OCS Study
MMS 96-0056

Proceedings:
Fifteenth Annual Gulf of Mexico Information Transfer Meeting

December 1995

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

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SUMMARY

The 1995 Information Transfer Meeting (ITM) was sponsored by the Gulf of Mexico OCS Region of the Minerals Management Service (MMS) at the Hotel Inter-Continental in New Orleans. The purpose of the ITM is to foster sharing of information among participants about current research, accomplishments, or issues of concern to the MMS. Presentations at the ITM pertained to the MMS Gulf of Mexico Outer Continental Shelf (OCS) oil and gas program, as well as regional environmental, social, or economic concerns, or current OCS industry activities or technologies. The audience included scientists, managers, and laypersons from government, academia, industry, environmental groups, and the general public.

Technical sessions this year included OCS Industry Issues, MMS Marine Minerals Program (INTERMAR), Forum on Issues in the Gulf States, Oil-Spill Geographic Information Systems, Marine Mammals, Neotropical Birds, Socio-economic Issues, Flower Garden Banks Issues, NE GOM Coastal and Marine Ecosystem Program, Air Quality Studies and Issues, Contaminants Research, GOOMEX and LATEX studies, Underwater Archaeology, and Progress Reports on MMS Environmental Studies and Coastal Marine Institute Studies.

The Minerals Management Service invites comment and constructive criticism on the Information Transfer Meetings and the resulting Proceedings documents.

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ACKNOWLEDGMENTS

The Minerals Management Service thanks all ITM participants. Recognition goes to the speakers whose timely individual and panel presentations stimulated discussions and exchange of information. Authors are listed by name with their articles and again in an index at the back of this publication.

We are grateful to the chairs and co-chairs for the many hours spent in organizing and chairing the sessions, as well as for their time spent gathering the presentation summaries. They are listed by name in the table of contents as well as at the beginning of each session.

Special recognition is given to the co-chairs of the OCS Industry Issues sessions, which were coordinated and developed using an informal customer-partnership arrangement through the ITM Coordinator. Mr. Paul L. Kelly, OCS Policy Chairman, and Mr. John D. Rullman, Offshore Operator Committee Technical Subcommittee Chairman, created impressive agendas addressing current and future issues of concern to the OCS oil and gas industry.

Particular appreciation is also extended to the University of New Orleans, Office of Conference Services, the contractor who handled the logistics for the meeting and compiled the proceedings, and to the UNO students who assisted the session chairs. The Hotel Inter-Continental staff were accommodating and always prepared to offer assistance, especially providing audio-visual support.

INTRODUCTION

Ms. Carla M. Langley
Office of the Regional Director
Minerals Management Service
Gulf of Mexico OCS Region

The primary purposes of the ITM are (1) to provide a forum for interchange on topics of current interest relative to environmental assessments in support of offshore oil and gas activities in the Gulf of Mexico OCS Region; (2) to present the accomplishments of the MMS Environmental Studies Program for the Gulf of Mexico and of other research programs or study projects; and (3) to foster an exchange of information of regional interest among scientists, staff members, and decision makers from MMS, other federal or state governmental agencies, regionally important industries, and academia and to encourage opportunities for these attendees to meet and nurture professional acquaintances and peer contacts.

The ITM agenda is planned and coordinated by the MMS staff in the Gulf of Mexico OCS Regional Office around the three themes mentioned above—issues of current interest to the Region or MMS oil and gas program; accomplishments of the agency; and regional information exchange. Presentations are by invitation through personal contacts between session chairpersons and speakers who have demonstrated knowledge or expertise on the subject.

Support funding is provided through the MMS Environmental Studies Program. Logistical support for the ITM is provided by a contractor and subcontractors selected through the Federal procurement process. A proceedings volume is prepared for each ITM based on summaries of brief technical papers submitted by each speaker and on each session chair's added comments.

The ITM is considered a meeting of regional importance and is one of the Region's primary outreach efforts. Attendance in recent years has been 400-500 persons, including scientists, managers, and laypersons from government, academia, industry, environmental groups, and the general public.

Carla Langley is a staff assistant in the Regional Director's Office with the Gulf of Mexico OCS Region of the Minerals Management Service. She joined MMS in 1982 and presently coordinates outreach efforts and special projects. In 1995 she was the Agenda and Logistics coordinator for the Region's Information Transfer Meeting.

From 1985 to 1991, Ms. Langley was a physical scientist with the Department of Defense. In this capacity, half of her time was spent overseas aboard U.S. Naval research vessels collecting and analyzing oceanographic and GPS data and monitoring bathymetric subsystem performance for application in the U.S. Fleet Ballistic Missile Program. She is a graduate of the University of New Orleans.

SESSION 1A

MARINE MAMMALS OF THE GULF OF MEXICO: A REVIEW OF THE RESULTS OF THE GULFCET PROGRAM AND FUTURE INVESTIGATION

Session: 1A - MARINE MAMMALS OF THE GULF OF MEXICO: A REVIEW OF THE RESULTS OF THE GULFCET PROGRAM AND FUTURE INVESTIGATION

Co-Chairs: Dr. Robert Avent and Ms. Dagmar Fertl

Date: December 12, 1995

Presentation	Author/Affiliation
Distribution and Abundance of Cetaceans in the North-Central and Western Gulf of Mexico	Dr. Randall W. Davis[1], Dr. Gerald P. Scott[2], Dr. Bernd Würsig[1], Dr. Giulietta S. Fargion[1], Dr. William E. Evans[1], Mr. Larry J. Hansen[2], Dr. Robert Benson[1], Dr. Keith D. Mullin[2], Dr. Thomas D. Leming[2], Dr. Nelson May[2], Dr. Bruce R. Mate[3], Dr. Jeffrey C. Norris[1], Dr. Thomas A. Jefferson[1], Dr. Dwight E. Peake[1], Mr. Spencer K. Lynn[1], Mr. Troy D. Sparks[1], and Ms. Cheryl Schroeder[1] [1] Texas Institute of Oceanography, Texas A&M University, Galveston [2] National Marine Fisheries Service, Miami, Florida [3] Hatfield Marine Science Center, Oregon State University, Newport
Distribution and Abundance of Cetaceans, Seabirds, and Sea Turtles over the Continental Slope of the Gulf of Mexico	Dr. Keith D. Mullin Mr. Larry J. Hansen Southeast Fisheries Science Center National Marine Fisheries Service, NOAA Dr. Randall W. Davis Dr. Dwight E. Peake Texas A&M University, Galveston
Behavior of Cetaceans in the Northern Gulf of Mexico Relative to Survey Vessels	Dr. Bernd Würsig Mr. Spencer K. Lynn Dr. Thomas A. Jefferson Texas A&M University at Galveston Marine Mammal Research Program Dr. Keith D. Mullin National Marine Fisheries Service Southeast Fisheries Science Center
Sperm Whale Abundance, Distribution, and Movement Patterns in the North-central and Western Gulf of Mexico	Dr. William E. Evans Dr. Jeff C. Norris Mr. Troy D. Sparks Dr. Bernd Würsig Mr. David W. Weller Texas A&M University, Galveston

DISTRIBUTION AND ABUNDANCE OF CETACEANS IN THE NORTH-CENTRAL AND WESTERN GULF OF MEXICO

Dr. Randall W. Davis[1], Dr. Gerald P. Scott[2], Dr. Bernd Würsig[1], Dr. Giulietta S. Fargion[1], Dr. William E. Evans[1], Mr. Larry J. Hansen[2], Dr. Robert Benson[1], Dr. Keith D. Mullin[2], Dr. Thomas D. Leming[2], Dr. Nelson May[2], Dr. Bruce R. Mate[3], Dr. Jeffrey C. Norris[1], Dr. Thomas A. Jefferson[1], Dr. Dwight E. Peake[1], Mr. Spencer K. Lynn[1], Mr. Troy D. Sparks[1], and Ms. Cheryl Schroeder[1]

[1] Texas Institute of Oceanography, Texas A&M University, Galveston
[2] National Marine Fisheries Service, Miami, Florida
[3] Hatfield Marine Science Center, Oregon State University, Newport

The Minerals Management Service (MMS) is responsible for assuring that the exploration and production of oil and gas reserves located more than three miles offshore and within the U.S. Exclusive Economic Zone are conducted in a manner that reduces risks to the marine environment. To meet their responsibilities under the Marine Mammal Protection Act of 1972 and the Endangered Species Act of 1973, the MMS must understand the effects of oil and gas operations on marine mammals. As the oil and gas industry moves into deeper water along the continental slope in its continuing search for extractable reserves, information is needed on the distribution, abundance, behavior, and habitat of cetaceans, especially large and deep-water species in the Gulf of Mexico (Table 1A.1). This study, hereafter called the GulfCet Program, was designed to help the MMS assess the potential effects of deep-water oil and gas exploration and production on marine mammals in the Gulf of Mexico.

The purpose of this study was to determine the distribution and abundance of cetaceans along the continental slope in the north-central and western Gulf of Mexico. The study was restricted to an area bounded by the Florida-Alabama border, the Texas-Mexico border, and the 100 m and 2,000 m isobaths (Figure 1A.1). This 3.75 year project commenced on 1 October 1991 and concluded on 15 July 1995. In addition to conducting aerial visual, shipboard visual, and shipboard acoustic marine mammal surveys, the GulfCet Program collected hydrographic data *in situ* and by remote sensing to characterize the marine habitat of cetaceans in the study area. An attempt was also made to tag sperm whales and track their movements using satellite telemetry.

The GulfCet Program was administered by the Texas Institute of Oceanography (TIO), which is part of the Texas A&M University System. Researchers at Texas A&M University campuses at Galveston and College Station provided expertise in marine mammal biology, bioacoustics, and oceanography. Expertise in aerial and shipboard surveys of marine mammals, satellite remote sensing, and Geographical Information Systems was provided by the National Marine Fisheries Service (NMFS) at the Southeast Fisheries Science Centers (SEFSC), with facilities in Miami, Pascagoula, and at Stennis Space Center. The NMFS effort was contracted under a separate Interagency Agreement with MMS. Finally, the program included scientists from the Hatfield Marine Science Center at Oregon State University, who had developed techniques to tag and track whales using satellite telemetry. The GulfCet Program had a Scientific Review Board composed of five scientists who reviewed and commented on the project's goals, methodologies, results, analyses, and conclusions.

Dr. Randall W. Davis has field experience in the physiological ecology and diving behavior of marine mammals and birds. Most of this work has focused on the physiological adaptations for diving and the at-sea behavior and metabolism of polar pinnipeds and penguins. Dr. Davis has complemented his field work with detailed laboratory studies of the fuel homeostasis, exercise metabolism and lipid metabolism of marine mammals.

Dr. Gerald P. Scott is currently chief of a division of 30 fishery biologists, operations research analysts, technicians, and support staff at the National Marine Fisheries Services' Southeast Fisheries Science Center. Dr. Scott's research interest include population dynamics modeling, marine mammal and fish population estimation, and multidisciplinary fisheries oceanography studies.

Dr. Bernd Würsig is Director of the Marine Mammal Research Program of Texas A&M University. His research interests include habitat-related changes in social structure and foraging, effects of industrial activity on the behavior and social organization of

Table 1A.1. Cetaceans of the Gulf of Mexico.

	Balaenidae*	
Northern Right Whale		*Eubalaena glacialis*
	Balaenopteridae*	
Blue Whale		*Balaenoptera musculus*
Fin Whale		*Balaenoptera physalus*
Sei Whale		*Balaenoptera borealis*
Bryde's Whale		*Balaenoptera edeni*
Minke Whale		*Balaenoptera acutorostrata*
Humpback Whale		*Megaptera novaeangliae*
	Physeteridae	
Sperm Whale		*Physeter macrocephalus*
Pygmy Sperm Whale		*Kogia breviceps*
Dwarf Sperm Whale		*Kogia simus*
	Ziphiidae	
Cuvier's Beaked Whale		*Ziphius cavirostris*
Blainville's Beaked Whale		*Mesoplodon densirostris*
Sowerby's Beaked Whale		*Mesoplodon bidens*
Gervais' Beaked Whale		*Mesoplodon europaeus*
	Delphinidae	
Melon-headed Whale		*Peponocephala electra*
Pygmy Killer Whale		*Feresa attenuata*
False Killer Whale		*Pseudorca crassidens*
Killer Whale		*Orcinus orca*
Short-finned Pilot Whale		*Globicephala macrorhynchus*
Rough-toothed Dolphin		*Steno bredanensis*
Fraser's Dolphin		*Lagenodelphis hosei*
Bottlenose Dolphin		*Tursiops truncatus*
Risso's Dolphin		*Grampus griseus*
Atlantic Spotted Dolphin		*Stenella frontalis*
Pantropical Spotted Dolphin		*Stenella attenuata*
Striped Dolphin		*Stenella coeruleoalba*
Spinner Dolphin		*Stenella longirostris*
Clymene Dolphin		*Stenella clymene*

* Rarely sighted

marine mammals, and integration of live animal studies with general necropsy and tissue toxin studies as a vehicle to use long-lived marine mammals as partial indicators of ecosystem problems.

Dr. Giulietta S. Fargion's research has been in the area of physical-biological oceanography. This research employs coastal oceanography, remote sensing data to study fronts and eddies, and the interaction between marine mammals and their habitats. Presently Dr. Fargion is a Senior Scientist in the Science Office of the EOSDIS Core System (Washington, D.C.) as part of NASA's Mission to Planet Earth Initiative.

During the past 30 years of his career, Dr. William Evans has designed and conducted original research in both the life and physical sciences. His personal research has concentrated on the use of remote sensing

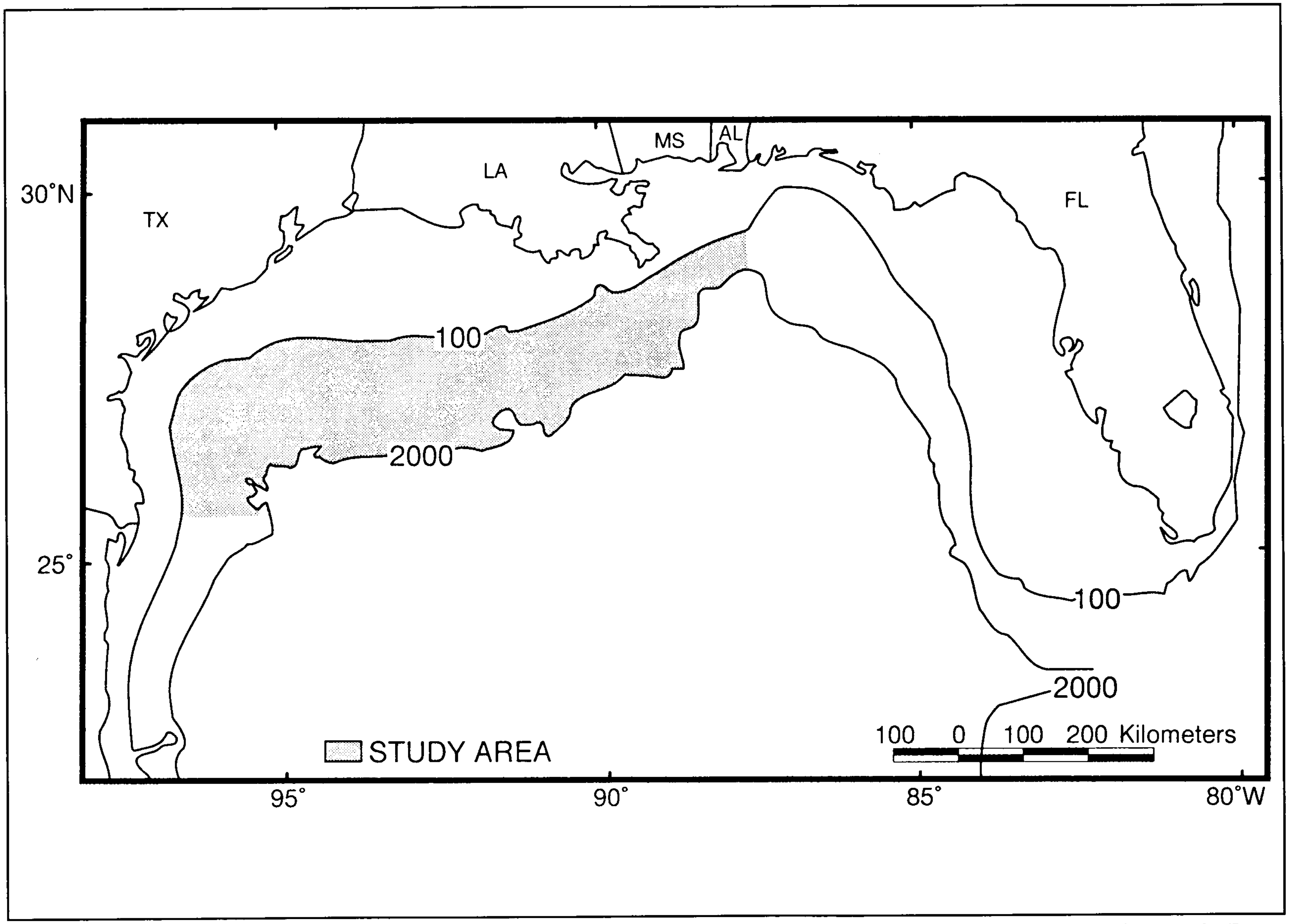

Figure 1A.1. Study area between the 100- and 2,000-m isobaths, extending as far east as the Florida-Alabama border, and as far southwest as the Texas-Mexico border.

technology in meso-scale studies of oceanic marine living resource dynamics and acoustics.

Larry J. Hansen is currently the Marine Mammal Research Program Coordinator for the Southeast Fisheries Science Center and has been involved in the Gulf of Mexico marine mammal assessment research since 1984. His research has involved the collection and analysis of information relating to describing the abundance and distribution of various marine mammal populations.

Dr. Robert Benson's primary research interest is in the field of bioacoustics. Other research interests are the application of modern instrumentation to problems in wildlife biology, the ecosciences, and engineering.

Dr. Keith D. Mullin was the principal investigator for the cooperative MMS/NMFS study of cetaceans on the upper continental slope in the north-central Gulf of Mexico during 1989-90. He was a co-principal investigator on the GulfCet Program and was responsible for implementation and analyses of the aerial survey portion of the GulfCet Program.

Dr. Thomas D. Leming has 24 years of experience in the study of physical oceanography with regards to fisheries management. In addition, he has 16 years of experience in the use of satellite and aircraft remote sensing to determine the distribution, abundance, and recruitment of commercial finfish.

Dr. Nelson May is a Remote Sensing Specialist at the Stennis Space Center, Mississippi. He is a member of a research unit that uses remote sensing and geographic information system analysis techniques to gain an understanding of how environmental variables affect the distribution and abundance of fisheries resources in the Gulf of Mexico.

Dr. Bruce Mate has been instrumental in the technological development and application of satellite telemetry for tracking marine mammals. His work includes the successful satellite tracking of humpback whales, manatees, pilot whales, right whales, and bottlenose dolphins. His VHF tracking experiences include the 94 day track of a gray whale, which is the longest tracking record for conventional tagging.

Dr. Jeffrey C. Norris has studies marine mammal bioacoustics, both in terms of vocal production and reception. His research interests include animal communication, acoustics, marine mammals, primates, and conservation biology. During GulfCet I, he was responsible for the acoustic survey.

Dr. Thomas A. Jefferson is currently a research associate and Acing Co-Director of the Ocean Park Conservation Foundation, Hong Kong. The foundation sponsors and funds 16 projects on cetacean conservation in southeast Asia and is currently conducting a two-and-a half-year study of the Indo-Pacific humpbacked dolphin population in Hong Kong waters.

Dr. Dwight E. Peake is a medical doctor at the University of Texas Medical Branch, Galveston, Texas, with a more than passing interest in birds. He has volunteered as the bird observer on most Texas A&M University GulfCet cruises.

Spencer K. Lynn's work has involved photo-identification, behavioral observation, radio-tracking, genetic biopsy sampling, and acoustic recording of free-ranging bottlenose dolphins along the Texas coastline as part of social affiliation and environmental monitoring studies. He was a visual observer during GulfCet I cruises. He obtained his master's degree from Texas A&M University in May 1995. Before moving to Galveston in 1991, he assisted in research on the behavior, communication, and cognition of captive bottlenose dolphins in San Francisco, California.

Troy D. Sparks is a research assistant at the Marine Acoustics Laboratory, Center of Bioacoustics, Galveston, Texas. He is a M.S. candidate in wildlife and fisheries science at Texas A&M University. His areas of interest include bioacoustics of cetaceans and resource management as it pertains to endangered species via remote sensing techniques such as passive and active acoustics, and satellite telemetry.

Cheryl Schroeder is currently working on her master's degree in biological oceanography at the University of Rhode Island's Graduate School of Oceanography. She received her B.S. in marine biology from Texas A&M University at Galveston.

DISTRIBUTION AND ABUNDANCE OF CETACEANS, SEABIRDS, AND SEA TURTLES OVER THE CONTINENTAL SLOPE OF THE GULF OF MEXICO

Dr. Keith D. Mullin
Mr. Larry J. Hansen
Southeast Fisheries Science Center
National Marine Fisheries Service, NOAA

Dr. Randall W. Davis
Dr. Dwight E. Peake
Texas A&M University, Galveston

Prior to 1990 very little was known about the abundance and distribution of oceanic (depths >200 m) cetaceans, sea turtles and seabirds in the northwestern Gulf of Mexico. From 1992-1994, a series of seasonal surveys were conducted on the continental slope (depths 100-2,000 m) from the Alabama-Florida border to the Texas-Mexico border (155,000 km^2). Line-transect surveys were conducted from ships to study cetaceans and seabirds and from aircraft to study cetaceans and sea turtles. Ship surveys covered 21,360 km with the majority (63%) of the effort occurring in spring. Survey effort from aircraft totaled 49,960 km with effort spread equally throughout all four seasons.

From ship and aerial platforms there were more than 800 sightings of 20 species of cetaceans. The majority of the sightings were of eight species and the overall abundance of each for the entire study area was as follows (abundance, C.V.): bottlenose dolphin (2,538, 0.26), pantropical spotted dolphin (7,105, 0.22), sperm whale (313, 0.25), Risso's dolphin (529, 0.26), dwarf sperm whale (88, 0.34), Clymene dolphin (1695, 0.37) and striped dolphin (2091, 0.52). The abundance of several species (e.g., Risso's dolphin, pantropical spotted dolphin) was much lower in the fall and the overall abundance of all cetaceans was 2-3 times lower in the fall than in the other season. By season, the number of species sighted ranged from 11 in fall to 15 in winter. Eight species were sighted in all four seasons. Cetaceans were sighted in every portion of the study area and, in general, were sighted throughout the study area each season. Each of the common species was widely distributed in the study area. Bottlenose and Atlantic spotted dolphins were usually sighted near the continental shelf-edge whereas all the other species, except Risso's dolphin, were generally in deeper waters. Short-finned pilot whales were almost exclusively sighted in the western portion of the study area.

All five species of marine turtles that are found in the Gulf of Mexico are listed threatened or endangered. During aerial surveys leatherback (90 sightings), loggerhead (12 sightings), and Kemp's ridley (2 sightings) sea turtles were sighted. In the aerial survey study area (85,000 km^2), the overall abundance of leatherbacks was estimated to be 153 turtles (C.V. = 0.19) with seasonal abundances ranging from zero (summer 1993) to 336 (0.46) (summer 1992). Leatherbacks were found throughout the study area but there were concentrations south of the Mississippi River delta and south of western Louisiana.

These surveys were the first extensive ship-based studies of seabirds in northwestern Gulf, and they added important new insights into the offshore seasonal occurrence, relative abundance and distribution of several species. There was a total of 2,692 seabird sightings that included 32 species representing three orders and nine families. Some of the commonly sighted species were as follows (number of sightings in parentheses): Laughing gull (369), herring gull (102), black tern (412), bridled tern (113), pomarine jaeger (292), Audubon's shearwater (127). There were 572 sightings of unidentified storm-petrels. Sightings that could be identified were split between Audubon's (54) and band-rumped (41) storm-petrels. In general, while some species were found closer to the shelf-edge than others, most of the more common species were widely distributed in the study area. Some species varied seasonally in relative abundance.

Dr. Keith D. Mullin was the principal investigator for the cooperative MMS/NMFS study of cetaceans on the upper continental slope in the north-central Gulf of Mexico during 1989-90. He was a co-principal investigator on the GulfCet Program and was responsible for implementation and analyses of the aerial survey portion of the GulfCet Program.

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BEHAVIOR OF CETACEANS IN THE NORTHERN GULF OF MEXICO RELATIVE TO SURVEY VESSELS

Dr. Bernd Würsig
Mr. Spencer K. Lynn
Dr. Thomas A. Jefferson
Texas A&M University at Galveston
Marine Mammal Research Program

Dr. Keith D. Mullin
National Marine Fisheries Service
Southeast Fisheries Science Center

There is great variability in morphology, group sizes, and behavior of the approximately 20 species of cetaceans that commonly occur in the Gulf of Mexico. The ranges are from small delphinids of about 2 m to sperm whales (*Physeter macrocephalus*) of over 15 m, from single individuals to groups of hundreds, and from those animals that habitually approach boats and even bowride to those that ignore or avoid vessels. It is intuitively obvious that differences in these factors can result in different abilities to detect, identify, and accurately count animals; but descriptive characteristics of such detection variables, especially those stemming from different behaviors, have been given only rarely.

During surveys, there are often differences in the distances at which cetaceans are first seen, first identified, and at which they are most accurately counted. These differences are determined by morphology, group size, and behavior but also by the variability of weather, or sighting, conditions. For example, sperm whales can often be seen, identified, and counted many kilometers from the survey vessel, and often in rather inclement weather. Beaked whales (*Ziphiidae*) or pygmy and dwarf sperm whales (*Kogia* spp.), on the other hand, may or may not be seen at distance, and their often cryptic behavioral nature may preclude identification. By and large, most marine mammal surveys have not taken into account variabilities in morphology, group size, and behavior as they relate to sighting capability

In the present analysis, cetacean behavioral responses to survey ships and aircraft were investigated from data collected during line transect surveys in the northwestern Gulf of Mexico, and initial sighting distances were calculated for several species categories. Sperm whales, killer whales, and several delphinid species that occur in large herds were detected at the largest distances. Beaked whales, *Kogia* spp., and most of the larger delphinids had smaller initial sighting distances. Many species showed negative or neutral reactions to the survey platform, but (with the exception of the striped dolphin) most of the smaller delphinids showed strong positive reactions, approaching the ship to ride the bow wave. These behavioral differences may have effects on resulting density estimates. Estimates for long-diving cetaceans, such as sperm whales, and species which often react negatively to the survey vessel, such as striped dolphins, may tend to be biased downwards unless data can be collected to estimate the value of the detection function.

Dr. Bernd Würsig is Director of the Marine Mammal Research Program of Texas A&M University. His research interests include habitat-related changes in social structure and foraging, effects of industrial activity on the behavior and social organization of marine mammals, and integration of live animal studies with general necropsy and tissue toxin studies as a vehicle to use long-lived marine mammals as partial indicators of ecosystem problems.

Spencer K. Lynn's work has involved photo-identification, behavioral observation, radio-tracking, genetic biopsy sampling, and acoustic recording of free-ranging bottlenose dolphins along the Texas coastline as part of social affiliation and environmental monitoring studies. He was a visual observer during GulfCet I cruises. He obtained his master's degree from Texas A&M University in May 1995. Before moving to Galveston in 1991, he assisted in research on the behavior, communication, and cognition of captive bottlenose dolphins in San Francisco, California.

Dr. Keith D. Mullin was the principal investigator for the cooperative MMS/NMFS study of cetaceans on the upper continental slope in the north-central Gulf of Mexico during 1989-90. He was a co-principal investigator on the GulfCet Program and was responsible for implementation and analyses of the aerial survey portion of the GulfCet Program.

SPERM WHALE ABUNDANCE, DISTRIBUTION, AND MOVEMENT PATTERNS IN THE NORTH-CENTRAL AND WESTERN GULF OF MEXICO

Dr. William E. Evans
Dr. Jeff C. Norris
Mr. Troy D. Sparks
Dr. Bernd Würsig
Mr. David W. Weller
Texas A&M University, Galveston

Sperm whales were sighted during all seasons throughout the GulfCet study area. Seventy-three sightings were made during ship surveys and twenty-eight during aerial surveys. Sperm whale abundance was estimated to be 313 animals (95% CI = 192-508) from visual surveys and 316 animals (95% CI = 265-377) from acoustic surveys. The five eastern-most track-lines (off the Mississippi delta) had the highest densities of sperm whales. An eight-day survey, concentrating on a 900 square mile area off the Mississippi Delta, was conducted in August 1993. Acoustic techniques were used to estimate the diving depths and movement patterns of a group of approximately 50 sperm whales. Using photographic techniques, 20 individuals were identified. Five of these were re-sighted during the eight-day study.

During the past 30 years of his career, Dr. William Evans has designed and conducted original research in both the life and physical sciences. His personal research has concentrated on the use of remote sensing technology in meso-scale studies of oceanic marine living resource dynamics and acoustics.

Dr. Jeffrey C. Norris has studies marine mammal bioacoustics, both in terms of vocal production and reception. His research interests include animal communication, acoustics, marine mammals, primates, and conservation biology. During GulfCet I, he was responsible for the acoustic survey.

Troy D. Sparks is a research assistant at the Marine Acoustics Laboratory, Center of Bioacoustics, Galveston, Texas. He is a M.S. candidate in wildlife and fisheries science at Texas A&M University. His areas of interest include bioacoustics of cetaceans and resource management as it pertains to endangered species via remote sensing techniques such as passive and active acoustics, and satellite telemetry.

Dr. Bernd Würsig is Director of the Marine Mammal Research Program of Texas A&M University. His research interests include habitat-related changes in social structure and foraging, effects of industrial activity on the behavior and social organization of marine mammals, and integration of live animal studies with general necropsy and tissue toxin studies as a vehicle to use long-lived marine mammals as partial indicators of ecosystem problems.

David Weller is a doctoral candidate in wildlife and fisheries sciences at Texas A&M University and is currently studying the behavior and ecology of wild bottlenose dolphins along the Texas coast. Particular research interests include the behavior and sociobiology of nearshore dolphin populations, the effects of anthropogenic disturbance on marine mammal behavior, and the movement and migration patterns of whales and dolphins.

SESSION 1B

NEOTROPICAL BIRDS AND THEIR RELATIONSHIP TO THE GULF OF MEXICO AND OIL AND GAS DEVELOPMENT

Session: 1B - NEOTROPICAL BIRDS AND THEIR RELATIONSHIP TO THE GULF OF MEXICO AND OIL AND GAS DEVELOPMENT

Chairman: Mr. Villere Reggio, Jr.

Date: December 12, 1995

Presentation	Author/Affiliation
Neotropical Birds and Their Relationship to the Gulf of Mexico and Oil and Gas Development	Mr. Villere C. Reggio, Jr. Minerals Management Service Gulf of Mexico OCS Region
Neotropical Migrants—Definition, Status, Trends, and Their Relationship to the Gulf of Mexico	Dr. Sidney A. Gauthreaux, Jr. Department of Biological Sciences Clemson University
Partners in Flight: Conservation of Neotropical Migratory Landbirds along the Gulf of Mexico	Mr. William C. Hunter Southeast Coordinator, Partners in Flight U.S. Fish and Wildlife Service
The Gulf Coast Bird Observatory (GCBO) and the Oil and Gas Industry as Conservation Partners	Mr. Ray Johnson Gulf Coast Bird Observatory Nassau Bay, Texas
Gulf Coast Neotropical Bird Watchers: An Outdoor Recreation Activity of Economic and Scientific Importance (Avitourism on the Texas Gulf Coast)	Ms. Madge Lindsay Texas Parks and Wildlife Department Austin, Texas
The National Biological Service's Neotropical Bird Research Program in the Chenier Plain of the Gulf of Mexico	Dr. Carroll L. Cordes Dr. Wylie C. Barrow, Jr. Southern Science Center National Biological Service

NEOTROPICAL BIRDS AND THEIR RELATIONSHIP TO THE GULF OF MEXICO AND OIL AND GAS DEVELOPMENT

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North America is home to about 900 species of native birds. Approximately one-fourth of these species are classified as neotropicals. Scientific evidence has indicated most of the neotropical species are in a state of steady decline, ranging from 2 to 4 percent a year. Indications are that a few neotropical species have declined as much as seventy percent from historic population levels.

Neotropicals are some of the smallest, most colorful and melodious birds encountered throughout urban, suburban, rural, and wilderness America. These are America's "songbirds," birds such as vireos, grosbeaks, warblers, tanagers, and buntings. They enrich the lives of a growing number of nature enthusiasts throughout the continental United States. The director of the U.S. Fish and Wildlife Service has said that 18 million bird watching Americans spend $5 billion a year on this increasingly popular outdoor activity, more than is spent on movie tickets and sports events!

What makes these birds unique and of interest to the OCS program is that they are intercontinental migrants. They cross the Gulf of Mexico twice a year between their temperate breeding grounds in North America and their tropical wintering grounds in South America. These birds are vulnerable to adverse weather conditions during this most critical biannual migratory phase in their life cycle, and it is not unusual for stressed and exhausted birds to seek last refuge on the four to five thousand structures scattered throughout the northcentral and northwestern Gulf of Mexico. Realizing there is frequent interaction between offshore structures and migrating neotropicals, MMS has proposed focused cooperative research in the spirit of the Partners in Flight program. This research could add positive and useful information to the long-term conservation of the Gulf's transmigrant neotropical bird species.

Included in this session are presentations on the current state of knowledge on neotropical bird migration:

- Comments on information opportunities relative to offshore petroleum structures from the world's foremost authority on Gulf of Mexico bird migration survey technology;
- A description by the southeast coordinator for the Partners in Flight program of the cross-continental public and private cooperation and organizational efforts being established to focus available funding on priority research and mitigation;
- A progressive review by the director of the Gulf Coast Bird Observatory Network on leadership within the private sector to identify and conserve the forested wetlands along the Gulf Coast that are critical to the survival of neotropical species with special emphasis on the relevant initiative and support from selected oil and gas operators;
- A review of the economic importance of birdwatching to Gulf Coast states and the burgeoning impact avitourism can have and is having on Gulf Coast communities by the biologist responsible for developing and promoting the Great Texas Coastal Birding Trail;
- And finally, the results from recent research by the National Biological Service on the effects of habitat modification on neotropical birds in the critical forested wetlands of the Chenier Plains of coastal Louisiana and Texas.

NEOTROPICAL MIGRANTS—DEFINITION, STATUS, TRENDS, AND THEIR RELATIONSHIP TO THE GULF OF MEXICO

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INTRODUCTION

Over the last two decades the decline in biodiversity throughout the world has been alarming (Wilson 1988). Of particular concern to ornithologists have been the reported declines in bird species, particularly those classified as Neotropical migrants—birds that breed north of the southern border of the United States and winter south of that border (Terborgh 1989, Robbins *et al.* 1989). This paper gives up-to-date information on the populations of these birds with an emphasis on the population trends over the last two decades. Much of the paper is devoted to the migration patterns of Neotropical migratory birds in the Gulf of Mexico, particularly the northern portion and the Gulf coast of the United States.

