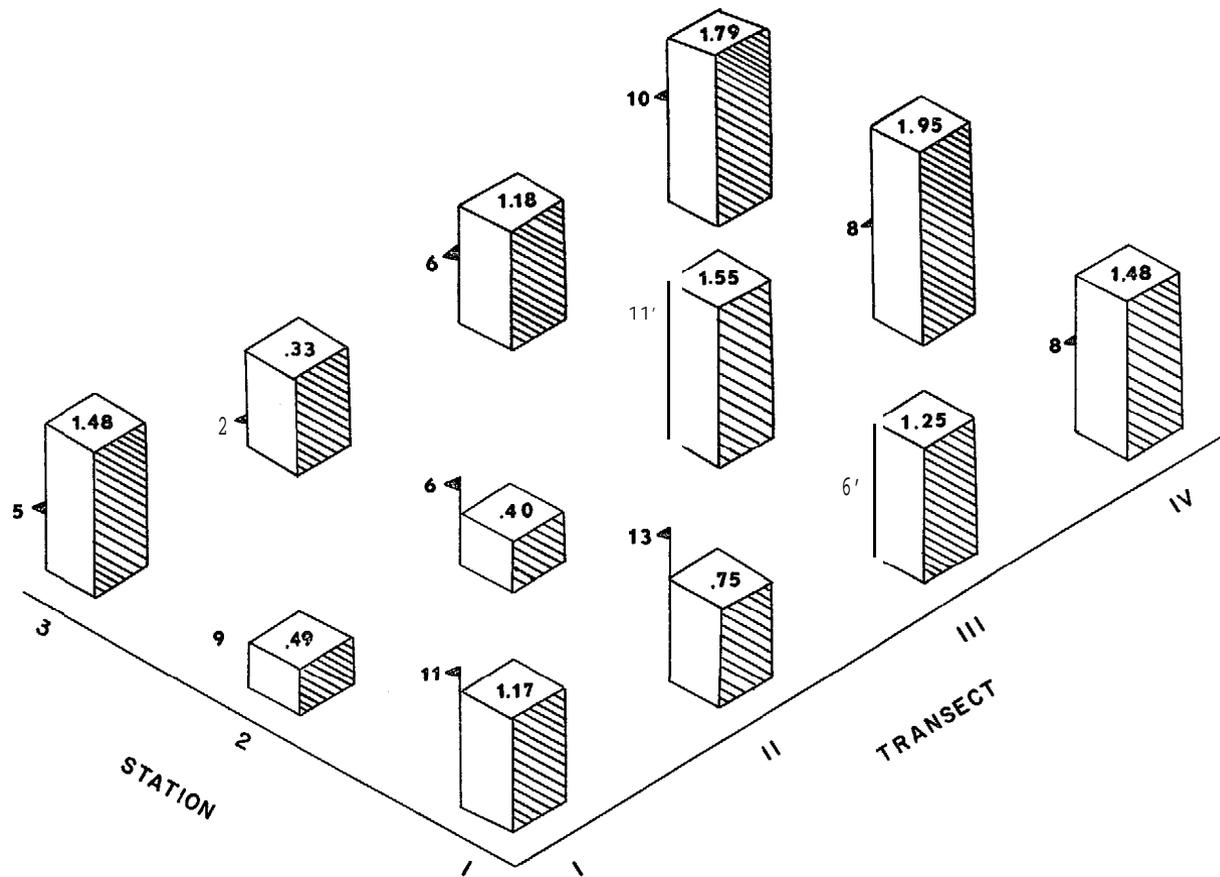


Figure 3. Shannon diversity values -  $H'$  (number on histograms) and number of species (flag on histograms) for the diurnal Spring epifauna samples.

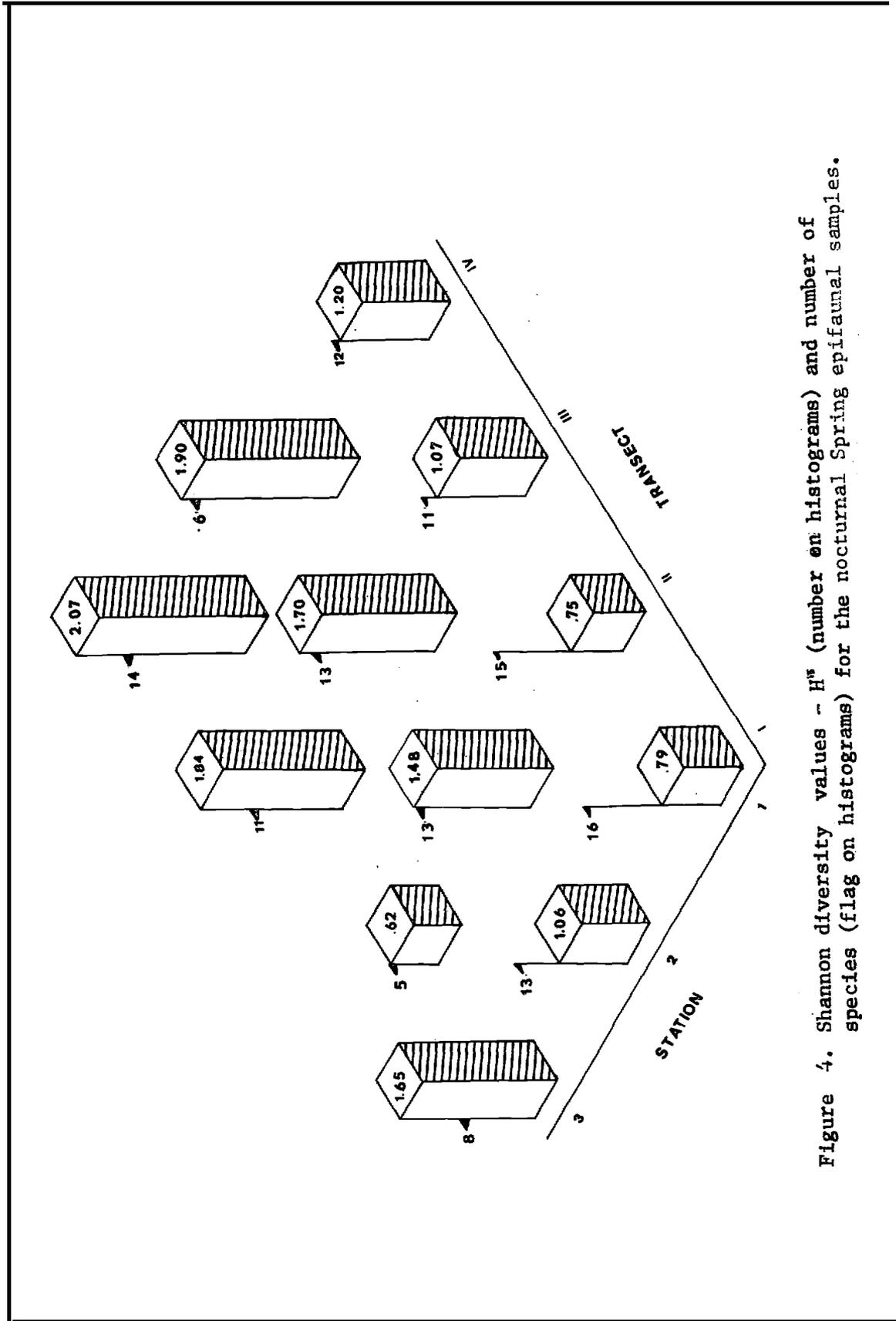


Figure 4. Shannon diversity values -  $H'$  (number on histograms) and number of species (flag on histograms) for the nocturnal Spring epifaunal samples.

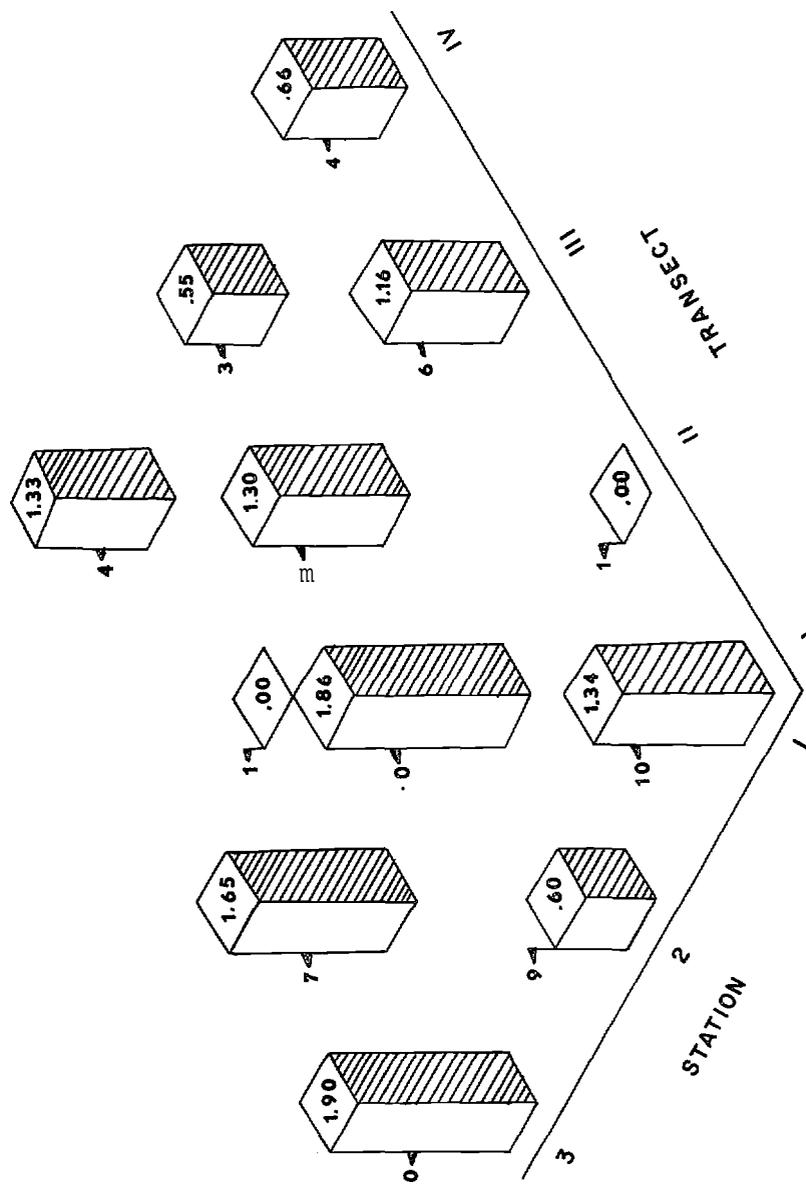


Figure 5. Shannon diversity values -  $H'$  (number on histograms) and number of species (flag on histograms) for the diurnal Summer epifauna samples.

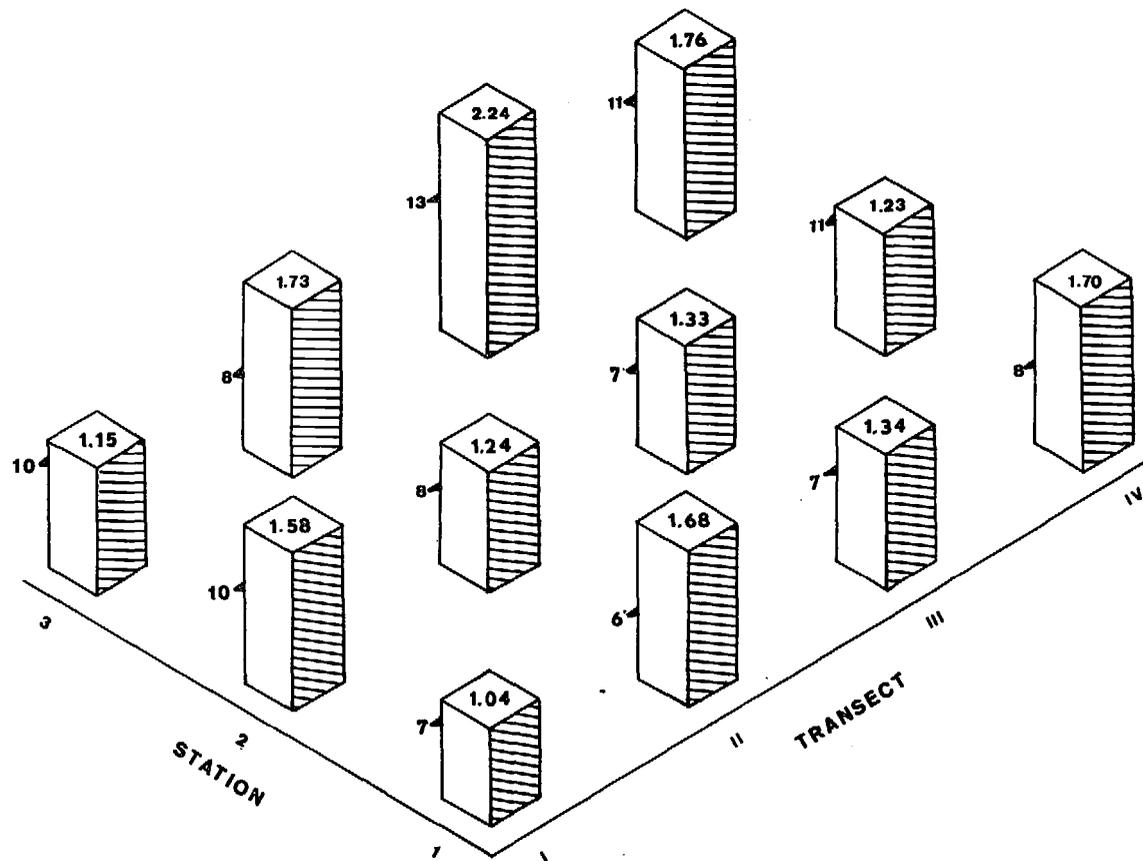


Figure 5. Shannon diversity values -  $H'$  (number on histograms) and number of species (flag on histograms) for the nocturnal Summer epifaunal samples.

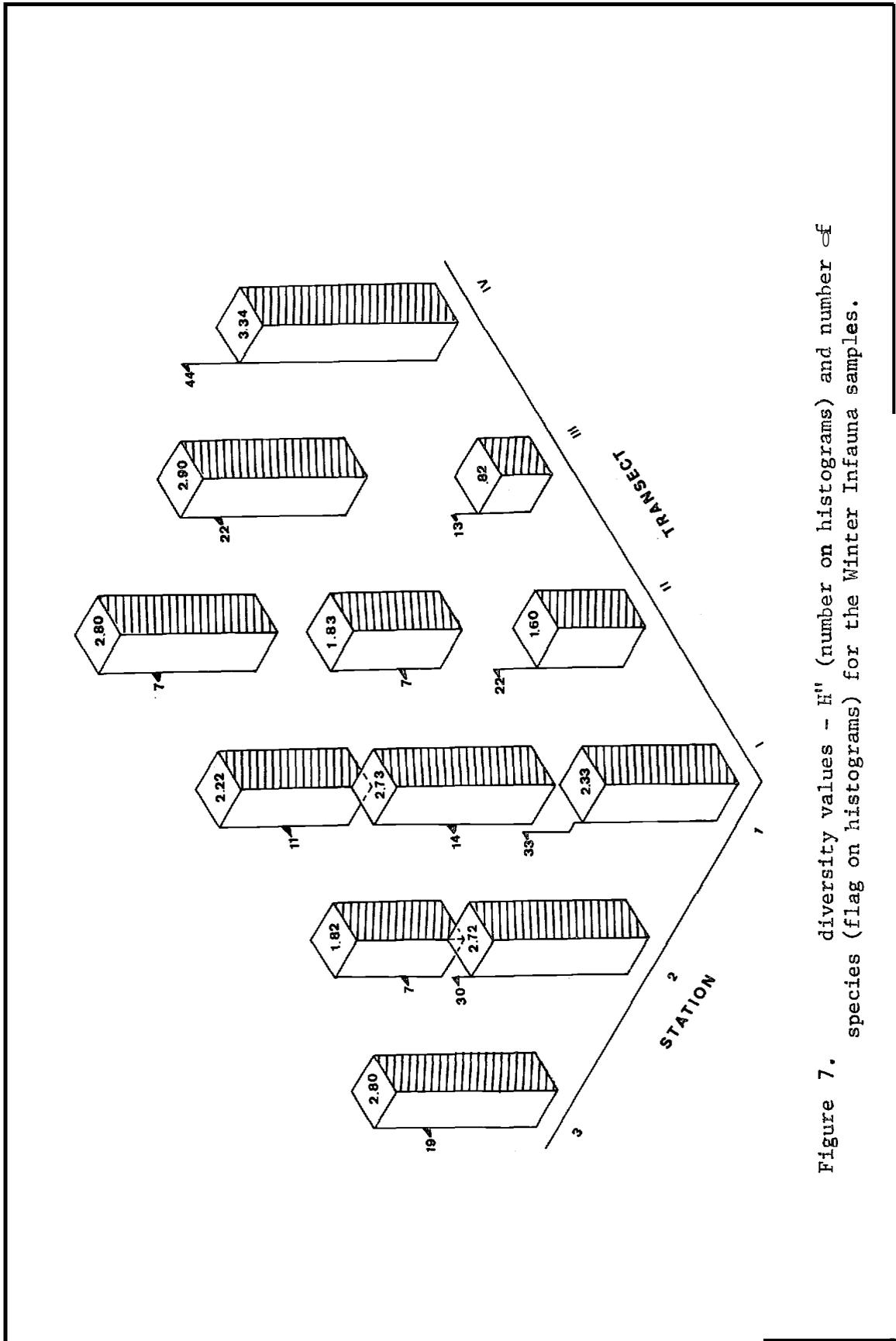


Figure 7. diversity values -  $H'$  (number on histograms) and number of species (flag on histograms) for the Winter Infauna samples.

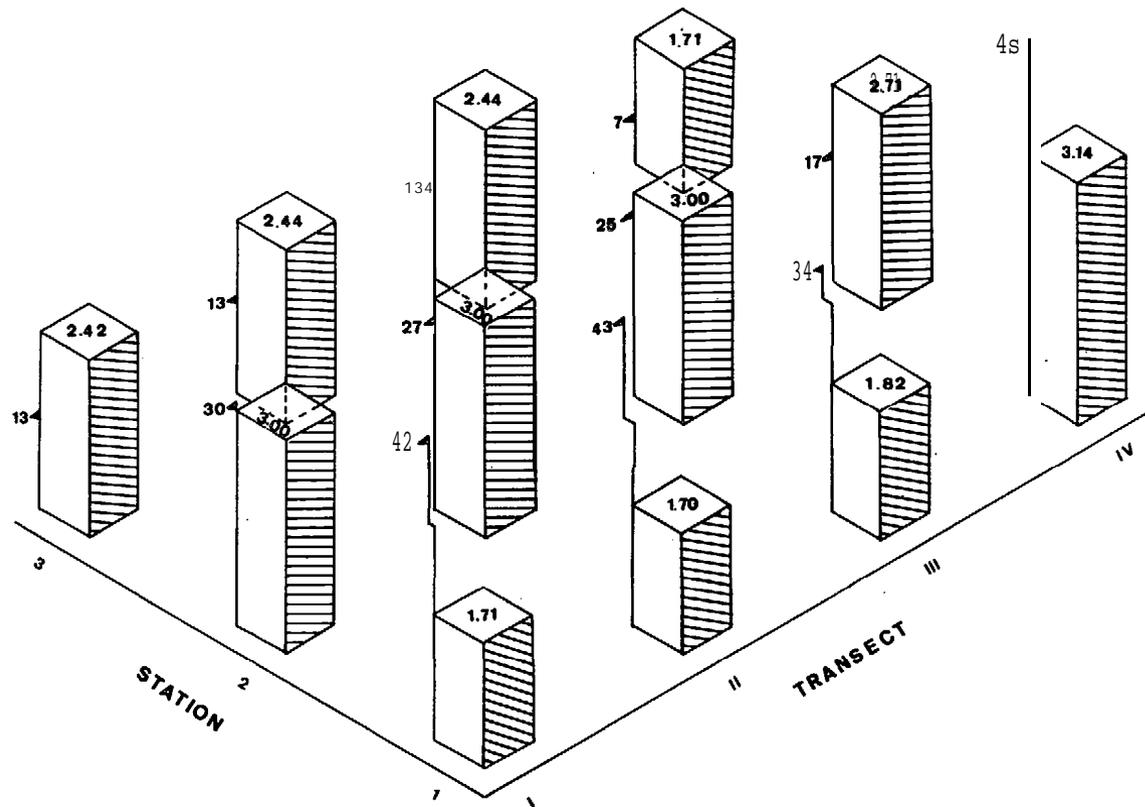


Figure 8. Shannon diversity values -  $H'$  (number on histograms) and number of species (flag on histograms) for the Spring Infaunal samples.

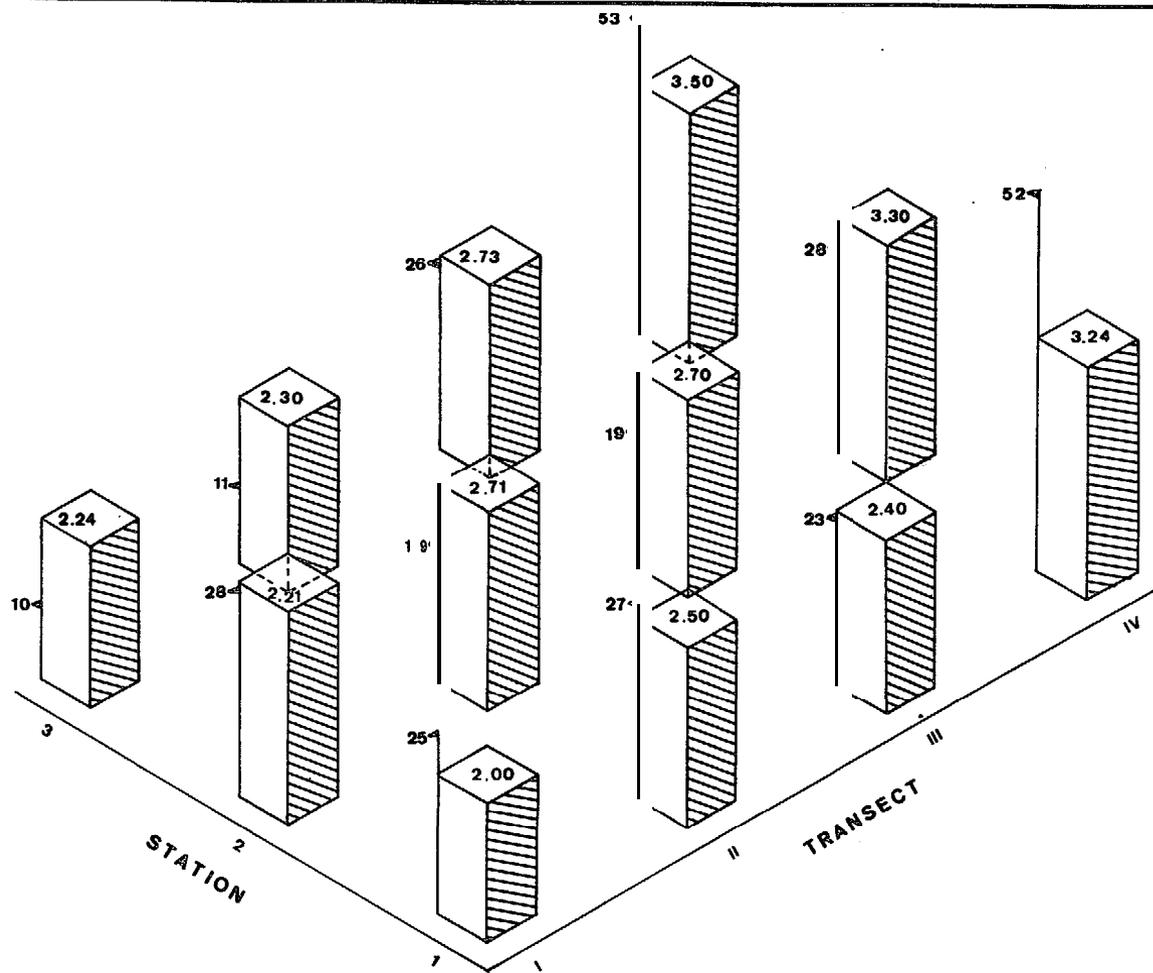


Figure 9. Shannon diversity values -  $H'$  (number on histograms) and number of species (flag on histograms) for the Sumner Infaunal samples.

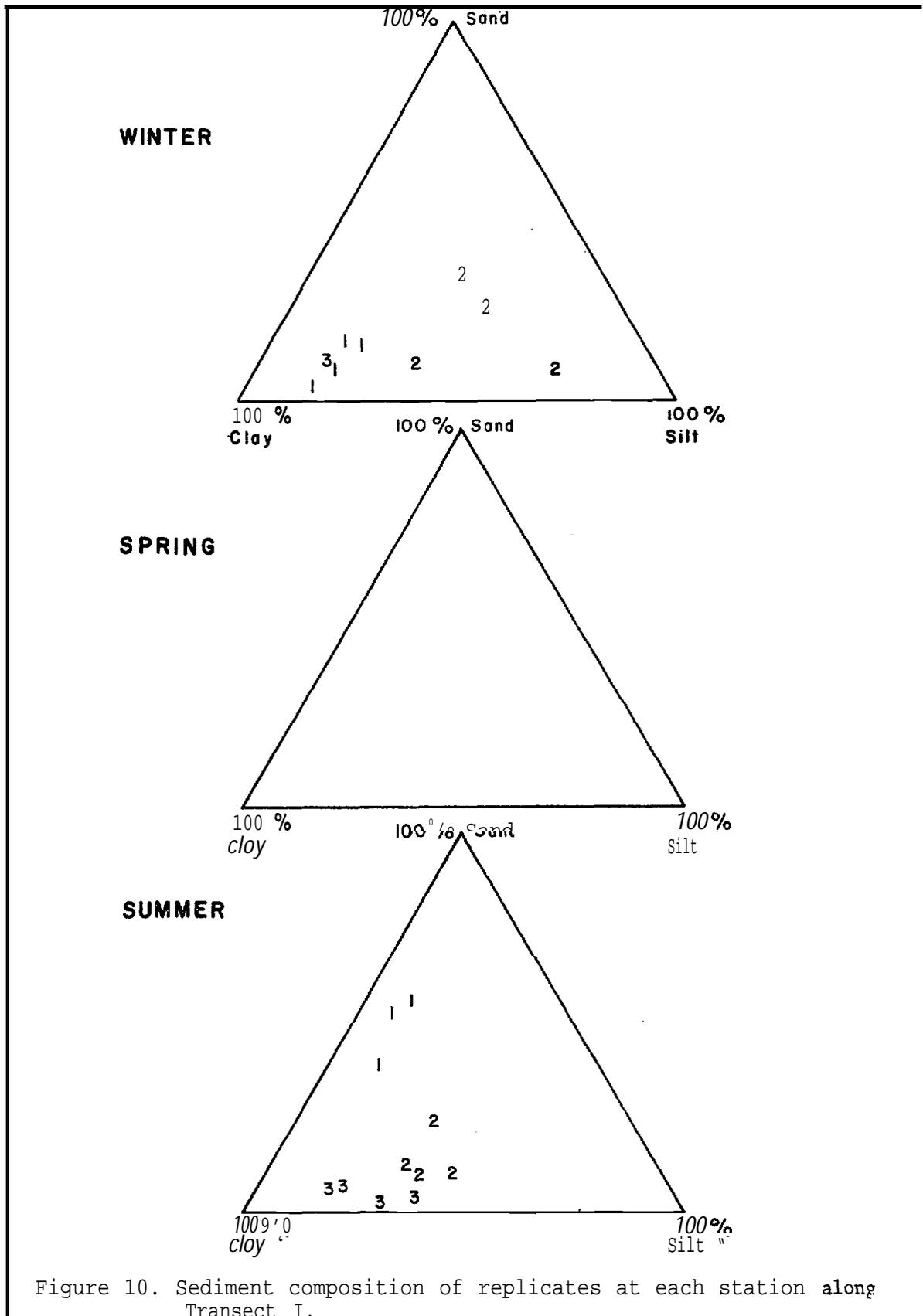


Figure 10. Sediment composition of replicates at each station along Transect I.

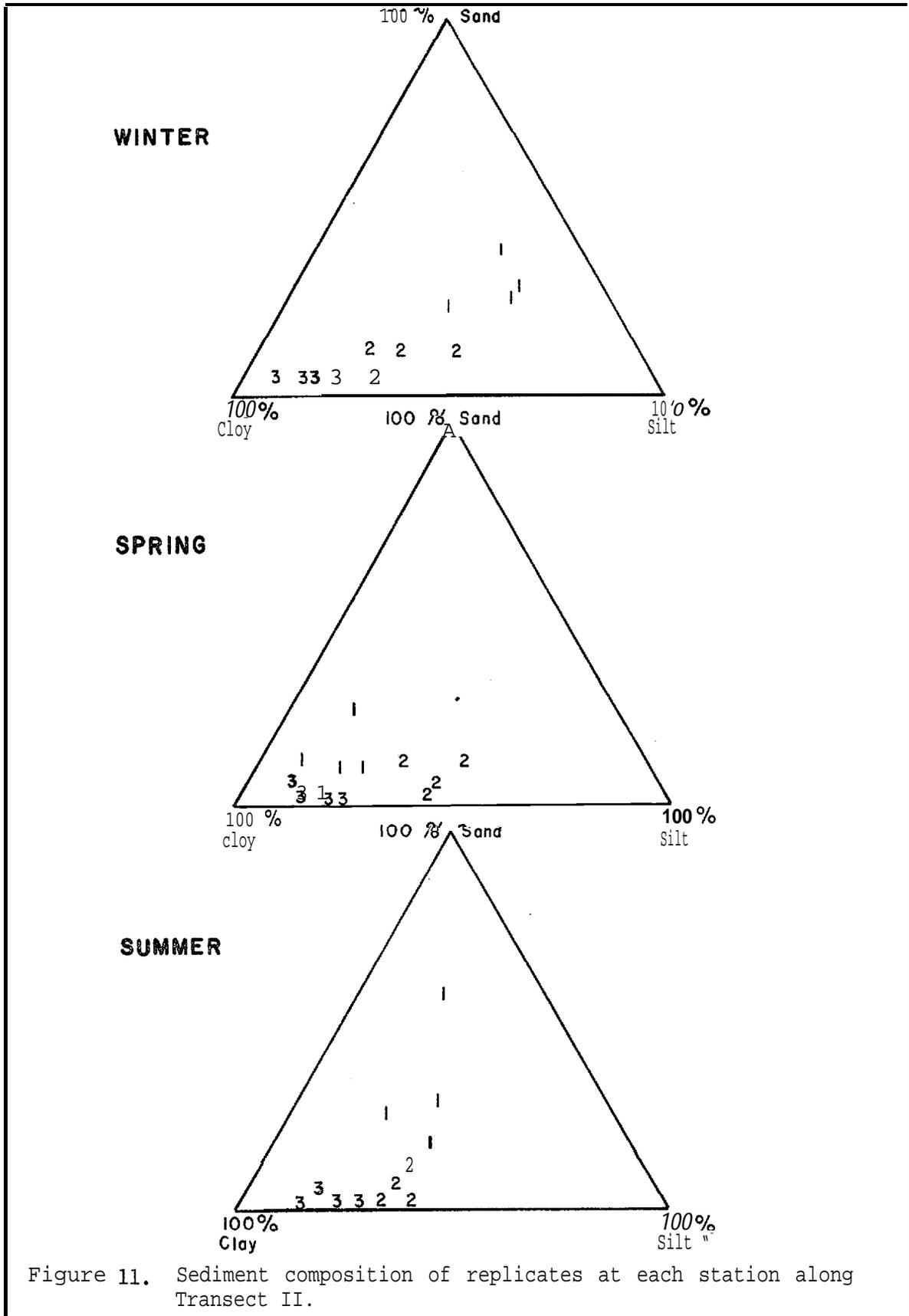


Figure 11. Sediment composition of replicates at each station along Transect II.

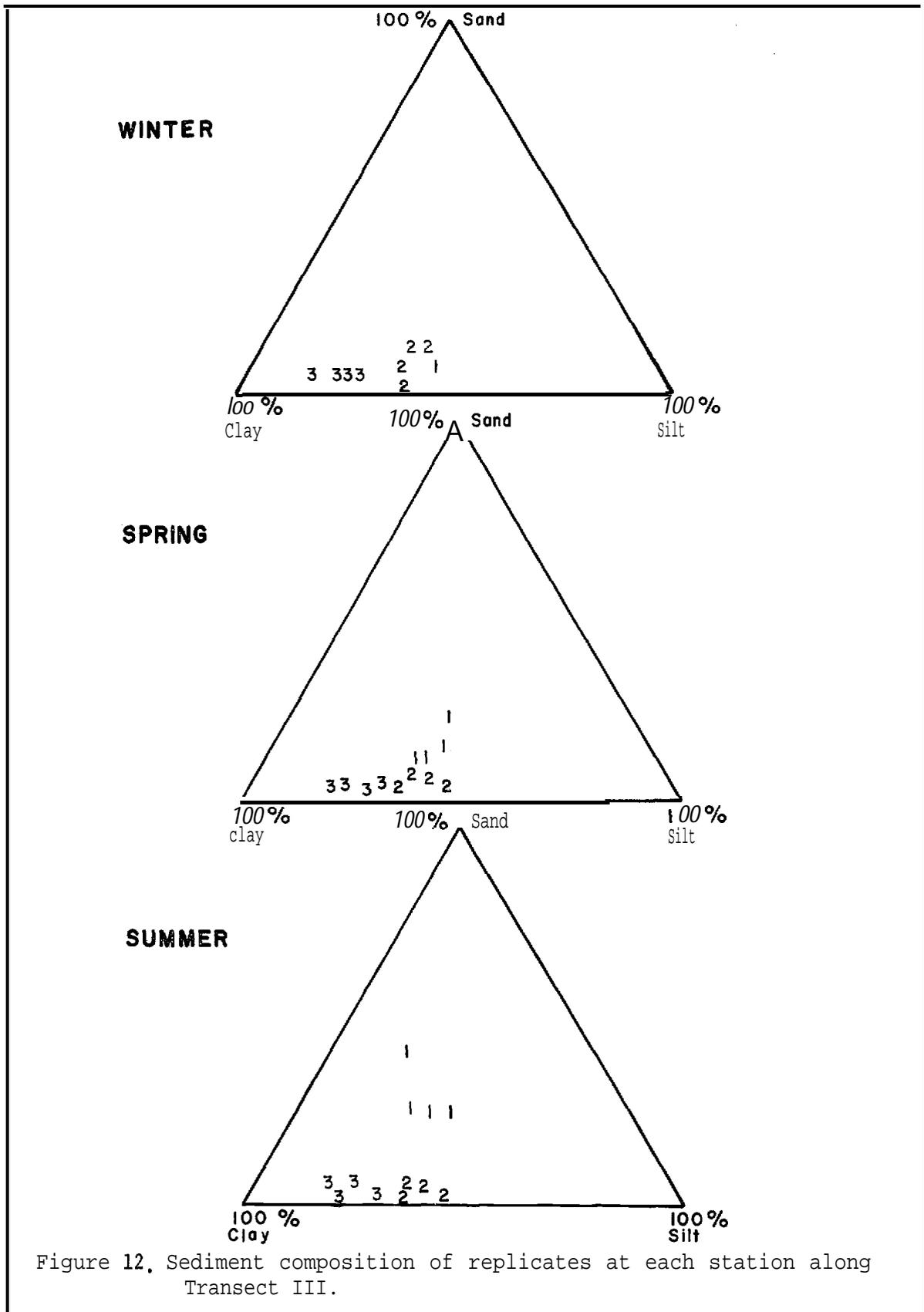


Figure 12. Sediment composition of replicates at each station along Transect III.

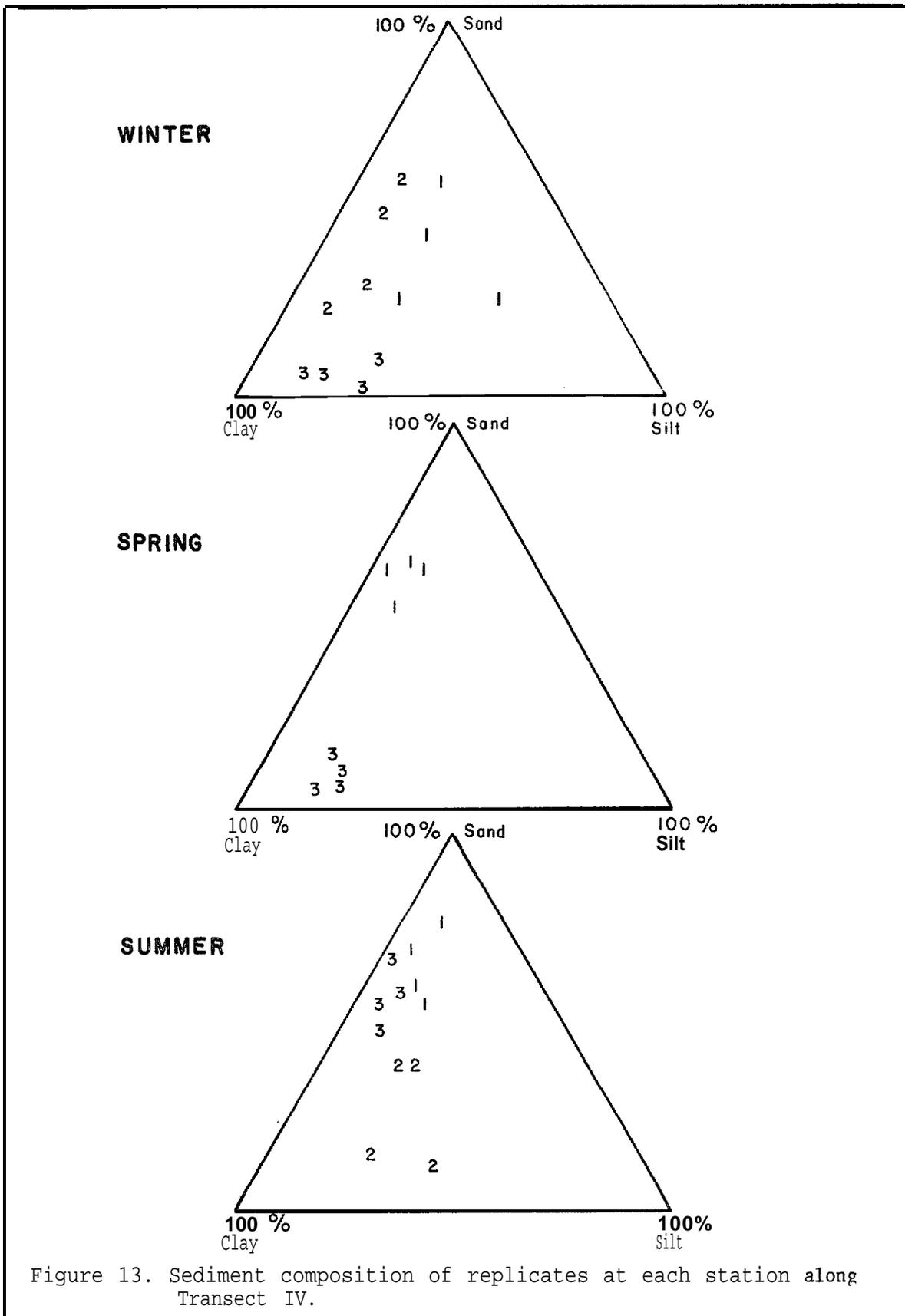


Figure 13. Sediment composition of replicates at each station along Transect IV.

BENTHOS PROJECT

EPIFAUNAL FISHES

University of Texas Marine Science Laboratory

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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 **measure-**

ments. 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 preceding 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) polypropylene 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	<b>28°12'N</b> 96°27'W (18 m)	<b>27°54.5'N</b> <b>96°19.5'W</b> (42 m)	<b>27°33.5'N</b> <b>96°06.5'W</b> (134 m)
II	<b>27°40'N</b> 96°59'W (22 m)	27°30'N <b>96°44.5'W</b> (42 m)	<b>27°17.5'N</b> <b>96°23'W</b> (131 m)
III	26°57.5'N <b>97°11'W</b> (25 m)	<b>26°57.6'N</b> <b>96°48'W</b> (65 m)	<b>26°57.5'N</b> <b>96°32.3'W</b> (106 m)
IV	26°10'N <b>97°00.5'W</b> (27 m)	26°10'N 96°39'W (47 m)	26°10'N <b>96°24'W</b> (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:

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

where  $n_i$  is the number of individuals in the  $i^{\text{th}}$  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  $i^{\text{th}}$  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  $i^{\text{th}}$  species in the community (or collection),

$N = \sum_1 N_i$  . 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<sup>n</sup> diversity index, equitability (E), and Hurlbert's probability of interspecific encounter (P.I.E.) for each sample in the Winter epifaunal collections.

	<u>Transect</u>	<u>Site No.</u>	<u>Code</u>	<u>Spp.</u>	<u>Ind.</u>	<u>H<sup>n</sup></u>	<u>E</u>	<u>P.I.E.</u>
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.

	<u>Transect</u>	<u>Site No.</u>	<u>Code</u>	<u>Spp.</u>	<u>Ind.</u>	<u><math>H'</math></u>	<u><math>E</math></u>	<u>P.I.E.</u>
Day	I	<b>1</b>	CBA	20	2,199	1.029	.100	.424
<b>Night</b>	I	<b>1</b>	CAG	21	1,018	1.409	.143	.579
Day	I	2	CEA	24	398	2.062	.250	.788
Night	1	2	<b>CDK</b>	29	216	2.836	.345	.913
Day	I	3	<b>CHK</b>	19	177	2.263	.316	.865
Night	I	3	<b>CGO</b>	18	193	2.071	.333	.824
Day	II	<b>1</b>	CKQ	24	830	1.710	<b>.167</b>	.722
Night	II	<b>1</b>	CJV	16	457	1.302	.187	.548
Day	II	2	CNT	23	508	2.164	.261	.832
Night	II	2	<b>CMY</b>	30	282	2.509	.266	.832
Day	11	3	CQV	11	125	2.075	.545	.858
Night	II	3	CQA	19	69	2.363	.368	.872
Day	III	1	<b>CUD</b>	20	502	2.270	.300	.870
Night	III	<b>1</b>	CTH	19	333	1.573	.210	.677
Day	III	2	<b>CXZ</b>	21	228	2.356	<b>.333</b>	.866
Night	111	2	CXK	30	285	2.282	.233	.779
Day	III	3	DBB	15	144	2.192	.400	.864
Night	111	3	<b>DAI</b>	25	289	2.107	.240	.765
Day	<b>IV</b>	<b>1</b>	DEB	25	405	2.023	.200	.811
Night	<b>IV</b>	<b>1</b>	DDI	24	215	2.279	.291	.825
Day	IV	2	<b>DHA</b>	20	354	2.023	.250	.809
Night	<b>IV</b>	2	DGH	32	114	3.738	.593	.806
Day	IV	3	<b>DKF</b>	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.

	<u>Transect</u>	<u>Site No.</u>	<u>Code</u>	<u>Spp.</u>	<u>Ind.</u>	<u><math>H'</math></u>	<u>E</u>	<u>P.I.E.</u>
Day	I	1	EBA	20	207	2.447	.350	.891
Night	I	<b>1</b>	EAG	23	648	1.589	.174	.653
Day	I	2	EEA	22	<b>316</b>	<b>1.957</b>	.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	<b>1.777</b>	.200	.694
Day	II	1	EKQ	15	147	2.348	.467	.889
Night	II	<b>1</b>	EJV	21	207	2.401	.333	.877
Day	II	2	ENU	17	86	2.391	.412	.886
Night	<b>II</b>	2	<b>EMY</b>	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	<b>1</b>	EUD	28	776	2.203	.214	.822
Night	III	1	ETH	19	278	1.392	.158	.587
Day	III	2	<b>EXZ</b>	14	28	2.465	.571	.931
Night	<b>III</b>	2	EXK	18	215	1.904	.278	.732
Day	III	3	FBB	15	106	2.154	.400	.850
Night	III	3	FAI	22	170	<b>1.928</b>	.227	.728
Day	<b>IV</b>	<b>1</b>	FEJ	25	275	2.655	.360	.906
Night	IV	<b>1</b>	FDP	34	762	2.316	.206	.829
Day	<b>IV</b>	2	FHK	20	234	2.247	.300	.831
Night	IV	2	<b>FGP</b>	30	514	2.111	.200	.751
Day	IV	3	<b>FKP</b>	19	171	2.196	.316	.837
Night	<b>IV</b>	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.

	<u>Transect</u>	<u>Site No.</u>	<u>Code</u>	<u>Spp.</u>	<u>Ind.</u>	<u>Weight (g)</u>	<u><math>H'</math></u>
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	<b>535</b>	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	<b>1.705</b>
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	<b>1.835</b>
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.

	<u>Transect</u>	<u>Site No.</u>	<u>Code</u>	<u>Spp.</u>	<u>Ind.</u>	<u>Weight (g)</u>	<u>H"</u>
Day	I	1	CBA	20	2,199	14365.1	2.002
Night	I	1	CAG	21	1,018	7638.6	<b>1.961</b>
Day	I	2	CEA	24	398	6560.8	2.237
Night	I	2	CDK	29	216	5206.3	2.688
Day	I	3	<b>CHK</b>	19	177	7454.2	1.928
Night	I	3	<b>CGO</b>	<b>18</b>	193	6363.0	<b>1.882</b>
Day	11	<b>1</b>	<b>CKQ</b>	24	830	12725.4	1.816
Night	II	<b>1</b>	CJV	16	457	<b>6126.9</b>	1.316
Day	II	2	CNT	23	508	6844.0	2.159
Night	II	2	<b>CMY</b>	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	<b>III</b>	<b>1</b>	CUD	20	502	4218.8	2.191
Night	111	1	CTH	19	333	4237.2	1.950
Day	111	2	<b>CXZ</b>	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	<b>1</b>	<b>DDI</b>	24	215	3065.3	2.058
Day	IV	2	DHA	20	354	3619.4	1.949
Night	<b>IV</b>	2	DGH	32	114	3746.5	2.920
Day	<b>IV</b>	3	DKF	25	239	5738.9	<b>1.763</b>
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.

	<u>Transect</u>	<u>Site No.</u>	<u>Code</u>	<u>Spp.</u>	<u>Ind.</u>	<u>Weight (g)</u>	<u>H"</u>
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	11	1	EJV	21	207	3106.1	2.380
Day	11	2	ENU	17	86	2182.3	2.216
Night	II	2	<b>EMY</b>	10	15	887.9	1.549
Day	11	3	EQV	<b>11</b>	60	2754.0	1.372
Night	11	3	EQA	15	93	3080.7	1.698
Day	111	<b>1</b>	EUD	28	776	21606.8	2.098
Night	III	1	ETH	19	278	11151.0	1.042
Day	III	2	<b>EXZ</b>	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	<b>1</b>	FEJ	25	275	5738.6	2.421
Night	<b>IV</b>	1	FDP	34	762	18616.3	1.523
Day	<b>IV</b>	2	<b>FHK</b>	20	234	6557.4	2.255
Night	<b>IV</b>	2	<b>FGP</b>	30	514	4179.3	2.557
Day	<b>IV</b>	3	<b>FKP</b>	19	171	7409.0	2.096
Night	<b>IV</b>	3	FJT	24	205	5449*5	2.165

tations. Figures 1-6 illustrate by histogram height the relative values of H<sup>n</sup> 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.

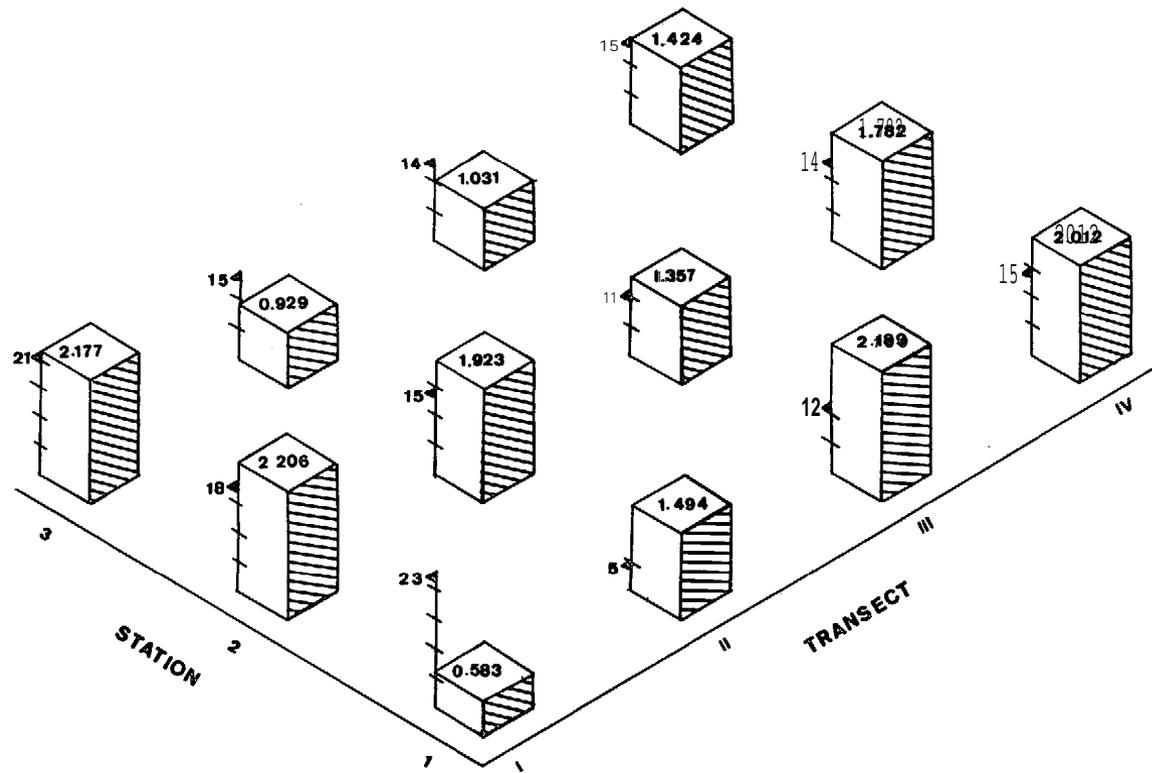


Figure 1. Shannon species diversity index,  $H'$  (height of block and number), and number of species (height of flag) for winter, day samples.

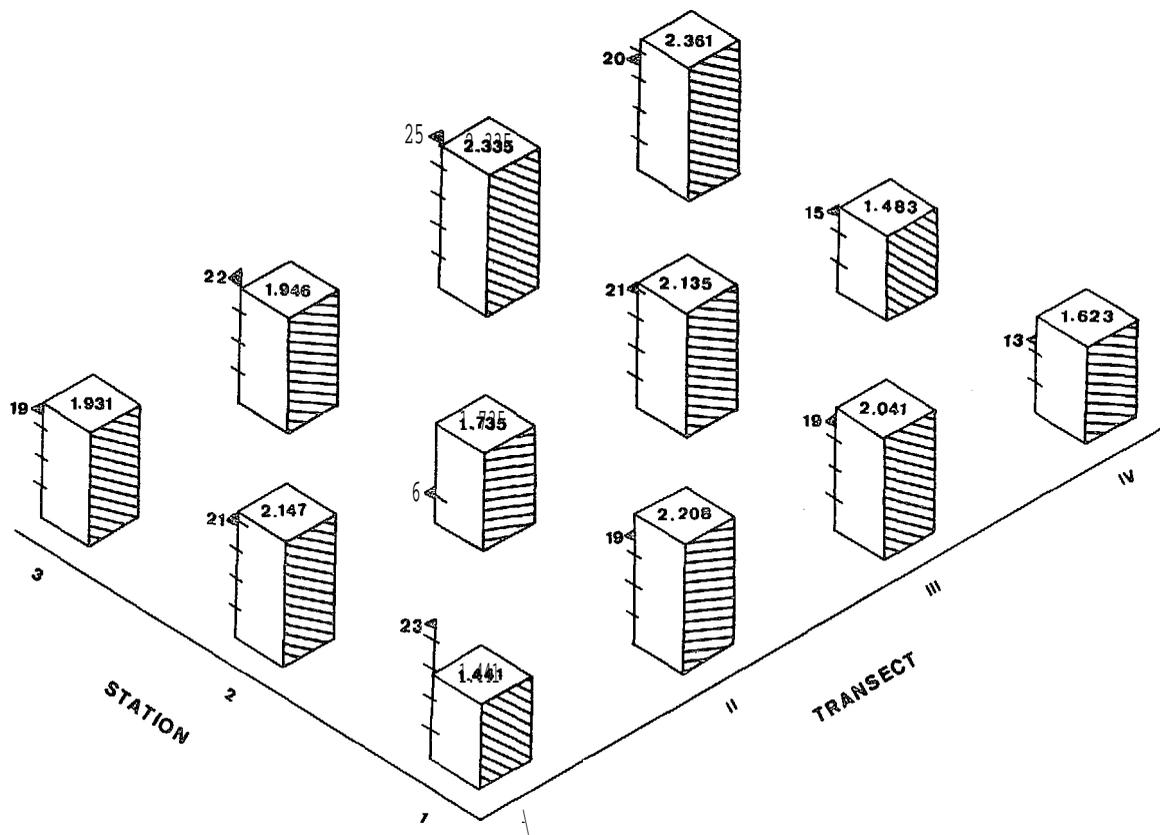


Figure 2. Shannon species diversity index,  $H'$  (height of block and number), and number of species (height of flag) for Winter, night samples.

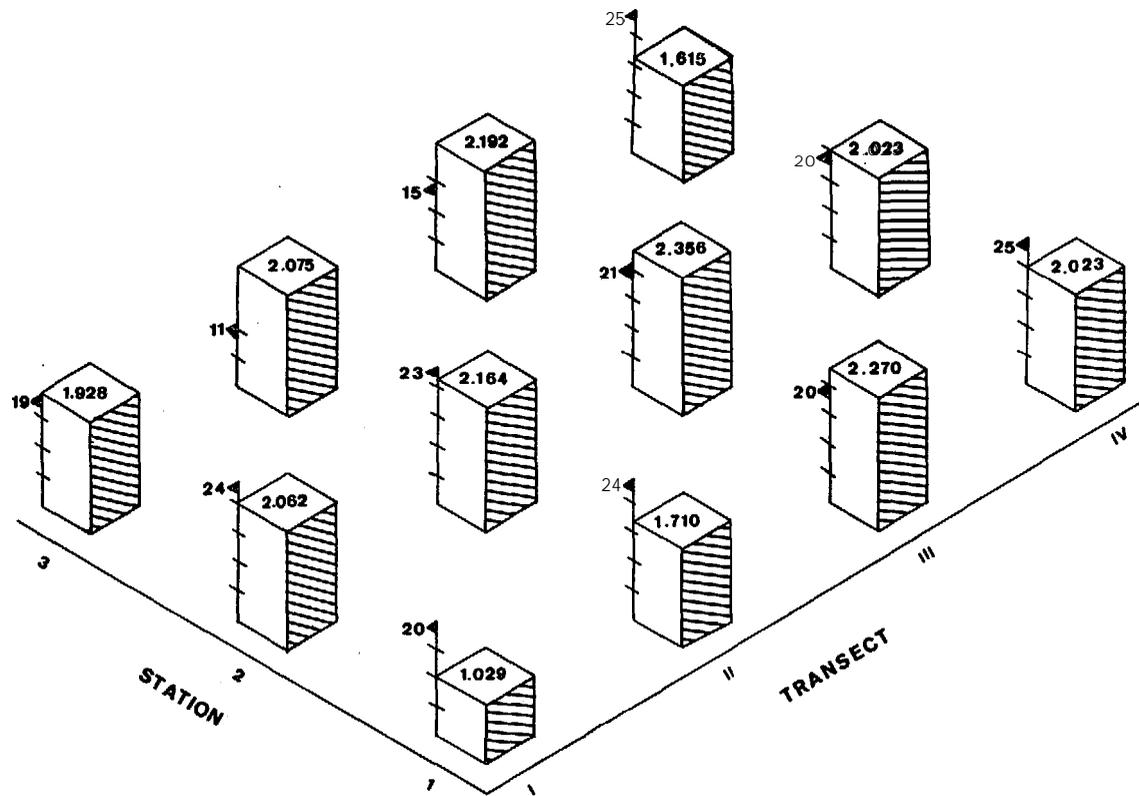


Figure 3. Shannon species diversity index,  $H'$  (height of block and number), and number of species (height of flag) for Spring, day samples.

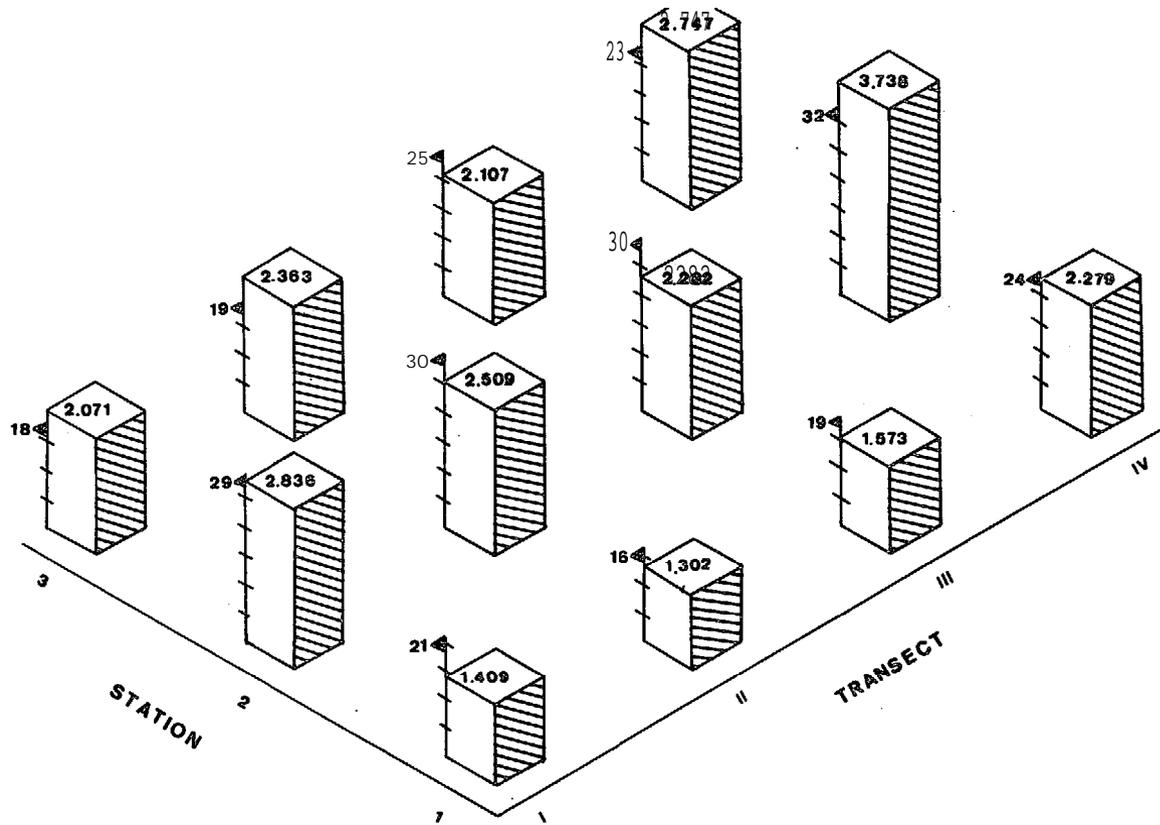


Figure 4. Shannon species diversity index,  $H'$  (height of block and number), and number of species (height of flag) for Spring, night samples.

