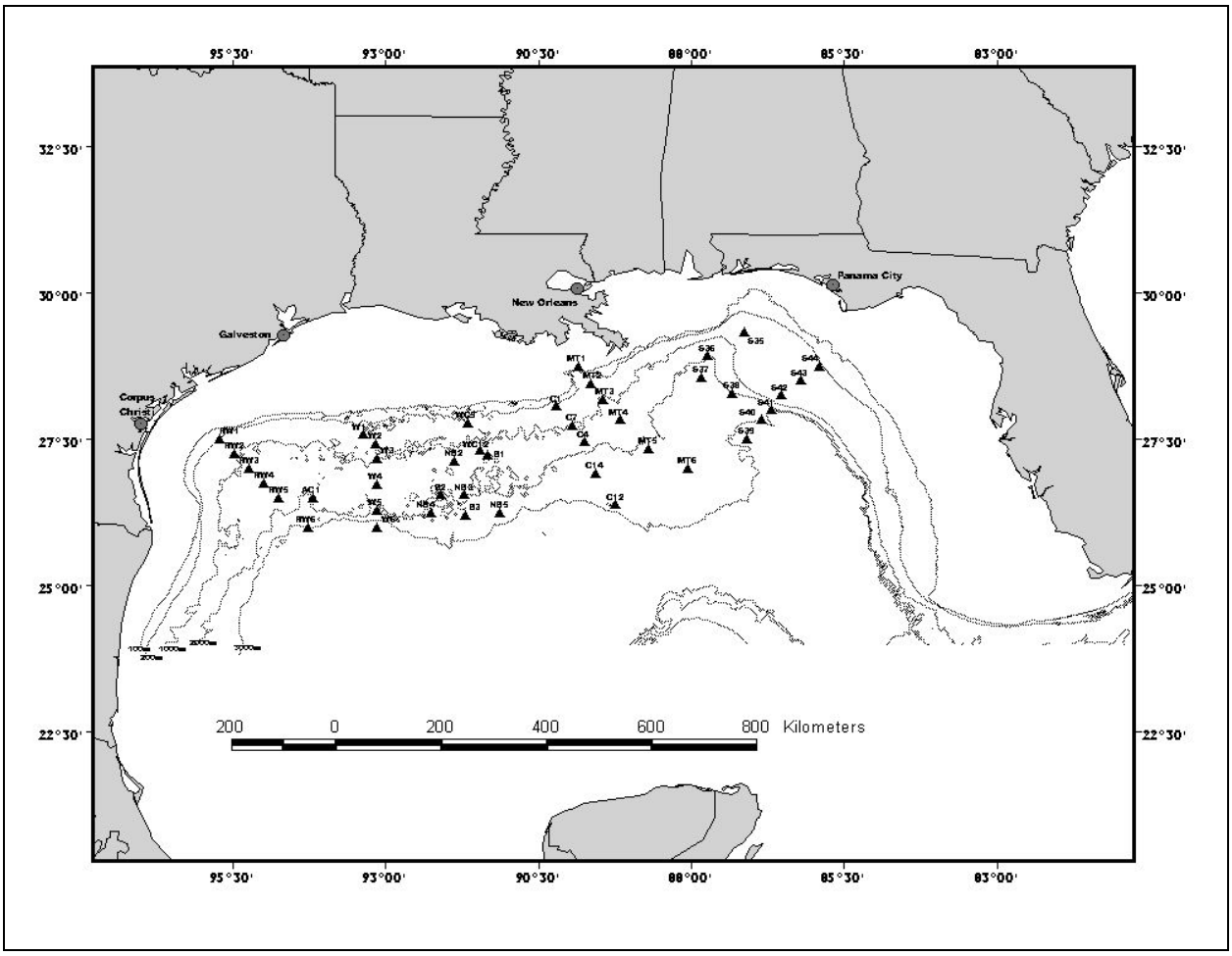
OCS Study
MMS 2001-091

Deepwater Program: Northern Gulf of Mexico Continental Slope Habitats and Benthic Ecology

Year I: Interim Report



U.S. Department of the Interior
Minerals Management Service
Gulf of Mexico OCS Region

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Deepwater Program: Northern Gulf of Mexico Continental Slope Habitats and Benthic Ecology

Year I: Interim Report

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TABLE OF CONTENTS

		PAGE
	List of Figures	ix
	List of Tables	xi
	Executive Summary	1
1.0	Introduction	1-1
	1.1 Program Objectives	1-3
	1.2 The Program	1-5
2.0	State of the Knowledge	2-1
	2.1 General Deep-Sea Ecology	2-1
	2.2 The Deep-Sea GOM - Geologic Setting	2-4
	2.3 The Geochemistry of Deep-Sea Sediments	2-5
	2.4 Physical Oceanography of the GOM	2-6
	2.5 Deep-Sea Ecology of the GOM	2-8
3.0	A Conceptual Model of the Deep-Sea	3-1
	3.1 Biotic Variables	3-3
	3.2 Community Structure	3-5
	3.3 Community Function	3-6
	3.4 Sediment Properties	3-7
	3.5 Water Column Properties	3-10
	3.6 Community "Health"	3-10
4.0	Sampling Design	4-1
	4.1 General Design Considerations	4-1
	4.2 Working Hypotheses and Station Selection	4-2
	4.3 Dependent and Independent Variables	4-10
	4.4 Statistical Analyses	4-11
	4.4.1 Univariate Analyses	4-11
	4.4.2 Power Analysis	4-16
	4.4.3 Multivariate Analyses	4-16
	4.5 Revision of Taxonomic Level of Analysis	4-17
5.0	The Field Program	5-1
	5.1 The Ship	5-1

5.2 Cruise I - Survey 5-2
5.3 Cruise II - Processes 5-2
5.4 Third Year Field Activities 5-6

6.0 Field Methods 6-1

6.1 Standard Sampling Techniques 6-1

6.1.1 Boxcoring 6-1
6.1.2 Trawling 6-1
6.1.3 Photo-Apparatus 6-3
6.1.4 Water Column Profiles 6-3

6.2 Community Structure 6-5

6.2.1 Bacteria 6-5
6.2.2 Protozoa (Foraminifera) 6-5
6.2.3 Meiofauna 6-5
6.2.4 Macrofauna 6-8
6.2.5 Megafauna and Fishes 6-8

6.2.5.1 Trawl Samples 6-8
6.2.5.2 Photosurveys 6-8

6.3 Community Function 6-9

6.3.1 Microbial Metabolism 6-9
6.3.2 Sediment Community Oxygen Demand 6-10
6.3.3 Foodweb Studies - Stable Isotopes 6-11

6.4 Sediment Properties 6-11
6.5 Chemical Contaminants 6-11
6.6 Geochemistry 6-11

7.0 Laboratory Methods 7-1

7.1 Taxonomy 7-1
7.2 Community Structure 7-3

7.2.1 Bacteria 7-3
7.2.2 Foraminifera 7-4
7.2.3 Meiofauna 7-4
7.2.4 Macrofauna 7-5
7.2.5 Megafauna and Fishes 7-5

7.3 Community Function (Process Studies) 7-5

7.3.1 Bacterial Metabolism 7-6

7.3.2 Meiofaunal Feeding Rates 7-6
7.3.3 Sediment Community Respiration 7-6
7.3.4 Foodweb Analyses - Stable Isotopes 7-6

7.4 Sediment Properties 7-7

7.4.1 Grain Size 7-7
7.4.2 Geotechnical Properties 7-7
7.4.3 Total Organic and Inorganic Carbon 7-7

7.5 Chemical Contaminants 7-8

7.5.1 Hydrocarbons 7-8
7.5.2 Trace Metals 7-8

7.6 Geochemical Properties 7-9
7.7 Water Column Profiles 7-12
7.8 Archival of Specimens 7-12

8.0 Status of DGoMB Program 8-1

8.1 Task 1 - Re-Examination of Previous Studies 8-1
8.2 Task 2 - Field Sampling 8-1
8.3 Task 3 - Sample Data Processing and Analysis 8-2

8.3.1 Physical Oceanography 8-2
8.3.2 Geology 8-3
8.3.3 Geochemistry and Contaminants 8-11
8.3.4 Biological Studies 8-12

8.4 Task 4 - Data Interpretation, Synthesis, and Reporting 8-13

8.4.1 Community Structure 8-13
8.4.2 Community Function 8-16
8.4.3 Sediment Properties 8-16
8.4.4 Water Column Chemistry and Oceanography 8-18
8.4.5 Ecosystem "Health" 8-18
8.4.6 Data Fusion and GIS 8-19

8.5 Data Management 8-20
8.6 Meetings, Interpretation, and Reporting 8-20

8.6.1 Planning 8-22
8.6.2 Field Program, *R/V Gyre,* June 1-20, 2001 8-23

9.0 Literature Cited 9-1

Appendix I - Cruise I Report AI-1

Appendix II - “The Edge of the Gulf Cruise, 16-31 October 2000” AII-1

LIST OF FIGURES

		PAGE
Figure 1.	A general model of a sediment-associated food-web	3
Figure 3.1	Preliminary conceptual model of the deep-sea Gulf of Mexico	3-2
Figure 3.2	Macrofauna submodel of system carbon food chain model	3-3
Figure 3.3	Sediment submodel of functional bacterial groups as defined by utilization of different terminal electron acceptors	3-9
Figure 4.1	Benthic survey stations in the northwestern GOM	4-4
Figure 4.2	Benthic survey stations across the Florida Escarpment	4-5
Figure 4.3	Benthic stations along the Mississippi Trough	4-6
Figure 4.4	Physiographic settings for benthic survey stations in the Central GOM	4-7
Figure 5.1	Benthic survey stations for Cruise I, May and June, 2000	5-3
Figure 5.2	Sampling sites during Cruise II, the first "processes" cruise, June 1-19, 2001	5-5
Figure 5.3	Proposed locations for two remaining cruises into the Mexican EEZ, June and August 2002	5-7
Figure 6.1	Schematic of quantitative boxcore station activities and sampling protocols	6-2
Figure 6.2	Schematic of trawl station activities and sampling protocols	6-4
Figure 6.3	Vertical distribution of meiofauna taxa for Cruise I	6-7
Figure 6.4	Benthic lander	6-10
Figure 8.1	Frozen versus fresh nutrient concentrations from station 32 on NEGOM cruise N8	8-5
Figure 8.2	Frozen versus fresh nutrient concentrations from station 33 on NEGOM cruise N8	8-6
Figure 8.3	Sea surface height field for 14 May 2000 based on analyzed height anomaly of TOPEX and ERS-2 altimeter data added to mean sea surface height field	8-7

Figure 8.4 Broad-band 150 kHz ADCP current vectors at average depth of 12.4 m on DGoMB leg 1 Cruise, 3-23 May 2000 8-8

Figure 8.5 Sea surface height field for 10 June 2000 based on analyzed height anomaly of TOPEX and ERS-2 altimeter data added to mean sea surface height field..... 8-9

Figure 8.6 Narrow-band 150 kHz ADCP current vectors at average depth of 11.6 m on DGoMB leg 2 Cruise, 21 May - 21 June 2000..... 8-10

Figure 8.7 Negative sulfate anomaly as a function of water depth in the pore of the top 5 cm of a core from each sampling site 8-11

LIST OF TABLES

		PAGE
Table 1.1	Program Team - Key Personnel	1-4
Table 2.1	GOM water masses with associated property extrema and potential densities	2-7
Table 4.1	Summary of benthic survey experimental design: null hypotheses, station selection criteria, number (No.) of stations (sta.), and number samples	4-9
Table 4.2	Independent variables fixed by the sampling plan design	4-12
Table 4.3	Dependent variables to be measured	4-12
Table 4.4	Ancillary variables to be measured at Survey and Experimental Stations	4-13
Table 5.1	Summary of sampling conducted during Cruise I	5-4
Table 6.1	Effect of core tubes size (inner diameter) on meiofauna counts and average density	6-6
Table 7.1	Taxonomists involved in the analysis of macrofauna and corresponding taxonomists working on UNAM Mexican national collections	7-2
Table 7.2	Summary of parameters to be analyzed and the methods to be used	7-10
Table 7.3	Chemical parameters to be analyzed	7-10
Table 8.1	Sample inventory for Cruise I (survey)	8-4
Table 8.2	Data collection summary and tracking	8-21
Table 8.3	General biological field collection form	8-22

EXECUTIVE SUMMARY

A research program has been initiated by the Minerals Management Service (Contract No. 1435-01-99-CT-30991) to gain better knowledge of the benthic communities of the deep Gulf of Mexico entitled "The Deepwater Program: Northern Gulf of Mexico Continental Slope Habitat and Benthic Ecology." This report describes the program and provides a summary of the progress to date at the end of the first year of the program. At this early stage in the program, sample analyses are still in progress with little or no data finalized. The program is on schedule and planning has been completed for the second year's field program.

Increasing exploration and exploitation of fossil hydrocarbon resources in the deep-sea prompted the Minerals Management Service of the U.S. Department of the Interior to support an investigation of the structure and function of the assemblages of organisms that live in association with the sea floor in the deep-sea. The program, Deep Gulf of Mexico Benthos or DGoMB, is studying the northern Gulf of Mexico (GOM) continental slope from water depths of 300 meters on the upper continental slope out to greater than 3,000 meters water depth seaward of the base of the Sigsbee and Florida Escarpments. The study is focused on areas that are the most likely targets of future resource exploration and exploitation. However, to develop a Gulf-wide perspective of deep-sea communities, sampling in areas beyond those thought to be potential areas for exploration has been included in the study design.

The program is designed to gain a better ability to predict variations in the structure and function of animal assemblages in relation to water depth, geographic location, time and overlying water mass. Biological studies are integrated with measurements of physical and chemical hydrographic parameters, sediment geochemical properties and geological characteristics that are known to influence benthic community distributions and dynamics. Eight (8) hypotheses are being tested on the basis of measures of benthic community structure. It is hypothesized that community structure varies as a function of:

1) water depth,
2) geographic location (east vs. west),
3) association with canyons,
4) association with mid-slope basins,
5) sea surface primary productivity,
6) proximity to hydrocarbon seeps,
7) time (seasonal and interannual scales), and
8) association with the base of escarpments.

Measures of community structure used to test the hypotheses are variations in diversity, similarities in assemblage composition (at the species level), variations in biomass and abundance, and the mean size of individuals within specific size categories.

The underlying premise of the hypotheses to be tested is that deep-sea communities are food limited. This premise leads to the hypothesis that variations in community structure in time and space are a function of the input of food to the seafloor. In other words, community dynamics and structure are dependent on the availability and quality of food resources. Corollary hypotheses test the possibility that each independent variable is related in some way to how organic matter from a variety of potential sources is utilized by the benthic community.

After defining community structure, the next set of objectives use this information to infer the flux of organic carbon into and through the ecosystem. The conceptual model assumes that community structure and function are tightly coupled. Presently there is little reason to reject this generalization, but direct evidence for it in the deep-sea is at best fragmentary.

The conceptual model represents each of the principal size categories of the living components as standing stocks at each study site in the survey. The model includes demersal fishes, megafauna, scavengers, macrofauna, meiofauna, and heterotrophic bacteria. This model (Figure 1), of a sediment-associated food web, can be coupled with a model of fossil hydrocarbon utilization by chemoautotrophic organisms including large invertebrates that house endosymbionts. This linkage is yet to be explicitly established and is the basis for one of the hypotheses being tested. The boxes in the model represent standing stocks which have units of biomass (organic carbon per unit area) whereas the arrows represent flux between boxes and hence have units of organic carbon per unit area per unit time. For consistency, the units are mg C m^{-2} and mg C m^{-2} day^{-1}. Data from the survey portion of the program quantifies standing stocks across the survey area. Respiration rates are estimated on the basis of organism size and temperature from established relationships in the published literature. The fluxes represent transfers between components and are calculated by difference to balance respiratory losses at steady state. Burial loss of carbon is organic carbon (detrital) concentration times sediment accumulation rate. Input to the bottom is assumed to be equal to the sum of the respiration and burial losses at steady state.

The second phase of the project is designed to test the model. Direct measurements will be made of fluxes. This will be carried out by two field programs in June of 2001 and 2002. Total sediment community respiration will be determined using a benthic lander and incubation chambers. Total respiration will be partitioned by measuring bacterial activity in pressure chamber incubations at *in situ* temperatures. Uptake and respiration will be determined using mixed amino acids labeled with radiocarbon. Sulfate reduction will be measured using radio-labeled sulfate incubation of samples from sediment cores. Lander/chamber fluxes that are to be measured include oxygen, dissolved inorganic carbon, inorganic nitrogen, phosphate, and silicate. Scavenger domains of occupation will be estimated using baited traps, time-lapse cameras and an ADCP to estimate vertical and horizontal eddy mixing and mean current direction. Stable isotopes of carbon and nitrogen will be used to determine the food chain's structure and linkages. Physical and biological mixing will be estimated using a suite of natural radionuclides characterized by an appropriate range of decay rates. Data from the second field year will be used to adjust model parameters. The location of the experimental sites will be evaluated according to the model, sampling results, and on-going testing of programmatic hypotheses. Experiments during the third field year will be designed to further validate the revised model rates and parameters. Sampling sites will be selected as needed to improve the resolution of the models and advance the testing of the hypotheses.

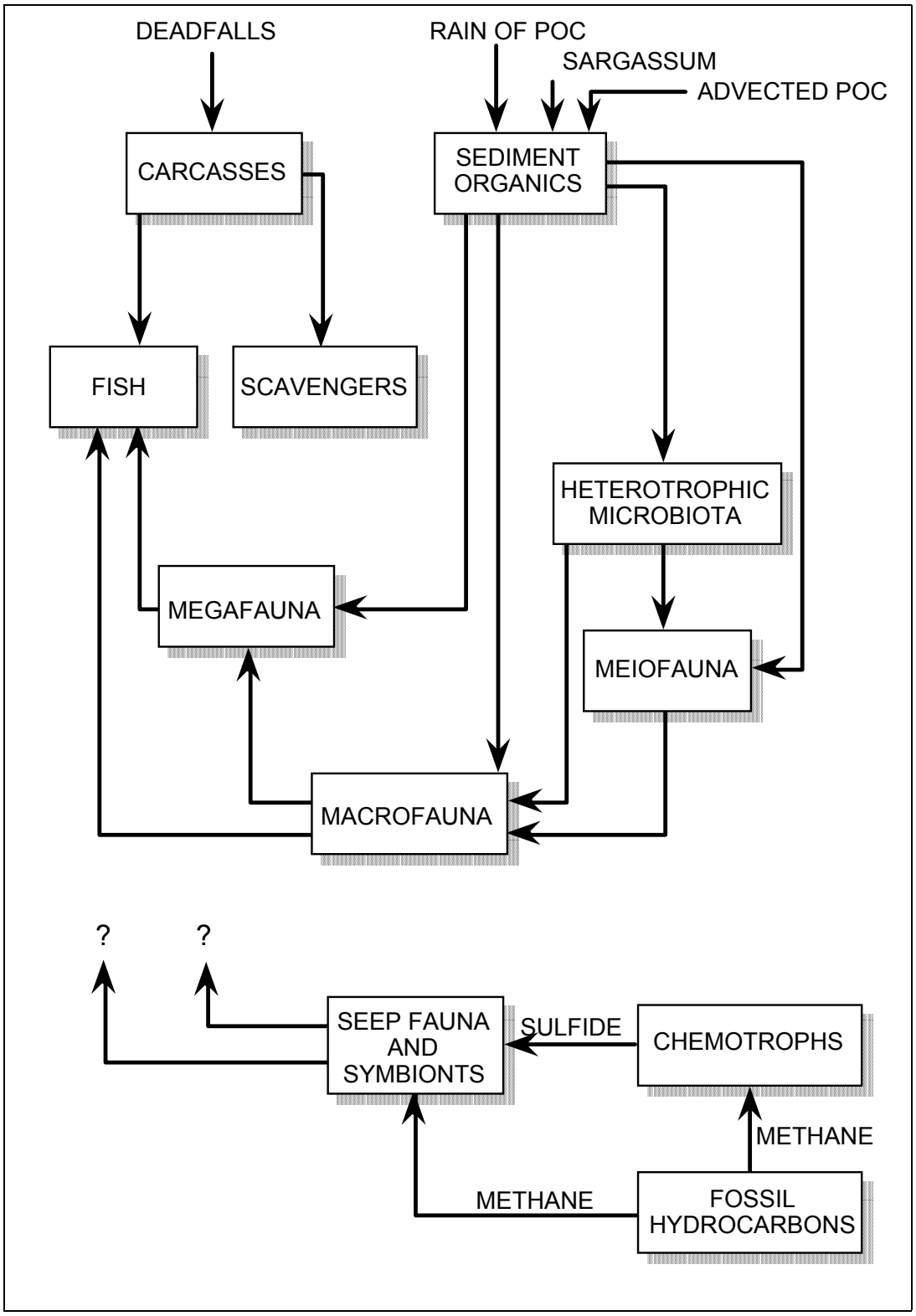

Figure 1. A general model of a sediment-associated food-web.

1.0 INTRODUCTION

The topography, geology, geophysics, currents, hydrography, chemistry and biota of the continental slope are much less well known than those of the continental shelf. The earliest information on the deep-sea biota of the Gulf of Mexico come from studies that used benthic trawling and photography (TerEco 1976, 1983). The largest study, The Northern Gulf of Mexico Continental Slope Study (NGOMCS), concentrated on geologic features, water circulation, chemistry, and biological communities (LGL and TAMU 1988). New scientific findings in the area, including chemosynthetic communities and a better understanding of the geological complexity of the region, have significantly altered our view of the northern GOM deep-sea (MacDonald 1998; MacDonald et al. 1996). Rapid expansion of energy industry activities into the deep-sea has occurred over the past decade. It is expected that this trend will continue and that deep-sea regions of the northern GOM will be the site of energy exploration and development activities for decades to come.

An MMS workshop report on the deepwater GOM concluded that there was a need for additional information on the composition and structure of benthic communities, the associated biogeochemical processes, habitat heterogeneity and physiography, trophic interactions, and the biological "health" of the region (Carney 1998). The deep-sea is a setting within which benthic communities survive and propagate in the northern GOM. The deep-sea is characterized by total darkness, low temperature, nearly featureless mud, sparse food resources, predictable biomass patterns, unusual diversity patterns, and poorly defined couplings to topography, biogeochemistry, and currents.

The DGoMB program will provide a better understanding of:

1) **the present condition of biological communities in the study area,**
2) **the distribution patterns of deep-sea biota,**
3) **the biological and physical processes that control the environmental setting, and**
4) **the effects that these processes have on the character of benthic and benthopelagic communities.**

The program emphasizes understanding the make-up and variability of soft-bottom biological communities with a secondary effort to characterize the important biological and abiotic processes that sustain or change the observed patterns. The study will:

1) **detail the composition and structure of slope biological communities,**
2) **infer the relationship between these communities and local conditions and forcing factors,**
3) **characterize the "health" and functioning of deep-sea communities, and**
4) **compare and contrast the GOM region with similar oceanic basins.**

The DGoMB program design was developed based on historical knowledge of deep-sea communities in the GOM. The interdisciplinary nature of the scientific objectives was recognized and the study design balances the benthic survey aspects of the program with experimental (or "process") oriented studies needed to understand the deep-sea community's structure and function. A careful analysis of previous information was used to focus the study on

the most relevant areas and those areas which will provide the greatest likelihood of establishing generalities about the structure and function of deep-sea benthic communities. The program will provide a predictive capability for areas not directly sampled or observed. This predictive capability is a framework for ascertaining the potential for, and the most likely impact from, fossil fuel exploration and exploitation in the deep-sea.

Each work element is nested in an integrated design that links data collection to a coherent framework that provides maximum complementary information based on a detailed model of the system. Survey station results were used to choose experimental stations. Experimental stations will be a subset of reoccupied survey stations tightly linking all observations and data in space and time. Each measurement is taken to provide quantitative estimates of unknown elements of the model, to improve the quantitative accuracy of the elements of the models, and/or to test and refine the underlying assumptions of the model.

A review of previous studies, particularly the NGOMCS slope study provided valuable insights for designing the new study (LGL and TAMU 1988). The program design incorporated the following strategic conclusions:

1. **An equal sampling effort must be concentrated at different water depths to determine if "zones" exist.** Site selection emphasized equally spaced depth intervals and replication at the treatment level (sites that are mostly similar except for depth) recognizing that gradients in ecosystem properties are more likely than "zones".

2. **Depth dependence in community structure and composition must be evaluated in the context of other recently recognized confounding factors** such as seafloor topography, and currents.

3. **Sampling sites must be chosen based on characteristics believed to be important in establishing biological patterns** such as detrital flux to the seafloor as influenced by near surface patterns of primary productivity.

4. **Proximity to the Mississippi River and Fan is an important spatial consideration.**

5. **Benthic communities are nestled in different topographic and sedimentologic settings** that are influenced by slope failure and varying inputs of terrigenous materials.

6. **Sampling sites must be selected to compare benthic communities associated with known physical features** such as the thermohalocline, the oxygen minimum, and high current regimes.

7. **The program is designed to provide flexibility by revising and rethinking the underlying strategy and design** on a regular basis in response to collection of new data and re-evaluation of historical data.

8. **Temporal variations in community structure and composition are important and can be quantified by reoccupying historical sites and visiting a subset of sites during each of the three planned field programs.**

9. **An improved understanding of community structure and composition requires better and more refined measurements of biomass** for input into the conceptual model.

10. **Improved estimates of the megafaunal role in the ecosystem are important** and include a three pronged approach to surveys: trawling (with improved quantitative methodologies), photosurveys, and baited traps.

11. **The number of sites sampled and the intensity of sampling must be increased over the previous studies.**

12. **Replication and the size of the sample must be increased over the previous studies** to ensure that the total number of animals collected adequately samples the diversity of the communities being studied.

13. **The data must be meticulously managed** so that it will be readily available for future reassessment as our understanding of the deep-sea evolves (this includes the use of standard and accepted methods in all aspects of the program and placement of data in a GIS framework).

The program will receive added value by its close linkages with previous and on-going MMS efforts in the GOM. Many members of the Team are participating in ongoing programs such as the deep water literature survey and review, the northeastern GOM hydrography and chemical oceanography program, the deep water physical oceanography re-analysis program, the Mississippi-Alabama pinnacles program, and chemosynthetic community studies (Table 1.1). The methods and approaches adopted for this program are the same, or compatible with, the methods of these other corollary programs allowing for seamless integration of new results with the results of other programs in the final synthesis. This will result in a holistic evaluation of the GOM deep-sea benthos and the linkages between abiotic and biotic processes that control the complex ecological patterns of the deep-sea benthos.

1.1 Program Objectives

The structure and function of deep-sea benthic communities is the end-result of complex interactions between and among the biota and the topography, geology, currents, hydrography, chemistry, and physical setting. The NGOMCS study was an attempt to describe the geology, water circulation, chemistry, and biologic communities on the vast northern GOM continental slope region (LGL and TAMU 1988). The current project is intended to build on, improve, and supplement this pioneering study. A reassessment of continental slope ecosystems, in the context of intensive oil and gas exploration and exploitation in the region, is considered essential for the management and protection of biological resources in the deep-sea.

Table 1.1 Program Team - Key Personnel*

Name	Discipline	Role	Institution
• Gilbert T. Rowe	• Deep-sea Benthic Ecology	• Project Manager • Principal Scientist • Chief Scientist • Group Leader-Deep-sea Ecology	• Texas A&M University
• Mahlon C. Kennicutt II	• Environmental Chemist	• Deputy Program Manager Contaminant Chemist	• Texas A&M University
• Gary A. Wolff	• Data Management	• Data Manager	• Texas A&M University
• Jody Deming	• Microbiology	• Co-PI Ecology	• University of Washington
• Paul Montagna	• Benthic Ecologist	• Co-PI Ecology • Study Design	• University of Texas
• Richard Haedrich	• Bottom Fishes • Megafauna	• Co-PI Ecology • Data Analysis	• Memorial University
• Richard Heard	• Macrofauna Taxonomy	• Co-PI Ecology	• University of Southern Mississippi
• John Morse	• Inorganic Geochemist	• Geochemistry Group Leader	• Texas A&M University
• William Bryant	• Geological Oceanographer	• Geology Group Leader	• Texas A&M University
• Worth Nowlin	• Physical Oceanography	• Oceanography Group Leader	• Texas A&M University
• Joan Bernhardt	• Foraminifera		• University of South Carolina
• Norman Guinasso	• Physical Oceanography Field Program		• Texas A&M University
• Bob J. Presley	• Metal Contaminants		• Texas A&M University
• Terry L. Wade	• Organic Contaminants		• Texas A&M University
• Steven DiMarco	• Physical Oceanography		• Texas A&M University
• Michael Rex	• Community Structure	• Science Review Board	• University of Massachusetts-Boston
• Kenneth L. Smith, Jr.	• Community Dynamics	• Science Review Board	• Scripps Institution of Oceanography
• William W. Schroeder	• Gulf of Mexico Ecology	• Science Review Board	• Dauphin Island Marine Laboratory, University of Alabama

*Does not include taxonomists.

The overarching goals of DGoMB are to:

- **determine in greater detail the composition and structure of slope bottom biological communities and to infer relationships between biological patterns and major controlling processes and**

- **characterize the area as to its present "health" and function and compare and contrast the region with similar oceanic regions.**

Specific DGoMB objectives are to:

- **improve the conceptual model that serves as the guide for the design and overall conduct of the study and to test specific hypotheses related to the models;**

- **compile and synthesize data from existing databases and on-going programs to interpret new results;**

- **conduct field collections to describe the distribution and structure of benthic communities on the continental slope of the GOM and to elucidate the functional interactions among them in known environmental settings;**

- **characterize the hydrographic structure and measure the dissolved and particulate water column nutrient concentrations, primary productivity, and chlorophyll *a* at the study sites;**

- **characterize the sediments at the study sites including grain size and hydrocarbon, metal, carbonate, and organic carbon concentrations;**

- **characterize the basic attributes of the benthic microbiota and biomass at the study sites;**

- **characterize the soft-bottom macro- and megafauna at the study sites;**

- **relate variations in benthic biota patterns to sedimentary processes and to the chemical and physical setting;**

- **define basic levels of animal and bacterial activity and production and describe interactions between and among benthic biota, the several ecological/biological compartments, and the abiotic environment; and**

- **compare and contrast the GOM benthic marine environment and communities with those in other basins of similar depth ranges and oceanic settings.**

The program is to be conducted over a 48-month period of performance. Major oceanographic cruises are to be conducted, one in each of the first three years of the program. The final year of the program will be dedicated to completing sample analyses begun in the first three years, data management and interpretation, model refinement, and production of the Synthesis Report. The field surveys will document the biota, the abiotic character of the slope and the important biotic and abiotic forcing factors. Station selection criteria included consideration of anticipated zonation, water depth, distance from shore, abiotic variables, physiography and topography, geochemical environment, anthropogenic effects, and present and future leasing trends.

1.2 The Program

The program consists of four tasks:

TASK 1 - Re-examination of Existing Data and Field Study Design

All available scientific records and databases have been identified, collected, and re-examined. Previous studies of particular importance are the TerEco Corporation synthesis (1976 and 1983), the MMS NGOMCS (LGL and TAMU 1988), and chemosynthetic ecosystem studies

(MacDonald 1998 and MacDonald et al. 1996). Industry data, MMS leasing history and production data, USGS Gloria data, NODC data, governmental holdings of results of various MMS physical oceanography programs (LATEX, NEGOM Deepwater), and other information will be integrated into the new findings. These data formed the basis for final recommendation of study sites to the Contracting Officer Technical Representative (COTR) and the Scientific Review Board (SRB). This information was used to describe the study sites, how each site contributed to the overall program design and verification of important features of the conceptual model.

TASK 2 - Field Sampling

The *R/V Gyre* was used to conduct Cruises I and II. Conventional sampling methodologies were used for the community structure survey and innovative experimental approaches are being used for process studies. Year II and III cruises are sampling those sites selected on the basis of information produced in Year I and II, respectively. The goal of the sampling program is to describe the benthic communities in distinct and identifiable settings in the study area in time and space. A phased-in approach concentrated the benthic survey portion of the work in Year I allowing ample time to process samples and analyze data. Year II and III are a mix of infilling of survey stations based on programmatic results. Experimental stations are addressing key questions related to processes and forcing factors during cruises in years two and three. Experimental stations have been chosen based on existing knowledge and Cruise I results. The experimental stations are a subset of survey stations providing for a close integration of all data collected. Water column sampling provides descriptive hydrography and water column chemistry (designed similar to the NEGOM program) at all sites. Seafloor sampling of sediments for benthic and benthopelagic fauna (design similar to the GOOMEX program) is the main activity at the survey stations. Basic ecological processes such as microbial activity; sources and fates of nutrients and detrital material; feeding habits; the relative importance of feeding guilds and taxa; and the presence of potential contaminants are provided at experimental stations.

TASK 3 - Sample and Data Processing and Analysis

All samples and data are being processed as specified in Chapters 7 and 8. The quality of data and samples is ensured by a comprehensive data management plan (i.e., the Program Management Plan). Chain-of-custody and sample tracking activities guarantee the integrity and quality of the samples and data from shipboard collection to final synthesis. All parameters that can be reasonably measured onboard the ship (nutrients, salinity, oxygen, etc.) are measured using standard protocols. Sample and data processing include descriptive hydrography and water chemistry; sediment properties, chemical contaminants, and sediment geochemical properties; benthic microbiota, meiofauna, macrofauna, megafauna, and fishes; and measurements of basic ecological processes. Experimental stations being studied in Year II and III are being planned in consultation with the COTR and the SRB.

TASK 4 - Data Interpretation, Synthesis and Reporting

Two (2) narrative Interim Reports and a Synthesis Report will be produced. This report is the first interim report. The reports will contain an assessment of historic information, the data collected, descriptions of methods and analyses, interpretations of the analyzed information, and the results and discussions of the findings. Models will be refined and recast as warranted in light of new information. The present "health" of the area will be assessed. These reports will contain appropriate charts, maps, or schematics that portray faunal and habitat variability and the major forcing factors related to community structure and function in the deep-sea GOM as data becomes available. Topics to be covered in these reports include relevant historical information; the hydrography and oceanography of the region; the biological, chemical, geological, and physical processes and interactions in the water column and at the sediment-water interface; the effects of biotic and abiotic forcing factors on slope biota; concentrations and sources of hydrocarbon and metal contaminants in the area including an assessment of potential biological effects; and the likely effects of OCS petroleum exploration and development and other human activities on biotic resources in the study area. The COTR, CO, and SRB are informed of progress in the program by monthly status reports.

2.0 STATE OF THE KNOWLEDGE

A comprehensive review of the state of the knowledge of the deep-sea is beyond the scope of this report. However, a brief review of the salient features of deep-sea ecology in general provides a context for the DGoMB program. This short review then focuses on the northern GOM. The review concentrates on the ecological and biological aspects of the deep-sea GOM with brief reviews of the chemistry, geology, sedimentology, and physical oceanography. References to more detailed discussions are provided.

2.1 General Deep-Sea Ecology

The biota of the deep-sea has been sampled for more than a century. An age of exploration, utilizing mostly rather simple qualitative gear (trawls and dredges), continued up until the middle of the 20th century. Quantitative sampling developed for fisheries research in shallow waters began finding wide use in the deep-sea shortly after World War II. Many of the early qualitative and quantitative studies resulted in global generalizations about the "community structure" of the deep benthos (Menzies et al. 1973). Benthic metazoans have been subdivided into meiofauna, macrofauna, and megafauna, and these categories are further defined on the basis of size or major taxa. Near-bottom or demersal fishes are often lumped with the megafauna. Microbiota include heterotrophic protists such as ciliates, flagellates and forams and a suite of functional groups of bacteria. All the size groups listed, decline markedly in biomass and abundance as water depth increases although some decline at faster rates than others. A similar decline in abundance was correlated with distance from shore and surface seawater productivity (Rowe 1971). Most species, it was concluded, exhibit "zonation" with depth (Rowe and Menzies 1969) although this is more accentuated in some groups than others. A number of authors have generated elaborate schemes of "zones" based on the occurrence of faunal groups. Although the deepest parts of the ocean are thought of as "deserts", in terms of biomass, the diversity of the fauna is high compared to shallow water depth (Hessler and Sanders 1967). Many genera appear to be cosmopolitan, but in fact, a great many species are endemic to specific oceanic basins or subsets of basins. In general, Menzies et al. (1973) supported the argument that the "oldest" forms, on geologic time scales, are found at intermediate depth (slope depths) rather than at the greatest depths. The deeper living forms tend to be more specialized and hence "younger" in a geologic sense.

The summary of Menzies et al. (1973) marked a significant turning point in deep-sea biology from studies of community structure to a recognition and inclusion of studies of the dynamic aspects of the biota. These studies have been summarized in a number of articles over the years. A decade after Menzies et al. (1973), a series of papers on deep-sea community structure and function was published (Rowe 1983). Gage and Tyler (1991) review community structure including an extensive natural history of the different functional, taxonomic and size groups of organisms. The review is most lucid in its description of animal growth rates. It is pointed out that many animals spawn in a seasonal manner, most likely in response to seasonal inputs of particulate organic carbon. The deep-sea is the ultimate sink for detrital particulate carbon (Rowe and Pariente 1991).

Recent investigations of "community function" were made possible by new observational capabilities such as deep submersibles, the most important being the *Deep Submergence Vessel*

(DSV) Alvin, and moorings and landers that operate remotely on the sea floor without attachments to a mother ship. Reviews have documented measurements of sediment community respiration (Smith and Teal 1973); time series studies of the rapid destruction of wood by deep-sea boring organisms (Turner 1973); baited traps to attract large scavengers that rapidly consume carcasses (Hessler et al. 1978); measurement of the slow rain of particulate matter to the deep ocean and its seasonality (Deuser and Ross 1980); and the seemingly slow deterioration of organic matter enclosed in *DSV Alvin* when it descended unintentionally to the sea floor. The reviews imply that low biomass, low rates of metabolic processes, and low growth rates (Gage and Tyler 1991) are a result of the minimal input of photoic zone organic carbon (Rowe and Gardner 1978). However, some taxonomically narrow groups of organisms can rapidly consume allocthonous organic matter (scavengers and wood borers, for example).

The decade of the 70's ended with a pivotal biological discovery in the deep-sea: extensive biological communities supported by reduced inorganic chemicals at hydrothermal vents (Hessler 1981). The spreading centers between the plates of the earth's crust are often characterized by fluids rich in sulfides. Symbiotic bacteria, living in the tissues of large invertebrates, oxidize the sulfide and the energy gained is used to synthesize organic matter for both the symbionts and the host. Numerous vents around the world are now known to support a wide variety of unusual but locally abundant organisms (Tunnicliffe et al. 1998). The latter review also notes that similar faunas occur near dead whales and petroleum seeps, including those in the GOM (Kennicutt et al. 1985). MMS has sponsored two programs to study GOM seep communities (MacDonald 1998; MacDonald et al. 1996) and no further discussion of seeps or vents is provided, except related to the potential effects of seeps on non-seep communities.

Contemporary studies of deep-sea benthic communities continue to address a series of long-standing questions. To a large degree, these studies are designed to explore the relationships between the structure and function of deep-sea communities. The consensus appears to be that biomass and animal abundance decline at log-normal rates with increasing water depth in many of the ocean's basins. However, meiofauna and bacteria decline less rapidly than macrofauna, creating an increase in the relative importance of these taxa as depth increases (Rowe et al. 1991). This has been assumed to reflect a decline in the reactivity of detrital organic matter that requires a bacterial recycling loop at the base of the food web (Richardson and Young 1987).

The reasons for variations in diversity remain elusive. Most new ideas are variations on Sander's original stability-time hypothesis (reviewed in Gage and Tyler 1991). Rex (1983) has pointed out that a monotonic increase in diversity does not exist in the deep-sea . To the contrary, Rex found that diversity indices peak between 2 to 3 km. Further work by others recently confirmed this pattern exists in many oceanic basins (Levin and Gage 1998). The idea that "a temporal and spatial mosaic" of physical and chemical variability enhances or preserves diversity has been tested by emplacement of sediment trays on the sea floor followed by harvesting of organisms after various deployment times. Snelgrove et al. (1996), for example, suggest that aged patches of *Sargassum* promote high diversity by providing fauna with a series of micro-habitats in time and space. However, the numbers of "expected species" in such experiments are lowest in the trays with added organic matter, leading to the possibility that competitive exclusion occurs in response to enrichment. However, this is only speculation.

Some progress has been made in allocating food resources to various size or functional groups (stocks) in the deep-sea. It has been suggested for example that among the suite of organisms living within the sediments, the bacteria consume approximately 30% of the available organic matter at some locations (Rowe and Deming 1985). In the benthic boundary layer above the sea floor, organic detritus is parceled among a wide variety of epibenthic holothuroids, benthopelagic crustacea and migrating fishes, but most of the total organic matter flux, according to Smith's carbon budget, is consumed by sedimentary organisms (Smith 1992). Another consensus is that the rain of pelagic detrital organic carbon is tightly coupled to water column processes. Although it has been proposed that the lateral transport of detrital organic carbon is important, in the deep Pacific there appears to be a long-term imbalance between the input of organic matter and its remineralization (Jahnke et al. 1990; Smith and Kaufman 1999).

A growing body of information suggests that the flux of organic matter to the seabottom has considerable control over both the structure and the dynamics of benthic communities. The basic structure of the living components of the near-bottom ecosystem have been identified in terms of functional groups (Rowe 1981). Information is mounting on the relative importance of some taxa in carbon cycling and energy flow (Rowe 1983; Smith 1986a; Deming and Baross 1993; Smith 1992). Using biomass spectra to estimate production, Haedrich and Merrett (1991) suggested that a number of characteristics of community energy or carbon flow among the fishes can be inferred. While fish densities drop markedly over the slope, biomass is relatively constant to depths of almost 2600 m, suggesting that mean size per fish increases with depth over the slope. Hence, it is inferred that the relative importance of fishes increases compared to other size and functional groups with increasing water depth to 2600 m. At greater water depths, fish biomass precipitously declines.

Sediment-dwelling organisms appear to respond directly to fresh inputs of organic matter. Working at 200 to 500 m depths in the sub-Arctic Atlantic Ocean, Rowe et al. (1997) were able to construct a budget that balances carbon input into sediment traps with total community respiration and sediment burial. A model of the functional components responsible for the cycling of carbon was then constructed. Evidence that little of the carbon was channeled through the bacteria supports the suggestion of others, that bacteria are less important at high latitudes. The dependence of the cycling of energy and carbon on input rates has also been demonstrated in comparisons of deep sub-oxic environments with oxic counterparts (Eldridge and Jackson 1991). Deep-sea sediment biomass, in general, appears to be enhanced by the fresh input of organic matter (Rowe et al. 1997). The latter work modified and simplified the conceptual benthic boundary layer model of Smith (1992), and conducted numerical simulations to determine how biomass and respiration were redistributed within a “fertilized” system. This model, validated independently by work at Deepwater Dump site #106 in the northwest Atlantic, implies that it might be possible to predict “bioenhancement” (of biomass) in response to new carbon. This does not mean that diversity would increase. To the contrary, some models suggest that diversity would actually decrease initially due to competitive exclusion, in agreement with data presented in Snelgrove et al. (1996). The rates at which new “steady states” are reached might be much slower than in shallow water at higher temperatures.

The deep-sea is seemingly benign, rather than stressful. However some exceptions should be noted. Low oxygen zones occur in isolated basins, near large rivers and in eastern tropical areas affected by upwelling (Levin and Gage 1997). Stress from low oxygen in the eastern Pacific for example causes a decrease in macrofauna and megafauna (Menzies et al. 1973; Rowe

and Deming 1985) and diminished diversity and tight zonation perpendicular to the oxygen gradient (Levin and Gage 1998). Likewise, hydrocarbon seeps are now known to occur widely around the world on continental margins. Some have unique communities that utilize petroleum as a source of carbon and energy, but the effects of the communities to either enhance or degrade the surrounding benthos is unclear (Montagna et al. 1989). Another natural potential "stress" studied in the deep-sea is high current velocities (Thistle et al. 1991). Recent observations have confirmed the occurrence of episodic strong currents at the base of the Sigsbee escarpment (Bryant and Nowlin, pers. comm.).

2.2 The Deep-Sea GOM - Geologic Setting

The GOM Basin is a study in physiographic contrasts. The simple topography of the West Florida and Campeche continental slope, the Mississippi and Bryant submarine fans and the extremely flat Sigsbee Abyssal Plain give way to the complex slump structure of the East Mexican Slope and the extremely complex topography of the Texas/Louisiana continental slope. The continental slope off Texas, Louisiana, and portions of Mississippi is geologically and physiographically the most complex in the world. Over ninety basins and seven submarine canyons dissect the continental margin of the northwestern GOM. The halokinesis of allochthonous salt is the main mechanism of interslope interlobal and interslope superlobal basin creation in mid- to lower-slope areas. Most slope basins are filled with turbidites and debris flow deposits overlain by a Holocene hemipelagic sediment cover that varies from 2 to 10 meters thick except in areas of active slumping such as the Beaumont Basin. The supralobal basins of the lower slope are probably formed by the downbuilding of salt withdrawal under the influence of turbidite sands. The termination of the slope, the Sigsbee Escarpment, is the southern most extent of a salt nappe that extends from the mid- to lower-slope. The salt nappe can prevent the migration of thermogenic gas and oil into overlying sediments. Major portions of the middle and lower slope appear to be devoid of gas seeps; thus, gas hydrate and chemosynthetic communities are not expected to be present except at the edge of the nappe (Sigsbee Escarpment) and in salt-free basins. In contrast, the upper slope contains numerous salt diapiric structures such as mud and gas mounds, fluid expulsion features, hard-grounds, erosional gullies, and numerous gas seeps and gas hydrate deposits.

Superimposed, and eroded into the complex topography of the Texas/Louisiana slope, are four major canyon systems: the Mississippi, Keathley, Bryant, and Alaminos Canyon. The Mississippi Canyon is a Pleistocene feature resulting from slumping processes, debris flows, and turbidity current flows that were most active during the Wisconsinian. Alaminos, Keathley, and Bryant Canyon were created by a combination of coalescing salt canopies and turbidity current and debris flow erosional events. Three smaller canyons, Farnella, Green, and Cortez breach the escarpment and were formed by mass flow events. Smaller upper- and mid-slope canyons that do not extend to the escarpment are common features related to mass flow processes.

Since the late Pleistocene; Alaminos, Bryant, and Keathley Canyon have undergone extensive alteration due to infilling of the canyons by the upward migration of salt. As much as 800 meters of infill has taken place within the Bryant Canyon system over the last 12,000 years. This equates to an average vertical salt movement of 6 cm/year. It is unknown if the upward motion of salt is continuous or episiodic. Recent seafloor faulting indicates that salt migration is ongoing today.

An unusual form of density flow resulting in extensive bedforms on the seafloor was recently found associated with Vaca Basin, a supralobal basin due east of Bryant Canyon. The salt infill of Bryant Canyon has resulted in brine eroding vast fields of gullies on the slopes of Vaca Basin and adjacent areas. Recent studies indicate that other large bed forms, seafloor furrows, occupy an area 15 km wide southward of the base of the Sigsbee Escarpment. These furrows are current induced structures and extensive erosion is taking place at the present time.

The geologic setting in the northern GOM is diverse, heterogeneous on several spatial scales, and actively changing within timeframes that might be expected to effect biological communities living in and on the sediments. This temporal and spatial heterogeneity of substrate in the deep-sea GOM has been fully appreciated only in recent years. This realization has lead a new perspective on how biological communities might be interacting with geological processes.

2.3 The Geochemistry of Deep-Sea Sediments

The two variables generally considered most important to the geochemistry of deep-sea sediments overlain by oxic seawater are the rate of sediment accumulation and the relative proportion of biogenic material to detrital minerals (e.g., Berner 1980). Both factors are closely related to the extent to which biologically driven reactions occur. Sediment accumulation rate controls the speed with which material is buried away from the sediment-water interface increasingly insulated from the overlying oxic waters. Consequently, the degree to which metabolizable organic matter is decomposed, at or very near the sediment-water interface, depends on sediment accumulation rate. If accumulation rates are low, little metabolizable organic matter is buried and the sediments may only reach suboxic conditions, whereas at higher accumulation rates sulfidic conditions can be reached. Related to these conditions is the second major variable, the relative input rate of the particulate organic carbon. Sediments on continental margins and beneath highly productive open ocean waters can have a much higher rate of carbon input than those beneath oligotrophic waters. Both of these factors combine to control how far down the redox "ladder" (e.g., Stumm and Morgan 1996) reactions will progress for electron acceptors associated with organic matter remineralization and the depth spacing between the various "rungs" on the redox ladder.

An important overall general concept that is basic to this program is that physical, chemical and biologic processes are intimately intertwined. It is also particularly germane that it is the availability of metabolizable organic matter that will largely control benthic biogeochemistry and community structure. This is not simply related to the total organic matter content of sediments (e.g., Morse and Emeis 1990, 1992; Boudreau 1996). It is, therefore, necessary to look at the consumption of electron acceptors (e.g., oxygen, nitrate, manganese and iron oxides, sulfate) and the production of reaction products (e.g., carbon dioxide, ammonium, hydrogen sulfide) to understand the rates and extents to which heterotrophic activity is occurring on and beneath the seafloor.

