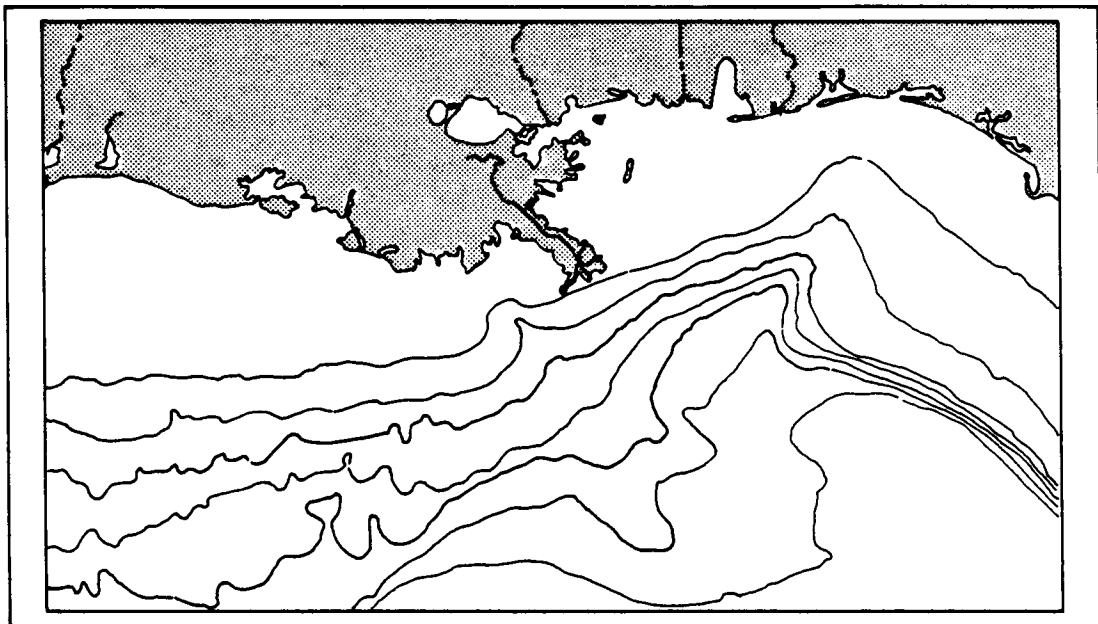


# Gulf of Mexico Continental Slope Study Annual Report Year 2

## Volume II: Primary Volume



# **Gulf of Mexico Continental Slope Study Annual Report Year 2**

## **Volume II: Primary Volume**

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## TABLE OF CONTENTS

	Page
ACKNOWLEDGEMENTS .....	iii
TABLE OF CONTENTS .....	vi
LIST OF FIGURES .....	ix
LIST OF TABLES .....	xiii
LIST OF APPENDICES .....	xviii
1.0 INTRODUCTION .....	1
2.0 STUDY AREA AND METHODS .....	5
2.1 <u>STUDY AREA</u> .....	5
2.2 <u>CRUISES</u> .....	7
2.3 <u>FIELD SAMPLING PROCEDURES</u> .....	9
2.4 <u>LABORATORY ANALYSES</u> .....	13
2.5 <u>DATA MANAGEMENT AND ANALYSES</u> .....	15
3.0 ENVIRONMENTAL RESULTS AND DISCUSSION .....	17
3.1 <u>WATER COLUMN STRUCTURE</u> .....	17
3.2 <u>SEDIMENT HYDROCARBONS</u> .....	21
3.2.1 HYDROCARBON SOURCES .....	21
3.2.2 AREAL DISTRIBUTION .....	26
3.2.3 TEMPORAL VARIATIONS .....	33
3.2.4 VARIABILITY ALONG ISOBATHS .....	38
3.2.5 TOPOGRAPHIC FEATURES .....	41
3.2.6 RELATIONSHIP TO BULK SEDIMENT PARAMETERS .....	41
3.2.7 AROMATIC HYDROCARBONS .....	45
3.3 <u>CARBON ISOTOPES</u> .....	45
3.3.1 SEDIMENTS .....	45
3.3.2 ORGANISMS .....	48
3.4 <u>ORGANISM HYDROCARBONS</u> .....	51

TABLE OF CONTENTS (cont'd)

	Page
4.0 BIOLOGICAL OCEANOGRAPHIC CHARACTERISTICS OF THE NORTHERN GULF .....	64
4.1 <u>MEGAFUNA</u> .....	64
4.1.1 ARTHROPODA .....	64
4.1.2 ECHINODERMATA .....	82
4.1.3 DEMERSAL FISH .....	92
4.1.4 ADDITIONAL MEGAFUNAL GROUPS .....	97
4.1.5 MEGAFUNAL ASSEMBLAGES AND ZONATION .....	97
4.2 <u>MACROFAUNA</u> .....	117
4.2.1 POLYCHAETA .....	128
4.2.2 CRUSTACEA .....	131
4.2.3 MOLLUSCA .....	134
4.2.4 ADDITIONAL MACROFAUNAL GROUPS .....	136
4.2.5 SPECIES COMPOSITION OF THE MACROFAUNAL ASSEMBLAGES OF THE SLOPE .....	136
4.2.6 MACROFAUNA AS PREY OF DEMERSAL FISHES .....	148
4.3 <u>MEIOFAUNA</u> .....	150
5.0 BENTHIC PHOTOGRAPHY RESULTS .....	153
5.1 <u>LEBENSSPUREN</u> .....	153
5.1.1 INDIVIDUAL RIDGES .....	156
5.1.2 SOLITARY LUMPS .....	158
5.1.3 SETS OF LUMPS .....	158
5.1.4 INDIVIDUAL GROOVES .....	158
5.1.5 SETS OF GROOVES .....	160
5.1.6 SOLITARY DEPRESSIONS .....	161
5.1.7 GROUPS OF DEPRESSIONS .....	166
5.1.8 ADJACENT STRIPS OF DEPRESSIONS .....	168
5.2 <u>CONSOLIDATED MATERIALS</u> .....	169
5.3 <u>MAN-MADE ARTIFACTS</u> .....	171
5.4 <u>BIOTA</u> .....	171
5.5 <u>UNIDENTIFIABLE ORGANISMS</u> .....	178
5.6 <u>SUMMARY</u> .....	179



TABLE OF CONTENTS (cont'd)

	Page
6.0 CHEMOSYNTHETIC ORGANISMS ON THE GULF OF MEXICO CONTINENTAL SLOPE .....	180
6.1 <u>INTRODUCTION</u> .....	180
6.2 <u>FINDINGS FROM SITES OF NATURAL HYDROCARBON SEEPAGE OFF LOUISIANA</u> .....	181
6.2.1 HYDROCARBONS: SEEP TO NON-SEEP COMPARISON .....	182
6.2.2 CARBON ISOTOPES .....	182
6.2.3 TRAWL SAMPLES FROM CENTRAL GULF SEEP SITES .....	186
6.3 <u>CHEMOSYNTHETIC ASSEMBLAGES AT CONTINENTAL SLOPE STUDY SAMPLING STATIONS</u> .....	188
6.3.1 STATION WC7 .....	191
6.3.2 STATION C7 .....	196
6.4 <u>STATISTICAL ANALYSIS</u> .....	203
6.5 <u>MACROFAUNA</u> .....	208
6.6 <u>DISCUSSION</u> .....	212
7.0 LITERATURE CITED .....	216

## LIST OF FIGURES

Figure		Page
2-1	Sampling locations for Cruises I-III .....	6
3-1	Extreme temperature recorded by depth during Cruises I-III .....	19
3-2	Typical depth profiles for temperature, dissolved oxygen, and salinity .....	20
3-3	Molecular level alkane distributions for sediments from the Central Transect during Cruise I .....	24
3-4	Variation in extractable organic matter and the aliphatic unresolved complex mixture along transects in the eastern, western, and central Gulf of Mexico continental slope .....	27
3-5	Variation in hydrocarbon source parameters along transects in the eastern, western, and central Gulf of Mexico continental slope .....	28
3-6	Variation in planktonic, terrestrial, and petroleum hydrocarbons along three transects presented as a cumulative concentration .....	29
3-7	The relationship between alkane petroleum indicators and a terrestrial indicator .....	31
3-8	The relationship between the aliphatic unresolved complex mixture and the planktonic and terrestrial alkane indicator .....	32
3-9	Variations in extractable organic matter and the aliphatic unresolved complex mixture during three samplings of the Central Transect .....	34
3-10	Variations in hydrocarbon source parameters during three samplings of the Central Transect .....	35
3-11	Variation in plankton, terrestrial and petroleum hydrocarbons during three samplings of the Central Transect presented as a cumulative concentration .....	36
3-12	Variation in the carbon preference index as a function of depth along the Central Transect during Cruise III and a representative fused silica gas chromatogram of the aliphatic hydrocarbons from Station C-5, Cruise III .....	37
3-13	The relationship between a terrestrial hydrocarbon indicator and the clay content of the sediment .....	43

LIST OF FIGURES (cont'd)

Figure		Page
3-14	The relationship between a terrestrial hydrocarbon indicator and the clay and sand content of the sediment during Cruise II .....	44
3-15	The relationship between two petroleum hydrocarbon indicators and the clay content of the sediment during Cruise II .....	46
3-16	Summary of the carbon isotopic composition of sedimentary organic matter from all five cruises .....	47
3-17	Summary of the carbon isotopic composition of organism tissues by transect and organism type for all five cruises .....	49
3-18	Summary of the carbon isotopic composition of organism tissues by organism type .....	50
3-19	Summary of the total alkane concentration in organism tissues for Cruises I, II, and III .....	52
3-20	Selected examples of alkane distributions in fish tissues .....	55
3-21	Selected examples of alkane distributions in crab and shrimp tissues .....	56
3-22	Selected examples of alkane distributions in eel tissues .....	57
3-23	Selected examples of terrestrial hydrocarbons detected in crab and fish tissues .....	59
3-24	Selected examples of terrestrial hydrocarbons detected in shrimp and fish tissues .....	60
3-25	Summary of total alkane concentrations as a function of tissue type .....	62
3-26	A suggested scheme for the sources and sinks of hydrocarbons on the Gulf of Mexico slope .....	63
4-1	Number of species of megafaunal invertebrates and demersal fishes taken by trawl .....	100

LIST OF FIGURES (cont'd)

Figure		Page
4-2	Numbers of individuals of megafaunal invertebrates and demersal fishes taken by trawl and plotted against depth, and lines of separation between adjacent faunal zones .....	101
4-3	Dendrogram of invertebrate species collected by trawl and clustered on the basis of dissimilarity .....	103
4-4	Dendrogram of demersal fish species collected by trawl and clustered on the basis of dissimilarity .....	104
4-5	Bar graphs showing depth ranges of demersal fish species .....	105
4-6	Patterns of species diversity for cumaceans, tanaidaceans, amphipods, and isopods .....	122
4-7	Pattern of species diversity for macrofaunal polychaetes for Stations C1-C5 of Cruise I only .....	123
4-8	Pattern of species diversity for macrofaunal bivalves from Stations 1-5 of Cruises I-III .....	124
4-9	Number of species of macrofauna taken by box core from five sampling stations on the West Transect and five stations on the East Transect .....	125
4-10	Relationships between the depth ranges of sipunculid species and four faunal zones .....	129
5-1	Density per hectare of solitary conical lumps, Cruise II stations .....	159
5-2	Density per hectare of shallow depressions, Cruise II stations .....	163
5-3	Density per hectare of deep depressions, Cruise II stations .....	164
5-4	Density per hectare of depressions arranged in a circle, Cruise II stations .....	167
5-5	Density per hectare of all megafauna observed by benthic photography, Cruise II stations .....	172
6-1	Comparison of <sup>13</sup> C values for pandemic continental slope fauna and for petroleum seep organisms .....	185
6-2	Cluster diagram (DICE) based on dissimilarity of co-occurrence of six chemosynthetic organiams .....	187

LIST OF FIGURES (cont'd)

Figure		Page
6-3	Similarity indices (DICE) for chemosynthetic taxa and for seep indicators .....	189
6-4	Station WC7 and C7 camera transect, trawl transect box-core locations and seismic features .....	190
6-5	Photographs of <u>Lamellibrachia</u> sp. and Vesicomysidae .....	193
6-6	Station WC7: density of vestimentiferans and pogonophorans on the segment of the photo-transect where they occurred .....	195
6-7	Percentage of dead Vesicomysidae per fram .....	200
6-8	Station C7: densities of living and dead vesicomysids on the segments of the photo-transect where they occurred ..	201
6-9	Length frequency of living vesicomysids and dead vesicomysid valves .....	202
6-10	Station C2: Cluster of the vestiferan <u>Lamellibrachia</u> sp. and the bivalves <u>Acesta</u> sp. ....	204
6-11	Power curves for sampling seep communities with benthic photography .....	209
6-12	Abundance of juvenile <u>Vesicomys</u> sp. in box core samples from the Central Transect on the Gulf of Mexico continental slope .....	211

LIST OF TABLES

Table		Page
2-1	Station locations for year one box core stations .....	8
2-2	Specifications of the vessel, HOS <u>Citation</u> .....	10
2-3	Supportive water column analyses .....	11
2-4	Total sampling effort for Cruises I, II, and III .....	12
2-5	Status of data files as of 7 March 1985 .....	16
3-1	Features of water masses in the Gulf of Mexico with depths of observed characteristics during Cruises I, II, and III .....	18
3-2	The ranges and averages for selected hydrocarbon para- meters in Gulf of Mexico continental slope sediments ....	22
3-3	Summary of Gulf of Mexico sediment hydrocarbon analyses .....	23
3-4	Suggested molecular-level indicators of specific hydro- carbon sources to sediments on the Gulf of Mexico continental slope .....	25
3-5	Variability in hydrocarbon parameters along isobaths - eastern Gulf of Mexico .....	39
3-6	Variability in hydrocarbon parameters along isobaths - west/central Gulf of Mexico .....	40
3-7	Comparison of sediment hydrocarbon parameters at two different topographic settings .....	42
3-8	Summary of the incidence of detectable hydrocarbons in organisms muscle tissue .....	53
3-9	Species in which no hydrocarbons were detected in organism tissues in the present study .....	54
3-10	Species in which a sediment hydrocarbon signature was detected in organism tissues .....	58
4-1	Megafaunal Crustacea collected by trawl during Cruises I, II, and III of the LGL study .....	65

LIST OF TABLES (cont'd)

Table		Page
4-2	Inventory of Penaeidea arranged in order of abundance by depth of maximum population on Cruises I-III .....	68
4-3	Comparison of numerical dominant penaeid species in the LGL and TerEco studies .....	67
4-4	Comparison of the zonal distribution of Penaeidea between LGL and TerEco studies .....	69
4-5	Inventory of Caridea arranged in order of abundance by depth of maximum population on Cruises I-III .....	70
4-6	Comparison of numerical dominant caridean species in LGL and TerEco studies .....	71
4-7	Comparison of the zonal distribution of Caridea between LGL and TerEco studies .....	72
4-8	Inventory of Galatheidae arranged in order of abundance of maximum population on Cruises I-III .....	73
4-9	Comparison of zonal distribution of Galatheidae in the LGL study, comparing <u>Munida</u> with <u>Munidopsis</u> .....	74
4-10	Comparison of numerical dominant galatheids in the LGL and TerEco studies .....	75
4-11	Inventory of Anomura arranged in order of abundance by depth of maximum population on Cruises I-III .....	76
4-12	The zonal distribution of species in the families Paguridae, Porcellanidae, Chirostylidae, and Lithodidae from the three sampling transects .....	77
4-13	Inventory of Macrura arranged in order of abundance by depth of maximum population on Cruises I-III .....	78
4-14	Comparison of numerical dominant species of Macrura in the LGL and TerEco studies .....	77
4-15	Distribution of Polychelidae and Nephropidae of the LGL collection among faunal zones .....	79
4-16	Inventory of Brachyura arranged in order of abundance by depth of maximum population on Cruises I-III .....	80
4-17	Comparison of the zonal distribution of Brachyura between LGL and TerEco studies .....	81

LIST OF TABLES (cont'd)

Table		Page
4-18	Comparison of numerical dominant brachyuran species in the LGL and TerEco studies .....	81
4-19	Number of megafaunal species collected in echinoderm classes and their bathymetric distribution .....	82
4-20	Inventory of Asteroidea arranged in order of abundance by depth of maximum population on Cruises I-III .....	83
4-21	Comparison of numerical dominant asteroid species in the LGL and TerEco studies .....	84
4-22	Comparison of the zonal distribution of asteroids between LGL and TerEco studies .....	84
4-23	Inventory of Ophiuroidea arranged in order of abundance by depth of maximum population on Cruises I-III .....	86
4-24	Comparison of the zonal distribution of ophiuroids between LGL and TerEco studies .....	87
4-25	Inventory of Echinoidea arranged in order of abundance by depth of maximum population on Cruises I-III .....	88
4-26	Inventory of Holothuroidea arranged in order of abundance by depth of maximum population on Cruises I-III ...	89
4-27	Comparison of the zonal distribution of holothuroids between LGL and TerEco studies .....	90
4-28	Inventory of Crinoidea arranged in order of abundance by depth of maximum population on Cruises I-III .....	91
4-29	Inventory of demersal fish arranged in order of abundance by depth of maximum population on Cruises I-III .....	93
4-30	Zonal distribution of demersal fishes .....	96
4-31	Comparison of the twelve most abundant species of fish between the LGL and TerEco studies .....	96
4-32	The numerical dominants of taxa in the phyla Porifera, Coelenterata, Mollusca, Annelida, Brachiopoda and Pycnogonida taken by the trawl .....	98
4-33	The mean number and ranges of species and individuals of demersal fishes for stations within each zone .....	117



LIST OF TABLES (cont'd)

Table		Page
4-34	Distribution of macrofaunal species among faunal zones by depth of maximum density .....	118
4-35	Total density (no/m <sup>2</sup> ) by station of macrofaunal species collected from all stations in Cruises I-III .....	120
4-36	Number of species in the principal macrofauna taxa that are confined to a single faunal zone .....	127
4-37	Densities of macrofaunal invertebrate groups from Cruise I .....	137
4-38	Densities of macrofaunal invertebrate groups from Cruise II .....	138
4-39	Densities of macrofaunal invertebrate groups from Cruise III .....	141
4-40	Stomach content analysis of the ten most abundant demersal fish species collected by trawl during Cruise I-III .....	149
4-41	Comparison of meiofaunal densities derived from sampling the Eastern, Western, and Central Transects during Cruises I, II, and III .....	151
5-1	Total area surveyed by benthic photography .....	154
5-2	Summary of lebensspuren observations obtained by benthic photography, Cruise II .....	155
5-3	Density per hectare of lebensspuren observations by benthic photography, Cruise II .....	157
5-4	Solitary depression areas .....	165
5-5	Consolidated materials .....	170
5-6	Density/hectare of major megafauna groups observed by benthic photography, Cruise II .....	174
5-7	Comparisons of decapod crustacean densities obtained from trawling and benthic photography for Cruise II observations common to both .....	176
5-8	Comparisons of fish densities obtained from trawling and benthic photography for Cruise II observations common to both .....	177

LIST OF TABLES (cont'd)

Table		Page
6-1	Comparison of sediment hydrocarbon parameters at seep and non-seep locations on the Western/Central Gulf of Mexico continental slope .....	183
6-2	Photographic sample for seep organisms .....	191
6-3	Density/hectare and raw counts of seep-related organisms at Stations C7 and WC7' .....	194
6-4	Density/hectare and raw count of background fauna at seep Stations C7 and WC7' .....	197
6-5	Diagnostic indices for vestimentiferan tubeworms at Station WC7 and vesicomid clams at Station C7 .....	207
6-6	Macrofauna samples containing <u>Vesicomya</u> sp. from Cruises I-III .....	210

## LIST OF APPENDICES

Appendix		Page
A-1	Trawl locations sampled on Cruises I, II, and III .....	A-2
A-2	Box core station locations for Cruises I, II, and III .....	A-3
A-3	Camera transect locations .....	A-8
A-4	Description of density estimates .....	A-10
B-1	Hydrographic data - Cruises I-V .....	B-2
B-2	Sediment data - Cruises I-V .....	B-10
B-3	Carbon isotope ratios for organisms - Cruises I-V .....	B-20
B-4	Sediment hydrocarbon data - extractable organic matter .....	B-24
B-5	Sediment hydrocarbon data - alkane concentrations (n-C <sub>15</sub> - n-C <sub>22</sub> ) - Cruises I-V .....	B-26
B-6	Sediment hydrocarbon data - alkane concentrations (n-C <sub>23</sub> - n-C <sub>32</sub> ) - Cruises I-V .....	B-28
B-7	Organism samples - hydrocarbons (extractable organic matter) .....	B-30
B-8	Organism samples - alkanes (C <sub>15</sub> - C <sub>21</sub> ) .....	B-35
B-9	Organism samples - alkanes (C <sub>22</sub> - C <sub>32</sub> ) .....	B-40
C-1	Station counts for trawl invertebrates from Cruises I-III .....	C-2
C-2	Station counts for trawl fish from Cruises I-III .....	C-47
C-3	Station counts of macrofaunal groups from boxcore samples of Cruises I-III .....	C-62
C-4	Station densities for macrofaunal species from box- core samples of Cruises I-III .....	C-67
C-5	Station counts for macrofaunal species from boxcore samples of Cruises I-III .....	C-121
C-6	Station densities of meiofauna groups from Cruises I-III .....	C-236
C-7	Station counts of meiofauna groups from Cruises I-III .....	C-241

LIST OF APPENDICES (cont'd)

Appendix		Page
D-1	Raw counts of all benthic photography observations, Cruise II stations .....	D-2
D-2	Density per hectare of all benthic photography observations, Cruise II stations .....	D-9
D-3	Summary of length measurements (cm) from benthic photography observations, Cruise II stations .....	D-16
D-4	Summary of area measurements (cm <sup>2</sup> ) from benthic photography observations, Cruise II stations .....	D-24
D-5	Summary of percent cover determinations from benthic photography observations, Cruise II stations .....	D-26

## 1.0 INTRODUCTION

Beginning in 1983, the Gulf of Mexico Regional Office of Minerals Management Service (MMS) initiated a multiyear study of the continental slope of the northern Gulf of Mexico. The overall objective of this program was to develop a basic knowledge of the components of the deep Gulf fauna, their environment and ecological processes in advance of pending petroleum development. The continental slope of the Gulf of Mexico appears promising in terms of hydrocarbon reserves, and is growing in importance. On the slope, commercial finds have already been announced and the move to deep water by the petroleum industry is now underway.

The biology of the continental slope is poorly known (for a review of available information through 1982 see Pequegnat [1983]), and while in the general sense there is no reason to expect the deep sea of the Gulf to be markedly different from other deep sea habitats--all are cold, dark and food-limited habitats from a biological sense. But the recent discovery of the presence of chemosynthetic organisms on the slope suggests unusual and unexpected biological resources are present in this habitat.

The scope of the program includes physical-chemical characterization of water masses overlying the bottom at depths between 200 and about 3000 m; the sedimentary characteristics of the bottom; and the abundance, structure and distribution of the bottom-associated animal communities at these depths. The groups of animals being investigated include the meiofauna (infauna passing through a 300-micron seive but retained on a 63-micron seive), macrofauna (infauna retained on a 300-micron seive) and the megafauna (organisms large enough to be captured in trawls or observed in photographs). The program also includes the charge to characterize present levels of hydrocarbon contamination in the sediments and selected biota in anticipation of petroleum resource development beyond the shelf-slope break.

The overall program incorporates five cruises, all of which have been conducted. Completion of sample analysis lags considerably behind the termination of sampling due to the taxonomic complexity of the system. Organisms are removed from the samples and classified to the lowest taxon practical--often Family level or above. These collections must then be

sent to specialists for species-level identification--a process requiring a considerable amount of time since many of the specimens represent rare species or species new to science. As a result of this process, the final data trickle back at uneven rates.

This problem was anticipated by MMS and the project sampling and reporting procedure was revised accordingly. The full complement of program samples have been taken in the first two years of the program allowing adequate time for completion of all taxonomic analyses before project completion. The Annual Reports for each of the first three years are not expected to be final treatments, but rather as detailed progress reports, each one becoming more complete and comprehensive in an iterative fashion as the database becomes more complete. In the final year of the program, a comprehensive analysis and synthesis will be compiled addressing the overall program objectives which are:

- (1) To determine the abundance, structure, and distribution of animal communities in the deep-sea in the Gulf of Mexico.
- (2) To determine the hydrographic structure of the water column and bottom conditions at selected sites within the study area.
- (3) To determine and compare sedimentary characteristics at selected sites within the study area.
- (4) To relate differences in biological communities to hydrographic, sedimentary, and geographic variables.
- (5) To assess seasonal changes in deep-sea biological communities in terms of abundance, structure, animal size, and reproductive state.
- (6) To measure present levels of hydrocarbon contamination in the deep-sea sediments and selected animals prior to, and in anticipation of, petroleum resource development beyond the shelf-slope break.
- (7) To compare the biological and non-biological characteristics of the deep Gulf of Mexico with that of other temperate and subtropical deep-sea regions.

- (8) To assemble together and synthesize appropriate published and unpublished data with the results of this study, summarizing on a seasonal and spatial basis all biological, habitat, and environmental observations and parameters. Relationships between biological and non-biological factors shall be delineated through illustrations (maps, diagrams, charts, etc.) as well as descriptive text. Appropriate statistical analyses shall be performed to support the interpretations leading to the syntheses and conclusions.
- (9) To conduct an effective quality assurance and quality control program which insures that all data acquired are accurate and repeatable within standards normally required for each type of observation, measurement, or determination.
- (10) To critically review, interpret, and analyze all observations and data acquired to redefine as necessary the research program in such a way as to avoid or minimize redundancy and to optimize the efficiency of all field, laboratory, and data management operations for future deep-sea studies sponsored by MMS in the Gulf of Mexico.
- (11) To assess the need for and determine the type of studies to be conducted in future program efforts.

In light of the above discussion, the reader should not view this second Annual Report as the definitive or final treatment of the data contained herein. This report includes, physical, chemical and biological data in various stages of completion for Cruises I-III, as well as some data from Cruises IV and V relating to the presence of chemosynthetic seep communities in the northwestern Gulf of Mexico. The first Annual Report (LGL Ecological Research Associates [LGL] and Texas A&M University [TAMU] 1985) contains a detailed description of methods and background information about the slope. This information is either not repeated or only summarized in this report.

As outlined, both the Year I Report and this one are by necessity descriptive in nature. The Year III report, should, however, be

reasonably complete and will provide characterizations of individual sites by season and year with respect to their biological, hydrographic and sedimentary character. These site-specific data will be used as the basis for making inter-site comparisons and regional characterizations. Further, the Year III report will include life history data obtained for the biota and relate biological distributional patterns to physical/chemical features of the environment. The Year III report, anticipated to be completed in December 1986, will be the first real opportunity to quantitatively address the stated objectives of the overall program.



## 2.0 STUDY AREA AND METHODS

The Statement of Work for this study limited the program to waters north of 25°N having depths between 200 and 2600 m. It was further specified that stations were to be located in depths likely to delineate faunal zonation or areas of transition and that sampling stations were to be located in each of the MMS Western, Eastern, and Central Gulf of Mexico Lease Planning Areas. Guidance was also provided to all potential contractors as to the general level of research effort being anticipated by MMS, the general categories of samples to be collected and the nature of the kinds of laboratory analyses which MMS believed appropriate.

The Statement of Work for the first two years of sampling defined the allocation of work as one cruise to the Central Lease Planning Area during fall-winter of 1983, sampling of all three Lease Planning Areas during spring-summer of 1984, and intensive sampling of the Central Lease Planning Area during fall-winter of 1984. These requirements provide a context for the study area and methods descriptions provided below.

### 2.1 STUDY AREA

Our sampling strategy was organized around three, five-station transects with one located in each of the three Gulf of Mexico Lease Planning Areas (Fig. 2-1). Stations were located along each transect such that one was sited in each of Pequegnat's (1983) faunal zones found within the depth limits of the study: namely the shelf/slope transition zone (150-450 m), the archibenthal zone - horizon A (475-740 m), the archibenthal zone - horizon B (775-950 m), the upper abyssal zone (975-2250 m), and the mesoabyssal zone - horizon C (2275-2700 m). A detailed discussion of these zones and their demarcation was presented in the first Annual Report. Fine tuning of station locations within each faunal zone was also influenced by water mass distribution. The shallowest station in each transect was located towards the deeper end of the shelf/slope transition faunal zone, below the zone of Gulf Common Water in Tropical Atlantic Central Water. Each of the two stations in the archibenthal faunal zone (horizons A and B) were located in the Antarctic Intermediate Water mass whereas the two deepest stations were in the Gulf Deep Water.

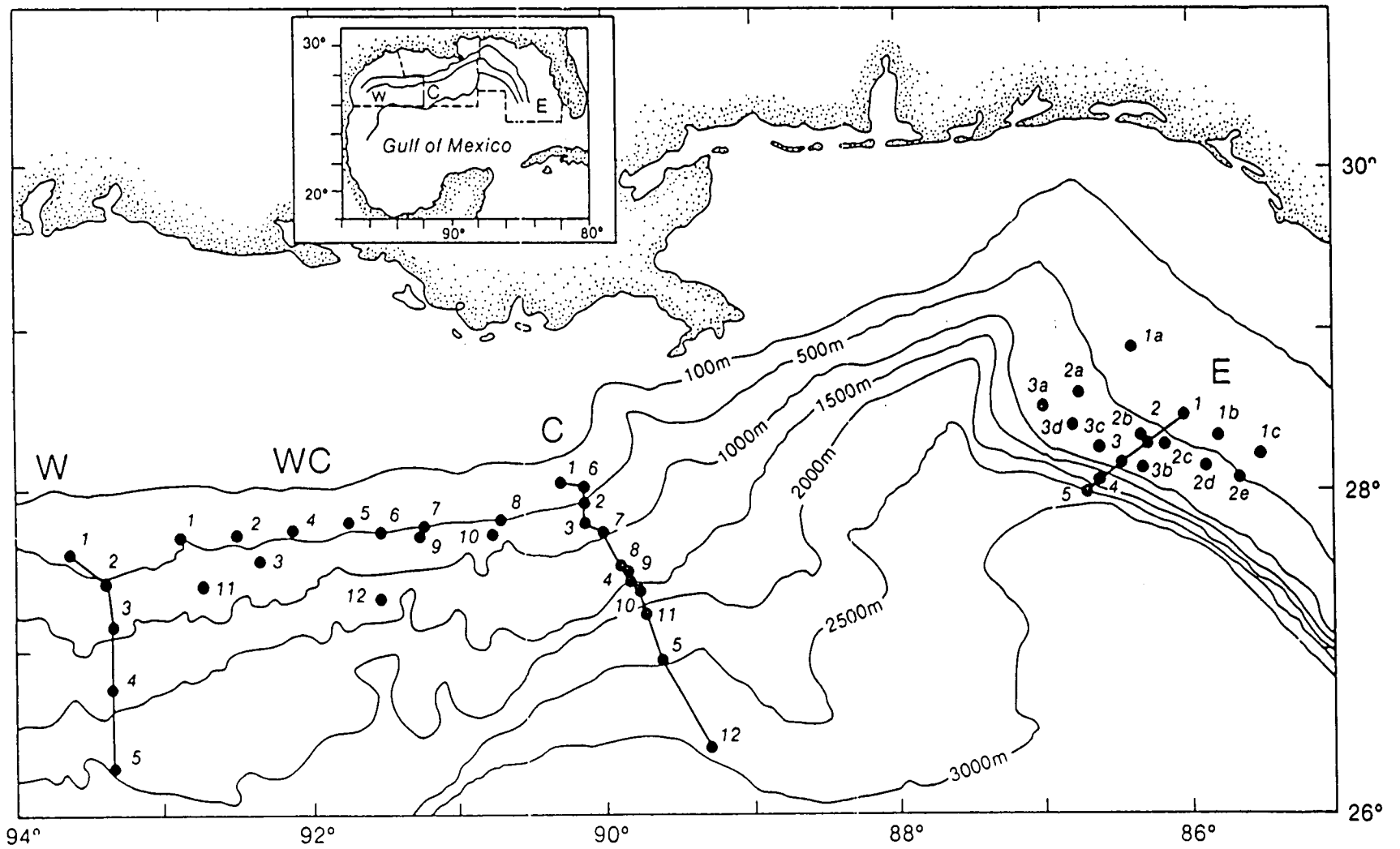


Figure 2-1. Sampling stations for Cruises I-V showing the West Transect (W), the West Central Transect (WC), the Central Transect (C) and the East Transect (E). Cruise I stations were C1-C5. Cruise II stations were W1-W5, C1-C5, and E1-E5. Cruise III stations were C1-C12. Cruise IV stations were all E stations. Cruise V stations were WC1-WC12.

Variation in water mass properties would be expected to be minimal at the deeper stations with the exception of events related to the passage of cold- and warm-core rings from the Loop Current. During Cruise III the five original central transect stations were sampled again and seven additional stations were sampled at depths that interdigitated those of the original station locations. The locations for the additional stations were chosen on the advice of the SAC so as to collect information that would more precisely determine differences in physical, chemical, and faunal features that occur with depth.

The exact location of each station is best defined by the position which was held for taking the first box-core cast. Subsequent box core and water column casts were oriented with respect to this position; and the trawl and camera transects were deployed, insofar as was possible, so that the first box core position bisected the transects. The samples were not, in fact, all taken from the exact same place, but attempting to group the sampling effort as close as possible contributed to better inter-sample comparability. In this context, station locations for Cruises I, II, and III are shown in Table 2-1. Positions and depths of the individual trawl and box core samples, and camera transects are given in Appendix Tables A-1, A-2, and A-3, respectively.

## 2.2 CRUISES

Cruises I and II were conducted on the R/V Gyre which is operated by the Department of Oceanography of TAMU for the Texas A&M Research Foundation. The first Annual Report detailed the dimensions and equipment specifications of the Gyre.

Prior to conducting each cruise, a planned sampling inventory list was prepared as part of the field logistics plan and included documentation for each replicate of each type of sample which was to be taken. The sample inventory list was prepared as the required First Level Data Inventory form. The sample inventory list was supplemented with preprinted labels for affixing collected samples, which provided an additional quality control check on completing the sampling schedule for each station. The labels had sufficient information to identify the sample to be collected as far as type, date and time of collection,

Table 2-1. Station locations for year one boxcore stations.

Station	Replicate	Depth (m)	N. Latitude	W. Longitude
<u>Cruise I</u>				
C1	1	320	28°03.7'	90°14.1'
C2	1	615	27°54.3'	90°05.9'
C3	1	845	27°49.2'	90°07.2'
C4	1	1440	27°28.3'	89°47.1'
C5	1	2470	26°58.2'	89°36.9'
<u>Cruise II</u>				
W1	1	366	27°35.0'	93°33.1'
W2	1	605	27°24.9'	93°20.5'
W3	1	860	27°10.6'	93°19.4'
W4	1	1419	26°44.1'	93°19.1'
W5	1	2524	26°17.0'	93°19.3'
C1	1	358	28°03.3'	90°15.2'
C2	1	595	27°54.4'	90°06.2'
C3	1	834	27°49.2'	90°07.1'
C4	1	1390	27°28.4'	89°46.8'
C5	1	2377	26°56.9'	89°36.7'
E1	1	347	28°27.7'	86°01.0'
E2	1	625	28°16.7'	86°15.1'
E3	1	845	28°09.6'	86°25.0'
E4	1	1330	28°04.3'	86°34.4'
E5	1	2853	28°00.4'	86°38.8'

location of collection, gear type used, preservation technique, and the organization to which it was to be transferred for analysis.

Cruise I was part of Cruise 83-G-16 of the Gyre which was conducted during the period 23 November-2 December 1983 (LGL and TAMU 1985). Cruise II was part of Gyre Cruise 84-G-4 and was accomplished over the period 3-20 April 1984. On each of the cruises, ship time was shared with National Science Foundation (NSF)-sponsored studies being conducted by Dr. Brooks of TAMU. During Cruise III sampling a large supply boat, the HOS Citation, was fitted for box coring, trawling, and benthic photographic sampling. Table 2-2 gives the vessel specifications of the HOS Citation. Biological and sediment sampling took place during 8-19 November 1984. Water column samples were collected using the Neil-Brown CTD system onboard the Gyre during 3-11 December 1984 (Table 2-3). All of the planned samples were obtained on each cruise (Table 2-4).

### 2.3 FIELD SAMPLING PROCEDURES

The field sample types collected were water column samples, box core samples of the bottom sediments, trawl samples of the megafauna and benthic photographs of the megafauna and their environment. The box core samples were divided to provide material for identification of the biota, sediment grain size determination, hydrocarbon concentrations and carbon isotope measurements.

Hydrographic data including temperature, dissolved oxygen, conductivity, nutrients and particulate organic carbon were obtained by discrete and/or continuous measurements throughout the water column at every station. A Neil-Brown Mark III CTD/Rosette/Transmissometer System was used to obtain both continuous data and at least 12 discrete water samples at selected depths. The first Annual Report describes sampling procedures and equipment specifications for each type of collection in detail.

Box core samples were taken at each station to collect samples of the macrofauna and meiofauna and to collect samples for sediment grain size determinations, carbon isotope measurements and hydrocarbon concentrations. The box coring devices measured 24.5 x 24.5 x 44 cm. Each box core contained six, 3.5 cm (i.d.) by 43.5 cm metal coring tubes



Table 2-3. Supportive water column analyses.

Parameters	Cruise I 5 Stations	Cruise II 15 Stations	Cruise III 12 Stations	Cruises I, II, & III Total
CTD Casts	5	15	5	20
Transmissometry Profiles	5	15	5	20
Dissolved Oxygen	60	180	60	300
Nutrient <sup>1</sup>				
Phosphate	60	180	60	300
Nitrate	60	180	60	300
Silicate	60	180	60	300
Nitrite	60	180	60	300
Salinity	60	180	60	300
POC <sup>1</sup>	60	180	60	300
Thermometry <sup>2</sup>	20	60	20	100

<sup>1</sup>Performed during the cruise using available facilities at no extra cost to the project.

<sup>2</sup>Up to four sets of thermometers were placed on the Rosette cast to check calibration of the CTD system.

Table 2-4. Numbers of samples collected for Cruises I-V.

Cruise Number/ Name/No. Stations	Sample Types					
	Macrofauna	Meiofauna	Grain Size	Sediment Chemistry	Trawl	Camera Transects
I/Central/5	30	60	30	30	5	5
II/Western/5	15	30	15	15	5	5
II/Central/5	15	30	15	15	5	5
II/Eastern/5	15	30	15	15	5	5
III/Central/12	66	132	66	66	11	12
IV/Eastern/16	96	192	96	96	15	16
V/West Central/12	72	144	72	72	12	12
<b>TOTAL</b>	<b>309</b>	<b>618</b>	<b>309</b>	<b>309</b>	<b>58</b>	<b>60</b>



used for obtaining separate meiofauna samples. The tubes were mounted against one side of the box and were isolated from the rest of the core by a steel septum extending the entire length of the box.

Megafauna sampling was performed using a standard 9 m, semi-balloon otter trawl with 60 cm steel doors, 3.8 cm stretch mesh and 1.3 cm cod-end mesh. Trawl times were 1 h at shallow stations ( $\leq 1300$  m) and 2+ h at deeper stations.

Benthic photography samples were obtained with the use of deep-sea camera apparatus manufactured by Benthos Inc. of North Falmouth, Massachusetts. The camera used was a Model 372 taking 800 exposures of color transparency film at every station. A 200 watt-second strobe provided artificial light for each exposure. The 28 mm camera lens provided an underwater angle of view of  $35^\circ \times 48.5^\circ$ .

#### 2.4 LABORATORY ANALYSES

Laboratory activities for physical/chemical and hydrocarbon samples included the following analyses: Sediment samples were analyzed to determine grain size, organic carbon content, carbonate carbon content, stable carbon isotopes ( $\delta^{13}\text{C}$  values), and high molecular weight (HMW) hydrocarbon content using both gas chromatography and mass spectrometry (GC/MS). Selected organism samples were analyzed to determine stable carbon isotopes ( $\delta^{13}\text{C}$  values) and HMW hydrocarbons. Laboratory procedures, summarized here, are thoroughly detailed in the first Annual Report including equipment specifications, calibration procedures and quality assurance. Laboratory activities for the biological samples included sorting, identifying, enumerating, weighing, measuring and analysis of gut contents for selected taxa, as well as benthic photographs for biota and lebensspuren. Laboratory procedures, including equipment specifications, calibration, and quality assurance, are thoroughly detailed in the first Annual Report (LGL and TAMU 1985).

Sediment grain size analyses followed procedures described in Folk (1974). Sand/gravel and silt/clay fractions were analyzed separately.

Organic carbon determinations were made using a Leco WR-12 Total Carbon System. Carbonate carbon was determined by either the difference

between total carbon and organic carbon using the above Leco system or by the direct method using infrared detection.

Stable carbon isotopic analyses were performed on freeze-dried sediment organic carbon and selected tissue samples using an isotope ratio mass spectrometer (Nuclide Corporation).

High molecular weight hydrocarbons were measured in megafauna, macrofauna and sediment samples from all stations. Sediment samples were first screened for aromatic hydrocarbons using total scanning fluorescence before detailed gas chromatography was performed. Hewlett Packard (HP) Model 5880 gas chromatographs were used. At least 10% of the samples were analyzed by gas chromatography/mass spectrometry to confirm sample component identity and distinguish any unknown compounds. Gas chromatography/mass spectrometry (GC/MS) was conducted with an HP Model 5996 GC/MS system.

Hydrocarbon analytical techniques for organism samples were similar to those for sediments. Fluorescence screening was not performed. Three tissue types were analyzed in fish specimens (liver, gonad and muscle) and only muscle tissue was analyzed in other benthic fauna (shrimp, crabs, etc.).

All biological samples involved laboratory analyses including meiofauna and macrofauna obtained from box cores, megafauna obtained from trawling and benthic photographs. Meiofauna samples were rinsed through a 300 micron seive to exclude macrofauna, the material passing through was then rinsed onto a 63-micron seive. The material retained on the 63 micron seive was then evaluated. Macrofauna samples were represented as those organisms retained on a 300 micron seive. In addition to standard sorting, identification, weighing and measuring of megafauna samples, gut contents of selected common species were analyzed for food habit information.

Benthic photography samples obtained from photographic transects were processed on a digitizing platten driven by a microcomputer. An analytical procedure was developed for this study enabling precise quantitative descriptions of benthic habitats and biota. Information obtained from photographs included: area (permitting density calculations), linear dimensions or length of bottom features or biota,

percent cover or areas of individual objects and spacial coordinates (permitting analysis of aggregation or distribution characteristics).

## 2.5 DATA MANAGEMENT AND ANALYSES

LGL is responsible for management of all data associated with the Continental Slope Study and for final transmission of these data to the National Oceanographic Data Center (NODC) in appropriate formats. Table 2-5 shows the status of all Continental Slope Study data files. The data are organized by nine file types. Note that for macrofauna there are two file types, reflecting first the rough sort data by major group, and second the final sort where the organisms are identified to the lowest possible taxon. The first Annual Report (LGL and TAMU 1985) provides details of data management tasks including equipment, software and quality assurance procedures.

In general the statistical methods utilized in this report are descriptive in nature, i.e., methods designed to estimate the size or structure of the sampled communities. In addition to estimation, clustering algorithms were used to indicate similarities in taxa or species assemblages found at various sampling sites.

The most important aspect of estimation for this report was the estimation of density from sample collections. The general ad-hoc estimate of density from data of this type is the simple calculation of the count divided by the area sampled, which is standardized to a common unit of area. The general ad-hoc estimation procedure was not always appropriate given the properties of the data obtained, particularly considering the photographic data. In Appendix A-4 we provide a review of the procedures used to estimate densities, including the exact application of the general ad-hoc procedure.

As has been noted by many authors, the appropriate clustering algorithm needs to be selected on the basis of the type of data to which it will be applied. The high variability in trawling effort may have greatly influenced the level of catch. This resulted in the need for a clustering procedure that did not depend on abundance. We selected the Dice binary similarity index for clustering following Boesch (1977).

Table 2-5. Status of data files as of 7 March, 1985.

File Name	Cruise	Received	Coded	Entered	Verified (KP, PI)	Sent To NODC	Total Records
<b>P511</b>							
Meiofauna	1	X	X	X	X	X	1047
	2	X	X	X	X		1284
	3	X	X	X	X		<u>1454</u> = 3785
<b>P512</b>							
Macrofauna	1	X	X	X	X	X	1289
	2	X	X	X	X		2062
	3	X	X	X	X		<u>983</u> = 4334
Final Sort	1	X	X	X	X		1906
	2	X	X	X	X		2884
	3	X	X	X	X		<u>1698</u> = 6484
<b>P513</b>							
Megafauna & Demersal Fish	1	X	X	X	X	X	231
	2	X	X	X	X		868
	3	X	X	X	X		<u>729</u> = 1828
Invertebrates	1	X	X	X	X		189
	2	X	X	X	X		1080
	3	X	X	X	X		<u>849</u> = 2119
<b>P514</b>							
Benthic Photography	CR 2 - complete; CR 3 - C1, C6 to C12. These data will not be sent to NODC.						
<b>P515</b>							
Ship Position and Depth	1	X	X	X	X	X	45
	2	X	X	X	X		110
	3	X	X	X	X		<u>88</u> = 243
<b>P517</b>							
Sediment	1	X	X	-	-		31
	2	X	X	-	-		63
	1	X	X	-	-		67
	3	X	X	-	-		72
	5	X	X	-	-		<u>97</u> = 330
<b>P518</b>							
Hydrocarbons							
Sediments	1-5	X	X	-	-		2950
Organisms	1-3	X	X	-	-		<u>7212</u> = 10,162
<b>P519</b>							
Hydrography	1	X	X	-	-		79
	2	X	X	-	-		188
	3	X	X	-	-		53
	4	X	X	-	-		60
	5	X	X	-	-		<u>60</u> = 440
<b>P51A</b>							
Carbon Isotopes	Nothing has been received yet.						
<b>P510</b>							
Stomachs	1	X	X	X	X		54
	2	X	X	X	X		269
	3	X	X	X	X		<u>159</u> = 482

### 3.0 ENVIRONMENTAL RESULTS AND DISCUSSION

#### 3.1 WATER COLUMN STRUCTURE

Results of hydrographic measurements for Cruises I, II, and III are shown in Appendix B-1.

The waters of the Gulf of Mexico are layered by distinct water masses that can be identified by temperature, salinity, and nutrient properties (Morrison et al. 1983). During Cruises I-III distinguishing characteristics of the water masses were usually found at expected depth ranges (Table 3-1), although the sampling depths were not always located to provide the fine-scale depth data needed to show a particular water mass characteristic. For example, at Station C5 on Cruise III identical silicate maximum values were observed at 800 and 1500 m (Table 3-1). Although these depths were outside the normal expected depth range, the wide gap between samples probably simply means the actual depth of maximum silicate concentration was not sampled.

Of the physicochemical variables that are likely to change at the depths found on the continental slope, temperature has the most effect on biota. Dissolved oxygen concentrations generally do not fall below levels capable of sustaining the needs of most organisms (MacDonald 1975). Bottom or near bottom water temperature ranges at depths sampled for biota (i.e., bottom temperature or water column temperature at depths sampled) are shown in Figure 3-1. Water temperatures were less variable with increased depth. During Cruises I-III temperature at ~300 m ranged from 10.7° to 13.6°C while at depths greater than ~1300 m the variation was less than 0.3°C (4.2-4.4°C). Typical depth profiles are shown in Figure 3-2.

The temperatures which have been shown to be important for describing or limiting biota in the deep sea are the 10 and 4°C isotherms. Bruun (1957) gives the lower limit of the epipelagic zone and the surface isotherm at the limits of the polar region as 10°C while 4°C marks the top of the bathypelagic zone. For this study the 10° isotherm was observed at depths ranging from about 350-400 m. Temperatures as low as 4.0°C were not measured, but below ~1300 m the maximum was <4.4°C. In the Atlantic

Table 3-1. Features of water masses in the Gulf of Mexico (adapted from Morrison et al. 1983) with depths of observed characteristics during Cruises I, II, and III. Depths presented are based on profiles measured at the deepest station for each transect (i.e., Stations W5, C5, and E5).

Water Mass	Feature(s) at	Approx. Depth (m)	Observed Depth (m)				
			Cruise I	Cruise II		Cruise III	
			C5	W5	C5	E5	C5
Gulf Common Water	Salinity Maximum	0- 250	100	150	150	100	75
Tropical Atlantic Central Water	Oxygen Minimum	300- 500	500	300	500	400	300
Antarctic Intermediate Water	Nitrate Maximum	500- 700	800	500	800	600	500
	Phosphate Maximum	600- 800	800	500	800	600	500
	Salinity Minimum	700-1000	800	1100	800	600	500
Caribbean Water	Silicate Maximum	1000-1200	1000	1100	800&1500	900	1899

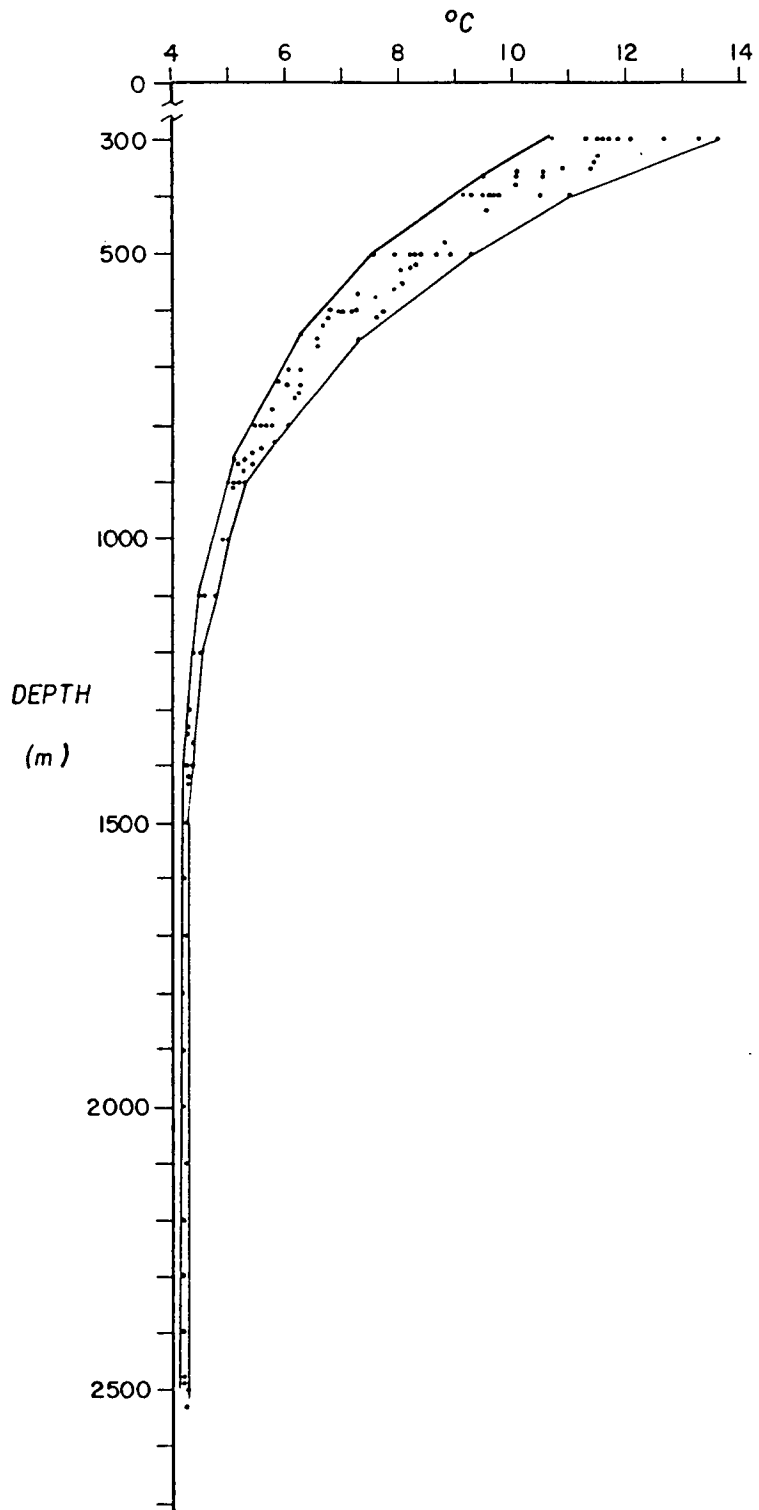


Figure 3-1. Extreme temperature recorded by depth during Cruises I-III.

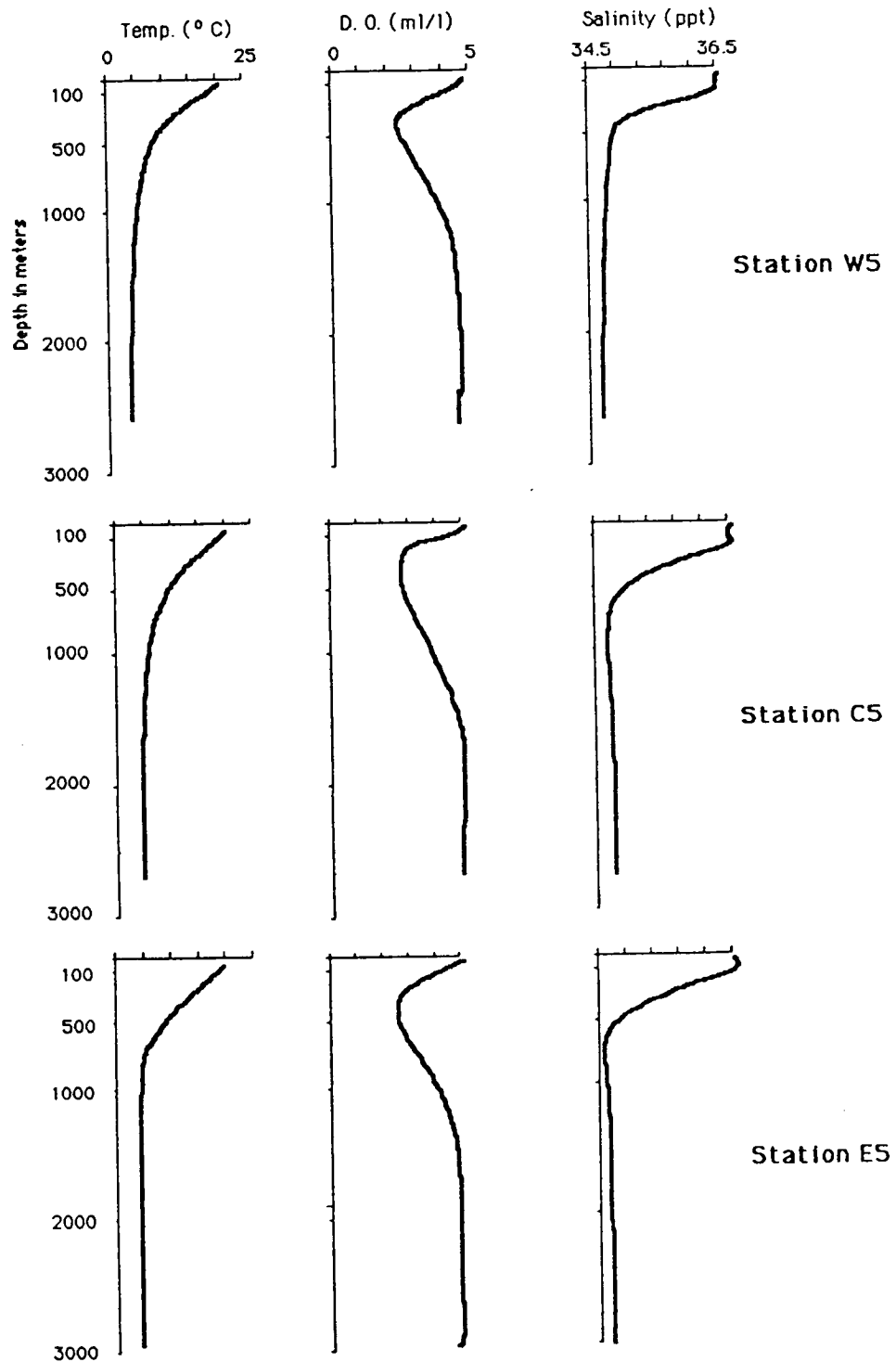


Figure 3-2. Typical depth profiles for temperature, dissolved oxygen, and salinity (Stations W5, C5, and E5 plotted).



Ocean the 4°C isotherm is reached at about 2000 m while the Indian and Pacific oceans have this isotherm at 100-1500-m deep (Bruun 1957).

### 3.2 SEDIMENT HYDROCARBONS

Sediments on the Gulf of Mexico continental slope contain a mixture of terrestrial, petrogenic and planktonic sourced hydrocarbons. The molecular-level alkane distribution was similar in all samples, but the quantitative importance of the three major sources varied with location, time of sampling, and depth. Hydrocarbon concentrations were relatively uniform across the slope given the large geographical area studied.

Concentrations ( $\mu\text{g}/\text{gm}$  dry weight of sediment) ranged from 4.0 to 94.2 for extractable organic matter, from 0.1 to 5.2 for the aliphatic hydrocarbons, and from 0.7 to 81.4 for the aliphatic unresolved-complex-mixture (Table 3-2). A comparison with previous studies presented in Table 3-3 shows that these concentrations are generally lower than reported values for Gulf of Mexico sediments, however, these baseline values are primarily for coastal and shelf sediments.

Individual hydrocarbon compounds were detected at concentrations of  $<0.01$  to  $>0.5 \mu\text{g}/\text{gm}$ . In general, the qualitative molecular-level alkane distribution was similar at all sites sampled. The dominant normal alkane between  $n\text{-C}_{15}$  and  $n\text{-C}_{22}$  was variable, whereas between  $n\text{-C}_{23}$  and  $n\text{-C}_{32}$  the dominant  $n$ -alkanes were consistently  $n\text{-C}_{29}$  or  $n\text{-C}_{31}$ . The alkane distribution in samples from the Central Transect during Cruise I are typical of all locations sampled (Fig. 3-3). Detailed sediment hydrocarbon data for each station are found in Appendices B-4, B-5, and B-6.

#### 3.2.1 HYDROCARBON SOURCES

Molecular-level and bulk parameters can be used to estimate the relative importance of hydrocarbon sources at a given location. These parameters are based on the premise that a hydrocarbon source has a unique "fingerprint", i.e., a recognizable suite of compounds. In nature, however, few unique end-members occur. Several diagnostic indicators were monitored to better understand the dynamics of hydrocarbons in Gulf of Mexico slope sediments (see Table 3-4).

Table 3-2. The ranges and averages for selected hydrocarbon parameters in Gulf of Mexico continental slope sediments ( $\mu\text{g}/\text{gm}$  dry weight of sediment).

Cruise	Location (Transect)	Extractable Organic Matter (ppm)	Aliphatic Hydrocarbons (ppm)	Aliphatic Unresolved-Complex-Mixture (ppm)
I	Central	28.4 (13.9 - 61.3) <sup>1</sup>	1.6 (1.3 - 2.0)	23.3 (19.3 - 29.8)
II	Central	21.7 (18.0 - 25.2)	1.7 (1.6 - 1.8)	8.9 (6.0 - 14.0)
	Western	26.0 (14.0 - 55.2)	1.1 (0.8 - 1.3)	11.1 (5.2 - 11.4)
	Eastern	8.6 (7.6 - 10.9)	0.7 (0.5 - 1.0)	5.4 (3.2 - 7.3)
III	Central	18.1 (4.0 - 44.4)	1.4 (0.6 - 4.6)	9.7 (4.4 - 17.4)
IV	West/Central	30.0 (17.7 - 94.2)	0.9 (0.4 - 5.2)	16.8 (4.2 - 81.4)
V	Eastern	7.2 (4.7 - 13.4)	0.2 (0.1 - 0.4)	2.0 (0.7 - 5.0)

<sup>1</sup>Ranges in values.

Table 3-3. Summary of Gulf of Mexico sediment hydrocarbon analyses.

Location	Concentrations in $\mu\text{g g}^{-1}$		Predominant Source	Reference
	Total HC	Saturated HC		
Texas/Louisiana - Coastal	20-190		B/P	Smith, Jr. 1952
Texas/Louisiana - Coastal	Low Concentrations <sup>1</sup>		B	Stevens et al. 1956
Gulf of Mexico - Coastal	Biogenic Waxes <sup>2</sup>		B	Bray and Evans 1961
Florida (Bay) - Sandy Sediments	Ave.=4.4 <sup>2</sup>	Ave.=2.0 <sup>2</sup>	B	Palacas et al. 1972
	- Muddy Sediments Ave.=86.0 <sup>2</sup>	Ave.=30.0 <sup>2</sup>	B	
N.E. Coast - Sandy Sediments	0.2-10.0 <sup>2</sup>	0.1-3.8 <sup>2</sup>	B(P)	Palacas et al. 1976
	Ave.=6.25	Ave.=1.4		
STOCS - Coastal	Very low levels <sup>2</sup>		B/(P)	Palacas et al. 1976
STOCS - Coastal (Before, during and after drilling activities)	0.22-5.60 <sup>2</sup>	(0.1-0.5) <sup>2</sup>	B/(P)	Parker et al. 1976
	Ave.=1.14	Ave.=0.2		
Texas/Louisiana - Coastal Banks	0.02-0.80 <sup>2</sup>		B	Parker 1978
MAFLA - Nearshore Florida (<40 m)	Ave.=1.90 <sup>2</sup>	0.29-1.60 <sup>2</sup>	B	Boehm 1979
		Ave.=0.86		
	- >40 m Florida	Ave.=1.39 <sup>2</sup>	0.29-1.89 <sup>2</sup>	B(P)
- Mississippi/Alabama Shelf	Ave.=1.61 <sup>2</sup>	0.28-2.89 <sup>2</sup>	B/P	
		Ave.=1.1		
Freeport, Texas - Coastal	0.9-45 <sup>2</sup>	0.1-2.4 <sup>2</sup>	B	Slowey 1980
	Ave.=39.7	Ave.=0.71		
Texas/Louisiana - Coastal	5.71-87.2 <sup>2</sup>	3.13-49.5 <sup>2</sup>	B/P	Nulton et al. 1981
	Ave.=39.7	Ave.=21.4		
Texas Shelf	Ave.=1.3 <sup>2</sup>		B	Lytle and Lytle 1979
Florida Coastal (<60 m)	Ave.=3.1 <sup>2</sup>		B	Gearing et al. 1976
W of Mississippi R. Coastal (<60 m)	Ave.=11.7 <sup>2</sup>		B/P	Gearing et al. 1976

<sup>1</sup>Method - gravimetry (expressed as a percentage of the total organic extract recovered from the silica gel).

<sup>2</sup>Method - GC, GC/MS.

<sup>B</sup>Biogenic.

<sup>P</sup>Petrogenic.