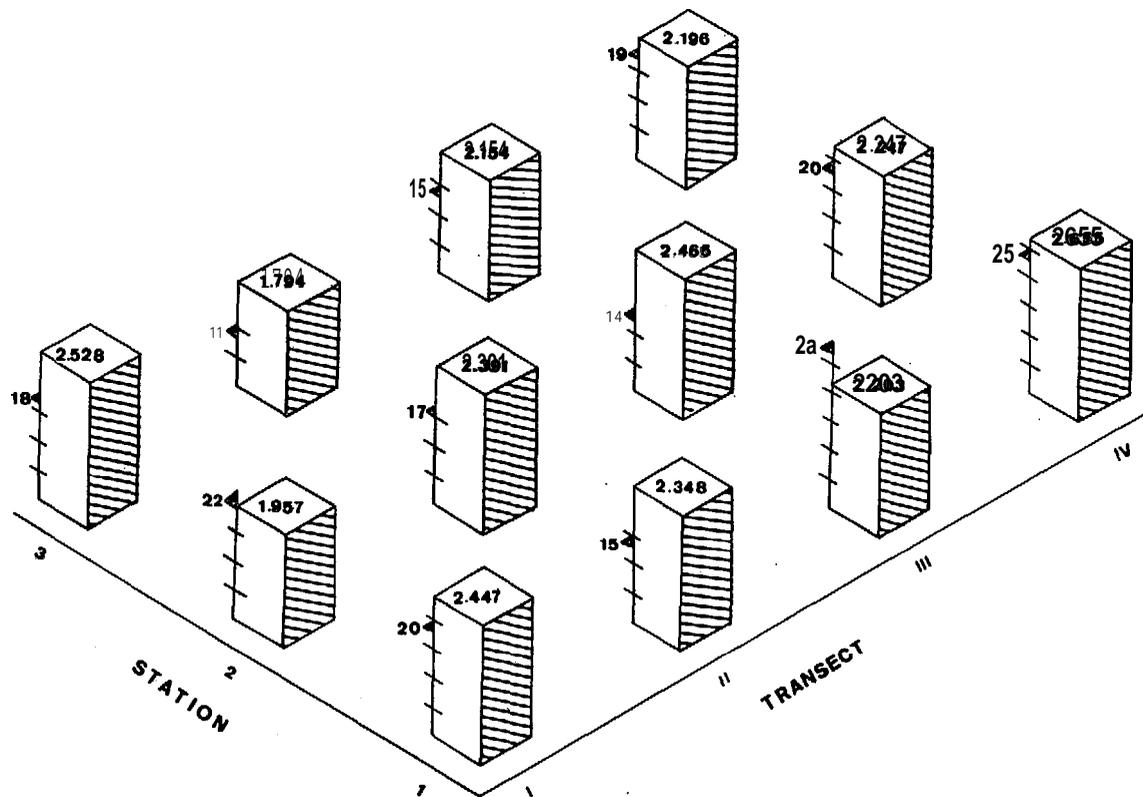


Figure 5. Shannon species diversity index,  $H'$  (height of block and number) and number of species (height of flag) for Summer, day samples. 9

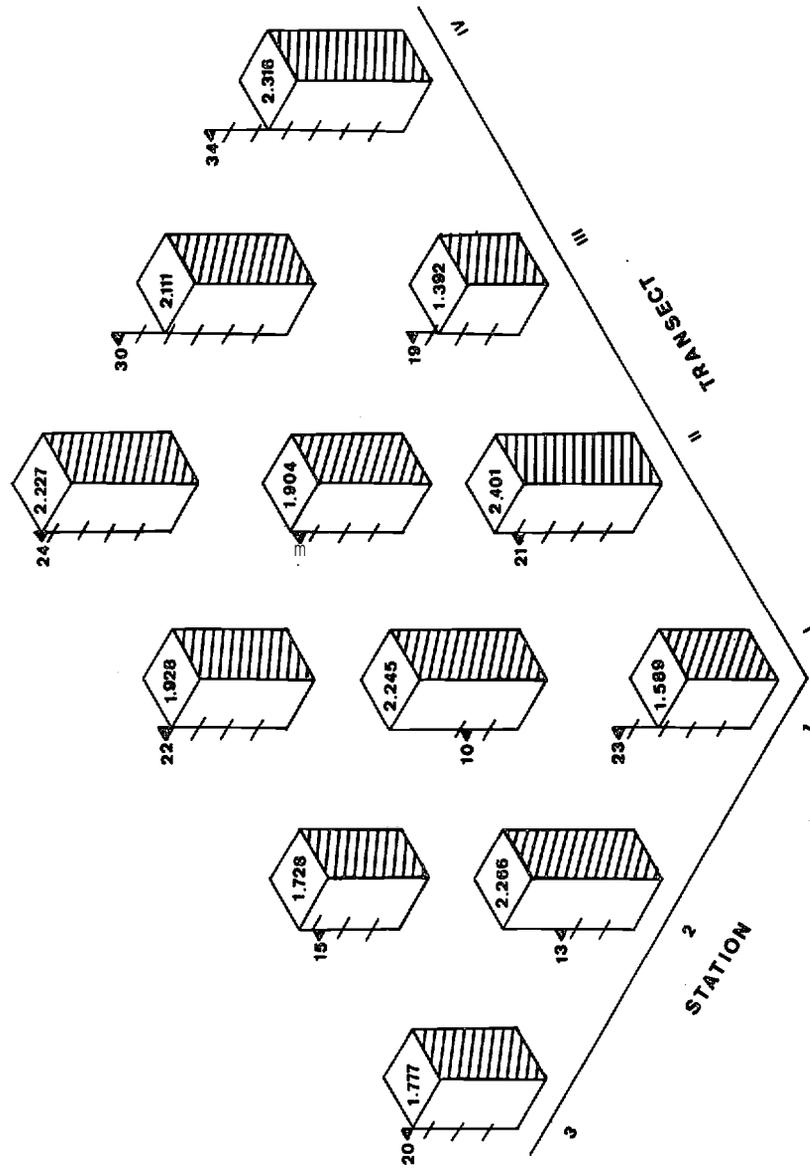


Figure 6. Shannon species diversity index, H' (height of block and number), and number of species (height of flag) for Summer, night samples.

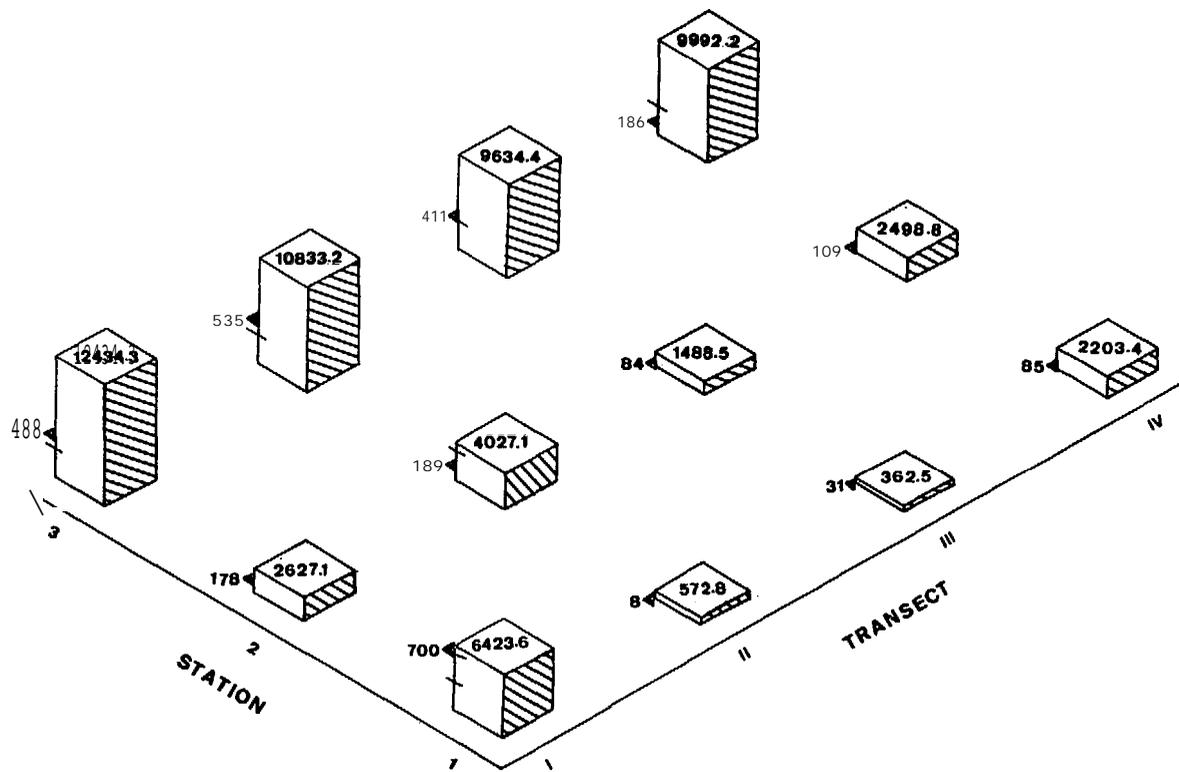


Figure 7. Total biomass in **grams** (height of blocks and numbers) and number of individuals (height of flags and numbers) for Winter, day samples.

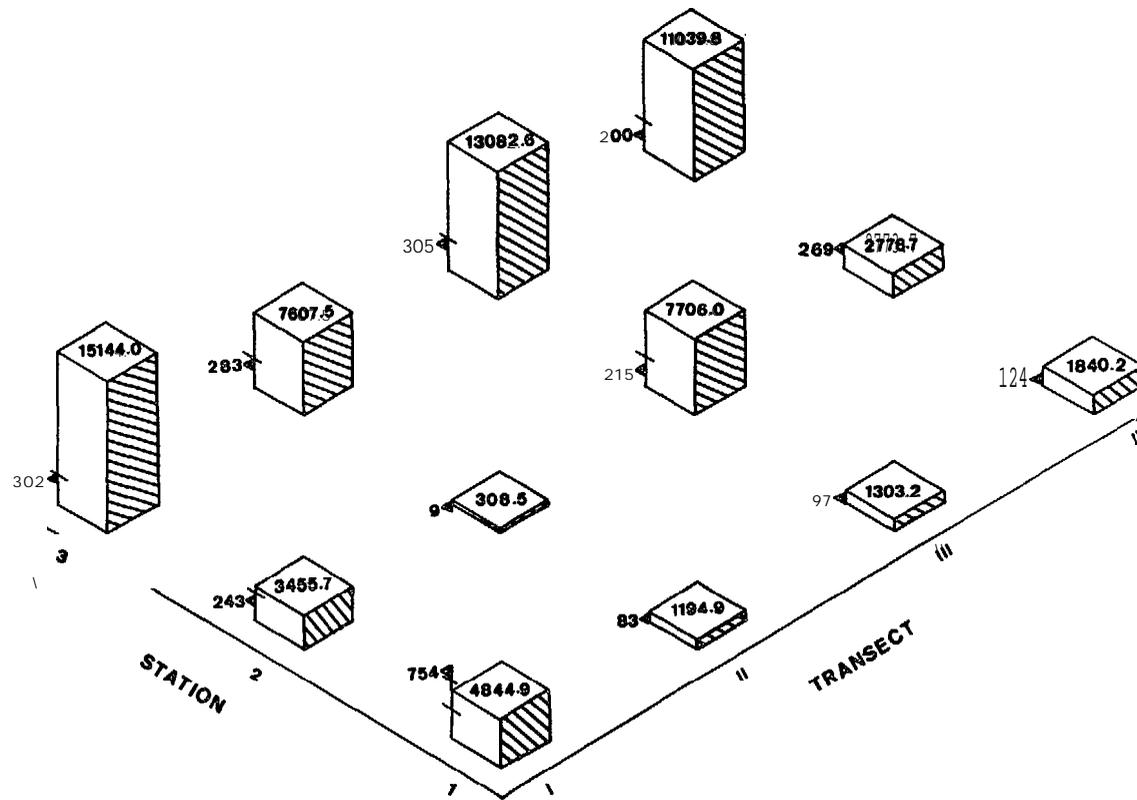


Figure 3. Total biomass in grams (height of blocks and numbers ) and number of individuals (height of flags and numbers) for Winter, night samples.

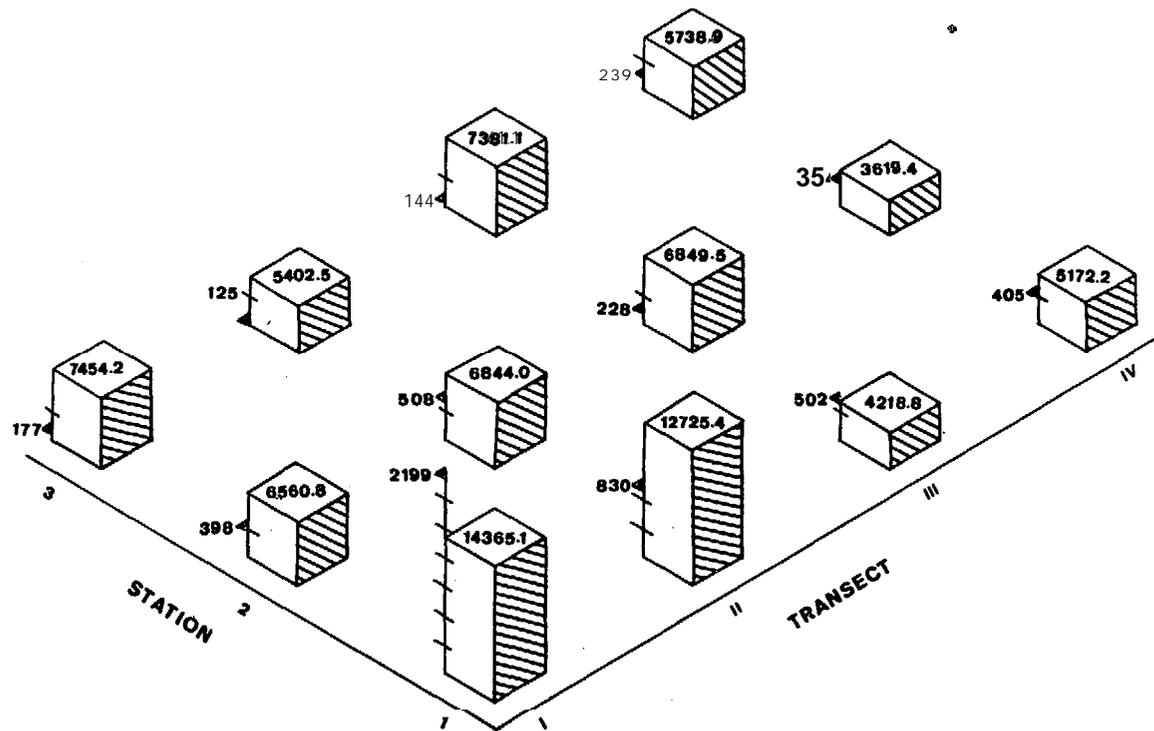


Figure 9. Total biomass in grams (height of blocks and numbers) and number of individuals (height of flags and numbers) for Spring, day samples.

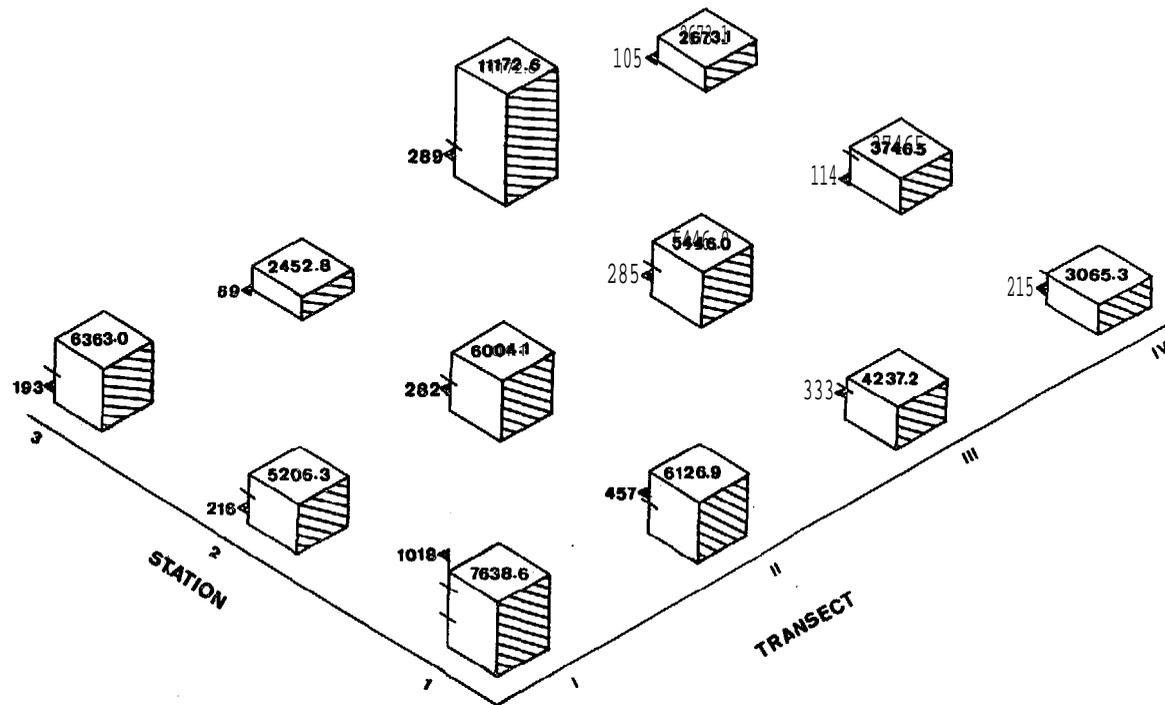


Figure 10. Total biomass in grams (height of blocks and numbers) and number of individuals (height of flags and numbers) for Spring, night samples.

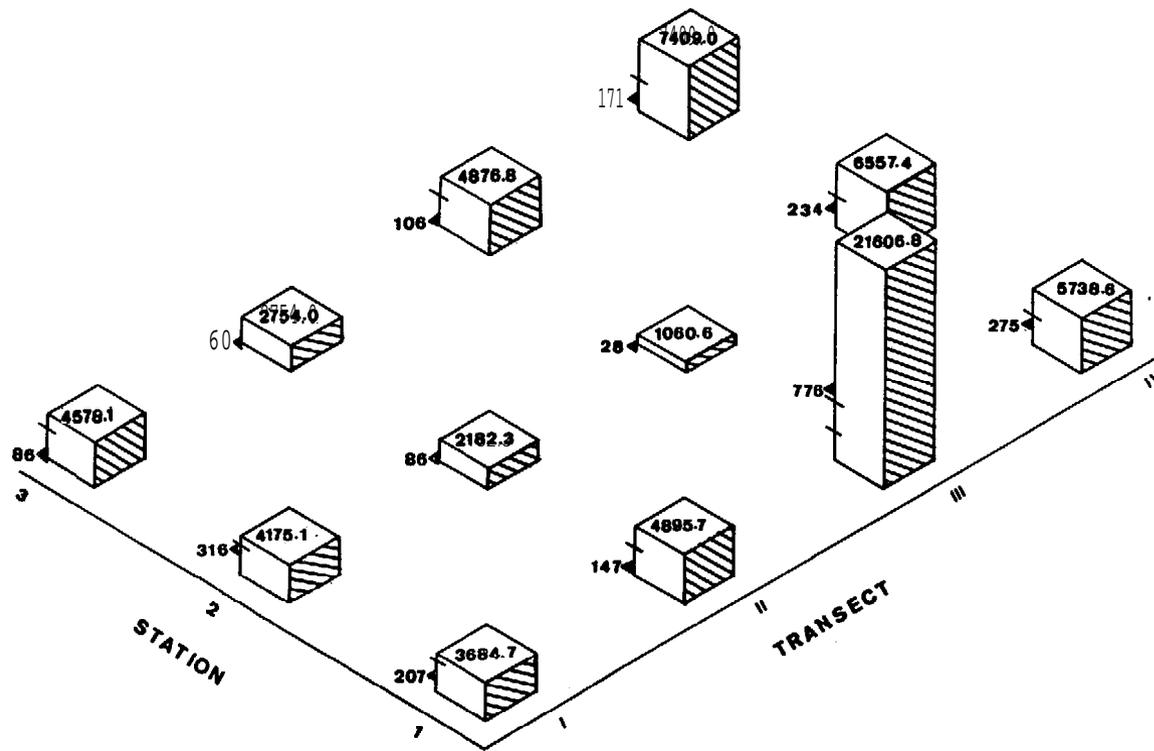


Figure 11. Total biomass in grams (heights of blocks and numbers) and number of individuals (height of flags and numbers) for Summer, day samples.

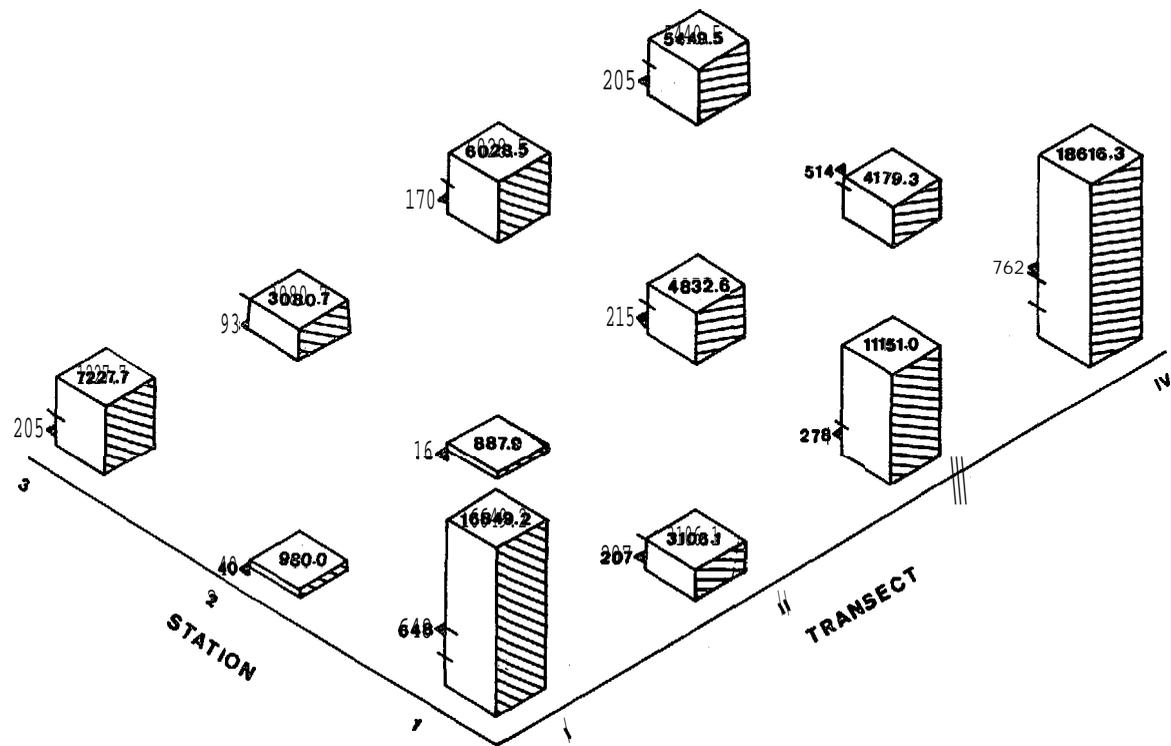


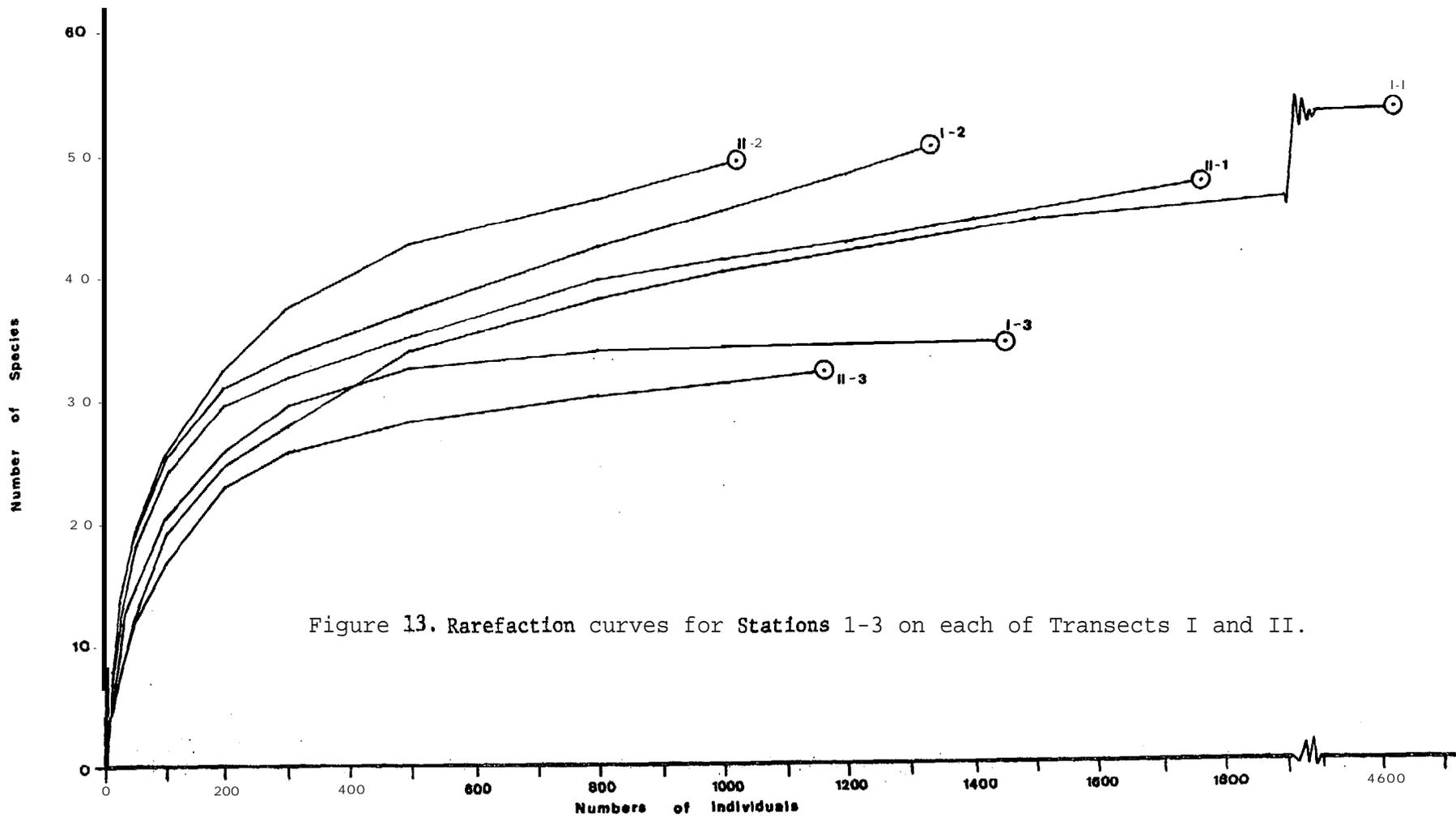
Figure 12. Total biomass in grams (height of blocks and numbers) and number of individuals (height of flags and numbers) for Summer, night samples.

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				
<b>1162</b>						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. Cent. '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	
<b>1700</b>	59.7		
1763			
1799			
1828	60.0		
3000			
4627			



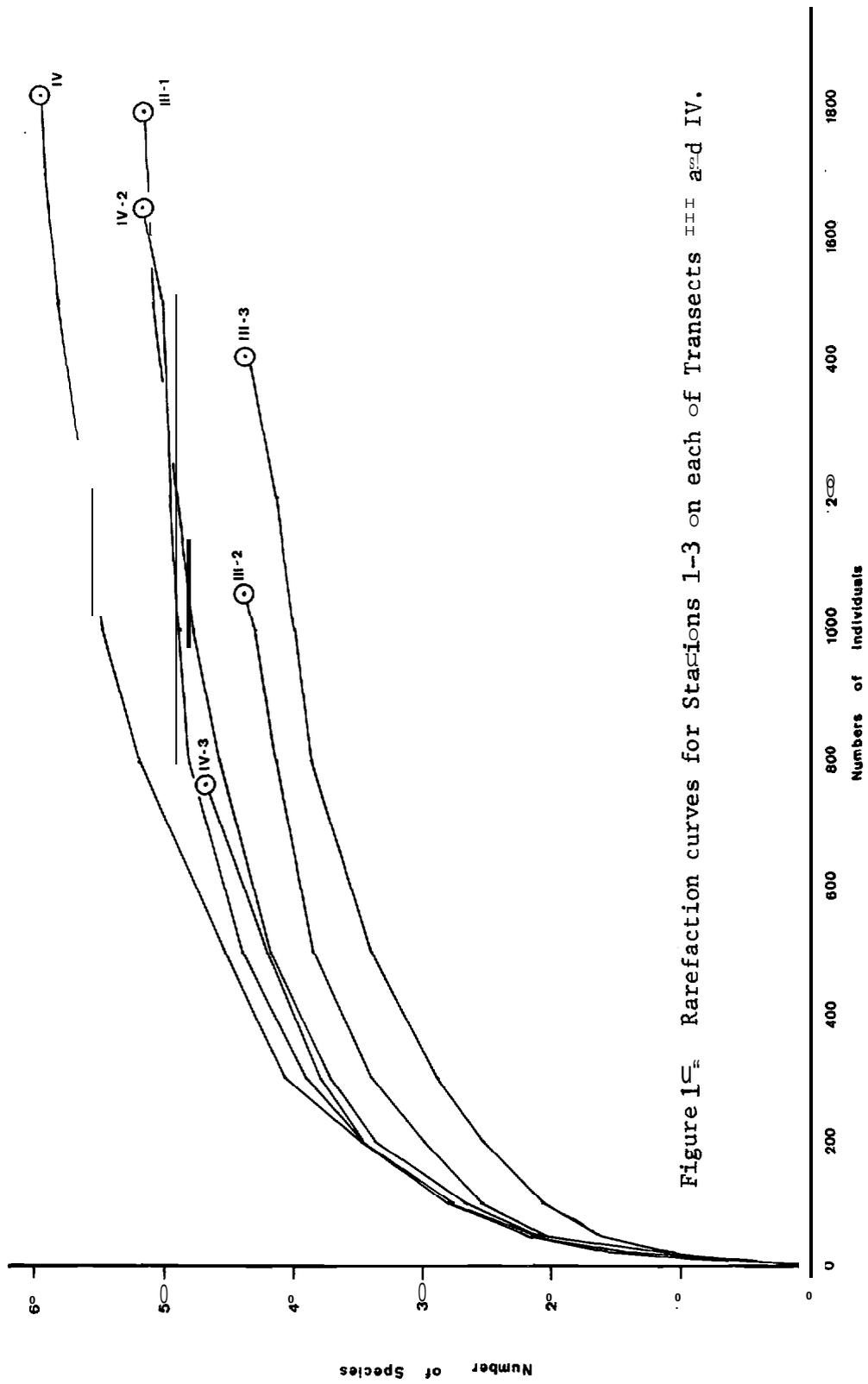


Figure 1C. Rarefaction curves for Stations 1-3 on each of Transects III and IV.





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	111	111	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						<b>1</b>	-	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						<b>1</b>	-	12				6
3.1-4		1				<b>3</b>	-	4	2			2
4.1-5		5				<b>3</b>	-	5	2			1
5.1-6		10				<b>4</b>	-					1
6.1-7		11					<b>1</b>		41	1	10	3
7.1-8		35	9			4	6		97	38	19	<b>1</b>
8.1-9			53				30		46	30	1	
9.1-10			23				3		<u>2</u>	3		
									( 88)			

cm.	SUMMER												
0.1-1													
1.1-2													
<b>2.1-3</b>													
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			<u>19</u>				10		-	<u>12</u>			
			(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 :	1	1	1	11	II	II	III	111	111	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			<b>1</b>				-					
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	2 1
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											-	-
											<u>(39)</u>	<u>(60)</u>

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	11	II	III	111	111	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 x.X 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 **Wore 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 **assess-**

ed. 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 Time	Winter		Spring		Summer	
	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	<b>8</b>	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	<b>171</b>	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 unevenness 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* no-thus 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:

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

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

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

(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  $H_n''$  indices. In a seasonal comparison of E with  $H_n''$  the regressions, with correlations r, are:

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

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

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

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 11-1 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 environmental 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 we're 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 judgments 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.

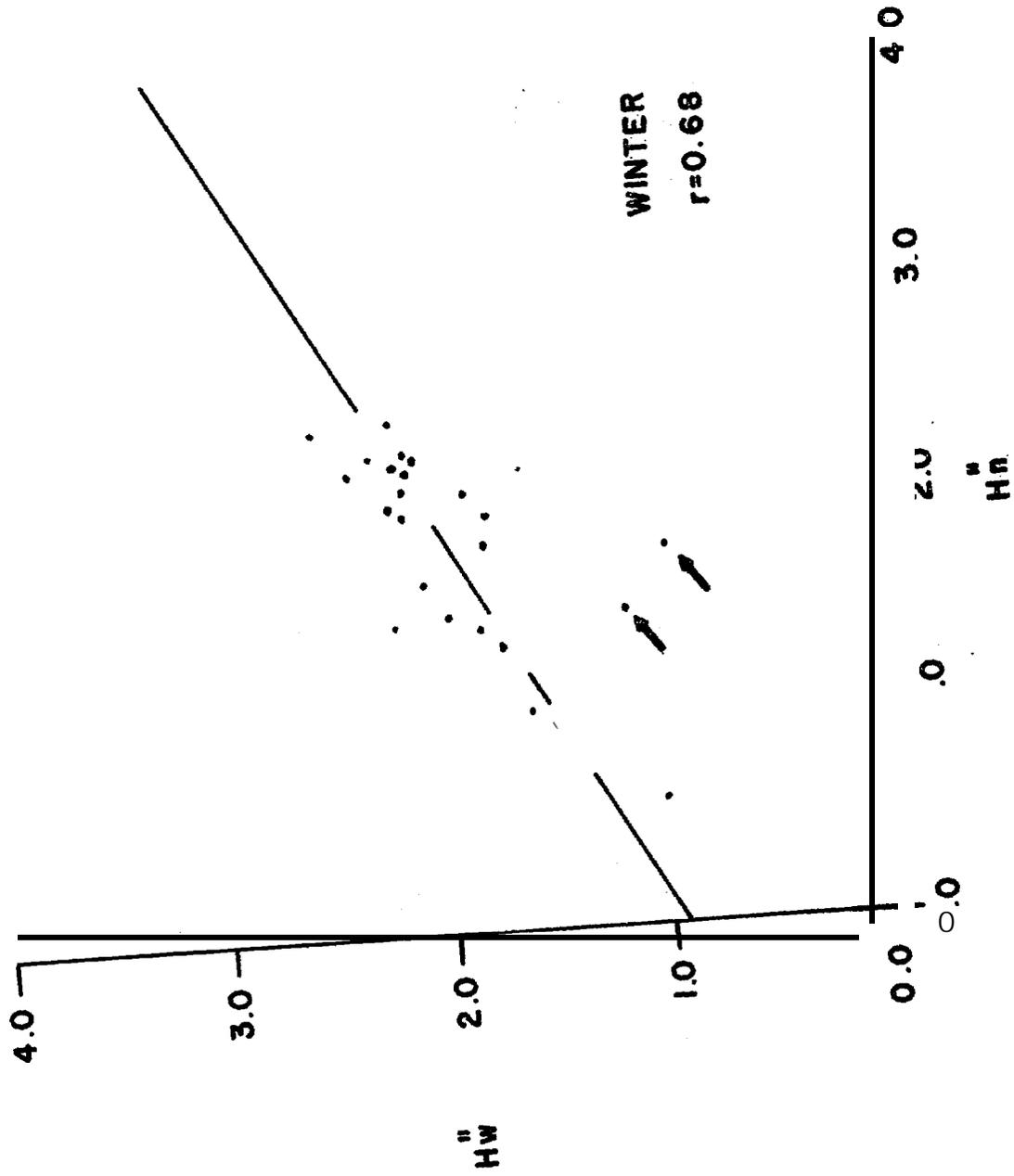


Figure 15. Relationship between fish diversity indices  $H_w''$  (biomass) and  $H_n''$  (numbers) for winter collections. See text for explanation of arrows.

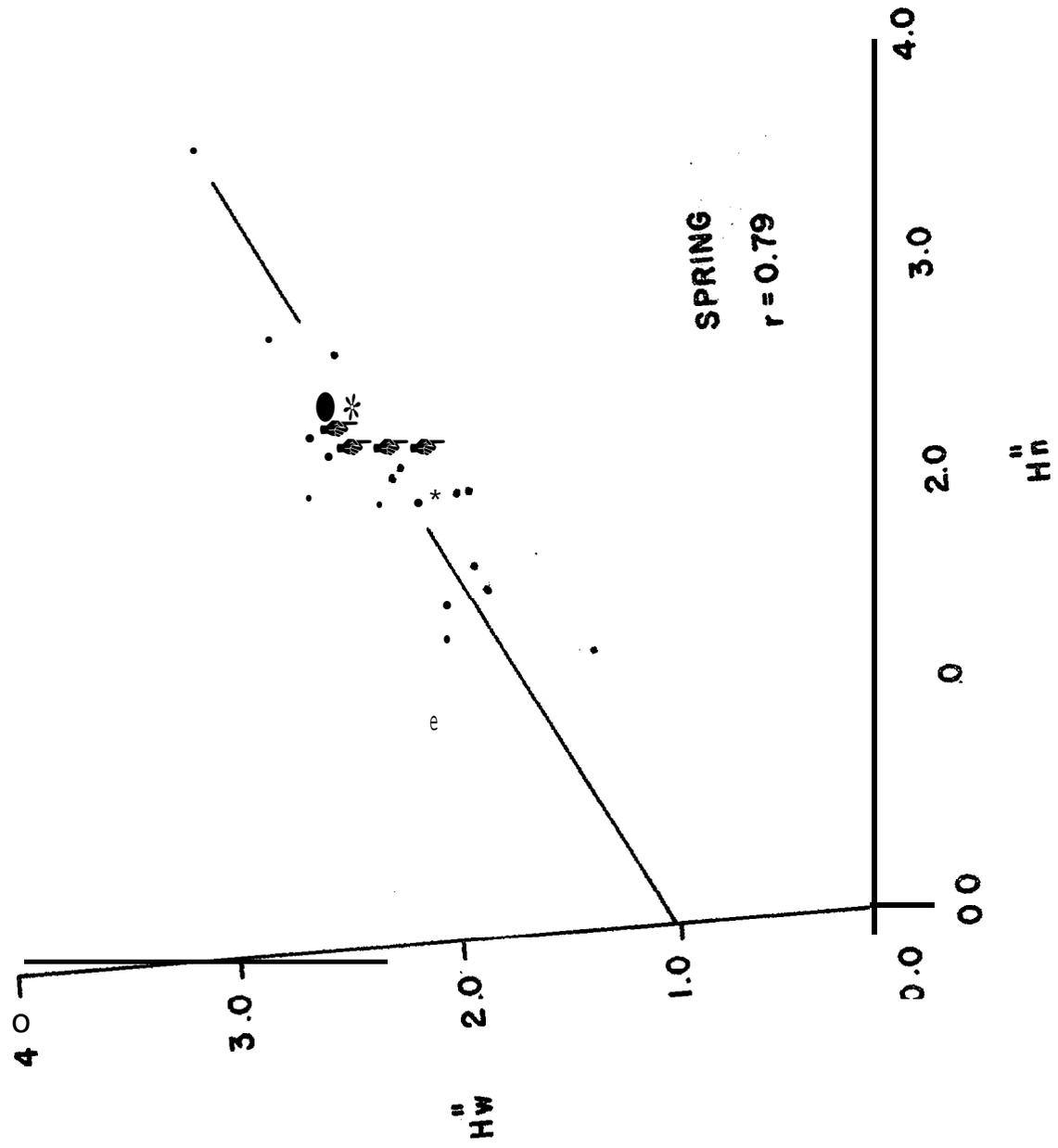


Figure 16. Relationship between fish diversity indices  $H_w''$  (biomass) and  $H_n''$  (numbers) for spring collections.

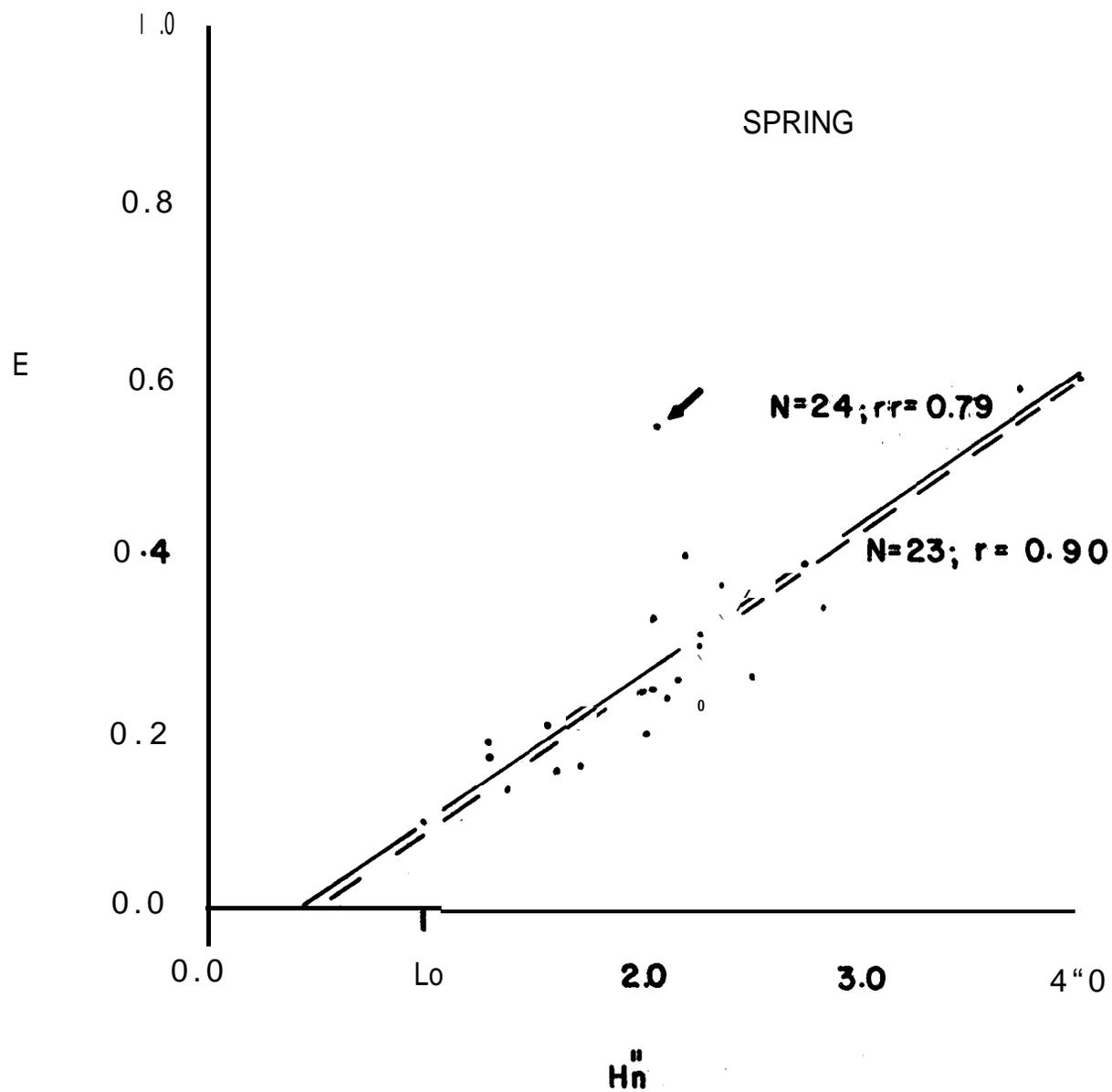


Figure 20. Relationships between equitability,  $E$ , and Shannon diversity index,  $H_n''$ , for spring fish collections. See text for explanation of arrow.

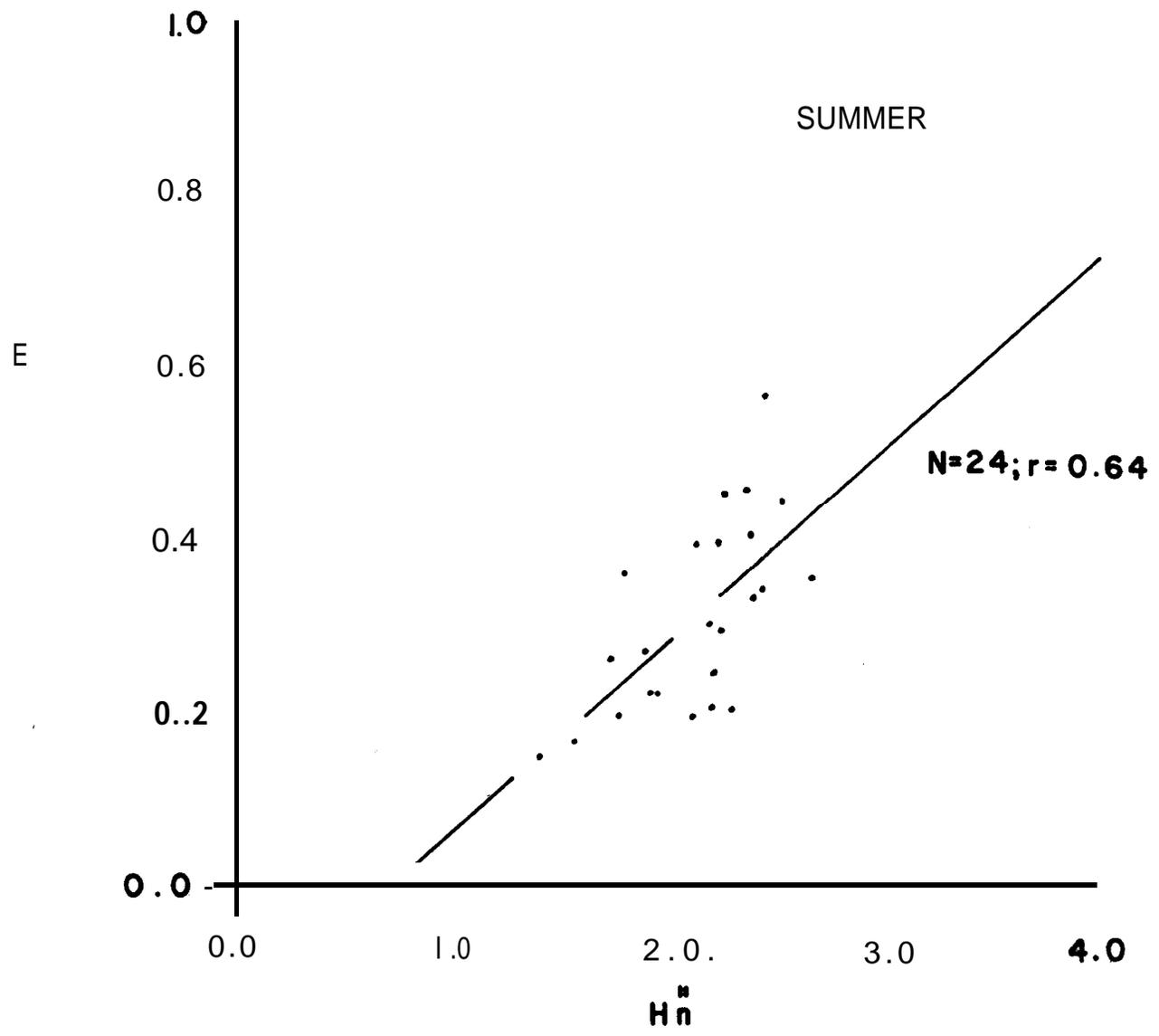


Figure 21. Relationship between equitability,  $E$ , and Shannon diversity index,  $H_n'$ , for summer fish collections.

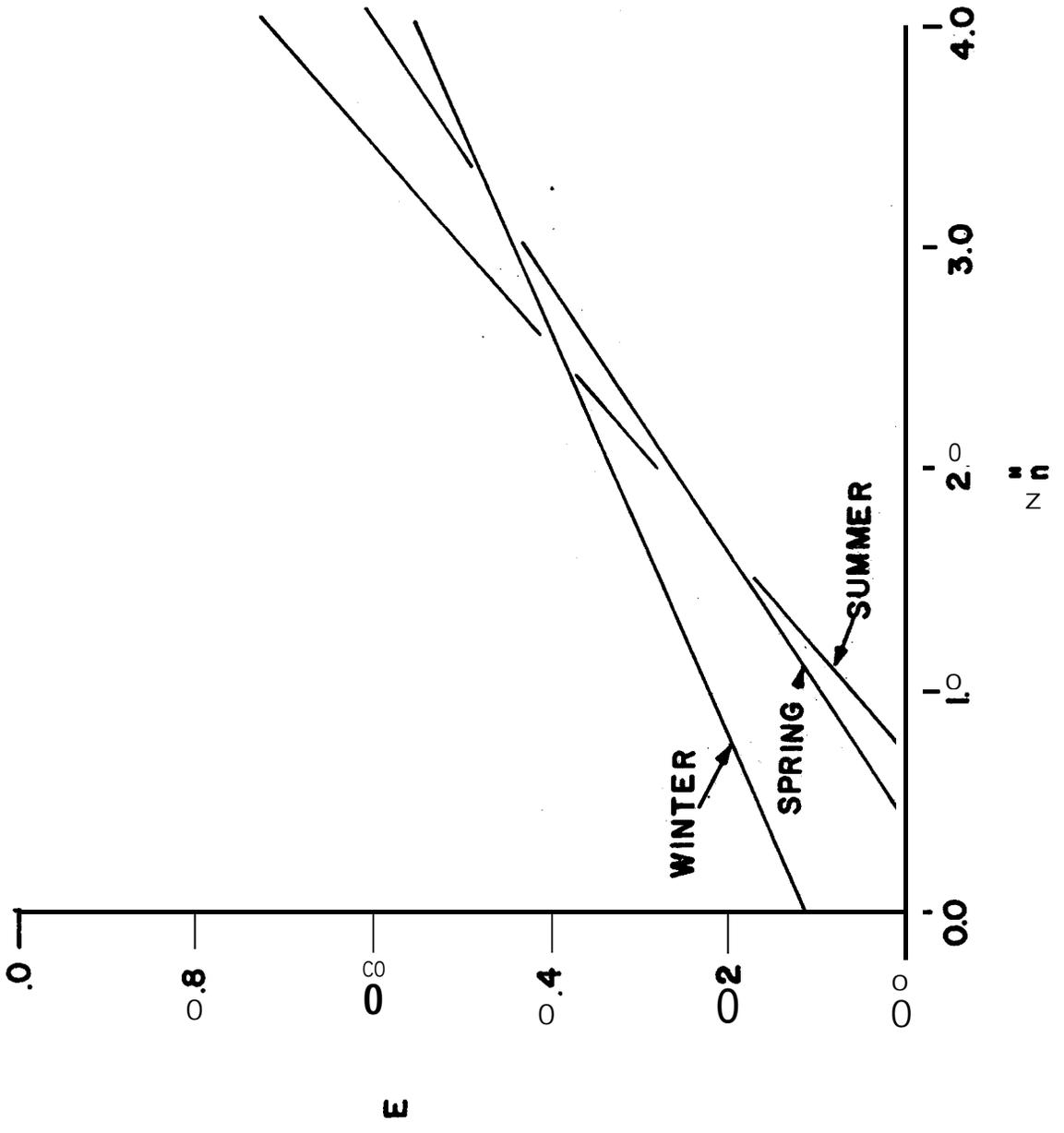


Figure 22. Relationships among equitability-diversity index regressions for 24 samples each season.

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  $H_{ij}$ " based on biomass with the same index  $H_{ij}$ " 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  $H_{ij}$ " also provide a system for identifying aberrant values.

➔ 3. The PIE index compared by regression to  $H_{ij}$ " indicates a close correspondence for the seasonal collections with few "outliers" from the regression Z-ha. This is interpreted to mean that PIE values may be theoretically sounder than are the Shannon index values.

➔ The regression relationships of  $H_{ij}$ ",  $E$ , or PIE to  $H_{ij}$ " do not show any striking seasonal differences.

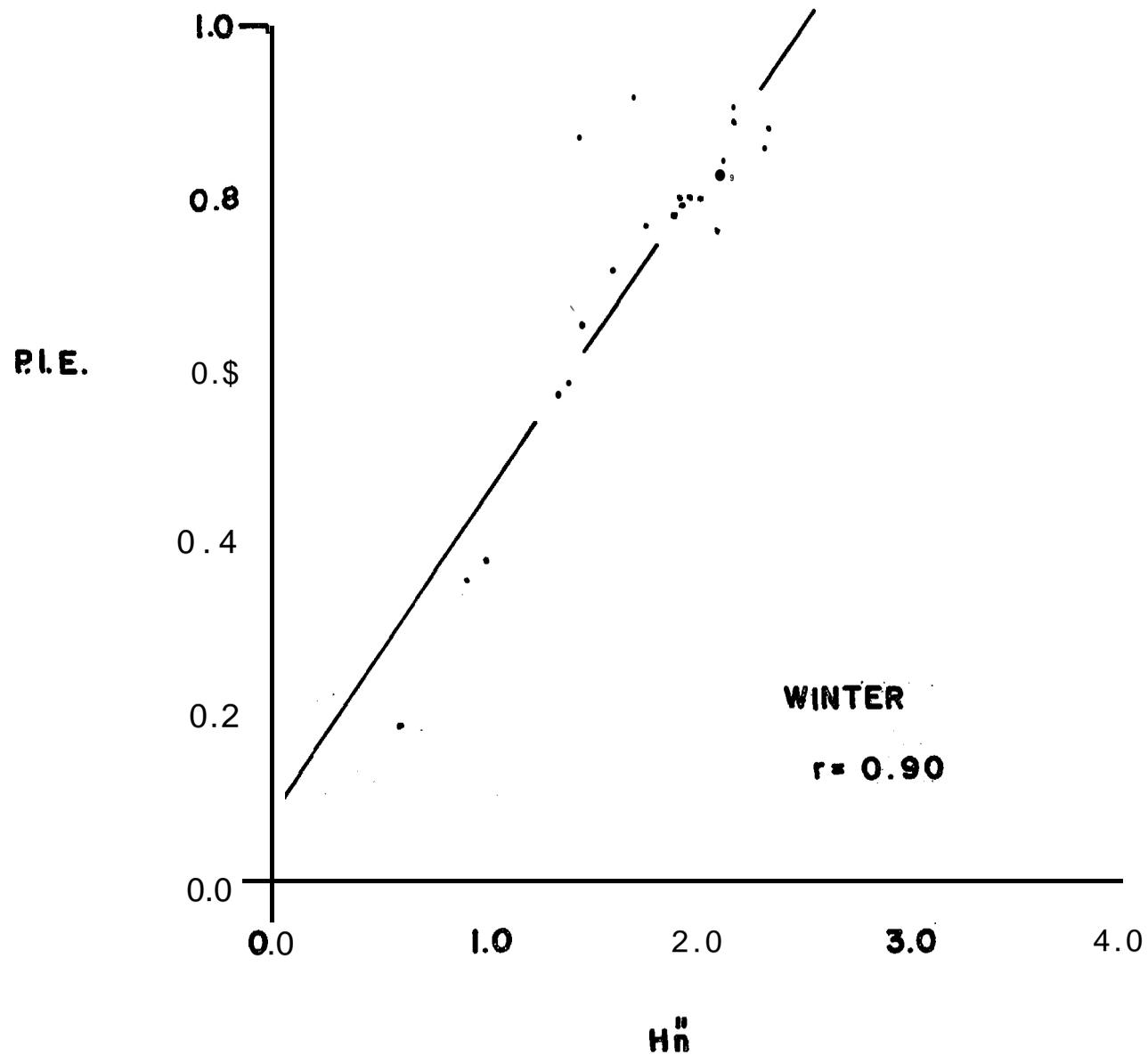


Figure 23. Relationship between the probability of interspecific encounter, P.I.E., and the Shannon index,  $H_n''$ , for winter fish collections.