Although there are of course many complicating factors leading to exceptions, the very general rule is that sediments tend to have lower accumulation rates and hence become less reducing with increasing water depth. This also reflects decreasing biologic activity with increasing water depth. The geochemistry of GOM sediments have been investigated over much

of the study area and adjacent regions (e.g., Lin and Morse 1991; Rowe et al. 1990; Morse and Rowe 1999) to a water depth of ~2000 m. A primary indicator of biologic activity is the integrated rate of sulfate reduction. This generally decreases with increasing water depth. However the rates are about three times higher at a given depth on the slope near the Mississippi River than at GOM slope far from the river. A distinct secondary maximum in sulfate reduction rate has been observed at ~500 m water depth. These results suggest that deep-sea biological community structure in the GOM is not simply related to depth, but may be influenced by factors such as down slope transport of sediments and organic matter. Further confounding simple relationships between structure and geochemical forcing factors, is the presence of hydrocarbon seeps. The MMS chemosynthetic community studies on the Louisiana slope, have documented integrated sulfate rates near seeps that exceed those in surrounding sediments by over a factor of fifty (Morse, unpublished data).

2.4 Physical Oceanography of the GOM

The GOM is a semi-closed basin with both broad and narrow continental shelves surrounding a deep abyss reaching 3600 m. At the boundary in the southwestern GOM, the energetic Loop Current intrudes northward into the GOM and exits east through the Straits of Florida. The Loop Current is a permanent feature of the circulation and virtually dominates the circulation in the eastern GOM and its influence is felt throughout the GOM as anticylonic rings and topographic Rossby waves spawned by the Loop Current translate west and south. GOM tides are modest. The world's third largest river, the Mississippi River, and dozens of lessor rivers discharge tremendous volumes of fresh water into the GOM affecting stratification over large areas and enhancing wind-driven coastal jets along frontal boundaries. Wind driven upwelling occurs with regularity along the western and northeastern GOM and along the Yucatan Peninsula. Winter cyclones and summer hurricanes are not uncommon events.

The open waters of the GOM can be divided into two regimes: the eastern GOM with the anticyclonic Loop Current and the western GOM with the anticyclonic Loop Current eddies and associated cyclones. Approximately every nine months (on average, but with considerable variability), it sheds anticyclonic, mesoscale current eddies with average lifetimes longer than one year (Elliott 1982). These eddies typically migrate to the western GOM, often decaying away in the northwest corner of the GOM. The eddies can spawn cyclonic rings during interaction with one another or the continental slope. The Loop Current eddies have characteristic diameters of 200-400 km when newly detached, decreasing by 45% within 150 days and 70% within 300 days (Vukovich and Crissman 1986). The eddies translate westward with an average speed of about 5 $km \cdot d^{-1}$ and a range of 1-14 $km \cdot d^{-1}$. Currents associated with the Loop Current and its eddies extend to depths near slightly greater than the sill depth of The Florida Straits (800 m). The currents may have surface speeds of 150-200 $cm \cdot s^{-1}$ or more; speeds of 10 $cm \cdot s^{-1}$ are not uncommon at 500 m (Cooper et al. 1990). Because of their longevity, the effects of the Loop Current eddies can persist at one location for weeks or even months.

Anticyclonic Loop Current eddies interact with one another and with the continental slope resulting in their decay. In the process of the interactions, and of the interaction of the Loop Current with topography, many cyclonic eddies are generated within the GOM. Some evidence exists that anticyclonic eddies may also be formed by ring-ring interactions, but they would not have the high salinity core characteristic of Loop Current eddies. Below 1000 m,

strong current events have been observed (e.g., SAIC 1989). The Loop Current and Loop Current eddies may influence the dynamics to the deepest portions of the GOM (~3500 m; Smith 1986b; Hamilton 1990) through the generation of phenomena such as barotrophic Rossby Waves. Likewise strong, episodic atmospheric events (e.g., hurricanes or cyclones) can generate currents that extend to depths of 1000 m or more. Speeds up to 50 $cm \bullet s^{-1}$ have been observed associated with these classes of deep currents. Deep currents are the main interest of the MMS-sponsored inventory and synthesis of physical oceanographic data in the deepwater GOM.

Characteristic relationships of physical and chemical water properties (e.g., temperature, salinity, dissolved oxygen, and nutrients) can be used to identify water masses and their sources. Surface waters of the GOM are greatly modified by heat and freshwater exchanges through the surface, river discharges, and wind mixing, but no subsurface water of consequence is thought to be locally formed. Waters from the global ocean enter the GOM only through the Yucatan Channel from the Yucatan Basin of the Caribbean Sea. Seawater properties can be used to identify the five water masses that enter the GOM (Table 2.1). Source regions for these waters are discussed in Morrison and Nowlin (1982). Morrison and Nowlin (1977) described the water masses found in the Loop Current of the eastern GOM, and Morrison et al. (1983) described the water masses and properties found offshore in the western GOM. As the waters of the Loop Current enter the GOM, those along its western boundary are vertically mixed by the interaction of the current with bathymetry, resulting in an averaging of properties (Nowlin 1972). Moreover, after separation, Loop Current eddies eventually spin down in the GOM. That process entails mixing, which likewise lessens property extrema. Below the Yucatan Channel sill depth of about 2000 m, the potential temperature, salinity, and dissolved oxygen concentrations show no measurable horizontal variation throughout the GOM (Nowlin 1972).

Table 2.1. GOM water masses with associated property extrema and potential densities.

Water Mass	~ Depth Range (m)	Identifying Feature(s)	Sigma-theta ($mg\ cm^{-3}$)
Subtropical Underwater	50-250	salinity maximum	25.40
18°C Sargasso Sea Water	150-250	oxygen maximum (weak in west)	26.50
Tropical Atlantic Central Water	250-500	oxygen minimum	27.15
Antarctic Intermediate Water	500-1000	salinity minimum; nitrate, phosphate, and silicate maxima	27.30-27.50
Upper North Atlantic Deep Water	> 1000	silicate maximum	≥ 27.70

The earliest attempt at a comprehensive synthesis of the physical oceanography of the GOM is found in Capurro and Reid (1970). Since then, and particularly in the last 15 years, the study of the physical oceanography of the GOM has greatly accelerated. Much, if not most, of this increased study has been funded by the MMS acting in response to intense energy exploration and production activities on the shelf, slope, and rise. The first such study, initiated in 1982, was a five-year program implemented as a series of regional studies. These studies included field work in the west, central, and eastern portions of the northern GOM. The results, detailed in a final report, emphasize eddy variability. MMS also sponsored a synthesis of GOM meteorology and climatology data during this same period (Florida A&M University 1988). A major MMS-funded physical oceanography study was the Texas-Louisiana Shelf circulation and Transport Process Study (LATEX) program which surveyed and maintained current moorings

between 1992-1994 along the Texas-Louisiana shelf from the 10 m isobath to the shelf break from Brownsville to 90.5ºW. The LATEX program was a joint effort accomplished by TAMU, Louisiana State University, and SAIC. Other study units sponsored by MMS, but not strictly part of LATEX, generated significant amounts of related collateral data during the same time period. Taken collectively, this study was the largest and most comprehensive shelf study ever conducted. Following LATEX, a new series of programs similar in scope to LATEX but organized differently, were initiated in the northeastern GOM. The most significant circulation studies include a large (>350 drifters) program conducted by Peter Niiler of Scripps Institute of Oceanography and Walter Johnson of MMS between February 1996 and February 1997, a moored array and hydrography program conducted by SAIC in DeSoto Canyon from March 1997 to March 1999, and an ongoing hydrography and water chemistry program over the shelf and slope between the Mississippi River and Tampa, Florida from November 1997 to August 2000. In 1998, a data synthesis study of the physical oceanography of the deep water GOM was begun by TAMU under MMS sponsorship. The results of this study, due in December 2000, will include a complete database of all available information and the design for a deep mooring array.

2.5 Deep-Sea Ecology of the GOM

The earliest studies of the deep GOM biota were by Alexander Agassiz (1888) but his voyages never penetrated the western Gulf. The National Marine Fisheries Service has long maintained an exploratory fishing fleet in Pascagoula, MS and information is available from extensive trawling on the continental slopes of the GOM and the Caribbean. In the mid-1960s studies on the biota of the deep GOM were initiated (Pequegnat et al. 1990). A wide range of investigations of the deep water ensued, including the first quantitative samples with a Campbell grab coupled with a camera (Rowe 1966). Several bottom contact and automatic cameras were used and camera lowerings were dispersed more or less evenly around the GOM margin, including the Gulf of Campeche near Veracruz, Mexico. A benthic "skimmer" was built to catch larger forms and it was outfitted with an odometer to determine bottom distance traveled. These samplings included the Caribbean, as well as the GOM. Faunal groups studied from the deep GOM included squids, crustaceans (Firth 1971; Pequegnat 1970), echinoderms (Carney 1971), molluscs, and fishes (Bright 1968) among others. Assemblages of both the megafauna and the macrofauna were also studied. Fish feeding habits were intended to link the two. Photographs of an "iron stone bottom" north of the Yucatan Strait suggested deep bottom currents sweep some areas free of sediments (Pequegnat 1972). Some taxa displayed remarkable "zonation" by species, such as the bivalve molluscs (James 1972) and the asteroid echinoderms. The macrofauna appeared to be grouped into assemblages, based on measures of similarity, that were distributed within "zones" down the slope and onto the abyssal plain, but no justification was found for separating deep-living fauna into zoogeographic provinces by latitude or longitude (Kennedy 1976).

In 1968, semi-quantitative samples were taken across the Sigsbee Abyssal Plain and then in 1972, quantitative samples were obtained from the lower slope up onto the continental shelf on two transects seaward of Galveston and Pascagoula. These quantitative data suggested that the deep biomass of the GOM was depauperate in numbers and biomass, and that the mean size of the macrofauna was in general smaller than that in the Atlantic at similar depths (Rowe 1971, Rowe and Menzel 1971, Rowe et al. 1974). Later studies, such as the NGOMCS, used the conversion factors from numbers and size to estimate biomass. The log-normal relationship

between biomass and depth has now been confirmed for numerous ocean basins (Rowe 1983), but the slope of the line for the GOM is steeper than that in most basins. It has been suggested that this is due to the low primary production in the GOM.

The most extensive sampling of the sediment biota of the northern GOM was the NGOMCS study supported by the MMS in the 1980's. This consisted of paired GOMEX (not to be confused with GOOMEX) boxcores (Boland and Rowe 1991), bottom survey camera lowerings and trawl samples. The stations studied included three transects down the slope in the western, the central and the eastern GOM with a line along the upper slope connecting the west and central transects along isobaths. A series of reports were written describing the work but the most concise summary is a paper by Pequegnat et al. (1990). In the descriptions of the characteristics of the three dominant size classes (the meiofauna, the macrofauna and the megafauna) the meiofauna appeared to dominate the biomass, a feature that would be odd for shallow water but a relationship that is becoming increasingly apparent at deep-sea stations when size groups are compared (Rowe et al. 1991). It was also suggested that the fauna were distributed in "zones" along isobaths on the upper slope, but less so on the lower slope. As is true for most deep ocean basins, the meiofauna were dominated by nematodes, the macrofauna by polychaetes and the megafauna by echinoderms. Lesser numbers in each size category were also quite predictably encountered in taxa such as the molluscs and crustaceans. Similarity indices suggested that the eastern GOM, east of the DeSoto Canyon, was not similar to that in the northwestern GOM at similar depths. "Zonation" with some groups was modest, at best. This was true of the polychaete annelids (Hubbard 1996). Within this group, no species was encountered below the sill depth of about 2 km that was not encountered at lesser depths as well.

An important discovery made during earlier slope studies were communities of large organisms associated with petroleum hydrocarbon seeps (MacDonald et al. 1996). Such communities, bearing a resemblance in both taxa and function to those associated with hydrothermal vents, have now been documented at numerous locations on the continental slope of the northwestern GOM in areas where fossil hydrocarbons make their way to the sediment surface. Bubbling or seeping gas appears as "wipeout zones" in acoustic surveys of the bottom. These communities are the subject of ongoing studies supported by MMS and other agencies and will not be described in detail here (see MacDonald et al. 1998). Cold seeps supported by hydrogen sulfide in "ground water" appears to support communities of large invertebrates, again being somewhat similar to those at hydrothermal vents, on the lower reaches of the Florida Escarpment (Paull et al. 1984).

The Instituto Ciencias del Mar y Limnologia of the Universidad Nationale Autonoma de Mexico (UNAM) has conducted extensive studies in the southern GOM. Early studies of megafauna on the shelf were expanded down slope into the "salt diapir zone" just west of the Campeche Bank. These studies were extended into the Sigsbee Abyssal Plain close to the EEZ between the U.S. and Mexico (26ºN. Lat.) as well. Pathways of carbon and nitrogen in the benthic foodweb were inferred by stable isotopic analysis (Soto and Escobar 1995). In deep water studies across the *Cordilleras Mexicanas* or "Mexican Ridges" of the upper continental rise out onto the Sigsbee Abyssal Plain regions that contain enhanced biomass have been identified under water masses that have high rates of primary production (Escobar-Briones et al. 1999). Polychaetes dominated the infauna and a mid-slope maximum in abundance similar to that encountered in the northern GOM has been documented (Pequegnat et al. 1990). The fauna could be partitioned into three groups within depth intervals of >3 km, between 1.5 and 3 km,

and <1.5 km. This contrasts with the view of Pequegnat et al. (1990) that five faunal groups can be divided into recurrent "zones".

Several studies currently being conducted in the GOM are also important. Studies in the Bay of Campeche in the northwestern GOM are producing important findings (TAMU/UNAM). In 1997, at a station in 3.6 km water depth (25º15' N. Lat. x 93º26' W. Long.) on the northern Sigsbee Abyssal Plain, the first sediment oxygen consumption measurements in the deep western GOM were made. The sediment oxygen consumption was equivalent to 3.8 mg carbon/m^2-day. Quantitative analysis of samples of the benthic community on the Sigsbee Abyssal Plain confirm that benthic biota are extremely sparse. Baited bottom traps in the area attracted deep-sea scavenging amphipods. The diversity of polychaetes was not appreciably different from that measured in the NGOMCS study (LGL and TAMU 1988).

Another important investigation is a study of mollusc shell "taphonomy" which measures preferential preservation of material in the fossil record. Ongoing, *in situ* experiments at about a dozen semi-permanent sites within the MMS study area have been established. The strategy is to set out shell material and assess diagenetic changes over time frames of years. Bottom chamber measures of sediment oxygen consumption and quantitative faunal samples at each site have also been collected. The hypothesis being tested is that the chemical dissolution of carbonate is accentuated in areas of high oxygen consumption. These sites stretch from the brine pool at the Flower Gardens down to ~1000 m depth. Oxygen consumption measurements have been taken at a number of locations in the study area.

3.0 A CONCEPTUAL MODEL OF THE DEEP-SEA

A conceptual model of the deep-sea, its living and non-living components, has been constructed to represent the interacting stocks of organisms that make-up a typical benthic boundary layer community (Figure 3.1). A biological boundary layer is defined as approximately 1 m deep into the sediments, extending up through the mixed layer of the water column to approximately 100 m above bottom. This biological boundary layer thus conforms to that previously used to describe the principal interacting components of a deep-sea benthic community (Smith 1992). This conceptual model has been drawn in software called STELLA II. The software allows flexibility in reformulating the structure and internal relationships within the system. The formulation presented is a modification of the model used by Smith (1992) and represents a deep-sea food chain. The modifications consist of defining every stock variable, living or non-living, as a "box" and every process, such as predation or respiration, as an "arrow". Thus all interactions between the biota and the sources and sinks of organic matter are explicit either as "boxes" or "arrows". On the other hand, "physical" processes are not explicitly represented. These implicit factors affect the "arrows" between the "boxes". Each "box" has a "size" in terms of concentration, biomass or abundance that is the sum of the "arrows" entering the "box" minus the "arrows" leaving the "box". At steady-state, each "box" does not change with time, and thus the inputs equal the outputs or losses. An important process, respiration, has been omitted in this conceptual food chain. Each stock can be taken separately in a submodel (Figure 3.2). Macrofaunal biomass, for example, is a function of what it consumes, what consumes it, respiration, and feces production. The contents of each stock can be expressed as a differential equation. The set of differential equations of all the stocks can be used to simulate the behavior of the entire food chain over time. The problem with doing this in the deep-sea is that data to quantify the stocks and processes are sparse at best. While considerable information exists on the stocks in a few locations and a few data exist on the rates of processes in others, the locations where both stocks and fluxes are known, even in the most minimal sense, are quite limited. One exception is a study of the central North Pacific, but even this study treated the sediment dwelling biota as one functional group due to a lack of detailed information on the foodweb (Smith 1992; Smith and Kaufmann 1999).

An advantage of this model is that with adequate data it can be used to simulate how the ecosystem will function under different conditions. Previously this approach has been used in an oligotrophic upper continental slope environment off eastern Greenland (Rowe et al. 1997). Boxcore standing stocks of the components represented were coupled with measures of community respiration (using a bottom lander with benthic chambers) and laboratory measures of bacterial activity to simulate the variations in biomass over time in response to a single seasonal pulse of organic matter related to a short ice-free period. In a purely hypothetical situation, the bioenhancement of infauna due to the disposal of organic rich material, such as sewage sludge or dredge spoils, was modeled, based on a simplified rendition of the Smith (1992) model (Rowe 1998). By adding organic matter in a pulse, the community "shifted up" to higher biomass and higher respiration and the alteration predicted by the model was validated by actual data at Deepwater Dumpsite 106 on the continental rise in the northwest Atlantic Ocean. This feature of "shifting" up or down in response to different input terms will be an important tool for interpreting the response of community structure and function in the deep-sea GOM in reaction to inputs from oil and gas exploration and production activities. The two most relevant inputs at platforms are organic enrichment due to a "reef" effect and the introduction of

contaminants.

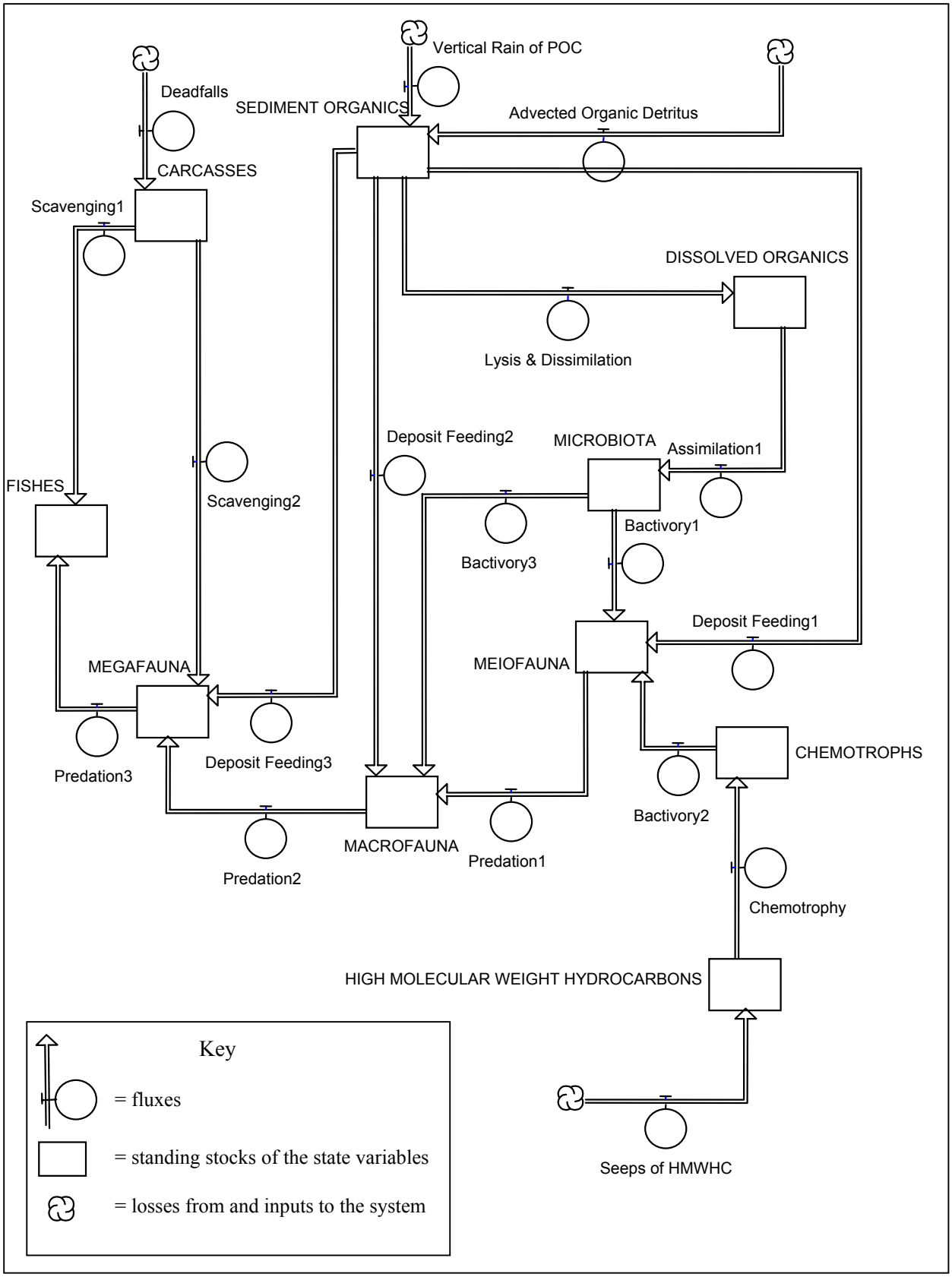

Figure 3.1. Preliminary conceptual model of the deep-sea Gulf of Mexico.

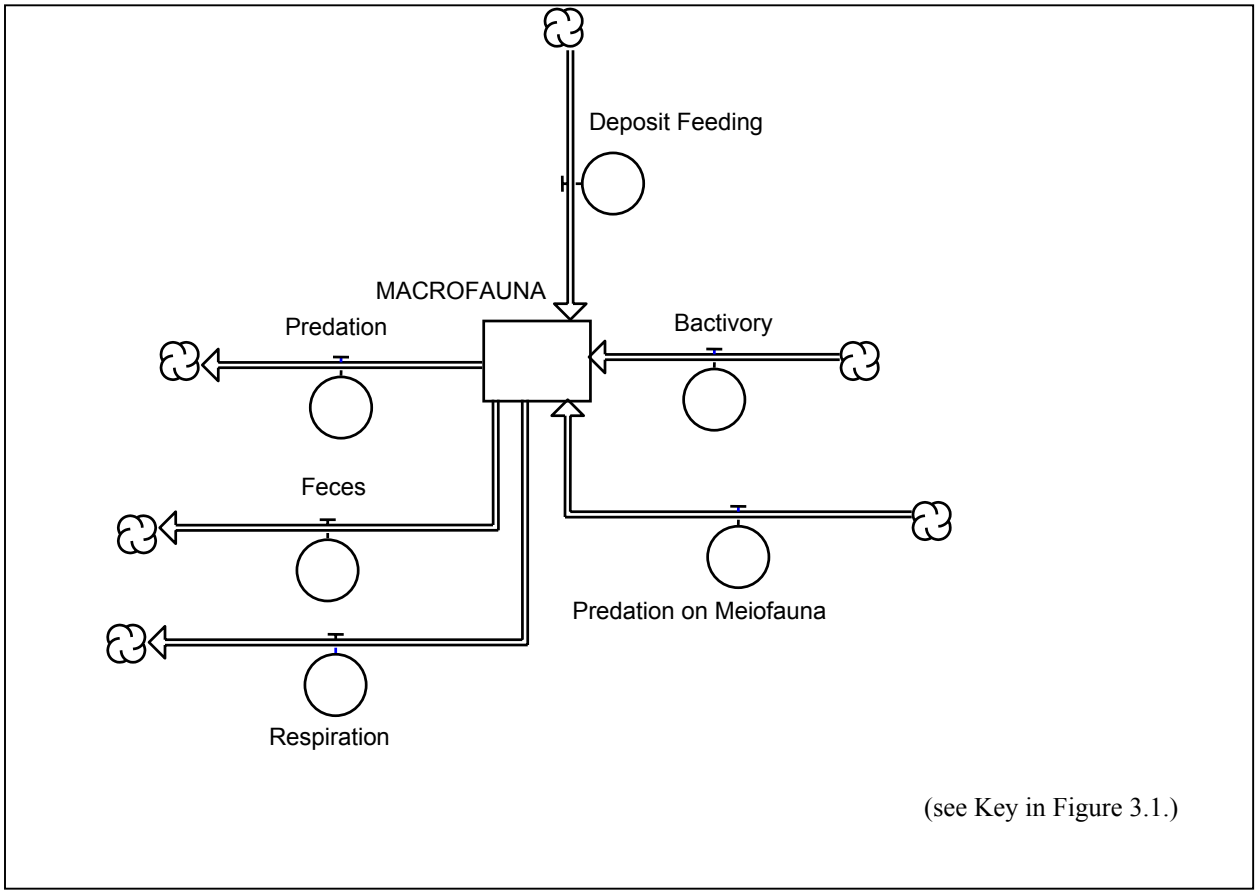

Figure 3.2. Macrofauna submodel of system carbon food chain model.

3.1 Biotic Variables

The details of the conceptual model can be described as a number of biotic (living and non-living) and abiotic variables. In addition, the model is described in terms of various derived variables related to community structure and function. In-the-end, an understanding of the model components and their interactions are used to select the set of variables to be quantified that best describe the functioning of the system being studied. These inferences are then ground-truthed by in-the-field observations and the model is revised as needed. The biotic variables include the microbiota, meiofauna, macrofauna, megafauna, and fishes. These groups of biota make up the overall stocks of the system which are estimated through conventional quantitative sampling as described in Sections 6.0 and 7.0.

Microbiota. The microbiota are the "bottom" of the food chain. Microbiota are represented by the bacteria and protists, including benthic foraminifera. Their principal food source is thought to be dissolved organic matter, although particulate material can be directly utilized if the biota can produce exoenzymes to mobilize particles. The protists can engulf and assimilate particulate material as well. The bacteria generally have a density of about 10^9 per mL of wet sediment, measure about a micrometer in size, and can have very short turnover rates in the presence of reactive organic substrates. The protists can be much larger and occur in far

fewer numbers than the bacteria. Protists are thought to be important components of ecosystems in areas of reduced oxygen. With the exception of the forams, microbiota have rarely been evaluated in the deep-sea.

Bacteria that are specially adapted to utilizing methane and sulfide are common in areas characterized by petroleum seeps (MacDonald et al. 1996; MacDonald 1998). Many of these are symbiotic, living in the tissues of large invertebrates. While these specialized associations are explicit in this model, they are presumed to be confined to "seep" areas.

Foraminifera are shelled protozoans. Foraminfera are large, often the size of metazoan meiofauna. Few studies have compared foraminiferal biomass to other benthos in the deep-sea, but biomass can exceed the meiofauna (Coull et al. 1977) and abundances commonly exceed the meiofauna plus the macrofauna (Snider et al. 1984; Gooday 1986). Although little is known regarding foraminiferal energetics, it has been shown that foraminiferal metabolism is markedly increased by organic enrichment (Linke 1992). Therefore, accurate deep-sea carbon and energy budgets should include the foraminifera.

Meiofauna. In this model, meiofauna are defined as metazoans that are retained on a 63 micron sieve. Meiofauna include nematode worms, harpacticoid copepods, and several other taxa. In some studies benthic forams are also included, but in this model, forams are considered part of the microbiota because they are single-celled organisms, rather than metazoans. Most meiofauna feed on small particles consisting of detritus, bacteria, other meiofauna, and small protozoa such as ciliates and flagellates. Turnover rates for meiofauna can be as short as a few days when temperatures are high and food is plentiful. No reliable generalizations can be made about their turnover times or growth rates in the deep-sea, but it is assumed that both are substantially slower than in shallow water due to food limitation and cold water temperatures. In shallow waters meiofauna biomass is less than that of the macrofauna, but in the deep-sea this appears to be reversed.

The finding that meiofauna biomass is higher than macrofauna biomass in the northern GOM (Pequegnat et al. 1990) indicates that meiofauna may be responsible for much of the organic matter metabolism in deep-sea sediments. Therefore, a survey of meiofauna community density and biomass is needed to characterize this energetically important group. In shallow coastal systems, meiofauna remove bacteria at a rate that equals sediment bacterial production (Montagna 1995). This indicates meiofauna are most likely responsible for maintaining bacterial populations in log-phase growth cycles and are therefore indirectly responsible for maintaining rates of nutrient recycling. Despite the apparent importance of meiofauna in deep-sea energetics, there is no knowledge of the rates at which these processes occur. Therefore, process studies are needed to assess meiofaunal consumption rates. Techniques to measure meiofaunal bacterial feeding rates on bacteria have only been used in shallow water (Montagna 1995).

Macrofauna. Macrofauna, in this model, are the invertebrates retained on a 300 micron sieve. The principal organisms are polychaete worms (≈50%), bivalve molluscs, and crustaceans in the groups Isopoda, Amphipoda, and Tanaidacea. The production to biomass ratio of the macrofauna in shallow water communities is often assumed to be unity, but this can vary widely. In the deep-sea, it is assumed the ratio is much lower but there is little evidence for this one way or the other. Biomass and densities decline sharply with depth in most ocean basins. Macrofauna

consume microbiota, meiofauna and organic detritus. Macrofauna are preyed upon by megafauna and fishes.

Megafauna. The megafauna are organisms that are routinely sampled by trawls with 2.5 cm stretch mesh or organisms that can be seen easily in bottom photographs, usually about 1 cm or so in diameter. They are composed for the most part of decapod crustaceans and echinoderms. Cnidaria, such as sea pens, soft corals and anemones, are also common in the megafauna. Megafauna can be suspension feeders, predators, scavengers or deposit feeders. For the purpose of the model, the swimming scavengers that consume carcasses, such as the large amphipod *Eurythenes grillus*, are included in this group. Megafauna have been extensively observed with photographic techniques.

Fishes. Demersal fishes are defined as those species that live on or near the bottom. Fishes are both predators and feed on dead falls, megafauna and macrofauna.

3.2 Community Structure

Community structure, in the context of this model, has two interpretations. It is represented explicitly in the conceptual model as the standing stocks of the living components of the ecosystem as discussed above, and as such it represents the relative and absolute importance of the stocks in terms of biomass and rates of processes in the model. Secondly, community structure refers to the parameters that quantify the living stocks, as described below.

Biomass. A measure of the standing stock in some currency of mass per unit area of seabottom is biomass. Wet weight is a common measure. It can also be measured as dry weight, ash-free dry weight or carbon. The model currency is carbon, so the ideal measure is in terms of carbon. Biomass tends to be inversely related to depth, in a log-normal fashion. Within the entire community, the highest biomasses are found in the total bacterial counts, both in shallow and deep water. All the size fractions in the deep-sea have biomass values that are somewhat lower that 1 g C/m^2. In shallow water, each fraction can have biomasses of 10's of g C/m^2 in unusually fertile conditions. This is not expected in the deep-sea.

Abundances. A surrogate for biomass, that is often measured in ecosystem studies, is animal abundance or density. However, mean sizes can vary. In the GOM, mean size seems to decrease with depth. Common abundances for the organismal groups in the model are bacteria, 10^9/mL wet sed.; meiofauna, 0.25 to 1.5 x $10^6/m^2$; macrofauna, 10^2 to $10^4/m^2$; megafauna and fishes, several hundred to a thousand per hectare. The abundances of each group are hypothesized to be a function of the input of carbon and energy to the stock. If the relationship of numbers to biomass is known, these abundances can be used in the model. The NGOMCS studies used conversion factors from the studies of Rowe (1971) to calculate biomass from densities.

Diversity. Measurements of the numbers of different species are expressed as diversity values. Diversity has been assessed on macrofauna, megafauna, and fishes. Diversity indices attempt to lessen the effects of sample size, to aid comparisons between regions of differing animal densities. Common indices of diversity are Sanders Rarefaction, Hurlburt's expected species number and the information function H'(s). The GOM appears to be somewhat different

from large ocean basins in that maximum diversity is not found on the deep slope or upper rise, but rather on the upper slope or outer shelf. Thus it is similar to other isolated "mediterranean" basins where diversity declines with depth down the slope. It is expected that intense inputs of organic matter will decrease diversity due to competitive exclusion. Diversity is not calculated by the model.

Zonation. The degree to which individual species and groups of species are isolated across isobaths (zonation), between geographic regions, or any other physico-chemical gradient is referred to as zonation. Zonation by groups of species as a function of depth has been measured by "rates of species change" across depth intervals or measures of percent similarity between depths. These can be measured on meiofauna, macrofauna, megafauna, and fishes. Groups of species appear to occur in zones, but considerable overlap has been observed as well, with few distinct, immutable boundaries. On the other hand, some individual species of megafauna tend to have a shallow water boundary that is sharp and severe and a deeper water boundary that is a slow decline in numbers with depth. Zonation down slope is hypothesized to be a function of competition along a gradient of declining food supplies. Zonation is not calculated by the model but can be addressed through hypothesis testing.

3.3 Community Function

The processes, or arrows, in the model encompass a wide range of interactions amongst the model's components.

Microbial activity. The respiration and the assimilation of organic substrates by the microbiota are dependent on inputs of organic matter and temperature. In the model this can be either sedimenting POC or hydrocarbons. The sedimenting POC can be derived from several sources, as indicated above. A basic assumption is that, in general, smaller organisms are consumed by larger organisms because it is more energy efficient. If the organic matter is reactive, the food web will compete for the organic matter. If the organic matter is highly refractory then it is assumed that a food chain will dominate in which the bacteria remobilize the organics in order to make it available to metazoans. Predation is represented as arrows between the living components of the model as indicated. It is assumed that large organisms will preferentially take large prey rather than small prey because it is more energy efficient. Macrofauna are assumed to be deposit feeders. Heterotrophic bacteria are assumed to consume sediment organic matter. Scavengers consume carcasses and are included in the megafauna. Fishes consume megafauna and carcasses. Respiration is one of the most important measures for each organismal group because it dominates the carbon cycle. However, respiration is not explicit in the conceptual model. Most carbon that is consumed (50 to 90%) is recycled to metabolic carbon dioxide. Respiration is estimated from animal size and temperature for the larger organisms based on literature values.

Growth, reproduction and recruitment. The rates of growth, reproduction, and recruitment are poorly known in deep-sea organisms. The model can calculate growth by fundamental or size group. Reproduction and recruitment are not well known. It is assumed that growth, reproduction and recruitment can be seasonal in some species but this kind of information for the GOM slope is inferential at best. It should be noted that in the NGOMCS study's central transect, it did appear that there were about 1.5 times as many macrofauna

individuals on the upper slope in the spring than in other sampling periods, suggesting that some type of growth, reproduction, and/or recruitment had occurred, but the mechanism that gave rise to this observation is unclear.

3.4 Sediment Properties

Non-living model variables include the "fuel" for the system and those processes that supply carbon and energy to the ecosystem. Inputs of carbon are critical to the functioning of the ecosystem and are often present in limiting amounts in the deep-sea. On the GOM slope, labile organic matter is transported to the communities from primary productivity (either directly settling to the site or being laterally advected), fossil sources of carbon (oil and gas to support chemosynthesis), and potentially from large animal carcasses and sinking *Sargassum*.

Sedimentary organic matter includes a suite of natural organic compounds found in deep-sea sediments. Organic matter is derived mostly from the slow rain of particulate organic matter (POM) originating from dead cells, crustacean molts, and fecal pellets produced by plankton in the overlying photic zone. Some POM sinks very slowly but aggregates and pellets can rapidly reach the seafloor. The composition of organic matter that reaches the sediment is largely unreactive and poorly characterized. POM is extensively reworked in the water column either being remineralized or transformed to dissolved organic matter (DOM). The amount of POM that reaches the sediment, its ultimate repository, is affected by many factors but, in particular, the water depth. POM concentrations in the sediments of the deep-sea are low. Relatively refractory terrigenous-sourced organic matter is an increased percentage of the POM close to shore and river discharge points. POM is usually inversely proportional to grain size, but does not correlate well with the biomass of the living components. In spite of its meager reactivity, it is assumed to be the basis of the deep-sea food chain except at hydrocarbon seep sites.

Three sources of sediment organic matter are possible in the deep-sea and two are explicit in the model: vertical transport from the photic zone and lateral export from the continental margin. The third source is slumping of material from organic matter-rich areas up-slope and its importance is unknown.

The discovery of chemosynthetic communities with large megafaunal communities dependent, through their symbionts, on methane and sulfide derived from natural seeps has highlighted a non-photosynthetic source of carbon and energy for deep-sea GOM organisms. Hydrocarbons migrate to near-surface sediments from deep subsurface reservoirs of oil and gas. The hydrocarbons can then serve as substrates for communities of organisms adapted to methane and sulfide utilization. "Seeps" support high biomass but its influence on biota outside of the immediate vicinity of the seeps is largely unknown. Recent chemical evidence indicates that the biogeochemical influences of seeps in sediments tend to be localized (John Morse, pers. comm.). The oil and gas is often degraded by bacteria inducing anoxic conditions in the adjacent sediments producing sulfidic environments.

A poorly quantified input of organics to the deep-sea are falls of carcasses that die or are killed in the water column, usually near the surface. Carcasses can range in size from a few centimeters to a whale of several tons. The relative importance of this source of organic matter is not well established. It is known that scavengers exist that can take advantage of such sources, if

and when they are available. Similarly, *Sargassum, Thallasia,* wood, etc. has been observed on the bottom as well.

There are a range of abiotic variables that have been shown to influence biotic patterns in marine environments. One type are those related to the physical texture of the sediment and include properties such as grain size, permeability, porosity, and organic and inorganic carbon content. As the substrate that supports the benthos, variations in these physical properties are important in understanding biotic patterns. In addition, it is known that influxes of organic matter and contaminants can cause changes in community structure and abundance. Introductions of labile carbon will cause opportunistic animals to flourish and others to do less well. Organic matter enhancement also leads to anoxic conditions that produce a range of toxic chemicals such as sulfides. Organisms are also known to be selectively sensitive to chemical contamination from hydrocarbons and trace metals. Some animals can tolerate exposure better than others causing shifts in populations when communities are exposed to pollution. In addition, hydrocarbons, particularly aliphatics can be metabolized by microbes and may actually enhance sedimentary microbial populations rather than exert a toxic effect, though as mentioned above, oxygen and sulfate consumption can produce toxic chemicals.

Explicit in the model is microbial biomass but functional groups of bacteria are not defined. All of the bacteria and protists are assumed to be heterotrophs, as opposed to possible chemoautotrophs in the “chemotrophs” stock. However, the terminal electron acceptors (oxidants) of heterotrophs can differ. In the oligotrophic central gyre areas of the deep-sea where sediments are oxic, all the bacteria are assumed to be aerobes. In sediments on continental margins, this is probably not true. Below the sediment-seawater interface the functional bacterial groups are defined by the terminal electron acceptor (TEA) they use (Figure 3.3). Few comparisons of the importance of the different TEA's (oxidants) have been made, but in rapidly accumulating sediments near the Mississippi delta, oxygen and sulfate were of equal importance. However, as oxygen declined and became limiting, sulfate reduction dominated heterotrophic metabolism. These processes are measured by examination of the porewater chemistry with depth in the sediment. These processes are important in situations where organic loading depletes oxygen in surficial sediments, thus forcing deeper living bacterial assemblages to depend on other oxidants. As the loading continues, the utilization of these other TEA's increases in intensity and rises up closer and closer to the sediment water interface. Profiles of TEA's are good indicators of organic loading to the sediment community. Ammonium is a principal excretory product of invertebrates and bacteria. The ammonium produced by the benthic community can be oxidized to nitrate by nitrifying chemoautotrophs, but it can then be used, along with nitrate diffusing in from the bottom water, as a metabolic oxidant. This can be measured with benthic chamber incubations and sediment pore water profiles of ammonium and nitrate. The importance of this process can be significant relative to oxygen consumption. Oxidized metals can also be used as oxidants. Comparisons with other oxidants is limited, but in some situations this process is thought to be important. In sediments containing even modest amounts of reactive organic compounds, sulfate reduction can become the dominant respiratory process, even greater than oxygen. This is because sulfate is the fourth most abundant ion in seawater, having a concentration that is 140 times that of oxygen at saturation. Lin and Morse (1991) have made a series of cross slope transects around the GOM in which they derived

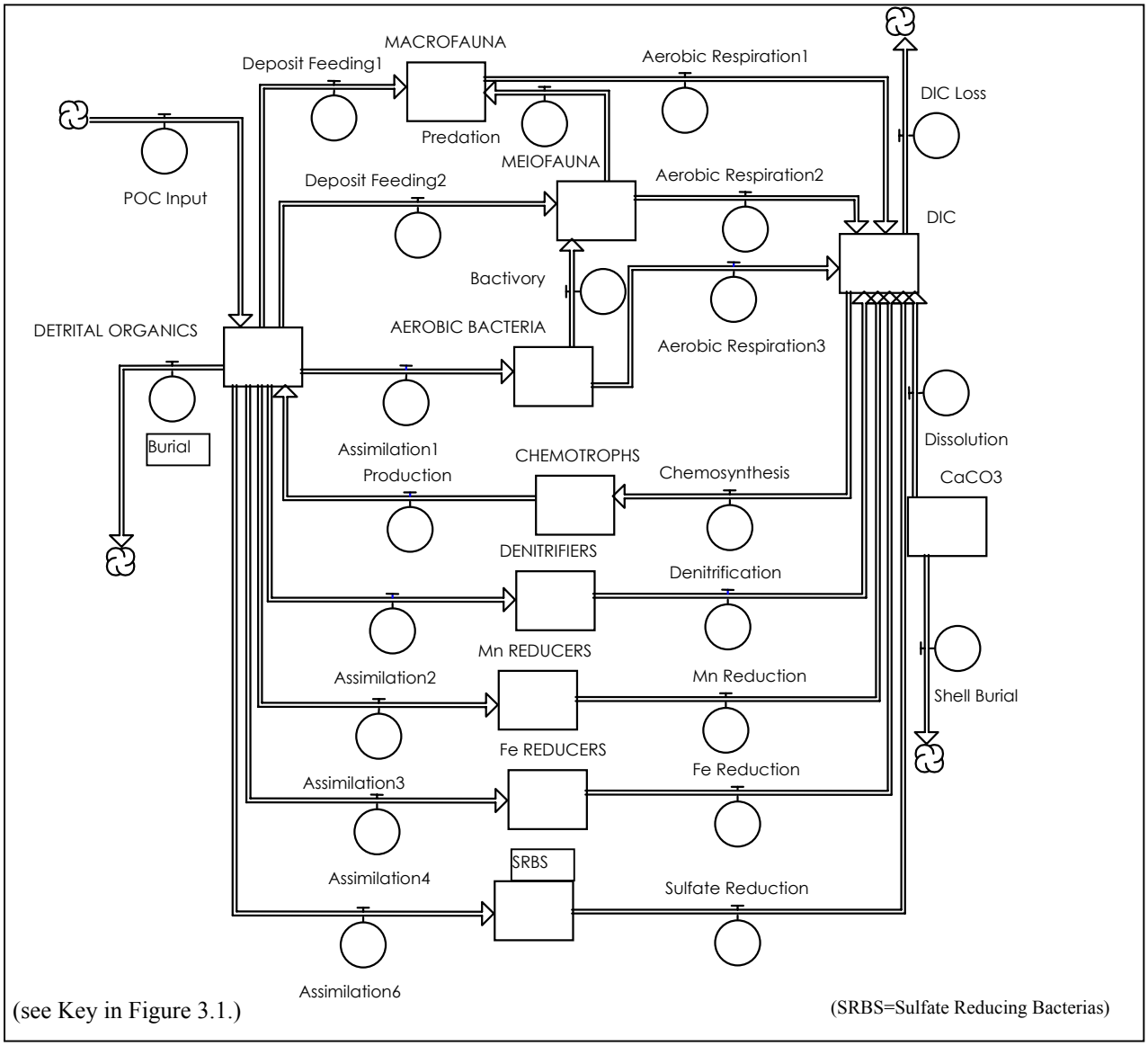

Figure 3.3. Sediment submodel of functional bacterial groups as defined by utilization of different terminal electron acceptors.

integrated sulfate reduction rates down core. Highest rates were near the Mississippi River. Lowest rates were in oligotrophic areas of the southern GOM. Methane can be produced as a breakdown product of metabolism of large carbon compounds and it can be formed when carbon dioxide is used as the oxidant. Methane can then be used as an energy source by bacteria. This methanotrophy occurs in methane seeps near hydrocarbon seeps. Therefore, characterization of the geochemical properties at a location is important for ascertaining the basic metabolic processes that are important to the base of the food chain. Significant alteration of the inputs to the system, in particular carbon, can result in large shifts in bacterial populations and metabolic strategies. In addition, the rate of sediment accumulation and the intensity of bioturbation

(mixing) are important in establishing the sediment redox conditions and provide insight into the reactivity of sedimentary organic matter.

3.5 Water Column Properties

The currents in the overlying water column are important when considering biotic patterns. Near-bottom currents are in part responsible for establishing the sediment properties by transport to the site and also winnowing/erosion of sediments. The water column is also the media through which the overlying primary productivity is transported to the sediment. The currents serve as a mechanism for transport of larvae and juveniles throughout the system. So any model of the deep-sea must take into account the dynamic nature of the physical oceanography and the hydrography of the water masses that overlie and interface with seabottom habitats.

3.6 Community "Health"

While widely discussed, the concept of ecosystem "health" remains elusive. Due to the complex nature of natural ecosystems an overall assessment of health is difficult to define. Specific portions of an ecosystem can be characterized by parasite infestation, pathologies, reproductive success, demographics (age distribution), and the presence of measurable responses to stress (such as stress proteins and the inducement of P450 detoxification enzymes) to name just a few potential indicators of "health". However, a mechanism or approach to provide an overall integrated assessment of the community "health" has yet to be agreed to. For example, in the past it was thought that simple increases in biomass were positive for a group of organisms, but now it is recognized that these biomass increases can be accompanied by significant changes in community structure. Is this positive or negative for the community and is the community "healthy"? Acute deterioration of a community, such as massive mortalities or disappearance of species, is easily recognizable, but over longer time frames it has become clear that some of the more intractable issues related to sublethal effects are often difficult to quantify or even recognize in the early stages of change. For example, loss of biodiversity is seen as a deterioration in ecosystem health, but the natural processes that also effect biodiversity are not well understood.

Ecosystem "health" may be measured by such things as community structure, e.g., the classic view that a healthy benthic community is one of high diversity and high productivity. Therefore, unhealthy ecosystems share a number of properties - lessened productivity, declining biodiversity, dominance by lower trophic levels and others. It has also been suggested that systems degraded beyond a certain point cannot recover (Rapport and Whitford 1999; Rapport et. al. 1998; Rowe and Haedrich 1979; Haedrich et al. 1980; Haedrich and Maunder 1985; Snelgrove and Haedrich 1985; Haedrich and Merrett 1988; Merrett and Haedrich 1997). Therefore "health" can be inferred from community composition, abundances, and size frequencies. "Health" will be assessed by comparisons of the structure of similar ecosystems world-wide that have been subjected to varying degrees and types of disturbance.

At the individual level, "health" has been inferred from physiological responses such as disease incidence, size and condition, and reproductive state. Parasites, and the diseases they cause, are often important determinants of population health. Measurable effects include

mortality, decreased reproductive effort, decreased condition, and reduced or aberrant growth. The outgrowth of these effects are increased morbidity, decreased fecundity and even effects on predator/prey relationships.

From another point of view, "health" may be a measure of response to the stresses a population experiences due to anthropogenic disturbances. As a first order indication of this exposure, inventories of chemicals in sediments and biological tissues are measured. While this is at least an indication that the potential for impact is present, simply documenting the presence of contaminants is not sufficient to infer biological effect in most instances. However, a range of biological effects criteria for sedimentary concentrations of contaminants have been used to infer the possibility of effects. Once the potential for exposure has been verified, first-order biological responses to contaminant exposure are often important variables to monitor. These include a range of responses including production of contaminant metabolites, the induction of detoxification enzyme systems, and molecular level indications of genetic damage, to name a few indicators of sublethal biological response to contaminant exposure.

4.0 SAMPLING DESIGN

The design of the sampling program involved a series of steps that relied on basic design principles, a thorough knowledge of the current understanding of the system to be observed, formulation of working hypotheses, application of appropriate statistical analyses (both univariate and multivariate), linkage of findings with model revision and update, and an objective approach to evaluate the utility of data being collected as the program acquires new data. Taking these issues into account, the program design includes those factors believed to be most important in characterizing the biological communities. Testable null hypotheses were formulated and the appropriate temporal and spatial scales and locations for sampling were chosen. All of these elements are essential for a full integration of the diverse interdisciplinary measurement program being undertaken.

4.1 General Design Considerations

Several general principles guided the development of the overall sampling plan.

First, treatments, or in this case similar stations, were chosen that will falsify the null hypothesis. That is, contrasts that don't delineate differences were avoided as unproductive. Due to resource limitations and the large geographic area to be studied, it is impossible to measure everything, everywhere. However, it is relevant to measure what are judged to be the most important variables at the most important sites.

Second, pseudoreplication was avoided, i.e., replication is at the treatment level. A treatment is a factor level, or combination of factor levels, applied to a sampling unit. Sampling units are stations or replicate samples within stations where all other variables but the variable to be tested are as similar as possible. The generic form of all null hypotheses is that the treatment level effect equals zero, i.e., the stations themselves are not fundamentally different by other than the variable being tested. For example, if each treatment is only represented by a single station, then in the end you only know that the stations are different, not why the stations are different.