NEOTROPICAL MIGRANTS

Neotropical migrants are birds that spend their breeding period north of the southern border of the United States and after breeding migrate across the border to spend their nonbreeding period in Central and South America. The preliminary list of Neotropical migrants for the Neotropical Migratory Bird Conservation Program called Partners in Flight contains four different lists of birds (Gauthreaux 1992). List "A" contains those species that breed in North America and spend their nonbreeding period primarily south of the United States. This list contains species generally recognized as "Neotropical" migrants. List "B" is comprised of species that breed and winter extensively in North America, although some populations winter south of the United States. List "C" contains species whose breeding range is primarily south of the U.S./Mexico border, and enter the United States along the Rio Grande Valley anywhere the Mexican Highlands extend across the border. These populations largely vacate the United States during the winter months. List "D" has species whose breeding range in the United States is restricted to the Florida Peninsula. These species withdraw from Florida during the nonbreeding season.

STATUS AND POPULATION TRENDS OF NEOTROPICAL MIGRANTS

In 1965 the U. S. Fish and Wildlife Service of the Department of the Interior began the Breeding Bird Survey (BBS) (Robbins *et al.* 1986), and it is currently managed by the National Biological Service. The BBS has been the source of most of the information used to examine the status and trends in the populations of Neotropical migratory birds. Species richness maps showing the number of Neotropical migrant species ever observed on BBS routes indicate that the highest species richness is found in eastern North America from the northern Great Lakes into New England and south along the Appalachian Mountains. The lowest richness of Neotropical migrants is in the southwestern deserts, Great Basin, and central Rocky Mountain regions (National Biological Service 1995).

Robbins *et al.* (1989) used data from BBS to show that most Neotropical migrant bird species that breed in forests of the eastern United States and Canada and winter in forest in Mexico declined during the period 1978-1987 after a period of stable or increased population growth from 1965-1979. The decline was not noted in most permanent residents and short-distance migrants, nor in populations of Neotropical migrants that winter in Mexico in scrub habitats. The role of forest destruction and habitat alteration as reasons for the declines have been addressed by Askins *et al.* (1990). There can be little doubt that forest destruction and fragmentation on breeding and wintering grounds, increased brood parasitism (Brown-headed Cowbird), increased nest predation, and possibly climatic factors have contributed to the declines, but considerably more work is needed on all of these factors (see Holmes and Sherry 1988). Recent analyses of BBS data (Peterjohn and Sauer 1994) indicate that from 1966-1979, 15 species of Neotropical migrants showed significant increases and only two showed significant declines. From 1982-1991 only four species experienced increases and 16 showed significant declines. When the entire survey data set from 1966-1991 was examined, six increased and seven declined significantly (e.g., Wood Thrush, Hylocichla mustelina, from National Biological Service 1995, Figure 1B.1).

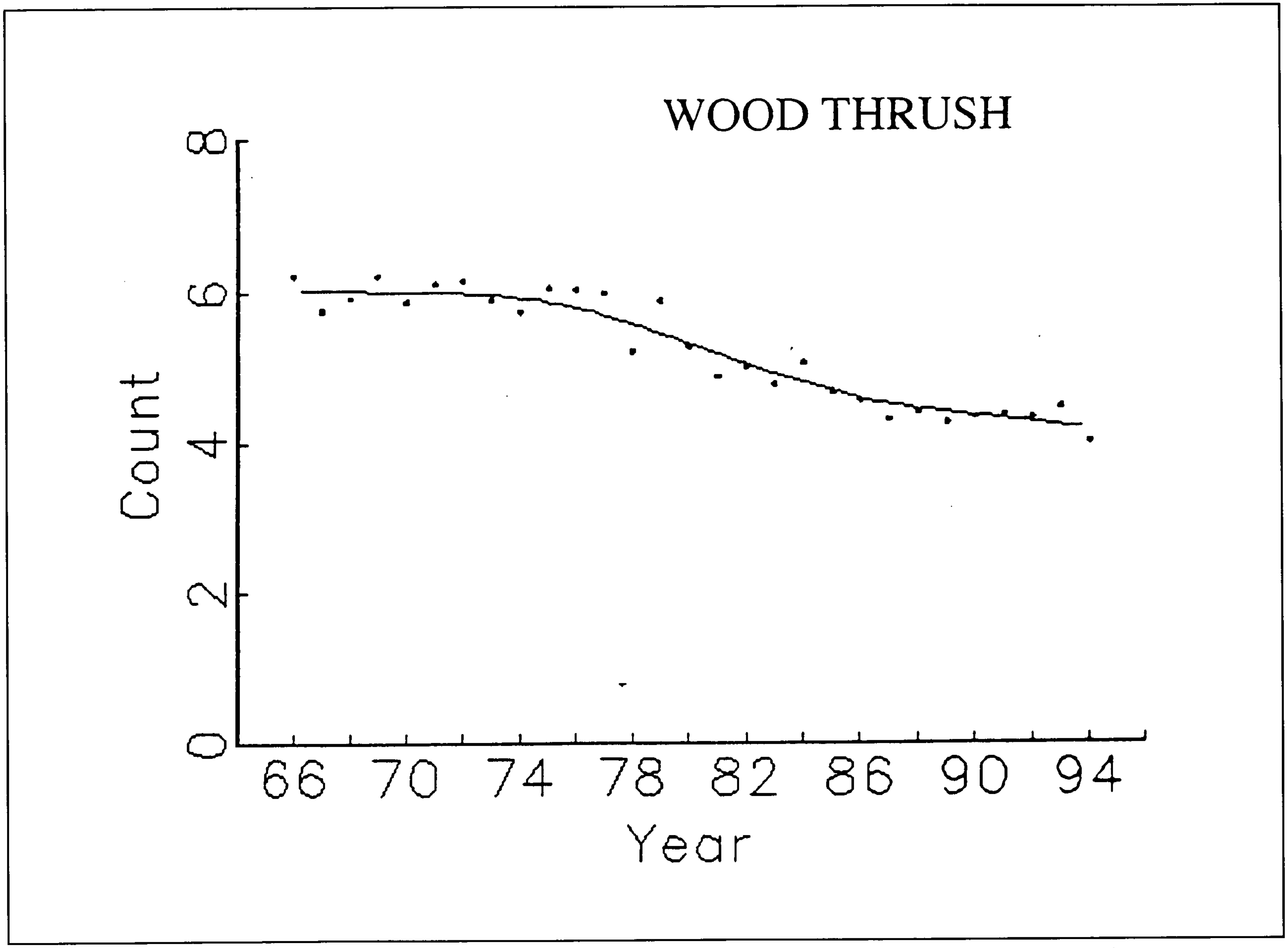

Figure 1B.1. BBS data for the Wood Thrush. The count respresents the mean number of individuals recorded per route in the nation by year.

The geographic map of the distribution of population increases and decreases is a mosaic with few evident patterns (National Biological Service 1995). In the West, negative trends are noted from northern California and Nevada northward to Washington and Idaho. In the South and East declines are noted from eastern Texas and Arkansas across the southeastern states, along the Appalachian Mountains to West Virginia, and in Florida. Positive trends in populations of Neotropical migrants occur along the Atlantic Coast from Georgia and the Carolinas northward to Pennsylvania and New York, in the Great Lakes region, and along the Rocky Mountains.

NEOTROPICAL MIGRANTS AND THE GULF OF MEXICO

The Gulf of Mexico has been of interest to students of bird migration since the analyses of Cooke (1904, 1915). G. C. Williams (1945) questioned the existence and regularity of trans-Gulf migration in spring, insisting that many of the species observed over the northern Gulf of Mexico had been blown there as they migrated circum-Gulf up from Mexico and Florida. His position appeared to be supported by the dearth of Neotropical migrants on the immediate northern coast of the Gulf of Mexico that some observers often encountered. Lowery (1945) addressed this problem in a paper on trans-Gulf spring migration in which he pointed out that during fine flying weather (clear to partly cloudy skies and a good wind from the south) trans-Gulf migrants do not typically land in the first available habitat but continue for some miles inland before landing. Moreover, the timetable of trans-Gulf migration is such that the early morning is the worst time to encounter trans-Gulf migrants in stopover areas along the coast. The relative magnitude of trans-Gulf and circum-Gulf migration has been reviewed by Stevenson (1957). In his paper he presents evidence (direct observation, comparative abundance, and sequence of dates) favoring each of the two migration routes for 164 species. Although there is clearly evidence that some Neotropical migrants fly circum-Gulf in their spring migration, 40 species are clearly trans-Gulf migrants as they are most common on the northern coast and not on the western and eastern Gulf coasts.

Since the pioneering studies of trans-Gulf migration by George Lowery and Robert Newman at Louisiana State University (using moon-watching, vertical telescope, and censuses of birds at stopover sites) we have continued to study the patterns of trans-Gulf migration. Since the 1960's the use of weather surveillance radars along the northern Gulf coast has permitted the detection, monitoring, and quantification of arriving trans-Gulf flights in spring (Gauthreaux 1970). In addition, the establishment of banding sites and studies of migrant bird-habitat associations at isolated stopover sites is greatly expanding our knowledge base (Moore *et al.* 1990).

Spring trans-Gulf migration begins typically in the first and second week of March, reaches a peak in late April and early May, and is essentially over by the third week in May. Only rarely do very small flights continue until the end of May (Gauthreaux 1971). The patterns of winds aloft over the Gulf of Mexico are critically important to the seasonal timing of trans-Gulf migration. In March the winds over the Gulf are influenced often by continental polar air masses (anticyclonic systems over southeastern United States) and winds blow from the East near the surface and aloft. Only when southerly return flow of maritime tropical air occurs are conditions good for a south-to-north trans-Gulf crossing, and this occurs aloft before it occurs on the surface. Consequently winds aloft are generally more favorable for a Gulf crossing than are surface winds. As spring progresses the number of days with good return flow increases. In April and May the favorableness of the pattern of winds aloft increases as cold fronts decrease in frequency (see also Duncan 1994). When powerful coldfronts move southward over the Gulf in late April and early May, spectacular fallouts of migrants often take place on offshore oil rigs and fishing boats in the northern Gulf. The birds are often exhausted and so lean, having catabolized breast muscle tissue after exhausting their fat supply, that the keel of their sternum is like a knife blade. Many of these migrants do not survive. When cold fronts are weak and shallow, most trans-Gulf migrants continue flying north in southerly air flow above the frontal boundary.

The arrival of a trans-Gulf flight on the northern Gulf coast is strongly influenced by weather conditions over the Gulf (Gauthreaux 1971). The pattern of the migration display on radar is easily recognized and can be discriminated from precipitation type echoes. Typically, with moderate southerly winds (5-8 mps, about 10-15 mph) the movements begin in the morning hours, reach peak densities in the afternoon and are largely finished by nightfall (Figure 1B.2).

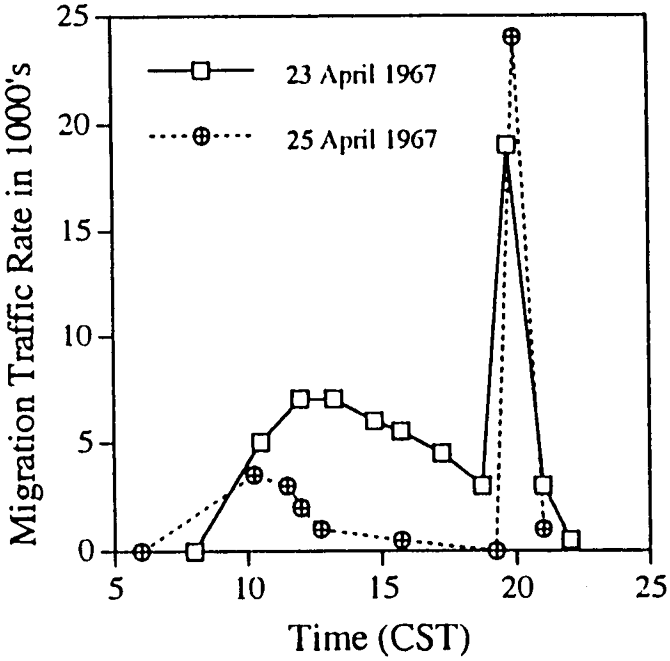

Figure 1B.2. Daily temporal patterns of the arrival of trans-Gulf migrations and the subsequent exodus. Migration traffic rate is the number of birds crossing 1.6 km (1 mile) of front per hour.

The arrival time of a flight is strongly correlated with the velocity of the southerly winds aloft. Most of the trans-Gulf migrants fly over the coast and make landfall in the bottomland forests inland from the coast. Only during adverse weather (hard rain or strong north winds) do substantial numbers put down in coastal woodlands. Most of the birds that put down on offshore oil rigs and in coastal woodlands when flying conditions are good are probably physiologically stressed (Spengler *et al.* 1995. Leberg *et al.* in press). Thirty to 40 minutes after sunset (during nautical twilight), most of the migrants that had landed earlier in the day depart the stopover areas flying toward the northeast and begin another leg of their migratory journey. This exodus is often spectacular on radar as the density of migrants aloft increases rapidly (Figure 1B.2). The duration of the exodus rarely exceeds three hours for radar stations on the central northern Gulf coast, but for stations on the Texas coast, the movement of migrants toward the NE continues for most of the night. These movements contain birds that arrived from over the Gulf as well as migrants moving up from eastern Mexico (Forsyth and James 1971). The seasonal pattern of the arrival of trans-Gulf migrations on the northern Gulf coast and the subsequent exodus of the migrants from "coastal" stopover areas can be seen in Figure 1B.3. These data were gathered using the WSR-57 weather surveillance radars at Galveston, TX (top), Lake Charles, LA (middle), and New Orleans (Slidell), LA (bottom) in the spring of 1990. Because the maximum range of the migration pattern displayed on the radar screen is related to the density of the flight (number of migrant flocks aloft in the radar beam) as summarized in Gauthreaux (1994), it is possible to measure quantitatively the increase in the magnitude of trans-Gulf flights as spring progresses. The relationship between the mean number of flocks in a 20° sector "x" (swept by a 2° radar beam elevated 2.5°) and the maximum range (in nautical miles, 1.852 km/ nautical mile) of the echo pattern from arriving trans-Gulf migrants "y" can be computed using the following equation: $x = 4.9y - 81.4$. The relationship is highly significant ($R^2 = .76$; $p < 0.0001$). As can be seen the largest trans-Gulf flights generally occur after Julian Date 100 (10 April) and

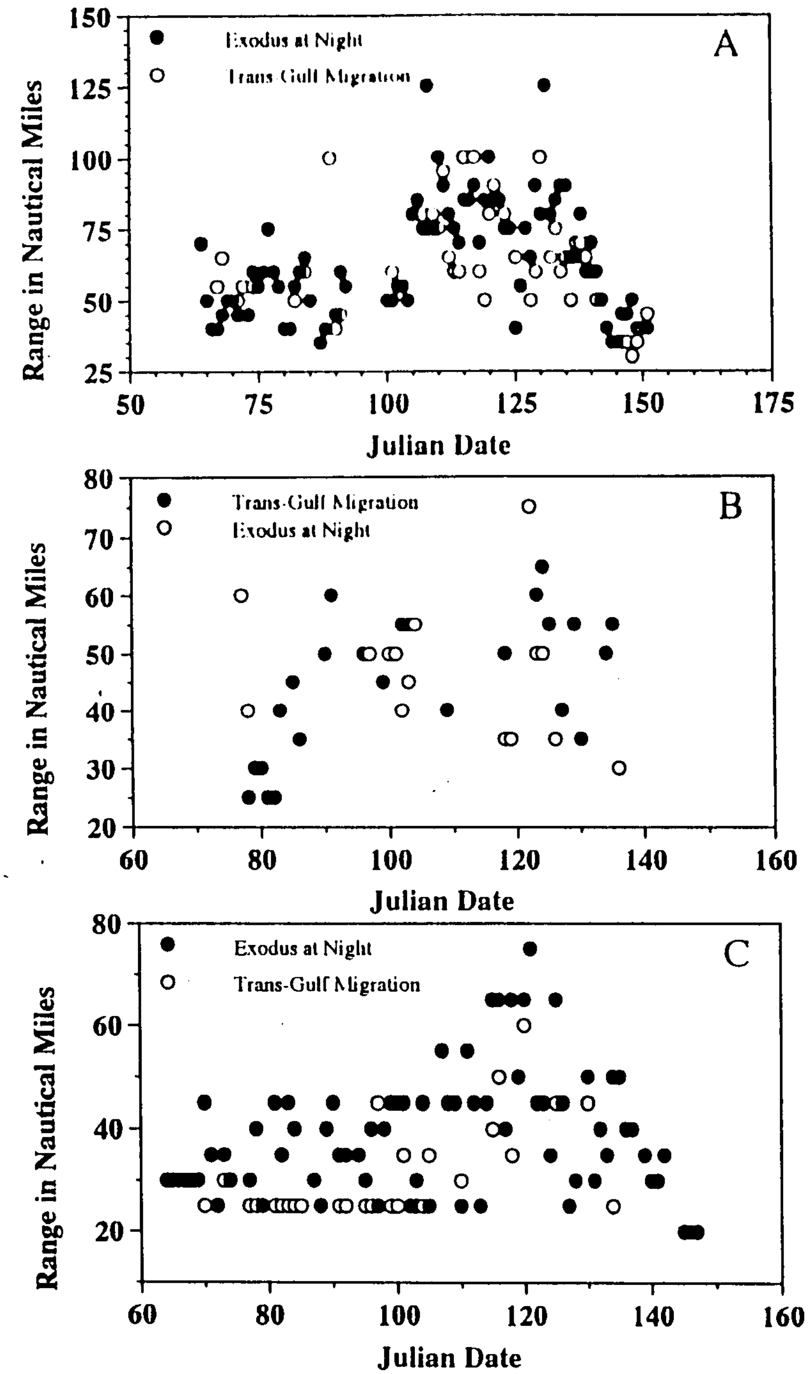

Figure 1B.3. The magnitude of trans-Gulf migrations and subsequent exoduses at (A) Galveston, TX, (B) Lake Charles, LA, and (C) New Orleans-Slidell, LA. The maximum range to which the migration pattern extends on the radar screen is related to the density of flocks aloft (see text).

begin to decline in size after Julian Date 130 (10 May). The data loss at Lake Charles, LA is from camera malfunction and low video gain settings on the radar repeater scope used for film records.

The altitude of trans-Gulf migration as it arrives on the northern coast of the Gulf is considerably higher than most migratory movements of songbirds over land. Figure 1B.4 shows the altitudinal distribution of trans-Gulf flights arriving in New Orleans, LA (upper), Lake Charles, LA (middle) and combined (lower). The diagrams show the altitudes at which peak densities of flocks were recorded during a three year period from 1965 through 1967. Note that the flight altitudes were higher over New Orleans than Lake Charles. This is because the migrants tend to climb higher as they cross the coast, and New Orleans is farther inland than Lake Charles. Although the exact reason for this is still unclear it may be cumulus clouds begin to form just north of the coastline and build higher in altitude as they move inland on southerly winds. The trans-Gulf migrants tend to stay above the cumulus clouds unless they build too high. In many instances, the thickness of the layer of trans-Gulf migrants aloft is on the order of 1,500 to 2,000 meters and the altitudinal distribution of flocks in a flight may range from 580 meters to 2,500 meters. The altitudinal distribution is strongly dependent on the patterns of the winds aloft. If the most favorable southerly flows are at low altitudes, then the distribution of trans-Gulf migrants is skewed to the lower altitudes. If the most favorable southerly winds are at higher altitudes, then the migrants will fly at those altitudes. In one instance trans-Gulf migrants were flying at altitudes of 3,657-4,572 meters (12,000-15,000 ft) as they moved inland above a shallow cold front that had penetrated the northern Gulf. When powerful cold fronts move well into the Gulf and trans-Gulf migrants cannot fly over the altitudinal zone of adverse winds, they lower their flight altitude and fly just above the waters of the Gulf. On these occasions they may actually be flying below the coverage of the radar, but can be readily detected when they depart the "coastal" areas during their exodus. Once over land trans-Gulf migrants do not fly against strong northerly winds.

Because of the decline in the populations of Neotropical migrants, continued work on the patterns of trans- and circum-Gulf migration will be essential. The new national network of NEXRAD (WSR-88D) weather surveillance radars will play an important role in the detection, quantification, and monitoring of Neotropical migrants in the northern Gulf of Mexico. The WSR-88D is a doppler radar that is more sensitive, more powerful, and has greater resolution than the older WSR-57 weather surveillance radars. These new radars can detect trans-Gulf migrants while still far offshore and are ideal for monitoring the arrival of flights over offshore oil platforms. We desperately need work on trans-Gulf migrants that putdown on offshore oil platforms. These platforms are the first "land" encountered by trans-Gulf migrants, and sampling migrants on these rigs may provide a better understanding of the physiological stress associated with trans-Gulf flights. By collecting dead migrants on offshore platforms we will be able to analyze total body fat stores and make other measurements that will determine if pesticides and other toxic substances have adversely affected the health of these migrants. There is still some debate about the species that cross the Gulf and those that migrate around it. Sampling migrants in spring that put down on the southernmost rigs in the northern Gulf will provide important information on the species composition of trans-Gulf migrants.

Although I have emphasized spring migration in this presentation, I want to emphasize the importance of conducting fall migration studies along the northern Gulf coast and over the northern Gulf. Preliminary findings using a network of WSR-88D radars on the northern Gulf coast during the fall of 1995 suggest that the pattern of trans-Gulf migration in the fall is very different from that in the spring. Because of the prevailing southerly wind patterns over the Gulf in fall, trans-Gulf flights are closely associated with frontal systems that penetrate the northern Gulf. The frequency of these fronts is low during most of the fall when Neotropical migrants are moving toward their wintering grounds. Consequently many of the flights on the northern Gulf coast following cold fronts appear to be directed toward the SW such that the migrants would reach the south Texas coast or the upper Mexican coast. In the absence of cold fronts the migrants appear to follow the Texas coast and also move down the peninsula of Florida. Although little has been published about migratory birds on offshore oil production platforms in the fall, Ortego's (1977) observations suggest that much can be learned by sampling these structures during fall migration.

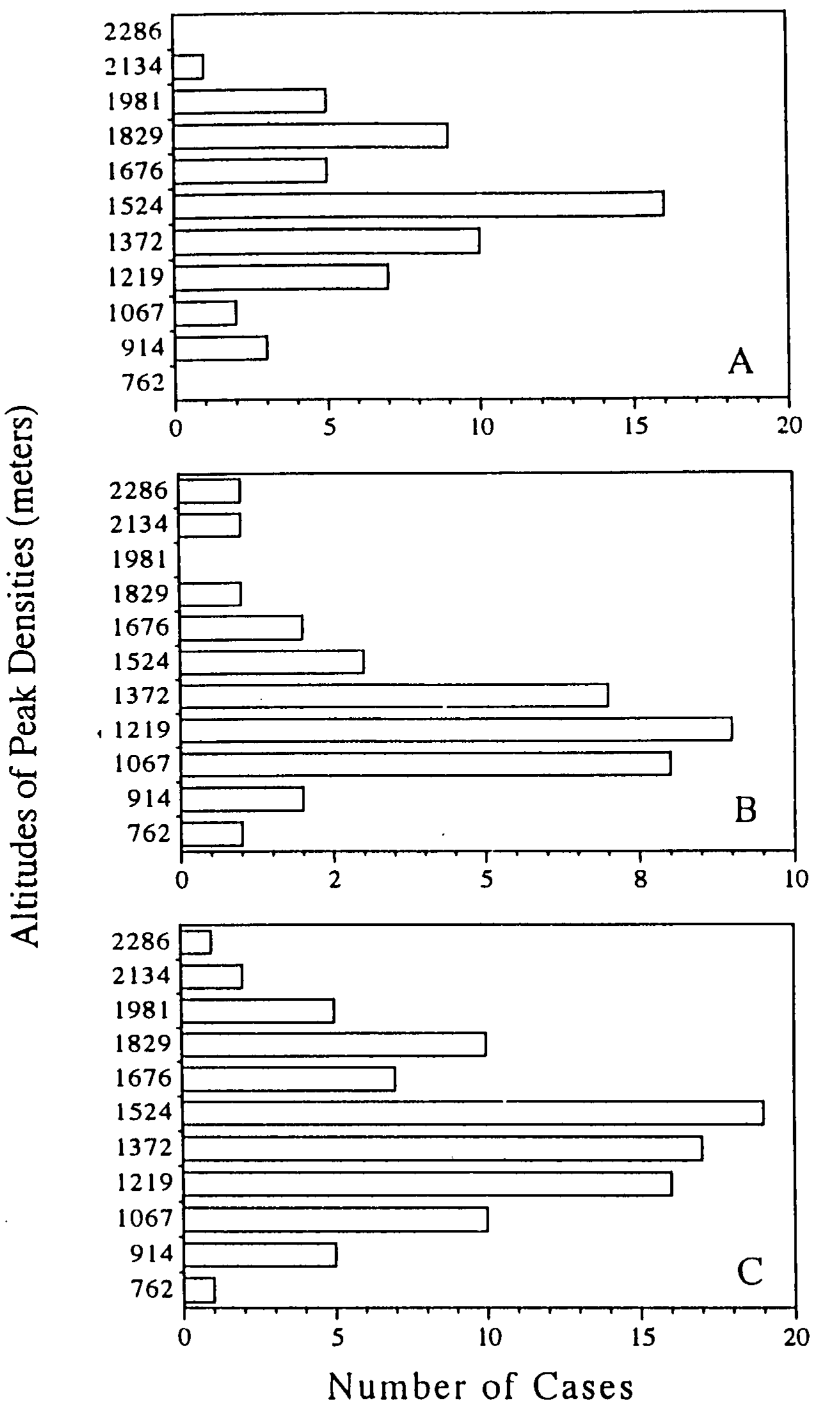

Figure 1B.4. The altitudinal distribution of peak densities of arriving trans-Gulf migrations. (A) New Orleans, LA (B) Lake Charles, LA, (C) both stations combined. The data were gathered during 1967 with WSR-57 radar.

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Dr. Sidney A. Gauthreaux, Jr. is a Professor of Biological Sciences at Clemson University in South Carolina. He has studied bird migration for over 35 years. Much of his work has concentrated on the use of remote sensing, particularly radar surveillance, to study the migration of birds through the atmosphere. He has used weather surveillance, air traffic control, and marine radar systems to detect, quantify, and monitor bird movements. He received his B.S. degree from the University of New Orleans in 1963, his M.S. (1965) and Ph.D. (1968) degrees from Louisiana State University. He did post-doctorate work with Dr.Eugene Odum at the Institute of Ecology at the University of Georgia from 1968-1970, and since 1970 he has held a faculty position in animal behavior, ornithology, and behavioral ecology at Clemson University.

PARTNERS IN FLIGHT: CONSERVATION OF NEOTROPICAL MIGRATORY LANDBIRDS ALONG THE GULF OF MEXICO

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Partners in Flight was formed to address the declining status of many neotropical migratory landbirds. These declining trends were documented from the Breeding Bird Survey and from interpretation of weather radar data covering the Gulf of Mexico (Robbins *et al.* 1989, Terborgh 1989, Gauthreaux 1992, in press this volume). Neotropical migrants include a wide diversity of birds, but for purposes of this discussion are landbirds breeding in temperate North America ("Nearctic-Neotropical") migrating to and from the West Indies and Middle and South America. The unifying theme of Partners in Flight is to keep common species from becoming rare, while stabilizing or reversing declining populations of rarer species. An underlying principle of Partners in Flight is recognition that effective conservation is more easily achieved while species are still common.

Partners in Flight, sparked by the efforts of Mr. Amos Eno of the National Fish and Wildlife Foundation, is modeled after the North American Waterfowl Management Plan and the Western Hemispheric Shorebird Reserve Network, both international efforts to reverse and stabilize waterbird populations and the wetland habitats they depend upon. Like these other bird conservation efforts, Partners in Flight brings together (1) federal agencies, (2) state agencies, (3) non-governmental conservation organizations, and (4) the private sector (including both industrial and non-industrial landowners) who share an interest in or concern for the effective conservation and management of migratory birds. As with waterfowl and shorebirds conservation efforts, those cooperating in Partners in Flight recognize the benefits of pooling resources and addressing concerns for vulnerable neotropical migratory landbirds while most species are still common. These partners also recognize that this approach to conservation is far superior to imposing greater protective legal measures such as the Endangered Species Act of 1973, as amended, when the continued survival of species come into doubt.

In addition, the spectacle of migration and the increasing popularity of birdwatching add to the momentum already evident to effectively conserve neotropical migrants, while also adding an important economic element to the Partners in Flight effort. Industrial landowners with interests in bird conservation want to know how to effectively manage these species within the context of a profitable operation. An increasing number of communities are interested in how to provide, as part of their conservation efforts, ecotourism ("avitourism") opportunities. Private citizens, who purely enjoy the birds themselves, want to know how to design their backyard habitats with neotropical migrants in mind, thus involving native plant nurseries, landscape designers and architects. Private interests when combined with the efforts of conservation groups and governmental agencies demonstrate that the level of effort involved in Partners in Flight is of hemispheric proportions.

A means to define conservation priorities becomes necessary with all these partners needing to know their roles and responsibilities, the broad geographic scope involved in this initiative, and the wide variety of habitats and threats these birds must face throughout their annual cycle. Partners in Flight has developed a prioritization scheme to help focus initiatives on high priority species and habitats at any appropriately defined spatial scale (Hunter *et al.* 1993a). While Partners in Flight concentrates on neotropical migratory landbird conservation, planning and implementation of specific actions requires taking into account the status and potential effects of these actions on all landbirds, in both temperate and tropical areas. Although many neotropical migrants require attention throughout the Western Hemisphere, significant concern also exists for some temperate migrants (those species remaining primarily north of the topics) and resident species that co-occur with neotropical migrants in both breeding and wintering habitats (Hunter 1995). In fact, neotropical migrants provide the common link by which cooperation in conservation should occur across states and nations, without taking anything away from conservation of highly endangered and narrowly distributed resident species, especially in the tropics.

The Partners in Flight Prioritization Scheme considers seven factors for calculating a total concern score. Three global factors scored the same across all spatial scales where each species occurs are (1) relative abundance, (2) breeding distribution, and (3) winter distribution. Two factors scored at the global scale, but subject to modification when better information exists at the spatial scale of interest, are (4) breeding threats and (5) non-breeding threats. The last two factors are scored only at the local level and measure (6) population trends and (7) importance of area. Population Trends may be based on Breeding Bird Survey or more specific information appropriate to the spatial scale of interest. For local breeding season population trends, only locally available data are used when judged to be adequate or, when existing data are inadequate, a median score is applied with a high uncertainty supplemental score. Importance of Area is the relative importance (often based on abundance) within a defined area (*e.g.*, state, Caribbean island, physiographic areas to local land management area) for each species compared with the rest of this species' distribution.

Thus far, most emphasis on setting priorities has been focused on birds during the breeding season. Physiographic areas were the spatial scale of choice used by the states in the Southeast for identifying high priority breeding species and their habitats (Hunter *et al.* 1993b). The Southeast approach encourages multi-state initiatives where similar species, and the land use patterns influencing conservation needs, co-occur. Along the Gulf of Mexico, breeding season species and habitat priorities have been identified specifically for landbirds in the Mississippi Alluvial Plain and East Gulf Coastal Plain (Hunter *et al.* in press, Mueller *et al.* in press). Similar efforts are nearing completion throughout the Southeast and specifically along the Gulf Coast in South Texas, the Coastal Prairies (including the Chenier Plain) of Texas and Louisiana, and the Florida Peninsula.

Once priorities are identified within a physiographic area, then the conservation process shifts to identifying goals and objectives to address conservation needs for species and their habitats. Much work has been compiled by Hamel (1992) on the habitat associations and suspected preferences for all breeding (and wintering) southeastern landbirds. These goals and objectives may include (1) setting spatial minimum patch sizes for some habitats, (2) defining roles and responsibilities among states and other cooperators within the physiographic area, (3) developing management guidelines tailored to different land use objectives, and (4) providing guidelines for cooperators about how to monitor success of ongoing management activities (*e.g.*, Hamel *et al.* in press). Research needs to be identified where goals and objectives cannot be achieved without testing of assumptions or effects of certain management practices.

Of specific interest to managers along the Gulf of Mexico is the unqualified importance of this area to birds actually migrating to and from Neotropics. The Partners in Flight Prioritization Scheme has yet to be applied widely to birds during the non-breeding seasons. However, progress on identifying priority species and habitats during migration and winter is most advanced in the Southeast and Caribbean regions where draft scores for all species during all seasons are under review.

Developing concern scores for birds during non-breeding seasons requires different sources of information than used during the breeding season for determining importance of area (*e.g.*, reviewing Root 1988 as opposed to Price *et al.* 1995) and Population Trend (*e.g.*, Christmas bird count data for many species as opposed to breeding bird survey data). The convention for scoring the non-breeding season population trend factor is to use continent-wide breeding bird survey or Christmas bird count data (as opposed to local trends used during breeding season), whichever database provides the best coverage for the species of interest. In addition, emphasis would be placed on revising the Global non-breeding threats score if better local data exist, while leaving alone the Global breeding threats score (the opposite is true for scoring species during the breeding season).

For species present during more than one season with different statuses in an area, the convention is to score breeding, wintering, and migrating periods separately as appropriate. If a high priority species is relatively more common in an area during migration (*i.e.*, has a higher concern score) than as a breeding or wintering species, then conservation emphasis in that area may be best targeted on habitats used by this species during migration. Many species staging along the Gulf of Mexico coast during southward migration and making first landfall during northward migration would likely receive higher concern scores during these periods than during breeding or wintering periods, at least in habitats within 100 miles inland of the coast. The Prioritization Scheme in this case could focus management attention along a specific area of coastline on those highest scoring transient species requiring special habitat features (*e.g.*, dense understory cover) or certain plants (*e.g.*, those that produce nutritious fleshy-fruits at the correct time) as discussed by Cordes (in press this volume).

With habitat priorities for breeding, migrating, and wintering species all established together, conservation roles and responsibilities would be comprehensively set for any specific area. Once the prioritization process is complete for all species throughout their distributions, partners would know what their local roles and responsibilities are throughout the year. Indeed, partners would also come to understand how their efforts fit within an hemispheric framework for high priority species.

Specifically for Minerals Management Service activities, the Partners in Flight Prioritization Scheme could be used to focus attention on key species and their habitats. Monitoring numbers and distribution of trans-Gulf migrants passing over off-shore platforms would include all species, but the Prioritization Scheme would focus data analysis on high priority species and not only frequently encountered species. Similarly, specimens collected from offshore oil platforms also would include all species, but data (*e.g.*, body condition, contaminants) from rarer high priority species would not be ignored in favor of only more common low priority species. In addition, outreach information provided by the Minerals Management Service to their landowning cooperators could focus on the cover and food requirements of high priority species if these requirements differ from low priority species.