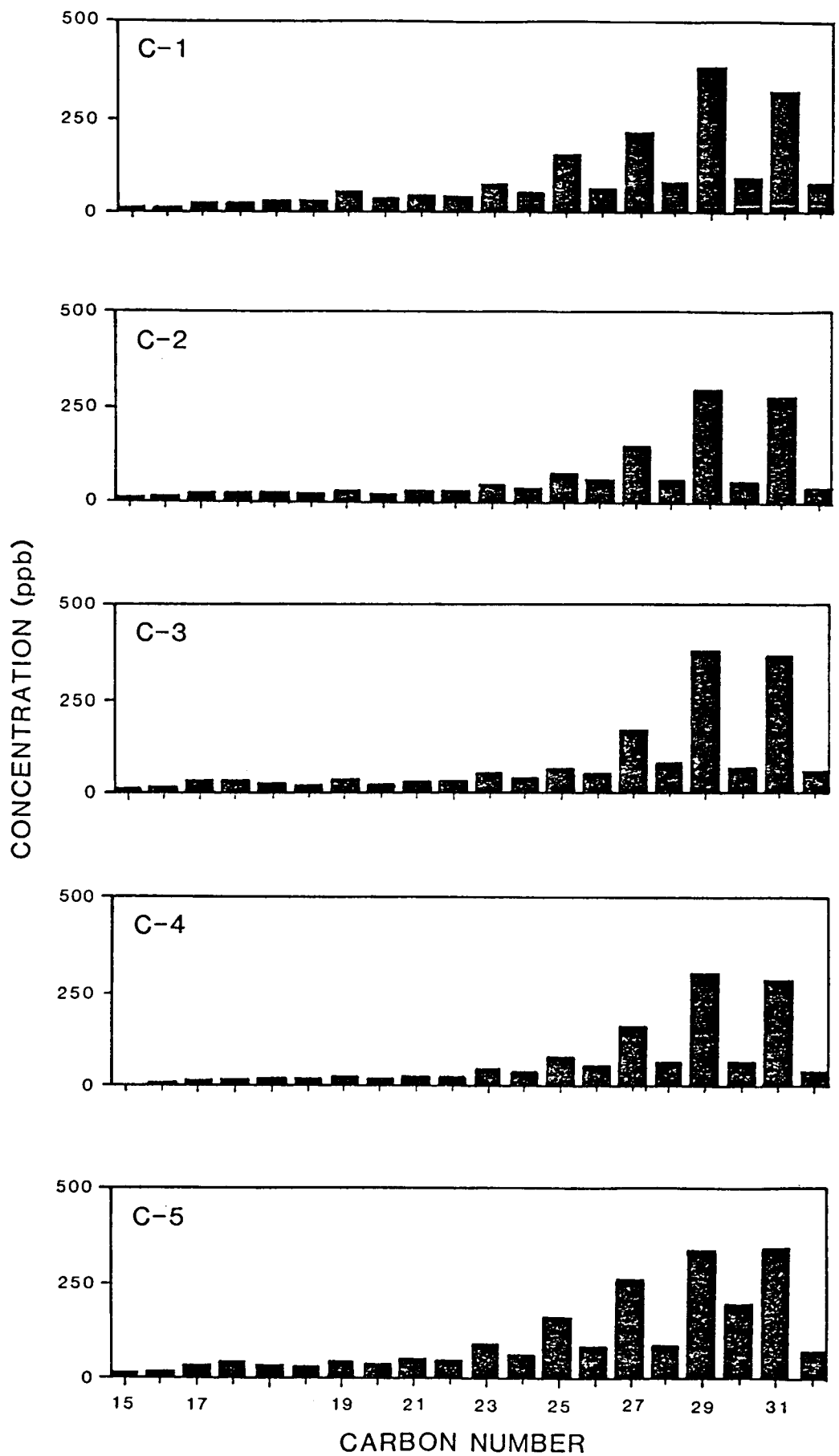


Figure 3-3. Molecular level alkane distributions for sediments from the central transect during Cruise I (ng/gm dry wet of sediment, ppb ).

Table 3-4. Suggested molecular-level indicators of specific hydrocarbon sources to sediments on the Gulf of Mexico continental slope.

Indicator Compound	Source	Abbreviation
n-C <sub>15</sub> , 17, 19 and Pristane	Planktonic/Petroleum	PL-1
n-C <sub>16</sub> , 18, 20 and Phytane	Petroleum/(Planktonic?)	PE-Lo
n-C <sub>25</sub> , 27, 29, 31	Land/(Petroleum)	TERR
n-C <sub>24</sub> , 26, 28, 30	Petroleum/(Biogenic)	PE-Hi
Unresolved-Complex-Mixture	Petroleum/(Biogenic?)	UCM

Certain assumptions need to be understood in order to properly evaluate these distributions as indicators of hydrocarbon sources. Plankton generally produce a simple mixture of hydrocarbons, including n-C<sub>15</sub>, n-C<sub>17</sub>, n-C<sub>19</sub> and pristane, so the presence of these compounds can indicate a planktonic hydrocarbon source (PL-1). Petroleum also contains these compounds, but usually also contains comparable amounts of the alkanes n-C<sub>16</sub>, n-C<sub>18</sub>, n-C<sub>20</sub>, and phytane as well. Thus a low molecular weight petroleum indicator (PE-Lo) can be used to assess the petroleum component of the planktonic indicator. To make this calculation we assume that the contribution of petroleum to each indicator is equal; therefore the planktonic component can be inferred as the difference between PL-1 and PE-Lo. Straight chain biowaxes with n-C<sub>25</sub>, n-C<sub>27</sub>, n-C<sub>29</sub>, and n-C<sub>31</sub> alkanes have been used extensively as an indicator of terrestrial or land-derived input. As such, the sum of these four normal alkanes can be used to indicate the terrestrial (TERR) hydrocarbon component. As with the planktonic indicator, these normal alkanes can also have a source in petroleum. Again, in general, petroleum also contains a near equal amount of the even alkanes n-C<sub>24</sub>, n-C<sub>26</sub>, n-C<sub>28</sub>, and n-C<sub>30</sub> (PE-Hi). As in the planktonic indicator, the terrestrial component can be estimated by subtracting the PE-Hi from the TERR concentration. Plants themselves can also contain significant amounts of indigenous even carbon alkanes; thus this type of indicator provides a measure of maximum petroleum contribution and a minimum terrestrial contribution over this molecular weight range. In summary the planktonic input is estimated as [(PL-1)-

(PE-Lo)], the terrestrial input as [TERR)-(PE-Hi)], and the petroleum input as [(PE-Lo)+(PE-Hi)]. These parameters are used to assess hydrocarbon inputs and not bulk organic matter since hydrocarbons represent only a small fraction of the total organic carbon present in a sediment.

These parameters, with the above mentioned limitations, can be used to study the hydrocarbon dynamics on the continental slope as a function of water depth, location, and time of sampling. Also included is the evaluation of parameters such as the unresolved-complex-mixture (UCM), an indicator of petroleum input; the carbon preference index (CPI), an indicator of the relative amounts of odd and even normal alkanes; and bulk sediment characteristics.

### 3.2.2 AREAL DISTRIBUTION

Cruise II assessed the distribution of sediment hydrocarbons on transects from the central, western, and eastern Gulf of Mexico continental slope. Extractable organic matter (EOM) is a composite of biogenic and petroleum related material. Extractable organic matter concentrations were generally lowest on the Eastern Transect and nearly equal on the Western and Central Transects, with the exception of Station W1 (Fig. 3-4). The aliphatic unresolved-complex-mixture (UCM), a petroleum indicator, was similar over all three transects though slightly elevated in Central Transect sediments (Table 3-2). The elevated EOM at Station W1 is due to an increased UCM i.e., petroleum component.

The amount of terrestrial hydrocarbons decreased from the Central to the Western to the Eastern Transect (Figs. 3-5 and 3-6). Terrestrial hydrocarbon concentrations, as indicated by the sum of  $n\text{-C}_{25}$ ,  $n\text{-C}_{27}$ ,  $n\text{-C}_{29}$ , and  $n\text{-C}_{31}$  (TERR) concentrations, are relatively uniform with water depth on the Central and Western Transects; whereas terrestrial hydrocarbons increase with water depth on the Eastern Transect. The influence of the land- and/or river-derived material is readily apparent in all three regions and accounts for a majority of the GC-resolvable alkanes.

In general, planktonic inputs accounted for less than 10% of the GC-resolvable alkanes. Sediment biogenic hydrocarbons on the slope were

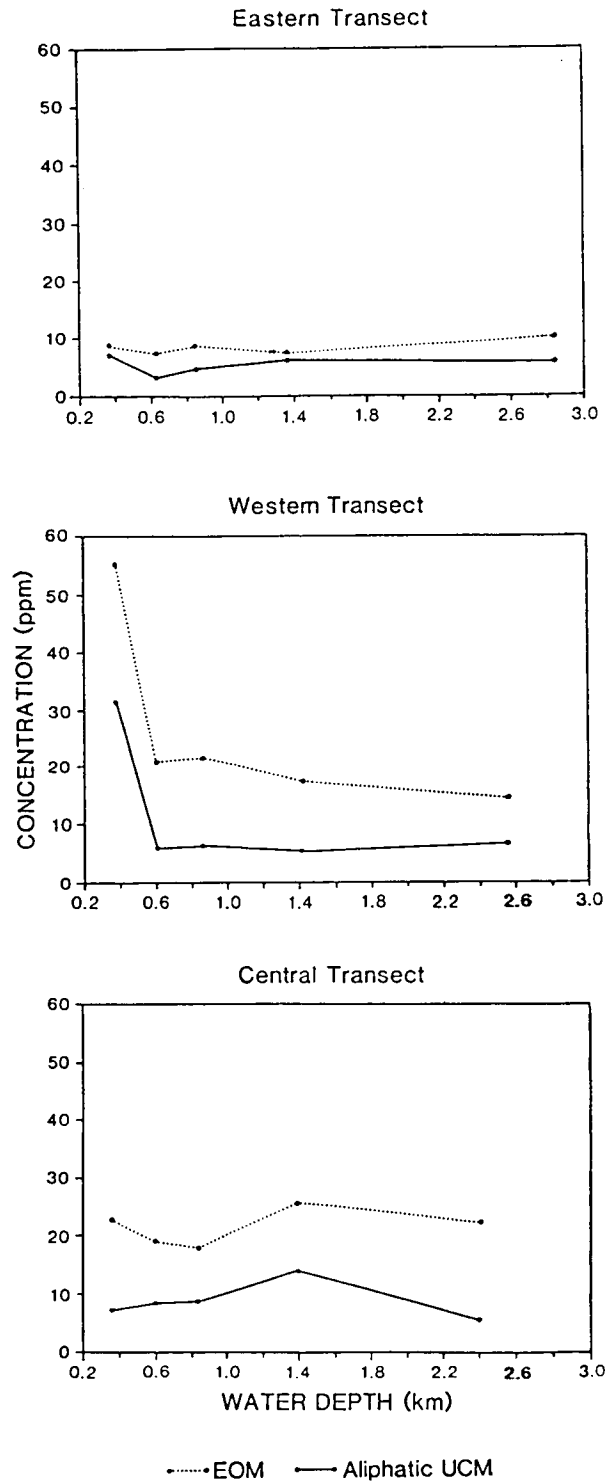


Figure 3-4. Variation in extractable organic matter (EOM) and the aliphatic unresolved complex mixture along transects in the eastern, western, and central Gulf of Mexico continental slope.

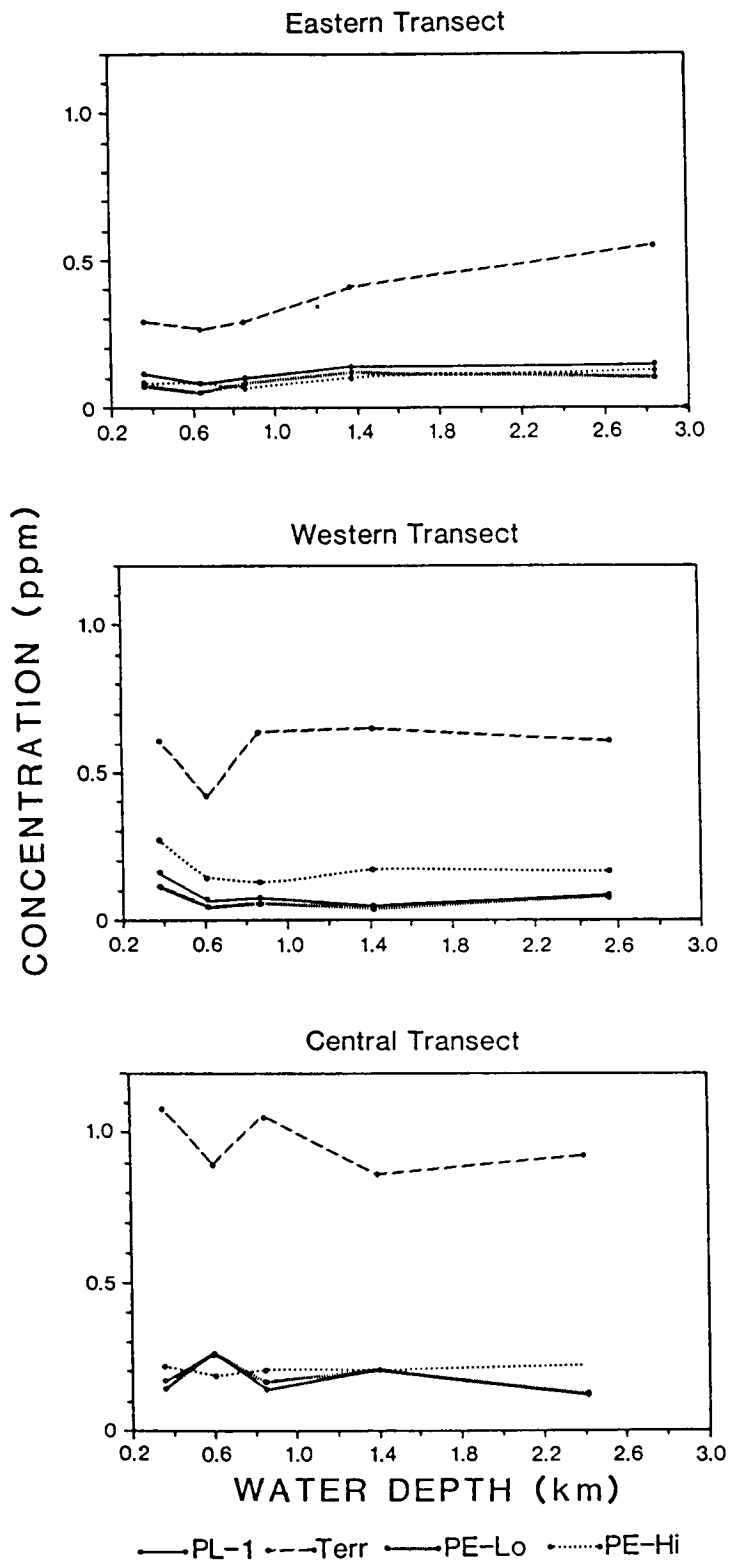


Figure 3-5. Variation in hydrocarbon source parameters along transects in the eastern, western, and central Gulf of Mexico continental slope (for definition of source parameters see Table 3-4).



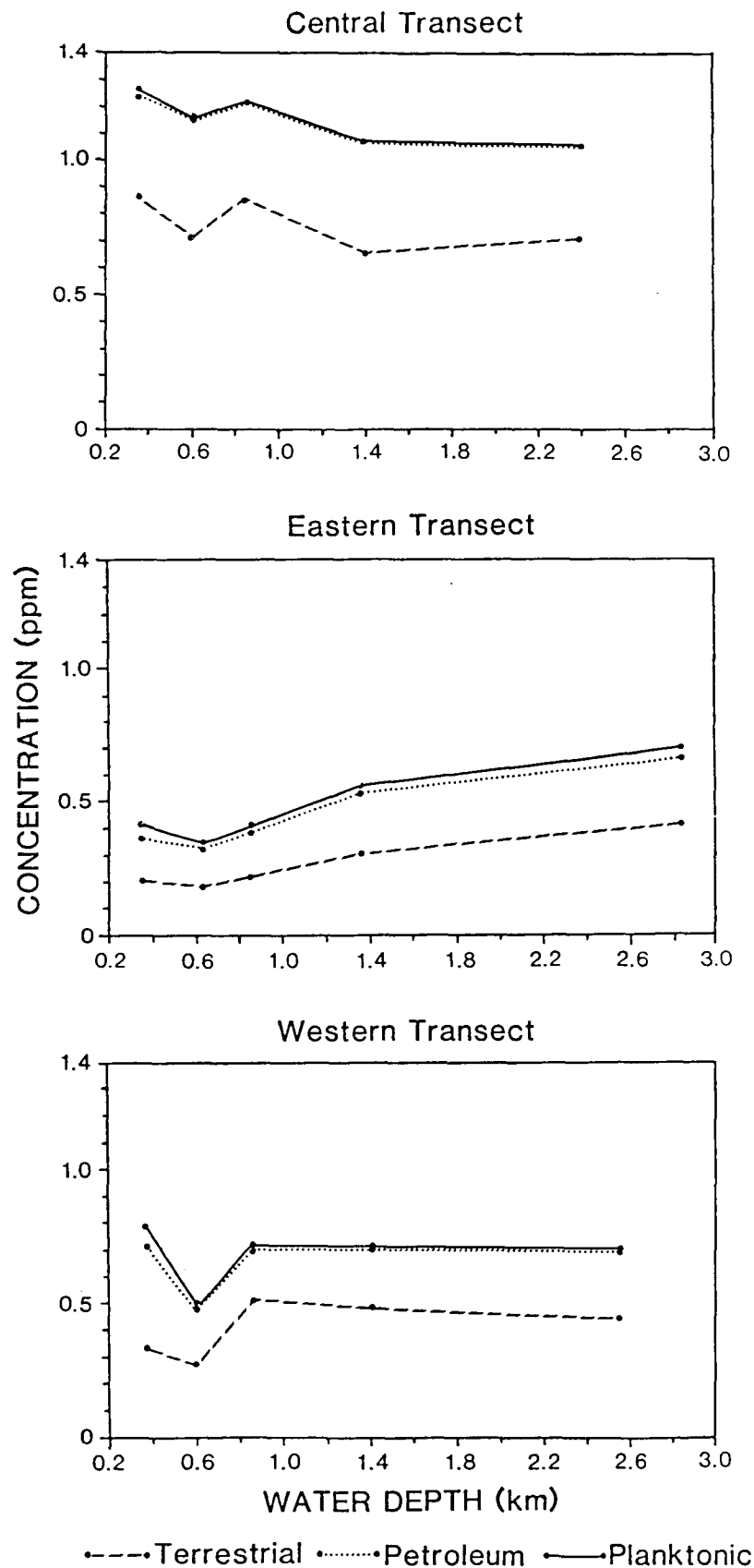
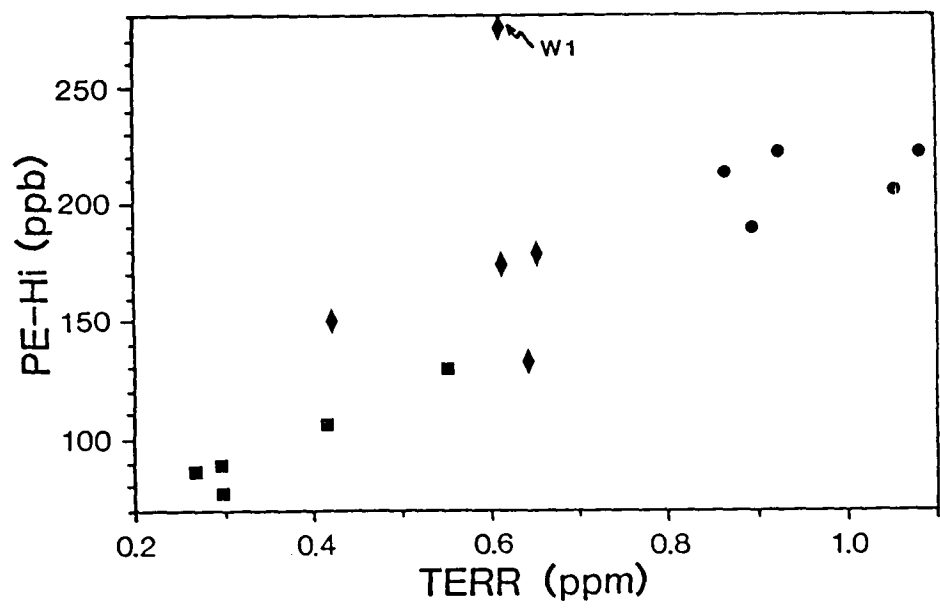
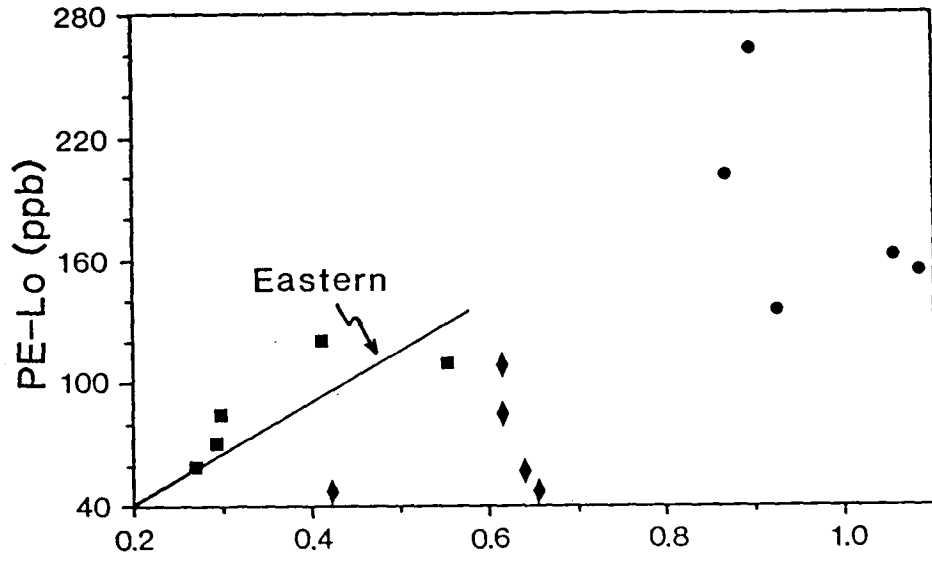


Figure 3-6. Variation in planktonic, terrestrial, and petroleum hydrocarbons along three transects presented as a cumulative concentration (i.e., the first concentration plotted is terrestrially sourced hydrocarbons, second is terrestrial + petroleum, and third is terrestrial + petroleum + planktonic).

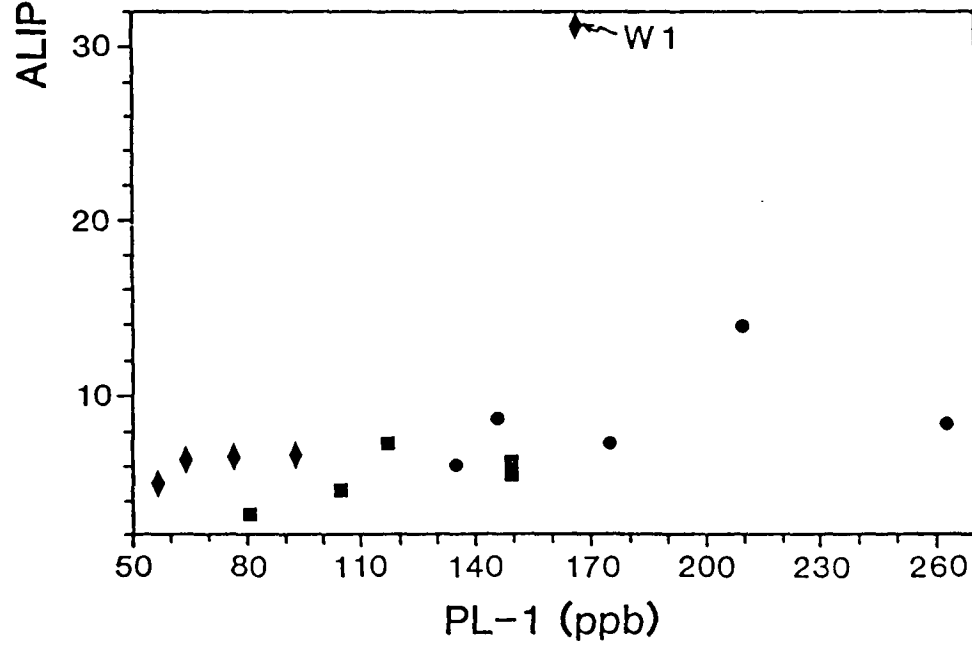
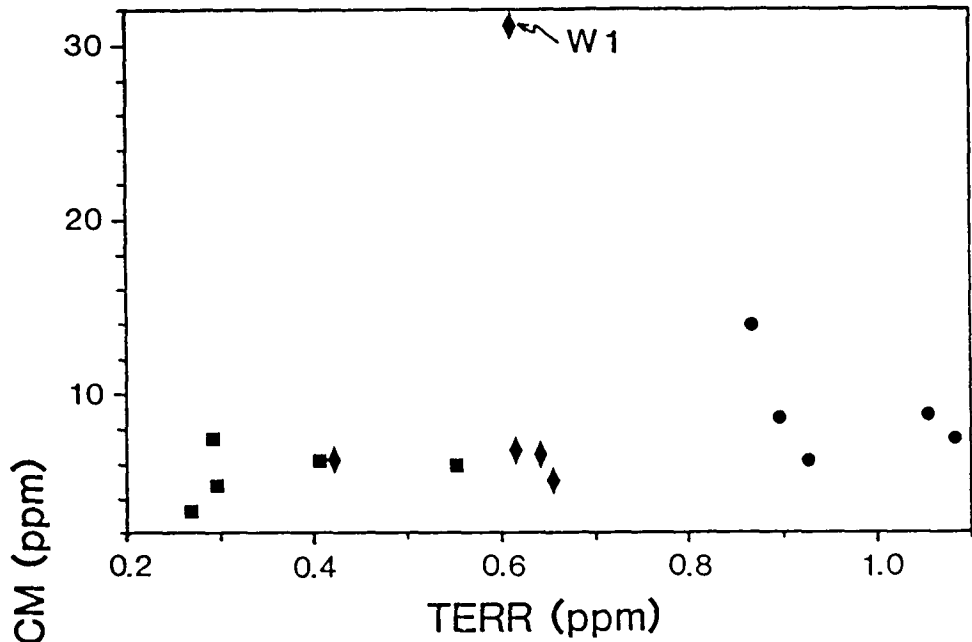
dominated by the more resistant terrestrial components and the degree of dominance was a function of proximity to the Mississippi River and delta. The steepness of the slope and the prevailing currents affect the observed distributions as well. Planktonic inputs were low and often difficult to discern on the Central and Western Transects (Figs. 3-5 and 3-6). The planktonic input was generally higher at the shallower stations of these two transects. The low planktonic hydrocarbon concentrations on the Central and Western Transects may be due to a high sedimentation rate and/or dilution with riverine material. On the Eastern Transect the planktonic input was discernible and relatively constant with depth.

Petroleum inputs, measured both by alkane parameters and the unresolved-complex-mixture, were detected at all sites (Figs. 3-5 and 3-6). In general, petroleum input was greatest on the Central Transect, with lesser amounts at the Western and Eastern Transects. The maximum estimate of petroleum-sourced hydrocarbons indicates relatively low concentrations at all locations. To determine if the petroleum hydrocarbons detected were due to transported terrestrial particles (most likely by mass movement and turbidity flows after initial deposition near the river's mouth) or to upward migration from deeper reservoired petroleum, the petroleum indicators were compared with the terrestrial and planktonic indicators (Fig. 3-7). These comparisons suggest a dual source for the sediment petroleum hydrocarbons. Low molecular weight hydrocarbons (PE-Lo) correlate with a terrestrial input on the Eastern Transect, but not on the Central and Western Transects. The higher molecular weight petroleum indicator (PE-Hi) strongly correlates with the terrestrial indicator (TERR). In this case this simply reflects the large biogenic contribution to PE-Hi indicator and cannot be used to infer source. From this cross-plot, the ratio of the two parameters give a carbon preference index of  $\sim 4.3$ , indicating that most of the PE-Hi in these samples is of biogenic origin. An estimate of the amount of petroleum hydrocarbons is also provided by the UCM (Fig. 3-8). The UCM is generally independent of the planktonic or terrestrial input and suggests a source such as upward migration from deeper reservoirs on the Central and Western Transects. An anomaly was seen at Station W1, which contains petroleum hydrocarbon concentrations that were significantly elevated in comparison with other Western Transect stations.



• Central    ■ Eastern    ◆ Western

Figure 3-7. The relationship between alkane petroleum indicators and a terrestrial indicator (for definition of the indicators see Table 3-4).



• Central    ■ Eastern    ◆ Western

Figure 3-8. The relationship between the aliphatic unresolved complex mixture (a petroleum indicator) and the planktonic and terrestrial alkane indicator (see Table 3-4).

This attempt to correlate petroleum and terrestrial sediment inputs assumes that the ratio of petroleum to terrestrial hydrocarbons transported to a location is constant with time, which may or may not be true. However, extensive natural hydrocarbon seepage has been documented on the Gulf of Mexico continental slope, further supporting natural seepage as a major petroleum hydrocarbon input to Gulf of Mexico continental slope sediments. It is also evident that some fraction of the petroleum hydrocarbons are transported to the slope by river/land-derived particles most likely by secondary movement such as slumps and/or turbidity flows.

### 3.2.3 TEMPORAL VARIATIONS

Cruises I (November 1983), II (April 1984), and III (November 1984) sampled the Central Transect in an attempt to document variability between samplings. The distribution of EOM and aliphatic UCM during these three sampling cruises is shown in Figure 3-9. On an average, the aliphatic UCM, a petrogenic indicator, was highest on Cruise I (Fig. 3-9, Table 3-2). UCM concentrations during Cruise II and at the shallower stations (<1500 m) of Cruise III, were similar. During Cruise III the UCM is significantly higher at stations deeper than 1500 m. Molecular-level indicators were similar along the Central Transect during Cruises I and II (Figs. 3-10 and 3-11).

Significant variability with depth was observed during Cruise III sampling. Shallower stations (<1500 m) during Cruise III are lower in hydrocarbons than the two previous samplings, which suggests dilution by inorganic material. Compared with Cruises I and II, terrestrial hydrocarbons are significantly reduced over the entire transect. The deepest stations (>1500 m) on Cruise III have elevated levels of petroleum hydrocarbons. This is substantiated by the hydrocarbon-source parameters previously discussed (Figs. 3-10 and 3-11). Examination of carbon preference index (PI) distributions and gas chromatograms suggest the presence of relatively fresh petroleum hydrocarbons, probably from oil seepage, at the deepest stations (Fig. 3-12). Station C7 also has a low CPI, suggesting anomalously high petroleum hydrocarbons. These differences between samplings most likely represent the patchiness of

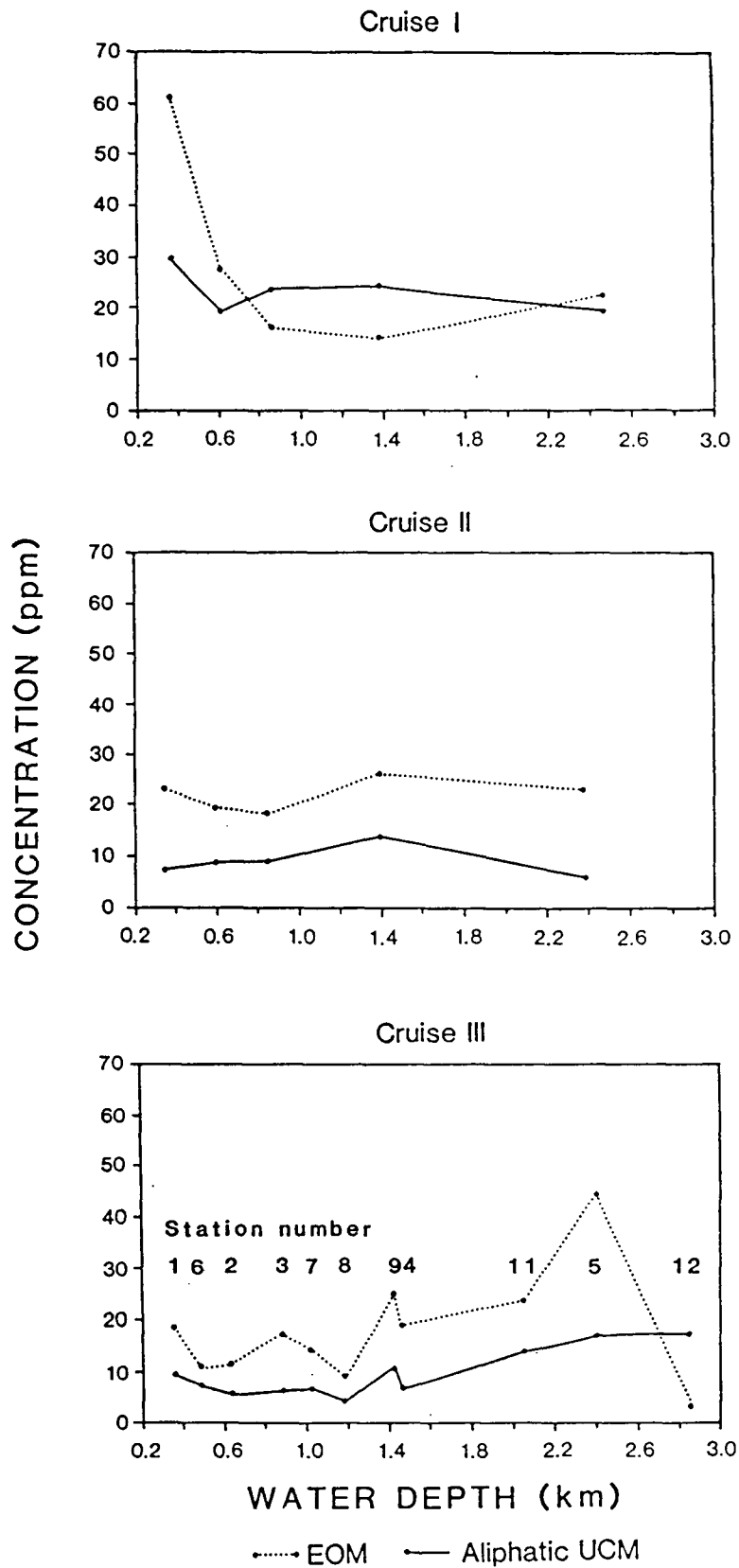


Figure 3-9. Variations in extractable organic matter and the aliphatic unresolved complex mixture during three samplings of the central transect.

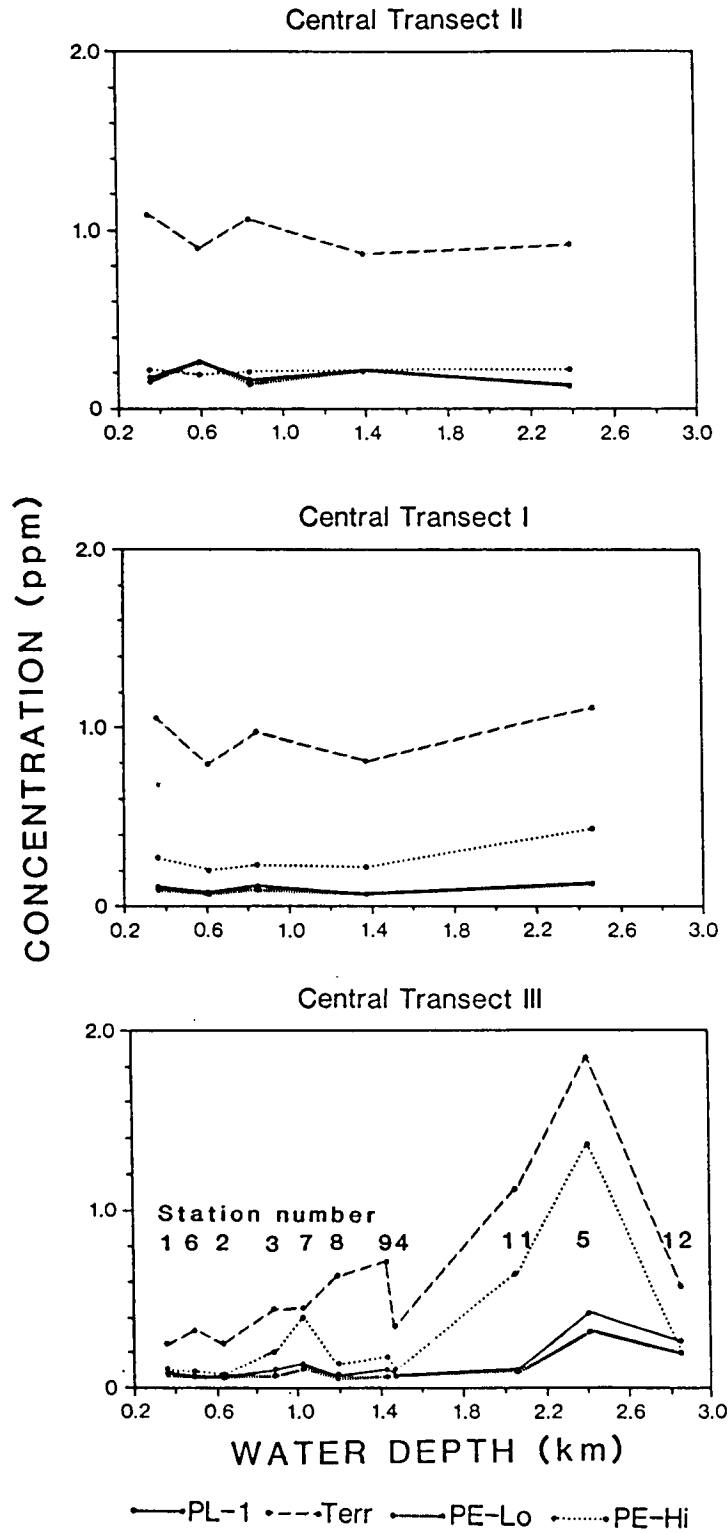


Figure 3-10. Variations in hydrocarbon source parameters during three samplings of the central transect (for definition of source parameters see Table 3-4).

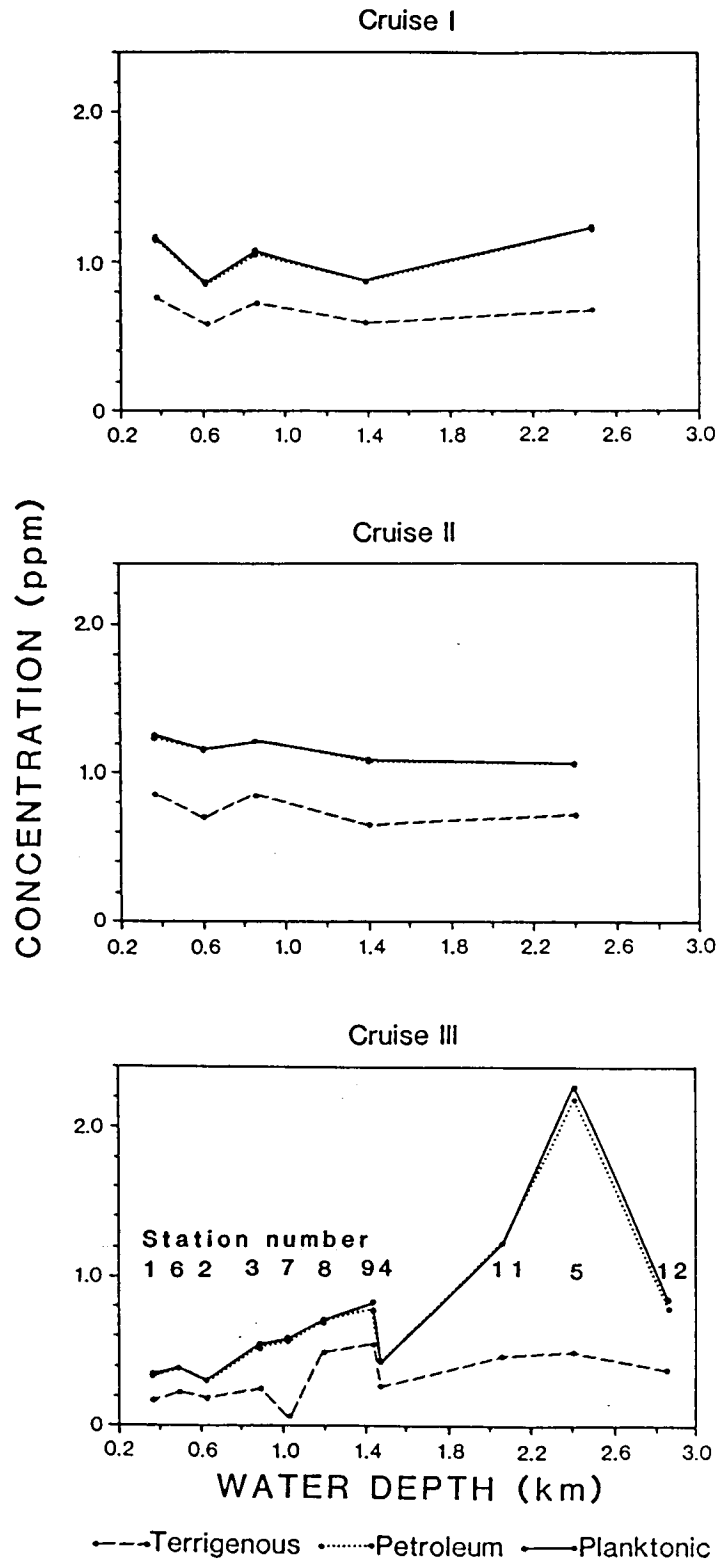


Figure 3-11. Variation in plankton, terrestrial and petroleum hydrocarbons during three samplings of the central transect presented as a cumulative concentration (for an explanation see Figure 3-6).



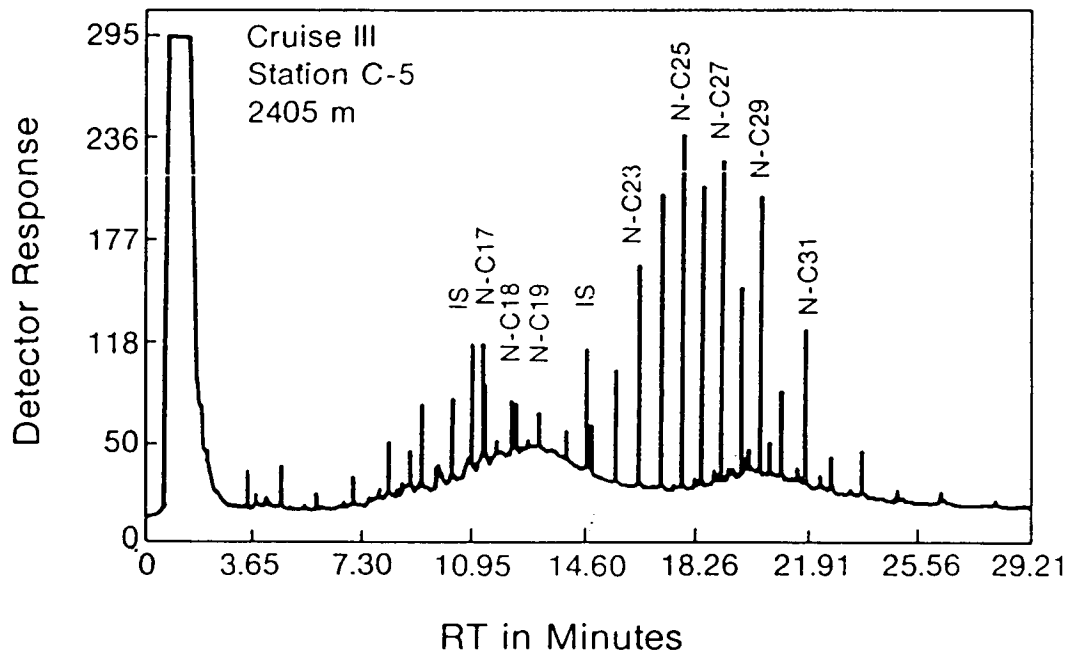
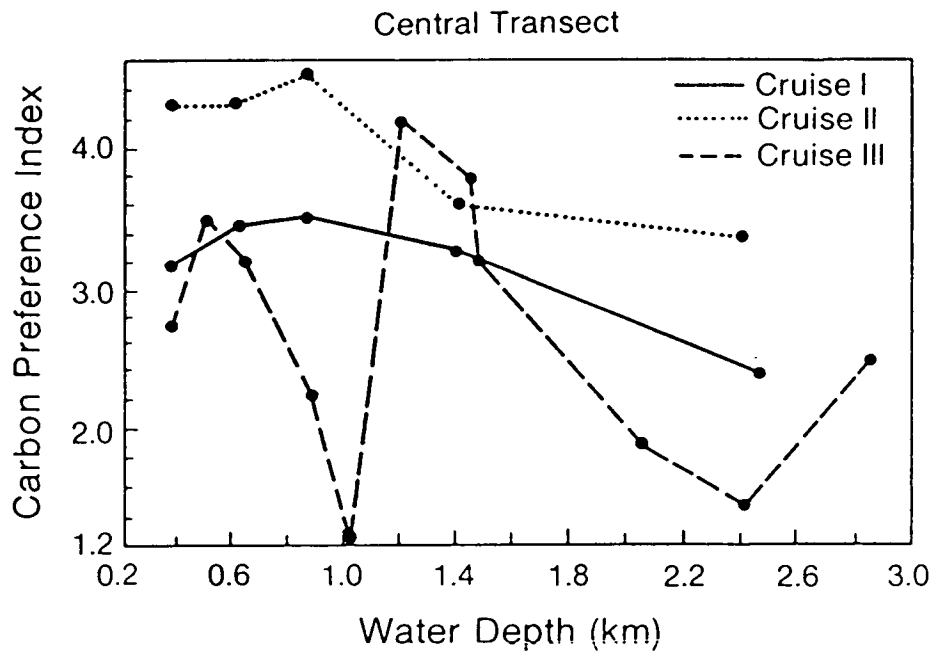


Figure 3-12. Variation in the carbon preference index (CPI) as a function of depth along the Central Transect during Cruise III and a representative fused silica gas chromatogram of the aliphatic hydrocarbons from Station C5, Cruise III (CPI =  $[\sum n-C_{23,25,27,29,31}] / [\sum n-C_{24,26,28,30,32}]$ ).

hydrocarbon distributions rather than a temporal change such as an influx of hydrocarbons.

#### 3.2.4 VARIABILITY ALONG ISOBATHS

Cruise V in the eastern Gulf of Mexico occupied stations along three isobaths to assess lateral variation in the measured parameters. Hydrocarbon parameters are summarized in Table 3-5. Bulk and molecular-level hydrocarbon parameters were low during this sampling and represent some of the lowest values measured during this study (Table 3-2), as such the variability observed along this transect is most likely a maximum. These sampling sites were also chosen to contrast sediment texture which will also contribute to the high degree of variability of hydrocarbon parameters observed. (Detailed sediment texture data for Cruises I-V may be found in Appendix B-2.) The aliphatic UCM and total EOM varied by factors of 1.7 to 7.6 at a given depth. Molecular-level indicators (i.e., individual component sums) varied by a factor of 2.0 to 7.6 along a given isobath. This data suggests that, at these low concentrations, hydrocarbons are as variable along isobaths as they are with water depth. This again emphasizes the patchy nature of hydrocarbon distributions. Bulk sediment parameters varied by as much as a factor of 3 along an isobath illustrating the variations observed in sediment texture.

Samples along isobaths in the central and western Gulf were also taken. Stations from Cruises I, II, III and IV at ~350 m are compared in Table 3-6. The variability in hydrocarbon parameters reflecting terrestrial input show the greatest variation, i.e., as much as 40 fold. The planktonic indicators are also highly variable, most likely due to dilution with terrestrially sourced material. Bulk parameters such as clay content varied by a factor of 2 and sand content varied from 0.5 to 36.6% at these six locations. These variations reflect the substantial influence of river/land derived material. Three samples from Cruise IV along the 550- and 750-m isobath were relatively uniform. The lateral extent covered at these isobaths was small relative to the 350-m isobath sampling. Bulk parameters were also uniform along these two isobaths.

Detailed sediment hydrocarbon data for each station sampled during Cruises I-V may be found in Appendices B-4, B-5, and B-6.

Table 3-5. Variability in hydrocarbon parameters along isobaths - eastern Gulf of Mexico.

Depth (m) Parameter	Variable Ranges		
	342-383 n=4	619-630 n=6	819-859 n=5
Total EOM (ppm)	5.8 - 13.4 ( 9.7) <sup>1</sup>	4.7 - 9.9 ( 6.8)	4.9 - 8.2 ( 5.8)
Aliphatic (ppm)	0.7 - 5.0 ( 3.0)	0.5 - 3.8 ( 1.8)	0.7 - 3.1 ( 1.7)
PL-1 <sup>2</sup> (ppb)	11.5 - 94.1 (54.3)	8.1 - 59.1 (29.9)	6.9 - 44.8 ( 23.4)
TERR <sup>2</sup> (ppb)	36.0 - 74.0 (55.9)	55.9 - 119.8 (78.6)	23.4 - 147.5 (121.6)
PE-Lo <sup>2</sup> (ppb)	13.3 - 100.7 (56.2)	13.5 - 39.8 (21.1)	11.0 - 27.3 ( 18.8)
PE-Hi <sup>2</sup> (ppb)	14.4 - 30.3 (22.3)	20.4 - 53.1 (33.1)	17.5 - 77.6 ( 48.6)
Terrigenous <sup>3</sup> (ppb)	21.6 - 49.8 (33.6)	24.0 - 66.7 (45.4)	5.9 - 99.5 ( 72.8)
Petroleum <sup>3</sup> (ppb)	33.5 - 118.3 (78.5)	34.6 - 67.9 (54.3)	28.5 - 103.5 ( 67.4)
Planktonic <sup>3</sup> (ppb)	0.0 - 2.8 ( 0.7)	0.0 - 20.1 ( 9.5)	0.0 - 17.5 ( 7.3)

<sup>1</sup> Average.

<sup>2</sup> PL-1 =  $\Sigma n-C_{15, 17, 19}$  and Pristane; TERR =  $\Sigma n-C_{25, 27, 29, 31}$ ; PE-Lo =  $\Sigma n-C_{16, 18, 20}$  and Phytane; PE-Hi =  $\Sigma n-C_{24, 26, 28, 30}$ .

<sup>3</sup> Terrigenous = (TERR) - (PE-Hi); Petroleum = (PE-Lo + PE-Hi); Planktonic = (PL-1) - (PE-Lo).

Table 3-6. Variability in hydrocarbon parameters along isobaths - west/central Gulf of Mexico.

Depth Parameter	298-371 <sup>1</sup> n=6	547-550 <sup>2</sup> n=3	748-759 <sup>3</sup> n=3
Total EOM (ppm)	15.9 - 61.3 ( 34.5)	17.4 - 23.9 ( 20.6)	17.0 - 57.9 ( 30.9)
Aliphatic UCM (ppm)	6.0 - 31.4 ( 15.6)	6.9 - 7.9 ( 7.6)	5.6 - 11.9 ( 8.4)
PL-1 (ppb)	36.3 - 174.9 (121.8)	47.4 - 65.3 ( 56.4)	50.0 - 68.0 ( 59.9)
TERR (ppb)	93.4 - 1082.8 (546.7)	109.8 - 273.1 (201.2)	169.7 - 180.5 (176.3)
PE-Lo (ppb)	36.2 - 154.5 (100.3)	39.1 - 52.5 ( 43.7)	43.4 - 48.9 ( 45.2)
PE-Hi (ppb)	70.9 - 279.7 (172.2)	80.6 - 121.9 ( 99.4)	48.0 - 96.6 ( 64.8)
Terrigenous (ppb)	22.5 - 860.6 (374.5)	29.2 - 252.2 (101.7)	83.9 - 130.8 (111.5)
Petroleum (ppb)	123.3 - 388.0 (127.4)	119.7 - 161.5 (143.2)	91.4 - 140.0 (110.1)
Planktonic 9ppb)	0.1 - 57.7 ( 21.5)	4.0 - 26.2 ( 12.7)	6.6 - 19.1 ( 14.7)

<sup>1</sup>Cruises I, II and III, Stations E1 and W1; Cruise IV, Stations WC01 and WC02.

<sup>2</sup>Stations WC02, WC04, WC08.

<sup>3</sup>Stations WC03, WC09, WC10.

### 3.2.5 TOPOGRAPHIC FEATURES

One set of paired stations (WC-11 and WC-12) were taken to compare topographic differences. In this pairing both stations had equivalent depths (1200 m), WC-11 was a topographic convexity, whereas WC-12 was a topographic concavity. The sediment sample at the convexity is elevated in petroleum hydrocarbons (Table 3-7). This difference cannot simply be ascribed to topographic differences and more likely suggests that seepage has occurred at Station WC-11. More detailed studies will need to be performed to understand the relationship between hydrocarbons and topographic expressions.

### 3.2.6 RELATIONSHIP TO BULK SEDIMENT PARAMETERS

In general, the highest aliphatic hydrocarbon concentrations were associated with the more clay sediments rich in organic carbons. To understand more fully sedimentological relationships it is most effective to consider the three primary hydrocarbon sources individually since their distribution may be controlled by different factors. The data must also be considered in the context of the hypothesis the sampling was designed to test, i.e., areal, temporal and water depth dependence. The terrigenous or land-derived component correlated with grain size distribution changes within a given sampling period (Fig. 3-13); however, when the data are considered as a complete set, these trends are not readily apparent. This is most likely due to the ratio of clay to terrigenous organic matter changing with time and location. Detailed sediment data from Cruises I-V are found in Appendix B-2.

Among the samples, the Cruise II Central and Cruise IV Western/Central samples correlate least with grain size. This may be due to a substantial petroleum input to the TERR indicator that is independent of the river. It is also probable that the seaward distance the material is transported and the composition of the transported material vary with time. The largest range in clay content was observed during Cruise II when the Western, Central and Eastern Transects were sampled (Fig. 3-14). In this case a positive correlation with clay content and a negative correlation with sand content is readily apparent; within a given transect

Table 3-7. Comparison of sediment hydrocarbon parameters at two different topographic settings (for definitions of hydrocarbon parameters see Tables 3-4 and 3-5).

Depth (m)	WC-11 Topo-Hi 1226	WC-12 Topo-Low 1236
Total EOM (ppm)	18.9	17.1
Aliphatic UCM (ppm)	81.4	4.2
PL-1 (ppb)	266.6	67.5
TERR (ppb)	3068.3	182.6
Petro-Lo (ppb)	248.2	45.7
Petro-Hi (ppb)	852.7	44.9
Terrestrial (ppb)	2233.7	137.7
Planktonic (ppb)	18.4	21.8
Petroleum (ppb)	1100.9	90.6

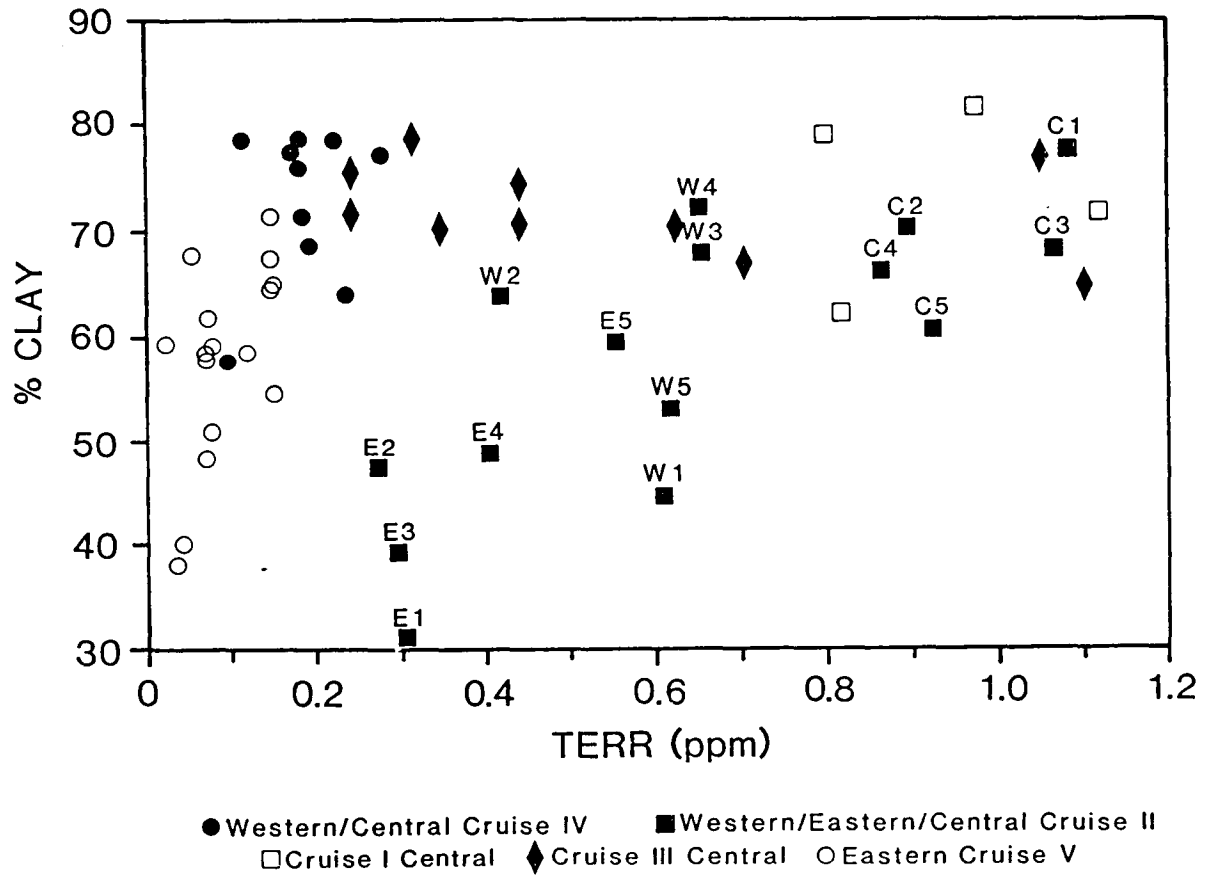


Figure 3-13. The relationship between a terrestrial hydrocarbon indicator and the clay content of the sediment.

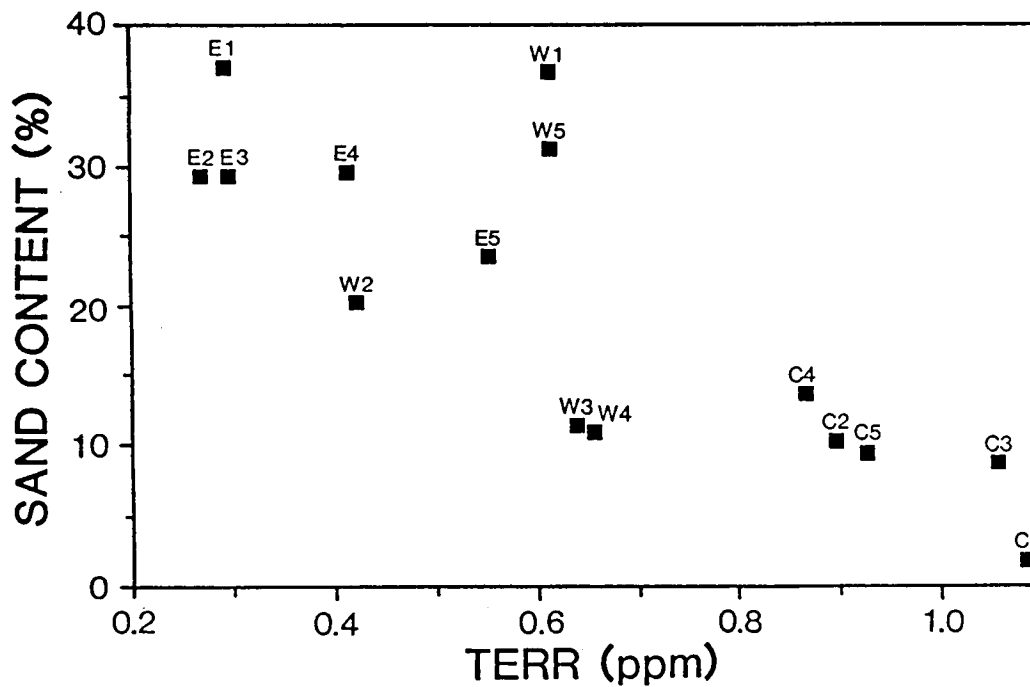
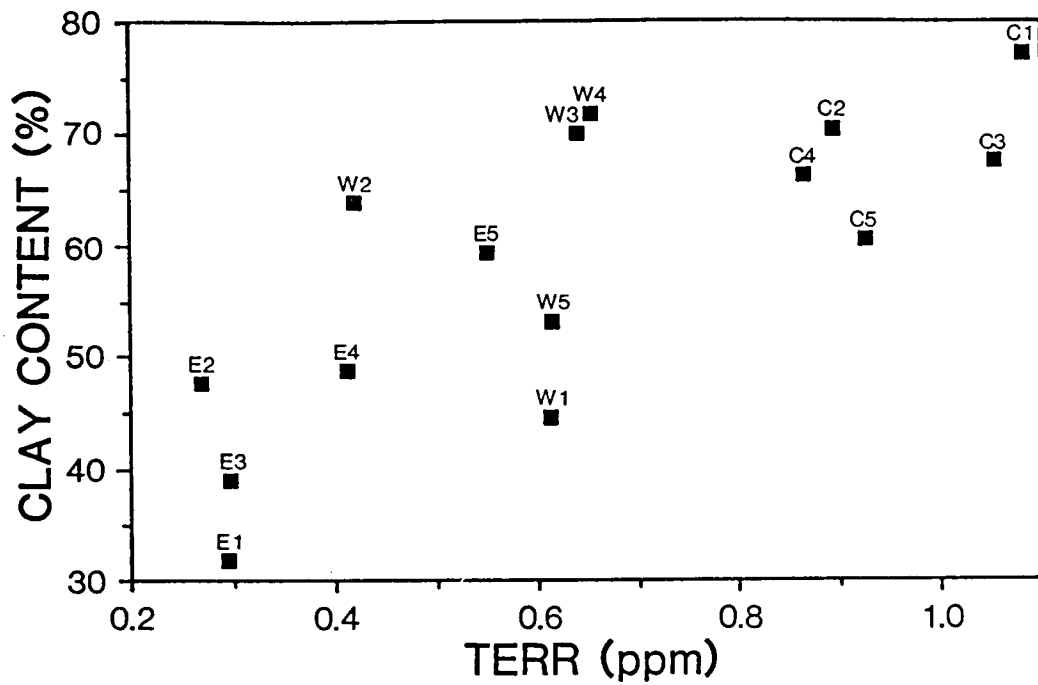


Figure 3-14. The relationship between a terrestrial hydrocarbon indicator and the clay and sand content of the sediment during Cruise II.



the correlation is less striking. The correlation of the terrigenous indicator with grain size supports the premise that these n-alkanes represent riverine or land-derived material. In general the relative importance of riverine material between geographical areas can be estimated though variability within a given area, i.e., along a transect, can be substantial.

The petroleum indicators were generally independent of grain size, though as previously mentioned some component of the petroleum is related to river-associated particles (Fig. 3-15). This river influence can be seen most clearly on the Eastern Transect where the PE-Lo indicator generally increases with increasing clay content. In contrast the aliphatic UCM is apparently independent of clay content (Fig. 3-15), which confirms a dual source for petroleum hydrocarbons. Phytoplankton-derived hydrocarbons did not correlate with grain size.

### 3.2.7 AROMATIC HYDROCARBONS

Sediment aromatic hydrocarbons were below the detection limit (-5 ppb) at all locations sampled. The presence of aromatic hydrocarbons at low concentrations was inferred by total scanning fluorescence analyses, supporting the conclusion that a low level petroleum input is present at all locations sampled.