Third, station locations were optimized to test more than one hypothesis. This is a cost reduction technique. For example, stations along a transect to test for depth differences can be paired with stations in specific habitats to test a second hypothesis.

Fourth, confounding factors were minimized. A common problem is that more than one variable is changing at a given station. For example, two stations could differ by water depth, distance from shore, and distance from the Mississippi River. In the end, you don't know which variable (or if an interaction of the variables) is causing the observed differences and thus generalities are difficult, if not impossible, to discern. Therefore, stations are chosen where comparisons can be based on differences in a single or related set of variables.

Fifth, balanced sampling designs were used. An uneven distribution of sampling effort causes distortion of sample means when there is a difference in the number of observations between the datasets being contrasted.

Sixth, a design of appropriate power was used. Power is the ability to detect change. The first five design considerations primarily protect at the α level against Type I errors (rejecting the null hypothesis when it is true). But, type II errors protected at the β level must also be considered (accepting the null hypothesis when it is false). Replication must be sufficient to detect the amount of change that is expected given variations in the variable of interest. A large multi-factorial design with little replication has many interactions terms that are often significant, thus limiting the interpretation and robustness of tests for the most important effects. In this case, previous studies suggest that a minimum of five replicate boxcores were needed at each station to adequately sample within-station heterogeneity.

Finally, there will be a meta-analysis (or synthesis) in the end. Most programs measure values for hundreds of dependent variables at hundreds of observational points (be they spatial, temporal, or random replicates). When assembled in its entirety, this meta-data set contains information that does not exist within the individual analyses. In-the-end, all of the stations and replicates are only surrogates for the environmental factors that regulate biological processes leading to the observed patterns of faunal composition. Therefore, measurements are made synoptically at locations or subsamples (replicates) are taken within a location so that a meta-data set can be created for the synthesis and integration of the overall study results.

4.2 Working Hypotheses and Station Selection

A sampling design is most effectively developed from a series of testable null hypotheses. The hypotheses are derived from the conceptual model which describes the current understanding of the system being observed (i.e., deep-sea communities). Hypotheses are then used to select stations so that the hypotheses are testable with sufficient power to detect differences in the dependent variables being measured (i.e., abundance, biomass, diversity, analyte concentrations, etc.). The null hypotheses were based on the current understanding of deep-sea benthic community structure and function and knowledge of the types of habitats that occur in the GOM.

The following characteristics are judged to represent a significant portion of the deep-sea GOM habitat and will be used to identify one area as being different from another:

1) water depth (transects perpendicular to isobaths);
2) geographic location - juxtaposition to the Mississippi River (east-west transects) and distance from shore;
3) physiographic position - in a basin, in a canyon, on an escarpment, and in a low relief area;
4) influx of organic carbon - primary productivity derived carbon, petroleum seep and chemosynthetic derived carbon;
5) energy level of the physical environment - high versus low bottom current velocity, juxtaposition to semi-permanent physical features (nitrocline, thermohalocline);
6) temporal changes -time series sampling; and
7) location of historical sampling sites.

The sampling design tests hypotheses rather than simply conducting a traditional geographic survey with closely spaced stations. This approach was adopted to establish

generalities about communities in the study area and because the area to be covered is so large that sampling everywhere is cost prohibitive. The hypothesis testing allows a prediction of when and where particular types of communities, both in terms of structure and function, will or will not be encountered. Hypothesis testing provides a powerful tool for either increasing or limiting sampling intensity in time and space as new data is collected and historical data is re-interpreted. Each hypothesis, as described below, explores mechanisms believed to explain much of the variation in community structure and function in the deep-sea GOM. Some mechanisms are well established, others are not.

Based on the above considerations the following kinds of contrasting environments or habitats were sampled for comparisons:

- Depth.

  - Water depth is probably the single most important gradient in determining faunal compositions and forcing factors in the study area (Hypothesis H_{O1}). Comparisons were made along a series of transects.

Stations: RW1-RW6, W1-W6, C1-C12, MT1-MT6, S35-S44 (Figures 4.1-4.3)

- Nutrients (organics)

  - The input of organic nutrients from Mississippi River discharge causes an east to west gradient in faunal compositions and forcing factors (Hypothesis H_{O2}). Comparisons were made along isobaths at similar distances from shore at varying distances from the Mississippi River.

Stations: RW1-RW6, C1-C12, S37-S42 (Figures 4.1-4.3)

- Basins.

  - The common mesoscale basins found on the slope, unless influenced by seeps, have the same faunal compositions and forcing factors as the "normal" slope because the entire slope is draped in a similar Holocene "blanket" of silt and clay within which the biological communities live (Hypothesis H_{O3}). Comparisons were made within and outside of basins at comparable water depths and distances from the Mississippi River and shore.

Stations: WC12, B1-B3, NB2-NB5 (Figure 4.4)

- Canyons.

- Faunal compositions and forcing factors are the same in or out of submarine canyons (Hypothesis H_{O4}). Comparisons were made between stations within and outside of canyons at comparable depths and distances from the Mississippi River and shore.

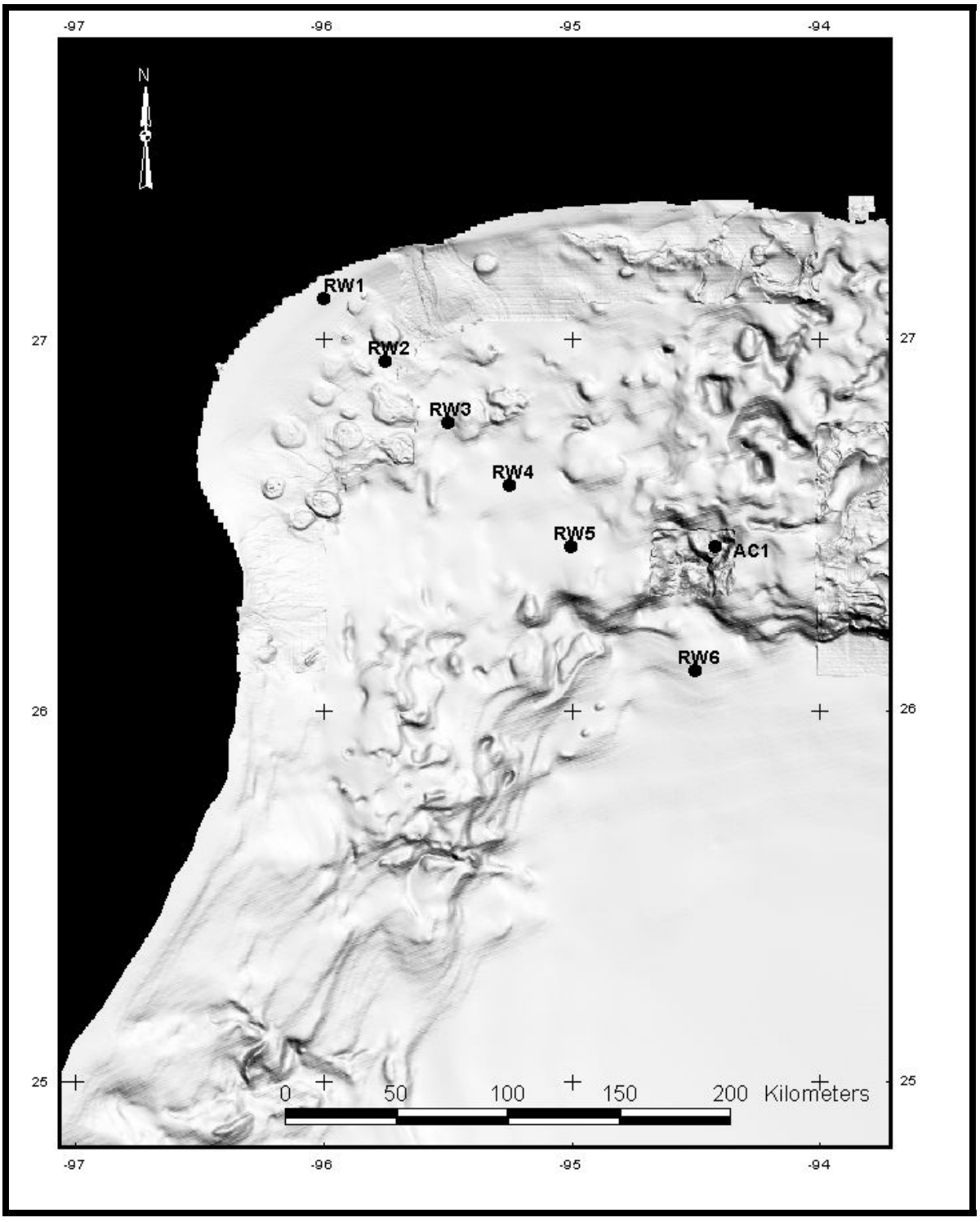

Figure 4.1. Benthic survey stations in the northwestern GOM (for regional context see map in Appendix I of survey cruise track).

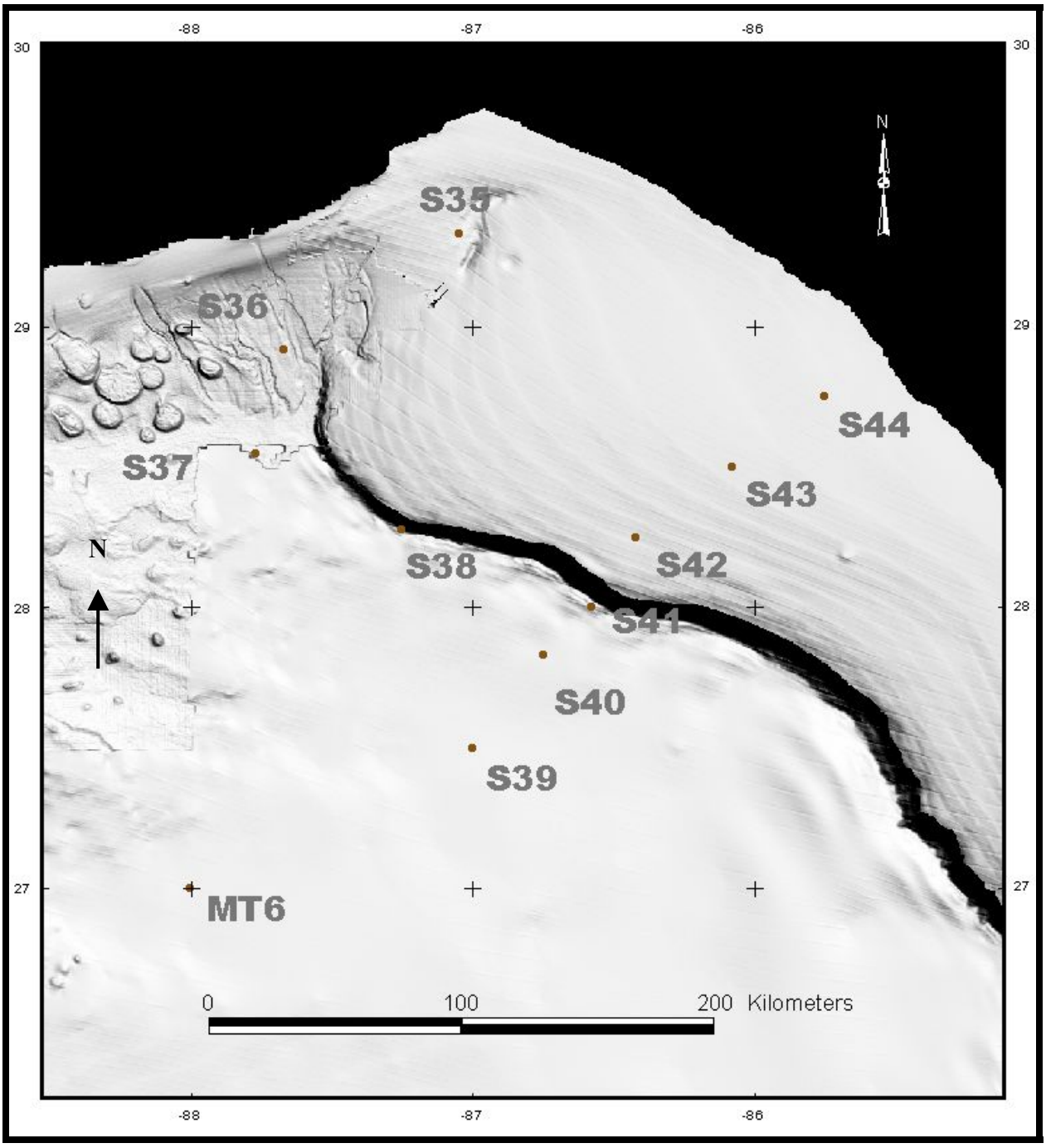

Figure 4.2. Benthic survey stations across the Florida Escarpment (for regional context see Figure 5.1).

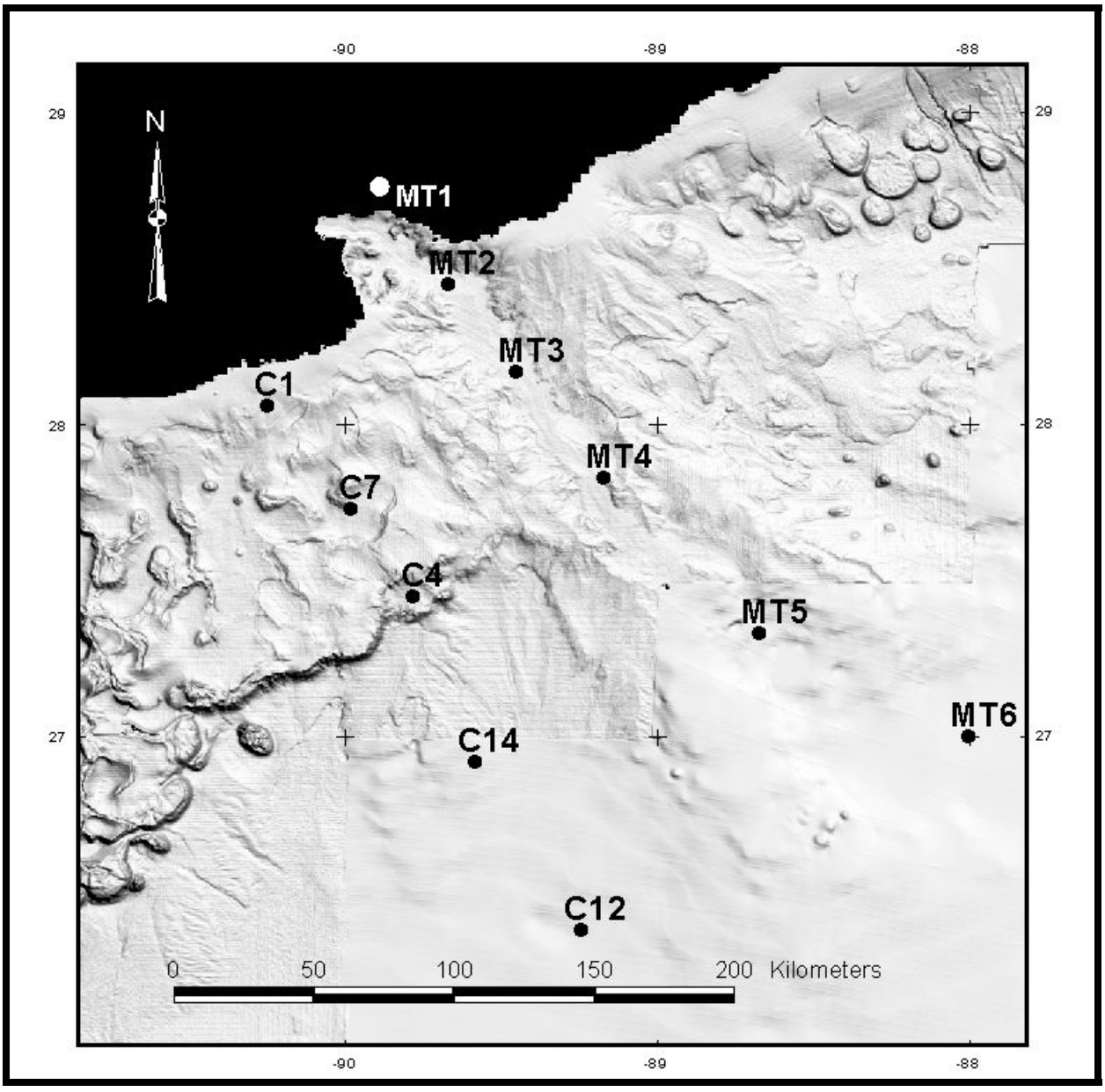

Figure 4.3. Benthic stations along the Mississippi Trough (MT1-MT6). Historical sites from the NGOMCS study are also included (C1-C14; for regional context see Figure 5.1).

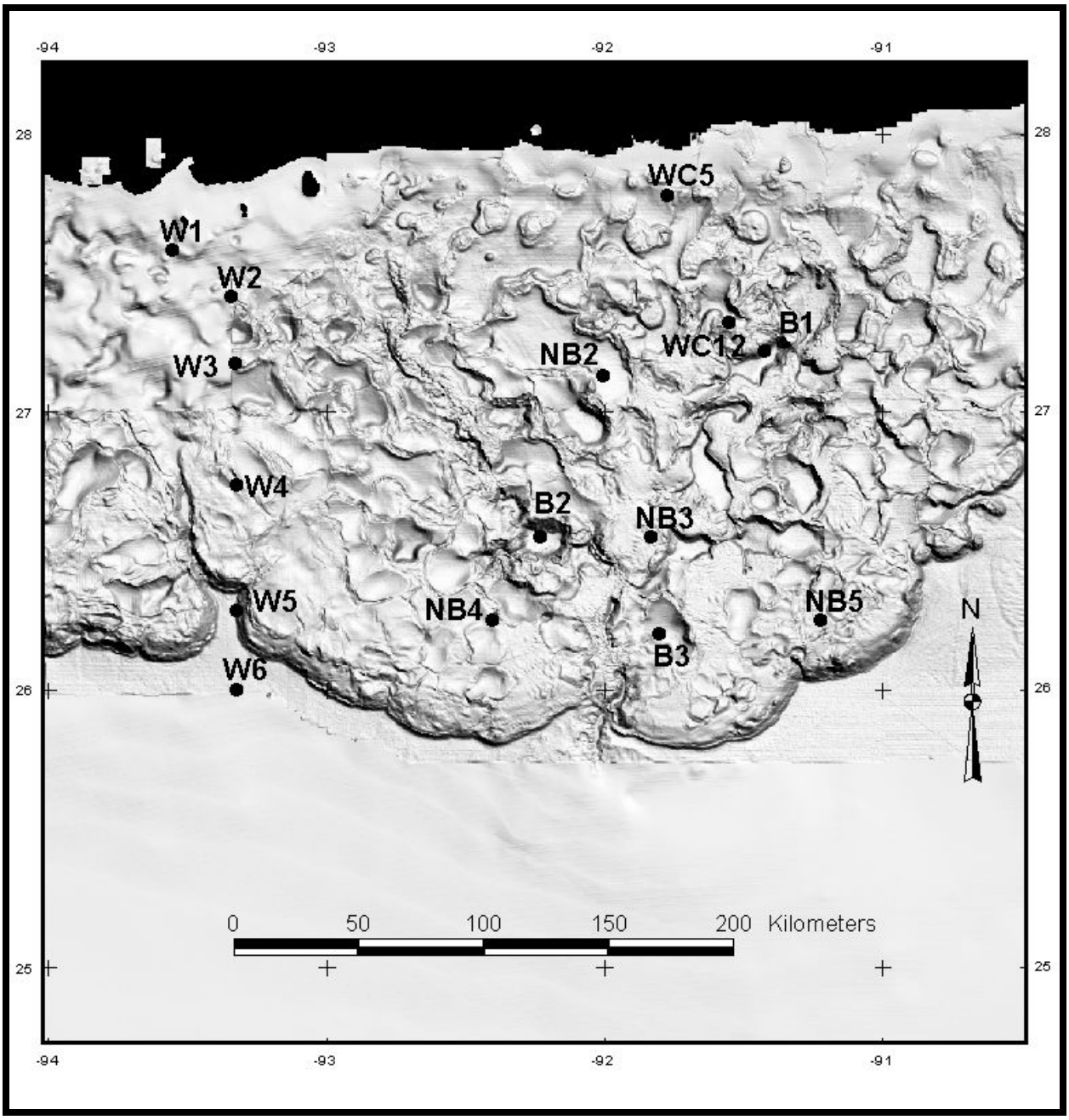

Figure 4.4. Physiographic settings for benthic survey stations in the Central GOM. Historical stations from the NGOMCS study are also included (W1-W6, WC-5, and WC-12; for regional context see Figure 5.1).

Stations: MT1-MT6, W5, W6, RW6 (Figures 4.1, 4.3, and 4.4)

- Steep Escarpments.

    - Faunal compositions and forcing factors are the same on the "normal" slope as they are at the base of the Sigsbee Escarpment (Hypothesis H_{O5}). Comparisons were made between stations on the slope and at the base of the Sigsbee escarpment at similar water depths.

Stations: S39-S42 (Figure 4.2)

- Productivity.

    - Cyclonic and anticyclonic features in the surface waters consistently alter surface primary productivity and this results in differing seafloor fauna compositions and forcing factors (Hypothesis H_{O6}). Comparisons were made between stations that underlie areas of historically documented differences in sea surface primary productivity, holding other variables as constant as possible.

Stations: RW1-RW6, S35-S36 (Figures 4.1 and 4.2)

- Hydrocarbon Seeps.

    - Hydrocarbon seeps have a major effect on energy and carbon supplies contributing to different faunal compositions and forcing factors (Hypothesis H_{O7}). This is tacitly true since chemosynthetic fauna are restricted to seep sites. Rather than a direct test, inputs of chemosynthetic carbon to the foodweb will be recognized by stable isotopic tracer studies. Data produced from the chemosynthetic community studies will also be contrasted with equivalent non-seep data. Explicit testing by paired stations will not be attempted. Questions of "how close is close" are still difficult to resolve even in studies concentrated at seep sites. The decision to address this question in a limited way is in recognition of the fact that the MMS is already supporting extensive studies at seep sites and that the primary focus of this program is non-seep environments.

- Temporal Changes.

    - Standing crops of benthic fauna vary with time (Hypothesis H_{O8}). Comparisons were made at a subset of survey stations sampled during each of the three planned cruise activities. In addition, to provide a longer timeframe for comparisons, historically sampled sites will be reoccupied. The intercomparibility of data between studies will be explicitly addressed to ensure whether inter- program comparisons are valid.

Stations: W1-W6, WC6, C1-C12 (Figures 4.3 and 4.4)

- The above comparisons have been translated into testable null hypotheses (Table 4.1). A critically important part of program design is selection of the most appropriate locations to conduct the measurement program to test the hypotheses. This is especially true for this program because the area to be characterized is large, the area contains a wide range of habitats and there are several important forcing factors that tend to confound delineation of cause and effect relationships. As summarized in the introductory materials, the northern GOM represents one of the most complex geological and oceanographic settings in the world. The challenge is to classify wide stretches of the slope into recognizable subregions that can then be sampled to test if the extant biological communities are different from area to area. Additional factors explicitly considered during the selection of proposed sampling sites include the location of historical sampling (to extend timeseries observations), the current and future trends in energy resource exploration and exploitation, and possible anthropogenic effects related to proximity to existing production facilities (primarily accommodated by screening all locations for contaminants). The study stations are explicitly tied to the hypothesis testing as listed above.

Table 4.1 Summary of benthic survey experimental design: null hypotheses, station selection criteria, number (No.) of stations (sta.), and number samples. The number of samples is based on five replicates per station.

Null Hypotheses	Design Criteria	No. Stations	No. Samples
H_{O1}: Variation in benthic fauna is explained by depth	3 Replicate transects over 7 depths; occupy historical stations and others	21	105
H_{O2}: Faunas exhibit an East to West gradient	Additional transect to H_{O1}; remove confounding geological effects and water mass effects	7	35
H_{O3}: Basin faunas are different from non-basin faunas	3 salt bottom and 3 salt surrounded basins	6	30
H_{O4}: Canyon fauna is different from slope fauna	4 Canyons to be compared to non-canyon and non-basin biota from H_{O1}-H_{O3}	8	40
H_{O5}: Fauna below escarpments different from slope	Add sta. below escarpment in addition to H_{O1}- H_{O4} in area of furrows	7	35
H_{O6}: Surface primary production explains faunal differences	Add sta. to (H_{O1}-H_{O2}) in "hot spot" defined by historical water column data	7	35
H_{O7}: Proximity to organic input causes bioenhancement	Add sta. in proximity to "geochemical anomalies" (hydrates, brine pools, methane seeps)	8	40
H_{O8}: No variation in benthic fauna over time.	6 stations (or other elements of the design, H_{O1} -H_{O7}) over 2 years	12	60

Survey stations were chosen to sample the broadest possible range of conditions at depths between 300 m and 3000 m and within the EEZ boundary with Mexico (see cruise track in Appendix I and Table 4.1). The site selection spans the range of known conditions providing the best tests of the hypotheses posed. Thus, sampling occurs along a transect just north of the Mexican border (RW1-RW6) over to one transect across the Florida escarpment (S37-S42; see Figures 4.2 and 4.3). This inclusive range of conditions enables us to gain an understanding of the whole GOM deep-sea benthos, rather than isolated parts. The smooth upper slope of the northern Florida slope is contrasted with the heterogeneous topography off Texas. A transect down the Mississippi Trough (MT1-MT6) provides a sampling of the effect of particulate and nutrient input from a large river (Figure 4.4). The basins on the upper slope can be categorized according to their structure and how they were formed, testing whether or not physiographic setting affects the biota (WC12, B1-B3, NB2-NB5; see Figure 4.4). Two locations at the upper end of the DeSoto Canyon (S36, S35) were chosen because one is frequented by whales and the other is characterized by high nitrate concentrations semi-permanently in the euphotic zone (see Figure 4.2).

Experimental, or "process" stations, will then be chosen to reflect the greatest range in community dynamics, as inferred from the benthic survey data. The survey site selection is based on inferences about where the greatest variations in community structure will be observed based on the model. The next step is to place the experimental stations where the greatest ranges in community structure are actually observed during the study. For example, a comparison of places with high and low total biomass will be important. Observations of processes, such as sulfate reduction or aerobic community respiration, will provide comparison of sites where biogeochemical cycling rates are different. Potential sites at mid-depths in the Mississippi Trough (C14, C12) are believed to experience high velocity current events below the Sigsbee Escarpment (Figure 4.4). The central line of the earlier slope study (C1, C7, C4, C14, C12) appears to be characterized by a seasonal signal in the biotic community (see Figure 4.4). If the statistical tests suggest that slope basins contain enhanced biomass, then rates of metabolic processes would be expected to be enhanced as well making a basin a candidate for an experimental site. Experiments designed to determine the causes of bioenhancement are considered to be important. The location of experimental stations must allow the community structure documented during the survey, guide site selection in the context of historical data. The type and placement of experimental stations will be carefully considered in consultation with the COTR and the SRB.

The first interim meeting in February 2001 was used to up-date the hypotheses based on Survey Cruise data, select sites to be repeated, add new sites to strengthen comparisons and identify sites for process studies. The process sites selected were MT3, S36, S42, and MT6. New sites to be added were in the furrows below Green Knoll on the top of Green Knoll, a site between the Mississippi Trough and the DeSoto Canyon, and hear the Bush Hill seep. See Section 5.3 for a discussion of the new sites.

4.3 Dependent and Independent Variables

Based on the various hypotheses described in the previous section, a series of dependent and independent variables were chosen that will provide the set of observations at each station to test the validity of the null hypotheses. Variable selection was based on a knowledge of the

system being observed, a current understanding of how the system functions, and an estimate of the relative importance of forcing factors as described in the conceptual model (see Section 4.0).

The set of variables measured at the survey stations are organized around the characteristics that define the system including physiographic setting, time, water masses, geographic location, abiotic and biotic water column properties, sediment properties, chemical contaminants in sediments, indicators of biogeochemical processes, community structure, and community function (Tables 4.2 to 4.4). These variables also quantify stocks and processes for input to the model.

4.4 Statistical Analyses

Statistical analyses to test for differences among treatment means are performed using parametric, general linear models. Prior to analysis, data are transformed, generally by natural logarithm, to achieve homogeneity of error variance, normality of residual errors, and additivity of effects. A data set of residual errors is created for each model and tested for normality. Both untransformed and transformed residuals are computed, and the datasets that are normally distributed with means of zero are used for analyses.

The models that follow describe the relationships among the independent design variables only. The measured dependent variables are described in the methods sections. The notation used follows conventions described by Kirk (1982).

4.4.1 Univariate Analyses

Univariate analyses will be used to test each hypothesis based on the following models. The stations to be used to test each hypothesis are summarized in Table 4.2.

The first two hypotheses are as follows:

***H_{O1}*: There is no variation in benthic fauna with depth, and**
***H_{O2}*: There is no difference in fauna along an east to west gradient.**

The effect of depth is tested with stations along transects. Multiple transects were necessary to replicate at the treatment level. Transects should also hold constant nuisance variables such differences in circulation, bottom complexity, or other physical factors. The effect of longitude is tested with stations on an east - west gradient along isobaths, so this design tests two major hypotheses. The experiment is a two-way completely random factorial analysis of variance (ANOVA) that is described by the following model:

$$Y_{ijk} = \mu + \alpha_j + \beta_k + \alpha\beta_{jk} + \in_{i(jk)}$$

where Y_{ijk} is the measurement for each individual replicate, μ is the overall sample mean, α_j is the main effect for transects and j=1-4, β_k is the main effect for depths and k=1-7 (300, 750, 1200, 1650, 2100, 2550, and 3000 m), $\alpha\beta_{jk}$, is an interaction term, and $\in_{i(jk)}$ is the random error for each replicate measurement and i=1-5.

Table 4.2. Independent variables fixed by the sampling plan design.

Physiographic Characteristics
Water Depth
Basins underlain by salt
Basins surrounded by salt
Basins subjected to slumping/erosion
Basins overlain by an undisturbed drape of Holocene silt and clay
Canyons
Escarpments
Proximity to seeps
Basin slope angle

Time
Months
Years

Water Masses
Loop Current
Consistently "cool" water between eddies
Warm eddies

Geographic Location
East vs West
Distance from shore

Table 4.3. Dependent variables to be measured.

Community Structure

Bacterial density	Macrofaunal species composition
Bacterial biomass	Megafaunal density
Foraminiferal biomass	Megafaunal biomass
Meiofaunal density	Megafaunal diversity
Meiofaunal biomass	Megafaunal species composition
Meiofaunal composition to major group	Fish density
Macrofaunal density	Fish biomass
Macrofaunal biomass	Fish diversity
Macrofaunal diversity	Fish species composition

Community Function

Bacteria growth rates	Fish respiration[1]
Bacteria respiration	Fish predation on megafauna[2]
Bacteria response to different substrates	Fish scavenging on carcasses[2]
Foraminiferal respiration[1]	Nutrient Regeneration
Foraminiferal feeding rates[1]	Denitrification rate
Meiofaunal respiration[1]	Sediment mixing rates (bioturbation)[2]
Meiofaunal feeding rates on bacteria	Sediment accumulation rate[2]
Macrofaunal respiration[1]	Sedimentary community oxygen consumption
Macrofauna growth rates[2]	Sulfate reduction rate
Macrofauna predation rates[2]	Foodweb studies
Macrofauna predation rates on meiofauna, bacteria, and organic matter	
Megafaunal respiration rates[2]	
Megafaunal predation rate on megafauna, meiofauna, bacteria, and organic matter[2]	
Megafaunal scavenging on carcasses[2]	

1-calculated based on size and temperature
2-estimated from sub-model

Table 4.4. Ancillary variables to be measured at Survey and Experimental Stations.

Water Column Profiles

- Depth
- Temperature
- Salinity
- Oxygen
- Nitrate and Nitrite
- Ammonium
- Silicate
- Phosphate
- Particulate Matter (PM)
- Particulate Organic Carbon (POC)
- Light
- Currents

Biotic Water Column Profile

- Photosynthetic Pigments
- Primary Production

Chemical Contaminants

- Hydrocarbons
- Metals

Sediment Properties

- Grain Size
- Porosity
- Elemental composition (organic carbon, nitrogen, sulfur)
- Percent inorganic carbon (TIC)
- Permeability
- Shear Strength
- Bulk Density

Geochemistry[1]

- Nutrients
- Dissolved Organic Carbon (DOC)
- $SO_4^{=}$/Cl-
- Dissolved Inorganic Carbon (DIC)
- $\delta^{13}C$ DIC
- Sulfate Reduction Rate
- pH
- H_2S
- O_2
- Reactive Fe
- Reactive Mn
- Acid Volatile Sulfide

[1]Composite sample at survey station, profiles for fluxes at experimental station.

The third hypothesis is:

***H_{O3}*: There is no difference between basin fauna and non-basin fauna.**

Geological complexity exists in the northern GOM. One expression of this complexity is basins. Basins may cause changes in current flow such that water masses are altered as they pass across the mouth of the basin or impact a sill. This could affect benthos. One station within a basin will be paired with two nearby stations already sampled for H_{O1} and H_{O2} above to test for basin effects. Station pairing is necessary to control for distance from shore and depth. For example, a station selected for H_{O1}/H_{O2} at 1200 m may have a nearby basin at 1650 m, so stations generally distant from shore and in the same water depth would be compared against the basin stations. The entire experiment is replicated at 6 different sites, so each location is a blocking effect. The experiment is a two-way completely random factorial ANOVA that is described by the following model:

$$Y_{ijk} = \mu + \alpha_j + \beta_k + \alpha\beta_{jk} + \in_{i(jk)}$$

where Y_{ijk} is the measurement for each individual replicate, μ is the overall sample mean, α_j is the main effect for replicate sites and j=1-6, β_k is the main effect for treatments and k=1-3 (basin,

non-basin same distance from shore, and non-basin same depth), $\alpha\beta_{jk}$, is an interaction term, and $\in_{i(jk)}$ is the random error for each replicate measurement and *i*=1-5. Differences between sites are not of interest because they replicate the basin effect, so it doesn't matter if that test is significant. The main test of interest is a multiple comparison tests among treatment levels if there is a significant difference among treatments.

The fourth hypothesis is:

***H_{O4}*: There is no difference between canyon fauna and non-canyon fauna.**

Another form of geological complexity in the GOM is canyons. Often sediment slumping occurs in canyons in addition to alteration in near-bottom current patterns. One station within a canyon will be paired with nearby stations at similar depths that are not in a canyon. The entire experiment is replicated at four (4) different sites. The experiment is a two-way completely random factorial ANOVA that is described by the following model:

$$Y_{ijk} = \mu + \alpha_j + \beta_k + \alpha\beta_{jk} + \in_{i(jk)}$$

where Y_{ijk} is the measurement for each individual replicate, μ is the overall sample mean, α_j is the main effect for replicate sites and *j*=1-4, β_k is the main effect for treatments and *k*=1-2 (canyon and non-canyon), $\alpha\beta_{jk}$, is an interaction term, and $\in_{i(jk)}$ is the random error for each replicate measurement and *i*=1-5.

The fifth hypothesis is:

***H_{O5}*: There is no difference between escarpment fauna and non-escarpment fauna.**

Another form of geological complexity in the GOM is escarpments. These steep walls may be different from more gently sloping areas. One station adjacent to the base of an escarpment will be paired with nearby stations at a similar depth that are not adjacent to an escarpment. The entire experiment is replicated at 7 different sites. The sites will be chosen based on pairing stations with samples already taken to test H_{O1}-H_{O5}. The experiment is a two-way completely random factorial ANOVA that is described by the following model:

$$Y_{ijk} = \mu + \alpha_j + \beta_k + \alpha\beta_{jk} + \in_{i(jk)}$$

where Y_{ijk} is the measurement for each individual replicate, μ is the overall sample mean, α_j is the main effect for replicate sites and *j*=1-7, β_k is the main effect for treatments and *k*=1-2 (escarpment and non-escarpment), $\alpha\beta_{jk}$, is an interaction term, and $\in_{i(jk)}$ is the random error for each replicate measurement and *i*=1-5. Depending on exact location of samples, this design may be altered to take into account distance from shore. In that case, the same model as that used for basins (H_{O3}) will be used.

The sixth hypothesis is:

***H_{O6}*: There are no differences in benthos in areas with different amounts of water column primary production.**

The sites will be chosen based on pairing stations with samples already taken to test H_{O1}-H_{O5}. The design is nested as a completely random hierarchical design described by the model:

$$Y_{ijk} = \mu + \alpha_j + \beta_{k(j)} + \in_{i(jk)},$$

where: μ = overall sample mean, α_j = main effect of treatments and j=1-3 (high, medium, and low productivity), $\alpha_{k(j)}$ = nested effect for replicate stations and k =1-7, and $\in_{i(jk)}$ is the random error for each replicate measurement and i=1-5. The appropriate F-test for treatments is to use the mean square error for stations as the denominator. Another approach to analyze this design is analysis of covariance, where actual values indicating primary production (e.g., measured values or chlorophyll standing stock) are used as covariates.

The seventh hypothesis is:

***H_{O7}*: There is no difference in benthic fauna near and far from seeps.**

Another form of geological complexity in the GOM is organic and inorganic inputs in geochemically anomalous environments, e.g., hydrocarbon or brine seeps. Eight (8) stations are added to pair with existing non-seep stations. The station pairs will be in 4 site regions. The sites will be chosen based on pairing stations with samples already taken to test hypotheses H_{O1}-H_{O6}. The experiment is a two-way completely random factorial ANOVA that is described by the following model:

$$Y_{ijk} = \mu + \alpha_j + \beta_k + \alpha\beta_{jk} + \in_{i(jk)}$$

where Y_{ijk} is the measurement for each individual replicate, μ is the overall sample mean, α_j is the main effect for replicate sites and j=1-4, α_k is the main effect for treatments and k=1-4 (brine seep, hydrocarbon seep, control for distance from shore, control for depth), $\alpha\beta_{jk}$, is an interaction term, and $\in_{i(jk)}$ is the random error for each replicate measurement and i=1-5. Differences between sites are not of interest because they are replicating seep effects, so it doesn't matter if that test is significant. The main test of interest is a multiple comparison test among treatment levels if there is a significant difference among treatments.

The eighth hypothesis is:

***H_{O8}*: There are no differences in benthic fauna among different sampling dates.**

Six of the stations sampled for H_{O1}-H_{O7} will be chosen for reoccupation in years 2 and 3 so that there will be a time series for at least 3 years. In addition, attempts will be made to include several stations that were occupied in previous studies, extending the time series to 5 or 6 sampling periods. Assuming depth and site (i.e., east-west) gradients, these two factors must be incorporated into the design. The experiment is a three-way completely random factorial ANOVA that can be described by the following model:

$$Y_{ijkl} = \mu + \alpha_j + \beta_k + \alpha\beta_{jk} + \gamma_l + \alpha\gamma_{jl} + \beta\gamma_{kl} + \alpha\beta\gamma_{jkl} + \in_{i(jkl)}$$

where Y_{ijkl} is the measurement for each individual replicate, μ is the overall sample mean, α_j is the main effect for sampling periods and j=1-3, β_k is the main effect for sites and k=1-2, γ_l is the main effect term for depths and l=1-3 (shallow, mid-depth, deep), $\alpha\beta_{jk}$, $\alpha\gamma_{jl}$, $\beta\gamma_{kl}$, and $\alpha\beta\gamma_{jkl}$ are interaction terms, and $\in_{i(jkl)}$ is the random error for each replicate measurement and i=1-5.

Hypotheses will be re-evaluated as data is collected and recast as needed. Year II and III will provide the opportunity to collect additional new survey station if needed to infill the dataset to increase the power of statistical tests.

4.4.2 Power Analysis

Power analysis is performed to determine the detectable change in the population at a given power (1−β) and sample size (n) Power is calculated by:

$$\Delta = \frac{(t_\alpha + t_\beta)\, x\, SD\, x \sqrt{\frac{2}{n}}}{\overline{X}}$$

where Δ is the percent change in the population, SD is the pooled standard deviation, t_α and t_β are tabled values for a two-tailed test assuming a pooled estimate of variance from a large sample size, and $\overline{X}$ is the sample mean. Values of α=0.05, and powers of 0.95, 0.80, 0.50 were used in the analysis.

4.4.3 Multivariate Analyses

A meta-analysis (or synthesis) will be performed at the end of the study. The goal of the synthesis is to merge all data sets of response variables to create one large data set. All the ANOVA's listed above can be analyzed in multivariate mode (MANOVA) to test the null hypothesis that the vector of population means equals zero. Without the jargon, test to find out if all measured variables respond to the dependent variables in the design in a similar fashion. The advantage of MANOVA is that multivariate error is controlled. That is, error rates are controlled at α across all response variables.

Once the meta-data set is assembled other questions can be queried. It can be tested if benthic fauna respond to abiotic environmental factors and which factors control distributions of responses. As stated previously, all stations and replicates are simply surrogates for the environmental factors that regulate biological processes at different scales. These scales vary greatly from small- (replicate boxcores), meso- (across transects, basins, or nearby stations) to large- (across the entire GOM). In addition, there is a temporal scale to the variation in all measurements. Multivariate analysis can be used to test the meta-data set for correlation or covariation among the independent variables that are measured. Two multivariate techniques will be employed: a parametric method (principal components analysis, PCA), and a non-parametric methods (multidimensional scaling, MDS).

Multidimensional scaling is a non-parametric multivariate technique for examining similarity or dissimilarity between stations, replicates, or other dependent variables in the experimental design. First, a similarity or dissimilarity index is computed for elements of the design (e.g., stations) and then a plot of the distance among points is created. The plot enables us to identify unknown variables that affect the similarity or dissimilarity between stations. Because

the MDS procedure is based on non-parametric (Kruskal-Wallis like) models, it is very popular among European benthic ecologists, but has rarely been used among American benthic ecologists. It is most useful to summarize biotic data (e.g., community structure), but new variables are not created, nor can one reduce the variables in a dataset.

Principal components analysis is a parametric variable reducing technique that makes a new set of uncorrelated variables in order of decreasing variance. Analysis of abiotic variables can be used to summarize the co-varying environmental influences on different levels of replications, i.e., different spatial and temporal scales. Factor loading scores are generated for abiotic summaries of observations (rows), which can be used in other analyses. For example, during GOOMEX several hundred environmental variables were reduced with PCA and the new PCA scores were shown to correlate with average macrofauna and meiofauna abundance and toxic responses. This allowed us to detect subtle sub-lethal effects within 100 m of platforms that could not be detected with univariate analysis of variance (Green and Montagna 1996). Also, the methods demonstrated functional responses of benthic fauna to abiotic variables, while separating confounding influences in the study related to differences in the natural background in which platforms were located. The same approach will be used in the deep-sea study to provide an understanding on how environmental influences regulate benthic communities.

4.5 Revision of Taxonomic Level of Analysis

Analysis of benthic infaunal communities has been widely used in environmental assessment and monitoring studies. The use of species level data is powerful, but expensive due to the level of expertise and labor intensive effort required. This has inspired efforts to determine if species level data is really necessary. For both meiofauna and macrofauna, a promising prospect is identification to only the suborder or family level. At the Group of Experts on Effects of Pollutants (GEEP) workshop, all levels of biological organization were studied from the molecular to the community, and all biological components from bacteria to macrofauna were included in both mesocosm and field experiments (Bayne et al. 1988). In the GEEP field study, diversity indices did not detect the pollution gradient, but community structure differences were distinct and species level data gave no more information for discrimination than did nematode suborder or harpacticoid family groupings (Heip et al. 1988). Macrofauna family groupings also were just as good for distinguishing the pollution gradient as was species level data (Warwick 1988). Higher level identifications were found to be just as good as species identifications to detect pollution gradients in the Southern California Bight (Ferraro and Cole 1990). During the GOOMEX study around Gulf of Mexico production platforms, it was not sufficient to analyze at the family level for either meiofauna or macrofauna to describe differences among platforms or distances from platforms (Montagna and Harper 1996). LGL data and Year I sampling data will be reanalyzed at both species and family levels to determine if a reduction in taxonomic effort is adequate to characterize communities in different environmental settings.

5.0 THE FIELD PROGRAM

The Field Program was designed to collect a range of discrete samples and deploy continuous measuring sensors at a large number of stations in the northern GOM. The Field Program includes three cruises in each of the first three years of the program. The first cruise concentrated on the benthic survey objectives of the program and the following two cruises will be a mixture of survey and experimental stations. The survey field effort (Cruise I) included boxcoring, trawling, photosurveys, and hydrocasts. Experimental stations (Cruises II and III) will include a variety of specialized sampling efforts designed to identify important processes and forcing factors at a limited number of selected survey stations.

In brief, the cruises and their objectives for the first two field seasons are as follows:

Cruise 1: Ship - *R/V Gyre*; Chief Scientist - Dr. Gil Rowe; Conducted May 3 to June 21, 2000. The cruise report is attached as Appendix I.

Cruise 2: Ship - *R/V Gyre*; Chief Scientist - Dr. Gil Rowe; Schedule - June, 2001; Duration 20 days; Activities - 12 survey stations (60 boxcores, 12 trawls, 12 CTD/hydrocasts, 12 photosurveys) and 4 experimental stations (20 boxcores, 4 trawls, 4 CTD/hydrocasts, 4 photosurveys, 4 ADCP casts, microbiological process studies, 4 benthic lander deployments, 4 pore water and solids geochemical studies, 4 stable isotope food web collections, and 4 specialized biological/ecological studies), Staffing - 23 scientists, students and observers.

The details of the field and laboratory methods are provided in Sections 6.0 and 7.0.

5.1 The Ship

A critical factor in ensuring the successful completion of the field program is selection of a ship of the proper size and capabilities to conduct the required sample and data collection activities in the deep-sea. The ship must accommodate a scientific party of adequate size to accomplish the sample collection and processing plan. In addition, adequate laboratories, deck handling equipment and electronics and workshop facilities must be available to support the field operations and to respond to any adverse conditions or equipment breakdowns encountered in the field. The chosen ship, the *R/V Gyre*, is owned by Texas A&M University and operated by the Department of Oceanography of Texas A&M University. The homeport of the *Gyre* is at the Texas A&M University at Galveston Pelican Island campus. The shore support facility is equipped to assist in mobilization and demobilization of cruises and includes a port administrative staff, a dock area, and a warehouse/machine shop complex. Several forklifts and a mobile crane are available at the water front for handling equipment.

The *R/V Gyre* was built for the US Navy by Halter Marine Services of New Orleans, LA. The ship was launched in mid-1973 and began research operations in early 1974. The vessel was extensively remodeled in 1980-1984 with the addition of a new deckhouse. The *Gyre* is a general-purpose, open-ocean research vessel. The deck plans and diagrams of the ship can be accessed at the ships URL:

http://www.ocean.tamu.edu/Cruise/plns.html

5.2 Cruise I - Survey (Figure 5.1; Table 5.1)

Cruise I was devoted to a survey of deep-sea communities of the northern GOM. Each standard survey station consisted of the following activities:

A. One (1) CTD: The CTD was deployed with the starboard hydrowinch using conductor cable (the CTD remains attached to the conducting cable for the entire cruise, unless problems are encountered);

B. Five (5) Boxcores: The boxcore was deployed with the hydraulic winch on the non-conducting cable. A pinger was attached to the wire above the boxcore at depths of 1 km and greater. Otherwise wire out and tension was adequate to determine bottom contact.

C. One (1) Camera Lowering: The camera system was deployed with the non-conducting cable on the starboard hydrowinch. A pinger was attached to the frame to determine bottom contact and distance to the bottom. The camer takes up to 50 exposures.

D. One (1) Bottom Trawl: The otter trawl was deployed with the heavy-duty winch on the fantail.

The shipboard scientific crew operated on watches of 12 hours on and 12 hours off. Between stations, the trawl samples were sorted to species and fixed in jars by those assigned to trawling. The five sievers on watch fixed and bottled the material and then assisted with the trawl sorting, displacement volume measurements (for biomass), preservation and labeling. Shipboard marine technicians analyzed samples for oxygen, nutrients, and salinities between stations.

Each watch was assigned a "watch chief" (Clif Nunnally and Chris Gudeman) who had the duty of keeping records, notifying the Chief Scientist when problems arose, notifying the watch when the ship was on station, waking the new watch at the appropriate hour, and notifying the bridge when station activities were completed. The watch chief maintained a log in the main laboratory on the main deck that documented each activity in chronological order. Comments on the success or failure of the activity and inventory of all samples taken were kept. The watch chief and assistant ensured that the station logs on the bridge agreed with those in the laboratory. Each "watch chief" reported directly to the Chief Scientist. The "watch chief" communicated between the bridge and scientists on the deck.

5.3 Cruise II - Processes (Figure 5.2)

Plans for the first processes cruise were made during the first interim meeting in February 2001. The plans were made on the basis of findings to date. Extremes of high and low densities in bacteria, meio- and macrofauna were used for selection criteria. The sites chosen were MT3, S35, S42, and MT6. High densities characterized MT3 and S36 at 1000 and 1850 m depth in the Mississippi and DeSoto Caynons, whereas low densities were found at S42 and MT6 at 750 and 2750 m depth.