Finally, the Partners in Flight Prioritization Scheme process is particularly important along the Gulf of Mexico for identifying "Important Bird Areas." Important Bird Areas as established by the American Bird Conservancy and National Audubon Society are intended to focus attention on areas demonstrated as important for bird conservation at state, regional, and/or continental levels. Upon identifying an Important Bird Area, Partners in Flight cooperators can assist communities in conserving these areas and provide recommendations for economically and ecologically sound avitourism.

Especially relevant to this discussion is the recent establishment of the Gulf Coast Bird Observatory Network (Johnson in press this volume) and an expansion of the Great Texas Coast Birding Trail into other Gulf Coast states, as well as Mexico, (Lindsay in press this volume). These efforts provide important conservation focus for migratory birds along the Gulf Coast by combining the strengths of outreach and education, public wildlife viewing opportunities, and local economic interests and incentives with the latest research and management guidelines. Securing the Gulf of Mexico as an important link in the conservation chain for a large proportion of North America's breeding neotropical migrants is dependent on the success of Partners in Flight, the Gulf Coast Bird Observatory Network, and the "Great Gulf Coast Birding Trail." The support of the Minerals Management Service, and especially Mr. Villere Reggio, in organizing this workshop and publishing these proceedings provides a solid step in the direction of closing this important conservation link.

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THE GULF COAST BIRD OBSERVATORY (GCBO) AND THE OIL AND GAS INDUSTRY AS CONSERVATION PARTNERS

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THE GCBO PROGRAM

On 28 April 1993 a partnership between Amoco Production Company, The Nature Conservancy of Louisiana and Texas, the Houston Audubon Society, Phillips Petroleum Company, U.S. Fish and Wildlife Service, Texas Parks and Wildlife, and the National Fish and Wildlife Foundation announced the Gulf Coast Conservation Initiative (GCCI), the High Island Initiative (HII) and a framework for a Gulf Coast Bird Observatory (GCBO). In June of 1994 a panel of recognized neotropical migrant scientists convened as the scientific advisory board for these programs, and recommended a Gulf of Mexico wide focus to conserve avifauna habitat. This approach focuses on the trans-gulf and circum-gulf migration paths and the habitat needs of the avifauna that use those migration paths. To eliminate the confusion of three programs to current partners as well as prospective partners and provide the focus for avifauna conservation along the entire coast of the Gulf of Mexico, the initiatives and the bird observatory have been merged to form one program, the Gulf Coast Bird Observatory (GCBO) with headquarters at High Island, Texas.

The Gulf Coast Bird Observatory (GCBO) is dedicated to the conservation of key avifauna habitat along the coast of the Gulf of Mexico through projects concerned with research, management, private lands initiatives, education and acquisition when necessary. To accomplish these objectives three major integrated programs have been developed.

(1) The GCBO Research Program: Given the expanse of the Gulf of Mexico, it would be impossible to preserve all of the avifauna habitat along its coastline. Therefore, the identification and conservation of areas most important to migratory birds is necessary to insure that the GCBO concentrates its efforts on those sites. To facilitate such habitat prioritization, scientific analysis and GIS technology will be used to assess areas frequented by migratory birds. Studies will be linked with radar work that indicates concentrations of birds during migration periods. Information obtained from GIS data and migration research, when combined with the concentration areas identified by radar, will pinpoint prime avifauna habitat around the Gulf of Mexico. Additionally, element occurrence data from BCD, Piping Plover census data, currently protected areas, roads, and hydrology will be layers within the GIS analysis tool. These data will be the basis for developing protection and management strategies on both the local, site-specific level and the regional level.

The GIS maps for the Gulf Coast will be a collaborative effort between the GCBO, Texas A&M at Galveston, Texas General Land Office, Rice University, Texas Parks and Wildlife, NBS Southern Science Center, TNC LA, Instituto Tecnologico Monterrey and R.A.R.E. There are more contacts to be made in Florida, Alabama and Mississippi regarding their GIS coastal activities.

This multi-faceted research project, which includes migration and habitat research and GIS habitat inventories, initially will be applied at three model sites: High Island, Little Pecan Island, and in the Columbia Bottomlands.

All these data, along with other past and future studies will be placed in a GCBO INTERNET Directory. The directory will provide GCBO staff and others from the scientific and conservation community with a vast information resource for migrant ecology studies. These entities could avoid costly duplication of effort by consulting the directory prior to planning and implementing a research project. The directory could be scanned to determine if research into the proposed area of study has been conducted and how to obtain the results.

(2) The GCBO Conservation and Land Management Program: The GCBO has already established a number of site-specific partners. These partners protect and manage migrant habitat on their lands. However, considerably more habitat must be protected to ensure the long-term health and survival of migratory birds and other species. By using the information obtained by the Research program, GCBO planners will know where vital habitats are located and can develop site-specific partnerships in those areas. Ecological research conducted on these new site-specific lands will be integrated with studies from other observatory sites and used as a basis for developing management strategies at the site-specific level.

In addition to small habitat bird concentration areas, GCBO studies will identify large, regional areas in need of protection. In many cases, a significant amount of that region's habitat will be contained on privately owned lands. An approach is needed to recruit numerous private partners in such areas if adequate protection levels are to be achieved. Private Lands Initiatives would be used as regional conservation campaigns to develop private site-specific partners who will voluntarily take measures to manage and protect migratory bird habitat found on their property.

(3) The GCBO Education and Outreach Program: Public education regarding the importance of coastal habitat for migrating, wintering, and breeding birds is

vital to long-term, successful avifauna conservation. The objective of this program is to reach the private communities along the Gulf Coast through the expansion of current site-specific partner educational efforts and the development of new education and public outreach projects. These projects will include community involvement; field study coordination; internship opportunities that will ensure the involvement of local academic institutions and publication of research activities in journals; and a GCBO newsletter.

ACCOMPLISHMENTS OF THE CONSERVATION PARTNERSHIP BETWEEN THE GCBO AND THE OIL AND GAS INDUSTRY

(1) The GCBO Research Program: Amoco Production Company funded the construction of a research center located at Little Pecan Island, Louisiana. This site is a 400 acre chenier owned and managed by The Nature Conservancy of Louisiana. The research center has accommodations for 15 plus a kitchen, conference area and light laboratory. This center was dedicated in October of 1994. Additionally Amoco funded the GCBO startup for two years.

Conoco has funded a leading edge hawk monitoring radar research program through the GCBO. Phillips Petroleum Company has funded land acquisition and enhancements at High Island and Bolivar Flats, Texas as well as funding the Geographic Information System (GIS) habitat inventory for the Upper and Middle Texas Coast.

(2) The GCBO Conservation and Land Management Program: Through the GCBO Site Specific Partner Development project: Amoco donated 155 acres to Houston Audubon Society at High Island Texas. This donation was achieved in December of 1994. Mobil donated 2,300 acres to The Nature Conservancy of Texas at Texas City, Texas. This property has one of the largest remaining populations of Attwater's Prairie Chicken, 18 birds. Additionally this site has significant habitat for wintering sparrows, migrating neotropical prairie/edge bird species, migrating hawks as well as breeding waterfowl. This donation was completed in March of 1995. Arco is working at hydrocarbon cleanup at The Nature Conservancy of Texas's 130 acre Shamrock Island, Texas colonial nesting bird preserve. In addition to the colonial waterbird the island has stopover habitat for migrating neotropical birds. This site was acquired in July of 1995 with the use of funds from the Natural Resource Damage Trustees.

FUTURE OPPORTUNITIES AND BENEFITS

Future opportunities for continued conservation partnerships between the GCBO and the Oil and Gas Industry would include: (1) conservation easements and donations; (2) management agreements for land owned by the industry that could be managed for neotropical migrants; (3) employee volunteers and inkind donation of equipment, supplies and services; (4) provide funding for specific programs, especially around industry facilities; and (5) work with the GCBO, Partners-in-Flight and Minerals Management Service to implement a migratory bird monitoring program from offshore platforms. Benefits to the oil and gas industry would be advertising opportunities, public recognition for conservation efforts and proactive good business that would positively influence the bottom line.

Mr. Ray Johnson is director of the Gulfcoast Bird Observatory Network. Ray has more than 15 years experience in business and personnel management along with worldwide new program development as a mid-level manager for IBM. Additionally, he is an experienced real estate broker and developer, an information systems manager and has a B.S. from North Carolina Central University in Computer Science. Taking an early retirement from IBM (after 30 years) he completed a Master's of wildlife biology at North Carolina State University. Prior to joining the Gulf Coast Bird Observatory, he worked for the U.S. Fish and Wildlife Service as an endangered species biologist and lead the Puerto Rico Conservation Foundation's land acquisition project.

GULF COAST NEOTROPICAL BIRD WATCHERS: AN OUTDOOR RECREATION ACTIVITY OF ECONOMIC AND SCIENTIFIC IMPORTANCE

Avitourism on the Texas Gulf Coast

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INTRODUCTION

Birdwatching, a growing form of outdoor recreation, is being pursued across North America and around the world. Avitourism, overnight travel to experience birds in a natural setting, is a significant part of the worldwide growth in ecotourism. Texas Parks and Wildlife Department (TPWD), Texas Department of Transportation (TXDOT), other government agencies, communities and tourism industry leaders are assisting the development of this market in Texas. Their goal is to promote sustainable economic development while conserving additional habitat for Texas birds. Projects under development such as the Great Texas Coastal Birding Trail, are designed to deliver a portion of the $238 billion spent worldwide annually on ecotourism to Texas coastal communities. Through conservation management and marketing, coastal communities, land-owners and industry can gain economically while protecting some of the habitat necessary to sustain neotropical migratory bird species.

TOURISM ECONOMIC DATA AND RECREATIONAL TRENDS

According to the Texas Department of Commerce as reported by Eubanks, Kerlinger and Payne in their economic research on nature tourism, Texas' third largest industry is tourism. Texas ranks fourth in direct travel expenditures among all 50 states at $24.5 billion. Of this amount, $21.5 billion is derived from domestic travelers with $3 billion from international travelers. This is a 5.3% increase from 1993. (Eubanks *et al.* 1995).

Texas travel expenditures generated 435,000 jobs in 1994, 5.6% of the total state non-agricultural employment of 7.7 million jobs. Travel-generated employment in Texas grew 1.8% from 427,500 jobs in 1993. (Eubanks *et al.* 1995).

Expenditures shown by the U.S. tourism industry amount to $417 billion, providing $58 billion in federal, state, and local tax revenues. The U. S. tourism industry is the second largest employer in America, providing 14.3 million jobs and $110 billion in travel-generated payroll (Eubanks *et al.* 1995).

A report published by the World Tourism Organization (WTO 1992) shows nature tourism as the fastest growing segment of the world travel industry with an average of 30% annual increase each year since 1987. Global sales total $238 billion. A U.S. Fish and Wildlife Service (USFWS) survey shows that in 1991, 35.6 million people fished, 14.1 million hunted and 76.1 million enjoyed nonconsumptive wildlife recreation. Over 76 million people 16 years old or older enjoyed observing, feeding or photographing wildlife. Thirty million took trips for the primary purpose of enjoying wildlife. Expenditures in 1991 equal $59 billion with $22.2 billion being trip related costs. Nonconsumptive participants spent $18.1 billion with $7.5 billion on trip-related expenses including food, lodging, and transportation (USFWS 1993). The National Trust for Historic Preservation found that travelers who travel to experience cultural, historical and natural history sites spend an average of $62 per day more than the average traveler (National Trust for Historic Preservation 1994).

Recent studies at the Aransas Wildlife Refuge showed 75,000 visitors annually to view wildlife, to fish and to hunt. Santa Ana National Wildlife Refuge shows that 99,000 of its 167,808 visitors in 1994 were bird-watchers. Avitourists interviewed in a survey there were middle-aged (50's-60's, 70.2%), well-educated (76.9% had attended some college), had incomes that were well above the national family average (49.5% had incomes in excess of $50,000 per year), and men (61.5%) outnumbered women. A majority did not fish (63%) or hunt (89.1%). According to this survey, these avitourists left $14.4 million in the local communities with $6.16 million spent on lodging, $2.18 million spent on meals, $0.44 million for fuel and $5.64 million for other purchases. The average visitor contributed between $88 and $145 to the local economy (Eubanks *et al.* 1995).

THE TEXAS COASTAL ADVANTAGE

A Roper Starch Worldwide survey for the Recreation Roundtable of 1,993 adults interviewed in person 16-23 April 1994 revealed that 14% of Americans involved in recreation were birdwatchers. A 1991 survey of

American Birding Association members showed that since 1988 more members of that association have traveled to Texas to pursue their hobby than to any other state (Wauer and Ellwonger 1993). According to *Birdwatcher's Digest*, a national publication, four of the top 12 birding destinations in North America are in Texas—two on the Texas Gulf Coast (High Island and Central Coast), one in South Texas adjacent to the Gulf Coast (Lower Rio Grande Valley) and one in the Trans Pecos (Big Bend National Park).

Why are birdwatchers traveling to Texas? Texas has documented more bird species than any state in the U.S. Nearly 600 species records are approved by the Texas Ornithological Societies' Birds Records Committee. The Texas Coast alone has more birds than most other states, with over 400 birds possible during the year. This is due to Texas' diverse habitats from the Upper Coast woodlands and prairies to the Lower Coast South Texas thorn shrub and Rio Grande riparian forests. Texas and the Texas Gulf Coast are known worldwide for their excellent birding experiences.

THE GREAT TEXAS COASTAL BIRDING TRAIL: LINKING USERS AND STAKEHOLDERS

In 1993, the author and Ted Eubanks (Fermata, Inc.) designed a project to capitalize on the potential for Texas to attract birdwatchers. The Great Texas Coastal Birding Trail, a sustainable development project, was initiated. The trail unifies existing and potential birding sites into a cohesive and marketable unit. When completed in 1997, the 500(+) mile highway trail network will link the users (birdwatchers) with the stakeholders (private landowners and community business interests). Ranches, lodging establishments, restaurants and other goods and service providers will become part of an organized network which will serve and market to traveling birdwatchers.

The $1.5 million dollar project, funded through the Texas Department of Transportation Intermodal Transportation Efficiency Act of 1991, is sponsored by the Texas Parks and Wildlife Department. Sites on the trail will soon be marked with a universal logo sign (Black Skimmer) and corresponding number identifying that site. Many sites are scheduled to receive enhancements such as highway turn-outs, boardwalks, viewing blinds, observation stations and hummingbird gardens. A free map distributed by TXDOT and a more-detailed trail guide (for purchase) are now in production.

Proceeds from marketing efforts will be used for trail maintenance. In addition to the trail guide, marketing will include a trail-sponsors program, trail products and events, quarterly newsletter, computer link-ups and a quality trail-experience. On-going marketing and trail maintenance will be coordinated by TPWD through site holders and communities.

The trail project, which is just completing its first phase on the Central Texas Coast, has been extremely popular with communities and birdwatchers alike. Over 95 sites are included on the Central Coast section. Four private ranches have been listed and thirteen site holders have provided many in-kind habitat and site enhancements. On 8 September 1994, Roger Tory Petersen, one of the world's most famous birdwatchers, ornithologist, and artists helped with dedication ceremonies where the first trail sign was unveiled at the Connie Hagar Cottage Sanctuary in Rockport, Texas.

Work is now underway to obtain funding for construction for the remainder of the Trail. TPWD is encouraging coastal communities, landowners and industries on the Upper and Lower Coasts to get involved in this valuable endeavor. They can begin by assessing their habitat resources for conservation management and recreational planning. In 1996, they can apply for the trail through public meetings to be held in their local TXDOT highway districts.

SUMMARY

When completed in 1997, the Great Texas Coastal Birding Trail will provide a model for others interested in avitourism. At least four other states have indicated that they will pursue a similar trail. TPWD and all site holders plan to provide a quality experience for trail users with good habitat, birding enhancements, conservation management, ongoing monitoring and marketing. Studies by Texas A&M University are already underway to survey the expectations of potential trail users. The Trail has generated a great deal of excitement and attention from both users and communities. Trail planners and participants eagerly await its completion.

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Madge Lindsay has worked for Texas Parks and Wildlife for five years. She is a program leader in the Nongame and Urban Program, which is part of the Wildlife Division. Her areas of responsibility include supervising the planning and development for nongame outreach programs including the Great Texas Coastal Birding Trail, nature tourism community technical guidance, Texas Partners in Flight, Nongame Special Fund, Eye on Nature Newsletter and the Texas Hummingbird Round-Up. Ms. Lindsay received her Bachelor of Science degree in Recreation, Parks and Tourism Sciences from Texas A&M University.

THE NATIONAL BIOLOGICAL SERVICE'S NEOTROPICAL BIRD RESEARCH PROGRAM IN THE CHENIER PLAIN OF THE GULF OF MEXICO

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INTRODUCTION

Conservationists are concerned over declines occurring in populations of Neotropical migratory songbirds, especially the decreases reported for forest-dwelling species (e.g., Terborgh 1980, Lovejoy 1983, Rappole *et al.* 1983, Steinhart 1984, Leahy 1985, Morton and Greenberg 1989, Terborgh 1989, Robbins *et al.* 1990). Causes of decreasing songbird numbers are not fully understood, but wildlife managers strongly suspect habitat loss and deterioration. Much of the research on this issue has focused on the hemispheric implications of deforestation in the tropics and fragmentation of deciduous forests in the eastern United States. Significantly less research has been directed to examining the effects that altered or disturbed en route (stopover) habitats may have on the long term survival of the Neotropical migratory bird community (Moore *et al.* 1993, Parker 1994).

The Chenier Plain of coastal Louisiana and Texas represents a strategic stopover area for Neotropical songbirds that traverse the Gulf of Mexico en route to breeding ranges in temperate North America and wintering habitats in the tropics. The French term "Chenier" means "place of oak," referring to the upland areas in the marshland of the Chenier Plain that are typically covered with a coastal live oak plant community. In Louisiana, the Chenier ridges are most often dominated by live oak and hackberry, while in Texas these ridges are often grasslands or shrub thickets that only locally support oak vegetation (Texas Bureau of Economic Geology 1976). Other species of woody plants, as well as numerous vines, epiphyses, mosses and lichens coexist on these forested ridges(Cocks 1904, 1907; Palmisano 1970). The cheniers provide a variety of micro habitats for songbirds that stage in these uplands during fall migration and stop over during spring migration.

In 1991 the National Biological Service's Southern Science Center initiated a research program on the Nearctic-Neotropical migratory bird system. Research focuses on the ecological role and importance of coastal stopover areas to songbirds migrating from various locations in Latin America across the Gulf of Mexico to nesting habitats in the United States. The primary goal of the program is to improve our understanding of factors influencing the long-term survival of the Neotropical migratory bird community. The southern Science Center is especially interested in assessing factors associated with the Gulf of Mexico region that may affect the successful conservation of these avian resources. The general objective of the research is to identify relationships between Neotropical migrants and their habitats in the Gulf of Mexico region.

Reported here is an overview of the national Biological Service's research project on the use of Chenier Plain habitats by trans-Gulf migrants.

METHODS

Investigations of in-transit songbirds were conducted at three locations approximately 60km apart in the Chenier Plain. These locations were Grand Chenier, Cameron Parish, Louisiana; Hackberry Ridge, Cameron Parish, Louisiana; and Smith Point, Chambers County, Texas. At each location, the study area consisted of a "disturbed" plot with reduced understory primarily due to grazing by cattle and a "control" plot where the understory showed little or no grazing impact. Paired plots were adjacent to one another, and each plot measured 1.5 ha in size. Abundance of birds within each plot was determined from strip transects (50 x 300 m) that were run twice daily (once between 8-9 a.m., and again between 3-6 p.m.) from 1 March 1993 through 15 May 1993.

Comparisons were made between the availability of plant species and their use by migrant songbirds. These comparisons were conducted only in the control plots because they most closely represented the "natural" forest conditions and would provide useful data for restoration of disturbed cheniers.

GENERAL OVERVIEW OF RESULTS

This report summarizes general preliminary findings related to Neotropical migratory songbirds using chenier habitats during the spring migration period. More extensive and specific results from these investigations can be found in Barrow *et al.* (1996).

The Chenier Plain case study provides a model for examining land use changes and their effects on Neotropical migrant songbirds. Studies conducted at three sites, two in Louisiana and one in Texas, indicate that many species of forest-dependent songbirds are tolerant of some degradation of chenier habitats. However, even subtle differences in vegetation structure and composition beneath the forest canopy can result in differential use by some en route migrants.

Early spring migrants (i.e., Ruby-throated Hummingbird, White-eyed Vireo, Yellow-throated Vireo, Northern Parula, Yellow-throated Warbler, Black-and-white Warbler, Louisiana Waterthrush, and Hooded Warbler) were most abundant on control sites, where a significant understory was present. Only after bird densities increased to higher levels on the cheniers did these species exploit the disturbed study plots. During the course of the spring migration period, the Ruby-throated Hummingbird, Gray Catbird, White-eyed Vireo, and Worm-eating Warbler were consistently more abundant on control than on disturbed plots.

Some migrants preferentially used plots where the understory vegetation was disturbed and reduced from grazing by cattle and browsing by deer. Densities of the eastern Wood-Pewee, Eastern Kingbird, Swainson's Thrush, Red-eyed Vireo, Bay-breasted Warbler, Black-and-white Warbler, Northern Waterthrush, Louisiana Waterthrush, and Indigo Bunting were higher on these disturbed sites than on the undisturbed control plots during the 1 March through 15 May measurement period.

Some songbird species were generally distributed across all habitats during their migration stopover. The Veery, Gray-cheeked Thrush, Tennessee Warbler, Northern Parula, Prothonotary Warbler, Common Yellowthroat, Summer Tanager, Scarlet Tanager, and Northern Oriole were found regularly on both control and disturbed plots.

During the stopover period, migrant songbirds demonstrated a preference for certain plant species. Hackberry, honey-locust, live oak, red mulberry, green hawthorn, yaupon, deciduous holly, poison ivy, green brier, rattan, Japanese honeysuckle, trumpet vine, and grape vine were used in greater proportion to their availability on the cheniers by a large variety of migrant birds. Three of four nonindigenous plants on the study plots—Cherokee rose, china berry and Chinese tallow—were used less by birds than one would expect based on the availability of these plants. Honeysuckle, as indicated above, was a species preferred by migrant songbirds.

Some birds were found to feed predominantly on certain plant species. The Tennessee Warbler and Orchard Oriole preferentially selected the flowers of the honey-locust, while the Rose-breasted Grossbeak fed on the fruit of the red mulberry. At the Smith Point study site the Hooded Warbler and Magnolia Warbler were observed to forage predominantly in yaupon thickets, while the White-eyed Vireo and the Black-and-white Warbler foraged in live oaks.

SUMMARY

Observations obtained in this study indicate that the vegetative structure and composition of habitats along the Gulf coast influence both the distribution and foraging patterns of spring-migrating songbirds. This study also demonstrates the importance of chenier woodlands as stopover habitats for migrants. These data will help managers decide how to maintain or improve (e.g., restore) the quality of cheniers for neotropical migrants. As staging habitats in Latin America are increasingly displaced and disturbed by expanding human development, birds arriving at stopover sites along the Gulf Coast of Texas and Louisiana following their trans-Gulf flight will be increasingly dependent upon food resources available in chenier habitats.

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SESSION 1C

AIR QUALITY STUDIES & ISSUES ON THE OUTER CONTINENTAL SHELF

Session: AIR QUALITY STUDIES & ISSUES ON THE OUTER CONTINENTAL SHELF

Co-Chairs: Mrs. Terry Scholten and Dr. Richard Defenbaugh

Date: December 12, 1995

Presentation	Author/Affiliation
Introduction	Mrs. Terry Scholten Minerals Management Service Gulf of Mexico OCS Region
An Overview of the Gulf of Mexico Air Quality Study: Data Analysis and Modeling Results	Mr. Jay L. Haney Ms. Sharon G. Douglas Systems Applications International San Rafael, California
Gulf of Mexico Air Quality Study—Industry Response	Mr. Brian E. Shannon ARCO Exploration & Production Technology
Measurements of Air Quality and Meteorological Characteristics in Delta and Breton Wildlife Refuges	Dr. S.A. Hsu Coastal Studies Institute SLouisiana State University

INTRODUCTION

Mrs. Terry Scholten
Minerals Management Service
Gulf of Mexico OCS Region

This session focuses on the primary air quality issues addressed by MMS during the past year and expected to be addressed by MMS in the near future, with emphasis upon the final results and implications of the Gulf of Mexico Air Quality Study. This study was required by Congress to determine the impact of the emissions of Outer Continental Shelf activities upon coastal ozone nonattainment areas. The severe ozone nonattainment area surrounding Houston and the serious ozone nonattainment area surrounding Baton Rouge became the primary foci of the study. Congress additionally required that after the study was complete that MMS and Environmental Protection Agency meet to review and determine if any of MMS' regulations governing air quality need to be changed.

Another area of high interest is the Class I area surrounding the Breton National Wildlife Refuges. Since baseline data was not collected in the area, discussion revolves around the issue of increment consumption, particularly for nitrogen oxides and sulfur compounds. Dr. Hsu has been monitoring sulfur dioxide and nitrogen oxides as well as limited meteorological data in the area.

AN OVERVIEW OF THE GULF OF MEXICO AIR QUALITY STUDY: DATA ANALYSIS AND MODELING RESULTS

Mr. Jay L. Haney
Ms. Sharon G. Douglas
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INTRODUCTION

This paper presents results of the Gulf of Mexico Air Quality Study (GMAQS) (SAI 1995), which was conducted from 1992 to 1995. The study, which included meteorological and air quality data collection, data analysis, and meteorological and photochemical modeling of the Central and Western Gulf of Mexico areas, was performed in response to a mandate in the Clean Air Act Amendments of 1990 (CAAA Title VIII, Sec 801(b)). The study was designed to assess the potential impacts of emissions from oil and gas exploration, development, and production in the Outer Continental Shelf (OCS) regions of the Gulf of Mexico on ozone concentrations in the onshore areas of Texas and Louisiana designated by the EPA as nonattainment areas with respect to the National Ambient Air Quality Standard (NAAQS) for 1-hour average ozone, 124 parts per billion (ppb).

Ozone is a secondary pollutant formed in the presence of sunlight from the reaction of volatile organic compounds (VOC) and oxides of nitrogen (NO_x). Exceedances of the ozone standard occur during all seasons in the study area, but about 85% of the exceedance days occur between April and October (inclusive) and are usually associated with generally stagnant or weak synoptic-scale wind conditions, subsidence (high pressure), low humidity, suppressed convection (little cloudiness), and ample solar radiation. Historically, most exceedances of the NAAQS for ozone in the study area occur near major urban and industrial source regions (Baton Rouge, New Orleans, Lake Charles, Houston, Galveston, Beaumont, Port Arthur, and Victoria County, Texas). Since 1980, ozone concentrations in excess of 124 ppb and as high as 340 ppb have been observed at shoreline and inland locations.

OBJECTIVES

The overall goal of this study was to assess, through data analysis and computer simulation modeling (meteorological and photochemical), the effects of current and future OCS petroleum development (OCSPD) in the Gulf of Mexico on ozone nonattainment areas in Texas and Louisiana. The project was divided into seven major tasks conducted in the following sequence: (1) analysis and preliminary modeling of historical episodes; (2) design and execution of a field study to collect appropriate meteorological and air quality data during the summer of 1993; (3) development of emission inventories for the 1993 ozone episodes and projection of emissions to prepare future-year (1999) emission inventories; (4) analysis of the 1993 data; (5) meteorological and photochemical modeling of selected 1993 ozone episodes using the SAI Mesoscale Model (SAIMM), a data-assimilating prognostic meteorological model (Kessler and Douglas 1992) and the UAM-V photochemical model (SAI 1995); (6) assessment of the ozone impacts of alternative OCS future (1999) development scenarios in the Gulf Coast area on the onshore ozone nonattainment areas; and (7) evaluation of the needs for future research or data collection efforts to provide an improved understanding of the OCSPD-related effects on ambient ozone onshore.

RESULTS OF THE DATA ANALYSIS

The analysis of historical episodes for the period 1982-1992 provided the basis for the design of the 1993 field program study. This analysis provided information for episode selection, development of a conceptual model of ozone formation, and the preliminary estimate of onshore impacts. The field program, which ran from April to October 1993, included the installation of supplemental air quality and/or meteorological measurement systems at three offshore platforms and five onshore sites. The intensive measurement portion of the field study ran from 18 July to 28 August 1993. During this time, two highly instrumented twin-engine aircraft were on alert in Beaumont to fly when conditions were favorable for ozone exceedances. The National Weather Service, which collects twice-daily measurements of wind, temperature, and humidity aloft, provided one additional upper-air meteorological measurement daily as needed from Slidell and Lake Charles, Louisiana. Additional soundings were made from the Garden Banks platform.

The 1993 GMAQS field study was uncommonly successful: several high-ozone episodes were captured, including those with peak ozone concentrations approximating historically high levels throughout the study area. A number of ozone episodes (29-31 July, 10-13 August, 18-21 August, and 7-11 September) occurred during the summer of 1993. The days 9-11 August, 17-21 August, and 7-11 September were selected for analysis, and from these the days 17-20 August and 7-11 September were selected for modeling.

The key findings of the data analysis were that ozone exceedance days in the southeast Texas portion of the GMAQS study are associated with a distinct flow reversal and that the land breeze "front" typically traveled 75 to 100 km offshore before the winds reversed and began blowing onshore again. After the passage of the gulf-breeze front and establishment of steady onshore flow (gulf breeze), ozone concentrations measured at coastal locations dropped dramatically. Shoreline flux estimates, calculated for both the August and September episodes, indicated that the amount of NO_x emissions transported into the Houston area from OCSPD sources is small compared to that from onshore sources. Similarly, for ozone, the flux calculations indicate that the amount of ozone transported onshore is small compared to that produced in the Houston area.

MODELING DOMAIN

Figure 1C.1 depicts the meteorological and photochemical modeling domain selected for this study. The domain consists of a coarse-resolution outer domain and a fine-resolution inner domain that encompasses the Houston metropolitan area, Galveston Bay, and the Beaumont/Port Arthur area. Seven vertical layers were specified: 0-50, 50-150, 150-450, 450-900, 900-1,500, 1,500-2,200, and 2,200-3,000 m. These vertical layer heights were chosen such that the layer midpoints coincide with the heights of the SAIMM levels, minimizing the need for interpolation or averaging to convert the SAIMM output to UAM-ready format.

RESULTS OF THE METEOROLOGICAL MODELING

Meteorological fields for application of the UAM-V to the GMAQS modeling domain were prepared using the SAI Mesoscale Model (SAIMM). The model was exercised using a one-way nested-grid approach with 16-km horizontal resolution for the coarse grid or outer domain and 4-km resolution for the inner domain. Routine and supplementary meteorological data collected during the GMAQS and COAST field programs were incorporated into the SAIMM simulations using four-dimensional data assimilation (FDDA). The evaluation of the model revealed that the model provided a reasonable representation of the observed regional-scale flow patterns and the temporal and spatial features of the gulf breeze and associated airflow patterns.

RESULTS OF THE PHOTOCHEMICAL MODELING

An advanced photochemical air quality model, the variable-grid version of the Urban Airshed Model (UAM-V), was applied for the GMAQS domain to provide simulations of the chemical and physical mechanisms affecting observed ozone concentrations within the study domain and to provide quantitative estimates of the impacts of OCSPD emissions on ozone concentrations within the onshore nonattainment areas.

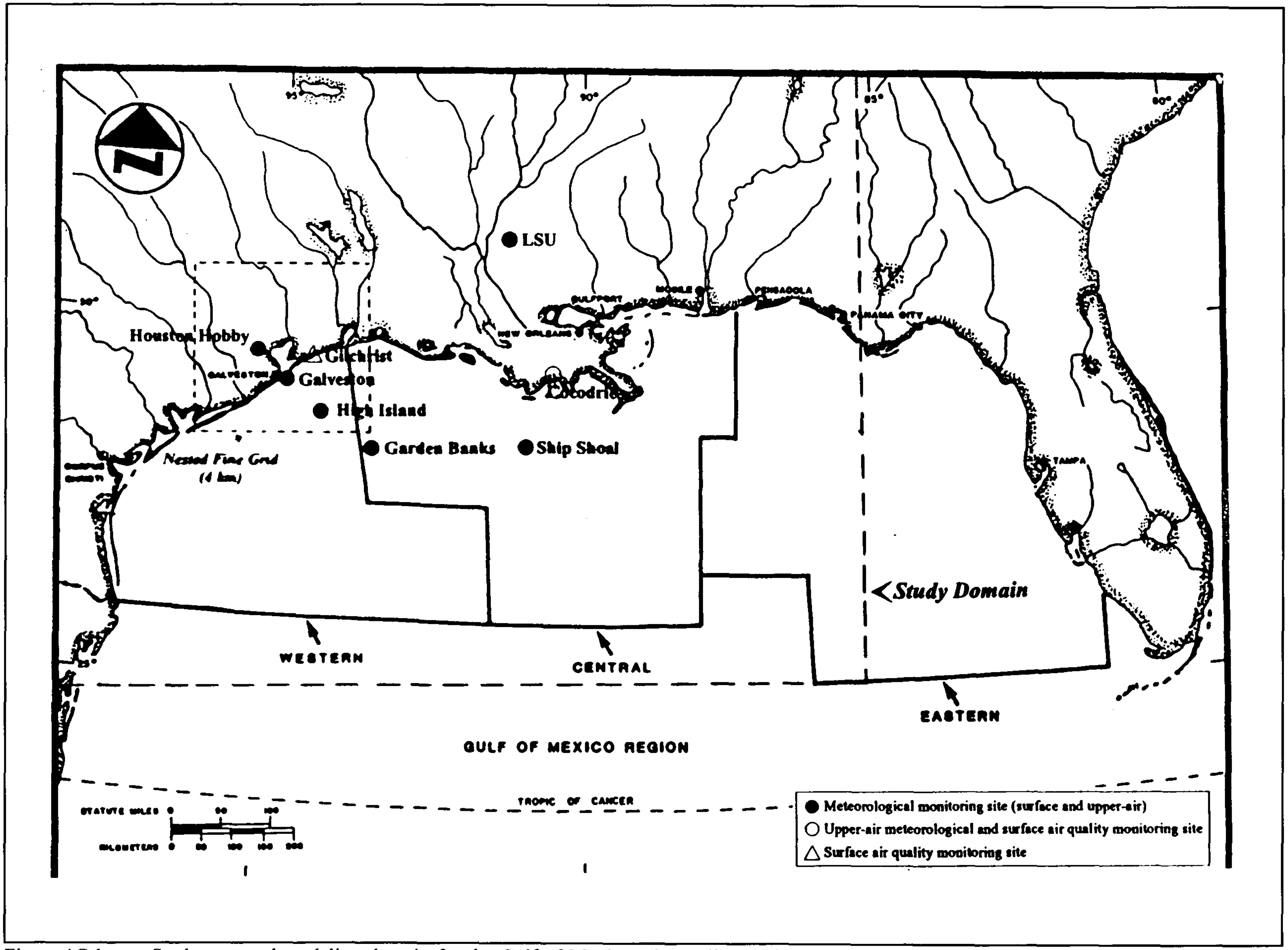

Figure 1C.1. Study area and modeling domain for the Gulf of Mexico Air Quality Study (GMAQS).