## 3.3 CARBON ISOTOPES

### 3.3.1 SEDIMENTS

The carbon isotopic composition of sedimentary organic matter for all five cruises is summarized in Figure 3-16. Isotopic data confirms the previously inferred influence of river-borne terrigenous material on the Gulf of Mexico continental slope. Though there are numerous complicating factors, in general a more negative carbon isotopic composition suggests greater land influence. Terrestrially sourced organic material,  $\delta^{13}\text{C}$  varies from approximately -25 to -28‰, while planktonic-derived carbon  $\delta^{13}\text{C}$  varies from approximately -16 to -21‰. As can be seen the average  $\delta^{13}\text{C}$  of sedimentary organic material is most positive at the

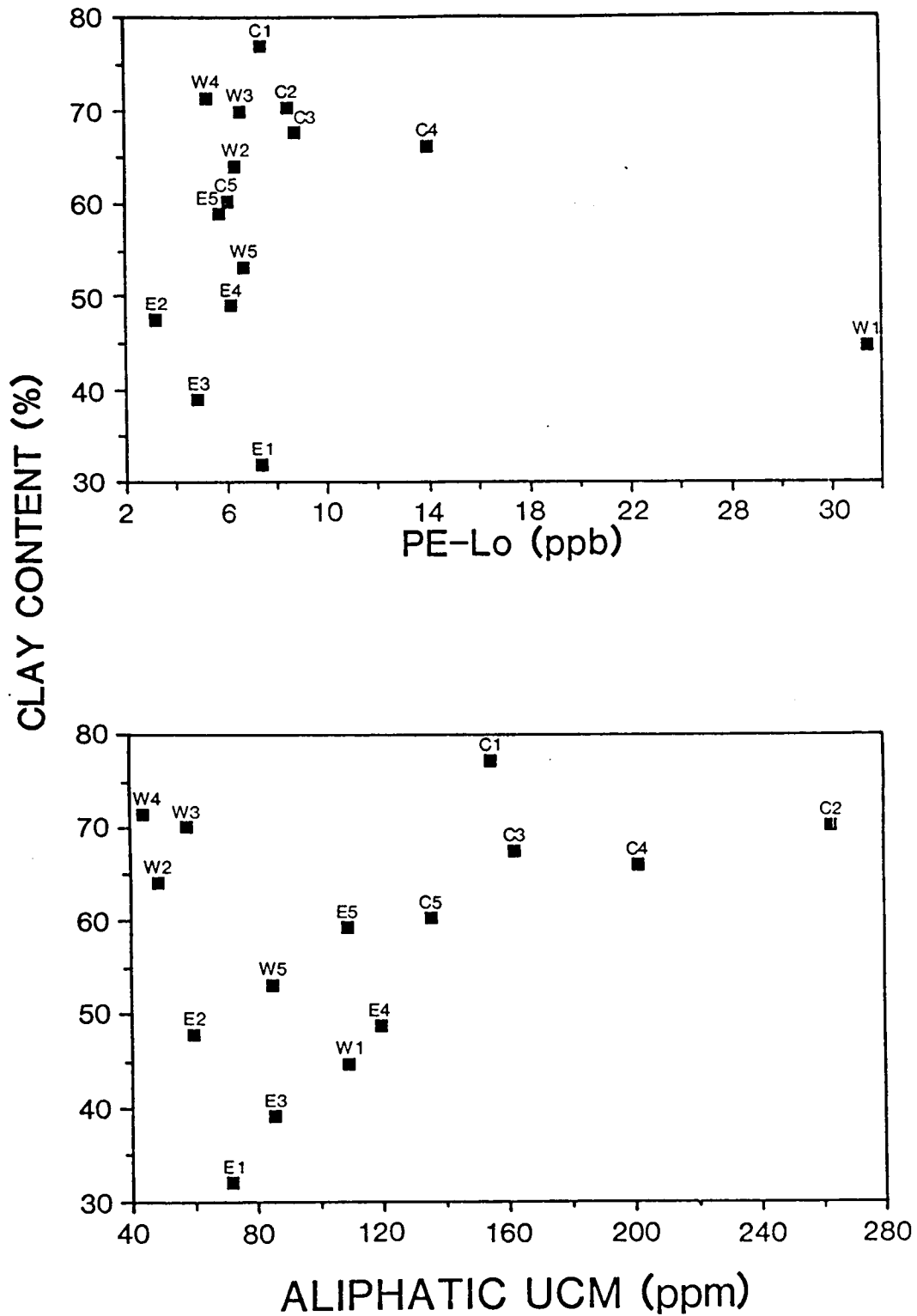


Figure 3-15. The relationship between two petroleum hydrocarbon indicators and the clay content of the sediment during Cruise II.

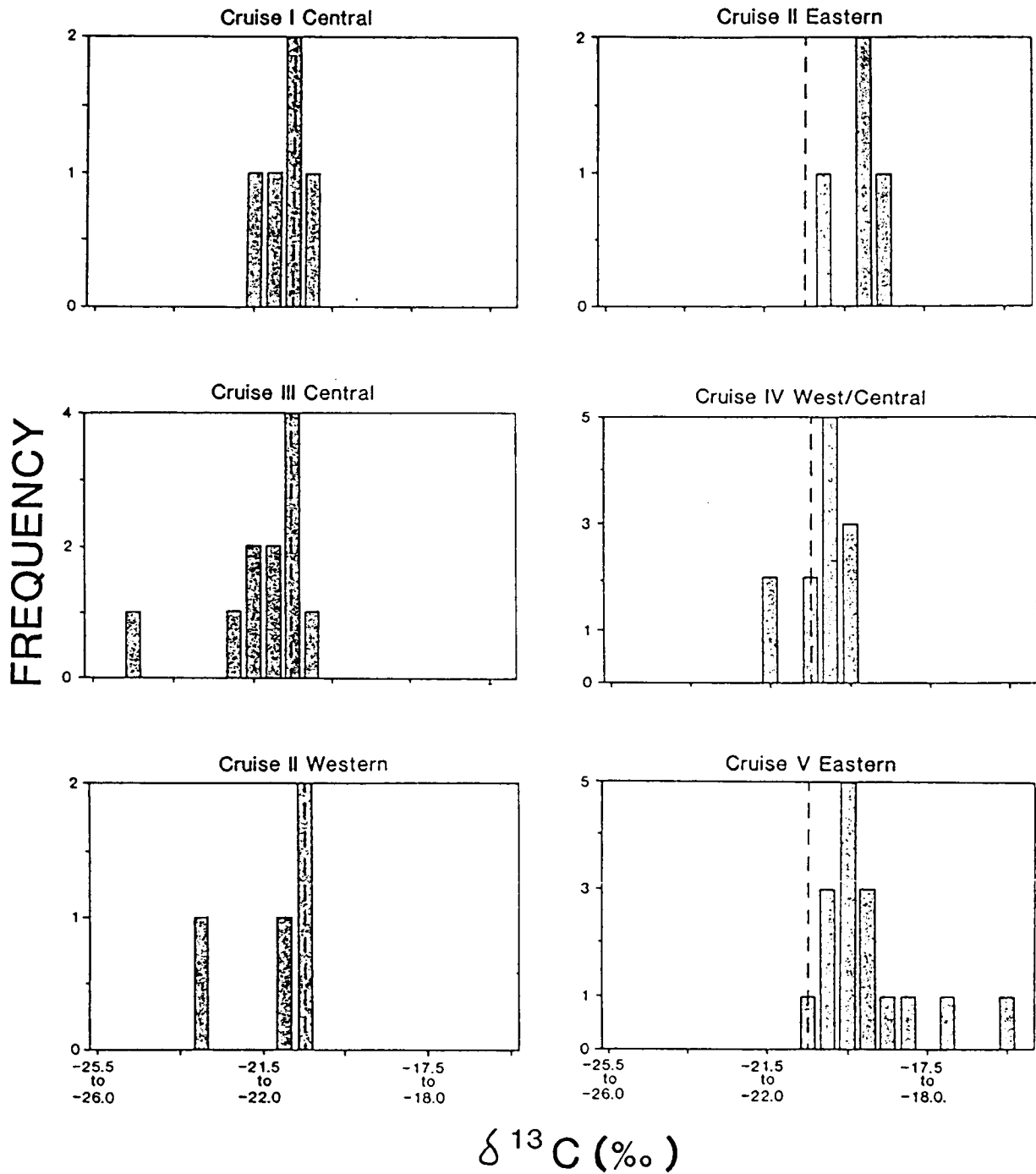


Figure 3-16. Summary of the carbon isotopic composition of sedimentary organic matter from all five cruises ( $\delta^{13}C$  in ‰, vs. Pee Dee Belemite).

eastern stations, most negative at the Central and Western sampling sites. This trend suggests an increased influence of planktonic material at the eastern sites. In general the average  $\delta^{13}\text{C}$  suggests a substantial planktonic contribution to the bulk organic matter, whereas the hydrocarbons are generally dominated by terrestrial sources.

### 3.3.2 ORGANISMS

Stable carbon isotopes have been widely used in marine research to trace the flow of carbon in ecosystems and the biogeochemical systems (Parker 1964, Sackett 1964, Calder and Parker 1968, Haines 1976, DeNiro and Epstein 1978, Haines and Montague 1979, Fry and Parker 1979, Fry 1981, Gearing et al. 1984). Several assumptions are inherent in their use including (1) a relatively constant isotopic composition of organic carbon produced by each plant source, (2) an unchanging isotopic ratio in plant carbon as it decomposes and is broken down into detritus, and (3) little or no isotopic fractionation between consumer and its carbon supply. Gearing et al. (1984) have recently provided an excellent review of the carbon isotopic literature relating to these assumptions.

The first assumption is generally applicable within a few parts per thousand for marine plankton. isotopic variability in marine phytoplankton has been correlated with species composition, temperature, water masses, latitude, and  $\delta^{13}\text{C}$  of the inorganic carbon that is fixed. Little isotopic fraction is generally observed in the aerobic decomposition of organic matter in seawater. They observed an overall pattern of increasing carbon isotope ratios with trophic levels, progressing from diatoms ( $-20.3 \text{ ‰}$ ), to zooplankton ( $-19.8 \text{ ‰}$ ), meiofauna ( $-19.5 \text{ ‰}$ ), non-carnivorous macrofauna ( $-18.6 \text{ ‰}$ ), and benthic predators ( $-16.6 \text{ ‰}$ ). Similar patterns have been documented in other studies and support an isotopic shift of a few parts per thousand to more positive values with increasing trophic level. The organism tissue isotopic data for all five cruises is summarized in Figures 3-17 and 3-18. Detailed carbon isotope data for organisms for each station sampled may be found in Appendix B-3.

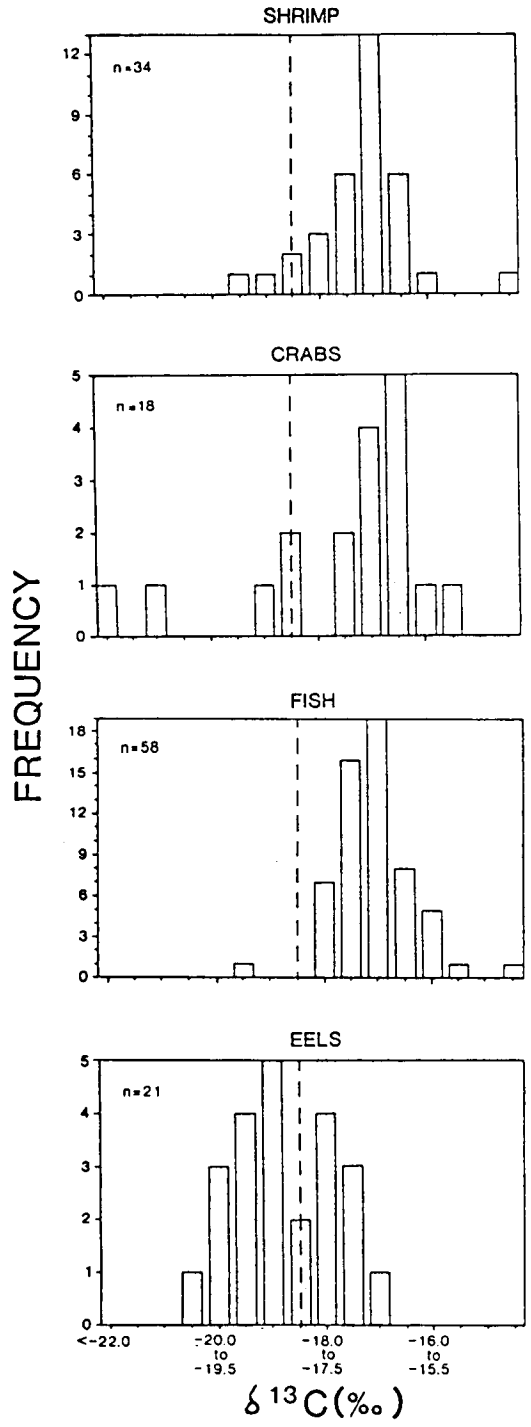


Figure 3-17. Summary of the carbon isotopic composition of organism tissues by organism type ( $\delta^{13}C$  in ‰ vs. PPB).

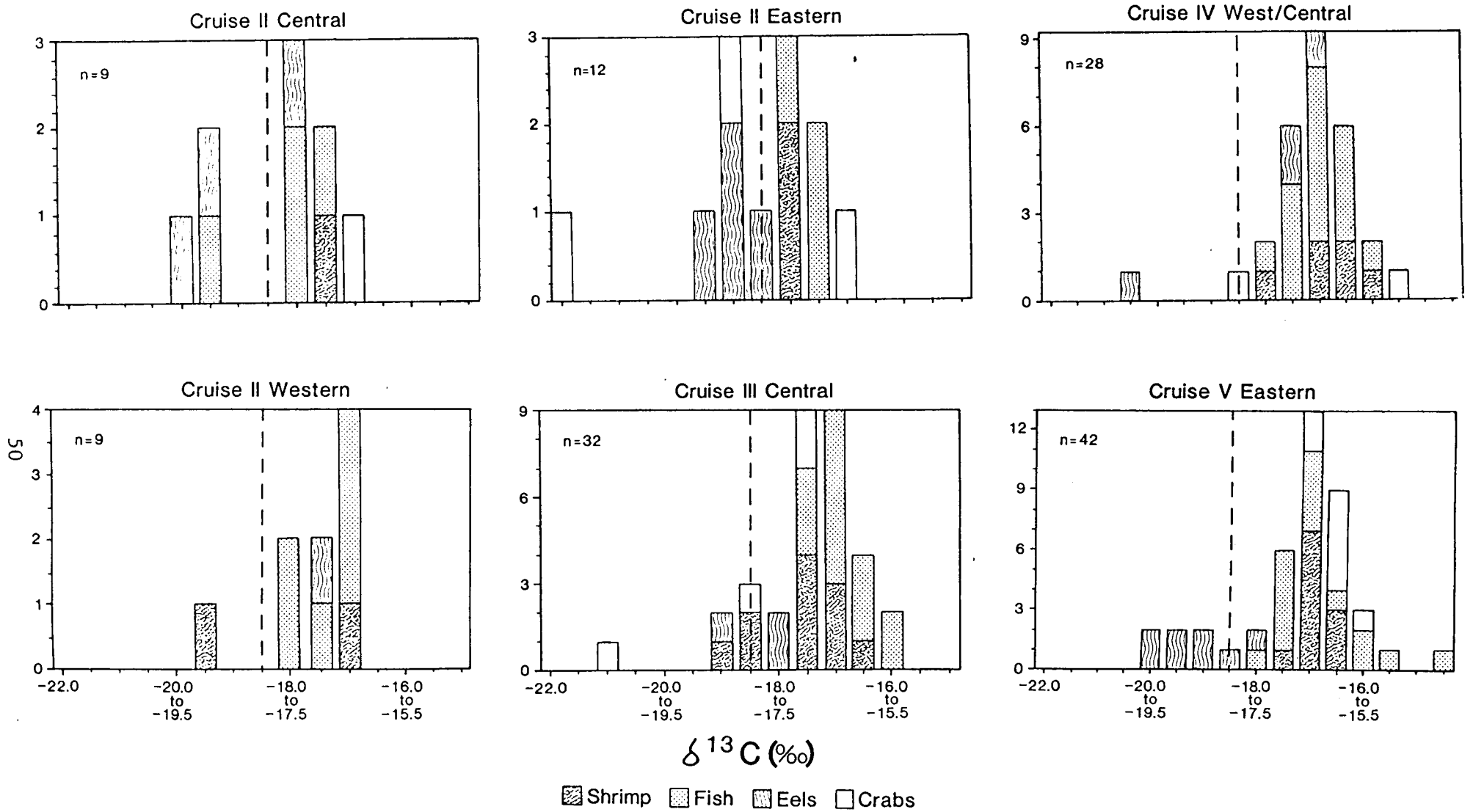


Figure 3-18. Summary of the carbon isotopic composition of organism tissues by transect and organism type for all five cruises ( $\delta^{13}C$  in ‰ vs. Pee Dee Belemite).

### 3.4 ORGANISM HYDROCARBONS

Hydrocarbon levels in Gulf of Mexico slope organisms are highly variable. Detailed hydrocarbon data for organisms sampled from Cruises I-V are found in Appendices B-7, B-8, and B-9. Total resolved alkanes in samples from Cruises I, II and III varied from non-detectable to >8000 ppb (Figure 3-19). Due to the variety of organisms and organ types analyzed, trends in variations as a function of location, water depth, and time of sampling are difficult to discern. The species collected and analyzed were highly variable thus making direct comparisons difficult if not impossible. No trends in hydrocarbon distributions were evident as a function of organism type (i.e., shrimp, fish, crab, or eel, Fig. 3-19). Of the organisms analyzed, crabs and shrimp had the lowest incidence of hydrocarbon occurrence in muscle tissue (Table 3-8). More than ~75% of the eel and fish muscle tissues analyzed contained detectable hydrocarbons. In the sampling provided by this study there were no detectable hydrocarbons in several species, primarily shrimp (Table 3-9). The sampling is often limited to a single individual and therefore cannot properly represent the entire population.

Tissue hydrocarbons were generally dominated by pristine, n-C<sub>17</sub>, n-C<sub>15</sub> and n-C<sub>19</sub> (Figs. 3-20 to 3-22). These hydrocarbons are predominantly planktonic in origin. In general n-C<sub>16</sub>, n-C<sub>18</sub> and phytane were also present. These may have a petroleum source but due to the low concentrations observed their source is not clear. It is also possible that this range of n-alkanes has a bacterial source. A few organisms also contained measurable amounts of higher molecular weight petroleum and plant biowax hydrocarbons (Table 3-10, Figs. 3-23 and 3-24). These organisms were all collected at the Central Transect except for one shrimp at Station E3 during Cruise II that contained primarily petroleum hydrocarbons. The presence of the plant biowaxes suggests that these organisms have acquired the hydrocarbon signature of the sediments. These hydrocarbons presumably reside in sediments and not in the water column at these water depths. In two organisms the plant biowaxes were detected in the liver and/or gonads as well as the muscle tissue. The presence of the sediment hydrocarbons in tissues suggest that these organisms either

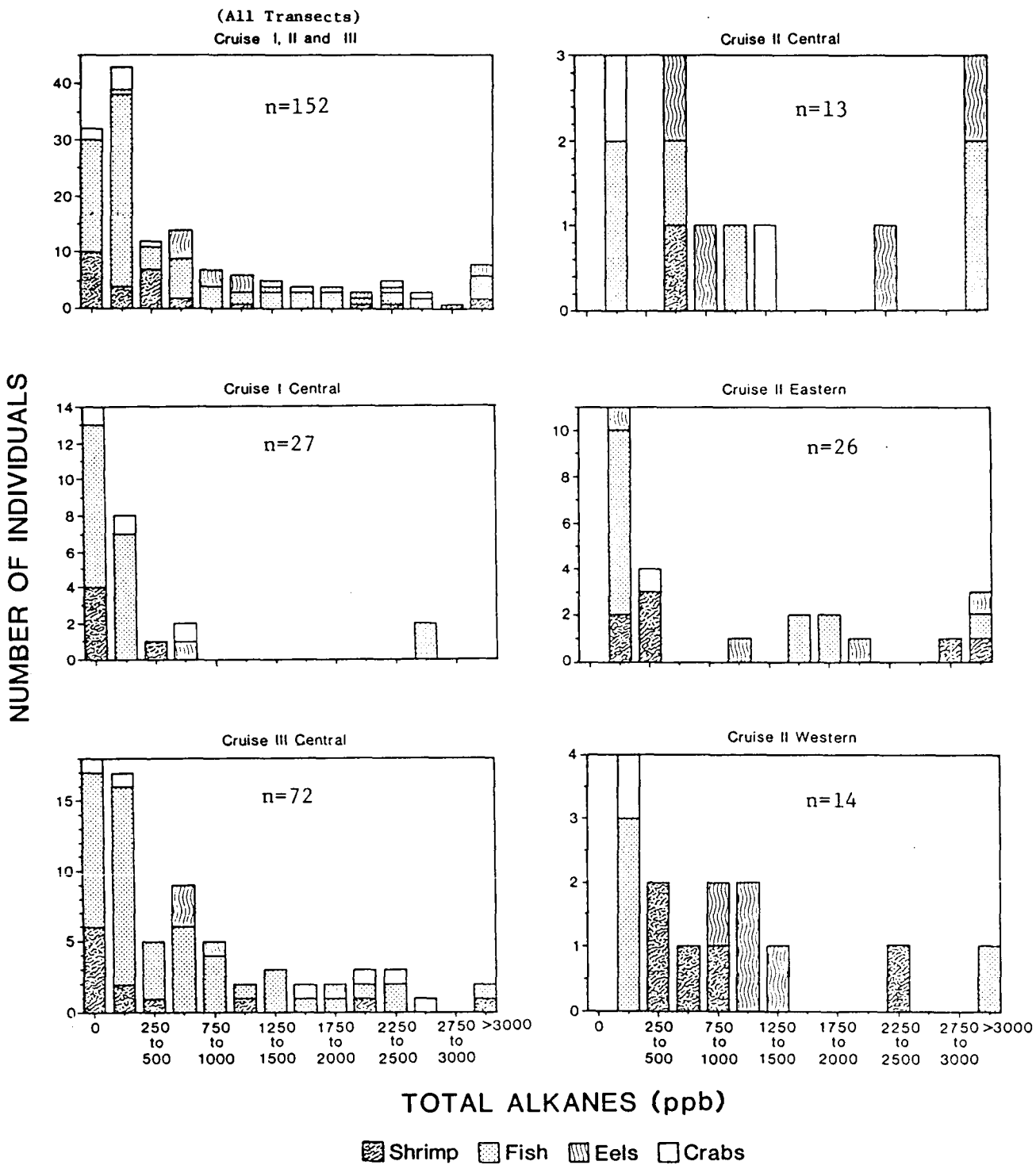


Figure 3-19. Summary of the total alkane concentration in organism tissues for Cruises I, II and III.



Table 3-8. Summary of the incidence of detectable hydrocarbons in organisms muscle tissue (Cruises I-V).

Type of Organisms	No. of Species	No. of Individuals Analyzed	No. of Individuals Hydrocarbon Free
Fishes	28	80	21 (26.3%)*
Eels	2(?)	17	3 (17.6%)
Crabs	4	19	11 (57.9%)
Shrimp	18	40	25 (62.5%)

\*Percent of individuals analyzed.

Table 3-9. Species in which no tissue hydrocarbons were detected in organism in the present study.

Cruise	Station	No. of Individuals Analyzed	Species	Type of Organism
5	E3D E2E E2B	3	<u>Munida valida</u>	Shrimp
4	WC08	1	<u>Hymenopenaeus robustus</u>	Shrimp
1	C2	1	<u>Acanthephyra armata</u>	Shrimp
1	C3	1	<u>Benthesicumus bartletti</u>	Shrimp
3	C6	1	<u>Nephropsis aculeata</u>	Shrimp
3	C1	1	<u>Parapenaeus longirostris</u>	Shrimp
3	C2	1	<u>Plesionika holthuisi</u>	Shrimp
4	WC6	1	<u>Merluccius albidus</u>	Fish
5	E2D	1	<u>Metanephrops binghami</u>	Shrimp
1	C4	1	<u>Cataetyx</u> sp.	Fish
5	E1	1	<u>Pocilopsetta beani</u>	Shrimp
4	WC05	1	<u>Polycheles typhlops</u>	Lobsters

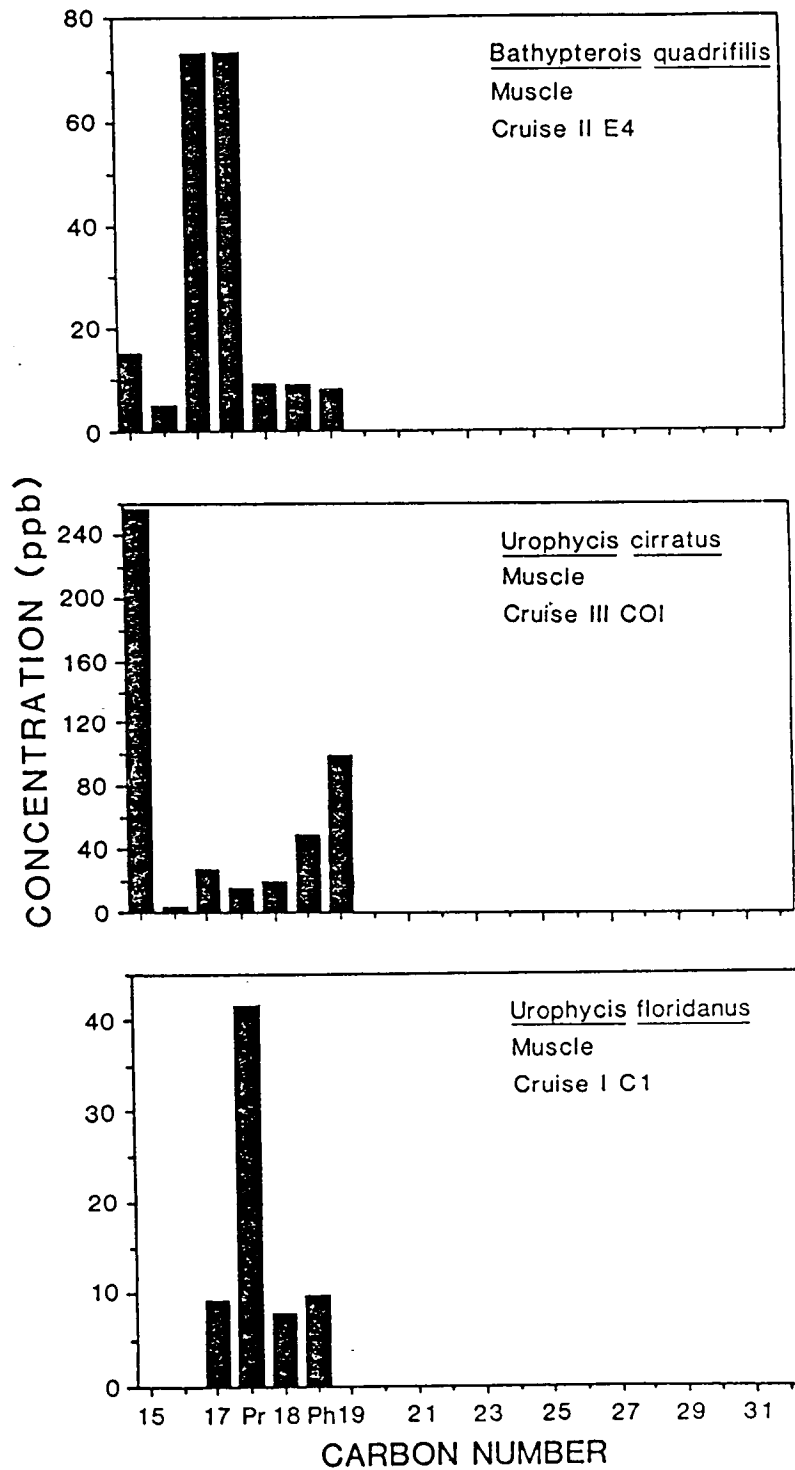


Figure 3-20. Selected examples of alkane distributions in fish tissues (Pr = pristane, Ph = phytane).

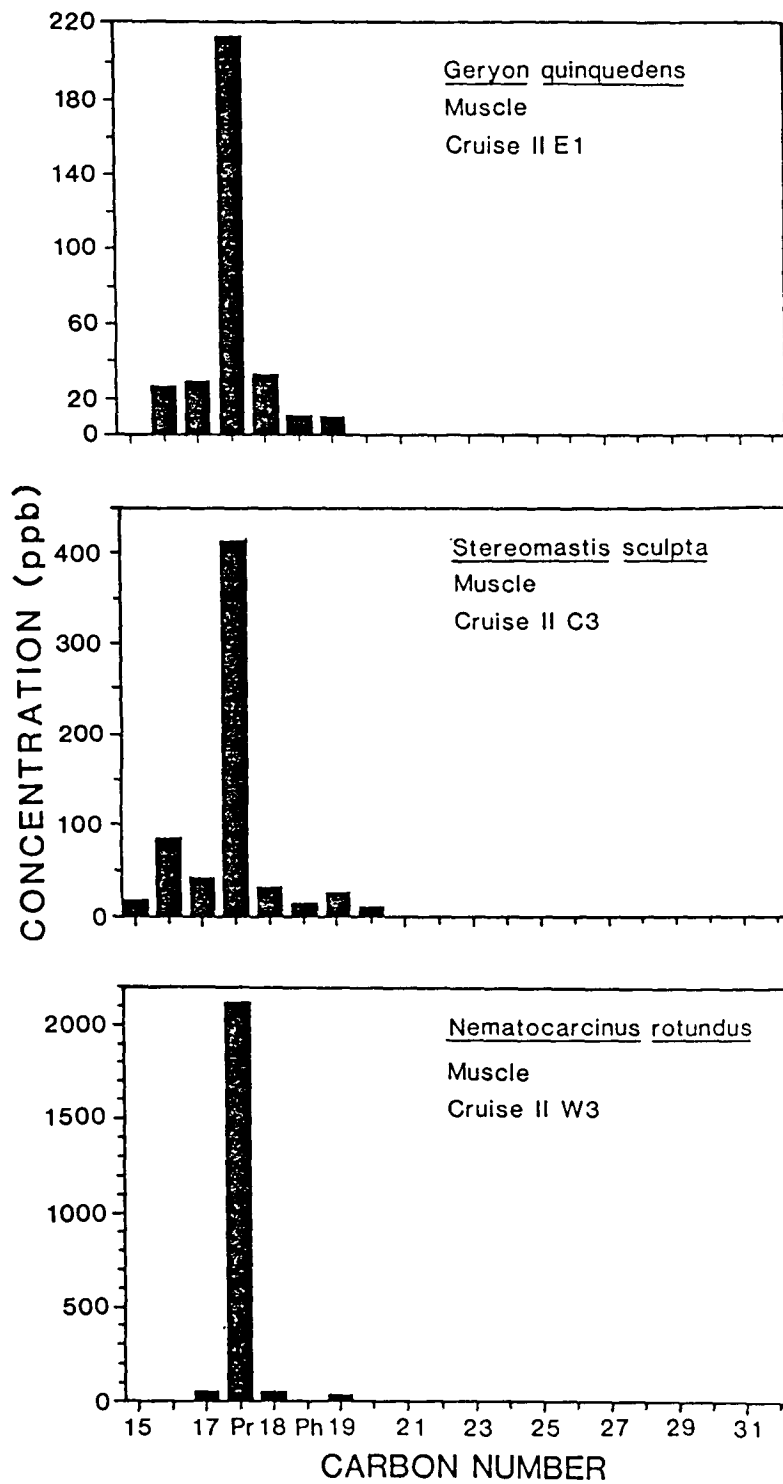


Figure 3-21. Selected examples of alkane distributions in crab and shrimp tissues (Pr = pristane, Ph = phytane).

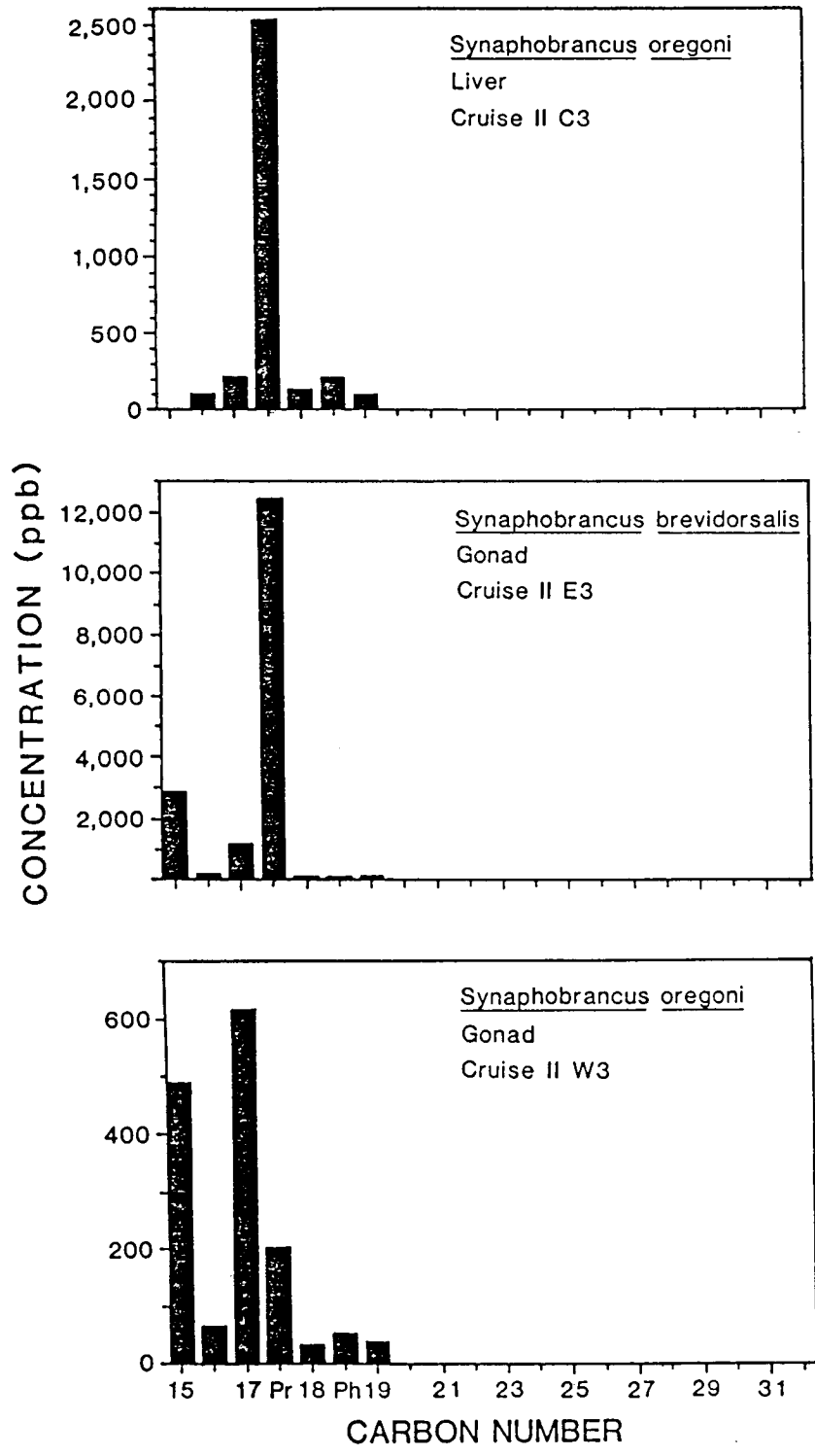


Figure 3-22. Selected examples of alkane distributions in eel tissues (Pr = pristane, Ph = phytane).

Table 3-10. Species in which a sediment hydrocarbon signature was detected in organism tissues.

Cruise	Station	Species	Organ	Type
III	C06	<u>Urophycis cirratus</u>	Gonad	Fish
III	C06	<u>Urophycis cirratus</u>	Liver	Fish
III	C10	<u>Geryon quinquedens</u>	Gonad	Crab
III	C08	<u>Geryon quinquedens</u>	Muscle	Crab
III	C10	<u>Geryon quinquedens</u>	Muscle	Crab
III	C07	<u>Geryon quinquedens</u>	Gonad	Crab
III	C01	<u>Steindachneria argentina</u>	Gonad	Fish
III	C08	<u>Coryphaenoides mexicanus</u>	Muscle	Fish
III	E3	<u>Nematocarcinus rotundus</u>	Muscle	Shrimp*
III	C07	<u>Heterocarpus oryx</u>	Gonad	Shrimp
III	C07	<u>Heterocarpus oryx</u>	Muscle	Shrimp

\*Petroleum signature.

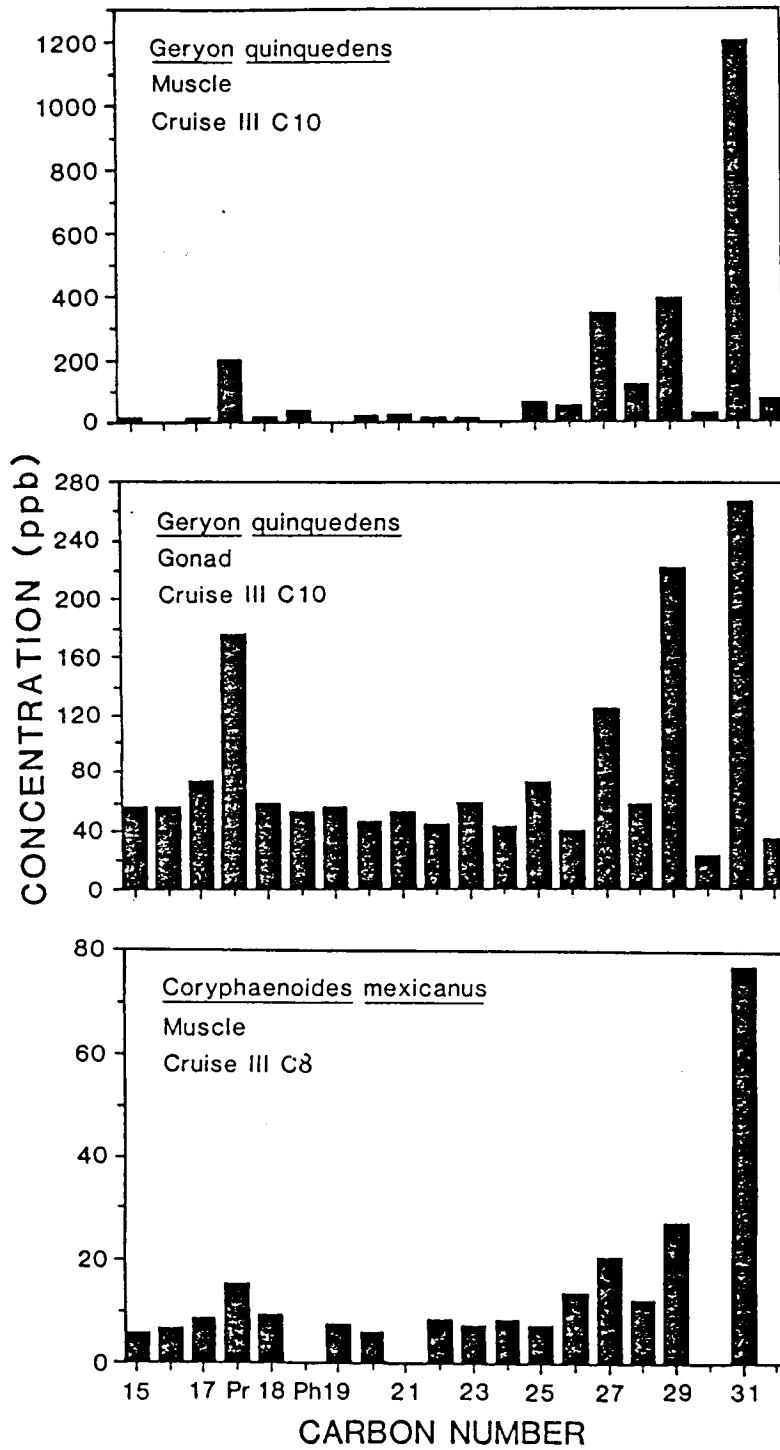


Figure 3-23. Selected examples of terrestrial hydrocarbons detected in crab and fish tissues (Pr = pristane, Ph = phytane).

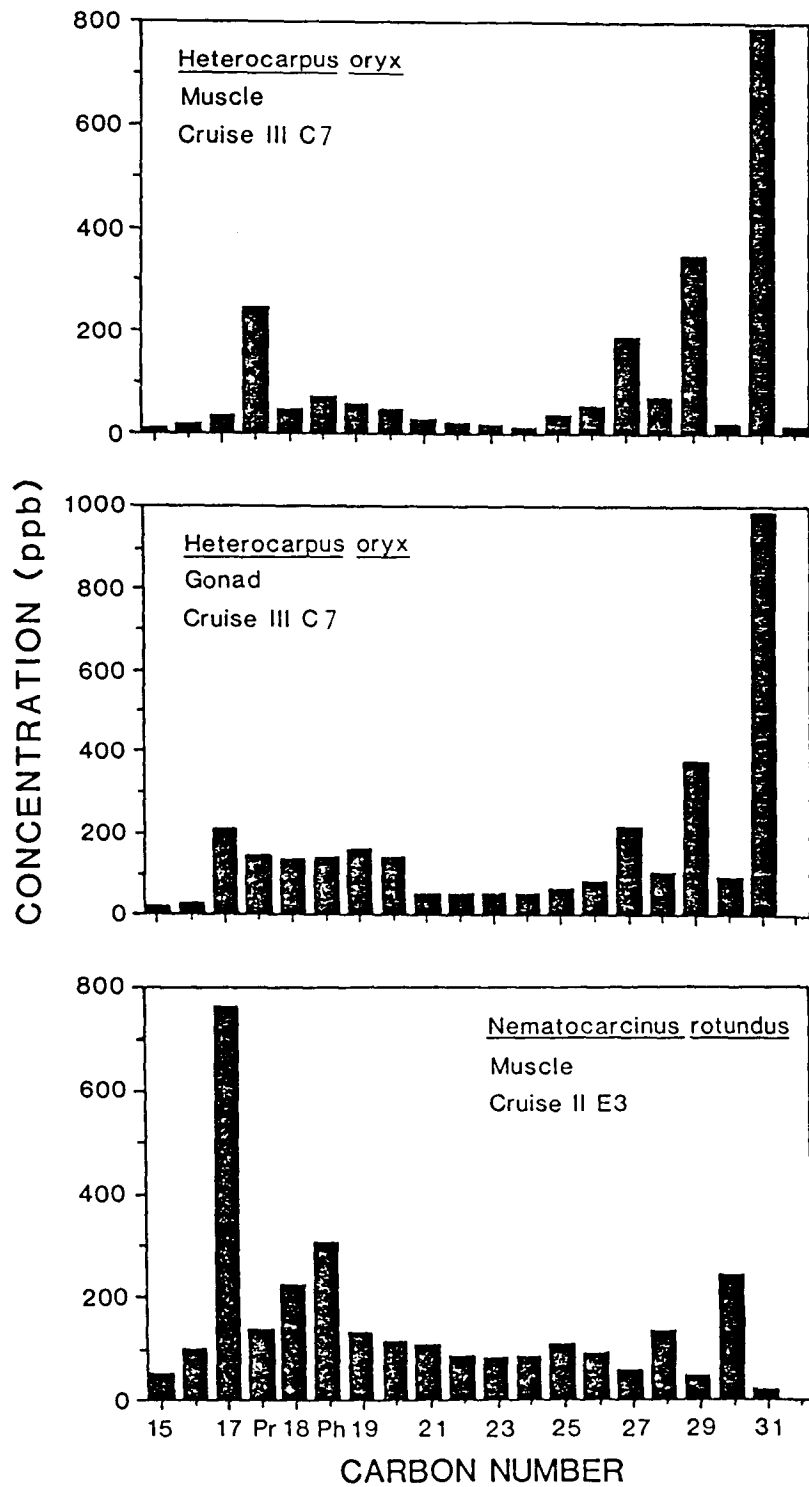


Figure 3-24. Selected examples of terrestrial hydrocarbons detected in shrimp and fish tissues (Pr = pristane, Ph = phytane).



ingested sediments and/or other organisms that had previously ingested sediments.

On average the highest alkane concentrations were detected in liver and gonad tissues, though there are high hydrocarbon levels present in some muscle tissues as well (Fig. 3-25). A suggested scheme of hydrocarbon sources and sinks on the Gulf of Mexico continental slope is shown in Figure 3-26.

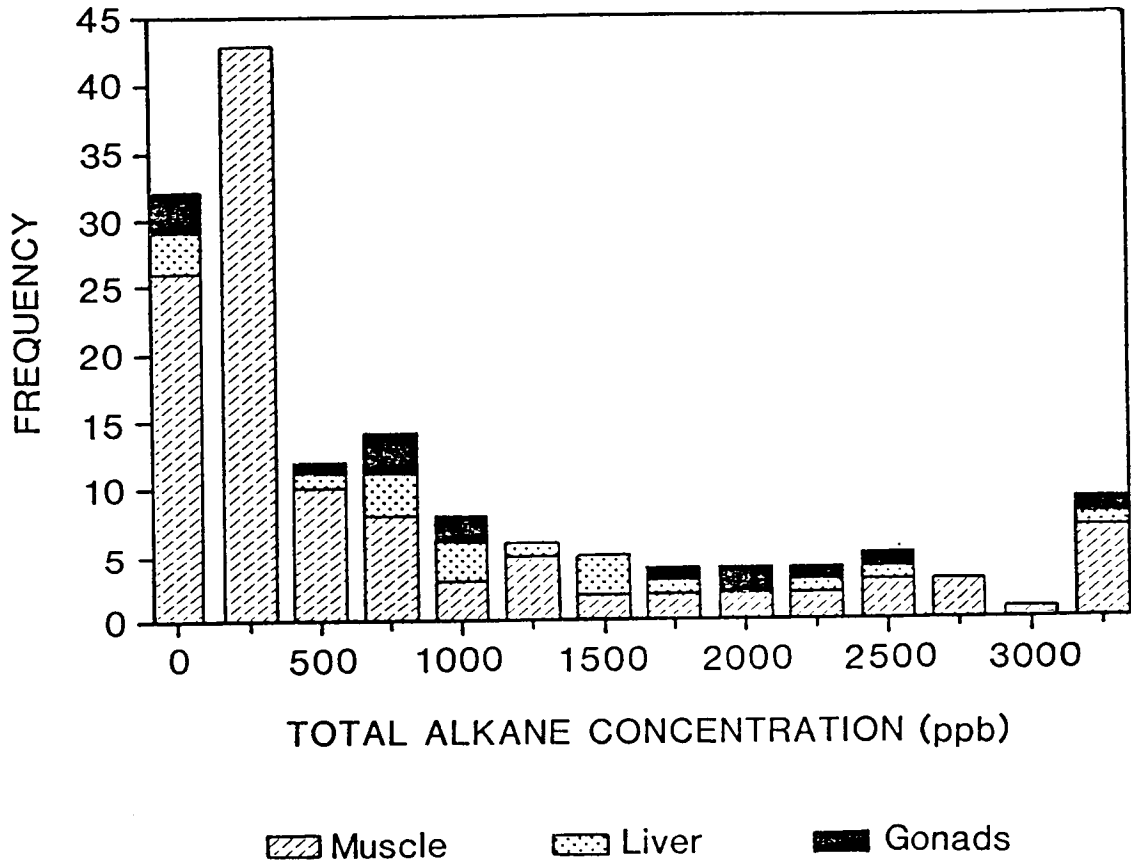


Figure 3-25. Summary of total alkane concentrations from Cruises I, II, and III as a function of tissue type of all organisms analyzed.

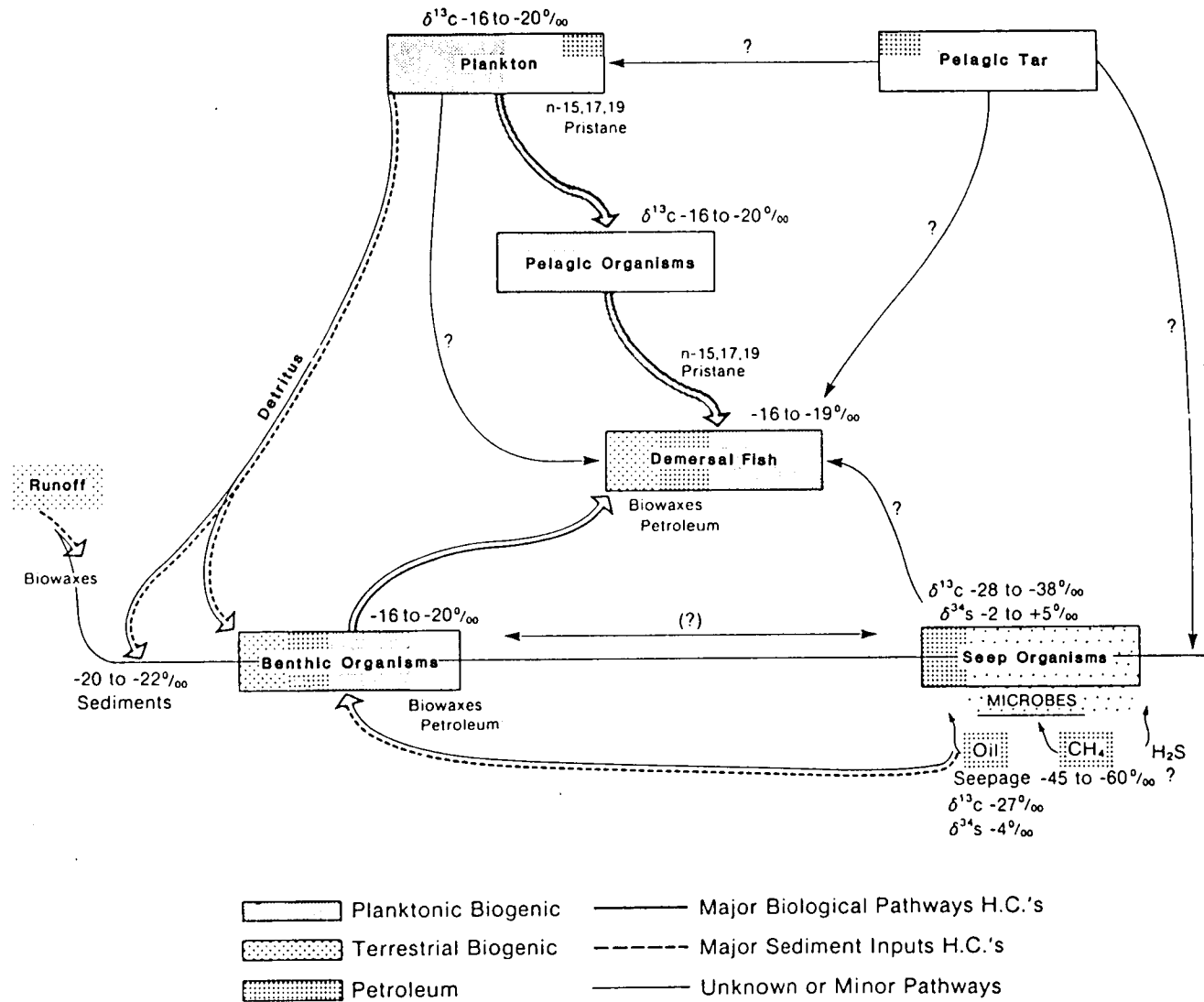


Figure 3-26. A suggested scheme for the sources and sinks of hydrocarbons on the Gulf of Mexico slope (note: the size of the various boxes do not represent quantitative importance).

#### 4.0 BIOLOGICAL OCEANOGRAPHIC CHARACTERISTICS OF THE NORTHERN GULF

The faunal groups examined in this study consist of the megafauna (invertebrates and demersal fishes) collected by trawling, the macrofauna (greater than 0.3 mm in size) collected by the box corer and the meiofauna (0.063-0.3 mm size) also collected by box core. Of these groups, only the meiofauna and certain macrofaunal groups, e.g., Nematoda, Harpacticoida, Aplacophora, Kinorhyncha, etc. were not identified to the species level. A complete list of species identified from Cruises I-III from all sampling types is found in Appendix C-8. (Fauna from Cruises IV and V await full analysis.)

##### 4.1 MEGAFUNA

###### 4.1.1 ARTHROPODA

One hundred and four species of benthic megacrustacea and other arthropods were collected in the trawl along the three sampling transects established in this study. Some 85% of the species were decapods (Table 4-1) and of these the Anomura yielded the most species, followed by the Caridea. In the TerEco study, second place was occupied by the Brachyura, a fact that is explained by the observation that the median depth for crabs in that study was only 300 m, which is shallower than any LGL station. Although some Isopoda and Amphipoda were collected with the trawl, attention is called to the fact that the overwhelming majority of these crustaceans were collected by the box corer and are thus discussed under the section of the report on Macrofauna.

About 70% of the crustacean species extend their bathymetric range below the 1000-m isobath, which marks the upper edge of the abyssal regions of the slope (Table 4-1). In terms of numbers of species, the Caridea and Anomura predominate below 1000 m, but percentagewise it is the penaeids, pagurids, polychelids and nephropids that are more characteristic of the slope waters. Station counts for the crustacean species, as well as for all of the other megafaunal invertebrate species, are found in Appendix C-1.

Table 4-1. Megafaunal arthropods collected by trawl during Cruises I, II, and III of the LGL study.

Taxa	No. Of Species	% Of All Arthropoda	No. Of Spp. At Or Below 1000 m	% Of Species Below 1000 m
<b>CRUSTACEA</b>				
CIRRIPELIA	7	7	4	57
ISOPODA	2	2	2	100
AMPHIPODA	5	5	5	100
DECAPODA	89	85	62	70
Penaeidea	11		6	55
Caridea	24		12	50
Anomura	28		15	54
Paguridae	(9)		5	56
Porcellanidae	(1)		0	0
Chirostylidae	(2)		2	100
Lithodidae	(1)		1	100
Galatheidae				
Munida	(6)		2	33
Munidopsis	(9)		5	56
Macrura	9		5	56
Polychelidae	(4)		3	75
Nephropidae	(3)		2	66
Scyllaridae	(1)		0	0
Axiidae	(1)		0	0
Brachyura	17		3	18
STOMATOPODA	1	1	0	0
<b>CHELICERATA</b>				
PYCNOGONIDAE (an arachnid)	1		1	100
	<u>104</u>	<u>100</u>	<u>73</u>	<u>Ave. 70%</u>
Crustacea				

### Cirripedia

Only seven species of barnacles were collected in trawl samples (Table 4-1). Two other species and recently settled cypris larvae were collected from the carapace of brachyuran crabs. Interestingly, not a single species in the table was reported in the TerEco study. Perhaps this is because six of the seven LGL species came from the Central Transect, a whole area that was not sampled at all during the previous study.

### Isopoda

Four species of isopods were collected by the trawl. Only two are worthy of note, the gigantic cirrolanid isopod Bathynomus giganteus and Aega sp. 285, which were collected in small numbers from all three transects. Both have depth ranges extending into the Abyssal Zones.

### Amphipoda

Five species of amphipods were collected by the trawl. None were taken on the Western Transect. All five species are found only in off-shelf depths.

### Stomatopoda

Only one species of stomatopod, Squilla edentata, was collected in the trawl on the Central Transect. The same species was reported in the TerEco study.

### Pycnogonida

Only one megafaunal species of pycnogonid was obtained in this study. Only one specimen of Pallenopsis scoparia was taken at a depth of 1064 m on the Central Transect.

Decapoda

Natantia: Penaeidea. Three additional species of benthonic penaeid shrimps were collected in Cruise III over the eight species noted from the first two cruises (Table 4-2). The three were taken from depths in excess of 2000 m in the Upper Abyssal and Mesoabyssal Zones. Although the total number of penaeid species collected thus far is only half the total taken by TerEco, the collection is a good representation of the species that achieve maximum populations within the sampling depths of the LGL study. Note, for instance in Table 4-3, that the six numerical dominants found in the LGL study differ only by one species from the list constructed in the TerEco study.

Table 4-3. Comparison of the most abundant penaeid species from Cruises I-III in the LGL study and all cruises in the TerEco study.

LGL			TerEco	
Species	Total Collected	Depth Max. Pop. (m)	Species	Depth Max. Pop. (m)
<u>Penaeopsis serrata</u>	888	342	<u>Penaeopsis serrata</u>	300
<u>Parapenaeus longirostris</u>	80	346	<u>Benthescymus bartletti</u>	1050
<u>Benthescymus bartletti</u>	77	1172	<u>Parapenaeus longirostris</u>	250
<u>Hymenopenaeus debilis</u>	10	516	<u>Hymenopenaeus debilis</u>	600
<u>Plesiopenaeus armatus</u>	9	2504	<u>Plesiopenaeus edwardsianus</u>	950
<u>Benthescymus cereus/iridescens</u>	7	2504	<u>Benthescymus cereus iridescens</u>	3250

The matter of the depths of maximum population are interesting in that they are quite close in the two studies except for the deeper living species such as Benthescymus cereus/iridescens which achieves its maximum populations deeper than the sampling depths of the LGL study.

Any attempt to analyze the east vs. west and central Gulf distribution of penaeid species will be heavily weighted toward the Central Transect, because it was sampled on all three cruises and at a greater range of depths. Thus, only four species were collected from the West and five species from the East Transects, whereas 11 species were collected from the Central Transect (Table 4-2). This is explained in part by the fact that several species of penaeids live at depths over 1000 m, and only two stations in excess of that depth were sampled on the East and West Transects while six were sampled on the Central Transect.

Table 4-2. Inventory of Penaeidea arranged in order of abundance by depth of maximum population on Cruises I-III.

Species Name	Total Indiv. at all Stations	Number of stations where Species Dominant*	Depth Range (m)	Depth of Max Pop. (m)	Occurrence on Transects	Transect of Deepest Occurrence
<i>Solenocera necopina</i>	1	0	329	329	-, C, -	C
<i>Penaeopsis serrata</i>	888	4	329-367	342	W, C, E	C
<i>Parapenaeus longirostris</i>	80	2	329-367	346	-, C, E	E
<i>Hymenopenaeus debilis</i>	10	1	516-1172	516	W, C, E	E
<i>Plesiopenaeus edwardsianus</i>	1	1	632	632	-, C, -	C
<i>Hymenopenaeus robustus</i>	32	0	342-653	653	W, C, E	W
<i>Benthescymus bartletti</i>	77	9	802-2074	1172	W, C, E	C
<i>Hemipenaeus carpenteri</i>	1	1	2074	2074	-, C, -	C
<i>Plesiopenaeus armatus</i>	9	1	2074-2504	2504	-, C, -	C
<i>Benthescymus cereus/iridescens</i>	7	0	2504	2504	-, C, -	C
<i>Hymenopenaeus aphoticus</i>	2	0	1438-2504	2504	-, C, -	C

\*"Dominant" applies to the most abundant species of its group at a given station. One individual may be considered to be dominant if no other species of its group (e.g., Penaeidea) was taken at any station of that depth.



In Table 4-4 it is apparent from the results of the LGL study that a substantial proportion of the penaeids occurring on the continental slope penetrate into the abyss. This finding is clearly confirmed by the TerEco samples where 12 of the 22 species collected were found to live in the abyssal zones.

Table 4-4. Comparison of the zonal distribution of Penaeidea between LGL and TerEco studies. Zones as in TerEco study.

Zone	No. of spp. With Max. Pop. in Zone		No. of Other Species That Live in Zone	
	LGL	TerEco	LGL	TerEco
Shelf/Slope Transition (150-450 m)	3	5	1	2
Archibenthal Zone (475-950 m)	3	5	2	2
Upper Abyssal (975-2250 m)	2	7	2	7
Mesoabyssal (2275-3200 m)	3	2	0	5
Lower Abyssal (3225-3850 m)	<u>Not Sampled</u>	<u>3</u>	-	3
Total Species	11	22		

Natantia: Caridea. Whereas 18 species of benthonic caridean shrimp were collected from the three transects during Cruises I and II, five additional species were taken in Cruise III giving a total of 23 for the study (Table 4-5). The carideans were taken from Stations 1 through 11 at depths ranging from 329 to 2857 m. Three of the five species added in Cruise III, viz., Prionocrangon pectinata, Plesionika tenuipes, and Acanthephyra microphthalma, were taken from previously sampled depths on the Central Transect, while the other two, Metacrangon jacqueti agassizii and Plesionika acanthonotus, came from new sampling depths of Cruise III at 964 and 516 m, respectively. It would appear that the latter species

Table 4-5. Inventory of Caridea arranged in order of abundance by depth of maximum population on Cruises I-III.

Species Name	Total Indiv. at all Stations	Number of stations where Species Dominant*	Depth Range (m)	Depth of Max Pop. (m)	Occurrence on Transects	Transect of Deepest Occurrence
<i>Heterocarpus ensifer</i>	2	0	342	342	W, -, -	W
<i>Parapandalus willisi</i>	47	3	329-367	346	W, C, E	E
<i>Pontocaris caribbaeus</i>	2	0	329-346	346	-, C, -	C
<i>Plesionika tenuipes</i>	15	0	346-367	367	-, C, E	E
<i>Plesionika acanthonotus</i>	1	1	516	516	-, C, -	C
<i>Plesionika holthuisi</i>	391	6	603-850	622	W, C, E	C
<i>Pontophilus gracilis</i>	37	0	603-2857	632	-, C, E	E
<i>Psolidopus barbouri</i>	2	0	632-786	632	-, C, -	C
<i>Periclimenes pandionis</i>	1	0	632	632	-, C, -	C
<i>Glyphocrangon longleyi</i>	6	0	603-653	653	W, C, -	W
<i>Prionocrangon pectinata</i>	3	0	632-786	786	-, C, -	C
<i>Glyphocrangon alispina</i>	33	1	603-850	802	-, C, E	C
<i>AcanthePHYra armata</i>	4	0	786-1172	802	W, C, E	E
<i>Metacrangon jacqueti agassizii</i>	2	0	964	964	-, C, -	C
<i>Nematocarcinus rotundus</i>	720	8	603-1510	1064	W, C, E	C
<i>Heterocarpus oryx</i>	71	0	964-1438	1064	-, C, E	C
<i>Glyphocrangon nobilis</i>	38	2	786-2314	1064	W, C, E	W
<i>Glyphocrangon aculeata</i>	158	2	828-2857	1172	W, C, E	E
<i>AcanthePHYra eximia</i>	19	0	1172	1172	-, -, E	E
<i>Bathypalaemonella serratipalma</i>	4	0	1064-1172	1172	-, C, E	E
<i>Bathypalaemonella texana</i>	1	0	1172	1172	-, -, E	E
<i>Spongicoloides</i> N.sp.	1	0	1172	1172	-, -, E	E
<i>Nematocarcinus ensifer</i>	6	3	2074-2504	2314	W, C, -	C
<i>AcanthePHYra microphthalmalma</i>	1	0	2504	2504	-, C, -	C

\*See Table 4-2 for explanation.

have limited vertical distributions. This possibility is strengthened by the fact that previous studies placed the depth range of P. acanthonotus around 500-600 m and did not collect Metacrangon jacqueti agassizii at all (Pequegnat et al. 1983). The LGL specimen is the first Gulf of Mexico record for the latter species. Twelve of the caridean species (50%) were taken at depths in excess of 1000 m which compares closely with the 49% found in previous work (Pequegnat et al. 1983).

The numerical dominants of the Caridea are compared with those of the 1983 study in Table 4-6. Although the rank order of species differs somewhat, the two lists share seven of the eight species. Moreover, the depths of maximum population differ only by an average of 43 m, which can be considered very close because of the range of depths generally produced by trawl sampling.