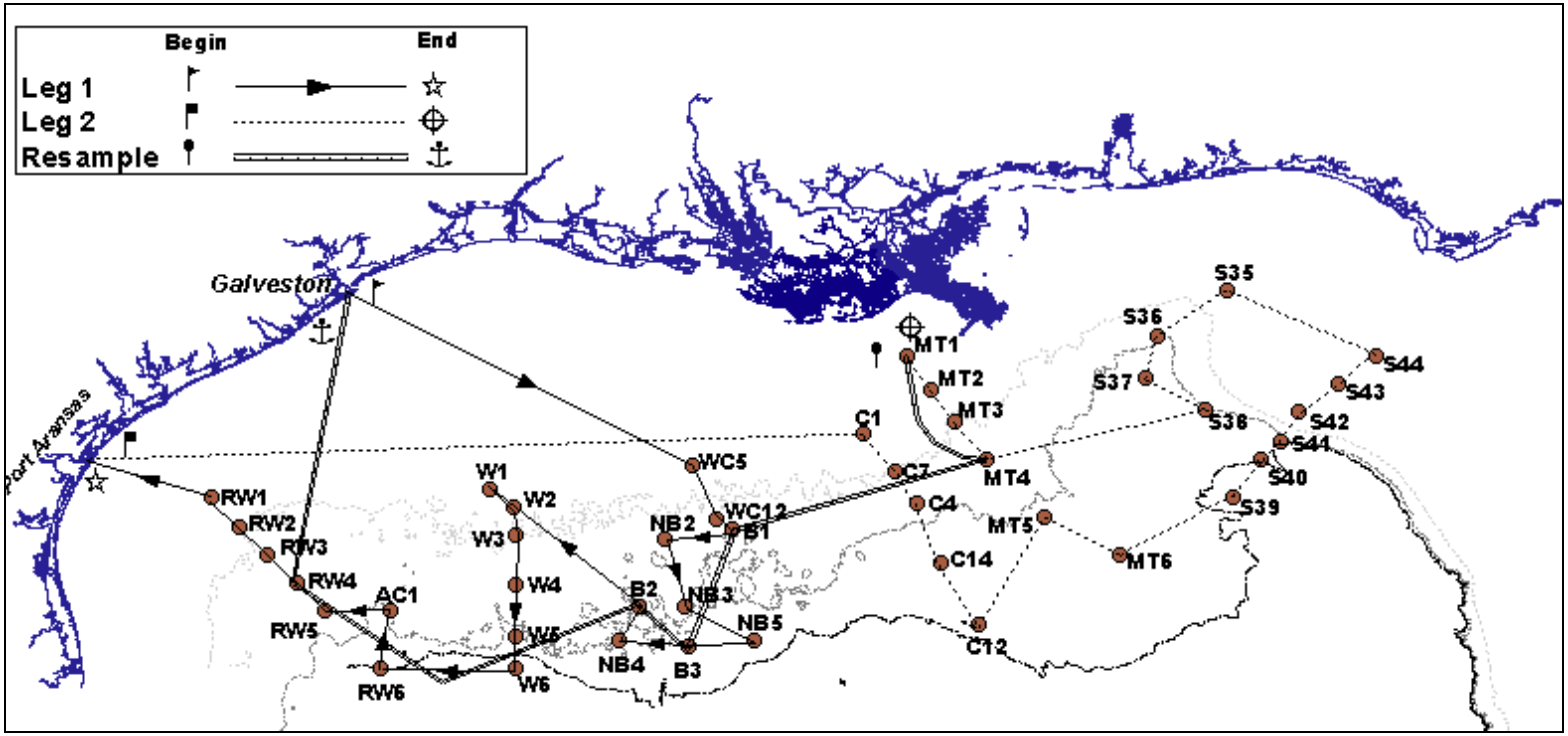

Figure 5.1. Benthic survey stations for Cruise I, May and June, 2000.

Table 5.1. Summary of sampling conducted during Cruise I.

Station	Trawl	Boxcore	Camera	CTD
RW1	1	5	1	1
RW2	1	5	1	1
RW3	0	5	1	1
RW4	0	5	1	1
RW5	0	5	1	1
RW6	1	5	0	1
AC1	0	5	1	2
W6	1	5	1	1
W5	0	5	1	1
W4	0	5	0	1
W3	1	5	1	1
W2	0	5	1	1
W1	1	5	1	1
WC5	1	5	1	1
WC12	0	5	1	1
B1	1	5	1	1
NB2	1	5	1	1
NB3	1	5	1	1
B2	3	5	1	1
NB4	1	5	0	2
B3	1	5	1	0
NB5	1	5	1	1
C12	1	4	1	1
C14	1	5	1	1
C4	1	5	1	1
C7	1	5	1	1
C1	1	5	1	1
S36	1	5	1	1
S37	1	5	1	1
S38	1	5	1	1
S35	1	5	1	1
S44	1	5	1	1
S43	1	5	1	1
S42	1	5	1	1
S41	1	5	1	1
S40	1	5	1	1
S39	1	5	1	1
MT6	1	5	1	1
MT5	1	5	1	1
MT4	1	5	1	1
MT3	1	5	1	1
MT2	1	5	1	1
MT1	1	5	1	1

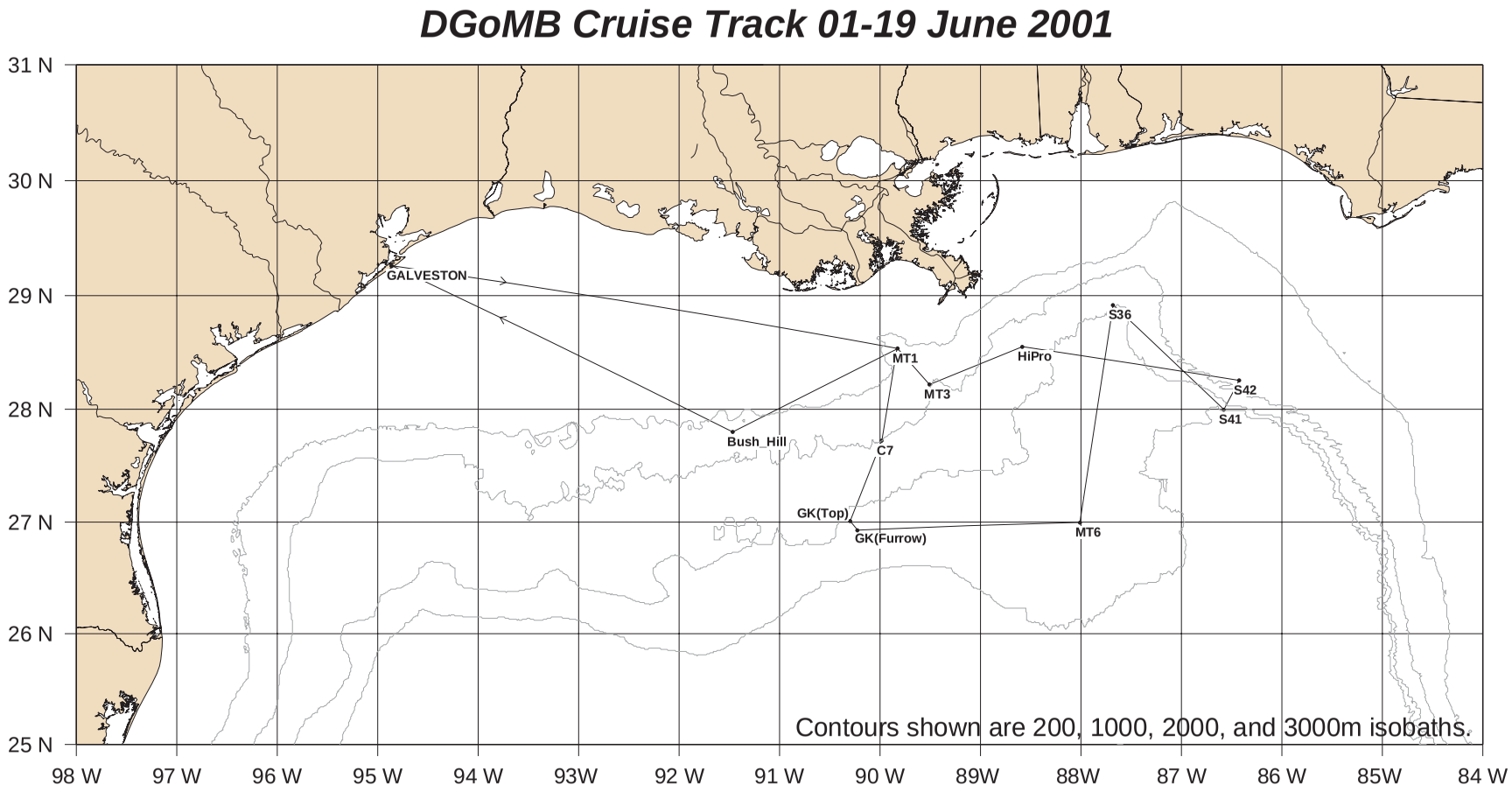

Figure 5.2. Sampling sites during Cruise II, the first "processes" cruise, June 1-19, 2001. Sites MT3, S36, S42, and MT6 were designated as experimental sits.

Other sites chosen for repeating were MT1 (Ho4-canyon), C7 (Ho8-time), and S41 (Ho5-escarpments). New sites added were "HIPRO" (Ho6-surface productivity), "furrows" (Ho9-effects of furrows), "Green Knoll" (Ho10-positive topographic anomalies), "Bush Hill" (Ho7-seeps), and "Fe Stone" (Ho11-iron crust).

Eleven sites were occupied during Cruise 2 (Processes; Figure 5.2). The lander was used successfully at S42 and MT3, providing estimates of total community respiration rates measured *in situ*. Shipboard incubations were made of total community oxygen uptake, sulfate reduction, thymidine incorporation into bacteria and bacteria grazing by meiofauna at four sites: MT3, S36, S42, and MT6. The experiments and the survey samples are being worked up at this time. Some of the preliminary findings will be presented at the annual Information Transfer Meeting (ITM), the Second Team Planning Meeting, and the Second Interim Report.

5.4 Third Year Field Activities

After the initial draft of this report, the original field work plan was altered. The original plan called for a single cruise of 20 days in June 2002. The new plan calls for two principal trips of 15 days each in June and August 2002. These will be into the Mexican EEZ on the Sigsbee Deep abyssal plain at depths of 3400 to 3650 m. The locations have been chosen on the basis of negotiation with collaborating Mexican scientists (Figure 5.3).

The first of the two will emphasize processes with use of the lander, ADCP mooring, and baited trap/camera array. Although the usual survey site sampling will be conducted to supplement and fill in the sampling, the survey activities will be emphasized on the August trip. Likewise, if any of the process or experimental measurements were missed, due to equpiment failture, weather, etc., they they will have the opportunity to be inserted into the latter field program. Both these trips will work principally in deep water.

In addition to this deep work, two short shallow trips will be made on transits from other work in the eastern gulf back to Galveston. These will allow sampling at those sites that have particularly rich biological communities. Placing them earlier in the overall schedule enhances our ability to stay on schedule. This allows us to take winter/spring samples of locations that are suspected to vary seasonally. The opportunity will also be taken to make up a lander site missed on Cruise II (site S36).

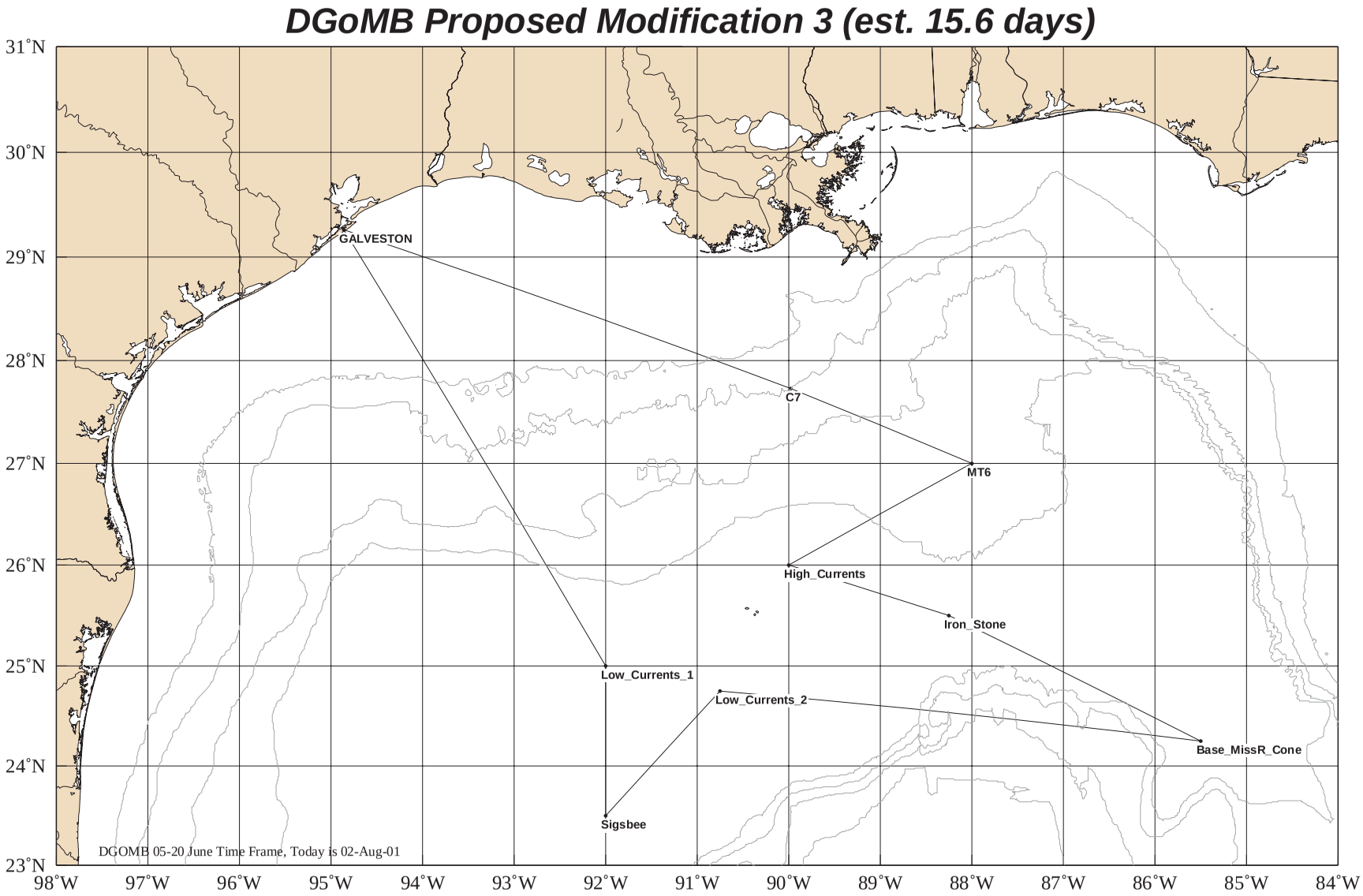

Figure 5.3. Proposed locations for two remaining cruises into the Mexican EEZ, June and August 2002.

6.0 FIELD METHODS

The Field Program is designed to collect a range of observations at survey and experimental stations. Survey stations are characterized by measuring a set of biological, chemical, sedimentological, hydrographic, and oceanographic variables. Samples and data are collected from the sediments, at the sediment-water interface, and in the overlying water column. At experimental sites, all standard survey variables are measured but in addition, fluxes are being measured to provide information about rates of metabolic processes.

6.1 Standard Sampling Techniques

As mentioned above several standard techniques such as coring, trawling, photosurveys, and hydrocasts are the techniques of choice to collect various types of samples and data.

6.1.1 Boxcoring

A 0.2 m^2 GOMEX or Gray-O'Hara boxcore (Boland and Rowe 1991) was used for the sampling on the Survey Cruise. Original plans called for the use of a USNEL Spade Corer outfitted with "vegematic" inserts. A comparison of sampling effiency prompted the boxcoring team to switch devices. Instead of the vegematic inserts, the boxcore was equipped with a cross bar onto which core liners of various diameters and lengths could be attached conveniently with hose clamps. Routinely the boxcoring team attached six (6) such subcores to the cross member. On return to the surface, caps were placed on the tops of the core liners to prevent contamination. Surface water was siphoned off through a 300 micron sieve. Then the surface 15 cm of sediment was removed for sieving for macrofauna. Once this surficial 15 cm was removed, the individual subcores were capped on the bottom, the hose clamps were opened, and the core liners were removed. Excess mud on the liners was washed through the 300 micron sieves to prevent loss of macrofauna.

The six subcores were used for meiofauna, bacteria, geology, geochemistry, and contaminants. All six subcores were taken on all five boxcore replicates at each station. The original proposal called for mixing these into a single sample for analysis of each of the variables. It was decided not to mix the samples but to initially analyze a single replicate and to archive the other cores. In that way, if odd or interesting values are observed in the single replicate, the whole suite of replicates from the other cores at each site are available for further measurements (Figure 6.1).

6.1.2 Trawling

Megafaunal invertebrates and fishes sampled were with bottom trawling, and bottom photography. Trawling was conducted using a 40' otter trawl with 2.5" stretch mesh. These types of trawls have been extensively employed during similar studies (Haedrich and Rowe 1977; Haedrich et al. 1975, 1980). Steel doors or conventional 7' x 14' wooden doors were used on a single warp (shrimp trawlers use a double warp with two wires). The trawl is lowered at a rate of 25 m of wire/minute. When the trawl is on the bottom, the vessel increases speed parallel to the isobaths (or into the wind or surface current, if this is required to control the vessel's position relative to the wire and its angle with the surface) up to a speed of approximately three to four

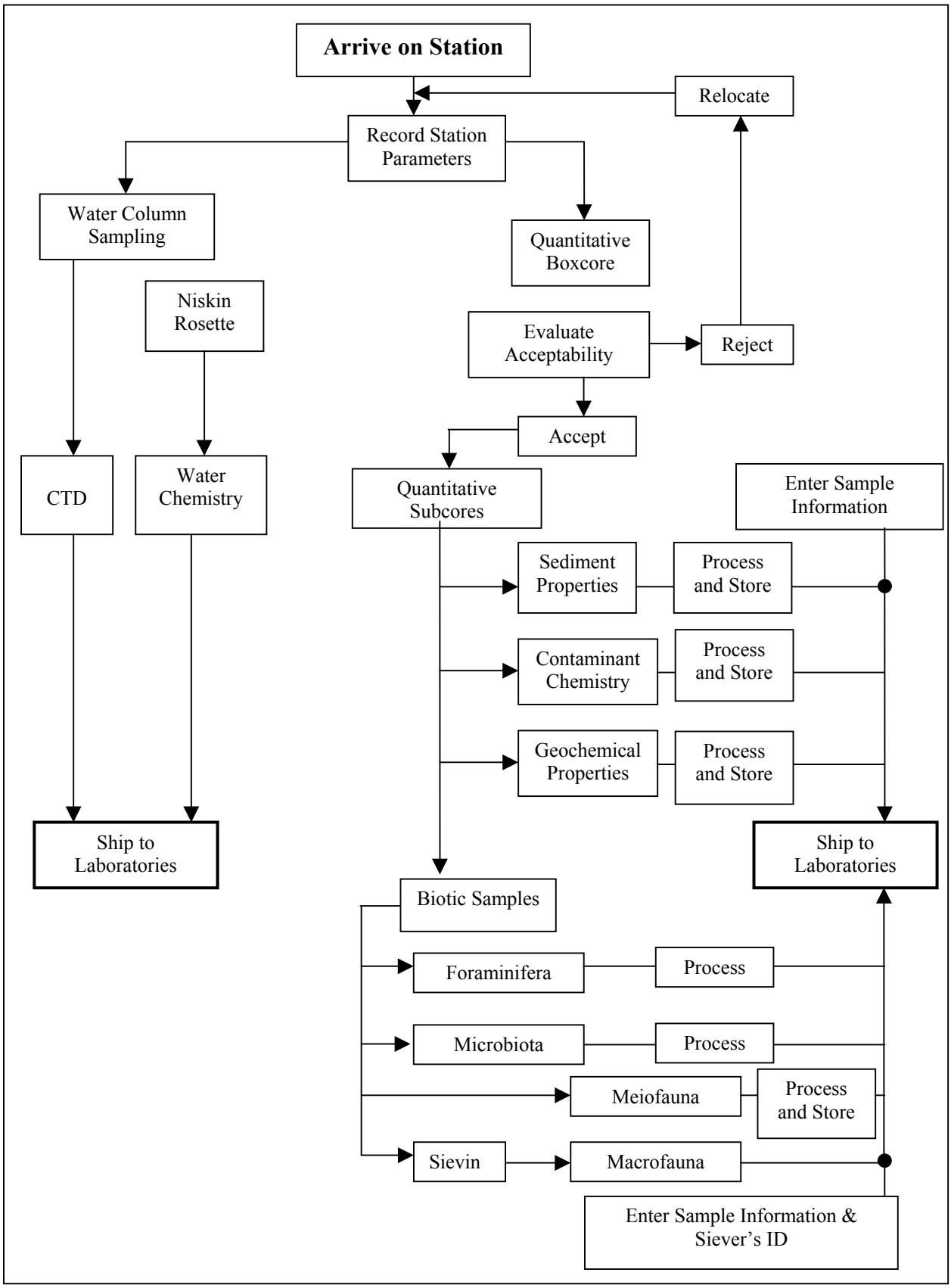

Figure 6.1. Schematic of quantitative boxcore station activities and sampling protocols.

knots. A DGPS fix is made at this point. As the trawl is pulled, the wire is gradually paid out until the "wire out" is approximately 1.5 to 2 times the water depth. Steaming continues until the total bottom time is equal to 30 minutes per 1000 m of water depth. That is, at 3000 m the bottom time would be 1.5 hours. At the end of the bottom time, another DGPS fix is taken to give over-ground distance traveled by the trawl. The trawl is then retrieved at speeds less than 50 m/minute. Samples retrieved by trawling were processed for standard survey work elements (Figure 6.2).

6.1.3 Photo-Apparatus

A Benthos digital camera, with a strobe, was utilized to take up to 50 photographs of the seafloor. The camera was actuated by a bottom contact switch in order to assure that the same area of sea bottom was photographed with each exposure at each station.

6.1.4 Water Column Profiles

CTD/rosettes casts were taken at all survey and all experimental stations (Figures 5.1 and 5.2). At each station, the CTD/rosette collects continuous vertical profiles of seawater conductivity/salinity, temperature, pressure, light transmission, light penetration, optical backscatter and fluorescence and trip Niskin-bottles are tripped to collect discrete water samples for dissolved oxygen, nutrients, particulate organic carbon, suspended particulate matter, and phytoplankton pigments. Salinity was measured on discreet bottle samples at selected depths to calibrate the conductivity sensor. Sampling is from the surface layer to as close to the bottom as can be safely accomplished with the CTD/rosette package and an acoustic pinger to determine depth off the bottom. A 24-bottle rosette was used. Bottle samples were closely spaced near the sediment/water interface as well as near the sea-surface.

All sampling was conducted to the same standards and using the same types of equipment and personnel as employed on the MMS-sponsored programs LATEX-A and NEGOM. A SeaBird Model 911plus CTD and a General Oceanics rosette with Niskin bottles were the equipment of choice. An altimeter allowed safe lowering of the package to within a few meters of the bottom. *In vivo* fluorescence was measured by a submersible fluorometer. Light penetration was measured as downwelling irradiance with a Biospherical Instruments, Inc. Model QSP-200L irradiance profiling sensor. Light transmission was measured with a SeaTech 25 cm transmissometer. Additionally a D&A Instruments and Engineering optical backscatter sensor provided continuous profiles of particle scattering. The CTD equipment and a complete back-up system was onboard.

In addition, a downward-looking Acoustic Doppler Current profiler (ADCP) was deployed to the seabottom at the beginning of each experimental station. The ADCP recorded bottom currents for the duration of each experimental station. The equipment of choice is a 300 kHzWorkhorse ADCP from RDI, model 300S Sentinal rated to 6000 m. The ADCP measures horizontal currents at 0.5 to 2.0 m intervals in the lower 50-90 m of the water column to define short-term variability in bottom currents. The instrument was equipped with a syntactic foam collar for floatation, weighted with expendable anchor material, and released using two Benthos acoustic releases. The backscatter data from the bottom-mounted ADCP will be used to

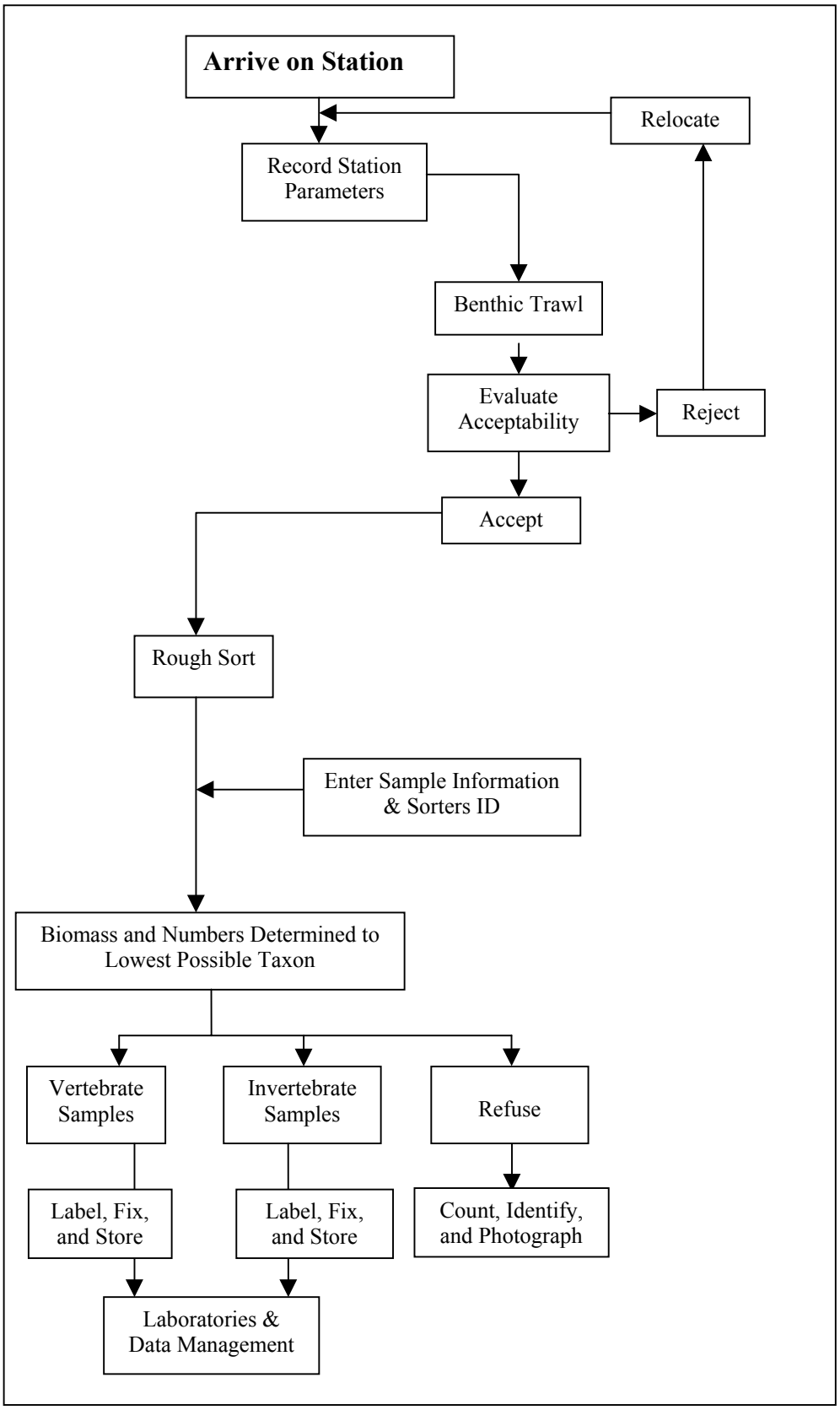

Figure 6.2. Schematic of trawl station activities and sampling protocols

quantify the temporal variability of the bottom nepheloid layer during experimental stations. The boundary layer advection and dispersion (mixing) rates will be used in a model of the "domain of occupation" of scavengers caught in baited traps (see below).

6.2 Community Structure

A wide variety of community structure measurements were made at the survey stations (Table 4.2) In order to provide quantitative information for the conceptual model, all important taxa were sampled including the microbiota, meiofauna, macrofauna, megafauna, and fishes. Each type of assemblage was sampled by different techniques that provide the best chance to quantitative sampling of the community. In some cases, multiple techniques are being employed as a cross-check (e.g., trawling, photosurveys and trap baiting for megafauna) and to provide complementary data from the same community. Each type of sample has specific field collection and processing techniques that are widely used and accepted as standard protocols. These protocols are described below.

6.2.1 Bacteria

Immediately upon boxcore retrieval shipboard, the temperature of the overlying seawater and the sediments was determined with a metal thermometer inserted in the sediment. Determining the temperature is important in evaluating the integrity and utility of the recovered sediment for measuring microbial activity under simulated *in situ* conditions.

For bacterial counts, the sediment subcores were extruded and sliced, using aseptic techniques, at predetermined depth intervals. The subsamples were fixed in a final concentration of 2% formaldehyde, prepared in a sterile, particle-free (0.2 um filtered) solution of artificial seawater (ASW) and stored (and shipped) in the dark at 4ºC for shore-based analysis.

6.2.2 Protozoa (Foraminifera)

Five replicate subcores were obtained from the boxcorer at each experimental station to measure foraminifera biomass. The cores were vertically sectioned at 0-1 cm, 5-6 cm, and 10-11 cm for analysis. Foraminifera densities at depths greater than ~10 cm were low and thereby precluded analysis in deeper sections. When feasible, individual organisms were sorted on ship-board, so the samples did not need to be preserved.

6.2.3 Meiofauna

Two core samples were taken from each boxcore sample, and stored for meiofaunal community analysis. Meiofauna were collected by a core tube (5.1 cm i.d.) that was mounted inside the boxcore. A mounted corer within a box will ensure that meiofauna are collected from an undisturbed surface. Insertion of a core tube after the sample has already been sloshed around the deck of the ship is known to create artifacts including loss of organisms. Surface disturbance can occur when the boxcore is placed on the ship's deck. Taking the sample from an inner subcore reduces edge effects (Eckman and Thistle 1988). The bow waves of sampling devices in deep water can have an impact on estimates of surface dwelling meiofauna (Hulings and Gray 1971).

The two critical sampling issues for meiofauna were core size and sampling depth. A 1.9 cm diameter core tube (2.8 cm^2) was used during previous MMS projects, e.g., Santa Barbara seeps (Montagna et al. 1989), CAMP (Montagna 1991), and GOOMEX (Montagna and Harper 1996) sampling programs. A 3.5 cm i.d. core was used to collect meiofauna in the NGOMCS study (Pequegnat et al. 1990). Densities in the deep-sea Gulf of Mexico are low (Table 1), so a large core must be used. About 80% of the meiofauna were in the top 4 cm of sediment. A sampling depth between 2 and 6 cm was used in seven of nine deep-sea studies reviewed by Thistle et al. (1991). The NGOMCS study (Pequagnat et al. 1990) sampled to a depth of 5 cm. To resolve these two issues, a study was performed during the shakedown cruise (16-18 February 2000) to determine the most appropriate core size and vertical sampling depth for meiofauna in the current study area. To compare sizes, four cores ranging from 2.2 to 6.7 cm inner diameter (i.d.) were used to collect the top 1 cm of sediment, and five replicates were taken. To exam the vertical distribution of meiofauna, a 5.1 cm core tube was used. Samples were taken at 1 cm intervals down to 20 cm, and five replicates were taken. All samples were taken at station W-2 in water depths of about 661 m.

More organisms were found in progressively larger cores (Table 6.1). But, there was no statistically significant differences for abundances of total meiofauna, nematodes, harpacticoids and other taxa among different core sizes. Although total abundance in the smallest core was about half that found in the three larger cores, it was not statistically different. Because each core yielded the same abundance estimate, total counts per core were used to choose the appropriate core size. For statistical purposes, it is imperative to obtain > 30 organisms in a taxon per sample. Therefore, the 5.1 cm core was chosen for the benthic survey.

Table 6.1. Effect of core tubes size (inner diameter) on meiofauna counts and average density. Based on five replicates taken at station W-2. Abundance is detransformed from ln, so taxa averages do not sum to the total average.

	Counts (*n*/core)				Abundance (*n*/10 cm^2)			
Core Size (cm i.d.)	2.2	3.1	5.1	6.7	2.2	3.1	5.1	6.7
Taxa								
Nematodes	20.2	64.8	161.0	219.0	31.3	59.4	50.5	54.3
Harpacticoids	5.4	30.8	74.2	99.4	2.3	26.1	20.8	24.4
Nauplii	7.2	38.6	72.2	85.6	0.2	29.2	22.9	19.0
Others	12.2	14.0	27.8	45.8	3.6	14.5	8.5	10.6
Total	45.0	148.2	335.2	449.8	54.0	135.7	111.3	112.2

There were no meiofauna found below 13 cm sediment depth, so just the top 13 cm are plotted (Figure 6.3). Most organisms were found in the top 3 cm. A total of 87% of total meiofauna were in the top 3 cm, and 97% of the harpacticoids. In addition, 77% of the harpacticoids were found in the top 1 cm. Because the distribution is so skewed to the surface, it was decided to sample the top 3 cm only during the benthic community survey cruise. Because harpacticoids were so restricted to the top 1 cm, the core was split into 2 sections: 0-1 cm and 1-3 cm.

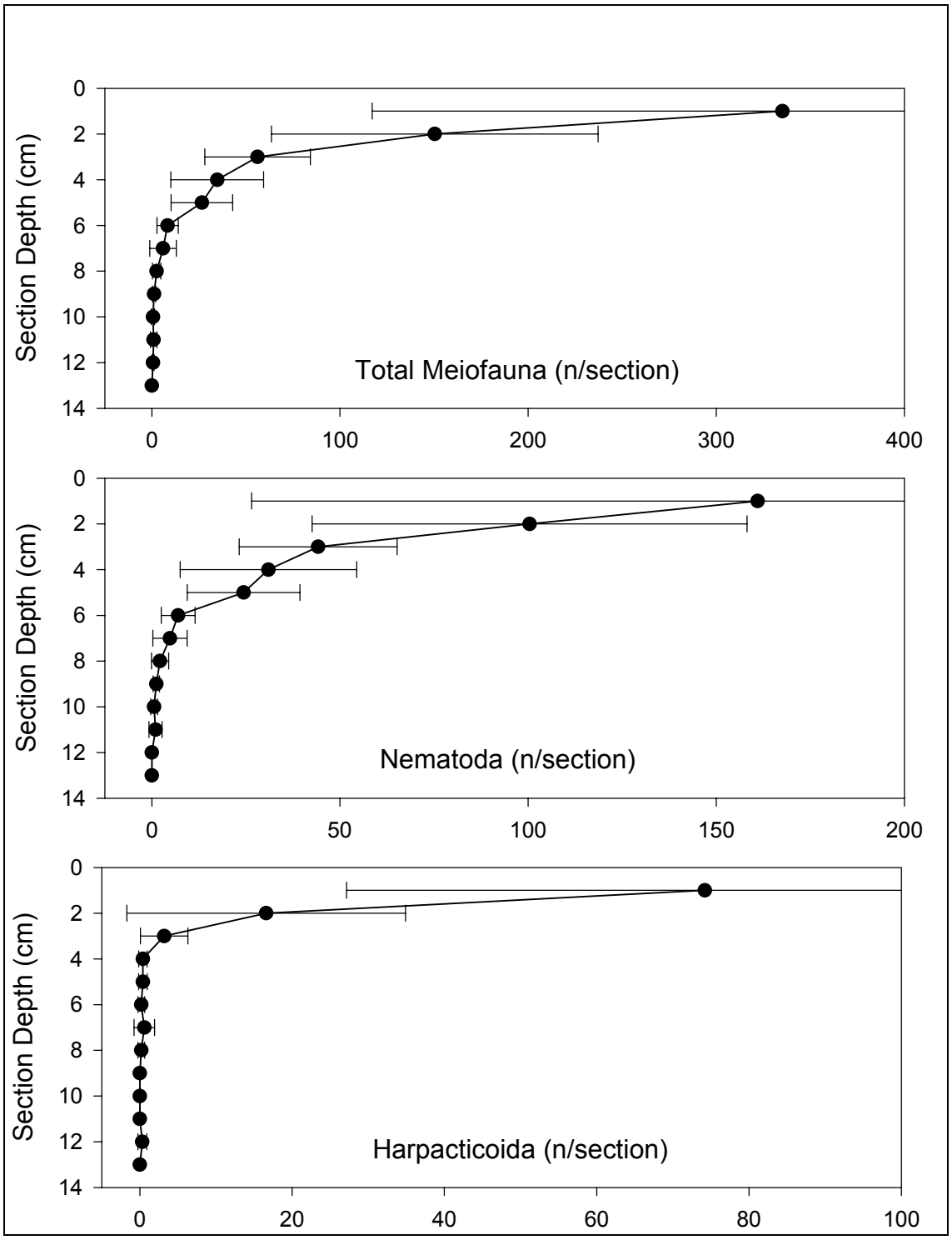

Figure 6.3. Vertical distribution of meiofauna taxa for Cruise I. Average of 5 replicates.

After the sections were collected, the meiofauna were relaxed in 7% $MgCl_2$ and preserved in an equal volume of 10% buffered formalin (yielding a final concentration of 5% formalin) (Hulings and Gray 1971). The buffered formalin was made up with seawater that was filtered through a 0.042 mm mesh to exclude plankton. Rose bengal was added to the preservative to distinguish cytoplasm-containing foraminifera from empty foraminiferal tests (shells).

6.2.4 Macrofauna

Macrofauna were sampled from five (5) replicate boxcores per station. Sieve size was 300 microns. Sieving, a critical stage in macrofauna analysis, was conducted using the gentle floatation method developed by Howard Sanders of the Woods Hole Oceanographic Institution (WHOI). A set of five (5) sieving stations were constructed, one for each replicate boxcore sample. Sievers were limited to experienced biologists. One was assigned to each core. The top 15 cm of each boxcore surface was copped out and deposited into a 50 gallon plastic trash can. Sea water, filtered with an in-line water filter to remove surface water organisms and particulate matter, was allowed to flow by hose into the bottom of the can with the sample. The trash cans are mounted in an adjustable frame, referred to as the "tipper" constructed of marine-grade plywood. The water flows into the trash can, through the sample at the bottom of the can, and out a 20 cm long, 3 cm diameter spout 20 cm from the top of the can. On exiting the spout goes immediately into a sieve, which is held in place by an adjustable sieve holder also constructed of marine grade plywood. This process floats the animals out of the sediments and onto the sieve with the least possible trauma. This is a critical step because severe losses of animals can occur. Each siever signed the boxcoring deck log and entered comments in the margin on sample quality at the end of the sieving process. The samples were fixed in 10% formalin with sea water that was filtered as above. Rose Bengal was added to aid in rough sorting in the laboratory. On return to the laboratory, the formalin-Rose Bengal solution was changed to a 70% EtOH solution. At this point, the samples are more or less permanently preserved.

6.2.5 Megafauna and Fishes

6.2.5.1 Trawl Samples

Once onboard, the trawl sample was removed from the net and placed in large plastic tubs (Figure 6.2). Organisms were then sorted to species to the best of sorters' abilities. Each species was counted, its displacement volume determined, and each individual's length was measured and recorded. The samples, sorted by species, were placed in ziplock bags or small plastic jars, labeled with indelible solvent proof labels, and preserved in 10% formalin and seawater solution. All species were stored together in five gallon plastic containers covered with tight plastic lids. For fishes, the body cavity of the larger individuals were opened to enhance fixation. Trash was separated out and stored in separate five gallon plastic containers. Larger items were photographed and discarded or saved for disposal on land.

6.2.5.2 Photosurveys

The purpose of the camera lowerings was to quantify the megafauna. This is important because the megafauna are an explicit component of the conceptual model of the ecosystem. If the biota are abundant, then good estimates can be made with few exposures. For example, it has

been demonstrated that from the upper slope down to the lower slope, on the order of 30 or so exposures, each covering an area of six square meters, is adequate to quantify the dominant megafauna (Rowe and Menzies, 1969; Grassle et al. 1975). At lower densities, more exposures are required. During the NGOMCS study, approximately 48,000 photographs were taken, but only 25% of them were ultimately analyzed. A digital camera was used so that the images could be easily scanned upon system retrieval. The images are also easily electronically transmitted and archived on CD ROMs.

6.3 Community Function

In addition to the standard set of analyses performed at all survey and experimental stations, a series of specialized studies are being conducted at experimental stations to develop a better understanding of important forcing factors and transfer functions at the sites being studied. These studies will be conducted on samples provided by the standard set of techniques and equipment, specialized sampling protocols, and gear lowerings. These methods have been used during Cruise II and will be employed during all future field work.

6.3.1 Microbial Metabolism

For microbial activity measurements, subsamples from three sediment depths per boxcore (per station) will be diluted in artificial seawater to prepare sediment slurries for homogeneous amendment with the desired radiolabeled substrates. Separate aliquots, in duplicate, will then be incubated and sacrificed at each of five time intervals to develop rate measurements of substrate respiration and incorporation into biomass. Such sediment slurries provide an upper bound on microbial activity due to the oxygenation and disruption of microniches caused by sample retrieval. Cross-site comparisons will be important.

6.3.2 Sediment Community Oxygen Demand

A key component of the experimental studies is the measurement of total sediment community oxygen demand using the benthic lander and *in situ* chambers (Figure 6.4). The GOMEX (for Gulf of Mexico) lander is designed to estimate fluxes of oxygen and metabolites into or out of the sediments by incubating the bottom water and sediment surface in enclosed, stirred chambers. Thorough descriptions of the GOMEX lander have been published in Pomeroy et al. (1991), Rowe et al. (1994), and Miller-Way et al. (1994).

The GOMEX lander, as used in this study, consists of a square aluminum-pipe frame measuring 2 m on a side. This frame holds 1) two acrylic incubation chambers, 2) a multi-function electronic timed release system, with "burn wire" release mechanisms, 3) a deep-sea multishot camera and strobe system, 4) two disposable anchor weights, and 5) glass floatation balls. The two chambers each contain an oxygen sensor and thermistor, a submersible pump, an additional stirring motor, and three 60 cc hypodermic syringes. Each chamber encloses a sediment surface area of 906 cm^2 under a volume of seven liters of bottom water. A stirring bar inside the chamber is driven by a magnet attached to an electric motor in an oil-filled water-tight case outside the chamber. The camera and strobe are attached to the frame opposite the chambers to monitor proper contact with the sediments and syringes. Two disposable anchors (totaling 200 lbs) composed of cylinders of lead are dropped under the control of the electronic

Figure 6.4. Benthic lander.

timed release, with corrosive links of variable duration as a backup. Relocation on the surface is aided by a flag, two radio direction finders and a strobe flasher. The chambers remain on the bottom for periods of 8 to 36 hours.

The sequence of events for this "free vehicle" involves floating to the bottom and then undergoing a series of programmed mechanical operations that are controlled by an electronic timer that burns release wires on command. The chambers incubate bottom water from which metabolic substrates are consumed and into which metabolic by-products are produced. The fluxes are calculated as:

$$Flux = \frac{(Change\ in\ Conc.)\ x\ Vol.}{area\ x\ time}$$

6.3.3 Foodweb Studies - Stable Isotopes

Organism tissues are being selected by the biologists for stable isotope analysis for the foodweb studies. The tissue is excised or the organism is frozen whole at -4ºC.

6.4 Sediment Properties

Subcores for sediment properties were taken from each of the five replicate boxcores. These were not pooled but are separately stored. The top two centimeters were sampled using a spatula or scoop. Shear strength is being measured in the shorebased laboratory.

6.5 Chemical Contaminants

Subcores for trace metals and hydrocarbons were taken from each of the five replicate boxcores. The subcores are extruded and the upper 2 cm of the sediment is sectioned with a teflon-coated spatula. Total organic and inorganic carbon are being measured on the hydrocarbon sample. Hydrocarbon subsamples were immediately placed into precleaned (combusted at 425°C) 1/2-pint glass jars with teflon-lined lids (~150 g). Trace metal samples were immediately placed into pre-cleaned plastic jars (~150 g). All sediment samples for contaminant chemistry are stored frozen (-20°C).

6.6 Geochemistry

At each survey site, near surface (about 0 to 2 cm) samples from each of the five (5) replicate samples were frozen but analytical work is being completed at shore-based laboratories on only one sample. The other five have been archived frozen.

7.0 LABORATORY METHODS

Once samples and data are collected on the various cruises, extensive shore-based laboratory analyses are performed. Wherever feasible, analyses are completed onboard the ship. In addition, other samples and data were processed to the fullest extent possible aboard the ship and properly and uniquely identified, labeled, and stored in appropriate facilities and media. The samples are preserved for storage onboard the ship to ensure their integrity during transport to the various PI's laboratories. The methods employ standard techniques widely used for similar programs ensuring that comparisons with historical studies are valid. This data compatibility is important to provide the greatest value in the final synthesis. The laboratory methods are described in detail below.

7.1 Taxonomy

Taxonomy is a vital component of the GOM slope study. Many of the hypotheses will be tested at the species level and therefore the taxonomists must be the best available. A team of taxonomists was selected on the basis of their international reputations, their familiarity with the GOM, and the management team's experience with them as productive scientists (Table 7.1). The first step is getting good samples and that is assured by the described shipboard sampling and processing protocols. The next step is accurate and thorough sorting of the samples to major group. That is accomplished by graduate students and experienced professional invertebrate zoologists.

The sorting laboratory sorts Rose Bengal-stained invertebrates and separates them to major taxonomic group: polychaetes, oligochaetes, molluscs, crustaceans, and others. QA/QC is performed by re-sorting the “waste” materials prior to storage. All materials collected during the program is stored until the program is complete so that it can be reviewed as needed. Poorly sorted samples discovered during resorting are sorted again. The initial sorter is identified and retrained to ensure proper sorting.

Taxa that are routinely considered meiofauna but are retained on the 300 micron sieve are separated and quantified. The numbers and biomass of these larger animals are added to the data from the meiofauna component. Most of these taxa are nematodes, harpacticoid copepods, and forams.

Determination of biomass as wet weight is accomplished at the group level prior to distribution to the taxonomists. For larger organisms, this is done by weighing the organisms in their alcohol preservative as a group (Rowe 1983). For smaller organisms, this is done by measuring them, calculating their displacement volumes, and assuming a density of 1.2 g/mL.

The major groups are sent to the appropriate lead taxonomist. The polychaete taxonomist is Dr. Fuinn Fain Hubbard (TAMU), an expert on deepwater polychaetes of the GOM.

Dr. Christer Erseus (Swedish National Museum of Natural History) is the oligochaete taxonomist. These make up about 5% of the fauna by number and are important in the GOM. Dr. Erseus has published extensively on the oligochaetes of the deep GOM.

Table 7.1. Taxonomists involved in the analysis of the macrofauna and corresponding taxonomists working on UNAM Mexican national collections. The last column lists alternatives or taxa for which no specialist has been identified (those listed are potential collaborators but have not yet been approached about the availability of the samples).

TAXON	DGoMBS	UNAM	Other
Fishes	John McEachran (TAMU)	Luis Zambrano	
Amphipoda	Richard Heard (USM)	Fernando Alvarez	
Aplacophora	Amely Scheltema (WHOI)		
Ascidiacea	Claude Monniot(U.Paris)		
Asteroidea	Gordon Hendler (LA Co. Mus.)	Alfredo Laguarda, Francisco Solis	
Bivalvia	Anders Waren(N. Mus. Sweden)		
Brachiopoda	Mary Wicksten (TAMU)		
Bryozoa			Nielsen
Cumacea	Heard	Alvarez	
Decapoda	Wicksten	Alvarez	
Echinoidea	Hendler	Laguarda, F. Solis	
Echiura			Eibye-Jacobsen
Gastropoda	Waren/Rex/Davenport	Garcia Cuba(*Conus* & *Terebra)*	
Harpacticoida	H. Lee (Montagna)	Alvarez	
Holothuroidea	Hendler	Laguarda, F. Solis	
Hydrozoa			
Isopoda	Geo. Wilson(Aust. Nat. Mus.)	Alvarez	
Kinorhyncha		Rhinehard Kristensen (Danish Mus.)	
Mysidacea	Heard	Alvarez	
Nematoda	N.A.		
Nemertini	Jon Norenburg(USNM)		
Oligochaeta	Christer Erseus(Nat. Mus. Sweden)		
Ophiuroidea	Hendler	Laguarda, F. Solis	
Ostracoda	L. Kornicker(USNM)	Gío Argaez	
Polychaeta	G. Fain Hubbard	Vivien Solis	
Porifera		Patricia Gomez	
Priapulida			
Pycnogonida	Allen Child		
Scaphopoda	Waren		
Scyphozoa			
Sipunculida	Mary Rice(USNM)		
Tanaidacea	Heard	Alvarez	
Turbellaria			
Anthozoa	Daphne Fautin (U.Kansas)		
Copepoda	Lee (Montagna)		
Chaetognatha	Gerald McLellan (USM)		
Halacaridae		Anna Hoffman-Mendizabel	
Crinoidea	Chas. Messing (FAU)	Laguarda, F. Solis	
Cladocera			

Dr. Anders Waren (S.N.M.N.H) is the molluscan taxonomist. He is a widely known taxonomist. Dr. Waren will be assisted by Mr. Roe Davenport. Mr. Davenport will assist Dr. Waren with provincial taxonomic issues.