The primary focus of the photochemical modeling analysis was the Houston area. Three multiday ozone episodes were simulated: 27-28 July 1988, 17-20 August 1993, and 6-11 September 1993. The assessment of UAM-V model performance for the August and September episodes indicated that the modeling system provided a reasonable simulation of each of the episodes. The simulation results were generally consistent with the conceptual models of the episodes developed through analysis of the air quality and meteorological data, and the statistical measures were generally within the ranges provided by the EPA for acceptable photochemical model performance.

The meteorological and air quality inputs were fixed and the UAM-V was used as a forecasting tool to provide likely future ozone concentration estimates ("predictions") for a number of future-year (1999) onshore and OCSPD emission scenarios to assess the simulated impacts of emissions from OCSPD sources on the onshore nonattainment areas. An emission inventory was prepared using growth factors for all components of the inventory to estimate the emissions for 1999. To assess the incremental impacts of expected OCSPD emissions for 1999 relative to the ozone standard of 124 ppb, two simulations of UAM-V were run; one simulation included OCSPD emissions and the other did not. The incremental impacts due to OCSPD emissions were derived by subtracting the ozone concentrations in the simulation without OCSPD emissions from those in the simulation that included OCSPD emissions.

Modeling of OCSPD impacts for 1999 for the August and September episodes revealed: (1) the maximum incremental increases to peak hourly ozone concentrations due to OCSPD emissions for both episodes were approximately 25-35 ppb, in locations over the central Gulf of Mexico region, more than 120 km south of the Louisiana coastline (near the area of highest OCSPD emission density); (2) the maximum simulated onshore incremental impacts due to OCSPD emissions were in the range of 6-8 ppb and were greatest during the nighttime hours for all episode days—these maximum simulated onshore incremental impacts occurred at coastal and inland locations throughout the GMAQS domain, when observed and simulated ozone concentrations were relatively low, and (3) during periods and at locations where ozone concentrations were simulated to exceed 124 ppb, the incremental ozone impacts due to OCSPD emissions, for both episodes in all nonattainment areas, were simulated to be 2-6 ppb.

SUMMARY OF OCSPD IMPACTS

The analysis of the 1993 supplemental field program data included estimates of shoreline flux, air parcel trajectories, and ventilation parameters. The results of the data analysis suggest that the contribution of the OCSPD emission sources on onshore ozone concentrations is small. The photochemical modeling analysis conducted with the UAM-V indicates that the maximum impact from OCSPD sources for 1993 and 1999 is in the range of 25-35 ppb, in offshore locations of the central Gulf of Mexico. The maximum simulated onshore impacts from OCSPD sources is in the range of 6-8 ppb when onshore concentrations are low. During the time of maximum measured onshore ozone concentrations, the simulated impacts from OCSPD sources were generally less than 2 ppb.

RECOMMENDATIONS FOR FUTURE WORK

Recommendations regarding future ozone air quality work in the Western and Central Gulf of Mexico include additional meteorological and air quality measurements, improvements to onshore and offshore emissions inventories, improvements in meteorological modeling analysis (e.g., use of surface temperature nudging and higher grid resolution), and improvements in the photochemical modeling analysis, including higher grid resolution and the application of process-oriented model performance evaluation procedures.

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Mr. Jay L. Haney, Director of the Urban and Regional Model Applications and Planning Department at Systems Applications International (SAI), is a Certified Consulting Meteorologist (CCM) and has an M.S. degree in meteorology from St. Louis University. Mr. Haney has over 15 years' experience in the refinement of data analysis and modeling techniques applied to the study of tropospheric ozone. Mr. Haney served as the Project Manager for the completion of Gulf of Mexico Air Quality Study.

Ms. Sharon G. Douglas, Director of the Meteorological Modeling, Analysis, and Forecasting Department at Systems Applications International has an M.S. degree in meteorology from the Pennsylvania State University and more than 10 years of experience in meteorological and air quality modeling. Ms. Douglas served as the manager for the meteorological modeling component of the Gulf of Mexico Air Quality Study.

GULF OF MEXICO AIR QUALITY STUDY—INDUSTRY RESPONSE

Mr. Brian E. Shannon
ARCO Exploration & Production Technology

INDUSTRY PARTICIPATION

From the markup of Section 328 of the Clean Air Act Amendments of 1990 (CAAA) until the present, the offshore oil and gas industry has had keen interest in the Minerals Management Service's (MMS) Gulf of Mexico Air Quality Study (GMAQS). Its results could have had a critical impact on emissions control requirements for offshore sources in the Central and Western Gulf of Mexico. In response to the proposed study, the Offshore Operators Committee (OOC) and the American Petroleum Institute (API) formed a temporary group, initially named the Gulf of Mexico Ozone Study Task Force, to provide industry input. The task force is now a permanent full subcommittee named the OOC Gulf of Mexico Air Quality Subcommittee.

Throughout the development of the GMAQS the offshore oil and gas industry has been represented on a Technical Review Group (TRG) which acts as a scientific advisory committee. This group is composed of air professionals from Environmental Protection Agency (EPA) Region VI, EPA Research Triangle Park, MMS Headquarters, MMS Gulf of Mexico Regional Office, Louisiana Department of Environmental Quality (LDEQ), Texas Natural Resource Conservation Commission (TNRCC), and Louisiana State University (LSU). The offshore exploration and production industry was represented on the GMAQS TRG by Dr. Steven D. Ziman, Chevron Research & Technology Company, and myself. Mr. David Scalfano, Chevron U.S.A. Inc., participated in all the TRG meetings.

It should also be mentioned that Vastar Resources Inc. (Ship Shoal Block 178 "A"), Texaco, U.S.A. (High Island Block 199 "A"), and Chevron U.S.A. Inc. (Garden Banks Block 236 "A") provided platform space during the GMAQS field sampling season. These operators also provided logistical and other support to the study.

To aid the MMS in designing the GMAQS, API's Air Modeling Task Force commissioned a study entitled Preliminary Scope for a Gulf Coast Ozone Study. This work, using similar modeling studies performed in Southern and Central California and the Lake Michigan region and some simple analysis of existing data, forecasted that a large-scale integrated modeling study should cost $24.1 million and would take at least five years. The MMS issued the GMAQS Request for Proposal (RFP) in May 1991, with a $5.5 million budget, and the final report was published in August 1995. Final cost of the GMAQS was $5.8 million. Thus the timing was about right; however, the cost was below the $7.3 million projected cost for an alternative limited study. The lower cost is attributable to a lower number of surface meteorology, surface air quality, and radar profiler sites in the GMAQS. In addition, a smaller number of aircraft were used in the GMAQS "Intensive Observation Period" (IOP), 18 July-28 August 1993, than in the recommended scope. A significant amount of GMAQS's Chapter 7, Recommendations for Future Gulf of Mexico Measurement and Modeling Programs, is dedicated to the need for additional field measurements.

Industry did attempt to persuade the MMS and the Department of Energy (DOE) to provide the GMAQS with additional funds in late 1992. These efforts were unsuccessful, due to budget constraints. Failing at the federal level of government, industry helped the Texas Air Control Board (TACB), now TNRCC, obtain $2.928 million in an emergency legislative appropriation for the Coastal Oxidant Assessment for Southeast Texas (COAST) Study ($700,000 was previously available). The COAST study, comprising 1993 field monitoring, was necessary to meet the 15 November

1994-CAAA deadline for a revised State Implementation Plan (SIP) for the Houston-Galveston severe ozone nonattainment area. The COAST study was designed to run concurrently with and to supplement the GMAQS. During the GMAQS IOP the deployment of both studies resources were coordinated to provide the optimum data acquisition with available resources.

1993 EPISODES—TYPICAL OF HISTORICAL OZONE EPISODES WITH OUTER CONTINENTAL SHELF (OCS) CONTRIBUTION

During the 1993 GMAQS and COAST field season, 19 April-17 October the southeast Texas area experienced three ozone (O_3) episodes (9-11 August, 17-21 August, and 7-11 September) while the Baton Rouge area experienced one episode (17-19 August). Maximum O_3 concentrations in each episode for the southeast Texas area were 170 ppb (10 August), 231 ppb (19 August), and 214 ppb (8 September). The maximum O_3 concentration in the Baton Rouge area was 127 ppb (18 August). The primary and secondary National Ambient Air Quality Standard (NAAQS) for O_3 are 120 ppb (235 g/m^3) based upon a one hour averaging period. As reported in Chang and Hanna (1995) and the GMAQS (Chapter 3.3, Climatology and Representativeness) these episodes are representative of those historical episodes in the period of 1982-1992.

Because of budget constraints, only two episodes could undergo data and modeling analysis. It was of the utmost importance to choose these episodes with the greatest magnitude and extent of high onshore O_3 concentrations and the greatest estimated potential for OCS emissions to contribute to these concentrations. Thus the GMAQS primary contractor, Systems Applications International, and the TRG chose the 17-21 August and 7-11 September 1993 southeast Texas episodes. During the 17-21 August episode there was both a strong land breeze and sea breeze. These gulf-breeze circulations and their associated flow reversals provided the means of getting OCS emissions to onshore O_3 nonattainment areas, northeast of the Houston Ship Channel. However, as the study showed these emissions arrived well after the O_3 NAAQS exceedance events took place. Aircraft data showed that there was no substantial day-to-day carryover of O_3 and precursor pollutants in the nonattainment area. The 7-11 September episode exhibited a slightly different meteorological pattern. An offshore directed pressure gradient enhanced the land breeze and suppressed the sea breeze. Therefore, onshore emissions were moved further offshore and a combination of these emissions mixed with OCS emissions did not penetrate as far inland as they did in the August episode. Although there were no aircraft data for the September episode, data analysis suggest that day-to-day carryover of O_3 and precursor pollutants did contribute to high O_3 concentrations monitored along the coast and Galveston Bay.

This data and modeling analysis provided two scenarios of the OCS emissions spatial and temporal contribution to onshore O_3 nonattainment. In both cases the UAM-V photochemical modeling analysis showed that the offshore contribution to an O_3 NAAQS exceedance to be 0 - 2 ppb.

AVERTED COSTS OF EMISSION CONTROLS

In advance of the final results of the GMAQS, the OOC and API saw the need to determine what costs would be imposed on the offshore E & P industry if the EPA's 40 CFR Part 55—Outer Continental Shelf Air Regulations were applied to sources in the Central and Western Gulf of Mexico. A subcontractor to the GMAQS, Sonoma Technology Inc. (STI), was retained to develop software which would provide such cost estimates.

Cost estimates were calculated for a variety of hypothetical control scenarios based upon source type, pollutant, and distance from either the nearest onshore area (NOA) or potential corresponding onshore area (COA). These cost estimates range from $400 million (Capital Costs) and $166 million (Annualized Costs) for controlling all sources greater than 25 tons/year of NOx or VOCs in a region 250 miles beyond state's seaward boundaries to $28 million (Capital Costs) and $58 million (Annualized Costs) for controlling all sources greater than 250 tons/year of NOx or VOCs in a region 25 miles beyond state's seaward boundaries.

EFFECT OF LOWER NAAQS FOR OZONE

The EPA is presently reviewing the primary and secondary NAAQS for O_3. EPA staff at the Office of Air Quality Planning and Standards (OAQPS) have recommended that the existing one-hour primary standard for O_3 (120 ppb) be replaced with a new eight-hour standard (70 - 90 ppb), with a maximum expected exceedance rate of three to seven per year. One expected exceedance means that a County or Parish can exceed the O_3 NAAQS once per year. The present one-hour standard allows a maximum expected exceedance rate of one per year, averaged over three years. If the fourth highest value (design value) is greater than the NAAQS, then the county or parish has failed to meet the standard. Consideration is also being given to replacing the one hour secondary standard for O_3 with a more appropriate averaging period. Lowering the standard and increasing the averaging period will result in numerous counties and parishes becoming nonattainment. New Orleans, Louisiana and its surrounding Parishes will likely become an O_3 nonattainment area. If EPA adopts the 70 ppb eight hour average, the entire United States east of the Mississippi River becomes nonattainment. Emission controls included in State Implementation Plans (SIPs) for a 120 ppb NAAQS for ozone may not be appropriate for a lower standard based upon a longer averaging period.

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Brian E. Shannon has worked for the Atlantic Richfield Corporation (ARCO) for 16 years and is presently employed as a Principal Environmental Scientist at ARCO Exploration and Production Technology. He currently serves as Chairman of the Offshore Operators Committee Gulf of Mexico Air Quality Subcommittee. Mr. Shannon received his B.S. in physics from the University of Minnesota and his M.S. in environmental science from the Florida Institute of Technology.

MEASUREMENTS OF AIR QUALITY AND METEOROLOGICAL CHARACTERISTICS IN DELTA AND BRETON WILDLIFE REFUGES

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INTRODUCTION

This is the second report in a series of studies related to the air quality and meteorological characteristics over the Gulf of Mexico east of the Mississippi River Delta. The first report was published by the Minerals Management Service of New Orleans as OCS Study MMS 95-0019. It described the results of a pilot study of the SO2 concentration and meteorological parameters conducted in this area during the summer of 1993. For 1994, the study was expanded to include not only SO2, but also NOx concentrations and limnological data from Gosier Island as well as regional meteorological conditions. This presentation presents some of the preliminary findings from the 1994 collected data.

METHODS AND RESULTS

Three monitoring stations were deployed from July through mid-September 1994 as shown in Figure 1C.2. Two stations were within the Breton Wildlife Refuge, on Gosier Island and on a moored vessel near Breton Island. The third site was in the Delta Wildlife Refuge at the Pass-A-Loutre (PAL) headquarters complex. The Breton and PAL sites were instrumented to continuously record concentrations of SO2 and NOx along with hourly meteorological values. The Gosier Island station was designed to record hourly SO2 and meteorological values as well as limnological data from an adjacent enclosed pond. All data was collected and stored via on-site dataloggers. The data was then downloaded on a one- to two-week basis, at which time routine monitor calibrations were performed.Finally,

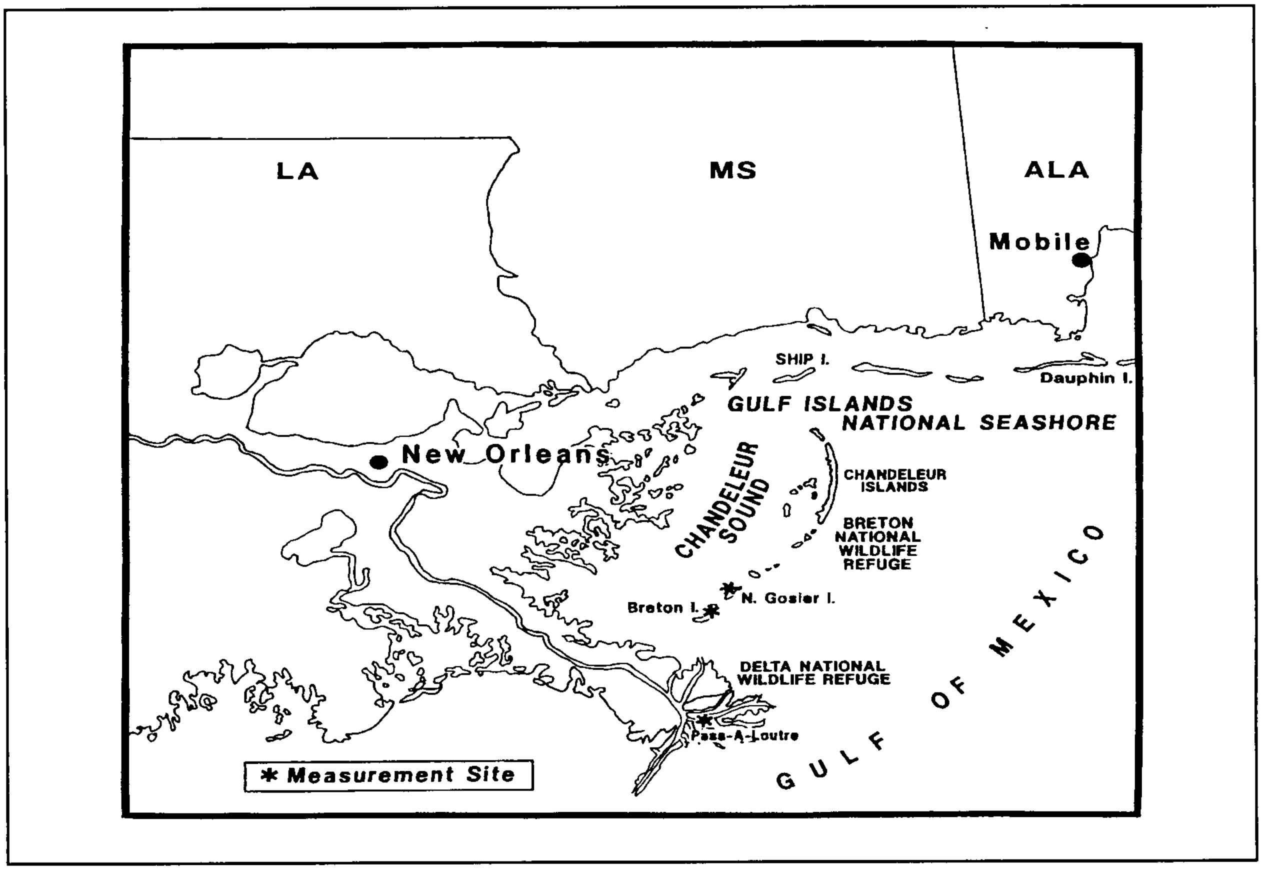

Figure 1C.2. The three monitoring stations deployed during the period of July through mid-September 1994.

Finally, radiosondes were launched from all three stations on several occasions throughout the field deployment.

Several results can be drawn from a preliminary analysis of this data set:

- In general, concentrations of SO2 and NOx appear to be well below the National Ambient Air Quality Standard (NAAQS) limits for Class I and II areas.
- Episodes of disturbed weather appear to be related to increased pollutant concentrations.
- This is evident in both tropical (the passage of Tropical Storm Alberto to the east of Breton Island, see Figure 1C.3) and extratropical (low pressure formation and subsequent passage of a weak cold front, see Figure 1C.4) systems.
- Periodic high concentrations (>100 ppb) of NOx are seen throughout the data record from Breton Island. During these maximum events, the dominant winds are about 10 knots from either North-Northeast or South-Southwest. The events are short-lived, typically less than one day.
- At Breton Island, the highest hourly average concentration of SO2 was 34 ppb and of NOx was 264 ppb. At PAL, the highest hourly average concentration of SO2 was 9 ppb and of NOx was 38 ppb.
- Pollutant concentrations, particularly NOx, are much more pronounced at Breton Island than at PAL.
- Regional airflow is nearly homogeneous over the study area as measured at our field stations and NOAA C-MAN sites even during tropical storms and atmospheric fronts.
- Increasing salinity measured in the Gosier Island pond may be due to high evaporation and light winds associated with high pressure over the area. A rapid salinity increase during the passage of Tropical Storm Alberto may be the result of increased water levels associated with the storm, i.e., storm surge.

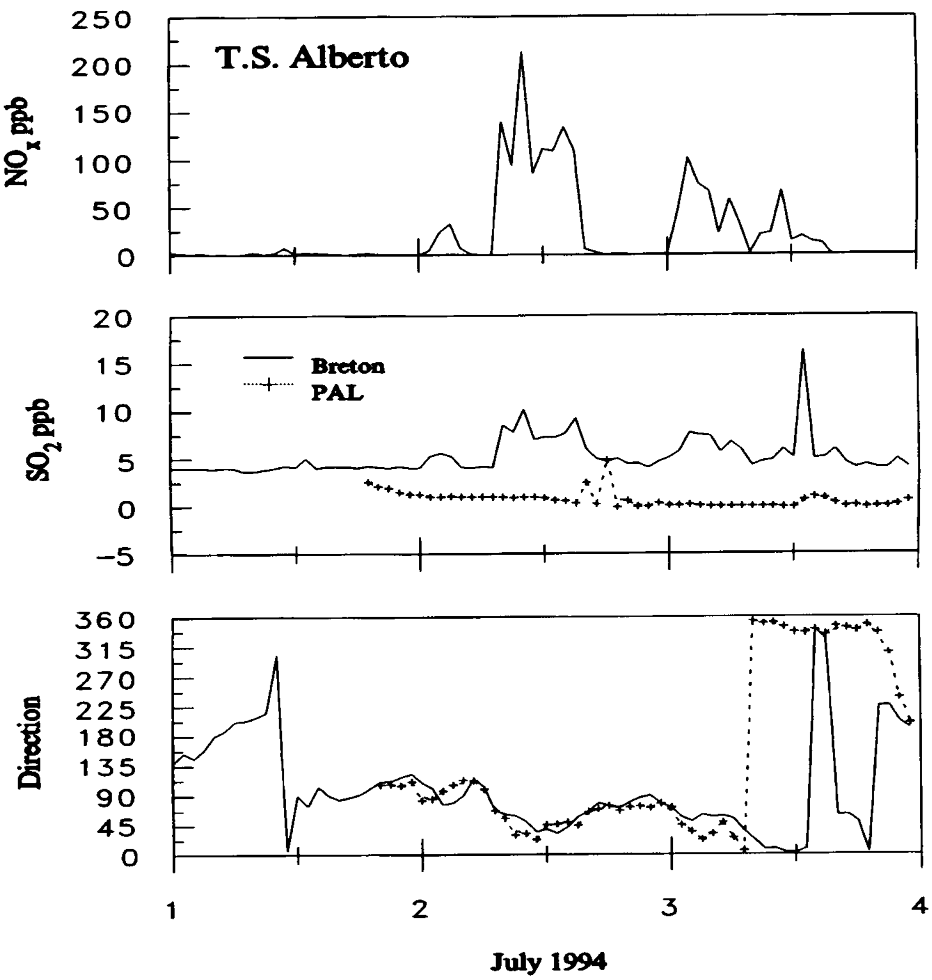

Figure 1C.3. The passage of Tropical Storm Alberto to the east of Breton Island, July 1994.

- Values of pH measured in Gosier pond were ≥ 7, indicating water more basic than acidic.
- Average surface dew-point depressions obtained both from radiosondes and station records were approximately 5 degrees. From theoretical point of view, this results in marine mixing heights of nearly 650 meters. Measured atmospheric profiles are in agreement with this value.

SUMMARY

A preliminary view of air quality and meteorological conditions during July-September 1994 over the Breton and Delta Wildlife Refuges show concentrations of SO2 and NOx well below NAAQS limits for these Class I and II areas. Periods of disturbed weather are often associated with higher than normal pollutant concentrations, particularly at Breton Island. The predominant wind direction during short-lived maximums of NOx concentrations recorded at Breton Island is either North-Northeast or South-Southwest. Average mixing heights over the study area range from 600-700 meters, considerably lower than those of nearby land stations.

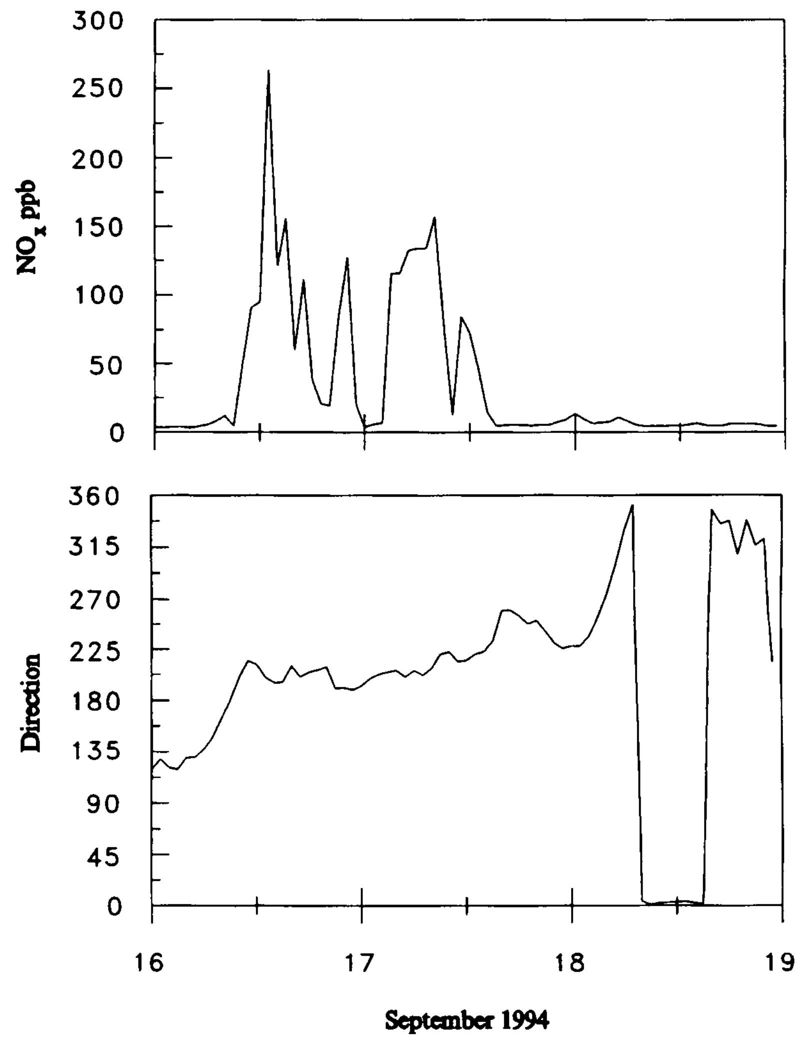

Figure 1C.4. A low pressure formation and the subsequent passage of a weak cold front, September 1994.

Dr. S. A. Hsu is a Professor of Meteorology at the Coastal Studies Institute of Louisiana State University. His research interests are in coastal and marine meteorology, including the physics of overwater pollution transport. Dr. Hsu has published extensively, including a textbook entitled *Coastal Meteorology*. Dr. Hsu received his B.S. in meteorology from the National Taiwan University, and his M.S. and Ph.D. in meteorology from the University of Texas.

SESSION 2A

FLOWER GARDEN BANKS (FGB) NATIONAL MARINE SANCTUARY: OPERATIONS, RESEARCH, ISSUES, & CONCERNS

Session: 2A - FLOWER GARDEN BANKS (FGB) NATIONAL MARINE SANCTUARY: OPERATIONS, RESEARCH, ISSUES, & CONCERNS

Co-Chairs: Mr. Les Dauterive and Dr. Stephen R. Gittings

Date: December 12, 1995

Presentation	Author/Affiliation
Flower Garden Banks National Marine Sanctuary Operations, Research, Issues, and Concerns	Mr. Les Dauterive Minerals Management Service Gulf of Mexico OCS Region
Long-term Monitoring at the East and West Flower Garden Banks	Mr. Stephen T. Viada Continental Shelf Associates, Inc.
Mass Spawning, *In Vitro* Fertilization, and Culturing of Corals at the Flower Garden Banks	Mr. Derek K. Hagman University of Texas Dr. Stephen R. Gittings National Oceanic and Atmospheric Administration, Flower Garden Banks National Marine Sanctuary
Reef Fish Monitoring at the Flower Garden Banks National Marine Sanctuary and Stetson Bank, Northwest Gulf of Mexico	Ms. Christy V. Pattengill Department of Biology and Department of Wildlife and Fisheries Mr. Brice X. Semmens Texas A&M University Mr. Christopher L. Ostrom NOAA, Sanctuaries and Reserves Division
Spatial and Temporal Habitat Use of the Flower Garden Banks by Charismatic Megafauna	Mr. Jeff Childs Department of Wildlife and Fisheries Sciences Texas A&M University Ms. Emma Hickerson Department of Biology Texas A&M University Dr. Ken Deslarzes Flower Garden Banks National Marine Sanctuary
The Minerals Management Service Flower Garden Banks National Marine Sanctuary Oil Spill Risk Assessment: an Example of Partnership	Dr. Alexis Lugo-Fernández Environmental Studies Section Minerals Management Service Gulf of Mexico OCS Region

FLOWER GARDEN BANKS NATIONAL MARINE SANCTUARY OPERATIONS, RESEARCH, ISSUES, AND CONCERNS

Mr. Les Dauterive
Minerals Management Service
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INTRODUCTION

This half day session was devoted to presentations on the present and ongoing oil and gas operations activity, research, and issues that concern the Minerals Management Service (MMS) and National Oceanic and Atmospheric Administration (NOAA) Flower Garden Banks (FGBs) Sanctuary offices.

Presentations by personnel in the MMS Field Operations and Resource Evaluations offices were provided on current drilling, production and pipeline operations, and seismic activity near the FGBs.

A panel of MMS, NOAA, and the oil and gas industry personnel provided information and discussion on a number of issues that are currently of concern and are under review and evaluation by the MMS and NOAA. These issues concern the disposition and disposal of the oil and gas platforms near the FGBs; the potential for subsidence from directional drilling beneath the banks to effect the bank's coral reef community; the presence, frequency, and effects of seismic activity on the biota of the FGBs; the probability of oil in the event of an oil spill reaching the waters over the FGBs; and a discontinuation of the need for preapproval of the use of oil dispersants at the FGBs.

Presentations on current ongoing research at the FGBs were given by the MMS and NOAA studies contractor on the continuation of monitoring the long-term health of the Banks; research scientists on monitoring of the reef fish, and the elasmobranch and sea turtle population and behavior at the FGBs; and the mass spawning, in vitro fertilization, and culturing of corals at the Flower Garden Banks Marine Sanctuary.

LONG-TERM MONITORING AT THE EAST AND WEST FLOWER GARDEN BANKS

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INTRODUCTION

The long-term monitoring program at the Flower Garden Banks National Marine Sanctuary detects and quantifies both catastrophic and gradual changes in reef-building coral communities within the high diversity zone of the Banks. Documentation of these changes over time provides information concerning natural variation in reef corals and associated communities. The present monitoring program, awarded in April 1994, represents a continuation in scope of the previous Minerals Management Service (MMS) contract, conducted from 1989-1992 by Texas A&M University, and includes standardized data collection and analysis methods used in studies conducted during this period. A contract modification was made by MMS during 1995 for purchase and installation of continually recording underwater light meters at the East and West Flower Garden Banks and a surface reference light meter on the Mobil High Island (HI)-389 A platform (East Flower Gardens Bank).

METHODS

Specifications of the present contract include analyses of photographic data collected by Texas A&M University during 1992 and field sampling efforts and data analyses to be conducted during 1994 and 1995. All field study stations and instrumentation were established within or along the boundaries of the existing 100 m x 100 m study sites located within the high diversity zone of each bank. When possible, study stations established during the previous monitoring study were utilized.

Random Transects

The structure of reef coral communities within the two study sites was estimated using stratified random photographic transect techniques. Fourteen 10 m transects were photographed within each study site using a Nikonos underwater camera and electronic flash mounted on a stainless steel frame. Sand flats were bypassed or avoided. The initial starting points and directions of all transects were randomized using values derived from a random number table. Areal coverage and abundance of corals on transect photographs were quantified in the laboratory using an electronic digitizing planimeter.

Accretionary Growth

Two methods were used to determine accretionary growth rates in the coral *Montastrea annularis*: permanent "growth spike" stations and sclerochronological measurements from collected coral cores.

Permanent Accretionary Growth Stations: Masonry expansion bolts were placed within the upper surface of 20 selected *Montastrea annularis* colonies and their emergent length measured. Accretionary growth rates of these colonies were determined by remeasurement of the bolts, or "growth spikes" during subsequent field efforts.

Sclerochronology: Determination of accretionary growth of *Montastrea annularis* via measurement of skeletal growth bands, or sclerochronology, was accomplished in 1995. Two 2.5 cm diameter coral core samples were collected from separate colonies of *M. annularis* within each study site. Sample cores were thin sectioned, x-ray photographed, and annual growth bands labeled and measured.

Lateral Growth

Lateral growth rates of 60 colonies of the coral *Diploria strigosa* were determined from permanent stations within both study sites. Each station comprised an edge, or border, of coral which lay adjacent to dead reefrock. Areas of apparent coral disease and inter- or intra-specific competition for available space were avoided. Two expansion bolts, placed within dead reefrock adjacent to the coral border, served as a reference or alignment guide during closeup photography using a Nikonos camera with lens diopter and framer. Growth or recession of coral tissue seen along the border of each station photograph were quantified in the lab using an electronic digitizing planimeter.

Repetitive Quadrats

Forty permanent quadrat stations established by Texas A&M University during the previous monitoring study contract were utilized during the 1994 and 1995 field efforts. Each station was marked with a single stainless steel rod placed vertically into an area of dead reefrock. Single photographs were taken at each station using a Nikonos underwater camera mounted on a 2-m, T-shaped frame. Photographic transparencies of each station were projected onto a table top, and outlines of living and dead portions of all visible colonies were traced on individual sheets of paper to produce a working template. Changes in colony borders detected on subsequent photographs were traced onto the templates and categorized. Percent cover of live corals and percent cover of coral colonies exhibiting tissue bleaching were determined using a series of transparent overlays with 100 randomly located points.

Ancillary Measurements

Recording Thermometers: Recording thermometers, deployed on both study sites during the previous monitoring study and presently owned by the National Oceanic and Atmospheric Administration (NOAA), were retrieved, downloaded onto the onboard computer, and redeployed during the 1994 and 1995 field efforts.

Water Profiles: Measurements of water temperature, salinity, dissolved oxygen, and ambient light were conducted daily from near surface and near bottom water depths. A Hydrolab Surveyor water quality probe was utilized for temperature, salinity, and dissolved oxygen parameters. A Licor 3006 light meter was used to calculate ambient light. Both instruments were calibrated daily prior to each profile.

Video Transects: Two diver-held video transects were photographed at each study site during the 1994 and 1995 field efforts. Each transect was 100 m in length and followed the site 100 m marker lines used for video transects during the previous monitoring study. The video transect was taken from approximately 2 m above the bottom at an angle of 45°. A weighted line suspended from the video camera housing provided a reference for camera angle and altitude during each transect. A working map of each transect, depicting large or conspicuous coral colonies, sand flats, sponges, etc., was constructed from the 1994 transects and provided reference to changes viewed in 1995 transects.

Light Recorders: Recording light meters were installed in August 1995 within the two study sites and on the Mobil HI-389 A platform. These units are designed to measure Photosynthetically Active Radiation in the 400 to 700 nm waveband, and record data expressed in units of $\mu mol/sec/m^2$ ($1 \mu mol = 6.022 \times 10^{17}$ photons). Both underwater and terrestrial reference light meters were programmed to record ambient light readings on an hourly basis. The data were downloaded in November 1995. Protective, clear plastic bags covering the underwater sensors were cleaned twice between August and November.