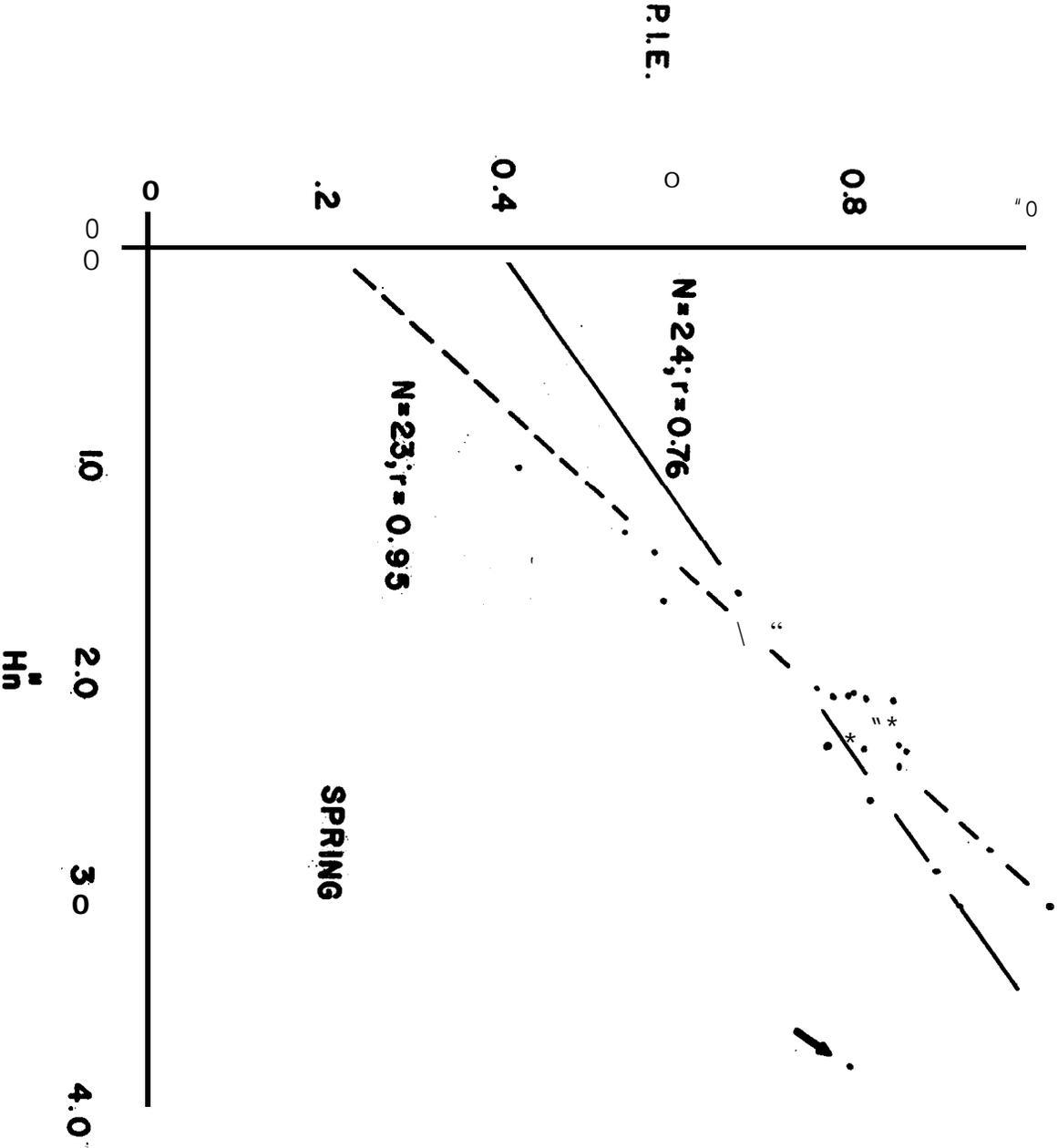


Figure 24. Relationship between P.I.E. and  $H_n$  for spring collections. Dashed line indicates relationship with deletion of outlying value indicated by arrow.

P.I.E.

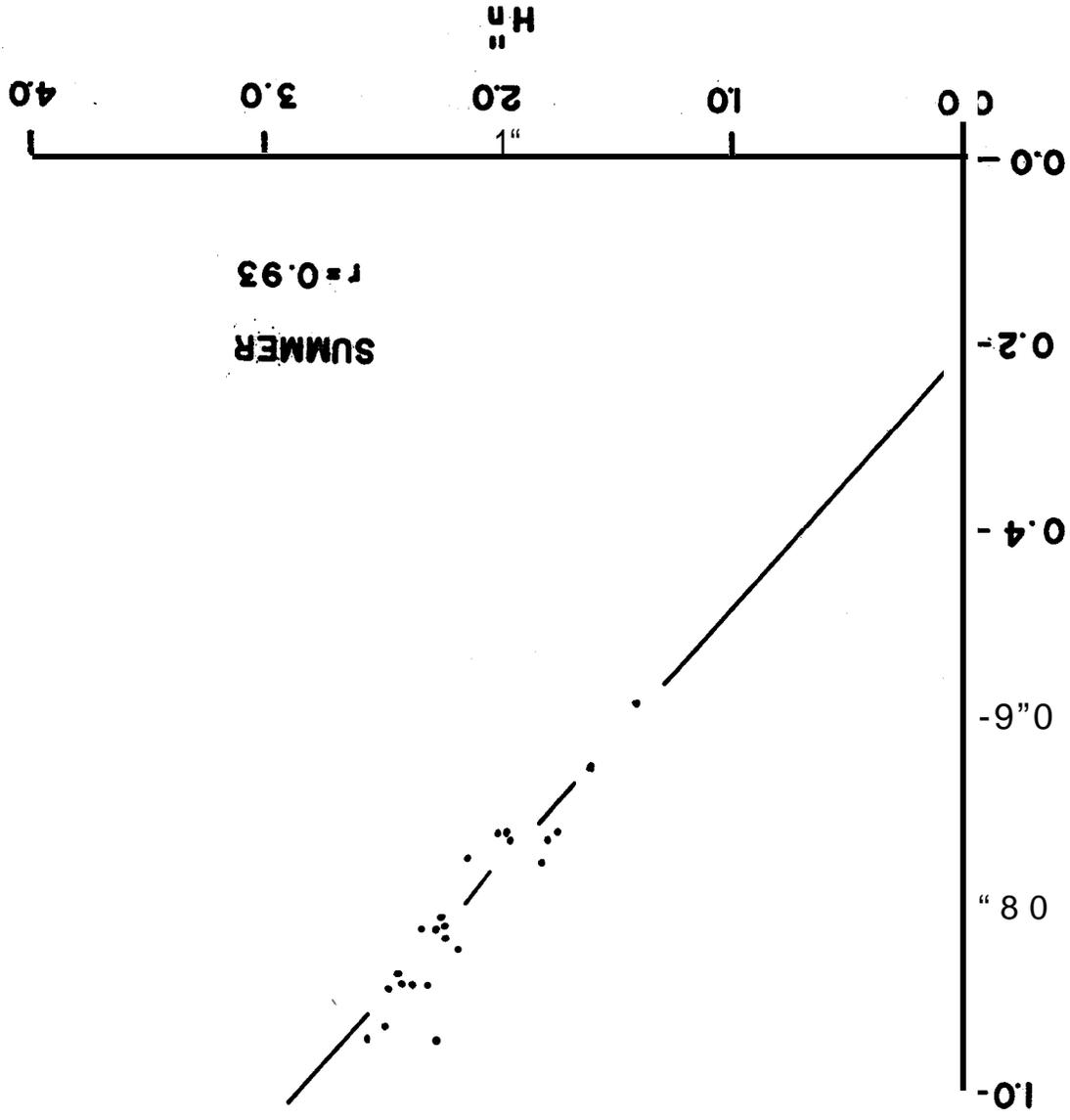


Figure 25. Relationship between P.I.E. and H<sub>n</sub> for summer collections.

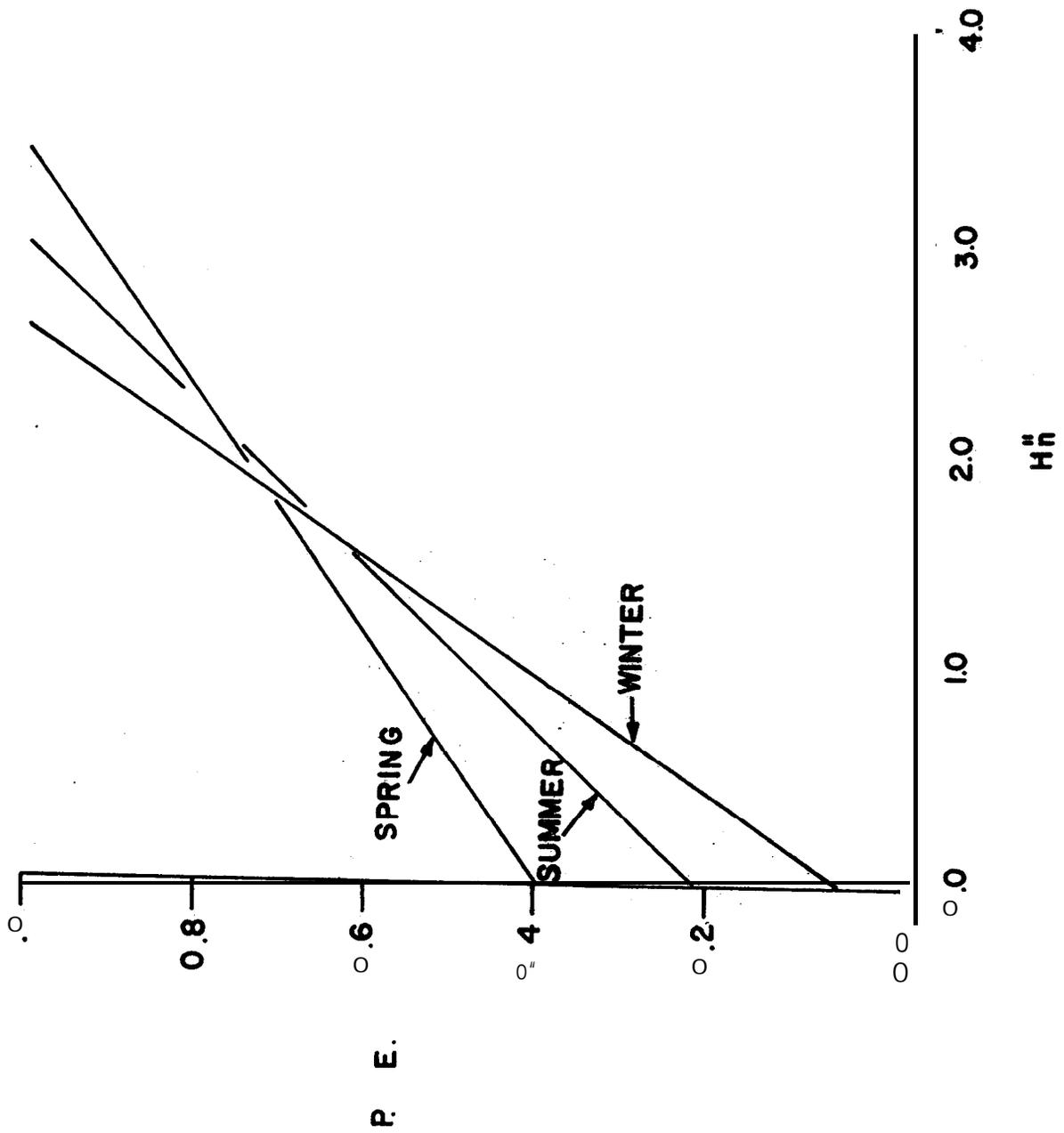


Figure 26. Relationships of seasonal PIE-H<sub>n</sub> regressions for 24 samples each season.

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  $r = 0.22$  ( $n = 23$ ); 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 processes.

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.

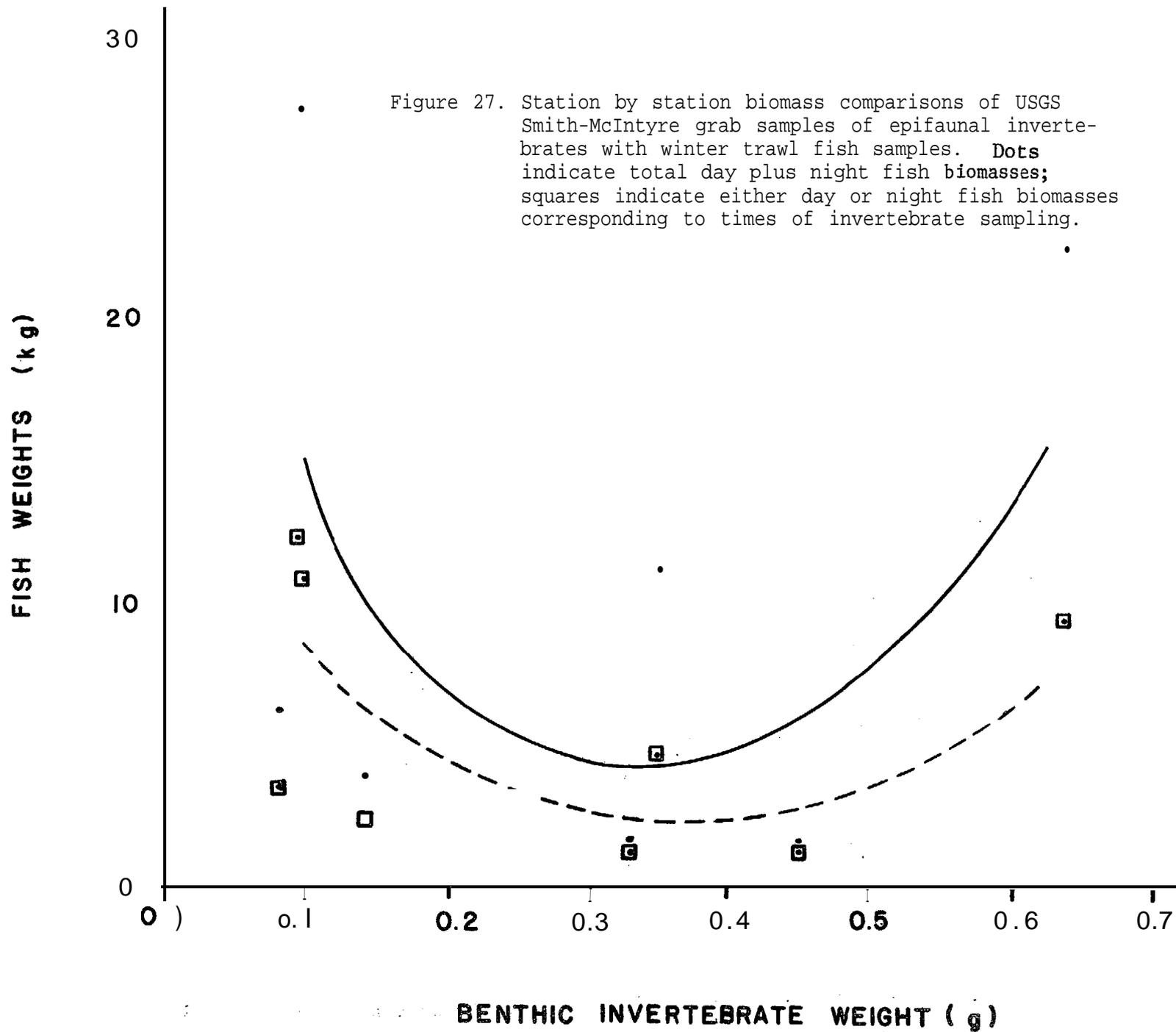
However, there are often some interesting interrelationships between standing crop biomasses of invertebrates and those of fishes, many of which forage directly on the invertebrate **trophic** levels. In the case of the **STOCS** study are the invertebrate data given in the USGS geological

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



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 unraveled 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

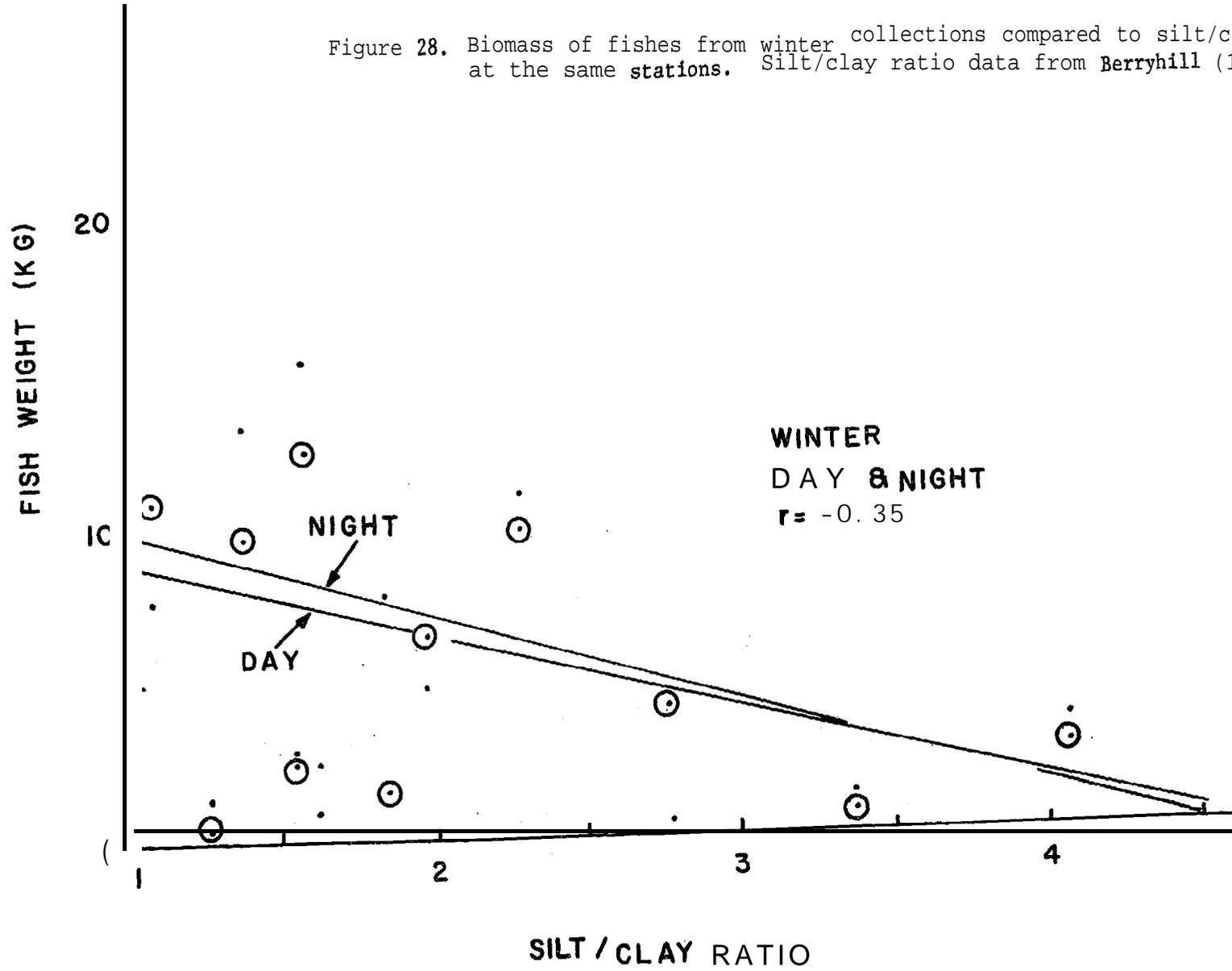
gear, it is instructive to evaluate sediment characteristics that may affect the abundance and distribution of fishes. From Berryhill (1975) it was noticed that some correspondence exists between sand/clay or silt/clay ratios and the invertebrates.

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.*

D = ⊙ N = ·

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-MOLECULARWEIGHT HYDROCARBONS PROJECT

Texas A&M University, College Station

Principal Investigator:  
William M. Sackett

Associate Investigator:  
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## 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  $\pm 0.01$  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  $\pm 0.001\%$  (ppt).

#### Dissolved Oxygen

Samples were analyzed 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  $\pm 0.01$  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 volatility 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 volatility coefficients, the equilibrium concentrations of methane, in nanoliters per liter (nl/L) as a function of salinity and temperature are as follows:

Temperature	Salinity (‰)			
	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

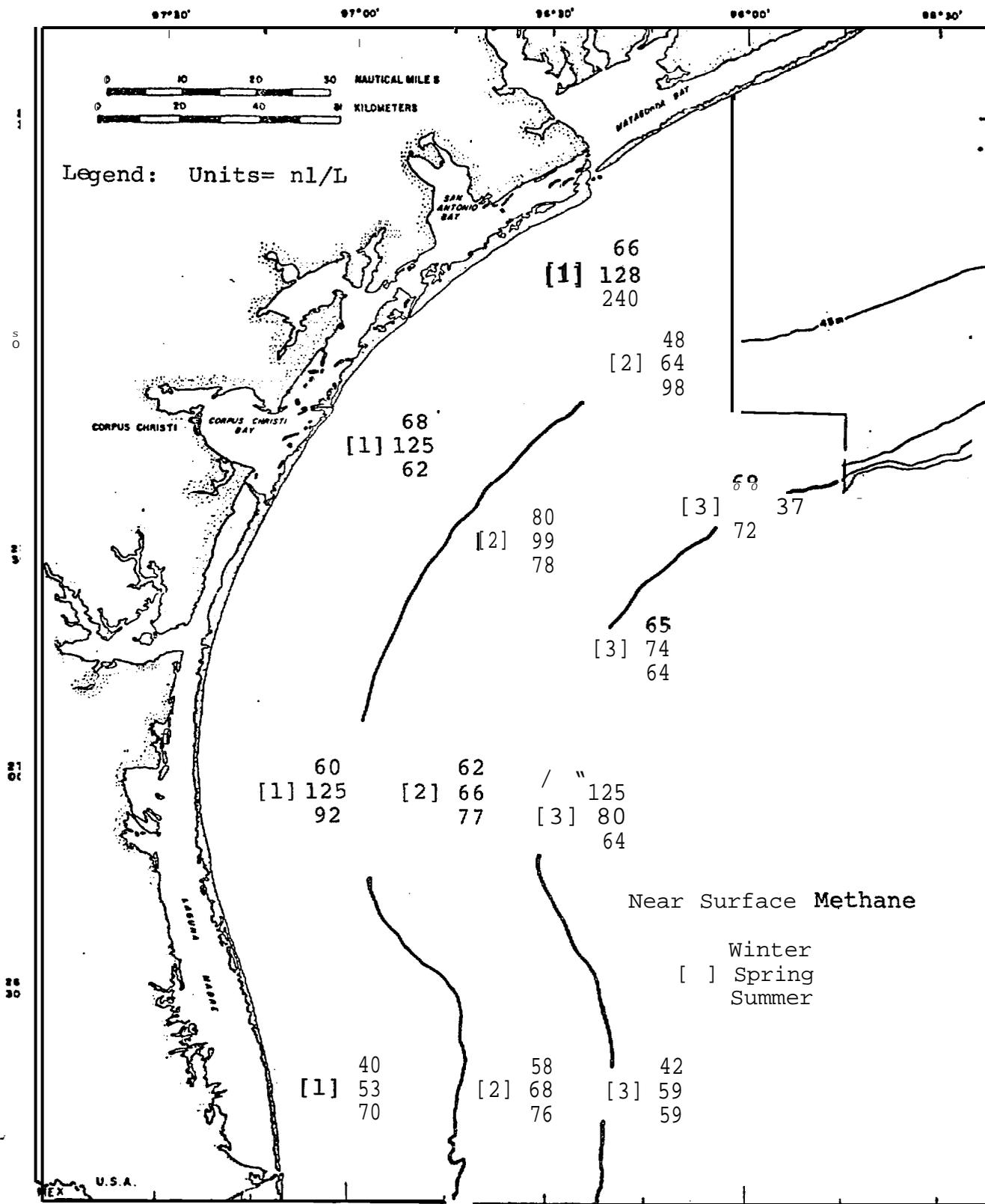


Figure 1. Near Surface Methane Concentrations, 1975.

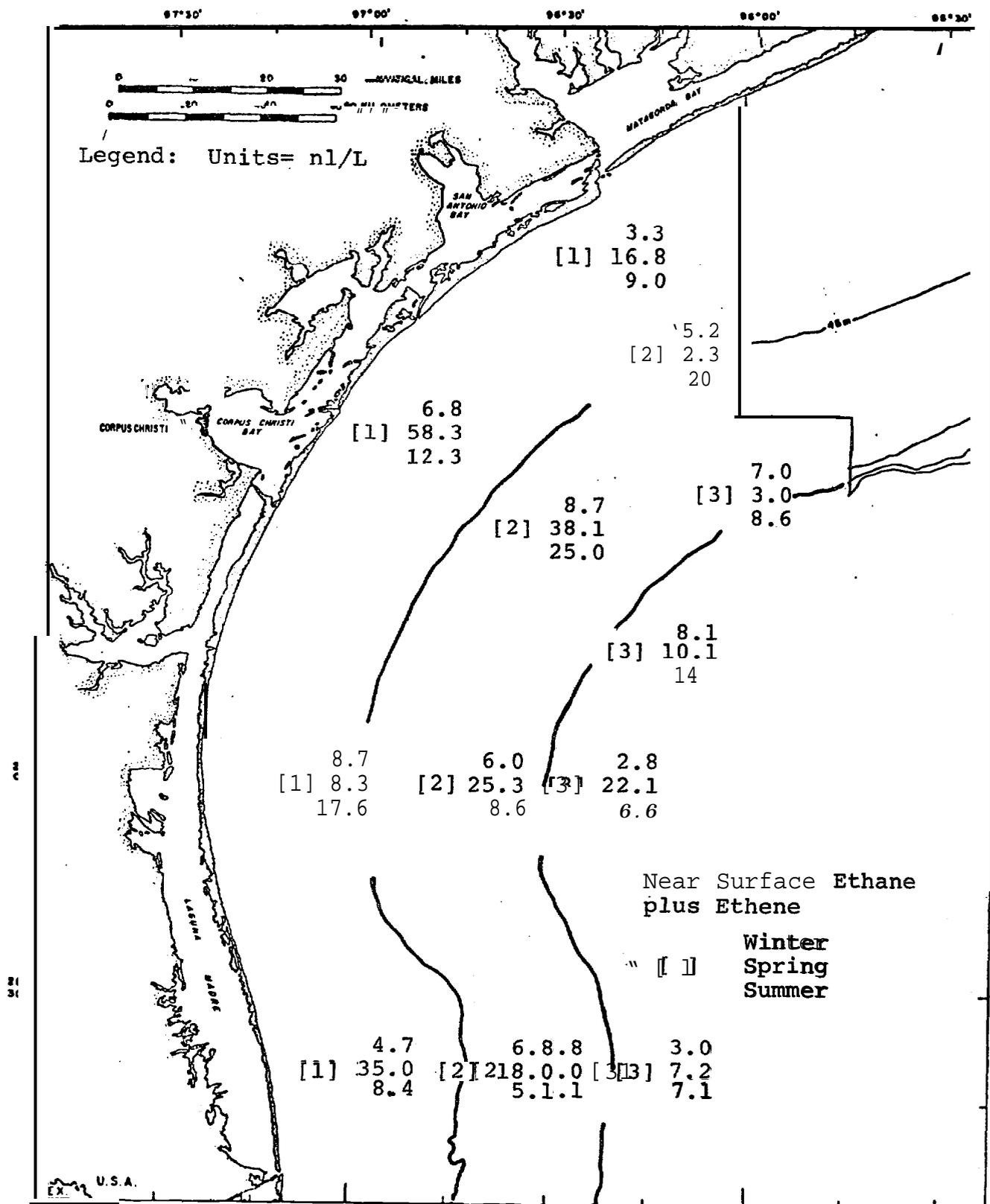


Figure 2. Near Surface Ethane plus Ethene Concentrations ,1975.

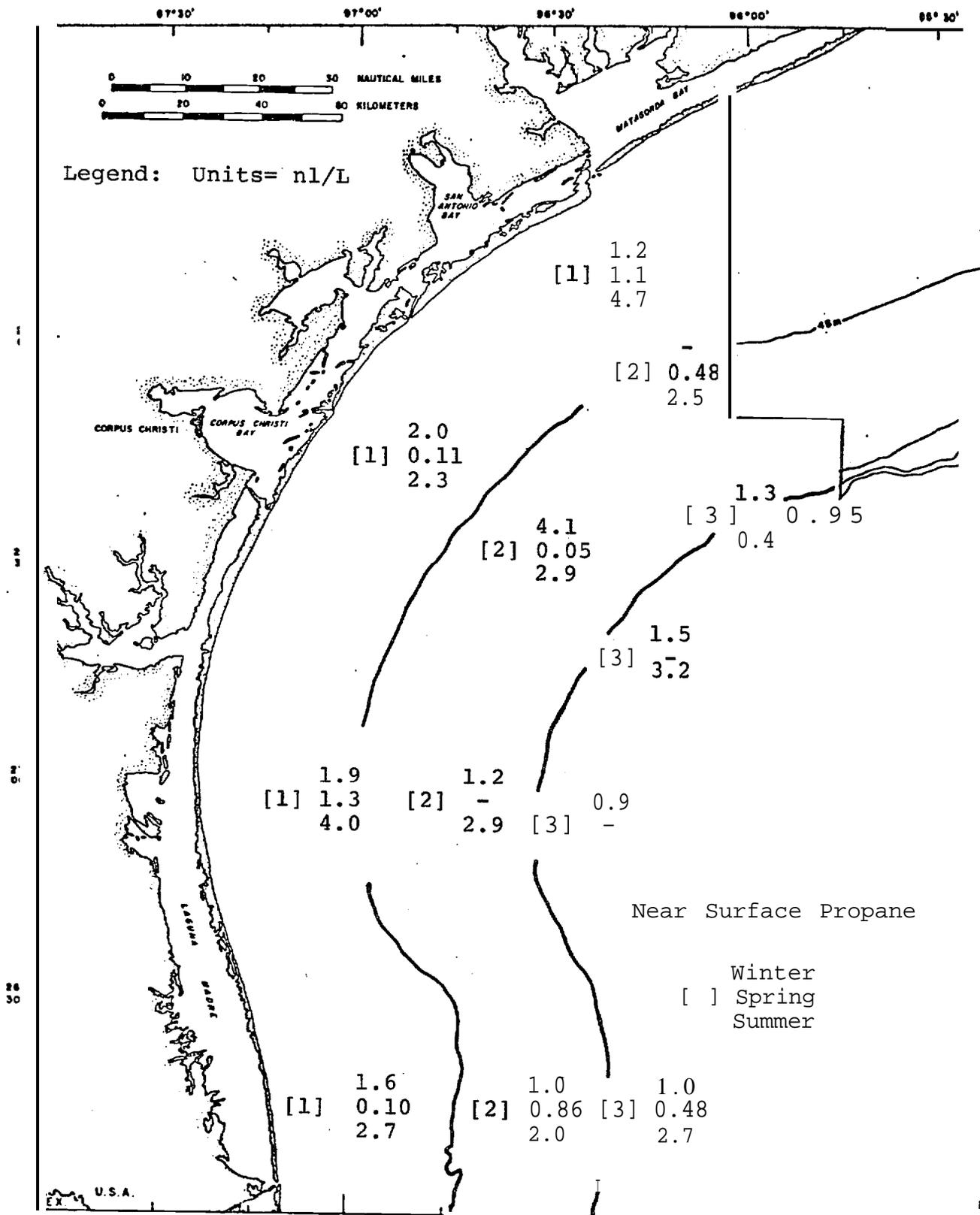


Figure 3. Near Surface Propane Concentrations, 1975.

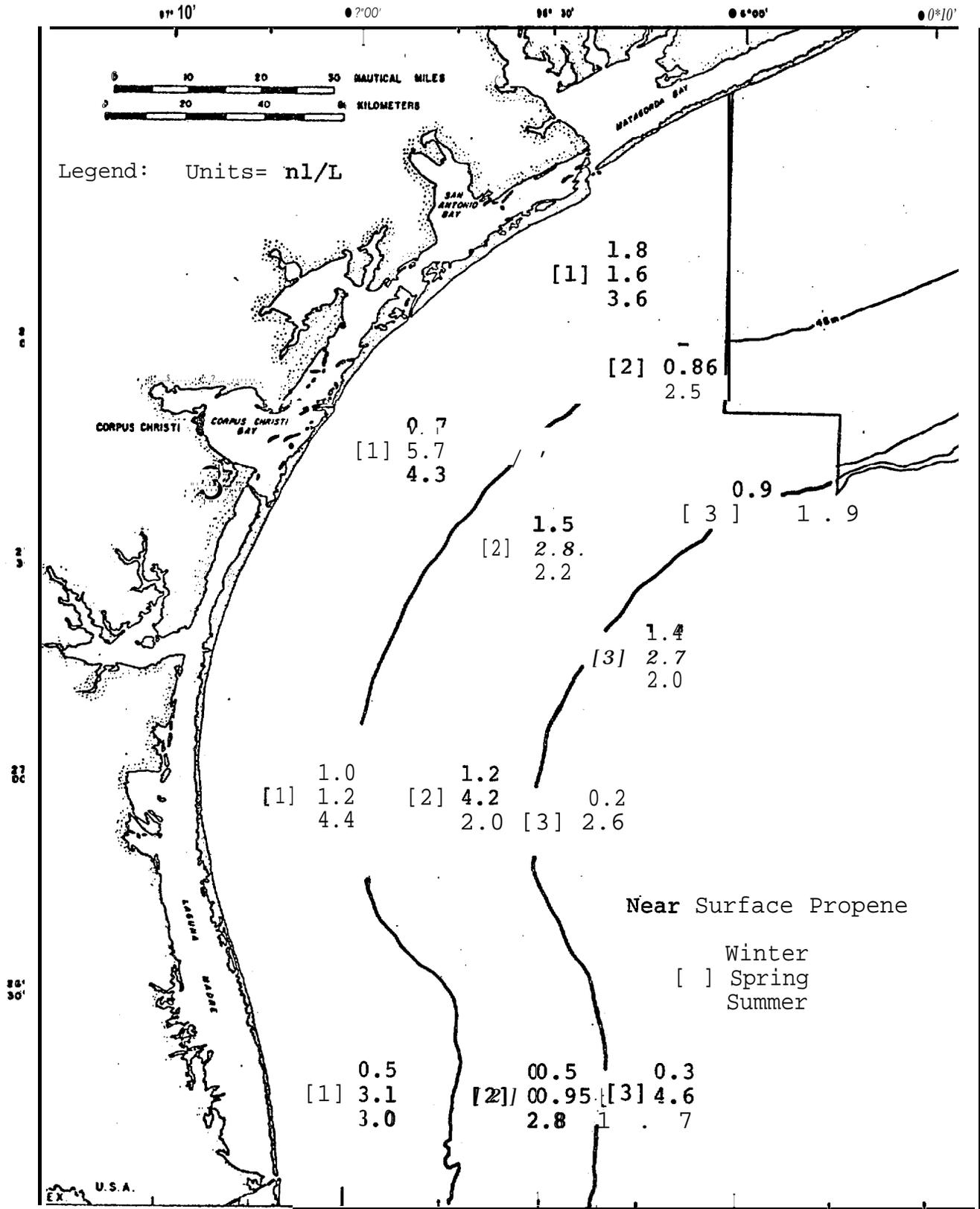


Figure 4. Near Surface Propene Concentrations, 1975.

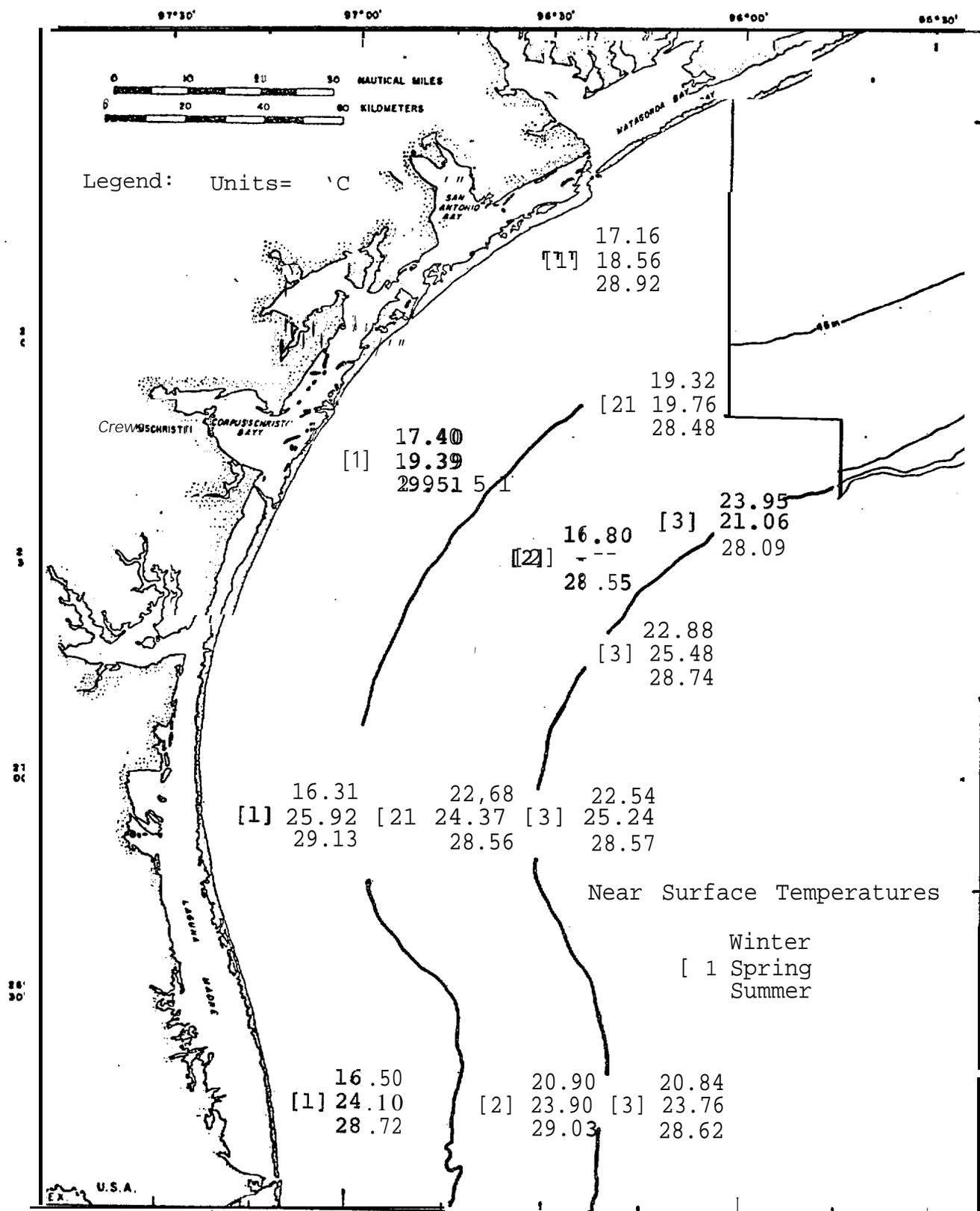


Figure 5. Near Surface Temperature Concentrations, 1975.

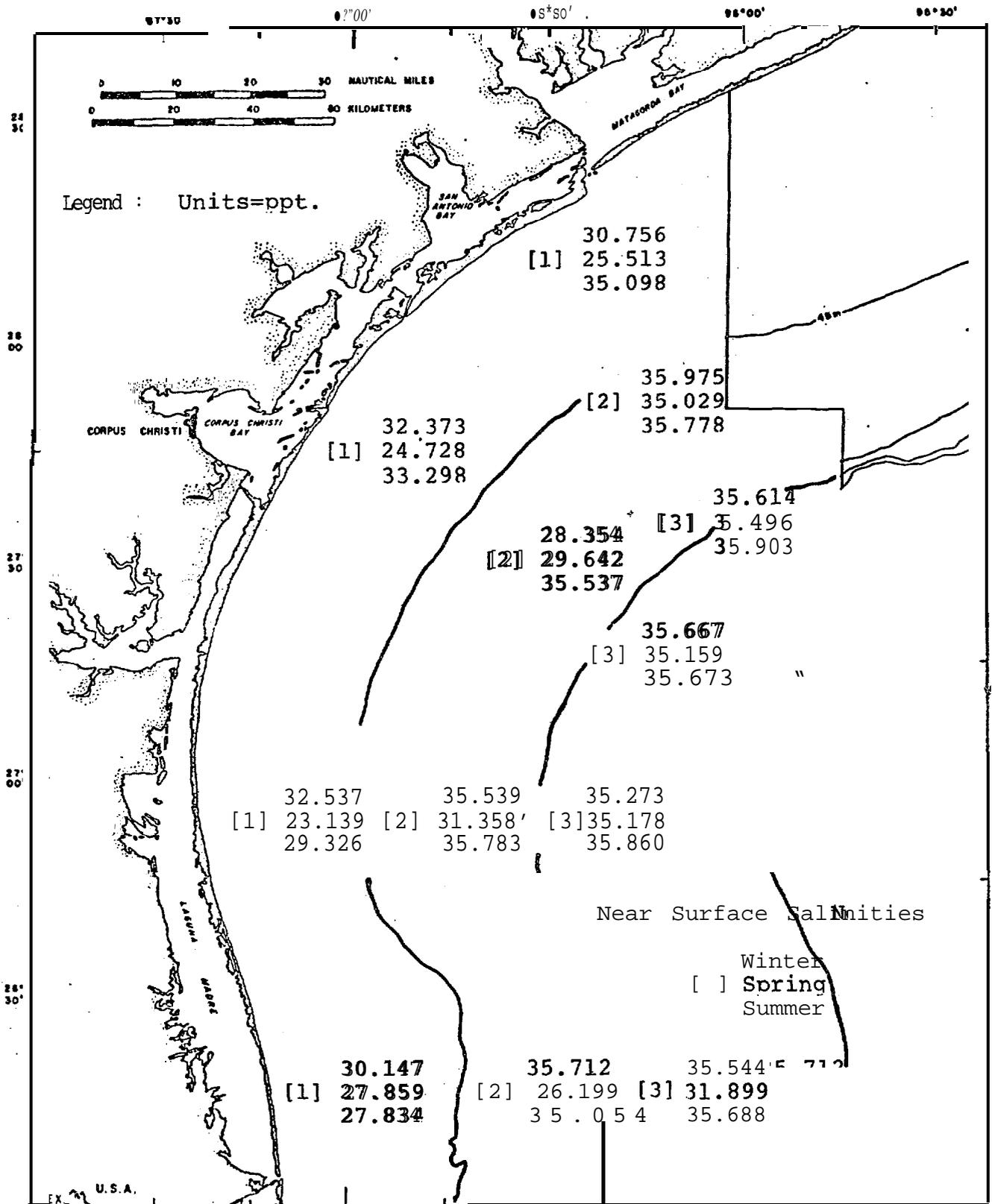


Figure 6. Near Surface Salt Concentrations, 1975.

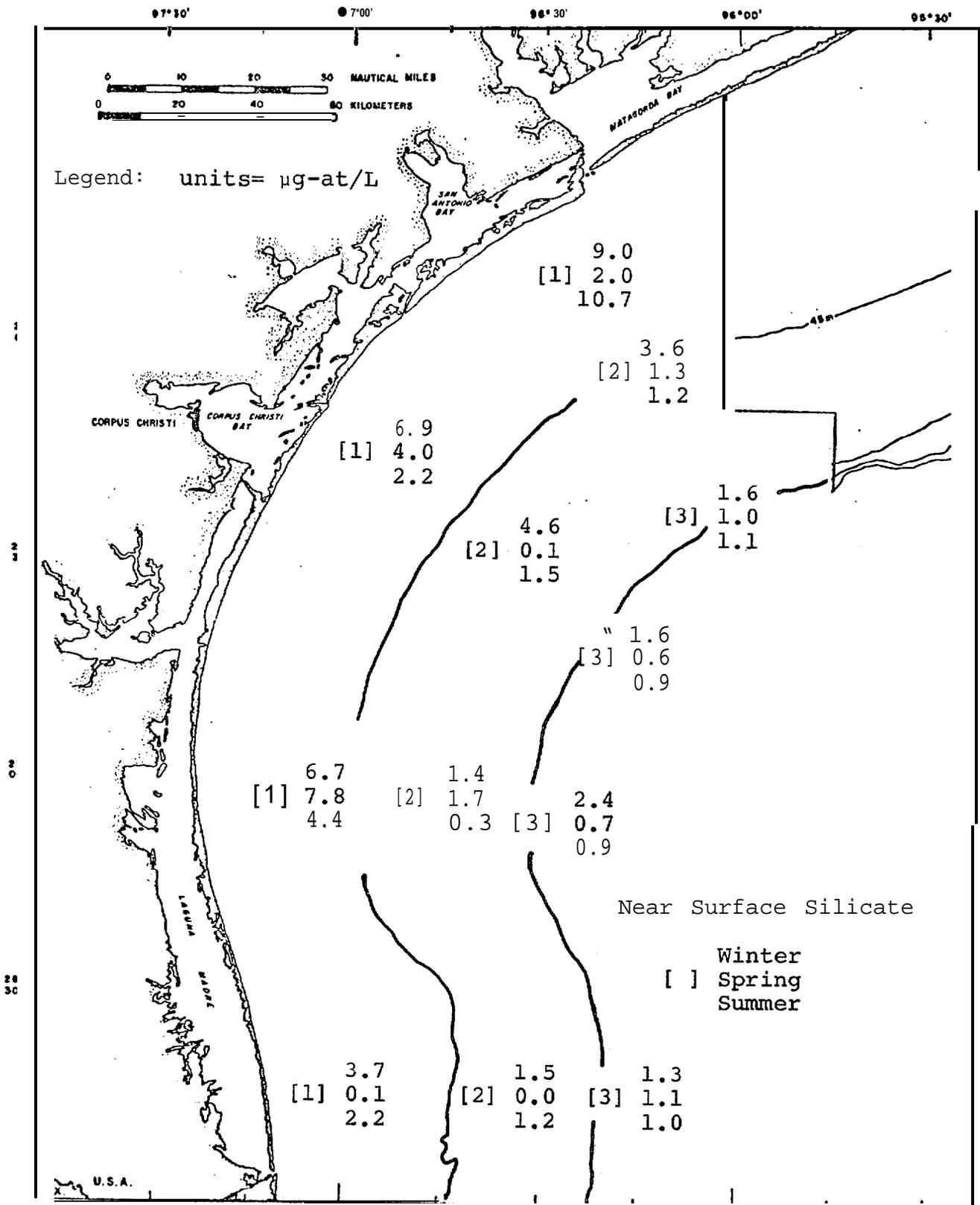


Figure 7. Near Surface Silicate Concentrations, 1975.

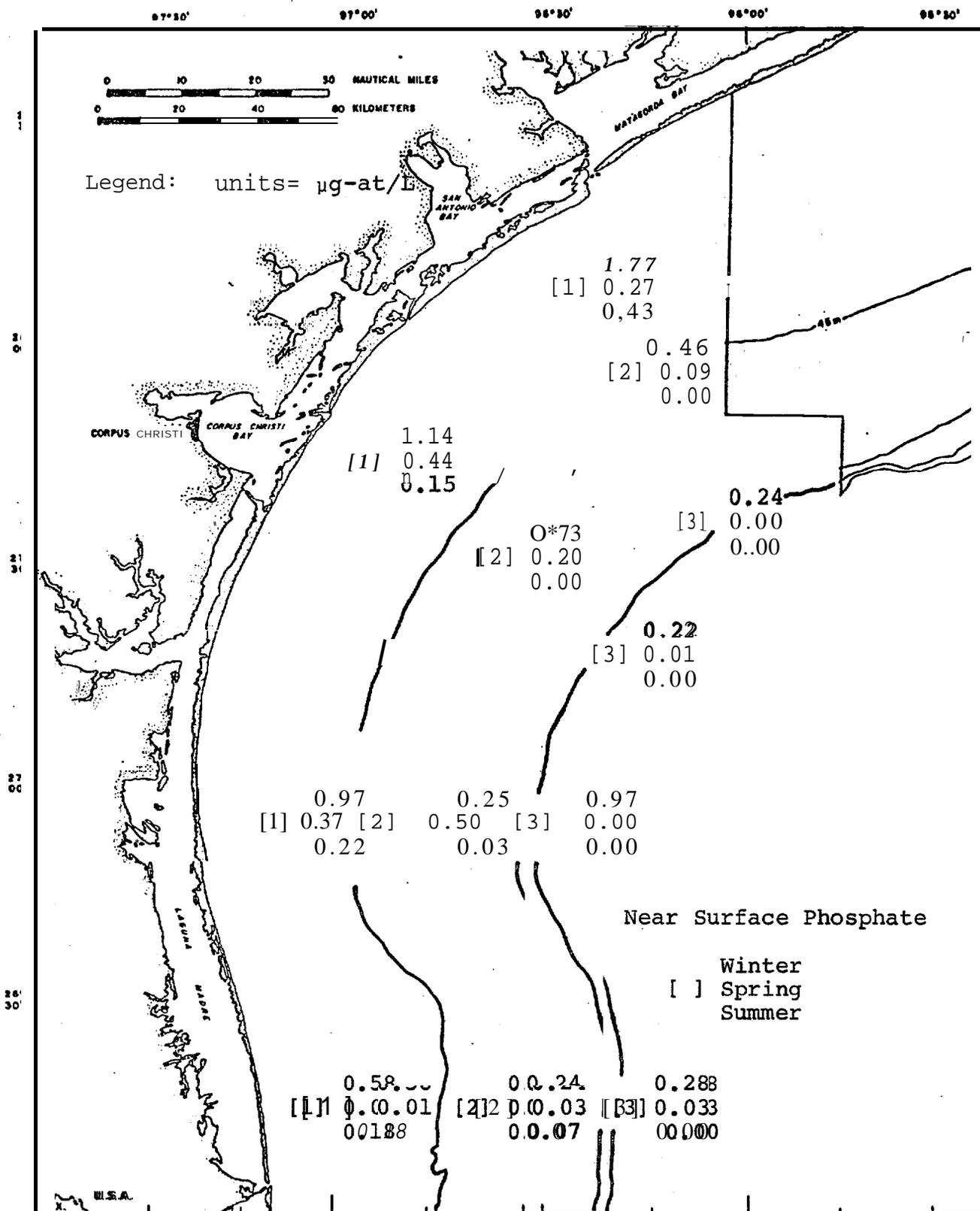


Figure 8. Near Surface Phosphate Concentrations, 1975.

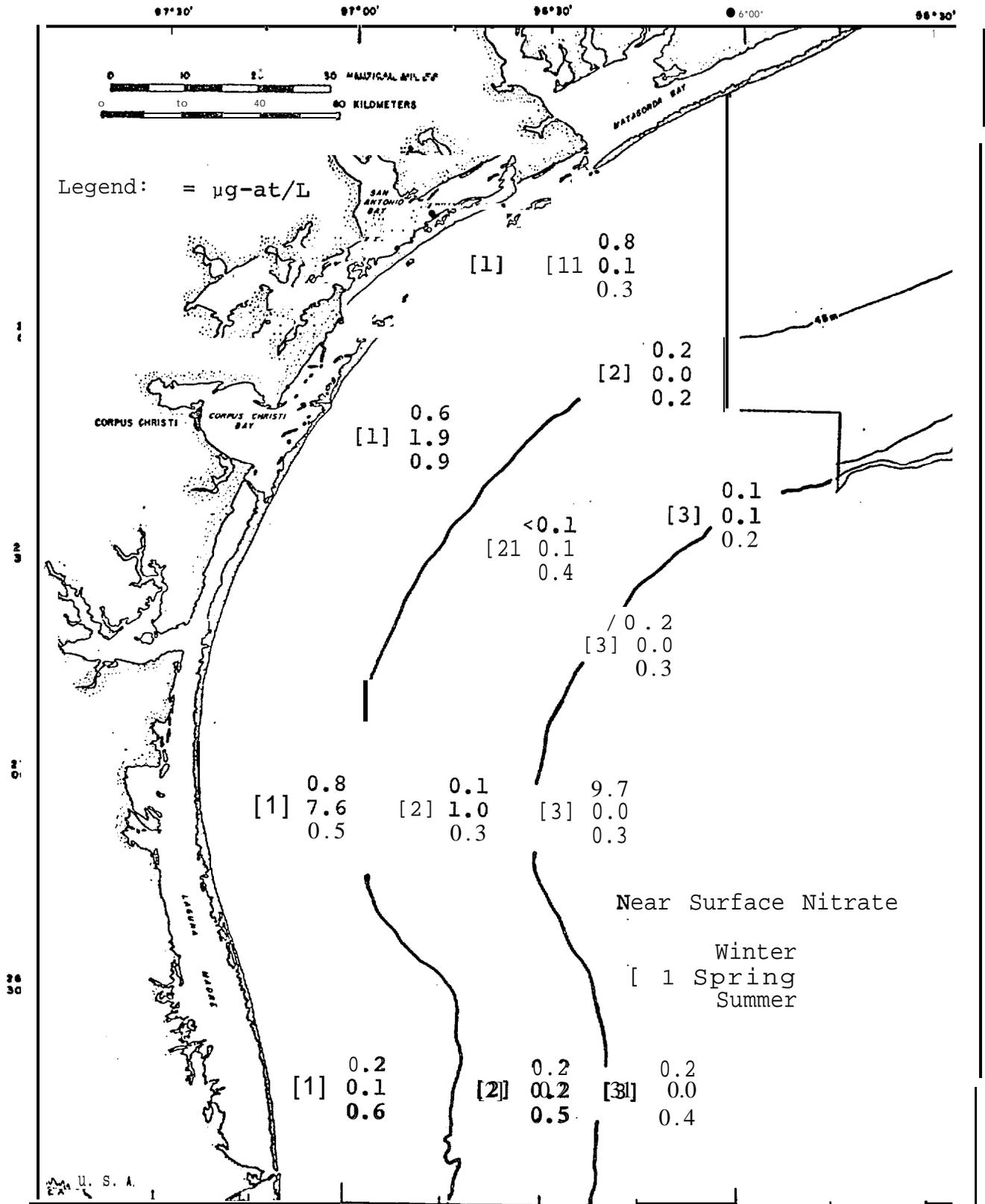


Figure 9. Near Surface Nitrate Concentrations, 1975.

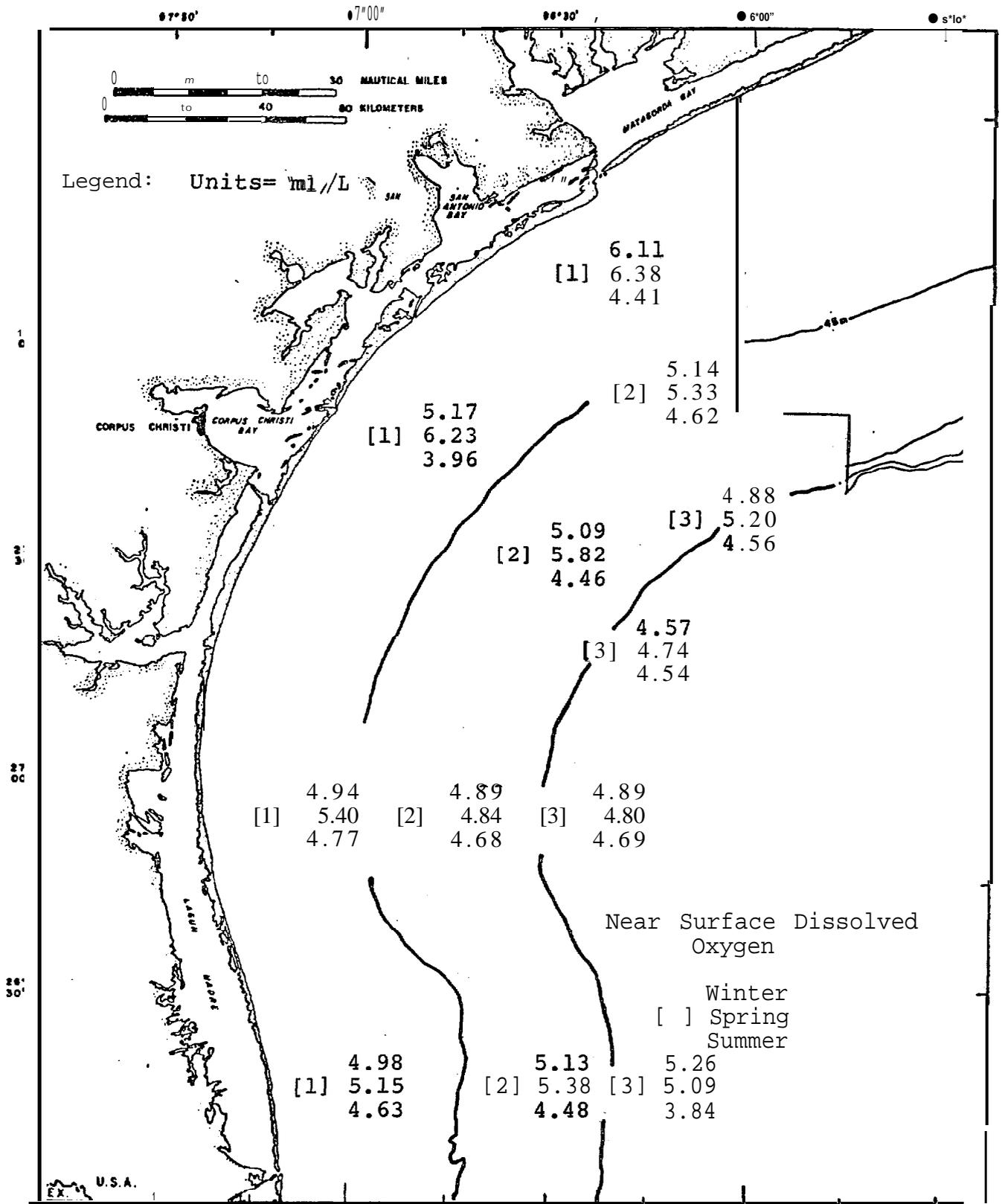


Figure 10. Near Surface Dissolved Oxygen Concentrations, 1975.