Dr. Richard Heard (University of Southern Mississippi) is the crustacean taxonomist. He is a well know taxonomist who worked on the NGOMCS study. Dr. Heard will distribute the crustacea among his group and other outside experts for identification including Dr. B. Wilson for isopods.

Dr. Gordon Hendler (L.A. County Museum), is the echinoderm taxonomist. While most of the adult echini will be taken in the trawl samples, juveniles may be frequently encountered in the boxcores.

Each lead taxonomist is responsible for identifications to the species level. Any misidentifications by the sorters that may be encountered in the bulk group samples are returned to the sorting laboratory for redirection. Species lists are regularly reviewed. The Data Manager archives and distributes species lists to the PIs and the taxonomists on a regular basis.

Sampling of benthic infauna is concentrated in the first two years of the program.

7.2 Community Structure

A wide range of taxa will be quantitatively assessed at each station for a variety of community structure characteristics. These analyses are key for understanding the complex deep-sea foodweb. The community structure analyses form the framework on which the program depends.

7.2.1 Bacteria

Bacterial abundance in sediments are being determined using a dual staining technique (acridine orange and DAPI stains) and standard epifluorescence microscopy for marine sediments (Relexans et al. 1996 and Schmidt et al. 1998). This procedure does not attempt to remove bacteria from the sediment grains prior to counting. Separating the bacteria from the sediment inevitably results in an underestimate of abundance, since bacteria tightly bound to the sediments are left behind. Instead, the method of choice views the bacteria directly in the presence of the grains after treatment with Triton-X detergent and sonication (to loosen the attached or aggregated cells). For each sediment core, a down-core profile of bacterial abundance will be determined at ten (10) closely spaced sampling intervals from 0-15 cm with spot checks to a depth of 30 cm. Sediment bacterial abundances are rarely examined at depths greater than 15 cm. The deeper samples (done to 30 cm) are important in understanding bacterial distributions in deep-sea sediments. The potentially unique nature of some of the targeted slope sediments suggests that significant variations from typical pelagic marine sediment downcore profiles known may be observed (Schmidt et al. 1998). Since ultimately abundance is integrated over depth in the sediment to provide benthic bacterial mass estimates at each station for modeling and hypothesis testing purposes, unusual abundance profiles in the deeper layers of sediment will be important.

Bacteria are also being sized in selected samples by measuring the length and width of photographed cells stained with acridine orange and projected onto a flat white surface (Lee and Fuhrman 1987) to convert bacterial abundance to biomass. Bacterial sizing in sediments is not an automated procedure. Benthic bacteria are rarely sized for biomass conversions. Researchers have instead assumed a constant volume based upon more easily sized bacterioplankton. The proposed method is a significant improvement in the accuracy of benthic bacterial biomass estimates.

7.2.2 Foraminifera

Biomass of foraminifera is difficult to measure because foraminiferal assemblages include a combination of live specimens and empty shells. Measurement of only the organic fractions is appropriately done by measuring ATP content. Benthic foraminiferal ATP will be measured at the experimental stations. From each sample, 50 specimens will be individually measured for length and subsequently extracted for ATP following the procedure of Bernhard (1989). If time and foraminiferal abundance permits, additional specimens will be extracted.

7.2.3 Meiofauna

Meiofauna are being extracted from sediment using the Ludox centrifugation technique (deJonge and Bouwman 1977). Recent QA/QC studies have shown that the technique extracts 95-99% of organisms over all sediment grain sizes (Burgess, submitted manuscript). Samples are then sieved and counted to major metazoan taxonomic category. Protozoan, primarily Foraminifera and Ciliata, are enumerated if stained as well and will be reported

The term “meiobenthos” was first coined by Mare (1942) to describe benthic organisms of intermediate size. These are metazoans that are smaller than macrofauna but generally larger than the single-celled microbenthos (e.g., bacteria, microalgae, and protozoans). By convention, the definition of meiofauna is those animals that pass through a 500 micron sieve but are retained on a 63 micron sieve (Hulings and Gray 1971; Coull and Bell 1979; Giere 1993). Because deep-sea organisms are small, most meiofaunal ecologists use 42 micron sieves to retain meiofauna (eight of nine papers reviewed in Thistle et al. 1991). To conform with other studies of deep-sea meiofauna, a 45 micron sieve was used to retain meiofauna.

Meiofauna are being identified to the major taxon level. Meiofaunal communities are composed of two groups. Temporary meiofauna are those juveniles of the macrofauna that will eventually grow into larger organisms. Permanent meiofauna are those groups where adults are less than 300 microns, e.g., Nematoda, Copepoda, Gastrotricha, Turbellaria, Acarina, Gnathostomulida, Kinoryncha, Tardigrada, Ostracoda, and some Rhyncocoela, Oligochaeta, and Polychaeta. In 1971, Thiel suggested that the grouping of benthic organisms according to size differences had little taxonomic or ecological justification, except convenience of sample processing (quoted from Thiel 1975). However, ecological literature since 1971 has shown that meiofauna are different from macrofauna and have different roles in marine ecosystems (for reviews see: Coull and Bell 1979, Coull and Palmer 1984, Giere 1993). Even where meiofauna share ecological properties with macrofauna the processes operate on much smaller spatial and shorter temporal scales for the meiofauna (Bell 1980).

Meiofauna biomass are being measured or calculated (Montagna 1984; Montagna and Li 1997) for all samples. There is an extensive literature on biomass techniques. It is well known that biomass is underestimated by 30-40% in formalin preserved samples, so biomass will be

adjusted for this loss (Frithsen et al. 1986). For small organisms (e.g., meiofauna) biomass is calculated based on volume measurements and conversion factors. Conversion factors specific to the deep-sea GOM do not exist, so they will be empirically determined in 10% of the samples by direct measurements using a CHN analyzer and electrobalance (Montagna 1984). There is also an extensive literature on how best to calculate the volume of meiofauna based on length and width measurements. Robinson (1984) compared five methods for nematode biomass and recommends calculating volume based on a cylinder the length of the nematode and the diameter of the nematode's area/length ratio. Pearre (1980) has compared five methods for copepod biomass and recommends calculating volume based on a cylinder. Techniques and formulas for other meiofauna are given in Duplisea and Hargrave (1996).

7.2.4 Macrofauna

The macrofauna are expected to be one of the most complex size groups to sort and analyze. After sieving, the macrofauna are being sorted under dissecting microscopes to major taxonomic groups. QA/QC is performed on all sorted samples. All residues are properly preserved and retained for the duration of the project for review as needed. After sorting to major group, wet weight biomass is determined and estimates of densities and biomass are calculated for each major group.

Each major group is sent to the lead taxonomists as described in Section 7.1. The lead taxonomists is responsible for sorting to species. If they find individuals that are misplaced, they are returned to the sorting laboratory for redirection. The final samples sorted to species are returned to TAMU for archival.

7.2.5 Megafauna and Fishes

In the field, the fishes and megafauna recovered by trawl were processed as followed: 1) sorting of fishes and megafauna to "tentative" species (along with volume, measurements, counts, and length by species; 2) selecting specimens for tissue samples for stable isotopic and DNA analyses; 3) processing, labeling, and storing tissue for shore-based analysis; 4) fixation in 10% neutral buffered formalin, and 5) recording any unusual occurrences in the trawl performance that might effect the catch. Upon return to the laboratory, tissues for stable isotopic analysis will be delivered to the appropriate PI. The fish subsamples are soaked in water to remove all traces of formalin and then transferred to 70% ethanol. The megafauna and fish identifications are verified and transferred to a single jar per species per station.

7.3 Community Function (Process Studies)

At each experimental station a specialized set of process studies will provide important information to support those data obtained at the standard survey stations during Cruises II and III. These studies are performed using techniques and methodologies specific to each programmatic component.

7.3.1 Bacterial Metabolism

Bacterial productivity was estimated in sediment samples from the process stations using the tritiated thymidine approach, as applied by Alongi (1990) to other deep-sea sediments. For comparative purposes, we tested for activity in undiluted and diluted surface sediments and in samples incubated at atmospheric pressure and in situ pressures, all at in situ temperature. We ran endpoint, time-course and variable substrate concentration experiments to assess isotope dilution and other procedural issues. Incubations were terminated shipboard using 80% ethanol. Returned samples were processed further to assess thymidine incorporation into DNA, again following procedures of Alongi (1990).

7.3.2 Meiofaunal Feeding Rates

Meiofaunal feeding rates on benthic bacteria were measured by incubating sediment cores with radiolabeled thymidine (3HTdr; Montagna 1984, 1993). Flow through core tubes in June 2002 will be fitted to the benthic lander (described below) and upon impact will fill with sediment and close off at the top. At that point 2 uCi of 3HTdr is injected and incubated for 8 h after which formalin is injected into the cores to stop label uptake. After retrieval of the benthic lander, a one ml subsample will be withdrawn from the core. The subsample will be filtered onto a 0.2 micron Millipore filter and rinsed three times with seawater to estimate uptake of 3HTdr by bacteria. The subsample will be dispersed and suspended in five mL of distilled water and 15 mL insta-Gel for dual label liquid scintillation counting at a shore-based facility. Meiofauna will be separated from sediments by diluting samples with 2% formalin, swirling to suspend animals, and decanting them and the supernate onto 63 micron Nitex screen filters. Meiofauna will then be rinsed into jars and kept refrigerated in 2% formalin until sorting at a shore-based facility.

The labeled meiofauna collected are sorted under a dissecting microscope in a shore-based laboratory. The individual taxa are placed in one mL of water in a scintillation vial. The meiofauna are then dried at 60ºC and solubilized in 100 µL Soluene tissue solubilizer for 24 h. Samples are ultimately counted by dual-label scintillation spectrophotometry in 15 mL of Insta-gel.

7.3.3 Sediment Community Respiration

The changes in the chemical concentrations of oxygen, dissolved inorganic carbon (DIC), ammonia, nitrate, nitrite, manganese, iron, silicate, and phosphate in the benthic chambers are being used to estimate total community respiration by organisms living within the sediments in benthic chamber incubations. The oxygen concentrations are determined from a continuously recording polarographic oxygen electrode, backed-up by a miniaturized Winkler method (uses 25 mL samples). The other chemicals will be measured in syringe samples from the beginning, middle, and end of the incubations. Conventional wet chemistry is employed as described in the geochemistry section.

7.3.4 Foodweb Analyses - Stable Isotopes

Selected organismal tissues have been sampled and preserved for stable isotope analysis. The tissues will be analyzed for carbon and nitrogen stable isotopic compositions. Most samples

will be measured with a Finnigan MAT Delta S Elemental Analyzer-Isotope Ratio Mass Spectrometer (EA-IRMS). If, for any reason, samples cannot be processed by EA-IRMS, they will be measured by standard tube combustion methods similar to those described in Cifuentes et al. (1988). Finally, the stable carbon isotope ratio of bacteria in sediments is being determined by proxy, in phospholipid fatty acids, a biomarker of bacterial biomass (Salata 1999).

7.4 Sediment Properties

Sediments retrieved from the boxcores are preserved and returned to shore-based laboratories for analysis (see below).

7.4.1 Grain Size

Grain size was determined by the standard Folk settling method. Fifteen to twenty grams of sediment are treated with hydrogen peroxide for twelve hours to remove organic matter. After washing with distilled water, the sediment is dispersed with hexametaphosphate solution and poured over the appropriate screen. The material that passes through the screen is then subjected to a series of prescribed settling techniques that are based on removing materials at set times. The individual fractions that are collected are dried and weighed to provide quantitative values for each size fraction as a percent of the total weight of sediment. Per cent gravel, sand, silt, and clay are calculated. Duplicates are analyzed with every batch of twenty samples to estimate precision.

7.4.2 Geotechnical Properties

All boxcore samples are examined and sampled for shear strength, bulk density, water content, and grain size. Selected samples are being tested for permeability. Shear strength is determined by hand held vane shear devices and is used to determine the cohesion of the sediment at several depths and locations in a non-contaminating and non-disturbing manner within each boxcore. Bulk density and water content is determined by standard geotechnical techniques. Porosity was determined from the bulk density measurements. Permeability is the capacity of the sediment to transmit fluids without impairment of the structure of the medium. Permeability regulates the rate of flow of interstitial waters resulting from the compaction process and is important in the transport of fluids and gases within sediments. Permeability was determined on selected samples by pressure permeameters and a constant gradient consolidometer. Of the above sediment physical properties, grain size is the only one for which a large number of correlations have been made with benthic communities. It is reasonable to presume however that they may correlate or co-correlate with animal distributions.

7.4.3 Total Organic and Inorganic Carbon

Total organic and inorganic carbon was determined by standard LECO combustion techniques or by Carlo Erba element analyzer. A freeze-dried and homogenized sample is burned in the presence of oxygen and accelerator to CO_2 which is swept from the combustion chamber into a detector. The detector is calibrated with rings of known carbon content and the sample carbon content is calculated from the detector response. Inorganic carbon is determined as the difference in carbon content between an untreated and acid-treated sediment sample.

7.5 Chemical Contaminants

Each survey and experimental site will be screened for the presence of chemical contaminants. Hydrocarbon and relevant metals will be measured at each site.

7.5.1 Hydrocarbons

Sediment samples are analyzed for polynuclear aromatic hydrocarbons (PAHs) using NOAA National Status and Trends Methods (Denoux et al. 1998; Qian et al. 1998). The proficiency and validity of this method has been established by 14 years of laboratory intercomparisons. Briefly, deuterated PAH are added before the extraction and are used to calculate analyte concentrations. Sediment samples are mixed with anhydrous sodium sulfate and are extracted with methylene chloride/acetone in an Automated Solvent Extractor (ASE). The extracts are separated from possible interfering compounds by silica/alumina columns. The purified extracts are analyzed on a HP 5890/5970 gas chromatograph with a mass selective detector (GC/MS) using a selected ion detection technique. The GC/MS is calibrated with known concentrations of analytes at five different concentration levels and the average response factors of the analytes are used for PAH concentration determination. Concentrations of PAHs are reported as nanogram/gram (ng/g) on dry weight basis for sediment samples. Both non-alkylated (parent PAHs) and alkylated PAHs are reported. Each sample batch of 20 samples or less includes a procedural blank, a matrix spike, a matrix spike duplicate and a standard reference material. These quality assurance samples ensure that the analytical results for each batch are valid and of acceptable accuracy and precision.

7.5.2 Trace Metals

Sediment samples are analyzed for Ba, Cd, Cr, Fe, Hg, Pb, and Zn. These have been shown to correlate with drilling and production in previous studies (e.g., Kennicutt, et al. 1996a,b) and/or are known to be toxic to organisms. The analyses follow the well-established National Status and Trends methods. Methods include atomic absorption spectroscopy (AAS), instrumental neutron activation analysis (INAA) and/or inductively coupled plasma spectrometry (ICP) depending on the metal and the concentration (e.g., Taylor and Presley 1998). INAA will be used to determine Ba, Cr and Fe. The precision and accuracy for these elements by INAA is excellent regardless of the matrix, including pure drilling mud. A more sensitive method is used when needed for other metals to insure accurate and precise values.

Sample preparation beings with freeze-drying a representative sediment aliquot and grinding it to a fine powder. No further treatment is needed for INAA providing a check on the sample dissolution techniques needed for AAS/ICP analysis. For INAA, 0.5 g aliquots of the powdered samples is weighed directly into plastic vials and heat sealed. The samples are irradiated for 12 hours in the 1 megawatt TRIGA reactor. After a 10 day cooling period to allow Na, Cl, and other interfering isotopes to decay to low levels, the samples are counted using a hyper-pure germanium detector coupled to a Nuclear Data Corp. model 9900 multichannel analyzer integrated with a Digital VAX II/GPX graphics workstation. Concentrations are obtained by comparing counts for each sample with those for sediment and rock reference materials of accurately known elemental composition. Details of this method are given in Boothe and James (1985), including information on counting geometry, reference materials, spikes, blanks and other aspects of QA/QC.

The National Status and Trends Program methods (Lauenstein and Cantillo 1998) are used in for AAS/ICP analysis. The method for Hg is the standard EPA sulfuric acid-permanganate digestion of a dry powdered sample followed by stannous chloride reduction to Hg metal and detection by cold vapor AA. For other metals, 200 mg aliquots of the powdered sediment samples are weighed into teflon "bombs" and completely dissolved in a mixture of nitric, hydrofluoric and boric acids by prolonged exposure of the closed bombs to a temperature of 130°C. Various dilutions are made on the clear digests to bring them into the working range of the AAS or ICP.

A Perkin-Elmer Corp. model 3300DV (dual view) ICP is used when element concentrations permit. When concentrations are too low for this instrument, a Perkin-Elmer 3030Z AA equipped with an HGA-600 graphite furnace and an auto sampler are used. Details of furnace programs, matrix modifiers, blanks, spikes, reference materials and other QA/QC information can be found in the reference given above. The proposed methods ensure that matrix spike recovery for all elements is greater than 90% and that recoveries of certified values for reference materials from the National Research Council of Canada are 90% or better as well.

7.6 Geochemical Properties

The geochemistry component will measure a range of relevant sedimentary properties at both survey and experimental sites. Single replicate samples are analyzed at the survey sites and detailed profiles will be determined at experimental sites to determine important flux rates. Various geochemical properties are measured on pore waters and solid phases. Analyses that are best performed immediately after sample retrieval will be conducted onboard, whereas other analyses which require more time consuming methods can only be performed at shore-based facilities (Tables 7.2 and 7.3). Pore water is separated from the solid phase by centrifugation or pressure filtering.

For pore water a combination of microelectrode, titrametric, ion chromatographic and other analyzers will be used. Dissolved pore water oxygen, hydrogen sulfide, iron (Fe+2), and manganese (Mn+2) are measured by microelectrodes. Sulfate concentrations in pore waters will be determined by a standard ion chromatographic technique. Total dissolved inorganic carbon in pore waters is determined by coulometric titration. Pore water nutrients (nitrate, nitrite, ammonia, urea, phosphate, and silicate) are determined by standard autoanalyzer techniques much like those for water column nutrients. Dissolved organic carbon in pore waters is determined with a high temperature combustion DOC analyzer.

The geochemistry studies at experimental stations include detailed depth profiles of biogeochemically important parameters, measurement of sulfate reduction rates, and benthic flux measurements in addition to survey variables. Isotopic studies are also being carried out at these stations. In addition to the shore-based analyses described for the survey stations, the following analytical work is being performed. Detailed near interfacial profiles of O_2, H_2S, Fe and Mn were acquired by the microelectrode method of Luther et al. (1998). Sulfate reduction rates were determined using the $^{35}SO_4^{2-}$ tracer technique in order to measure the approximate rate of hydrogen sulfide generation within the sediment (Lin and Morse 1991). Pore waters were extracted from sectioned cores to produce depth profiles of nutrients, pH, dissolved inorganic

Table 7.2. Summary of parameters to be analyzed and the methods to be used.

Type of Component	Component	Analytical Method
Pore water	O_2, H_2S, Fe and Mn	Microelectrodes
	Total CO_2 (DIC)	Coulimetric titration
	Sulfate and chloride	Ion chromatograph
	pH	Electrodes
	Nutrients	Auto analyzer
	Dissolved organic C (DOC)	DOC analyzer
Sediment Solids	C stable isotopes	Extract/mass spectrometer
	Porosity	Wt. change on drying
	CHNS	Carla Erba analyzer
	Reactive Fe and Mn	CD extraction, FAAS
	Carbonate carbon	Leco C analyzer
	Metals	NS&T Methods
	Hydrocarbons	NS&T Methods
	Radioisotopes	Counting
Biologic	SO_4^{2-} reduction rate	^{35}S tracer method

The following table lists the chemical parameters to be analyzed and categorizes them by column as to which type of station, survey or experimental, they will be utilized and whether they are field (F) or laboratory (L) measurements. Note that at the survey station combined surficial sediment samples will be analyzed whereas at experimental stations depth profiles will be determined for most parameters.

Table 7.3. Chemical parameters to be analyzed.

Parameter	Survey Station	Experimental Station
Sediment Properties		
CHNS	L	L
Carbonate content	L	L
Contaminants		
Metals	L	L
Hydrocarbons	L	L
Indicators of Biologic Activity	L	L
Nutrients	L	L
DOC	L	L
SO^4/Cl	L	L
DIC		L
δC^{13} DIC		L
Radioisotopes		L
Reactive Fe and Mn		L
Sulfate reduction rate		F
pH		F
H_2S		F
O_2		F
Dissolved Fe		F
Dissolved Mn		F

carbon (DIC), DOC, and sulfate/chloride ratios. All of these were analyzed on shore. Carbon stable isotopes are being determined on the DIC samples.

All solid components, except trace metals and hydrocarbons, are also being determined in depth profiles. Reactive Fe and Mn are being measured by extraction with citrate dithionite and analyzed by FAAS of radioisotopes.

For the solid phase, the methods for grain size, TOC, TIC, and porosity have already been described. In addition total reduced sulfides will be determined by an extraction technique which is followed by colorimetric detection. Sulfate reduction rates will be determined by incubation with ^{35}S labeled sulfate and measurement of the production of labeled sulfide. To determine the source of organic carbon in sediments, organic carbon will be analyzed for its stable carbon isotopic composition by standard tube combustion (Cifuentes et al. 1988). Selected measurements of the stable carbon isotope ratio of porewater dissolved inorganic carbon will be performed according to Salata et al. (1996).

Analysis of selected radionuclides will be used to determine sediment accumulation and mixing (bioturbation) rates at experimental stations. Samples along a depth profile will be gamma counted and analyzed for ^{210}Pb and $^{239,240}Pu$ by wet chemistry followed by alpha counting. Gamma counting of samples will be carried out on a HPGe Well Detector for ^{210}Pb (46 keV), ^{234}TH (63 keV), ^{226}Ra (351 keV), ^{7}Be (575 keV), and ^{137}Cs (661 keV).

The radionuclide analyses will:

- measure the natural ^{7}Be and ^{234}Th activity concentrations in the surface sediments by gamma counting to determine short-term, near-surface mixing (bioturbation) rates,

- measure the natural $^{210}Pb_{xs}$ (^{210}Pb-^{226}Ra) activity concentrations in sediments from boxcores to determine the steady-state sediment accumulation rates and ^{210}Pb inventories for the assessment of radionuclide and sediment focusing effects.

- measure the bomb fallout nuclide ^{137}Cs and $^{239,240}Pu$ activity concentrations in sediments to determine sediment accumulation rates from the 1963 bomb fallout peak. It is necessary to determine both nuclides as ^{137}Cs can show substantial post-depositional mobility in marine sediments.

For analysis, core material is dried and homogenized. Sediment samples of about 10 g size will be used for non-destructive gamma counting in a low-background, high-efficiency high purity Germanium (HPGe) well detector followed by wet chemical extraction procedures and alpha counting for individual radionuclides. Procedures are given in Santschi et al. 1999 and references therein.

For ^{210}Pb determinations, samples of approximately 1 g each are used for by alpha counting for complete digestion and chemical separation. Gamma counted samples will provide a less precise ^{210}Pb value used as a cross-check. For ^{226}Ra, ^{234}Th, ^{137}Cs, ^{7}Be, and ^{137}Cs samples of 10 g each are analyzed by non-destructive gamma counting. For $^{239,240}Pu$, samples of 10 g each are analyzed by wet chemistry and alpha counting.

7.7 Water Column Profiles

As summarized in Section 6.1.4, most water column properties are measured at sea by standard techniques: autoanalyzer for nutrients, Winkler titration for oxygen, and salinometer for salinity. In addition, total suspended particulate matter is determined by gravimetric analysis of filters. Particulate organic carbon is determined by total combustion of an acidified filter sample followed by detection of CO_2. Phytoplankton pigments are determined by a high performance chromatography (HPLC) method with quantitative UV detection. The pigment analysis quantitatively determines chlorophylls and carotenoids used to assess the relative importance of the various phytoplankton groups. The methods to be employed are those of NEGOM (Jochens and Nowlin 1998).

Continuous monitoring sensors produce detailed profiles at each of the stations during the hydrocasts (see Section 6.1.4). A “quick look'“ at the data was performed at-sea to uncover potential problems in the data at the earliest possible opportunity. A quick-look also provides the opportunity to scan for features and to revise sampling plans to more appropriately sample any observed features. Data is further validated on return to shore by checking all of the metadata (e.g., times of sampling, depths, positions, or calibration checks) against the cruise logs and the data file format. For CTD data, pressure versus time is examined to remove ship motions. All out-of-range, unrealistic outliers, gaps and discontinuities in the dataset are manually checked. The continuous data is then discretized at 0.5 m intervals and written into computer files as space delimited columns of plain ASCII text. Characteristic plots are prepared for each station.

The water column chemical measurements were done aboard with discrete water samples collected on the upcast of the rosette sampler. A Guideline Model 8400B salinometer was used for salinity analyses. The microWinkler technique was used for measurement of dissolved oxygen. Nutrients (nitrate, nitrite, ammonia, urea, phosphate, and silicate are analyzed using a Technicon Autoanalyzer and standard colorimetrc techniques. At-sea analysis ensures high precision and accurate measurements as opposed to preservation, storage, and shipment to shore-based laboratories. In addition, water is sampled for various particulate matter parameters. Two-liter water samples were vacuum filtered through pore-weighed filters for total suspended particulate matter (PM) analysis. Another liter of water was filtered through 25-μm precombusted GFF filters for determination of particulate organic carbon (POC). Another liter of water was filtered through 0.45 micron Millipore filters for analysis of the major phytoplankton pigments. All filters were carefully placed in combusted aluminum foil or plastic bags and properly stored for transport to shore-based laboratories for analysis.

7.8 Archival of Specimens

All the biological material in this study that is identified to species by taxonomists will be retained for the duration of the project by the taxonomists, at the sorting lab in the Oceanography Department, or at the Pequegnat Deep-Sea Systematics Collections. At the end of the project, voucher specimens will be made available for archiving at the USNM of the Smithsonian Institution as directed by the MMS. These will include the megafaunal invertebrates, the macrofauna and the fishes. It does not include the bacteria or the meiofauna because they will not be identified to species. In addition to the voucher specimens to be given to the Smithsonian, regional working systematic reference collections will also be encouraged to access, curate and catalogue voucher specimens for future research and education when such specimens are

available. This will include the LA County Museum, the Texas Cooperative Wildlife Collections, the Pequegnat Deep-Sea Invertebrate Collections, The Australian National Museum of Natural History, and the Swedish National Museum.

8.0 STATUS OF DGoMB PROGRAM

8.1 Task 1 - Re-Examination of Previous Studies

Several sources of information were readily available to review and assess. These can be categorized as theses and dissertations of students of Willis E. Pequegnat; the MMS-supported slope study overseen by LGL Ecological Research Associates, Inc. (NGOMCSS); and the peer-reviewed literature. Practically all of this material has been included in a review of the deep GoM environmental information conducted by Continental Shelf Associates under contract with the MMS. DGoMB personnel participated in that review (G. Rowe, W. Nowlin, W. Bryant, D. Biggs, and M.C. Kennicutt II). That report should be consulted for specific details on individual sub-disciplinary studies.

All megafauna, macrofauna, megafauna, meiofauna and sediment raw data files were supplied to DGoMB by LGL Ecological Associates, Inc.. These have been sorted by discipline and restored as individual Microsoft Excel files. These files have been made available on the internet to DGoMB principal investigators. Dr. Richard Haedrich has plotted megafauna and fish distributions to assess the effect of depth and east-west gradients on species composition. Macrofaunal polychaete diversity (taken from the Ph.D. dissertation of G. Fain Hubbard) using several complementary indices has been plotted with depth by transect to consider potential internal GoM gradients (E to W, depth, etc.) and for comparison with other ocean basins.

Several tentative conclusions can be concluded from earlier studies:

1. biomass and densities of the size groups studied decrease in general as a function of depth down the continental slope, but with frequent exceptions to this rule;
2. densities of macrofauna differed between sampling dates on the C transect (for Central), with high densities in spring and low densities in the fall;
3. three depth zones can be defined tentatively, based on species composition: the upper slope, the mid slope and deep water;
4. the continental slope in the western GoM is different in species composition (macrofauna and megafauna) from the eastern GoM;
5. sediments contained no anomalous contaminants that would not be expected in a typical deep-sea environment;
6. diversity maxima are encountered on the upper slope (as opposed to the lower slope/upper rise, in other basins); and
7. biomass and densities of the different size groups studied are lower than observed on other ocean basin margins when studied with similar approaches.

8.2 Task 2 - Field Sampling

The initial field work was a short shakedown cruise conducted on February 16-18, 2000, to test gear and to evaluate procedures with survey participants. The main outcome of this trip was the conclusion to change from the USNEL spade corer to the GOMEX boxcore.

A survey cruise was conducted on the *R/V Gyre* from May 3 to June 23, 2000. Four different activities were carried out at each of 43 sites: CTD, box cores (5 replicates with a 0.2 m^2 GOMEX corer), bottom camera (up to 50 exposures per site covering ca. 5 m^2 area per shot) and 40' otter trawl (Table 8.1). In addition, two ADCPs collected information on near surface currents continuously throughout the cruise. The boxcores were subsampled for meiofauna, bacteria, geology, contaminants and geochemistry. Some of the results, where available, are discussed below. A separate cruise report was developed and is available as Appendix I. The distribution of samples collected is provided in Table 8.1 along with an estimate of when each set of data will be available to the rest of the program. The data generated from Cruise I will be used to choose the locations of the process study sites to be occupied in June 2001.

DSRV *Alvin* aboard the *R/V Atlantis* were at sea from October 16 to October 31 occupying a suite of continental margin sites in and amongst the DGoMB study area. Observations were made by Drs. Ian MacDonald, William Bryant, and Joan Bernhard who were accompanied by three DGoMB-supported graduate students. The results of their work are reported in a separate cruise report (Appendix II). Drs. Bryant and MacDonald reported on their observations at the December 2000 MMS Information Transfer Meeting (ITM). The *Alvin* cruise was a multi-agency project and the full cruise report is included in Appendix II.

The first process cruise (Cruise II) was conducted from June 1-19, 2001. It will be described in the Second Interim Report. The sites studied are discussed in Section 5.0 and the sites are mapped in Figure 5.2.

8.3 Task 3 - Sample Data Processing and Analysis

Four kinds of information were collected at each observational site during the survey cruise on *Gyre*, May 4 to June 23, 2000: physical and chemical properties of the water column, geological characteristics of the sediments, geochemistry of the sediments, and kinds and numbers of organisms present. The present status of these individual sets of data will be separately described along with some preliminary interpretation of their significance and how the results might affect the future direction of the program.

8.3.1 Physical Oceanography

During the first year, cruise collection of most of the physical data scheduled was successful. This included shipboard 38 kHz ADCP measurements and 150 kHz broad- and narrow-band ADCP measurements added as options to the original contract. Analyses and quality control of the POC, TSPM, and pigment samples from the first year cruise are complete. Quality control has begun on the CTD and bottle data from the first DGoMB cruise. The possibility of freezing nutrient samples and analyzing them ashore rather than carry out shipboard analyses was considered. To assess the potential of the stability of the preservation technique, duplicate nutrient samples from several stations during NEGOM cruise N8 carried out in April 2000 were frozen and analyzed onshore. The results were compared to those carried out aboard ship. The samples for shoreside analyses were poisoned and frozen immediately after collection.

Fresh versus frozen nutrient sample analyses for phosphate, silicate, nitrate, nitrite, ammonium, and urea from two stations are compared in Figures 8.1 and 8.2. These stations were in water depths of approximately 1000 m representing twelve water samples that extended throughout the water column. Agreement is seen to be excellent for silicate and nitrate, somewhat less for phosphate and nitrite, and poor for ammonium and urea. The poor agreement for ammonium and urea is expected in view of the relative ease with which those nutrients are utilized by organisms during storage.

The shipboard ADCP measurements recorded during both legs of DGoMB are of good quality. Comparisons of the near-surface (40-60 m) currents measured simultaneously by the 38 and 150 kHz instruments are favorable. No large gaps exists in the data set; however, short gaps due to GPS dropout and computer down time for data backups exist. The short gaps do not affect the overall data quality.

Based on TOPEX/ERS-2 sea surface height anomaly (SSHA) plots, the Loop Current was hammer-shaped during leg 1 of the survey cruise, intruding northward of 27°N and westward to 89°W. The SSHA field for June 10, 2000 is shown in Figure 8.3. Thus, the Loop Current was east of the study region during that leg. However, two Loop Current Eddies were present in the western Gulf and their presence is seen in the ADCP vector fields. Figure 8.4 shows current vectors at a vertical bin centered at 12.4 m depth are shown in Figure 8.4. The weaker of the two eddies was centered at 91.5°W, 24°N. The leg 1 cruise track passed through the northern limb of this eddy at 26°N between 90°W and 91°W. The stronger eddy was centered at 94.5°W, 26°N. The anticyclonic current field is clearly seen in the horizontal vector stick plots along the cruise track. Particularly strong southward currents (of order 100 cm/s) are seen along the eastern side of this eddy at around 93.5°W.

During Leg 2 of Cruise I, the stronger LCE drifted west about 0.5° of longitude. The SSHA field for June 10 is shown in Figure 8.5. The anticyclonic structure of the stronger eddy is again seen in the Leg 2 ADCP data. ADCP vectors for a vertical bin centered at 11.6 m during Leg 2 are shown in Figure 8.5. The westward movement of the eddy is also seen in the data as the strongest southward currents are located at 94°W and are reduced in amplitude about 50-70 cm/s. The cruise track of leg 2 was well north of the weak LCE, centered at that time near 92°W, 23°N.

During Leg 2 of Cruise I, the Loop Current did not intrude into the Gulf as far north as 27°N (see Figure 8.6), and thus did not influence directly the currents along the cruise track. However, a weak LCE centered at 90°W, 26°N and a stronger cyclonic eddy centered at 87°W, 27°N are both seen in SSHA plots and in the ADCP data.

8.3.2 Geology

Sub-samples (15 to 40 cm deep cores) were taken from each of the 5 replicates at each of the 43 sampling sites on Cruise I. These are being analyzed for a suite of physical properties by conventional methods as described in previous chapters.

Table 8.1. Sample inventory for Cruise I (survey).

Biology	Samples	Water Column	Samples	Sediment	Samples	Geochemistry	Samples
Bacterial	201	Depth	44	Grain Size	212	Nutrients	209
Foraminiferal	0	Temperature	44	Porosity	212	Dissolved Organic Carbon (DIC)	209
Meiofaunal	208	Salinity	44	Elemental composition (organic carbon, nitrogen, sulfur)	212	SO_4=/C_l-	209
Macrofaunal	212	Oxygen	44	Percent inorganic carbon (TIC)	212	Dissolved Inorganic Carbon (DIC)	209
Megafaunal	43	Nitrate and Nitrite	44	Permeability	212	$\delta^{13}C$ DIC	209
Fish	43	Ammonium	44	Shear Strength	212	Sulfate Reduction Rate	209
"Trash"	43	Silicate	44	Bulk Density	212	pH	209
		Phosphate	44			H_2S	209
		Particulate Matter (PM)	44	Hydrocarbons	212	O_2	209
		Particulate Organic Carbon (POC)	44	Metals	186	Reactive Fe	209
		Light	44			Reactive Mn	209
		Currents	44	**Pore water**	209	Acid Volatile Sulfide	209
		Photosynthetic Pigments	44	O_2, H_2S, Fe and Mn	209		
		Primary Production	44	Total CO_2 (DIC)	209		
				Sulfate and chloride	209		
				pH	209		
				Nutrients	209		
				Dissolved organic C (DOC)	209		
				Sediment Solids	209		
				C stable isotopes	209		
				Porosity	209		
				CHNS	209		
				Reactive Fe and Mn	209		
				Carbonate carbon	209		
				Metals			
				Hydrocarbons	209		
				Biologic	209		
				Radioisotopes			
				SO_4^{2-} reduction rate			

4 bacterial aliquots (0, 5, 10, 15) per sample
2 meiofaunal aliquots per sample
filtered samples (POC, pigments, and PM) at three (3) different depths (bottom, chl max or mid, and surface water)

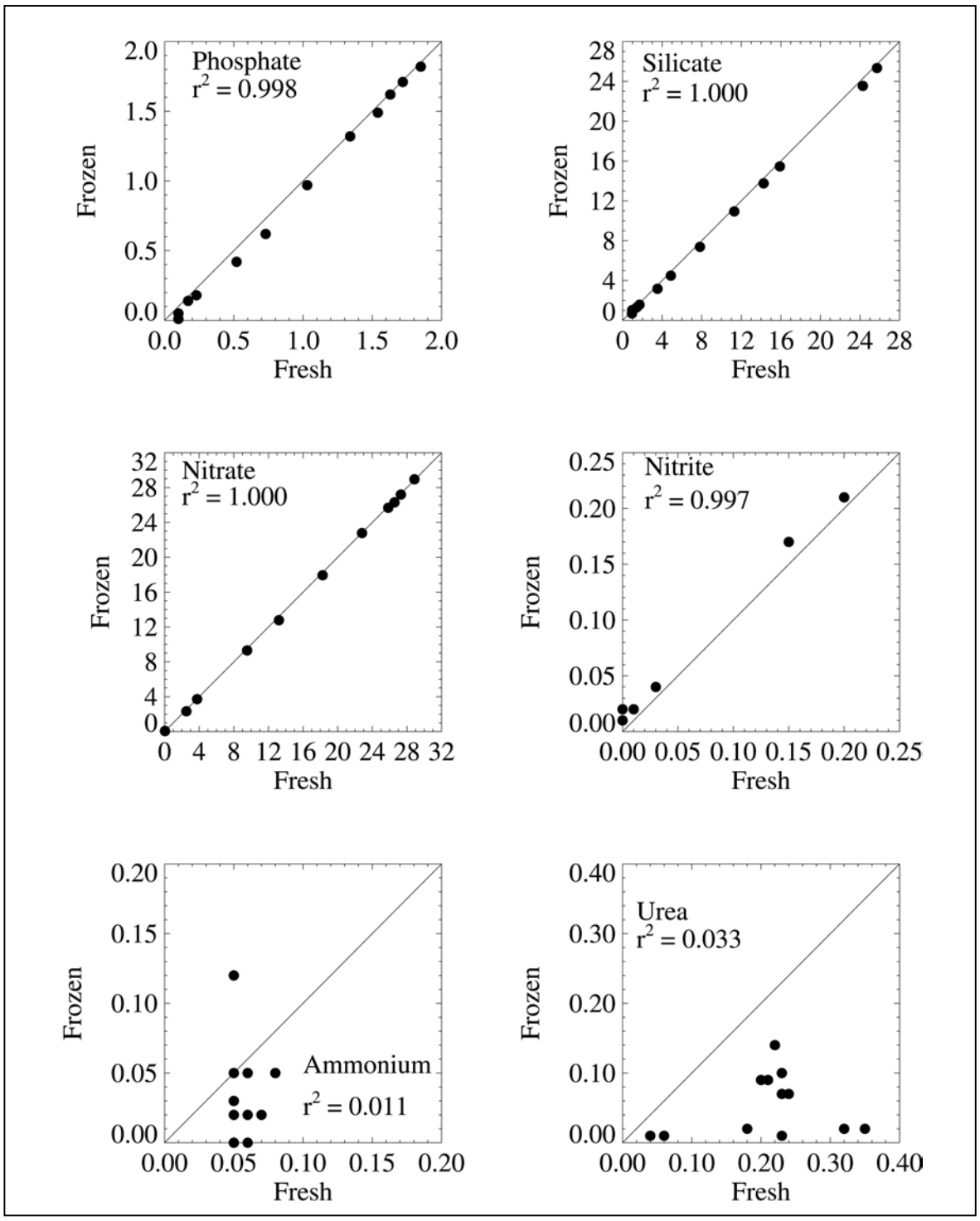

Figure 8.1. Frozen versus fresh nutrient concentrations (micromoles) from station 32 on NEGOM cruise N8 (April 2000). There are 12 pairs each.

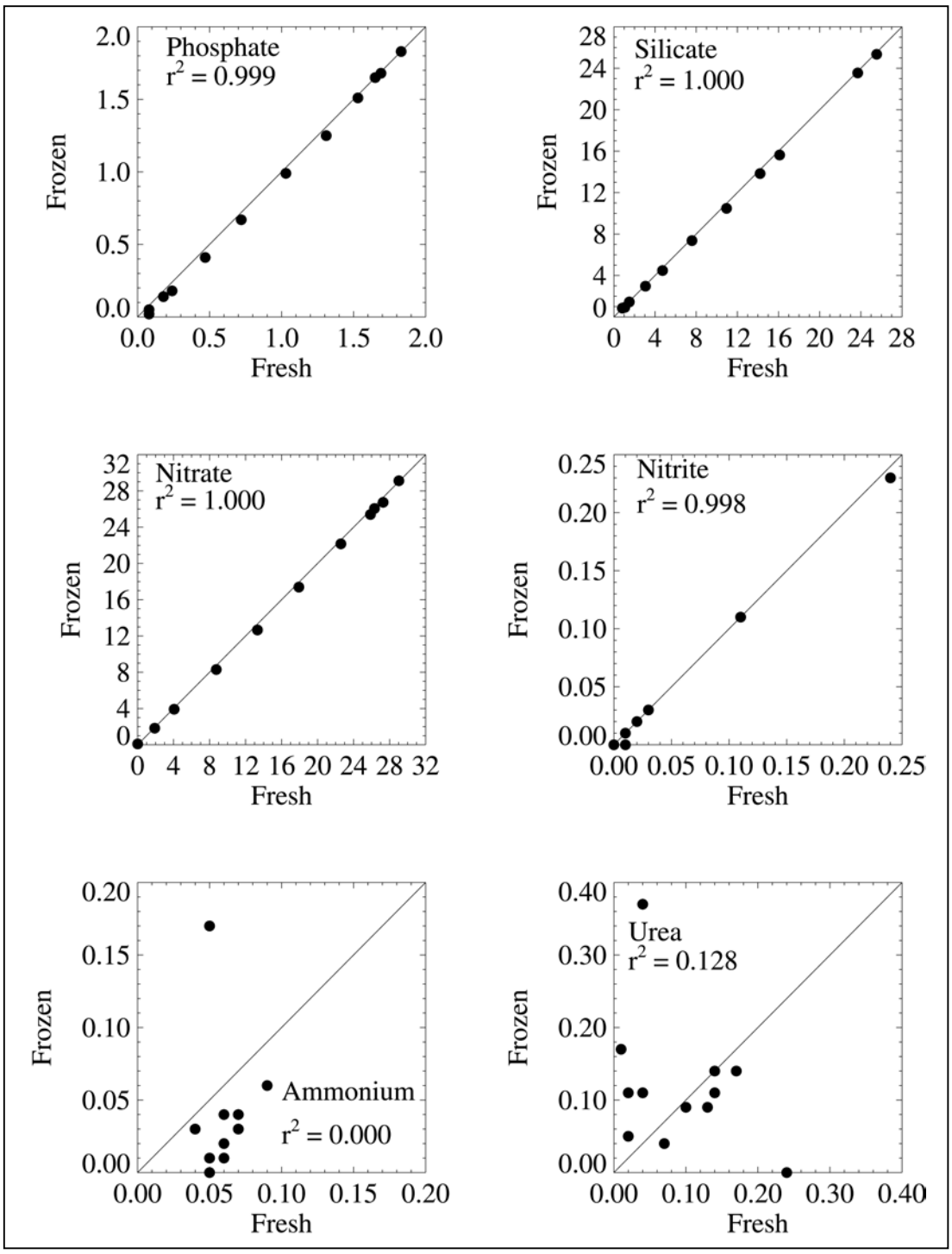

Figure 8.2. Frozen versus fresh nutrient concentrations (micromoles) from station 33 on NEGOM cruise N8 (April 2000). There are 12 pairs each.

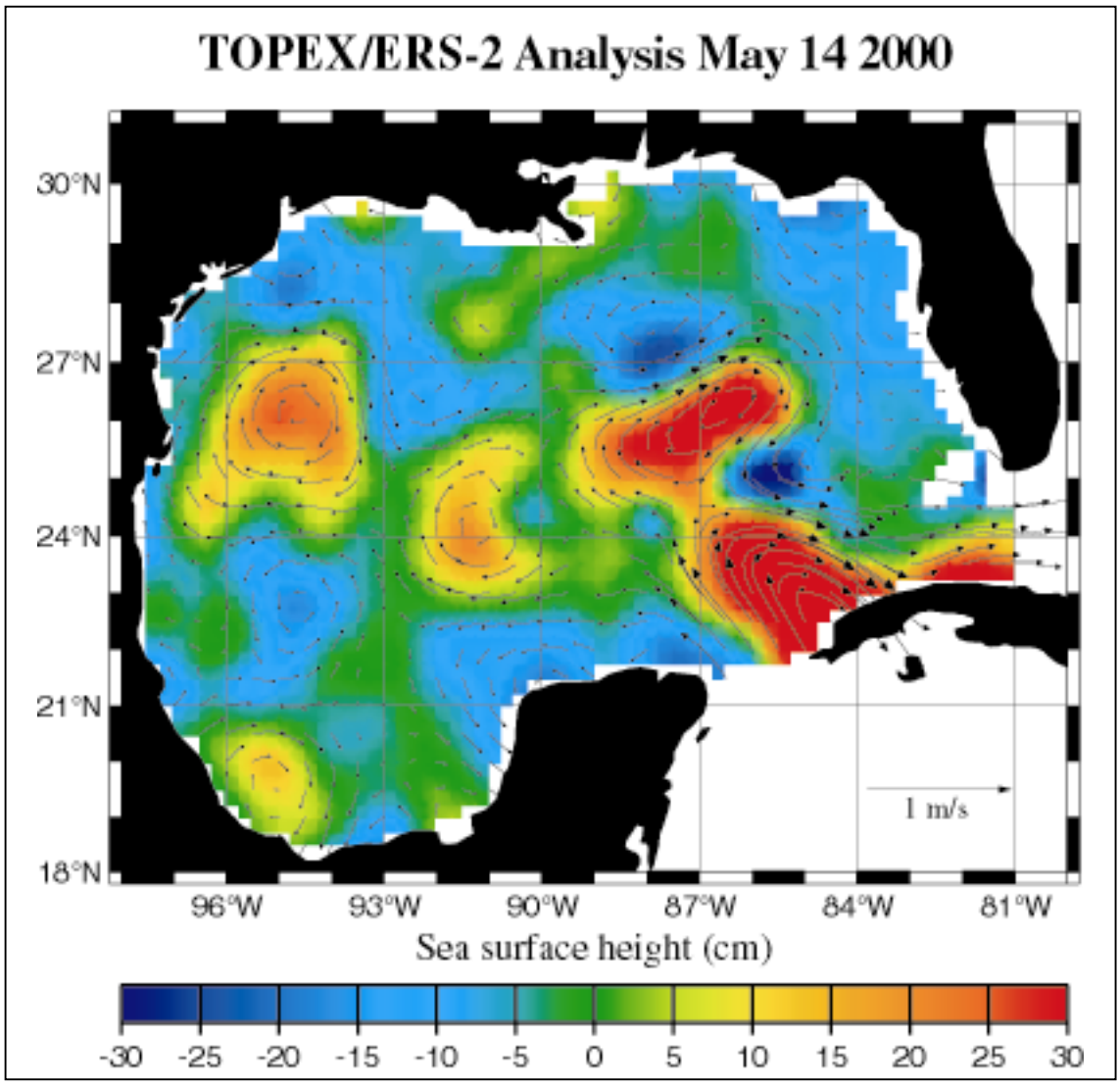

Figure 8.3. Sea surface height field for 14 May 2000 based on analyzed height anomaly of TOPEX and ERS-2 altimeter data added to mean sea surface height field. Anticyclonic (cyclonic) circulation features have clockwise (counterclockwise) currents and positive (negative) sea surface height values. Courtesy of Robert Leben (University of Colorado).