RESULTS

Field efforts were conducted from 12-16 September 1994 and 21-25 August 1995. Field work on both occasions was performed aboard the M/V FLING (Rinn Boats, Inc.), based in Freeport, Texas.

Random Transects

Fourteen transects were photographed within each study site during the 1994 and 1995 field efforts. These transects, along with a total of 28 transects collected during 1992, were analyzed in the lab. Figures 2A.1 and 2A.2 show percent cover of reef biota and relative dominance of coral species seen within transects collected during the 1995 field effort. The results are representative of 1992 and 1994 data. These data show that the biological communities of the study sites are dominated by the coral *Montastrea annularis*. Other prominent coral species include *Diploria strigosa*, *Colpophyllia* spp., *Montastrea cavernosa*, and *Porites astreoides*. The relative dominance of other coral species observed within the transects was significantly lower. From 1995 data, the mean percent coral cover for all species within the

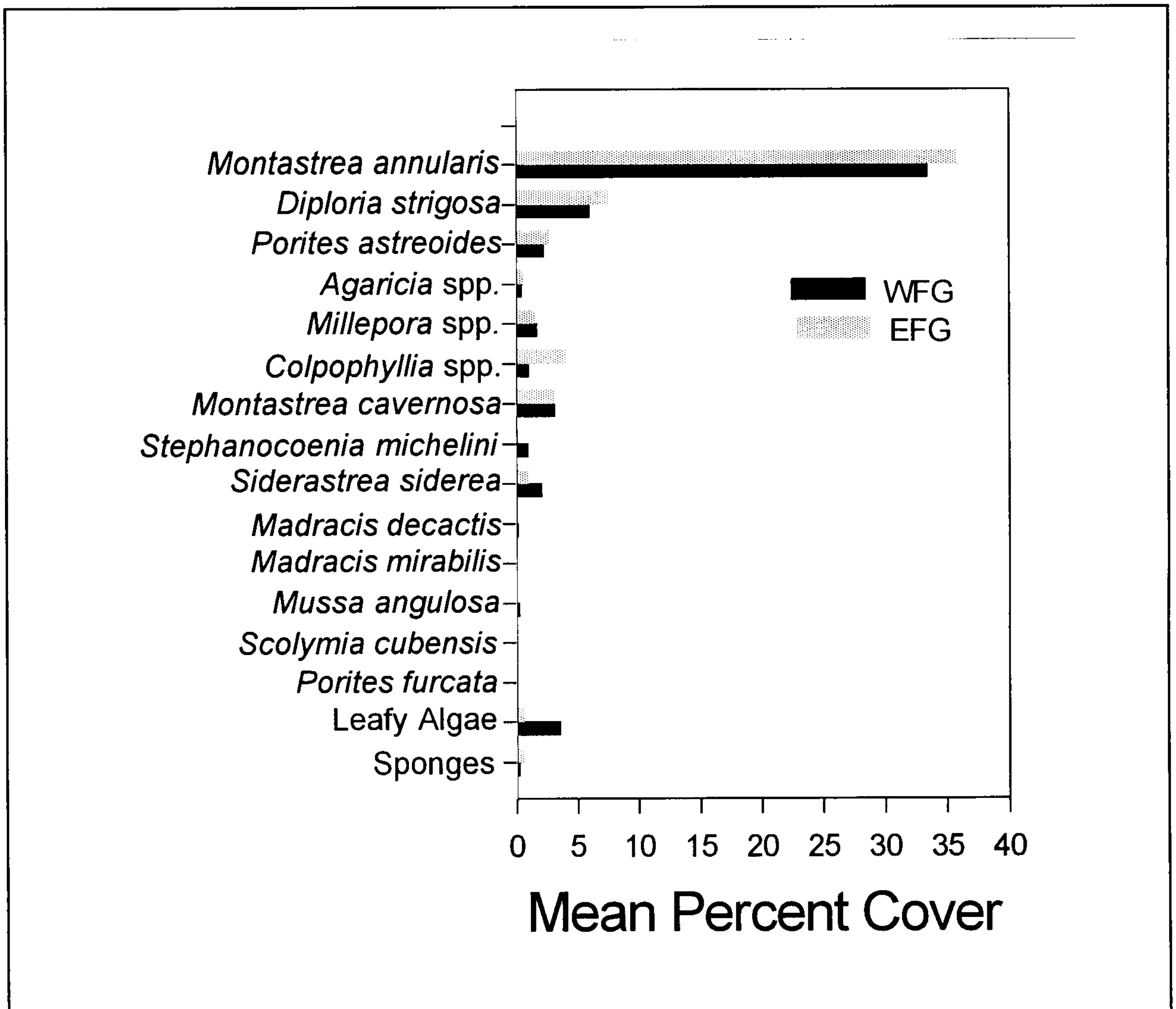

Figure 2A.1. Percent cover of reef biota on the Flower Garden Banks, 1995.

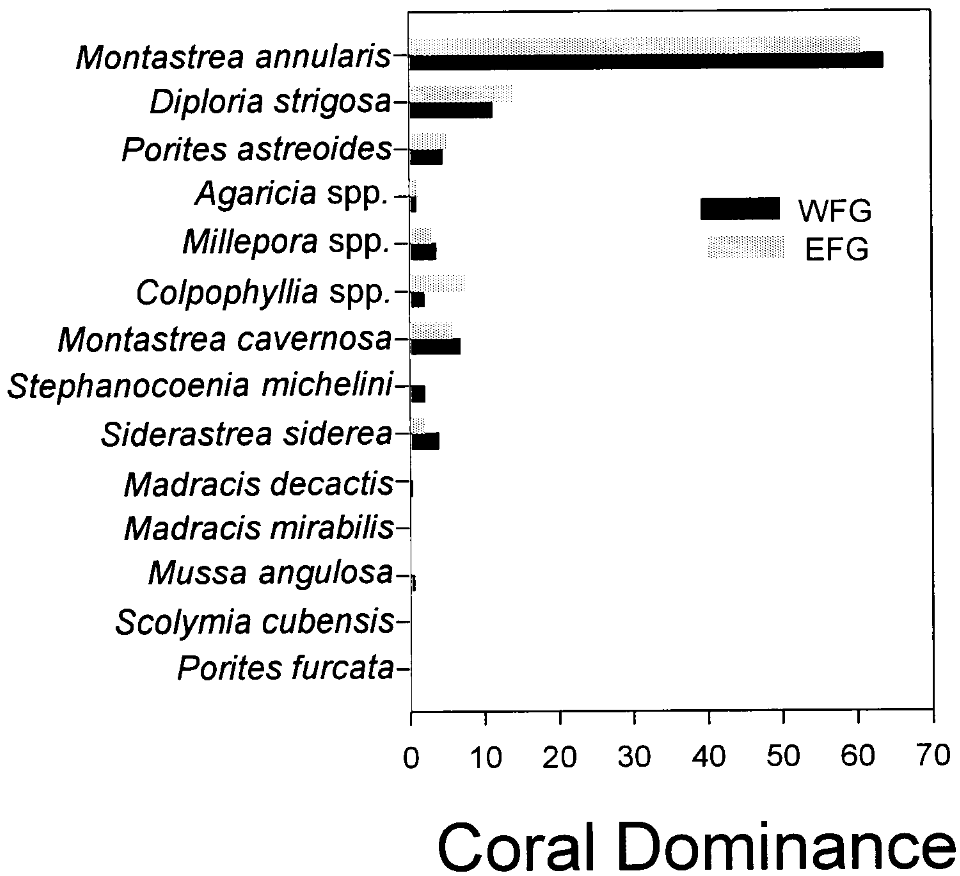

Figure 2A.2. Mean coral dominance on the Flower Garden Banks, 1995.

East and West Flower Garden Banks was 57.2% and 51.7%, respectively.

Accretionary Growth

Accretionary growth stations of *Montastrea annularis* were not measured during data collection in 1992. New stations were established during the 1994 field effort. Mean growth rates from 1994 to 1995 as estimated from permanent stations at the East and West Flower Garden Banks were 5.7 mm/yr and 5.5 mm/yr, respectively. Growth rates determined by sclerochronological measurements from collected coral cores were somewhat higher over the same time period (East Flower Gardens = 10.0mm/yr and 6.0 mm/yr; West Flower Gardens = 8.3 mm/yr and 8.7 mm/yr).

Lateral Growth

Lateral growth stations from the previous monitoring program were unusable. New stations were set up and photographed within both sites during 1994 and analyzed for lateral growth subsequent to the 1995 field effort. Net lateral growth (the average rate of change of all areas observed to advance or retreat) of *Diploria strigosa* within East and West Flower Garden Banks study areas from 1991 to 1992 was -0.01 cm/yr and from 1994 to 1995 was +0.23 cm/yr.

Repetitive Quadrats

Repetitive quadrat stations established during the previous monitoring program were utilized during both 1994 and 1995 field efforts. Three stations were replaced within the West Flower Bank study site during 1994. Coral cover in East and West Flower Garden Bank quadrats averaged 50.1% and 46.8%, respectively. Coral colony growth and mortality were identified on visible colonies in quadrat photographs. New disease (318 occurrences) observed on coral colonies during the 1992-1995 period was accompanied with high tissue mortality. Disease appeared to be limited to coral "ridge mortality" and bleaching events. Coral bleaching observed in quadrat photographs during 1995 was much greater than in 1994 and 1992. Figure 2A.3 shows relative numbers of coral colonies exhibiting bleaching and mean percent cover of bleached corals within the quadrats during 1992, 1994, and 1995. During 1995, bleaching was observed in numerous, isolated areas on many colonies within the quadrats from both study sites. The relative percent cover of bleached coral tissue, as determined by overlays, remained relatively low and comparable to 1992 observations. No bleaching was observed in quadrats from the West Flower Garden Bank during 1994.

Ancillary Measurements

Recording Thermometers: Data from recording thermometers were collected during both the 1994 and 1995 field efforts. That data are depicted on Figure 2A.4. Data were not collected from April-August 1995 on the West Flower Garden Bank. Temperatures were in excess of 30°C during the summer months of 1995.

Water Profiles: Water profiles were collected daily during the field efforst of 1994 and 1995. These profiles included measurements of water temperature, salinity, dissolved oxygen, and ambient light, taken at

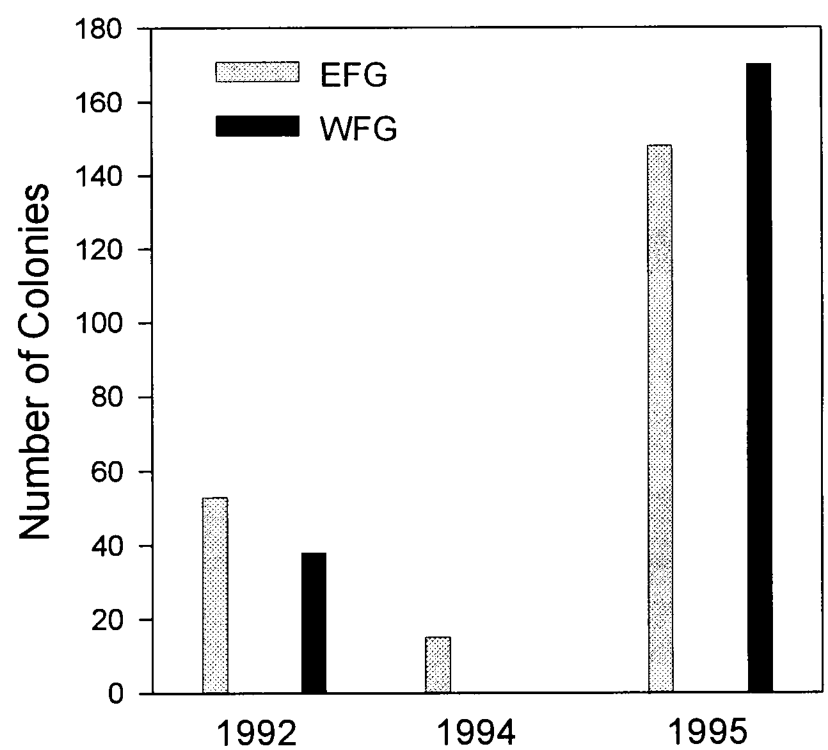

Figure 2A.3. Coral bleaching observed in 8 m^2 quadrats, 1992, 1994, and 1995.

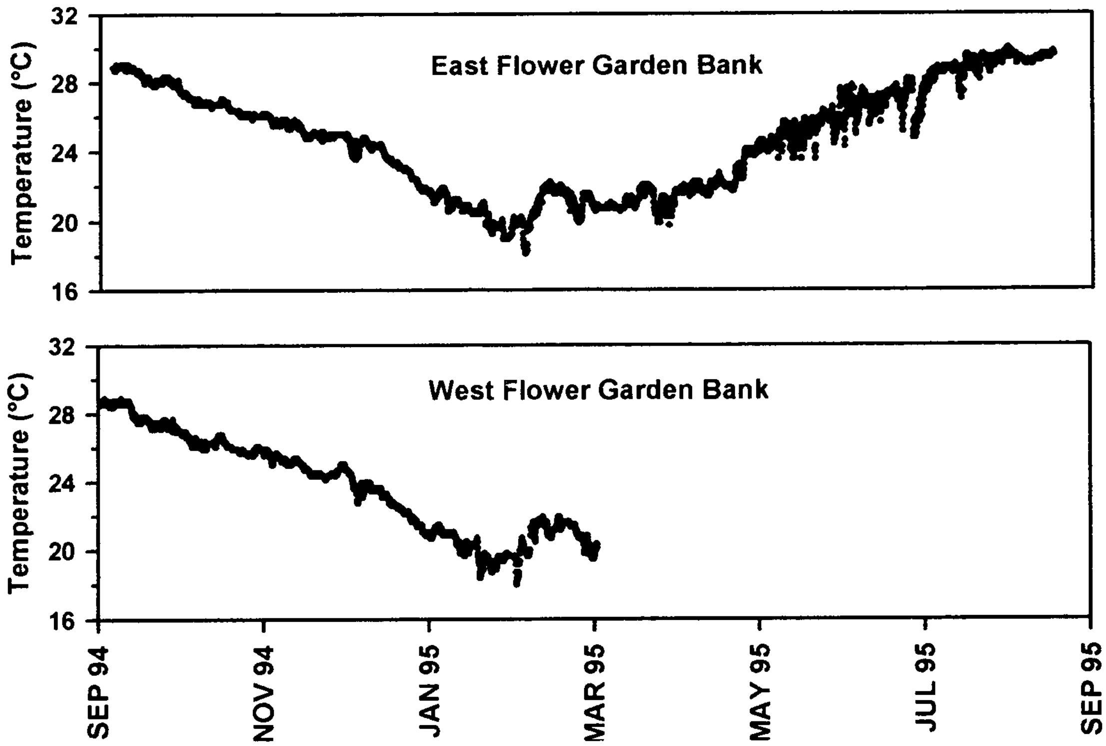

Figure 2A.4. Seafloor temperature data on the Flower Garden Banks, September 1994 to September 1995.

near surface (1 m) and near bottom (1 m above) depths.

Video Transects: Transects were photographed along selected site marker boundary lines during the 1994 and 1995 field efforts. The relative positions of these 100 m lines between surveys were highly variable, especially toward the middle of the sites, and can be attributed to variability in the position of the lines during their initial layout and effects from near-bottom currents on the floating line. Similarly, variations in camera angle and altitude were common during the hand-held video transects. Attempts to compare transects quantitatively are therefore not possible. Qualitative working maps were constructed from the 1994 video transects, and were used to detect large-scale changes or events such as coral bleaching observed along the perimeters of the study sites during the 1994 and 1995 field efforts. Overall, observations of increased bleaching were made on transects taken during 1995. Conversely, some bleached colonies observed on the West Flower Garden Bank during 1994 were found restored during 1995.

Light Recorders: Figure 2A.5 shows baseline total daily irradiance levels for the two study sites and the surface reference station over the three-month sampling period between August and November 1995.

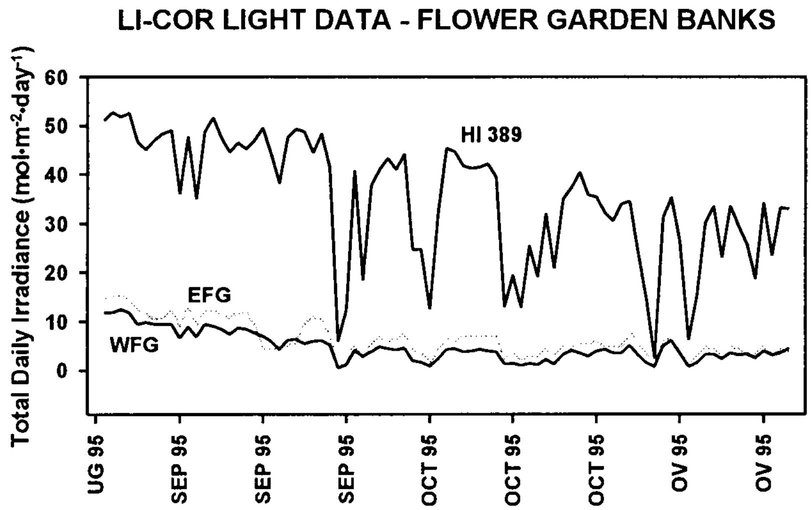

Figure 2A.5. Total daily irradiance on the Flower Garden Banks, August - November 1995.

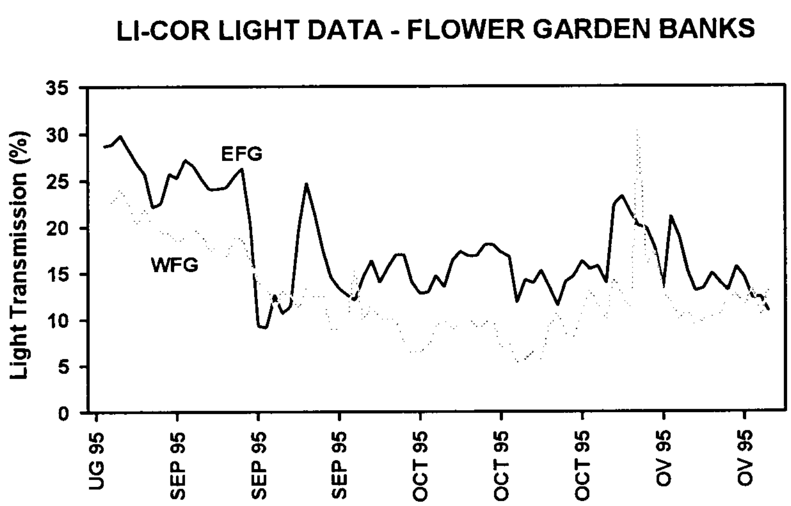

Figure 2A.6. Percent light transmission on the Flower Garden Banks, August - November 1995.

As an indicator of water transparency, Figure 2A.6 shows the percent of surface light transmission to reef coral communities at the two study sites during the three-month period.

SUMMARY

The current long-term monitoring program at the Flower Garden Banks consists of the analysis of photographic data collected during the previous contract in 1992 and field efforts and data analyses during 1994 and 1995. The benthic community structure within the two study sites is dominated by scleractinian corals, predominantly the species *Montastrea annularis* and *Diploria strigosa*. Accretionary growth rates of *Montastrea annularis* from both sites, using both growth spike and sclerochronology techniques averaged 7.4 mm/yr from 1994 to 1995. Net lateral growth rates of *Diploria strigosa* from both sites averaged -0.01 cm/yr from 1991 to 1992 and +0.23 cm/yr from 1994 to 1995. Corals observed in repetitive quadrat stations from both study sites exhibited significant bleaching during 1995. Data collected from recording thermometers showed temperatures in excess of 30°C during the summer months. These data suggest that thermal stress during the summer of 1995 was responsible for the significant bleaching observed during this period. Recording light meters were installed on the two study sites and on the Mobil High Island 389 A platform on the East Flower Garden Bank. Underwater light data, when compared with surface ambient light data, provide a continuous record of water transparency within the two study sites.

Stephen T. Viada received his B.S. (1978) and M.S. (1980) from Texas A&M University. His master's thesis pertained to studies on the population levels of scleractinian corals and prominent reef biota on the East Flower Garden Bank, as part of the Bureau of Land Management's ongoing long-term monitoring program on the Flower Garden Banks. He is presently a staff scientist for Continental Shelf Associates, Inc., in Jupiter, Florida.

MASS SPAWNING, *IN VITRO* FERTILIZATION, AND CULTURING OF CORALS AT THE FLOWER GARDEN BANKS

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BACKGROUND

In August of 1990, the first observation was made of mass spawning of several coral species at the Flower Gardens Banks, northwest Gulf of Mexico (Gittings *et al.* 1992a). Coinciding with the first observations of the spawning, Gittings *et al.* (1992b) were conducting a long-term monitoring study of the coral populations at the Flower Gardens. While this study demonstrated that the coral populations were stable and in good condition, questions remained about the mechanisms by which they maintain themselves. While the mass spawnings provided evidence that the populations might benefit from local reproduction, we still do not know the relative importance of local reproduction and long-distance dispersal of larvae from outside sources (Harrison *et al.* 1984; Willis and Oliver 1988; Black 1993).

This may become an important issue for resource managers. These banks are under the protection of both the National Oceanic and Atmospheric Administration (NOAA) and the Minerals Management Service (MMS). Both agencies have enforced strict regulations to preserve their pristine condition. Unfortunately however, unforseen events sometimes lead to widespread mortality of important species, such as occurred with the Caribbean-wide die-off of *Diadema antillarum* (Lessios 1988) or the mass mortalities of corals following the 1982-1983 ENSO events in the eastern Pacific (Glynn 1984). It is important to know the potential for recovery of isolated reefs like the Flower Gardens following such events.

In addition, unlike the Flower Gardens, the majority of coral reefs around the world are experiencing some form of decline, with most of the impacts directly attributable to human activities (Crosby *et al.* 1995). Depending on the reliance of isolated reefs on larval input from other locations, the condition of isolated, pristine reefs may be in jeopardy due to the deteriorating condition of those in more heavily populated regions. The mass spawning by corals at the Flower Gardens has facilitated studies of coral reproduction, fertilization success, and recruitment, all of which relate to the viability, resilience, and persistence of the reefs. The phenomenon has also enabled studies of the potential for culturing of larval and juvenile coral colonies. This paper describes a portion of this research and discusses the implications of the findings to date.

GAMETE COLLECTIONS

To evaluate fertilization and larval development processes at the Flower Gardens, gamete collections were made at the East Flower Garden Bank during spawning periods in 1993, 1994, and 1995. Collections were also used to evaluate the potential for hybridization between closely related species. Specifically, three purported species once thought to be conspecific morphotypes (Weil and Knowlton 1994) can now be tested for their ability to reproduce with one another. All three types exist in abundance at the Flower Gardens. In this study, gametes from two of these three were collected for experimental manipulation.

Using small hand held nets to sweep the colony surface, gamete bundles were collected as they were released from parent colonies during mass spawning events between 1993 and 1995. Each sample was transferred to a pre-labeled zip-loc bag marked with species identity and a sample number, and transported to the surface for crossing and hybridization studies. During 1993 and 1994, gametes were collected from the hermaphroditic species *Diploria strigosa* (brain coral) and *Montastraea franksi* (bumpy form of massive star coral; Weil and Knowlton 1994; Van Veghel 1994) and the dioecious (i.e. separate male and female colonies) *M. cavernosa* (cavernous star coral). In addition to these species, we collected gametes from two other species, *M. faveolata* (smooth form of massive star coral) and *Colpophy llia natans* (large grooved brain coral) in 1995.

Self- and cross-fertilization success rates were determined for each species except *C. natans*. For each sample collected, some of the material was isolated for selfing and the rest used to cross with similar material from other samples from the same species. Attempts at hybridization or inter-specific crossings were accomplished in August 1995 between the hermaphrodites *Montastraea faveolata* and *M. franksi*. No attempts were made to cross the gametes of *D. strigosa* with any of the *Montastraea* species or between the hermaphroditic and dioecious species of *Montastraea* (i.e., the *M. "annularis"* complex and *M. cavernosa*).

All fertilization counts and observations of embryonic and larval development were made at a field laboratory established on a nearby natural gas production facility, Mobil HI-A389A. Following the completion of the gamete manipulations on the boat, samples were transported to the platform. Fertilization rates for all crossed and selfed samples were determined by doing direct counts under dissecting scopes. Three small sub-samples were removed from each sample, and the ratio of unfertilized to fertilized embryos was determined. Embryonic and larval development was recorded in 1993 and 1995 by mounting a video camera on a dissecting scope.

FERTILIZATION AND DEVELOPMENT

Gametes from *D. strigosa*, *M. franksi* and *M. cavernosa* were collected on the nights of 7 and 8 September 1993. Conscious attempts were made to either cross or self the gametes of *D. strigosa* and *M. franksi*, but we were unable to collect sperm from male colonies of the dioecious *M. cavernosa* to enable controlled experiments. Three samples of eggs were collected from separate female colonies. Sampling in 1994 focused on *D. strigosa* on 28 August and *M. franksi* on the previous night, as very few observations of *M. cavernosa* spawning were made. One sample of *M. faveolata* was collected on the night of the 27th. In 1995, gametes were collected for *C. natans*, *D. strigosa*, *M. cavernosa*, *M. faveolata*, and *M. franksi*. (see Table 2A.1) on the nights of 16, 17, and 19August. Observations on fertilization and development were only conducted on the night of 17 August.

Crossed samples of *D. strigosa* gametes typically yielded fertilization levels exceeding 90%, while selfed samples ranged from 40-80% fertilization. Peak levels of fertilization were measured within two hours of gamete crossing(s). Similar results for *M. faveolata* were obtained, with greater than 90% fertilization when the gametes were crossed. However, fertilization in selfed samples rarely exceeded 10%. In addition, the maximum levels of fertilization were not reached until four and a half hours after the gametes were combined. While selfing rates in *M. franksi* were comparable to those of *M. faveolata*, rarely exceeding 20%, the crossing experiments did not perform as well. For the

Table 2A.1. Summary of sampling effort by year for the coral species participating the mass spawning at the Flower Gardens. Numbers in parenthesis indicate number of samples.

	Hermaphroditic species					*Dioecious sp.*
	Diploria strigosa	*Colpophyllia natans*	*Montastraea faveolata*	*Montastraea franksi*	*Montastraea annularis*	*Montastraea cavernosa*
1993	(8)	-	-	(7)	-	(3)
1994	(14)	-	(3)	(8)	-	-
1995	(4)	(1)	(3)	(7)	-	(1)

most part, fertilization in this species did not exceed 85%. As in its sibling species, the maximum levels of fertilization were delayed for extended periods, in this case nearly seven hours. Crossing trials between these two *Montastraea* species yielded fertilization levels similar to the individual selfing rates. The observed gamete incompatibility supports the recent separation of these two species (Weil and Knowlton 1994) and the low potential for hybridization. Since sperm samples for *M. cavernosa* were never obtained, we were unable to perform crossing trials with this species. However, upon examination of the spawned egg samples of this species it was noted that greater than 95% of "eggs" were developing embryos within two and half hours of collection (see Table 2A.2).

Holoblastic radial cleavage was observed in all four species examined Szmant-Froelich *et al.* 1980; Babcock and Heyward 1986) and is presumed to occur in *M. annularis* as well. The second cleavage plane is perpendicular to the first and is followed by some form of rotation of the blastomeres leading to a pseudospiral pattern (Szmant-Froelich *et al.* 1980; Babcock and Heyward 1986). Following the third cleavage, subsequent divisions are asynchronous and in some cases can lead to very unorganized embryos.

Planulae of both *D. strigosa* and *M. cavernosa* were brought to shore and maintained in culture for over eight months. The majority of the *D. strigosa* larvae settled within 3-5 days following fertilization, while the planulae of *M. cavernosa* for the most part remained free-swimming. As Szmant (1986) observed, no algal symbionts were present in the eggs, larvae or recently settled spat in of any of the four species studied.

DISCUSSION

Fertilization data should be considered a measure of the maximum potential. Heyward and Babcock (1986), Levitan *et al.* (1991) and Lasker and Stewart (1992) found that fertilization levels were higher *in vitro* than *in situ*. Among the most important factors influencing fertilization success are sperm concentration, sperm-egg contact time and sperm age (Levitan *et al.* 1991). As this investigation of fertilization rates was conducted *in vitro*, the high sperm concentration probably played the most critical role. Gamete fusion and development for *Diploria strigosa* was rapid, resulting in the production of a large number of robust planulae. Recruitment by this species on the Flower Gardens, although not reported by Baggett and Bright (1985) on artificial substrates, occurs on the reefs and nearby platforms. Juvenile corals of this species are frequently observed during dives much more so than juvenile *Montastraea* spp. colonies.

Both species of the *M. annularis* complex studied had delayed fertilization, even in the presence of high sperm concentrations. The nature of the mechanism causing the delay is unclear but suggests the presence of a self fertilization barrier (Heyward and Babcock 1986), or that sperm-egg contact time, as described by Levitan *et al.* (1991), may play a more critical role in the fertilization process than sperm concentration. Although Levitan *et al.* (1991) found that sperm concentration was the dominant factor at high and low dilutions, at intermediate levels contact time between the gametes became more significant. Based on the low self fertilization rates in these species one might argue that any barriers against self compatibility may also act to artificially reduce the sperm concentration by simply

Table 2A.2. Summary of cross- and self-fertilization experiments, indicating percent of fertilized eggs.

Species	Cross	Self	Notes
Diploria strigosa	>90%	40-80%	Peak within 2 hours after spawning
Montastraea faveolata	>90%	<10%	Peak at 4.5 hours after spawning
Montastraea franksi	<80%	<20%	Peak at 7 hours after spawning
Montastraea cavernosa	>95%	NA	95% fertilized & developing 2.5 hours after release, probably fertilized prior to release
M. faveolata x *M. franksi*	<30%	-	Supports separate species hypotheses

not recognizing its sibling sperm. In this case the gametes, once fused, would need to undergo an extended period of association prior to acceptance and fertilization. While the selfing trials conducted for *M. faveolata* and *M. franksi* clearly indicate the presence of barriers against self fertilization (Heyward and Babcock 1986), it is not clear how they may, if at all, delay the fertilization rates in the cross-fertilization trials.

Among the more interesting observations made during this study is the possibility of internal fertilization within female polyps of *M. cavernosa*. Eggs from female colonies were collected as they were released and placed in sealed containers until observation 2.5 hours later. Nevertheless, fertilization levels in this species exceeded 95 percent. This suggests either internal fertilization (sperm release begins earlier in the evening and may lead to internal fertilization among female colonies) or the presence of a high density of sperm in the water over the reefs to ensure such high fertilization rates. Similar results were obtained by Brazeau and Lasker (1989) in their investigation of the gorgonian coral *Plexura A*. They felt that fertilization was occurring internally or at the surface of the female colonies.

The only known scleractinian species to utilize internal fertilization are brooders (Szmant 1986). Parthenogenesis has only been documented in one octocoral species and is unknown in scleractinians (Brazeau and Lasker 1989). The presence of a high concentration of sperm surrounding individual female colonies would be unlikely without a proximate male colony. Lasker and Stewart (1992) found that sperm densities and fertilization rates declined drastically within several meters of male colonies of *Plexura A* as a result of dilution. Levitan *et al.* (1991) found that fertilization rates for sea urchins were influenced most heavily by sperm concentration. All of these factors suggest that internal fertilization, although not previously described in broadcast spawning species, may well exist within *M. cavernosa*.

This study is being expanded to include recruitment and population data to address resource management issues. In 1995, an attempt was made to culture corals in enclosed chambers during their planktonic phase. Within the chambers, conditioned quarry tiles were offered as substrate for settlement. After two weeks, the plates were removed and placed on recruitment racks for long-term observations on growth and survival. These frames also contain non-cultured tiles for examining natural recruitment as described by Baggett and Bright (1985).

Future work will involve monitoring recruitment at the Flower Gardens with both the artificial substrates and by making observations of naturally occurring recruitment on exposed reef rock. In addition, we are planning genetically to compare certain species of Flower Garden corals (adults and recruits) with other populations throughout the Gulf of Mexico. Allozyme starch gel-electrophoresis, based on the methods developed by Stoddart (1983) and Weil and Knowlton (1994) will be used to examine variations in enzyme systems between populations as a basis for establishing the origins of Flower Garden corals.

ACKNOWLEDGMENTS

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REEF FISH MONITORING AT THE FLOWER GARDEN BANKS NATIONAL MARINE SANCTUARY AND STETSON BANK, NORTHWEST GULF OF MEXICO

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IMPORTANCE OF FISH ASSEMBLAGE STRUCTURE

Improper management of fisheries on coral reefs can lead to the demise of entire reef ecosystems, particularly when critical species are taken in excess. This is because fish play an important part in maintaining and controlling benthic assemblages. Fishes can therefore serve as indicators of aquatic community health. Most are mobile and dependent on specific types of substrate and food. Studying reef fish assemblages and the factors controlling their structure has become an integral aspect of monitoring overall reef health. The role of competition, predation, recruitment success, and abiotic factors such as temperature, water currents, and salinity, all play a role in shaping this structure. Recently it has also been argued that fish assemblage structures are not in a state of equilibrium but rather vary substantially over time (Sale *et al.* 1994; Sale and Guy 1992). Temporal persistence is thought to be affected by the chance access to a limited resource (habitat space in the case of reefs) that results from fish recruitment patterns (Sale 1988). In other words, these almost exclusively pelagically-dispersed organisms enter a "lottery" when their larvae are taken by the currents (Mapstone and Fouler 1988). Understanding the ecology of reef fish systems is necessary for effective resource management.

The present understanding of the ecology of reef fish assemblages is based strongly on a large set of information from the Great Barrier Reef. While there have been studies in the Caribbean, more are needed since ecosystem differences make it likely that reef fish communities in these two geographic areas are organized differently (Sale 1991). The Flower Garden Banks National Marine Sanctuary (FGBNMS) is located 110 miles southeast of Galveston, Texas at around 28°N. These unique banks support flora and fauna similar to those found in Caribbean reef areas. These reefs are near the latitudinal limit for reef development. Stetson Bank is a smaller area seventy miles offshore that is too extreme in terms of temperature to support extensive coral growth. However, this claystone and siltstone bank supports a well-developed reef fish assemblage. Monitoring the fish assemblages of these two areas will provide insight to the variability of community structures near the edge of their distribution and will be useful for the future management of these unique and isolated areas.

Previous fish research at the FGBNMS and Stetson Bank has mostly been done using video from submersibles and remotely operated cameras (Bright *et al.* 1974; Bright and Cashman 1974, Boland *et al.* 1983; Rezek *et al.* 1985; Dennis and Bright 1988). The most comprehensive work of the Flower Gardens compiled work done over a ten-year period (1974-1984) and reported 165 species above 45 meters (Rezek *et al.* 1985). The fish community of Stetson Bank has been less extensively studied. Bright *et al.* (1974) recorded 48 species between 22 and 58 meters.