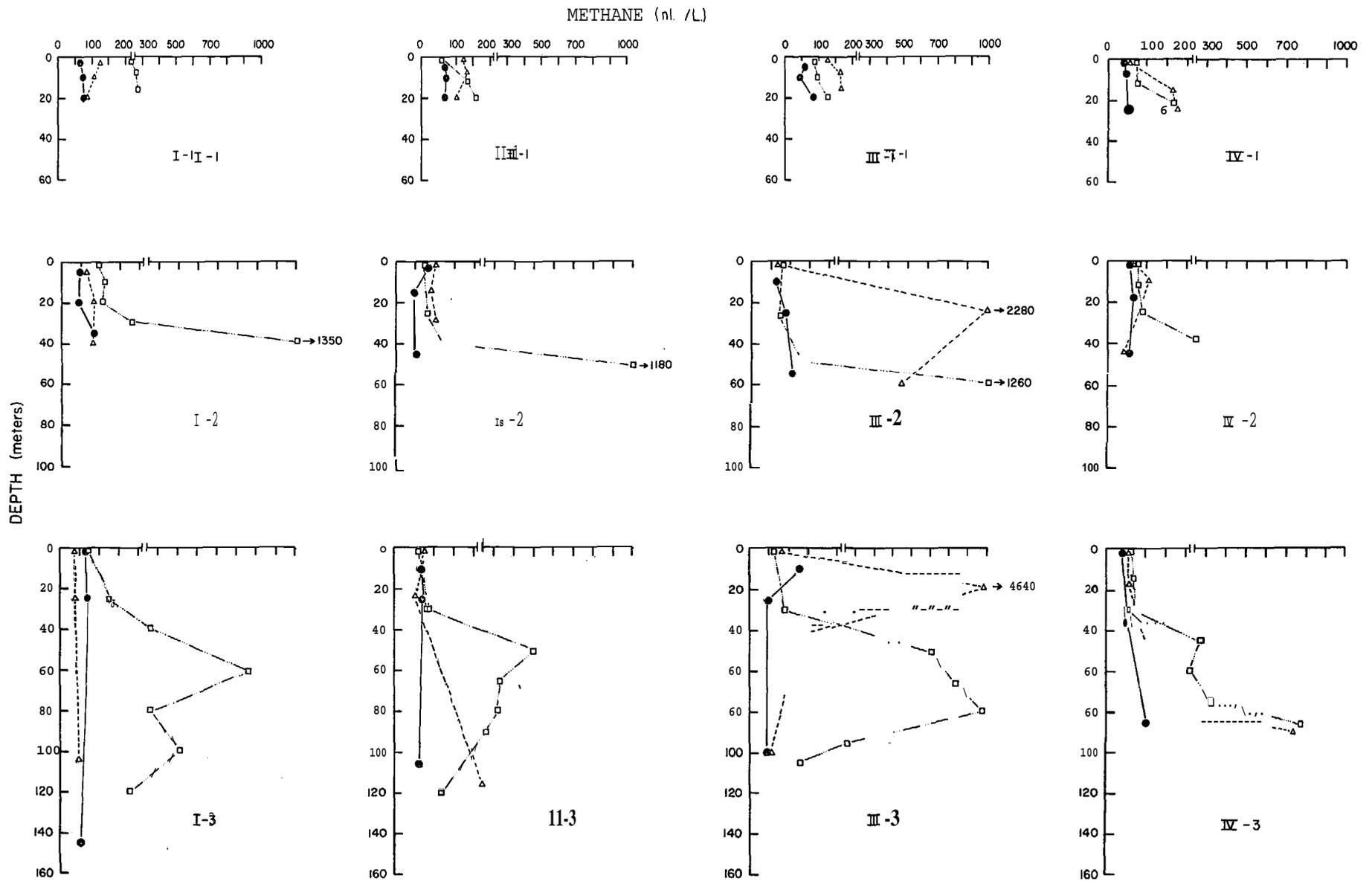


Figure 11. Vertical Methane Profiles for Winter (circles) , Spring (triangles) , and Summer (squares) Sampling Periods.

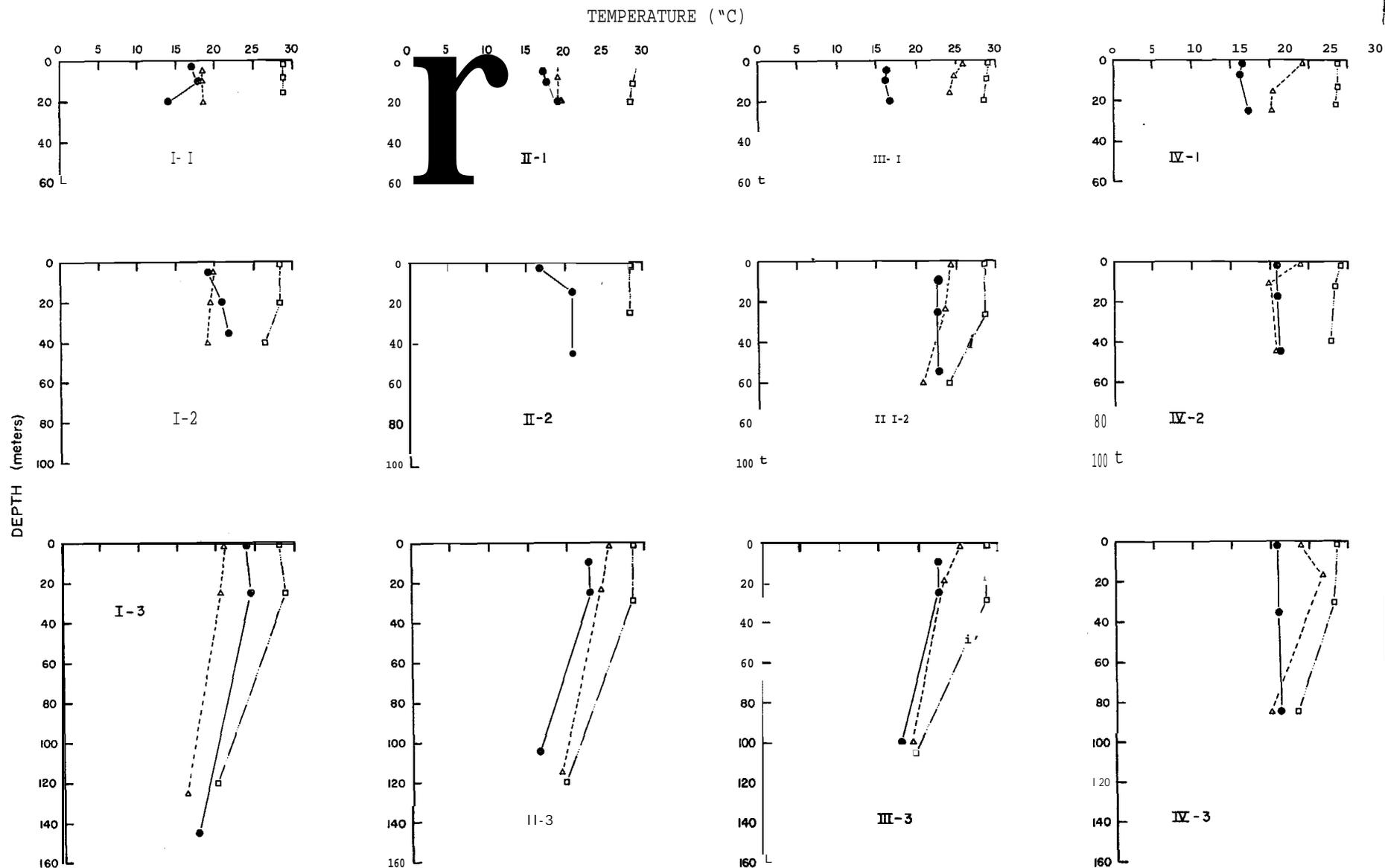


Figure 12. Vertical Temperature Profiles for Winter (circles), Spring (triangles) and Summer (squares) Sampling Periods.

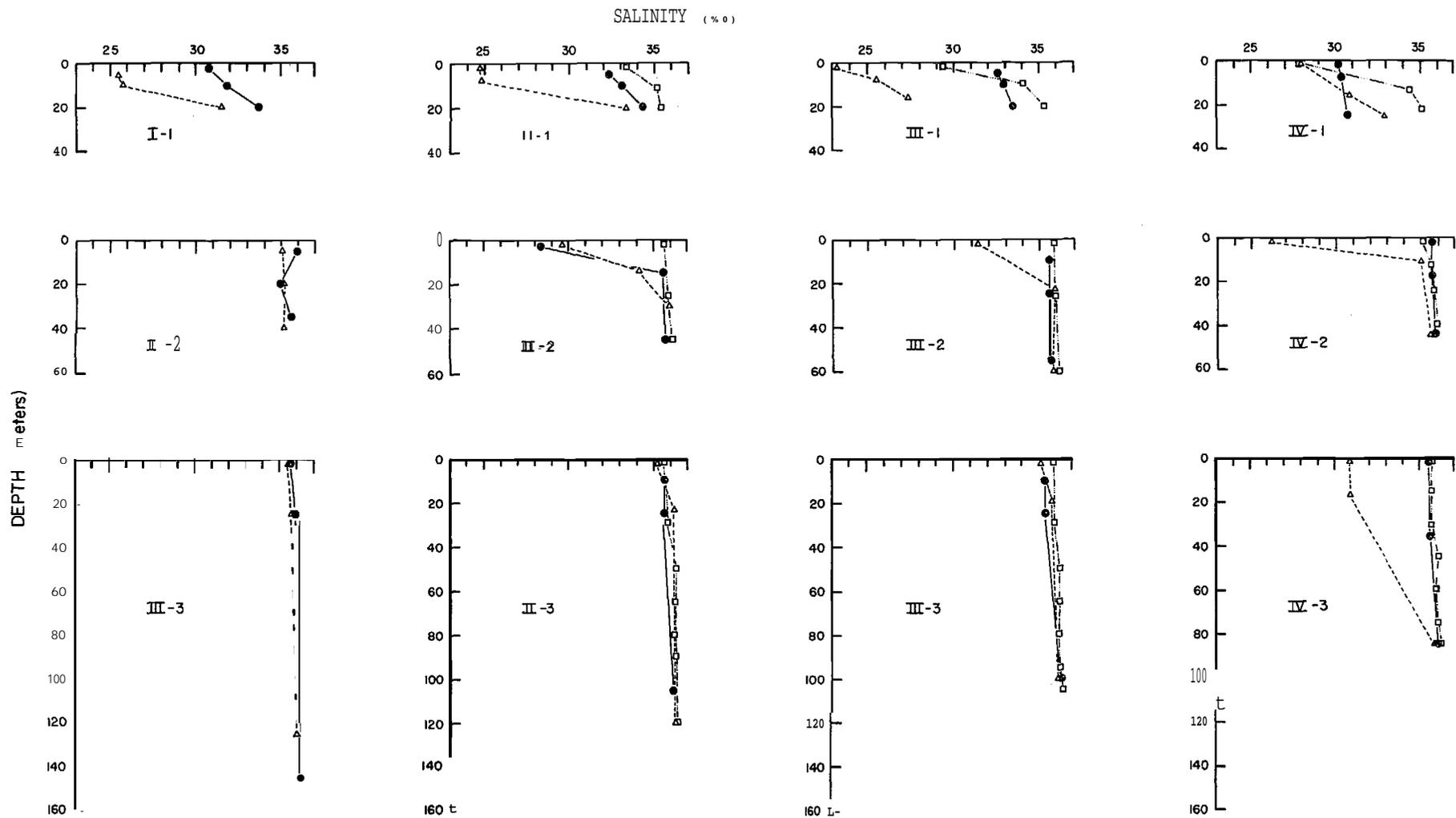


Figure 13. " Vertical Salinity Profiles for Winter (circles) , Spring (triangles) , and Summer (squares) sampling Periods.

SILICATE (ug-at./ L.)

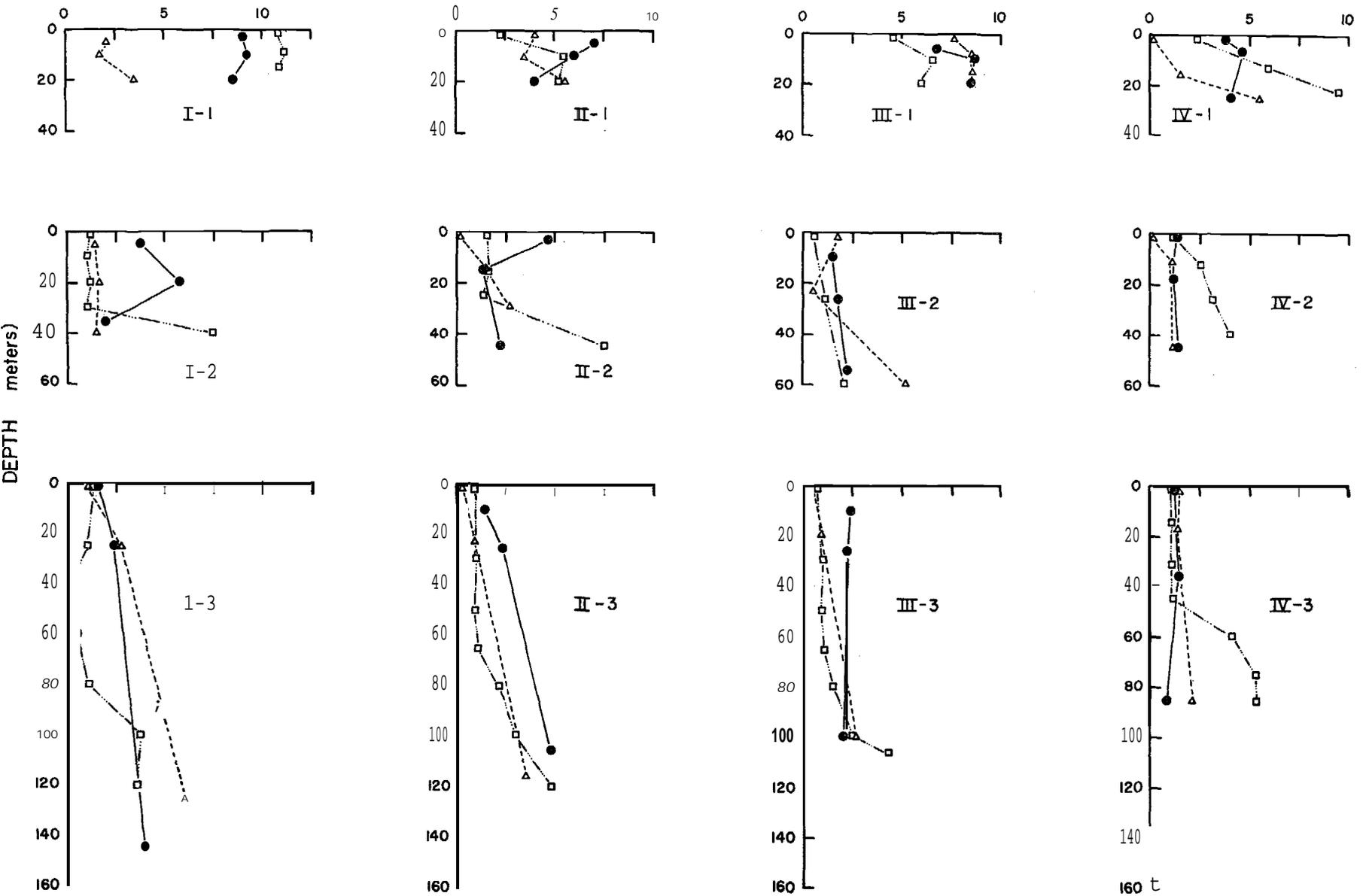


Figure 14. Vertical Silicate Profiles for Winter (circles) , Spring (triangles) , and Summer (squares) Sampling Periods.

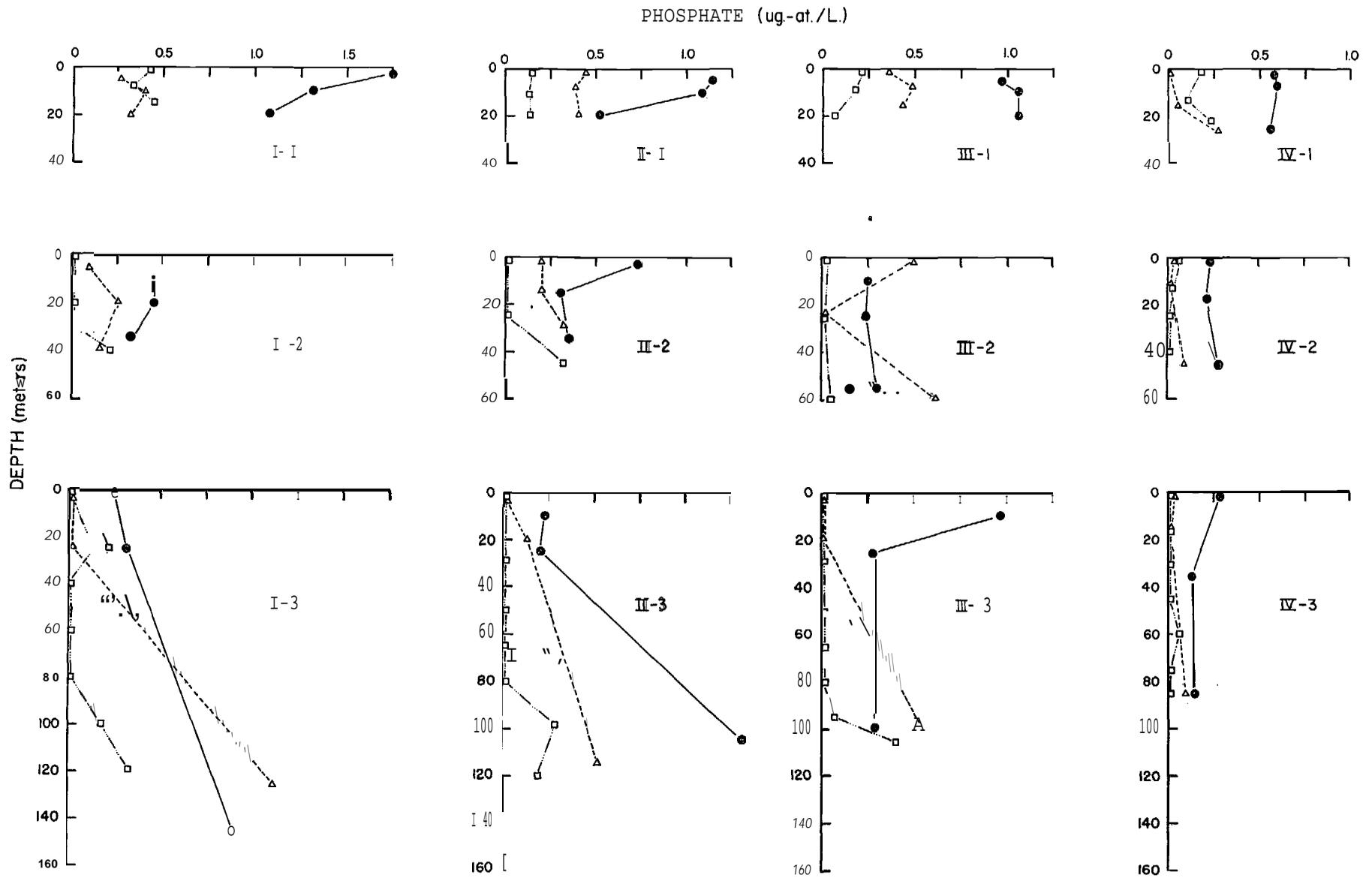


Figure 15. Vertical Phosphate Profiles for Winter (circles) , Spring (triangles) , and Summer (squares) Sampling Periods.

NITRATE (ug-at./L.)

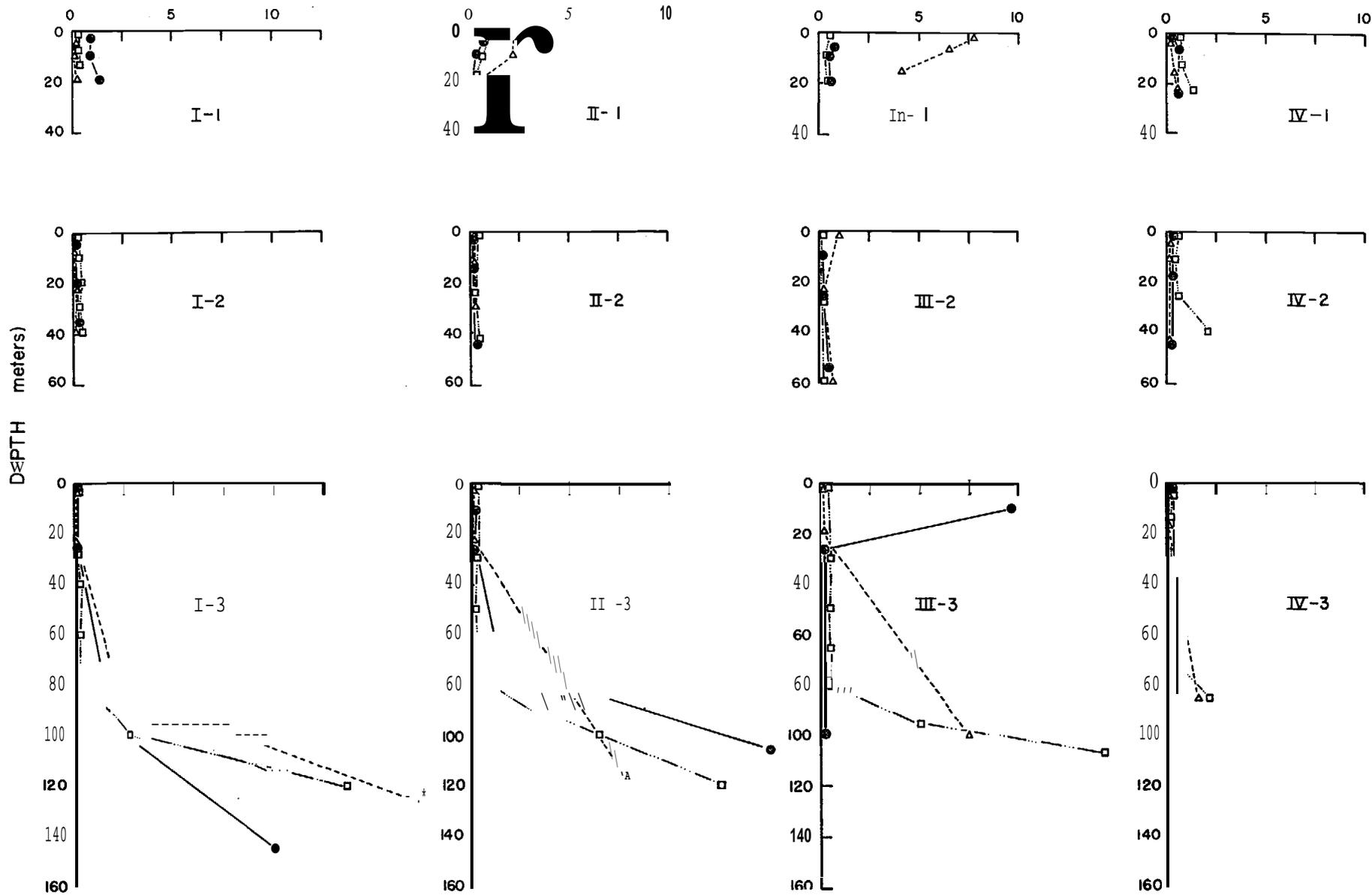


Figure 16. Vertical Nitrate Profiles for Winter (circles) , Spring (triangles) , and Summer (squares) Sampling periods.

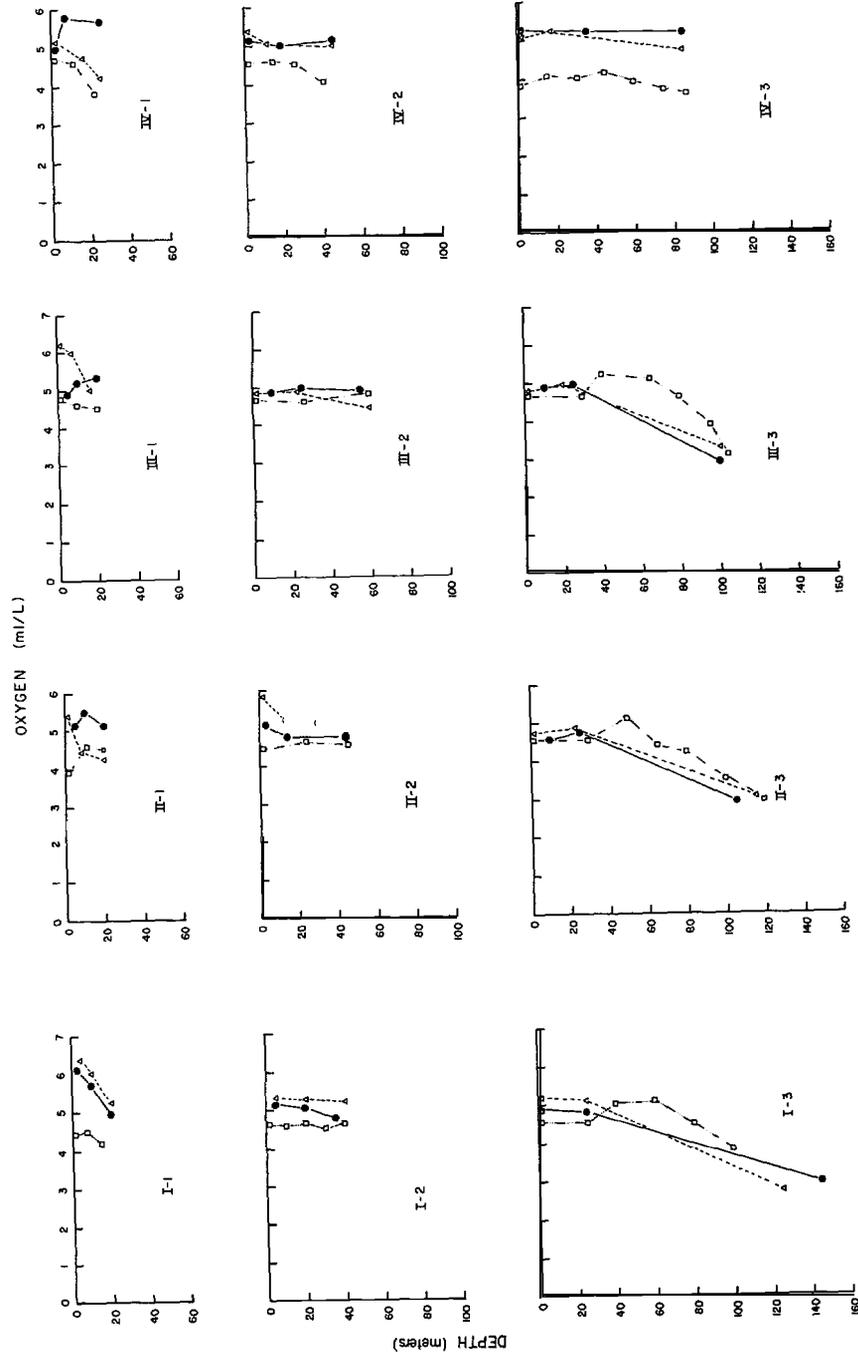


Figure 17. Vertical Oxygen Profiles for Winter (circles), Spring (triangles), and Summer (squares) Sampling Periods.

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 (0,00)	SILICATE µg-at/L	PHOSPHATE µg-at/L	NITRATE µg-at/L	OXYGEN mL/L
I/1 2.5 m 10 m 20 m	17.16 17.91 14.12	30.756 31.863 33.698	9.0 9.2 8.5	1.77 1.32 1.08	0.8 0.8 1.3	6.11 5.71 4.95
1/2 5 m 20 m 35 m	19.32 21.00 21.81	35.975 34.999 35.583	3.6 5.7 1.9	0.46 0.45 0.33	0.2 0.2 0.3	5.14 5.06 4.79
I/3 * 1 m 25 m 145 m	23.95 24.24 17.76	35.614 35.983 36.343	1.6 2.4 3.9	0.24 0.31 0.90	0.1 < 0.1 10.1	4.88 4.81 2.97
II/1 5 m 10 m 20 m	17.40 17.83 19.34	32.372 33.066 34.319	6.9 6.0 4.0	1.14 1.09 0.52	0.6 0.4 0.1	5.17 5.49 5.16
II/2 3 m 15 m 45 m	16.80 20.82 20.98	28.354 35.598 35.737	4.6 1.3 2.2	0.73 0.30 0.35	< 0.1 0.1 0.3	5.09 4.76 4.79
11/3 10 m 25 m 105 m	22.88 22.95 16.40	35.667 35.684 36.181	1.6 2.3 4.8	0.22 0.20 1.31	0.2 0.1 16.4	4.57 4.78 2.92
III/1 5 m 10 m 20 m	16.31 16.22 16.74	32.537 32.932 33.414	6.7 8.7 8.0	0.97 1.06 1.06	0.8 0.6 0.5	4.94 5.23 5.34
111/2 10 m 25 m 55 m	22.69 22.60" 22.66	35.539 35.545 35.593	1.4 1.6 2.2	0.25 0.24 0.30	0.1 0.1 0.4	4.89 4.98 4.91

Table 1. Cent 'd.

STATION DEPTH	TEMPERATURE (DEGREE'S C)	SALINITY (0/00)	SILICATE $\mu\text{g-at/L}$	PHOSPHATE $\mu\text{g-at/L}$	NITRATE $\mu\text{g-at/L}$	OXYGEN
III/3 10 m 25 m 100 m	22.54 22.50 17.82	35.273 35.283 36.318	2.4 2.2 2.1	0.97 0.28 0.31	9.7 0.1 <0.1	4.69 4.96 2.91
IV/1 2 m 7 m 25 m	16.50 16.19 17.37	30.147 30.309 32.745	3.7 4.4 4.0	0.58 0.60 0.56	0.2 0.3 0.5	4.98 5.78 5.67
Iv/2 2 m 18 m 45 m	20.90 20.91 21.08	35.712 35.712 35.808	1.5 1.2 1.4	0.24 0.22 0.28	0.2 0.2 0.2	5.13 4.99 5.11
Iv/3 2 m 36 m 85 m	20.84 20.92 21.09	35.544 35.686 36.014	1.3 1.4 0.7	0.28 0.13 0.15	0.2 0.3 0.4	5.26 5.22 5.20

Table 1. Cent' d.

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

STATION DEPTH,	TEMPERATURE (DEGREE'S C)	SALINITY ( ‰)	SILICATE µg-at/L	PHOSPHATE µg-at/L	NITRATE µg-at/L	OXYGEN ml/L
I/1 5 m 10 m 20 m	18.56 18.46 18.74	25.513 25.779 31.508	2.0 1.8 3.4	0.27 0.40 0.32	0.1 0.0 0.1	6.383 6.007 5.230
I/2 5 m 20 m 40 m	19.76 19.49 19.10	35.029 35.212 35.208	1.3 1.6 1.5	0.09 0.26 0.15	0.0 0.1 0.0	5.32? 5.282 5.226
I/3 1 m 25 m 125 m	21.06 20.59 16.18	35.496 35.740 36.095	1.0 3.2 6.0	0.00 0.02 1.12	0.1 0.0 15.7	5.195 5.116 2.750
I/1 0 m 8 m 20 m	19.39 19.31 19.48	24.728 <b>24.761</b> 33.381	4.0 3.5 5.5	0.44 0.38 0.40	1.9 1.9 <b>0.5</b>	6.226 6.006 5.084
I/2 0 m 14 m 29 m		29.642 34.197 35.953	<b>0.1</b> 1.5 2.8	0.20 0.20 0.32	<b>0.1</b> 0.1 0.2	5.816 5.198 5.128
I/3 1 m 23 m 115 m	25.48 24.08 19.16	35.159 36.233 36.243	0.6 0.9 3.4	0.01 <b>0.13</b> 0.53	0.0 <b>0.0</b> 8.2	4.736 <b>4.860</b> 3.081

Table 1. Cant' 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
111/1 1 m 7.5 m 16 m	25.92 24.68 24.18	23.139 25.496 27.381	7.8 8.3 8.3	0.37 0.49 0.41	7.6 6.5 4.1	5.399 4.458 4.261
III/2 1 in 23 m 60 m	24.37 23.47 20.76	31.358 35.880 35.766	1.7 0.8 5.2	0.50 0.00 0.62	1.0 0.1 0.6	4.836 4.916 4.459
111/3 1 m 19 m 100 m	25.24 23.24 19.24	35.178 35.748 36.230	0.7 0.9 2.6	0.00 0.00 0.54	0.0 0.1 7.8	4.801 4.941 3.314
IV/1 1 m 16 m 25 m	24.10 20.41 20.23	27.859 31.878 32.891	0.1 1.4 5.6	0.03 0.05 0.28	0.1 0.3 0.5	5.149 4.713 4.217
Iv/2 1 m 11 m 45 m	23.90 19.94 20.90	26.199 35.018 35.594	0.0 1.1 1.2	0.03 0.01 0.08	0.2 0.0 0.1	5.384 5.030 5.000
Iv/3 in-i 17 m 85 m	23.76 26.63 19.86	31.899 31.918 35.870	1.1 1.2 1.8	0.03 0.00 0.10	0.0 0.0 1.4	5.089 5.237 4.740

Table 1. Cont'd.

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

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

Table 1. Cont'd.

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

STATION DEPTH	TEMPERATURE (DEGREE'S C)	SALINITY (o/∞)	SILICATE μg-at/L	PHOSPHATE μg-at/L	NITRATE μg-at/L	OXYGEN ml/L
III/1 1 m 9 m 20 m	29.13 28.85 28.51	29.326 34.068 35.275	4.4 6.5 5.9	0.22 0.18 0.07	0.5 0.4 0.3	4.77 4.63 4.53
111/2 1 m 26 m 60 m	28.56 28.66 24.03	35.783" 35.867 36.138	0 . 3 1.1 2.0	0.03 0.0 0.05	0.3 0.3 0.3	4.68 4.61 4.80
111/3 1 m 29 m 50 m 65 m 80 m 95 m 105 m	28.57 28.53    19.50	35.860 35.902 36.213 36.216 36.186 36.224 36.338	0.9 1.0 1.0 1.0 1.6 2.6 4.1	0.0 0.0 0.0 0.0 0.0 0.08 0.43	0.3 0.5 0.4 0.4 0.4 5.0 14.1	4.69 4.65 5.17 5.03 4.59 3.76 3.08
IV/1 1 m 13 m 22 m	28.72 28.95 28.64	27.834 34.464 35.148	2.2 6.2 9.6	0.18 0.11 0.24	0.6 0.6 1.2	4.63 4.52 3.75
IV/2 1 m 13 m 25 m 40 m	29.03 28.48  27.86	35.054 35.701 35.763 35.922	1.2 2.5 3.2 4.2	0.07 0.03 0.0 0.0	0.5 0.4 0.4 2.0	4.48 4.52 4.47 3.99
IV/3 1 m 15 m 31 m 45 m 60 m 75 m 85 m	28.62  28.19   23.40	35.688 35.704 35.719 36.133 35.971 36.106 36.226	1.0 1.1 1.1 1.0 4.2 5.2 5.1	0.0 0.0 0.0 0.0 0.06 0.01 0.01	0.4 0.4 0.4 0.4 0.3 0.8 1.9	3.84 4.02 3.96 4.12 3.87 3.69 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
1/2 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
11/2 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
11/3 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. Cent '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		6.5	2.2	1.0	1.9
10		3.0	1.5	0.7	1.4
20		2.7	1.5	0.7	1.3
III/2 10 m		4.5	1.5	1.2	1.2
25		4.8	1.5	0.9	1.1
55	- - '	4.2	1.3	<0.2	1.6
111/3 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
[v/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
[V/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, Cent 'd.

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

STAT 10N DEPTH	METHANE (nl/L)	ETHANE + ETHENE (n/L)	PROPENE (nl/L)	PROPANE (nl/L)
I/1 5 m 10 m 20 m	1 2 8 107 85	16.8 12.1 55	1.6 1.9 1.9	1.1 1.0 0.86
I/2 5 m 20 m 40 m	64 82 8 0	2.3 13.8 4.0	0.86 1.1 2.1	0.48 0.67 1.2
I/3 1 m 25 m 125 m	37 37 46	3.3 3.0 0.5	1.9 1.6 0.95	0.95 1.3 0.61
II/1 0m 8m 20 m	125 134 106	58.3 14.0 4.3	5.7 4.9 2.7	0.11 0.23 0.10
11/2 0m 14 m 29 m	99 88 99	38.1 5.8 4.5	2.8 2.3 2.2	0.05 0.24 t
11/3 1 m 23 m 115 m	74 53 265	1.0.1 6.3 1.2	2.7 0.3 0.3	--- --- ---
111/1 1 m 75 m 16 m	125 162 165	8.3 13.3 11.3	1.2 3.5 3.5	1.3 t t
111/2 1171 2 3 m 60 m	66 2280 456	25.3 22.2 3.0	4.2 2.0 1.2	--- --- ---

Table 2. Cent 'd.

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

STATION DEPTH	METHANE (nl/L)	ETHENE + ETHANE (n/L)	PROPENE (nl/L)	PROPANE (nl/L)
111/3 1 m 19 m 100 m	80 4640 55	22.1 10.6 1.6	2.6 1.3 1.9	--- --- ---
IV/1 1 m 16 m 25 m	53 164 176	35.0 10*5 5.6	3.1 2.7 4.7	0.10 0.19 0.48
Iv/2 1 m 11 m 45 m	68 105 46	18.0 4.6 4.6	0.95 --- ---	0.86 0.81 1.1
IV/3 1 m 17 m 85 m	59 57 722 "	7.2 15.9 3.8	4.6 1.7 2.1	0.48 t 0.47

Table 2. Cent'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
1/2	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
1/3	0 m	72	8	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
11/1	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
11/2	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

Table 2. Cent' 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)
111/1	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
111/2	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	3.6	4.0
	29 m	87	7.1	2.2		
	50 m	710				
	65 m	840				
	80 m	990				
	105 m	290	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 3/11. 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 2/111 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 3/1, 3/II, 3/111 and 3/IV during the summer sampling. This same increase at 40 to 50 meters was observed also at stations 2/1, 2/11, 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 volatility 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 chromatography 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<sub>2</sub> and C<sub>3</sub> 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 nanoliters 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 2/11 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 2/1 (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 1/1, 1/11, 1/III, 2/111, 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 volatility 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 parameters 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 not 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<sub>5</sub> , C<sub>10</sub> 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 **60/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-**

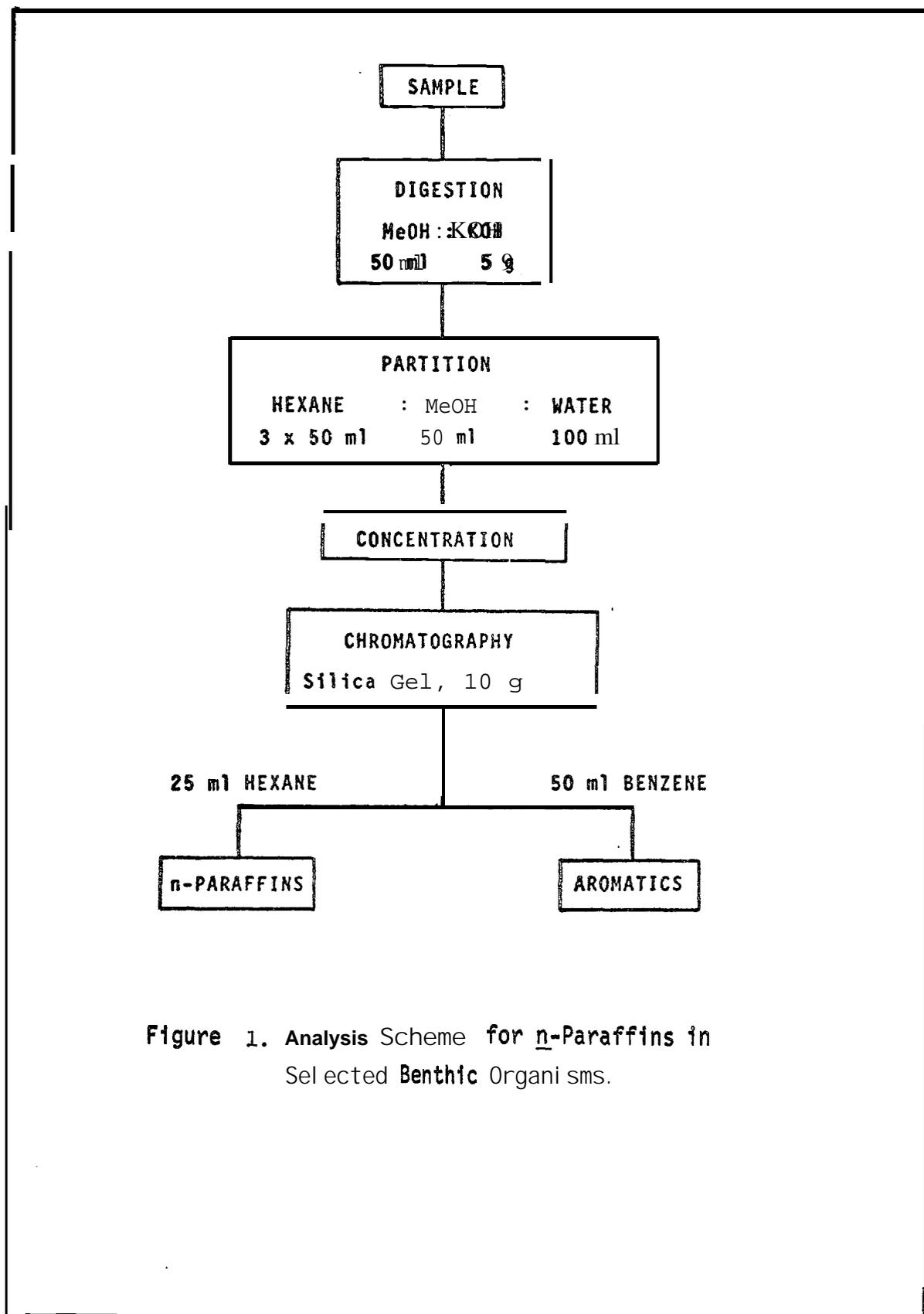


Figure 1. Analysis Scheme for n-Paraffins in Selected Benthic Organisms.

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 separator 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 ca 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 absorbents.

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<sub>18</sub>**, **n-C<sub>27</sub>**, **n-C<sub>32</sub>** and **n-C<sub>34</sub>** 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

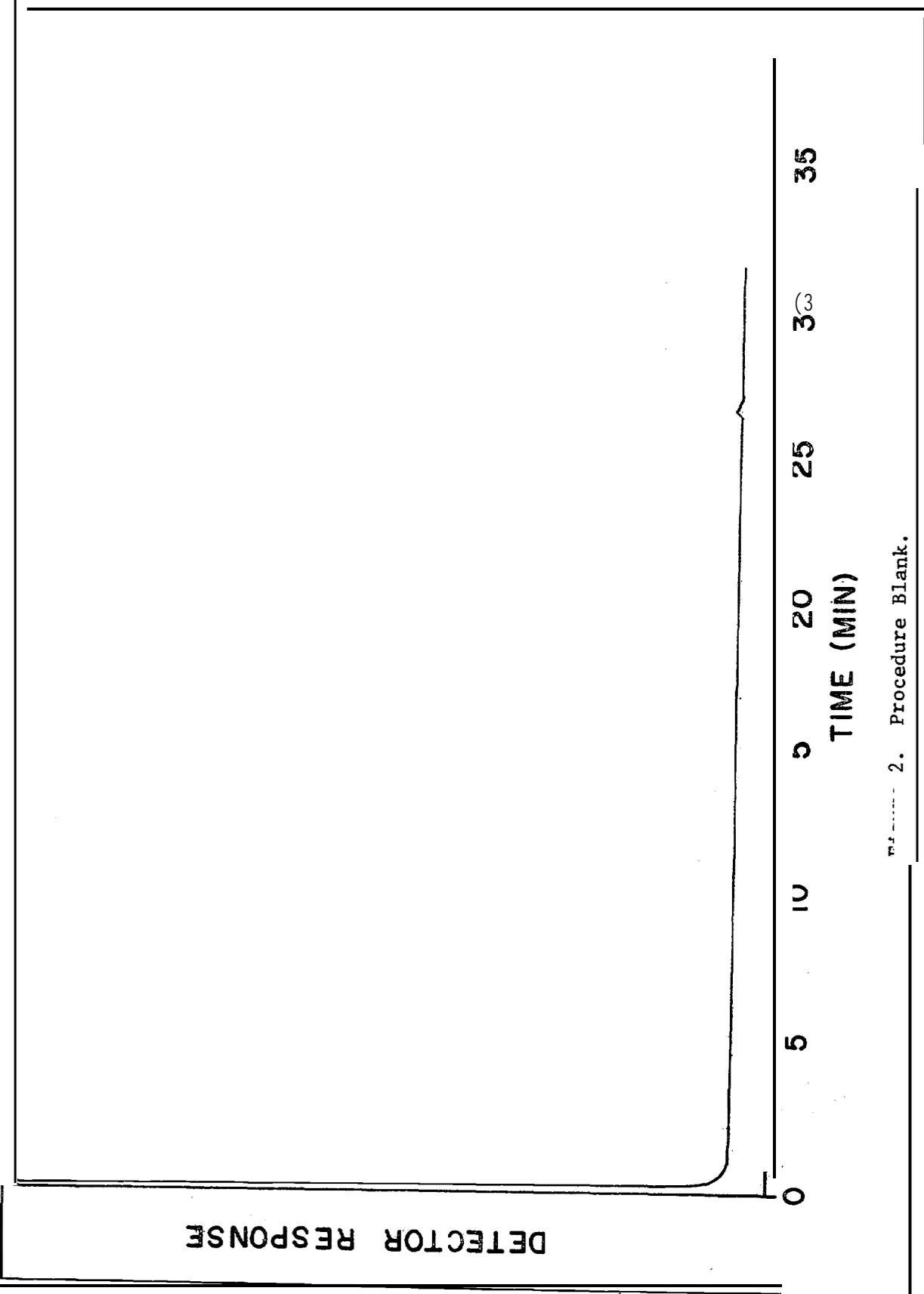
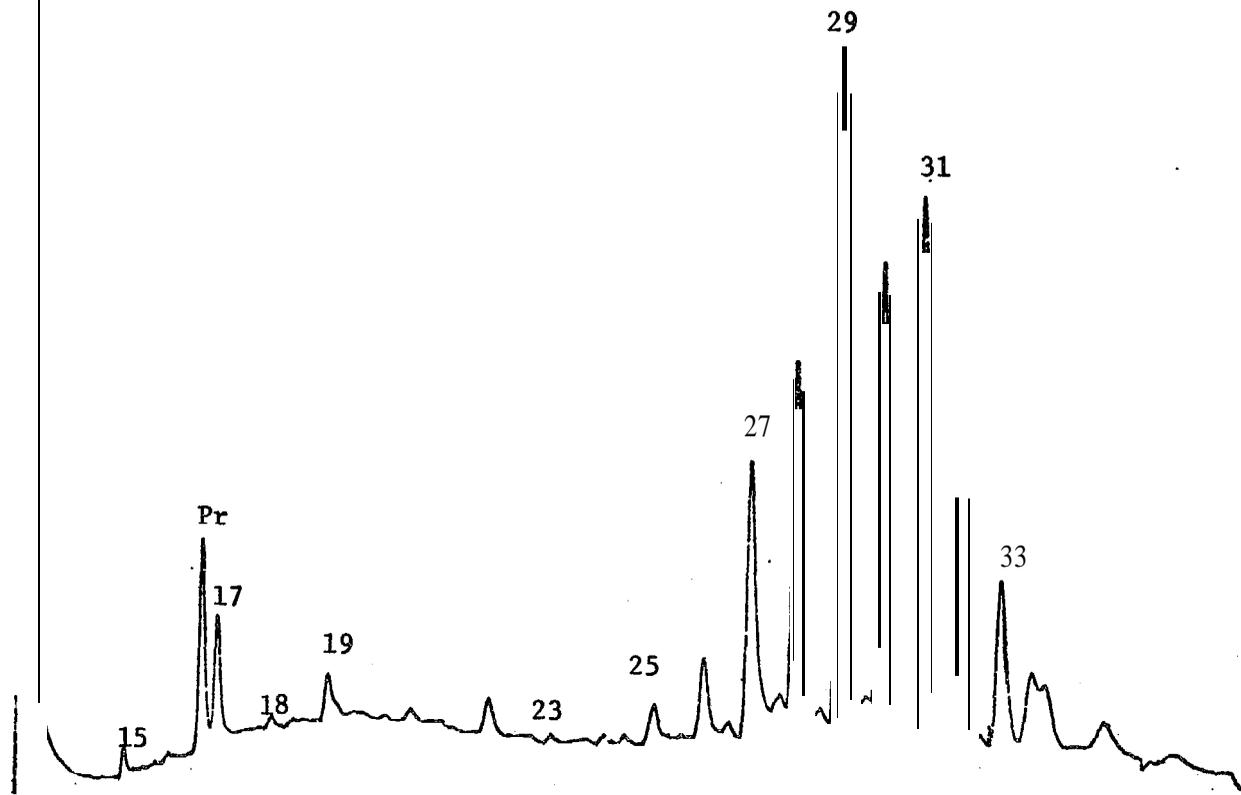


Figure 2. Procedure Blank.

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



Figure

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

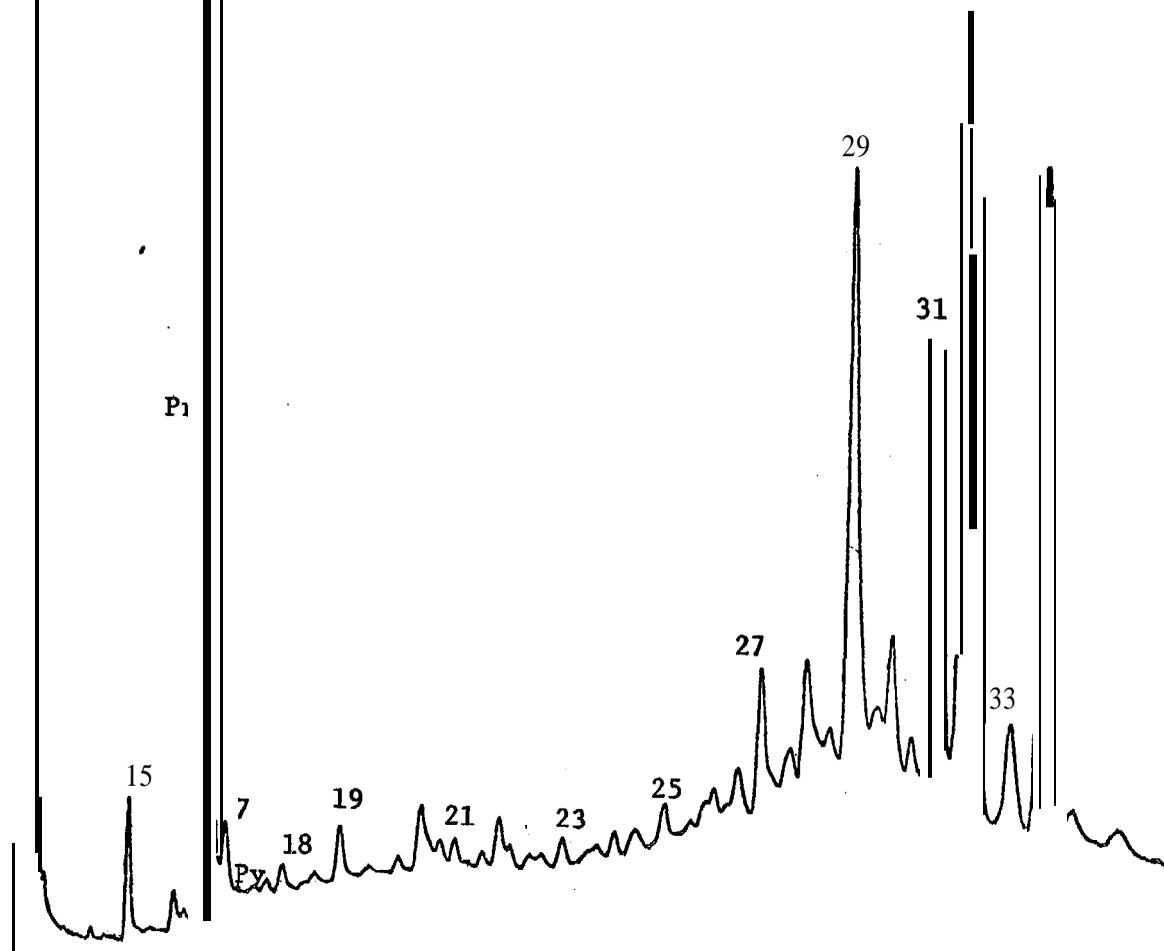


Figure 5. Gas Chromatogram of Hexane Eluate of Sand Seatrout  
(Cynoscion arenarius) Extract on 5% FFAP.

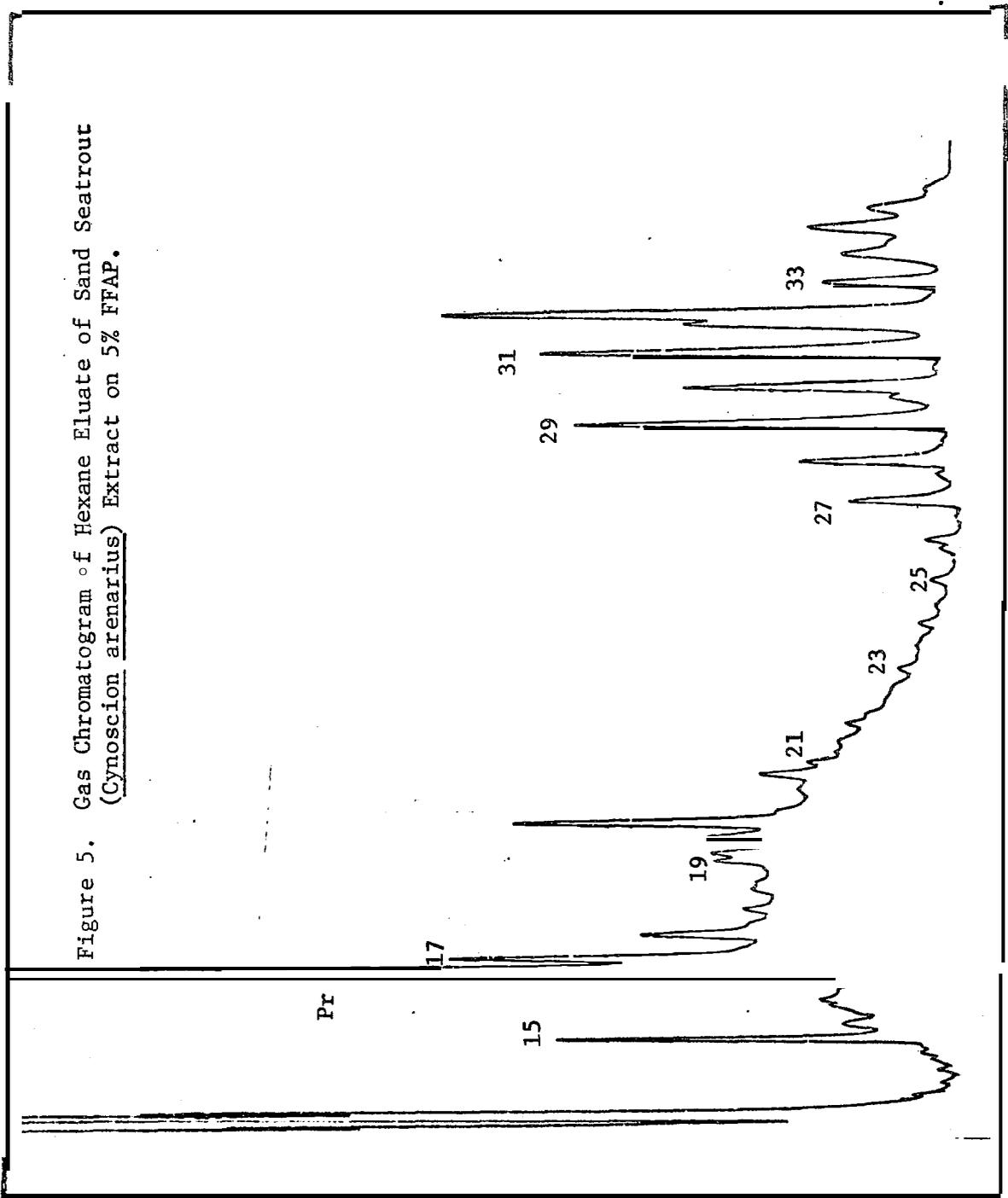
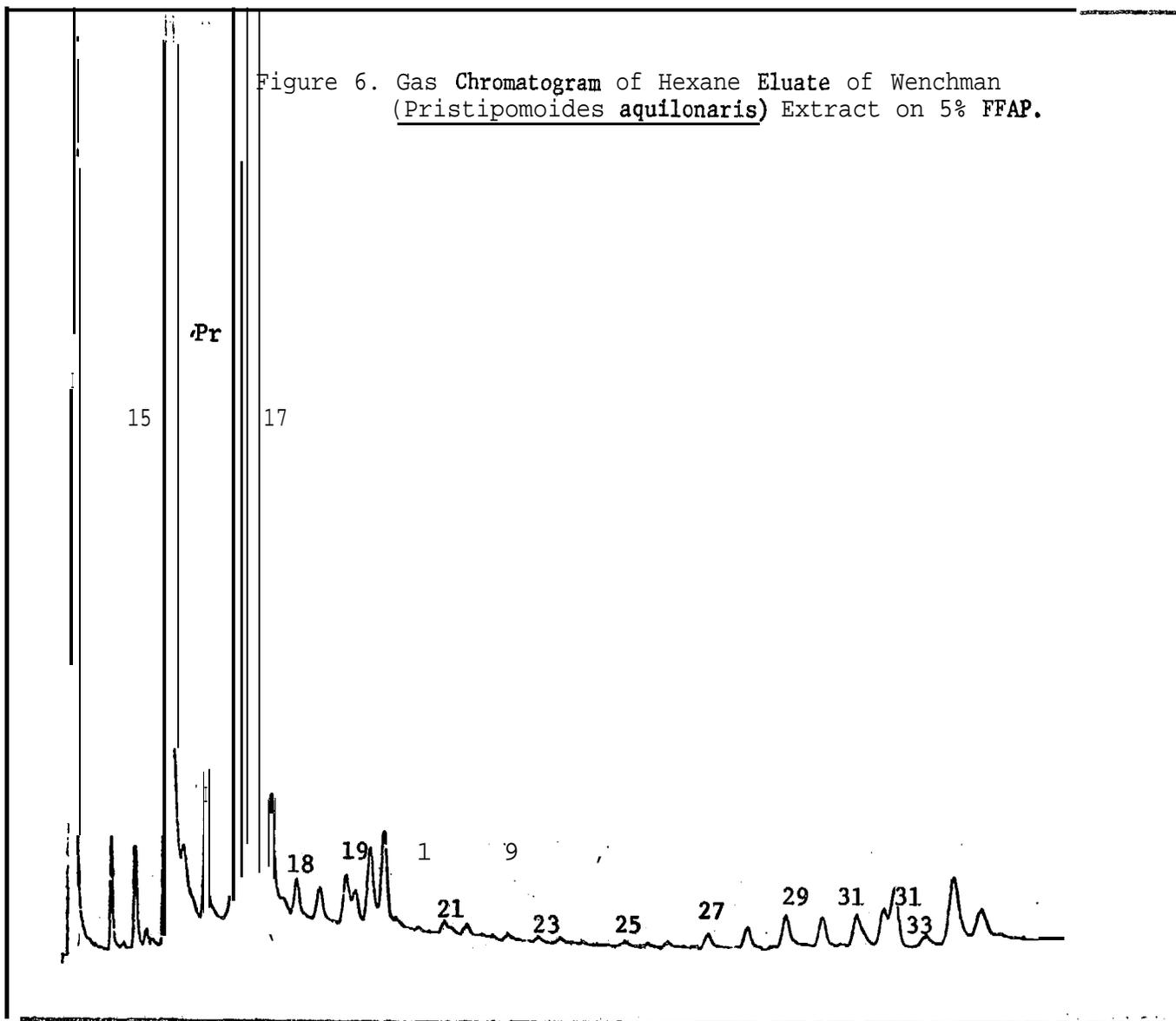
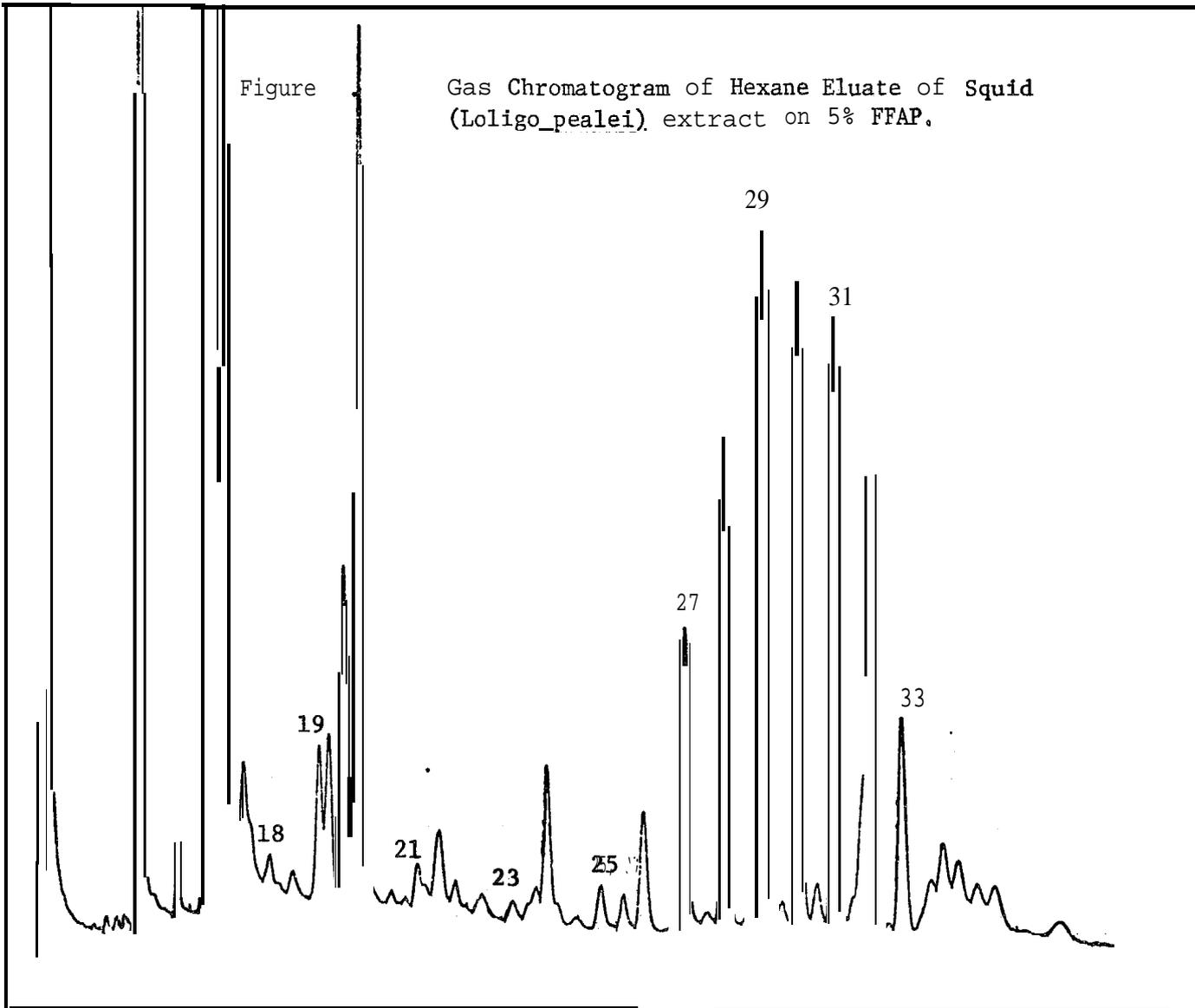


Figure 6. Gas Chromatogram of Hexane Eluate of Wenchman  
(Pristipomoides aquilonaris) Extract on 5% FFAP.