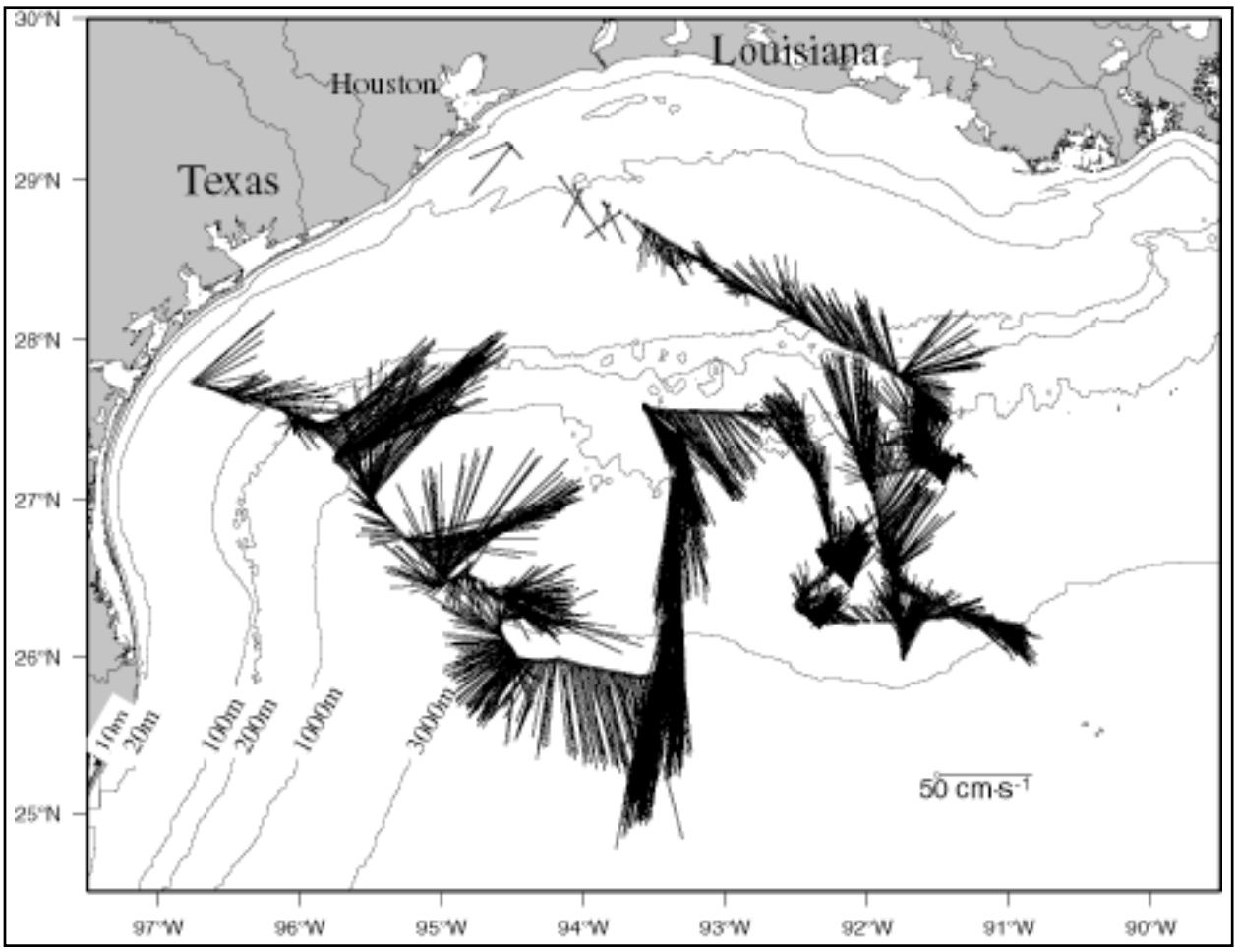

Figure 8.4. Broad-band 150 kHz ADCP current vectors at average depth of 12.4 m on DGoMB leg 1 Cruise, 3-23 May 2000.

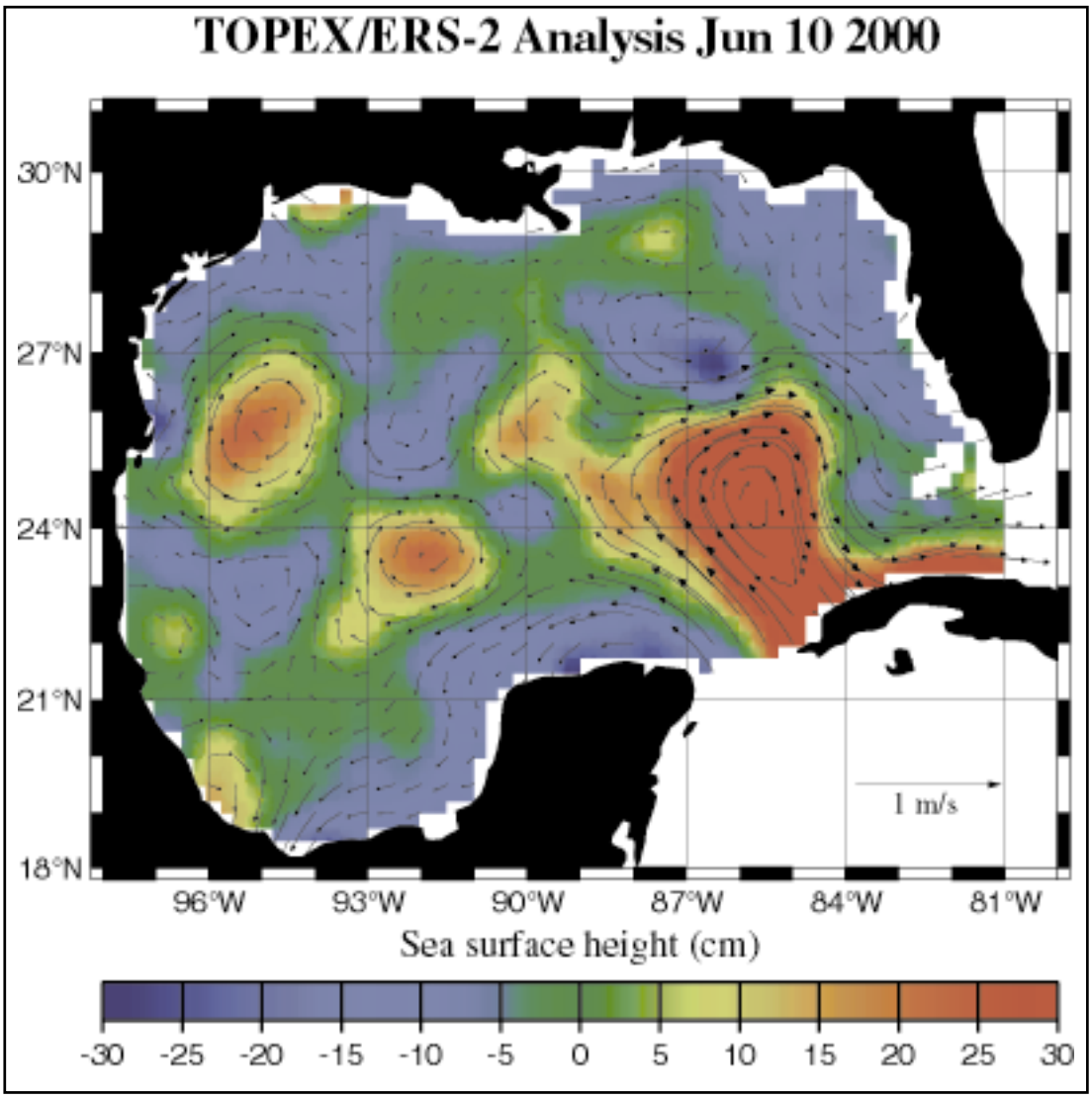

Figure 8.5. Sea surface height field for 10 June 2000 based on analyzed height anomaly of TOPEX and ERS-2 altimeter data added to mean sea surface height field. Anticyclonic (cyclonic) circulation features have clockwise (counterclockwise) currents and positive (negative) sea surface height values. Courtesy of Robert Leben (University of Colorado).

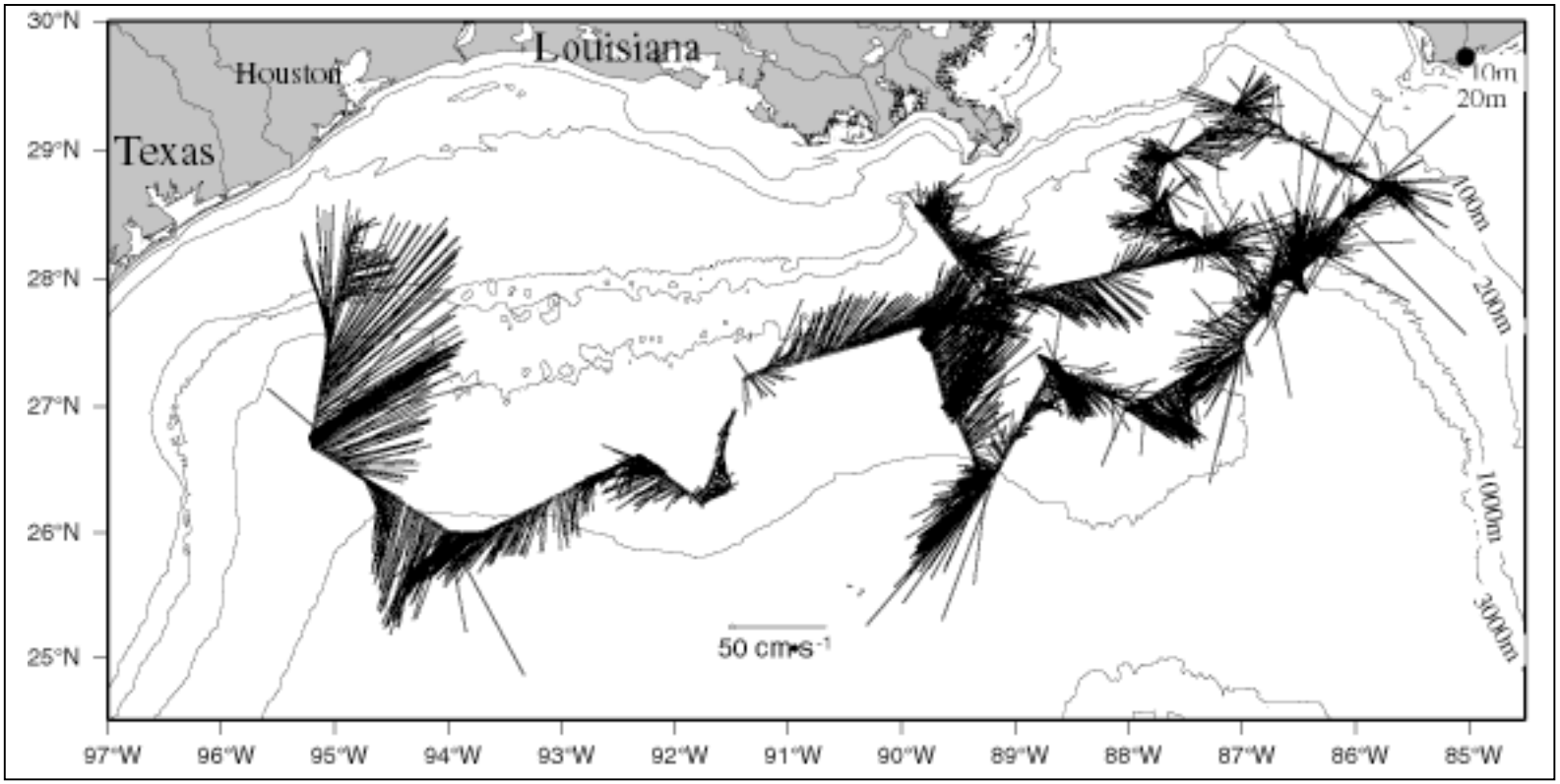

Figure 8.6. Narrow-band 150 kHz ADCP current vectors at average depth of 11.6 m on DGoMB leg 2 Cruise, 21 May - 21 June 2000.

8.3.3 Geochemistry and Contaminants

Subsamples were collected for chemical analyses during Cruise I. These samples consisted of 5 replicate cores covering the upper 5 cm of depth in the sediment obtained from box cores at each site. Of these 5 cores for each site, one was selected for initial analysis and the others have been archived.

Chemical analyses are currently underway. Extracted pore waters have been analyzed for sulfate to chloride ratio (an indicator of sulfate reduction), inorganic nutrients and dissolved organic carbon. Because several samples indicated significant sulfate reduction, total reduced sulfur was determined in the solid phase. Solid-phase C-H-N-S analyses are currently underway. Analytical results produced during the first year (up to October 1, 2000) of the project are summarized in Figure 8.7.

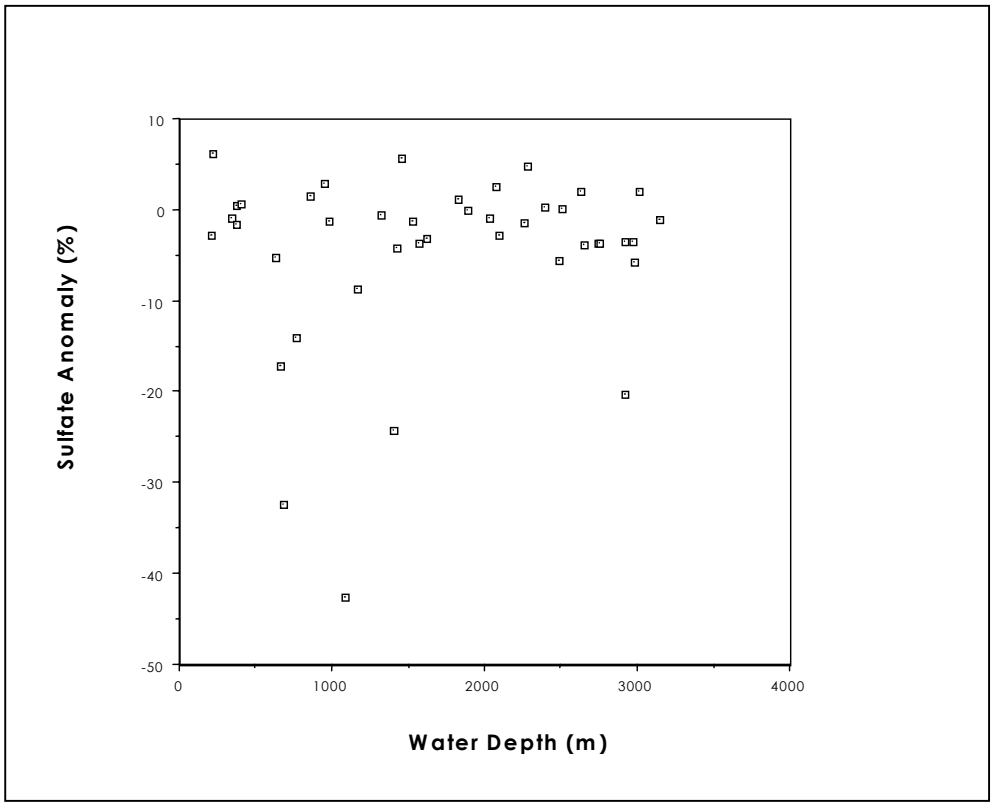

Figure 8.7. Negative sulfate anomaly as a function of water depth (the degree to which the ratio of sulfate to chloride diverges from that of sea water) in the pore water of the top 5 cm of a core from each sampling site. This is an assessment of the loss of sulfate to bacterial sulfate reduction. Note the negative values around a depth of 1 km, a suspected depocenter.

8.3.4 Biological Studies

All size categories of the sediment-associated biota were sampled on Cruise I. These included 1) microbiota, 2) meiofauna, 3) macrofauna, 4) megafauna and 5) demersal fishes. Each fraction was fixed and labeled aboard ship as described above and distributed to respective PI's immediately after the termination of the survey. Analyses of the biological samples are in a preliminary stage of processing and therefore no conclusions can yet be reached.

Macrofauna sample rough sorting to major taxon was initiated immediately on return of the samples to the Benthic Sorting Laboratory in College Station. To date, six graduate students have been trained to rough sort deep ocean invertebrate samples by Dr. Fain Hubbard.

Photographs have been printed for all bottom exposures. Pictures of a variety of organisms encountered in the trawls and in the bottom photographs were presented at the MMS Fisheries meeting in New Orleans in October, 2000, by G. Rowe. Mary Wicksten, Rowe and several graduate students have assisted Dr. Benny Gallaway in identifying invertebrates encountered in the 48,000 bottom photographs taken during the MMS NGOMCS study of the early 1980's. Additional photographic documentation of bottom animals is being accomplished with the *ROV Millenium* on the drill ship *Enterprise* through a cooperative study with BP at a drill site at 1.9 km depth (Crazy Horse 2).

Those components derived from the box cores have a maximum of 215 samples that are on the order of 50% complete in the initial assessment of the densities of organisms within each set of samples. The macrofauna studies required the training of a sorting team, and this was accomplished by the end of August. The next steps with the sorted macrofauna include 1) determination of biomass, 2) distribution to taxonomists for identification to species, and 3) archiving voucher specimens in appropriate collections.

Trawl samples were initially spit into three components aboard ship: trash, invertebrates and fishes. Each animal was identified to the lowest possible taxon, weighed by taxon (by volume displacement) and preserved as appropriate in 5 gallon plastic tubs. Geographic location of the start and end of each trawl, ship's speed and time on bottom were all recorded and thus rough estimates can be made of the area covered by each trawl. A comparison can thus be made of animal densities in the trawl samples. The trash was not preserved but is being stored wet sealed in 5 gallon plastic buckets. When there was too much for one container, it was photographed, weighed (when possible), discarded over the side (biodegradable material), or stored aboard ship for land disposal.

The megafaunal invertebrates were delivered to Dr. Mary Wicksten (Texas A&M University). The megafauna were then separated into major taxon and distributed to recognized taxonomists for identification. Dr. Wicksten identified the crustaceans. Mr. Roe Davenport identified trawl-caught molluscs.

The fish were delivered to Dr. John McEachran at Texas A&M. He has finished the identifications.

8.4 Task 4 - Data Interpretation, Synthesis, and Reporting

While at a very preliminary stage, data interpretation, synthesis, and reporting will be conducted by the following protocols.

8.4.1 Community Structure

As summarized in the methods sections, a wide range of taxa will be counted, identified, and sized. The most common and useful transformation of these taxa data are to derive measures of community density, biomass, species composition, and diversity. The following variables will be measured - bacterial density and biomass; foraminiferal biomass; meiofauna density, biomass, and composition by major group; macrofaunal density, biomass, diversity, and species composition; megafaunal density, biomass, diversity, and species composition; and fish density, biomass, diversity, and species composition.

Biomass. A key variable for interpreting the "state" of a system is biomass. It is the currency of the carbon budget and it is the variable that changes when the model is used to simulate the system. Therefore biomass will be measured directly or estimated for *all* the biotic components: bacteria, protists, meiofauna, macrofauna, megafauna and fishes. Regression analysis has long been used to estimate the rates of change of the total fauna with depth (Rowe 1983), so biomass is a powerful tool for assessing effects of depth or things that co-vary with depth such as food input.

Abundance. The ratio of abundance to biomass is important in assessing the age structure of the populations that make up the community. Thus, if and when the ratios of numbers to weights change over time at a site, then it is known that the population is either growing or dying. Growth and production rate are very difficult to measure and are contentious issues in the deep-sea because it is assumed that such rates are relatively slow (Rowe 1983). However, this is not necessarily true for the upper slope. The NGOMCS study of the slope suggested that abundances change with time on the upper slope, with the highest numbers in the spring (Hubbard 1995). It is not known if this was accompanied by a change in biomass. It will be important to investigate the possibility that growth can be observed on the upper slope and then to simulate this variation in time with the model. Similar investigations of the data and the model can be undertaken for each functional group in the community. At this point, it is not known which will exhibit growth responses and which will not. Alien sources of organic matter might be expected to have a similar "shift up" effect.

Diversity. A key finding in the NGOMCS study was that the variation in diversity of the macrofauna of the northern GOM was different from similar habitats in the Atlantic Ocean (Pequegnat et al. 1990). The finding is at once exciting and flawed. The flaw is that the conclusion is based on uneven sampling efforts by depths, which could lead to statistical biases. It is exciting if true. One goal of the program is to rigorously determine the diversity of species of the study area. Diversity can be measured by two types of indices: species independent and species dependent. Species independent methods (e.g., the Shannon-Wiener diversity index) do not take into account community structure. Therefore, the same values could be computed for two communities that have no species overlap. In contrast, species dependent methods use a multivariate approach (e.g., multidimensional scaling or principal components analysis) to

compare the species present in different communities to classify habitats. Both approaches have inherent strengths and weaknesses, so both will be computed in the current study.

Two species independent methods will be used to assess community diversity: the Shannon-Weiner diversity index and the Hurlbert rarefraction method. The Shannon index is the average uncertainty per species in an infinite community made up of species with known proportional abundances (Shannon and Weaver 1949). The Shannon index is calculated by:

$$H' = -\sum_{i=1}^{S}\left[\left(\frac{n_i}{n}\right) ln\left(\frac{n_i}{n}\right)\right]$$

where n_i is the number of individuals belonging to the ith of S species in the sample and n is the total number of individuals in the sample. Rarefaction curves compare species numbers between communities (Ludwig and Reynolds 1988). The model calculates the proportion of potential interindividual encounters in a given sample (Hurlbert 1971). The expected number of species, $E(S_n)$, found in a sample of n individuals drawn from a population of N total individuals distributed among S species is:

$$E(S_n) = \sum_{i=1}^{S}\left[1 - \frac{\binom{N - N^i}{n}}{\binom{N}{n}}\right]$$

where N^i is the number of individuals of the ith species. This sampling model computes the expected number of species in a random sample of size n as the sum of the probabilities that each species will be included in the sample (Ludwig and Reynolds 1988). A series of curves is generated, with the steepest representing the highest diversity.

Three species-dependent multivariate approaches will be used. There is much controversy on which approach is best. The obvious solution is to seek consensus among the competing approaches and assume that the same trend found in all analyses is the most robust trend. The three techniques are different, but all perform multivariate analysis: a cluster method (NESS similarity), a parametric method (principal components analysis, PCA), and a non-parametric method (multidimensional scaling, MDS).

Similarity analyses are performed to determine which stations resemble one another in terms of species composition. Group-averaged sorting, also know as the unweighted pair-group method (Sneath and Sokal 1973), is used as the clustering method and the normalized expected species shared (NESS; Grassle and Smith 1976) was used as the resemblance measure. The results are given in dendrograms where stations are ordered into groups of increasing similarity on a scale from 0 to 1, with 1 being the highest similarity. The NESS similarity measurement is based on the expected number of taxa shared between random subsamples of size m drawn from

each of the two populations being compared. This similarity method is particularly useful since it measures the contribution of rare species.

Principal components analysis is a parametric technique that makes a new set of uncorrelated variables in order of decreasing variance. Because community data sets have many rare species with zero occurrence at most stations, the PCA must be performed on the covariance matrix. The usual approach is to perform the analysis on the correlation matrix, and the resultant misleading results leading many to discount the utility of this tool. For example, two species with zero occurrence at many stations may be highly correlated (near 1), but their covariance is still small (near 0). Therefore, performing analyses on the covariance matrix of count data fixes this problem. It also solves the problem of what do with rare species, they need not be deleted, as often is erroneously recommended. The PCA also has another enormous advantage, factor loading scores are generated for each species (columns) and observation (rows), which can be used in other analyses. For example, during GOOMEX several hundred environmental variables were reduced with PCA and the new PCA scores were shown to correlate with biological and toxicological responses detecting very subtle sub-lethal effects that could not be detected with univariate analysis of variance (Green and Montagna 1996).

Multidimensional scaling is a non-parametric multivariate technique for examining similarity or dissimilarity between stations. First, a similarity index is computed for stations (usually the Bray-Curtis index), then a plot of the distance among points is created. The plot enables you to identify unknown variables that affect the similarity or dissimilarity between stations. The MDS procedure is very popular among shallow water benthic ecologists, because station separation is often more clear than in MDS. However, new variables are not created, nor can one reduce the variables in a dataset.

Zonation. The degree of species isolation along or parallel to isobaths is referred to as zonation. It is measured at the species level and at the community level. Species ranges as a function of depth will be plotted individually. Highly zoned species have narrow depth ranges of several hundred meters (Rowe and Menzies 1969; Grassle et al. 1975). Poorly zoned species have much broader ranges. Zones of recurrent groups are determined using measures of similarity or dissimilarity, discussed above. A somewhat arbitrary boundary of 50% can be used to conclude that zones are the same or different or to identify zonal boundaries. Pequegnat et al. (1990) suggested they could identify five zones on the northern GOM slope using the megafauna, but Escobar et al. (1999) could discern only three in work with macrofauna. Another way to discern group boundaries is to find depths of maximum faunal change. These are depths with maximum numbers of first and last occurrences. Minimal faunal change occurs in the "center" of zones. Zones are thought to occur due to competition along a gradient. In shallow water, this can be competition for space or food, but is also affected by predator-prey relationships. In the deep-sea, space is probably not an issue. the most plausible explanation is competition for declining food supplies. Thus, each zone should be represented by a different "level" of input to the model. This results in different levels of biomass in each functional group. The model for an upper slope zone would "shift down" as one proceeds down the slope.

8.4.2 Community Function

Data produced at experimental stations will be directly incorporated into the model. The stock values of the major groups will be determined by the survey portion of the program. The purpose of the experimental stations will be to add rates of processes to the conceptual model. The most important measurements in understanding rates is the respiration for each ecosystem component. The sum of the respiration for the entire system is a first order estimate of the total "carbon demand". This "sum" should be equal to the sum of the input of carbon to the system. Inequalities indicate that some set of unidentified components have been left out, or that the system is not in steady state. Community function variables that will be measured include bacterial growth rates and response to different substrates and meiofauna feeding rates on bacteria. Other community function variables that are calculated from established size and temperature relationships including foraminifera, meiofaunal and fish respiration rates, and foraminiferal feeding rates. Predation and scavenging rates for macrofauna, megafauna, and fishes are determined from submodels (see Section 3.0). There is not "unique solution" to the relationships, but the model allows us to put boundaries on their values.

The total sediment community respiration in carbon units as measured by benthic chambers is equal to the following:

SOC = RESP (macrofauna) + RESP (meiofauna) + RESP (aerobic bacteria) + CHEM OXID (reduced end products of anaerobic metabolism)

This should equal the sum of the calculated values and the experimental rate measures. Aerobic rates by bacteria are measured by oxygen consumption and anaerobic rates are estimated by summing the rate at which denitrification, iron reduction, and manganese reduction are occurring, as estimated by the changes in concentrations in the chambers and pore water profiles of geochemical properties.

It is assumed that 0.85 moles of DIC is produced per mole of oxygen consumed (RQ=0.85). Plus, it is assumed that the carbon to nitrogen ratio of organic matter is ~6.8 to 1. Thus, the amount of nitrogen regeneration can be calculated from oxygen demand and dissolved inorganic carbon (DIC) flux. If less than the predicted nitrogen is measured by a chamber incubation, then a loss of fixed N is inferred and it is assumed this loss is denitrification. A goal is to develop reasonable steady-state budgets of carbon fluxes at each of the experimental sites.

8.4.3 Sediment Properties

The sediment is the substrate that supports the benthic communities. The properties of sediment directly influence ecosystem patterns. The most obvious property is grain size which is well known to influence biotic patterns. At all stations sediments will be characterized as to grain size, porosity, carbon content, permeability, shear strength, and bulk density. Also in the deep-sea, carbon limiting conditions make the organic carbon in the sediment and its "bioavailability" important issues. Though less well studied, others properties may or may not influence biological patterns. The shear strength or cohesion of the sediment is expected to be a factor in determining and organism's ability to move around and burrow into sediments and is reflected in variables such as grain size, porosity, and bulk density. The permeability of a sediment will also be important in determining or regulating movement of interstitial waters

through the sediment which is in turn important for the transport of fluids and gases in sediments. These fundamental properties will be important to the establishment and maintenance of geochemical gradients in the sediment column.

Hydrocarbon and metal contaminant concentrations will be used to infer the presence or absence of previous anthropogenic disturbances at the study sites. In trying to understand ecological systems and their functioning it is important to determine if the system has been subjected to perturbations in the past, such as pollution, that might have already altered the community structure and function. It is expected that areas will be relatively contaminant-free. The contaminant data can be reduced through Principal Components Analysis (PCA) to one or two PCs that then can be regressed against any other variable to determine if there is a correlation or the PCs are used in multivariate statistical analyses.

The objective of the porewater and solid phase geochemical studies is to establish the relationship between the chemistry of the sediments and the benthic biological community. The concentrations and sources of dissolved and total organic carbon in the sediment which represents the "fuel" for the community (source can be inferred from the stable carbon isotopic composition), determine the near interfacial gradients of the redox reactive reactants and products as indicators of interfacial fluxes and biological activity, determine the products of organic matter remineralization near the sediment-water interface as a measure of biological activity, and determine if the redox environment has reached a point where sulfate reduction is important will be determined. The detailed down-core profiles at experimental stations will be used to calculate sulfate reduction rates, denitrification rates, manganese reduction rates, and iron reduction rates. Flux measurements will also be determined for cross-calibration with the benthic chambers.

Hydrogen sulfide and carbon dioxide are important biological products. Pore water profiles of important metabolites will be used to estimate rates of anaerobic and aerobic metabolism. The rate at which dissolved inorganic carbon is produced will be compared with oxygen consumption to estimate a sediment Respiratory Quotient, the oxygen utilized versus the metabolic dissolved inorganic carbon (DIC) produced. The estimated DIC produced by all functional groups will be summed and added to total heterotrophic metabolism. This value will be added to the bacterial values. Iron distributions are important to fully understand the sulfide chemistry as it actively uptakes sulfide. Nutrients and dissolved organic carbon will be used to determine fluxes and understand the diagenesis of the sediments. Sulfate reduction, in organic rich sediments, can be as important as oxygen consumption. In general, this is not expected to be high in oligotrophic waters, but earlier studies suggest that it can be important in GOM sediments on the upper slope. Integrated sulfate reduction rates will be measured and added to the other suboxic and anaerobic processes to estimate total sediment metabolism. Sulfate reduction tends to be accelerated in response to inputs of organic matter.

The geochemistry work element will also determine sediment accumulation rates and rates of bioturbation at the experimental sites from radionuclide profiles. Mixing and accumulation rates are needed to fully calculate metabolism rates. Finally, isotopic measurements of both sedimentary organic carbon and porewater inorganic carbon will aid in elucidating the source and fate of carbon in the system.

8.4.4 Water Column Chemistry and Oceanography

Oceanographic data will provide information on the physical setting at each station. The upper water column will be characterized for those variables (nutrients, oxygen, particulates, organic carbon, and phytoplankton pigments). Energetic features such as the Loop Current, Loop Current eddies, cyclonic eddies, or bottom -intensified currents will also be identified a forcing factor. These data provide estimates of water currents and information on the water column chemistry. The water column work element will characterize the photic zone as to the amount, origins, and type of particulate matter present.

The oceanographic studies will provide near-bottom flow-fields during the experimental stations to define the physical setting at each location (ADCP studies). The dynamics and origins of the near-bottom nepheloid layer will also be documented. This work element will also identify any large amplitude current events during the study. Estimates of vertical measures of coherence of currents through the bottom boundary layer will be provided. Backscatter intensity will be used to quantify nepheloid layer occurrences, depth, thickness, and temporal variability.

In cooperation with the SeaWiFS analysis group at the University of South Florida, the annual mean Gulf of Mexico basin-wide distribution of surface chlorophyll concentration was calculated using SeaWiFS ocean color data from January 1998 through December 1999. Locations of each of the DGoMB survey stations were then overlaid so that the incidence of locally high chlorophyll concentrations in deepwater could be compared along and between DGoMB station lines. This map was posted to the DGoMB web page; the resolution of the ocean color annual mean is 4 km x 4 km.

In cooperation with the TOPEX/Poseidon analysis group at the University of Colorado, the Gulf of Mexico basin-wide mean surface height anomaly (SSH) was computed for the calendar years 1998 and 1999 using altimetry from January-December 1998 and January-December 1999. The locations of the DGoMB stations were overlaid for comparison and this map was also posted to the DGoMB web page.

During Year Two of DGoMB, biweekly mean (and standard deviation) chlorophyll concentrations for a 5 x 5 pixel area (287 km^2) centered at each of the DGoMB station locations will be extracted.

8.4.5 Ecosystem "Health"

The "health" of the ecosystem in the area to be studied will be explicitly evaluated based on fundamental community structure variables (biomass, density, species composition, and diversity) measured as part of the benthic survey. The northern GOM ecosystem will be compared with other similar deep-sea settings world-wide. These comparisons will give a perspective on what features of the GOM ecosystem are similar or dissimilar to those of other areas. The qualitative degree of disturbance or alteration that has occurred in comparative ecosystems will provide a perspective on the current status of disturbance, stress, and/or "health" for the northern GOM ecosystem.

In addition, screening of the stations for chemical contaminants will provide a first-order determination of whether significant anthropogenic influences can be recognized at the study sites. While the levels of contaminants in the deep-sea are expected to be low, if any are encountered the potential for biological effects will be evaluated versus various biological effects criteria for sediment contaminant levels. By inference if no chemical contaminants are present, the current structure is reflective of an undisturbed state as far as toxic responses would be concerned.

As an in-the-end evaluation, the model will be capable of predicting the ecosystem response to various types of "unnatural" inputs. In particular, organic enrichment from the possible reef effects of offshore platforms and the possible introduction of chemical contaminants. While these effects have been documented near production platforms, in deep water the likely impact on the seabottom is greatly attenuated due to dispersion, dilution and vertical transport through the long overlying water column. On the continental shelf the areal extent of these effects around platforms are localized (within 10's of meters) and the attenuation of surface inputs would be significant in deep water. As mentioned above, the presence of chemical contaminants in sediments will be directly assessed. However, model predictions can be used to develop a set of diagnostic changes or trends in community structure and function in variables that might be expected under given "disturbance" conditions. Subsequently the sampled areas could be re-examined for these trends to determine if the sampled communities show any of the expected signs of disturbance or diminuation in "health".

Other more direct measures of population and individual "health" were judged to be beyond the scope of the current program and the available resources. However, additional indicators of ecosystem "health" have been proposed as potential optional add-ons to the main program.

8.4.6 Data Fusion and GIS

The complexity of the datasets being developed for this Program and the diversity of the types of data calls for innovation in developing tools for data synthesis and reporting. It is also a requirement of the solicitation that all data be geo-referenced in a machine-readable format capable of being incorporated directly into ARC/INFO using ARC/INFO's default data conversion capabilities. These requirements will be met by adopting a GIS based approach to data management, control, utilization, and synthesis. Data management protocols are detailed in the Program Management Plan.

Program data will be submitted to MMS for incorporation into their CORIS database. Separate coverages for each type of data collected or a single coverage for each type of topology will be produced. Any attributes contained in the coverage will be carried over to the SDE layer in the CORIS database. Two INFO tables will be created for each type of data (point, line, or poly). The ENVM_SOURCES table will hold source information about the data collected (e.g. depth). The second INFO table is a cross-reference table that will tie the features in the coverages to the data in the ENVM_SOURCES INFO table. ESRI software (ArcInfo, ArcMap) will be used to generate these data products.

The proposed Program will produce a wealth of mappable data at regional and local (station) spatial scales. This will include a wide range of data types from actual images from

benthic cameras to community structure and function, chemical, geochemical, geological and oceanographic variables. In addition, diverse data sets from previous investigations will be incorporated into the synthesis. In order to facilitate cross-work element and interdisciplinary integration, the data must be readily available and in a compatible format. Standard GIS methods will be used to fuse and disseminate data as digital and hard-copy maps using a multi-layered data approach. Spatial statistical methods will be used to aid in the testing of hypotheses. Interactive tools will be tailored to the Program so that the datasets are easily queried, sorted and displayed in a geo-referenced framework. The intent is to make the Program database as user friendly as possible and to provide state-of-the-art tools for data presentation and mapping.

8.5 Data Management

Data management plays a key role in complex environmental programs involving sample collection, monitoring, archiving, and chemical/physical/biological analyses and it's stated objectives are to monitor, control and facilitate data flow, ensuring the integrity of the data through each phase of the program.

Data management prepared a detailed summary of the planned data collection for the program and designed sample field collection forms (Tables 8.2 and 8.3).

Information was received directly from the ship during the first cruise and posted to the web (http://www.gerg.tamu.edu/GERG/dgomb.htm) with daily updates and weekly summaries. Data received to date for the first cruise includes collection information which has been incorporated into a GIS database and POC, TSPM, pigment data from three depths.

8.6 Meetings, Interpretation, and Reporting

Seven different meetings, with oral reports or formal written reports, have been conducted as of this Interim Report. A post-award meeting was held in College Station in October 1999, of the Principal Investigators, in the presence of the MMS personnel, to discuss the overall plan and goals of the project. This included a time line for deliverables, future meetings, and field work.

The Program Manager (Rowe) attended the December 1999, MMS Information Transfer Meeting in New Orleans and presented an overview of the project. This included presentation of the hypotheses, the conceptual model and the latest version of the complex topography over which the stations were to be placed.

A cruise plan for the May/June survey was developed and distributed to all components and MMS one month prior to the field work. A report of the activities on the survey was submitted one month after the cruise was finished (Appendix I). The latter report included critical information on each site, such as geographic positions, depths, observations, etc. It also included an inventory of all samples in hand and to whom they are distributed.

Table 8.2. Data collection summary and tracking.

Dependent Variables to be Measured.	
Community Structure	Community Function
Bacterial density	Bacteria growth rates
Bacterial biomass	Bacteria respiration
Foraminiferal biomass	Bacteria response to different substrates
Meiofaunal density	
Meiofaunal biomass	
Meiofaunal composition to major group	
Macrofaunal density	
Macrofaunal biomass	
Macrofaunal diversity	
Macrofaunal species composition	
Megafaunal density	
Megafaunal biomass	
Megafaunal diversity	
Megafaunal species composition	Megafaunal scavenging on carcasses
Fish density	
Fish biomass	
Fish diversity	
Fish species composition	Nutrient Regeneration
	Denitrification rate
	Sediment mixing rates (bioturbation)
	Sediment accumulation rate
	Sedimentary community oxygen consumption
	Sulfate reduction rate
	Foodweb studies
	[2]-estimated from sub-model

Ancillary Variables to be Measured at Survey and Experimental Stations.	
Water Column Profiles	**Geochemistry[1]**
Depth	Nutrients
Temperature	Dissolved Organic Carbon (DIC)
Salinity	SO_4=/C_l-
Oxygen	Dissolved Inorganic Carbon (DIC)
Nitrate and Nitrite	$\delta^{13}C$ DIC
Ammonium	Sulfate Reduction Rate
Silicate	pH
Phosphate	H_2S
Particulate Matter (PM)	O_2
Particulate Organic Carbon (POC)	Reactive Fe
Light	Reactive Mn
Currents	Acid Volatile Sulfide
	[1]Composite sample at survey station, profiles for fluxes at experimental station.
Sediment Properties	**Biotic Water Column Profile**
Grain Size	Photosynthetic Pigments
Porosity	
Elemental composition (organic carbon, nitrogen, sulfur)	
Percent inorganic carbon (TIC)	**Chemical Contaminants**
Permeability	Hydrocarbons
Shear Strength	Metals
Bulk Density	

Table 8.3. General biological field collection form.

	Var	Cruise	Sta	Sppcode	Abun	Biomas	S_Gear	Method	Sampid	Labsamp
	Descrip.	Cruise ID	Station ID	Species Code (NODC)	Abundance	Biomass (g)	Sampling Gear (Box, Trawl)	Sed, Tis, Wat, etc	Sample ID	Lab ID
	Units				#	g				
Obs 1										
Obs 2										
Obs 3										
Obs 4										
Obs n										

The Program Manager (Rowe) attended the MMS-sponsored Fisheries and Offshore Ecology meeting in New Orleans, October 24-26, 2000. He presented an overview of the results of the program to date. This included the hypotheses, the conceptual model, a carbon budget for the deep Sigsbee Abyssal Plain, and photographs of typical samples taken on the Survey Cruise. This included photographs of the wide spectrum of trash sampled with the trawl. Another paper was presented by Dr. Douglas Biggs and Mr. Patrick Roessler on levels of surface water productivity and potential 'hot spots' that might influence deep water secondary productivity and biomass.

The Program Manager met with the Scientific Advisory Committee on November 28, 2000 to present an overview of the status of work so far and a list of overall goals of DGoMB.

Four talks were presented at the December 5-7, 2000 MMS Information Transfer Meeting in New Orleans. The Program Manager (Rowe) presented an overview of the Survey Cruise, results, status of the hypothesis testing, status of model runs, and potential activities on the up-coming process-oriented field work on GYRE in June, 2001. Additional talks were given by Drs. Ian MacDonald and William Bryant on the *Alvin/Atlantis* expedition in October 2000. Dr. Elva Escobar summarized activities in deep-sea ecology by Mexico in the deep Gulf of Mexico.

In addition to the above, the Program Manager (Rowe) presented overviews of the DGoMB program in the weekly seminar of the Department of Oceanography at Texas A&M, at the BP environmental science seminar series, at the Jefferson Breakfast Club in Houston, and in the monthly seminar series of the Department of Oceanography at the University of Concepcion in Concepcion, Chile. Dr. Rowe also provided an overview of the program to the MMS Science Committee.

A "quick look" report required by NOAA has been written that describes the *Alvin* dive results (Appendix II).

8.6.1 Planning

The Executive Committee (EC; Rowe, Kennicutt, Nowlin, Morse, and Bryant) met during December 2000 to discuss sample analysis progress and a schedule for preliminary

interpretations for planning purposes. A preliminary draft of the June "processes" cruise plan will be reviewed, with emphasis on sampling and observations to be conducted at each site, how many sites to study and where the sites ought to be placed. Definite decisions on these issues will not be made at this time because too little data are available yet, but the EC will start to set a reasonable decision-making protocol in which priorities are defined. Top priority will be placed on locations and activities that are important to hypothesis testing and model variables. The EC will also discuss potential data reports that ought to be assembled. Options for data distribution that go beyond the contract requirements will also be discussed. If necessary, DGoMB data manager Dr. Gary Wolff was asked to attend to participate in this issue. [DGoMB would like to develop strategies to make all data generated widely available.]

A meeting for Principal Investigators was held in February 2001 at which each PI was asked, in the first half of the meeting (1/2 day), to bring everyone up-to-date on the status of sample analysis, status of hypothesis testing and status of model development. The second half of the meeting entailed discussions of the "processes" cruise on GYRE, June 1-20, 2001. Investigators with suggestions about hypothesis testing and sampling strategies for determining rates important to model development was asked to present their ideas. Others will be expected to respond with constructive criticism of the ideas and suggestions presented. This meeting was important for planning the next field work because enough data were available by this time to give the issues serious thought ahead of time. The report from that meeting explained the rationale for adding three new hypotheses and thre reasoning behind the choices of the four experimental sites (MT3, S36, S42, and MT6).

8.6.2 Field Program, *R/V Gyre*, June 1-20, 2001

The second DGoMB Cruise was conducted on the *R/V Gyre* in June, 2001. Planning to decide on sites to be studied and activities at each site was done at the Team Planning Meeting in February, 2001. Priorities were placed on hypothesis testing and model development, as presented in the original proposal. Significant progress is expected in the EC and PI meetings referred to above, but this will be fine-tuned through discussions between the Program Managers, the EC and the Principal Investigators. A final plan for the 'processes' field work was available one month (on May 1, 2001) before the scheduled trip. The cruise was conducted from June 1-19, 2001, in and out of Galveston.

Future field activities are scheduled for June and August, 2002. However, this is subject to discussion and revision based on developing issues and new data.

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Appendix I

Deep Gulf of Mexico Benthos Program (DGoMB)
Cruise I Report
R/V Gyre
May 3-June 21, 2000

Texas A&M University
University of Texas
etc.

MMS Contract 1435-01-99-CT-30991

RV GYRE DGOMB SURVEY CRUISE REPORT

Background

Texas A&M University, in cooperation with a number of subcontractors (see list of participants), is under contract to the Minerals Management Service (Contract No. 1435-01-99-CT-30991, Deep Gulf of Mexico Benthos-DGoMB) of the US Dept. of the Interior to investigate the structure and function of the deep ocean benthic communities in the northern Gulf of Mexico. The program has been designed to be conducted in two phases: a census of the composition of the communities, followed by measurements of principal biogeochemical and eco-physiological processes that characterize the dominant populations of the communities. Conceptual models, steady state budgets, and dynamic numerical simulations will be constructed from the census information. The models will be tested and adjusted appropriately based on the new data collected during the field programs in the second phase. This present report is on the field work conducted in support of the first phase: the survey (census) of the biota.

Purpose

The purpose of the "Survey" in DGoMB was to characterize the principal components of benthic communities over the entire northern Gulf of Mexico (GoM) from the continental shelf break out to the southern boundary of the Exclusive Economic Zone (EEZ) at 26^{o} N. Latitude. This characterization was intended to assess the abundances and biomasses of each of the important size classes of the communities (bacteria, meiofauna, macrofauna, megafauna and demersal fishes). Species composition is to be determined for the macrofauna, megafauna and fishes. The diversity and zoogeographic distribution patterns for each of these size groups will be determined for assessments of variations within the GoM and comparisons of the deep GoM with other continental margins. The variations in biomass within the groups and in space will be used to construct steady state budgets of carbon flux within the study area.

Dates

May 3 to June 21, 2000, with a port stop in Port Aransas from May 22 to May 28.

Participants

Leg One Participants

1) Rowe, Gilbert T., Chief Scientist, TAMU, Prof., Oceanogr., DGoMB Pgm. Mgr.,
2) Kalke, Richard, UT-MSI Res. Assoc.,
3) Gilbert, Marianne, UT-MSI, graduate student,
4) Lee, Wonchoel, UT-MSI, postdoctoral investigator
5) Loughy, Lindsey, TAMU, Bio., undergrad. stu.
6) Salas Hernandez, Juan Antonio, UNAM, Mexican representative
7) Oseguera Perez, Luis Alberto, UNAM, Mexican representative
8) Ziegler, Mathew, TAMU grad. stu., Oceanography
9) Gudeman, Christopher, TAMU grad. stu., Oceanography
10) Carpenter, Shelly, U. Washington Res. Asst.
11) Debeukelaer, Sophie, TAMU Ocean. grad. student

12) Nunnelly, Cliff, TAMU graduate student, Oceanogr.
13) Guichard, Aurelien, TAMU graduate student, Ocean. Engineering
14) Ammons, Archie, TAMU grad. stu., Biology
15) Zednai, Leslie, marine technician, TAMU, GERG
16) Clark, Paul, TAMU, GERG, winch operator, deck engineer, CTD, ADCP
17) Guffy, Dennis, TAMU, Ocean. Tech.
18) Rowe, Sherrylynn, Memorial Univ., Nfld, CA
19) Davenport, Roe, independent consultant, San Antonio, TX

Leg Two Participants

1) Rowe, Gilbert T., TAMU, Ocean., Prof. and DGoMB Pgm. Mgr., Chief Scientist
2) Goff, John, TAMU, Res. Asst., WFS
3) Wicksten, Mary, TAMU, Bio., DGoMB PI
4) Ammons, Archie, TAMU, Bio., grad. stu.
5) Ziegler, Mathew, TAMU, Ocean., grad. stu.
6) Gilbert, Marianne, UT-MSI, graduate student
7) Loughy, Lindsey, TAMU, undergraduate biol.
8) Gudeman, Christopher, TAMU, Ocean., grad. stu.
9) Jones, Brian, TAMU grad. stu., Oceanography
10) Debeukelaer, Sophie, TAMU grad. stu., Oceanography
11) Nunnelly, Cliff, TAMU Grad. stu., Ocean.
12) Walpert, John, TAMU, GERG
13) Zednai, Leslie Anne, marine technician, TAMU, GERG
14) Webb, Eddie, TAMU, Dept. of Oceanography, electronics technician
15) Lee, Wonchoel, UT-MSI, postdoctoral investigator
16) Methven, David, Memorial Univ., Nfld, CA
17) Davenport, Roe, independent consultant

Narrative (Figure 1-Site Map)

Forty-three sites were selected to determine the relationship between the biota and a general set of environmental variables: 1) an east to west gradient, 2) a depth gradient, 3) basins vs. non-basins, 4) canyons vs. non-canyons, 5) proximity to the Mississippi River plume, and 6) proximity to fossil hydrocarbon seeps. These sites were placed along a series of west to east transects. Where possible, earlier sampling sites from previous studies were re-occupied. Each transect had approximately 6 sites ranging in depth from the shallow upper slope down to the upper continental rise at the base of the Sigsbee (west area) and Florida (east area) escarpments. The west sites were located along the 26^{o} North Latitude line, which marks the border with Mexico.

At each site the following sampling sequence was carried out: 1) CTD, 2) 5 box cores, 3) camera lowering and 4) bottom trawl.

CTD and Associated Hydrography:

The CTD and rosette water sampler was deployed at each site. Samples were taken to within 2 m of the bottom to characterize the bottom water. The near bottom bottles were sampled for particulate matter, POC, plant pigments, dissolved inorganic nutrients, oxygen and salinity. The oxygen, temperature, salinity, in vivo fluorescence, light intensity and light transmission were measured continuously with sensors and recorded aboard ship in real time. The oxygen and salinity were calibrated aboard ship with samples from the bottles. The inorganic nutrients were run with an autoanalyzer aboard ship on the first leg and frozen on the second leg for analysis in the shore-based laboratory.

The CTD, 24 bottle rosette and associated sensors, and a bottom-finding pinger were lost at site B2 on the first leg. For the remainder of the 1st leg the backup CTD and a 12 bottle rosette were used. A replacement 24 bottle rosette was put aboard ship in Port Aransas and this was utilized during the entire 2nd leg.

Profiles are now available of temperature, salinity, oxygen concentration, and light transmission from each site. Inquiries about the hydrographic data should be directed to Dr. Worth Nowlin (wnowlin@ocean.tamu.edu) or Dr. Norman Guinasso (norman@gerg.tamu.edu).

Box Cores (see table of sample inventory):

The GOMEX box cores were taken to provide quantitative information on macrofauna, meiofauna, bacteria, geological properties, geochemical properties, trace metals, and trace organic contaminants. The subsamples were taken by mounting core liners within the core box to prevent artifacts due to redistribution of surficial sediments during recovery. The geology core was taken from the core after recovery. This allowed the geo-sample to be taken with no overlying water. A total of 215 0.2 m^2 box cores were taken; these covered a total of 43 square meters of sea floor.