Table 4-6. Comparison of numerical dominant caridean species in LGL and TerEco studies.

LGL			TerEco (1983)	
Species	Total Collected	Depth Max. Pop. (m)	Species	Depth Max. Pop. (m)
<u>Nematocarcinus rotundus</u>	720	1064	<u>Nematocarcinus rotundus</u>	1050
<u>Plesionika holthuisi</u>	391	622	<u>Glyphocrangon nobilis</u>	1050
<u>Glyphocrangon aculeata</u>	158	1172	<u>Glyphocrangon aculeata</u>	1150
<u>Heterocarpus oryx</u>	71	1064	<u>Glyphocrangon alispina</u>	750
<u>Parapandalus willisi</u>	47	346	<u>Plesionika holthuisi</u>	650
<u>Glyphocrangon nobilis</u>	38	1064	<u>Parapandalus willisi</u>	400
<u>Pontophilus gracilis</u>	37	632	<u>Heterocarpus oryx</u>	950
<u>Glyphocrangon alispina</u>	33	802	<u>Pasiphaea merriami</u>	600

Also, there is a close comparison between the distributions of caridean species in the faunal zones established in the 1983 study, as is shown in Table 4-7.

Table 4-7. Comparison of the zonal distribution of Caridea between LGL and TerEco studies. Zones as in TerEco study.

Zone	No. of spp. With <u>Max. Pop. in Zone</u>		No. of Other Species <u>That Live in Zone</u>	
	LGL	TerEco	LGL	TerEco
Shelf/Slope Transition (150-500 m)	4	7	1	2
Archibenthal Zone (525-950 m)	9	14	3	5
Upper Abyssal (975-2250 m)	8	8	2	6
Mesoabyssal (2275-3200 m)	2	2	3	2
Lower Abyssal (3225-3850 m)	<u>Not Sampled</u>	<u>2</u>		
	23	33		

Here again, the comparison of maximum populations is very close between the two studies, considering that the TerEco study was more nearly gulfwide and also sampled at shallower depths.

Anomura. The anomuran decapod crustaceans are represented on the continental slope of the northern Gulf of Mexico by five families, viz., the Galatheidae with the genera Munida and Munidopsis (Table 4-8); the Paguridae having numerous genera and at least two undescribed species (Table 4-11); the Chirostylidae with two species, Uroptychus nitidus and Gastroptychus spinifer; the Lithodidae with the king-crab-like Lithodes agassizii; and the one species of porcelain crab, Porcellana sigsbeiana, that is found in the family Porcellanidae (Table 4-11).

Galatheidae--As noted in earlier reports, the two genera of galatheids tend to have very different bathymetric characteristics. That is to say, the genus Munida is found primarily on the upper slope (only

Table 4-8. Inventory of Galatheidæ arranged in order of abundance by depth of maximum population on Cruises I-III.

Species Name	Total Indiv. at all Stations	Number of stations where Species Dominant*	Depth Range (m)	Depth of Max Pop. (m)	Occurrence on Transects	Transect of Deepest Occurrence
<i>Munida forceps</i>	3	1	329-338	338	-, C, -	C
<i>Munida longipes</i>	66	3	329-367	342	W, C, E	E
<i>Munida irrasa</i>	1	0	342	342	W, -, -	W
<i>Munidopsis robusta</i>	44	2	342-622	516	W, C, E	E
<i>Munida valida</i>	164	6	516-1172	622	W, C, E	E
<i>Munidopsis erinaceus</i>	15	0	516-622	622	-, C, E	E
<i>Munida</i> sp.	2	0	367-622	622	-, -, E	E
<i>Munidopsis alaminos</i>	1	0	622	622	-, -, E	E
<i>Munidopsis spinosa</i>	8	1	828	828	W, -, -	W
<i>Munida microphthalma</i>	11	2	964-2401	964	-, C, E	C
<i>Munidopsis sigsbei</i>	22	1	828-1510	1064	W, C, E	C
<i>Munidopsis longimanus</i>	9	1	622-1172	1172	-, C, E	E
<i>Munidopsis simplex</i>	9	3	1172-1510	1172	W, C, E	C
<i>Munidopsis polita</i>	3	0	342-1172	1172	W, -, E	E
<i>Munidopsis abbreviata</i>	2	0	1172	1172	-, -, E	E

\*See Table 4-2 for explanation.

one species penetrates into the abyssal zones), whereas Munidopsis is a characteristic megafaunal component of the middle and lower slope. Accordingly, the galatheids are good signature organisms of faunal zones (Table 4-9).

Table 4-9. Comparison of the zonal distribution of Galatheidae in the LGL study, comparing Munida with Munidopsis.

Zone	No. of spp. With Max. Population in Zone		No. of Other Species That Live in Zone	
	<u>Munida</u>	<u>Munidopsis</u>	<u>Munida</u>	<u>Munidopsis</u>
Shelf/Slope Transition (150-450 m)	3	0	1	3
Archibenthal Zone (475-950 m)	3	4	0	3
Upper Abyssal (975-2250 m)	0	5	1	0
Mesoabyssal (2275-3200 m)	0	0		
	6	9		

This zonal distribution compares very closely with the TerEco study.

Table 4-10 presents a comparison of the numerical dominant galatheids between the LGL and TerEco studies. The compositions of the two lists are remarkably close, differing only in regard to the inclusion of Munidopsis erinaceus on the LGL list. This species was the eighth most abundant in the TerEco study. The agreement between depths of maximum population is considered to be quite good, differing significantly only in regard to Munidopsis longimanus, particularly in view of the fact that collecting gear and techniques were not the same.

Table 4-10. Comparison of numerical dominant galatheids in the LGL and TerEco studies.

LGL			TerEco	
Species	Total Collected	Depth Max. Pop. (m)	Species	Depth Max. Pop. (m)
<u>Munida valida</u>	164	622	<u>Munida longipes</u>	400
<u>Munida longipes</u>	66	342	<u>Munidopsis sigsbei</u>	950
<u>Munidopsis robusta</u>	44	516	<u>Munida valida</u>	650
<u>Munidopsis sigsbei</u>	22	1064	<u>Munidopsis simplex</u>	1350
<u>Munidopsis erinaceus</u>	15	622	<u>Munidopsis longimanus</u>	750
<u>Munidopsis longimanus</u>	9	1172	<u>Munida forceps</u>	200
<u>Munidopsis simplex</u>	9	1172	<u>Munidopsis robusta</u>	500

Paguridae--The hermit crabs are a very complex group in which the deep-water representatives had not been studied very intensively until recently. The genus Parapagurus in particular is very speciose and, indeed, three species in the LGL collection appear not to have been described (Table 4-11). Note also that the genus Parapagurus contains species that are confined to either shallow or deep zones.

Chirostylidae, Lithodidae, and Porcellanidae--Since there is a total of only four species in these three families, they are combined with the pagurids in Table 4-11. Because the taxonomy of the pagurids has been expanded so much in the last three years, a comparison between the pagurids in the LGL and TerEco studies would not be very edifying at this time. Nevertheless, it will be useful to scan the zonal distributions of all the LGL Anomura, as in Table 4-12.

Table 4-11. Inventory of Anomura (except Galatheidae) arranged in order of abundance by depth of maximum population on Cruises I-III.

Species Name	Total Indiv. at all Stations	Number of stations where Species Dominant*	Depth Range (m)	Depth of Max Pop. (m)	Occurrence on Transects	Transect of Deepest Occurrence
<i>Paguristes</i> sp.	1	0	329	329	-, C, -	C
<i>Porcellana sigsbeiana</i>	3	2	329-338	338	-, C, -	C
<i>Pagurus rotundimanus</i>	2	0	342	342	W, -, -	W
<i>Axiopsis</i> sp.A	1	1	367	367	-, -, E	E
<i>Parapagurus pictus</i>	12	4	342-2314	516	W, C, -	W
<i>Parapagurus pilosimanus</i>	47	4	603-1510	603	-, C, E	C
<i>Uroptychus nitidus</i>	29	4	622-1510	622	W, C, E	C
<i>Parapagurus</i> sp.	1	0	802	802	-, C, -	C
<i>Lithodes agassizii</i>	4	2	850-1438	850	-, C, -	C
<i>Parapagurus bicristatus</i>	1	0	850	850	-, C, -	C
<i>Catapaguroides microps</i>	4	1	850-1440	964	-, C, -	C
<i>Gastroptychus spinifer</i>	1	1	2401	2401	-, C, -	C
<i>Parapagurus</i> n. sp.	18	3	850-2504	2504	W, C, -	C
<i>Parapagurus nudus</i>	1	0	2504	2504	-, C, -	C

\*See Table 4-2 for explanation.



Table 4-12. The zonal distribution of species in the families Paguridae, Porcellanidae, Chirostylidae, and Lithodidae from the three sampling transects.

Zone	No. of spp. With Max. Pop. in Zone	No. of Other spp. That Live in the Zone	Tot.
Shelf/Slope Transition			
(150-450 m)	4	1	5
Archibenthal Zone			
(475-950 m)	6	2	8
Upper Abyssal			
(975-2250 m)	1	4	5
Mesoabyssal			
(2275-3200 m)	3	1	4
	14	8	22

Macrura. The macuran decapod crustaceans are represented in the LGL collection by nine species of which the polychelids and nephropids are the most numerous (Table 4-13). This compares very closely with the 12 species noted in the TerEco report (Pequegnat et al. 1983). Details of the comparison between numerical dominants found in the two studies is presented in Table 4-14. We see that the comparison is very close, not only with regard to the species collected, but also as to depths of capture and to a lesser extent to their rank order of abundance.

Table 4-14. Comparison of numerical dominant species of Macrura in the LGL and TerEco studies (Polychelidae and Nephropidae).

Species	LGL		Species	TerEco	
	Total Collected	Depth Max. Pop. (m)		Depth Max. Pop. (m)	
<u>Stereomastis sculpta</u>	223	1172	<u>Stereomastis sculpta</u>	1050	
<u>Polycheles typhlops</u>	21	516	<u>Polycheles typhlops</u>	500	
<u>Polycheles crucifer</u>	2	1064	<u>Polycheles validus</u>	2100	
<u>Polycheles validus</u>	1	2074	<u>Polycheles crucifer</u>	1200	
<u>Nephropsis aculeata</u>	90	516	<u>Nephropsis aculeata</u>	500	
<u>Nephropsis rosea</u>	5	603	<u>Nephropsis agassizii</u>	950	
<u>Nephropsis agassizii</u>	3	828	<u>Nephropsis rosea</u>	600	

Table 4-13. Inventory of Macrura arranged in order of abundance by depth of maximum population on Cruises I-III.

Species Name	Total Indiv. at all Stations	Number of stations where Species Dominant *	Depth Range (m)	Depth of Max Pop. (m)	Occurrence on Transects	Transect of Deepest Occurrence
<u>Scyllarus cnacei</u>	1	1	342	342	W, -, -	W
<u>Nephropsis aculeata</u>	90	3	329-632	516	-, C, E	C
<u>Polycheles typnops</u>	21	2	338-653	516	W, C, -	W
<u>Nephropsis rosea</u>	5	2	603-1172	603	-, C, E	E
<u>Nephropsis agassizi</u>	3	0	828-1172	828	W, -, E	E
<u>Polycheles crucifer</u>	2	0	1064	1064	-, C, -	C
<u>Stereomastis sculpta</u>	223	15	603-2857	1172	W, C, E	E
<u>Polycheles validus</u>	1	1	2074	2074	-, C, -	C

\*See Table 4-2 for explanation.

It is evident in Table 4-15 that the centers of the populations of Polychelidae are considerably deeper than those of the nephropids.

Table 4-15. Distribution of Polychelidae and Nephropidae of the LGL collection among faunal zones.

Zone	No. of spp. With Max. Population in Zone		No. of Other Species That Live in Zone	
	Polychelidae	Nephropidae	Polychelidae	Nephropidae
Shelf/Slope Transition				
(150-450 m)	0	0	1	1
Archibenthal Zone				
(475-950 m)	1	3	1	0
Upper Abyssal				
(975-2250 m)	3	0	0	2
Mesoabyssal				
(2275-3200 m)	0	0	0	0
	—	—	—	—
	4	3	2	3

Brachyura. It is manifest in Tables 4-16 and 4-17 that the true crabs are much more abundant on the upper than lower parts of the continental slope. For instance, only three of the 17 species collected penetrate deeper than 1000 m and, indeed, no less than 11 of the 17 occur no deeper than about 500 m. Also, the distribution of brachyurans according to faunal zones (Table 4-17) illustrates their greater abundance in the shallower areas of the slope. This pattern of decline in numbers of both species and individuals at depths between 300 and 400 m is generally attributed to the decline in food sources for these predominantly predatory and scavenging organisms.

Table 4-16. Inventory of Brachyura arranged in order of abundance by depth of maximum population on Cruises I-III.

Species Name	Total Indiv. at all Stations	Number of stations where Species Dominant*	Depth Range (m)	Depth of Max Pop. (m)	Occurrence on Transects	Transect of Deepest Occurrence
<i>Acanthocarpus alexandri</i>	9	0	329-342	329	W, C, -	W
<i>Colloides leptocheles</i>	1	0	329	329	-, C, -	C
<i>Chacellus filiformis</i>	1	0	329	329	-, C, -	C
<i>Pyromaia arachna</i>	45	0	329-367	338	W, C, E	E
<i>Ethusa microphthalma</i>	18	0	329-786	338	-, C, -	C
<i>Palicus gracilis</i>	6	0	329-346	338	W, C, -	C
<i>Bathynectes superba</i>	4	0	338-342	338	W, C, -	W
<i>Thalassoplax angusta</i>	3	0	338	338	-, C, -	C
<i>Lyreidus bairdii</i>	74	2	329-346	342	W, C, -	C
<i>Stenocionops spinimana</i>	1	0	342	342	W, -, -	W
<i>Benthochascon schmitti</i>	395	4	329-828	516	W, C, E	E
<i>Bathyplox typhla</i>	309	8	367-1438	632	W, C, E	C
<i>Rochinia crassa</i>	24	0	338-1172	632	W, C, E	E
<i>Trichopeltarion nobile</i>	20	0	603-786	632	-, C, -	C
<i>Rochinia umbonata</i>	1	0	850	850	-, C, -	C
<i>Cymonomus</i> n. sp.	2	0	850	850	-, C, -	C
<i>Geryon quinquedens</i> **	51	8	367-2074	1510	W, C, E	C

\*See Table 4-2 for explanation.

\*\**Geryon fenneri* was collected on the Florida slope during Cruise IV.

Table 4-17. Comparison of the zonal distribution of Brachyura between LGL and TerEco studies. Zones as in TerEco study.

Zone	No. of spp. With Max. Pop. in Zone		No. of Other Species That Live in Zone	
	LGL	TerEco	LGL	TerEco
Shelf/Slope Transition				
(150-450 m)	10	30	4	4
Archibenthal Zone				
(475-950 m)	6	7	2	6
Upper Abyssal				
(975-2250 m)	1	2	2	4
Mesoabyssal				
(2275-3200 m)	0	0	1	0
Lower Abyssal				
(3225-3850 m)	<u>Not Sampled</u>	<u>1</u>	0	0
	17	40		

The comparison of numerical dominants between the LGL and TerEco studies is shown in Table 4-18. There are obvious similarities but the comparison is not as close as with other decapod groups.

Table 4-18. Comparison of numerical dominant brachyuran species in the LGL and TerEco studies.

Species	LGL		Species	TerEco	
	Total Collected	Depth Max. Pop. (m)		Depth Max. Pop. (m)	
<u>Benthochascon schmitti</u>	395	516	<u>Bathyplox typhla</u>	550	
<u>Bathyplox typhla</u>	309	632	<u>Lyreidus bairdii</u>	300	
<u>Lyreidus bairdii</u>	74	342	<u>Geryon quinquegens</u>	950	
<u>Geryon quinquegens</u>	51	1510	<u>Acanthocarpus alexandri</u>	200	
<u>Pyromaia arachna</u>	45	338	<u>Benthochascon schmitti</u>	400	

#### 4.1.2 ECHINODERMATA

Eighty-four species of megafaunal echinoderms were collected by the trawl from the three sampling transects. Station counts for each species are found in Appendix C-1. Asterooids and ophiuroids, which were represented by nearly equal numbers of species, accounted for about 70% of all of the echinoderms (Table 4-19). Some 60% of the echinoderm species were collected at depths greater than 1000 m, and surprisingly about 50% attained their maximum populations in the abyssal areas. As might be expected from experience, on the order of 94% of the holothurian species occurred deeper than 1000 m and, indeed, 87% reached maximum populations between 1000 and 2504 m.

Table 4-19. Number of megafaunal species collected in echinoderm classes and their bathymetric distribution.

Class	No. of Species	% of all Echinoderm spp.	No. Species Below 1000 m	% of Group Below 1000 m
Asteroidea	28	33	15	54
Ophiuroidea	30	36	13	43
Echinoidea	8	10	5	63
Holothuroidea	16	20	15	94
Crinoidea	2	1	2	100
	84	100	50	Ave. 60

#### Asteroidea

Although only 28 species of asteroids have been collected (Table 4-20) as compared with 61 species in the TerEco report (Pequegnat et al. 1983), the LGL collection contains seven species not previously reported. These are Astropecten comptus, Pseudarchaster gracilis, Mediaster pedicellaris, Norodinia antillensis, Tosia parva, Pectinaster gracilis, and Henricia antillarum. All seven were collected from the Central Transect, but the first five were restricted to that transect.

Table 4-20. Inventory of Asteroidea arranged in order of abundance by depth of maximum population on Cruises I-III.

Species Name	Total Indiv. at all Stations	Number of stations where Species Dominant*	Depth Range (m)	Depth of Max Pop. (m)	Occurrence on Transects	Transect of Deepest Occurrence
<i>Astropecten americanus</i>	12	1	329-342	329	W, C, _	W
<i>Astropecten comptus</i>	1	0	329	329	_ , C, _	C
ASTROPECTINIDAE	1	1	338	338	_ , C, _	C
<i>Odontaster hispidus</i>	2	1	342	342	W, _ , _	W
<i>Persephonaster echinulatus</i>	19	4	516-632	622	_ , C, E	C
HYMENASTERIDAE	1	0	622	622	_ , _ , E	E
<i>Pectinaster gracilis</i>	30	2	603-850	653	W, C, E	C
<i>Hymenaster</i> sp.	3	0	653-1172	653	W, _ , E	E
<i>Nymphaster arenatus</i>	54	2	653-1725	802	W, C, _	C
<i>Goniopecten demonstrans</i>	27	2	802-850	802	_ , C, _	C
<i>Cheiraster mirabilis</i>	1	0	802	802	_ , C, _	C
<i>Pseudarchaster gracilis</i>	1	0	802	802	_ , C, _	C
BRISINGIDAE	5	0	850-2504	850	_ , C, _	C
GONIASTERIDAE	1	0	850	850	_ , C, _	C
<i>Mediaster pedicellaris</i>	2	0	964	964	_ , C, _	C
<i>Novodinia antillensis</i>	1	0	964	964	_ , C, _	C
<i>Plinthaster dentatus</i>	23	0	516-2504	1064	_ , C, E	C
<i>Henricia antillarum</i>	2	0	1064-1172	1064	_ , C, E	E
<i>Dipsacaster</i> sp.	4	0	850-2314	1172	W, C, E	W
<i>Tosia parva</i>	1	0	1313	1313	_ , C, _	C
<i>Ceramaster grenadensis</i>	1	0	1438	1438	_ , C, _	C
<i>Plutonaster intermedius</i>	143	6	850-2504	2074	_ , C, _	C
<i>Zoroaster fulgens</i>	10	1	964-2074	2074	_ , C, E	C
<i>Pteraster personatus</i>	7	0	2074	2074	_ , C, _	C
<i>Litonotaster intermedius</i>	2	0	2074-2504	2074	_ , C, _	C
<i>Pseudarchaster</i> sp.	3	1	2314	2314	W, _ , _	W
<i>Dytaster insignis</i>	36	1	2504	2504	_ , C, _	C
<i>Benthopecten simplex</i>	9	0	2074-2504	2504	_ , C, _	C

\*See Table 4-2 for explanation.

In view of this substantial number of "new finds" it is surprising that the first three numerical dominants are the same in both studies. It is only from the fourth onward that differences appear with species not shared in the two studies (Table 4-21).

Table 4-21. Comparison of numerical dominant asteroid species in the LGL and TerEco studies.

LGL			TerEco	
Species	Total Collected	Depth Max. Pop. (m)	Species	Depth Max. Pop. (m)
<u>Plutonaster intermedius</u>	143	2074	<u>Nymphaster arenatus</u>	900
<u>Nymphaster arenatus</u>	54	802	<u>Plutonaster intermedius</u>	1050
<u>Dytaster insignis</u>	36	2504	<u>Dytaster insignis</u>	3250
<u>Pectinaster gracilis</u>	30	653	<u>Ampheraster alaminos</u>	3250

In Table 4-22 we note that the asteroids reach maximum diversity on the slope in the Archibenthal and Upper Abyssal Zones in both studies.

Table 4-22. Comparison of the zonal distribution of asteroids between LGL and TerEco studies.

Zone	No. of spp. With Max. Pop. in Zone		No. of Other Species That Live In Zone	
	LGL	TerEco	LGL	TerEco
Shelf/Slope Transition (150-450 m)	4	13	0	5
Archibenthal Zone (475-950 m)	10	20	4	5
Upper Abyssal (975-2250 m)	11	18	4	13
Mesoabyssal (2275-3200 m)	3	3	5	7
Lower Abyssal (3225-3850 m)	Not Sampled	5		3



## Ophiuroidea

Thirty species of ophiuroids were collected in the trawl from the three sampling transects (Table 4-23). This compares with 43 species listed in the TerEco study. Although these totals are reasonably close, considering differences in the sampling depth ranges in the two studies, other comparisons are far apart. For instance, only six of the 30 LGL species were reported in the TerEco study. In other words, about 24 species found by LGL appear not to have been taken by TerEco, and the inverse is also true. Several reasons for these disparities come to mind. First, all but three of the LGL species were collected from the Central and Eastern Transects, areas in the Gulf not sampled by TerEco. Second, there are several species in both studies where the taxonomic specialists could not assign a specific name to common genera; hence they may prove to be the same species. Finally, the level of taxonomic awareness in relation to deep-sea ophiuroids appears to have been improving in recent years.

In view of the major species differences in the two studies, it is perhaps surprising to note that two of the four numerical dominants cited in the two studies are the same.

There is a somewhat greater agreement in regard to the bathymetric or zonal distribution of ophiuroids in the two studies (Table 4-24). It is clear from both studies that more ophiuroid species occur in the Archibenthal and Upper Abyssal regions than elsewhere on the slope.

Table 4-23. Inventory of Ophiuroidea arranged in order of abundance by depth of maximum population on Cruises I-III. The question marks indicate that the species identification is uncertain at this time.

Species Name	Total Indiv. at all Stations	Number of stations where Species Dominant*	Depth Range (m)	Depth of Max Pop. (m)	Occurrence on Transects	Transect of Deepest Occurrence
<i>Ophiolipus agassizii</i>	79	2	329-850	329	_, C, _	C
<i>Ophiura acervata</i>	2	0	329	329	_, C, _	C
<i>Asteroschema tenue?</i>	1	1	342	342	W, _, _	W
<i>Ophiomusium eburneum</i>	2	1	346	346	_, C, _	C
<i>Ophiochiton grandis</i>	35	3	603-1172	622	_, C, E	E
<i>Ophiacantha</i> sp.A	24	0	622-850	622	_, C, E	C
<i>Ophiomusium armigerum</i>	8	0	622-2504	622	_, C, E	C
<i>Ophiomusium leptobrachium</i>	4	0	622	622	_, _, E	E
<i>Amphiura</i> sp.	2	0	622	622	_, _, E	E
<i>Ophiacantha</i> sp.B	2	0	622	622	_, _, E	E
<i>Ophiozonella nivea</i>	1	0	622	622	_, _, E	E
<i>Ophiomusium</i> sp.	1	0	622	622	_, _, E	E
<i>Ophiura falcifera</i>	1	0	622	622	_, _, E	E
<i>Ophiocamax fasciculata</i>	783	2	632-1438	632	_, C, _	C
<i>Ophiacantha echinulata</i>	1	0	802	802	_, C, _	C
<i>Ophiernus adpersus</i>	75	4	516-850	850	_, C, E	C
<i>Ophiocreas spinulosus</i>	1	0	850	850	_, C, _	C
<i>Ophiochondrus convolutus?</i>	1	0	850	850	_, C, _	C
<i>Ophiomusium testudo?</i>	1	0	850	850	_, C, _	C
OPHIURIDAE	3	1	622-964	964	_, C, E	C
<i>Amphiactis duplicata</i>	6	2	1064-1510	1064	W, C, _	C
<i>Ophiomusium testudo</i>	4	1	1064-2857	1064	_, C, E	E
<i>Amphioplus incisus</i>	1	0	1064	1064	_, C, _	C
<i>Ophioprium permixtum</i>	2	0	850-1172	1172	_, C, E	E
<i>Ophiura</i> sp.A	5	2	1172-1440	1413	W, C, E	C
<i>Amphiophiura sculptilis</i>	2	0	850-1440	1440	_, C, _	C
<i>Homalophiura inornata</i>	7	0	850-2504	2074	_, C, _	C
<i>Ophiernus vallinicola</i>	1	0	2074	2074	_, C, _	C
<i>Bathypectinura heros</i>	120	3	367-2504	2504	_, C, E	C
<i>Amphilepis ingolfiana?</i>	72	0	2504	2504	_, C, _	C

\*See Table 4-2 for explanation.

Table 4-24. Comparison of the zonal distribution of ophiuroids between LGL and TerEco studies.

Zone	No. of spp. With Max. Pop. in Zone		No. of Other Spp. That Live in Zone	
	LGL	TerEco	LGL	TerEco
Shelf/Slope Transition (150-450 m)	4	7	1	3
Archibenthal Zone (475-950 m)	15	19	5	6
Upper Abyssal (975-2250 m)	9	11	4	6
Mesoabyssal (2275-3200 m)	2	4	3	6
Lower Abyssal (3225-3850 m)	Not Sampled	2	0	4

#### Echinoidea

Eight species of echinoids were collected during the first three cruises (Table 4-25). As noted in earlier reports, for some unknown reason, all eight species were taken only from the Central Transect. Although 31 echinoid species were listed in the TerEco report (Pequegnat et al. 1983), the LGL collection contains two species not previously reported. There is a curious bathymetric hiatus in the distribution of the LGL echinoids in that only one species was taken between depths of 329 and 1064 m and none reached maximum population there (Table 4-25).

Again, in spite of the large disparity in collection numbers between the two studies, the three top numerical dominants in both are Plesiodiadema antillarum, an unidentified species of Brissopsis, and Phormosoma placenta. The zonal distribution of the eight LGL species is three in the Shelf/Slope Transition and five in the Upper Abyssal.

Table 4-25. Inventory of Echinoidea arranged in order of abundance by depth of maximum population on Cruises I-III.

Species Name	Total Individ. at all Stations	Number of stations where Species Dominant*	Depth Range (m)	Depth of Max Pop. (m)	Occurrence on Transects	Transect of Deepest Occurrence
<i>Brissopsis</i> sp.	10	1	329	329	-, C, -	C
<i>Brissopsis alta</i>	4	0	329	329	-, C, -	C
<i>Brissopsis atlantica</i>	1	0	329	329	-, C, -	C
<i>Echinochlamys macrostomus</i>	1	1	1064	1064	-, C, -	C
<i>Aspidodiadema jACOBYI</i>	1	0	1064	1064	-, C, -	C
<i>Plesiodiadema antillarum</i>	18	2	786-1440	1440	-, C, -	C
<i>Phormosoma placenta</i>	6	2	1438-1510	1510	-, C, -	C
<i>Echinus tyloides</i>	1	1	1725	1725	-, C, -	C

\*See Table 4-2 for explanation.

## Holothuroidea

Sixteen species of holothurians were collected from the three sampling transects (Table 4-26). This compares with 38 species listed in the TerEco report. As can be seen in Table 4-27 the holothuroids clearly prefer the deeper aspects of the slope. Note also in Table 4-27 that only one species each reached maximum populations in the Shelf/Slope Transition and Archibenthal Zones. Unlike the findings in regard to other echinoderm classes, especially the Ophiuroidea, the LGL collection does not contain any holothurian species not cited in the TerEco study.

Table 4-27. Comparison of the zonal distribution of holothuroids between LGL and TerEco studies.

Zone	No. of spp. With <u>Max. Pop. in Zone</u>		No. of Other Spp. <u>That Live in Zone</u>	
	LGL	TerEco	LGL	TerEco
Shelf/Slope Transition (150-450 m)	1	1	0	3
Archibenthal Zone (475-950 m)	1	13	3	7
Upper Abyssal (974-2250 m)	8	11	3	12
Mesabyssal Zone (2275-3200 m)	6	7	2	10
Lower Abyssal (3225-3850 m)	Not Sampled	5	0	5

## Crinoidea

Only two species of crinoids were collected from the three sampling transects (Table 4-28). These were Atelecrinus balanoides and Democrinus brevis, both of which live in the Archibenthal and Upper Abyssal Zones. In the northern Gulf crinoids appear to be more common at shallower depths

Table 4-26. Inventory of Holothuroids arranged in order of abundance by depth of maximum population on Cruises I-III.

Species Name	Total Indiv. at all Stations	Number of stations where Species Dominant*	Depth Range (m)	Depth of Max Pop. (m)	Occurrence on Transects	Transect of Deepest Occurrence
<i>Molpadia cubana</i>	1	1	338	338	-, C, -	C
<i>Mesothuria lactea</i>	105	8	516-1172	802	-, C, E	E
<i>Molpadia barbouri</i>	10	1	828-1172	1172	W, C, E	E
<i>Molpadia musculus</i>	7	1	1172	1172	-, -, E	E
<i>Echinocucumis hispida</i>	3	1	1438-1440	1438	-, C, -	C
<i>Deima validum</i>	1	0	1510	1510	-, C, -	C
<i>Psychropotes depressa</i>	24	1	2074-2504	2074	-, C, -	C
<i>Pseudostichopus</i> sp.	7	0	1064-2074	2074	-, C, -	C
<i>Molpadia blakei</i>	7	1	850-2074	2074	-, C, -	C
<i>Benthodytes lingua</i>	6	0	2074-2504	2074	-, C, -	C
<i>Pseudostichopus</i> sp.A	6	2	1438-2314	2314	W, C, -	W
<i>Pseudostichopus</i> sp.B	3	0	2314	2314	W, -, -	W
<i>Benthodytes typica</i>	99	1	2074-2504	2504	-, C, -	C
<i>Enypniastes</i> sp.	70	0	2504	2504	-, C, -	C
<i>Protankyra</i> sp.	1	0	2504	2504	-, C, -	C
<i>Bathyploetes natans?</i>	1	0	2504	2504	-, C, -	C

\*See Table 4-2 for explanation.

Table 4-28. Inventory of Crinoidea arranged in order of abundance by depth of maximum population on Cruises I-III.

Species Name	Total Individ. at all Stations	Number of stations where Species Dominant*	Depth Range (m)	Depth of Max Pop. (m)	Occurrence on Transects	Transect of Deepest Occurrence
<i>Atelecrinus balanoides</i>	14	2	653-1064	653	W, C, _	C
<i>Democrinus brevis</i>	17	2	653-1172	1172	W, C, E	E

\*See Table 4-2 for explanation.

than sampled by LGL. Note for instance that six of the 14 crinoid species listed in the TerEco study were found at depths of 150 m or less.

#### 4.1.3 DEMERSAL FISHES

A total of 112 species of demersal or benthopelagic fishes has been collected on the three sampling transects during Cruises I, II and III. Detailed station counts for the fish species are found in Appendix C-2. The complete inventory of species arranged by decreasing abundance within depths of maximum population is found in Table 4-29. Here too one can see that 32 of the 112 species (39%) are represented in the collection by a single individual. This suggests that the transects were not sampled sufficiently. Seven of the species having only one individual came from the Western Transect where four successful stations were sampled; seven came from the Eastern Transect with five stations; and eighteen came from the Central Transect with nineteen stations. In the latter case half of the species came from depths between 329 and 632 m suggesting that these depths could produce proportionally more fish species than are now in the collection. These possible gaps may be filled by results of Cruises IV and V.

In Table 4-30 we note that 31 species attain maximum populations between depths of 329 and 367 m in the Shelf/Slope Transition; that 44 species attain maximum populations between depths of 603 and 850 m in the Archibenthal; that 33 species are most abundant between depths of 964 and 1725 m in the Upper Abyssal; and only four species reach maximum populations at a depth of 2504 m in the Mesoabyssal. Many of the species having a maximum population in one zone extend into a shallower or deeper area. Although 329 m is the shallowest depth sampled by LGL, making it impossible to ascertain what species occur at shallower depths, we can get some of this information from the TerEco study. The results are presented below for all LGL species.



Table 4-29. Inventory of demersal fish arranged in order of abundance by depth of maximum population on Cruises I-III.

Species Name	Total Individ. at all Stations	Number of stations where Species Dominant	Depth Range (m)	Depth of Max Pop. (m)	Occurrence on Transects	Transect of Deepest Occurrence
<i>Coelorinchus caribbaeus</i>	135	2	329-786	329	W, C, -	C
<i>Poecilopsetta beani</i>	76	0	329-850	329	W, C, E	C
<i>Parasudis truculenta</i>	25	0	329-1172	329	W, C, E	E
<i>Hemanthias vivanus</i>	8	0	329-346	329	W, C, -	C
<i>Urophycis floridanus</i>	6	0	329-338	329	-, C, -	C
<i>Pontinus longispinis</i>	6	0	329-342	329	W, C, -	W
<i>Argentina striata</i>	5	0	329-338	329	-, C, -	C
<i>Peristedion miniatum</i>	4	0	329-342	329	W, C, -	W
<i>Prionotus stearnsi</i>	1	0	329	329	-, C, -	C
<i>Macrorhamphosus scolopax</i>	1	0	329	329	-, C, -	C
<i>Lepophidium brevibarbe</i>	1	0	329	329	-, C, -	C
<i>Malacocephalus occidentalis</i>	42	0	329-632	338	W, C, E	C
<i>Bembrops gobioides</i>	86	0	338-1172	342	W, C, E	E
<i>Setarches guentheri</i>	65	1	329-367	342	W, C, E	E
<i>Chlorophthalmus agassizi</i>	57	0	329-367	342	W, C, E	E
<i>Epigonus pandionis</i>	41	0	329-828	342	W, C, E	W
<i>Merluccius albidus</i>	14	0	329-653	342	W, C, E	W
<i>Gurgesiella sinusmexicanus</i>	6	0	342-632	342	W, C, -	C
<i>Gnathagnus egregius</i>	5	0	329-346	342	W, C, -	C
<i>Polymetme corythaeola</i>	3	0	338-342	342	W, C, -	W
<i>Synagrops spinosa</i>	1	0	342	342	W, -, -	W
<i>Raja lentiginosa</i>	1	0	342	342	W, -, -	W
<i>Steindachneria argentea</i>	29	1	329-346	346	-, C, -	C
<i>Brosmiculus imberbis</i>	17	0	342-802	346	W, C, -	C
<i>Synagrops bella</i>	7	0	346-367	346	-, C, E	E
<i>Polymixia lowei</i>	5	0	329-346	346	-, C, -	C
<i>Raja garmani</i>	2	0	329-346	346	-, C, -	C
<i>Peristedion greyae</i>	33	0	329-1172	367	W, C, E	E
<i>Hymenocephalus italicus</i>	30	1	342-367	367	W, -, E	E
<i>Lophiodes monodi</i>	5	0	367-622	367	-, -, E	E
<i>Helicolenus dactylopterus</i>	1	0	367	367	-, -, E	E
<i>Urophycis cirratus</i>	184	1	329-632	475	W, C, E	C
<i>Dibranchius atlanticus</i>	112	3	475-964	475	W, C, E	C
<i>Coelorinchus coelorhynchus</i>	70	0	329-632	475	W, C, E	C
<i>Laemonema barbatulum</i>	27	0	475-653	475	W, C, E	W
<i>Etmopterus hillianus</i>	16	0	475-632	475	-, C, -	C
<i>Hoplostethus occidentalis</i>	5	0	329-475	475	W, C, E	C
<i>Nezumia sclerochynchus</i>	4	0	475	475	-, C, -	C
<i>Symphurus marginatus</i>	2	0	367-475	475	-, C, E	C
<i>Eptatretus springeri</i>	2	0	475-632	475	-, C, -	C
<i>Etmopterus virens</i>	1	0	475	475	-, C, -	C
<i>Anacanthobatus foliostriis</i>	1	0	475	475	-, C, -	C

Table 4-29 (cont'd)

Species Name	Total Indiv. at all Stations	Number of stations where Species Dominant	Depth Range (m)	Depth of Max Pop. (m)	Occurrence on Transects	Transect of Deepest Occurrence
<i>Halosaurus oventi</i>	1	0	603	603	-, C, -	C
<i>Bathygadus macrops</i>	23	0	603-1172	622	W, C, E	E
<i>Chaunax pictus</i>	20	0	475-828	622	W, C, E	E
<i>Etmopterus schultzi</i>	4	0	603-622	622	-, C, E	E
<i>Synaphobranchus</i> sp.	2	0	622-1440	622	-, C, E	C
<i>Nezumia aequalis</i>	59	4	475-1438	632	W, C, E	C
<i>Diplacanthopoma</i> sp.	13	0	603-828	632	-, C, E	E
<i>Coryphaenoides colon</i>	11	0	603-964	632	W, C, E	C
<i>Nettastoma melanura</i>	3	0	632-653	632	W, C, -	W
<i>Facciolella</i> sp.	1	0	632	632	-, C, -	C
<i>Nezumia bubonis</i>	1	0	632	632	-, C, -	C
<i>Luciobrotula</i> sp.	1	0	632	632	-, C, -	C
CONGRIDAE	1	0	632	632	-, C, -	C
<i>Neoscopelus macrolepidotus</i>	10	0	622-850	653	W, C, E	C
<i>Yarella blackfordi</i>	4	0	603-850	653	W, C, -	C
<i>Hoplunnis</i> sp.	1	0	653	653	W, -, -	W
<i>Ophichthus cruentifer</i>	1	0	653	653	W, -, -	W
MACROURIDAE	1	0	653	653	W, -, -	W
<i>Pseudophichthys laterodorsalis</i>	7	0	603-786	786	-, C, E	C
<i>Cruriraja rugosa</i>	2	0	786	786	-, C, -	C
<i>Decapterus punctatus</i>	1	0	786	786	-, C, -	C
<i>Coryphaenoides mexicanus</i>	28	0	802-2074	802	W, C, E	C
<i>Bathygadus melanobranchus</i>	19	0	603-1064	802	W, C, E	C
<i>Malacoraja purpuriventralis</i>	4	0	802-1438	802	-, C, -	C
<i>Apristrurus parvipinnus</i>	2	0	802-850	802	-, C, -	C
<i>Synaphobranchus oregoni</i>	146	6	632-1510	828	W, C, E	C
<i>Monomitopus</i> sp.	42	0	802-1172	828	W, C, E	E
<i>Halosaurus guentheri</i>	16	0	802-1172	828	W, C, E	E
<i>Epigonus macrops</i>	2	0	828	828	W, -, -	W
<i>Leptoderma macrops</i>	1	0	828	828	-, -, E	E
<i>Hydrolagus</i> sp.	1	0	828	828	W, -, -	W
<i>Epigonus occidentalis</i>	1	0	850	850	-, C, -	C
<i>Bathyroconger vicinus</i>	1	0	850	850	-, C, -	C
<i>Cataetyx</i> sp.	4	1	964-1440	964	-, C, E	C
<i>Bathypterois viridescens</i>	3	0	828-1172	964	W, C, E	E
<i>Gadomus arcuatus</i>	3	0	828-1172	964	-, C, E	E

Table 4-29 (cont'd)

Species Name	Total Individ. at all Stations	Number of stations where Species Dominant	Depth Range (m)	Depth of Max Pop. (m)	Occurrence on Transects	Transect of Deepest Occurrence
<i>Ilyopsis brunneus</i>	55	1	828-1172	1064	-, C, E	E
<i>Dicrolene</i> sp.	38	0	786-1438	1064	W, C, E	C
<i>Aldrovandia affinis</i>	13	2	1064-1725	1064	W, C, E	C
<i>Acromycter perturbator</i>	11	0	964-1172	1064	-, C, E	E
<i>Sphagemacurus grenadae</i>	6	0	1064	1064	-, C, -	C
<i>Nezumia</i> sp.	3	0	653-1064	1064	W, C, -	C
<i>Polyacanthonotus merretti</i>	2	0	1064	1064	-, C, -	C
?NEOBYTHITINAE	1	0	1064	1064	-, C, -	C
?MORIDAE	1	0	1064	1064	-, C, -	C
? <i>Rinactes nasutus</i>	1	0	1064	1064	-, C, -	C
<i>Gadomus longifilis</i>	53	0	850-1172	1172	-, C, E	E
<i>Stephanoberyx monae</i>	38	1	1064-1510	1172	W, C, E	C
<i>Nezumia cyrano</i>	26	0	828-1172	1172	W, C, E	E
<i>Bathypterois quadrifilis</i>	16	0	964-1725	1172	-, C, E	C
<i>Bathygadus favosus</i>	12	0	1064-1172	1172	-, C, E	E
<i>Venefica procera</i>	10	2	964-2857	1172	-, C, E	E
<i>Nezumia suilla</i>	8	0	828-1172	1172	W, C, E	E
<i>Conocara</i> sp.	6	0	1172	1172	-, -, E	E
<i>Bathypterois phenax</i>	4	0	1172	1172	-, -, E	E
<i>Xyelacyba myersi</i>	2	0	1172	1172	-, -, E	E
<i>Coelorinchus</i> sp.	1	0	1172	1172	-, -, E	E
<i>Apistrurus laurussoni</i>	1	0	1172	1172	-, -, E	E
<i>Trachonurus villosus</i>	1	0	1172	1172	-, -, E	E
<i>Squalogadus modificatus</i>	1	0	1172	1172	-, -, E	E
<i>Bembrops anatirostris</i>	1	0	1172	1172	-, -, E	E
<i>Ipnops murrayi</i>	1	0	1413	1413	W, -, -	W
<i>Bathophilus</i> sp.	1	0	1440	1440	-, C, -	C
<i>Barathronus bicolor</i>	5	0	603-1725	1725	-, C, E	C
<i>Aldrovandia gracilis</i>	3	0	1064-1725	1725	-, C, E	C
<i>Nezumia longebarbatus</i>	2	0	1725	1725	-, C, -	C
<i>Bathypterois gallator</i>	5	2	2074-2504	2504	-, C, -	C
<i>Coryphaenoides macrocephalus</i>	4	0	1064-2504	2504	-, C, -	C
<i>Acanthonus armatus</i>	2	0	2504	2504	-, C, -	C
<i>Bassozetus</i> sp.	1	0	2504	2504	-, C, -	C

Table 4-30. Zonal distribution of demersal fishes.

Zone	Species With Max. Pop.	Number That Are Found:	
		Shallower	Deeper
Shelf/Slope Transtion	31	8	11
Archibenthal	44	4	11
Upper Abyssal	33	9	1
Mesoabyssal	<u>4</u>	<u>2</u>	<u>0</u>
Totals	112	23	23

In Table 30 we see that whereas 46 of the 112 species (41%) extend their bathymetric range beyond the depth limits of a zone, 66 of the species (59%) stay within the zonal depth limits. Of the 75 species that are found in the shallower zones, 22 penetrate to deeper zones and only 12 to shallower areas. However, we note that the trend is reversed in the deeper zones where 11 species moved into shallower areas and only one species extends its range from the Upper Abyssal into the Mesoabyssal.

In Table 4-31 a comparison is made of the 12 most abundant fish species in the LGL study up to now with those in the TerEco study.

Table 4-31. Comparison of the twelve most abundant species of fish between the LGL and TerEco studies. Arranged in order of numbers collected.

LGL		TerEco	
Species	Depth of Max. Pop. (m)	Species	Depth of Max. Pop. (m)
<i>Urophycis cirratus</i>	475	<i>Gadomus longifilis</i>	1050
<i>Synophobranchus oregoni</i>	1064	<i>Poecilopsetta beani</i>	250
<i>Coelorinchus caribbaeus</i>	329	<i>Dicrolene intronigra</i>	1200
<i>Dibranchius atlanticus</i>	475	<i>Dibranchius atlanticus</i>	650
<i>Bembrops gobioides</i>	475	<i>Nezumia aequalis</i>	900
<i>Poecilopsetta beani</i>	329	<i>Synophobranchus oregoni</i>	1000
<i>Coelorinchus coelorhynchus</i>	475	<i>Hymenocephalus italicus</i>	450
<i>Setarches guentheri</i>	329	<i>Monomitopus</i> sp.	1050
<i>Nezumia aequalis</i>	632	<i>Bembrops gobioides</i>	400
<i>Chlorophthalmus agassizii</i>	346	<i>Bathygadus mmelanobranchus</i>	900
<i>Ilyopis brunneus</i>	1064	<i>Aldrovandia gracilis</i>	1450
<i>Gadomus longifilis</i>	1064	<i>Urophycis cirratus</i>	450

The two lists share only seven of the twelve species compared; and the order of abundance between the list shows little similarity. This stands in bold contrast with the results of Cruises I and II where the first 13 species in the two lists had perfect correlations in abundance and rank order. One point of unclear significance is the fact that all but one of the LGL species not found in the TerEco list reach maximum populations in the shallow Shelf/Slope Transition. It is this part of the Central Transect that is most affected by the plume of the Mississippi River, but it is not now possible to establish a causal relationship. Nevertheless, this shift from a strong agreement to major differences by the addition of data from Cruise III suggests very clearly that few conclusions should be drawn prior to inclusion of data from Cruises IV and V.

#### 4.1.4 ADDITIONAL MEGAFUNAL GROUPS

In addition to the various megafaunal groups, and subgroups discussed above, representatives of other phyla were taken in the trawl and are therefore treated as megafauna in this report. Thus, in order to acquire a complete picture of some groups, for example, the Mollusca or the Polychaeta, it will be necessary for the reader to consult the sections of the report on Macrofauna as well as the Megafauna. In the present section we proposed to simply tabulate the numerical dominants of the various groups not discussed earlier (Table 4-32). A more detailed treatment of the station counts for each species will be found in Appendix C-1.

#### 4.1.5 MEGAFUNAL ASSEMBLAGES AND ZONATION

It has been established that the megabenthic fauna of the northern Gulf of Mexico undergoes a compositional change with depth from shore to the abyssal plain (Pequegnat et al. 1983). It is reported that few species so far observed occupy the full extent of this sequential gradient. Available data show also that there are more species at one point than another along this gradient because of uniformity of responses of the assembled species to a particular set of physico-chemical and biotic parameters. No area down the slope is known to be actually devoid of megafauna. Rather there appear to be clusters of species and as their

Table 4-32. The numerical dominant species in the phyla Porifera, Coelenterata, Mollusca, Annelida, and Brachiopoda taken by the trawl.

Taxon	Total Individuals (All Stations)	Depth of Max. Pop. (m)
<u>PORIFERA</u>		
<u>Polymastia</u> sp.	149	1172
<u>Thenea</u> sp.	29	2504
<u>Regadrella</u> sp.	15	1172
<u>Tethya</u> sp. 13	14	1172
<u>COELENTERATA</u>		
Alcyonaria (6)		
<u>Anthoptilum</u> <u>grandiflorum</u>	76	2504
<u>Acernella</u> <u>arbuscula</u>	12	1172
Actinaria (7)		
<u>Actinauge</u> <u>longicornis</u>	136	2074
<u>Antholoba</u> <u>perdix</u>	4	329
Scleractinea (3)		
<u>Caryophyllia</u> <u>ambrosia</u>	11	828
<u>Stephanocyathus</u> <u>diadema</u>	11	1510
<u>MOLLUSCA</u>		
Gastropoda (18)		
<u>Oocorys</u> <u>sulcata</u>	42	2504
<u>Scaphander</u> <u>watsoni</u>	21	329
<u>Leucosyrinx</u> <u>tenoceros</u>	16	964
<u>Hyalorisia</u> <u>galea</u>	9	338
<u>Buccinum</u> <u>canetae</u>	8	850
Bivalvia (19)		
<u>Propeamussium</u> sp.	174	338
<u>Anodontia</u> <u>philippiana</u>	117	342
<u>Propeamussium</u> sp. A.	80	1510
<u>Propeamussium</u> sp. C.	18	632
<u>Lucinoma</u> <u>filosa</u>	10	342
Scaphopoda (1)		
<u>Dentalium</u> <u>perlongum</u>	2	1440
Cephalopoda (7)		
<u>Semirossia</u> <u>equalis</u>	3	329
<u>Octopus</u> <u>burryi</u>	2	338
<u>Rossia</u> <u>bullisi</u>	2	622
<u>Opisthoteuthis</u> <u>agassizii</u>	2	802
<u>ANNELIDA</u>		
Polychaeta (23)		
<u>Hyalinoecia</u> <u>tubicola</u>	104	802
<u>Sarsonuphis</u> <u>hartmanae</u>	12	2074
<u>Eunice</u> <u>conglomerans</u>	10	342
<u>Eunice</u> <u>norvegica</u>	5	802
<u>Eunoe</u> sp. A.	4	516
<u>BRACHIOPODA</u> (1)		
<u>Ecnomiosa</u> <u>gerda</u>	45	964

component species change the clusters also change in a predictable sequence along the depth gradient. It is these clusters or changing assemblages of species that constitute the essence of faunal zones. Assigning single depths to the lines of separation between clusters is a matter of convenience. It is probably more realistic to consider zone separations as bands of varying width that mark where the rates of change in composition are relatively large, i.e., where some species drop out while others first appear.

Because substantial amounts of important data on vertical distribution and abundance of the megafaunal invertebrates and demersal fishes will be provided by an analysis of the findings of Cruises IV and V, the present cursory examination of zonation must be considered to be exploratory. But we tentatively examine the hypothesis that the megafauna conforms to a discernable zonal pattern in three ways. First, the way that the abundance and number of species of the mega-invertebrates and fishes vary with increasing depth is displayed graphically. Second, variations in the pattern of species richness with increasing depth is analyzed by means of a similarity index and clustered in the form of a dendrogram. Third, the depth ranges of the demersal fishes are presented as horizontal bars on a common bathymetric base in what are called "starts-and-stops" graphs. These can facilitate analysis of the species that are confined to a single zone where they join with others of wider range to form species clusters with unique compositions.

The following illustrations of the above techniques are considered to be tentative in that decisions as to their future usage must await the availability and application of information only now being put into the data bank. The changes in the numbers of species and individuals of the megafauna taken by trawl are plotted against depth in Figures 4-1 and 4-2, respectively. The curves are laid over the separation between zones as established in the TerEco study. The curves are based solely on data from the Central Transect that covers an area not sampled in that study. Although the peaks and troughs do not conform exactly with the zonal limits, as established in the TerEco study, they are judged to be reasonably close when allowances are made for the uncertainties of trawl depths and the points at which the species were collected in largest numbers.

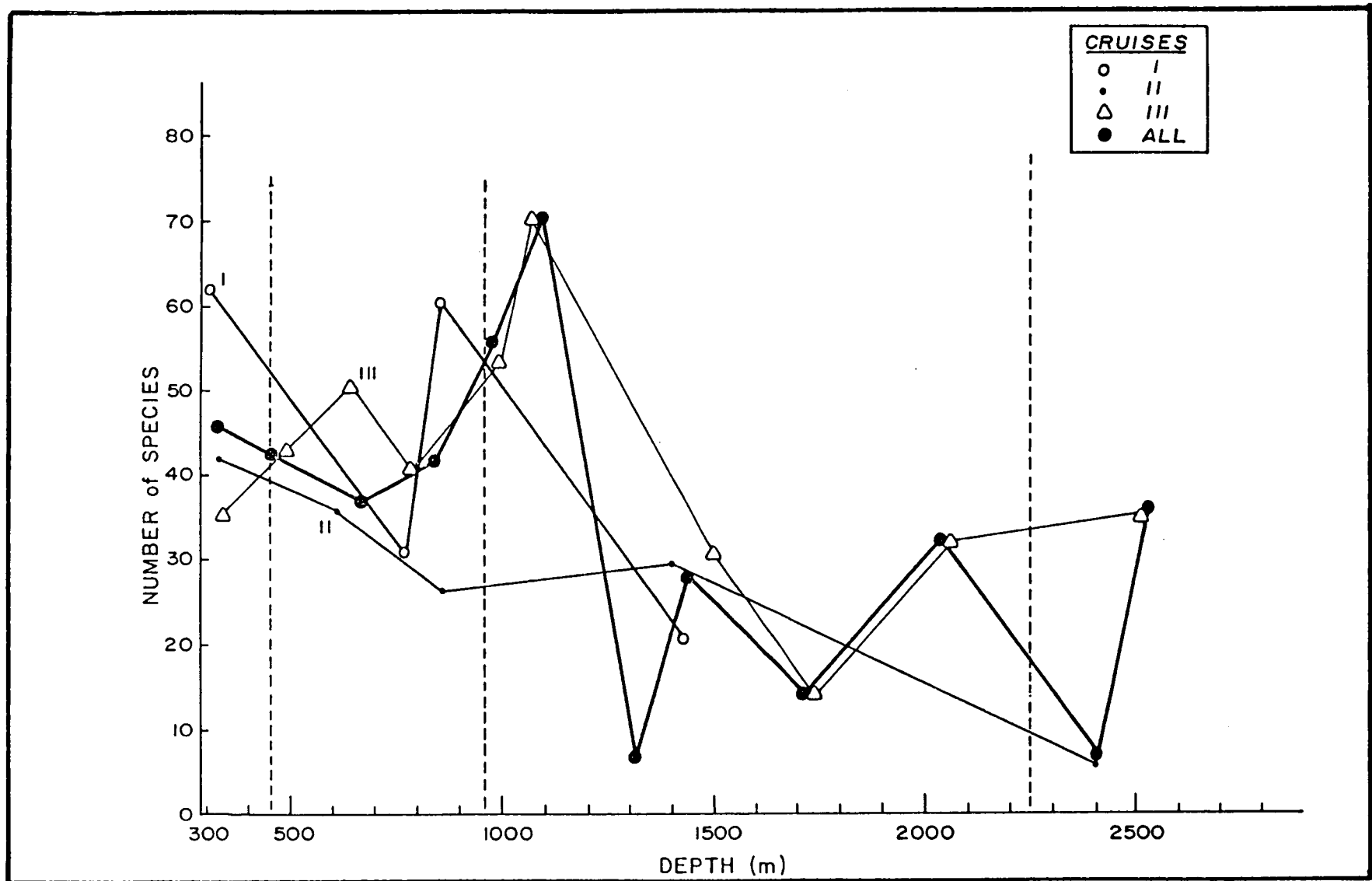


Figure 4-1. Total number of species of megafaunal invertebrates and demersal fishes taken by trawl. Plotted against depth and lines of separation between adjacent faunal zones, as established in TerEco study. Data derived from the Central Transect only.



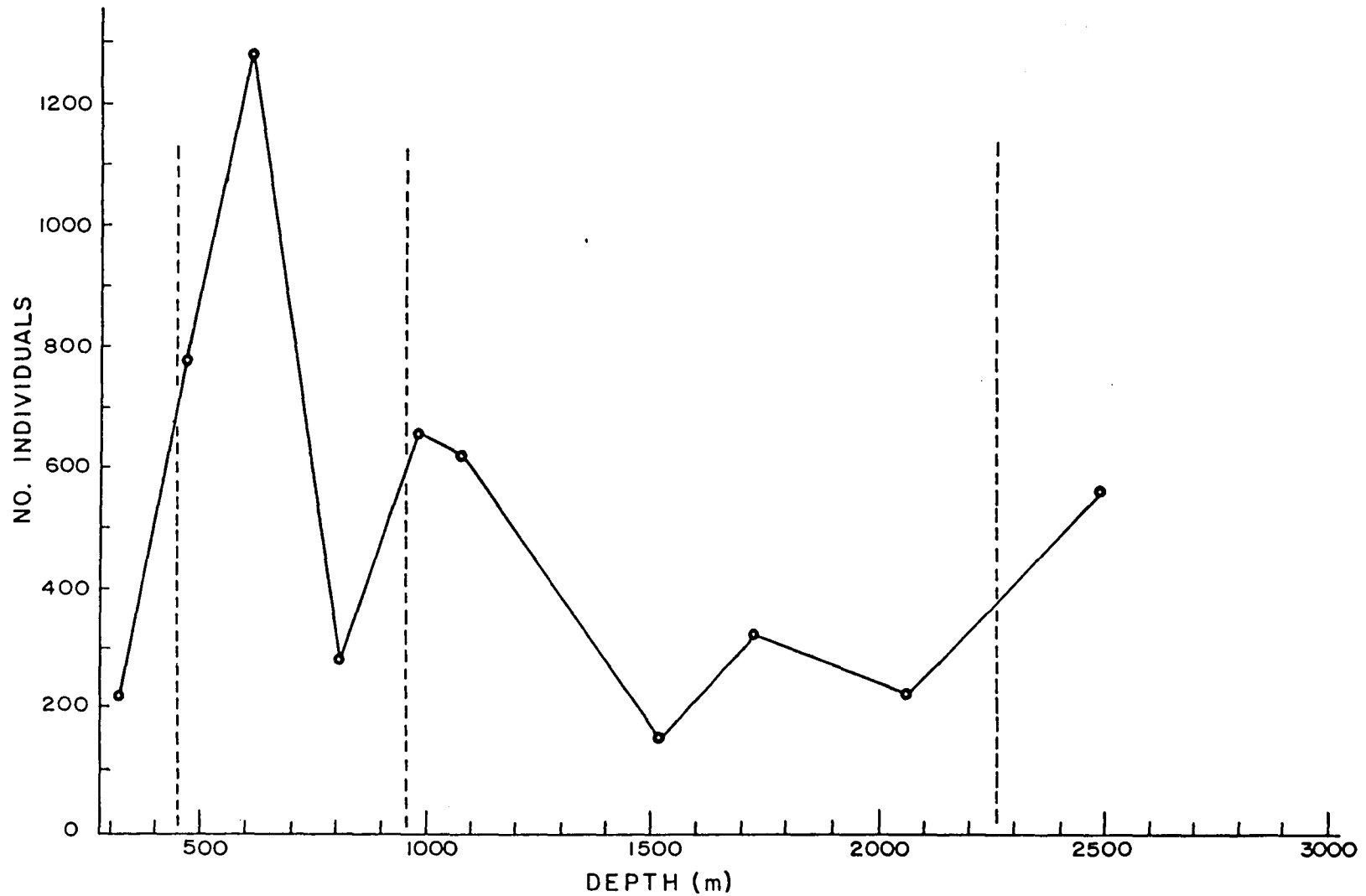


Figure 4-2. Total numbers of individuals of megafaunal invertebrates and demersal fishes taken by trawl and plotted against depth, and lines of separations between adjacent faunal zones, as established in TerEco study. Data derived from Central Transect only from Cruises I, II and III.

In Cruise I of the present study five sampling stations were trawled on the Central Transect (depths 329, 786, 850, 1440, and 2450 m); in Cruise II attempts were made to visit these central stations (depths 338, 603, 850, 1438, and 2401 m) and 10 additional stations were trawled--five on the Western Transect at 342, 653, 828, 1413, and 2314 m depths and five on the Eastern Transect at depths of 367, 622, 828, 1172, and 2857 m. In the first Annual Report one finds a dendrogram (p. 188) showing similarity of station results based on clustering of the most abundant decapod, echinoderm and demersal fish species. This preliminary attempt to classify the results seemed to support the pattern of zones for the continental shelf suggested in the TerEco study. Thus, stations with a mean depth of 2530 m stood apart as the Mesoabyssal Zone, and stations at 348 m were set apart as the Shelf/Slope Transition, and stations at 657 m as the Archibenthal Zone. Stations at 839 m and 1341 m appeared to be closely related, with the former standing for the lower part of the Archibenthal and the latter the upper part of the Upper Abyssal. After that study was circulated, it was suggested that the station depths trawled in Cruises I and II had been assigned more or less in the center of the zones suggested in the 1983 TerEco study. Because this plan tended to produce the same relationships in the zonation dendrogram as observed previously, additional stations were intercalated in the sampling gaps between Stations C1 and C5 in Cruise III. Twelve sampling stations were established on the Central Transect, but unfortunately three trawl stations had to be deleted because the trawl either did not reach bottom or it filled with mud before sampling. For the same reasons, two stations were discounted in the previous cruises. As a result, only 15 stations are utilized in constructing the dendrograms seen in Figures 4-3 and 4-4.

Horizontal bar graphs depicting the depth ranges of demersal fishes are shown in Figure 4-5. Where available, data from the TerEco study were used to extend the depth ranges of species. This is particularly useful in the case of the Shelf/Slope Transition Zone where LGL sampled only the lowest 100 m of the 350 m extension of the zone. This resulted in several species being represented by one or a few individuals.

Megafauna Invertebrates Central Transect Cruises I-III  
(Barnacles and some Stations Deleted)

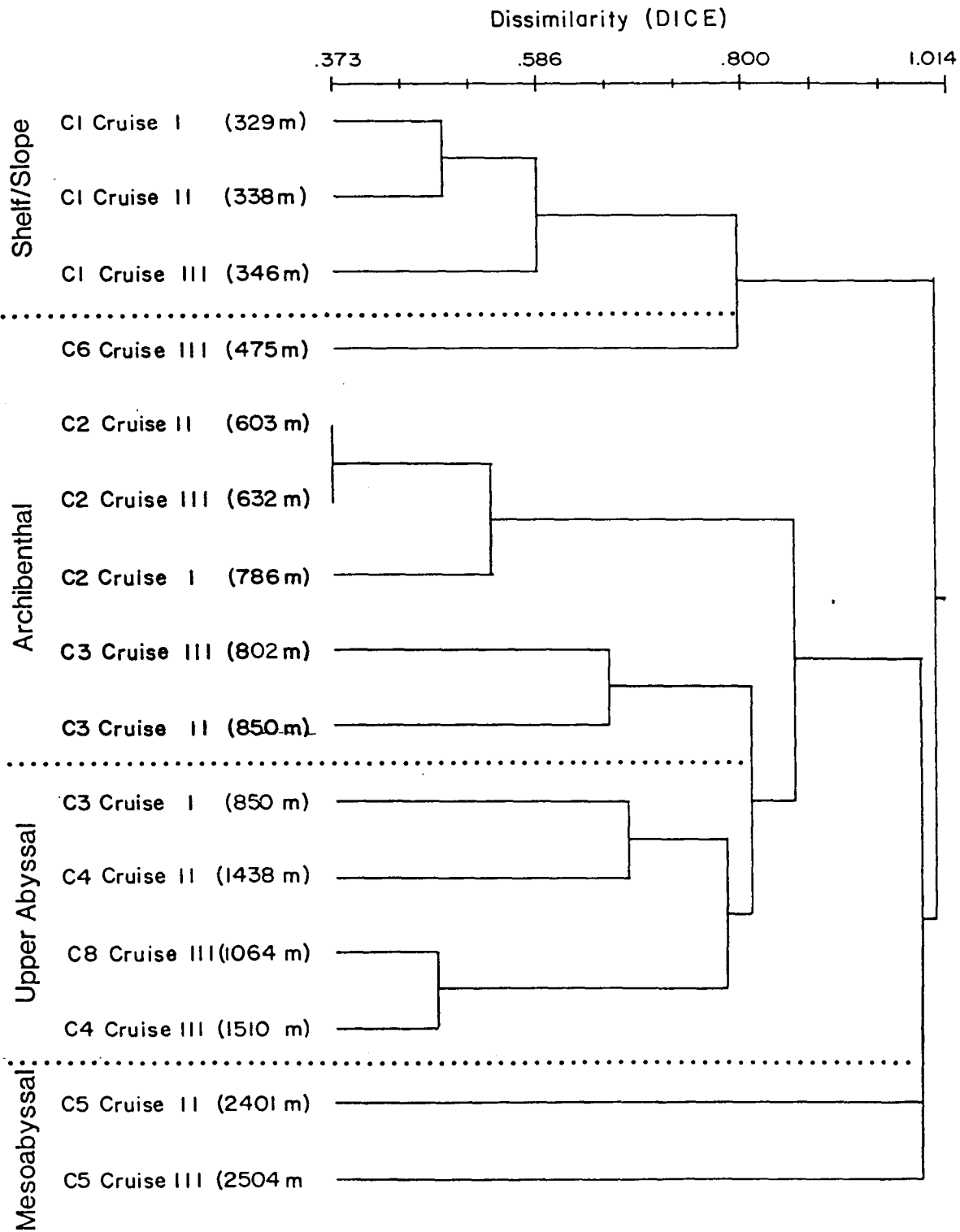


Figure 4-3. Dendrogram of invertebrate species collected by trawl and clustered on the basis of dissimilarity. For comparison, the dotted lines of zonal separation are as established in the TerEco study.