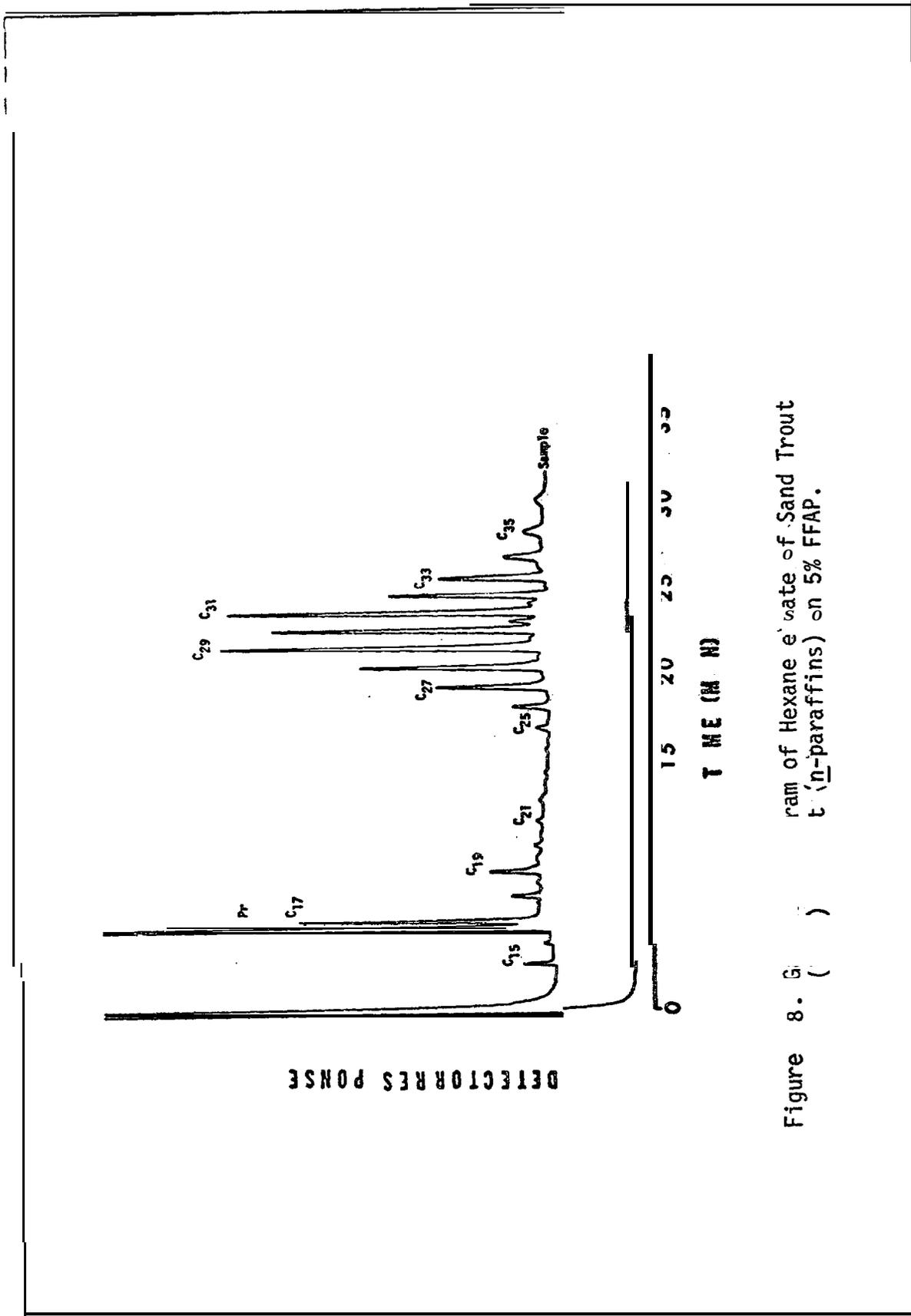


Figure 8. Chromatogram of Hexane extract of Sand Trout fat (n-paraffins) on 5% FFAP.

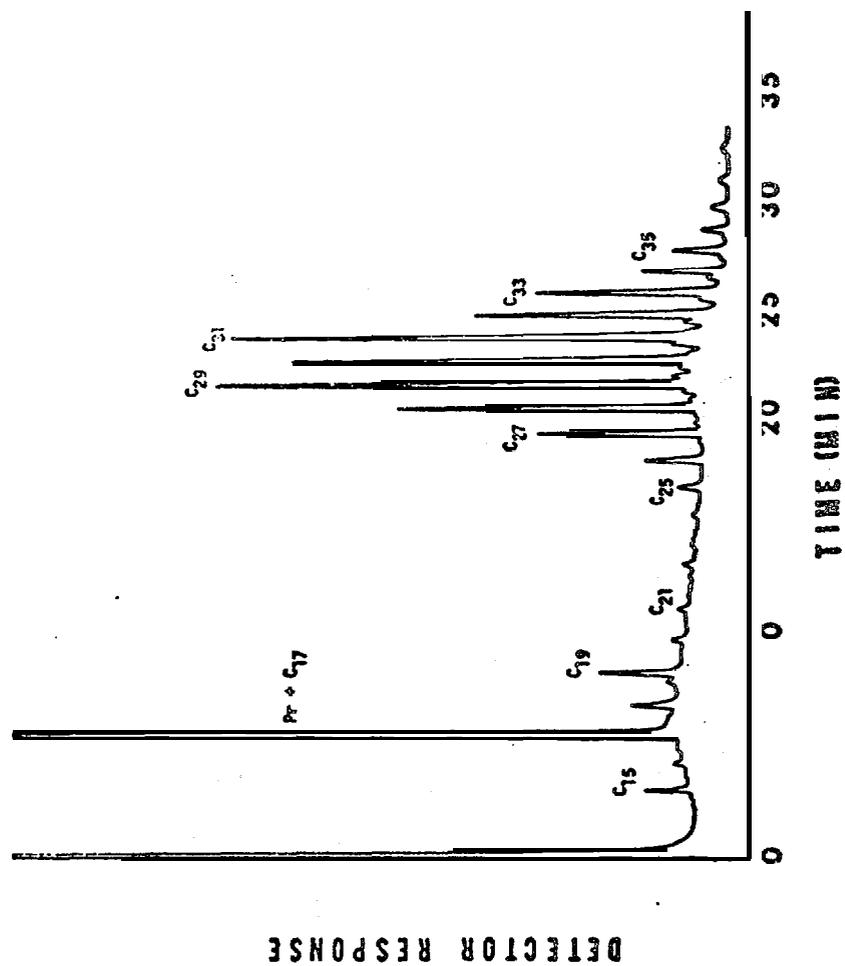


Figure 9. Gas Chromatogram of Hexane eluate of Sand Trout (338C) extract ( $\beta$ -paraffin) on 3% SE-30.

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 (Barrington and Medeiros, 1975). The use of **methanolic** potassium hydroxide in our labs was found to be as efficient and much less **time consum-**ing 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 quantitateableseparation** of the **n-C<sub>17</sub>** 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 **spec-**  
**trometry.**)

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

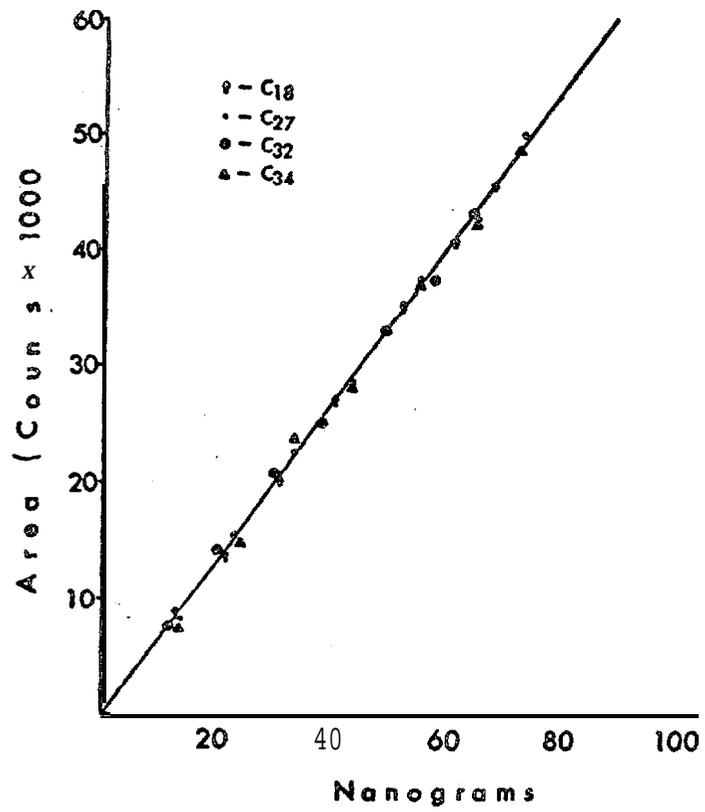


Figure 10. Calibration Curve

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<sub>15</sub>** and **C<sub>17</sub>** n-paraffins or of the **C<sub>31</sub>** 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<sub>15</sub>** and **C<sub>17</sub>** 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<sub>17</sub>** was generally found in higher concentrations than the **C<sub>15</sub>** n-paraffin while **C<sub>15</sub>** 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<sub>15</sub>** than **C<sub>17</sub>**.

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<sub>14</sub> -C<sub>34</sub>**) found in individual members of the species. By inspection of

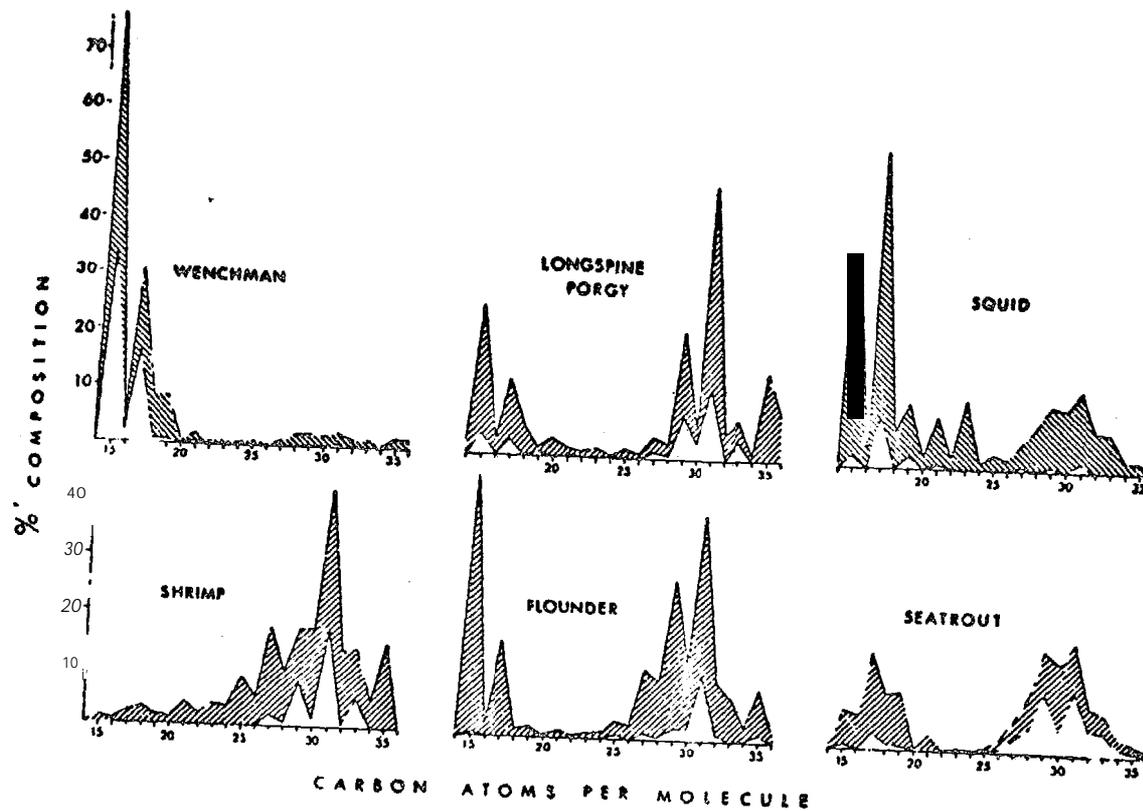


Figure 11. Hydrocarbon. Distribution in Selected Benthic Organisms.

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<sub>17</sub>** 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

<u>STATION</u>	<u>CODE</u>	<u>SAMPLE NAME</u>	<u>Sample Weight</u> (wet )	<u>dry weight</u> <u>wet weight</u> Conversion factor
1/I	AFM-EPI	<u>Cynoscion nothus</u> Silver sea trout	21.0	0.24
	AFM-EPI	<u>Stellifer lanceolatus</u> Star drum	7.0	0.26
	AHP-EPI	<u>Penaeus aztecus</u> Brown shrimp	17.2	0.24
	AHP-EPI	<u>Cynoscion nothus</u> Silver sea trout	34.0	0.24
2/I	ACV-EPI	<u>Syacium sp.</u> Flatfish	29.3	0.25
	ACV-EPI	<u>Penaeus aztecus</u> Brown shrimp	20.0	0.24
	AFE-EPI	<u>Lutjanus campechanus</u> Caribbean red snapper	16.5	0.28
	AFE-EPI	<u>Loligo pealei</u> Squid	10.5	0.28
3/I	AAF-EPI	<u>Solenocera viosci</u> Broken-back shrimp	5.0	0.24
	AAF-EPI	<u>Syacium sp.</u> Flatfish	22.5	0.25
	AAF-EPI	<u>Pristipomoides aquilonaris</u> Wenchman	46.3	0.22
	AAL-EPI	<u>Prionotus paralatus</u> Mexican sea robin	40.0	0.26
1/11	AIK-EPI	<u>Penaeus aztecus</u> Brown shrimp	12.0	0.24
	AIK-EPI	<u>Centropristis philadelphicus</u> Rock sea bass	24.5	0.26
	AJD-EPI	<u>Loligo pealei</u> Squid	26.6	0.28
	AJD-EPI	<u>Penaeus setiferus</u> White shrimp	18.0	0.25

Table 1. Cent.1d

<u>STATION</u>	<u>CODE</u>	<u>SAMPLE NAME</u>	Sample Weight	<u>dry weight</u>
			<u>(wet)</u>	<u>wet weight</u>
			<u>Conversion</u>	<u>factor</u>
2/II	ALH-EPI	<u>Loligo pealei</u> Squid	22.8	0.28
	AME-EPI	<u>Syacium sp.</u> Flatfish	50.0	0.25
	AME-EPI	<u>Squilla sp.</u> Mantis shrimp	15.2	0.23"
	AME-EPI	<u>Penaeus aztecus</u> Brown shrimp	44.0	0.24
3/II	AOK-EPI	<u>Prionotus sp.</u> Sea robin	5005	0.26
	APF-EPI	<u>Trachurus lathami</u> Rough scad	58.5	0.2:
	APF-EPI	<u>Pristipomoides aquilonaris</u> Wenchman	50.8	0.2(
	APF-EPI	<u>Lopholalitus chameleonticeps</u> Tile fish	63.5	0.2t
1/III	ARN-EPI	<u>Penaeus aztecus</u> Brown shrimp	6.0	0.24
	ARN-EPI	<u>Loligo pealei</u> Squid	14.7	0.28
	ASH-EPI	<u>Trachurus lathami</u> Rough Scad	18.9	0.22
	ASH-EPI	<u>Syacium sp.</u> Flatfish	12.0	0.25...,
2/III	AUQ-EPI	<u>Prionotus rubio</u> Black-finned sea robin	41.5	0.26
	AUQ-EPI	<u>Sicyonia dorsalis</u> Rock shrimp	4.5	0.24'
	AVM-EPI	<u>Pristipomoides aquilonaris</u> Wenchman	9.0	0.22
	AVM-EPI	<u>Loligo pealei</u> Squid	19.8	0.28
3/III	AXP-EPI	<u>Prionotus paralatus</u> Mexican sea robin	31.7	0.26

Table 1. Cent. 'd

<u>STATION</u>	<u>CODE</u>	<u>SAMPLE NAME</u>	<u>Sample Weight (wet)</u>	<u>dry weight wet weight Conversion factor</u>
3/III	AYJ-EPI	<u>Pristipomoides aquilonaris</u> Wenchman	67.8	0.22
	AYJ-EPI	<u>Loligo pealei</u> Squid	77.2	0.28
	AYJ-EPI	<u>Trachurus lathami</u> Rough scad	33.0	0.22
1/IV	BAN-EPI	<u>Sicyonia brevirostrus</u> Rock shrimp	1 9 . 6	0.24
	BBI-EPI	<u>Penaeus aztecus</u> Brown shrimp	29.6	0.24
	BBI-EPI	<u>Trachurus lathami</u> Rough scad	40.8	0.22
	BBI-EPI	<u>Syacium papilosa</u> Dusky flounder	55.5	0.26
2/IV	BDN-EPI	<u>Penaeus aztecus</u> Brown shrimp	32.2	0.24
	BDN-EPI	<u>Centropristis philadelphicus</u> Rock sea bass	68.8	0.24
	BEK-EPI	<u>Loligo pealei</u> Squid	74.1	0.28
	BEK-EPI	<u>Trachurus lathami</u> Rough scad	45.0	0.22
3/IV	BGO-EPI	<u>Penaeus aztecus</u> Brown shrimp	45.6	0.24
	BGO-EPI	<u>Sicyonia brevirostrus</u> Rock shrimp	34.5	0.26
	BPF-EPI	<u>Upeneus parvus</u> Dwarf goatfish	55*5	0.30
	BPF-EPI	<u>Prionotus paralatus</u> Mexican sea robin	50.5	0.26

Table 1. Cent. 'd

Second Sampling

<u>STATION</u>	<u>CODE</u>	<u>SAMPLE NAME</u>	<u>Sample Weight (wet )</u>	<u>dry weight wet weight Conversion factor</u>
1/I	CBC-EPI	<u>Penaeus setiferus</u> White shrimp	33.5	0.25
	CBC-EPI	<u>Cynoscion arenarius</u> Sand Seatrout	51.3	0.24
	CBC-EPI	<u>Urophycis floridanus</u> Gulf Hake	53.5	0.26
	CAI-EPI	<u>Cynoscion arenarius</u> Sand Seatrout	59.5	0.24
	CAI-EPI	<u>Menticirrhus americanus</u> Gulf Kingfish	55.5	0 . 2 6
2/1	CEC-EPI	<u>Loligo pealei</u> Squid	68.0	0.28
	CEC-EPI	<u>Penaeus aztecus</u> Brown shrimp	29.0	0.24
	CDM-EPI	<u>Prionotus</u> rubio Black-finned sea robin	50.0	0.26
	CDM-EPI	<u>Syacium gunteri</u> Shoal flounder	52.0	0.25
3/I	CHM-EPI	<u>Pristipomoides aquilonaris</u> Wenchman	164.0	0.22
	CHM-EPI	<u>Prionotus paralatus</u> Mexican sea robin	52.0	0.26
	CGO-EPI	<u>Stenotomus caprinus</u> Longspine porgy	91.5	0.30
	CGO-EPI	<u>Penaeus aztecus</u> Brown shrimp	57.0	0.24
1/II	CKS-EPI	<u>Loligo pealei</u> Squid	56.0	0 . 2 8
	CJX-EPI	<u>Syacium gunteri</u> Shoal Flounder	48.0	0.25
	CJX-EPI	<u>Penaeus setiferus</u> White shrimp	40.0	0.25
	CJX-EPI	<u>Cynoscion arenarius</u> Sand seatrout	47.5	0.24
2/II	CNV-EPI	<u>Pristipomoides aquilonaris</u> Wenchman	52.5	0 . 2 2

Table 1. Cont. td

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

Table 1. Cont. 'd

<u>STATION</u>	<u>CODE</u>	<u>SAMPLE NAME</u>	<u>Sample Weight (wet )</u>	<u>dry weight wet weight Conversion factor</u>
3/III	DAK-EPI	<u>Pristipomoides aquilonaris</u> Wenchman	91.0	0.22
1/IV	DED-EPI	<u>Loligo pealei</u> s q u i d	62.0	0.28
	DED-EPI	<u>Trachurus lathami</u> Rough scad	60.5	0.22"
	DDK-EPI	<u>Syacium gunteri</u> Shoal flounder	55.0	0.25
	DDK-EPI	<u>Sicyonia dorsalis</u> Rock shrimp	50.0	0.24
2/IV	DHC-EPI	<u>Syacium gunteri</u> Shoal flounder	61.0	0.25
	DGJ-EPI	<u>Penaeus aztecus</u> Brown shrimp	37.0	0.24
	DGJ-EPI	<u>Pristipomoides aquilonaris</u> Wenchman	50.0	0.22
	DGJ-EPI	<u>Loligo pealei</u> Squid	20.0	0.28
3/?s7	DKH-EPI	<u>Syacium gunteri</u> Shoal flounder	50.0	0.25
	DKH-EPI	<u>Pristipomoides aquilonaris</u> Wenchman	46.9	0.22
	DJL-EPI	<u>Stenotomus caprinus</u> Longspine Porgy	51.3	0.30
	DJL-EPI	<u>Penaeus aztecus</u> Brown shrimp	35.0	0.24 "

Table 1. Cent. 'd

Third Sampling

<u>STATION</u>	<u>CODE</u>	<u>SAMPLE NAME</u>	<u>Sample Weight (wet)</u>	<u>dry weight wet weight Conversion factor</u>
1/I	EAI-EPI	<u>Leiostomus xanthurus</u> Spot	47.2	0.26
	EAI-EPI	<u>Penaeus aztecus</u> Brown shrimp	42.7	0.24
	EBC-EPI	<u>Loligo pealei</u> Squid	51.1	0.28
	EBC-EPI	<u>Synodus foetens</u> Lizard fish	55.0	0.27
2/I	EDM-EPI	<u>Solenocera vioscai</u> Broken-back shrimp	38.6	0.26
	EDM-EPI	<u>Trachurus lathami</u> Rough scad	46.0	0.22
	EDM-EPI	<u>Synodus foetens</u> Inshore lizard fish	50.4	0.27
	EEC-EPI	<u>Sicyonia dorsalis</u> Rock shrimp	48.7	0.24
	EEC-EPI	<u>Centropristis philadelphicus</u> Rock sea bass	50.2	0.26
3/I	EGQ-EPI	<u>Pristipomoides aquilonaris</u> Wenchman	51.0	0.22
	EGQ-EPI	<u>Serranus atrobranchus</u> Black ear bass	48.3	0.26
	EGQ-EPI	<u>Stenotomus caprinus</u> Longspine porgy	58.3	0.30
	EHM-EPI	<u>Syacium gunteri</u> Shoal flounder	49.7	0.25
	EHM-EPI	<u>Pristipomoides aquilonaris</u> Wenchman	50.4	0.22
	EHM-EPI	<u>Prionotus paralatus</u> Mexican sea robin	37.6	0.26
1/II	EKS-EPI	<u>Chloroscombrus chrysurus</u> Atlantic bumper	54.6	0.26
	EKS-EPI	<u>Lutjanus campechanus</u> Red Snapper	37.9	0.28
	EKS-EPI	<u>Loligo pealei</u> Squid	57.5	0.28

Table 1. Cent.'d

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

Table 1. Cent.'d

<u>STATION</u>	<u>CODE</u>	<u>SAMPLE NAME</u>	<u>Sample Weight (wet)</u>	<u>dry weight wet weight Conversion factor</u>
	EYB-EPI	<u>Upeneus parvus</u> Dwarf goat fish	51*5	0.29
3/III	FAK-EPI	<u>Pristipomoides aquilonaris</u> Wenchman	57.5	0.22
	FAK-EPI	<u>Stenotomus caprinus</u> Longspine porgy	109 .5	0.30
	FAK-EPI	<u>Penaeus aztecus</u> Brown shrimp	70.0	0.24
	FBD-EPI	<u>Pristipomoides aquilonaris</u> Wenchman	61.8	0.22
	FBD-EPI	<u>Loligo pealei</u> Squid	"78.3	0.28
1/IV	FDR-EPI	<u>Penaeus duorarum</u> Pink shrimp	85.0	0.25
	FDR-EPI	<u>Syacium gunteri</u> Shoal flounder	50.0	0.25
	FEL-EPI	<u>Loligo pealei</u> Squid	80.5	0.28
	FEL-EPI	<u>Peprilus burti</u> Butterfish	62.0.	0.26
	FEL-EPI	<u>Trachurus lathami</u> Rough scad	49.0	0.22
2/IV	FGR-EPI	<u>Penaeus aztecus</u> Brown shrimp	63.0	0.24
	FHM-EPI	<u>Upeneus parvus</u> Dwarf goatfish	49.5	0.29 "
	FHM-EPI	<u>Loligo pealei</u> Squid	102,5	0.28
	FHM-EPI	<u>Trachurus lathami</u> Rough scad	50.0	0.22
3/IV	FJV-EPI	<u>Penaeus aztecus</u> Brown shrimp	70.0	0,24
	FJV-EPI	<u>Loligo pealei</u> Squid	72.8"	0.28

Table 1. Cont. 'd

<u>STATION</u>	<u>CODE</u>	<u>SAMPLE NAME</u>	Sample Weight (wet)	<u>dry weight</u> wet weight Conversion factor
<b>3/IV</b>	<b>FKR-EPI</b>	<u>Pristipomoides aquilonaris</u> Wenchman	51.4	0.22
	<b>FKR-EPI</b>	<u>Trachurus lathami</u> 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	<u>n-Alkane % composition</u> x 10 <sup>-5-4</sup>	Aromatic Fraction wt % composition x 10 <sup>-2</sup>
1/I	AFM-EPI	<u>Cynoscion nothus</u> Silver sea trout	0.054	1.09
	AFM-EPI	<u>Stellifer lanceolatus</u> Star drum	=0.015 <sup>b</sup>	<0.10
	AHP-EPI	<u>Penaeus aztecus</u> Brown shrimp	0 <sup>a</sup>	<0.06
	AHP-EPI	<u>Cynoscion nothus</u> Silver sea trout	•1.070	0.53
2/I	ACV-EPI	<u>Syacium sp.</u> Flatfish	0.103	0.20
	ACV-EPI	<u>Penaeus aztecus</u> Brown shrimp	0.030	0.8S
	AFE-EPI	<u>Lutjanus campechanus</u> Caribbean red snapper	0.175	15.88
	AFE-EPI	<u>Loligo pealei</u> Squid	0.226	38.95
3/I	AAF-EPI	<u>Solenocera viosci</u> Broken-back shrimp	0.060	<0.20
	AAF-EPI	<u>Syacium sp.</u> Flatfish	0.088	0.40
	AAF-EPI	<u>Pristipomoides aquilonaris</u> Wenchman	0.097	0.32
	AAL-EPI	<u>Prionotus paralatus</u> Mexican sea robin	1.315	0.40
1/11	AIK-EPI	<u>Penaeus aztecus</u> Brown shrimp	=0.001	<0.08
	AIK-EPI	<u>Centropristis philadelphicus</u> Rock sea bass	0.228	0.20
	AJD-EPI	<u>Loligo pealei</u> Squid	0.108	0.22
	AJD-EPI	<u>Penaeus setiferus</u> White shrimp	0.0	<0.06

Table 2. Cont.'d

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

Table 2. Cont.td

STATION	CODE' 9	SAMPLE NAME	n-Alkane % composition x 10 <sup>-5</sup>	Aromatic Fraction wt % composition x 10 <sup>-2</sup>
3/III	AYJ-EPI	<u>Pristipomoides aquilonaris</u> Wenchman	0.429	1.09
	AYJ-EPI	<u>Loligo pealei</u> Squid	0.144	0.13
	AYJ-EPI	<u>Trachurus lathami</u> Rough scad	0.243	0.03
1/IV	BAN-EPI	<u>Sicyonia brevirostrus</u> Rock shrimp	0.0	<0.05
	BBI-EPI	<u>Penaeus aztecus</u> Brown shrimp	0	<0.03
	BBI-EPI	<u>Trachurus lathami</u> Rough scad	0.246	0.20
	BBI-EPI	<u>Syacium papilosa</u> " Dusky flounder	0.090	0.23
2/IV	BDN-EPI	<u>Penaeus aztecus</u> Brown shrimp	0.065	0.09
	BDN-EPI	<u>Centropristis philadelphicus</u> Rack sea bass	0.122	0.19
	BEK-EPI	<u>Loligo pealei</u> Squid	0.636	0.36
	BEK-EPI	<u>Trachurus lathami</u> Rough scad	0.407	0.18
3/IV	BGO-EPI	<u>Penaeus aztecus</u> Brown shrimp	0	<0.02
	BGO-EPI	<u>Sicyonia brevirostrus</u> Rock shrimp	0.656	1.28
	BPF-EPI	<u>Upeneus parvus</u> Dwarf goatfish	0.121	0.05
	BPF-EPI	<u>Prionotus paralatus</u> 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 $\times 10^{-5}$	Aromatic Fraction wt % composition $\times 10^{-2}$
1/I	CBC-EPI	<u>Penaeus setiferus</u> White shrimp	0.072	1.10
	CBC-EPI	<u>Cynoscion arenarius</u> Sand Seatrout	0.449	24.05
	CBC-EPI	<u>Urophycis floridanus</u> Gulf Hake	0.122	0.69
	CAI-EPI	<u>Cynoscion arenarius</u> Sand Seatrout	0.243	0.10
	CAI-EPI	<u>Menticirrhus americanus</u> Gulf Kingfish	0.426	0.14
2/I	CEC-EPI	<u>Loligo pealei</u> Squid	0.599	0.22
	CEC-EPI	<u>Penaeus aztecus</u> Brown shrimp	0.056	0.38
	CDM-EPI	<u>Prionotus rubio</u> Black-finned sea robin	0.137	26.94
	CDM-EPI	<u>Syacium gunteri</u> Shoal flounder	0.202	0.37
3/I	CHM-EPI	<u>Pristipomoides aquilonaris</u> Wenchman	2.863	0.09
	CHM-EPI	<u>Prionotus paralatus</u> Mexican sea robin	0.233	0.02
	CGO-EPI	<u>Stenotomus caprinus</u> Longspine porgy	0.197	0.33
	CGO-EPI	<u>Penaeus aztecus</u> Brown shrimp	0.164	0.37
1/II	CKS-EPI	<u>Loligo pealei</u> Squid	0.052	0.73
	CJX-EPI	<u>Syacium gunteri</u> Shoal Flounder	0.383	0.38
	CJX-EPI	<u>Penaeus setiferus</u> White shrimp	0.067	0.25
	CJX-EPI	<u>Cynoscion arenarius</u> Sand seatrout	0.657	0.55
2/II	CNV-EPI	<u>Pristipomoides aquilonaris</u> Wenchman	0.447	0.36

Table 2. Cent. 'd

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

Table 2. Cent.'d

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

Table 2. Cent.'d

Third Sampling

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

Table 2. Cent.'d

STATION	CODE	SAMPLE NAME	n-Alkane % composition $\times 10^{-5}$	Aromatic Fraction wt % composition $\times 10^{-2}$
	EKS-EPI	<u>Cynoscion nothus</u> Silver sea trout	0.8409	0.10
2/II	ENA-EPI	<u>Squilla chydrea</u> Mantis shrimp	0.0440	0.54
	ENA-EPI	<u>Sicyonia dorsalis</u> Rock shrimp	0.0181	<0.06
	ENW-EPI	<u>Synodus foetens</u> Inshore lizard fish	0.4859	0.01
	ENW-EPI	<u>Loligo pealei</u> Squid	0.9380	0.04
3/II	EQC-EPI	<u>Stenotomus caprinus</u> Longspine porgy	0.1140	0.02
	EQX-EPI	<u>Pristipomoides aquilonaris</u> Wenchman	0.8857	<0.02
	EQX-EPI	<u>Loligo pealei</u> Squid	0.1308	0.04
	EQX-EPI	<u>Upeneus parvus</u> Dwarf goat fish	0.4335	<0.02
1/III	ETJ-EPI	<u>Syacium gunteri</u> Shoal flounder	0.2587	0.16
	EUF-EPI	<u>Stellifer lanceolatus</u> Star drum	0.0602	<0.02
	EUF-EPI	<u>Loligo pealei</u> Squid	1.1207	0.08
	EUF-EPI	<u>Penaeus aztecus</u> Brown shrimp	0.0065	<0.02
2/III	EXM-EPI	<u>Centropristis philadelphicus</u> Rock sea bass	0.0173	0.20
	EXM-EPI	<u>Penaeus aztecus</u> Brown shrimp	0.0255	0.2-8
	EXM-EPI	<u>Synodus foetens</u> Inshore lizard fish	6.5023	0.02
	EYB-EPI	<u>Centropristis philadelphicus</u> Rock sea bass	0.0170	0.01 "

Table 2. Cont.td

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

Table 2. Cent.'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)

<u>CPI<sub>14-20</sub> or CPI<sub>20-36</sub> range</u>	<u>% Samples with CPI<sub>14-20</sub></u>	<u>% Samples with CPI<sub>20-36</sub></u>
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.

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None of the above samples have both CPI<sub>14-20</sub> and CPI<sub>20-36</sub> in the low range of 1-1.9; suggesting **that** the hydrocarbons are probably **biogenic**. A small percentage (<5%) have either low CPI<sub>14-20</sub> or CPI<sub>20-36</sub>; 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 COCS

FIRST SAMPLING

<u>n-Hydrocarbons</u>	<u>Samples*</u>						
	B1C	B2C	B4B	B4D	B5B	B5D	B7C
C-15		a			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. Cent.'d

<u>n-Hydrocarbons</u>	<u>S a m p l e s</u>						
	<u>B7 D</u>	<u>B8B</u>	<u>B1 0D</u>	<u>B11A</u>	<u>B1 3D</u>	<u>B14B</u>	<u>B16C</u>
c-15	21.7	0.4					
<b>C-16</b>	1.0	0.2					
<b>C-18</b>		<b>0.2</b>					
C-19		<b>0.1</b>	0.5		<b>0.1</b>		
C-20		0.1	<b>0.4</b>	3.3	<b>1.1</b>		
C-21		<b>0.7</b>	2.9	4.0	1.6	1.6	2.2
c-22	1.6	0.1	<b>0.8</b>	1.7	<b>1.2</b>		0.3
C-23	7.5	1.1	7.8	46.1	21.2		<b>11.7</b>
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
<b>C-31</b>	10.4	19.0	<b>19.3</b>	<b>10.4</b>	14.2	62.8	73.5
<b>C-32</b>		<b>0.3</b>	3.7	2.1	<b>5.1</b>	0.6	
c-33	57.8	72.2	<b>15.0</b>	0.8	6.5		
c-34					2.3		
c-35					2.5		
TOTAL ppm	(0.097)	(1.315)	(0.228)	(0.108)	(0.027)	<b>(0.115)</b>	(0.252)

Table 4. Cont. 'd

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

Table 4. Cent.'d

<u>n-Hydrocarbons</u>	<u>Samples</u>							
	<u>B23D</u>	B25A	B26A	B26B	B26C	B29C	B29D	B31A
c-1 5		<b>14.3</b>	1.5	34.3		<b>15.8</b>		
C-16				2.2				
C-1 8				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	<b>0.2</b>		0.6
C-23	25.4	21.9		18.5	24.5	<b>24.1</b>	<b>1.4</b>	2.2
C-24	7.2	0.8		0.3	0.7	<b>0.9</b>	1.5	2.2
C-25	8.3	0.9	<b>0.2</b>	12.1	4.2	<b>1.0</b>	2.1	2.9
C-26	5.8	0.5	<b>0.1</b>	0.8	1.0	0.5	4.2	1.2
C-27	6.6	1.1	<b>0.2</b>		1.6	1.2	8.2	3.9
C-28	3.4	0.4	<b>1.1</b>		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
<b>C-31</b>	43.3	56.2	93.0	<b>5.1</b>	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	<b>(0.028)</b>	(0.350)	(0.429)	<b>(0.144)</b>	(0.243)	(0.246)	<b>(0.090)</b>	(0.065)

Table 4. Cent.'d

<u>g-hydrocarbons</u>	<u>Samples</u>					
	B31 B	B32C	B32D	B34C	B35C	B35D
C-15		57.9	44.4			
C-16						
C-18						
C-19		5.6			<b>2.1</b>	0.7
C-20						
C-21		<b>1.1</b>	5.5	0.7	2.0	0.2
C-22			0.2			<b>0.1</b>
C-23	<b>21.6</b>	6.9	14.3		6.2	<b>0.5</b>
C-24	<b>1.5</b>		0.7		0.8	<b>0.1</b>
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	<b>0.9</b>
C-28	7.9	5.0	2.6		9.0	<b>1.3</b>
C-29	9.6	<b>5.3</b>	4.2		<b>11.7</b>	2.3
C-30	7*9	4.2	2.9		9.8	1.8
C-31	37.8	0.9	<b>19.0</b>	99.3	16.5	90.9
C-32	3.2	<b>6.1</b>	<b>1.6</b>		4.3	<b>0.6</b>
c-33		1.4			25.5	
c-34		0.8				
C-35						
TOTAL ppm	(0.122)	(0.636)	(0.407)	(0.656)	<b>(0.121)</b>	(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

<u>n-Hydrocarbons</u> <sup>1</sup>	<u>Samples</u> *						
	<u>B37A</u> <sup>c</sup>	B37C	<b>B37D</b>	B38C	B38D	B39B	B39C
C-14						0.2	
c-15		<b>1.8</b>	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	<b>9.1</b>	6*8	14.0	
C-18	1.4	<b>1.8</b>	0.1	1.2	0.5	1*7	
<del>C-19</del>		0*5		2.1	0.9	2.5	
C-20				<b>0.2</b>		0.3	
C-21	<b>10.4</b>			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	<b>1.4</b>	2.5	2.5	1.6	2.6	1.8	<b>1.8</b>
C-27	9.7	5.8	5.7	5.3	7.3	4.7	5.4
C-28	9.7	11.0	11.3	<b>9.7</b>	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	<b>15.8</b>	13.8	14.2	<b>13.6</b>	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	<b>8.1</b>	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	<b>1.3</b>	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)

<sup>1</sup> Percentage Distribution; <sup>2</sup> AMG-Code

Table 5. Cent.'d

<u>n-Hydrocarbons</u>	<u>Samples</u>						
	<u>B40B</u>	<u>B40C</u>	<u>B41A</u>	<u>B41B</u>	<u>B42B</u>	<u>B42C</u>	<u>B43B</u>
c-14		0.1	0.4		<b>1.0</b>		
<b>C-15</b>	2.2	3.0	58.3	2.2	26.4		<b>13.4</b>
C-16	1.5	<b>0.1</b>	4.3	0.4	2.0	<i>0.6</i>	<b>1.0</b>
<b>C-17</b>	2.9		28.3	1.8	13.2		55.8
C-18	0.7		2.6	0.4	0.5	<i>2.4</i>	<b>1.7</b>
<b>C-19</b>	<b>0.7</b>	0.5	<b>1.6</b>	0.2	<b>1.0</b>	<i>1.8</i>	<b>11.5</b>
C-20			0.3		0.5	<b>1.2</b>	<b>0.2</b>
<b>C-21</b>	4.4	0.5	0.3	0.4	1.5	<i>3.7</i>	<b>0.6</b>
c-22		<b>0.1</b>	0.1	0.4	<b>1.0</b>		
C-23	0.7	<b>0.1</b>	<b>0.1</b>	0.4	1.0	<i>3.7</i>	
C-24	0.7	0.2	<b>0.1</b>	0.4	<b>0.5</b>	3.0	
C-25	2.2	2.0	0.1	0*9	1.5	4.3	
C-26		<b>1.0</b>	0.1	<b>1.3</b>		<b>1.2</b>	
C-27	5.8	<b>1.0</b>	0.2	4.0	<b>1.5</b>	9.8	<b>1.2</b>
C-28	6.6	0.5	0.3	4.0	1.0	3.0	<b>1.2</b>
C-29	12.4	26.0	0.8	14.8	7.6	16.5	3.8
C-30	10.2	<b>11.6</b>	0.5	<b>8.0</b>	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	<b>16.0</b>	6.4	0.2	9.3	<b>7.1</b>	7.3	
C-34		2.0	0.2	1.3	1.0		
C-35		9.4	<b>0.1</b>	0.4			
C-36							
TOTAL ppm	(0.137)	(0.202)	(2.863)	(0.225)	(0.197)	(0.0164)	(0.052)

Table 5. Cent.1d

<u>n-Hydrocarbons</u>	<u>Samp l es</u>						
	<b>B44A</b>	B44B	B44D	B45A	B45B	<b>B46C</b>	B46D
C-14			0.3	0.4	0.5		
c-1 5	<b>0.5</b>	<b>0.1</b>	6,7	33.6	28.7	<b>1.0</b>	2.3
C-16	0.3		5.9	4.0	3.0	<b>0.1</b>	0.7
C-17			16.7	30.3	25.6		<b>1.7</b>
C-18	0.3	0.1	9.7	8.3	6.4	<b>1.3</b>	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	<b>1.9</b>	3.0	0.9	3.0	3.2	0.5
C-22	0.3	<b>1.6</b>		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	<b>1.0</b>	0.4	<b>1.3</b>
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	<b>11.2</b>	<b>10.2</b>	<b>1.8</b>	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	<b>15.5</b>
C-32	10.4	3.9	4.3	0.7		0.6	2.0
C-33	7.6	9.8	4.0	0.4	<b>1.0</b>	8.2	7.8
c-34	2.6	2.2	1.2	0.2		0.4	0.5
C-35	<b>3.1</b>	7.9	0.9	<b>1.8</b>		<b>17.4</b>	4.8
C-36	<b>1.3</b>		0.5				0.3
TOTAL ppm	(0.383)	(0.067)	(0.657)	(0.447)	(0.202)	(0.077)	(0.400)

Table 5. Cent'.'d

<u>n-Hydrocarbons</u>	<u>Samples</u>							
	<u>B47A</u>	<u>B47C</u>	<u>B48B</u>	<u>B48C</u>	<u>B49A</u>	<u>B50A</u>	<u>B50C</u>	<u>B50D</u>
C-14	0.3							
<b>C-15</b>	64.5	12.4	3.6	0.4	27.7		3.2	
<b>C-16</b>	3.7	0.5		0.8	0.8		0*4	
C-17	22.0	9.4	7.2	1.0	16.6		<b>0.1</b>	<b>1.5</b>
C-18	2.3	0.9		1.0	0.4		0.9	
<b>C-19</b>	2.0	2.4	<b>1.4</b>	0.8	0.4		0.4	
<b>C-20</b>	0.4	0.5		0.6				
<b>C-21</b>	0.5	<b>1.9</b>	0.4	<b>1.2</b>				<b>1.5</b>
C-22	<b>0.1</b>	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		<b>1.4</b>	<b>1.5</b>
C-25	0.2	<b>1.9</b>	0.7	1.4	0.8	5.0	3.2	8.6
<b>C-26</b>	0.1	<b>1.9</b>		0.4		5.0	2.3	2.8
C-27	0.3	4.2	3.6	2.0	<b>4.1</b>	10.0	12.3	<b>17.4</b>
C-28	0.3	7.0	0.5	2.0	3.7	5.0	<b>9.1</b>	<b>10.2</b>
C-29	<b>0.6</b>	11.4	22.5	8.8	<b>13.4</b>	<b>15.0</b>	25.6	<b>17.5</b>
C-30	0.5	<b>10.8</b>	2.9	5.6	<b>8.1</b>	5.0	<b>8.7</b>	2.8
<b>C-31</b>	1.0	12.4	48.6	23.4	<b>11.4</b>	25.0	<b>21.5</b>	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	<b>11.5</b>
c-34	0.1	2.4		1.4	1.2	5.0	0.9	1.4
c-35	<b>0.1</b>	1.4	3.6	15.2	2.0	5.0	3.2	<b>1.5</b>
C-36		0.9		15.2				
<b>TOTAL ppm</b>	(2.488)	(0.212)	(0.0555)	(0.050)	(0.246)	(0.020)	(0.219)	(0.069)

Table 5. Cent.'d

<u>n-Hydrocarbons</u>	<u>Sampl es</u>							
	<u>B51A</u>	<u>B51 C</u>	<u>B52A</u>	<u>B52AW</u>	<u>B53A</u>	<u>B53B</u>	<u>B54A</u>	<u>B54B</u>
<b>C-14</b>	5*4				0.1	1.2		<b>1.1</b>
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	<b>1.2</b>	3.0	0.4	3.0
C-17	13.5	11.2		<b>1.3</b>	61.7	12.2		26.5
C-18	<b>1.6</b>	1.1	0.6	0.7	1.2	5.3	0.9	<b>1.8</b>
<b>C-19</b>	1.6	2.2		0.3	0.6	1.1	0.9	2.4
C-20	3.2	<b>1.7</b>		<b>0.1</b>	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	<b>1.8</b>	0.1
C-23	1.6	11.2		0.7	<b>1.2</b>	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	<b>1.1</b>	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	<b>17.9</b>	9.7	21.1	22.4	<b>1.6</b>
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.qd

<u>n-Hydrocarbons</u>	<u>Samples</u>							
	<u>B55A</u>	<u>B55D</u>	<u>B56C</u>	<u>B56D</u>	<u>B57C</u>	<u>B58A</u>	<u>B58B</u>	<u>B58C</u>
C-14	0.2	2.3	0.4		<b>0.1</b>		0.6	
<b>C-15</b>	45.8	64.2	46.6	0.5	20.0		47.6	20.0
C-16	2.0	3.5	<b>2.2</b>	0.4	0.9		<b>1.9</b>	
C-17	28.7	23.5	13.8	2.2	9.8		22.6	48.4
C-18	<b>5.1</b>		1.3	0.4	<b>1.1</b>		2.1	
c-19	6.4		<b>1.8</b>	0.4	1.8		4.5	2.9
C-20	0.7		0.4		0.2		0.4	
<b>C-21</b>	2.9		1.3	1.8	0.7		<b>1.7</b>	<b>2.9</b>
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	<b>1.8</b>	0.9		0.6	
C-26	0.4	0.3	1.1		<b>1.1</b>	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	<b>0.6</b>	1.3	4.4	4.9	0.9	2.1	
C-29	0.9	<b>1.1</b>	4.6	<b>12.9</b>	<b>17.3</b>	<b>10.1</b>	2.3	5.7
C-30	0.7	0.8	2.0	5.8	6.7	<b>1.4</b>	2.1	
C-31	1.6	<b>1.5</b>	13.8	32.4	20.5	65.9	4.3	<b>14.3</b>
C-32	0.7	0.5	<b>1.1</b>	5.5	2.2	8.3	<b>1.5</b>	
<b>C-33</b>	<b>0.4</b>	0.3		<b>11.3</b>	3.3	6.0	1.5	2.9
c-34		0.1	0.2	<b>1.8</b>	0.4		0*4	
c-35		0.2	2.9	<b>9.1</b>	2.2		<b>1.5</b>	
C-36			<b>1.3</b>					
TOTAL ppm	<b>(0.453)</b>	<b>(1.371)</b>	<b>(0.456)</b>	<b>(0.055)</b>	[0.450)	(0.022)	(0.470)	(0.035)

Table 5. Cent. 'd

<u>n-Hydrocarbons</u>	<u>Samples</u>			
	659A	B59B	B60A	B60D
<b>C-14</b>			2.8	
c-15	21.6	<b>76.2</b>	22.2	2.0
C-16	1.3	<b>3.7</b>	1.3	
C-17	0.0	<b>16.2</b>	8.2	
<b>C-18</b>		<b>0.8</b>	0.5	
c-19		<b>0.8</b>	0.8	
C-20		0.2	0.3	
<b>C-21</b>	0.5	0.6	<b>1.5</b>	
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	<b>0.1</b>	5.4	11.8
C-31	39.0	0.5	<b>12.7</b>	39.2
C-32	2.6	0.1	3.6	23.5
c-33	<b>5.1</b>	0.1	3.6	5.9
c-34	0.3		<b>1.0</b>	
c-35	1.3		<b>12.9</b>	
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

<u>n-Hydrocarbons</u>	<u>Samples</u>							
	B61 B	B61 c	B62C	B62D	B63B	B63C	B63D	B64B
C-14			0.2	0.3		<b>0.1</b>	0.4	
<b>C-15</b>	1.8	8.3	36.2	57.0	1.7	<b>61.0</b>	<b>51.4</b>	<b>3.8</b>
<b>C-16</b>			2.8	3.0		5.2		
C-17	<b>1.8</b>	<b>4.1</b>	<b>51.0</b>	34.6	<b>0.9</b>		<b>35.5</b>	<b>3.7</b>
C-18	0.4	0.4	<b>1.8</b>	<b>1.7</b>			0.7	<b>3.4</b>
<b>C-19</b>	0.2		2.9	2.6		7.5	3.6	
C-20	<b>0.1</b>	0.8	0.7	0.3			0.2	
C-21	0.9	2.1	<b>1.1</b>		0.6	4.9	0.7	5
C-22		0.4	0.2					<b>1.0</b>
C-23	<b>0.9</b>		0.6		0.5	<b>1.5</b>	0.4	2.0
C-24	0.6		0.1		0.3		0.2	2.0
C-25			<b>0.1</b>		0.7	0.4	0.2	<b>1.7</b>
C-26	<b>0.1</b>			<b>0.1</b>				1.3
C-27	0.9	0.8	<b>0.1</b>	<b>0.1</b>	<b>5.2</b>	0.4		3.7
C-28	<b>0.9</b>	0.4	0.2		2.6	0.4	1.4	<b>1.3</b>
C-29	<b>10.5</b>	24.8	0.3		12.0	3.7	5.3	2.0
C-30	<b>18.4</b>	<b>12.4</b>	0.2		<b>6.0</b>	2.6		0.4
C-31	62.5	45.5			<b>31.8</b>	12.3		2.0
C-32								22.6
C-33			1.5	0.3	37.7			<b>41.6</b>
C-34								
C-35								
TOTAL ppm	(.1135)	(.0242)	(.6513)	(3.521)	(.1165)	(.2674)	<b>(.0563)</b>	(.0528)

Table 6. Cont. td

<u>n-Hydrocarbons</u>	<u>Samples</u>							
	<b>B64D</b>	665A	B65C	B65D	666A	6666	B66C	668A
<b>C-14</b>						0.3		0.2
c-15	4.7	4.3	1.9	13.4	2.8	34.7	1.7	48.9
<b>C-16</b>	1.1	0.9		1.9	0*2	3.9		3.5
c-17	<b>21.9</b>	33.0	1.9		2.3	51.0	2.9	36.2
C-18	1.6	<b>1.4</b>	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		<b>1.1</b>
c-22		0.7						<b>0.6</b>
c-23	1.3	1.4	0.6	5.7	<b>1.1</b>	0.5		<b>0.7</b>
C-24	0.3	1.0	0.6		0.3			.01
C-25	0.5	1.1	0.5	1.1	0.6			<b>0.1</b>
C-26	0.5	0.9	0.8		0.1		2.0	0.1
C-27	0.5	<b>1.0</b>	<b>1.0</b>	<b>1.9</b>	<b>1.7</b>		5.7	0.2
C-28	1.3	1.4	<b>7.8</b>		2.8		<b>1.7</b>	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	<b>12.5</b>			0.2
<b>C-31</b>	47.0	24.3	34.9	45.8	54.9		22.9	<b>1.0</b>
C-32				0.6			<b>57.4</b>	
<b>C<sub>7</sub>-33</b>			27.2	9.5				<b>1.0</b>
c-34								
c-35								
<b>TOTAL ppm</b>	<i>(.0637)</i>	<i>(.0699)</i>	<i>(.1030)</i>	<i>(.0524)</i>	<i>(.1764)</i>	<i>(.3862)</i>	<i>(.0349)</i>	<i>(3.3090)</i>

Table 6. Cont.td

<u>n-Hydrocarbons</u>	<u>samples</u>						
	<b>B68B</b>	B68C	B68D	B69B	<b>B69D</b>	<b>B70A</b>	B70C
<b>C-14</b>	0.2	0.2					0.4
<b>C-15</b>	28.0	41.3	<b>31.3</b>	13.6	22.0	10.2	58.8
C-16	<b>1.1</b>	2.9	3.0			<b>1.9</b>	3.6
<b>C-17</b>	21.3	35.1	42.9	9.1	<b>16.6</b>	64.9	<b>19.1</b>
<b>C-18</b>	0.9	3.5	4.9			4.5	<b>1.8</b>
c-19	<b>1.3</b>	5.8	6.4			<b>10.5</b>	<b>1.6</b>
C-20		1.7	1.4			<b>1.9</b>	
<b>C-21</b>	0.4	2.5	0.7			<b>1.9</b>	<b>1.4</b>
c-22		0.3					0.2
C-23		1.0	<b>1.0</b>		<b>1.7</b>	0.6	<b>1.1</b>
C-24							<b>0.1</b>
C-25	0.2	<b>0.1</b>	<b>0.1</b>			<b>0.1</b>	<b>0.3</b>
C-26					2.8		0.2
C-27	1.3	0.3	0.6	6.8	5.5	0.2	0.2
C-28	<b>1.9</b>	0.7	0.5	2.3	<b>1.7</b>		0.4
C-29	6.3	<b>1.0</b>	2.5	18.2	<b>16.6</b>		0.5
<b>C-30</b>	12.9	<b>1.6</b>	<b>1.0</b>	50.0	<b>5.5</b>	0.2	
<b>C-31</b>	<b>10.5</b>	<b>1.0</b>	2.4		<b>11.1</b>	0.8	10.3
C-32	5.0	<b>0.1</b>	<b>1.3</b>				
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. Cent.'d

<u>n-Hydrocarbons</u>	<u>Samples</u>							
	<u>B71D</u>	<u>B72A</u>	<u>B72C</u>	<u>B72D</u>	<u>B73C</u>	<u>B74B</u>	<u>B74C</u>	<u>B74D</u>
C-14		0.1	0.5			<b>5.0</b>	0.3	
c-1 5	7.0	38.6	53.6	27.6	0.4		48.7	30.8
<b>C-1 6</b>	0.8		2.3	1.2	0.1	0.3	2.9	
C-17	<b>17.5</b>	53.3	23.8	14.1	0.8	15.0	37.2	30.8
c-1 8		3.4	1.5	0.7		0.3	2.0	
c-1 9	2.6	4.1	<b>1.5</b>			3.3	5.4	
C-20							0.9	
<b>C-21</b>	0.9	0.3	3.1	1.2		0.2	1.5	
c-22			0*5			1.0	<b>0.2</b>	
C-23	0.9	0.2	<b>3.1</b>	3.2		0.7	<b>0.8</b>	
C-24			0.6	0.1		0.2		
C-25	0.4			0.9	<b>0.2</b>			1.5
C-26			0.6	0.2	<b>2.3</b>	0.2		
C-27	1.8		1.5	1.4	<b>6.2</b>	0.3	0.1	<b>6.2</b>
c-28	0.6		0.6	0.5	<b>10.4</b>	1.2		
C-29	6.1		5.3	3.0	<b>27.1</b>	8.3		30.7
C-30	<b>1.8</b>			1.2	<b>17.4</b>	<b>1.0</b>		
C-31	18.4		<b>1.5</b>	8.5	<b>16.2</b>	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.f.d

<u>n-Hydrocarbons</u>	<u>Samples</u>							
	875A	B75C	S75D	B76C	B76D	B77A	B77B	B77C
C-14			0.5				<b>0.1</b>	
C-15	<b>11.6</b>	3.9	65.3	29.4	33.1	<b>9.6</b>	<b>3.8</b>	<b>3.9</b>
C-16			2.7	4.7	<b>1.8</b>	<b>1.7</b>	0.3	
C-17	17.3	3.1	26.3	29.3	<b>19.1</b>	<b>62.6</b>	8.6	3.9
C-18			<b>0.9</b>	2.4	<b>1.1</b>	<b>2.4</b>	3.2	
C-19			3.0	2.4	<b>1.8</b>	<b>7.2</b>	4.8	
C-20			0.5		0.7			
C-21			<b>0.5</b>	<b>1.2</b>	<b>1.8</b>	0.5	8.6	
C-22								
C-23	<b>1.7</b>	<b>1.6</b>	0.2	<b>1.8</b>	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		<b>1.8</b>	0.5	0.2	3.8	<b>1.2</b>
C-26	1.7					0.2		
C-27	3.5	<b>2.8</b>			0.7	<b>1.0</b>	2.7	<b>1.9</b>
C-28	0.6				0.7	0.2		0.8
C-29	11.6	<b>11.8</b>	0.1		0.2	<b>1.2</b>	<b>16.0</b>	61.4
C-30				2.9	<b>1.6</b>	0.5	4.8,	
C-31	<b>4.1</b>	27.4		23.5	34.9	<b>12.0</b>	35.3	
C-32	28.8							<b>3.5</b>
C-33	17.3	47.0						23.0
C-34								
C-35								
<b>TOTAL ppm</b>	(.0173)	(.0255)	(6.5023)	(.0170)	(.0572)	(.0416)	(.1867)	(.0260)

Table-6. Cent.ld

<u>n-Hydrocarbons</u>	<u>Samples</u>								
	<u>B78A</u>	<u>B78C</u>	<u>B79C</u>	<u>B79D</u>	<u>B80B</u>	<u>B80C</u>	<u>B80D</u>	<u>B81 A</u>	
C-14	17.2				0.1	0.2	0.2		
<b>c-15</b>		4.5	4.7	1.9	41.0	41.7	57.7		
<b>C-16</b>	2.1	0.5		0.2		2.4	3.3		
<b>C-17</b>	55.8	24.8	4.7	<b>2.4</b>	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		
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	<b>1.5</b>	1.4		0.3				
C-25	<b>0.3</b>	2.5	1.9	1.4	0.3		0.4		
c-26	0.2	<b>2.0</b>	1.4	3.0					
C-27	0.5	4.5	4.2	<b>10.0</b>		0.4			
C-28	0.6	3.5	2.3	12.2		<b>0.1</b>			
C-29	0.2	4.0	14.0	29.4		<b>1.4</b>			
C-30	1.4	1.0	3.7	12.7		0.3			
C-31	12.4	34.7	23.2	<b>11.9</b>		0.9			
C-32			32.5	9.2		<b>1.9</b>			
c-33				3.0					
c-34									
C-35									
TOTAL ppm	(.14521)	(.0201)	(.0215)	(0.3686)	[.3052)	(0.2132)	(.2460)	(<.010)	for all <.0005 ppm

Table 6. Cont. rd

<u>n-Hydrocarbons</u>	<u>Samples</u>						
	<u>B82B</u>	B82C	B82D	B83C	B83D	B84A	B84C
<b>C-14</b>	<b>0.5</b>		<b>0.3</b>			0.5	<b>1.2</b>
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
<b>C-17</b>	13.0	26.9	62.2	<b>2.1</b>	52.7	32.1	22.0
<b>C-18</b>	6.8	<b>1.0</b>	0.8		<b>1.8</b>	2.3	
<b>C-19</b>	<b>9.7</b>	5.4	7*5		<b>14.5</b>	3.9	<b>1.9</b>
<b>C-20</b>	18.7	0.7			<b>0.2</b>		
<b>C-21</b>			<b>2.1</b>		1.6	0.4	<b>0.6</b>
c-22							<b>0.1</b>
C-23	<b>1.1</b>	0.3	3.8	0.7	12.7	<b>0.1</b>	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		<b>0.1</b>
C-27		3.7	0.4	3.5	7.3	0.2	0.3
C-28		0.7		<b>1.4</b>	0.7	0.2	<b>0.1</b>
C-29	<b>1.1</b>	<b>0.7</b>	0.4	7.0	3.6	0.4	<b>1.2</b>
<b>C-30</b>	<b>0.7</b>	1.7	0.4		0.2	<b>1.3</b>	<b>1.1</b>
<b>C-31</b>	<b>1.1</b>	10.4	2.9	27.9		0.6	
C-32	0.9	27.7	3.3			0.6	
c-33	<b>1.7</b>	10.4	3.8	52.2			3.3
c-34'							
c-35							
TOTAL ppm'	<b>(0.6472)</b>	<b>(.2970)</b>	(0.2396)	(.0287)	(.0551)	(1.0090)	(.7284)

Table 7.