On recovery, the overlying water of each box core was siphoned off through a 300 micrometer sieve with the retained material added to the macrofauna sample. The subcores (plastic core liners mounted in the box) were covered with core caps immediately to prevent contamination. Then the surface sediment down to a depth of 15 cm was removed from around the mounted subcores. This material was then sieved through 300 micrometer mesh sieves by floating and elutriating the composite animal-containing sediment from 30 gallon plastic ash cans out into the sieves, using filtered sea water to prevent contamination by plankton. The macrofauna samples and associated sediments retained by the sieve were soaked in sea water containing ca. 50 cc of Epsom Salts ($MgSO_4$) for 30 minutes to narcotize and thus relax the animals prior to fixation in 10% formalin and filtered sea water solution. The fixed animals and associated sediments retained by the sieves were stored in 5 gallon plastic containers on deck. The fixative solution volume was in all cases more than 2 times the volume of the sediment retained in the sample after sieving. The containers were labeled inside and out using approved "MMS-DGoMB" labels. They were also labeled with the sequential event or activity number (see Appendix) on the container's top with a black permanent felt-tipped marker.

Following the removal of the surficial 15 cm for macrofauna, the subcores were stoppered or capped on the bottom and removed from the core box. They were extruded from the bottom up and the top 2 cm were taken for the non-biological samples. A profile of bacteria samples was taken at surface, 5, 10 and 15 cm depth intervals. The meiofauna cores were subsampled at two intervals: the top 0 to 1 cm, followed by a layer that included cm's 2 and 3. The meiofauna samples were preserved in 5% formalin sea water solution containing Rose Bengal stain. These samples were transferred to the University of Texas Marine Science Institute in Port Aransas. The bacteria were preserved in 2% glutaraldehyde and filtered sea water solution and kept refrigerated until air freighted to the University of Washington at the end of the 2nd leg. The geochemical, trace metal and trace organic samples, each 2 cm thick, were frozen aboard ship. The geology cores were stored on deck.

The GOMEX box core covers an area that measures 18" x 18". This is equivalent to 0.209 m^2. The areas covered by the subcores were 36.3 cm^2 for each of the 5 larger subcores (geology, geochemistry, bacteria, trace metals and trace organics) and 24.6 cm^2 for each of the two meiofauna cores. Thus a total of 230.8 cm^2 was removed from the 2,090 cm^2 box. Therefore, the macrofauna sample was 1860 cm^2, or 0.185 m^2. Although two meiofauna cores were routinely mounted in the core, only one was retained for further study.

Bottom Camera Lowerings (see sample inventory below):

A Benthos digital still camera and strobe, housed in deep-sea housings, were used to take multiple exposures of the sea floor. This camera system was set up on a vertical frame with a bottom trigger switch so that each exposure would cover approximately the same area of sea floor (ca. 5 m^2). A pinger was mounted 25 m above the camera frame on the hydrographic wire. Bottom contact, and thus the triggering of each exposure, was accomplished by lowering the camera until it hit bottom (as evidenced by the PGR trace or deflection of the spring accumulator) and then immediately recovering it to a height of 10 to 15 m above bottom. This lowering and recovery was repeated every one to two minutes until 25 to 50 exposures were made of the sea floor. On recovery back aboard ship, the digital images were downloaded onto a PC for viewing on computer screen, printing and storage.

A total of 43 attempts were made to take photographs of the sea floor at the sites designated in Figure 1. Three of these attempts failed: on one occasion (B1, May 6) the camera batteries failed. At W4 and RW6 the photographs were exposed by pre-tripping in the water column during transit to the bottom. A total of 1380 photographs were taken where the camera was successful at taking pictures of the sea floor. The mean number was 32 good exposures per site. These covered an approximate area of 6900 m^2.

Bottom Trawling (see sample inventory table):

The sea floor was trawled at 40 sites. Of these, two were failures in which the trawl nets, doors and bridles were all lost (RW6 on May 19; RW4 on June 20). At another site, most of the net was lost but the doors and bridle were recovered (W2 on May 14). After the loss on May 19 near the end of the 1st leg, the backup beam trawl was used successfully.

The otter trawl had a 40' gape. One pair of steel doors measuring 3' x 4' was used on the first leg. Wooden doors measuring 7' x 40 inches were used on the second leg. It is assumed that the net spreads to an effective width of ca. 33'. Thus, the trawl, when working properly, sampled a path that was approximately 10 m across. The area covered can be estimated by multiplying path width times the distance over which the trawl was on bottom. In the case of the beam trawl, it had a width of 4 meters. The net's mesh size in both trawl types (otter trawl and beam trawl) was 1.75 inch stretched. The wire let out was approximately 1.5 to 2 times the water depth. Bottom time was 30 min per 1000 m depth. Ship speed was 1.7 to 2.3 knots. Wire pay out was 25 m per min; recovery was 25 m per min until the trawl was off bottom. Then it was increased to 50 m per min.

The trawl samples were sorted into three categories: invertebrates, fish and trash. The invertebrates and the fish were then sorted to the "species" level, counted, and weighed (by volume displacement). Types of trash were counted and stored with no preservative in 5 gallon plastic containers with an appropriate label on the inside and out. The biological samples were placed in 5 gallon plastic containers with 10% buffered formalin and sea water solution with labels on the inside and outside of the containers. The lids of trawl samples were also labeled with the activity number (see Appendix) and designated either fish, invertebrate or trash.

ADCP

Acoustic Doppler Current Profilers (ADCP) were operated on station and with the ship underway to obtain an integrated picture of current direction and velocity in the upper 1000 m of the water column. A 38 kHz OS-ADCP was operated for the entire cruise. A BB-ADCP (broadband) was utilized for the first leg and then switched to the narrow band system on May 31 when direction could not be resolved with the broadband system. On inspection of the system, a deep gash in transducer # 4 was discovered that probably occurred while the ship was tying up in Port Aransas. Processing of the data is ongoing.

Mapping

Maps were made during the sampling at each site at scales of 10 to 50 km around each site, with topography plotted at 50 m intervals. The locations of each sampling activity were plotted to show the spatial relationships between each sampling device and sampling replicates.

"Make-up" Sampling

The sampling planned for leg 2 was completed ahead of schedule and so an attempt was made to "make-up" sampling that had been unsuccessful or for some reason needed repeating. Thus, when MT1 (the last scheduled site) was finished, we returned to MT4 for a trawl. Then we did camera lowerings in B1, B3 and B2, in that order. This was followed by trawling at B2, an intermediate site between W6 and RW 6, and a final trawl near RW4. All this make-up sampling was successful, with the exception of the last trawl: the wire parted and the whole system was lost. Most of the damage to trawl gear occurred on transects W and RW.

Inventory of Deep Bottom Samples from DGoMB

	Trawls			Box Cores							
SITE	Fish	Invertebrates	Trash	Macrofauna	Meiofauna	Bacteria	Geology	Geochemistry	Trace Metals	Trace Organics	Camera Photo Images
RW1	1	1	1	5	5	5	5	5	4	5	45
RW2	1	1	1	5	5	5	5	5	3	5	42
RW3	0	0	0	5	5	5	5	5	3	5	28
RW4	0	0	0	5	5	5	5	5	3	5	41
RW5	0	0	0	5	5	5	5	5	3	5	40
RW6	1	1	1	5	5	5	5	5	5	5	0
AC1	0	0	0	5	5	3	5	5	3	5	25
W1	1	1	1	5	5	5	5	5	5	5	25
W2	0	0	0	5	5	5	5	5	3	5	40
W3	1	1	1	5	5	5	5	5	3	5	6
W4	0	0	0	5	5	5	5	5	3	5	0
W5	0	0	0	5	5	5	5	5	3	5	1
W6	See RW6 for trawl			5	5	4	5	5	3	5	43
WC5	1	1	1	5	5	5	5	5	5	5	4
WC12	0	0	0	5	5	5	5	5	5	5	3
B1	1	1	1	5	5	5	5	5	5	5	45
B2	1	1	1	5	5	4	5	5	3	5	4
B3	1	1	1	5	5	5	5	5	5	5	19
NB2	1	1	1	5	5	5	5	5	5	5	28
NB3	1	1	1	5	5	5	5	5	5	5	28
NB4	1	1	1	5	5	5	5	5	5	5	0
NB5	1	1	1	5	5	5	5	5	5	5	28
C1	1	1	1	5	4	4	4	4	4	4	43
C7	1	1	1	5	5	5	5	5	5	5	41
C4	1	1	1	5	5	5	5	5	5	5	45
C14	1	1	1	4	3	1	5	3	3	3	42
C12	1	1	1	4	4	4	4	4	4	4	45
MT1	1	1	1	5	3	3	5	3	3	3	43
MT2	1	1	1	5	5	5	5	5	5	5	42
MT3	1	1	1	5	5	5	5	5	5	5	44
MT4	1	1	1	5	5	5	5	5	5	5	45

Inventory of Deep Bottom Samples from DGoMB (Cont.)

	Trawls			Box Cores							Camera Photo
SITE	Fish	Invertebrates	Trash	Macrofauna	Meiofauna	Bacteria	Geology	Geochemistry	Trace Metals	Trace Organics	Images
MT5	1	1	1	5	5	5	5	5	5	5	38
MT6	1	1	1	5	5	5	5	5	5	5	26
S35	1	1	1	4	5	4	5	5	5	5	45
S36	1	1	1	5	5	5	5	5	5	5	45
S37	1	1	1	5*	5	5	5	5	5	5	45
S38a*	1	1	1	5*	5	5	5	5	5	5	45
S44	1	1	1	5*	4	5	5	5	5	5	45
S43	1	1	1	5	5	4	4	5	5	5	23
S42	1	1	1	5	5	5	5	5	5	5	46
S41	1	1	1	5	5	5	5	5	5	5	46
S40	1	1	1	5	5	5	5	5	5	5	45
S39	1	1	1	5	5	5	5	5	5	5	46

* Box core leaked from some samples on recovery; see original field notes.

a* Original S38 moved 5 n.mi. due west because of difficult sampling at base of Florida escarpment.

Appendix-Event or Activity Log. UTC refers to Universal Central Time, often referred to as Greenwich Time. This is 5 hours ahead of the local time aboard ship. Sample types are discussed above in the text. The site names are shown on the map. PDR refers to the water depth as read off the Precision Depth Recorder. Wire out is the amount of wire let out from the winch.

DATE-UTC	TIME UTC	LAT/MIN	LONG/MIN	SEQ. No.	SITE NAME	SAMPLE TYPE	WIRE OUT (m)	PDR (m)	COMMENTS
4-May-00	1241	27 46.9694N	91 46.2067W	1	WC5	CTD	329	322.3	Start
4-May-00	1417	27 46.3012N	91 46.3146W	2	WC5	Box Core			No sample
4-May-00	1437	27 46.2817N	91 46.1895W	3	WC5	Box Core	475	440	No sample
4-May-00	1525	27 46.2838N	91 45.7293W	4	WC5	Box Core	448	400	Good core
4-May-00	1723	27 47.1151N	91 45.8502W	5	WC5	Box Core	358	320	Good core
4-May-00	1857	27 46.5547N	91 45.9407W	6	WC5	Box Core	420	348	Good core but was dragged
4-May-00	2018	27 46.906N	91 45.9578W	7	WC5	Box Core	405	330	Good core
4-May-00	2206	27 46.9893N	91 45.8800W	8	WC5	Box Core	368	325	Good core
5-May-00	0028	27 46.9633N	91 45.6946W	9	WC5	Camera	330	328	First hit on bottom
5-May-00	0037	27 46.9673N	91 45.6070W	10	WC5	Camera	330	328	Last hit on bottom
5-May-00	0414	27 41.8766N	91 39.4832W	11	WC5	Trawl	1755	845	Start trawl, off WC5
5-May-00	0444	27 40.9851N	91 38.6803W	12	WC5	Trawl	1755	670	End trawl
5-May-00	0828	27 19.0946N	91 32.8177W	13	WC12	CTD	1161	1150	Start
5-May-00	1301	27 19.3945N	91 33.3486W	14	WC12	Box Core	1168		Good core
5-May-00	1432	27 19.1120N	91 33.2314W	15	WC12	Box Core	1125		Good core
5-May-00	1549	27 19.4320N	91 33.1625W	16	WC12	Box Core	1175		Good core
5-May-00	1715	27 19.185N	91 33.0650W	17	WC12	Box Core	1169		Good core
5-May-00	1855	27 19.6198N	91 33.0871W	18	WC12	Box Core	1194		Good core
5-May-00	2042	27 19.6546N	91 33.0179W	19	WC12	Camera	1198		Start
5-May-00	2125	27 20.1211N	91 33.0853W	20	WC12	Camera	1295	1300	End
5-May-00	2345	27 19.3666N	91 35.4967W	21	WC12	Trawl	2100	1050	Start- trawl on bottom
6-May-00	0016	27 19.5117N	91 36.8079W	22	WC12	Trawl	2100	1150	End trawl
6-May-00	0432	27 12.0201N	91 24.1077W	23	B1	CTD	2279	2265	CTD in water
6-May-00	0725	27 12.2050N	91 23.9837W	24	B1	Box Core	2206	2260	Good core
6-May-00	0858	27 12.1374N	91 24.1806W	25	B1	Box Core	2195	2255	No sample
6-May-00	1019	27 12.1853N	91 24.2407W	26	B1	Box Core	2197	2255	Good core
6-May-00	1208	27 12.1704N	91 24.3638W	27	B1	Box Core	2195	2253	Good core
6-May-00	1348	27 12.0086N	91 24.3648W	28	B1	Box Core	2196	2254	Good core
6-May-00	1515	27 12.1525N	91 24.3131W	29	B1	Box Core	2196	2254	Good core

Appendix-Event or Activity Log (Cont.).

DATE-UTC	TIME UTC	LAT/MIN	LONG/MIN	SEQ. No.	SITE NAME	SAMPLE TYPE	WIRE OUT (m)	PDR (m)	COMMENTS
6-May-00	1720	27 12.3258N	91 24.2320W	30	B1	Camera	2297	2260	Start camera
6-May-00	1815	27 12.5960N	91 24.4054W	31	B1	Camera	2194	2250	End camera
6-May-00	2208	27 10.4993N	91 25.2956W	32	B1	Trawl	7000	2250	Start- trawl on bottom
6-May-00	2308	27 12.3807N	91 23.8718W	33	B1	Trawl	7000	2250	End trawl
7-May-00	0623	27 7.8630N	92 0.0356W	34	NB2	CTD	1546	1530	CTD in water
7-May-00	0843	27 8.0243N	91 59.9584W	35	NB2	Box Core	1490	1530	Good core
7-May-00	1044	27 8.2040N	91 59.9207W	36	NB2	Box Core	1490	1530	Good core
7-May-00	1202	27 7.9710N	92 0.0170W	37	NB2	Box Core	1490	1530	Good core
7-May-00	1328	27 8.1027N	91 59.9891W	38	NB2	Box Core	1495	1530	Good core
7-May-00	1450	27 8.2605N	92 0.0126W	39	NB2	Box Core	1528	1530	No sample
7-May-00	1546	27 8.0900N	92 0.0041W	40	NB2	Box Core	1490	1530	Good core
7-May-00	1717	27 8.4208N	92 0.1543W	41	NB2	Camera	1548	1530	Start camera
7-May-00	1804	27 8.6513N	91 59.8378W	42	NB2	Camera	1527	1540	End camera, 40 hits
7-May-00	2045	27 8.8370N	92 0.4277W	43	NB2	Trawl	4000	1525	Start trawl
7-May-00	2130	27 7.1924N	91 59.6843W	44	NB2	Trawl	4000	1540	End trawl
8-May-00	0309	26 33.1686N	91 49.7059W	45	NB3	CTD	1986	1875	CTD in water
8-May-00	0555	26 33.4820N	91 49.3530W	46	NB3	Box Core	1890	1875	Good core
8-May-00	0729	26 33.6122N	91 49.3738W	47	NB3	Box Core	1902	1875	No sample
8-May-00	0841	26 33.3912N	91 49.4683W	48	NB3	Box Core	1885	1875	Good core
8-May-00	1010	26 32.9725N	91 49.1853W	49	NB3	Box Core	1846	1875	Good core
8-May-00	1131	26 33.3039N	91 49.4705W	50	NB3	Box Core	1840	1875	Good core
8-May-00	1248	26 33.2733N	91 49.5132W	51	NB3	Box Core	1845	1875	Good core
8-May-00	1425	26 32.8549N	91 49.3671W	52	NB3	Camera	1858	1885	1st hit cam
8-May-00	1519	26 32.7164N	91 48.9535W	53	NB3	Camera	1838	1863	Last hit on bottom
8-May-00	1908	26 31.3028N	91 48.9448W	54	NB3	Trawl	4700	1850	Trawl on bottom, 4700 m wire
8-May-00	2008	26 29.0239N	91 47.8046W	55	NB3	Trawl	4700	1910	End trawl
9-May-00	0112	26 15.0457N	91 13.0378W	56	NB5	CTD	2113	2080	CTD in water
9-May-00	0414	26 15.1137N	91 12.6102W	57	NB5	Box Core	2085	2070	Good core
9-May-00	0608	26 15.0855N	91 12.7524W	58	NB5	Box Core	2040	2060	Good core
9-May-00	0928	26 15.0428N	91 12.7712W	59	NB5	Box Core	2040	2060	No sample
9-May-00	1053	26 14.8501N	91 12.7500W	60	NB5	Box Core	2025	2060	Good core
9-May-00	1224	26 15.2157N	91 12.6639W	61	NB5	Box Core	2025	2060	Good core

Appendix-Event or Activity Log (Cont.).

DATE-UTC	TIME UTC	LAT/MIN	LONG/MIN	SEQ. No.	SITE NAME	SAMPLE TYPE	WIRE OUT (m)	PDR (m)	COMMENTS
9-May-00	1358	26 14.7240N	91 12.5945W	62	NB5	Box Core	2055	2065	Good core
9-May-00	1548	26 14.6013N	91 12.2397W	63	NB5	Camera	2067	2070	1st hit on, Camera start
9-May-00	1739	26 14.4129N	91 11.2416W	64	NB5	Camera	2140	2150	Last hit on bottom
9-May-00	2111	26 14.9971N	91 12.1544W	65	NB5	Trawl	5140	2110	All 5140 m of wire out
9-May-00	2211	26 15.0416N	91 14.4178W	66	NB5	Trawl	5140	2100	1 hour trawl End
10-May-00	0329	26 12.2946N	91 46.0718W	67	B3	CTD	2649	2650	Pinger at 25 m
10-May-00	0600	26 13.5570N	91 45.3033W	67	B3	CTD			Tube locked , CTD lost
10-May-00	0907	26 9.8667N	91 44.1060W	68	B3	Box Core	2545	2650	Good core
10-May-00	1055	26 9.7884N	91 43.9954W	69	B3	Box Core	2554	2580	Good core
10-May-00	1241	26 9.9750N	91 43.9772W	70	B3	Box Core	2555	2590	Good core
10-May-00	1442	26 9.9760N	91 44.1386W	71	B3	Box Core	2570	2610	Good core
10-May-00	1637	26 9.8542N	91 44.0725W	72	B3	Box Core	2545	2600	Good core
10-May-00	2224	26 6.4804N	91 44.5135W	73	B3	Trawl	6200	2300	Start trawl
10-May-00	2354	26 10.0902N	91 44.9254W	74	B3	Trawl	6200	2620	End trawl
11-May-00	0603	26 15.2211N	92 24.0743W	75	NB4	CTD	2055	2038	CTD (backup,12 bottle rosette)
11-May-00	0901	26 15.2711N	92 23.6978W	76	NB4	Box Core	1965	2030	Good core
11-May-00	1051	26 14.9693N	92 23.4731W	77	NB4	Box Core	2000	2050	Good core
11-May-00	1221	26 14.8748N	92 23.6513W	78	NB4	Box Core	1977	2050	No sample
11-May-00	1337	26 15.0096N	92 23.7449W	79	NB4	Box Core		2020	Good core
11-May-00	1514	26 14.9712N	92 23.5933W	80	NB4	Box Core	1990	2050	Good core
11-May-00	1643	26 14.8050N	92 23.5372W	81	NB4	Box Core	2004	2060	Good core
11-May-00	1755	26 14.9346N	92 23.6610W	82	NB4	CTD	267	250	CTD in water
11-May-00	2129	26 15.3007N	92 23.4718W	83	NB4	Trawl	5100	2070	All 5140 m of wire out
11-May-00	2229	26 16.7577N	92 25.5074W	84	NB4	Trawl	5100	1950	End trawl
12-May-00	0303	26 33.0193N	92 13.6845W	85	B2	CTD	2798	2623	CTD in water
12-May-00	0650	26 33.0774N	92 12.9990W	86	B2	Box Core	2615	2630	Good core
12-May-00	0858	26 33.3750N	92 13.4716W	87	B2	Box Core	2600	2630	Good core
12-May-00	1056	26 32.9491N	92 13.1357W	88	B2	Box Core	2594	2625	Good core
12-May-00	1247	26 32.9158N	92 13.3885W	89	B2	Box Core	2578	2625	Good core
12-May-00	1432	26 33.0007N	92 12.9049W	90	B2	Box Core	2661	2635	Good core
12-May-00	1918	26 32.1216N	92 11.7171W	91	B2	Trawl	6200	2650	6200 m of wire out
12-May-00	2048	26 34.4042N	92 14.9502W	92	B2	Trawl	6200	2450	End trawl

Appendix-Event or Activity Log (Cont.).

DATE-UTC	TIME UTC	LAT/MIN	LONG/MIN	SEQ. No.	SITE NAME	SAMPLE TYPE	WIRE OUT (m)	PDR (m)	COMMENTS
13-May-00	0318	26 33.7775N	92 14.1248W	93	B2	Beam trawl	2620	2610	All wire out
13-May-00	0405	26 33.7179N	92 13.4326W	94	B2	Beam trawl	2620	2630	
13-May-00	1939	27 34.6599N	93 33.0201W	95	W1	CTD	434	418	CTD in water
13-May-00	2042	27 34.7791N	93 32.8573W	96	W1	Box Core	379	375	Good core
13-May-00	2120	27 34.8829N	93 33.0319W	97	W1	Box Core	389	385	Good core
13-May-00	2217	27 34.5256N	93 33.0286W	98	W1	Box Core	412	420	Good core
13-May-00	2309	27 34.5441N	93 33.0153W	99	W1	Box Core	410	420	Good core
13-May-00	2354	27 34.6299N	93 33.0603W	100	W1	Box Core	419	415	Good core
14-May-00	0143	27 34.5165N	93 33.2362W	101	W1	Camera	430	441	Camera start
14-May-00	0244	27 34.1729N	93 33.7450W	102	W1	Camera	455	488	Last hit on bottom
14-May-00	0409	27 34.5799N	93 32.8831W	103	W1	Trawl	1200	400	1200 m wire out
14-May-00	0439	27 33.7587N	93 32.0068W	104	W1	Trawl	1200	400	End trawl
14-May-00	0712	27 24.7201N	93 20.2936W	105	W2	CTD	646	623	CTD in water
14-May-00	0826	27 24.8008N	93 20.2579W	106	W2	Box Core	611	625	Good core
14-May-00	0919	27 24.7019N	93 20.3849W	107	W2	Box Core	620	625	Good core
14-May-00	1042	27 24.8517N	93 20.4010W	108	W2	Box Core	619	625	Good core
14-May-00	1131	27 24.8855N	93 20.4223W	109	W2	Box Core	618	625	Good core
14-May-00	1215	27 24.8356N	93 20.4197W	110	W2	Box Core	619	625	Good core
14-May-00	1317	27 24.8902N	93 20.4991W	111	W2	Camera	605	620	Camera start
14-May-00	1410	27 24.8822N	93 20.5403W	112	W2	Camera	610	619	Last hit on bottom
14-May-00	1615	27 24.4216N	93 20.5061W	113	W2	Trawl	1875	650	1875 m wire out
14-May-00	1645	27 23.3197N	93 21.1637W	114	W2	Trawl	1875	675	End trawl, net lost
14-May-00	1853	27 10.4567N	93 19.4560W	115	W3	CTD	901	878.3	CTD in water
14-May-00	2021	27 10.3711N	93 19.3081W	116	W3	Box Core	852	860	Good core
14-May-00	2126	27 10.3840N	93 19.3315W	117	W3	Box Core	869	860	Good core
14-May-00	2229	27 10.4482N	93 19.4034W	118	W3	Box Core	864	875	Good core
14-May-00	2340	27 10.4739N	93 19.2691W	119	W3	Box Core	859	860	Good core
15-May-00	0027	27 10.3438N	93 19.3976W	120	W3	Box Core	859	860	Good core
15-May-00	0136	27 10.3525N	93 19.4711W	121	W3	Camera	867	875	Camera start
15-May-00	0306	27 10.5371N	93 19.4659W	122	W3	Camera	856	875	50 pictures taken
15-May-00	0540	27 9.0861N	93 18.3774W	123	W3	Trawl	2500	910	2500 m wire out
15-May-00	0616	27 8.6938N	93 20.0004W	124	W3	Trawl	2500	990	End trawl

Appendix-Event or Activity Log (Cont.).

DATE-UTC	TIME UTC	LAT/MIN	LONG/MIN	SEQ. No.	SITE NAME	SAMPLE TYPE	WIRE OUT (m)	PDR (m)	COMMENTS
15-May-00	0948	26 43.9179N	93 19.1384W	125	W4	CTD	1507	1475	CTD in water
15-May-00	1143	26 43.9027N	93 19.1708W	126	W4	Box Core	1429	1420	Good core
15-May-00	1324	26 43.8500N	93 19.1843W	127	W4	Box Core	1435	1460	Good core
15-May-00	1443	26 43.8088N	93 19.2061W	128	W4	Box Core	1435	1460	Good core
15-May-00	1554	26 43.7675N	93 19.2508W	129	W4	Box Core	1450	1460	Good core
15-May-00	1656	26 43.8494N	93 19.1836W	130	W4	Box Core	1425	1460	Good core
15-May-00	1817	26 43.8238N	93 19.1276W	131	W4	Camera	1432	1460	Camera start
15-May-00	1952	26 42.8721N	93 19.2633W	132	W4	Camera	1472	1457	Last hit on bottom
16-May-00	0003	26 16.7711N	93 21.5289W	133	W5	CTD	2875	2745	CTD in water
16-May-00	0323	26 15.9654N	93 21.6653W	134	W5	Box Core	2871	2755	Good core
16-May-00	0545	26 16.2566N	93 21.6885W	135	W5	Box Core	2786	2750	Didn't trip
16-May-00	0747	26 16.5781N	93 21.7309W	136	W5	Box Core	2665	2740	Good core
16-May-00	1004	26 16.1395N	93 21.7915W	137	W5	Box Core	2750	2750	Good core
16-May-00	1205	26 16.1871N	93 22.0669W	138	W5	Box Core	2742	2745	Good core
16-May-00	1450	26 16.0663N	93 19.9634W	139	W5	Box Core	2810	2775	Good core
16-May-00	1650	26 16.4216N	93 21.7870W	140	W5	Camera	2721	2740	Camera start
16-May-00	1853	26 16.1884N	93 21.7605W	141	W5	Camera	2772	2745	50 pictures taken
17-May-00	0028	26 12.7951N	93 22.6483W	142	W5	Trawl	6500	2820	All 6500 m of wire out
17-May-00	0158	26 8.2760N	93 23.6074W	143	W5	Trawl	6500	2950	End trawl
17-May-00	0501	25 59.9254N	93 19.2382W	144	W6	CTD	3127	3140	CTD in water
17-May-00	0856	26 0.2171N	93 19.6175W	145	W6	Camera	3185	3130	Camera start
17-May-00	1014	26 0.0288N	93 19.4049W	146	W6	Camera	3058	3120	Last hit on bottom
17-May-00	1148	26 0.1707N	93 19.2166W	147	W6	Box Core	3055	3140	Good core
17-May-00	1353	25 59.7526N	93 18.8003W	148	W6	Box Core	3100	3145	Good core
17-May-00	1542	25 59.7601N	93 18.5516W	149	W6	Box Core	3128	3150	Good core
17-May-00	1744	25 59.8101N	93 18.4085W	150	W6	Box Core	3182	3145	Good core
17-May-00	1800	25 59.1728N	93 18.6528W	151	W6	Box Core	3114	3150	Best Core
18-May-00	0725	26 0.0684N	94 30.1112W	152	RW6	CTD	3033	3015	CTD in water
18-May-00	1200	25 59.9222N	94 29.7608W	153	RW6	Box Core	2978	3015	Good core
18-May-00	1438	26 0.1959N	94 29.9143W	154	RW6	Box Core	3045	3015	Didn't Fire
18-May-00	1643	26 0.142N	94 29.381W	155	RW6	Box Core	3000	3015	Good core
18-May-00	1907	25 59.9982N	94 29.5629W	156	RW6	Box Core	2941	3000	Good core

Appendix-Event or Activity Log (Cont.).

DATE-UTC	TIME UTC	LAT/MIN	LONG/MIN	SEQ. No.	SITE NAME	SAMPLE TYPE	WIRE OUT (m)	PDR (m)	COMMENTS
18-May-00	2059	25 59.8684N	94 29.9071W	157	RW6	Box Core	2976	3010	Good core
18-May-00	2259	25 59.8382N	94 29.7347W	158	RW6	Box Core	2972	3010	Good core
19-May-00	0111	25 59.5948N	94 29.6375W	159	RW6	Camera	3022	3005	Camera start
19-May-00	0227	25 59.0106N	94 28.9461W	160	RW6	Camera	3218	3020	Bounced 36 times
19-May-00	0754	26 5.9275N	94 32.8059W	161	RW6	Trawl	7475	2850	Max cable on winch
19-May-00	0928	26 9.0176N	94 34.6319W	162	RW6	Trawl	7475	2830	Cable-snapped, trawl lost
19-May-00	1658	26 23.4249N	94 34.1794W	163	AC1	CTD	2548	2520	CTD in water (deep)
19-May-00	1945	26 23.4437N	94 34.2073W	164	AC1	CTD	225	225	CTD in water (shallow)
19-May-00	2120	26 23.4995N	94 33.5773W	165	AC1	Box Core	2510	2505	Good core
19-May-00	2335	26 23.4723N	94 33.3804W	166	AC1	Box Core	2552	2480	No closure
20-May-00	0119	26 23.2813N	94 33.2633W	167	AC1	Box Core	2572	2450	Good core
20-May-00	0333	26 23.7397N	94 33.3984W	168	AC1	Box Core	2689	2485	No closure
20-May-00	0512	26 23.5394N	94 33.4048W	169	AC1	Box Core	2510	2480	Good core
20-May-00	0944	26 23.1654N	94 33.2954W	170	AC1	Box Core	2580	2440	Good core
20-May-00	1148	26 23.6140N	94 34.3849W	171	AC1	Box Core	2519	2580	Good core
20-May-00	1408	26 23.4040N	94 33.8642W	172	AC1	Camera	2695	2520	Camera start
20-May-00	1515	26 23.3167N	94 34.4586W	173	AC1	Camera	2560	2580	Last hit on bottom
21-May-00	0010	26 30.2819N	95 0.1866W	174	RW5	Box Core	1600	1620	Good core
21-May-00	0136	26 30.0261N	95 0.1315W	175	RW5	Box Core	1600	1620	Good core
21-May-00	0248	26 30.0206N	95 0.0512W	176	RW5	Box Core	1589	1620	Good core
21-May-00	0405	26 30.0206N	95 0.0025W	177	RW5	Box Core	1589	1620	Good core
21-May-00	0525	26 30.4516N	94 59.8033W	178	RW5	Box Core	1625	1620	Good core
21-May-00	0712	26 30.1581N	94 59.2757W	179	RW5	Camera	1618	1637	Camera start
21-May-00	0816	26 29.7972N	94 58.5118W	180	RW5	Camera	1719	1620	Last hit on bottom
21-May-00	0917	26 30.1921N	95 0.0324W	181	RW5	CTD	1652	1625	CTD max depth 1478
21-May-00	1320	26 43.1654N	95 14.9221W	182	RW4	CTD	1599	1580	CTD in water
21-May-00	1514	26 44.8861N	95 14.7680W	183	RW4	Box Core	1599	1570	Good core
21-May-00	1619	26 44.9468N	95 14.6826W	184	RW4	Box Core	1542	1580	Good core
21-May-00	1734	26 44.9707N	95 14.9825W	185	RW4	Box Core	1539	1575	Good core
21-May-00	1859	26 45.1621N	95 15.0741W	186	RW4	Box Core	1539	1570	Good core
21-May-00	1959	26 45.0852N	95 15.0105W	187	RW4	Box Core	1537	1575	Good core
21-May-00	2132	26 45.0626N	95 14.9965W	188	RW4	Camera	1532	1570	Camera start

Appendix-Event or Activity Log (Cont.).

DATE-UTC	TIME UTC	LAT/MIN	LONG/MIN	SEQ. No.	SITE NAME	SAMPLE TYPE	WIRE OUT (m)	PDR (m)	COMMENTS
21-May-00	2245	26 45.0528N	95 14.9725W	189	RW4	Camera	1539	1570	End, 42 total
22-May-00	0150	27 0.0399N	95 30.0197W	190	RW3	CTD	1395	1326	CTD in water
22-May-00	0350	27 0.2983N	95 30.1920W	191	RW3	Box Core	1324	1320	Good core
22-May-00	0503	27 0.2956N	95 30.0541W	192	RW3	Box Core	1295	1325	Good core
22-May-00	0619	27 0.1881N	95 29.7639W	193	RW3	Box Core	1311	1340	Good core
22-May-00	0727	27 0.2706N	95 29.8642W	194	RW3	Box Core	1320	1330	Good core
22-May-00	0845	27 0.5014N	95 29.5417W	195	RW3	Box Core	1455	1335	Good core
22-May-00	1005	27 0.8138N	95 29.5962W	196	RW3	Camera	1342	1320	Camera start
22-May-00	1132	27 1.1573N	95 29.1856W	197	RW3	Camera	1279	1315	Last hit on bottom
22-May-00	1427	27 15.0391N	95 44.8585W	198	RW2	CTD	1107	950	CTD in water
22-May-00	1606	27 15.2435N	95 44.6186W	199	RW2	Box Core	985	950	Good core
22-May-00	1707	27 15.2852N	95 44.6402W	200	RW2	Box Core	1100	950	Good core
22-May-00	1805	27 14.9757N	95 44.8287W	201	RW2	Box Core	937	950	Good core
22-May-00	1904	27 15.0531N	95 45.1451W	202	RW2	Box Core	927	950	Good core
22-May-00	1955	27 15.2416N	95 44.8084W	203	RW2	Box Core	971	950	Good core
22-May-00	2132	27 15.3675N	95 44.5235W	204	RW2	Camera	986	950	Camera start
22-May-00	2250	27 16.1523N	95 43.6107W	205	RW2	Camera	1025	940	47 total hits
23-May-00	0053	27 16.5674N	95 44.2286W	206	RW2	Trawl	2000	920	Beam trawl, 2000 m out
23-May-00	0124	27 17.0968N	95 43.9536W	207	RW2	Trawl	2000	915	End trawl
23-May-00	0417	27 30.0191N	96 0.0307W	208	RW1	CTD	211	213	CTD in water
23-May-00	0500	27 30.0242N	96 0.1437W	209	RW1	Box Core	211	210	Good core
23-May-00	0534	27 29.8191N	96 0.1854W	210	RW1	Box Core	215	213	Good core
23-May-00	0613	27 30.0733N	95 59.9273W	211	RW1	Box Core	215	212	Good core
23-May-00	0658	27 30.0550N	96 0.1154W	212	RW1	Box Core	215	212	Good core
23-May-00	0740	27 30.0085N	96 0.1708W	213	RW1	Box Core	219	213	Good core
23-May-00	0828	27 30.0345N	96 0.0243W	214	RW1	Camera	220	210	Camera start
23-May-00	0934	27 30.4524N	95 59.7840W	215	RW1	Camera	225	204	47 total hits
23-May-00	1023	27 30.3054N	96 0.5796W	216	RW1	Trawl	423	200	On Bottom
23-May-00	1110	27 31.3722N	96 1.8897W	217	RW1	Trawl	470	175	End trawl
30-May-00	0443	28 3.5416N	90 14.9880W	218	C1	CTD	355	344	CTD in water
30-May-00	0554	28 3.6046N	90 14.9329W	219	C1	Box Core	333	334	Too full, macro & geol only
30-May-00	0650	28 3.5783N	90 14.9483W	220	C1	Box Core	333	336	Good core

Appendix-Event or Activity Log (Cont.).

DATE-UTC	TIME UTC	LAT/MIN	LONG/MIN	SEQ. No.	SITE NAME	SAMPLE TYPE	WIRE OUT (m)	PDR (m)	COMMENTS
30-May-00	0742	28 3.5629N	90 14.9494W	221	C1	Box Core	334	336	Good core
30-May-00	0830	28 3.5875N	90 14.9610W	222	C1	Box Core	332	336	
30-May-00	0916	28 3.5903N	90 14.9950W	223	C1	Box Core	333	336	Good core
30-May-00	1017	28 3.4286N	90 15.1303W	224	C1	Camera	349	345	Camera start
30-May-00	1132	28 3.2753N	90 15.3698W	225	C1	Camera	352	356	44 total hits
30-May-00	1300	28 5.0111N	90 15.1054W	227	C1	Trawl	650	310	On bottom
30-May-00	1329	28 3.8464N	90 15.0643W	228	C1	Trawl	656	340	End Trawl
30-May-00	1706	27 43.7236N	89 58.8081W	229	C7	CTD	1113	1069	CTD in water
30-May-00	1853	27 43.6967 N	89 58.7782 W	230	C7	Box Core	1050	1080	Good core
30-May-00	2004	27 43.9713 N	89 58.6291 W	231	C7	Box Core	1047	1070	Good core
30-May-00	2105	27 43.8913 N	89 59.0119 W	232	C7	Box Core	1041	1066	Good core
30-May-00	2204	27 43.8089 N	89 59.1213 W	233	C7	Box Core	1043	1070	Good core
30-May-00	2302	27 43.8262N	89 58.9220W	234	C7	Box Core	1039	1072	Good core
31-May-00	0034	27 43.9291N	89 59.2277W	235	C7	Camera	1041	1057	Camera start
31-May-00	0132	27 44.0789N	89 59.9186W	236	C7	Camera	989	987	41 total hits
31-May-00	0333	27 44.9881N	89 59.4243W	237	C7	Trawl	1036	910	Trawl on bottom
31-May-00	0411	27 43.5643N	89 58.6686W	238	C7	Trawl	1851	1085	Net on bottom
31-May-00	0802	27 26.9570N	89 46.7507W	239	C4	CTD	1540	1468	CTD in Water
31-May-00	1043	27 27.5640 N	89 47.1391 W	240	C4	Box Core	1465	1455	Good core
31-May-00	1242	27 27.6103 N	89 46.7720 W	241	C4	Box Core	1487	1452	Good core
31-May-00	1355	27 27.1450 N	89 46.5588 W	242	C4	Box Core	1438	1463	Good core
31-May-00	1504	27 27.0322 N	89 45.7167 W	243	C4	Box Core	1442	1476	Good core
31-May-00	1607	27 27.189N	89 45.785W	244	C4	Box Core	1447	1472	Numero malo
31-May-00	1743	27 27.5173N	89 45.9066W	245	C4	Camera	1547	1465	Camera start
31-May-00	1851	27 28.5639N	89 45.7584W	246	C4	Camera	1721	1426	Last hit, total of 46 hits
31-May-00	2158	27 29.4518N	89 47.7782W	247	C4	Trawl	3050	1355	Called bottom contact
31-May-00	2244	27 28.2744N	89 46.5667W	248	C4	Trawl	3506	1362	Let out more wire
1-Jun-00	0419	26 55.3279N	89 34.6815W	249	C14	CTD	2693	2487	CTD in Water
1-Jun-00	0833	26 55.7737N	89 34.2830W	250	C14	Box Core	2434	2487	Only macro and geocore
1-Jun-00	1116	26 55.7970N	89 34.2245W	251	C14	Box Core	2491	2487	Good core
1-Jun-00	1331	26 55.7900N	89 33.8676W	252	C14	Box Core	2598	2495	Good core
1-Jun-00	1525	26 55.7932N	89 34.2542W	253	C14	Box Core	2499	2487	Good core

Appendix-Event or Activity Log (Cont.).

DATE-UTC	TIME UTC	LAT/MIN	LONG/MIN	SEQ. No.	SITE NAME	SAMPLE TYPE	WIRE OUT (m)	PDR (m)	COMMENTS
1-Jun-00	1719	26 56.2943N	89 34.3503W	254	C14	Box Core	2487	2478	Good core
1-Jun-00	2000	26 56.4673N	89 33.6881W	255	C14	Camera	2867	2483	Camera start
1-Jun-00	2106	26 57.1821N	89 32.8457W	256	C14	Camera	2775	2506	Total of 41 hits
1-Jun-00	2329	26 59.0446N	89 36.8130W	257	C14	Trawl	1	2405	Net and doors in water
2-Jun-00	0506	26 53.5933N	89 31.5261W	258	C14	Trawl	1	2580	Net resurfacing
2-Jun-00	0926	26 22.7693N	89 14.4295W	259	C12	CTD	2955	2915	CTD in Water
2-Jun-00	1309	26 22.4008N	89 14.2480W	260	C12	Box Core	2900	2917	Shallow penetration
2-Jun-00	1504	26 22.7651N	89 14.4849W	261	C12	Box Core	2848	2922	Good core
2-Jun-00	1707	26 22.9752N	89 14.4854W	262	C12	Box Core	2847	2920	Good core
2-Jun-00	1915	26 22.4978N	89 14.5836W	263	C12	Box Core	2846	2924	Only macro samples taken
2-Jun-00	2130	26 22.4015N	89 14.2552W	264	C12	Box Core	2840	2918	Good core
3-Jun-00	008	26 22.7838N	89 14.4179W	265	C12	Box Core	2840	2920	Logged twice by mistake
3-Jun-00	235	26 22.8460N	89 14.6947W	266	C12	Camera	2856	2922	Camera start
3-Jun-00	343	26 22.9637N	89 14.9572W	267	C12	Camera	2860	2922	Last hit, total of 46 hits
3-Jun-00	537	26 16.4897N	89 20.9440W	268	C12	Trawl	1	3000	Net and doors in water
3-Jun-00	1308	26 30.1817N	89 9.2097W	269	C12	Trawl	1	2830	End, total of 7212 m wire
3-Jun-00	1915	27 19.8258N	88 40.2892W	270	MT5	CTD	2354	2280	CTD in water
3-Jun-00	2147	27 19.9308N	88 40.0690W	271	MT5	Box Core	2213	2275	Good core
3-Jun-00	2344	27 19.5810N	88 40.1733W	272	MT5	Box Core	2230	2290	Fish in boxcore
4-Jun-00	0159	27 20.0759N	88 39.7337W	273	MT5	Box Core	2269	2267	Good core
4-Jun-00	0344	27 20.1910N	88 39.5716W	274	MT5	Box Core	2281	2263	Good core
4-Jun-00	0525	27 19.9703N	88 39.3639W	275	MT5	Box Core	2370	2280	Good core
4-Jun-00	0728	27 19.7201N	88 39.0161W	276	MT5	Camera	2515	2288	Camera start
4-Jun-00	0842	27 20.0206N	88 38.5334W	277	MT5	Camera	2501	2301	Last hit, 39 hits
4-Jun-00	1048	27 23.5939N	88 46.6155W	278	MT5	Trawl	1	2075	Net submerged, doors spread
4-Jun-00	1613	27 15.8017N	88 33.8526W	279	MT5	Trawl	1	2410	Trawled 1 hour , 5236 m out
4-Jun-00	2014	26 59.9938N	87 59.8019W	280	MT6	CTD	2790	2745	CTD in water
4-Jun-00	2325	27 00.0067N	87 59.8697W	281	MT6	Box Core	2673	2745	Good core
5-Jun-00	0129	27 0.0892N	87 59.2938W	282	MT6	Box Core	2719	2750	Good core
5-Jun-00	0333	26 59.7904N	87 59.9247W	283	MT6	Box Core	2673	2745	Good core
5-Jun-00	0541	26 59.9689N	87 59.7695W	284	MT6	Box Core	2677	2745	Good core
5-Jun-00	0735	27 0.0989N	87 59.9478W	285	MT6	Box Core	2676	2743	Good core

Appendix-Event or Activity Log (Cont.).

DATE-UTC	TIME UTC	LAT/MIN	LONG/MIN	SEQ. No.	SITE NAME	SAMPLE TYPE	WIRE OUT (m)	PDR (m)	COMMENTS
5-Jun-00	0949	27 0.2679N	87 59.3911W	286	MT6	Camera	2800	2748	Camera start
5-Jun-00	1052	26 59.8111N	87 58.9553W	287	MT6	Camera	2918	2751	Last hit, 34 shots
5-Jun-00	1350	26 59.2975N	87 58.9824W	288	MT6	Camera	3145	2755	Camera start
5-Jun-00	1458	26 58.8683N	87 58.1482W	289	MT6	Camera	3463	2760	Last hit, 43 shots
5-Jun-00	1703	26 55.9383N	88 08.3722W	290	MT6	Trawl	1	2680	Net down, doors spread
5-Jun-00	2349	27 2.2772N	87 51.6737W	291	MT6	Trawl	1	2790	Trawled 1.5 hours, 6540 m out
6-Jun-00	0544	27 29.9929N	87 0.0569W	292	S39	CTD	3049	3023	CTD in water
6-Jun-00	0924	27 29.9500N	87 0.0849W	293	S39	Box Core	2980	3007	Good core
6-Jun-00	1112	27 29.6965N	86 59.8982W	294	S39	Box Core	2946	3000	Good core
6-Jun-00	1319	27 29.2661N	87 0.0122W	295	S39	Box Core	3018	3000	Good core
6-Jun-00	1540	27 29.2518N	86 59.8236W	296	S39	Box Core	3008	3000	Good core
6-Jun-00	1738	27 29.0205N	86 59.9889W	297	S39	Box Core	3013	2998	Good core (150th boxcore)
6-Jun-00	2015	27 28.7018N	87 0.1820W	298	S39	Camera	3024	3000	Camera start
6-Jun-00	2119	27 28.0412N	87 0.2562W	299	S39	Camera	3102	2997	Last hit, 46 hits
6-Jun-00	2329	27 21.6638N	87 6.3576W	300	S39	Trawl	1	2937	Net submerged , doors spread
7-Jun-00	0621	27 31.8311N	86 59.4062W	301	S39	Trawl	1	3005	Trawl 1.5 hours, 7124 m out
7-Jun-00	0913	27 49.9613N	86 44.8975W	302	S40	CTD	2999	2973	CTD in water
7-Jun-00	1326	27 50.3354N	86 45.1549W	303	S40	Box Core	2910	2975	Good core
7-Jun-00	1507	27 50.1707N	86 45.0821W	304	S40	Box Core	2907	2975	Good core
7-Jun-00	1651	27 50.2944N	86 45.0489W	305	S40	Box Core	2886	2972	Good core
7-Jun-00	1853	27 49.9965N	86 45.2125W	306	S40	Box Core	2905	2978	Good core
7-Jun-00	2107	27 50.3686N	86 45.0849W	307	S40	Box Core	2894	2971	Good core
8-Jun-00	0010	27 49.6843N	86 44.9811W	308	S40	Camera	2913	2986	Camera start
8-Jun-00	0124	27 49.4359N	86 44.9994W	309	S40	Camera	2938	2995	Last hit, 46 shots
8-Jun-00	0326	27 43.3428N	86 46.4221W	310	S40	Trawl	1	3050	Net submerged , doors spread
8-Jun-00	1040	27 59.4280N	86 43.3657W	311	S40	Trawl	1	2970	Trawl 1.5 hours, 7016 m out
8-Jun-00	1436	28 00.0388N	86 34.8241W	312	S41	CTD	3174	2979	CTD in water
8-Jun-00	1903	28 0.8463N	86 34.5587W	313	S41	Box Core	3022	2974	Good core
8-Jun-00	2136	28 1.4243N	86 34.2753W	314	S41	Box Core	3006	2974	Good core
9-Jun-00	0017	28 0.7328N	86 34.1930W	315	S41	Box Core	2915	2978	Good core
9-Jun-00	0237	28 0.6970N	86 33.9732W	316	S41	Box Core	3005	2983	Good core
9-Jun-00	0510	28 0.8185N	86 34.4009W	317	S41	Box Core	2956	2976	Good core

Appendix-Event or Activity Log (Cont.).