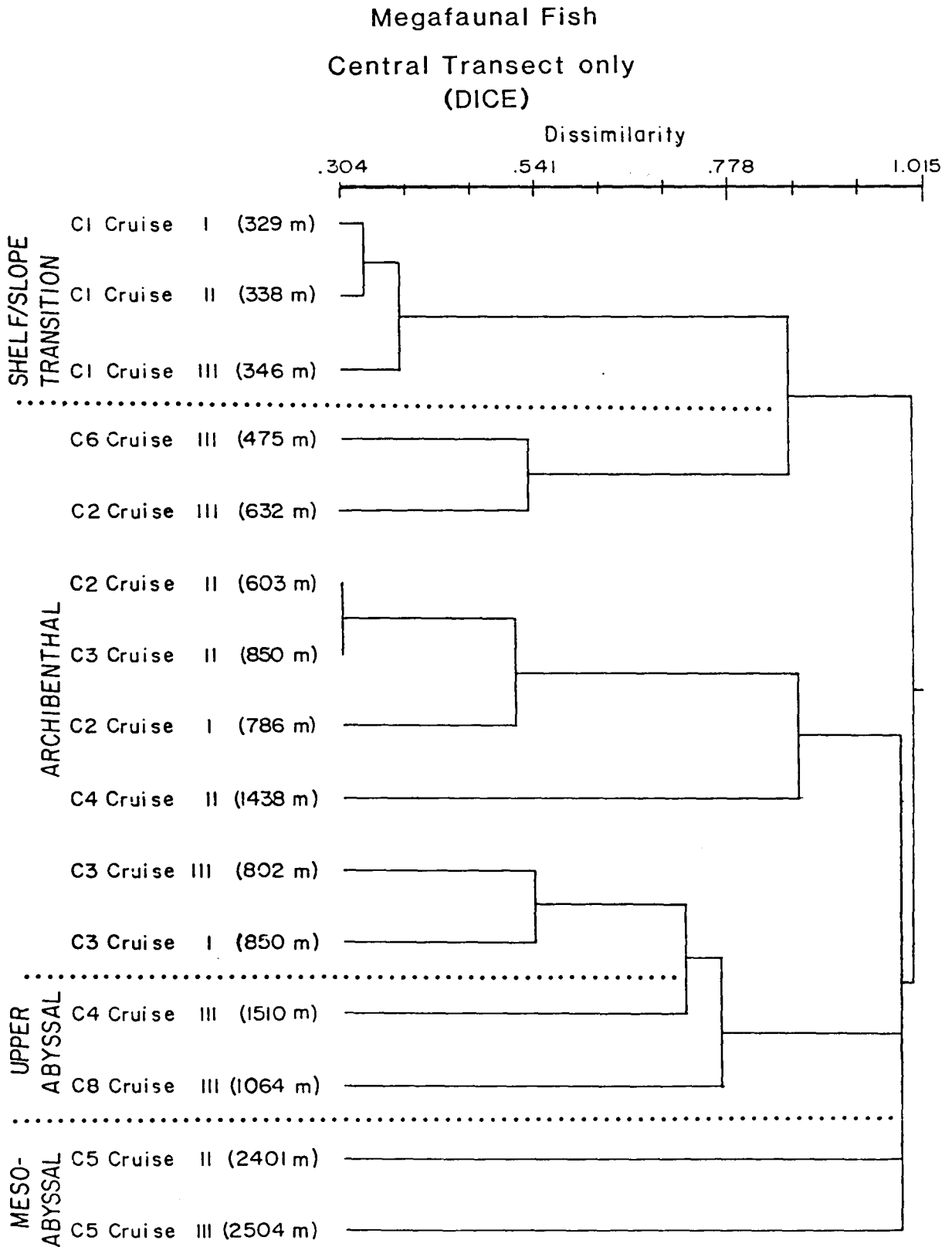


Figure 4-4. Dendrogram of demersal fish species collected by trawl and clustered on the basis of dissimilarity.

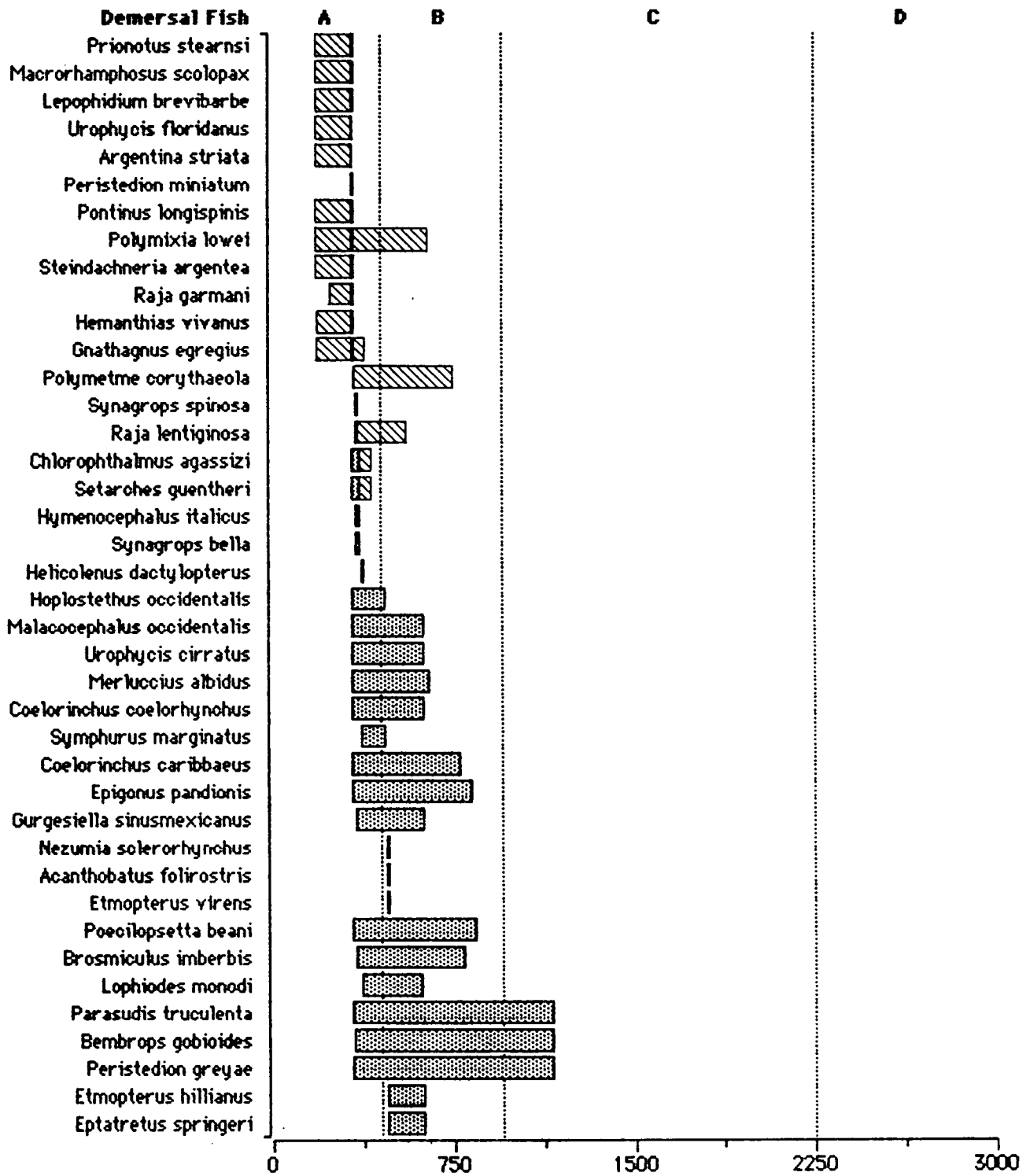


Figure 4-5. Bar graphs showing depth ranges of demersal fish species. Cross-hatched part of bars based on data from the TerEco study. Vertical lines mark position of zones established in that study: (A) Shelf/Slope Transition, (B) Archibenthal, (C) Upper Abyssal, (D) MeSo-abysal.

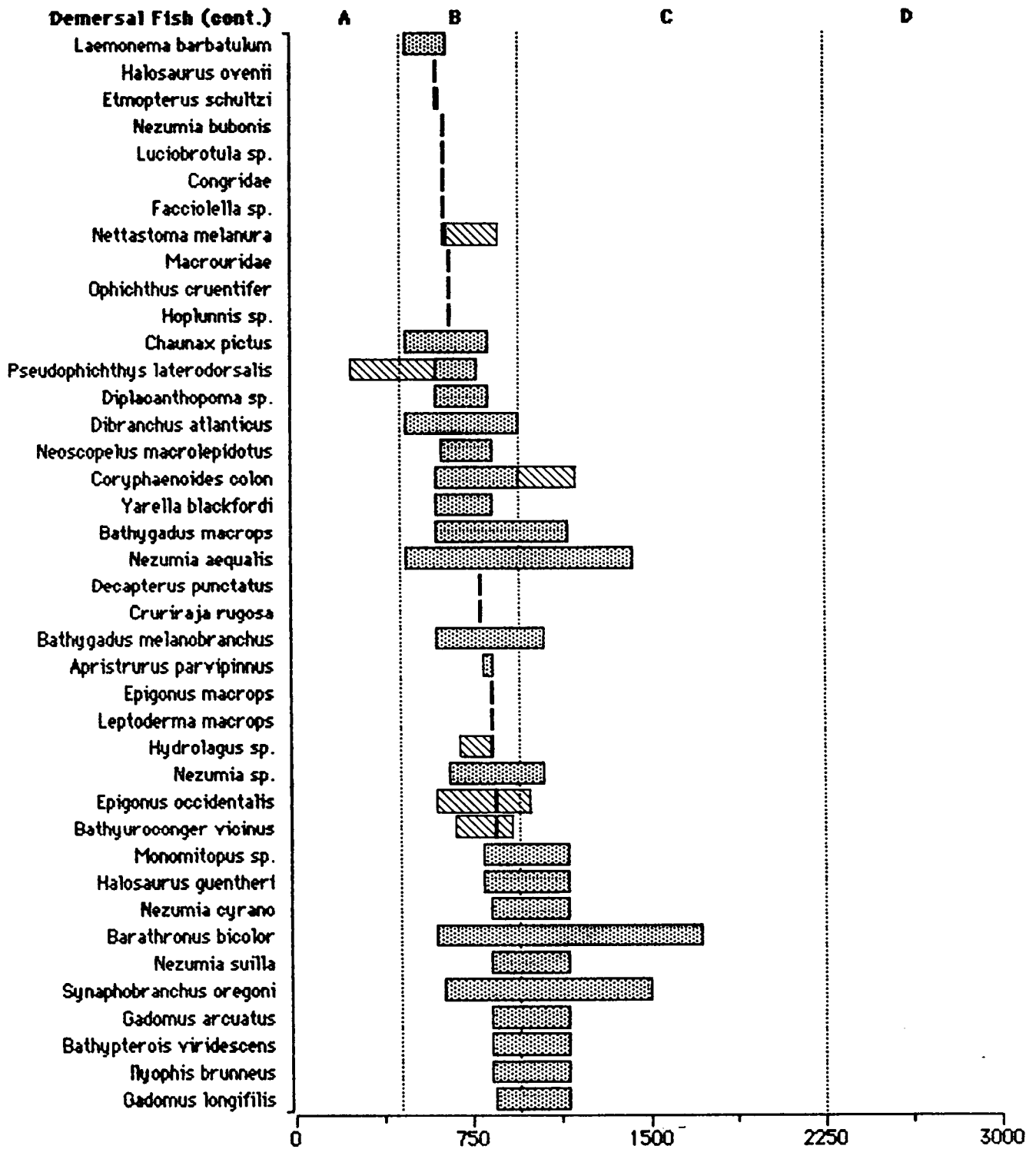


Figure 4-5 (cont'd)

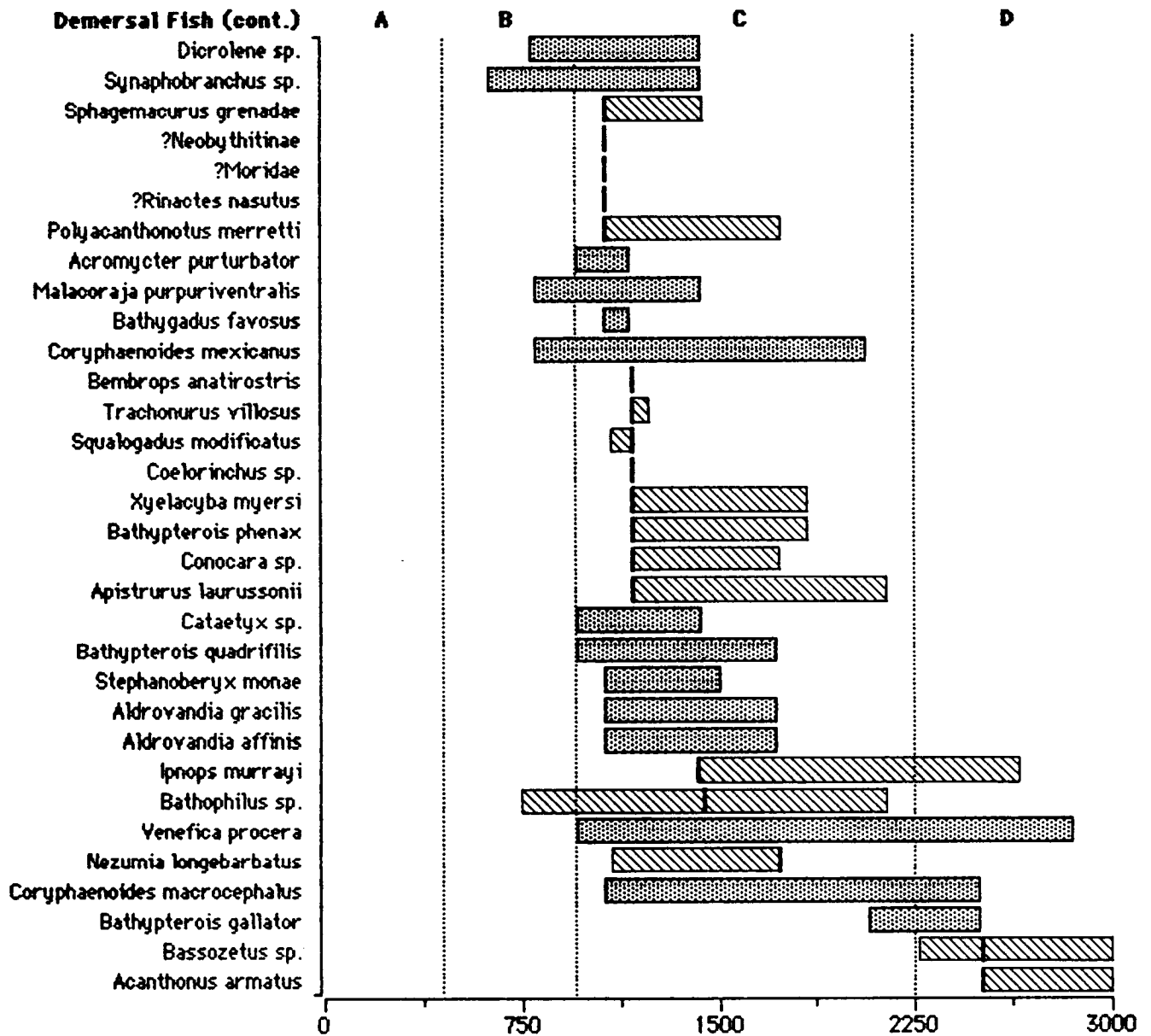


Figure 4-5 (cont'd)

### Species Composition of the Faunal Assemblages of the Slope

The following lists contain representative species of the megafaunal assemblages found on the continental slope that attain maximum populations within the depth limits specified at the head of the list. There is a high probability that these species will, as a minimum, be obtained when trawling within the depth limits specified for each assemblage. In some cases even a class of organisms (e.g., Asteroidea or Holothuroidea) may be represented in an assemblage by a single individual of a single species. Obviously such occurrences pose a problem, but the decision to include them in some places was made when the species was not collected in any other assemblage. For purposes of comparison, the assemblages are labelled here as they were in the 1983 TerEco study.

#### Shelf/Slope Transition Zone (150-450 m)

A comparison of faunal assemblages between those established in the TerEco study (Pequegnat et al. 1983) and the present LGL study is very interesting. For instance, in the 1983 study some 90 species of demersal fishes were assigned to this zone with 66 of them believed to attain maximum populations here also, whereas only 35 species of demersal fish of which 31 attain maximum population were taken by LGL in the zone's depth limits. These differences are readily attributable to the fact that by depth LGL sampled only the bottom third of the zone (actually only 100 of the 300 m of the zone), thereby precluding the chance of sampling species that live shallower and particularly those who move onto the slope from their centers of population on the continental shelf. In Figure 4-5 we show the number of fish species that were collected in small numbers by LGL that do live shallower than shown.

The fact that a proportionally smaller number of species listed in the TerEco study (as compared with LGL) attained maximum population in the zone, simply indicates that significant numbers of species that live on the shelf do penetrate to the greater depths of the upper slope. These assertions will be strengthened in the discussion of the Archibenthal Zone.



This zone is also characterized by the abundance of brachyuran crabs, large echinoids of the genus Brissopsis, as well as by the paucity of large sea cucumbers. Also, among galatheids, the genus Munida predominates over Munidopsis.

DEMERSAL FISHES

Coelorinchus caribbaeus  
Bembrops gobioides  
Poecilopsetta beani  
Setarchus guentheri  
Chlorophthalmus agassizii  
Epigonus pandionis  
Peristedion greyae  
Hymenocephalus italicus  
Parasudis truculenta  
Brosmiculus imberbis

ASTEROIDEA

Astropecten americanus  
Odontaster hispidus  
Astropecten comptus

HOLOTHUROIDEA

Molpadia cubana

ECHINOIDEA

Brissopsis sp.  
Brissopsis alta  
Brissopsis atlantica

OPHIUROIDEA

Ophiolipus agassizii  
Ophiura acervata  
Ophiomusium eburneum  
Asteroschema tenu

CIRRIPIEDIA

Verruca nexa  
Euscalpellum stratum

CRUSTACEA

Stomatopoda

Squilla edentata

Decapoda-Caridea

Parapandalus willisi  
Heterocarpus ensifer  
Pontocaris caribbaeus  
Plesionika tenuipes

Decapoda-Palinura

Scyllarus chacei

Decapoda-Anomura

Munida longipes  
Munida forceps  
Munida irrasa

Porcellana sigsbeiana  
Pagurus rotundimanus

Paguristhes sp.

Decapoda-Brachyura

Lyreidus bairdii  
Pyromaia arachna  
Ethusa microphthalma  
Acanthocarpus alexandri  
Palicus gracilis  
Bathynectes superba  
Thalassoplax angusta

## ANTHOZOA

ActiniariaAntholoba perdix

## CEPHALOPODA

Semirossia equalisOctopus burryi

## GASTROPODA

Scaphander watsoniHyalorisia glaea

## POLYCHAETA

Eunice conglomerans

## BIVALVIA

Propeamussium sp.Anodontia philippianaLucinoma filosaArchibenthal Zone - Horizon A (475-750 m).

Demersal fishes are well represented here with a total of 45 species of which 29 have maximum populations here. However, the total number of individuals taken in those species that have maximum populations in the zone drops from 718 in the Shelf/Slope Transition to 604. Asteroids are well represented, but the Brissopsis echinoids are almost absent. Their place is taken by such echinoids as Phormosoma placenta and Plesiadiadema antillarum. It is here also that the galatheid genus Munidopsis begins to replace Munida.

## DEMERSAL FISHES

Urophycis cirratusDibranchius atlanticusCoelorinchus coelorhynchusNezumia aequalisLaemonema barbatulumBathygadus macropsChaunax pictusEtmopterus hillianus

## ASTEROIDEA

Pectinaster gracilisPersephonaster echinulatusHymenaster sp.

Hymenasteridae

## HOLOTHUROIDEA

Bathyploetes natans

ECHINOIDEA

Phormosoma placenta  
Plesiodiadema antillarum

OPHIUROIDEA

Ophiocamax fasciculata  
Ophiochiton grandis  
Ophiacantha sp. A

CRINOIDEA

Atelecrinus balanoides

CIRRIPIEDIA

None with maximum population

CRUSTACEA

Decapoda-Penaeidea

Hymenopenaeus debilis  
Hymenopenaeus robustus

Decapoda-Caridea

Plesionika holthuisi  
Pontophilus gracilis  
Glyphocrangon longlevi  
Psolidopsus barbouri

Decapoda-Astacidea

Nephropsis aculeata  
Nephropsis rosea

Decapoda-Palinura

Polycheles typhlops

Decapoda-Anomura

Parapagurus pilosimanus  
Parapagurus pictus  
Uroptychus nitidus  
Munida valida  
Munidopsis robusta  
Munidopsis erinaceus

CRUSTACEA (cont'd)

Decapoda-Brachyura

Benthochascon schmitti  
Bathyplox typhla  
Rochinia crassa

Trichopeltarion nobile

Isopoda

Bathynomus giganteus

GASTROPODA

Scaphella dubia

BIVALVIA

Amygdalum politum  
Propeamusium sp. C  
Propeamusium sp. P  
Poromya sp.

CEPHALOPODA

Rossia bullisi

POLYCHAETA

Eunoe sp. A  
Aphrodita sp. A  
Asychia gotoi

Archibenthal Zone - Horizon B (775-950 m)

Demersal fishes are still moderately well represented here with a total of 36 species, but there is a sharp reduction in those that reach maximum populations to 15 species from the 29 in Horizon A. Also, there is a marked reduction in the number of individuals in these latter species, dropping from 604 in Horizon A to 272 here. These reductions suggest the division of the demersal fish fauna into two bathymetric groups, one above and one below about the 1000-m isobath. This possible division will become evident when it is noted that in the adjacent lower zone the number of species attaining maximum populations rises substantially.

This horizon is characterized by the marked reductions in brachyuran crabs, the comparative increase of Munidopsis over Munida species, and the abundance of large sea cucumbers of the Mesothuria lactea type.

DEMERSAL FISHES

Synaphobranchus oregoni  
Monomitopus sp.  
Coryphaenoides mexicanus  
Bathygadus melanobranchus  
Halosaurus guentheri  
Pseudophichthys laterodorsalis

ASTEROIDEA

Nymphaster arenatus  
Goniopecten demonstrans  
Brisingidae  
Cheiraster mirabilis

HOLOTHUROIDEA

Mesothuria lactea

ECHINOIDEA

None collected

OPHIUROIDEA

Amphiura sp.  
Ophiernus adspersus

CRINOIDEA

None with maximum population

CRUSTACEA

Decapoda-Penaeidea  
None with maximum population

Decapoda-Caridea  
Glyphocrangon alispina  
Acathephyra armata  
Prionocrangon pectinata

Decapoda-Astacidea

Nephropsis agassizi

Decapoda-Palinura

None with maximum population

CRUSTACEA (cont'd)

Decapoda-Anomura

Parapagurus bicristatus

Lithodes agassizii

Munidopsis spinosa

Decapoda-Brachyura

Rochinia umbonata

Cymonomus n. sp.

ANTHOZOA

Scleractinia

Carvophyllia ambrosia caribbeana

GASTROPODA

Scaphander clavus

Oocorys bartschi

Gaza fischeri

Buccinum canetae

Scaphander bathymophilus

Trochida n. sp.

Upper Abyssal Zone (975-2250 m)

The number of species of demersal fishes increases in this zone with a total of 44 (see following section on station counts). It is, however, the most populous species that show the greatest increase, there being 30 species that reach maximum populations here, which is about equal to that of Horizon A and double that of Horizon B. As would be expected, the number of individuals in these species increases from 273 in Horizon B to 331 in this zone. However, this is only about half the number in Horizon A in spite of its narrow bathymetric range (275 m) as compared with the range of 1275 m in this zone.

BIVALVIA

Tellina sp. B

Calyptogena ponderosa

Limopsis sp.

Vesicomva cordata

CEPHALOPODA

Opisthototeuthis agassizi

POLYCHAETA

Hyalinoecia tubicola

Eunice norvegica

Maldanidae

DEMERSAL FISHES

Ilyophis brunneus  
Gadomus longifilis  
Dicrolene sp.  
Stephanoberyx monae  
Nezumia cyrano  
Bathypterois quadrifilis  
Aldrovandia affinis  
Bathygadus favosus  
Acromycter perturbator  
Venefica procera

ASTEROIDEA

Plutonaster intermedius  
Plinthaster dentatus  
Zoraster fulgens  
Pteraster personatus

HOLOTHUROIDEA

Psychropotes depressa  
Molpadia barbouri  
Molpadia musculus  
Pseudostichopus sp.  
Molpadia blakei  
Benthodytes lingua

ECHINOIDEA

Echinocyamus macrostomus  
Echinus tylodes  
Aspidodiadema jacobyi

OPHIUROIDEA

Homalophiura inornata  
Amphiactis duplicata  
Ophiura sp. A  
Ophiomusium testudo

CRINOIDEA

Democrinus brevis

CIRRIPEDIA

Verum idioplax  
Catherinum albatrossianum

CRUSTACEA

Decapoda-Penaeidea  
Benthesicymus bartletti  
Hemipenaeus carpenteri

Decapoda-Caridea

Nematocarcinus rotundus  
Glyphocrangon aculeata  
Heterocarpus oryx  
Glyphocrangon nobilis

Decapoda-Palinura

Stereomastis sculpta  
Polycheles crucifer  
Polycheles validus

Decapoda-Anomura

Catapaguroides microps  
Munidopsis sigsbei  
Munida micropthalma  
Munidopsis longimanus  
Munidopsis simplex

Decapoda-Brachyura

Geryon quinquedens

AMPHIPODA

Epimeria n. sp. 1  
Epimeria n. sp. 2  
Oediceroides abyssorum  
Valettiosis sp. 1

PYCNOGONIDA

Pallenopsis scoparia

ANTHOZOA

Gorgonacea

Acanella arbuscula

Chrsogorgia agassizi

Candidella sp.

Acanella sp.

Actiniaria

Actinauge longicornis

Actinoscyphia saginata

Scleractinia

Deltocyathus italicus

Stephanocyathus diadema

GASTROPODA

Leucosyrinx tenoceras

Cantrainea n. sp.

Corinnaeturris sp.

Trophon aculeatus

Mesoabyssal Zone Horizon C (2275-2700 m)

The number of demersal fishes undergoes a precipitant drop in numbers in this shallower part of the zone, as described in the TerEco study. Only five species of fishes were collected in the zone, but four attain maximum populations here. This parallels the situation found in the TerEco study where only five species were found to achieve maximum populations in the entire zone. Moreover, the number of individuals in these species totals only 12, which is about 4% of the number in the Upper Abyssal and 1% of the number in the Archibenthal Zone-Horizon A, which has a depth range of only 275 m.

BIVALVIA

Propeamussium sp. A

Limopsis aurita

Cardiomya sp.

CEPHALOPODA

Pholidoteuthis adami

POLYCHAETA

Sarsonuphis hartmanae

Gyptis sp. B

Terebellidae

BRACHIOPODA

Economiosa gerda

DEMERSAL FISHES

Bathypterois grallator  
Coryphaenoides macrocephalus  
Acanthonus armatus  
Bassozetus sp.

ASTEROIDEA

Dytaster insignis  
Benthopecten simplex  
Pseudarchaster sp.

HOLOTHUROIDEA

Benthodytes typica  
Enypniastes sp.  
Pseudostichopus sp. A  
Pseudostichopus sp. B

ECHINOIDEA

None collected

OPHIUROIDEA

Bathypectinura heros  
Amphilepis ingolfiana

CRINOIDEA

None with maximum population

CIRRIPEDIA

Megalasma carinatum

CRUSTACEA

Decapoda-Penaeidea  
Plesiopenaeus armatus  
Benthesicymus cereus/iridescens  
Hymenopenaeus aphoticus

Decapoda-Caridea

Nematocarcinus ensifer  
Acathephyra microphtalma

Decapoda-Palinura

None with maximum population

Decapoda-Anomura

Parapagurus n. sp.  
Gastroptychus spinifer

Decapoda-Brachyura

None collected

Amphipoda

Trischizostoma longirostre

ANTHOZOA

Pennatulacea

Anthoptilum grandiflorum

GASTROPODA

Oocorys sulcata

BIVALVIA

Lyonsiella sp. A  
Cuspidaria sp.

CEPHALOPODA

Octopus defilippi  
Octopus joubini



## Mean Station Counts of Species and Individuals of Demersal Fishes

Although the number of species found within the depth limits of a particular zone, as calculated from all collecting stations, may rise above the total in the next shallower zone or horizon (as in the case of the Upper Abyssal and Horizon B of the Archibenthal, discussed in the previous section), it does not follow that the mean for the stations will rise commensurately. For example, note in Table 4-33 that the station means for species (all stations of all cruises) fall consistently from the upper to the lower slope with the reduction being most marked between Upper Abyssal and Mesoabyssal. The mean number of individuals per station within the zones follows about the same pattern. Means were used because of the disparity in numbers of sampling stations assignable to the zones and horizons.

Table 4-33. The mean number and ranges (in parentheses) of species and individuals of demersal fishes for stations within each zone.

	<u>Shelf/Slope Transition</u>	<u>Archibenthal</u>		<u>Upper Abyssal Zone</u>	<u>Mesoabyssal Zone</u>
		<u>Horizon A</u>	<u>Horizon B</u>		
No. of stations in zone	5	6	6	9	3
Vertical range of zone (m)	100	275	175	1275	225
Mean number of species at stations of zone	19 (15-24)	16 (11-20)	11 (5-15)	10 (2-24)	2 (1-4)
Mean number of individuals at stations of zone	147 (96-226)	84 (22-271)	46 (22-73)	44 (3-196)	3 (1-8)

### 4.2 MACROFAUNA

The present LGL collections from the northern Gulf of Mexico contain a minimum of 980 taxa of macrofauna (organisms held on a 0.3 mm screen) that are or eventually will be designated as species (Table 4-34). However, this total does not include some less important groups such as nemerteans, aplacophorans, priapulids and podocopid ostracods that likely

Table 4-34. Distribution of macrofaunal species among faunal zones by depth of maximum density. Numbers in parentheses are other species that occur in the zone. Underlined numbers mark the zone in which the largest number of species of a given taxon attain maximum densities. Data derived from all transects.

Taxa	Faunal Zones				Totals Max. Density Only
	Shelf/Slope Transition (150-450 m)	Archibenthal Zone (475-950 m)	Upper Abyssal (975-2250 m)	Mesoabyssal (2275-3225 m)	
Porifera	0 ( 0)	3 ( 4)	<u>17</u> ( 3)	11 ( 0)	31
Coelenterata	5 ( 2)	<u>6</u> ( 2)	5 ( 2)	0 ( 0)	16
Polychaeta	92 ( 62)	<u>143</u> ( 87)	62 ( 84)	6 ( 50)	322
Gastropoda	<u>10</u> ( 5)	6 ( 7)	8 ( 1)	0 ( 0)	24
Bivalvia	9 ( 11)	6 ( 16)	<u>24</u> ( 5)	10 ( 9)	49
Scaphopoda	1 ( 2)	0 ( 6)	<u>6</u> ( 3)	3 ( 3)	10
Mydocopa	3 ( 2)	<u>9</u> ( 4)	2 ( 6)	1 ( 1)	15
Cumacea	6 ( 12)	20 ( 15)	<u>23</u> ( 11)	6 ( 4)	55
Tanaidacea	7 ( 19)	48 ( 46)	58 ( 28)	20 ( 21)	133
Isopoda	11 ( 3)	24 ( 42)	<u>51</u> ( 27)	14 ( 21)	100
Amphipoda	16 ( 13)	<u>27</u> ( 20)	18 ( 15)	1 ( 6)	62
Sipuncula	16 ( 3)	12 ( 7)	8 ( 4)	1 ( 2)	37
Bryozoa	14 ( 6)	22 ( 7)	<u>24</u> ( 6)	10 ( 3)	70
Brachiopoda	0 ( 1)	0 ( 1)	2 ( 0)	0 ( 1)	2
Ascidacea	0 ( 0)	0 ( 2)	<u>8</u> ( 0)	2 ( 1)	10
Asteroidea	1 ( 0)	0	1 ( 0)	0 ( 0)	2
Ophiuroidea	4 ( 1)	4 ( 4)	<u>5</u> ( 2)	3 ( 0)	16
Echinoidea	0 ( 1)	0 ( 2)	1 ( 1)	<u>2</u> ( 1)	3
Holothuroidea	1 ( 0)	2 ( 2)	<u>6</u> ( 3)	0 ( 2)	9
Crinoidea	0 ( 0)	0 ( 0)	2 ( 0)	0 ( 0)	2
MAX. DENSITY TOTALS	196	332	331	88	968*
OTHER SPECIES TOTALS	(143)	(274)	(201)	(125)	
GRAND TOTALS IN ZONES	339	606	532	213	

\*Does not include undetermined species of podocopid ostracods and a few oligochaeta.

represent a large number of species, but were not originally scheduled for identification to the species level. A detailed list of station counts and densities for macrofaunal species from Cruises I, II, and III is found in Appendices C-4 and C-5.

The total station densities (no./m<sup>2</sup>) of macrofaunal species on the three sampling transects are presented in Table 4-35. The density values follow an irregular parabolic pattern with minima tending to occur at the shallow and deep ends, both of which are truncated in the LGL study. The density value of the deepest station is in all cases a fraction of that of the shallowest station (Table 4-35), particularly on the East and West Transects where the deepest value is less than 50% of that of the shallowest station. This may be attributed in part to physiography as well as depth in that the deepest stations on these transects (2827 m and 2506 m) are located on steep escarpments. In the vicinity of the West Transect the top of the Sigsbee Escarpment is marked by the 2100-m isobath. The west Florida Escarpment cuts across the lower part of the East Transect. Although a decline of station density is reported on the Central Transect (Table 4-35), it is not as pronounced--the value at Station 5 ranging from 71 to 99% of the density at Station 1. There is no escarpment on the Central Transect.

There are some differences in density among cruises that might be related to seasonal recruitment. Cruises I and III were made in November (of 1983 and 1984), while Cruise II occurred in April 1984 (Table 4-35). A comparison of Stations C1 and C5 (Central Transect) among the three cruises shows a significant increase in density during the April cruise. We note, however, that the values at these stations during Cruise III are below those of Cruise I, so a decision as to any involvement of seasonality must await analysis of faunal data from Cruises IV and V.

Macrofaunal diversity also appears to follow a pattern similar to that of density. Rex (1983) found in the northwestern Atlantic that the diversity of macrofaunal bivalves, gastropods, polychaetes and cumaceans increases with depth to a maximum at intermediate depths and then decreases in the abyss. Maximum diversity in these groups was attained at depths between 2000 and 3000 m. Rowe et al. (1982) reported similar findings for the macrofaunal assemblages taken by box cores in the northwestern Atlantic. Their data show an increase from depths of 32 to

Table 4-35. Total density (no/m<sup>2</sup>) by station of macrofaunal species collected from all stations in Cruises I-III. For densities of individual groups, consult Tables 4-35, 4-36, and 4-37.

<u>CRUISE NUMBER (DATE)</u>	<u>STATION (DEPTH m)</u>					
	<u>C1 (365)</u>	<u>C2 (563)</u>	<u>C3 (853)</u>	<u>C4 (1381)</u>	<u>C5 (2475)</u>	
I (Nov. 23-Dec. 2 1983)	3258	3648	3119	3937	2814	
II (April 3-20 1984)	<u>C1 (353)</u>	<u>C2 (598)</u>	<u>C3 (838)</u>	<u>C4 (1390)</u>	<u>C5 (2389)</u>	
	3495	6873	4463	5681	3451	
	<u>W1 (359)</u>	<u>W2 (604)</u>	<u>W3 (854)</u>	<u>W4 (1410)</u>	<u>C5 (2506)</u>	
	4652	4490	3611	1936	2082	
	<u>E1 (354)</u>	<u>E2 (627)</u>	<u>E3 (846)</u>	<u>E4 (1350)</u>	<u>E5 (2827)</u>	
	5316	5023	5991	4606	2343	
III (November 8-19 1984)	<u>C1 (357)</u>	<u>C2 (633)</u>	<u>C3 (881)</u>	<u>C4 (1465)</u>	<u>C5 (2518)</u>	
	2258	1939	2046	2646	1606	
	<u>C6 (492)</u>	<u>C7 (1021)</u>	<u>C8 (1192)</u>	<u>C9 (1430)</u>	<u>C11 (2101)</u>	<u>C12 (2945)</u>
	3163	5720	3484	5992	1592	1378

3000 m followed by a decline at the deepest station at 3659 m. Our preliminary results agree with the general pattern described by Rex, but maximum diversities in four crustacean orders were observed at depths between 800 and 1500 m (Fig. 4-6). The pattern for polychaetes differs in that maximum diversity is reached at 600 m (Fig. 4-7). Bivalves on the other hand reach maximum diversities between 1400 and 1500 m (Fig. 4-8). A comparison of diversity between the East and West Transects is shown in Figure 4-9. The reason for the larger diversity on the east transect is not known.

Rex (1983) also noted that both megafaunal invertebrates and fishes showed a trend similar to that of the macrofauna in the northwestern Atlantic. Our results from Cruises I-III do not agree with this observation. We do see a lower diversity in the abyss, but our data indicate we are not as likely to find a diversity peak at intermediate as at shallow depths.

The relative role of species competition in accounting for species diversity in the deep sea is a topic of continuing interest. One approach to investigating the changes in biological interactions with depth is to ascertain the pattern of what Rex (1983) has referred to as taxonomic diversity. In simplest terms this is the ratio of the number of species per genus (S/G) in the components of a faunal assemblage. It is generally accepted that congeneric species will relate to each other with more intense competition than with species of other genera. Hence low values of the S/G ratio are taken to indicate more intense competition than where they are high. Rex and Warren (1981) found that gastropods in the Atlantic had S/G values of 1 on the shelf and abyssal plain, while at intermediate depths they ranged from 1.2 to over 1.4. Our results tend to agree with this pattern. For example, the S/G values for macrofaunal isopods were 1.0 at all Stations C1 (average 357 m) and C5 (average 2543 m), 1.45 at C2 (average 605 m), 1.13 at C3 (average 854 m), and 1.25 at C4 (average 2543 m). The polychaetes collected at all stations on Cruise I followed the same general pattern but the shallowest and deepest stations were not as extreme: S/G values were C1, 1.20; C2, 1.34; C3, 1.30; C4, 1.42; and C5, 1.28.

In Table 4-36 it is evident that about 70% of the 980 macrofaunal species have their maximum population densities (no./m<sup>2</sup>) in the

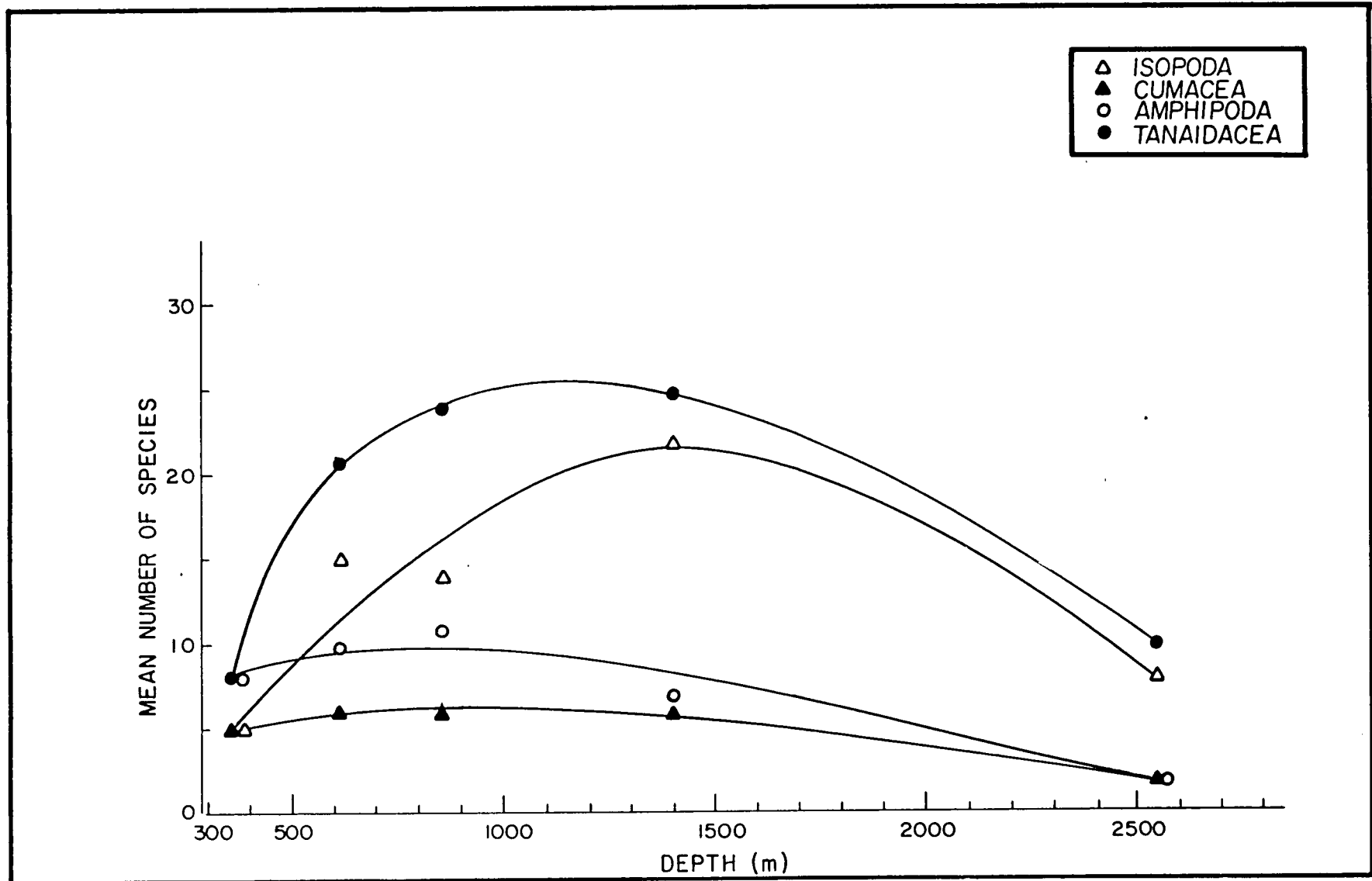


Figure 4-6. Patterns of species diversity for cumaceans, tanaidaceans, amphipods, and isopods. All groups have a maximum diversity at intermediate depths. Data derived from Stations 1-5 on Cruises I-III.

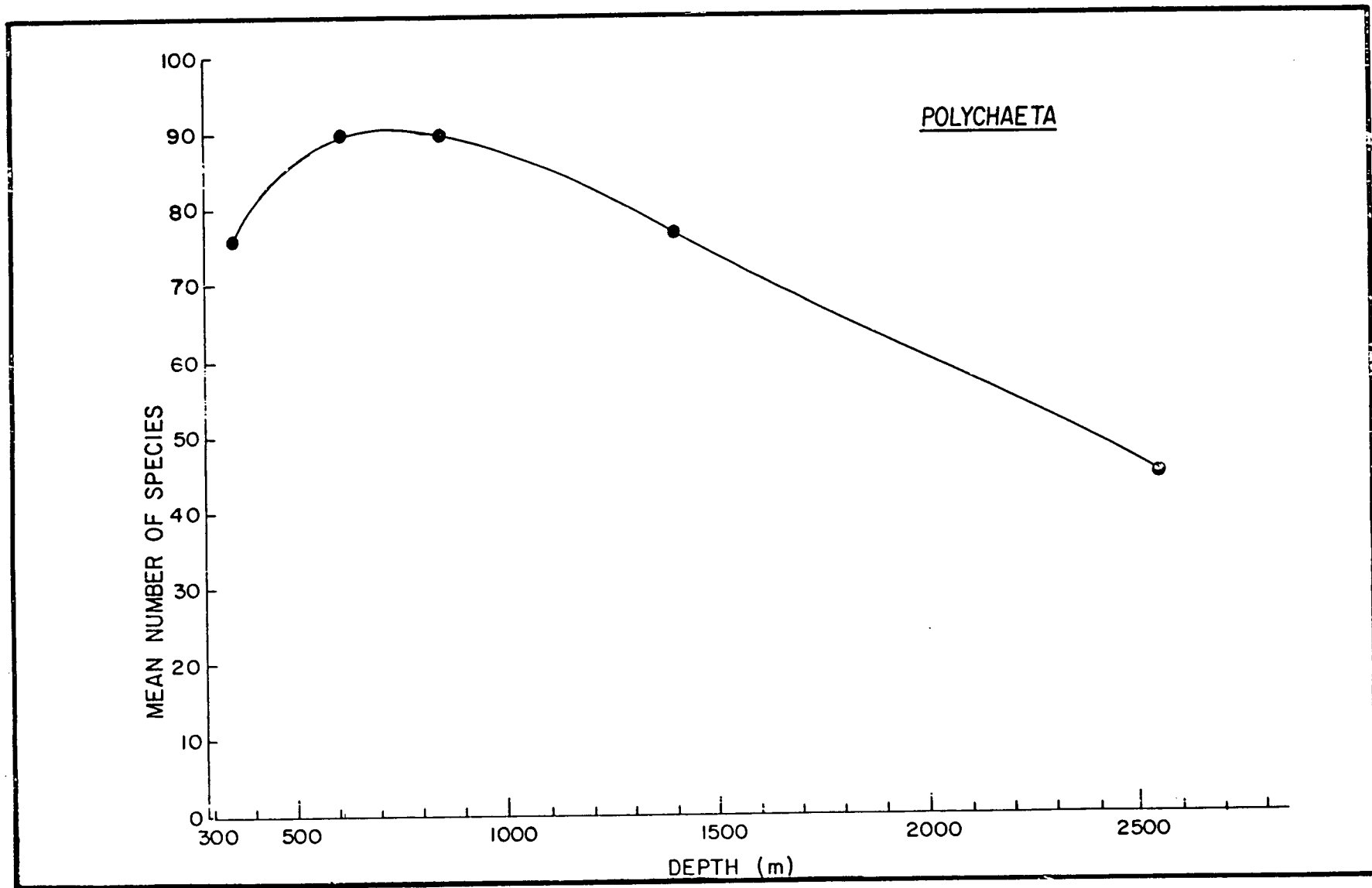


Figure 4-7. Pattern of species diversity for macrofaunal polychaetes from Stations C1-C5 of Cruise I only. Maximum diversity is attained at an intermediate depth around 600 m, considerably shallower than for other groups graphed.

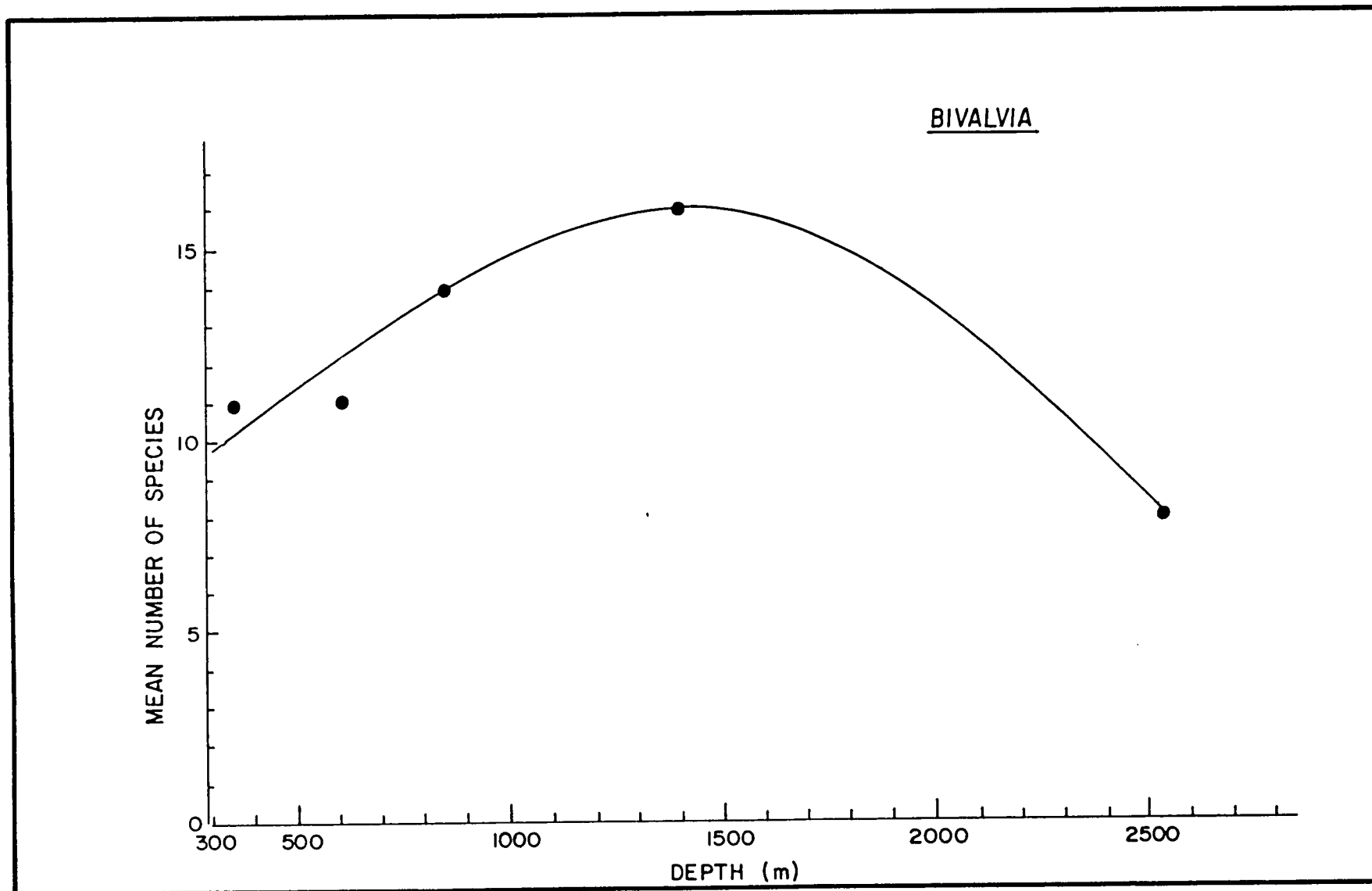


Figure 4-8. Pattern of species diversity for macrofaunal bivalves from Stations 1-5 of Cruises I-III. Maximum diversity is attained between 1400 and 1500 m.



NUMBER OF MACROFAUNAL SPECIES  
 $H'$ -DIVERSITY INDEX & EQUITABILITY  
 CRUISE II  
 Comparing East and West Transects

Number of species ( $N$ ) ———  
 Diversity Index ( $H'$ ) ———

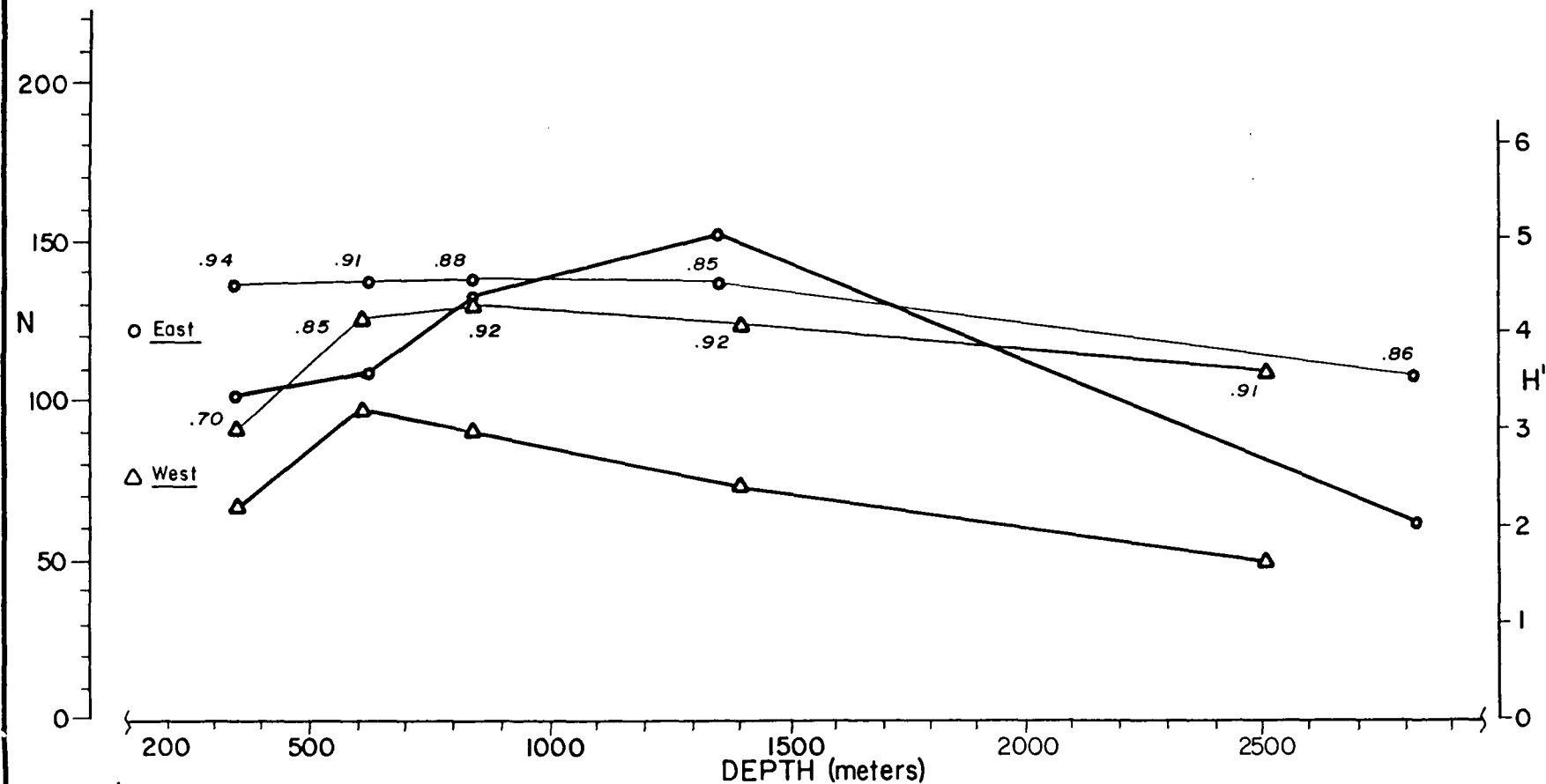


Figure 4-9. Number of species of macrofauna taken by box core from five sampling stations on the West Transect and five stations on the East Transect. Both transects sampled in April 1984. We see a substantially larger number of species on the East than West Transect.

Archibenthal (337 spp.) and Upper Abyssal (336 spp.) Zones, followed by 20% in the Shelf/Slope Transition (199 spp.) and 10% (89 spp.) in the Mesoabyssal Zones. Polychaete annelids have by far the largest number of species in the macrofauna; they are followed by tanaidaceans, isopods, and bryozoans. The large number of species of Bryozoa and the Sipuncula are unexpected, based on past deep-sea experience in the Gulf of Mexico.

The distribution of macrofaunal species among faunal zones is quite interesting. Table 4-34 shows three totals: (1) the number of species that attain maximum densities in each zone, with the Archibenthal and Upper Abyssal about even, (2) the number of other species (numbers in parentheses) that were collected in the zone, and (3) the sum of the above two totals. Although the totals do show a gradual reduction in numbers of species down the slope, it indicates that the Mesoabyssal Zone is well populated in spite of the reduced numbers of species. Much of the reduction is attributable to a marked reduction in polychaetes.

Table 4-36 reveals that an average of 65% (with a range of 35 to 100%) of the macrofaunal species appear to be confined within the depth limits of a single faunal zone. The totals show that 115 species are confined to the Shelf/Slope Transition, 195 to the Archibenthal, 139 to the Upper Abyssal, and 53 to the Mesoabyssal. Actually there are probably considerably more in the Shelf/Slope Transition and Mesoabyssal Zones, given that LGL did not sample the full bathymetric extent of either zone. It is considered quite significant that four groups typical of the macrofauna have 70% or more of their species confined to only one or another of the four zones. These groups are the Porifera (77%) with most species in the Upper Abyssal, the Sipuncula (70%) with most in the Archibenthal, the Bryozoa (77%) with most in the Archibenthal, and the Ascidacea (70%) with most in the Upper Abyssal Zone. Percentagewise, the polychaetes, amphipods and isopods are not particularly good as zone indicators. Inclusion of the Isopoda in that category is unexpected in view of the fact that other investigators employed them as indicators of their faunal zones. The polychaetes appear to be poor zone indicators, as noted by the figures in parentheses (Table 4-36) where 170 species occur in two or more zones. In part this may result from the difficulties involved in identifying many of them to the species level. Finally, we

Table 4-36. Number of species in the principal macrofauna taxa that are confined to a single faunal zone. The percentage of each group so confined given in last column. Numbers in parentheses following taxa show the species that occur in two or more zones.

Taxa	No. of Species	Archibenthal Zone		Upper Abyssal Zone		Mesoabyssal Zones	Percent of Group Confined to Zones
		No. of Species	% 1000 m	No. of Species	% 1000 m		
Porifera ( 7)	0	3	12	13	88	8	77
Coelenterata ( 5)	4	3	64	4	36	0	69
Polychaeta (170)	51	83	88	11	12	7	47
Gastropoda ( 7)	10	5	88	2	12	0	71
Bivalvia ( 35)	4	1	36	5	64	4	58
Scaphopoda ( 6)	0	0	0	3	100	1	67
Myodocopa ( 8)	1	5	86	1	14	0	47
Cumacea ( 25)	3	12	50	13	50	2	55
Tanaidacea ( 74)	5	27	44	25	56	16	50
Isopoda ( 65)	5	8	37	19	63	3	35
Amphipoda ( 34)	5	15	71	7	29	1	45
Sipuncula ( 11)	11	9	77	6	23	0	70
Bryozoa ( 16)	12	21	61	14	39	7	77
Brachiopoda ( 1)	0	0	0	1	100	0	50
Asidiacea ( 3)	0	0	0	5	100	2	70
Asteroidea ( 0)	1	0	50	1	58	0	100
Ophiuroidea ( 7)	3	3	67	2	33	1	56
Echinoidea ( 2)	0	0	0	0	100	1	50
Holothuroidea ( 4)	0	0	0	5	100	0	56
Crinoidea ( 0)	0	0	0	2	100	0	100
TOTALS	115	195		139		53	x 65

see that the preponderance of indicator species occur in zones deeper than 1000 m (62%) and the remaining 38% less than 1000 m.

A more graphic depiction of the distribution of the Sipuncula is shown in Figure 4-10. The horizontal bars indicate the depth range of each species. The dotted vertical lines simply indicate the zone boundaries that were derived for three megafaunal groups (echinoderms, decapod crustacea, and demersal fishes) in the TerEco study. Figure 4-10 is only given as an example of a technique that can be employed in zonal studies. The results are tentative at this time. A final decision to use them in any future report must await inclusion of results from Cruises IV and V. Inclusion in the figures of a species represented by a single individual is justified by the possibility that its low frequency results from a narrow bathymetric range.

There is no reason to believe at this time that if faunal zones are erected for the macrofauna and the megafauna that they have to be the same.

#### 4.2.1 POLYCHAETA

The polychaete annelids are thus far represented in the LGL collections by 43 families containing an aggregate of 176 genera that in turn contain a total of 322 species. The families having the most species are

Capitellidae -- 35	Orbiniidae -- 13
Syllidae -- 28	Lumbrineridae -- 12
Spionidae -- 26	Sabellidae -- 12
Paraonidae -- 15	Flabelligeridae -- 11
Onuphidae -- 13	Ampharetidae -- 11
Opheliidae -- 13	Maldanidae -- 9

The 12 families account for 111 (63%) of the 176 genera and 198 (61%) of the species. Many of these groups are either burrowers or tubicolous or both. Among the principal burrowers are the Capitellidae, Spionidae, Orbiniidae, Lumbrineridae, and Flabelligeridae. Principals among the tube builders are Onuphidae, Ampharetidae, Maldanidae, and Sabellidae.