Previous to these studies, tropical fishes were thought to be transitory members of the northern Gulf of Mexico icthyofauna that were not able to sustain permanent populations (Dawson 1962; Caldwell 1963). In addition to the hard banks in the Gulf of Mexico, thousands of offshore oil and gas platforms have enhanced the amount of hard substrate available for reef dwelling organisms and have probably increased the number of species found at the FGBNMS and Stetson Bank.

The purposes of the present study were: 1) to establish a long-term monitoring database of reef fishes using a protocol that can easily be replicated; and 2) to analyze three seasons of data to establish seasonal trends exhibited by the fish assemblages of the Flower Garden Banks and Stetson Bank.

In addition to the primary author's dissertation objectives which encompass the above, we have also initiated several sport diver training programs intended to raise awareness of the natural system while teaching the basics of reef fish identification. The seminar techniques of the Reef Environmental Education Foundation (REEF) have been used.

METHODS

Two different non-destructive techniques were used to visually census the FGBNMS and Stetson Bank. The long-term monitoring study sites were used for the East and West Flower Garden Banks (Buoy #2 and #5, respectively). The other buoys will be sub-sampled during future efforts to ensure that these study sites are representative of the entire reefs. Stetson Bank was divided into four regions, delineated by lines set during monitoring efforts, and each region was equally surveyed.

The Modified Roving Diver method (Pattengill 1995), a variation of the Rapid Visual Count (Jones and Thompson 1978), provides a comprehensive species list. During each survey, the divers had free-swimming range over the reef and recorded every fish species that was seen. Additionally two different abundance codes were assigned, the five-minute time interval the species was first encountered and a relative abundance.

Relative abundance codes are:

A=1
B=2-10
C=11-100
D=>100

The Stationary Diver Method (Bohnsack and Bannerot 1986) was used to provide quantitative data. The method required a diver to sit in the middle of an imaginary cylinder, with a radius of 6.5 meters and a height of approximately 4 meters, and record all fish species seen within the cylinder during an initial five-minute time period. After the initial time period, the stationary diver counted each recorded species seen within the cylinder at that time. Each survey area or cylinder was randomly chosen using a random number of kicks and compass heading. It was assumed that the stations chosen were similar to the areas of the bank not sampled.

For each method, a team of six divers made a series of four dives throughout one day. Both methods survey visually identifiable, diurnally active, non-cryptic species that are located on, within, or above the reef structure. All census dives were made between 20 meters and 33 meters.

After the data were collected, population parameters were calculated. From the stationary data, these included Simpson's Diversity and evenness. Simpson's Diversity was calculated using the following formula:

$$\frac{1}{\sum_{i=1}^{s} P_i^2}$$

where Pi^2 is the square of the proportion of species i abundance. Evenness is Diversity divided by the total number of species, s.

To date, field survey time has been "piggy-backed" on existing cruises. For the Flower Gardens, space has been provided on the Continental Shelf Associates, Inc. (CSA) monitoring cruises during September 1994 and late-August 1995. A cruise in June 1995 was funded through the National Fish and Wildlife Foundation with matching funds from the Flower Gardens Fund, Gulf Reef Environmental Action Team (GREAT) and Oceanographic Expeditions. This cruise consisted of half researchers and half REEF participants. Twenty-five sport divers were trained in reef fish identification and conducted 212 surveys.

All of the Stetson Bank research has been conducted during the GREAT monitoring cruises. Data for this study were collected on the October 1994, May 1995, and October 1995 cruises.

RESULTS

Table 2A.3 shows the results of the Roving Diver surveys and the number of surveys done during each cruise. The cumulative number of fishes recorded at the East and West Flower Garden Banks combined and at Stetson Bank is 115 and 139 respectively.

Figure 2A.7 summarizes the Stationary Diver data. For both the East and West Flower Gardens, the spring diversity values are higher than the fall diversity values, which correspond with the opposite result seen in the total number of individuals recorded.

Table 2A.4 is the cumulative list for the Flower Gardens and Stetson Bank. Species that were not seen during either of the survey methods but were seen during the cruise are marked with an asterisk (*).

SUMMARY

Despite the well-developed reefs and the fact that Stetson Bank is much smaller than either of the Flower Gardens, the total number of species recorded at Stetson Bank is substantially higher. The habitat-types and food-types available to fishes at the Flower Gardens is more homogeneous than at Stetson Bank. The Flower Garden Banks resemble a sea of coral with small patches of sand intermixed. However, Stetson Bank has clay flats with sand, claystone pinnacles, coral patches and a vertical wall. Each of these areas support different species of fishes. Therefore, a larger diversity of fishes might be supported by Stetson Bank due to increased opportunities and niches. However, in addition to the degree of habitat and food heterogeneity, multitude of factors probably interact to support more species at Stetson Bank.

Table 2A.3 Roving diver data from three cruises at each bank is shown. Total number of surveys per cruise is n. The cumulative species count over the three cruises is 115 at the East and West Flower Gardens and 139 at Stetson Bank.

ROVING DIVER DATA

	East FGB			**West FGB**			**Stetson Bank**		
Date	Sept. 1994	June 1995	Aug. 1995	Sept. 1994	June 1995	Aug. 1995	Oct. 1994	May 1995	Oct. 1995
Total # Species	75 n=12	84 n=23	94 n=42	74 n=18	76 n=23	79 n=24	98 n=24	92 n=20	94 n=22

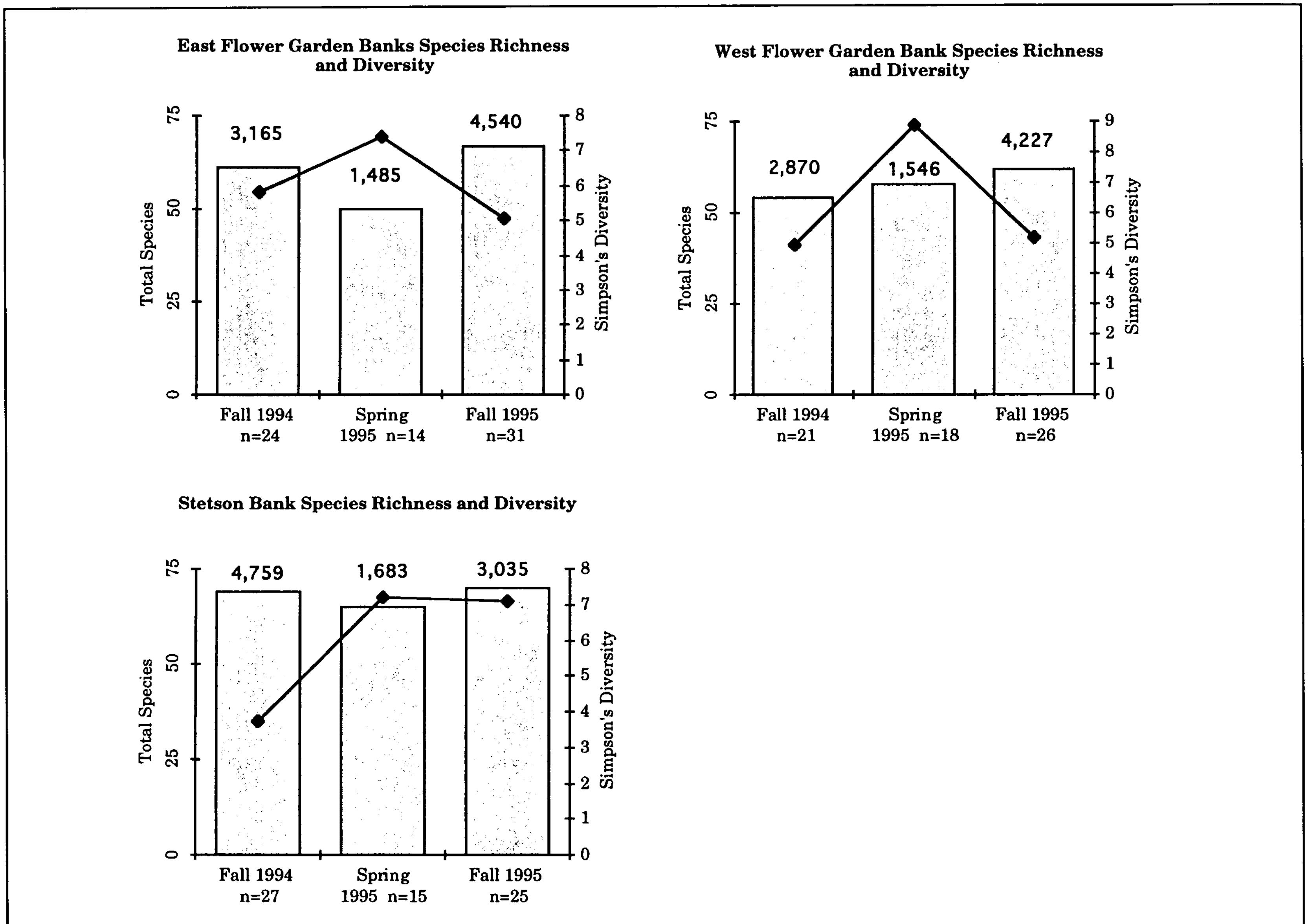

Figure 2A.7. These graphs represent stationary diver data. The bars are total species seen, the line indicates the diversity values, and the bold numbers are the total number of individual fishes seen.

Table 2A.4. A cumulative fish species list for the Flower Garden Banks National Marine Sanctuary and Stetson Bank. Species that were not seen during the surveys, but were seen during the cruise are marked with an asterisk(*). An "i" indicates the species has only been sited once and is considered incidental.

Cumulative Species List

	Flower	Stetson		Flower	Stetson
Acanthuridae			**Echeneididae**		
Acanthurus bahianus	x	x	*Echeneis naucrates*	x	x
Acanthurus chirugus	x	x	**Ephippidae**		
Acanthurus coelruleus	x	x	*Chaetodpterus faber*		x
Apogonidae			**Gobiidae**		
Apogon affinis		*	*Coryphopterus eidolon*	x	
Apogon maculatus	*	x	*Coryphopterus punctipectophorus*		*
Apogon pseudomaculatus	*	x	*Gobiosoma oceanops*	x	x
Apogon quadrisquamatus		*	*Gnatholepis thompsoni*	x	x
Balistidae			*Ioglossus calliurus*		x
Balistes capriscus		x	*Quisquilius hipoliti*		x
Balistes vetula	x	x	**Holocentridae**		
Canthidemis sufflamen	x	x	*Holocentrus adescensionis*	x	x
Melichtys niger	x	x	*Holocentrus bullisi*		x
Bothidae			*Holocentrus marianus*		x
Bothus lunatus		x	*Holocentrus rufus*	x	x
Bothus ocellatus	x		*Myripristis jacobus*	x	x
Carangidae			*Sargocentron vexillarius*		x
Alectis ciliaris		x	**Inermiidae**		
Caranx bartholomaei	x	x	*Emmelichthyops atlanticus*	x	
Caranx crysos	x	x	*Inermia vittata*	x	
Caranx hippos	x	x	**Kyphosidae**		
Caranx latus	x	x	*Kyphosus sectatrix*	x	x
Caranx lugubris	x	x	**Labridae**		
Caranx ruber	x	x	*Bodianus pulchellus*	x	x
Elagatis bipinnulata	x		*Bodianus rufus*	x	x
Serola dumerilli	x	x	*Clepticus parrai*	x	x
Seriola rivoliana	x	x	*Halichoeres bivittatus*	x	x
Carcharhinidae			*Halichoeres maculipinna*	x	x
Carcharhinus brevipinna	x		*Halichoeres garnoti*	x	x
Carcharhinus falciformis	x		*Halichoeres radiatus*	x	x
Carcharhinus plumbeus		x	*Thalassoma bifasciatum*	x	x
Chaetondontidae			*Xyrichtys splendens*	x	x
Chaetodon aculeatus	x	x	**Lutjanidae**		
Chaetodon aya	i		*Lutjanus griseus*	x	x
Chaetodon ocellatus	x	x	*Lutjanus joco*	x	x
Chaetodon sedentarius	x	x	**Malacanthidae**		

Cumulative Species List

	Flower	Stetson		Flower	Stetson
Chaetodon striatus	x	x	*Malancanthus plumieri*	x	x
Cirrhitidae			**Mobulidae**		
Amblycirrhitus pinos	x	x	*Manta birostris*	x	x
Clinidae			*Manta hypostoma*	x	
Emblemaria pandionis		x	**Monacanthidae**		
Ophioblennius alanticus	x	x	*Aleterus monoceros*		x
Parablennius marmoreus	x	x	*Aluterus scrptus*	x	x
Dasyatidae			*Cantherhines macroceros*	x	x
Dasyatis americana	x	x	*Cantherhines pullus*	x	x
Diadontidae			**Mullidae**		
Chilomycterus schoepfi		x	*Mulloidichthys martinicus*	x	x
Diodon holocanthus	x		*Pseudupeneus maculatus*	x	x
Diodon hystrix	x	x	*Equetus lanceolatus*		x
Muranidae			*Equetus punctatus*	x	x
Echelycore nigricans		x	*Equetus umbrosus*		x
Gymnothorax miliaris	x	x			
Gymnothorax moringa	x	x	**Scombridae**		
Gymnothorax vicinus	x	x	*Acanthocybium solanderi*	x	x
Myliobatidae			*Sarda sarda*		x
Aetobatus narinari		x	*Scomberomorus cavalla*		x
Orectolobidae			**Scorpionidae**	x	
Ginglymostoma cirratum	*	x	*Scorpaena plumieri*		x
Ostraciontidae			*Scorpaenodes caribbaeus*		*
Lactophyrs bicaudalis	x	x	**Serranidae**	x	
Lactophyrs polygonia	x	x	*Cephalopholis cruentata*	x	x
Lactophyrs quadricornis	x	x	*Cephalopholis fulvus*	x	x
Lactophrys triqueter	x	x	*Epinephelus adscensionis*	x	x
Pomacanthidae			*Epinephelus guttatus*	x	x
Centropyge argi	x	x	*Epineplelus inermis*		x
Holacanthus bermudensis	x	x	*Epinephelus morio*		x
Holocanthus ciliaris	x	x	*Hypoplectrus gemma*		i
Holocanthus tricolor	x	x	*Hypoplectrus puella*		i
Pomacanthus paru	x	x	*Liopropoma eukrines*	x	x
Pomacentridae			*Liopropoma rube*	x	x
Abudefduf saxatilis	x	x	*Mycteroperca bonaci*	x	x
Chromis cyanea	x	x	*Mycteroperca interstitalis*		x
Chromis enchrysura		x	*Mycteroperca microlepis*	x	x
Chromis insolata	x	x	*Mycteroperca phenax*	x	x
Chromis multilineata	x	x	*Mycteroperca venenosa*		x
Chromis scotti	x	x	*Mycteroperca rubra*	x	x

Cumulative Species List

	Flower	Stetson		Flower	Stetson
Microspathodon chrysurus	x	x	*Mycteroperca tigris*	x	x
Stegastes diencaeus	x	x	*Paranthias furcifer*		x
Stegastes fuscus	x	x	*Serranus annularis*		x
Stegastes partitus	x	x	**Sparidae**	x	
Stegastes planifrons	x	x	*Calamus calamus*	x	x
Stegastes variabilis	x	x	*Calamus nodosus*		x
Pomadasyidae			**Sphyraenidae**	x	
Haemulon macrostomum		x	*Sphyraena barracuda*		x
Haemulon melanurum	x	x	**Synodotidae**	x	
Priacanthidae			*Synodus intermedius*	x	x
Priacanthus arenatus		x	*Synodus saurus*	x	x
Priacanthus cruentatus	x		*Snyodus snyodus*		x
Rachycentridae			**Tetradontidae**	x	
Rachycentron canadum		x	*Canthigaster rostrata*	x	x
Scaridae			*Sphoeroides spengleri*		x
Scarus coelestinus	*i				
Scarus iserti	x	i	TOTAL # SPECIES	115	139
Scarus taeniopterus	x	i			
Sparisoma atomarium	x	x			
Sparisome aurofrenatum	x	x			
Sparisoma viride	x	i			
Sciaenidae					
Equetus acuminatus		x			

There appeared to be higher diversity and fewer individuals in the late spring/early summer than in the late summer/early fall. The majority of the recruitment in the Gulf occurs in late spring to early fall (McGowen 1985) and therefore, a larger number of individuals should be present after this pulse. Mortality due to relatively low temperatures (around 19°C) in the winter may reduce populations prior to spring.

It is unclear why the diversity value of the fall 1995 survey at Stetson remained high. More detailed analysis of the species composition and future data points could provide insight.

These data represent only the first half of a three-year study. Future cruises will be in May/June 1996, October 1996, and May/June 1997. In addition, REEF involvement at the FGBNMS and Stetson Bank will increase, thus raising awareness and involvement of the sport divers who use these resources. Future data analysis will include statistical measures for differences between the three banks, between seasons, and between sampling methods. Temporal variability in species composition, species abundance and trophic structure will be measured.

The Flower Gardens and Stetson Bank are under relatively little pressure from human activity compared to reefs and banks elsewhere. Studies of natural temporal variation at these locations may influence opinions about the nature of community health in marine ecosystems in general and enable more effective monitoring programs on these and other reefs. Ultimately, a better understanding of factors influencing reef fish populations will also enable more effective management of these important resources.

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SPATIAL AND TEMPORAL HABITAT USE OF THE FLOWER GARDEN BANKS BY CHARISMATIC MEGAFAUNA

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INTRODUCTION

Conservation of our living natural resources is largely dependent on our understanding of how ecological communities are composed and the processes molding them. The Flower Garden Banks National Marine Sanctuary represents a unique ecological community composed of a broad spectrum of resources, including those organisms residing there. The banks serve as home to many reef species, while also serving as important habitat for many wide-ranging pelagic species, such as whale sharks, hammerhead sharks, manta and devil rays, and sea turtles. Little is known regarding the ecology of these organisms, due in large part to the difficulty of locating them and observing their behavior and movements over time. The Flower Garden Banks and Stetson Bank present an opportunity for scientists to study these nomadic animals, their associations with topographic highs, and how they utilize resources at them.

The purpose of these studies is to investigate and to interpret patterns of both behavioral resource use and habitat association of pelagic elasmobranchs and sea turtles with the Flower Garden Banks, Stetson Bank, and MOBIL's High Island 389A platform. The reason for including the platform in these studies is to investigate whether these organisms will utilize a man-made topographic feature in addition to the natural ones.

The significance of this research unfolds across several levels of scale. Firstly, such knowledge will prove important in the management of this sanctuary, for example when scheduling seismic surveys or research cruises. Knowledge of seasonal occurrences of these species would be useful for the promotion of the flourishing ecotourism industry there. Monitoring several of these species at the Flower Gardens may be useful in evaluating the ecological health and the integrity of the sanctuary. Secondly, the conclusions drawn from these studies may be extrapolated for the purpose of identifying topographic highs which potentially serve as important habitats for these species in other regions.

METHODS

This study consists largely of field observations conducted at the study sites by trained and untrained observers. Observation types include underwater, surface, and aerial surveys. Underwater observations are conducted on SCUBA and recorded by description, photographs, or video. Surveys are collected year-round opportunistically with the greatest concentrations occurring during the summer months. Data recorded includes species identification, individual natural markings, estimated size, sex, relative abundance, activity, depth, location, time of day, date, and environmental conditions. Observations are then evaluated for accuracy of data. Seasons are categorized as follows: Spring (March-May); Summer (June-August); Fall (September-November); Winter (December-February).

Manta rays and sea turtles possess useful characteristics in identifying individuals. A library composed of current and historical photographic or video documentation is utilized in conjunction with personal observations to identify individuals. The photographic library is used to create a catalog of individuals. The maintenance of this catalog and library allows scientists to track the individuals' habitat use over time at these sites. It may also be useful in monitoring an individual's growth and in estimating the size of the population.

Selected sea turtles are captured at the study sites on SCUBA using large mesh turtle bags. The animals are brought on board ship for observations and sampling. Data recorded includes straight and curved carapace lengths, width, weight (when possible), tail length, sex, evidence of plastron softening, and claw length. Identifying characteristics such as carapace or flipper notching and barnacle coverage is recorded through the use of photography. Blood samples are taken from the large sinus in the neck for histological and genetic analysis. An ultrasound is conducted in order to ascertain the sex of a subadult or juvenile turtle or to gauge the reproductive state of an adult individual. The turtle is then tagged with monel flipper tags on both front limbs, and a PIT tag is injected into one of the front shoulder muscles for future identification. Radio and/or satellite transmitters are fiberglassed onto the animal's carapace to permit remote monitoring of its movements. Turtles not captured but encountered underwater by divers are measured, photographed and then logged into the database. Sargassum floats passing over the study sites are sampled for hatchling sea turtles which may use this resource as refuging habitat during the "lost year."

RESULTS

Observations conducted at the study sites reveal a diverse assemblage of sharks, rays and sea turtles. Tables 2A.5 and 2A.6 reflect pooled seasonal observations of charismatic megafauna by trained and untrained observers. These tables do not include all data gathered to date. Five species of both sharks and rays have been identified at the Flower Garden Banks, while several species of carcharhinid and sphyrnid sharks remain to be identified. One devil ray species encountered at the Flower Garden Banks, *Mobula tarapacana*, is a newly documented species for the

Table 2A.5. Observations, Flower Garden Banks.

TAXA	SPRING	SUMMER	FALL	WINTER
Sharks				
Carcharhinus sp.	J-schooling	J	J	J-schooling
Carcharhinus falciformis	J-schooling	J	J	J-schooling
Carcharhinus perezii		J	J	
Ginglymostoma cirratum	A	A	A	
Rhincodon typus		S/A	S/A	
Sphyrna lewini	A-schooling	A	A	A-schooling
Sphyrna sp.		A	A	
Rays				
Aetobatis narinari	A-schooling			A-schooling
Dasyatis americana	A	A		
Manta birostris	J/S/A	J/S	J/S	J/S/A
Mobula hypostoma		A		
Mobula tarapacana		A		
Sea Turtles				
Caretta caretta	S/A	H, S/A	S/A	
Dermochelys coriacea		S/A		

Atlantic waters off North America. In the Atlantic, this species was previously known to occur in tropical and warm temperate waters along the east coast of South America.

During the winter and spring months (December-May), scalloped hammerhead sharks (*Sphyrna lewini*) are found schooling at the Flower Garden Banks. These schools are composed of adult males and possibly females, which utilize this area as winter feeding habitat. As many as 100 individuals have been reported at a time by divers. Spotted eagle rays (*Aetobatis narinari*) are also observed schooling there, with estimates of 200 not uncommon. Sexes have been difficult to ascertain for these species in the water, as they are wary of divers approaching them. Manta rays (*Manta birostris*) frequent the Flower Gardens year-round; however, it is during the winter and spring when large (>3.5 m DW) mantas may be observed. Both sexes are recorded in the area and sometimes swim in pairs during the late winter and spring months. Several carcharhinid sharks (*Carcharhinus sp.*) have been reported as schooling at this time also, by trained and untrained observers. Due to the difficulty in identifying carcharhinid sharks, they have been identified to genus, awaiting photographic documentation or specimens that will confirm species identification. Specimens of the Caribbean reef shark (*C. perezii*) and silky shark (*C. falciformis*) have been obtained using hook and line or fish traps, thus confirming their presence at the study sites.

Schooling hammerheads and eagle rays depart the Flower Garden Banks as coastal waters warm in the spring. In June of 1995, what appears to be a neonate manta ray was filmed by Dr. Steve Gittings at the East Bank. This individual was swimming with another manta of unknown sex with an estimated disc width of

Table 2A.6 Observations, Stetson Bank.

TAXA	SPRING	SUMMER	FALL	WINTER
Sharks				
Carcharhinus sp.	J/S-schooling	J/S	J/S	J/S-schooling
Carcharhinus plumbeus	S/A		S/A	
Ginglymostoma cirratum	A		A	
Rhincodon typus		S/A	S/A	
Sphyrna lewini		S/A		
Rays				
Aetobatis narinari	A			A
Dasyatis americana	S/A			
Manta birostris	J/S	J/S	J/S	
Mobula hypostoma		A		
Sea Turtles				
Caretta caretta	S/A		S/A	
Eretmochelys imbricata	A	S/A		

J=Juvenile, H=Hatchling, S=Subadult, A=Adult

2.5 m. Very little is known about the age and growth of manta rays; female specimens harpooned during the first half of the century (with a disc width of greater than 4.0 m) were found to be gravid. A 3.6 m male specimen was examined in the 1950s and determined to be sexually immature. Manta rays observed at the Flower Gardens during the summer and fall months range in size from 1.5 to 3.4 m in disc width. These data in addition to the neonate observed earlier this year all suggest these banks are utilized by neonate and juvenile manta rays as nursery habitat. Nursery habitat for manta rays has not been identified in other large marine ecosystems.

Aggregations of up to five individual manta rays have been observed at the Flower Garden Banks. Loop and line feeding behavior is observed, particularly in the early morning and late afternoons along the reef escarpments. Manta rays apparently seek out divers underwater, permitting interactions that do not threaten the rays. One manta ray during the past summer consistently sought out divers and appeared to enjoy the attention received. These animals do not pose a threat to divers, and easily outswim and outmaneuver people in the water.

Whale sharks (*Rhincodon typus*) are not known to frequent the banks during the winter months but do so during the summer and fall months. These animals may be considered uncommon over the reef crest; however, they may be more common in the region. Aerial surveys over the banks during the past several years, (sponsored in part by MOBIL and ANR Pipeline), show whale sharks aggregating in groups of 3-25 individuals, the day following a mass coral spawning. One such aggregation, which also included other shark species, jackfish and various baitfish, was observed feeding at the surface within a 30 m diameter area near the West Bank. All whale sharks observed to date are larger than 3.6 m in length.

An interesting phenomenon observed is the schooling of juvenile silky sharks at the MOBIL High Island 389A platform, adjacent to the East Flower Garden

Bank. Schools of 100 or more are encountered there during the late fall, winter and spring seasons. These schools disperse during the warmer months of the spring and summer, although individuals may be observed there at night. Juvenile sharks are thought to seek refuge in nursery areas (primary or secondary), a strategy to avoid predation by larger sharks. Such a hypothesis may hold true in this situation. Juvenile silky sharks are found in the waters over the East Flower Garden Bank during the summer months also.

Stetson Bank offers habitat to several elasmobranch taxa, although the species richness at this site appears to be lower than for the Flower Garden Banks. Whale sharks, manta and lesser devil rays (*Mobula hypostoma*), eagle rays, hammerhead sharks, and several other species are recorded for this site. Sandbar sharks (*C. plumbeus*) are common at the site, while reports of spinner sharks (*C. brevipinna*) and bull sharks (*C. leucas*) have yet to be confirmed. A large carcharhinid shark was reported there in October, possibly a tiger shark (*Galeocerdo cuvieri*), but this also remains to be determined. Tiger sharks are occasionally observed also at the Flower Garden Banks.

Three of the five species of sea turtles known to inhabit the Gulf of Mexico have been identified at the study sites. The loggerhead (*Caretta caretta*) is the most abundant marine turtle found at both the Flower Garden Banks and Stetson Bank. The hawksbill sea turtle (*Eretmochelys imbricata*) has been observed at Stetson Bank, while the largest marine turtle—the leatherback (*Dermochelys coriacea*)—has been observed at the surface at the East Flower Garden Bank. All of these turtles have been either subadult or adult animals. Confirmation of their maturity and sex can only be done by capturing the turtle and performing histological tests.

In addition to these large turtles, two hatchling loggerheads have been observed utilizing the sargassum floats passing through the sanctuary.

On 22 June 1995, a male subadult loggerhead sea turtle (curved carapace length 99cm) was captured at approximately 27 meters depth. This animal had blood taken, flippers tagged, and had a radio transmitter fiberglassed to the carapace. Since release, 53.5 hours of tracking time have been recorded, the last transmission being 16 September 1995. Preliminary data show the average surface time being 3.5 minutes, and average submergence time as 36.23 minutes.

There is much more knowledge to be gained on the sea turtles inhabiting the Sanctuary and Stetson Bank.

SUMMARY

The Flower Garden Banks and Stetson Bank serve as important habitat to a diverse assemblage of elasmobranch and sea turtle taxa. During the winter this area is used as feeding habitat for scalloped hammerhead sharks, spotted eagle rays, and manta rays. Such habitat may be important to these species' population dynamics in the region, as this period is critical in the development of embryos. If gravid female sharks and rays inhabit these sites during this period, then it is likely upon their dispersal, they seek nursery habitat along the Gulf coast in which to leave their offspring. During the spring, summer, and fall neonate and juvenile manta rays may be found in the waters of the Sanctuary, indicating this area functions as a nursery habitat for the species. Observations of devil rays at the banks may indicate habitat associations as well. The occurrence of whale sharks over the banks, although uncommon, may reflect a courser scale of habitat use than exhibited by the manta rays. Both manta rays and whale sharks are filter feeders, and the largest organisms of their respective groups. It is possible there exists some resource partitioning demonstrated by these two species, but has yet to be experimentally tested. The schooling of silky sharks around an artificial topographic high (platform) presents an interesting question as to whether such structures increase the cohort survival of these animals, and may be useful in fisheries management should the species be exploited by humans.

A preliminary study of one subadult loggerhead sea turtle that was radio tagged and tracked for a total of 53.5 hours has demonstrated habitat association. Ninety-nine percent of a sea turtle's life is spent in the water, but over ninety percent of the research accomplished with these animals has been on the nesting beaches. A priority for sea turtle researchers is to conduct these deep water habitat studies with efforts to fill the gaping holes in the known life history stages (pelagic subadults, adults, and hatchlings) of these endangered species.

Catalogs of individual animals are presently under development. Video or photographic documentation of these species at the study sites is sought to expand our database library.

The Flower Garden Banks are unique structures on the North American Continental Shelf, and support a diverse and complex community of resident and nomadic organisms. Our ability to manage natural resources in the Northwestern Gulf of Mexico wisely is strongly linked with our knowledge and understanding of ecological patterns and processes structuring this ecosystem. Charismatic megafauna are an important component of the region's ecosystem and must be considered in resource management plans of the sanctuary.

Jeff Childs is a M.S. candidate in the Wildlife and Fisheries Sciences Department at TAMU. His professional interests include ecology and behavior of large pelagic fauna, ecosystem management, and diving science and technology.

Emma Hickerson has been in the zoology master's program of the Department of Biology at Texas A&M University since August, 1994. She also received her B.S. in Zoology from TAMU in December, 1993. Her present area of interest is sea turtle ecology and behavior.

Dr. Ken Deslarzes is a research coordinator at the Flower Garden Banks National Marine Sanctuary. His research interests are the ecology of coral reefs and using corallum as a sentinel of environmental changes. He received a License of Biology in 1987 and Diploma of Biology in 1990 from the University of Lausanne, Switzerland, and a Ph.D. in oceanography in 1992 from Texas A&M University, College Station.

THE MINERALS MANAGEMENT SERVICE FLOWER GARDEN BANKS NATIONAL MARINE SANCTUARY OIL SPILL RISK ASSESSMENT: AN EXAMPLE OF PARTNERSHIP

Dr. Alexis Lugo-Fernández
Environmental Studies Section
Minerals Management Service
Gulf of Mexico OCS Region

A risk assessment was initiated to identify the blocks from which slicks could reach and "contact" the Flower Garden Banks National Marine Sanctuary (FGBNMS) in the event of an oil spill on the Outer Continental Shelf (OCS). By contact, it is meant that a spill has transited or touched the FGBNMS; no physical contact of the resource with oil is implied. This clarification is needed because these banks are submerged.

The Minerals Management Service's (MMS) Oil Spill Risk Analysis (OSRA) model was employed to estimate the oil spill contact probabilities. These probabilities are denoted as "conditional probabilities" because they depend on the condition that a spill has occurred. The domain of the model extended between longitudes 88° and 97°W and from latitude 26°N to the coastline. The FGBNMS was represented as a quadrilateral whose corners coincide with the extreme points in the official boundary of the sanctuary. In the domain, 636 hypothetical oil spill point sources were distributed evenly. Five hundred (500) hypothetical spills per season were released from each point source for a total of 2,000 spills over a year. Contacts with the resource were counted and a relative frequency estimated and equated to conditional probabilities.

The oceanic currents advecting the oil in the model were obtained from a state-of-the-art model being developed for MMS by Dynalysis of Princeton. The model incorporates monthly climatological wind stress fields, heat flux, river freshwater inputs, and transport boundary conditions at the Yucatán Channel and Florida Straits. The model was run for 12 years and a climatological representative year was selected. Monthly averaged currents were computed for this year and used as the main input for this assessment. Additional current data were obtained from another MMS-funded study, the Surface Current and Lagrangian-Drift Program or SCULP. These currents represent quasi-Eulerian velocities estimated as averages in geographical boxes defined in Price and Lear (1995). The data were collected in the period from 15 October 1993, to 15 May 1994. The mean vectors were located at the center of each box and were substituted for the model's currents corresponding to the above period in the climatological year. Wind-drift of the slick was calculated using the 3% rule and Navy Corrected Geostrophic Wind Fields (Rhodes *et al.* 1989). The wind fields, which cover a time period of 27 years, are gridded every degree squared and are averaged over 12 hours.

Conditional or contact probabilities were estimated at 3-, 10-, and 30-day intervals. For each season and time interval, contours of conditional probabilities, expressed in percentages, were determined. The resulting contours were combined in a Geographical Information System (GIS) environment to produce composite contours for each time interval and were superimposed over OCS blocks. The GIS program can be used to identify blocks within selected composite contours. The MMS provided a copy of all maps to the FGBNMS manager for other applications.

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Dr. Alexis Lugo-Fernández has been an oceanographer with the MMS Gulf of Mexico OCS Region since 1989. His experience at the MMS includes preparation of NEPA Documents and management of Physical Oceanographic Studies in the Environmental Studies Section. His primary interests are physical processes on coral reefs and circulation in the shelf. Dr. Lugo-Fernández obtained his B.S. in physics and M.S. in marine sciences from the University of Puerto Rico, and Ph.D. in marine sciences (physical oceanography) from Louisiana State University.

SESSION 2B

NORTHEASTERN GULF OF MEXICO COASTAL AND MARINE ECOSYSTEM PROGRAM

Session: 2B - NORTHEASTERN GULF OF MEXICO COASTAL AND MARINE ECOSYSTEM PROGRAM

Co-Chairs: Dr. Robert Rogers and Dr. Robert Meyers

Date: December 12, 1995

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Northeastern Gulf of Mexico Coastal Characterization: Seagrass Mapping	Mr. Arturo Calix Dr. Lawrence Handley National Biological Service Southern Science Center
Northeastern Gulf of Mexico Coastal Characterization: Habitat Mapping	Mr. Lawrence R. Handley National Biological Service Southern Science Center
Manuscript not submitted	Mr. Christopher Friel Florida Department of Environmental Protection
Northeastern Gulf of Mexico Coastal and Marine Ecosystem Program: Offshore Data Search and Synthesis	Dr. Evans Waddell Science Applications International Corporation Raleigh, North Carolina
Characterization and Trends of Recreational and Commercial Fishing from the Florida Panhandle	Mr. David B. Snyder Continental Shelf Associates, Inc.