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

<u>Location</u>	<u>Sample Number</u>		<u>Sample Name</u>	<u>Hydrocarbon Concentration</u> in ppm, wet weight
	UTMSI Code	TAMU Code		
<b>I-1</b>	<b>AFM-EPI</b>	AMG <b>B1C</b>	Silver sea trout	0.054
	<b>AFM-EPI</b>	AMG <b>B1D</b>	Star drum	<b>≈0.015<sup>b</sup></b>
	<b>AHP-EPI</b>	AMG B2A	Brown shrimp	<b>0<sup>a</sup></b>
	<b>AHP-EPI</b>	AMG B2C	Silver sea trout	<b>1.070</b>
<b>I-2</b>	<b>ACV-EPI</b>	AMG B4B	Flatfish	0.103
	<b>ACV-EPI</b>	AMG B4D	Brown shrimp	0.030
	<b>AFE-EPI</b>	"AMG B5B	Caribbean red snapper	0.175
	<b>AFE-EPI</b>	AMG B5D	Squid	0.226
<b>I-3</b>	<b>AAF-EPI</b>	AMG B7A	Broken-back shrimp	<b>≈0.060</b>
	<b>AAF-EPI</b>	AMG B7C	Flatfish	0.088
	<b>AAF-EPI</b>	AMG B7D	<b>Wenchman</b>	0.097
	<b>AAL-EPI</b>	AMG B8B	Mexican sea robin	<b>1.315</b>
<b>II-1</b>	<b>AIK-EPI</b>	AMG <b>B10A</b>	Brown shrimp	<b>≈0.001</b>
	<b>AIK-EPI</b>	<b>AMG B10D</b>	Rock sea bass	0.228
	<b>AJD-EPI</b>	<b>AMG 611A</b>	Squid	0.108
	<b>AJD-EPI</b>	AMG <b>B11C</b>	White Shrimp	0
<b>II-2</b>	<b>ALH-EPI</b>	<b>AMG B13D</b>	Squid	0.027
	<b>AME-EPI</b>	AMG B14B	Flatfish	<b>0.115</b>
	<b>AME-EPI</b>	AMG B14C	Mantis shrimp	<b>≈0.010</b>
	<b>AME-EPI</b>	AMG <b>B14D</b>	Brown shrimp	<b>≈0.008</b>

Table 7. Cont.f.d

<u>Location</u>	<u>Sample Number</u>		<u>Sample Name</u>	<u>Hydrocarbon Concentration in ppm, wet weight</u>
	UTMSI Code	TAMU Code		
II-3	AOK-EPI	AMG B16C	Sea robin	0.252
	APF-EPI	AMG B17A	Rough scad	<b>0.083</b>
	APF-EPI	AMG B17B	Wenchman	0.622
	APF-EPI	AMG B17C	Tile fish	0.045
III-1	ARN-EPI	AMG B19B	Brown shrimp	<b>≈0.013</b>
	ARN-EPI	AMG B19C	Squid	0.295
	ASH-EPI	AMG B20C	Rough scad	<b>0.048</b>
	ASH-EPI	AMG B20D	Flatfish	<b>≈0.010</b>
III-2	AUQ-EPI	AMG B22B	Black-finned sea robin	0.097
	AUQ-EPI	AMG B22D	Rock shrimp	<b>≈0.005</b>
	AVM-EPI	AMG B23B	Wenchman	0.632
	AVM-EPI	AMG B23D	Squid	0.028
III-3	AXP-EPI	AMG B25A	Mexican sea robin	<b>0.350</b>
	AYJ-EPI	AMG B26A	Wenchman	0.429
	AYJ-EPI	AMG B26B	Squid	<b>0.144</b>
	AYJ-EPI	AMG B26C	Rough scad	0.243
IV-1	BAN-EPI	AMG B28A	Rock shrimp	<b>0</b>
	BBI-EPI	AMG B29B	Brown shrimp	<b>0</b>
	BBI-EPI	AMG B29C	Rough scad	0.246
	BBI-EPI	AMG B29D	Dusky flounder	<b>0.090</b>
IV-2	BDN-EPI	AMG B31A	Brown shrimp	0.065
	BDN-EPI	AMG B31B	Rock sea bass	<b>0.122</b>

Table 7. Cont.f.d

<u>Location</u> - UTMSI	<u>C o d e</u>	<u>Sample Number</u> TAMU Code	<u>Sample Name</u>	<u>Hydrocarbon</u> <u>Concentration</u> i n ppm, wet weight
	BEK-EP I	AMG B32C	Squi d	0.636
	BEK-EPI	AMG B32D	Rough scad	0.407
IV-3	BGO-EPI	AMG B34B	Brown shrimp	<b>0</b>
	BGO-EPI	AMG B34C	Rock shrimp	0.656
	BPF-EPI	AMG B35C	Dwarf goatfish	<b>0.121</b>
	BPF-EPI	AMG B35D	Mexican sea robin	<b>1.075</b>

(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"

<u>Location</u>	<u>Sample Number</u>		<u>Sample Name</u>	<u>Hydrocarbon Concentration in ppm, wet weight</u>
	<u>UTMSI Code</u>	<u>TAMU Code</u>		
I-1	CBC	AMG 537A	White shrimp	0.072
	CBC	AMG B37C	Sand Seatrout	0.449
	CBC	AMG B37D	Gulf Hoke	<b>0.122</b>
	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	<b>0.197</b>
	CGO	AMG B42C	Brown shrimp	<b>0.164</b>
II-1	CKS	AMG B43B	Squid	<b>0.052</b>
	CJX	AMG B44A	Shoal Flounder	0.383
	CJX	AMG B44B	White shrimp	<b>0.067</b>
	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. tent.ld

<u>Location</u> - UTMSI	<u>C o d e</u>	<u>Sample Number</u> TAMU Code	<u>Sample Name</u>	<u>Hydrocarbon</u> <u>Concentration in</u> ppm, <b>wet weight</b>
	<b>CNA</b>	<b>AMG B46D</b>	<b>Shoal</b> Fl ounder	0.400
11-3	Cox	AMG B47A	<b>Wenchman</b>	2.488
	Cox	AMG B47C	<b>Squid</b>	0.212
	<b>COC</b>	AMG B48B	<b>Longspine</b> Porgy	0.0555
	Coc	AMG B48C	<b>Brown shrimp</b>	0.050
III-1	<b>CUF</b>	AMG 849A	Shoal Fl ounder	0.246
	<b>CTJ</b>	AMG B50A	Brown shri mp	0.020
	CTJ	AMG B50C	Shoal Fl ounder	0.219
	CTJ	AMG B50D	Manti s shri mp	0.069
<b>III-2</b>	CYB	AMG <b>B51A</b>	<b>Longspine</b> Porgy	<b>0.185</b>
	<b>CYB</b>	<b>AMG B51C</b>	Squi d	0.177
	<b>CXM</b>	AMG B52A	Brown shri mp	0.032
	<b>CXM</b>	AMG <b>B52AW</b>	Brown shri mp	0.749
<b>III-3</b>	<b>DBD</b>	AMG B53A	Pi nfi sh	<b>0.166</b>
	DBD	AMG B53B	<b>Longspine</b> Porgy	0.565 "
	DAK	AMG B54A	Brown shri mp	0.022
	<b>DAK</b>	AMG B54B	<b>Wenchman</b>	<b>1.126</b>
<b>IV-1</b>	DED	AMG B55A	Squi d	<b>0.453</b>
	<b>DED</b>	AMG B55D	Rough Scad	1.371
	<b>DDK</b>	AMG B56C	Shoal Fl ounder	0.456
	<b>DDK</b>	<b>AMG B56D</b>	Rock shri mp	0.055
IV-2	<b>DHC</b>	AMG B57C	Shoal Fl ounder	0.450

Table 8. Cent.'d

<u>Location</u>	<u>Sample Number</u>		<u>Sample Name</u>	<u>Hydrocarbon Concentration in ppm, wet weight</u>
	UTMSI Code	TAMU Code		
	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

<u>Location</u>	<u>Sample Number</u>	<u>Sample Name</u>	<u>Hydrocarbon Concentration in ppm, wet weight</u>
<b>UTMSI</b>	<b>Code</b> <b>TAMU Code</b>		
1-1	<b>EAI-EPI</b> <b>AMG-B61B</b>	<b>spot</b>	<b>0.1135</b>
	<b>EAI-EPI</b> <b>AMG-B61C</b>	Brown shrimp	0.0242
	<b>EBC-EPI</b> <b>AMG-B62C</b>	Squid	0.6513
	<b>EBC-EPI</b> AMG-B62D	Lizard fish	3.5210
<b>I-2</b>	<b>EDM-EPI</b> <b>AMG-B63B</b>	Broken-back shrimp	0.1165
	<b>EDM-EPI</b> <b>AMG-B63C</b>	Rough scad	0.2674
	<b>EDM-EPI</b> <b>AMG-B63D</b>	Inshore <b>lizard</b> fish	0.0563
	<b>EEC-EPI</b> <b>AMG-B64B</b>	Rock shrimp	0.0528
	<b>EEC-EPI</b> <b>AMG-B64D</b>	<b>Rock sea bass</b>	0.0637
<b>I-3</b>	<b>EGQ-EPI</b> <b>AMG-B65A</b>	<b>Wenchman</b>	0.0699
	<b>EGQ-EPI</b> <b>AMG-B65C</b>	<b>Black ear bass</b>	0.1030
	<b>EGQ-EPI</b> <b>AMG-B65D</b>	<b>Longspine porgy</b>	0.0524
	<b>EHM-EPI</b> <b>AMG-B66A</b>	<b>Shoal flounder</b>	<b>0.1764</b>
	<b>EHM-EPI</b> <b>AMG-B66B</b>	Wenchman	0.3862
	<b>EHM-EPI</b> <b>AMG-B66C</b>	<b>Mexican sea robin</b>	0.0349
<b>II-1</b>	<b>EKS-EPI</b> <b>AMG-B68A</b>	<b>Atlantic bumper</b>	3.3090
	<b>EKS-EPI</b> AMG B68B	Red Snapper	0.5419
	<b>EKS-EPI</b> <b>AMG-B68C</b>	Squid	2,0860

Table 9. Cont.td

<u>Location</u>	<u>Sample Number</u>		<u>Sample Name</u>	<u>Hydrocarbon Concentration in ppm, wet weight</u>
	UTMSI Code	TAMU Code		
II-1	EKS-EPI	AMG-B68D	Silver sea trout	<b>0.8409</b>
II-2	ENA-EPI	AMG-B69B	Mantis shrimp	<b>0.0440</b>
	ENA-EPI	AMG-B69C	Rock shrimp	0.0181
	ENW-EPI	AMG-B70A	Inshore lizard fish	0.4859
	ENW-EPI	AMG-B70C	Squid	0.9380
	EQC-EPI	AMG-B71 D	Longspine porgy	<b>0.1140</b>
II-3	EQX-EPI	AMG-B72A	Wenchman	0.8857
	EQX-EP I	AMG-B72C	Squid	<b>0.1308</b>
	EQX-EPI	AMG-B72D	Dwarf goat fish	0.4335
	ETJ-EPI	AMG-B73C	Shoal flounder	0.2587
III-1	EUF-EPI	AMG-B74B	Star drum	0.0602
	EUF-EPI	AMG-B74C	Squid	<b>1.1207</b>
	EUF-EPI	AMG-B74D	Brown shrimp	0.0065
	EXM-EPI	AMG-B75A	Rock sea bass	<b>0.0173</b>
III-2	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
	FAK-EPI	AMG-B77A	Wenchman	<b>0.0416</b>
III-3	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

<u>Location</u>	<u>Sample Number</u> UTMSI Code      TAMU Code	<u>Sample Name</u>	<u>Hydrocarbon Concentration in ppm, wet weight</u>
	FBD-EPI      AMG-B78C	Squid	<b>0.0201</b>
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	<b>0.2132</b>
	FEL-EPI      AMG-B80D	Rough scad	0.2460
IV-2	FGR-EPI      AMG-B81A	Brown shrimp	<0.0100
	FHM-EPI      AMG-B82B	Dwarf <b>goatfish</b>	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	<b>Wenchman</b>	1.0090
	FKR-EPI      AMG-B84C	Rough scad	0.7284

## HEAVY HYDROCARBON PROJECT

Water, Zooplankton, Neuston and Sediment

University of Texas Marine Science Laboratory

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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.

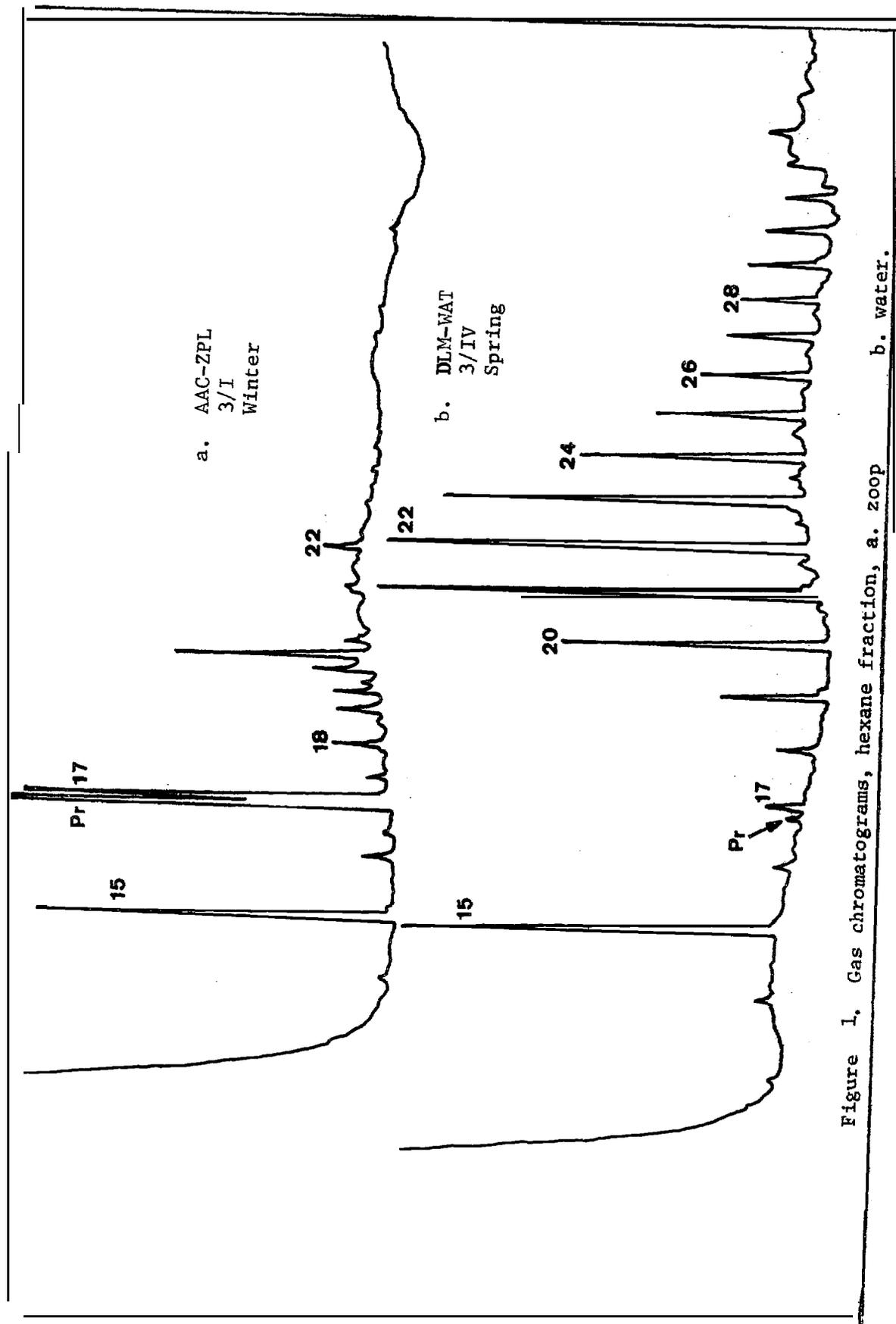


Figure 1. Gas chromatograms, hexane fraction, a. zoop b. water.

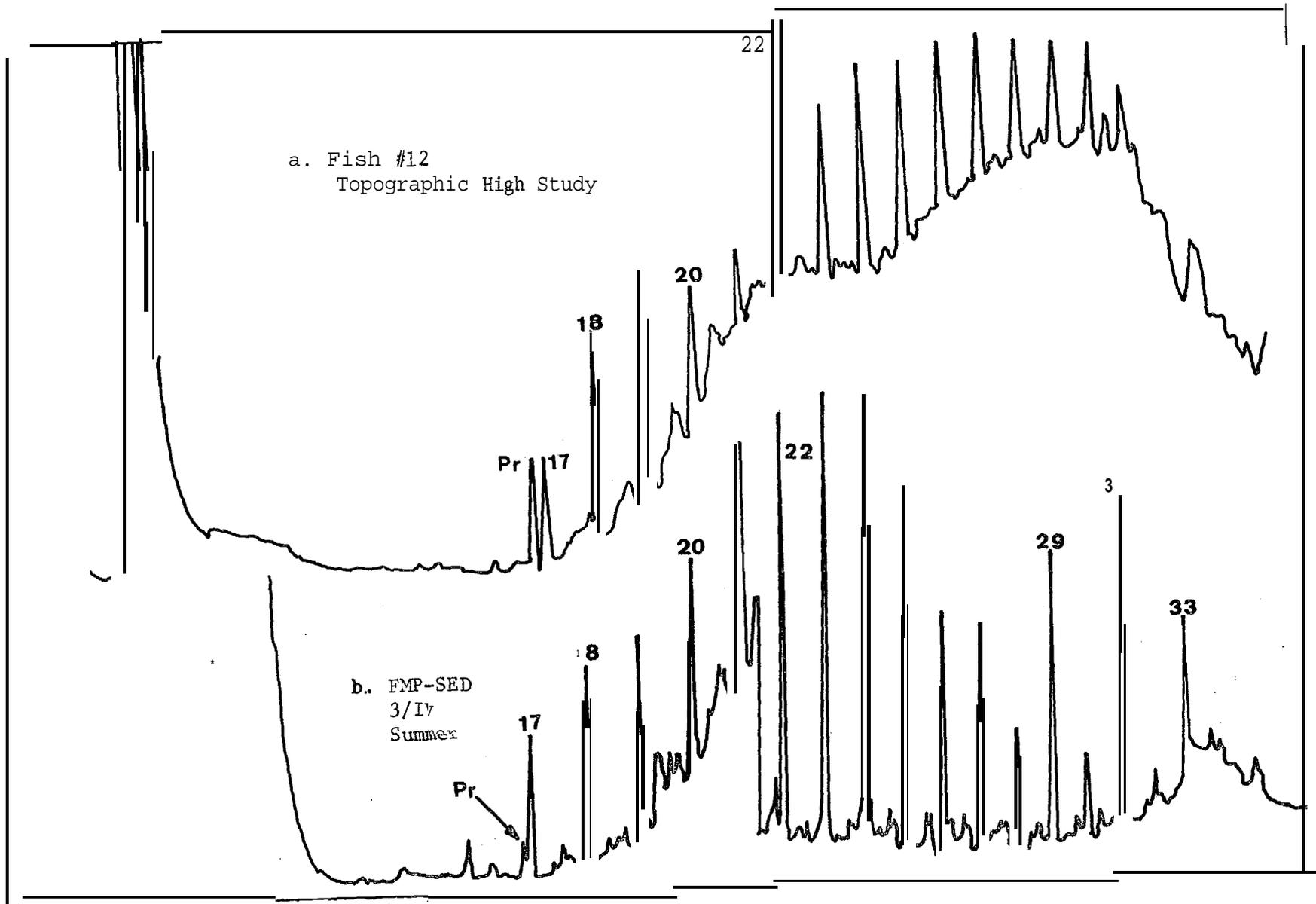


Figure 2. Gas chromatograms, hexane fraction, a. fish, b. sediment.

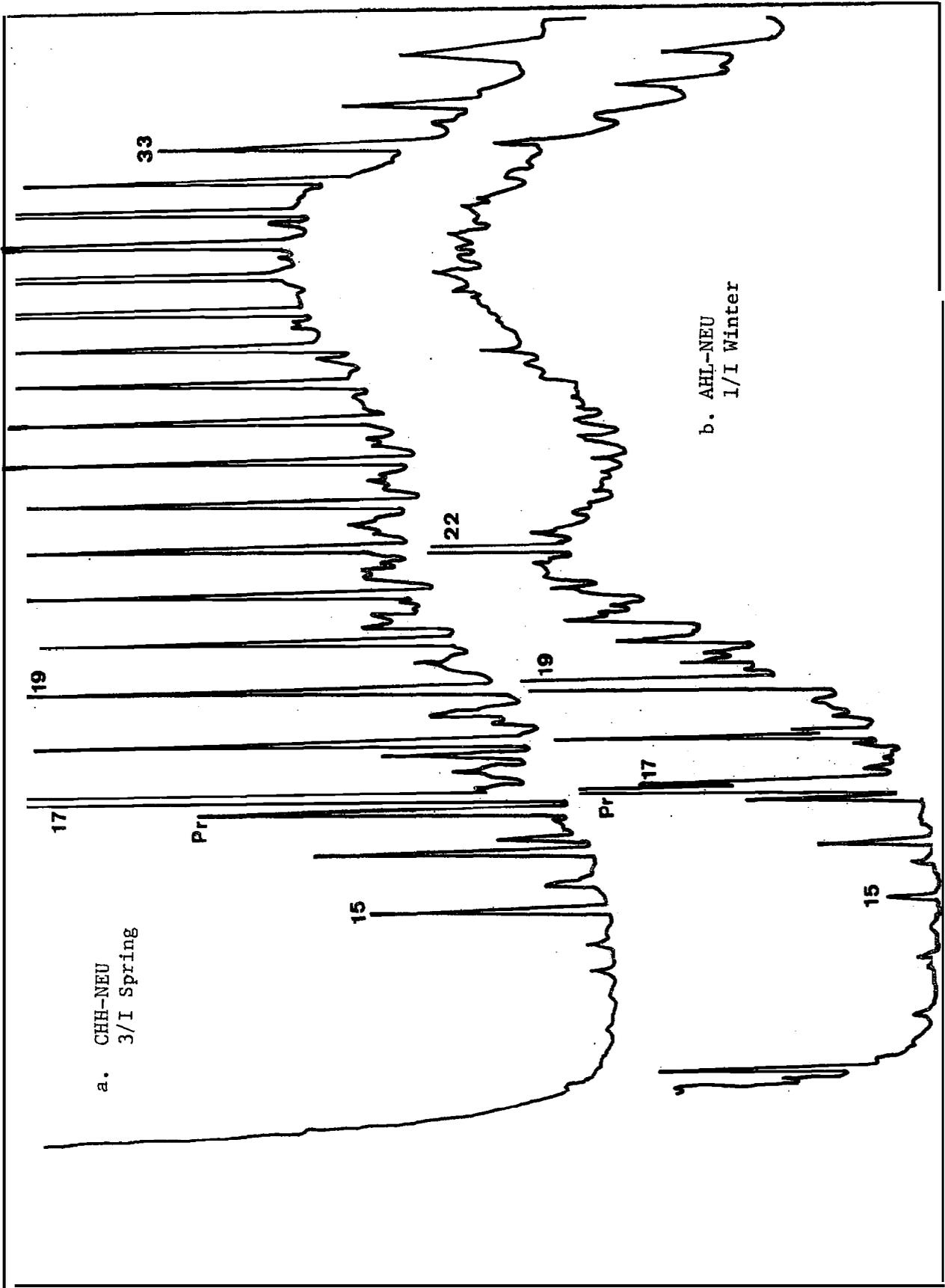


Figure 3. Gas chromatograms, hexane fraction, neuston.

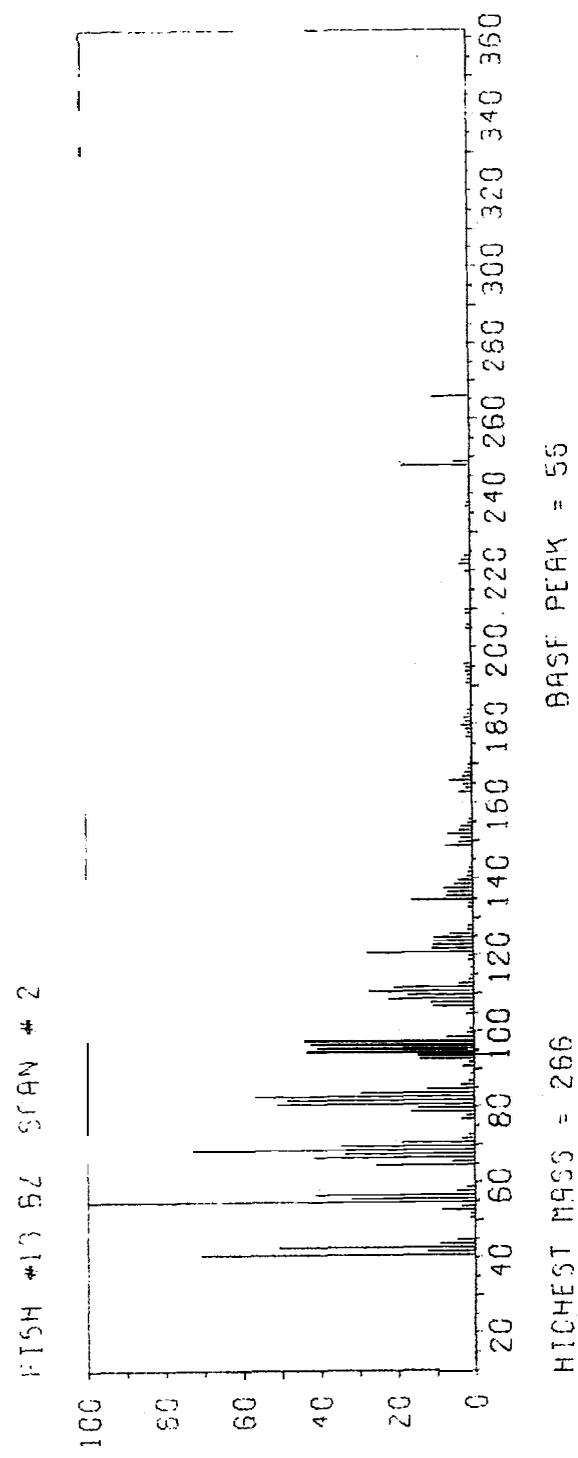
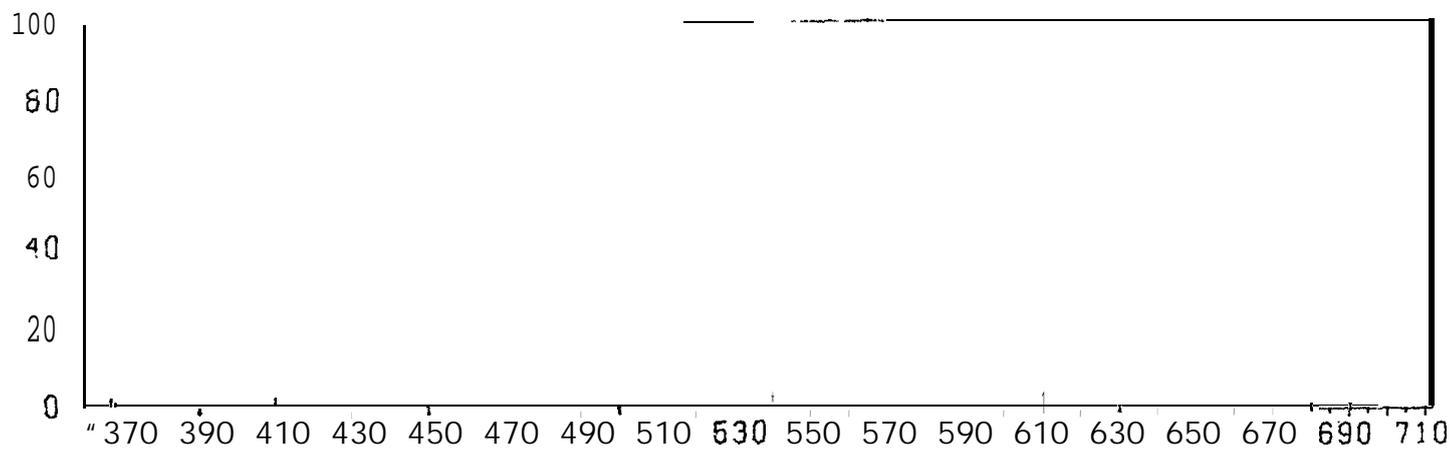
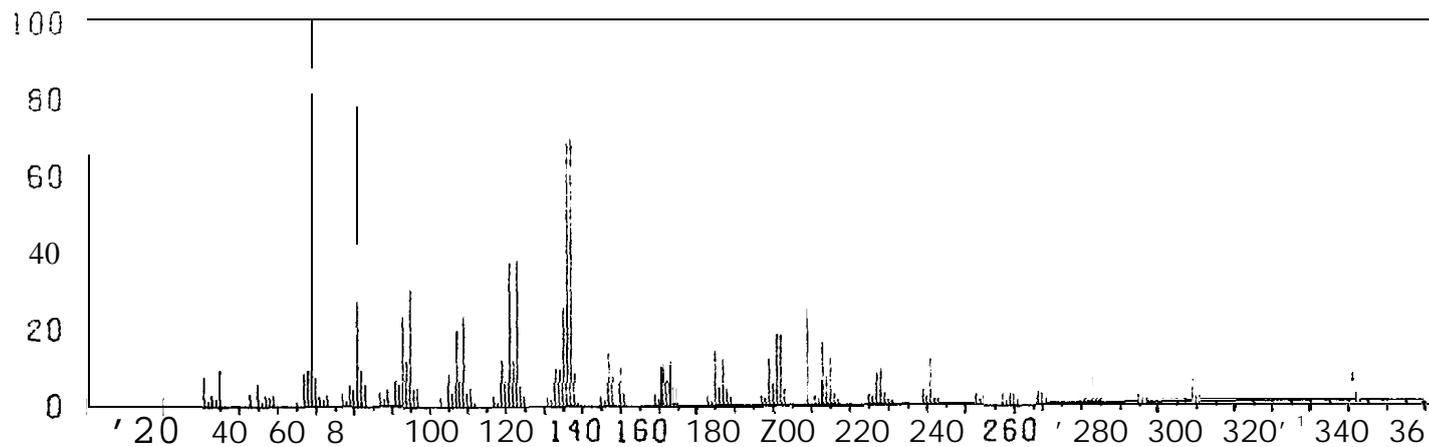


Figure 4. Mass Spectra of C<sub>19</sub>:1, Benzene Fraction Component, Fish #13, Topographic High Study.



FISHSKIN LIPID M/E = 410



HIGHEST MASS = 410

BASE PEAK = 69

Figure 5. Mass Spectra of Squalene, Benzene Fraction, Fish, Topographic High Study.

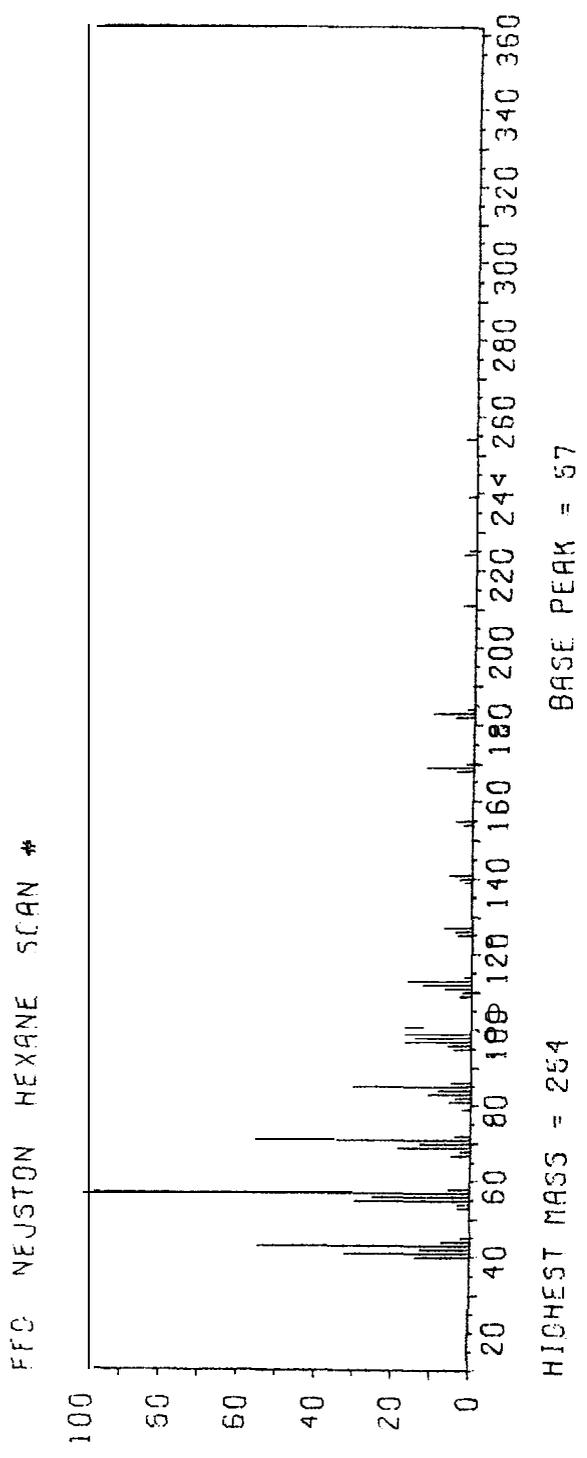


Figure 6. Mass Spectra of a Branched C<sub>18</sub> Paraffin from Neuston Sample FEG.

8-

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 had 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  $\mu$ l 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 separator 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  $\mu$ g/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 ( $\mu$ g)	Recovery		Average Recovery (%)
		#1	#2	
<b>Biphenyl</b>	80.8	78.7	92.3	85.5
<b>Methylbiphenyl</b>	45.9	81.1	93.4	87.2

Compound	Sample Weight ( $\mu\text{g}$ )	Recovery		Average Recovery (%)
		#1	#2	
Methylflourene	14.8	82.3	92.3	87.3
<b>nC18</b>	23.0	90.9	95.7	93.3
<b>nC20</b>	32.7	93.8	100.4	97.1
<b>nC21</b>	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 **C18**. 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

(1/1 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 2/1 Table 4.

There was no apparent consistent change in percentage composition with

Legend:

Order = Winter  
 Spring  
Summer  
 Average

Units =  $\mu\text{g}/\text{l}$

\* = Not included in average

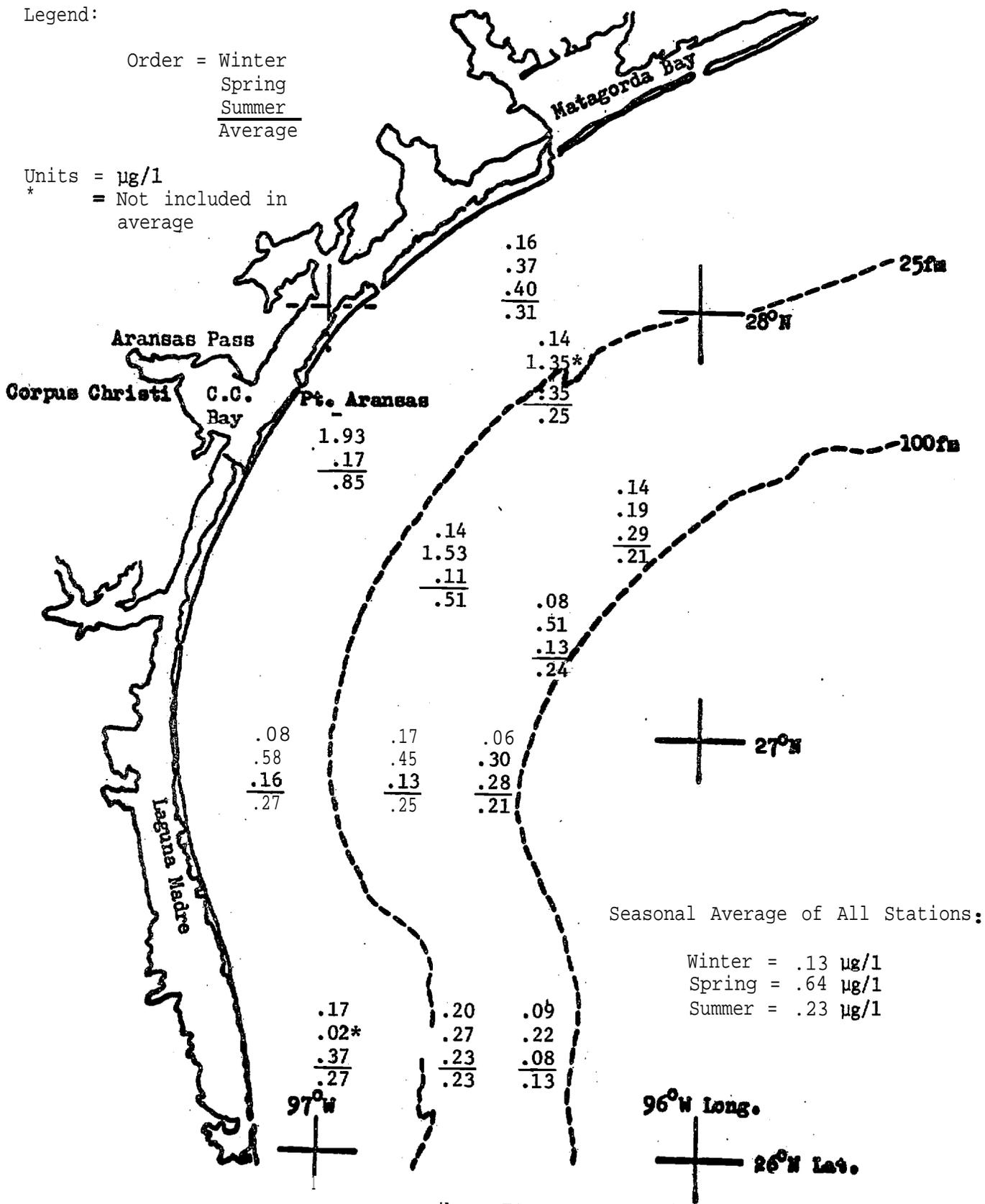


Figure 7. Average Total n-Paraffin Concentration in Seawater.

Legend: Units  $\mu\text{g}/\text{l}$

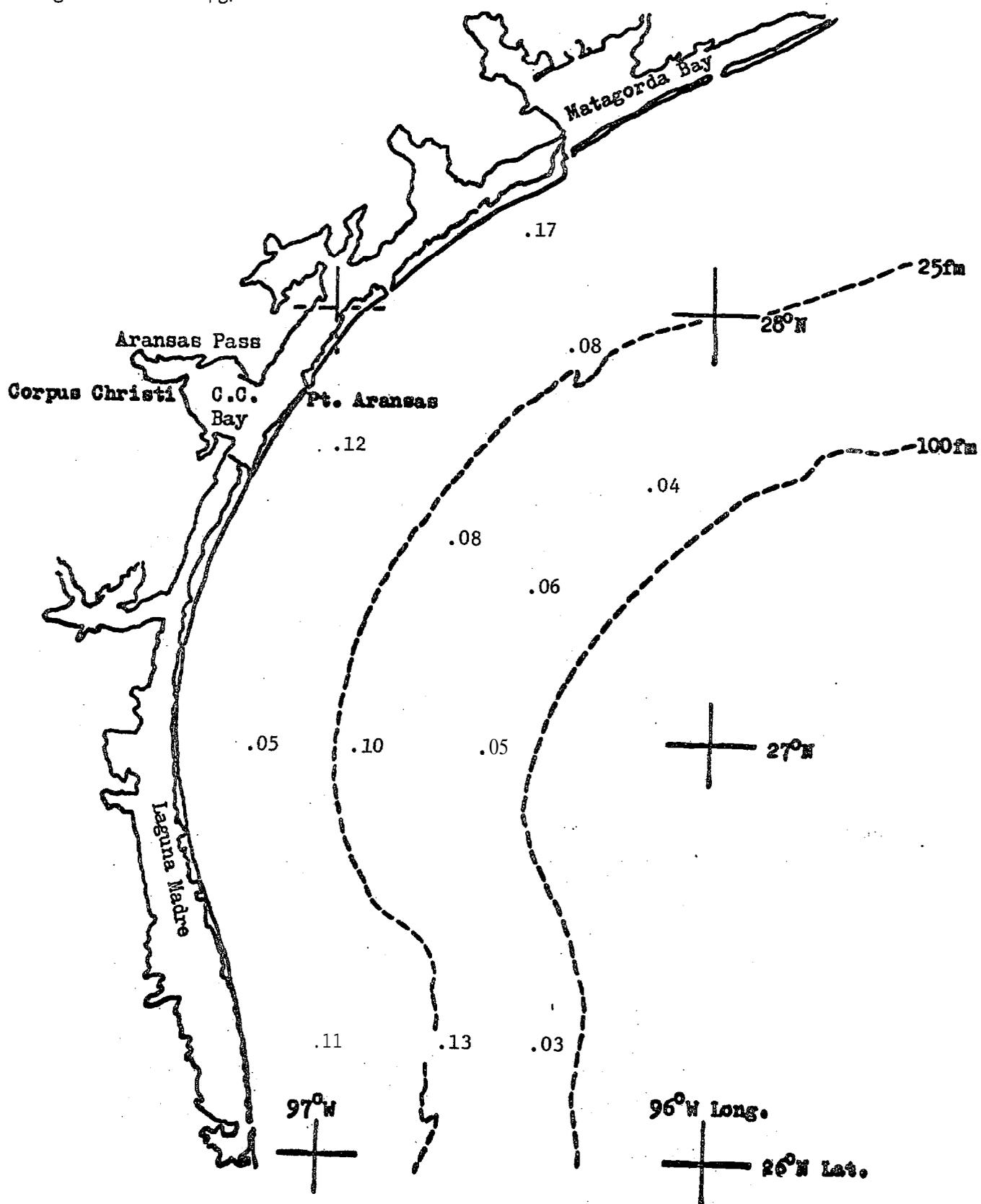


Figure 8. Average Total n-Paraffin Concentration in Particulate Matter from Seawater, August 1975.

Legend: Order = Dissolved  
 Particulate

Units =  $\mu\text{g/l}$

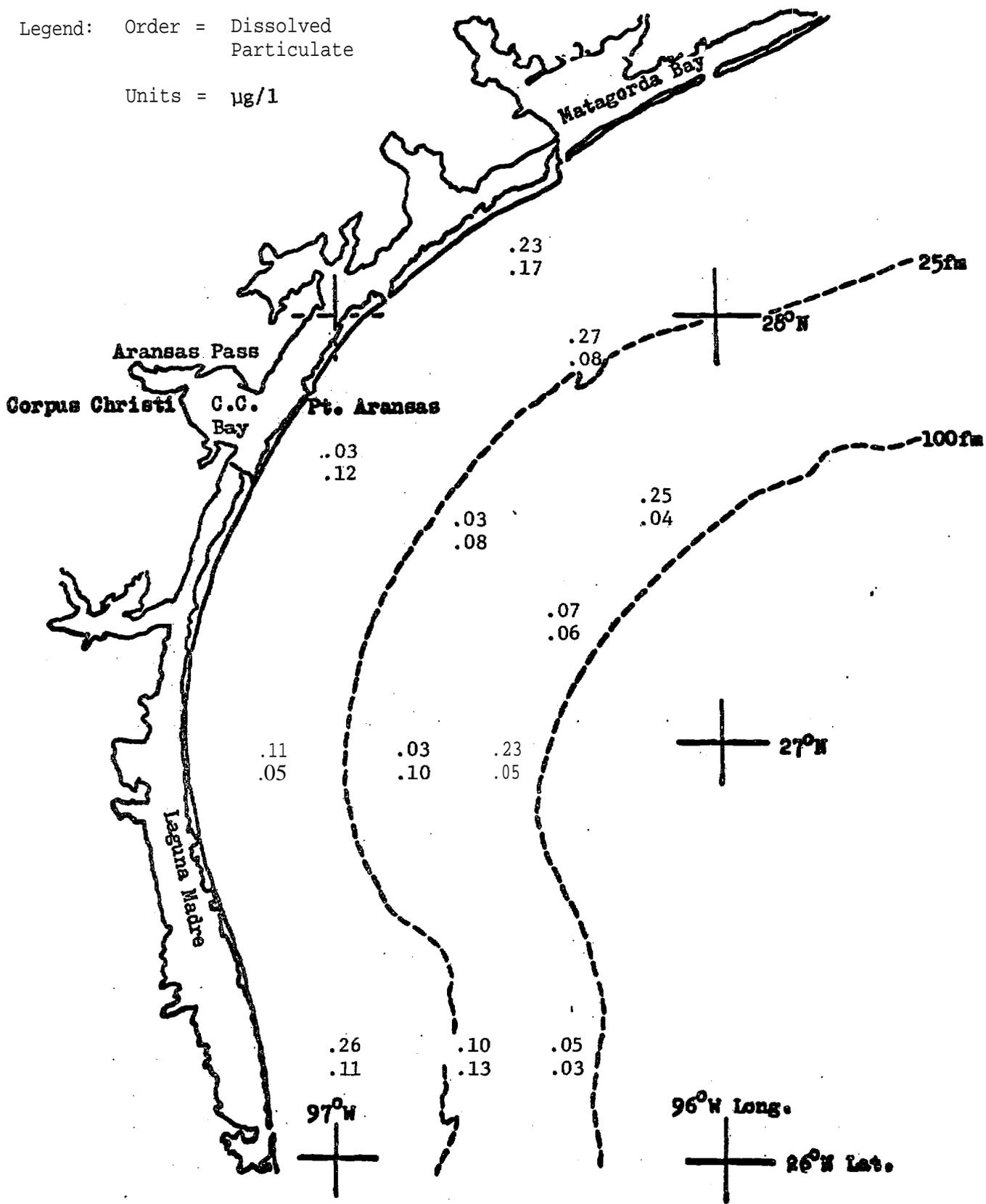


Figure 9. Average Total n-Paraffin Concentration in "Dissolved" and Particulate Organics from Seawater, August 1975.

Table 1. Components in samples from **STOCS** studies confirmed by combined Gas Chromatography-Mass **Spectrometry**.

<u>Sample Code</u>	<u>Sample Type</u>	<u>Component Code</u> <sup>1</sup>
AM!	<b>Zooplankton</b>	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	<b>2,5,11</b>
ALW	<b>Neuston</b>	7,14,17,26
BEG	Neuston	25
BPJ	Neuston	1,2,4,5,20
CAX	<b>Neuston</b>	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	<b>13,21</b>
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	<b>Epifauna</b>	<b>13</b>
AIK-D	Epifauna	13
BEK-C	<b>Epifauna</b>	2,11
BEK-D	<b>Epifauna</b>	2,11,26
Other Epifauna <b>samples</b> <sup>2</sup>		
Fish 11	Reef fishes	26
Fish 12	Reef fishes	26
Fish 13	Reef fishes	10
Fish 22	Reef fishes	10

<sup>1</sup>Key to component code

<u>Key</u>	<u>Mass</u>	<u>Component</u>
1	210	<b>C<sub>15</sub>H<sub>30</sub> (C<sub>15</sub>:1)</b>
2	212	<b>C<sub>15</sub>H<sub>32</sub> (nC<sub>15</sub>)</b>
3	226	<b>C<sub>16</sub>H<sub>34</sub> (nC<sub>16</sub>)</b>
4	238	<b>C<sub>17</sub>H<sub>34</sub> (C<sub>17</sub>:1)</b>
5	240	<b>C<sub>17</sub>H<sub>36</sub> (nC<sub>17</sub>)</b>
6	254	<b>C<sub>18</sub>H<sub>38</sub> (nC<sub>18</sub>)</b>
7	258	<b>C<sub>19</sub>H<sub>30</sub> (C<sub>19</sub>:5)</b>
8	262	<b>C<sub>19</sub>H<sub>34</sub> (C<sub>19</sub>:3)</b>
9	264	<b>C<sub>19</sub>H<sub>36</sub> (nC<sub>19</sub>:2)</b>

Table 1. Cont.td

<u>Key</u>	<u>Mass</u>	<u>Component</u>
10	266	C <sub>19</sub> H <sub>38</sub> (C <sub>19</sub> :1)
11	268	C <sub>19</sub> H <sub>40</sub> (Pristane)
12	268	C <sub>19</sub> H <sub>40</sub> (nC <sub>19</sub> )
13	270	C <sub>17</sub> H <sub>34</sub> O <sub>2</sub> (methyl palmitate)
14	278	C <sub>20</sub> H <sub>38</sub> (Phytadiene)
15	282	C <sub>20</sub> H <sub>42</sub> (Phytane)
16	282	C <sub>20</sub> H <sub>42</sub> (nC <sub>20</sub> )
17	285	C <sub>21</sub> H <sub>32</sub> (C <sub>21</sub> :6)
18	288	C <sub>21</sub> H <sub>34</sub> (C <sub>21</sub> :4)
19	296	C <sub>21</sub> H <sub>44</sub> (? , not nC <sub>21</sub> )
20	310	C <sub>22</sub> H <sub>46</sub> (nC <sub>22</sub> )
21	340	C <sub>22</sub> H <sub>44</sub> O <sub>2</sub> (methylester of C <sub>21</sub> FA)
22	340	C <sub>23</sub> H <sub>48</sub> O ?
23	346	C <sub>25</sub> H <sub>44</sub> (C <sub>25</sub> :4)
24	370	C <sub>27</sub> H <sub>46</sub> (not cholestene but very close)
25	390	C <sub>24</sub> H <sub>38</sub> O <sub>4</sub> (di-C <sub>8</sub> -Phthalate)
26	410	C <sub>30</sub> H <sub>50</sub> (Squalene)
27	410	C <sub>30</sub> H <sub>50</sub> (Squalene isomer ?)
28	414	C <sub>30</sub> H <sub>54</sub> (C <sub>30</sub> :4 ?)
29	422	C <sub>30</sub> H <sub>62</sub> (Squalane)
30	442	C <sub>30</sub> H <sub>50</sub> O <sub>2</sub> (Betulin)

<sup>2</sup>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	1-1	1-1	I-2	I-3	I-3	11-2	II-2	II-3	111-1
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	<b>1.3</b>	2.0
<b>18+Phytane</b>	2.1	1.4	Tr	.8	1.1	<b>2.6</b>	1.1	Tr	Tr
<b>19</b>	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	<b>5.0</b>
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	<b>10.1</b>	14.9	14.4	12.8	12.5	6.5	Tr	15.8	11.5
24	<b>7*9</b>	12.0	12.9	10.4	10.5	4.8	Tr	13.7	11.4
25	<b>6.2</b>	8.4	10.4	8.3	8.3	4.6	<b>Tr</b>	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	<b>12.9</b>
28	2.7	2.5	5.0	3.2	<b>3.0</b>	2.4	5.4	<b>4.1</b>	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	<b>2.0</b>	1.2	3.7	2.6	2.4	1.4	4.7	3.4	6 . 2
32	Tr	Tr	1.8	Tr	<b>1.5</b>	.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 <sub>15</sub> -C <sub>20</sub> *	1.9	.9	.6	.8	.7	6.2	6.6	1.0	1.4
C.P.I. C <sub>25</sub> -C <sub>38</sub>	1.7	1.8	1.6	1.7	1.6	1.4	1.1	2.1	<b>1.4</b>
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
<b>18+Phytane</b>	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	<b>13.2</b>
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	<b>8.8</b>	2.3	9.4	.5	1.2
26	6.4	<b>Tr</b>	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 <sub>15</sub> -C <sub>20</sub> *	2.0	3.2	2.0	1.0	.9	.8	1.6
C.P.I. C <sub>25</sub> -C <sub>38</sub>	1.5	.8	1.3	1.5	1.8	1.0	<b>1.3</b>
<b>Pristane/Phytane</b>							

\* Carbon Preference Index C.P.I. C<sub>15</sub> - C<sub>20</sub> = 
$$\frac{C_{15} + C_{17} + C_{19}}{C_{16} + C_{18} + C_{20}}$$

Table 3. Percentage Composition of n-Paraffins in Seawater, April-May, 1975.