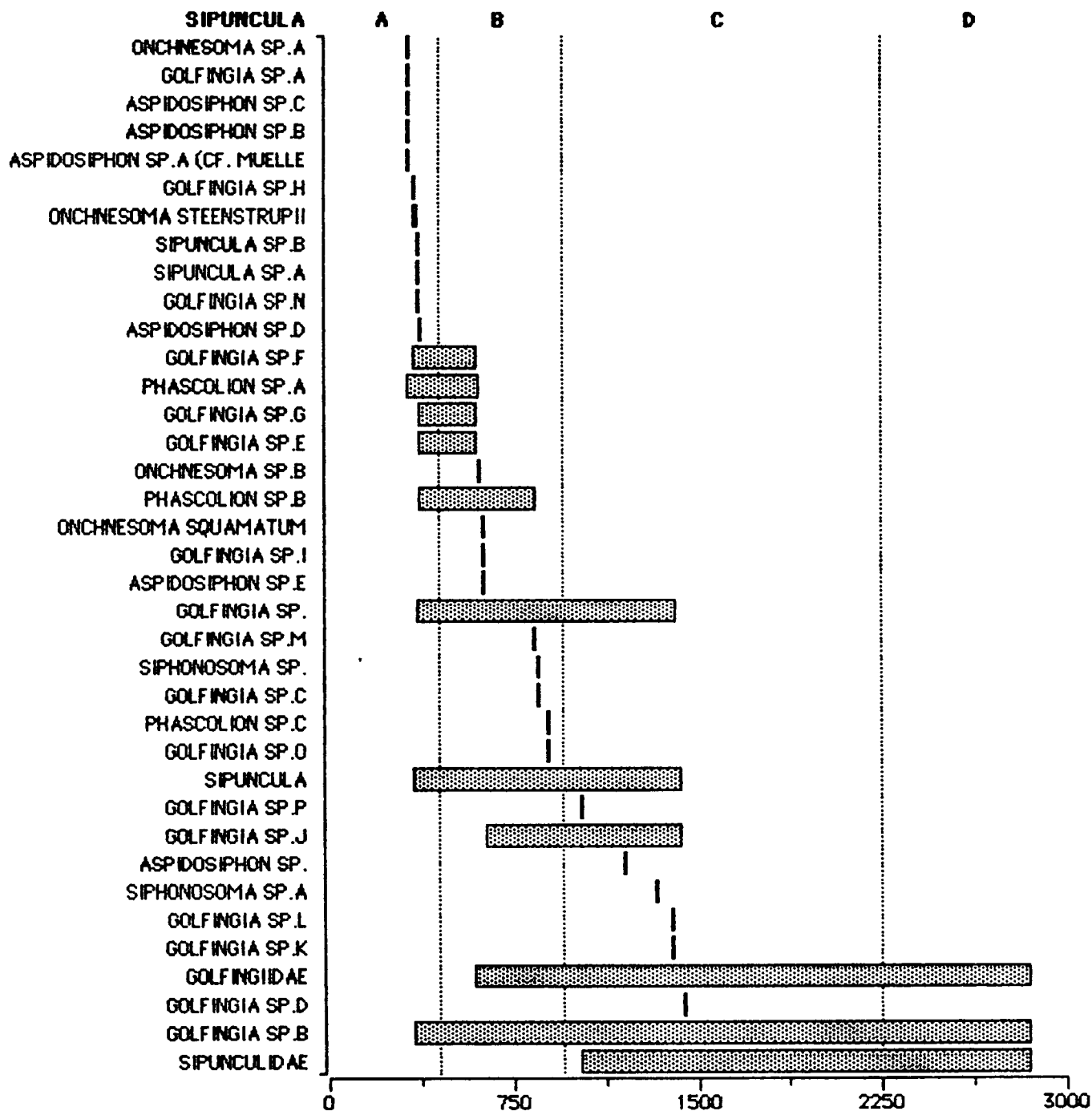


Figure 4-10. Relationships between the depth ranges of sipunculid species and four faunal zones. Thirty of the 37 species (81%) are confined to a single zone, three are found in two zones and four in three. (A) Shelf/Slope Transition, (B) Archibenthal, (C) Upper Abyssal, and (D) Mesoabyssal.

Inclusion of the Sabellids in the deep-sea fauna is somewhat surprising because they are filter feeders. The principal free-crawling species in the above list of families are found in the carnivorous Syllidae. Other carnivorous species are found in the Glyceridae, Onuphidae, and Sigalionidae. More characteristic of deep-sea feeding modes are the nonselective deposit feeders in the Opheliidae and Maldanidae, and the selective deposit feeders in the Ampharetidae, Spinoidae, Oweniidae, Cirratulidae, and Terebellidae.

Some 38 species of macrofauna had mean densities of 10 or more individuals per m<sup>2</sup> in all three cruises. Of these, 24 species or 63% were polychaetes, which are listed below in rank order with their overall densities (number in parentheses is maximum density at a single station). Rank order is for all macrofaunal taxa.

<u>Species</u>	<u>Density (no./m<sup>2</sup>)</u>	
	<u>Mean</u>	<u>Maximum</u>
1. <u>Prionospio cirrifera</u> (Spionidae)	85.3/m <sup>2</sup>	( 716/m <sup>2</sup> at W1)
2. <u>Maldane</u> "Sp. A" (Maldanidae)	79.2	(1095 at C9)
3. <u>Aricidea suecica</u> (Paraonidae)	69.7	( 202 at C1)
4. <u>Prionospio ehlersi</u> (Spionidae)	49.6	( 421 at C6)
5. <u>Tharyx marioni</u> (Terebellidae)	42.5	( 126 at W4)
6. <u>Litocarsa</u> Sp. A (Pilargidae)	42.1	(1053 at W1)
7. <u>Aedicira</u> Sp. (Paraonidae)	38.4	( 168 at C2&E4)
8. Spionidae (Spionidae)	37.4	( 274 at C1)
9. <u>Terebellides stroemi</u> (Trichobranchiidae)	37.4	( 295 at C2)
10. <u>Tachytrypane</u> Sp. A (Opheliidae)	37.4	( 295 at C2)
11. <u>Exogone</u> Sp. A (Syllidae)	29.2	( 147 at E3)
12. <u>Spiophanes berkeleyorum</u> (Spionidae)	25.5	( 274 at C2)
-		
-		
15. <u>Paramphinome pulchella</u> (Amphinomidae)	20.7	( 73 at C1)
16. Maldanidae	19.7	( 105 at W1)
-		
-		
19. Ampharetidae	17.0	( 84 at several sta.
20. <u>Paraonis gracilis</u> (Paraonidae)	16.3	( 126 at C6)

<u>Species</u>	<u>Density (no./m<sup>2</sup>)</u>	
	<u>Mean</u>	<u>Maximum</u>
21. <u>Ophelina</u> Sp. A (Opheliidae)	15.3	( 84 at C4&C6)
22. <u>Sarsonuphis hartmanae</u> (Sabellidae)	15.3	( 126 at W1)
-		
24. Syllidae	15.0	( 126 at E2)
-		
-		
27. <u>Glycera papillosa</u> (Glyceridae)	12.9	( 84 at C4)
-		
-		
30. <u>Notomastus americanus</u> (Capitellidae)	11.6	( 84/m <sup>2</sup> at C6)
31. <u>Fauveliopsis</u> Sp. B (Fauveliopsidae)	11.6	( 63 at W1&E2)
-		
33. <u>Diplocirrus capensis</u> (Flabelligeridae)	11.2	( 105 at C4)
-		
-		
-		
37. Acrocirridae	10.5	( 126 at E3)

A detailed listing of station counts and densities of polychaete species from Cruises I, II, and III may be found in Appendices C-4 and C-5. The calculation of density values is presented in Appendix A-4.

#### 4.2.2 CRUSTACEA

One of the significant contributions to our knowledge of the deep sea that the present study is making has revealed the great diversity of small macrofaunal crustaceans on the slope. Perhaps the most unexpected contribution centers in the Tanaidacea where on the order of 147 species, most of which are undescribed, have been collected thus far, and in the Isopoda with 100 species of which many are new. Essentially the same level of unexpected contributions have been made to our knowledge of the Amphipoda and the poorly known Cumacea. Each of these groups will be discussed only briefly at this time, because there are so many undescribed species.

## Tanaidacea

The 133 tanaidacean species identified thus far in this study are contained in six families and 11 genera. However, 72 of the 133 species are contained in the genus Leptognathia of the family Leptognathidae. Almost all species are new, prompting one specialist to comment, "---. If the species of Tanaidacea from the collections we now have from the Gulf of Mexico were described, the total number of species known from the world would be increased by 20 percent!" We should add, however, that of the 350 species presently described most live in the littoral zone; hence the present MMS collection has very great value.

Most of the tanaids are small, measuring from one to two mm, but a few in the deep Gulf in the genus Neotanais are several cm in length. Tanaidaceans range in feeding habit from filter feeders that strain particles from self-generated currents by means of maxillae to detritus feeders to carnivores. It is possible that some deep-sea forms feed on components of the meiofauna with which they are closely associated. The most abundant tanaids in the present collection occur in the genera Pseudotanais, with an average density of 11.5 individuals per m<sup>2</sup>, Apseudes with 8.3 individuals per m<sup>2</sup>, and Leptognathia also with 8.3 individuals per m<sup>2</sup>. Maximum densities for these species at any one station were 35, 49, and 116/m<sup>2</sup>, respectively. Detailed station counts and densities of the species of Tanaidacea are found in Appendices C-4 and C-5.

## Isopoda

In spite of the fact that there are in excess of 4000 described species of Isopoda, most of which live in the sea, many of the 100 species in the present collection are new. Most are small, measuring 0.5 to 1.5 cm, but the megafaunal species Bathynomus giganteus can attain a length of 42 cm.

Some of the isopods in the present collection are very abundant. For example, species of Gnathia and Prochelator have average densities ranging from 15 to 19 individuals per m<sup>2</sup>. Maximum densities for these species at



any one station are 407 and 172/m<sup>2</sup>, respectively. The feeding habits of isopods range generally from parasitic to omnivorous with a few exceptional forms, such as Bathynomus, that are carnivores. The deep-sea species are thought to be primarily scavengers and deposit feeders. Detailed station counts and densities of the species of Isopoda are found in Appendices C-4 and C-5.

### Cumacea

Somewhere between 800 and 850 described species of cumaceans are known. All are marine and live largely buried in the sediments with only the so-called false rostrum projecting. Most described species live in the Shelf/Slope Transition and Archibenthal Zones. Many of the 55 species in the present collection occur in the abyssal zones, attesting again to the paucity of information available on these small crustaceans. Detailed station counts and densities of the species of Cumacea are found in Appendices C-4 and C-5. Some of them are known to be widespread in the Atlantic, while others have a northerly distribution, but for the most part the Gulf cumacean fauna seems most closely related to that farther south on the continental slope of Surinam.

The cumaceans in the present collection are less abundant than the tanaidaceans and isopods. The most abundant species have overall densities ranging from 1.0 to 2.2 individuals per m<sup>2</sup>. Maximum densities at individual stations reach up to 28 per m<sup>2</sup> for the most abundant species. The feeding habits of deep-sea species are poorly known, but it is suspected that most are gleaners, scraping organic materials from the surfaces of sediment grains. Some of those that live in shallower habitats are known to be better feeders.

### Amphipoda

The Amphipoda is the most speciose order of small crustaceans described in this report, 62 species having been identified. The 5500 known species are placed in over 100 families. The majority of known species are marine, but there are some freshwater and terrestrial species as in the Isopoda. Amphipods are extremely abundant in shallow marine

waters and, indeed, are moderately abundant in the deep sea. Species in the present collection range in total population density at all stations from less than one to nearly nine individuals per m<sup>2</sup>. Maximum densities at individual stations reach up to 144/m<sup>2</sup> for the most abundant species. Some species are burrowers, others are tubicolous, and still others are free-living. The majority of those found in the deep sea are thought to be either scavengers or detritus feeders, or both. Detailed station counts and densities of the species of Amphipoda are found in Appendices C-4 and C-5.

### Ostracoda

Of the four orders of Ostracoda, the present study has thus far dealt only with the Myodocopa. A specialist in the order Podocopa has not been available. Unfortunately, the podocopans appear to be considerably more abundant in the present collection than the myodocopans. For instance, the overall population density of the podocopans is 183.7 individuals per m<sup>2</sup>, whereas that of all of the myodocopans is only 53.3. However, the density of the species Euphilomedes sp. A is 21.4/m<sup>2</sup>, which is considerably greater than most other small crustacean species. The maximum density reached by Euphilomedes sp. A at an individual station is 235/m<sup>2</sup> at Station C2, Cruise III. See Appendices C-4 and C-5 for detailed station counts and densities of the species of Ostracoda identified from this study.

All of the myodocopan species are marine and live from the shelf to the abyss where they range in feeding habits from carnivores to filter feeders. The majority in the deep sea are believed to be detritus feeders.

### 4.2.3 MOLLUSCA

#### Gastropoda

Although the class Gastropoda contains more species than any other class of mollusks, the snails are not well represented in the present collection of macrofauna simply because a box corer is not an effective

collecting device for these organisms. Nevertheless, a few interesting observations can be made. Several species are primitive opisthobranchs, especially Philene, Acteon, and Scaphander, that can be considered to be infaunal. Some of these, Scaphander in particular, are known to feed on forams, as well as bivalves, and scaphopods. Typically, deep-sea marine gastropods reach their best development on the upper part of the continental slope, and that is true of the species in the present collection. Twenty-three of the 27 macrofaunal species occur shallower than the 1000-m isobath, and only three species penetrate deeper than 2000 m isobath. This stands in sharp contrast to the substantially higher percentage of bivalves that thrive in abyssal depths. The carnivore and scavenger foraging modes of many gastropods constrains them from living in areas of low food production.

Detailed station counts and densities of the species of Gastropoda are found in Appendices C-4 and C-5.

### Bivalvia

Forty-nine species of bivalves are represented in the present collection. The majority of these are protobranchs in the subclass Palaeotaxodonta to which such genera as Nucula, Nuculana, Malletia, and Yoldiella belong. These are typically deep-sea bivalves, which are primitive of form and adapted for deposit-feeding. As a direct result of this adaptation, protobranch bivalves in particular are not as restricted bathymetrically as are gastropods. Accordingly, 39 of the 49 species occur at depths greater than 1000 m, and, indeed, 23 species penetrate below the 2000-m isobath. One of the latter, however, Cuspidaria sp., belongs to the subclass Septibranchia that is noted for its carnivorous habit, feeding upon small crustaceans and worms. The depth of maximum density of Cuspidaria sp. is around 350 m where its maximum density reaches 70/m<sup>2</sup> at Station E1. Its mean density at all stations sampled is four individuals/m<sup>2</sup>.

Detailed station counts and densities of the species of Bivalvia are found in Appendices C-4 and C-5.

## Scaphopoda

The present sampling has yielded nine species of Scaphopoda, all of which penetrate to depths of greater than 1000 m with five species extending to beyond 2000 m. One apparently eurybathic species, Dentalium perlongum, extends from 366-2470 m, but attained its depth of maximum density at the shallow 366-m level. Many of the specimens were juvenile forms unable to be identified to the species level.

Scaphopods burrow in soft bottoms like the bivalves. They feed on microscopic interstitial organisms, especially forams, in the surrounding sediment and water which are collected by means of small tentacles and ingested with a minutely toothed radula.

Station counts and densities of the species of Scaphopoda are found in Appendix C-4.

### 4.2.4 ADDITIONAL MACROFAUNAL GROUPS

Station densities for all of the macrofaunal groups, including many groups not selected for detailed discussion in this report, are listed in Tables 4-37, 4-38, and 4-39. In addition, detailed station counts and densities for the identified species in most of the macrofaunal groups are presented in Appendices C-4 and C-5.

### 4.2.5 SPECIES COMPOSITION OF THE MACROFAUNAL ASSEMBLAGES OF THE SLOPE

Only species with maximum population densities in the zone are listed, and the list is further limited by usually presenting no more than the top 10 species in order in each taxon.

Table 4-37. Densities\* of macrofaunal invertebrate groups from Cruise I (no/m<sup>2</sup>).

Taxon	Cruise I Stations					Mean Transect Density
	Depth(m)					
	365	563	853	1381	2475	
	C 1	C 2	C 3	C 4	C 5	
POLYCHAETA	1227	1511	1095	1075	633	1108
NEMATODA	469	618	343	1175	1500	821
HARPACTICOIDA	179	310	214	483	252	288
OSTRACODA	70	375	630	231	50	271
BIVALVIA	138	91	179	240	141	158
TANAIDACEA	105	290	149	193	29	153
ISOPODA	580	185	161	146	64	227
AMPHIPODA	190	97	85	53	9	87
BRYOZOA	3	12	21	64	3	21
APLACOPHORA	56	47	56	26	9	39
NEMERTEA	41	26	35	53	18	35
CUMACEA	79	23	18	47	3	34
SCAPHAPODA	12	15	23	38	23	22
SIPUNCULA	18	6	21	18	.	12
PORIFERA	.	3	3	12	3	4
GASTROPODA	35	9	21	3	3	14
SCYPHOZOA	18	.	.	3	.	4
BRACHIOPODA	.	9	.	.	.	2
ASCIDIACEA	.	.	9	32	.	8
HOLOTHUROIDEA	.	.	.	.	.	.
OPHIUROIDEA	23	12	32	44	26	28
HYDROZOA	.	.	.	.	.	.
PRIAPULIDA	.	.	3	.	21	5
ECHINOIDEA	3	.	3	3	15	5
HALACARIDA	.	.	.	.	.	.
OLIGOCHAETA	9	.	3	.	12	5
KINORHYNCHA	3	.	3	9	.	3
ECHIURA	.	.	.	.	.	.
ACTINIARIA	.	.	.	.	.	.
TURBELLARIA	.	.	3	.	.	<1
DECAPODA	.	6	.	.	.	1
SCLERACTINEA	.	.	.	.	.	.
POGONOPHORA	.	.	.	.	.	.
MYSIDACEA	.	.	.	3	.	<1
PYCNOGONIDA	.	.	.	3	.	<1
COPEPODA	.	.	9	.	.	2
CRINOIDEA	.	.	.	.	.	.
ASTEROIDEA	.	.	.	.	.	.
CEPHALOCORDATA	.	.	.	3	.	<1
CIRRIPIEDIA	.	.	.	.	.	.
HEMICHORDATA	.	.	.	.	.	.
TOTAL STATION DENSITY	3258	3645	3119	3957	2814	

\*See Appendix A-4.

Table 4-38. Densities\* of macrofaunal invertebrate groups from Cruise II (no/m<sup>2</sup>).

Taxon	Cruise II Stations					Mean Transect Density
	Depth(m)					
	359	604	854	1410	2506	
	W 1	W 2	W 3	W 4	W 5	
POLYCHAETA	2905	1853	947	737	484	1385
NEMATODA	667	1396	1235	323	547	834
HARPACTICOIDA	204	281	456	232	484	331
OSTRACODA	14	204	168	77	126	118
BIVALVIA	218	112	189	182	84	157
TANAIDACEA	126	147	189	140	112	143
ISOPODA	105	196	91	154	21	114
AMPHIPODA	21	63	35	14	7	28
BRYOZOA	84	7	70	14	77	51
APLACOPHORA	77	14	49	7	21	34
NEMERTEA	49	63	42	14	7	35
CUMACEA	21	21	42	7	7	20
SCAPHAPODA	14	.	28	7	7	11
SIPUNCULA	140	49	.	14	.	41
PORIFERA	.	7	7	7	84	21
GASTROPODA	.	7	21	.	7	7
SCYPHOZOA	.	.	7	.	.	1
BRACHIOPODA	.	.	.	7	.	1
ASCIDIACEA	.	14	7	.	7	6
HOLOTHUROIDEA	.	42	14	.	.	11
OPHIUROIDEA	.	.	.	.	.	.
HYDROZOA	.	.	.	.	.	.
PRIAPULIDA	.	.	7	.	.	1
ECHINOIDEA	.	.	7	.	.	1
HALACARIDA	.	.	.	.	.	.
OLIGOCHAETA	.	7	.	.	.	1
KINORHYNCHA	.	.	.	.	.	.
ECHIURA	.	.	.	.	.	.
ACTINIARIA	.	.	.	.	.	.
TURBELLARIA	.	.	.	.	.	.
DECAPODA	.	7	.	.	.	1
SCLERACTINEA	.	.	.	.	.	.
POGONOPHORA	.	.	.	.	.	.
MYSIDACEA	.	.	.	.	.	.
PYCNOGONIDA	7	.	.	.	.	1
COPEPODA	.	.	.	.	.	.
CRINOIDEA	.	.	.	.	.	.
ASTEROIDEA	.	.	.	.	.	.
CEPHALOCORDATA	.	.	.	.	.	.
CIRRIPIEDIA	.	.	.	.	.	.
HEMICHORDATA	.	.	.	.	.	.
TOTAL STATION DENSITY	4652	4490	3611	1936	2082	

\*See Appendix A-4.

Table 4-38 (Con't)

Taxon	Cruise II Stations					Mean Transect Density
	Depth(m)					
	353	598	838	1390	2389	
	C 1	C 2	C 3	C 4	C 5	
POLYCHAETA	1874	3495	1474	1853	989	1937
NEMATODA	604	940	786	1147	1274	950
HARPACTICOIDA	168	705	491	807	323	499
OSTRACODA	35	512	519	312	225	321
BIVALVIA	204	133	263	368	189	232
TANAIDACEA	81	432	330	239	74	231
ISOPODA	193	312	154	379	112	230
AMPHIPODA	70	133	154	74	32	93
BRYOZOA	39	49	35	137	28	58
APLACOPHORA	91	21	53	49	11	45
NEMERTEA	32	32	49	46	28	37
CUMACEA	11	63	25	39	18	31
SCAPHAPODA	.	4	7	14	35	12
SIPUNCULA	11	4	7	25	.	9
PORIFERA	.	.	4	18	.	4
GASTROPODA	42	11	46	35	14	29
SCYPHOZOA	7	.	7	.	14	6
BRACHIOPODA	7	11	4	.	25	9
ASCIDIACEA	.	.	14	46	.	12
HOLOTHUROIDEA	.	4	14	14	4	7
OPHIUROIDEA	.	.	.	.	.	.
HYDROZOA	14	4	11	11	.	8
PRIAPULIDA	4	.	4	4	28	8
ECHINOIDEA	.	.	4	14	14	6
HALACARIDA	.	.	.	18	.	4
OLIGOCHAETA	.	.	.	4	4	1
KINORHYNCHA	.	.	.	7	.	1
ECHIURA	.	.	4	.	.	<1
ACTINIARIA	4	.	.	7	.	2
TURBELLARIA	.	.	.	7	.	1
DECAPODA	4	4	.	.	.	1
SCLERACTINEA	.	.	.	.	.	.
POGONOPHORA	.	.	.	.	.	.
MYSIDACEA	.	4	.	.	.	<1
PYCNOGONIDA	.	.	.	.	.	.
COPEPODA	.	.	.	.	.	.
CRINOIDEA	.	.	.	7	.	1
ASTEROIDEA	.	.	.	.	.	.
CEPHALOCORDATA	.	.	4	.	.	<1
CIRRIPEDIA	.	.	.	.	.	.
HEMICHORDATA	.	.	.	.	.	.
TOTAL STATION DENSITY	3495	6873	4463	5681	3441	

\*See Appendix A-4.

Table 4-38 (Con't)

Taxon	Cruise II Stations					Mean Transect Density
	Depth(m)					
	354	627	846	1350	2827	
	E 1	E 2	E 3	E 4	E 5	
POLYCHAETA	1768	1895	2063	1789	526	1608
NEMATODA	1691	1895	1789	1124	774	1380
HARPACTICOIDA	344	295	456	396	305	360
OSTRACODA	182	161	421	345	174	262
BIVALVIA	372	147	267	257	68	218
TANAIDACEA	63	147	358	194	89	168
ISOPODA	49	70	105	160	95	103
AMPHIPODA	.	105	91	42	11	47
BRYOZOA	189	21	91	93	16	80
APLACOPHORA	182	91	28	29	5	60
NEMERTEA	28	21	21	17	21	21
CUMACEA	21	7	77	34	37	35
SCAPHAPODA	21	.	.	17	.	8
SIPUNCULA	77	35	35	17	21	34
PORIFERA	.	21	7	25	116	37
GASTROPODA	21	.	14	13	21	14
SCYPHOZOA	105	.	42	13	11	30
BRACHIOPODA	.	7	.	.	.	1
ASCIDIACEA	.	7	28	8	11	11
HOLOTHUROIDEA	21	56	35	21	.	25
OPHIUROIDEA	.	.	.	.	.	.
HYDROZOA	42	.	28	.	.	12
PRIAPULIDA	.	.	14	.	.	2
ECHINOIDEA	.	7	.	4	5	4
HALACARIDA	.	.	14	.	16	6
OLIGOCHAETA	28	28	.	4	21	15
KINORHYNCHA	35	.	.	.	.	6
ECHIURA	63	.	.	.	.	11
ACTINIARIA	.	.	7	4	.	2
TURBELLARIA	7	.	.	.	.	1
DECAPODA	.	7	.	.	.	1
SCLERACTINEA	.	.	.	.	.	.
POGONOPHORA	.	.	.	.	.	.
MYSIDACEA	7	.	.	.	.	1
PYCNOGONIDA	.	.	.	.	.	.
COPEPODA	.	.	.	.	.	.
CRINOIDEA	.	.	.	.	.	.
ASTEROIDEA	.	.	.	.	.	.
CEPHALOCORDATA	.	.	.	.	.	.
CIRRIPEDIA	.	.	.	.	.	.
HEMICHORDATA	.	.	.	.	.	.
TOTAL STATION DENSITY	5316	5023	5991	4606	2343	

\*See Appendix A-4.



Table 4-39. Densities\* of macrofaunal invertebrate groups from Cruise III (no/m<sup>2</sup>).

Taxon	Cruise III Stations											Mean Transect Density
	Depth(m)											
	357	492	633	881	1021	1192	1430	1465	2101	2518	2945	
	C 1	C 6	C 2	C 3	C 7	C 8	C 9	C 4	C 11	C 5	C 12	
POLYCHAETA	1516	2505	779	842	1558	968	1642	484	147	253	737	1039
NEMATODA	225	144	288	228	1568	884	2782	807	463	449	256	736
HARPACTICOIDA	60	84	63	88	358	309	288	267	119	144	53	167
OSTRACODA	28	42	347	246	393	379	253	168	21	253	77	201
BIVALVIA	112	109	147	218	396	218	337	214	95	193	91	194
TANAIDACEA	28	46	119	189	502	189	133	109	32	60	35	131
ISOPODA	70	98	39	46	232	95	137	154	28	63	60	93
AMPHIPODA	46	88	35	42	221	98	112	28	7	11	.	63
BRYOZOA	.	.	18	18	7	53	98	112	386	39	4	67
APLACOPHORA	91	25	42	42	211	56	35	32	.	11	.	49
NEMERTEA	21	14	11	18	39	35	7	42	11	7	4	19
CUMACEA	18	.	21	18	74	28	39	7	.	7	18	21
SCAPHAPODA	.	4	.	21	28	18	21	32	28	32	4	17
SIFUNCULA	7	.	4	7	21	18	4	7	4	4	.	7
PORIFERA	.	.	.	4	7	46	28	25	25	7	28	15
GASTROPODA	7	4	7	.	32	14	11	7	.	.	.	7
SCYPHOZOA	7	.	4	.	14	32	21	53	39	7	.	16
BRACHIOPODA	.	.	.	.	4	7	4	.	158	25	.	18
ASCIDIACEA	.	.	.	7	.	4	21	39	7	4	.	7
HOLOTHUROIDEA	.	.	.	4	7	18	11	11	7	18	.	7
OPHIUROIDEA	.	.	.	.	.	.	.	.	.	.	.	.
HYDROZOA	.	.	7	.	4	.	.	18	.	.	.	3
PRIAPULIDA	.	.	.	.	.	.	.	.	.	7	7	1
ECHINOIDEA	.	.	4	.	.	.	4	.	.	4	4	1
HALACARIDA	.	.	4	.	14	11	.	.	7	.	.	3
OLIGOCHAETA	4	.	.	.	.	.	.	.	.	.	.	<1
KINORHYNCHA	.	.	.	.	4	.	.	7	4	4	.	2
ECHIURA	.	.	.	.	.	.	.	.	.	.	.	.
ACTINIARIA	.	.	.	.	.	.	.	4	4	.	.	<1
TURBELLARIA	.	.	.	4	.	4	.	.	.	4	.	1
DECAPODA	.	.	.	.	4	.	.	.	.	.	.	<1
SCLERACTINEA	14	.	.	4	.	.	.	7	.	.	.	2
POGONOPHORA	.	.	.	.	18	.	.	.	.	.	.	2
MYSIDACEA	.	.	.	.	.	.	.	4	.	.	.	<1
PYCNOGONIDA	.	.	.	.	.	.	.	4	.	.	.	<1
COPEPODA	.	.	.	.	.	.	.	.	.	.	.	.
CRINOIDEA	.	.	.	.	.	.	4	.	.	.	.	<1
ASTEROIDEA	4	.	.	.	4	.	.	.	.	.	.	<1
CEPHALOCORDATA	.	.	.	.	.	.	.	.	.	.	.	.
CIRRIPEDIA	.	.	.	4	.	.	.	.	.	.	.	<1
HEMICHORDATA	.	.	.	.	.	.	.	4	.	.	.	<1
TOTAL STATION DENSITY	2258	3163	1939	2050	5720	3484	5992	2646	1592	1606	1378	

\*See Appendix A-4.

Shelf/Slope Transition Zone (150-450 m)

MALACOSTRACA-CRUSTACEA

Cumacea

Eudorella n. sp. C  
Campylaspis bicarinata  
Leptostylus macrura

Tanaidacea

Leptognathia sp. 2  
Leptognathia sp. 3  
Apseudes sp. 2  
Leptognathia sp. 61

Isopoda

Gnathia sp. 201  
Prochelator sp. 202  
Prochelator sp. 235  
Torwolia sp. 203  
Conilera sp. 214

Amphipoda

Phoxocephaliidae  
Byblis n. sp. 1  
Mayerella redunca  
Lysianassidae n. sp. 1

Myodocopa

Angulorostrum sp. A  
Harbansus sp. B

POLYCHAETA

Prionospio cirrifera  
Aricidea suecica  
Litocorsa sp. A  
Spionidae  
Paramphinomme pulchella  
Ophelina sp. A  
Sarsonuphis hartmanae  
Myriowenia sp. A

POLYCHAETA (cont'd)

Terebellidae

Lumbrinereis verrilli

BIVALVIA

Lucina sp.  
Tellina sp. A  
Pecten sp.  
Cuspidaria sp.  
Nuculana sp. D

SCAPHOPODA

Dentalium perlongum

SIPUNCULA

Golfingia sp. F  
Onchnesoma steenstrupii  
Sipuncula sp.  
Sipuncula sp. G

BRYOZOA

Metalcyonidium sp.  
Setosellina goesii  
Setosellina sp.  
Cheilostomata sp. 2169

HOLOTHUROIDEA

Myriotrochus sp.

OPHIUROIDEA

Amphiura semiermis

Archibenthal-Horizon A (475-750 m)

CRUSTACEA

Cumacea

Cumella erecta  
Cumella antipai  
Cumella dayae  
Campylaspis sp.  
Leptostylus n. sp. D  
Macrokyllindrus sp.

Tanaidacea

Aseudidae sp. 1.  
Paratanaididae sp. 1  
Neotanais sp. 1  
Leptognathia sp. 8  
Leptognathia sp. 30  
Strongylura sp. 2

Isopoda

Prochelator sp. 235  
Prochelator sp. 209  
Prochelator sp. 238  
Ischnomesus sp. 227  
Ischnomesus sp. 222  
Mirabillicoxa sp. 261

Amphipoda

Corophiidae  
Phoxocephalus sp. 1  
Melita sp. 2  
Synopiidae sp. 3  
Carangolia n. sp. 1

Mydocopa

Euphilomedes sp. A  
Philomedes sp. A  
Cylindroleberidinae  
Scleraner sp. A

POLYCHAETA

Prionospis ehlersi  
Terebellides stoemi  
Tachytrypae sp. A  
Spiophanes berkeleyorum  
Ampharetidae  
Paraonis gracilis  
Syllidae  
Cirrophorus lyra  
Ampharete sp. A  
Aglaophamus circinata

GASTROPODA

Cima sp.  
Scaphander watsoni  
Eulima sp.

BIVALVIA

Eulamellibranch sp. F  
Dacrydium vitreum  
Tindaria sp. E

SIPUNCULA

Golfingia sp. E  
Golfingia sp. I  
Phascolion sp. A  
Onchnesoma squamatum

BRYOZOA

Sphaerulobryozoon sp.  
Ctenostomata sp. 2249

HOLOTHUROIDEA

Synaptidae

Archibenthal-Horizon B (775-950 m).

CRUSTACEA

Cumacea

Petalosarsia longirostris

Mesolamprops n. sp. B

Cyclaspis longicaudata

Campylaspis pilosa

Tanaidacea

Leptognathia sp. 15

Paratanaidae sp. 2

Typhlotanais sp. 2

Pseudotanaididae genus A (n. sp.)

Apseudes sp. 6

Leptognathia sp. 37

Leptognathia sp. 34

Tanaella p. 2

Isopoda

Eugerda sp. 215

Leptanthura sp. 219

Whoia sp. 225

Gnathia sp. 226

Nannoniscus sp. 233

Amphipoda

Metaphoxus n. sp.

Melita sp. 3

Lysianassidae

Gammaropsis sp. 1

Mydocepa

Pterocypridina sex

Scleroconcha sp. A

OPHIUROIDEA

Ophiostriatus sp.

Ophiernus sp.

POLYCHAETA

Maldanidae

Notomastus americanus

Acrocirridae

Exogone longicirrus

Spiophanes bombyx

Aricidea cerruti

Exogone atlantica

Pholoe minuta

Tharyx annulosa

Spiophanes wigleyi

Maldane glebifex

Pholoe sp. C

GASTROPODA

Lissospira sp.

Alvania xanthias

Benthonella fischeri

BIVALVIA

Propeamussium sp.

Tellina sp. B

Calyptogenia ponderosa

Lucinoma filosa

Vesicomya cordata

SIPUNCULA

Golfingia sp. B

Phascolion sp. C

BRYOZOA

Notoplites sp.  
Cheilostomata  
Metrarabdodomorpha sp.

Upper Abyssal (975-2250 m)

CRUSTACEA

Cumacea

Procampylaspus acanthomma  
Epileucon tenuirostris  
Cumella compacta  
Campylaspis spinosa  
Cumella acuminata  
Campylaspis cognata

Tanaidacea

Pseudotanaeis sp. 1  
Leptognathia sp. 57  
Tanaella sp. 1  
Typhlotanaeis sp. 1  
Leptognathia sp.  
Leptognathia sp. 51  
Agathotanaeis sp. 1  
Paranarthrura insignis  
Paranarthrura sp. 1  
Leptognathia sp. 41

Isopoda

Macrostylus sp. 256  
Ischnomesus sp. 275  
Chelator sp. 237  
Macrostylus sp. 223  
Ischnomesus sp. 208  
Whoia sp. 216  
Chelator sp. 251  
Prochelator sp. 228

HOLOTHUROIDEA

Moldadia sp.

OPHIUROIDEA

Ophiuroidea juv. sp. C

Isopoda (cont'd)

Acanthocope sp. 231  
Exiliniscus sp. 255  
Rapaniscus sp. 265

Amphipoda

Phoxocephalus sp.  
Pardisynopia n. sp. 1  
Harpiniinae  
Leptophoxus sp.  
Ampelisca sp. 2

Myodocopa

Habansus sp. A  
Spinacopia sp. A

POLYCHAETA

Maldane sp. A  
Exogone sp. A  
Glycera papillosa  
Diplocirrus capensis  
Paralacydonia paradoxa  
Notomastus latericeus  
Sphaerosyllis piriferopsis  
Prionospio sp.  
Sthenelais sp. A  
Laonice cirrata  
Ceratocephala oculata  
Myriochele heeri

GASTROPODA

Skeinidae

Melanalla sp.

Philene sp.

Benthomangelia sp.

Sequenzia sp.

BIVALVIA

Vesicomya sp.

Yoldiella sp. A

Malletia sp. B

Crenella sp. A

Nuculanidae sp. B

Eulamellibranch sp.

Thyasira sp. B

Astarte sp. A

SCAPHOPODA

Siphonodentaliidae

Dentalium callithrix

SIPUNCULA

Sipunculida sp.

Golfingia sp. J

Golfingia sp. K

Aspidosiphon sp.

BRYOZOA

Euginoma cavaleri

Noella sp.

Cheilostomata sp. 2166

Sphaerulobryozoon pedunculatum

Ctenostomata sp. 23124

Cheilostomata n. sp. A

ECHINOIDEA

Aceste bellidifera

HOLOTHUROIDEA

Protankyra sp.

Pseudostichopus sp.

Echinocucumis hispida

CRINOIDEA

Monachocrinus caribbeus

Democrinus brevis

OPHIUROIDEA

Ophiotholia sp.

Ophiuroidea juv. sp. A

BRACHIOPODA

Cyrtopora rectimarginata

Argyrotheca n. sp.

ASCIDIACEA

Dicarpa simplex

Bathysteloides n. sp.

Pseudocliazona abyssa

Minipera n. sp.

Mesoabyssal-Horizon (2275-3200 m)

CRUSTACEA

Cumacea

- Leucon turgidus
- Epileucon sp.
- Leucon tener
- Murilamprops brasiliensis

Tanaidacea

- Leptognathia sp. 23
- Leptognathia sp. 10
- Leptognathia sp. 28
- Leptognathia sp. 29
- Anarthruridae sp. 1
- Paranarthrura sp. 3
- Apseudes sp. 3
- Typhlotanais sp. 14
- Leptognathia sp. 68
- Typhlotanais sp. 15

Isopoda

- Prochelator sp. 290
- Haploniscus sp. 273
- Mirabilicoxa sp. 254
- Chelator sp. 212
- Thaumastasoma sp. 279
- Panetela sp. 224
- Eurycope sp. 277
- Pseudomesus sp. 293
- Ischnomesus sp.

Amphipoda

- Synopiidae n. gen. 2

Myodocopa

- Igene sp. A

POLYCHAETA

- Aedicira sp.
- Fauveliopsis sp. B
- Lumbrinerides davi
- Paraonis cornatus
- Synelmis klatti
- Scoloplos sp.
- Augeneria bidens
- Spiochaetopterus costarum
- Tharyx marioni
- Chaetozone sp. C
- Orbiniidae
- Mystides borealis
- Ceratocephale loveni

BIVALVIA

- Eulamellibranch sp. B
- Thyasira sp. A
- Lima sp.
- Malletia sp. A
- Pristogloma nitens

SCAPHOPODA

- Episiphon sp.
- Cadulus sp.
- Dentalium didymum

SIPUNCULA

- Golfingiidae

## BRYOZOA

Euginoma n. sp.  
Cheilostmata sp. 2153  
Cheilostomata sp. 2145  
Ctenostomata sp. 2271  
Ctenostomata sp. 2219

## ECHINOIDEA

Hemiaster expergitus  
Schizaster orbignyamus

## OPHIUROIDEA

Amphilepis sp.  
Ophiuroidea juv. sp. D  
Ophiuroidea juv. sp. H

## ASCIDIACEA

Minipera pedunculata  
Hexacrobylus arcticus

### 4.2.6 MACROFAUNA AS PREY OF DEMERSAL FISHES

Stomach analyses were conducted in 10 species of demersal fishes (Table 4-40). The species selected are among the most abundant forms collected by trawl and their depths of maximum population range from 250 to 1200 m at about 100-m intervals. Two hundred and forty-four individuals were dissected and 165 (68%) were found to have prey organisms in them. Stomach eversion was observed only in the scorpaenid Setarches guntheri. About half of the few individuals of this species in which the stomach was not everted contained prey organisms.

Aside from the unknown category, which was made up of unidentifiable bits of organisms, amphipods, calanoids, polychaetes and small fishes were the prey of choice of several fish species. Also, various other crustacea listed in Table 4-40 as "Decapoda", "Crustacea", and "Brachyura" were found in a total of 73 individuals. Amphipods led the list of readily identifiable categories in that they were eaten by 65 individuals of 7 species. The bat-fish Dibranchus atlanticus consumed the widest variety of prey types (23) followed by the grenadier Coelorhynchus caribbaeus (16) and the greeneye Chlorophthalmus agassizii (Table 4-40). It is suspected from the data shown in the table that such species as Synaphobranchus oregoni, Bembrops gobioides, and Setarchus guntheri feed on other prey than small macrofaunal organisms.

The ability of some of the demersal fish species to selectively gather prey organisms is remarkable. For instance, the stomach of one



Table 4-40. Stomach content analysis (number of fish with prey items) of the ten most abundant demersal fish species collected by trawl during Cruise I-III.

Prey	FISH SPECIES																														Total			
	<u>Gadomus longifilis</u>			<u>Setarches guentheri</u>			<u>Poecilopsetta beanii</u>			<u>Coelorinchus caribbaeus</u>			<u>Bembrops gobioides</u>			<u>Dibranchius atlanticus</u>			<u>Chlorophthalmus agassizi</u>			<u>Stephanolepis hispidus</u>			<u>Nezumia aequalis</u>			<u>Synaphobranchus oregoni</u>						
	I	II	III	I	II	III	I	II	III	I	II	III	I	II	III	I	II	III	I	II	III	I	II	III	I	II	III	I	II	III				
Amphipoda	2		2				1	3	2		5	5	5				7	8		1	6	2		3	3		3	7						65
Decapoda			1		2							3	1		4	4				2	3						1	5		1	1			27
Polychaeta								1			5	1	3									1						1						19
Cumacea																																		5
Foraminifera											1				2					2														6
Calanoida	2	5	4				1	2			3	5	3							4	2			5	3		4						43	
Nematoda							1				1	2	1				1	1		3											2			12
Harpacticoida	1										1						1					2												6
Mysidacea	1		2					3					1		1					1	1		3	0										14
Tanaidacea		1									1		1							1	1	0		3	1		2	1						12
Isopoda												1					8							1				1						11
Crustacea	5	3	2		1			3			1	2			4	2			2	1	2	4	1		4		5	1					43	
Trematoda																	1	1																4
Osteichthyes											1											2	1											14
Ophiuroidea																	2						1											4
Brachyura												1						1																3
Ostracoda			2								1									2				3										9
Strobila																	1																	1
Unknown	4	2	6				2	3	2		4	5	5		3		18	11		5	9	3		3		1	7		11	4			94	
Coleoidea											2																							6
Thecostomata																	2																	2
Paguroidea																	2																	2
Gastropoda																	1				1													2
Crangonidae																	1																	1
Chrysopetalidae																	1																	1
Amphinomidae																	1																	1
Propeamussium sp.																	1																	1
Pycnogonida																	3																	3
TOTAL PREY TYPES IN STOMACH	9			2			7			16			5			23			15			10			11			6						

individual of the greeneye was filled with remains of polychaetes belonging to the family Aphroditidae.

#### 4.3 MEIOFAUNA

The meiofauna are defined in the present report as those infaunal organisms that pass through a 0.3 mm sieve but are retained on a 0.063 mm sieve. The counts of meiofaunal components presented in this report are those totals derived from an analysis of the top 5 cm of an approximately 10-cm<sup>2</sup> subsample core. It is not very productive attempting to compare LGL's results with those few others who have studied the meiofauna of the deep sea because of different methodologies. For instance, Thiel (1983) used mesh sizes of 1.0 mm to 0.042 mm and others used 0.5 mm to 0.063 mm. Also, various investigators have studied different lengths of the subsample cores, ranging from 2 to 10 cm. Nevertheless, when all data are in hand from Cruises I through V, earnest attempts will be made to compare LGL results with those obtained in the western Atlantic Ocean.

Most of the data available from the present study are summarized in Table 4-41. Raw counts and densities of meiofaunal groups from Cruises I, II, and III are found in Appendices C-6 and C-7. The calculation of density values is presented in Appendix A-4. In our brief analysis of these findings, we have been mindful of the following points:

1. Results are derived from three cruises and from three transects.
2. Only the Central Transect was sampled during all three cruises--the Eastern and Western Transects only once.
3. The Central Transect was sampled in November 1983 and April and November of 1984--the Eastern and Western only in April of 1984.
4. Attempts were made to maintain rather uniform depths for Stations 1 through 5 (see bottom line of Table 4-41) on all three transects, but considerable deviation occurred at Station 5 on the Western and Central Transects. As noted in Table 4-41, an additional six stations were inserted on the Central Transect during the November 1984 cruise.

Table 4-41. Comparison of meiofaunal densities derived from sampling the Eastern, Western, and Central Transects during Cruises I, II, and III. Note that the stations of Cruise III are arranged in order of increasing depth (see bottom line).

Taxon	Meiofaunal Densities (No./10 cm <sup>2</sup> from top 5 cm of core) Transect and Cruise																															
	Cruise II Stations Only (April 1984)															Central Transect Only																
	West Transect					East Transect					Central Transect					Cruise I (Nov. 1983)					Cruise III (Nov. 1985)											
	1	2	3	4	5	1	2	3	4	5	1	2	3	4	5	1	2	3	4	5	1	6	2	3	7	8	9	4	11	5	12	
Nematoda	165	96	107	68	65	122	108	116	95	112	483	254	229	204	145	275	269	219	166	196	291	319	232	138	333	96	79	212	103	206	124	
Foraminifera	23	7	7	2	5	13	8	6	6	12	422	224	252	241	56	59	30	29	15	14	133	314	62	102	119	94	147	163	106	51	44	
Harpacticoida	85	35	48	32	26	28	43	41	36	40	109	109	88	69	41	114	130	94	67	48	83	90	100	71	87	59	58	67	43	52	31	
Polychaeta	15	6	9	6	3	9	11	12	8	4	30	30	14	12	4	17	7	5	6	3	44	46	18	13	52	12	12	12	7	6	5	
Ostracoda	5	6	4	3	4	6	3	4	6	4	11	12	11	7	4	9	11	8	5	4	9	11	13	10	14	10	8	14	6	4	9	
Kinorhyncha	7	0.5	1	1	2	3	0.5	2	1	1	16	2	5	3	2	9	5	4	2	2	7	5	3	3	3	2	1	2	1	3	3	
Isopoda	1	0.3	0.2	1	0.2	1	0.2	1	0.3	0.4	3	2	2	1	0.3	0.2	0.1	0.1	1	0	0.4	1	1	0.3	1	0.4	0.2	0.4	0.4	0.3	0.1	
Bivalvia	1	0.2	0.4	1	1	1	0.3	1	0.3	0	1	1	1	1	0.4	1	1	1	1	1	1	1	0.4	1	3	2	2	1	1	1	1	
Tanaidacea	1	0.3	0.4	0.2	0	0.2	0	0.2	0.1	1	2	0.3	1	0.3	0.2	1	0.2	0	0	0	3	1	0.3	1	2	0.4	0.3	0.2	0	0.4	1	
Halacarida	3	1	0.4	0.2	0.2	0.2	1	0.3	0	1	0.4	0.3	0	0.3	0	0	0.1	0.1	0.3	1	1	1	0.4	0.2	0.3	0	0.2	1	0.4	0.2	0.4	
Cyclopoida	3	2	0	0	0.3	0	1	0.2	1	1	0.2	0	0	0.3	0.1	0	0	0	0	0	0.4	1	1	1	1	1	0.4	1	1	0.3	0.1	
Loricifera	1	0.2	0.2	0	0	0.2	0.3	1.4	1	0	0	0	0.1	1.4	0.3	0	0	0	0	0	0	0	0.1	0	1	0.3	0.3	1	1	0.4	0.4	
Sipuncula	1	0	0	0	0	0	0.2	0	0.1	0	0.4	0.4	1	0	0	0.1	0	0	0	0	0	0	0	0	0	0	0.1	0.1	0.1	0	0	
Gastropoda	1	0	0.2	0.2	0	0	0.2	0	0.1	0	0.3	0	0.2	1	0.2	0.3	0	0.1	0	0	0	1	5	0	0	0	0	0.1	0.1	0	0.1	0
Tardigrada	0.2	0.2	0	1	1	0	0.3	1	0	0	0	0	0	0	0.2	0	0.1	0.1	0	0.1	0	0	0.3	0	1	0.1	0	0	0	0.3	0	0.1
Nemertinea	2	0	0	0	0.2	0	0	0	0	0	0	1	0.1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Aplacophora	0.2	0	0	0	0	0.3	0	0	0	0	0.3	0.1	0.1	0.3	0	0.1	0.4	0.1	0	0	1	0.2	0.2	0.4	2	0	0.3	0	0	0.2	0	
Priapulida	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0.4	0	0	0	0	0.2	0.1	0	0	0	0	0.1	0.2	0	0	0	0.1	
Bryozoa	1	0	0	0	0	0.3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.3	0	0	0	0	0	0.1	0.3	0.1	0.1	
Scaphopoda	0	0	0	0	0	0	0	0	0	0	0.1	0	0	0	0	0.1	0	0	0	0	0.1	1	0	0.1	0.3	0.3	0.2	0.2	0.3	0.3	0.3	
Gastrotricha	0.2	0	0	0	0	0	0	0	0	0	0.1	0	0	0	0	0	0	0	0	0	0.3	0	0	0	0.3	0	0	0	0	0.1	0.1	0
Nauplii	37	22	17	18	17	15	21	20	13	21	60	43	47	42	20	33	37	34	21	25	33	55	47	33	45	34	31	49	38	44	27	
Station Total	353	177	165	134	125	199	198	206	168	198	1139	679	652	584	274	519	491	395	285	294	608	842	479	374	666	313	340	525	310	370	247	
Depth (m)	355	604	854	1410	2497	352	627	846	1353	2826	353	600	838	1390	2389	363	615	852	1381	2474	357	492	633	883	1020	1192	1429	1477	2105	2518	2943	

Keeping the above factors in mind, it is appropriate to make the following observations:

1. There is in general an orderly decrease of total meiofaunal density as the depth of sampling increases. There are some perturbations at intermediate depths in Cruise III, but in no case are the totals of the deepest stations as great as those of the shallowest stations.
2. The Nematoda are clearly the most abundant taxon in the meiofauna (Table 4-41), a fact noted by all other studies consulted. The second most abundant group shifts between the Foraminifera and the Harpacticoida. In Table 4-41 we see that the Harpacticoida are second followed by the nauplii and Foraminifera on the Eastern and Western Transects during the April 1984 cruise and on the Central Transect during the November 1983 cruise. But on the Central Transect during the April and November 1984 cruises (Cruises II and III) the forams far outnumbered the harpacticoids and nauplii. Hence the overall rank order in abundance is Nematoda, Foraminifera, Harpacticoida, nauplii (copepod), Polychaeta, Ostracoda, and Kinorhyncha.
3. As noted in No. 1 above, there is a trend of reduction in total meiofauna from shallow into deep water. However, it is not as marked as in some macrofaunal groups. Except for the general impact of pressure upon the meiofauna as upon other organisms, it is not easy to understand why this group should exhibit much decline from lack of food source since they are dependent upon in-sediment organics both living and nonliving. One may speculate then, that the declines in abundance that we do see in the meiofauna may result from a greater degree of predation upon them resulting from more drastic declines in other food sources for larger metazoan organisms.

## 5.0 BENTHIC PHOTOGRAPHY RESULTS

One photo-transect consisting of 800 color slides was planned for each sampling station on Cruises I-V. All transects were completed successfully and the film has been processed. In all, 48,000 photographs were taken at 60 stations (see Table 2-4, p. 12). This report presents the completed analyses from the 15 Cruise III stations, which included stations on the Western, Central and Eastern sampling transects in water depths of from 300 to 3000 m. A total of 1142 m<sup>2</sup> of the sea bottom has been photographed and analyzed for the Western Transect, 1151 m<sup>2</sup> for the Central Transect, and 1221 m<sup>2</sup> for the Eastern Transect resulting in a total of 3514 m<sup>2</sup> for all of Cruise II (Table 5-1). The camera system, field methods, and photographic analysis techniques have been reported in the first Annual Report (LGL and Texas A&M 1985). Four categories of subjects were analyzed in the photographs: lebensspuren (tracks, trails, etc. left by animals), consolidated materials, man-made artifacts, and megafauna. Each category is discussed below.

### 5.1 LEBENSSPUREN

Lebensspuren, meaning literally "life-tracks", was the most abundant category of observations represented in the photography, exceeding all other categories by at least two orders of magnitude. Lebensspuren classification for this study follows Ewing and Davis (1967) and includes the following (singular or multiple) major categories; ridges, lumps, grooves, depressions, combinations of grooves and depressions, and sculptured strips. Each of these major groups was observed in this study with the exception of combinations of grooves and depressions. The major categories were further subdivided by two additional levels of hierarchy permitting a fairly distinct morphological description of lebensspuren features. Table 5-2 presents summary data of raw counts and density per ha for all major categories documented during digitizing analyses. We have digitized 26,798 individual lebensspuren features represented in the benthic photographs obtained at Cruise II stations. The Western Transect included 9621 features, the Central 7390 and the Eastern 9787. Whereas the raw counts are deceptive due to unequal sample sizes, the standardized

Table 5-1. Total area surveyed by benthic photography taken for comparing West, Central and East Regions of the Gulf of Mexico.

Transect		Cruise II Stations					Total
		1	2	3	4	5	
West	No. frames	97	98	50	100	100	
	Area (m <sup>2</sup> )	260.6	262.3	100.1	227.6	291.2	1141.8
Central	No. frames	79	43	100	100	100	
	Area (m <sup>2</sup> )	190.1	119.0	338.6	232.5	271.1	1151.3
East	No. frames	90	34	100	100	99	
	Area (m <sup>2</sup> )	303.7	130.0	304.7	249.5	233.0	1220.9
						Total	3514.0

Table 5-2. Summary of lebensspuren observations obtained by benthic photography, Cruise II.

	Raw Count																		
	Western Transect						Central Transect						Eastern Transect						
	W1	W2	W3	W4	W5	T	C1	C2	C3	C4	C5	T	E1	E2	E3	E4	E5	T	
Individual ridges	0	3	3	47	121	174	1	9	17	2	7	36	0	46	13	6	512	577	
Solitary lumps	93	239	21	124	112	589	129	114	62	170	44	519	94	65	69	38	220	486	
Sets of lumps	0	0	4	4	0	8	0	0	2	2	20	24	0	2	6	5	14	27	
Individual grooves	91	136	338	1254	67	1886	4	156	402	61	650	1273	56	20	768	818	99	1761	
Sets of grooves	27	95	7	14	40	183	0	28	10	0	55	93	0	14	12	17	167	210	
Solitary depressions	187	917	283	271	364	2022	405	337	1734	296	1286	4058	987	396	610	257	380	2630	
Groups of depressions	4364	368	21	6	0	4759	179	86	479	8	603	1355	3918	28	89	2	56	4093	
Adjacent strips of depressions	0	0	0	0	0	0	0	0	5	0	27	32	3	0	0	0	0	3	
Totals	4762	1758	677	1720	704	9621	718	730	2711	539	2692	7390	5058	571	1567	1143	1448	9787	

density values shown in Table 5-3 show a similar pattern of relationship. The Central Transect showed the lowest density of lebensspuren features of the three transects from Cruise II with a total density of 64,183/ha or 6.4/m<sup>2</sup>. The Western and Eastern Transects were similar to each other with densities of 8.4 and 8.0 lebensspuren features/m<sup>2</sup>, respectively.

Detailed results of Cruise II digitized benthic photographs appear in Appendix Tables D-1 to D-5. Appendix D-1 includes all raw counts, Appendix D-2 contains density per ha for all detailed categories, Appendix D-3 presents length measurements of lebensspuren and biota obtained from processed digitized data, Appendix D-4 contains all area calculations for appropriate categories and Appendix D-5 contains percent cover information for all subjects digitized as a closed figure (area). Due to the large number and complexity of specific individual lebensspuren classifications contained in Appendices D-1 to D-5, the data are summarized below by the major groupings shown in Table 5-2.

#### 5.1.1 INDIVIDUAL RIDGES

The shadow created by the angled strobe shows these features to be elevated above the sediment surface. Ridge features can be created by organisms such as holothuroids or asteroids either crawling on the surface of the sediment and thereby reworking it into ridges or by burrowing organisms such as echinoderms or polychaetes.

The Eastern Transect exhibited the highest density of individual ridge structures with 4726/ha (Table 5-3) followed by the Western with 1523 and the Central Transect with an average of only 313/ha. The Eastern Transect mean was elevated by an extremely high density at Station E5 (21,972/ha), the highest ridge density observed at any of the 15 Cruise II stations. Individual ridge density from the other 14 stations ranged from 0 at Station W1 to 4155/ha at Station W5. Mean lengths for the dominant type of ridge structure ranged from 7.0 cm for the Eastern Transect (Appendix D-3) to 8.1 cm for the Western and 15.0 cm for the Central Transect stations.



Table 5-3. Density per hectare of lebensspuren observations obtained by benthic photography, Cruise II.

	Western Transect						Density Per Hectare Central Transect						Eastern Transect					
	W1	W2	W3	W4	W5	W (x)	C1	C2	C3	C4	C5	C (x)	E1	E2	E3	E4	E5	E (x)
Individual ridges	0	114	300	2,065	4,155	1,524	53	756	502	86	258	313	0	3,538	427	240	21,972	4,726
Solitary lumps	3,569	9,110	2,097	5,448	3,846	5,158	6,785	9,579	1,831	7,311	1,623	4,508	3,095	4,999	2,265	1,523	9,441	3,981
Sets of lumps	0	0	399	176	0	70	0	0	59	86	738	208	0	154	197	200	601	221
Individual grooves	3,492	5,184	33,753	55,099	2,301	16,517	210	13,108	11,872	2,623	23,973	11,056	1,844	1,538	25,209	32,779	4,249	14,423
Sets of grooves	1,036	3,621	699	615	1,374	1,603	0	2,353	295	0	2,028	808	0	1,077	394	681	7,167	1,720
Solitary depressions	7,177	34,955	28,260	11,907	12,500	17,708	21,302	28,317	51,211	12,729	47,429	35,244	32,501	30,454	20,023	10,298	16,308	21,541
Groups of depressions	167,479	14,028	2,097	264	0	41,678	9,415	7,226	14,146	344	22,239	11,768	129,017	2,153	2,921	80	2,403	33,524
Adjacent strips of depressions	0	0	0	0	0	0	0	0	148	0	996	278	99	0	0	0	0	25
All Lebensspuren features	182,753	67,012	67,605	75,574	24,176	84,258	37,739	61,339	80,064	23,179	99,284	64,183	166,556	43,913	51,256	45,801	62,141	80,161

### 5.1.2 SOLITARY LUMPS

Individual mounds of sediment designated as solitary lumps were present at all stations. These features were elevated above the surrounding bottom and were presumed to be produced through some method of excavation by a living organism. This process was most evident in the case of conical lumps resembling volcanos complete with a small apical holes. These features, both with and without apical holes, were common at most Cruise II stations (Fig. 5-1). Densities of these lebensspuren ranged from a high of 6795/ha at Station C4 to a low of only 111/ha at Station C5 (see Appendix Table D-2). The density at Station C4 would appear anomalous given that the observed density was over four times that of other stations at comparable depths on the Eastern and Western Transects. An additional anomaly at Station C4 was a very high density of the holothuroid Scotoplanes sp. (6150 Scotoplanes sp./ha, an order of magnitude higher than at any other Cruise II station) (Appendix D-2).

### 5.1.3 SETS OF LUMPS

Sets of lumps were not common, appearing in only two transects, the Central and Eastern. Stations C5 and E5 were the only locations with significant densities. At these locations, sets of lumps were found in densities of 738 and 601 lump sets per ha, respectively.

### 5.1.4 INDIVIDUAL GROOVES

Individual grooves are defined as a sediment interface concavity with a shape strongly oriented in a single dimension, being at least eight times as long as wide (Hersey 1967). These features are made primarily by animals moving across the surface of the sediment and dragging all (armored polychaete worms) or some part (crab walking legs) of their bodies. Some types of individual grooves have in fact been related to at least major taxa, i.e., the type of short groove produced by the walking movement of crabs.

The general category of individual grooves was relatively abundant at all Cruise II stations; density values ranged from a low of 210/ha at

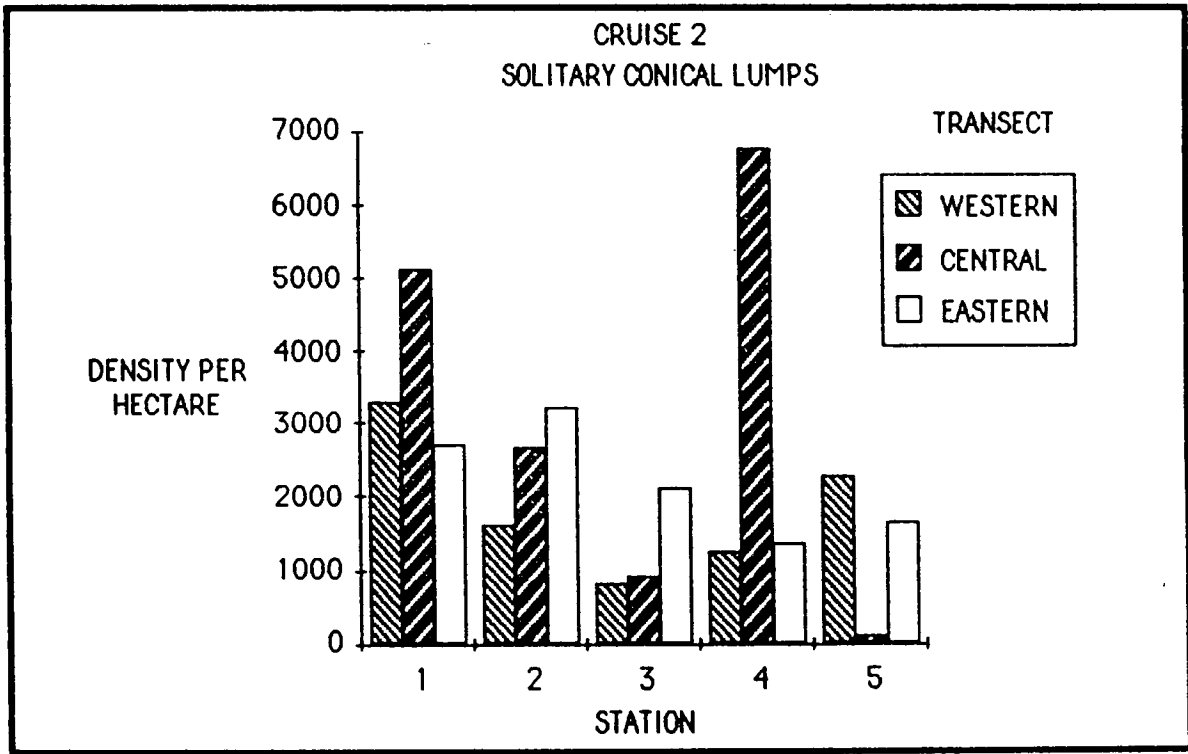


Figure 5-1. Density per hectare of solitary conical lumps, Cruise II stations.

Station C1 to a high of 55,099/ha at Station W4 (Table 5-3). Mean densities by transect ranged from a high of 16,517/ha on the Western Transect followed by the Eastern Transect with 14,423/ha and the Central Transect with 11,056 individual grooves/ha. The only major trend of groove densities by depth was that the lowest densities of individual grooves were always observed at the shallowest stations (W1, C1 and E1) within each transect. The digitized lengths of several types of grooves were quite consistent between stations and transects.

For the category described specifically as short, narrow, straight and shallow, unsculptured grooves (Appendix D-3), a total of 237 grooves were recorded over all depths of the Western Transect stations. Similarly, 236 were counted over all depths on the Central Transect. However, 1493 of these features were counted on the Eastern Transect. The mean lengths of these grooves on each transect were 2.5, 2.6 and 2.4 cm, respectively.

#### 5.1.5 SETS OF GROOVES

This category includes some types of lebensspuren having characteristics that can be very specifically associated with particular animals. These include asteroid-shaped impressions, ophiuroid-shaped impressions and grooves radiating from a central hole as a result of a burrowing animal's feeding activities (e.g., ampharetid polychaetes). Overall densities of these features were relatively low (Table 5-3). The Eastern Transect had highest observed densities of groove sets (1720/ha) followed by the Western Transect at 1603/ha and the Central Transect at 808/ha. Sets of grooves were not observed on two stations (C1 and C4) on the Central Transect.

Appendix D-2 breaks down the general category "sets of grooves" into the specific features of interest described above. Asteroid-shaped impressions were seen at all stations along the Western Transect, with a high of 877/ha at Station W2 and a low of 230/ha at Station W1. Results from trawling on this transect during Cruise II also indicated that asteroids were most abundant at Station W2 (LGL and Texas A&M 1985). Benthic photography from the Central Transect stations yielded observations of asteroid-shaped impressions at only two stations, C3 and

C5, each having a relatively low density (148 and 443/ha, respectively). Asteroid-shaped impressions were also seen at only two stations on the Eastern Transect, Stations E4 and E5. Densities for Stations E4 and E5 were 401 and 5107/ha, respectively. Interestingly, no asteroids were trawled from either of the deep stations C5 and E5 on Cruise II.

Ophiuroid-shaped impressions were found on the Western Transect at Stations W1, W2 and W5 where densities were 792, 915 and 790/ha, respectively. Ophiuroid impressions were seen at only two stations on the Central Transect (Stations C2 and C5) where estimated densities were 2353 and 922/ha, respectively. Likewise, on the Eastern Transect, ophiuroid-shaped impressions were photographed at only Stations E2 and E5, having respective densities of 1077 and 1073/ha.