NORTHEASTERN GULF OF MEXICO COASTAL AND MARINE ECOSYSTEM PROGRAM: COASTAL CHARACTERIZATION

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INTRODUCTION

As gas and oil leasing proceeds in the northeastern Gulf of Mexico, environmental studies information is needed for future pre-leasing decisions and for necessary protective lease stipulations. The coastal area adjacent to the proposed development contains natural resources and socioeconomic infrastructures that may be affected by the proposed activities. During the early 1980s, available environmental and socioeconomic information pertaining to the Gulf of Mexico coastal habitats was synthesized by Southern Science Center (SSC), formerly USFWS's National Coastal Ecosystems Team, for the Minerals Management Service (MMS) in a series of "Coastal Ecosystem Characterizations." For the proposed offshore oil and gas development to proceed in a timely manner, federal, state, and local agency and private decision-makers need current information on coastal natural resources and processes, and pertinent socioeconomic infrastructure upon which to base their decisions. This study will update these data bases.

This Northeastern Gulf of Mexico Coastal Characterization update, which includes the coastal areas of southeast Louisiana, Mississippi, Alabama, and the Florida panhandle (Figure 2B.1), focuses on updating the information related to the previous characterizations of the area. The two existing characterizations, the Mississippi Deltaic Plain Region (southeastern Louisiana and Mississippi) and the Northeastern Gulf of Mexico Coast (Alabama and the Florida panhandle), are based on data that are now over 10-15 years old.

STUDY OBJECTIVES

- Develop electronically accessible seagrass, habitat, natural resource and selected socioeconomic features databases and maps for the northeast coast of the Gulf of Mexico
- Develop live bottom "Community Profile" for the northeastern Gulf of Mexico

STUDY TASKS

A. Tasks: This 30-month effort will be divided into five major tasks—

Task 1: Seagrass and Habitat Maps and Database Development

Task 2: Natural Resources and Socioeconomic Features Database Development. Develop maps and digital (GIS) coverages, where possible, for:

- (1) Biological Resources
  - (a) Bird Resources
    - i) Coastal seabirds and wading birds
    - ii) Shorebirds
    - iii) Waterfowl concentration areas
  - (b) Shellfish harvest areas
  - (c) Finfish harvest areas, including live bottoms
  - (d) Endangered and threatened species
- (2) Natural Resource Areas of interest
  - (a) Marine and Estuarine Sanctuaries
  - (b) National Wildlife Areas
  - (c) State Parks
  - (d) State Wildlife Management Areas
  - (e) Wild and Scenic Rivers
  - (f) National Natural Landmarks
  - (g) National Audubon Society Sanctuaries
  - (h) Intensively used Recreational beaches
  - (i) Other, as defined by NBS, MMS, and States
- (3) Digital Line Graphs from U.S. Geological Survey 1:100,000 quadrangles)
  - (a) Hydrology
  - (b) Transportation

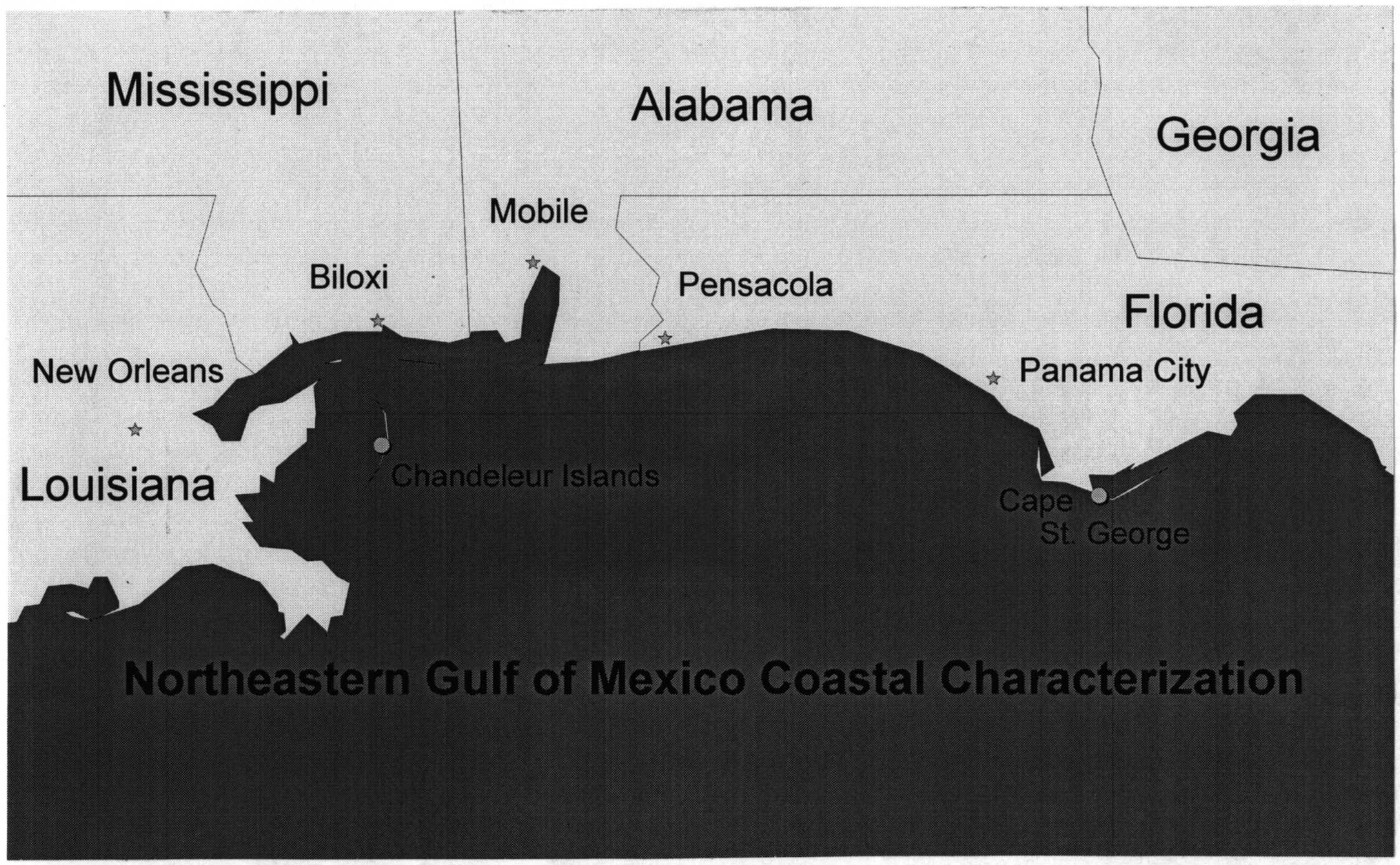

Figure 2B.1. Northeastern Gulf of Mexico coastal characterization.

(c) Political Boundaries
(d) 1990 Population
(4) Geology—Develop coverages for coastal erosion rates
(5) Oil and Gas Infrastructure (State Waters only)
(6) Landfills/Disposal Sites
(7) Develop Satellite Image Backdrop from Landsat Data

Task 3: Database Management and Transfer

Task 4: Prepare Live Bottom Community Profile

Task 5: Synthesis Report for the Project

B. Timing: 30 months, May 1995–October 1997.

C. Location: Northeastern Gulf of Mexico—Coastal southeast Louisiana, Mississippi, Alabama and Florida panhandle.

DATABASE MANAGEMENT/TRANSFER

To facilitate the dissemination of digital data and other information gained from the characterization study, an information infrastructure system involving many partners in study area will be developed. This information infrastructure system will allow users from federal, private, state, local, and other sources to access, manipulate, organize, and use data and information. All spatial data and metadata presented will adhere to the guidelines and procedures set forth in the Executive Order entitled "Coordinating Geographic Data Acquisition and Access: The National Spatial Data Infrastructure," signed by President Clinton on 11 April 1994. Data and metadata will adhere to standards for thematic information set forth by the U.S. Department of the Interior's Federal Geographic Data Committee (FDGC).

The system will be implemented in three overlapping steps of increasing complexity and capability by SSC and MMS. The products of these steps are not static but evolving, growing systems. These steps are:

1. Development of a Data Directory: Through a dial-up or Internet address a user (client) will be able to query the directory (server) and locate points of contact for desired information. Users can then contact the custodian of the data to determine whether the data meet their needs and, if so, determine how to acquire the data. Hard copy of directory will also be produced for those not on a network.
2. Development of an Automated Information Clearinghouse: The "directory" step will be extended to the "clearinghouse" so that users will be able to search a network of on-line SSC computers to find sources of information and access descriptive information (metadata) about the data sets to determine if the data sets meets their needs. The user can then contact the source of the data to determine how to acquire the data. Additionally, other means, i.e. CD-Rom and floppy disks, will be used where electronic networks are unavailable.

Lastly, SSC and MMS are developing the capability for increased access and integration of natural resource information from a number of organizations and locations that house this information, e.g., federal and state governments, museums, universities, and other entities. Once completed, the information will become part of MMS/NBS's Information Infrastructure that allows users to access a home page and download datasets and descriptions.

LIVE BOTTOM COMMUNITY PROFILE

SSC has contracted with continental Shelf and Associates, Inc. to prepare a live bottom community profile for the marine ecosystem of the northeastern Gulf of Mexico. Live bottoms for the profile are defined as hard substrate, including artificial reefs, that support sponge and soft coral communities. These communities are extremely important for recreational and commercial fishing. The profile will synthesize the available literature on live bottoms into a comprehensive and definitive reference source (report).

SUMMARY

Results of this effort will be used by a while variety of users. High priority applications include:

- Environmental Impact Statement Preparation
- Oil Spill Planning and Response
- Onshore Facility Siting
- Pipeline Routing
- Natural Resource Damage Assessments

Dr. James B. Johnston serves as Chief of the Spatial Analysis Branch at the National Biological Service's Science Center. Dr. Johnston's interests include (1) improving responsiveness and efficiency of decisionmaking by enhancing and establishing partnerships among government entities and the private sector to protect and restore coastal habitats, (2) applying state-of-the-art technoligies to monitor, map, analyze, and predict habitat changes and impacats; and (3) implementing innovative research and developmental studies that address resource issues.

Mr. Lawrence R. Handley is supervisor of the mapping section of the Southern Science Center. The mapping section is responsible fore the acquisition of aerial photography, the photointerpretation of seagrass, wetland and upland habitats, and the cartographic representation of the photointerpretation on base maps.

Dr. Robert Rogers serves as Program Manager of Coastal Studies under the Minerals Management Service's environmental studies program. He serves to coordinate the activities on this characterization between the NBS and MMS, insuring the utility of this information in management decisions and within the context of the Northeastern Gulf of Mexico Coastal and Marine Ecosystem studies program.

NORTHEASTERN GULF OF MEXICO COASTAL CHARACTERIZATION: SEAGRASS MAPPING

Mr. Arturo Calix
Mr. Lawrence Handley
National Biological Service
Southern Science Center

The mapping laboratory at the National Biological Service's Southern Science Center is presently engaged in a comprehensive assessment of the distribution and extents of seagrass habitat communities along the northeast Gulf of Mexico. Although initially sponsored by the Environmental Protection Agency's EMAP program, the project has evolved to include the sponsorship of Minerals Management Service and Florida Department of Environmental Protection, with active participation of staff from a host of federal, state and public entities.

The seagrass mapping project will eventually cover the coastal habitats from Brownsville, Texas to Anclote Keys, Florida mapped at scale of 1:24,000. To date, final maps have been completed for an area ranging from Chandeleur Islands, Louisiana to Perdido Bay, Florida, and St. Andrew Bay (Panama City), Florida. Photointerpretation and draft maps are currently in progress for Pensacola, Choctawhatchee, and St. Joseph Bays in Florida. The rest of the Florida panhandle from St. Vincent Island to Anclote Keys will be mapped by the spring of 1997.

The mapping protocol consists of stereoscopic photointerpretation, cartographic transfer, and digitization in accordance with strict mapping standards and conventions. Other important aspects of the protocol include the development of a classification system, groundtruthing, quality control, and peer review.

The process begins with the acquisition of large scale aerial photography from which the seagrass habitats can be determined and delineated. The information derived from the photography is subsequently transferred using a Zoom Transfer Scope onto a stable medium overlaying USGS 1:24,000 scale quadrangle basemaps. The primary data source is 1:24,000 scale natural color aerial photography flown by NASA-Stennis in the fall of 1992. In those cases where the data was inadequate or incomplete, contemporary supplemental data was acquired from other sources and used to complete the photographic coverage.

The classification system consists of two classes of open water-RIV (riverine, fresh water) and EST (estuarine or marine open water); and five classes of seagrass habitats. One class of continuous seagrass - CSG, for which no density distinction was made; and four classes of patchy seagrass based on percent ground cover -PSG1 (0-10% -very sparse), PSG2 (15-40% -sparse), PSG3 (45-70% -moderate), and PSG4 (75-95% -dense).

The photointerpretation groundtruthing phase included the participation of field staff from Gulf Islands National Seashore, U.S. Fish and Wildlife Service, Dauphin Island Sea Lab, Mississippi State University, Alabama Department of Conservation and Natural Resources, and Florida Department of Environmental Protection. Draft maps are sent out to the aforementioned agencies and staff for review. Digitization of all maps produced will begin in the summer of 1996.

NORTHEASTERN GULF OF MEXICO COASTAL CHARACTERIZATION: HABITAT MAPPING

Mr. Lawrence R. Handley
National Biological Service
Southern Science Center

The Northeastern Gulf of Mexico Coastal Characterization, which includes the coastal areas of southeast Louisiana (the Chandeleur Islands), Mississippi, Alabama, and the Florida panhandle, focuses on updating the wetland and upland habitat maps of the mid-1950s and 1978. These habitat maps are now at least 18 years old. The objective of the project is to update wetland and upland habitat maps and to complete seagrass mapping for these areas.

The system used for the wetland delineation is the *Classification of Wetlands and Deepwater Habitat of the U.S.* by Cowardin, *et al.* The *Land Use and Land Cover Classification System for Use with Remote Sensor Data* by Anderson, USGS, as modified by Handley, is used for upland habitat delineations. The seagrass maps that are being developed by the Southern Science Center will be merged with the new habitat maps so that seagrasses, upland habitats, and wetland habitats will be on the same maps. The habitat mapping completed under this project will use 1:24,000 scale USGS quadrangles as basemaps. There will be a total of 54 quads produced; 39 in Florida and 15 in Mississippi. All maps produced in this project will be in close proximity to both the Gulf and estuary shorelines.

Aerial photography will be acquired in March 1996 by NASA-Ames. The photography will be color infrared and at a scale of 1:65,000. The wetland and upland photointerpretation, as well as the cartography, will be completed by the U.S. Fish & Wildlife Service's National Wetlands Inventory in St. Petersburg, Florida. The review and quality control will be done by the regional coordinator of the National Wetlands Inventory in Atlanta, John Hefner and Charlie Storrs, and by Larry Handley of the National Biological Service's Southern Science Center. The management of the habitat mapping will begin with photo acquisition, followed by photo indexing, data prep, a groundtruthing field trip, quality control, draft maps, corrections, peer review, a second field review, and a final map. The delineated photos and maps are taken to the field for groundtruthing a minimum of two times. The draft maps are sent out for peer review to state and federal agencies, and local experts. Wetlands will be interpreted with a minimum mapping unit of one acre and uplands with a minimum mapping unit of five acres. Maps will also be digitized by the National Wetland Inventory.

The habitat mapping is scheduled to be completed in the early summer of 1997 with the digital data to be available in the fall of 1997.

Mr. Lawrence R. Handley is supervisor of the mapping section of the Southern Science Center. The mapping section is responsible for the acquisition of aerial photography, the photointerpretation of seagrass, wetland and upland habitats, as well as the cartographic representation of the photointerpretation on base maps.

NORTHEASTERN GULF OF MEXICO COASTAL AND MARINE ECOSYSTEM PROGRAM: OFFSHORE DATA SEARCH AND SYNTHESIS

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INTRODUCTION

With the possibility for oil and gas development and production and the associated potential for ecological impacts, the National Biological Survey initiated a phased sequence of studies which should produce a comprehensive description of the dominant environmental processes, the ecological communities, and their potential sensitivities in the project study area (Figure 2B.2). As the first phase in the process of establishing a rational base for management decisions, the present project will conduct a comprehensive search and integration of environmental information.

Specific project objectives are to gather environmental and socioeconomic information related to the continental shelf ecosystem and associated coastal and estuarine communities. This information will then be used to describe elements of the ecosystem in the study area, establish an understanding of the environmental

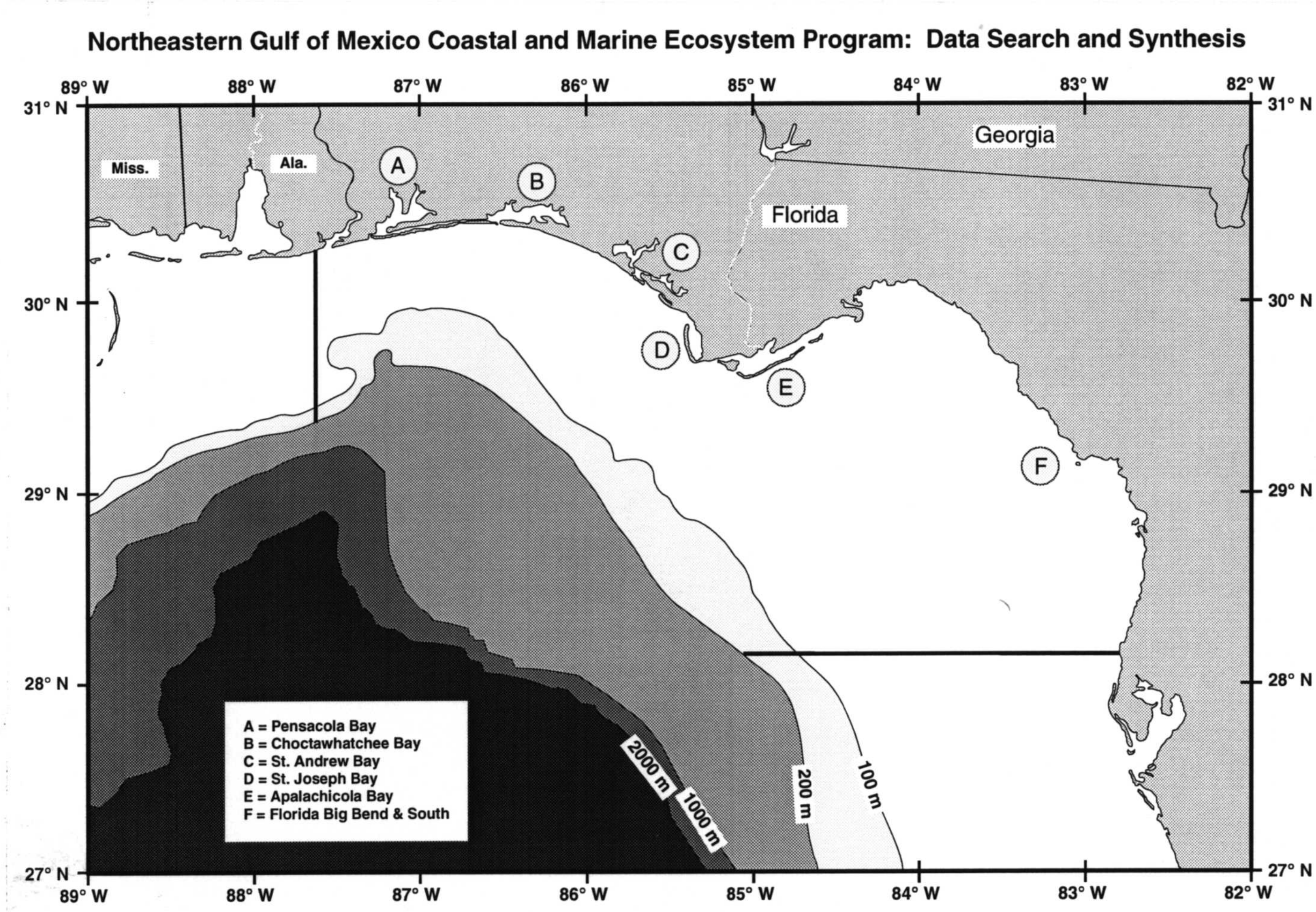

Figure 2B.2. Along shore extent of the study area is indicated by the black lines east of Mobile Bay and north of Tampa Bay. The six nearshore areas to be described separately are indicated by the letters A-F.

processes that drive the system, and identify those processes that are potentially sensitive to anthropogenic activities, particularly oil and gas operations.

PROJECT ORGANIZATION

Project activities are focused on three primary goals:

1. Create an annotated bibliography and unpublished data summary for the study area,
2. Produce a synthesis report describing the key components of the ecosystem in the study area with additional separate descriptions for the six nearshore regions shown in Figure 2B.2, and
3. Develop a conceptual ecosystem model to help organize requirements and activities in future and to help identify important data gaps.

For items 1 and 2, material is being organized topically into sections on biology, physical oceanography/ meteorology, chemistry, geology and socioeconomic processes and conditions in the study area. The conceptual ecosystem model will be incorporated into and follow the synthesis report chapters.

The above activities are ordered such that following identification and documentation of relevant literature and data sets, the program principal investigators would produce a well founded description of the present understanding of those topical conditions in the study area. Using this information, a conceptual model will be formulated to help integrate the ecosystem structure and related environmental conditions.

PROJECT STATUS

As of early December 1995, the annotated bibliography is essentially complete. The responsible principal or lead investigators are writing the chapters for the Synthesis Report. Using preliminary information from the synthesis material, the group responsible for developing the conceptual ecosystem model has begun work.

In its final form, the annotated bibliography will contain sections for each of the topical program disciplines. This structure has been adopted to make references easy to find. During the literature search, we have taken an inclusive rather than exclusive approach. Hence, citations are generally included in the overall project bibliography if they had either direct or potential application to the overall project objectives. When topical bibliographic sections are produced, a given citation may be present in more than one section. This is being done to minimize the need for users to look through all the topical sections to locate items to specific interest.

While a very few additional references are being added, the present status of citations is as follows:

Biology	-	1,409
PO/Meteorology	- 864/235 =	1,099
Geology	-	458
Chemistry	-	161
Socioeconomics	-	216
Total	-	3,347

PROGRAM ORGANIZATION

A group of scientists with knowledge of the study area has been brought together to support the project objectives. While several of the tasks are the result of a team effort, lead individuals have been defined for each area. These are as follows:

- Biology: Dr. Sneed Collard (UWF) and personnel from Barry Vittor and Associates
- Geology: Dr. Richard Davis (USF) and Mr. Dave Inglin (SAIC)
- Physical Oceanography/Meteorology: Dr. Peter Hamilton (SAIC)
- Chemistry: Dr. Jane Caffrey (U. of Calif, Santa Cruz)
- Socioeconomics: Dr. Fred Bell (FSU)
- Ecosystem Model Development: Dr. Roy Jacobson (SAIC) and Dr. Barry Vittor (BVA)

Supporting the program manger (Evans Waddell) is the Science Review Board which has as members Dr. Will Schroeder (Dauphin Island Sea Lab) and Dr. John Hitron (FSU). Dr. Hitron has the additional responsibility of reviewing work being done by Continental Shelf Associates in a companion study that focuses on fisheries in the study area.

The project period of performance extends through the end of April 1996 at which time the final synthesis report is due. The final annotated bibliography (in hard copy and digital form) is expected to be submitted in March 1996.

Dr. Evans Waddell has worked at Science Applications International Corporation (SAIC) for the past 18 years where he is presently an Assistant Vice President. He has been involved as either a program manager or principal investigator on marine studies (usually physical oceanographic) in the Gulf of Mexico over the past 15 years. Dr. Waddell received a B.A. and M.A. from the University of Virginia and a Ph.D. in Marine Science from Louisiana State University.

CHARACTERIZATION AND TRENDS OF RECREATIONAL AND COMMERCIAL FISHING FROM THE FLORIDA PANHANDLE

Mr. David B. Snyder
Continental Shelf Associates, Inc.

BACKGROUND AND OBJECTIVES

The Florida panhandle Outer Continental Shelf (OCS) region supports abundant fish and shellfish resources that form the basis for multi-species commercial and recreational fisheries. The region is also an area of interest for oil and gas exploration potentially leading to development and production activities. Due to industry interest and the potential for impact to fisheries, the National Biological Service (NBS) contracted Continental Shelf Associates, Inc. (Contract Number: 1445-CT09-95-0047) to characterize the commercial and recreational fisheries of the Florida panhandle by analyzing existing landings and survey data. This study will help to improve understanding of the area's fishing activities and identify potential conflicts with oil and gas operations. The information gathered will help to ensure that development of petroleum resources, if it occurs, will exert minimal impacts upon recreational and commercial fisheries of the Florida panhandle region.

The main goal of this project is to provide a profile of marine recreational and commercial fishing from the Florida panhandle during the time period 1 January 1983 through 31 December 1993. Specific objectives are as follows:

- Determine the total number of recreational and commercial fishing trips initiated from the Florida panhandle;
- Determine the fishery gear type and species targeted for the trips;
- Determine the locations, including but not limited to features such as natural live bottoms or artificial reefs, where fishing was performed during the trips;
- Describe trends in recreational and commercial fishing related to the first three objectives; and
- Identify any relationship(s) between recreational and commercial fishing initiated from the panhandle and oil and gas structures in the Gulf of Mexico.

METHODS

Recreational and commercial fishery data for the Florida panhandle were requested from the National Marine Fisheries Service (NMFS) and the Florida Department of Environmental Protection (FDEP). Two recreational fishing data sets, both administered by NMFS, provided information needed to describe recreational fisheries. The Marine Recreational Fishing Statistics Survey (MRFSS) estimated catch (species, numbers, weight, and size), mode (shore, bridge, private boat, charter boat), and distance from shore (inland, ≤ 10 miles, >10 miles) for fishing trips made by recreational anglers. The MRFSS survey was designed to estimate catch and effort (trips) for the entire west coast of Florida, so it was necessary to post-stratify the raw catch and effort data for the Florida panhandle sub-region. We applied NMFS's recently developed methods to extract and post-stratify the raw survey data for Florida's gulf coast into a smaller panhandle sub-region. Post-stratification was applied to MRFSS data from 1983 to 1993.

The NMFS Headboat Survey (HS) was the second source of recreational fisheries information. The HS data set contained catch and effort data from head or party boats operating in different regions of the southeastern United States. The HS recognizes the Florida panhandle (Carabelle to Perdido Pass) as a subdivision of the overall survey, so it was not necessary to post-stratify the HS data. The HS data were available from 1986 to 1993.

Commercial fisheries data were obtained from FDEP and the NMFS. The Florida Trip Ticket System (FTTS), maintained by the FDEP, provided catch and effort (number of trips) for all coastal counties from 1986 to 1993. FTTS data were requested from the eight counties comprising the Florida panhandle: Bay, Escambia, Franklin, Gulf, Okaloosa, Santa Rosa, Wakulla, and Walton. There were no estimates of commercial trips available before 1986. Prior to 1986, NMFS gathered all county-level landings data.

The second commercial data set acquired was NMFS's General Canvass Landings Statistics. This data set provided landings estimates by gear-type for each species. Landings are reported by cells in NMFS's statistical grid system. These grids ostensibly represent where the fish were actually caught (or landed). Statistical Grids 7 through 10 encompass the eight panhandle counties.

To aid the interpretation of general trends in catch and effort, the catch for all data sets was classified into ecological groups. The groups and their key species are as follows:

- Baitfishes: Gulf menhaden, Spanish sardine, scads;
- Coastal Pelagic Fishes: ladyfish, jack crevalle, king and Spanish mackerels;
- Demersal Fishes: striped mullet, black drum, spot, seatrouts;
- Oceanic Pelagic Fishes: swordfish, tunas, billfishes, dolphin;
- Reef Fishes: groupers, snappers, porgies, amberjacks; and
- Invertebrates: shrimps, oysters, blue crab.

RESULTS

The following results on recreational and commercial fisheries are preliminary and based upon work completed to this point. Final results will be explicated in a characterization and trends report submitted to NBS upon completion of the project.

The post-stratified MRFSS data revealed that an average of 373,000 fishing trips were made annually from the Florida panhandle during the 1983 to 1993 period. Most of these trips were made within 10 miles of shore or in inland waters. Post-stratified catch estimates for the Florida panhandle have not been analyzed.

The number of trips made by headboats operating from panhandle ports averaged 2,463 for the 1986 to 1993 period. Most headboat trips were half day or full day trips. The average number of fish landed by headboat anglers was 987,141 per year. The average annual weight of the catch was 336,879 lbs. The average number and weight of fish caught have declined slightly since 1986. Headboat anglers primarily caught reef fishes. Vermilion snapper, red porgy, and tomtate dominated the catches.

Commercial landings for the eight panhandle counties averaged 51,691,643 lbs per year over the 1983 to 1993 period. Annual totals fluctuated slightly around the average with a low of 45,244,784 lbs reported in 1991 and a high of 59,529,010 lbs reported in 1989. No trends were evident in the overall landings. Baitfishes and invertebrates accounted for 29% and 25% of these annual average landings, respectively. Coastal pelagic species, mostly ladyfish, jack crevalle, and blue runner, contributed about 17% of the average landings for the period. Demersal fishes (striped mullet and seatrouts), reef fishes (snappers and groupers), oceanic pelagic fishes (yellowfin tuna and swordfish) and various unclassified species contributed the remaining portion of the average annual catch.

At the county level, Gulf County produced the highest average landings of all panhandle counties over the 11-year period followed by Bay, Franklin, Okaloosa, Escambia, Wakulla, Santa Rosa, and Walton Counties. Gulf, Bay, Okaloosa, and Santa Rosa County landings consisted mostly of baitfishes (menhaden, Spanish sardine, round scad, and thread herring), coastal pelagic fishes (ladyfish), and demersal fishes (striped mullet). These species were caught with purse nets and to a lesser extent with beach seines and gillnets. The striped mullet was also a major contributor to the top landings for Escambia, Franklin, Santa Rosa, Walton, and Wakulla Counties. Striped mullet were caught with gillnets and trammel nets set in inshore waters. Escambia and Okaloosa Counties were the only counties where reef fishes (red and vermilion snappers) ranked in the top five landings. Reef fishes were taken primarily by hook and line and bottom longline. Invertebrates were important to several panhandle counties fisheries. In Franklin, Santa Rosa, Walton, and Wakulla Counties, oysters and blue crab were important components of the landings. Blue crabs were caught with traps, and oysters were harvested with tongs. Shrimps were most important to Escambia, Franklin, and Walton Counties where they are caught with bottom trawl gear. Bay County was the only county with an oceanic pelagic species ranked in the top five—yellowfin tuna. Yellowfin tuna were caught on drifting longlines.

The number of commercial fishing trips made annually from the Florida panhandle during 1986 to 1993 averaged 94,551. The total number of trips reported ranged from 66,401 in 1986 to 108,653 in 1987. Invertebrates and reef fishes accounted for over 70% of the average trips. The highest number of fishing trips 33,496 trips were made from Franklin County. Over 90% of these trips targeted oysters. Bay and Escambia Counties represented the next highest averages with 17,045 and 15,133 trips, respectively. Most of the trips were attributed to invertebrates including blue crab, oysters, and brown shrimp. Gulf County, which reported the highest average landings, had the next to lowest average number of trips. This is due to the large catches made by the purse nets set for baitfish and coastal pelagic species that characterize Gulf County's fisheries.

SUMMARY

Most recreational anglers fish in the Gulf of Mexico within 10 miles of shore or in inland waters. The Florida panhandle region supports diverse recreational and commercial fisheries. Recreational fishers on headboats catch mostly reef fishes. Headboat catches have declined during the 1986 to 1993 period while the number of trips reported has increased slightly. Commercial fishers landed an average of about 51 million pounds over the 1983 to 1993 period. In terms of landings, the most important species groups are baitfishes (menhaden, Spanish sardines, and round scad), invertebrates (shrimps, oysters, and blue crab), and coastal pelagic fishes (ladyfish, jack crevalle, and blue runner). These three groups collectively accounted for over 70% of the pounds landed in the Florida panhandle. Most commercial fishing trips were made for invertebrates, reef fishes (snappers, groupers, and amberjacks), and demersal fishes (striped mullet). The principal gear used includes purse nets for baitfishes and coastal pelagic fishes; gillnets for striped mullet; hook and line for reef fishes; drifting longlines for oceanic pelagic species; bottom trawls for shrimps; traps for blue crabs; and tongs for oysters.

David B. Snyder received his B.S. in zoology from the University of Florida and his M.S. in marine biology from Florida Atlantic University. He has been with Continental Shelf Associates, Inc. (CSA) since 1984 and manages or participates in all fishery-related projects for CSA.

SESSION 2C

FORUM ON ISSUES IN THE GULF STATES

Session: 2C - FORUM ON ISSUES IN THE GULF STATES

Co-Chairs: Ms. Bonnie LaBorde Johnson and Mr. Gary D. Goeke

Date: December 12, 1995

Presentation	Author/Affiliation
Forum on Issues in the Gulf States	Ms. Bonnie LaBorde Johnson Mr. Gary D. Goeke Minerals Management Service Gulf of Mexico OCS Region
Legislative Update: The 104th Congress	Ms. Jill Martin Office of Communications and Congressional Affairs Minerals Management Service
Improving the State of the Texas Gulf Coast: Geophysical Exploration, Geographic Information Systems, and the Texas Coastal Management Program	Mr. William D. Grimes Ms. Diana A. Ramirez Coastal Division Texas General Land Office
The Louisiana Coastal Management Division's Recent Advancements and Concerns Including Offshore Oil and Gas Exploration and Development	Mr. Greg DuCote Mr. Jon Truxillo Louisiana Department of Natural Resources
Mississippi: Issues in the Gulf States	Mr. Jerry Mitchell Mississippi Department of Marine Resources
Forum on Issues in the Gulf States	Mr. Brad Gane Alabama Department of Environmental Management
Coastal and Marine Issues: Florida	Ms. Lisa Polak Office of the Governor, Florida

FORUM ON ISSUES IN THE GULF STATES

Ms. Bonnie LaBorde Johnson
Mr. Gary D. Goeke
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This session provided the Gulf States with an open forum on coastal and marine issues of current concern in their respective states. The Minerals Management Service (MMS) strives to ensure that the public has an opportunity to provide input to its information base and decisionmaking process and aims to recognize and consider the public's concerns at every opportunity.

The session opened with a legislative update on specific legislation affecting both the Gulf States and MMS. A panel of State representatives gave a historical perspective on their interaction with OCS oil and gas exploration and development. Speakers discussed numerous issues including sand and gravel mining, fisheries, National Marine Sanctuaries, casinos, coastal nonpoint source pollution programs, shoreline erosion, geophysical exploration, geographic information systems, and updates on Coastal Zone Management Programs. Presentations were followed by an open-forum discussion.