Station	I-1	I-1	I-2	I-3	11-1	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	<b>12.8</b>	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	<b>1.1</b>	3.2
29	8.3	9.2	9.5	7.0	3.5	1.9	3.0	<b>1.9</b>	4.5
30	4.7	7.8	13.2	5.8	.4	1.1	2.5	1.9	<b>5.5</b>
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
3 5	.2	.6	5.6	.3				.7	2.3
36			3.5					.3	.5
37			3.5						.4
38									
Total n-paraffins ( $\mu\text{g/l}$ )	.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		<b>1.0</b>	<b>1.0</b>	1.4		2.0	

Table 3. Cent.'d

Station	111-1	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		<b>.1</b>	
<b>Pristane</b>	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	<b>21.0</b>
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	<b>11.7</b>	8.6	10.7
24	12.4	.2	6.2	4.9	.68	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	<b>4.1</b>	2.7
31	5.5	17.2	6.1	2.0	1.7	1.3	<b>2.7</b>	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	<b>07</b>	.4		.7	<b>1.1</b>
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					
<b>Total</b>	.08	1.09	.45	.42	.19	.02	.50	.05
n-paraffins ( $\mu\text{g/l}$ )								
<b>C.P.I. C<sub>15</sub>-C<sub>20</sub>*</b>	.9	1.0	.8	3.2	.4	.23	.9	.1
<b>C.P.I. C<sub>25</sub>-C<sub>38</sub></b>	1.2	1.0	1.1	1.4	1.6	1.0	1.2	<b>1.3</b>
<b>Pristane/Phytane</b>	1.0	1.0	3.0		1.5		2.0	

Table 3. Cent. 'd

Station	IV-3	IV-3
Sample Code	DLM	DLN
Carbon No.		
15	12.1	
16	.6	
<b>Pristane</b>	.4	
17	.7	Tr
Phytane	Tr	
18	1.0	Tr
<b>19</b>	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	<b>10.4</b>
25	4.2	6.0
26	2.9	4.5
<b>27</b>	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	.28	.15
<b>n-paraffins</b> (µg/l)		
<b>C.P.I. C<sub>15</sub>-C<sub>20</sub>*</b>	1.7	1.0
<b>C.P.I. C<sub>25</sub>-C<sub>38</sub></b>	1.5	1.3
<b>Pristane/Phytane</b>	8.0	

\* Carbon Preference Index C.P.I.  $C_{15}^{20} = \frac{C_{15} + C_{17} + C_{19}}{C_{16} + C_{18} + C_{20}}$

Tab 1e 4. Percentage Composition of n-Paraffins in Seawater, August-September, 1975.

Station	I-1	I-1	I-2	I-2	I-3	I-3	11-1	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	<b>Tr</b>			Tr		
17	1.8		Tr	Tr			1.9		
<b>Phytane</b>	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	<b>7.2</b>	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 <sub>15</sub> -C <sub>20</sub> *	.7			1.2	.7		.4	.6	.7
C.P.I. C <sub>25</sub> -C <sub>38</sub>	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	<b>Tr</b>	1.2			3.0	2.8		
<b>Phytane</b>		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	<b>10.5</b>	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	<b>10.5</b>	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	<b>9.1</b>
<b>29</b>	8.2	3.2	14.8	5.0	4.9	8.4	7.0	<b>10.1</b>
30	5.1	2.9	11.1	4.2	4.5	7.0	4.7	<b>13.0</b>
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	<b>1.2</b>	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 <sub>15</sub> -C <sub>20</sub> *	.1	.7	.6		.98	.9	.7	8.7
C.P.I. C <sub>25</sub> -C <sub>38</sub>	1.3	1.5	1.6	1.0	1.1	1.4	1.4	1.1
Pristane/Phytane					<b>1.0</b>			

Table 4. Cent. ' 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 <sub>15</sub> -C <sub>20</sub> *	1.0		.9		1.2	.9
C.P.I. C <sub>25</sub> -C <sub>38</sub>	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	11-1	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			
<b>Total</b> n-paraffins ( $\mu\text{g/l}$ )	1.79	1.94	1.54	1.24
<b>C.P.I. C<sub>15</sub>-C<sub>20</sub>*</b>	.4	.4	.5	.4
<b>C.P.I. C<sub>25</sub>-C<sub>38</sub></b>	1.3	1.5	1.5	1.4
Pristane/Phytane	5.0	4.0	2.5	4.0

$$* \text{ Carbon Preference Index } \text{C.P.I. } C_{15} - C_{20} = \frac{C_{15} + C_{17} + C_{19}}{C_{16} + C_{18} + C_{20}}$$





Table 6. Cent. ' 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							
<b>Pristane</b>				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	<b>1.1</b>	6.3	2.1
24	<b>1.9</b>	.1	.1	2.9	.4	5.9	<b>1.6</b>
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	<b>10.6</b>	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	.08	.09	<b>.12</b>	.19	.07	.02	.05
n-paraffins (µg/l)							
C.P.I. C <sub>15</sub> -C <sub>20</sub> *	32.0	14.0	2.5	8.8	.8	1.5	.9
C.P.I. C <sub>25</sub> -C <sub>38</sub>	1.2	1.9	1.9	1.1	1.2	1.6	1.3
Pristane/Phytane				13.0			

\* Carbon Preference index C.P.I. C<sub>15</sub>-C<sub>20</sub> =  $\frac{C_{15} + C_{17} + C_{19}}{C_{16} + C_{18} + C_{20}}$

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<sub>15</sub> - C<sub>20</sub> range and less in the C<sub>30</sub> - C<sub>35</sub> range than spring and summer samples. The most abundant n-paraffin in spring particulate samples was C<sub>22</sub>; in summer C<sub>31</sub> 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<sub>15</sub> - C<sub>20</sub> and C<sub>25</sub> - C<sub>38</sub> and the value included in Tables 2 - 5. Over the C<sub>15</sub> - C<sub>20</sub> range the OEP is greatly influenced by the C<sub>15</sub>/C<sub>16</sub> and C<sub>17</sub>/C<sub>18</sub> ratios. Samples with a relatively large C<sub>15</sub> and C<sub>17</sub> contribution, presumably from **phytoplankton** and zooplankton, have large OEP values in this range, which differ greatly from samples in which little if any C<sub>15</sub> or C<sub>17</sub> is present. Over the C<sub>25</sub> - C<sub>38</sub> 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  $\mu\text{g}/\text{l}$ ) 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 C22. This hydrocarbon, C22, 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 **C15** and **C20** (winter samples) or between C25 and C35 (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" **hydro-**carbon 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  $\mu\text{g}/\text{l}$** ) with a maximum at **C21** while summer samples averaged **.09  $\mu\text{g}/\text{l}$**  with a maximum at **C31**. 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 (**C21** 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 **C31**) was often significantly different from the distribution of "dissolved" hydrocarbons (maximum at **C22**). Odd carbon preference between C25 and C35 **in**

summer particulate hydrocarbons appears to be somewhat greater than that found in summer "dissolved" hydrocarbons.

Further speculation with regard to the interrelationship of **phyto-** plankton, **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  $\mu\text{m}$  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 pre-cleaned 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 **hydro-**

carbons. 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.

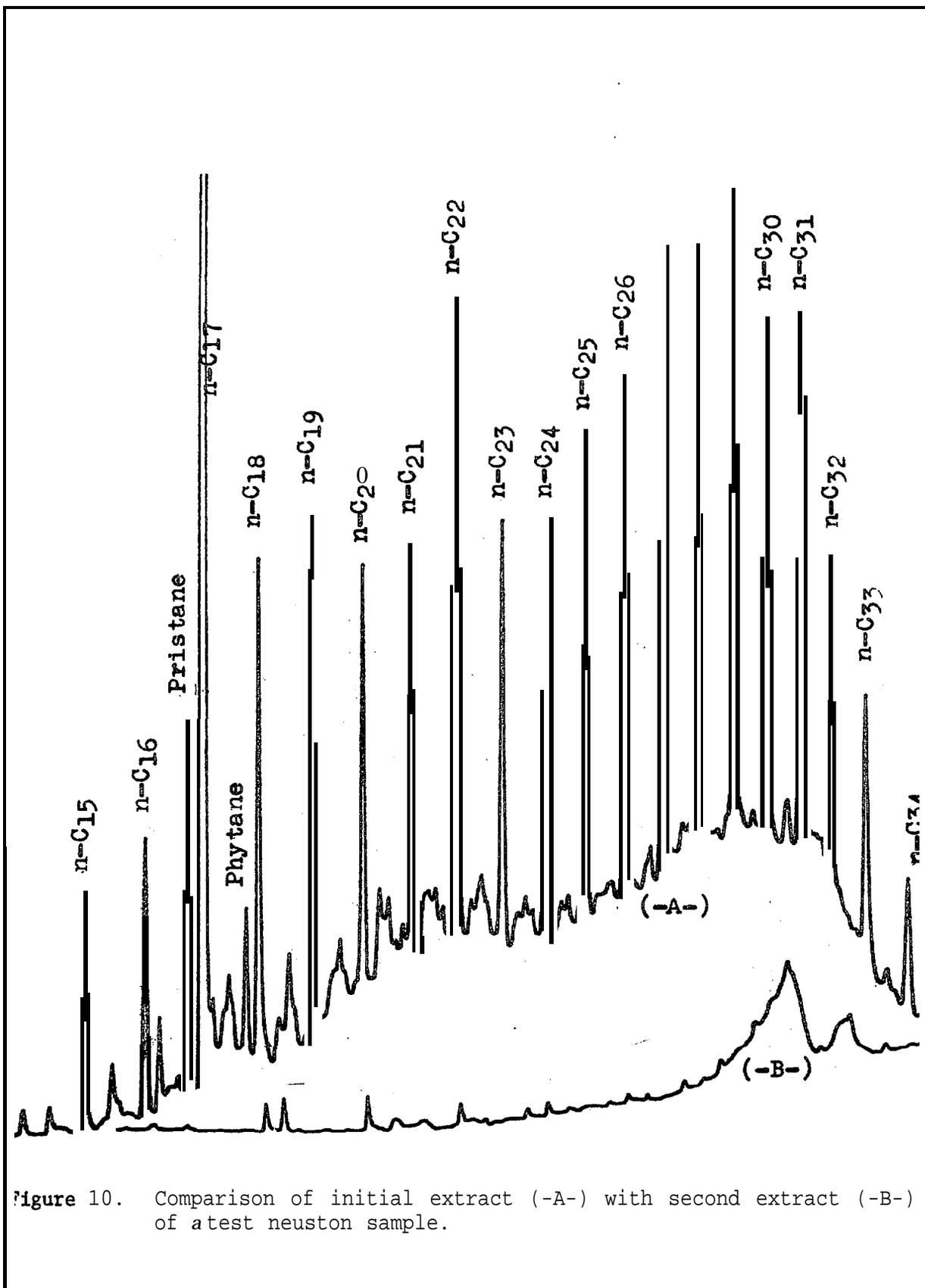
The extracts were recovered from the solvents by evaporation under partial vacuum on a flash-evaporator (BUCHLER Instruments) at 45°C. Approximately 50 ml of a solution of potassium hydroxide in methanol (30 g KOH per liter CH<sub>3</sub>OH) were added for saponification. The mixture was **refluxed** 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.



The **eluting** solvents were evaporated from the saturate and non-saturate hydrocarbons with a nitrogen stream at  $\sim 40^{\circ}\text{C}$ . 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<sub>15</sub>**, **nC<sub>19</sub>**, **nC<sub>22</sub>**, a phytadiene and singly unsaturated **C<sub>19</sub>**.

Gas chromatograms of the saturate and non-saturate hydrocarbons generally are not complex. That is, a relatively few prominent 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 **analysis** 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<sub>22</sub>** and even these samples did not contain a "full suite" of **n-alkanes** from **nC<sub>15</sub>** to nC<sub>35</sub> usually associated with petroleum contamination. Table 13 gives the relative weight percentages of **n-alkanes** in these samples. The **alkanes** **nC<sub>15</sub>**, **nC<sub>17</sub>** and **nC<sub>22</sub>** 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)

				<u>nC<sub>15</sub></u>	<u>nC<sub>16</sub></u>	<u>nC<sub>17</sub></u>	<u>nC<sub>18</sub></u>	<u>nC<sub>19</sub></u>	<u>nC<sub>22</sub></u>
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	1	1	D		1.3	1.8		11.6
AMD	2	1	1	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	111	D						
ARG	1	III	N	0.4	0.5	4.2	1.3	3.0	2.6
AVD	2	III	D						
AUL	2	111	N						
AYA	3	111	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	I	V	N		0.8	0.7	4.1	7.8
BEA	2	1	V	D	0.1	0.04	3.9	0.6	2.2
BDI	2	1	V	N	6.4	1.3	18.0	1.7	0.1
BPA	3	1	V	D		1.9	0.3	3.0	1.0
BGJ	3	1	V	N	0.7	0.1	7.2	0.6	

Table 7. Cont. rd

				<u>Prist</u>	<u>Phyt</u>	<u>Phyt :2</u>	<u>nC20</u>	<u>nC21+</u>	<u>C19:1</u>	<u>C21:2</u>
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	<b>1.0</b>	<b>1.0</b>			
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					
<del>AOW</del>	3	11	D	0.07						
<del>AOD</del>	3	II	N	70.1		11.3	12.8			
ARY	1	III	D							
ARG	1	111	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						
<del>AXK</del>	3	III	N	117.3	<b>1.8</b>	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	<b>6.1</b>		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)

			<u>"15</u>	<u>"16</u>	<u>"17</u>	<u>"18</u>	<u>nC<sub>19</sub></u>	<u>nC<sub>22</sub></u>
CAU	1 1	D	0.9	<b>1.0</b>	1.9	1.5	1.7	1.8
<b>CAE</b>	1 1	N	1.6	0.1	1.4	0.5	0.7	0.7
CDY	2 1	D	2.7	0.7	41.0	1.5	0.2	2.6
<b>CDG</b>	2 1	N	28.0	2.0	49.0	2.5	3.1	2.1
CHE	3 1	D	8.2	0.6	17.5	3.3	3.4	7.0
CGK	3 1	N	22.6	2*2	80.3	2,0	1.7	2.2
<b>CKK</b>	1 II	D			0*4			
CJT	1 II	N	1.8	0.5	6.2	<b>1.4</b>	1.6	3.3
<b>CNN</b>	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	<b>3.1</b>	<b>1.8</b>	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	<b>3.8</b>	328.1	6.4	<b>6.6</b>	9.0
DAG	3 III	N	7.2	<b>0.4</b>	28.5	0.5	0.4	2.2
DDV	1 IV	D	0.7		1.4	0.3	0.3	1.2
DDG	1 I V	N	5.1	<b>0.5</b>	2.4	3.9	3.4	7.2
DMJ	2 IV	D	0.9		7.3	0.9	1.3	1.1
DGF	2 1 V	N	3.6	0.09	3.9	2.7		3.3
DJZ	3 1 V	D	4.5	0.7	10.5	3.1	3.6	6.5
DJF	3 1 V	N	3.5	1.8	35.0	4.1	6.1	6.8

Table .8. Cent. ' d

				<u>Prist</u>	<u>Phyt</u>	<u>Phyt: 2</u>	<u>" 20</u>	<u>" 21+</u>
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	1	D	9.8	0.01	1.8	0.7	0.8
CDG	2	1	N	56.7		2.9	1.7	1.5
CHE	31		D	13.8			0.9	0.4
CGK	3	1	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	1	1	159.9	0.05	7.6	0.8	
CQP	3	II	D	9.6				
CPY	3	1	1	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	111	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	1	V	11.8	0.5		0.6	1.8
DGF	2	IV	N	36.6			1.4	<b>1.3</b>
DJZ	3	1	V	13.4	0.3	0.9	1.9	1.1
DJF	3	1	V	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)

			<u>nC<sub>15</sub></u>	<u>nC<sub>16</sub></u>	<u>" 17</u>	<u>nC<sub>18</sub></u>	<u>nC<sub>19</sub></u>	<u>" 22</u>	
EAU	1	I	D	2.1		7.1	0.4	0.9	0.7
<b>EAE</b>	II	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
<b>EHE</b>	3	I	D						1.0
EGK	3	I	N	2.4		29.0	1.0	0.9	2.9-
EKK	1	11	D	1.4	1.6	5.0	5.3	4.6	19.6
EJT	1	II	N				0.04	0* 3	3.3
<b>ENØ</b>	2	II	D			14.1	0.9	1.4	7.8
EMU	211	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	111	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	111	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	<b>8.3</b>	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. Cent.'d

				<u>Prist</u>	<u>Phyt</u>	<u>Phyt<sub>12</sub></u>	<u>n C<sub>20</sub></u>	<u>"21+</u>
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	11	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	111	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 He(%)	Sat. (%)	Non-Sat. (%)	<u>Pr</u> <u>Ph</u>	<u>Pr</u> <u>C<sub>17</sub></u>	<u>C<sub>17</sub></u> <u>C<sub>18</sub></u>	<u>Sat.</u> <u>Non-Sat.</u>	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	<b>(a)</b>
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 1 111 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	<b>1300.</b>	4.26	6.93	2.53	<b>1.21</b>
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. (%)	Pr Ph	Pr C <sub>17</sub>	C <sub>17</sub> C <sub>18</sub>	% Sat. Non-Sat.	Sample Wt. (g)
CAU	1 I	D	0.58	0.10	0.03	133.	14.1	1.25	2.79	6.23
<b>CAB</b>	11	N	2.37	0.05	0.66	276.	8.75	2.73	0.08	2.69
CDY	21	D	48.8		6.92	1052.	0.24	27.6		2.41
CDG	21	N	4.83	0.08	0.03	-	1.16	19.3	0.23	1.35
<b>CHE</b>	31	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
<b>CKK</b>	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
<b>CNN</b>	2 II	D	12.6	0.05	<b>0.13</b>	-	16.7	6.25	0.41	1.53
<b>CMU</b>	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
<b>CPY</b>	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
<b>DDV</b>	1 IV	D	5.24	0.05	0.002	-	3.98	4.57	22.0	(a)
DDG	1 IV	N	<b>5.14</b>	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
<b>DGF</b>	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. (%)	<u>Pr Ph</u>	<u>Pr C17</u>	<u>C17 C18</u>	<u>Sat. Non-Sat.</u>	Sample wt. (g)
EAU	<b>1 I</b>	D	1.29	0.02	0.02		2.46	20.1	0.90	1.64
EAE	11	N	1.74	0.02	0.03		1.22	0.17	0.83	1.82
ADY	21	D	1.08	0.03	0.03	5180.	1.28	21.0	1.05	1.56
EDG	21	N	1.95	0.05	0.04				1.35	0.51
EHE	31	D	1.02	0.03	0.03				8.33	0.92
EGK	31	N	3*55	0.05	0.06		1.32	30.2	0.89	0.79
EKK	111	D	2.62	0.16	0.03	37.9	3.58	0.96	5.38	0.44
EJT	111	N	0.66	0.03	0.01				<b>2.11</b>	0.68
ENO	211	D	1.79	0.04	0.03	365.	1.14	14.7	<b>1.11</b>	1.06
<b>EMU</b>	211	N	3.85	0.06	0.08	595.	3.49	7.45	0.08	<b>1.11</b>
EQP	311	D	0.64	0.04	0.04		0.43	<b>14.0</b>	1.07	0.35
EPY	<b>3 II</b>	N	2.54	0.12	0.21	321.	1.24	7.06	0.57	0.37
<b>ETX</b>	<b>1 III</b>	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	2 111	D	2.14	0.06	0.02		1.68	<b>0.12</b>	3.35	0.93
EXI	2 III	N	5.05	0.09	0.12	28.6	<b>1.73</b>	3.82	0.72	1.19
<b>FBG</b>	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	<b>1.39</b>
FED	<b>1 IV</b>	D	2.55	0.04	0.002		19.7	2.08	26.0	0.64
FDN	<b>1 IV</b>	N	2.43	0.03	0.03		4.94	<b>11.0</b>	<b>1.03</b>	1.09
<b>FHE</b>	21V	D	0.75	0.008	0.001		4.83	1.43	7.00	0.82
FGN	21V	N	4.06	0.04	0.03		<b>7.14</b>	2.96	1.24	1.27
FKJ	<b>3 IV</b>	D	0.56	0.02	0.01		<b>0.80</b>	16.9	<b>1.30</b>	0.71
FJP	31V	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<sub>22</sub>.

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	<b>21.3</b>	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		<b>1.5</b>				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 C25 to C35 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** C22 and a maximum or upward trend at **C17** 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 C15 to C35**. 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 **zoo-** plankton. 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 (**≠ C17**) 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-sapon-**

ifiable organic matter content between winter and spring collections of zooplankton. There is a significant (> 99.9% confidence level) greater average quantity 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 **nC17** and **pristane**, and to a lesser extent, peaks at **nC15**, **nC19** and **nC22**; and (b) those which are apparently contaminated with petroleum-like **alkanes** having a full suite of **n-alkanes** from **nC5** to **nC35**. 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 **distrib-**

Table 14. Analyses of Neuston Hydrocarbons of Winter Collection, 1974-1975.

Component concentration (micrograms/gram extracted dry sample)

Sample	AHL	AEY	ATE	AJI*	ALW	AOZ	ASC	AVH	AYE	BBD	BEG	BPJ
Component												
nC <sub>14</sub>										0.58		
nC <sub>15</sub>	1.4	sample not available for analysis		7.3	0.59	0.03	3.6			6.4		
nC <sub>16</sub>	3.8		0.76	0.57	0.08	1.0			3.6	1.3		
nC <sub>17</sub>	10.8		0.75	4.2	5.5	6.5	4.9	1.4	83.1	7.8		
nC <sub>18</sub>	0.42		2.4	1.3	2.6	0.87	3.1	0.48	20.2	8.5		
nC <sub>19</sub>	13.2		2.2	1.7	3.3	1.5	3.9	0.72	27.1	12.2		
nC <sub>20</sub>	7.4		1.7	1.9	2.5	1.2	2.2	0.30	30.6	16.6		
nC <sub>21</sub>	0.14		0.47	0.20	1.5	0.71	0.92	0.02	59.7	25.6		
nC <sub>22</sub>	12.9		9.0	2.2	6.1	2.6	4.0	1.7	109.6	29.4		
nC <sub>23</sub>									173.5	35.4		
nC <sub>24</sub>									218.3	41.1		
nC <sub>25</sub>								221.2	51.4			
nC <sub>26</sub>								177.7	57.0			
nC <sub>27</sub>								120.9	66.5			

n-alkanes and isoprenoids were not detected

Table 14 (cont.)

Sample	AHL	AEY	ATE	AJI*	ALW	AOZ	ASC	AVH	AYE	BBD	BEG	BPJ
Component												
" 28										81.1	59.4	
nC <sub>29</sub>										89.9	59.2	
nC <sub>30</sub>										80.1	54.9	
nC <sub>31</sub>										167.1	58.8	
nC <sub>32</sub>										56.8	26.4	
" 33										48.3	26.1	
" 34										34.5	14.8	
nC <sub>35</sub>										22.0	10.8	
nC <sub>36</sub>										8.4		
nC <sub>37</sub>										20.3		
nC <sub>38</sub>										20.6		
" 39										27.2		
nC <sub>40</sub>										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 <sub>17</sub> /nC <sub>18</sub>	25.4		0.31	3.2	2.1	7.5	1.6	2.9		4.1	0.92	
Pris/nC <sub>17</sub>	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	1/1	1/2	I/3	11/1	11/2	11/3	111/1	III/2	111/3	IV/1	IV/2	IV/3
Sample Wt.(g)	1.20	-	0.63	8.08	2.85	3.31	<b>2.75</b>	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	CAX	CEI	CHH	CKN	CNQ	CQS	CUA	CYF	DAY	DDY	DGX	DKC
Component												
nC <sub>15</sub>	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 <sub>16</sub>	0.25	0.49	5.2		0.03	0.98	0.02	0.39	0.46	0.19	0.26	0.26
nC <sub>17</sub>	4.3	5.0	75.4		2.3	18.6	3.1	10.0	5.8	9.2	10.5	6.3
nC <sub>18</sub>	1.0	1.7	9.5		0.78	2.6	0.14	1.5	3.7	1.1	0.57	1.1
" 19	1.1	1.4	11.1		1.4	3.1	0.33	1.6	3*7	1.6	0.84	1.3
nC <sub>20</sub>	0.49	0.86	8.0		0.24	1.8	1.8	0.82	1.6	0.66	0.51	0.26
nC <sub>21</sub>	0.37	0*03	7.1		0.05	1.3	0.04	0.34	0.66	0.89	0.03	0.19
" 22	3.5	2.8	12.4		2.0	8.2	1.6	3.6	8.6	3.0	1.8	1.9
nC <sub>23</sub>			7.8									
nC <sub>24</sub>			7.8									
" 25			9.7									
nC <sub>26</sub>			10.4									
nC <sub>27</sub>			12.4									
nC <sub>28</sub>			11.0									

Table 15 (cont.)

Sample	CAX	CEI	CHU	CKM	CNQ	CQS	CUA	CYF	DAY	DDY	EGX	DKC
Component												
nC <sub>29</sub>			13.2									
nC <sub>30</sub>			9.7									
nC <sub>31</sub>			10.2									
nC <sub>32</sub>			5.4									
nC <sub>33</sub>			5.3									
nC <sub>34</sub>			3.2									
nC <sub>35</sub>			4.4									
Pristane	0.68		7.3									
Phytane	0.02		2.6									
Ratios												
nC <sub>17</sub> /nC <sub>18</sub>	4.3	2.9	7.9		2.9	7.1	22.1	6.7	1.6	8.4	18.4	
Pris/nC <sub>17</sub>	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. %	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	0.75	6.49	0.43	0.41

Table 16. Analyses of Neuston Hydrocarbons of Summer Collection, 1975.

Component concentration (micrograms/gram extracted dry samples)

Sample	EAX	EEI	EHH	EKN	ENR	EQS	EUA	EYF	FAY	FEG	FHH	FKM
Component												
nC <sub>14</sub>	0.14											
nC <sub>15</sub>	3.0			2.4		83.6		1.2	2.4	7.4		
nC <sub>16</sub>	1.2			0.28		304.6		0.22	1.7	4.7		
nC <sub>17</sub>	4.4	4.3	0.92	5.8	13.9	709.2	218.5	2.7	11.2	15.0	31.8	19.1
n <sub>18</sub>	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 <sub>19</sub>	1.7	1.3	0.43	2.1	3.3	1135.	197.0	1.5	7.3	8.1	39.7	9.8
nC <sub>20</sub>	1.4	0.87	0.33		1.7	1158.	188.9	1.4	6.7	6.6	46.0	9.8
nC <sub>21</sub>	1.3	0.98	0.41		1.3	1171.	181.1	1.6	3.1	6.2	34.4	9.4
nC <sub>22</sub>	1.6	1.7	0.60		3.2	1141.	191.7	2.4	11.8	6.4	44.1	10.1
nC <sub>23</sub>	0.92	1.3			0.96	1211.	185.7	0.65		4.4	50.6	9.1
nC <sub>24</sub>	0.90	1.3			0.68	1280.	178.0	1.8		4.2	54.2	8.1
nC <sub>25</sub>	0.65	1.2			1.9	1472	182.9	2.3		4.6	61.2	7.5
n <sub>26</sub>	0.94	1.1			1.4	1596.	213.1	2.5		4.0	80.3	6.2
nC <sub>27</sub>	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 <sub>28</sub>	1.4	1.3			1.3	1616.	266.0	3.3		5.1	103.0	4.1
nC <sub>29</sub>	1.0	1.1			1.7	1624.	270.4	3.0		5.2	103.4	4.1
nC <sub>30</sub>	0.84	1.3			0.96	1345.	224.3	2.3		4.5	92.4	3.0
nC <sub>31</sub>	0.70	1.5				1139.	262.3	1.9		3.7	103.4	4.1
nC <sub>32</sub>	0.67	1.7				743.4	219.7	1.1		3.2	79.1	2.3
nC <sub>33</sub>		1.8				650.0	210.5	1.6			79.2	2.6
nC <sub>34</sub>		2.8				520.5	161.5	0.75			58.8	2.0
nC <sub>35</sub>		1.8				417.8	165.9				56.1	1.3
nC <sub>36</sub>		2.2				388.6	108.7				35.3	
nC <sub>37</sub>		1.8				381.4	84.3				9.8	
nC <sub>38</sub>							90.0				8.6	
nC <sub>39</sub>							75.9				10.7	
nC <sub>40</sub>							72.0				10.1	
nC <sub>41</sub>							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
Rat ios												
<b>nC<sub>17</sub>/nC<sub>18</sub></b>	2.4	3.6	3.5	11.4	7.7	0.71	1.2	2.4	1.6	1.8	0.97	3.0
<b>Pris/nC<sub>17</sub></b>	0.23			11.5	0.18		0.72		0.20	0.32		0.41
<b>Pris/Phyt</b>	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
	1/1	2/1	3/1	1/11	2/11	3/11	1/111	2/111	3/111	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<sub>17</sub>**, pristane and **nC<sub>22</sub>**. 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<sub>2</sub>**, and maxima at **C<sub>17</sub>**. 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<sub>17</sub>** ratio, **C<sub>17</sub>/C<sub>18</sub>** ratio are shown in Figures 12, 13 and 14. There are no obvious **areal** trends among these **distributions**.

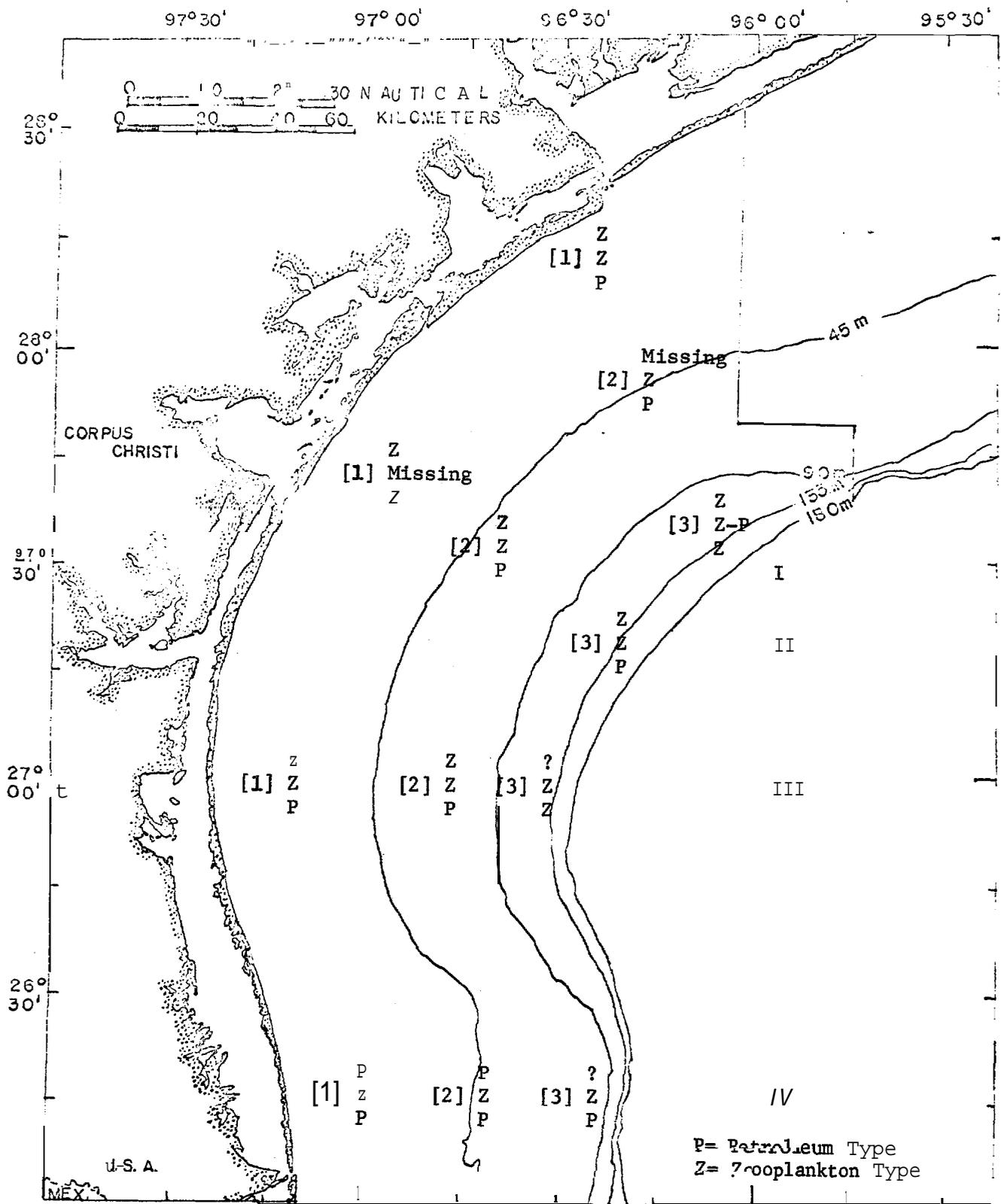


Figure 11. Distribution of the Character of Neuston Saturates.

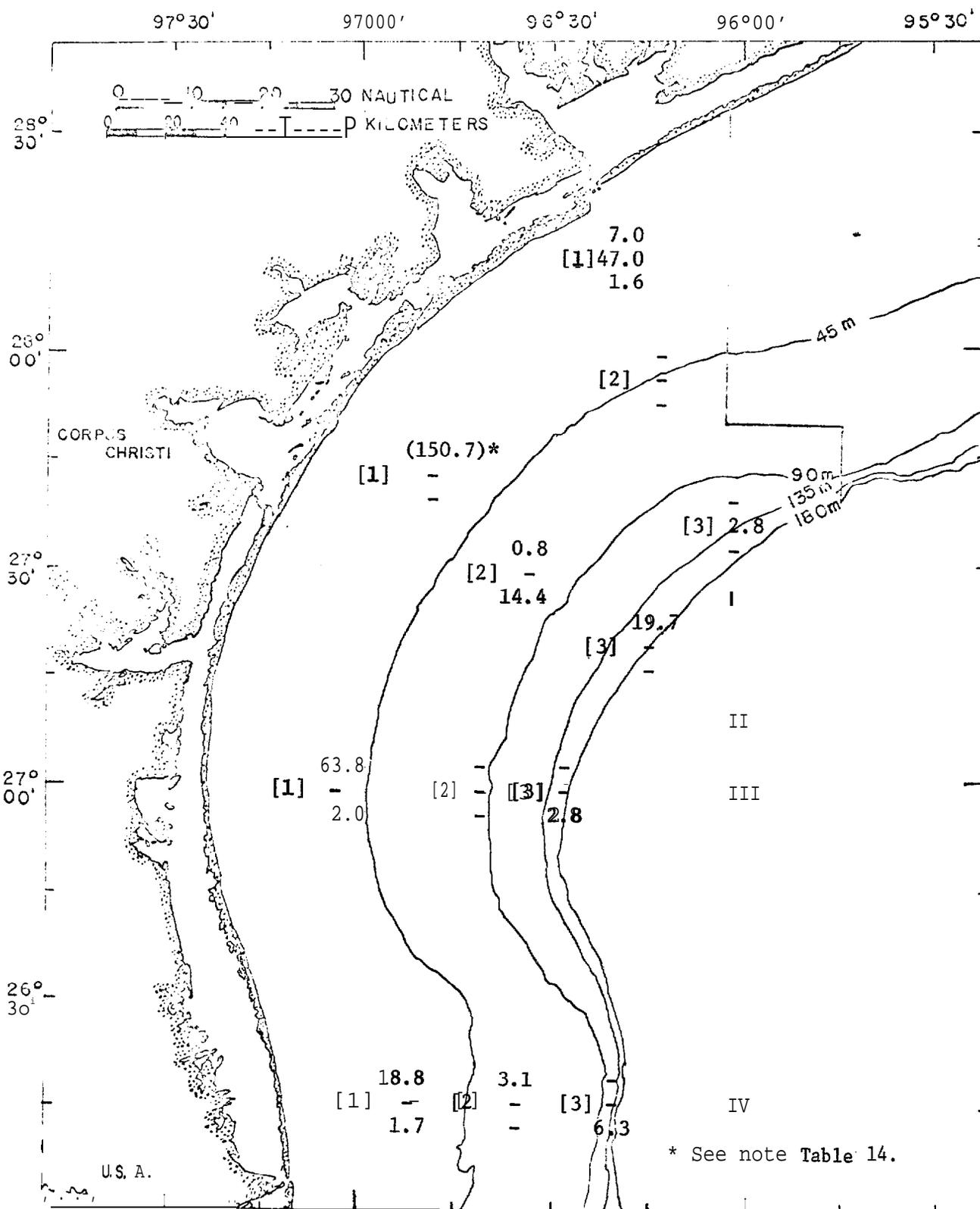


Figure 12. The Ratio Pristane/Phytane in Neuston Samples.

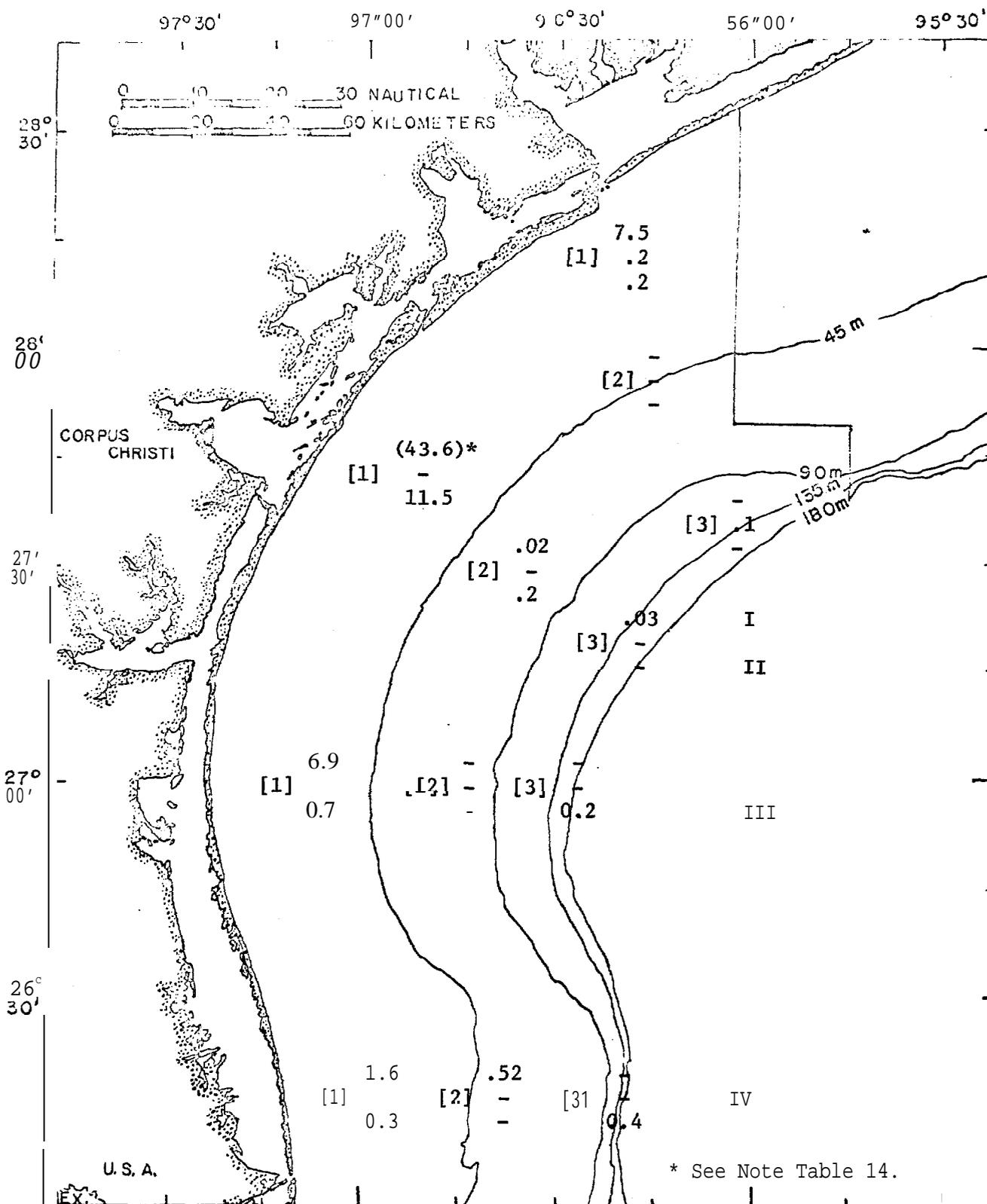


Figure 13. The Ratio **Pristane/C<sub>17</sub>** in Neuston Samples.

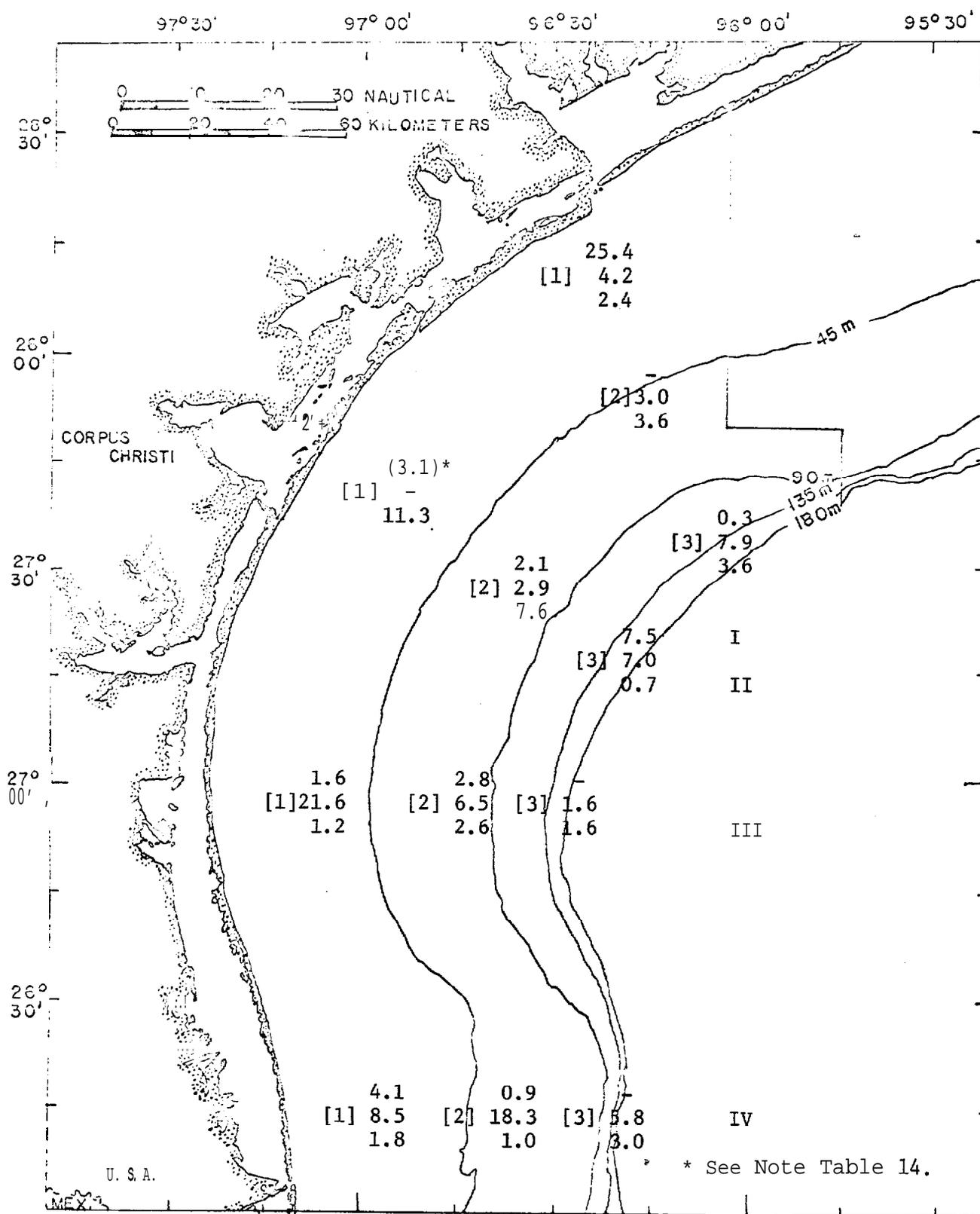


Figure 14. The Ratio  $C_{17}/C_{18}$  in Neuston Samples.

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									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

sample contained no n-alkanes

Table 17 (cont. )

Carbon Number	<u>Winter Lines</u>				<u>Spring Lines</u>				<u>Summer Lines</u>			
	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	<b>12.22</b>	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 hydro- carbons (%)	0.02	0.02	0.03	0.0009	0.004	0.02	0.006	0.001	0.0002	0.0009	0.01	0.0001
<b>Sample</b> Wt.	195.0	451.0	33.1	182.4	1653.9	675.5	228.3	930.5	448.0	389.2	352.3	<b>583.0</b>
Ratio <u>Saturate</u> 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		<b>1.28</b>	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	<b>3.81</b>	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	<b>22.60</b>	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	<b>2.21</b>	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				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
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 hydro- carbons (%)	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
1	5											
16										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	<b>11.33</b>	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	<b>6.13</b>	5.87	2.73	<b>16.03</b>	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	<b>1.36</b>	<b>8.36</b>	<b>3.06</b>	2.65		5.98	<b>2.74</b>	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	<b>1.20</b>	1.82	5.69	1.86	<b>1.34</b>	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	<b>2.21</b>	0.67	5.20	4.59		5.06	3.56	3.46	2.70

Sample contained no n-alkanes

Table 19 (cont. )

Carbon Number	Winter Lines				Spring Lines				Summer Lines			
	I	II	III	IV	I	II	III	IV	I	II	III	IV
Sample	ABH	AOX	AZZ	<b>BOZ</b>	CJF	Csv	DCX	DME	EJF	ESW	FDE	<b>FMP</b>
29	3.74	13.90	16.38	16.85	8.17	27.02	16.77		8.46	17.30	<b>12.28</b>	6.37
30	0.47	1.95	3.51	1.88	4.18	1.62	0.83		6.07	2.68	<b>1.04</b>	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 Hydro- carbons (%)	0.04	0.17	0.03	0.03	0.02	0.007	0.05	0.001	*	0.0008	0.004	0.0002
Ratio $\frac{\text{aturate}}{\text{NonSat.}}$	<b>1.3</b>	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<sub>25</sub>** to **C<sub>35</sub>** 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, Line IV of the spring season. Sample FGE is unusual in that **nC<sub>17</sub>** 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 may have been contaminated with petroleum-like hydrocarbons.

The average of OEP values from **C<sub>25</sub>** to **C<sub>35</sub>** for a sample gives an 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  $C_{n-2}$  through  $C_{n+2}$ .

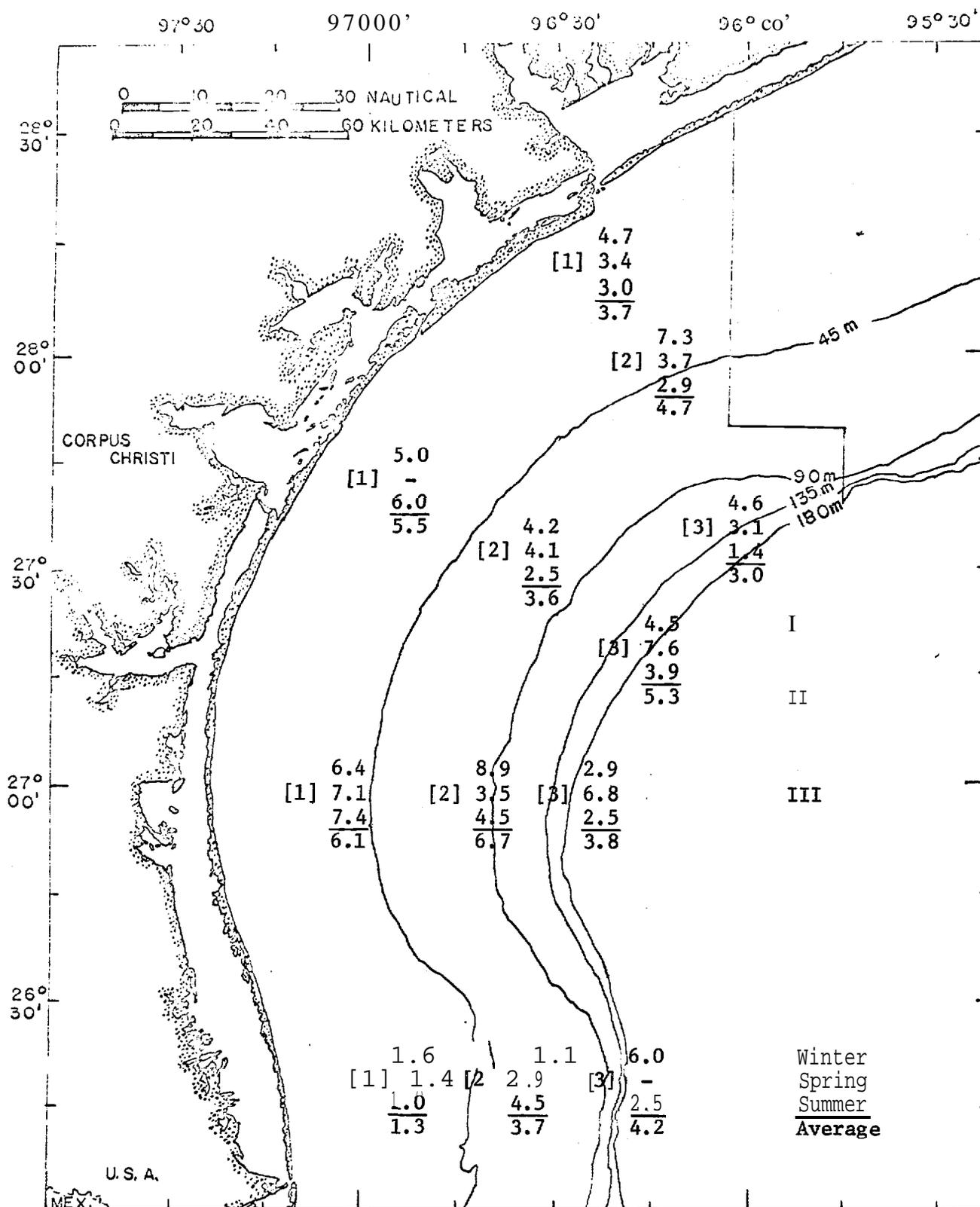


Figure 15. Average OEP values of Sediment n-Alkanes.

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<sub>20</sub> to C<sub>24</sub>) **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 Stations			Smoothed Relative Percentage <b>n-Alkanes</b> 'Lines			
	<b>1</b>	2	3	I	II	<b>III</b>	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
<b>19</b>	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		

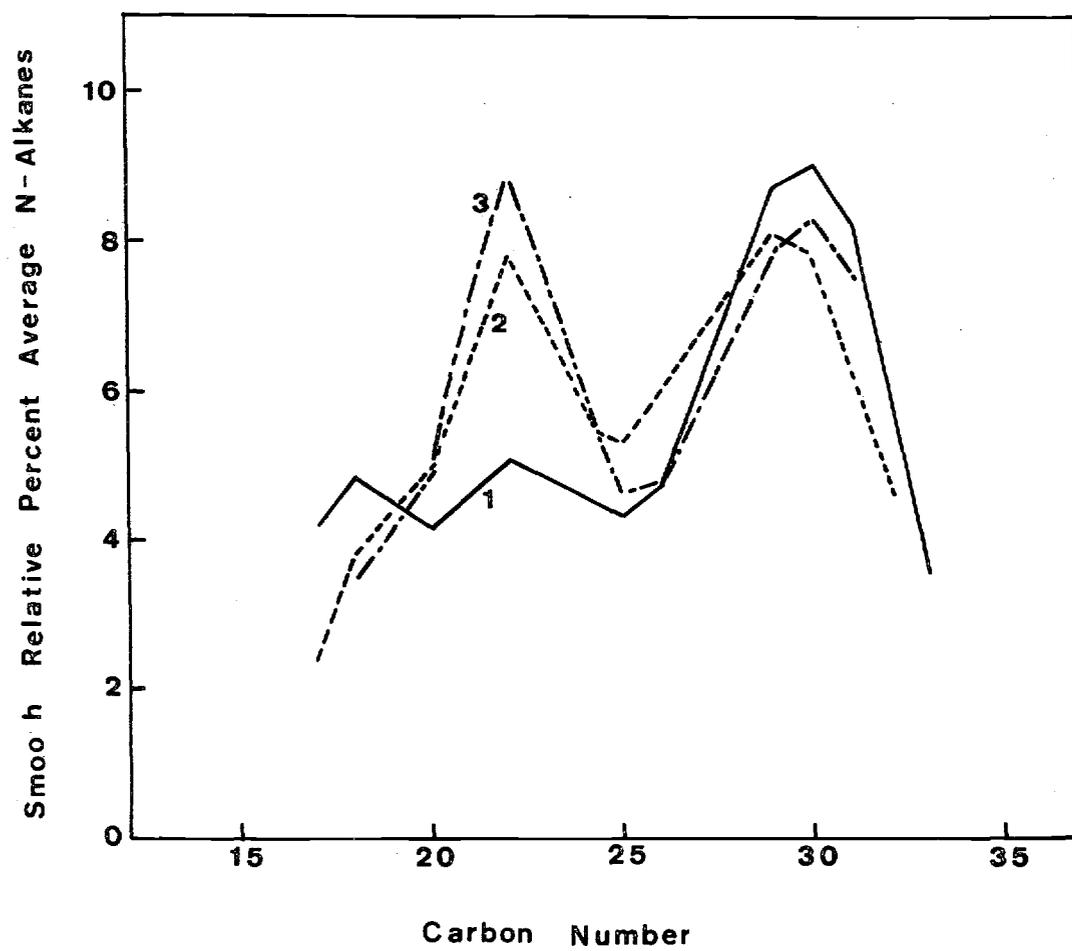


Figure 16. Smoothed n-Alkanes Distributions for Averages of Stations 1, 2 and 3.

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-**sectioned 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 **mucoïd** 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 C22. 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 C25 except for Fish #20 which has an unusually large concentration of **nC28**. 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<sub>22</sub> 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<sub>25</sub> 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.

<u>Fish</u>	<u>Species</u>	<u>Location</u>	<u>Weight (grams)</u>	<u>Saturate/Non-Saturate</u>
1	<i>Rhomboplites aurorubens</i>		110	1.4
2	<i>Rhomboplites au.roru.hens</i>		170	*
3	<i>Rhomboplites aurorubens</i>	Baker Bank	370	8.1
4	<i>Lutjanus campechanus</i>	South Baker	1420	3.6
5	<i>Lutjanus campechanus</i>	Adam Bank	450	10.0
6	<i>Rhomboplites aurorubens</i>	Baker Bank	450	1.2
7	<i>Rhomboplites aurorubens</i>	Baker Bank	340	0.7
8	<i>Lutjanus campechanus</i>	Baker Bank	400	50.0
9	<i>Rhomboplites au.rom.hens</i>	Dream Bank	480	*
10	<i>Lutjanus campechanus</i>	Baker Bank	570	6.0
11	<i>Lutjanus campechanus</i>	Baker Bank	450	0.2
12	<i>Lutjanus campechanus</i>	Big Adam Bank	510	1.4
13	<i>Rhomboplites auroru.hens</i>	Dream Bank	710	0.7
14	<i>Rhomboplites aurorubens</i>	South Baker	230	2.0
15	<i>Rhomboplites aurorubens</i>	South Baker	450	6.2
16	<i>Lutjanus campechanus</i>	South Baker	600	1.8

Table 21. (cont. )

<u>Fish</u>	<u>Species</u>	<u>Location</u>	<u>Weight (grams)</u>	<u>Saturate/Non-Saturate</u>
17	<i>Lutjanus campechanus</i>	South Baker	680	1.8
18	<i>Lutjanus campechanus</i>	Big Adams Bank	510	*
19	<i>Rhomboplites aurozwhens</i>	Big Adams Bank	280	2.2
20	<i>Lutjanus campechanus</i>	Baker Bank	450	1*0
21	<i>Lutjanus campechanus</i>	Baker Bank	790	5*5
22	<i>Lutjanus campechanus</i>	Big Adam Bank	620	1.4
23	<i>Lutjanus campechanus</i>	Big Adam Bank	570	8.0
24	<i>Lutjanus campechanus</i>	Hospital Bank	2950	8.0
25	<i>Mycteroperia</i> 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 <sub>15</sub>			4*7								No peaks resolved from large background "hump".	No other peaks resolved.			9.2		
" 16			9.1		1.3										0.6		1.8
\cl 7	7.2	4.0	18.2	1.3	15.2		5.3	6.9	0.9						3.9		8.6
nC <sub>18</sub>	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 <sub>19</sub>	20.2	16.8	11.1	2.9	24.4	8.2	13.8	15.7	22.7						8.0	3.9	11.6
" 20	14.0	14.4	6,7	<b>2.4</b>	9.4	7.7	12.0	10.8	14.7						4.9	4,1	6.7
nC <sub>21</sub>	6.3	9.5	3.5	<b>2.3</b>	3.5	13.9	9.2	5.5	5.2						2.5	3.1	2.4
nC <sub>22</sub>	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 <sub>23</sub>				8.4											6.6	5.2	
nC <sub>24</sub>				10.6											7.5	12.1	
nC <sub>25</sub>				10.6											6.8	7.3	
nC <sub>26</sub>				9.9											6.1	7.6	
nC <sub>27</sub>				8.2											5.4	7.3	
nC <sub>28</sub>				6.8											4.5	7.4	
nC <sub>29</sub>				5.6									4.1	7.6			

Table 22. (cent. )

	Relative Weight Percentage for Fish No.													
<u>Component</u>	1	2	3	4	5	6	7	8	9	10	11	12	13	14
<b>nC<sub>30</sub></b>				"4.5								3.9	7.7	
<b>nC<sub>31</sub></b>				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
<b>"3050"</b>	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 <b>Pris/Phyt</b>	1.1		2.5	0.48			18.1		1.8			38.0		17.0
<b>Pris/nC<sub>17</sub></b>	0.12		0.42	5.3	0.10		3.1	1.3	1.0			0.97		0.99
<b>nC<sub>17</sub>/nC<sub>18</sub></b>	0.43	0.36	0.98	6.5	0.66		0.57	0.55	0.08			0.53		0.74

Table 22. (cont.)