DATE-UTC	TIME UTC	LAT/MIN	LONG/MIN	SEQ. No.	SITE NAME	SAMPLE TYPE	WIRE OUT (m)	PDR (m)	COMMENTS
9-Jun-00	0805	28 1.2769N	86 34.9737W	318	S41	Camera	3050	2971	Camera start
9-Jun-00	0922	28 2.1552N	86 35.0977W	319	S41	Camera	3124	2955	Llast hit , 46 hits
9-Jun-00	1205	27 54.2334N	86 26.0841W	320	S41	Trawl	1	3030	Net and doors in water
9-Jun-00	1858	28 4.3344N	86 40.6499W	321	S41	Trawl	1	2930	Trawl 1.5 hours, 7000 m out
9-Jun-00	1136	28 30.07218N	86 4.7604W	322	S42	CTD	778	763	CTD in Water
9-Jun-00	2320	28 15.1557N	86 25.0663W	323	S42	Box Core	750	767	Good core
10-Jun-00	0011	28 15.1070N	86 25.0209W	324	S42	Box Core	753	768	Good core
10-Jun-00	0101	28 15.2344N	86 24.7995W	325	S42	Box Core	762	763	Good core
10-Jun-00	0157	28 15.1049N	86 24.8363W	326	S42	Box Core	763	766	Good core
10-Jun-00	0252	28 15.0602N	86 25.1562W	327	S42	Box Core	760	772	Good core
10-Jun-00	0359	28 15.0859N	86 24.9248W	328	S42	Camera	752	768	Camera start
10-Jun-00	0504	28 15.0358N	86 24.3089W	329	S42	Camera	760	764	Last hit, 46 hits
10-Jun-00	0557	28 15.9809N	86 27.8529W	330	S42	Trawl	1	800	Net and doors submerged
10-Jun-00	0839	28 13.8930N	86 21.4547W	331	S42	Trawl	1	770	Trawl 0.5 hours, 2102 m out
10-Jun-00	1128	28 30.0153N	86 4.7775W	332	S43	CTD	366	366	CTD in Water
10-Jun-00	1255	28 30.1035	86 04.7983	333	S43	Box Core	358	366	Good core
10-Jun-00	1331	28 30.1434N	86 4.8562W	334	S43	Box Core	361	360	Good core
10-Jun-00	1419	28 30.0613N	86 4.8672W	335	S43	Box Core	363	362	Only macro sample taken
10-Jun-00	1633	28 30.1982N	86 4.5881W	336	S43	Box Core	358	357	Good core
10-Jun-00	1713	28 30.1766N	86 4.6074W	337	S43	Box Core	358	358	Good core
10-Jun-00	1800	28 30.0545N	86 4.6404W	338	S43	Camera	356	360	Camera start
10-Jun-00	1902	28 30.3610N	86 4.4865W	339	S43	Camera	355	358	Last hit, 46 hits
10-Jun-00	2004	28 30.9292N	86 6.1705W	340	S43	Trawl	1	360	Net and doors submerged
10-Jun-00	2130	28 28.9484N	86 3.2172W	341	S43	Trawl	1	358	Trawl 0.5 hours , 1111 m out
11-Jun-00	0022	28 45.0483n	85 44.8818W	342	S44	CTD	215	215	CTD in Water
11-Jun-00	0105	28 45.0140N	85 44.9642W	343	S44	Box Core	214	215	Good core
11-Jun-00	0151	28 45.0188N	85 44.9499W	344	S44	Box Core	213	213	Good core
11-Jun-00	0231	28 45.0632N	85 44.8807W	345	S44	Box Core	215	212	Good core
11-Jun-00	0309	28 45.0093N	85 44.8686W	346	S44	Box Core	215	212	Good core
11-Jun-00	0349	28 44.9996N	85 44.8622W	347	S44	Box Core	215	212	Good core
11-Jun-00	0438	28 44.9522N	85 44.6851W	348	S44	Camera	226	211	Camera start
11-Jun-00	0545	28 44.7038N	85 44.9938W	349	S44	Camera	225	214	Last hit, 46 hits
11-Jun-00	0641	28 45.5760N	85 45.2641W	350	S44	Trawl	1	214	Net and doors submerged
11-Jun-00	0755	28 43.0225N	85 44.3370W	351	S44	Trawl	1	217	Trawl 0.5 hours, 747 m out
11-Jun-00	1712	29 19.8058N	87 3.0254W	352	S35	CTD	679	674	CTD in Water

Appendix-Event or Activity Log (Cont.).

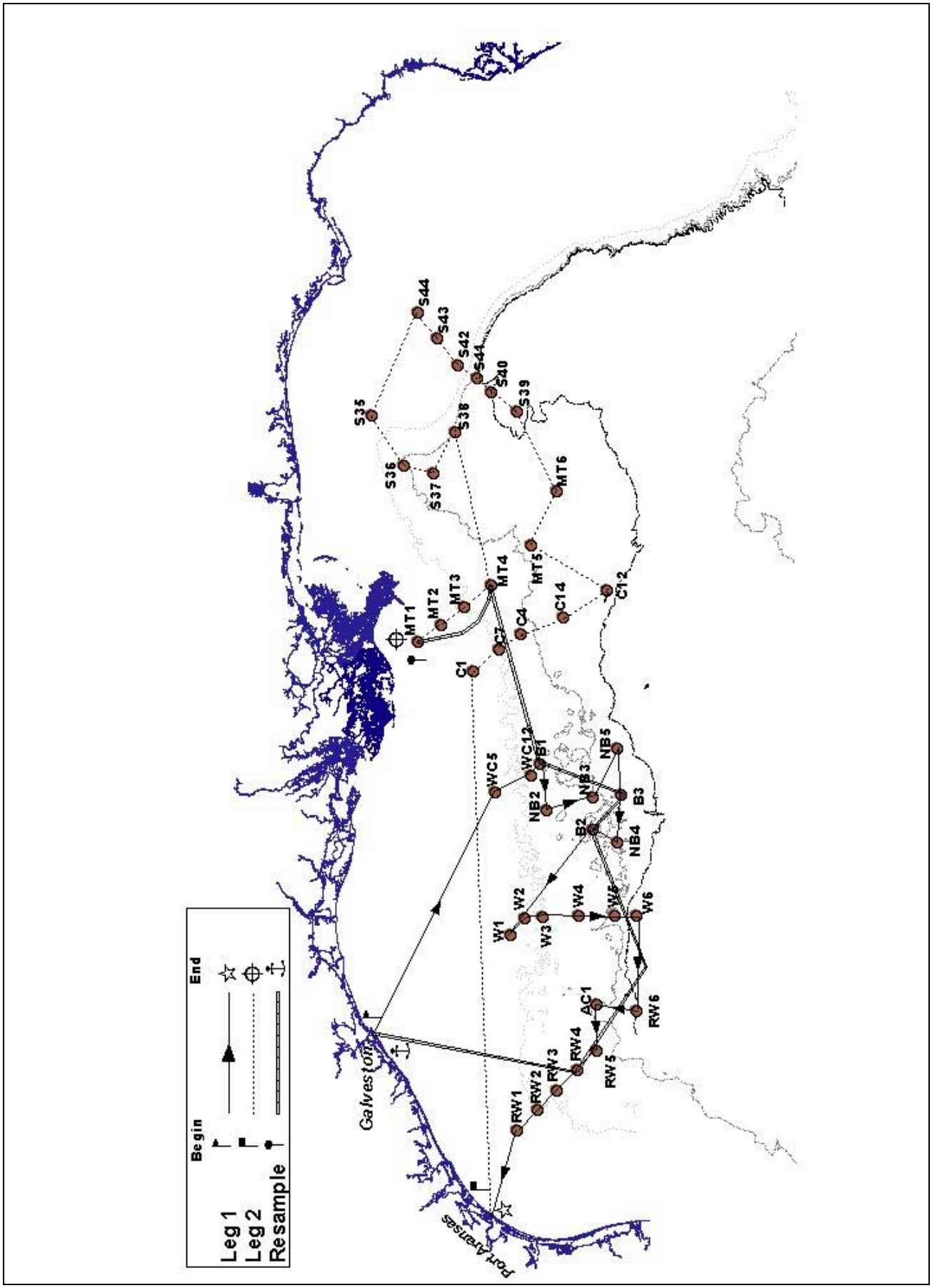
DATE-UTC	TIME UTC	LAT/MIN	LONG/MIN	SEQ. No.	SITE NAME	SAMPLE TYPE	WIRE OUT (m)	PDR (m)	COMMENTS
11-Jun-00	1847	29 20.0500N	87 3.3758W	353	S35	Box Core	646	658	Good core
11-Jun-00	1932	29 19.9897N	87 2.9021W	354	S35	Box Core	660	667	Good core
11-Jun-00	2025	29 19.9337N	87 3.0166W	355	S35	Box Core	664	668	Good core
11-Jun-00	2117	29 19.9877N	87 2.9860W	356	S35	Box Core	655	668	Good core
11-Jun-00	2208	29 20.1091N	87 2.7818W	357	S35	Box Core	653	666	Good core
11-Jun-00	2305	29 20.2815N	87 2.8106W	358	S35	Camera	688	664	Camera start
12-Jun-00	0009	29 20.7205N	87 2.2753W	359	S35	Camera	664	663	Last hit, 46 hits
12-Jun-00	0052	29 22.5489N	87 1.7647W	360	S35	Trawl	1	645	Net and doors submerged
12-Jun-00	0250	29 18.9650N	87 2.7294W	361	S35	Trawl	1	695	Trawl 0.5 hours, 1731 m out
12-Jun-00	0742	28 55.1114N	87 40.1292W	362	S36	CTD	1874	1845	CTD in Water
12-Jun-00	1013	28 55.1647N	87 40.2232W	363	S36	Box Core	1786	1825	Good core
12-Jun-00	1136	28 55.0080N	87 40.0627W	364	S36	Box Core	1785	1832	Good core
12-Jun-00	1255	28 55.1634N	87 40.2154W	365	S36	Box Core	1777	1826	Good core
12-Jun-00	1359	28 55.1792N	87 40.5743W	366	S36	Box Core	1774	1827	Good core
12-Jun-00	1508	28 55.1108N	87 40.3290W	367	S36	Box Core	1784	1830	Good core
12-Jun-00	1644	28 55.1044N	87 40.4810W	368	S36	Camera	1825	1827	Camera start
12-Jun-00	1801	28 54.8887N	87 41.7574W	369	S36	Camera	2034	1850	Last hit, 46 hits
12-Jun-00	2010	28 57.8923N	87 33.6681W	370	S36	Trawl	1	1715	Net and doors submerged
13-Jun-00	0025	28 54.0969N	87 43.7377W	371	S36	Trawl	1	1852	Trawl for 1 hour , 4280 m out
13-Jun-00	0307	28 33.0343N	87 46.2957W	372	S37	CTD	2418	2380	CTD in Water
13-Jun-00	0623	28 33.4054N	87 45.7357W	373	S37	Box Core	2370	2388	Good core
13-Jun-00	0800	28 33.4292N	87 45.6441W	374	S37	Box Core	2349	2382	Good core
13-Jun-00	0917	28 33.2345N	87 45.8373W	375	S37	Box Core	2326	2382	Good core
13-Jun-00	1035	28 33.2196N	87 45.7768W	376	S37	Box Core	2316	2382	Good core
13-Jun-00	1149	28 33.2176N	87 46.0109W	377	S37	Box Core	2311	2381	Good core
13-Jun-00	1350	28 33.2457N	87 46.0066W	378	S37	Camera	2314	2380	Camera start
13-Jun-00	1502	28 33.3825N	87 45.5462W	379	S37	Camera	2339	2384	Last hit, 46 hits
13-Jun-00	1649	28 40.5318N	87 40.2689W	380	S37	Trawl	1	2365	Net and doors submerged
13-Jun-00	2243	28 29.9693N	87 49.4744W	381	S37	Trawl	1	2373	Trawl 1.5 hours, 5676 m out
14-Jun-00	0229	28 16.8037N	87 14.8865W	382	S38	CTD	2224	2155	CTD in water
14-Jun-00	0536	28 16.9406N	87 14.7745W	383	S38	Box Core	2370	2130	Poor, some subsamples saved
14-Jun-00	0716	28 17.0006N	87 14.6903W	384	S38	Box Core	2611	2090	No mud
14-Jun-00	0905	28 16.8185N	87 13.9942W	385	S38	Box Core	2720	2083	No mud
14-Jun-00	1124	28 16.4749N	87 19.9043W	386	S38	Box Core	2599	2635	Moved five nm west, Good core
14-Jun-00	1323	28 16.3144N	87 19.5165W	387	S38	Box Core	2583	2642	Good core

Appendix-Event or Activity Log (Cont.).

DATE-UTC	TIME UTC	LAT/MIN	LONG/MIN	SEQ. No.	SITE NAME	SAMPLE TYPE	WIRE OUT (m)	PDR (m)	COMMENTS
14-Jun-00	1514	28 16.7846N	87 20.1025W	388	S38	Box Core	2596	2627	Good core
14-Jun-00	1703	28 16.9551N	87 20.1877W	389	S38	Box Core	2553	2627	Washed out
14-Jun-00	1840	28 16.7579N	87 20.2446W	390	S38	Box Core	2557	2630	Good core
14-Jun-00	2037	28 16.7968N	87 19.6555W	391	S38	Box Core	2577	2632	Good core, bounced twice
14-Jun-00	2238	28 16.2454N	87 19.9944W	392	S38	Camera	2606	2647	Camera start
14-Jun-00	2347	28 16.2815N	87 19.8962W	393	S38	Camera	2561	2647	Last hit, 46 hits
15-Jun-00	0144	28 23.1182N	87 27.1776W	394	S38	Trawl	1	2565	Net and doors submerged
15-Jun-00	0803	28 15.2889N	87 14.6914W	395	S38	Trawl	1	2650	Trawl 1.5 hours, 6200 m out
15-Jun-00	2015	27 49.9268N	89 10.2049W	396	MT4	CTD	1410	1402	CTD in
15-Jun-00	2218	27 49.6198N	89 9.9526W	397	MT4	Box Core	1363	1401	Good core
15-Jun-00	2322	27 49.7018N	89 9.8829W	398	MT4	Box Core	1364	1401	Good core
16-Jun-00	0014	27 49.6810N	89 10.0723W	399	MT4	Box Core	1365	1401	Good core
16-Jun-00	0132	27 50.0087N	89 9.9487W	400	MT4	Box Core	1366	1402	Good core
16-Jun-00	0238	27 49.6563N	89 9.9687W	401	MT4	Box Core	1366	1402	Good core
16-Jun-00	0357	27 50.0274N	89 10.0346W	402	MT4	Camera	1373	1403	Camera start
16-Jun-00	0503	27 50.1708N	89 9.3478W	403	MT4	Camera	1413	1403	Last hit, 46 hits
16-Jun-00	1033	28 13.2930N	89 29.9627W	404	MT3	CTD	1014	985	CTD in Water
16-Jun-00	1231	28 13.2246N	89 29.7679W	405	MT3	Box Core	977	983	Good core
16-Jun-00	1329	28 13.1533N	89 29.7860	406	MT3	Box Core	986	987	Good core
16-Jun-00	1422	28 13.1426N	89 29.5065W	407	MT3	Box Core	1007	990	Good core
16-Jun-00	1514	28 13.0561N	89 29.6289W	408	MT3	Box Core	997	988	Good core
16-Jun-00	1616	28 13.2906N	89 29.6427W	409	MT3	Box Core	978	985	Good core
16-Jun-00	1731	28 13.2712N	89 29.2921W	410	MT3	Camera	996	990	Camera start
16-Jun-00	1840	28 13.1632N	89 28.3526W	411	MT3	Camera	1044	1001	Last hit, 47 hits
16-Jun-00	1947	28 10.9546N	89 27.0007W	412	MT3	Trawl	1	1050	Net and doors submerged
16-Jun-00	2209	28 14.7585N	89 31.0703W	413	MT3	Trawl	1	954	Trawl 0.5 hours, 2701 m out
17-Jun-00	0033	28 27.0528N	89 40.1187W	414	MT2	CTD	688	681	CTD in Water
17-Jun-00	0156	28 27.0646N	89 40.3563W	415	MT2	Box Core	660	676	Good core
17-Jun-00	0245	28 27.0726N	89 40.2206W	416	MT2	Box Core	660	677	Good core
17-Jun-00	0330	28 27.0327N	89 40.3636W	417	MT2	Box Core	660	676	Good core
17-Jun-00	0415	28 27.0168N	89 40.4000W	418	MT2	Box Core	662	677	Good core
17-Jun-00	0454	28 26.8755N	89 40.3167W	419	MT2	Box Core	662	680	Good core
17-Jun-00	0541	28 26.9984N	89 40.1315W	420	MT2	Camera	664	681	Camera start
17-Jun-00	0654	28 27.1138N	89 40.2103W	421	MT2	Camera	656	678	Last hit, 46 hits

Appendix-Event or Activity Log (Cont.).

DATE-UTC	TIME UTC	LAT/MIN	LONG/MIN	SEQ. No.	SITE NAME	SAMPLE TYPE	WIRE OUT (m)	PDR (m)	COMMENTS
17-Jun-00	0747	28 28.1309N	89 42.1489W	422	MT2	Trawl	1	635	Net and doors submerged
17-Jun-00	1016	28 24.9338N	89 37.3878W	423	MT2	Trawl	1	737	Trawl 0.5 hours, 1917 m out
17-Jun-00	1253	28 32.5092N	89 49.8284W	424	MT1	CTD	502	480	CTD in Water
17-Jun-00	1407	28 32.5129N	89 49.7324W	425	MT1	Box Core	472	480	Good core
17-Jun-00	1448	28 32.3703N	89 49.7338W	426	MT1	Box Core	484	482	Good core
17-Jun-00	1525	28 32.4686N	89 49.6283W	427	MT1	Box Core	485	482	Good core
17-Jun-00	1607	28 32.4352N	89 49.7257W	428	MT1	Box Core	492	481	Good core
17-Jun-00	1652	28 32.4666N	89 49.5011W	429	MT1	Box Core	479	481	Good core
17-Jun-00	1749	28 32.7388N	89 49.4905W	430	MT1	Camera	495	475	Camera start
17-Jun-00	1853	28 33.1631N	89 48.9497W	431	MT1	Camera	472	473	Last hit, 46 hits
17-Jun-00	1958	28 34.3289N	89 51.7153W	432	MT1	Trawl	1	420	Net and doors submerged
17-Jun-00	2139	28 31.7427N	89 48.9855W	433	MT1	Trawl	1	501	Trawl 0.5 hours, 2701 m out
18-Jun-00	0331	27 53.5820N	89 17.2670W	434	MT4	Trawl	1	1340	Net and doors submerged
18-Jun-00	0657	27 49.6495N	89 9.7183W	435	MT4	Trawl	1	1397	Trawl 45 minutes, 3318 m out
18-Jun-00	2157	27 11.7196N	91 24.2305W	436	B1	Camera	2222	2256	Camera start
18-Jun-00	2300	27 11.3731N	91 23.8160W	437	B1	Camera	2236	2256	Last hit, 46 hits
19-Jun-00	0718	26 12.2787N	91 46.1872W	438	B3	Camera	2627	2651	Camera start
19-Jun-00	0827	26 12.8443N	91 45.9065W	439	B3	Camera	2662	2647	Last hit, 46 hits
19-Jun-00	1340	26 33.1067N	92 13.9513W	440	B2	Camera	2546	2610	Camera start
19-Jun-00	1457	26 32.9413N	92 13.6736W	441	B2	Camera	2574	2612	Last hit, 46 hits
19-Jun-00	1656	26 29.1157N	92 5.6651W	442	B2	Trawl	1	2320	Net and doors submerged
19-Jun-00	2307	26 36.8264N	92 19.6109W	443	B2	Trawl	1	2140	Trawl 1.5 hours, 6278 m out
20-Jun-00	0747	25 59.9764N	93 41.8014W	444	W6/RW6	Trawl	1	3000	Net and doors submerged
20-Jun-00	1452	26 0.1963N	93 59.9278W	445	W6/RW6	Trawl	1	3150	Trawl 1.5 hours with 7200 m out
20-Jun-00	2302	26 40.9015N	95 11.1034W	446	RW4	Trawl	1	1605	Net and doors submerged
21-Jun-00	0238	26 49.6196N	95 10.6836W	447	RW4	Trawl	1	1600	Lost, cable broke, 600 m out


Begin
End
Leg 1
Leg 2
Resample
Galveston
Port Arthur
S44
S43
S42
S41
S40
S39
S35
S38
S36
S37
MT6
MT5
MT4
MT3
MT2
MT1
C12
C14
C4
C7
C1
WC12
B1
NB5
WC5
NB3
NB2
B3
B2
NB4
W1
W2
W3
W4
W5
W6
AC1
RW6
RW4
RW3
RW5
RW2
RW1

Appendix II

The Edge of the Gulf Cruise
16-31 October 2000

RV Atlantis, Cruise 3 Leg 58
DSV Alvin, Dives 3624-3637

A cruise report prepared by:
Ian R. MacDonald (Texas A&M University)
Joan Bernhard (University of South Carolina)
Barun Sen Gupta (Louisiana State University)
Cindy Lee Van Dover (College of William and Mary)

Introduction

This is the report for *RV Atlantis* Cruise 3, Leg 58, which completed *DSV Alvin* Dives 3624-3637 at eight sites across the northern Gulf of Mexico (Figure 1) during 16-31 October 2000. The cruise embarked in Galveston, Texas and demobilized in Key West Florida. There was an at-sea exchange of thirteen scientific personnel on 25 October. In all, thirty six scientists and observers participated in the cruise (Table 1).

The cruise was jointly funded by National Oceanographic and Atmospheric Administration (National Undersea Research Program), Minerals Management Service, and Dept. of Energy (National Energy Technology Laboratory). The overall objectives of the cruise were to provide submersible and ship support for research being conducted by four separate projects. The way the dives and ship operations were completed, there was significant overlap and cooperation among the projects. Therefore, a single report will be submitted to all cruise sponsors. This document provides a preliminary summary of individual project results and narrates the day to day activities. An appendix details the observations and sample collections made dive-by-dive and day-by-day. The shipboard scientific support program of *RV Atlantis* provided a series of digital data files and other records on CD ROM, with copies going to each project investigators.

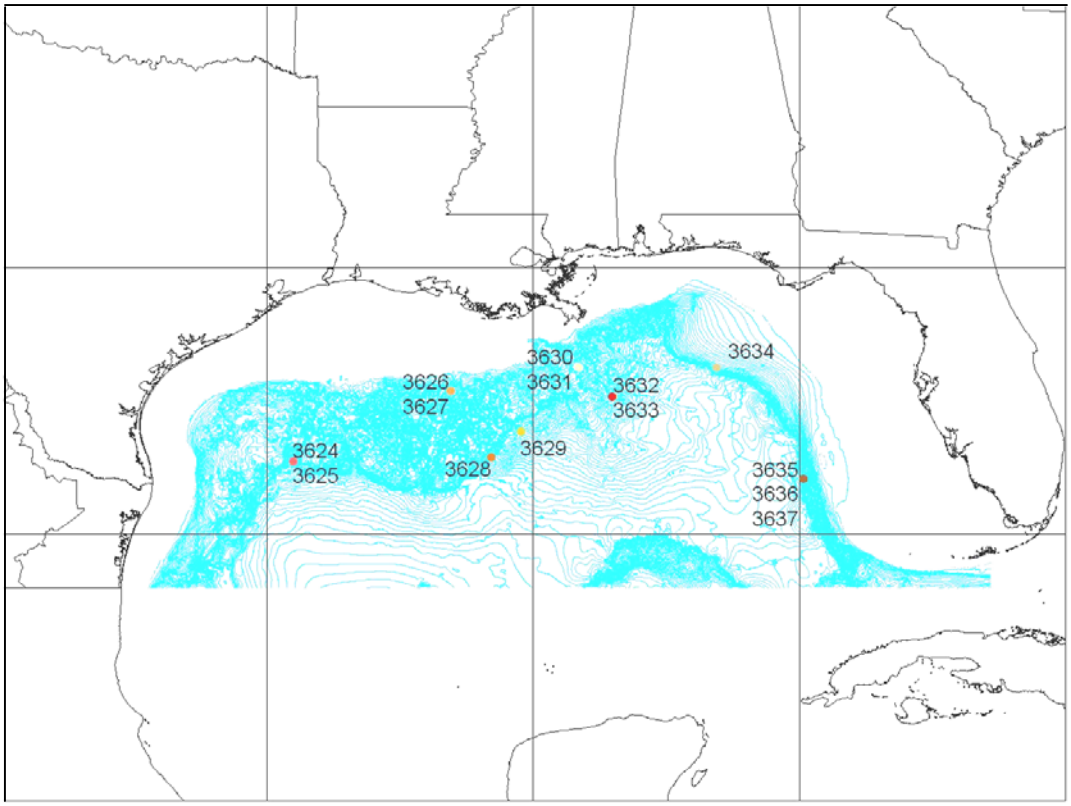


Figure 1. Dive sites and dive numbers for the 14 dives completed during 16-31 October 2000, northern Gulf of Mexico.

Table 1. Cruise participants, affiliations, roles, and contact information. Stage 1 of the cruise was 16-25 October; stage 2 was 25-31 October.

Participant	Stages	E-Mail
Joan Bernhard, USC, Principal Investigator	1 and 2	jmbernha@sph.sc.edu
Dan Bean, TAMU, Student	1 and 2	dbean@ocean.tamu.edu
Marty Bohn, TAMU, Technician	1 and 2	marty@gerg.tamu.edu
Bill Bryant, TAMU, Principal Investigator	1 and 2	bbryant@ocean.tamu.edu
Paul Clark, TAMU, Technician	1 and 2	pclark@gerg.tamu.edu
Tom Cole, ATT Broadband Inc. Video Producer	1 and 2	tcole@broadband.att.com
Sophie DeBeukelaer, TAMU, Student	1 and 2	sophie@gerg.tamu.edu
Tim Dellapenna, TAMU-G, Investigator	1 and 2	
Chris Gudeman, TAMU, Student	1 and 2	cgudeman@ocean.tamu.edu
Ian MacDonald, TAMU, Chief Scientist	1 and 2	ian@gerg.tamu.edu
Erik Scott, BHP, Inc., Observer	1 and 2	
Andrew Shepard, NURP, Coordinator	1 and 2	sheparda@uncwil.edu
Evan Vetter, UNCW, Cameraman	1 and 2	evan_vetter@hotmail.com
David Volz, USC, Student	1 and 2	dcvolz@hotmail.com
Matt Zeigler, TAMU, Student	1 and 2	mziegler@ocean.tamu.edu
Paul Aharon, LSU, Investigator	1	aharon@geol.lsu.edu
Robert Avent, MMS, Observer	1	robert.avent@mms.gov
Samuel Bowser, Wadsworth Center, Investigator	1	
Matt Hackworth, LSU, Student	1	
Samuel Huisman, LSU, Student	1	
Barun Sen Gupta, LSU, Principal Investigator	1	barun@geol.lsu.edu
Lorene Smith, LSU, Technician	1	
Daniel Van Gent, LSU, Investigator	1	
Sarah Fangman, NOAA, Observer	2	sarah.fangman@noaa.gov
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Karen Jacobsen, *In Situ* Illustrations, Artist	2	kjnorhtherncross@aol.com
Margaret Landry, WM, Student	2	margolan@yahoo.com
John McDonough, NOS, Observer	2	john.mcdonough@noaa.gov
Zoe McKinness, Harvard, Student	2	zmckiness@oeb.harvard.edu
Thomas Mroz, DOE-NETL, Observer	2	thomas.mroz@netl.doe.gov
Joshua Osterberg, WM, Student	2	joste@wm.edu
William Sager, TAMU, Principal Investigator	2	wsager@ocean.tamu.edu
Mary Turnipseed, WM, Student	2	mturnips@hotmail.com
Cindy Lee Van Dover, WM, Principal Investigator	2	cindy_vandover@wm.edu
Megan Ward, WM, Student	2	meward@wm.edu

General Results

Support from the crew of RV *Atlantis*, the *Alvin* team, and the Woods Hole shipboard scientific service group was outstanding. The scientific personnel were unanimous in their praise for the thoroughly professional and unfailingly hospitable atmosphere on board. Fourteen dives at eight separate sites were completed. None of the planned dives were cancelled due to weather or other problems. The *Atlantis/Alvin* group elected not to dive at one scheduled site, Bush Hill, because it was situated less than one mile from an energy production platform. Sites, divers, and localities are summarized in Table 2.

Table 2. Summary of dives, sites visited, and scientific divers during cruise.

Dive #	Site	Depth	Sci-1	Sci-2	Latitude	Longitude
3624	Alaminos Canyon	2230	Paul Aharon	Sam Bowser	26.35667	-94.50267
3625	Alaminos Canyon	2230	Barun Sen Gupta	Joan Bernhard	26.35709	-94.48397
3626	Green Canyon 272	687	Paul Aharon	Lorene Smith	27.68644	-91.53670
3627	Green Canyon 272	687	Joan Bernhard	Matt Hackworth	27.68401	-91.53703
3628	Farnella Canyon	2930	Ian MacDonald	Tom Cole	26.44713	-90.77330
3629	Green Knoll	2457	Bill Bryant	Erik Scott	26.92353	-90.21502
3630	Miss. Canyon 853	1079	Ian MacDonald	Anthony Tarantino (PIT)	28.12663	-89.14367
3631	Miss. Canyon 853	1079	Dan Bean	Tim Dellapenna	28.12640	-89.14172
3632	Atwater 425	1955	Ian MacDonald	Andy Shepard	27.57516	-88.48793
3633	Atwater 425	1955	Joan Bernhard	Will Sager	27.57898	-88.51056
3634	N. FL. Escarpment	2873	Ian MacDonald	Sarah Fangman	28.03697	-86.55668
3635	S. Fl. Escarpment	3288	Cindy Van Dover	Karen Jacobsen	26.03069	-84.91954
3636	S. Fl. Escarpment	3288	Mary Turnipseed	Joshua Osterberg	26.03069	-84.91954
3637	S. Fl. Escarpment	3288	Cheryll Jenkins	Anthony Tarantino (PIT)	26.03069	-84.91954

Images taken with video and digital still cameras comprised an important part of the cruise records. Two high resolution systems were added to *Alvin's* standard suite of cameras for selected dives during the cruise. These were a high definition television (HDTV) camera provided by the Visual Data Systems and Development group at Woods Hole Oceanographic Institution and a digital macro camera (Seapix) developed by the Geochemical and Environmental Research Group at Texas A&M University. The standard video records and the Seapix images were copied to principal investigators at the conclusion of the cruise. Although the right to further reproduce and distribute these images resides with the responsible investigators, the cruise participants agreed to freely share the images among themselves for educational purposes. HDTV images will be made available on a best-effort basis in the months following the cruise. Table 3 summarizes the image types recorded during the dives.

Two instruments for physical oceanography were mounted on *Alvin* throughout the cruise. These were a 300 kHz acoustic doppler current profiler (ADCP) manufactured by RD Instruments, Inc. and a SBE11 conductivity, temperature, and depth recorder (CTD) manufactured by Sea Bird, Inc. Additional data recorded throughout the cruise included multibeam bathymetry and navigation records for the ship and submarine. Additional over-the-side sampling was conducted at most sites.

Subsequent sections provide details of the accomplishments of the individual research projects.

Table 3. Summary of image types taken during cruise. One Hi-8mm tape series was recorded from a 3-chip color camera mounted on the starboard manipulator arm of *Alvin* and usually comprised three, two-hour tapes per dive. Additional recording of the 3-chip camera's output was sometimes placed on beta format tapes for higher image quality. Input from other cameras on the submarine was selectively recorded on a separate set of three, two-hour "*Alvin*" tapes in Hi-8mm format. When sampling plans allowed, high quality video records were obtained from the HDTV camera system and were recorded on special digital tape. The Seepix camera is a Nikon Coolpix 990 digital macro-camera, which recorded jpeg-formatted image files on internal Compact Flash cards for subsequent copying.

Camera system:		**3-Chip**	***Alvin***	**HDTV**	**Seapix**
Dive #	3624	**x**	**x**		
	3625	**x**	**x**		
	3626	**x**	**x**		
	3627	**x**	**x**		**x**
	3628	**x**	**x**	**x**	**x**
	3629	**x**	**x**	**x**	**x**
	3630	**x**	**x**		
	3631			**x**	**x**
	3632	**x**	**x**		**x**
	3633	**x**	**x**		**x**
	3634	**x**	**x**	**x**	**x**
	3635	**x**	**x**		
	3636	**x**	**x**		
	3637	**x**	**x**		**x**

Louisiana State University and University of South Carolina Group: Barun Sen Gupta and Joan Bernhard, Principal Investigators.

PROJECT DESCRIPTION

Benthic foraminifera, often the most abundant meiofaunal group in many marine habitats, respond rapidly to environmental disturbances, and their large natural populations and well-preserved shells make them excellent recorders of present and past marine biodiversity. These organisms are capable of inhabiting environments where oxygen is depleted to extremely low levels, or even absent. Hydrocarbon vents provide a special window to study the foraminifera of such dysoxic and anoxic environments. A previous NURP-supported initial study of the foraminifera associated with Gulf of Mexico hydrocarbon vents, especially those found in or under bacterial (*Beggiatoa*) mats, has indicated the existence of facultative anaerobes within this community. However, that study was too limited in scope for an understanding of distribution patterns or physiological adaptions. The broad objective of the present research proposal is to do a detailed study of the distributions, ultrastructures, and shell carbon isotopes of the foraminifera occurring in Gulf of Mexico hydrocarbon vents. It involves on site retrieval of samples from foraminiferal habitats around the vents (especially, but not exclusively, bacterial mats) and in nearby, non vent (control) areas. The diving plan for a deeper-water submersible involves operation at different bathymetric levels- at 600 to 700 m in Green Canyon and at 2200 m in Alaminos Canyon. The laboratory work will include a) studies of dominance and diversity trends in both living and dead assemblages from surface and subsurface samples of diverse habitats, and b) ultrastructural, physiological, and carbon-isotope studies of species from bacterial mats. Foraminiferal species found in *Beggiatoa* mats are emphasized because of encouraging past results, including the finding of several apparently facultative anaerobes, in this environment.

The specific objectives for this group of foraminifera will include the determination of a) horizontal and vertical distributions of species, using stained and live individuals, b) ultrastructural characteristics of common species, c) their physiologic responses to anoxia and dysoxia (i.e. ATP analyses), and d) whether observed ultrastructural features of the common species reflect measured ∂^{13} C signals of their shells. In addition, taphonomic effects of

shells of diverse foraminiferal species will be assessed from the subsurface distribution of empty shells in vent cores; this information would be useful in future studies of ancient vent assemblages of benthic foraminifera.

SUMMARY OF RESULTS

Much of the work by the LSU-USC group on board was related to sampling operations on the first four dives (3624-3627)-- two in Alaminos Canyon (water depth about 2200 m) and two in Green Canyon (Block 272, depth 680-720 m). Eighteen push cores were taken for the foraminiferal distribution study and stable-isotope analysis. In addition, 12 push cores were taken exclusively for pore-fluid analysis related to the geochemical work; these fluids have been extracted on board, using a new technique for sediment squeezing. Four good to excellent box cores were also taken for the species distribution study, using NURP-designed equipment. Subcores (replicates from each box core) were frozen, removed from their metal casings, and frozen again for laboratory analysis. Portions of a few subcores were preserved in ethanol, to which the Rose Bengal stain had been added. For the foraminiferal physiological studies, a suite of 11 push cores were recovered in an insulated container to minimize core warming upon ascent (Table 4). This approach is crucial because ultrastructural and physiologic methods require live specimen recovery. This push-core suite consists of four cores from control sites and seven from bacterial mats. The presence of small annelids (~2 mm) and other metazoans in the *Beggiatoa* mats suggests the eukaryotic community in these Gulf of Mexico seeps is similar in many respects to that of the Santa Barbara Basin. Preliminary results of bacterial mats suggest the presence of benthic foraminifera in *Beggiatoa* mats although their physiologic state (e.g., live vs dead) remains to be determined in shore-based laboratories.

The sampling operation was highly successful, in spite of the last-minute change of one dive site (from Green Canyon Block 185 to Block 272) because of unallowable proximity to an oil rig. We expect multiple scientific publications to result from the laboratory data that would be based on these samples.

Table 4. Insulated cores collected for study of protozoa associated with bacterial mats. Core types comprised controls (C), orange mats (OM), and white mats (WM).

Date	Dive #	Site	Depth	Core #	Time	Core Type
10/17/00	3624	Alaminos Canyon	2238	17	9:53	C
10/17/00	3624	Alaminos Canyon	2238	18	9.55	C
10/18/00	3625	Alaminos Canyon	2222	24	12:46	OM
10/18/00	3625	Alaminos Canyon	2222	23	13:01	WM
10/18/00	3625	Alaminos Canyon	2215	26	13.51	WM
10/18/00	3625	Alaminos Canyon	2215	25	13:56	WM
10/19/00	3626	Green Canyon 272	723	39	No video	C
10/19/00	3626	Green Canyon 272	723	40	No video	C
10/20/00	3627	Green Canyon 272	695	45	9:21	WM
10/20/00	3627	Green Canyon 272	692	46	10:19	WM
10/20/00	3627	Green Canyon 272	667	47	12:12	WM
10/20/00	3627	Green Canyon 272	700	48	14:31	WM
10/21/00	3628	Farnella Canyon	2917	62	No video	C
10/21/00	3628	Farnella Canyon	2884	63	No video	C
10/22/00	3629	Green Knoll	2457	67	14:34	C
10/22/00	3629	Green Knoll	2463	66	9:44	C
10/23/00	3630	Mississippi Canyon	1068	71	13:52	OM
10/23/00	3630	Mississippi Canyon	1068	72	13:52	OM

Texas A&M University Group:
Ian MacDonald, William Sager, and William Bryant Principal Investigators

PROJECT DESCRIPTION

This program element collected otherwise unobtainable samples from the base and flanks of the Sigsbee and Florida Escarpments. Together, the Sigsbee and Florida Escarpments extend for ~1000km and span a depth gradient of >1000m in most regions. This topographic regime is a significant component of the benthic environment in the northern Gulf of Mexico and may comprise a significant zoo-geographic boundary between the lower continental slope and the abyss. With use of *Alvin*, however, it was possible to collect sediment samples for infaunal and geochemical analysis. It also provided detailed photographic documentation and verbal description of the benthic ecology and geology of the sites.

The Sigsbee Escarpment forms the southern margin of the central sampling area. Like the Florida Escarpment, its precipitous slope poses considerable challenges to sampling from surface ships. Little is known regarding the benthic ecology of the site. A major type of the benthic environment has recently been documented that required reconnaissance by submersible for basic characterization. The features have been designated furrows (W. Bryant, personal communication) and comprise deep, steep-sided gullies, which are often 10m deep and 30m wide. Furrows tend to run parallel to the base of the escarpment and have been identified as contiguous features that extend 100km or more. The sediment cover, and presumably the benthic communities, is entirely different between the bottom of furrows and their upper rims. It was anticipated that in the bottom, the fine Holocene sediments will have been eroded away, exposing coarser sediment. On the rims, the Holocene drape is still present. The origin of furrows is unknown, but they are thought to be formed as a result of intense current events. Because of their small cross section, furrows can only be accurately sampled with use of submersibles.

The investigators also used *Alvin* and the sampling capabilities of *Atlantis* to extend sampling and observation at two sites where deposits of gas hydrate occurs near the seafloor. Gas hydrate generates a dynamic seafloor response, including complex biological and geological interactions. This phenomenon is fairly well-known in the Gulf of Mexico and has been investigated with sampling from submarines in depths of about 500 m. This is a setting where it is possible to directly observe and sample the in-situ characteristics of the material. The two sites where these dives were conducted are MC853 and AT425, located at depths of 1040 m and 1900 m, respectively. These sites are being considered for an Ocean Drilling Program leg to investigate hydrate deposits in 2003.

SUMMARY OF RESULTS

Seven dives were completed as to support this project (Table 2, dive numbers 3628 through 3634). Sample collection during the dives included push cores, and two small box cores (Table 5). Additional sediment samples were collected with the *Atlantis* deck winch and large box cores (Table 6). Continual acoustic Doppler current profile (ADCP) data were collected from *Atlantis* along the ship's track throughout the cruise. A second ADCP was mounted on *Alvin* along with a conductivity, depth, and temperature (CTD) instrument. These instruments collected data at the seafloor during each of the dives. Bottle cast and CTD casts were also collected with the *Atlantis* rosette. Swath bathymetry data were recorded with the Sea Beam system mounted on *Atlantis*. These data provided detailed bathymetric maps at each of the dive sites.

A preliminary review of dive results indicates that most of the project objective were met. The dives at Farnella Canyon and Green Knoll (dives 3628 and 3629, respectively) confirmed that the interpretation of geophysical data from the furrows region was essentially correct. Furrows were found to be distinct, steep-sided features arrayed in parallel bands along the base of the escarpment. The steep angle of furrow edges and the accumulation of sorted, coarse sediment along the bottom of furrow indicated that strong currents continue to shape furrows in the present day. At the Green Knoll site, *Alvin* encounter a strong bottom current sweeping the base of the escarpment along the length of the furrow zone. Concentrations of suspended sediments, including coarse sediments were high. Additional sculpting and erosion of bottom sediments was evident on the slope of the escarpment above the furrow zone.

Four of the dives targeted two potential sites for an Ocean Drilling Program leg (MC853 and At425, Table 2). These dives performed an extensive reconnaissance of possible bore-hole locations, collected sediment samples, and provided the first inspection of active hydrocarbon seeps in water depths of 1000 m or greater. The preliminary results confirm that oil saturated sediments and shallow hydrate deposits occur at the MC853. Macro oil seepage was also confirmed at AT425 and shallow hydrates were probably sighted as well. Both sites supported seep-related

biological communities comprising seep mussels, vesicomyid clams, and extensive bacterial mats. Strikingly, vestimentiferan tube worms, which are the ecosystem forming species at seeps in 500-600m, appeared to be completely absent at these deeper sites. Extensive brine seepage was also noted, mostly on the flanks of topographic highs associated with shallow hydrates.

A single dive was completed to conduct a video survey of the Florida Escarpment off the northern part of the state (dive 3634, Table 2). The scientist encountered intense sedimentation which had produce a large accumulation of flocculent material at the base of the escarpment. They transited approximate 700m up the vertical face of the escarpment. The effects of ongoing sedimentation were evident in the relative paucity of sessile fauna. Corals, sponges, crinoids, and other forms were found in abundance only where rocky overhangs protected that animals from the settling material. The escarpment appears to be a stressed habitat over much of its surface.

These investigations are expected to produce a number of presentations and peer-review publications. Proposals for follow-on work are also anticipated. The public response and media interest in the cruise has been very high. The logistic arrangements offer a model for inter-agency cooperation in deep-sea science.

College of William and Mary Group
Cindy Lee Van Dover, Principal Investigator:

SUMMARY OF CRUISE RESULTS

Three *Alvin* dives were completed at the historic Florida Escarpment site (26 01.8'N, 84 54.9'W; 3388 m) Sixteen quantitative mussel pots were collected, containing in total 681 mussels and occupying a total volume of 27 liters. Fine and coarse washings from the mussels were preserved for subsequent laboratory analysis of species identifications and abundance. Systematic sub-sampling of mussels was undertaken for measurement of condition indices. A number of ancillary projects were also begun, including preservation of mussels for a comparative histological analysis of pathology among Florida Escarpment seep and Mid-Atlantic Ridge vent populations (W&M Master's project), preservation of mussel commensal polychaetes for reproductive studies, and preparation of mussel tissues for symbiont population studies (Harvard Ph.D. project). Tissue and blood samples were also collected for other investigators, including Chuck Fisher and two of his students at Penn State and for Joe Bonaventura at the Duke Marine Lab.

GENERAL SCIENTIFIC CONTRIBUTION OF THE CRUISE

The sampling program was successful, and will allow us to develop a robust, quantitative assessment of biodiversity at the Florida Escarpment seep site. Because we used methods and standards routinely employed by my lab at vent mussel beds, the seep data will be directly comparable and will allow insight into patterns of diversity. From these patterns, we expect to develop hypotheses regarding processes that control biodiversity and the distribution of species at seep and vent sites. From initial examination of the seep samples, it is immediately clear that the seep mussel bed fauna differs from that of vents in the high abundance of echinoderms at seeps, both holothurian and ophiuroid, and in the relative paucity of limpets and amphipods at seeps compared to vents.

SPECIFIC ADVANTAGES OF RESEARCH TO NURP

This program rigorously assesses diversity, which is one of the most fundamental descriptors in ecology. As such, it is a direct contribution to the NURP priority of understanding the ecology of chemosynthetic systems. Seeps are biodiversity hot spots and are thought to support a higher degree of endemicity than vent ecosystems. This hypothesis needs to be rigorously tested by sampling other seep sites with similar efforts and methods to allow quantitative comparisons.

Table 5. Push cores collected from *Alvin* for macrofauna.

Site Name	Date	Core	Marker	Dive Number	Latitude (N)	Longitude (W)	Depth (m)	Time (CST)	Comments and Notes
Green Knoll	10-21-00	PC-01	#2	#3629	26.56.64	90.14.2161	2457	10:58	In furrow
Green Knoll	10-22-00	PC-02	#3	#3629	26.56.64	90.14.2161	2457	10:57	In furrow
Green Knoll	10-22-00	PC-03	#4	#3629	26.56.64	90.14.2161	2457	10:55	In furrow
Green Knoll	10-22-00	PC-04	#10	#3629	26.56.64	90.14.2161	2457	11:39	Out furrow
Green Knoll	10-22-00	PC-05	#11	#3629	26.56.64	90.14.2161	2457	11:48	Out furrow
Green Knoll	10-22-00	PC-06	#12	#3629	26.56.64	90.14.2161	2457	11:42	Out furrow
MC853	10-23-00	PC-07	#3	#3630	28.12663	89.14367	1058	9:45-9:54	Clam trail
MC854	10-23-00	PC-08	#4	#3630	28.12663	89.14367	1058	9:45-9:54	Clam trail
MC855	10-23-00	PC-09	#6	#3630	28.12663	89.14367	1058	9:45-9:54	Clam trail
MC856	10-23-00	PC-10	#8	#3630	28.12663	89.14367	1058	9:45-9:54	Non-clam trail
MC857	10-23-00	PC-11	#7	#3630	28.12663	89.14367	1058	9:45-9:54	Non-clam trail
MC857	10-23-00	PC-12	Not available - core fell-off rack on the submersible						
AT425	10-25-00	PC-13	#3	#3632	27.58122	88.50515	1943	13:30-13:40	In Sargassum debris patch
AT425	10-25-00	PC-14	#4	#3632	27.58122	88.50515	1943	13:30-13:40	In Sargassum debris patch
AT425	10-25-00	PC-15	#5	#3632	27.58122	88.50515	1943	13:30-13:40	In Sargassum debris patch
AT425	10-25-00	PC-16	#6	#3632	27.58122	88.50515	1943	13:30-13:40	Outside Sargassum patch
AT425	10-25-00	PC-17	#7	#3632	27.58122	88.50515	1943	13:30-13:40	Outside Sargassum patch
AT425	10-25-00	PC-18	#10	#3632	27.58122	88.50515	1943	13:30-13:40	Outside Sargassum patch
N.FL Escarp	10-27-00	PC-19	#7	#3634	28*	86.583*	2873	10:16	In burrow
N.FL Escarp	10-27-00	PC-20	#8	#3634	28*	86.583*	2873	10:20	Burrow opening
N.FL Escarp	10-27-00	PC-21	#9	#3634	28*	86.583*	2873	10:22	In burrow
N.FL Escarp	10-27-00	PC-22	#10	#3634	28*	86.583*	2873	10:28	Control
N.FL Escarp	10-27-00	PC-23	#11	#3634	28*	86.583*	2873	10:32	Control
N.FL Escarp	10-27-00	PC-24	#12	#3634	28*	86.583*	2873	10:36	Control

*Approximate values - data not yet available

Table 6. Box cores collected with use of the *Atlantis* winch and from *Alvin*.

Site Name	Date	Activity	Marker	Time Deployed	Time on Bottom	Latitude (N)	Longitude (W)	Depth (m)	Line Out	Surface Time
Farnella Canyon	102100	EB-01	*Alvin*	Dive #3628	NA	26.269119	90.46.4224	2917	w/in Sargassum patch	
Farnella Canyon	102100	EB-02	*Alvin*	Dive #3628	NA	26.269119	90.46.4224	2917	non-Sargassum patch	
Farnella Canyon	102100	Box-01	N/A	8:00	8:45	26.26.7483	90.46.4594	2933	did not trigger	
Green Knoll	102200	Box-02	B1	3:46	4:32	26.55.4994	90.12.9999	2473.53	2466	5:20
Green Knoll	102200	Box-03	B2	5:32	6:21	26.55.3007	90.12.9999	2473	2470	7:11
Green Knoll	102200	Box-04	B3	7:17	8:01	26.55.4977	90.12.9998	2476	2468	8:55
Green Knoll	102200	Box-05	N/A	9:02	9:49	26.55.4994	90.12.9997	2480	2466	10:38
MC853	102400	Box-06	B4	6:15	6:45	28.07.6064	89.08.4112	1056	did not trigger	
MC853	102400	Box-07	B5	7:28	7:51	28.07.6064	89.08.4112	1056	1058	8:15
MC853	102400	Box-08	N/A	8:30	8:51	28.07.6074	89.08.4100	1058	did not trigger	
MC853	102400	Box-09	N/A	9:24	9:49	28.07.6100	89.08.4099	1058	did not trigger	
AT425	102500	Box-10	N/A	6:00	6:41	27.34.9303	88.30.4923	1955	did not trigger	
AT425	102500	Box-11	N/A	7:22	7:59	27.34.9297	88.30.4304	1955	1945	8:59
AT425	102600	Box-12	B6	2:37	3:12	27.34.9312	88.30.4285	1953	1945	3:55
AT426	102600	Box-13	N/A	5:00	5:38	27.34.9309	88.30.4289	1949	1947	6:20
AT426	102600	Box-14	N/A	6:32	7:11	27.34.9314	88.30.4273	1955	Did not sample for macrofauna	
S. FL Escarp	102900	Box-15	N/A	2:25	3:21	26.01.9003	84.55.1691	3307	3317	4:29
S. FL Escarp	102900	Box-16	N/A	4:40	5:38	26.01.8996	84.55.1685	3302	3322	6:29
S. FL Escarp	102900	Box-17	N/A	6:41	7:39	26.01.9004	84.55.1687	3303	3323	8:38
S. FL Escarp	102900	Box-18	N/A	8:44	9:40	26.01.9002	84.55.1696	3304	3324	10:45