#### 5.1.6 SOLITARY DEPRESSIONS

Depressions are described by Hersey (1967) as distinct concavities less than eight times as long as wide. These features typically represent burrows. Heezen and Hollister (1971) report a large variety of organisms observed producing burrows including enteropneusts, crabs, amphipods, shrimp, worms, starfish, gastropods, holothuroids, pelecypods and fish. This category of lebensspuren is one of the most difficult to interpret. Size or area measurements of the burrow opening provides additional descriptive data available to this study which may assist in the delineation of specific depression types.

The solitary nature of this category was at times difficult to designate in situations where a large number of depressions were concentrated in a small area. In general, the term "groups of depressions" was employed when at least three depressions formed a distinct pattern with each depression apparently having some relationship to the others (i.e., arranged in a circle as opposed to numerous solitary depressions).

Solitary depressions were the dominant lebensspuren feature at all but two of the 15 Cruise II stations. The Central Transect exhibited the highest mean density of solitary depressions with an overall density of 35,244/ha (Table 5-3). The Eastern Transect followed with 21,541/ha and a mean density of 17,708 solitary depressions was observed on the Western

Transect. Two prominent subcategories are shown in Appendix D-2 which should be addressed separately. These are shallow depressions and deep depressions. The difference between these two may be a direct result of deterioration of the burrows after an organism has abandoned it. Shallow depressions were designated when the bottom of the depression could be easily distinguished in the photograph and the extent of the shadow at the edge of the depression indicated the depression's lack of relief. Deep depressions or holes were seen as completely black features indicating a significant hole depth where the strobe lighting could not penetrate, possibly indicating a relatively recent mechanism keeping the burrow cleared. Shallow depressions may be considered, at least for the time being, as relicts of deeper depressions.

Results of density observations for shallow solitary depressions are shown graphically in Figure 5-2. Figure 5-3 shows density values for deep depressions. Supportive data for these figures appear in Appendix D-2. In general, the density of shallow solitary depressions was much higher than the density of deep solitary depressions. Solitary depressions of each type were most abundant on the Central Transect where shallow depression density was 93,076/ha compared to 65,043/ha for deep depressions. The second highest solitary depression density was observed on the Eastern Transect (64,853 shallow depressions/ha compared to 30,666 deep depressions/ha) followed by the Western Transect with a shallow depression density of 59,536/ha and a deep depression density of 29,590/ha.

Interestingly, the exceptions to the general trend of shallow depression density exceeding deep depression density was at both depth extremes represented by #1 and #5 stations on both the Central and Western Transects (C1, C5, W1 and W5). One additional shallow station exception was Station E1 where more than five times as many deep depressions were observed as there were shallow depressions. The ratio of deep depressions (recent?) to shallow depressions (relict?) may prove to be an indicator of lebensspuren longevity in the benthic environment.

Two other digitized data types are pertinent for the category of solitary depressions. These are calculated sizes or areas of the depressions and percent cover. Table 5-4 summarizes mean areas of both shallow and deep depressions. In general, the observed mean size (area)

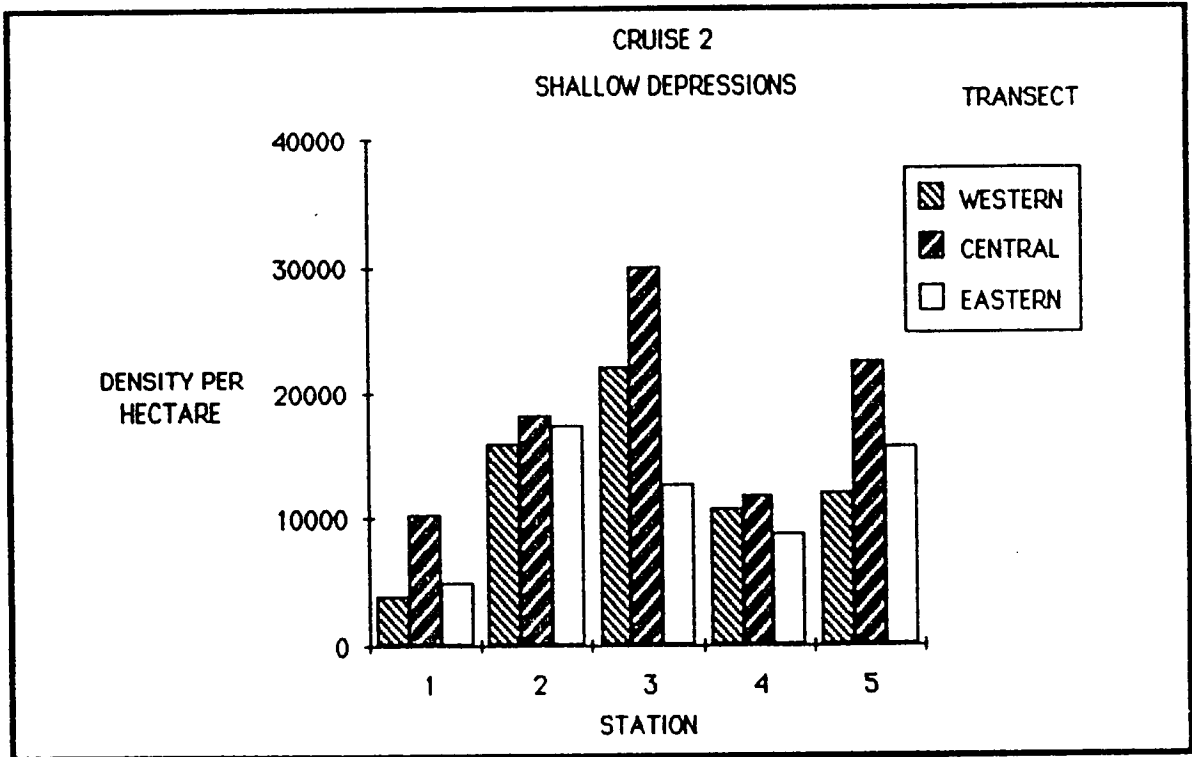


Figure 5-2. Density per hectare of shallow depressions, Cruise II stations.

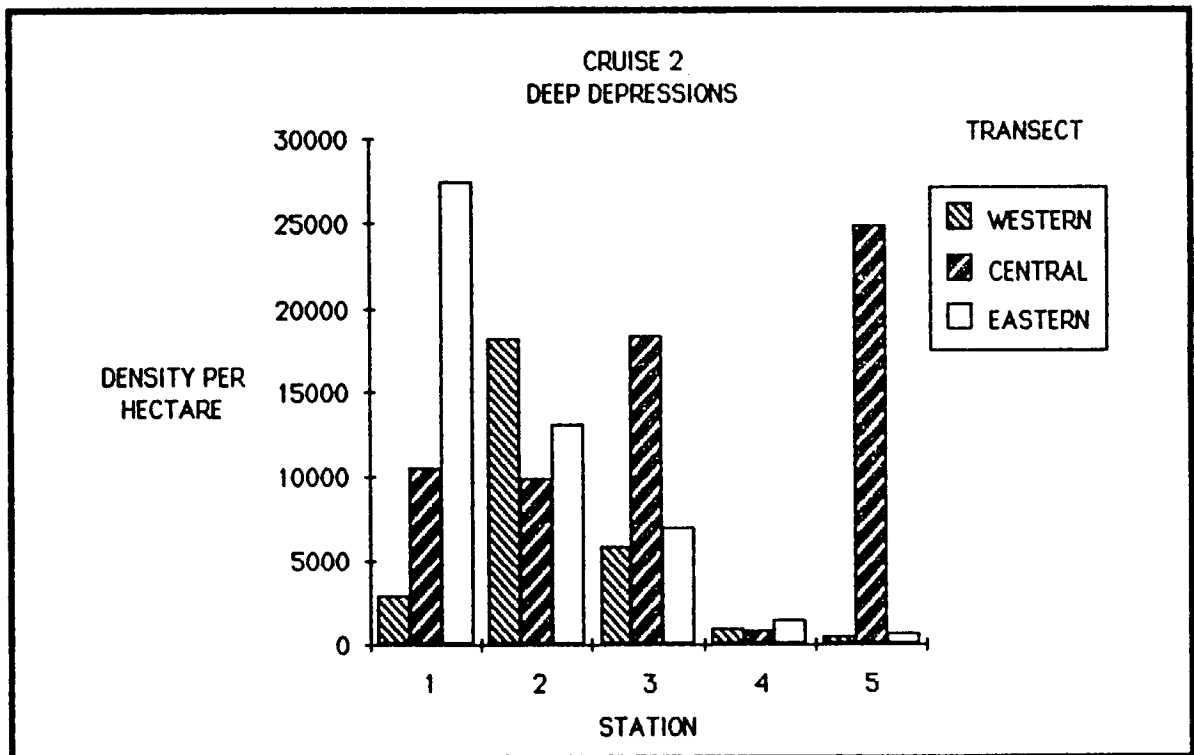


Figure 5-3. Density per hectare of deep depressions, Cruise II stations.



Table 5-4. Solitary depression areas.

Station	Shallow Depressions			Deep Depressions		
	No.	Mean Area cm <sup>2</sup>	Mean for Transect	No.	Mean Area cm <sup>2</sup>	Mean for Transect
W1	104	32.2		77	8.4	
W2	371	50.2		431	5.4	
W3	222	38.7		56	11.4	
W4	197	38.4		16	2.3	
W5	297	64.4	48.1	8	5.3	6.3
C1	197	38.9		199	4.7	
C2	197	33.2		99	6.5	
C3	480	35.7		91	9.5	
C4	143	25.5		4	1.8	
C5	409	10.8	27.6	328	2.2	4.4
E1	152	24.4		832	6.6	
E2	223	40.5		166	21.3	
E3	336	37.7		162	12.1	
E4	176	58.8		26	2.3	
E5	315	31.4	38.0	5	1.7	9.3

of shallow depressions was approximately five times that of deep depressions. This large disparity may be evidence supporting the possibility that shallow depressions have been eroded after being abandoned by an organism.

As noted above, the Central Transect had the highest overall densities of both shallow and deep depressions. The calculated mean area of deep depressions on the Central Transect was determined to be 4.4 cm<sup>2</sup> with a corresponding shallow depression mean area of 27.8 cm<sup>2</sup>. The largest mean area of shallow depressions was observed at Station W5 where these features averaged 74.4 cm<sup>2</sup>. The mean area for all shallow depressions along the entire Western Transect (48.1 cm<sup>2</sup>) was also the highest in comparison to those features at the other transects. The mean area for deep depressions on the Western transect was only 6.3 cm<sup>2</sup>. Mean areas for shallow depressions at the Eastern Transect ranged from 58.8 to 24.4 cm<sup>2</sup> with an overall mean of 38.0 cm<sup>2</sup> compared to a mean area of 9.3 cm<sup>2</sup> for deep depressions.

#### 5.1.7 GROUPS OF DEPRESSIONS

Groups of depressions was the second most abundant lebensspuren category at all but two stations, W1 and E1 where it was the most abundant. These features are made up of a series of three or more deep depressions arranged in a pattern indicating an interrelationship. Several types of organisms have been suggested as the source of these features including annelid worms by Heezen and Hollister (1971) and caridean shrimp by Pequegnat (1983). These groups of depressions were the most abundant features (overall mean density for the entire transects) on both the Western and Eastern Transects which had densities of 41,678 and 33,524/ha, respectively (Table 5-3). On the Central Transect, the mean density of groups of depressions (11,768/ha) trailed behind solitary depressions (over 60,000/ha).

Two particular types of grouped depressions are addressed in this discussion which may be produced by one specific group of organisms. These are depressions arranged in either a partial circle or full circle (Appendix D-2). At this time, these two categories have been added together as shown in Figure 5-4. It is not clear whether there is any

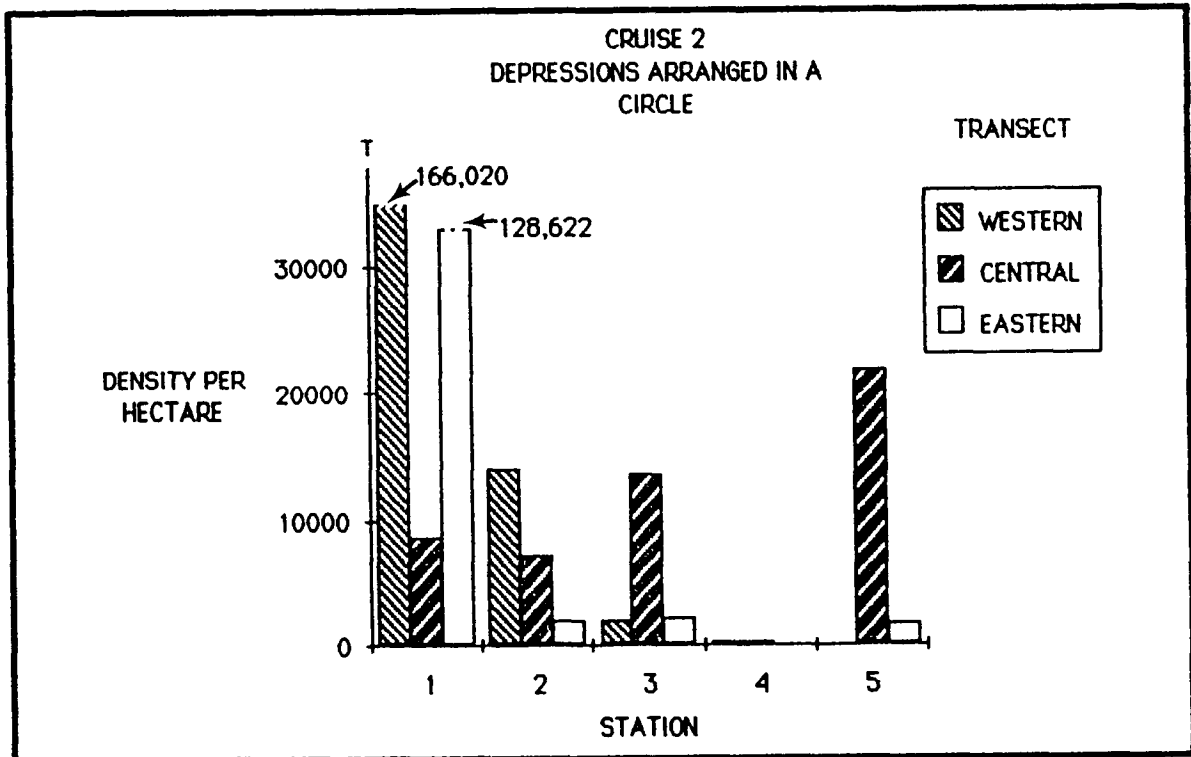


Figure 5-4. Density per hectare of depressions arranged in a circle, Cruise II stations.

significance involved if a pattern of depressions completes a circular pattern or appears as only a partial ring of depressions. The density of depression groups arranged in a complete circle was very small in comparison to the incomplete circle patterns (Appendix D-2).

The greatest number of depressions arranged in a circle (complete and partial) was observed at Station W1 and E1, with W1 having the highest density (166,020/ha) followed by Station E1 with 128,622/ha (Fig. 5-4). These two densities were the highest of any lebensspuren feature observed throughout all 15 Cruise II stations. Apparently the taxa of organisms responsible for this type of lebensspuren feature is either more abundant at Stations W1 and E1 than elsewhere, or conditions allowing lebensspuren persistence are exceptionally favorable at these shallow stations. Station C1 was quite different, having 8679 grouped depressions/ha. This density was approximately 19 times less than that of Station W1 and almost 15 times less than Station E1. The density of depressions arranged in a circle at Station C5 (21,834/ha) was the third highest level but was also much smaller than the densities observed at Stations W1 and E1. The densities of this feature at the remaining 12 stations ranged from 0 to 14,028/ha (Fig. 5-4). Stations W4, C4, and E4 all had very low densities of grouped depressions, with Station E4 not showing any grouped depressions.

Groups of depressions were one of the few lebensspuren features which made up a significant proportion of bottom area. Appendix D-5 presents percent cover data for all significant feature types digitized as a closed figure or area. Very few categories of features appeared in sufficient numbers or with significant size to make up even one percent of the surface area of bottom analyzed. At their highest density, depressions arranged in a partial circle covered only 1.01% of bottom area at Station W1.

#### 5.1.8 ADJACENT STRIPS OF DEPRESSIONS

Adjacent strips of depressions or sculptured strips are defined by Ewin and Davis (1967) as a distinct strip impression other than merely smooth or randomly rough. Sculptured strips in this study are almost all certainly produced by holothuroids (see cucumbers). These strips appear

as a multiple series of regularly spaced depressions (sometimes bordered by ridges or grooves) created by either the holothuroid's mantle (if the depressions appear along the edges of the strip) or by tube feet.

Sculptured strip lebensspuren features were rare throughout the Cruise II stations. None were observed at any of the Western Transect stations nor were any holothuroid animals seen in benthic photographs (Appendix D-2). The highest density of sculptured strips (995/ha) was observed at Station C5. Holothuroid animals were also observed in benthic photographs at Station C5 where the estimated density was 74/ha. Sculptured strips were seen at Station C3 at a density of 148/ha which corresponded to a density of 118 holothuroids/ha. The only other station where sculptured strips were observed was Station W1 where the density was 99 strips/ha. No holothuroid animals were photographed in conjunction with these lebensspuren features.

## 5.2 CONSOLIDATED MATERIALS

Consolidated materials such as hard rocks, nodules and silt stones are included in this category. Although relatively low in density, indicating an extreme paucity of hard substrate, these types of objects were observed at all but two stations, C3 and E4 (Appendix D-2). Table 5-5 presents the two major categories of consolidated materials, apparent rocks or nodules, and dark-colored consolidated objects, observed at a total of 10 stations. Densities of rock or nodule-like objects ranged from 4807/ha at Station E5 to a low of 33/ha (a single observation) at Station E1. Consolidated objects appearing much darker than the surrounding sediment were observed in much higher numbers ranging from a density of 10,690/ha at Station E2 to 252/ha at Station C2. These dark-colored objects may be some type of "clinker" thought to be derived from ocean-going coal-fired vessels which disposed of huge amounts of waste material during their era of operation. These objects were also commonly found in trawl samples.

Table 5-5. Consolidated materials.

Transect/Station	Apparent Rock or Nodule		Consolidated Object Darker Than Surrounding Sediment	
	No.	Density/Hectare	No.	Density/Hectare
W1	0	0	0	0
W2	1	38	14	534
W3	0	0	7	699
W4	1	44	48	2,109
W5	14	481	53	1,820
C1	0	0	0	0
C2	12	1,008	3	252
C3	0	0	0	0
C4	0	0	0	0
C5	1	37	0	0
E1	1	33	0	0
E2	58	4,461	139	10,690
E3	15	492	0	0
E4	0	0	0	0
E5	112	4,807	140	6,008

### 5.3 MAN-MADE ARTIFACTS

Man-made artifacts (cans, trash, etc.) were only observed in photographs at three of the Cruise II Stations C1, C4 and E3. On the Central Transect, two cans were observed at Station C1, one piece of unidentifiable trash was recorded at Station C4, and on the Eastern Transect, another piece of trash was observed at Station E3. From impressions of cruise participants the continental slope, in general, was far more littered than expected. Virtually every otter trawl surfaced with at least a few items of garbage in the net including beer cans, soda cans, plastic, rope, and a variety of other man-made debris. This accumulation of trash on the continental slope is no doubt a result of the general practice of throwing garbage overboard by virtually all shipping vessels in the Gulf of Mexico (including the two research vessels utilized in this study). The question of the impact of this situation may not be as obvious. What may be one taxon's pollution is another's hard substrate in a habitat virtually devoid of this commodity. The majority of the garbage trawled from the bottom had some variety of organism attached to it.

### 5.4 BIOTA

A total of 437 animals were enumerated from digitized photographs of the 15 Cruise II stations. Even though absolute numbers were low, we believe they may provide a good representation of actual megafauna densities on the continental slope within the limitations of the sample sizes involved. As discussed in the first Annual Report (LGL and Texas A&M 1985) the technique of flying the camera above the bottom as opposed to towing a sled is considered a superior means of obtaining density estimates of megafauna. Virtually no frames of the 12,000 obtained from Cruise II showed sediment plumes due to the avoidance reactions of animals affected by the camera sled.

Appendix D-2 details megafauna densities observed at Cruise II stations. These observations were divided into several major groups including; Plants, Decapod Crustaceans, Echinoderms, Other Invertebrates, and Fishes. Figure 5-5 presents a summary of overall megafauna densities

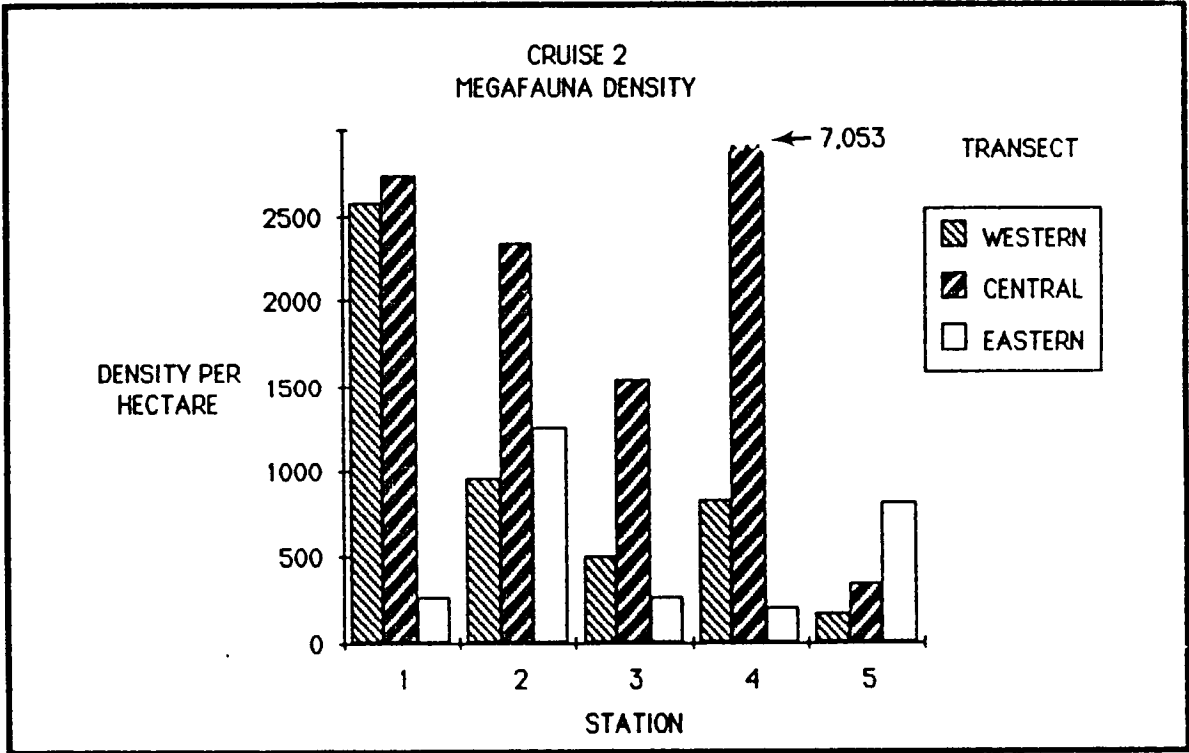


Figure 5-5. Density per hectare for all megafauna observed by benthic photography, Cruise II stations.



(including some partially identified classifications from the unknown category) for all 15 Cruise II stations. The majority of the biota observed were also measured for length (Appendix D-3). These data will provide additional life history information to that obtained for specimens collected by trawling.

Except for Station C4, a general trend of decreasing macrofauna density with depth was indicated (Fig. 5-5). Station C4 was a marked exception having a megafauna density of 7053 animals/ha, more than 2.5 times the densities of megafauna observed at shallow Stations W1 and C1. This peak was almost entirely due to the abundance of the holothurian Scotoplanes sp. This taxa was observed to have a density of 6150 individuals/ha at Station C4 (Appendix D-2). Station E1, which would be expected to have a relatively high overall megafauna density, had one of the lowest megafauna densities of all 15 Cruise II stations. Trawl megafauna densities were also low for many groups at Station E1. Only one echinoderm, a single ophiuroid, was obtained from the E1 trawl.

Western Transect megafauna densities were highest at Station W1 with an overall megafauna density of 2570/ha (Figure 5-5). Decapod crustaceans and fish taxa dominated at this station with densities of 767 and 729/ha, respectively. The remaining Western Transect Station megafauna densities decreased progressively to a low at Station W5 of 171/ha.

On the Central Transect, relatively high megafauna densities (other than Station C4) were observed at both Stations C1 and C2, having 2737 and 2330 individuals/ha, respectively. Station C1 was dominated by decapod crustaceans (1947/ha) while Station C2 was dominated by echinoderms (primarily holothuroids) at a density of 1092/ha. The lowest megafauna density along the Central Transect was noted at the deepest station, C5.

A very low overall megafauna density (264 animals/ha) was observed at Station E1 as mentioned above. Other Eastern Transect stations had megafaunal densities ranging from a high of 1253/ha at Station E2, to a low of 200/ha at Station E4. Both Stations E2 and E4 were dominated by decapod crustaceans having densities of 637 and 80 individuals/ha, respectively.

Table 5-6 summarizes raw count and density data for megafauna observed at all Cruise II stations (detailed descriptions appear in Appendices D-1 to D-3). Although the raw numbers of observations are

Table 5-6. Density/hectare of major megafauna groups observed by benthic photography, Cruise II.

Transect/Station	Megafauna Groups						Total
	Sponges	Coelenterates	Annelids	Decapod Crustaceans	Echinoderms	Fishes	
W1	614	230	-	767	230	729	2,570
W2	114	-	38	191	420	191	954
W3	-	200	-	300	-	-	500
W4	-	-	-	615	220	-	835
W5	-	34	-	34	103	-	171
C1	-	-	53	1,947	53	684	2,737
C2	-	168	-	902	1,092	168	2,330
C3	30	-	355	148	797	207	1,537
C4	43	43	645	86	6,236	-	7,053
C5	-	74	-	-	265	-	339
E1	-	66	-	99	-	99	264
E2	-	385	-	637	77	154	1,253
E3	-	-	-	33	33	198	264
E4	-	40	-	80	40	40	200
E5	86	43	172	301	214	-	816
	887	1,283	1,263	6,140	9,780	2,470	21,823

low, they in fact represent considerably higher densities than were obtained by trawling. A typical trawl catch of a particular species was on the order of a few individuals for most taxa up to about 20 or 30 specimens. A one hour trawl catching 30 fish would represent a density in the neighborhood of 12/ha. A few decapod species and a very few fish species exceeded a total abundance of 50 individuals per trawl tow, equivalent to a density of approximately 20/ha (LGL and Texas A&M 1985).

Tables 5-7 and 5-8 present specific density data obtained from abundance of two major animal groups collected by trawling and observed in analyzed benthic photographs for Cruise II stations. The area sampled for each trawl was estimated from the expected width of the 9 m otter trawl while fishing normally (4.5 m) times the length of the trawled area (derived from the logged speed of the vessel times the number of hours the trawl was on the bottom at each station). These estimated sample areas ranged from 1.8 to 7.7 ha. The size of the area sampled by benthic photography during Cruise II ranged from approximately 0.01 to 0.03 ha (see Table 5-1). Density comparisons were made for these two major megafaunal groups sampled by both gear types, decapod crustaceans and fish. Some taxa were combined depending on the level of identification possible for each gear type.

Two major differences between trawling and benthic photography were apparent (Tables 5-7 and 5-8). The first was that trawling produced a higher diversity of species than did benthic photography. These tables are already biased in favor of benthic photography due to the fact that only taxa common to both gear types are presented and very few species were sampled by benthic photography that were not obtained by trawling. Even given this bias, trawling remains far superior. The difference in numbers of taxa sampled is primarily due to two factors, most obvious of which is the much larger area sampled by the trawl (up to 770 times that of benthic photography) and to a lesser extent, but possibly very significant, the ability of the trawl to sample megafauna buried beneath the sediment's surface not directly visible by photographic techniques.

The other major difference between these two gear types is the tremendous variation in calculated densities. In only one case (Station W1, *Penaeopsis serrata*) did a trawling density estimate exceed that of benthic photography (227/ha vs. 154/ha) (Table 5-8). In all other co-

Table 5-7. Comparisons of decapod crustacean densities obtained from trawling and benthic photography for Cruise II observations common to both.

STATION:		Density per Hectare														
		W1	W2	W3	W4	W5	C1	C2	C3	C4	C5	E1	E2	E3	E4	E5
TRAWL AREA (ha):		2.8	2.6	7.7	6.3	6.5	3.2	2.7	5.6	4.8	4.9	1.8	2.1	4.5	5.6	4.8
<i>Penaeopsis serrata</i>	T*	227	-	-	-	-	-	-	-	-	-	54	-	-	-	-
	BP	154	-	-	-	-	1210	-	-	-	-	-	-	-	-	-
<i>Hymenopeneus robustus</i>	T	1	-	-	-	-	-	-	-	-	-	4	-	-	-	-
	BP	307	-	-	-	-	-	-	-	-	-	-	-	-	-	-
<i>Plesiopenaeus edwardsianus</i>	T	-	<1	<1	-	-	-	-	-	-	-	<1	-	-	-	-
	BP	-	-	200	44	-	-	-	-	-	-	-	-	-	-	43
<i>Glyphocrangon</i> sp.	T	-	2	3	-	<1	-	1	<1	3	-	-	2	-	<1	19
	BP	-	-	-	-	34	-	84	-	-	-	-	-	-	-	-
<i>Stereomastis</i> sp.	T	-	-	2	1	-	-	1	3	1	-	-	<1	1	8	<1
	BP	-	-	-	-	-	-	84	-	-	-	-	-	-	-	-
Galatheididae	T	14	2	2	<1	-	<1	3	<1	-	<1	16	55	-	4	-
	BP	154	38	-	-	-	53	-	-	-	-	-	-	-	-	-
<i>Pyromaia arachna</i>	T	3	-	-	-	-	6	-	-	-	-	1	-	-	-	-
	BP	-	-	-	-	-	-	-	-	-	-	33	-	-	-	-
<i>Trichopeltarion nobile</i>	T	-	-	-	-	-	-	2	-	-	-	-	-	-	-	-
	BP	-	-	-	-	-	-	84	-	-	-	-	-	-	-	-
<i>Benthochascon schmitti</i>	T	<1	-	-	-	-	9	-	-	-	-	34	-	<1	-	-
	BP	115	-	-	-	-	368	-	-	-	-	66	-	-	-	-
<i>Bathyplox typhla</i>	T	-	8	<1	-	-	-	14	-	1	-	<1	43	-	<1	-
	BP	-	-	-	-	-	-	-	-	-	-	-	77	-	-	-
Other Shrimp (Natantia)	T	4	20	9	2	<1	<1	6	1	1	-	6	56	1	42	<1
	BP	-	153	100	571	-	53	725	118	86	-	-	461	33	80	300

\*T = Trawl; BP = Benthic Photography

Table 5-8. Comparisons of fish densities obtained from trawling and benthic photography for Cruise II observations common to both. Dash "-" is equal to "0".

STATION:		Density per Hectare														
		W1	W2	W3	W4	W5	C1	C2	C3	C4	C5	E1	E2	E3	E4	E5
TRAWL AREA (ha):		2.8	2.6	7.7	6.3	6.5	3.2	2.7	5.6	4.8	4.9	1.8	2.1	4.5	5.6	4.8
<u>Synaphobranchus</u> sp.	T*	-	-	4	<1	-	-	-	<1	-	-	-	<1	5	3	-
	BP	-	112	-	-	-	-	89	-	-	-	-	-	-	-	-
<u>Pseudoplichthys laterodorsalis</u>	T	-	-	-	-	-	-	<1	-	-	-	-	<1	-	-	-
	BP	-	-	-	-	-	-	30	-	-	-	-	-	-	-	-
<u>Halosaurus</u> sp.	T	-	-	<1	-	-	-	<1	-	-	-	-	-	-	<1	-
	BP	-	-	-	-	-	-	-	-	-	-	-	-	66	-	-
Alepocephalidae	T	-	-	-	-	-	-	-	-	-	-	-	-	<1	1	-
	BP	-	-	-	-	-	-	84	30	-	-	-	154	33	-	-
<u>Chlorophthalmus agassizi</u>	T	13	-	-	-	-	<1	-	-	-	-	6	-	-	-	-
	BP	154	-	-	-	-	105	-	-	-	-	-	-	-	-	-
<u>Dibranchius atlanticus</u>	T	-	6	<1	-	-	-	<1	<1	-	-	-	6	2	-	-
	BP	38	-	-	-	-	-	-	59	-	-	-	-	-	-	-
<u>Urophycis</u> sp.	T	3	-	-	-	-	3	-	-	-	-	7	-	-	-	-
	BP	105	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Ophidiidae	T	-	-	2	<1	-	-	-	<1	<1	-	-	-	1	3	-
	BP	-	-	-	-	-	-	-	-	-	-	-	-	33	-	-
<u>Cataetyx</u> sp.	T	-	-	-	-	-	-	-	-	-	-	-	-	-	<1	-
	BP	-	-	-	-	-	-	-	-	-	-	-	-	-	40	-
Macrouridae	T	5	4	2	-	-	17	3	1	<1	-	33	7	2	11	-
	BP	738	76	-	-	-	315	84	-	-	-	-	-	66	-	-
<u>Bembrops gobioides</u>	T	16	<1	-	-	-	5	-	-	-	-	3	-	-	3	-
	BP	38	-	-	-	-	53	-	-	-	-	98	-	-	-	-

\*T = Trawl; BP = Benthic Photography.

occurring samples, density estimates based upon photography generally exceeded trawl density estimates by one or two orders of magnitude and in some cases even more. Several explanations for these large discrepancies are possible, the most likely being trawl avoidance. Some species with the largest variation in density estimates are highly motile such as the macrourids and some of the large penaeid shrimps such as Hymenopenaeus robustus. Another possibility for low trawl density estimates is that the trawl was not fishing properly.

Benthic photography provides a very different context for density observations in comparison to trawls. Due to the relatively small area surveyed by photographic transecting techniques (on the order of hundreds of m<sup>2</sup> compared to tens of thousands for a trawl), the observation of only a few individuals represents a very high megafauna density (with respect to the deep-sea). The large discrepancy between density figures for similar taxa estimated from trawl catches as compared to those obtained from benthic photography would indicate a strong bias of the trawl's ability to sample large, motile deep-sea megafauna. The inefficiency of trawls in obtaining an unbiased sample of bottom oriented species is discussed in Uzmann et al. (1977). The distinct advantage of obtaining actual specimens enabling greater taxonomic resolution remains with the trawling technique but trawling may underestimate the actual density of the majority of deep-sea species by at least one order of magnitude and often considerably more.

#### 5.5 UNIDENTIFIABLE ORGANISMS

This diverse category (Appendices D-1 and D-2) includes, at present, a variety of animals that could not be identified visually at the time of sample processing. Various levels of nomenclature were assigned to these animals given that in some instances even the phylum was not known whereas in others, the organism could be identified only to class. Most of these will be further identified as work progresses. Most of the partially identified megafauna appearing in Appendix D-2 were included in the generalized table of megafauna densities (Table 5-6).

## 5.6 SUMMARY

Overall, 48,000 benthic photographs have been obtained from 60 locations spread over depths between 300 and 3000 m. Lebensspuren were the most common features seen in the photography analyzed to date, exceeding observations of all other categories by at least two orders of magnitude. Solitary depressions and groups of depressions arranged in an identifiable pattern were the most numerous features and mainly represent burrow openings.

Hard substrate was widely distributed but nowhere abundant. An unexpected level of "artificial" hard substrate was represented in the form of cans and bottles, etc.

Observations of megafauna were not numerous, but densities of biota estimated from the photography were typically higher than densities estimated based upon trawl catches. Holothuroid density levels corresponded to a characteristic lebensspuren feature.

## 6.0 CHEMOSYNTHETIC ORGANISMS ON THE GULF OF MEXICO CONTINENTAL SLOPE

### 6.1 INTRODUCTION

Biological communities dependent upon chemosynthetic processes are known from hydrothermal vent sites at several locations in the eastern Pacific Ocean (Grassle 1983, Hessler and Smithy 1983, Tunnicliffe et al. 1985) where they are characteristically associated with an effluent of reduced sulfides. Prominent vent and seep megafauna include vestimentiferan tubeworms of the genera Riftia, Escarpia, and Lamellibrachia (Jones 1981, 1985) and vesicomid clams of the genera Calyplogena and Vesicomya (Boss and Turner 1980, Hecker 1985). Jannasch (1983) reports that the megafauna from these communities depend upon internal symbionts that are able to fix carbons by oxydizing sulfides. Reports of taxonomically similar communities from a cold sulfide seep at the base of the Florida Escarpment (Paull et al. 1984), from a methane vent on the continental margin off Oregon (Suess et al. 1985), and from a petroleum seep in the central Gulf of Mexico (Kennicutt II et al. 1985) greatly increase the geographic area where they may occur.

Descriptions of the spatial distribution and ecology of seep communities in the Gulf of Mexico have been based on otter trawl catches and observations from a submersible. Concern for potential damage to rare or unusual seep communities resulting from oil and gas exploitation in the Gulf of Mexico suggests that the distributional patterns of these communities should be studied at both the macro (Gulf-wide) and micro level. Questions regarding the petroleum seep communities were taken into account in planning Cruise V of the Continental Slope Study. Two sets of sampling stations at different depths were selected to provide a basis for comparison between seep and non-seep locations. Seep stations were WC6 and WC7; non-seep stations were WC2, WC4 and WC8 (see Fig. 2-1, p. 6). In addition, careful examination of macrofauna and benthic photographic material revealed samples of seep organisms that were taken fortuitously in Cruises I-III. The results of hydrocarbon analyses, benthic photography, and macrofauna and megafauna sampling that are relevant to Gulf of Mexico chemosynthetic communities are presented in this section. Field and analytical methods that have been described elsewhere in this



report are only briefly reiterated in this section. Macrofauna data for Cruise V are not yet available. In addition to the findings from the Continental Slope Study cruises, preliminary results from a series of trawls at seep sites were made available by TAMU/GERG (Brooks et al. 1986) and are discussed below.

## 6.2 FINDINGS FROM SITES OF NATURAL HYDROCARBON SEEPAGE OFF LOUISIANA

Regions of oil and gas seepage have been shown to be common to the continental slope of the Gulf of Mexico (Brooks et al. 1984, Brooks et al. 1986). Hydrocarbons in the upper few meters of the bottom sediments provide a source of chemical enrichment at the seep sites that is utilized by organisms containing chemoautotrophic bacterial-symbionts (Childress et al. 1986) and presumably by free-living chemoautotrophic bacteria (Jannasch 1984). The bacteria provide a non-photosynthetic carbon source that can be detected in organisms containing symbionts, and to a lesser degree in background fauna, by lowered carbon isotope values in their tissue (Rau and Hedges 1979, Kennicutt et al. 1985). The assemblage of organisms at seep sites can be referred to as chemosynthetic communities in order to distinguish the source of organic carbon being utilized at seeps from the photosynthetic food chain. However, the actual level of dependence on chemosynthesis and the trophic interactions within the assemblages is still unclear.

The chemosynthetic organisms found at the Gulf of Mexico hydrocarbon seeps are taxonomically similar to those found at seeps at the base of the Florida Escarpment (Hecker 1985) and the Oregon subduction zone (Suess et al. 1985), as well as to organisms found at hydrothermal vents in the eastern Pacific Ocean (Hessler et al. 1985). These organisms include vestimentiferan tube worms of the genus Lamellibrachia, clams of the species Vesicomya cordata and Calyptogena ponderosa, and mussels of the genus Bathymodiolus, all of which have been shown to support symbionts (C. Fisher, pers. comm.). Characteristics unique to the Gulf of Mexico petroleum seep communities are the hydrocarbon-based sources of the reduced inorganic compounds nourishing the assemblage, the sub-surface features of the sediments, and the generally diffuse spatial distribution of the community (Kennicutt et al. 1985).

### 6.2.1 HYDROCARBONS: SEEP TO NON-SEEP COMPARISON

Stations occupied in known seep areas of the west/central Gulf of Mexico were compared with control stations. In general the petroleum indicators were elevated at the seep sites by a factor of 2 to 3 (Table 6-1). Most of the petroleum was in the form of EOM and aliphatic UCM, which suggests that the petroleum was substantially biodegraded. Variability in hydrocarbon parameters at the seep/non-seep areas is of the same order of magnitude as along isobaths with varying sediment type. Previous samplings have retrieved sediments with total EOM as high as 150,000 ppm as contrasted to the average of 60.3 ppm for the two seep sites sampled in this study. This demonstrates the patchy nature of hydrocarbon distributions and in particular the nonuniform distribution of petroleum seepage in a given area. The extremes of petroleum hydrocarbon input to slope sediments were not represented in this set of samples, though previous work documents that the samples were taken in an active area of natural oil seepage.

### 6.2.2 CARBON ISOTOPES: CHEMOSYNTHETIC ECOSYSTEMS

Five studies have reported on the stable carbon isotope composition of seepage/chemosynthetic marine ecosystems. Three of these analyzed organisms (bivalves and tube worms) were from the Pacific hydrothermal vents (Rau and Hedges 1979, Rau 1981, Williams et al. 1981). Carbon isotope values are reported as per mil deviations from the Pee Dee Belemite standard (Brooks et al. 1984):

$$\delta^{13}\text{C} = \frac{(^{13}\text{C}/^{12}\text{C})_{\text{sample}} - (^{13}\text{C}/^{12}\text{C})_{\text{std}}}{(^{13}\text{C}/^{12}\text{C})_{\text{std}}} \times 1000$$

Mussel tissue  $\delta^{13}\text{C}$  values near  $-33 \text{ ‰}$  were cited in support of the hypothesis that the food source for these organisms is not photosynthetically derived. These measurements suggest that chemoautotrophic bacteria fix  $^{12}\text{CO}_2$  to a greater extent than do photoautotrophs, thus producing biomass with more negative  $\delta^{13}\text{C}$  values. Vestimentiferan tubeworm tissue was ca.  $-11 \text{ ‰}$  heavier than the light

Table 6-1. Comparison of sediment hydrocarbon parameters at seep and non-seep locations on the western/central Gulf of Mexico continental slope.

Parameter <sup>1</sup>	Seep <sup>2</sup> n=2	Non-Seep <sup>3</sup> n=3
Total EOM (ppm)	26.3 - 94.2 ( 60.3)	17.4 - 23.9 ( 20.6)
Aliphatic UCM (ppm)	6.8 - 46.2 ( 26.5)	6.9 - 7.9 ( 7.6)
PL-1 (ppb)	152.7 - 271.7 (212.2)	47.4 - 65.3 ( 56.4)
TERR (ppb)	146.7 - 236.7 (191.7)	109.8 - 273.1 (201.2)
Petro-Lo (ppb)	92.7 - 219.0 (155.9)	39.1 - 52.5 ( 43.7)
Petro-Hi (ppb)	99.9 - 119.3 (109.6)	80.6 - 121.9 ( 99.4)
Terrigenous (ppb)	46.8 - 117.4 ( 82.1)	29.2 - 151.2 (101.7)
Petroleum (ppb)	192.6 - 238.3 (215.5)	119.7 - 161.5 (143.2)
Planktonic (ppb)	52.1 - 60.0 ( 56.1)	4.0 - 26.2 ( 12.7)

<sup>1</sup>For definitions see Tables 3-4 and 3-5.

<sup>2</sup>Stations WC6, WC7.

<sup>3</sup>Stations WC2, WC4, WC8.

isotopic composition of mussel tissue at hydrothermal vents. One possible explanation for this observation is that there is  $\text{CO}_2$  limitation as a result of internal symbiotic chemosynthesis (Rau 1981, Williams et al. 1981). Spies and DesMarais (1983) have also used stable carbon isotopes to document a petroleum contribution to possible chemosynthetic ecosystems around offshore California seeps. Paull et al. (1984) have reported carbon isotope values near  $-70 \text{ ‰}$  for seep organisms at the Florida escarpment brine seep site.

Initial measurements made on northern Gulf slope and seep organisms are summarized in Figure 6-1. All the vent-type taxa (bivalves, tube worms, gastropods) are isotopically light ( $-27$  to  $-37 \text{ ‰}$ ) compared to other benthic slope organisms that derive their carbon from photosynthetic carbon. These values are similar to the  $-32$  to  $-34 \text{ ‰}$   $\delta^{13}\text{C}$  values reported for the organisms from the Pacific hydrothermal vent communities (Rau and Hedges 1979, Rau 1981, Williams et al. 1981). Organisms from the Escarpment site (Paull et al. 1985) were considerably lighter ( $-70 \text{ ‰}$ ) than either the Louisiana slope fauna or the hydrothermal vent organisms. Considering the large difference in carbon isotope values between the chemosynthetic and photosynthetic carbon, even a minor contribution of chemosynthetic carbon to a slope ecosystem should be discernible. One crab from the Florida slope has a  $\delta^{13}\text{C}$  ( $-23.1 \text{ ‰}$ ) that is considerably lighter than any of the other non-seep taxa. This value may be due to the species, petroleum contamination, or a contribution from chemosynthetic carbon.

At the Louisiana seep ecosystems, the  $\delta^{13}\text{C}$  of the tubeworm is only slightly heavier ( $4$ - $7 \text{ ‰}$ ) than the bivalves and gastropods. In fact, one measurement of a tube worm attached to a carbonate rock ( $\text{CaCO}_3, \delta^{13}\text{C} = -50 \text{ ‰}$ ) had a  $\delta^{13}\text{C}$  value of  $-37 \text{ ‰}$ . This is in marked contrast to tube worm  $\delta^{13}\text{C}$  values at the Pacific spreading centers in which the tube worm  $\delta^{13}\text{C}$  values were  $20$  to  $25 \text{ ‰}$  heavier than the mussels (Rau 1981, Williams et al. 1981). These differences were related to chemoautotrophic synthesis occurring internally (symbiotically) in the tube worms. The Louisiana seep tube worms may thus fix carbon internally with fractionation similar to the bivalves and gastropods. The final isotopic composition of the tissue may ultimately depend on the carbon isotopic composition of the original carbon source. The isotopically light

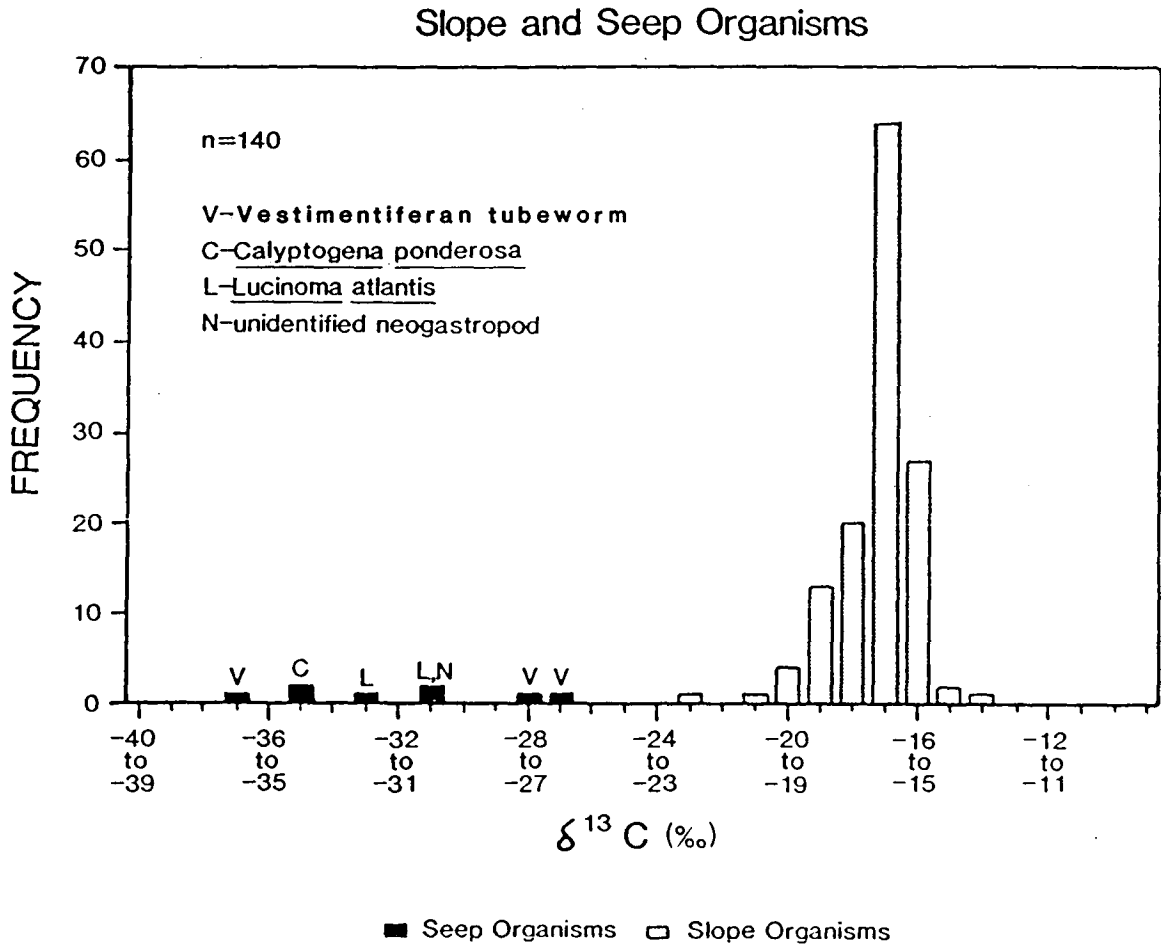


Figure 6-1. Comparison of  $\delta^{13}C$  values for pandemic continental slope fauna and for petroleum seep organisms.

organisms in the seep regions apparently derive their energy from bacteria that utilize light CO<sub>2</sub> either from the bacterial breakdown of oil or from the seeping oil/gas. However, the CO<sub>2</sub> system in the seep/hydrate regions is complex.

### 6.2.3 TRAWL SAMPLES FROM CENTRAL GULF SEEP SITES

TAMU conducted out a trawling and piston coring program for the Offshore Operators Committee at 39 sites on the continental slope which were identified as probable petroleum or natural gas seeps (Brooks et al. 1986). The sites were in water depths of from 180 to 900 m from Mississippi Canyon to East Breaks. Carbon isotope analysis of the samples confirmed the use of chemosynthetically-derived carbon by six taxa: pogonophorans, vestimentiferans, the vesicomid clams Calyptogena and Vesicomya, the mussel Bathymodiolus, and an unidentified turrid. A symbiosis between a methanotrophic bacteria and the mussels was demonstrated. Seismic data and core samples from the sites were used to define four proposed physical indicators of chemosynthetic communities: wipe-out zones, oil-stained cores, natural gas pockets, and H<sub>2</sub>S in the sediment.

Examination of the presence or absence of the six chemosynthetic taxa in the trawl samples reveals that their occurrence was not homogeneous among the 39 trawls. A cluster diagram of their occurrence based on the DICE index of similarity (Fig. 6-2) shows two major groupings. Calyptogena and Vesicomya formed a distinct group, co-occurring more often with one another than with the other taxa. These bivalves co-occurred with one another at 57% of the locations sampled. Within the second group, the vestimentiferans and pogonophorans almost always co-occurred and turrids were also present in some 57% of the samples containing these tubeworms. The mussels were caught at only four of the sites, each of which also contained tubeworms and two of these sites were characterized by the presence of bivalves. Although mussels are more closely allied to Group II than to Group I, they could be considered to comprise a separate category in themselves, as they are not convincingly allied with the tubeworms and turrids (Fig. 6-2).

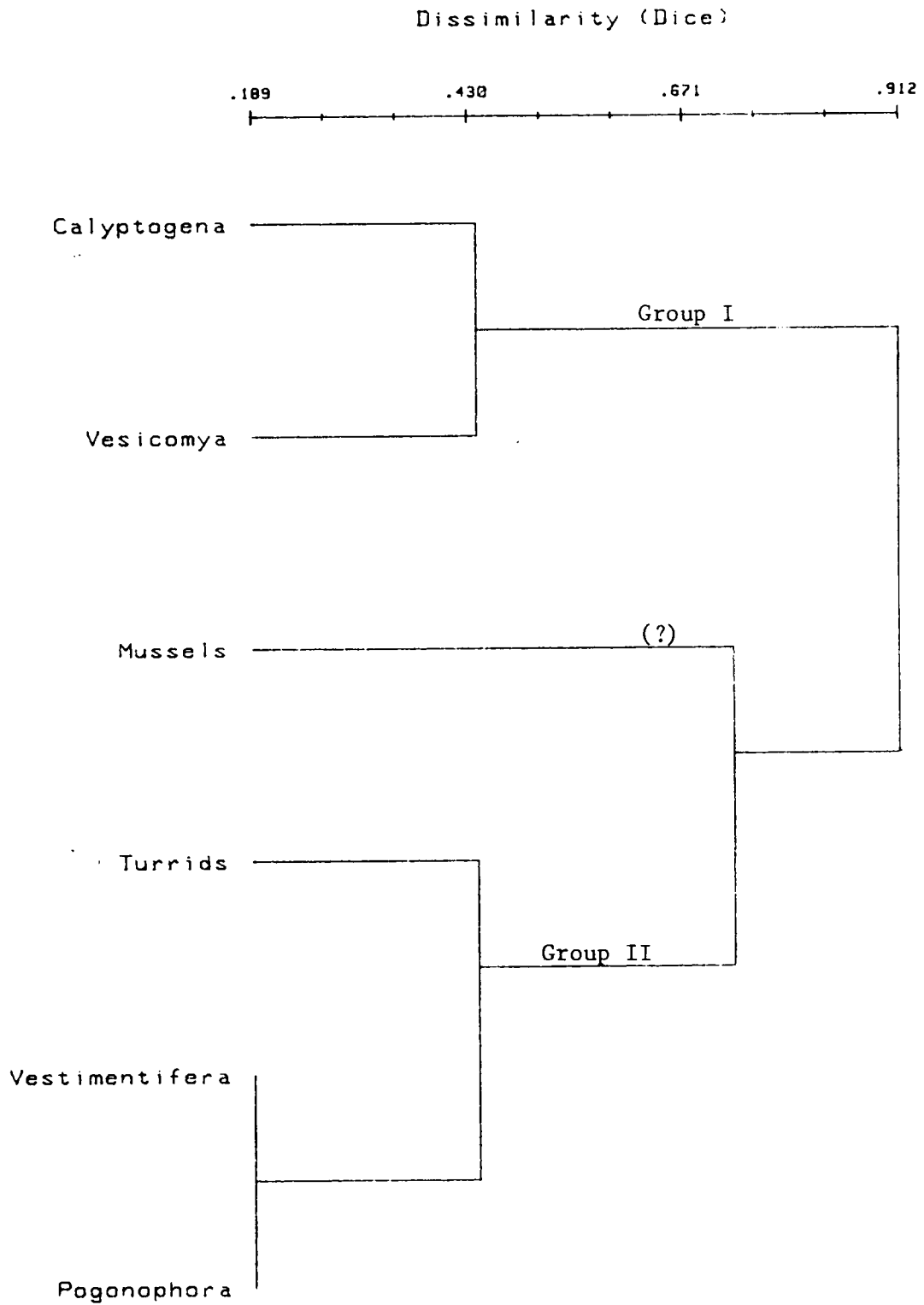


Figure 6-2. Cluster diagram (DICE) based on dissimilarity of co-occurrence of six chemosynthetic organisms. Data from Brooks et al. (1986).

The six chemosynthetic taxa were not consistently captured at sites where the indicators of chemosynthetic communities listed above were present. DICE similarity indices show the co-occurrence of each of the seep organisms and wipe-out zones, oil-stained cores, gas pockets, or H<sub>2</sub>S (Fig. 6-3). The indicators were less consistent predictors of the occurrence of the clams and mussels than of tubeworms and turrids. The bar plots shown in Figure 6-3 suggest that the chemosynthetic taxa had differing environmental preferences. Vestimentiferans, pogonophorans, and the turrids show a similar pattern of co-occurrence with the physical indicators and were more commonly observed in the seep zones than the bivalves. Within the bivalve group, mussels showed more affinity for areas characterized by the presence of gas pockets than did the clams. This is not surprising given their demonstrated dependence upon methane (Fig. 6-2).

### 6.3 CHEMOSYNTHETIC ASSEMBLAGES AT CONTINENTAL SLOPE STUDY SAMPLING STATIONS

The photographs from three Continental Slope Study sampling stations, WC7 (27°45.6'N and 91°13.1'W), C7 (27°44.6'N and 89°58.9'W) and C2 (27°53.6' N and 90°07.1'W) were found to contain recognizable pictures of large tubeworms and clams. Station WC7 is near areas of previously reported petroleum seepage (Brooks et al. 1984) and trawl catches of suspected chemosynthetic organisms (Kennicutt II et al. 1985). The photo-transect from WC7, shown in Figure 6-4a, is close to several seismic wipe-out zones thought to be associated with petroleum seepage (Brooks et al. 1986). Seismic records are not available for the photo-transect at Station C7 (Fig. 6-4b). However, sediments from both WC7 and C7 have lowered carbon preference indices (the ratio of odd to even n-alkane), 1.48 and 1.16, respectively, which suggests the presence of petroleum-sourced hydrocarbons. Station C2 had neither a low carbon preference index in the sediment samples, nor was there seismic evidence of hydrocarbon seepage. Vent-type organisms were documented at this site but appeared in only two of the 800 photographs taken at the site.



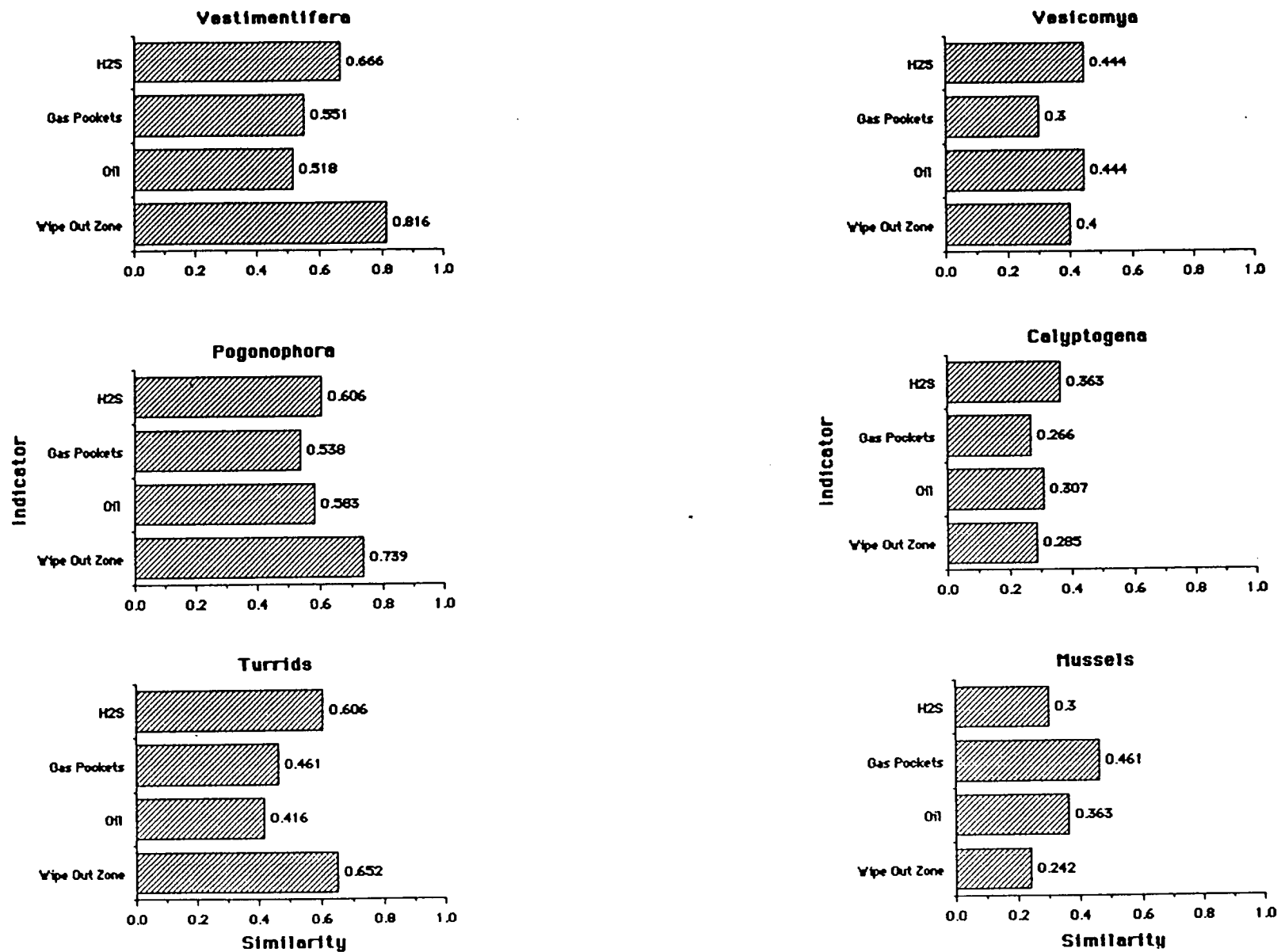


Figure 6-3. Similarity indices (DICE) for chemosynthetic taxa and four seep indicators. The values of each bar show the percentage of occurrence for each taxa at trawl sites where the indicators were present. Data from Brooks et al. (1986).

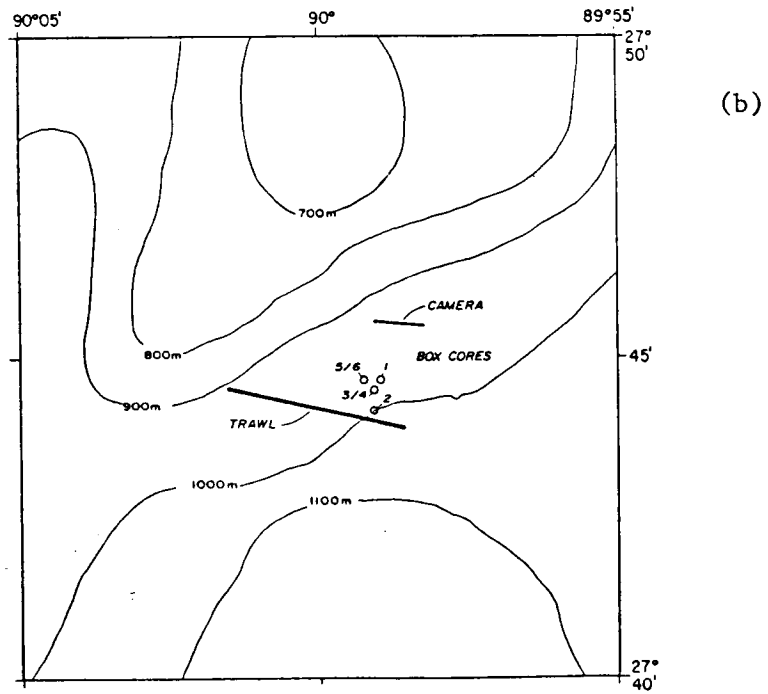
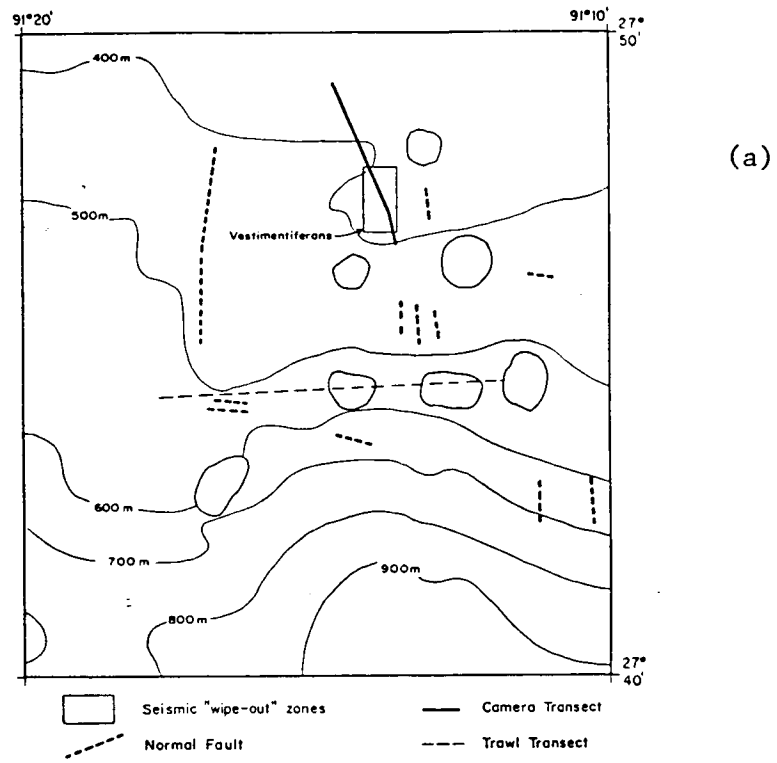


Figure 6-4. Station WC7 (a) and C7 (b): camera transect, trawl transect, box core locations, and seismic features.