<u>Component</u>	Relative Weight Percentage for Fish No.											
	15	16	17	18	19	20	21	22	23	24	25	26
nC <sub>15</sub>	2.1				12.1	5,6	6.0	5.9		0.42	0.17	0.93
<b>nC<sub>16</sub></b>	3.5				10.5	3.5	5.6	7.3		1.1	0.82	3.8
nC <sub>17</sub>	13.7	5.5	9.4		16.4	10.9	9.9	15.3	7*5	4.5	3.1	14.3
<b>nC<sub>18</sub></b>	15.2	8.3	16.0		11.6	7,3	9.6	12.8	15.4	7.0	4.9	10.5
nC <sub>19</sub>	13.7	14.5	17.4		8,0	8.3	7.9	10.1	19.9	10.9	7.0	14.87
nC <sub>20</sub>	8.0	9.7	9.2		6.1	5.0	4.7	7.1	11.9	9.2	<b>5.1</b>	8.2
nC <sub>21</sub>	3,6	4.5	5.1		4.5	4.8	2.0	2.8	3.4	4.6	1.2	5.6
nC <sub>22</sub>	25.7	34.2	35.6	100 .	8.8	8.7	45.2	9.5	31.6	28.9	15.8	39.3
nC <sub>23</sub>						1.6						
<b>nC<sub>24</sub></b>						2.3		6.2	4.2	2.5	0.95	1.8
nC <sub>25</sub>						2.4			0.55	1.0	0.45	0.65
<b>nC<sub>26</sub></b>						2.4		6.6	5.5	29.85	60.6	
nC <sub>27</sub>						2.4						
<b>nC<sub>28</sub></b>		18.0				11.2		6.2	*	*	*	*
nC <sub>29</sub>						3.6						

Table 22. (cent. )

## Relative Weight Percentage for Fish No.

<u>Component</u>	15	16	17	18	19	20	21	22	23	24	25	26
nC <sub>30</sub>						3.2						
nC <sub>31</sub>												
<b>Pristane</b>	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	-I-		3.3	+	+	+	0.55	1.0	0.45	0.65
11305*11						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	*	*	*	*
<b>Pris/Phyt</b>	11.1	5.5			5.7				7.6	2.5	2.1	2.8
<b>Pris/nC<sub>17</sub></b>	0.97	0.8	0.77		1.1	1.3	0.91	0.59	0.56	0.56	0.31	0.13
<b>nC<sub>17</sub>/nC<sub>18</sub></b>	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.

<u>Fish</u>	<u>Species</u>	<u>Location</u>	<u>Sat./Non-Sat.</u>
27	<i>Rhomboplites aurorubens</i>	Southern Bank	8.3
28	<i>Lutjanus campechanus</i>	Big Adam Bank	2.5
29	<i>Lutjanus campechanus</i>	Southern Bank	3.8
30	<i>Rhomboplites aurorubens</i>	North Hospital	2.2
31	<i>Lutjanus campechanus</i>	Southern Bank	2.4
32	<i>Lutjanus campechanus</i>	Southern Bank	4.6
33	<i>Rhomboplites aurorubens</i>	Southern Bank	7.0
34	<i>Rhomboplites aurorubens</i>	Southern Bank	1.8
35	<i>Rhomboplites aurorubens</i>	Southern Bank	2.0
36	<i>Rhomboplites aurorubens</i>	Southern Bank	2.9
37	<i>Rhomboplites aurorubens</i>	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 <sub>15</sub>				7.0		6.2	3.2
nC <sub>16</sub>				0.9		1.8	0.9
nC <sub>17</sub>	4.9	5.8	7.7	2.8	3.2	5.7	7.5
nC <sub>18</sub>	8.9	3.1	8.4	3.2	10.3	6.6	9.5
nC <sub>19</sub>	12.4	5.4	14.1	3.9	15.5	7.6	11.4
nC <sub>20</sub>	8.2	6.8	9.4	3.6	8.0	6.5	11.5
nC <sub>21</sub>	4.7	4.0	5.1	3.4	3.5	3.9	3.9
nC <sub>22</sub>	22.8	20.8	22.8	13.4	34.3	28.8	40.6
nC <sub>23</sub>	2.4	2.9	1.8	3.3	0.5	1.9	1.8
" 24	3.0	6.1	2.3	3.9	1.6	5.0	1.8
nC <sub>25</sub>	2.6	4.1	1.3	<b>7.1</b>	0.8	<b>5.4</b>	0.6
nC <sub>26</sub>	2.3	3.4	0.8	5.8	<b>0.9</b>	4.6	1.4
nC <sub>27</sub>	2.7	5.4	3.4	7.4	2.1	6.8	0.9
" 28	3.1	4.3	0.6	3.3	0.2	1.6	0.8
" 29	3.4	6.2	2.7	17.9	4.3	5.3	2.2
" 30	2.0	3.6	0.9	5.9	1.5	1.3	1.3
nC <sub>31</sub>	3.0	5.4	3.3	7.0	2.7	1.0	0.6
nC <sub>32</sub>	1.7	4.5	5.7		1.0		
nC <sub>33</sub>	2.2	8.1	9.6		1.3		
nC <sub>34</sub>	4.9				1.1		
nC <sub>35</sub>	4.7				2.7		
nC <sub>36</sub>					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

Principal Investigator:  
Bobby J. Presley

Associate Investigators:  
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 analyzed 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 activation analysis (INAA) and is given in the tables. Barium was determined on  $\frac{1}{2}$  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 analysis 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 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  $\text{HNO}_3:\text{HClO}_4$  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  $\text{HNO}_3:\text{HClO}_4$  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 a 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 benches. 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 averaged 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 considerable 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. **Further-**more, 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 (see **Zooplankton** Project). 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 interpreting 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)	<b>Cu</b>	(b)	(a)	<b>Zn</b>	(b)
Sargassum Weed	7.5		7.3	<b>50.0</b>		<b>48.0</b>
Deveined Shrimp	11.3		11.4	62.5		60.0
Squid	<b>21.3</b>		20.6	75.0		75.0
<b>Jackfish</b> Muscle	8.8		<b>8.2</b>	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	<b>(12)</b>	10.9	28.0	(25)	30.0

Sample	( a )	Cd	(b)	(a)	Pb	(b)
<b>Sargassum</b> 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
<b>Jackfish</b>	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. Cent'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**  $\text{HNO}_3\text{-HClO}_4$  digestion.

(b) - **Values** in column are from a determination after a **3:1**  $\text{HNO}_3\text{-HClO}_4$  digestion and and APDC - Chloroform extraction with a back extraction into **1N**  $\text{HNO}_3$ .

Table 2. Chemical Composition of Zooplankton from the South Texas OCS Winter Sampling (ppm dry weight)

Station	Sample #	Dry wt. (gins)	Cu	Zn	Cd	Pb	Ni	Cr	% Water	v
1/1 D	ADB *	1.0	6.4	143	.86	34.1	9.6	26.5	86.1	23
1/1 N	BHT	1.0	8.0	149.5	1.1	4.5	5.7	5.5	85.7	18
2/1 D	AEW	1.0	6.0	85.5	1.61	13.9	5*7	7.2	86.1	12
2/1 N	ACS	1.0	11.0	110	2.40	15.1	4*1	3.0	86.6	7.2
3/1 D	AAU *	0.5	38.0	560	4.60	474	10.2	82.0	92.3	6.8
3/1 N	AAD *	1.0	26.0	248	4.30	215	8.1	36.0	90.8	< 9.1
1/11 D	AIX	1.0	2.7	26.5	0.93	3*4	3.1	2.4	79.2	5.8
1/11 N	AHY	1.0	4.4	62.5	2.36	1.8	2.8	1.9	88.3	5.2
2/11 D	ALU	1.0	46.0	170	2.38	14.6	7.0	7.6	86.8	9.2
2/11 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
3/11 N	AOF	1.0	7.0	72.0	3.49	16.8	5.75	3.0	85.6	6.8
1/111 D	ARZ *	1.0	13.0	235	2.25	85.0	7*50	32.3	88.8	< 9.7

Table 2 . Cent'd.

Station	Sample #	Dry wt. (gins)	Cu .	Zn	Cd	Pb	Ni	Cr	% Water	V
1/111 N	ARI	1.0	9.5	151.5	2.60	6.25	5.38	<b>7.3</b>	85.4	< 9.9
2/111 D	AVE	1.0	13.2	112	4.20	14.0	8.00	10.1	72.2	< 15
2/111 N	AUM	1.0	15.5	96.0	5.25	3.1	5.88	3.2	87.5	< <b>11</b>
3/111 D	<b>AYB</b>	1.0	6.8	86.0	4.40	6.8	<b>6.5</b>	7.1	87.4	< 14
3/111 N	<b>AXL *</b>	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 . 5 5	90.0	13
1/IV N	<b>BAJ</b>	1.0	6.8	<b>160.0</b>	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	<b>5.1</b>	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. (gins)	Cu	Zn	Cd	Pb	Ni	Cr	% Water	V
1/1	BIM +	1.0	5.20	42.0	.46	24.0	3.60	3.6	84.5	18
2/1	AEz -t	2.0	9.00	152.5	2.10	13.7	5.90	9.2	82.3	< 12
3/1	AAR +	0.5	9.00	156.0	2.76	7.0	7.50	6.2	87.8	17
1/11	AJJ +	2.0	8.00	130.0	3.0	2.8	2.15	2.6	85.8	< 6.3
2/11	ALX *	2.0	7.00	41.0	1.25	3.85	7.05	2.6	89.2	18
3/11	APA	Sample not available from UT/MSI								
1/111	ASD +	2.0	9.50	118.0	.80	23.5	4.15	5.5	82.8	18
2/111	AVI *	2.0	4.10	35.0	2.04	4.65	4.30	1.5	79.0	< 4.2
3/111	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
<b>2/IV</b>	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. (gins)	Cu	Zn	Cd	Pb	Ni	Cr	% Water	V	Ba
1/1	D AQH * #2	1.0	67.0	290	1.18	2.7	2.3	3.0	73.1	< 3.3	< 6.3
2/1	D AFF + #3	1.0	8.5	56.0	2.56	1.6	4.3	7.6	76.7	< 5.5	< 7.0
1/11	D AJF * #2	1.0	61.0	94.0	1.00	1.3	2.1	5.1	77.4	< 1.8	<16.4
1/111	D ASJ * #1	2.0	69.0	50.0	0.91	2.0	2.5	6.1	74.5	3.7	
2/111	D AVO + #1	2.0	15.5	41.0	1.30	1.8	3.2	7.3	69.1	< 0.8	< 6.8
3/111	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

Average w/skin

\* 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	
<u>Penaeus aztecus</u> (brown shrimp)												
1/1	N	AFN #1	2.0	20.5	20.5	0.20	1.38	1.9	2.1	75.8	4.1	< 15.6
2/1	N	ACW #4	2.0	27.0	48.0	0.11	1.3	1.4	2.6	81.9	< 1.7	< 2.9
1/11	N	AIL #4	2.0	28.5	51.5	0.11	1.8	1.6	0.4	72.8	< 1.9	< 4.6
2/11	N	ALI #1	2.0	24.0	57.5	0.19	1.65	2.2	2.1	74.8	0.8	< 15.6
1/111	N	ARO #3	1.0	26.0	55.0	0.11	0.8	0.9	2.1	73.7	< 1.8	< 2.9
3/111	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 . Cent' d.

Station	Sample #	Dry wt. (gins)	Cu	Zn	Cd	Pb	Ni	Cr	% Water	v	Ba	
<u>Sicyonia spp.</u> (rock shrimp)												
2/1	N	ACW #3	1.0	26.0	62.0	0.23	2.0	3.3	4.2	73.6	< 6.5	< 15.5
1/111	N	ARO #2	1.0	23.0	57.0	<b>0.10</b>	1.1	0.8	2.2	74.3	NA	< 15.6
2/111	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				<b>31.1</b>	56.3	.25	1.6	1.6	2.8			

Penaeus setiferus (white shrimp)

1/11	D	AJF #3	2.0	20.5	52.5	0.08	0.8	1.9	3.2	72.0	1.1	< 20.6
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Rock shrimp identifications were as follows:

ACW #3 Sicyonia sp.  
 ARO #2 Sicyonia dorsalis  
 BGP #3 Sicyonia brevirostris

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. (gins)	Cu	Zn	Cd	Pb	Ni	Cr	% Water	v
<b><u>Syacium spp. (flatfish)</u></b>										
3/1 * N	AAG #4	1.0	1.1	16.0	0.19	1.6	1.0	3.0	77.5	< 3.8
2/1 N	ACW #2	2.0	1.2	18.5	0.14	1.3	7.4	13.3	76.5	< 2.5
1/1 D	AHQ #4	1.0	1.5	17.0	0.07	.04	1.1	3.1	76.3	< 3.7
1/11 N	AIL #2	2.0	0.6	14.0	0.10	0.5	0.6	0.8	76.9	< 2.0
1/111 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			<b>1.1</b>	16.7	0.14	0.9	3.1	6.0		
<b><u>Stenotomus caprinus (long-spined porgy)</u></b>										
2/11 D	AMF #2	2.0	1.7	13.0	0.11	0.8	2.0	2.6	77.7	2.3
3/11 D/N.	APG /AOL #3 #2	2.0	1.4	23.0	<b>0.11</b>	0.9	0.6	0.9	77.0	< <b>1.3</b>
3/111 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. (gins)	Cu	Zn	Cd	Pb	Ni	Cr	% Water	V
<b><u>Stenotomus caprinus</u> (long-spined porgy) continued</b>										
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		
<b><u>Trachurus lathami</u> (rough scad)</b>										
1/11 D	AJF #4	2.0	2.5	34.0	0.21	1.0	0.8	3.2	76.5	< 1.5
3/11 D	APG #2	2.0	2.4	35.0	0.25	0.9	0.8	3.2	77.4	< 1.4
1/111 D	ASJ #2	0.5	3.6	24.0	0.28	3.2	2.4	16.4	78.4	< 3.3
3/111 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	<b>31.5</b>	0.22	1.5	1.3	6.0		

Table 6. Cent 'd.

Station	Sample #	Dry wt. (gins)	Cu	Zn	Cd	Pb	Ni	Cr	% Water	V
<u>Prionotus spp.</u> (sea robins)										
3/1 D	AAM #1	2.0	1.1	15.5	0.05	0.7	1.2	3.9	77.4	< 1.8
3/11 N	AOL #3	2.0	0.8	16.5	0.11	1.5	0.8	2.6	77.3	< 1.6
3/111 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)										
2/1 * 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
3/11 * D	APG #4	2.0	0.9	26.5	0.10	2.2	1.4	4.4	74.1	NA
2/111 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 . Cent'd.

Station	Sample #	Dry wt. (gms )	Cu	Zn	Cd	Pb	Ni	Cr	% Water	v	
<u>Pristipomoides aquilonaris</u> (wenchman)											
3/1	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		
<u>Cynoscion spp.</u> (sea trout)											
1/1	D/N	AHQ/AFN #3 #3	2.0	1.8	22.0	0.10	1.5	2.8	5.5	76.5	< 2.4
1/111	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	<b>15.5</b>	0.11	0.6	5.1	8.3	78.7	< 0.7
Average				1.7	20.2	0.10	<b>1.1</b>	3.0	4.9		

Table 6. Cont'd.

Station	Sample	Dry wt. (gins)	Cu	Zn	Cd	Pb	Ni	Cr	% Water	v
<u>Micropogon undulatus</u> (Atlantic croaker)										
2/11 N	ALI #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 Syacium sp. except AIL #2 as Syacium gunteri and BBJ #4 as Syacium papilosa.

All sea robins were identified as Prionotus paralatus except AXQ #2 as Prionotus sp.

All sea trout were identified as Cynoscion arenarius except BGP #1 as Cynoscion nothus.

Table 7. Chemical Composition of Zooplankton from the South Texas OCS Spring Sampling (ppm dry weight).

Station	Sample #	Dry wt. (gins)	Cu	Zn	Cd	Pb	Cr	Ni	v	% Water
<b>Zooplankton</b>										
1/1 D	CAV	1.0	26.6	65.7	1.31	6.6	6.8	21.7	29	85.7
1/1 N	CAF	1.0	10.4	74.9	1.14	5.6	4.8	13.9	43	80.7
2/1 D	CDZ	1.0	8.6	130	2.86	3.5	4.1	11.0	10	84.4
2/1 N	CDI	1.0	9.8	205	2.81	12.4	7.5	11.4	15	84.6
3/1 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
1/11 D	CKL	1.0	75.8	102	1.42	17.8	7*5	9.8	15	82.8
1/11 N	CJU	1.0	12.8	96.9	1.66	8.0	9.9	9.1	72	86.2
2/11 D	CNO	1.0	8.7	133	2.16	9.4	3.5	7.1	63	81.7
2/11 N	CMW	1.0	9.8	161	2.03	7.0	3.8	7.4	26	79.6
3/11 D	CQQ	0.4	11.0	104	4.62	8.1	7.3	5.0	< 16	86.6
3/11 N	CPZ	1.0	16.1	80.6	6.05	5.4	1.6	6.0	< 4.9	85.4
1/111 D	CYT	1.0	10.1	104	2.66	15.9	7.4	10.6	16	83.4

Table 7. Cent' d.

Station	Sample #	Dry wt. (gins)	Cu	Zn	Cd	Pb	Cr	Ni	V	% Water
<b>Zooplankton</b> (continued)										
1/111 N	CTF	1.0	7.2	126	2.35	15.5	3.9	2.8	13	88.0
2/111 D	<b>CXY</b>	1.0	9.1	87.4	4.48	3.4	4.3	5.4"	13	88.3
2/111 N	<b>CXJ</b>	<b>1.0</b>	10.2	104	<b>4.31</b>	7.6	2.8	4.8	13	84.3
3/111 D	DBH	1.0	13.2	100	5.78	2.1	3.0	6.1	6.0	87.1
<b>3/III</b> N	DAH	1.0	10.9	111	4.16	3.3	3.5	6.6	4.1	84.7
<b>1/IV</b> 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
<b>2/IV</b> D	<b>DMK</b>	1.0	9.5	80.0	3.41	4.0	5.9	4.5	37	87.6
2/IV N	DGG	<b>1.0</b>	7.9	109	2.80	8.8	2.7	6.0	83	87.1
<b>3/IV</b> D *	DKA	1.0	30.2	108	3.45	49.5	10.3	4.4	24	88.3
<b>3/IV</b> 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. (gins)	Cu	Zn	Cd	Pb	Cr	Ni	V	% Water
<b>Neuston and Sargassum</b>										
1/1	<b>CAY</b>	1.0	8.5	377 **	1.47	2.3	2.3	12.0	96	89.2
<b>2/I</b>	CEJ	2.0	5.8	60.0	<b>1.97</b>	<b>1.7</b>	1.9	<b>19.0</b>	2.2	79.0
3/I	<b>CHI</b>	0.2	8.4	27.7	1.72	2.5	7.4	108 **	19	87.4
1/11	CKO	2.0	8.5	60.5	1.10	4.0	7.4	8.5	< 29	86.6
2/11	CNR	2.0	6.9	66.9	<b>1.86</b>	5.9	1.7	8.0	8.3	81.2
3/11	CQT	1.0	3.8 "	39.1	1.55	6.5	2.0	5.4	< 7.6	83.2
1/111	CUB	<b>2.0</b>	3.9	32.5	1.70	2.8	1.2	7.5	9.6	84.1
2/111	<b>CYG</b>	2.0	3.8	29.3	1.95	4.5	.4	8.5	3.3	85.6
<b>3/III</b>	DAZ	2.0	4.0	24.9	1.53	4.5	.7	5.6	2.0	82.2
<b>1/IV *</b>	DDZ	0.25	6.3	42.8	2.44	10.3	3.8	<b>11.8</b>	<b>11</b>	87.7
2/IV	<b>DCZ</b>	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. Cent'd.

Station	Sample #	Dry wt. (gins)	Cu	Zn	Cd	Pb	Cr	Ni	V	% Water
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\* samples include tar balls

\*\* average does not include these values

	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

Table 9. Chemical Composition of Muscle Tissue of Invertebrates  
from the South Texas OCS Spring Sampling (ppm dry weight)

Station	Sample #	Dry wt. (gins).	Cu	Zn	Cd	Pb	Cr	Ni	V	Ba	% Water	
<u><i>Loligo pealei</i></u> (common squid)												
2/1	D	CEE #1	2.0	6.5	31.7	.23	.8	2.0	2.8	< 2.0	< 4.1	74.6
3/1	D	CHN #4	2.0	8.4	40.1	.13	.8	4.4	2.4	< 2.7	< 4.8	73.7
1/11	D	CKT #2	2.0	63.7**	41.7	.66	2.4	1.8	.5	< 2.8	< 3.6	74.5
2/11	D	CNW #2	2.0	15.2	45*4	.16	2.1	2.5	1.0	< 2.3	< 7.7	74.1
3/11	D	CQY #2	2.0	5.2	30.8	.24	1.2	1.5	.4	< 2.6	< 4.2	75.8
1/111	D	CUG #1	2.0	8.1	47.0	.16	1.2	2.1	.5	< 2.2	< 4.5	75.4
2/111	D	CYC #1	2.0	8.1	35.3	.22	1.0	2.0	.6	< 2.1	< 4.0	74.7
3/111	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. Cent'd.

Station	Sample #	Dry wt. (gins)	Cu	Zn	Cd	Pb	Cr	Ni	V	Ba	% Water
<u>Penaeus setiferus</u> (white shrimp)											
1/1	N/D CAJ/CBD #1 #1	2.0	19.2	46.1	.10	.9	1.7	.9	< 1.8	< 4.9	74.5
1/11	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			
<u>Penaeus duorarum</u> (pink shrimp)											
1/111	N CTL #1	2.0	31.0	65.2	.21	1.4	1.8	.7	< 1.8		74.5
<u>Penaeus aztecus</u> (brown shrimp)											
2/1	D/N CEE/CDN #3 #1	2.0	26.2	46.2	.11	.8	3.4	3.0	< 1.8	< 4.2	75.1
3/1	N CGS #4	2.0	20.3	42.5	.17	1.0	2.6	.4	< 2.2		75.2
2/11	N CNC #1	2.0	23.1	56.4	.24	2.1	1.5	1.0	< 2.2		75.1
2/111	N CXN #1	2.0	19.4	61.3	.13	1.1	1.4	.4	< 2.0		74.5
3/111	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. (gins)	Cu	Zn	Cd	Pb	Cr	Ni	V	Ba	% Water
<u>Penaeus aztecus</u> (brown shrimp)											
1/IV D	DEE #3	2.0	24.3	51.2	.16	.4	1.7	.3	< .22	< 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 dorsalis</u> (rock shrimp)											
2/1 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. (gins)	Cu .	Zn	Cd	Pb	Cr	Ni	v	Ba	% Water
<u>Callinectes similis</u> (blue crab)											
1/1	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	
<u>Stenotomus caprinus</u> (longspine porgy)											
3/1	D	CHN #3	2.0"	1.2	16.9	.12	.7	3.2	.6	< 1.5	79.5
3/1	N	CGS #1	2.0	.7	12.1	.10	1.5	1.6	1.9	< 1.7	78.5
3/11	D	CQY #3	2.0	1.0	13.9	.08	1.1	1.4	.5	< 1.4	78.6
2/111	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		
<u>Syacium gunteri</u> (shoal flounder)											
2/1	D	CEE #4	2.0	.7	27.2	.15	.7	2.4	2.6	1.0	79.5
1/11	D	CKT i/4	2.0	.9	12.7	.12	1.3	1.1	.4	< 1.5	78.8
2/11	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 gunteri</u> (shoal flounder) (continued)										
3/II N	CQD #1	2.0	.5	15.6	.10	.9	1.5	.4	< 1.6	79.3
1/II <sup>F</sup> D	CUG #2	2.0	1.1	13.9	.06	.5	1.3	1.2	< 1.3	79.3
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	13.5	.17	.3	1.5	.9	1.5	80.0
3/IV N	DJN #2	2.0	.3	18.5	.11	.4	1.5	.7	< 2.2	79.1
Average			.7	17.9	.12	.7	1.6	1.0		
<u>Trachurus 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	.5		

Table 10. Cont'd.

Station	Sample #	Dry wt. (gms)	Cu	Zn	cd	Pb	Cr	Ni	V	% Water
<u>Pristipomoides 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 nothus</u> (silver seatrout)										
1 III N	CTL #2	2.0	1.0	18.9	.09	1.0	1.4	.5	< 1.3	79.2
<u>Cynoscion 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. Cent 'd.

Stat ion	Sample #	Dry wt. (gins).	Cu	Zn	Cd	Pb	Cr	Ni	V	% Water
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Lagodon rhomboids ( p i n f i s h )

2/IV D	DHD #4	2.0	1.7	33.0	.11	.5	1.2	.6	< 1.5	78.1
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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	Z Water	
Zooplankton											
<b>1/I D</b>	EAv	1.0	18.2	216	2.5	22.7	7.23	19.1	38	88.4	
<b>1/I N</b>	EAF	1.0	9.0	83.5	1.92	6.03	7.93	7.32	17	81.3	
2/1 D	EDZ	1.0	15.5	162	4.57	6.64	2.54	10.1	< 9.0	82.3	
<b>2/I N</b>	EDI	1.0	25.3	139	4.68	9.83	4.03	8.37	< 7.4	81.6	
3/1 D	<b>EHF</b>	0.9	11.8	120	4.72	10.2	2.54	8.17	< 11	85.1	
3/1 N	EGM	<b>1.0</b>	20.3	135	6.04	12.9	3.30	8.00	5.7	82.0	
1/11 D	EXL	0.54	9*5	88.1	5.48	9.69	2.17	3.16	< 12	89.1	
1/11 N	EJU	1.0	8.3	120	1.42	4.60	3.10	3.59	< 13	86.6	
2/11 D	ENP*	1.0	13.9	144	5.35	8.58	2.29	8.47	< 19	83.6	
<b>2/II N</b>	<b>EMW</b>	1.0	18.5	114	4.74	5.15	1.89	7.01	7.1	82.1	
3/11 D	EQQ	0.8	21.6	93.5	6.47	3.81	1.10	6.28	< 13	83.7	
3/11 N	EPZ	0.39	14.0	94.4	6.95	17.9	4.55	4.55	NA	86.1	
1/111 D	ETY	1.0	5.4	93.8	1.38	8.27	0.74	0.93	< 14	90.1	

Table 11. Cent'd.

Station	Sample #	Dry wt. (gins)	Cu	Zn	Cd	Pb	Cr	Ni	v	% Water
<b>Zooplankton</b> (continued)										
1/111 N	ETF	0.5	11.1	108	2.07	7.47	1.81	2.28	< 14	91.2
2/111 D	EXY	0.6	18.0	81.2	4.88	3.82	1.28	5.00	< 12	86.1
2/111 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
3/111 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. (gins)	Cu	Zn	Cd	Pb	Cr	Ni	V	% Water
<b>Neuston</b>										
1/1 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
3/1 D	EHI	0.25	5.38	24.1	1.26	1.51	< .50	29.0	< 13	83.7
1/11 D	EKO	0.32	11.9	130	1.88	8.05	4.15	37.3	NA	83.5
2/11 D	ENS	1.22	9.94	77.7	2.40	1.35	1.31	7.03	NA	84.8
3/11 D	EQT	0.33	18.7	176	0.96	48.4	9.83	8.67	NA	83.8
1/111 D	EUB	0.35	13.2	164	10.0	14.7	4.85	13.7	NA	86.1
2/111 D	EYG	0.5	7.21	56.7	1.51	15.5	4.26	5.57	NA	83.3
3/111 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 pealei</u> (common squid)												
1/1	D	EBD #3	2.0	6.01	48.7	0.11	0.40	1.60	33.9	< 2.9	74.5	
2/1	D	EEE #1	2.0	7.14	43.2	0.30	0.63	1.33	16.7	< 2.9	74.1	
1/11	D	EKT #2	2.0	7.58	52.7	0.09	0.68	1.22	0.23	< 2.8	< 10	74.7
2/11	D	ENX #3	2.0	6.67	44.4	0.35	0.54	1.47	13.5	< 2.6	< 7.2	75.5
3/11	D	EQY #3	2.0	7.65	45.4	0.29	0.51	1.33	1.72	c 3.6	< 10	75.6
1/111	D	EUG #4	2.0	6.39	47.8	0.05	0.33	1.37	0.24	< 2.8		74.6
3/111	D	FBE #4	2.0	10.3	50.9	0.40	0.48	1.47	0.08	c 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 aztecus</u> (brown shrimp)												
1/1	N	EAJ #3	2.0	32.0	58.4	0.18	0.36	0.93	0.42	< 2.2	< 7.6	74.5
2/1	N	EDN #1	2.0	32.7	54.5	0.21	0*21	1.24	1.35	< 2.5	< 9.8	75.6

Table 13. Cent'd.

Station	Sample #	Dry wt. (gins)	Cu	Zn	Cd	Pb	Cr	Ni	V	Ba	% Water
<u>Penaeus aztecus</u> (brown shrimp) (continued)											
3/1	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
2/11	N ENC #2	1.4	22.2	38.4	0.13	0.70	1.48	1.09	< 4.9		76.6
1/111	D EUG #3	2.0	24.7	65.8	0.08	0.51	1.41	1.84	< 3.2		74.6
2/111	D EYC #1	2.0	26.5	52.9	0.26	0.46	1.00	0.13	< 2.4	< 9.4	74.9
3/111	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 vioscai</u> (broken back shrimp)											
2/111	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. Cent'd.

Station	Sample #	Dry wt. (gms)	Cu	Zn	Cd	Pb	Cr	Ni	V	Ba	% Water
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Penaeus duorarum (pink shrimp)

1/IV N	1?DS #3	2.0	20.8	62.7	0.09	0.27	0.83	0.30	< 2.2	< 9.0	74.9
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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
<b><u>Micropogon undulatus</u> (Atlantic croaker)</b>											
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			
<b><u>Pristipomoides aquilonaris</u> (wenchman)</b>											
3/1	N EGS #3	2.15	0.95	11.7	0.04	0.18	1.05	0.088	< 2.0	< 7.8	78.3
3/11	D EQY* #1	2.27	1.04	34.0	0.05	0.30	0.92	0.074	< 3.0		78.7
3/111	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. Cent'd.

Station	Sample #	Dry wt. (gms)	Cu	Zn	Cd	Pb	Cr	Ni	V	Ba	% Water
<u>Upeneus parvus</u> (dwarf goatfish)											
3/1	D EHN #3	2.30	1.71	16.9	0.06	0.37	0.83	0.19	< 3.6	< 9.0	76.7
3/11	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 atrobranchus</u> (black ear bass)											
2/11	D EXN #2	2.39	2.05	14.5	0.14,	0.97	1.54	0.19	NA		76.9
3/11	N EQD #2	2.09	0.81	14.2	0.05	0.42	1.47	0.62	NA		78.5
2/111	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. Cent'd.

Station	Sample #	Dry wt. (gins)	Cu	Zn	Cd	Pb	Cr	Ni	V	Ba	% Water
<b><u>Lutjanus campechanus</u></b> (red snapper)											
1/1	D EBD #1	2.18	1.74	18.4	0.10	0.38	1.31	0.11	< 10		76.4
1/11	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			
<b><u>Centropristes philadelphicus</u></b> (rock sea bass)											
3/111	N FAL #3	2.28	0.61	14.8	0.007	0.18	1.07	<.08	c 2.3	< 9.4	77.5
2/1	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	<b>1.12</b>	<b>&lt;.09</b>			
<b><u>Stenotomus caprinus</u></b> (longspine porgy)											
3/111	D FBE #2	<b>2.49</b>	0.89	13.3	0.04	0.17	0.95	0.82	< 2.3		76.8
3/1	N EGS #4	2.37	1.10	15.2	0.04	0.46	1.12	0.19	< 2.2	< 7.9	77.4
Average			<b>1.00</b>	14.2	0.04	0.32	1.03	0.14			

Table 14. Cent' d.

Station	Sample #	Dry wt. (gms)	Cu	Zn	Cd	Pb	Cr	Ni	V	Ba	% Water
<u>Syacium gunteri</u> (shoal flounder)											
1/111 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	<b>15.5</b>	0.03	0.30	1.25	0.21			
<u>Synodus foetens</u> (inshore lizard fish)											
2/1 N	EDN #2	2.24	1.09 "	18.2	0.10	0.30	1.32	0.74	< 1.8	< 7.8	78.3
2/11 D	ENX #1	2.44	0.92	<b>14.0</b>	0.34	0.18	1.06	.021	< 2.4	< 8.5	75.8
2/111 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	19.1	0.10	0.34	1.10	.08	< 1.5	< 6.4	77.2
			$\pm$ .11	$\pm$ 2	$\pm$ .06	$\pm$ .13	$\pm$ .09	$\pm$ .01			
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 Ea.

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. (gins)	Zn	Cu	Cd	Pb	Cr	Ni	Fe	Mn	v	% Water
<u>Rhomboplites aurorubens</u> (vermilion snapper)												
Flesh <sup>1</sup>	SB	2.0	9.4	0.7	0.11	1.4	1.3	0.8	4.9	0.2	< .58****	77.2
Fins <sup>1</sup>	"	2.0	52.4	0.1	1.34	10.8	3.2	4.8	26.8	6.5	< .72**	57.1
Scales <sup>1</sup>	"	2.0	48.5	0.1	0.95	9.8	3.0	2.9	21.5	4.7	.64	41.1
Skin <sup>1</sup>	II	1.72	21.8	2.2	0.53	2.1	2.8	3.1	23.0	0.4	NA	61.6
Gills <sup>1</sup>	"	2.0	71.4	1.5	1.06	5.9	3.9	4.3	110.0	7.5	1.2	72.7
Stomach <sup>1</sup>	"	1.46	74.8	2.7	1.60	4.7	2.3	3.2	69.4	1.9	NA	79.7
Liver <sup>1</sup>	"	0.5	268.0	13.4	5.51	1.8	2.2	( ) .9	827.0	3.3	NA	72.9
Heart <sup>1</sup>	"	0.27	52.9	7.5	0.29	2.9	1.4	1.0	925.0	1.2	NA	80.4
Intestinal"		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. Cent' d.

Sample	Site	Dry wt. (gins)	Zn	Cu	Cd	Pb	Cr	Ni	Fe	Mn	V	% Water
<u>Lutjanus campechanus</u> (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
<u>Mycteroperca sp.</u> (grouper)												
Flesh	SB	2.0	10.6	0.7	0.09	0.7	1.0	1.1	3.6	0.1	< .82**	78.6
<u>Lutjanus campechanus</u> (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. Cent 'd.

Sample	Site	Dry wt. (gins)	Zn	Cu	Cd	Pb	Cr	Ni	Fe	Mi-l	V	% Water
<u>Rhomoboplites aurorubens (vermillion napper)</u>												
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
<b>Fins<sup>2</sup></b>	"	0.86	55.0	<b>0.6</b>	0.90	12.6	3.5	5.4	37.0	7.3	NA	39.4
<b>Scales<sup>2</sup></b>	"	1.5	37.5	0.1	0.90	8.6	2.9	3.9	27.8	5.7	1.1	42.2
Skin <sup>2</sup>	"	1.7	30.6	1.7	0.36	5.4	2.7	4.1	108.0	3.6	5.4	59'
<b>Gills<sup>2</sup></b>	"	0.94	72.2	0.8	0.48	5.6	3.6	4.0	130.0	9.6	NA	64.8
<b>Gonads<sup>2</sup></b>	"	0.83	302.0	3.0	0.13	1.3	1.1	1.0	40.3	1.6	NA	69.6
Stomach <sup>2</sup>	"	0.5	63.4	7.2	0.74	3.4	2.5	3.9	166.0	4.6	NA	78
Intestine <sup>2</sup>	"	0.33	114.0	11.6	3.87	<b>1.8</b>	2.9	4.6	274.0	6.5	9.4	75.5
Liver <sup>2</sup>	"	1.0	183.0	15.0	2.87	1.0	2.5	0.7	410.0	3.0	2.0	65.5
Heart <sup>2</sup>	"	0.25	59.9	4.5	0.26	0.4	<b>1.1</b>	0.9	947.0	1.0	NA	70.1

Table 15. Cent' d.

Sample	Site	Dry wt. (gins)	Zn	Cu	Cd	Pb	Cr	Ni	Fe	Mn	V	% Water
<u>Lutjanus campechanus</u> (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	<b>1.1</b>	<b>0.8</b>	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
<u>Rhomboplites aurorubens</u> (vermilion snapper)												
Flesh	<b>BA</b>	2.0	11.4	0.9	0.08	1.3	1.8	1.8	9.8	0.2	.48	77.3
<b>Flesh<sup>3</sup></b>	"	2.0	10.2	0.7	0.09	2.5	<b>1.1</b>	1.2	6.7	0.3	< .6****	78.1
Fins <sup>3</sup>	"	0.62	54.5	0.9	1.02	18.1	3.2	4.8	37.0	8.5	NA	55.0
Scales <sup>3</sup>	"	0.96	41.4	0.02	0.84	12.7	3.3	3.9	22.7	6.3	NA	40.7
Skin <sup>3</sup>	"	0.58	25.1	1.2	0.35	4.4	<b>2.8</b>	<b>3.4</b>	17.8	0.8	NA	69.9
Gills <sup>3</sup>	"	0.76	64.4	0.7	<b>0.64</b>	10.1	4.0	4.8	108.0	10.8	NA	75.5
<b>Gonads<sup>3</sup></b>	"	0.10	67.8	3.1	2.19	2.6	0.9	0.8	35.7	2.0	NA	80.0
Liver <sup>3</sup>	"	0.37	100.0	9.3	6.13	2.2	2.2	0.9	555.0	3.8	NA	76.9

Table 15. Cent' d.

Sample	Site	Dry wt. (gins )	Zn	Cu	Cd	Pb	Cr	Ni	Fe	Mn	V	% Water
Stomach <sup>3</sup>	BA	0.50	69.3	4.8	1.60	2.5	3.0	2.4	79.4	3.0	NA	77.8
Intestine <sup>3</sup>	"	0.43	154.0	7.5	6.42	7.9	3.4	3.0	535.0	18.0	NA	83.5
Heart <sup>3</sup>	"	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
<b>Flesh<sup>4</sup></b>	NH	2.0	10.8	1.0	0.06	1.8	1.3	0.9	0.9	0.6	< .56****	77.1
<b>Fins<sup>4</sup></b>	"	1.46	42.4	2.6	0.92	9.5	3.1	5.1	34*7	6.7	NA	52.3
<b>Scales<sup>4</sup></b>	"	1.5	45.0	2.0	0.77	11.3	3.4	3.5	33.8	6.5	1.0	42.5
<b>Skin<sup>4</sup></b>	"	0.99	17.6	4.0	0.19	3.1	3.0	3.7	27.4	1.6	NA	65.7
<b>Gills<sup>4</sup></b>	"	0.64	54.9	1.2	0.37	8.2	3.7	4.9	104.0	10.0	NA	68.7
<b>Heart<sup>4</sup></b>	"	0.17	58.9	7.1	0.33	6.1	1.3	1.0	942.0	1.2	NA	76.3
<b>Liver<sup>4</sup></b>	"	0.16	105.0	9.0	3.70	7.6	2.1	1.0	533.0	3.1	NA	68.4
<b>Testes<sup>4</sup></b>	"	0.25	69.5	3.9	1.25	0.8	0.9	0.7	49.2	0.8	NA	77.4
Intestine <sup>4</sup>	"	0.65	121.0	6.3	1.98	3.8	2.7	4.5	233.0	5.2	NA	80.3
<b>Stomach<sup>4</sup></b>	"	0.6	102.0	5.7	0.89	4.5	2.6	4.2	209.0	2.8	NA	76.4

Table 15. Cent' d.

Sample	Site	Dry wt. (gins )	Zn	Cu	Cd	Pb	Cr	Ni	Fe	Mn	V %	Water
<u>Rhomboplites aurorubens</u> (vermilion 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
<u>Rhomboplites aurorubens</u> (vermilion snapper)												
Flesh <sup>s</sup>	BB	2.0	11.7	0.9	0.13	0.9	1.0	1.1	4.4	0.1	< .38****	77.1
Fins <sup>5</sup>	"	0.7	65.5	0.3	0.96	9.8	3.8	5.0	41.9	7.2	1,4	50.6
Scales <sup>5</sup>	"	1.23	70.0	0.1	0.83	9.6	3.6	4.2	43.0	5.0	NA	39.2
Skin <sup>s</sup>	"	1.0	36.3	1.6	0.49	4.2	3.0	3.2	35.6	1.2	< 3.1	66.5
Gills <sup>5</sup>	"	0.5	63.2	1.1	0.86	8.6	3.5	5.0	123.0	10.0	1.7	75.2
Gonads <sup>5</sup>	"	0.45	439.0	3.6	0.24	1.2	1.3	1.1	60.0	1.0	NA	79.5
Spleen and Intestine <sup>5</sup>	"	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. (gins)	Zn	Cu	Cd	Pb	Cr	Ni	Fe	Mn	V	% Water
<b>Stomach</b> <sup>5</sup>	BB	1.0	45.0	<b>5.2</b>	1.23	1.3	2.8	3.4	410.0	5.6	NA	79.7
Liver	<sup>5</sup> "	1.0	180.0	14.0	5.70	2.3	2.0	0.9	700.0	4.7	3.6	76.8
Heart	<sup>5</sup> "	0.09	67.8	10.2	0.69	6.8	1.2	1.1	319.0	2.7.	NA	80.8
<b>Flesh</b>	"	2.0	9.6	0.6"	0.13	<b>1.9</b>	<b>1.8</b>	1.9	11.6	0.2	< .65***	75.3
Flesh	II	2.0	9.8	<b>0.6</b>	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
<b><u>Lutjanus campechanus</u></b> (red snapper)												
Flesh	BB	2.0	<b>13.1</b>	0.6	0.10	0.7	1.9	1.3	15.1	0.1	< .66	75.0
<b>Flesh</b>	"	2.0	9.8	0.7	0.11	1.1	<b>1.1</b>	1.1	6.4	0.2	< .61	75.9

Table 15. Cent' d.

Sample	Site	Dry wt. (gins )	Zn	Cu	Cd	Pb	Cr	Ni	Fe	Mn	V	% Water
<u>Rhomboplites auroubens</u> (vermillion snapper)												
Flesh <sup>6</sup>	D	2.0	10.3	0.9	0.05	1.3	1.3	1.1	6.5	0.4	< . 47****	70.6
Fins <sup>6</sup>	"	1.5	46.9	0.1	0.96	13.1	3.4	5.7	18.8	6.4	1.9	47.7
Scales <sup>6</sup>	"	2.0	32.4	0.1	0.79	11.6	<b>3.8</b>	4.8	18.4	4.5	<b>1.1****</b>	38.3
Skin <sup>6</sup>	"	2.0	14.6	1.4	0.10	3.0	3.2	3.6	29.6	1.1	5.9**	56.8
Gills <sup>6</sup>	"	1.5	58.8	0.5	0.59	9.2	3.8	4.6	121.0	9.4	<b>1.4***</b>	70.6
Gonads <sup>6</sup>	"	1.18	52.1	1.4	0.51	5.8	1.1	0.8	24.5	1.2	NA	77.3
Liver <sup>6</sup>	"	1.8	103.0	12.6	3.30	2.0	2.2	0.8	360.0	2.4	NA	67.5
Stomach <sup>6</sup>	"	1.0	62.7	7.3	0.83	1.5	2.6	3.1	69.5	1.7	.78	78.4
Intestine <sup>6</sup>	"	1.2	92.0	6.6	5.36	8.6	2.8	4.3	136.0	17.6	94	82.1
Heart <sup>6</sup>	"	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	<b>11.4</b>	0.1	< .72	73.4

Table 15. Cent'd.

Sample	Site	Dry wt. (gins)	Zn	Cu	Cd	Pb	Cr	Ni	Fe	Mn	V	% Water
<u>Lutjanus campechanus</u> (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
<b>Zooplankton</b>						
Winter	13.4	103	2.95	8.0	5.6	6.0
Spring	<b>13.7</b>	108	3.37	8.2	4.7	8.4
Summer	15.3	<b>127</b>	3.99	10.4	3.5	8.9
<b>Sargassum + Neuston</b>						
Winter	4.1	36.0	1.82	4.7	1.6	5.2
Spring	<b>5.7</b>	40.5	1.86	4.7	2.2	9.1
Summer	10.6	130	2.84	10.4	4.0	<b>12.5</b>
<b>Squid (probably all <u>Loligo pealei</u>)</b>						
Winter	15.0	47.4	0.77	1.3	4.7	2.5,
Spring	8.0	39.7	0.23	<b>1.3</b>	2.1	1.1
Summer	7.7	48.0	0.31	0.5	1.4	13.0
<b>Brown Shrimp (<u>Penaeus aztecus</u>)</b>						
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
<b>Rock Shrimp (<u>Sicyonia spp.</u>)</b>						
Winter	31.1	56.3	0.25	1.6	2.8	1.6
Spring	24.9	54.3	0.20	1.5	2.0	<b>2.1</b>
<b>Flatfish (<u>Syacium spp.</u>)</b>						
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
<b>Porgy (<u>Stenotomus caprinus</u>)</b>						
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
<b>Rough Scad (<u>Trachurus lathami</u>)</b>						
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 ± 2	128 ± 1-2	0.22 ± .04	0.5 ± .1	0.4 ± 0	0.3 ± .1
Spring (4)	170 ± 4	119 ± 1	0.30 ± .03	0.3 ± .05	0.3 ± 0	0.3 ± .1
Summer (4)	163 ± 5	122 ± 2	0.23 ± .03	0.36 ± .13		0.9 ± .5
N.B.S. Values	193 ± 10	130 ± 10	0.27 ± .02	0.34 ± .08	NA	NA
Orchard Leaves						
Winter (8)	11.5 ± .5	24.7 ± 2.6	0.20 ± .04	43.9 ± 3	2.5 ± .2	1.5 ± .1
Spring (4)	11.4 ± .4	24.4 ± 0.7	0.22 ± .01	42.5 ± 3	2.5 ± .2	1.4 ± .1
Summer (4)	10.7 ± .5	24.6 ± 1.4	0.11 ± .02	39.6 ± 3	2.9 ± .1	1.9 ± .5
N.B.S. Values	12 ± 1	25 ± 3	0.11 ± .02	45 ± 3	2.6 ± .2	1.3 ± .2

(The ± values are 1 standard deviation, determined from the number of replicates indicated.)

The precision based on 20 pairs of duplicate samples is as follows:

4%                      4%                      11%                      9%                      7%                      7%

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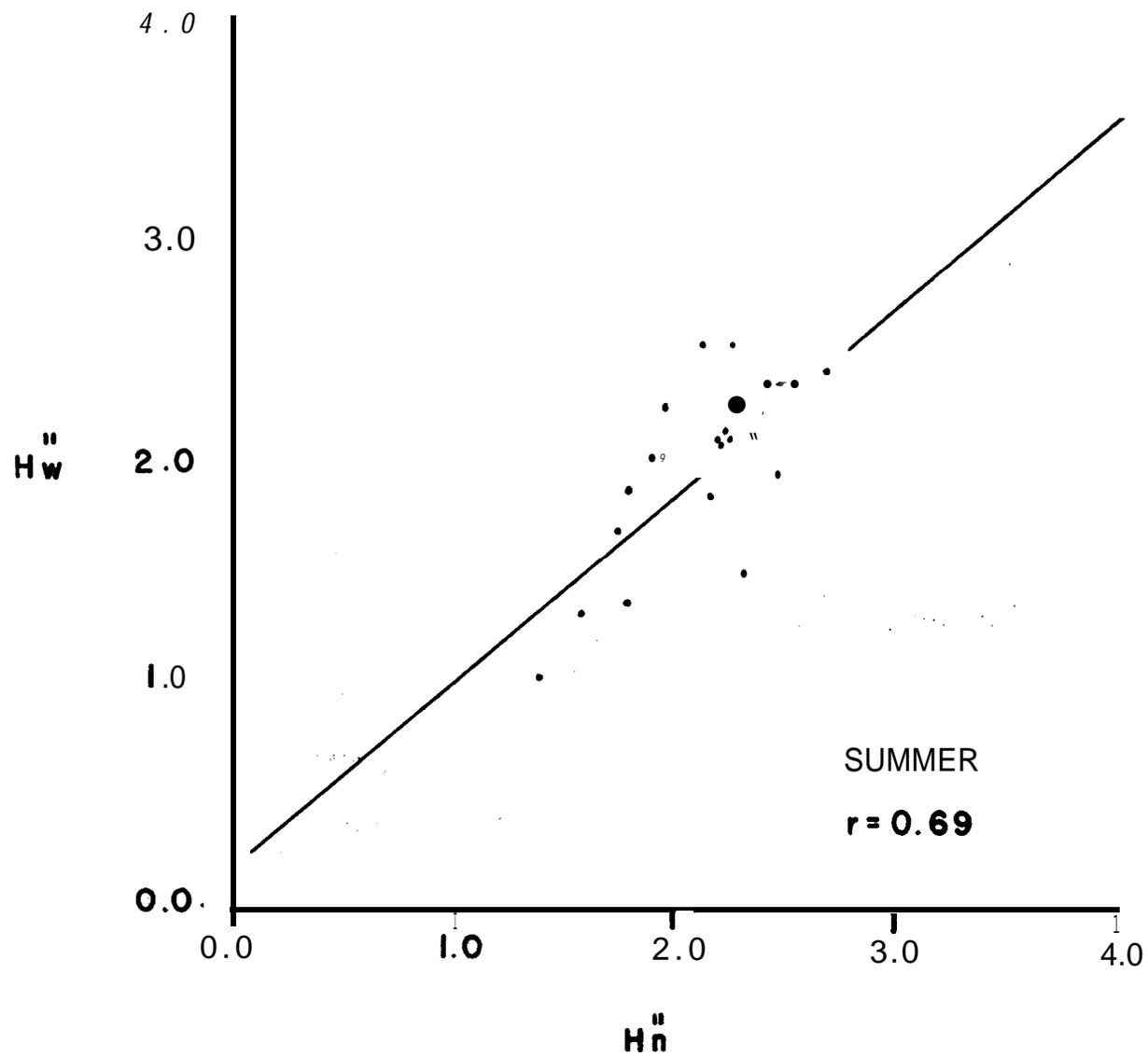


Figure 17. Relationship between fish diversity indices  $H_w''$  (biomass) and  $H_n''$  (numbers) for summer collections.

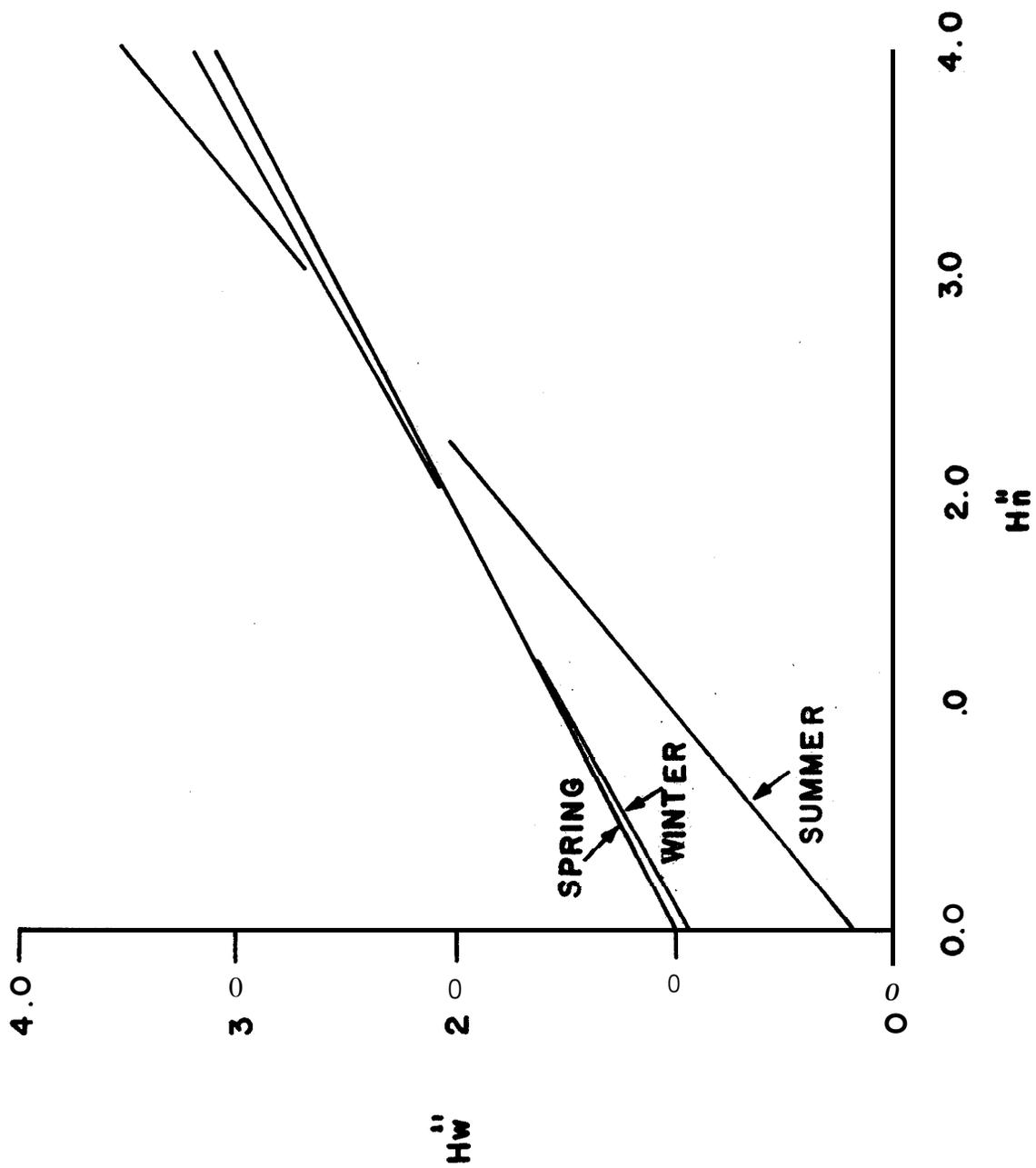


Figure 18. Relationships of seasonal diversity regressions of  $H_w''$  on  $H_n''$  for 24 samples each season.

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  $r$  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.

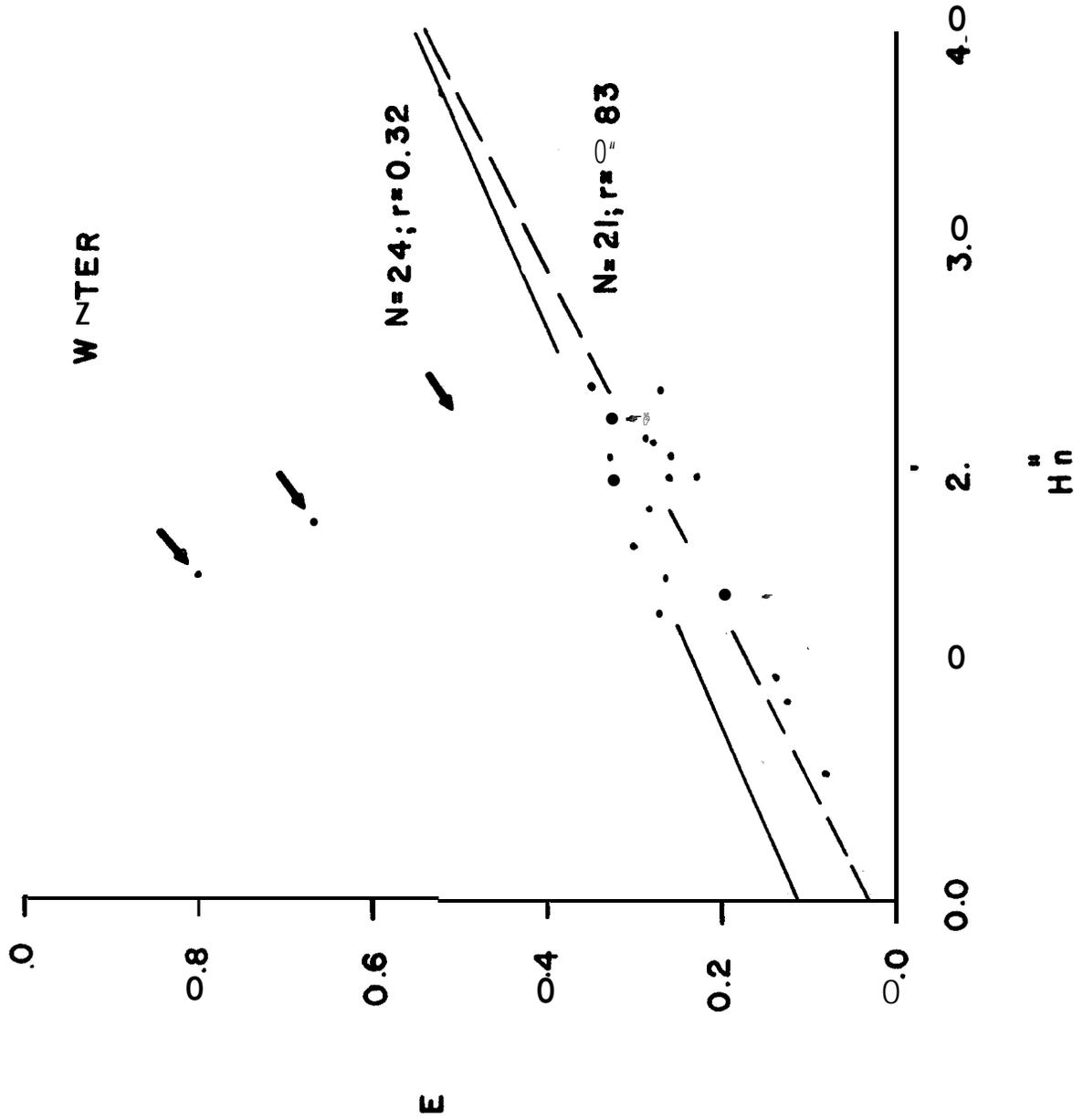


Figure 19. Relationship between equitability, E, and Shannon diversity index,  $H_n$ , for winter fish collections. See text for explanation of arrows.