Table 6-2 shows the overall lengths of photo-transects obtained at the three stations, the number of acceptable frames on each transect, and the area of bottom surveyed by the frames. All frames containing either tubeworms or clams were digitized; in the remaining frames only the frame areas were recorded in order to determine the total area of the transect.

Table 6-2. Photographic sample for seep organisms: total number of acceptable photographic frames from each transect, the total area of these frames, the number containing seep organisms, and the area of the frames containing seep organisms.

Station	Number of Frames	Sum of Frame Areas m <sup>2</sup>	Frames with Seep Organisms	Area of Analyzed Frames m <sup>2</sup>
C2	750	2700	2	20.9
C7	492	1480	101	267
WC7	707	2117	138	471

### 6.3.1 STATION WC7

Six nearly complete and several partial vestimentiferans were obtained in the trawl at Station WC7. The specimens came up entangled in the trawl door fittings, the teeth of a rake slung in front of the foot rope, and inside the cod end. The tubes of the most complete specimens were from 60 to 85 cm in length and had an exterior diameter that tapered from 1.5 cm at the anterior end to less than 1 mm at the posterior end. The opisthisome was broken off in all specimens. The anterior third of a typical tube was straight, becoming more convoluted in the middle third, and increasingly slender and tightly coiled toward the posterior tip. On several of the tubes there was a distinct difference in color between the posterior and anterior ends. The anterior ends were a brownish tan, while the posterior ends were coated with a black substance that came off on contact and smelled of H<sub>2</sub>S. These tubeworms were identified as Lamellibrachia sp. (M.L. Jones, pers. comm.). A total of 152 empty tubes

of a second tubeworm, an undescribed species of Pogonophora (M.L. Jones, pers. comm.), was also seen. The pogonophorans could be distinguished from the vestimentiferans by the appearance of their tubes, which were uniformly black, slender and straight, and were commonly encrusted with barnacles and zoanthids.

Tubeworms were the most abundant organism seen in the photographs from Station WC7 (Fig 6-5a and 6-5b). Two species of tubeworms could be distinguished in the photographs from WC7. The most common appeared as slender, slightly curved cylinders, tan in color and protruding from the sediments, usually at an angle of less than  $45^{\circ}$  and sometimes leaning so sharply that they had produced a visible trace in the sediments. A reddish plume was visible in some specimens when highly magnified by projection. A second, less common tubeworm was dark and whip-like, and was never observed with a visible plume. The taxonomy of the tubeworms in the photographs is unclear. Other samplings of seep communities (Brooks et al. 1986) have suggested that the Lamellibrachia sp. taken in the trawl at this station usually occur in dense clusters or thickets attached to pieces of hard substrate. The complete absence of hard substrate and of clusters of more than three or four individuals suggest that the tan-colored tubeworms in the photographs are (1) an atypical occurrence of Lamellibrachia sp., (2) another seep-related pogonophoran or vestimentiferan species, or (3) some other species such as a tube-dwelling polychaete or a gorgonian. The Lamellibrachia sp. caught in the trawl at WC7 were quite similar in appearance to the tan-colored tubeworms in the photographs; the trawl specimens were not caught in clusters and showed evidence of having been inserted in a soft, anoxic sediment, and there were no other stalked or tube-dwelling organisms caught in the trawl at WC7. We will refer to the tan-colored tubeworms in the photographs as vestimentiferans and to the black, whip-like tubeworms as pogonophorans, with the caveat that more sampling and photography will be needed to resolve their taxonomy.

A total of 439 vestimentiferans was seen in the photo-transect (Table 6-3); however their distribution along the transect was not constant. Within the total transect length of 4616 m, the greatest numbers were seen over a segment of 965 m between  $27^{\circ}46.51'$ ,  $91^{\circ}13.85'$  and  $27^{\circ}47.02'$ ,  $91^{\circ}14.13'$  (Fig. 6-6a). As an aggregate, the mean density of

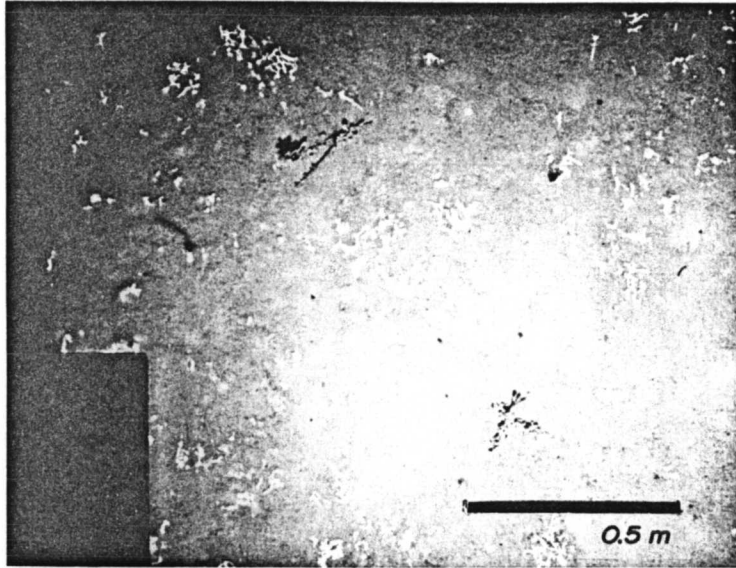


Fig. 5 a. Vestimentiferan tubeworms with bacterial mats; Station WC7, depth 433 m.

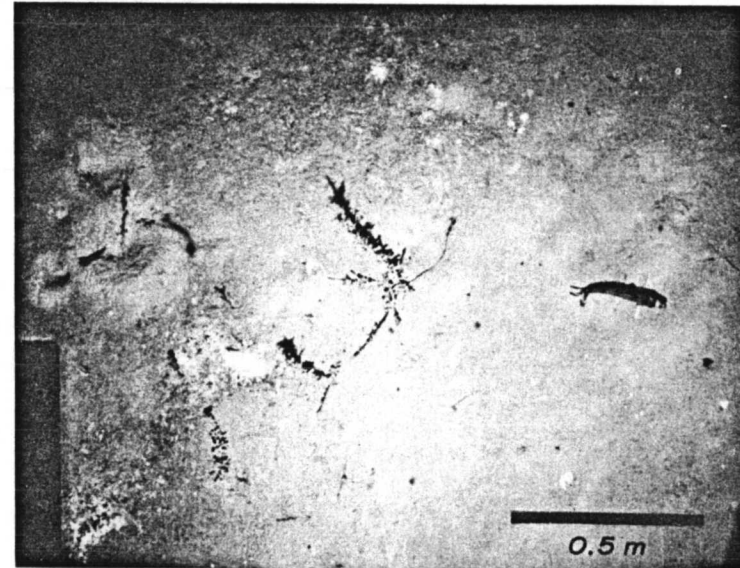


Fig. 5 b. Vestimentiferan tubeworms and greeneye Chloropthalmus agassizi; Station WC7, depth 439 m.

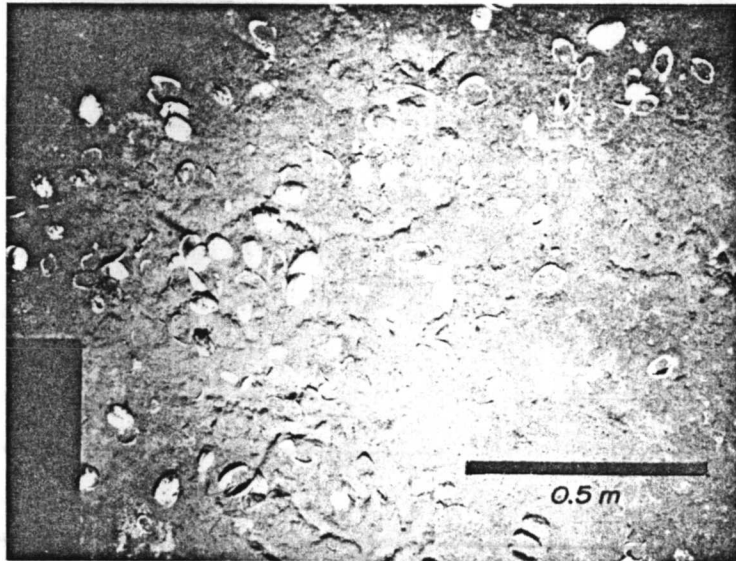


Fig. 5 c. Aggregation of live and dead vesicomyid clams; Station C7, depth 948 m.

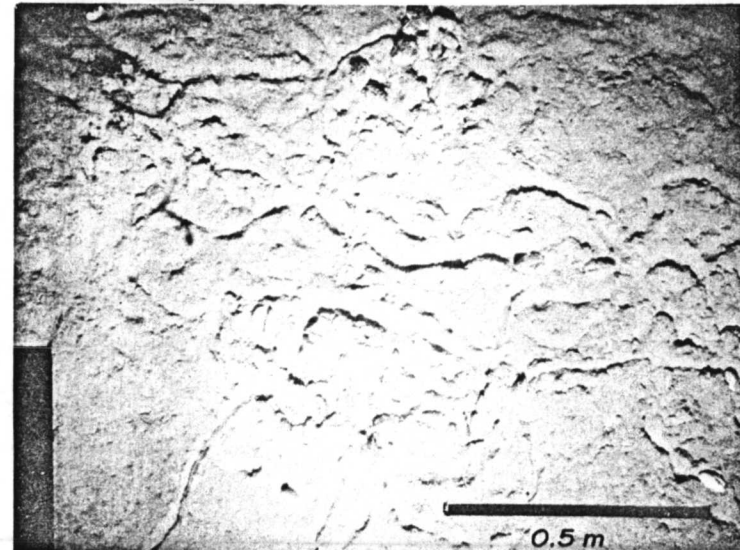


Fig. 5 d. Predominantly live vesicomyid clams and furrows in sediments; Station C7, depth 949 m.

Table 6-3. Density/hectare and raw counts of seep-related organisms at Stations C7 and WC7.

Organisms	Station			
	C7		WC7	
	No.	Density/ Hectare	No.	Density/ Hectare
<u>Vestimentifera</u> -with plume-encrusted	-	-	40	189
<u>Vestimentifera</u> -with plume-bare	-	-	17	80
<u>Vestimentifera</u> -without plume-encrusted	-	-	261	1,233
<u>Vestimentifera</u> -without plume-bare	-	-	121	572
Pogonophora-without plume-bare	-	-	16	76
Pogonophora-without plume-encrusted	-	-	1	5
Vesicomidae-live	310	2,095	-	-
Vesicomidae-dead shell half	2,002	13,527	6	28
Vesicomidae-possibly live	523	3,534	4	19
Neogastropoda	3	20	-	-

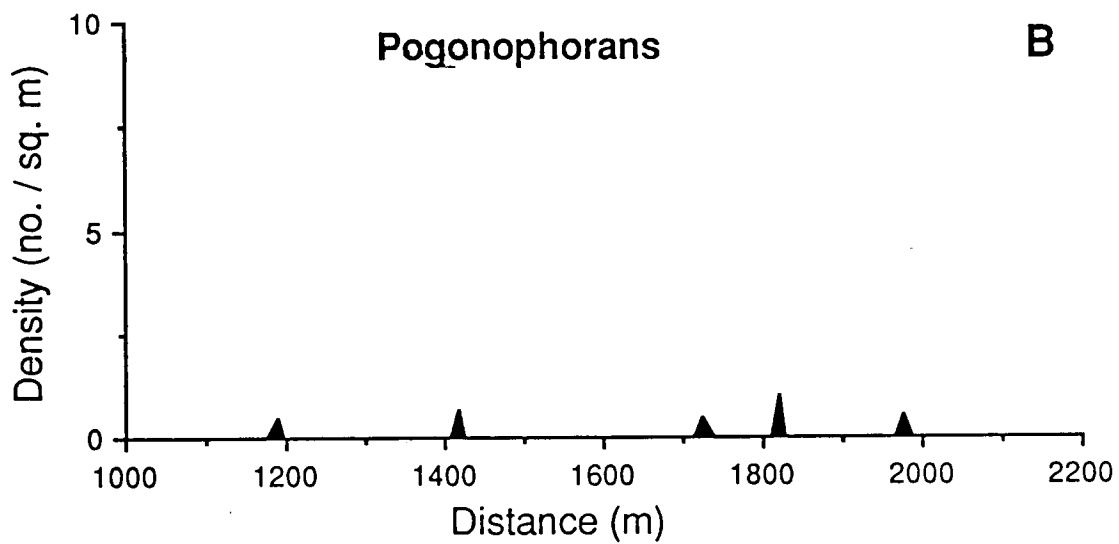
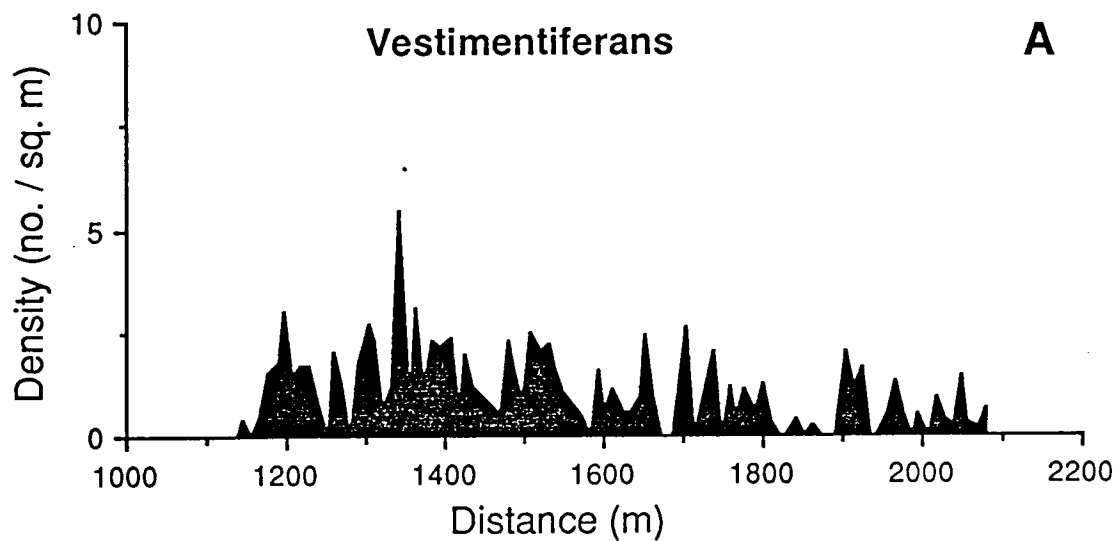


Figure 6-6. Station WC7: density of A) vestimentiferans and B) pogonophorans on the segment of the photo-transect where they occurred. Total transect length was 4616 m.

vestmentiferan was 1.0 per m<sup>2</sup> (s.e. 0.057). Their density along the transect varied from 0.2 to 3.2 per m<sup>2</sup>.

Figure 6-4a shows that occurrence of vestimentiferan roughly coincided with proximity to seismic wipe-out zones; however its abundance did not correlate convincingly with depth along the transect. Careful examination showed that the obturaculum, or plume, was visible in only 15% of the specimens (Table 6-3). Distribution of plumed specimens was constant along the transect. A total of 382 vestimentiferan were measured using the digitizing procedures and found to have a mean length of 15 cm (s.e. 1.7 cm). Although these results must be viewed with caution since upright, individuals appear foreshortened they provide an estimate of the visible length in situ. Unbroken tubes of vestimentiferan caught in the trawl had a mean length of ~65 cm. The photographs of pogonophorans show a very scant occurrence along the transect (Fig. 6-6b).

Other features noted in the photographs containing tubeworms were background fauna, consolidated material, and lebensspuren. A total of 1521 lebensspuren was observed in the 138 frames digitized from Station WC7. The dominant features were depressions (both shallow and deep), conical lumps, ridges, and grooves. One type of groove, noteworthy because it can be associated with clam movement (Figs. 6-5c and 6-5d), was seen five times. A second, distinctively broad and sculptured groove, probably formed by holothuroids, was seen 11 times. There were 18 observations of consolidated material, including rocks, nodules, or other conglomerates, usually darker than the surrounding sediments and ~5 cm in diameter. The 33 observations of background fauna (Table 6-4) included a penaeid (Hymenopenaeus robustus), a polychelid (Nephropsis aculeata), and a brachyuran (Benthochascon schmitti). The most frequent fish was the Atlantic batfish (Dibranchus atlanticus).

### 6.3.2 STATION C7

Vesicomid clams were the most abundant organism seen in photographs from Station C7. Photographs showed live specimens, disarticulated shells, and distinctive, furrowed trails. The living specimens appeared amid a scatter of partly buried shells (Fig. 6-5c). Living specimens were oriented with the foot angled down; many appeared at the ends of deep,



Table 6-4. Density/hectare and raw count of background fauna at seep Stations C7 and WC7.

Biota Group	Station			
	C7		WC7	
	No.	Density/ Hectare	No.	Density/ Hectare
<b>DECAPOD CRUUSTACEANS</b>				
<u>Hymenopenaeus robustus</u>	0	0	4	84.9
<u>Nephropsis aculeata</u>	0	0	1	21.2
Galatheididae	1	37.4	0	0
<u>Benthochascon schmitti</u>	0	0	1	21.2
<u>Gervon quinquedens</u>	4	149.4	0	0
Natantia	4	149.4	1	21.2
<b>ECHINODERMATA</b>				
Asteroidea	0	0	3	63.7
<u>Nymphaster arenatus</u>	0	0	1	21.2
<u>Scotoplanes</u> sp.	168	6275.9	0	0
<b>OTHER INVERTEBRATES</b>				
Octocorallia-Gorgonacea	0	0	2	42.5
Zoantharia-Actinaria	0	0	5	106.1
<b>FISHES</b>				
Nettastomatidae	0	0	2	42.5
<u>Synaphobranchus</u> sp.	1	37.4	0	0
Ophichthidae	1	37.4	0	0
<u>Ilyopis brunneus</u>	1	37.4	0	0
Alepocephalidae	0	0	1	21.2
<u>Chlorophthalmus agassizi</u>	0	0	3	63.7
<u>Dibranchus atlanticus</u>	0	0	4	84.9
<u>Urophycis cirratus</u>	0	0	3	63.7
Macrouridae	1	37.4	0	0
<u>Coryphaenoides</u> sp.	2	74.7	0	0
<u>Hymenocephalus italicus</u>	0	0	1	21.2
<u>Peristedion</u> sp.	0	0	1	21.2
<u>Bembrops gobiodes</u>	0	0	0	42.5

meandering furrows in the sediment which were up to 205 cm in length (Fig. 5-3d). Vesicomylid clams seen in the photographic transect from Station C7 were identified as two species of the genera Calyptogena and Vesicomya (F.J. Rokop, pers. comm.). Vesicomylids caught in trawls near Station WC7 were identified as the species Calyptogena ponderosa and Vesicomya cordata (Kennicutt et al. 1985). Careful comparison of these specimens with the clams in the photographs enabled us to identify a few exceptionally well-photographed individuals and showed that the species C. ponderosa and V. cordata were present in the aggregations. Most specimens in the photographs could only be identified as vesicomylids and many could not be identified at the family level; however, general similarities of the shape and color of the shells and of the trails left by living bivalves leads us to believe that clams in the photographs were predominantly C. ponderosa and V. cordata.

The vesicomylids occurred in two aggregations along the transect. Aggregation I extended 150 m between 27°45.51', 89°58.69' and 27°45.53', 89°58.77'. Aggregation II extended 100 m between 27°45.55', 89°58.91' and 27°45.57', 89°59.06'. The end of aggregation II coincided with the preprogrammed end of the photo-transect, so the actual length of the aggregation may have been greater than the portion photographed. Both aggregations contained a mixture of living individuals and disarticulated shells. The living clams usually appeared amid a dense scatter of dead and partly buried valves, and most were oriented in a nearly horizontal position with their hinges visible. Only those clams that were leaving plowing trails could be identified as alive with certainty. Clams in plowing position without clear trails were, however, also counted as living. Individual valves from dead clams were those that either gaped widely or were disarticulated with the valve concavity visible; each valve was counted. The specimens that could not immediately be classified were valves that were partly buried with the convex side uppermost; these specimens were added to the count of gaping or disarticulated valves. The total number of dead individual bivalves was then calculated as half the number of gaping or disarticulated valves. Some of the doubtful specimens may have been alive, so classifying them as dead would over-estimate the number of dead specimens; however, clearly dead valves constituted the dominant category in almost all photographs.

Figure 6-7a shows the percentages of dead clams per frame in aggregations I and II. Figure 6-7b shows the percentage of dead clams per frame in aggregations of *Calyptogena* from the "Clam Acres" hydrothermal vent site in the eastern Pacific Ocean (Hessler et al. 1986). The densities of living and dead vesicomys are plotted along the transect in Figure 6-8. Figure 6-9 shows the length measurements of living vesicomys and dead individual valves. Only those valves which were completely visible were measured, so the histogram is a subsample of the living and dead vesicomys on the transect. In addition, it should be noted that the measurement sample comprises at least two species.

Other features noted in the photographs from Station C7 were co-occurring fauna, consolidated material, and lebensspuren (Table 6-4). A total of 1815 lebensspuren was observed in the 101 digitized frames; the most prominent features were grooves, followed by depressions and lesser numbers of ridges and lumps. Live clams often appeared at the ends of furrowed grooves similar to those described from Station WC7; 420 of these grooves were seen in aggregates I and II. When they were measured using the methods described above, the mean length of the grooves was 27.2 cm (s.e. 1.5 cm). Other distinctive grooves included 46 of the sculptured holothuroid grooves also described from Station C7 and 416 short, narrow grooves probably formed by brachyuran crabs. Co-occurring fauna (Table 6-4) included 168 holothuroids (*Scotoplanes*) and four large crabs (*Geryon quinquedens*). A total of 36 small (~2 cm) consolidated objects was seen.

### 6.3.3 STATION C2

During routine processing of the benthic photographs from Cruise III, two slides were discovered that showed aggregations of vestimentiferan tubeworms and a species of bivalve not previously seen in the photographs. The tubeworms occurred in dense thickets, 50 to 100 cm in diameter, containing several hundred individuals. The tubeworms were tan in color, sinuous, about 1 cm in diameter, and up to 80 cm in length. They were similar in appearance to the *Lamellibrachia* sp. seen in the trawl samples from Station WC7. The tubeworms were encrusted on large, dark pieces of what appeared to be carbonate. Nestled in the base of one of the tubeworm

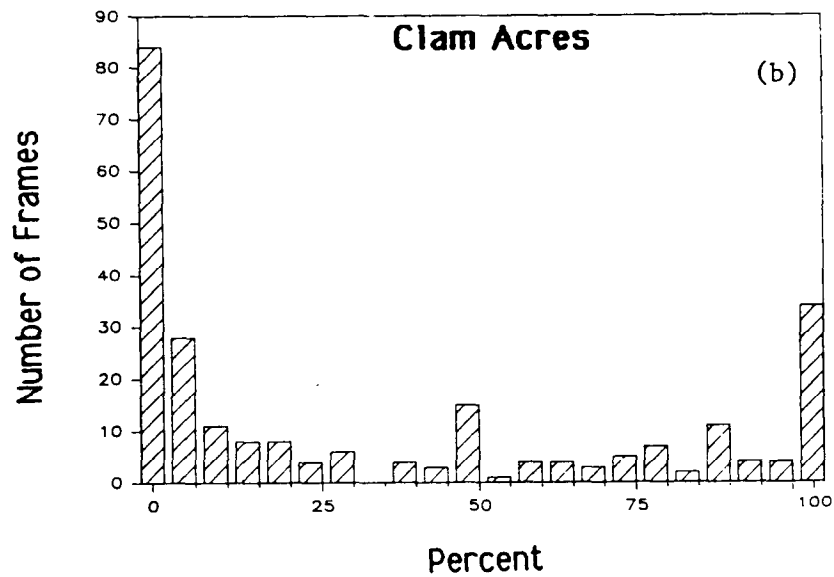
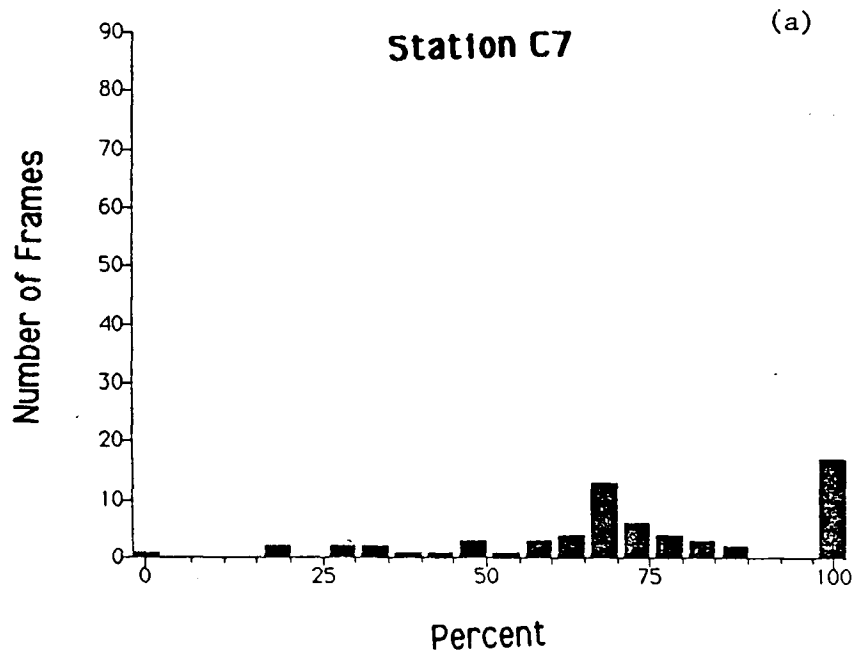


Figure 6-7. Percentage of dead Vesicomidae per frame. Five percent intervals except for 0% and 100%: Aggregations I & II combined (a), and Calyptogena from Clam Acres on the East Pacific Rise (b). Reproduced with permission from Hessler et al. (1985).

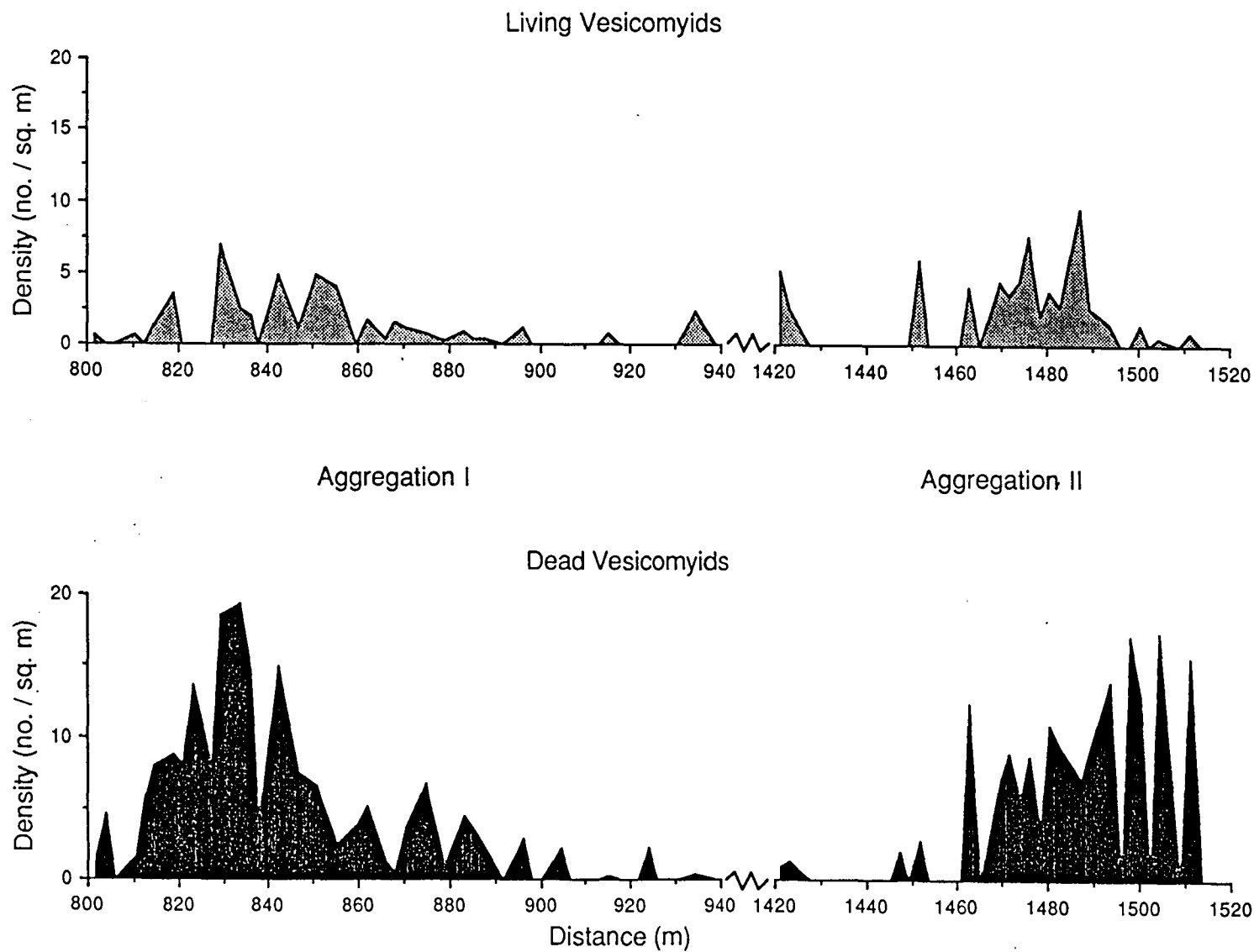


Figure 6-8. Station C7: densities of living and dead vesicomyids on the segments of the photo-transect where they occurred. Total transect length was 1520 m. The number of dead vesicomyids is half the number of dead valves seen in the photographs.

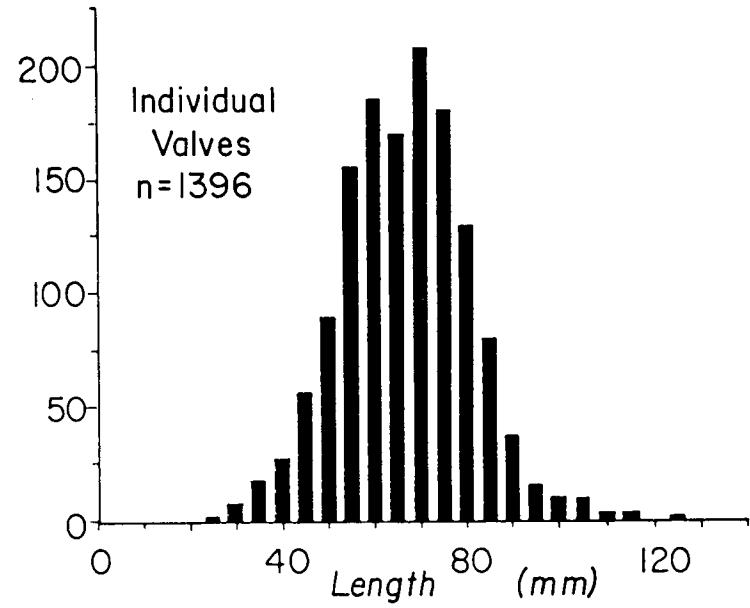
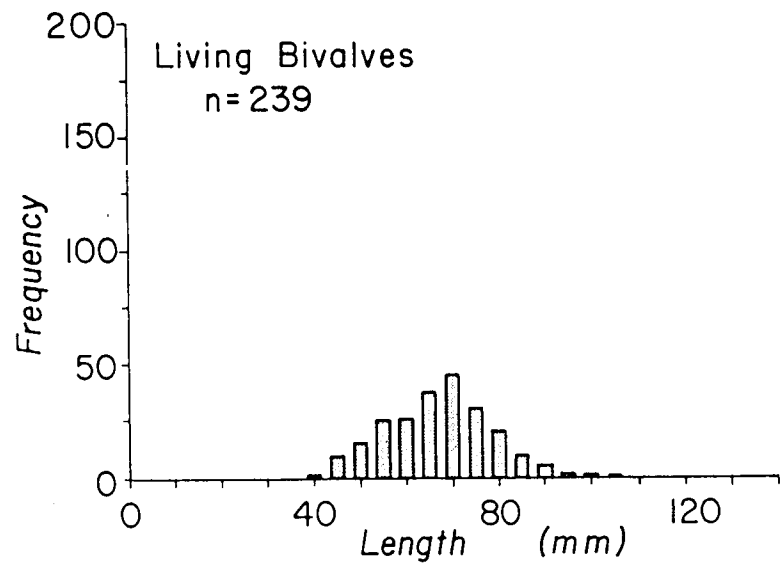


Figure 6-9. Length frequency of living vesicomyids and dead vesicomyid valves. Lengths were measured on the projected photographs.

thickets were three eel-like fish. Several patches of Lophihelia corals were also attached to the rock surface (see Fig. 6-10).

The most interesting feature of these clusters were the bivalves and their relationship with the tubeworms. From the appearance of the bivalves and from trawl specimens obtained from M.C. Kennicutt, the bivalves are most likely of the family Limidae, genus Acesta, probably A. bullisi. The most pronounced morphological feature was a concave process on the dorsal that is visible in several dead valves lying next to the tubeworm thicket (Fig. 6-10). All of the living Acesta in the photographs existed with the anterior end of a tubeworm inserted into this process in such a way that the obturaculum of the tubeworm, if it was present, was entirely enclosed by the mantle cavity of the Acesta (Fig. 6-10). The attachment of the bivalves appeared solid; several individuals are held completely clear of the substrate by the support of the worm tubes.

#### 6.4 STATISTICAL ANALYSES

The frequency and spacing of seep organisms in the photographs were used to estimate their abundance in the vicinity of the sampling stations. Frequency and spacing were determined from the area of each photograph, the number of organisms it contained, and its location on the transect. These data were used to construct a statistical model based on the sampling procedures and on appropriate assumptions regarding the spatial distribution of the organisms (Ripley 1980).

Study of the photo-transects suggested that seep organisms occurred in distinct spatial patterns (Figs. 6-6 and 6-8). Photographic material has been used by previous researchers to determine the spatial patterns that are characteristic of epibenthic species (Grassle 1975). Several techniques can be used to identify spatial patterns; they include diagnostic procedures and confirmatory goodness of fit tests. The approach taken here was a composite of these two methods. Diagnostic procedures were used to identify likely spatial models; confirmatory tests were then used to verify which of the models was most appropriate. Mathematical examination of the underlying distributional form of an appropriate spatial model made it possible accurately to estimate the abundance of an organism and to determine the distributional properties of

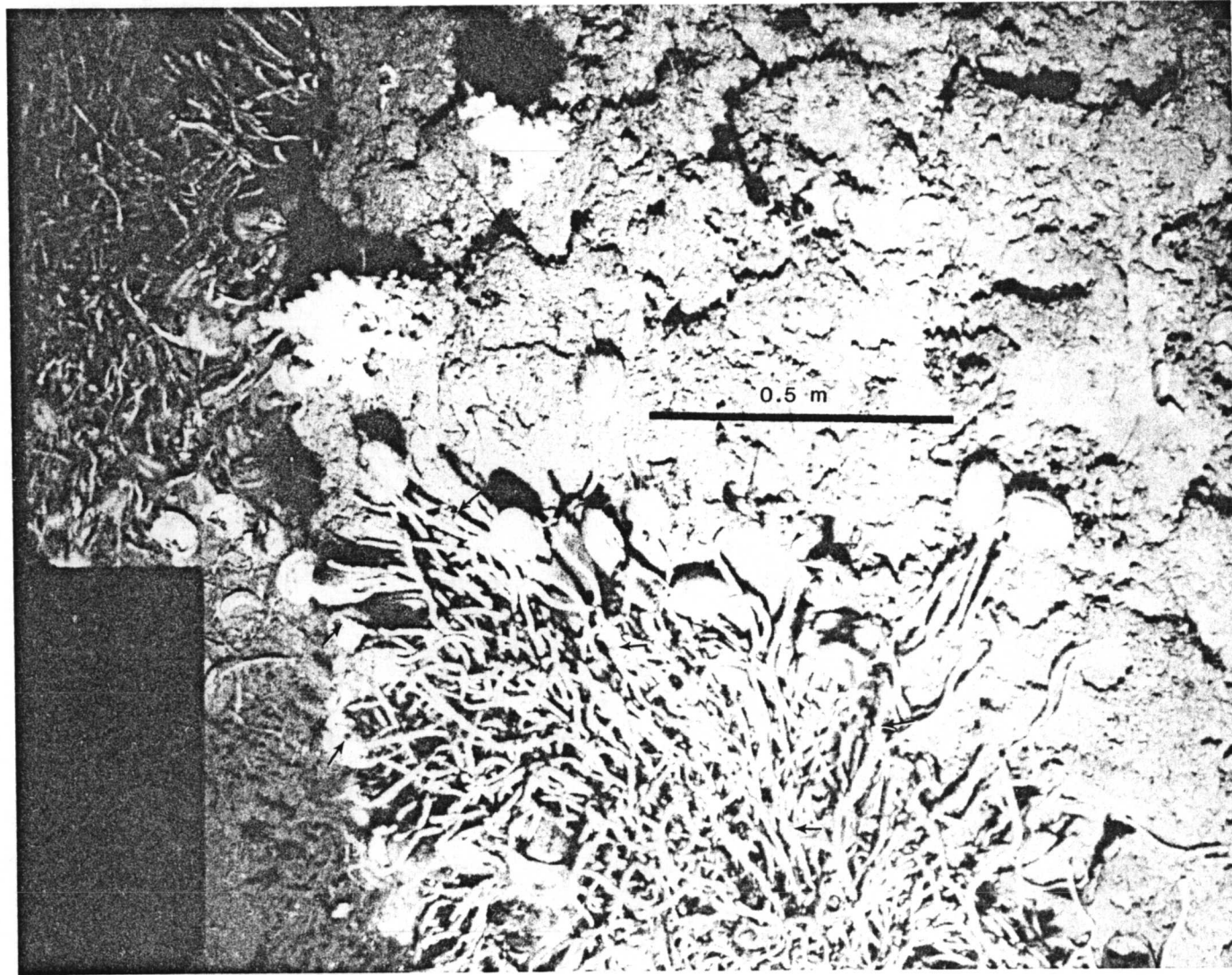


Figure 6-10. Station C2: Cluster of the vestimentiferan Lamellibrachia sp. and the bivalves Acesta sp. Arrows indicate Lamellibrachia sp. plumes. Note the attachment of the Acesta sp. on the ends of the tubes. Substrate is carbonate with the scleractinian corals Lophohelia sp. forming small outcroppings in center left.



that estimate, i.e., its variance and bias. This result can be used to detect statistically significant changes in abundance over time and/or between locations. In addition, it can be used to determine the amount of sampling effort required to detect changes of a given magnitude at an appropriate level of confidence.

The topography of the bottom at Stations WC7 and C7 appeared nearly homogeneous for the entire area of the photo-transects. Spatial patterns that have been described for benthic megafauna in homogeneous areas of the deep-sea are regular spacing, random occurrence, and aggregation (Grassle et al. 1975). It was thought that the seep organisms might occur in one of these patterns. Three diagnostic indices were selected that have been used to detect occurrence of these patterns (Ripley 1980): Index of Cluster Size (ICS), Index of Cluster Frequency (ICF), and Morisita's I.

Because the camera altitude was constantly being adjusted during the photo-transect, the area of the bottom shown in each photograph ranged from 0.5 to 11.2 m<sup>2</sup>, with most photographs showing between 1.5 and 3.5 m<sup>2</sup> of the bottom. Knowledge of the scale of the photographs made it possible to interpret the area of the bottom shown in each photograph as a quadrat sample of the survey site. The quadrat areas were rounded to 1 m<sup>2</sup> intervals between 0.5 and 11.5 m<sup>2</sup> and the three indices were calculated for the pooled quadrat areas at each interval for which there was a sufficient number of photographs. This minimized the effect of the varying quadrat areas in the data and yielded information about the apparent scales of the spatial patterns.

When the diagnostic indices were calculated for the entire photo-transects from WC7 and C7, an aggregated pattern was evident for the vestimentiferans at WC7 and for the living vesicomids at C7 at all levels of quadrat size. Data for the pogonophorans were too sparse for reliable interpretation. The I values were all substantially greater than zero, and a Chi-square test of the ICS values was significant for all levels of quadrat size (p=0.05). These results supported the intuitive impression of broad aggregations seep organisms that was obtained when their density in the quadrats is plotted against the position of the quadrats on the transects (Fig. 6-8). However, although the indices indicate that both vestimentiferans and vesicomids occur in distinct aggregations, the characteristics of these aggregations were quite different. The

aggregation of vestimentiferans was comparatively large and diffuse, while the aggregations of vesicomysids were about one-tenth as large but contained a much greater density of animals. The diagnostic indices were re-calculated for the quadrats from within the aggregations of vestimentiferans and the vesicomysids in order to compare their distribution on the sections of the transect where they were most abundant. Tables 6-5a and 6-5b show the diagnostic indices calculated for vestimentiferans and living vesicomysids, respectively, for each of the nominal quadrat areas. The pogonophorans were too sparse to provide reliable results.

The indices shown in Tables 6-5a and 6-5b suggested that the vestimentiferans at WC7 were distributed differently from the vesicomysids at C7. Within the region of high density at WC7, the vestimentiferans do not appear to be aggregated. The  $I\delta$  values are not substantially greater than zero and a Chi-square test of the ICS values shows only two of the seven values to be significantly greater than zero ( $p=0.05$ ) (Table 6-5a). These results suggest that tubeworms occurred randomly within the region of high density. In contrast, the living vesicomysids did appear aggregated within their regions of high density at C7. The  $I\delta$  values are substantially greater than zero, and a Chi-square test of the ICS values shows all to be significantly greater than zero ( $p=0.05$ ). There are two probable distributional forms that could result in the type of aggregation indicated by these diagnostic indices: a point clustering process and a random-rate Poisson process. In a point-clustered distribution, the organisms would tend to occur in association with discrete environmental features (e.g., fish clustered around points of topographic relief; see Boland et al. 1983, p. 299-306). Diagnostically, this would result in ICF values that had a strong positive correlation with quadrat size (Ripley 1980). This trend was not evident in the ICF values for vesicomysids from C7. It is likely therefore that the distribution of clams at C7 could best be modeled with a random-rate Poisson process; that is, within the aggregations the living clams occurred randomly, but with a varying rate of intensity.

For a given aggregation, determination of changes in vesicomysid densities over time can be tested using photo-transects similar to those reported on in this paper. Sample size, that is, the number of frames

Table 6-5. Diagnostic indices for vestimentiferan tubeworms at Station WC7 and vesicomvid clams at Station C7. The indices shown are Index of Cluster Size (ICS), Index of Cluster Frequency (ICF), and Morista's  $I\delta$  ( $I\delta$ ). The altimeter of the camera system was accurate to tenths of meters, the corresponding quadrat areas were rounded in order to increase sample size. The quadrat areas shown below are pooled intervals; results obtained for the actual quadrat sizes were consistent with these intervals. The pooled results were used to increase sample size. Index values significantly greater than zero are an indication of aggregation for ICS values. The ICF values are an indicator of the aggregating mechanism. The  $I\delta$  values are calculated as a consistency check on the pooled results.

A. Vestimentiferans: Station WC7

Nominal Quadrat Area	Number of Quadrats	ICS	ICF	$I\delta$
1.5	15	0.626	1.384	1.866
2.5	21	0.280	8.503	1.140
3.5	20	1.687	2.282	1.457
4.5	10	1.208	2.648	1.422
5.5	9	1.131	5.992	1.186
6.5	6	0.829	8.448	1.146
7.5	8	-0.673	-5.759	0.854

B. Vesicomvids: Station C7

Nominal Quadrat Area	Number of Quadrats	ICS	ICF	$I\delta$
1.5	8	2.619	0.573	2.996
2.5	24	4.867	0.728	2.403
3.5	18	14.192	0.348	3.914
4.5	8	4.591	1.552	1.674
5.5	8	12.000	0.500	3.064

monitored, will depend upon the magnitude of change one is interested in detecting and the degree of certainty with which the change is to be ascertained. Major changes in density can be detected with relatively few frames, while smaller changes would require greater sampling effort to be detected. Aggregations I and II had densities of 2.32 (s.e. 0.67) and 2.71 (s.e. 2.27) vesicomysids per m<sup>2</sup>. Assuming that all aggregations of vesicomysids are similar to these, the sampling effort required to detect a unit change in density of clams per m<sup>2</sup> can be plotted as a power curve. Figure 6-11a shows the number of frames required to detect a change in density of up to 1 per m<sup>2</sup>. It can be seen that a change of 0.5 clams per m<sup>2</sup>, or ~20% of the present densities, could be detected with 95% certainty by repeating the 800 frame transect.

A similar approach can be taken on the problem of detecting the presence of vesicomysids in an area of interest such as a seismic "wipe-out" zone, although the question is less well posed since the boundaries of a "wipe-out" zone are difficult to fix. In this case one is concerned not with an aggregate, but the density of clams over the entire area surveyed. The overall density of vesicomysids on the photo-transect from Station C7 was 0.42 (s.e. 0.167) per m<sup>2</sup>. Assuming that this transect is typical of areas where vesicomysids occur, determining that clams occur with this density (or some other target density) rather than zero, density can be assigned to the power curve shown in Figure 6-11b. It can be seen that roughly 1250 frames would be required to detect densities similar to those seen on the C7 photo-transect.

## 6.5 MACROFAUNA

Macrofauna samples of bivalves from Stations W1-W5, C1-C12, and E1-E5 contained small (0.5-6 mm) specimens of Vesicomysa sp. on all three sampling transects (see Table 6-6). When the counts of Vesicomysa sp. are divided by the area of the box core, the resulting estimates of density were seen to range from 0 to 85 per m<sup>2</sup>. When the densities of Vesicomysa sp. at each station are plotted against the station depths it is seen that, on the Central Transect, the peak densities occurred at between 800 and 900 m, and at 1500 m, with a maximum at Station C3 (850 m) (Fig. 6-12.)

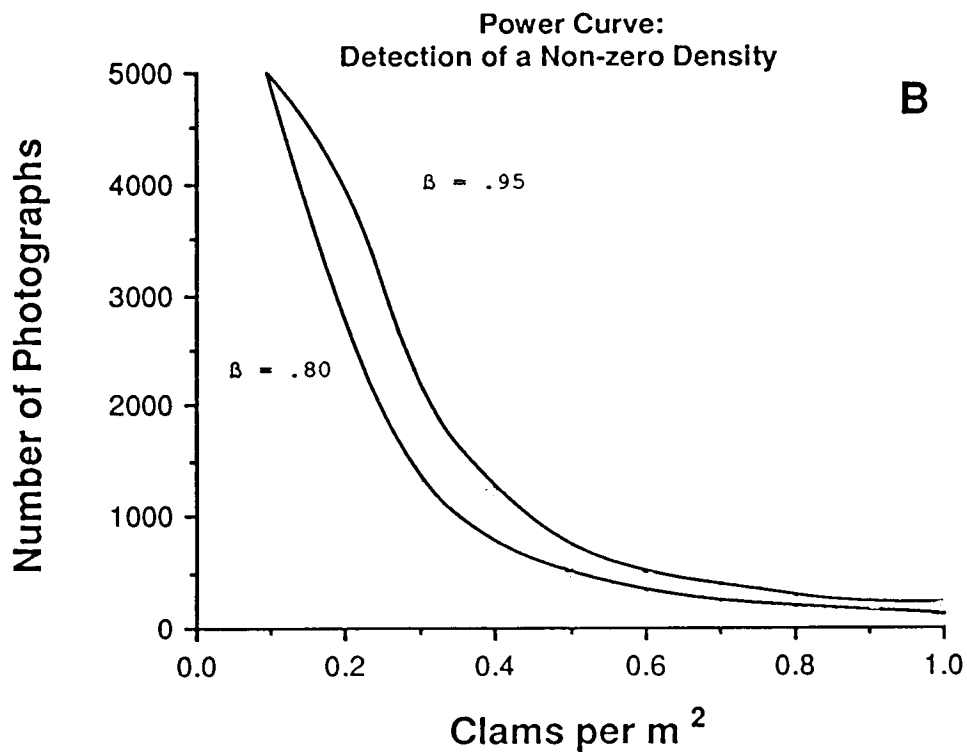
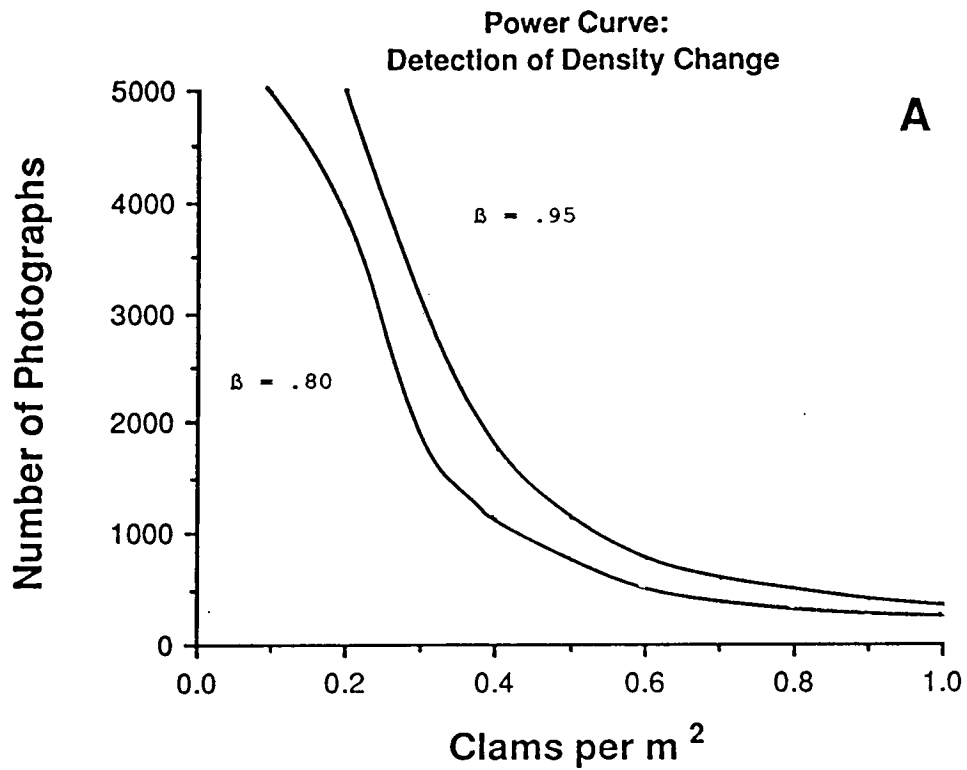


Figure 6-11. Power curves for sampling seep communities with benthic photography. A. Number of photographs required to detect a change in number of clams per meter in aggregations similar to those at C7. B. Number of photographs required to detect the presence of aggregations of different densities. The alpha level of the curves is fixed at .05. Beta is the probability of rejecting a false null hypothesis at  $\alpha = .05$ .

Table 6-6. Macrofauna samples containing Vesicomya sp. from Cruises I-III.

Station	Number of Individuals
W2	1
W3	1
W4	3
C1	1
C2	12
C3	70
X4	16
C5	4
C7	11
C9	12
E1	1
E2	3
E3	5
E4	13

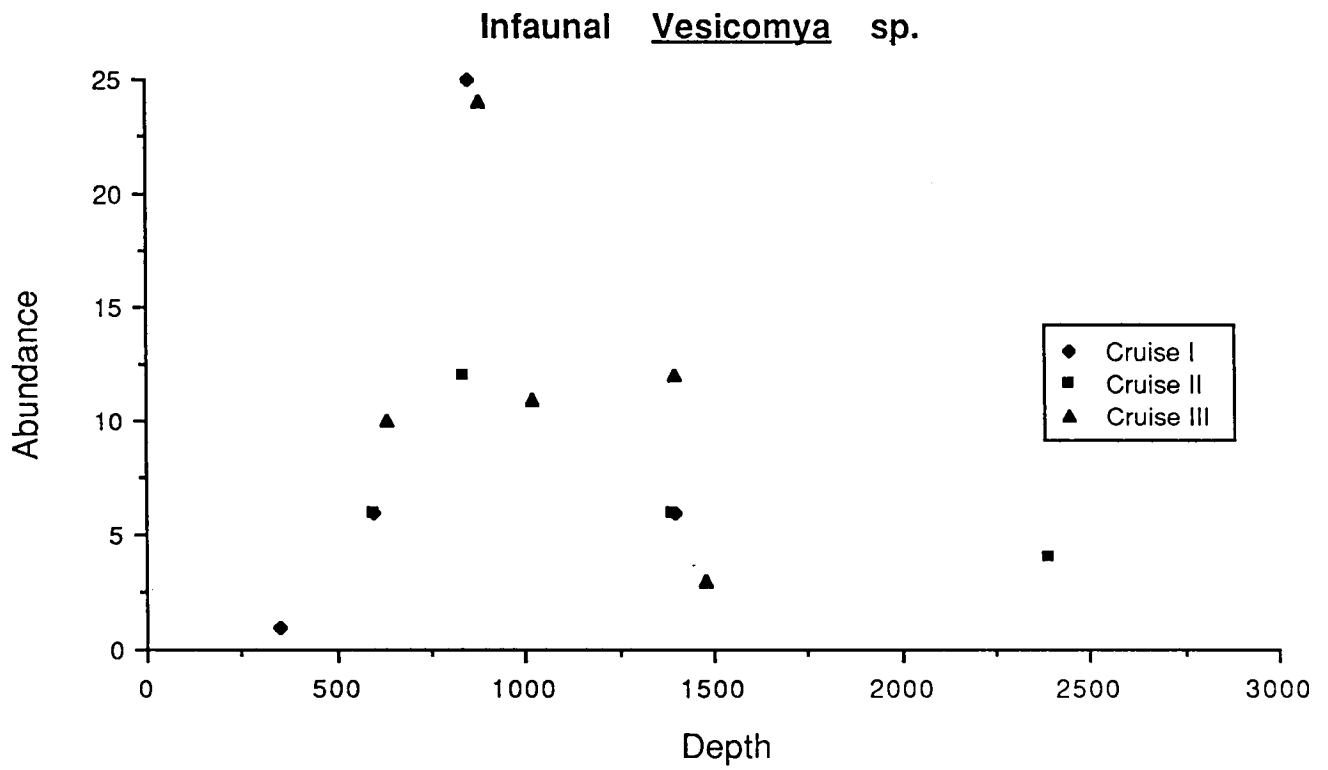


Figure 6-12. Abundance of juvenile Vesicomya sp. in box core samples from the Central Transect on the Gulf of Mexico continental slope.

Plots for the Eastern and Western Transects show lower densities with peaks at 1350 and 1425 m, respectively.

## 6.6 DISCUSSION

The trawl and macrofauna samples from the Continental Slope Study provided control samples of non-seep sites. The chemosynthetic organisms did not appear in trawl samples from non-seep sites. Samples of Lamellibrachia sp. and an undescribed pogonophoran species taken at Station WC7 provided the basis for identifying specimens in the photo-transect from that station, and demonstrated that individual Lamellibrachia sp. can occur on soft bottom. Juvenile Vesicomya were the only seep-type organisms that appeared in the macrofauna samples. Their abundance was greatest on the Central Transect at depths between 750 and 1500 m, and was reduced on the Eastern and Western Transects. These results are consistent with the widespread chemosynthetic communities proposed by Brooks et al. (1986).

Analysis of the photo-transects showed three assemblages of chemosynthetic organisms. These assemblages had distinctly different characteristics: (1) they were geographically separated; (2) they occurred at different depths; (3) they contained different taxa, and (4) the assemblages had significantly different spatial distributions. These in-situ observations provide a means for comparing the ecological features of the chemosynthetic communities of the Gulf of Mexico continental slope with those of communities from the Florida Escarpment and eastern Pacific Ocean hydrothermal vents.

The tubeworms at Station WC7 were sparse, usually recumbent, and occurred on a soft, apparently homogeneous substrate. This assemblage presents a marked contrast to the photographs of luxuriant thickets of Riftia pachyptila from the East Pacific Rise (Hessler et al. 1985, Jones 1984) and of Lamellibrachia at Station C2. Similarly, photographs of Escarpia laminata from the Florida Escarpment (Hecker 1985) show stands of erect tubeworms, both encrusted with anemones and unencrusted, so densely packed that in places all of the available substrate appears to be occupied. At the East Pacific Rise the substrate is fissured basalt; at the Florida Escarpment the tubeworms are attached to limestone talus at



the base of the escarpment. The absence of hard substrate at Station WC7 may have been a limiting factor for Lamellibrachia sp., since vestimentiferans are usually found attached to hard surfaces (Jones 1984).

The trawl specimens from this station had a mean length of 65 cm, the posterior sections of the tubes were coated with anoxic sediment, and the opisthosomes (the flattened, anterior-most end of the tubes) were broken off. In the photographs, the mean length of the tubes visible above the substrate was 15 cm. Even allowing for inaccurate measurements that result from foreshortening in the photographs, this difference suggests that the tubeworms bury at least half of their length in the sediment. The recumbent position seen in many of the specimens may be a behavior that brings the gas-exchanging plume into closer contact with the sediments. Hessler et al. (1985) describe tufts of short, contorted, and recumbent R. pachyptila in areas where the vent flow rate was thought to be reduced.

Only 22% of the vestimentiferan tubes in the trawl sample from WC7 contained live animals. A plume was visible in only 15% of the tubes in the photographs. It is quite possible therefore that many of the tubes in the photographs are the remains of dead animals. In general, the sparse occurrence of Lamellibrachia sp. at Station WC7 suggest a marginal population when it is compared with other reports of aggregations of vestimentiferans. Limiting factors may have been the lack of hard surface and reduced concentrations of nutrients.

The clams at Station C7 had a population structure that was different from that seen at hydrothermal vent sites. Hessler et al. (1985) describes clusters of Calyptogena wedged foot down into cracks in a basalt substrate and so densely packed that there appeared to be competition for crack space. Absorption of sulfides apparently takes place in the cracks across the thin epidermis of the feet (Childress and Mickel 1985). Hessler et al. (1985) speculates that clams jostled out of position have limited mobility on the rock substrate and will die if they are unable to resituate themselves in the fissures. Clams in the fissures are therefore at the mercy of continued sulfide flow. Although Calyptogena are very numerous in the fissures, they are absent from the surrounding rock. Hessler et al. (1985) reports that the Calyptogena at Clam Acres occur with a density per unit area ranging from 2.5 to .26 m<sup>2</sup>. Hecker (1985)

reports Vesicomidae in the areas of tan sediment between mussle beds, but gives no density estimates. Vesicomids photographed in the soft sediments at Station C7 were much less densely packed than those at Clam Acres; however, the areal densities seen were 1.5 to 28 m<sup>2</sup>, quite similar to the Clam Acres findings. The curving furrows provide strong evidence of mobility, perhaps in response to fine-scale changes in sulfide concentrations. The mobility results in varying densities of living clams within the aggregations. This is consistent with varying levels of inorganic nutrients within the seep fields.

Shell dissolution rates have been studied for Calyplogena magnifica at Pacific vent sites (Grassle et al. 1985, Lutz et al. 1985). These results show that Calyplogena shells need only 15 to 20 years to dissolve completely. Findings of dead shells provide evidence regarding the longevity of chemosynthetic communities. Determination of the percentage of dead clams and the variation in this percentage across the community is therefore an important analysis.

Calyplogena aggregations at Clam Acres (Hessler et al. 1985) were either predominantly live or predominantly dead. At Station C7, live and dead individuals appeared together in 68% of the frames. Figure 6-7a shows the percentage of dead vesicomids versus the number of occurrences. When this figure is compared with an equivalent figure (Fig. 6-7b) showing the percentage of dead Calyplogena reproduced from Hessler et al. (1985), the right hand side of the two distributions appear quite similar; missing from the C7 frames are the preponderance of 100% living frames. Hessler et al. (1985) interpret the lack of dead shells in some areas as evidence that the living clams were the first to have settled there. In other areas, isolated beds of dead Calyplogena indicate the complete demise of a vent field (Ballard et al. 1982, Hessler et al. 1983). These observations suggest that hydrothermal vent fields are dynamic habitats for chemosynthetic organisms, with sources of nutrients appearing and disappearing in response to variations in hydrothermal activity. The persistent mixture of living and dead individuals in the clam aggregations at Station C7 suggests a more stable habitat, with recruits settling together with the accumulated shells from individuals that have died from "natural" causes rather than loss of their nutrient supply.

This impression of stability is supported by the length measurements of the living and dead clams. The mixture of species in the measurement sample makes it impossible to interpret mortality or recruitment rates from the length frequency distribution; however, the range in lengths seen in both the living and dead specimens could have resulted from either a range of ages or from marked variation in growth rates among individuals of the same age. The former explanation seems more likely. If this is true, the living clams at Station C7 consisted of successive age classes, and successive age classes were represented among the dead specimens as well. The smallest individuals are missing from the measurement sample, probably because they are either buried in the sediment or were too small to be distinguished clearly in the photographs.

The photographic data for the seep organisms at Station C2 are too few for statistical analysis of the type shown above; however, the very high density of organisms on the two carbonate boulders and their absence from the remainder of the transect strongly suggested clustering on a specific environmental feature. This anecdotal interpretation of the photographs from Station C2, taken with the treatment of the statistical interpretation of the photographic data from Station WC7 and C7, suggested that seep organisms occurred in several distinct spatial patterns. In all cases, the seep organisms were restricted to a discrete portion of the transect, which suggested the requirement for particular environmental conditions. Within the areas of occurrence, we observed (1) a diffuse, random distribution (vestmentiferans at WC7), (2) patches of varying size and density (vesicomysids at C7), and (3) very dense clusters restricted to small areas of hard substrate (Lamellibrachia sp. and Acesta on carbonate boulders at C2). The mathematical properties of these distributions can be used to design sampling programs that will reliably detect changes in the density of chemosynthetic organisms.

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