LEGISLATIVE UPDATE: THE 104TH CONGRESS

Ms. Jill Martin
Office of Communications and Congressional Affairs
Minerals Management Service

On 3 January 1996, the House and Senate officially ended the first session of the 104th Congress and immediately began the second session. The legislative agenda of the first session was dominated by the "Contract With America" and budget and appropriations legislation. However, despite the intense and ongoing focus on these issues, a variety of other legislation, some impacting the programs of MMS, was debated and/or enacted by the Congress. In fact, between legislation already enacted or pending, both the Offshore and Royalty Management programs could be significantly impacted by the work of the 104th Congress. Listed below is a more in-depth discussion of legislation affecting MMS.

However, prior to a discussion of specific legislation affecting the bureau, a general overview of the status of environmental, budget, and appropriations legislation will be outlined for purposes of information and context.

ENVIRONMENTAL LEGISLATION

Many environmental initiatives were discussed at the end of the first session of the 104th Congress, but no major movement has occurred on items such as the Endangered Species Act, Superfund legislation, the Clean Water Act, and the Safe Drinking Water Act. Action is expected on some items (possibly Superfund and the Clean Water Act) during the second session.

It is interesting to note that while a reauthorization of these laws has been slow, Congress has used the appropriations and budget processes to affect environmental policy by attaching "riders" to pending legislation. In addition, several "Contract With America" initiatives, such as regulatory reform (including risk assessment and cost/benefit analysis requirements) and property rights legislation, could ultimately have a major impact on a broad range of environmental programs. All of the above-listed items have passed the House, but many are still pending in the Senate.

FISCAL YEAR 1996 APPROPRIATIONS

Currently, only seven of the 13 appropriations bills have been enacted into law—and only one reached the President's desk before 1 October. Of the six appropriations bills still pending enactment, three have been vetoed (including the Department of the Interior bill) and three are still pending before Congress. Part of the delay in completing the appropriations process was due to interest in the House to first enact the "Contract With America" initiatives. Therefore, the appropriations process got off to a late start. However, since the appropriations bills also made deep cuts in domestic spending and proposed elimination of programs which the Administration has deemed to be high priority, the appropriations process has been slowed by philosophical differences as well between the Congress and the Administration.

Obviously, finding a way to conclude the FY 1996 appropriations process will be one of the first items of interest in the second session of the 104th Congress since the FY 1997 process is scheduled to begin in February. However, it is also possible that the FY 96 process could entail a protracted debate with no clear resolution achieved in the near future.

BUDGET RECONCILIATION

The most important piece of legislation still pending enactment is Budget Reconciliation legislation. Budget Reconciliation is a mechanism to "reconcile" tax and spending policy with budget targets. This particular legislation proposes to balance the budget in seven years by a variety of actions, and in the process, makes sweeping policy changes to a broad array of federal programs (including the Royalty Management program). A bill was enacted by Congress but was vetoed by the President in December 1995.

Negotiations are currently underway between Congress and the Administration to bridge their differences on a range of budget and policy-related issues; however, it is impossible to say at this point whether or when a final budget reconciliation package can be completed. But it is safe to assume that, given the high priority of this legislation by Congress, the issue will continue to dominate the second session of Congress.

As a final item of general interest, the first session of the 104th Congress (and the beginning of the second session) has been notable in that announced retirements, etc. from both the House and Senate continue to run ahead of 1992's record-setting pace. To date, 25 House Members have already announced retirement (three whom are Committee Chairmen) and 12 other Members are seeking other offices. In the Senate, 13 Members have announced their retirement, many of whom have served three terms or more. Senate retirements have broken the previous record, which was set in 1896 when 11 Members retired.

SPECIFIC LEGISLATION AFFECTING MMS

- P.L. 104-58 (Deepwater Royalty Relief): On November 28, 1995, the President signed S. 395 into law—a bill to authorize and direct the Secretary of Energy to sell the Alaska Power Administration and to authorize the export of Alaska North Slope (ANS) crude oil. Title II of the bill lifts the 22 year ban on the export of ANS oil and allows export unless the President finds that selling the state's oil abroad is not in the national interest. It also requires that transport of ANS crude oil be by U.S. owned and crewed vessels.

Title III of the law is entitled "OCS Deepwater Relief." Listed below is a short summary of the major provisions of the legislation:

- Section 302 contains a discretionary provision which amends section 8(a) of the OCSLAA to promote development, increased production, and production of marginal resources from producing or non-producing leases. This provision includes non-producing leases and allows the Secretary to grant reductions on other than a case-by-case basis, but limits this discretionary authority to the Central and Western Gulf of Mexico (and that portion of the Eastern Gulf lying west of 87 degrees, 30 minutes West Longitude—offshore Alabama).

- Section 302 also contains a mandatory provision which provides royalty relief for existing leases located in water depths of 200 meters or greater in the Western and Central Gulf (as well as offshore Alabama). A suspension generally shall be granted within 180 days of application if the Secretary determines that a project is not economic in the absence of the relief. If relief is granted, then at a minimum, it shall be for a specified volume of production (depending on water depth—200-400 meters, 17.5 BOE; 400-800 meters, 52.5 BOE; and greater than 800 meters, 87.5 BOE).

  Further, if the Secretary fails to make an economic viability determination within the required time frame, the applicant will automatically receive the specified minimum volume relative to water depth (for leases where no production has occurred) or a royalty-free period of one year (for leases where production is already occurring).

- Section 303 contains a discretionary provision which adds a new bidding system to those already authorized by section 8 of the OCSLAA. Specifically, leases located anywhere on the OCS can be offered with suspension of royalties for a period, volume, or value of production, as determined by the Secretary.

- Section 304 contains a mandatory provision which requires the new bidding system authorized in section 303 to be used for the next five years for tracts located in water depths of 200 meters or greater in the Western and Central Gulf, as well as offshore Alabama. The suspension volumes would be the same as those used in section 302, depending on water depth.

- Financial Responsibility Requirements for "Offshore Facilities": On 17 November 1995, the Senate passed S. 1004 (US Coast Guard reauthorization legislation). Amendment 3059 to that bill was approved by voice vote and would clarify section 1016(c)(1) of the Oil Pollution Act of 1990 (OPA). Earlier, the House had passed their version of U.S. Coast Guard reauthorization legislation (H.R. 1361) which also included language clarifying section 1016(c)(1).

  Both versions of clarifying language address the major issues outlined by Secretary in his 20 July 1995 letter: jurisdiction; level of financial responsibility certification to be required; and *de minimis* exemptions. However, the Senate version comports more closely with the Secretary's specific recommendations with regard to the three issues mentioned above.

  Currently, the House and Senate are working to resolve differences over the two bills, including language pertaining to section 1016(c)(1). It is very likely that a final bill will be completed by Spring 1996 for signature by the President.

IMPROVING THE STATE OF THE TEXAS GULF COAST: GEOPHYSICAL EXPLORATION, GEOGRAPHIC INFORMATION SYSTEMS, AND THE TEXAS COASTAL MANAGEMENT PROGRAM

Mr. William D. Grimes
Ms. Diana A. Ramirez
Coastal Division
Texas General Land Office

INTRODUCTION

Many improvements are being made in the management of the Texas Gulf Coast's natural resources, often in response to changing technologies. The increasing use of airguns for geophysical exploration and the advent and availability of geographic information systems are two technological advances creating the need for state government to make regulatory and policy changes.

Additionally, the submission of the Texas Coastal Management Program to the U.S. Department of Commerce by Governor George W. Bush in October 1995 puts Texas on track to becoming the twenty-fifth state to participate in the federal Coastal Zone Management Program.

GEOPHYSICAL EXPLORATION

The Texas General Land Office (GLO) is the management agency for state-owned lands and mineral-right properties totaling 20.5 million acres. Included are beaches, bays and estuaries, and submerged lands extending 10.3 miles into the Gulf of Mexico.

An improving economy has helped push oil and gas leasing and, subsequently, seismic exploration on state-owned submerged lands to highs not seen since 1991. Exploration in the transition zone has increased 150 percent since 1994. The most significant trends in this renewed exploration are the increased use of airguns as an energy source and, more important, the use of 3-D instead of 2-D surveys.

It is widely accepted that the impacts of airguns on natural resources are less severe than those associated with conventional shothole/dynamite surveys. However, the expanded use of airgun technology—i.e., the use of multiple gun arrays and the increase in periodicity required for 3-D surveys—has raised state concern about potential impacts to living marine resources.

Three-dimensional surveys, whether airgun or shothole, by their sheer size are a cause of concern to both state and federal resource agencies. One current prospect in Texas covers approximately 110 square miles and will utilize 7,000 dynamite shots in the bay segment and 2,500 airgun shots in the Gulf of Mexico segment.

Unfortunately, current state regulations do not differentiate between the two technologies, and little research has been done that can address the questions raised by the resource agencies about short- and long-term environmental impacts.

In the mid-1980s, the GLO developed a computerized coding system to assist prospective developers of state-owned submerged land in addressing state and federal resource agency concerns. Participating agencies assign two-letter resource management codes to state land tracts that indicate environmental concerns or other features that may affect tract development. This system has worked well for the regulated community as well as the five participating regulatory agencies: the U.S. Fish and Wildlife Service, the U.S. Army Corps of Engineers-Galveston District, the National Marine Fisheries Service, the Texas Parks and Wildlife Department, and the Texas Historical Commission. However, it does not address long-term and cumulative impacts.

The General Land Office and Texas Parks and Wildlife Department are attempting to address this problem through the development of interim guidelines. These allow the acquisition of seismic data to continue so long as it meets the conditions set forth in the guidelines. For example, one guideline calls for the use of third-party observers to quantify small but potentially significant impacts resulting from seismic work.

The ultimate goal is to hold a workshop involving all stakeholders to consider a range of options, identify information gaps, identify research needs, and develop long-term criteria or thresholds that would satisfy both regulators and the regulated community.

GEOGRAPHIC INFORMATION SYSTEMS

The General Land Office is the project lead for WetNet, a project funded by the U.S. Environmental Protection Agency, Region 6. Through WetNet, the GLO will use the Internet to link all federal and state permitting and resource agencies with jurisdiction over wetlands. The Internet will be used to give agencies, universities, and the public on-line access to wetlands permitting information.

Participants in the project include EPA, Region 6, the U.S. Fish and Wildlife Service, the National Marine Fisheries Service, the U.S. Army Corps of Engineers, the Texas Department of Information Resources, the Texas Natural Resources Information System, the Texas Natural Resource Conservation Commission, and the Texas Parks and Wildlife Department.

Objectives of the project are (1) to implement the networked wetlands data-sharing structure developed under a previous EPA/GLO cooperative agreement; (2) to empower key users of the networked system by moving GIS technology onto the desktop of non-GIS staff at participating agencies; (3) to expand the WetNet distribution network; and (4) to educate nonparticipating representatives of local governments along the Texas Gulf coast, academic institutions, and public organizations about the availability of wetlands data through WetNet.

TEXAS COASTAL MANAGEMENT PROGRAM

Texas has been developing the Texas Coastal Management Program (CMP) for over five years. The two main focuses of the program are (1) improving interagency coordination to make decision-making in the coastal zone predictable, effective, and efficient; and (2) protecting coastal natural resources and enhancing the economy that depends on those resources.

In December 1994, Governor Ann Richards submitted the CMP to the U.S. Department of Commerce for federal approval. In January 1995, Texas inaugurated a new governor, George W. Bush, who withdrew the CMP from the federal approval process and submitted it to the 74th Texas Legislature for review.

The legislature amended the Coastal Coordination Act of 1991 and other statutes related to the CMP. Among the changes were these: (1) Special Area Management Plans were prohibited; (2) the boundary defining the coastal zone was moved seaward, narrowing the area subject to the program; (3) two additional coastal citizen representatives, appointed by the governor, and three additional state agency officials were added to the Coastal Coordination Council that oversees the program; and (4) the consistency review process of the Council was changed to give the attorney general final review. Several amendments incorporated parts of the program rules into the law: the definitions of coastal natural resource areas; an exclusive list of agency actions subject to the CMP goals and policies; and identification of the elements of the CMP. In addition, the legislature provided for establishment of a permitting assistance group for individuals and small businesses.

The CMP has been approved by the Coastal Coordination Council, the Texas Legislature, and the governor. Federal approval of the program is expected by 1 October 1996.

THE LOUISIANA COASTAL MANAGEMENT DIVISION'S RECENT ADVANCEMENTS AND CONCERNS INCLUDING OFFSHORE OIL AND GAS EXPLORATION AND DEVELOPMENT

Mr. Greg DuCote
Mr. Jon Truxillo
Louisiana Department of Natural Resources

In 1972, Congress enacted the Coastal Zone Management Act (CZMA) to provide assistance to coastal states in developing and implementing programs for managing their coastal areas. This legislation encouraged states to take a more active role in the conservation of resources within the coastal zone by allowing the states to develop processes for reviewing and evaluating federal actions for consistency with the programs the states developed; by providing monies to be expended under a coastal energy impact fund; by encouraging the states to take a more active role in the conservation of resources within the coastal zone; and by providing for other mechanisms to insure public input and participation within the programs. In response to the CZMA, the Louisiana State and Local Coastal Resources Management Act (SLCRMA) was passed in 1978 to protect, develop, restore and enhance the resources of the state's coastal zone. In July of 1980, the implementation and management of the Louisiana Coastal Resources Program (LCRP) became the responsibility of the Louisiana Department of Natural Resources.

This legislation memorialized the fact that we citizens of Louisiana are proud of our heritage and consider ourselves fortunate to enjoy the unique economic, ecological, and cultural qualities that make Louisiana such a vibrant place to live. It also demonstrates our willingness to conserve these resources for ourselves as well as for the rest of the nation. Unfortunately, many of the environmental features intrinsic to Louisiana that have helped to shape who we are and determined our distinct way of life are threatened, in many cases by the dynamic processes responsible for their creation. Unfortunately, too often, unplanned, unwise development fueled by ill-conceived policies has caused and\or exacerbated many of these problems in coastal Louisiana.

Louisiana is endowed with 40% of the wetlands in the continental United States; however, 80% of the wetlands lost yearly in the United States are Louisiana's. We are currently losing approximately thirty five square miles of coastal wetlands a year. The causes of coastal wetland loss are complex and include natural and man-induced influences such as sediment deprivation, subsidence, salt-water intrusion, storm activity, hydrological transportation systems alterations, and relative sea-level rise. Wetland restoration methods currently being employed to combat these losses include freshwater diversions, sediment diversions, beneficial use of dredge materials, hydrologic restoration, canal-bank and shore-line erosion control, sediment-capture/wave-dampening structures, and vegetative plantings of wetland species.

Louisiana's coastal wetlands occupy a crucial ecological niche for the entire marine ecosystem. Wetlands serve as an important hurricane and storm surge buffer. Without these buffers losses from storms such as Hurricane Andrew with its 12'-plus tidal surge would do even more damage and endanger even more lives than at present. These areas serve as refugia for oil and gas vessels supporting the OCS when they are also in need of shelter from these Gulf storms. In addition, these vegetated wetlands protect an enormous oil and gas infrastructure, a large portion of which supports OCS activities. Without these wetlands the oil and gas industry in Louisiana would look considerably different than it does today.

In addition, nearly all commercially important fisheries species are dependant upon the coastal wetlands. Louisiana's dock-side fisheries catch is valued at $680 million annually and comprises 25% of the total U.S. harvest. Wetlands are also the major habitat for important commercial and recreational wildlife species, including migratory waterfowl, fur-bearers and alligators, whose annual values can range from $2 to $20 million, depending on the season and market; consequently Louisiana's coastal wetlands convey important economic and ecological benefits not only for the citizens of Louisiana, but for the entire nation.

The Coastal Restoration Division of the Office of Coastal Restoration and Management is responsible for planning, implementing, operating, maintaining, and monitoring projects that are designed to conserve, enhance, restore and create coastal vegetated wetlands. This division works very closely with many state, local and federal agencies to identify, develop, and implement these projects on dwindling funds. Much of the work being undertaken is an effort to reverse past practices, some of which were initiated to encourage the fledgling oil and gas industry to flourish. These efforts of encouragement did not come cheaply for the coastal zone.

Coastal Management Divisions's responsibility is to achieve the proper balance between coastal resource use, and the conservation, protection and enhancement of wetlands and other coastal resources. Our mandate is to balance the impacts and benefits of proposed coastal resource uses for the overall well-being of those resources that are the property of the citizens of Louisiana. This is the regulatory side of the coastal restoration and management house.

Some applicants for a coastal use permit or consistency determination from Coastal Management Division (CMD) may find the requirements for consistency with the Louisiana Coastal Resource Program somewhat confusing. This past year, Coastal Management has made substantial headway toward closing the information gap that exists between CMD and potential users of Louisiana's coastal resources.

CMD recently aired an interagency coastal resource information special on Louisiana Public Broadcasting, which included our newly-established 800 telephone information number, which can be utilized by applicants with questions regarding Coastal Management. In order to minimize the time and expense of applicants seeking Coastal Use Permits (CUPs), CMD has began accepting applications for permits by FAX. In addition, several new methods of fee payment options are now available, including Visa, MasterCard, set-asides or escrow accounts, and electronic transfer of funds. For many large oil companies requiring Consistency Determinations the internal company cost of issuing a check can exceed the $300 Consistency Fee.

CMD has recently completed the promulgation of mitigation regulations which clearly define the standards that determine how much restorative work will be required of applicants to offset damage to wetlands from activities such as development or oil and gas exploration activities.

CMD has also completed, and submitted to the National Oceanic and Atmospheric Administration and the Environmental Protection Agency, The Louisiana Coastal Non-Point Source Pollution Control Program Document which will establish a Louisiana non-point source pollution control program.

The Consistency Section of CMD in Baton Rouge, and the Plans and Pipelines Division of MMS in New Orleans closely coordinate our respective reviews of individual offshore oil exploration and production activities, and we have established and refined a very productive working relationship over the past several years. Working together we have establish protocols that address or protect:

- Historic Cultural Resources
- Chemosynthetic Organisms
- Topographic High areas
- Oil Spills
- Air and Water Emissions
- Shipping Fairway and Anchorage Area Navigation
- Drainage of Louisiana's State Oil Reserves
- and many other Socioeconomic and Environmental Concerns

The Consistency Section reviews Development Operations Coordination Document's (DOCD's), Plans of Exploration (POE'S) as well as federal lease sale Environmental Impact Statements and other documents related to the oil and gas activities in the outer continental shelf off Louisiana's coast for consistency with the state's coastal program. Over the last six years the numbers of documents reviewed has ranged from a low of approximately 190 in 1991 to 381 in 1992. On average the Consistency Section reviews about 250 documents related to oil and gas for consistency with our program.

The State of Louisiana plays the leading role in supplying the nation with energy resources. Ninety-nine percent of the Nation's offshore oil and gas platforms are in the vicinity of Louisiana's coast. Consequently, Louisiana has experienced many benefits from OCS oil exploration and development. In this regard, Louisiana is wholeheartedly committed to continued oil and gas development in the OCS; however, this development does not come without cost to the State; and the Federal government needs to take into account the many significant adverse impacts to Louisiana from OCS oil and gas development. Siting of oil and gas facilities and the infrastructure to supply it is an issue of national interest—it would seem naturally to follow that protecting the environment that houses this infrastructure would also be in the national interest.

Section 18 of the Outer Continental Shelf Lands Act requires that the MMS five-year OCS leasing program be prepared in a manner consistent with attainment of "a proper balance among potential for environmental damage, discovery of oil and gas, and adverse impacts on the coastal zone," as well as "consideration of laws, goals and policies of affected states." The development and maintenance of the infrastructure necessary to support continued offshore oil and gas exploration and development, which benefits the entire nation, has clearly had tremendous impacts on Louisiana's vulnerable coastal wetlands and consequently on our, and the entire nation's, valuable commercial seafood industry. The Louisiana Department of Natural Resources would like to recapitulate the position of responsible oil and gas operators that the MMS aggressively pursue impact assistance to states, such as Louisiana, that bear the brunt of OCS activity.

The areawide leasing strategy implemented in 1983 by Secretary of the Interior James Watt, in which the entire central or western area of the Gulf is offered for lease in each lease sale, has greatly exacerbated the negative aspects of OCS leasing activities. By opening up virtually the entire Gulf OCS region for leasing at bargain prices, foundations are laid, which in periods of extreme or sudden oil price inflation, allow exploration, development, and production's immediate and unconstrained expansion. The damaging consequence for Louisiana is another uncontrollable oil boom and bust cycle. The oil and gas industry has been a major factor in the development of coastal Louisiana's economic structure and infrastructure. With the exceptions of agriculture and commercial seafood, non-oil and gas exploration and production dependent industries are all but non-existent. The oil industry's boom, bust, and resurgent growth cycle, with the subsequent unplanned and unsustainable on-shore infrastructure development and the in- and out-migration of the residents of coastal parishes that results, have greatly complicated the attempts of rural, coastal Louisiana parishes at economic diversification. In addition, sound economic principles, as well as, the persistent and drastic declines in per-acre bid prices as a direct result of area wide leasing offer proof that areawide leasing destroys competition in the Gulf. Competition can normally be expected to decline if the government as a lessor suddenly floods the market with millions of acres of previously unleased lands. Some other negative economic impacts of area wide leasing are that areawide leasing increases imperfection and inadequacy of market information (firms no longer have knowledge of each others' bidding strategies), increases per lease firm risk thereby decreasing demand, and fails to adequately compensate the Federal government for the time value of money. Area wide leasing represents a windfall to the oil and gas industry at the expense of the American taxpayer, and the resulting failure to collect fair market value for a non-renewable resource is illogical.

Mr. Greg DuCote has been with the Louisiana Department of Natural Resources since 1987 and is currently the program manager of the Interagency Affairs branch of the Coastal Management Division. He has also served in the Office of the Governor as a Natural Resources Specialist and as the Deputy Oil Spill Coordinator for the state. He received a B.A. degree from the University of Southwestern Louisiana and completed two years of graduate studies at Louisiana State University.

Mr. Jon Truxillo has been with the Louisiana Department of Natural Resources since 1994 and currently works as a consistency analyst in the Coastal Management Division. He has been responsible for the review of individual OCS plans, MMS lease sales, and MMS five-year plans. Mr. Truxillo received a B.S. in agricultural business and a M.S. in agricultural economics from Louisiana State University.

MISSISSIPPI: ISSUES IN THE GULF STATES

Mr. Jerry Mitchell
Mississippi Department of Marine Resources

The Mississippi Department of Marine Resources (DMR) which became effective 1 July 1994, was formed from the Mississippi Department of Wildlife, Fisheries and Parks (WFP), and the Bureau of Marine Resources. The DMR has attained full agency status. The department is governed by an eclectic, seven-member coastal commission and chaired by Dr. Vernon Asper, an educator and scientist with the University of Southern Mississippi at the Stennis Space Center. DMR offices are in Biloxi and it has maintained all current coastal programs, coastal wetlands, fisheries and administrative staffs. All existing marine programs and activities of the WFP, Bureau of Marine Resources are now administered by the DMR. Coastal marine enforcement personnel remain with the WFP.

In addition to the creation of the DMR, other activities have occurred that affect coastal management in Mississippi. These activities include staff assignments and re-alignments, aggressive efforts for hiring additional staff, Section 6217 nonpoint progress and legislative changes to the Coastal Wetlands Protection Law, and the establishment of a coastal interagency economic and environmental council. Other activities include the routing of Mississippi Public Trust Tidelands funds (resulting from leases of state water bottom land by the casinos) to DMR through the Mississippi Secretary of State's office. Other services include the assignment of the Marine Boat and Water Safety Program responsibilities to the DMR.

It should be noted that the DMR is at an important threshold in relation to the coastal zone management. The DMR's promotion to separate state agency status and the appointment of an impressive set of commissioners and executive director provide an excellent opportunity for the state to evaluate its coastal program and realign its efforts. This will be accomplished through the development of a strategic plan addressing the DMR's role in monitoring and enforcement, federal consistency, public outreach, casino policy development, and other coastal concerns such as fisheries management and shellfish sanitation.

Mississippi's Coastal Zone, which spans from Louisiana to Alabama, comprises nearly 400 miles of tidal shoreline, and includes several large barrier islands. The coastal composition varies from artificial sand beaches to freshwater swamps, with over 66 thousand acres of saltwater marsh. These wetlands provide nourishment for prolific forms of marine life, many of which enter the Gulf of Mexico. It is this abundant marine life that historically form the basis of the seafood industry in the three coastal counties of Hancock, Harrison, and Jackson. Of the approximate 350,000 residents of these counties, most are employed or impacted by water-related industries such as shipyards, marinas, resorts, off-shore oil and gas efforts, seafood harvesting and processing and most recently the casino industry. The rise in population and income associated with these industries has created a major need for housing, shopping areas and associated public facilities. Most coastal communities have developed or are developing comprehensive land use plans and zoning ordinances. Only one, Jackson County, of the three coastal counties has adopted a land use plan and zoning ordinance.

Estuarine Research Reserve (NERRS) that include both pine savannahs and coastal wetlands in southeast Jackson County referred to as the Grand Bay area. The NERRS site will combine 4,200 acres of the state lands, with 5,400 acres currently being purchased by the U.S. Fish and Wildlife Service and 5,400 acres of water bottoms. The total site will be in excess of 15,000 acres. The NERRS site when operational will be utilized for education and research.

Dealing with Outer Continental Shelf (OCS) development has not been an issue with Mississippi as most OCS developments are addressed through the federal consistency provision of the Coastal Zone Management. The state has opportunity to review lease sales and individual operational plans.

Mississippi has prepared and submitted to both NOAA and EPA a coastal nonpoint source pollution program to address the various nonpoint sources meeting the mandates of §6217 of the Coastal Zone Act Reauthorization Amendments of 1990. The program submission represents the cooperative efforts of the sub-committees including agriculture, forestry and an urban sub-committee. According to this study and others conducted by the department, urban run-off and failing, improperly installed, maintained or sited individual home treatment systems are the two primary sources of nonpoint sources of pollution in coastal Mississippi.

Mississippi has requested conditional approval of the nonpoint program with a forestry exclusion request. Implementation of the nonpoint program through funding and staffing will be a major issue in Mississippi.

In summary, some of the issues facing coastal Mississippi include:

- the need to address the cumulative and secondary impacts on coastal resources and nearshore uplands that have partially resulted from dockside gaming and ensuing population gains.
- the demand gaming boats have created for new and expanded marine facilities because they rest on space formerly occupied by seafood processing sites.
- the fate of the nonpoint source pollution, given the scarcity of federal and state funds.
- the future of Coastal Zone Management on a national level, where states have historically

counted on financial support under the National Act as well as effectively dealing with activities through the federal consistency provisions of the CZMA.

FORUM ON ISSUES IN THE GULF STATES

Mr. Brad Gane
Alabama Department of Environmental Management

INTRODUCTION

The 1995 year in coastal Alabama has been an interesting one, sometimes intriguing, sometimes trying, and sometimes downright torturous. Hopefully, the users will find that 1995 has been a positive year for coastal resource management in Alabama.

OUTER CONTINENTAL SHELF ACTIVITIES AND REVIEW

The OCS review process through the Alabama Coastal Area Management Program stipulates that the state reviews all sales, plans of exploration and development, and the other permitted activities of the MMS for consistency with Alabama's Coastal Area Management Program, and more specifically, ADEM's Division 8 Coastal Program regulations. Upon receipt of a complete application, ADEM issues a 15-day public notice and begins review of the project. This review includes in-house coordination with other ADEM Divisions, and other state and federal resource trustee agencies.

To date, ADEM has not denied coastal program certification of any lease sale, exploration, or development plan. The state has objected, however, to certain aspects of the proposals. In those cases where objections have arisen, ADEM works directly with the disagreeing parties, or indirectly as a mediator of sorts, in the event that another trustee agency objects to a proposal or one of its parts. Consistency letters are routinely conditioned to address issue areas, and issues of concern have ultimately been resolved.

OCS issue areas have mostly involved protection of Alabama's hydrocarbon reserves, maintenance of water quality, and conservation of unique geologic structures and biological communities.

The most controversial OCS projects are those that have the potential to remove state hydrocarbons from beneath state waterbottoms because of their proximity to the three-mile line. The Geological Survey of Alabama reviews each OCS proposal at ADEM's request and advises the coastal program if the proposed well is to be drilled on a structure common to both state and federal lands beneath waters. If the Survey determines that extraction of state resources could occur, then the coastal program initiates discussion between the applicant and the Survey. This is primarily an economic issue; for this reason, the coastal program has elected to allow the State Oil and Gas Board, an arm of the Geological Survey, to resolve the matter with the lessee. The matter will be resolved before drilling will commence.

Another area of concern has been the Pinnacle Trend, located approximately seventy to eighty miles south of the Alabama coast. These pinnacles contain sensitive biologic communities which are attracted to the naturally occurring hard or rocky formations. The formations lie in 73 to 100 meters of water. Although Alabama has not denied certification in these areas, the Geological Survey has commented to us on their interests in the area. The MMS live bottom stipulation requires leaseholders in that area to conduct a bathymetric survey prior to beginning operations in the area. If it is determined that live bottoms might be adversely impacted, measures are imposed to protect these areas.

The placement of pipelines is a secondary impact of OCS activities on which ADEM has had to spend considerable time. Coastal Alabama has large quantities of natural gas available for production, and coupled with increased activity in the Gulf of Mexico OCS off both Alabama and the panhandle of Florida, pipeline-laying activities are not only frequently proposed, but are becoming a way of life. While no official pipeline corridors have been established, the nature of the shoreline, bathymetry, and estuarine hydrology have brought most pipelines through one relatively narrow corridor—the entrance to Mobile Bay. Having a relatively restricted area through which pipelines are most often placed has advantages, but disadvantages also exist. Routes are not far from productive oyster reefs. The nature of Mobile Bay sediments and the duration of pipe-laying operations often spells turbidity or sedimentation problems. Suits have been filed over resource losses, and waterfront residents claim that erosion has increased, current patterns have been changed, and what is left is soup. They claim that their relatively firm bottom sediment character is gone.

OIL SPILL PLANNING ACTIVITIES

Another area of management activity that we have been involved in is oil spill planning. OPA 90 mandated many planning activities that have taken place to date, and many other planning activities will follow in the years ahead. Federal Regional Response Teams, Local Planning Committees, and the regulated transporters and facility operators have all been working hard to fulfill their legislated mandates. ADEM works with the Region IV Regional Response Team, inclusive of the southeastern states, on oil spill planning and response issues. The RRT IV, not unlike RRT VI, has worked on dispersant use plans, in-situ burn preapprovals, and bioremediation issues. ADEM also works with the U.S. Coast Guard and the Mississippi/Alabama local planning committee to conduct spill planning and response awareness on the local level. Many state agencies have contributed data and expertise to NOAA to develop, through contract, an Environmental Sensitivity Atlas that covers the coastal portions of Alabama. And, ADEM sits as a steering committee member and participant in the MMS funded and LSU conducted GWIS, or Gulf Wide Information System, project. This project is a geographic information system comprised of four priority levels with a multitude of data layers, all designed to provide uniform, seamless, geographically referenced databases to be used for oil spill planning.

SHORELINE EROSION AND MANAGEMENT

Shoreline management is currently a hot issue in coastal Alabama. While we are not confronted with shorelines threatened by subsidence and loss of sediments necessary to sustain the marshes such as Louisianians have experienced for years, coastal Alabama is threatened by burgeoning development. The placement of hard structures like homes and towering condominiums on a soft, changeable, storm prone and easily overwashed shoreline is occurring at an unprecedented rate. Hurricane Opal wreaked its havoc on October 4th. Fortunately for coastal Alabama, its havoc was about 100 miles down the coast. Opal merely brushed our shores, giving coastal Alabama a taste like we have not had since Hurricane Elena hit us in the mid 1980s. It became apparent that the washover sands should be placed back on the beach. How fortunate we were that the sand could be easily picked up and placed back - it was not even full of house, roadway and other pieces of infrastructure, like we would find further east. Our hurricane cleanup was an inconvenience, not a complete rebuilding. We can, and should, learn a lot from those to our east who were not as fortunate.

Certain areas were damaged more heavily than others, particularly those where development is lower or closer to the water. Shoreline management needs to be intensified where the areas are built out and the dunes are flattened (or were not as expansive in the first place because so many structures were in their midst). Hazard mitigation opportunities exist that need further development. These opportunities could be best developed by teaming coastal management, emergency management, flood insurance, and local planning programs.

Activities that have been ongoing for years are now being looked at differently because of newly pressing shoreline erosion and management issues. The U.S. Army Corps of Engineers has been dredging the Mobile Ship Channel for decades, an activity without which the Port of Mobile would close. Resource trust agencies worked for years to see that all its dredged material would be disposed either upland or deep in the Gulf of Mexico. This was a preferred, though more expensive, alternative to dumping the dredged material next to the channel. Now, very high rates of erosion are occurring on Dauphin Island's east end. Jetties placed earlier this century stand completely in the water, no longer anchored to the shoreline. Offshore shoals are moving closer to the barrier island's shoreline and a weld is expected soon. A new subdivision's homes are now much closer to the water and the residents watch anxiously as their property and their setback buffer are being washed away. Deep Gulf disposal is being reconsidered, particularly where the dredging is from the Mobile Bar portion of the channel, approximately five miles south of Dauphin Island. There are some who believe that removal of material from the bar channel is lowering the shoals that lie west of the channel, thereby affecting the flow of sediments that ultimately flow to the west end of Dauphin Island. Also, these same persons believe that lowering the shoals also lessens the level of protection that the shoals potentially afford for the protection of the east end of Dauphin Island.

A joint resolution of the State Legislature was passed last session which established a Shoreline Management Task Force. This task force will look at the coastal erosion problem and other shoreline management issues and make recommendations to the Legislature as to the best course of action to manage this exceptionally valuable resource.

COASTAL ZONE MANAGEMENT ISSUES AND OTHER MANAGEMENT INITIATIVES

1995 has been a busy and productive year for the state's coastal management program. Major self-generated regulatory changes occurred in the program in June 1994. These changes constituted the first major program regulatory rewrite since the coastal program was adopted in 1979. Consequently, policy and procedures have had to be developed to implement these new regulations.

The usual pressures for development have intensified, surely a result of the increased demand created by the area's burgeoning population. Proposals for projects, the likes of which were previously unseen, have been flowing to us with great frequency. And the "new" Federal government with its realigned priorities, anticipated funding cuts, and policy exemplified by the U.S. Army Corps of Engineers' recent proposal to allow one-half acre of fill in non-tidal wetlands for residential construction, have all combined to fill our plates. We have a good handle on wetland impacting activities. We work closely with the Corps of Engineers. Approvals for proposed wetland impacting projects are rare, and wetland mitigation is required invariably for those projects that are approved. The proposal by the Corps to allow that one-half acre of fill-in wetlands for residential construction has been denied in the coastal area.

ADEM's Coastal Program has also promulgated regulations to address construction on beaches and dunes and has an established Coastal Construction Control Line. Regulations have been promulgated that require evaluation of water quality in new marinas. Also, ADEM requires all subdivisions greater than five acres in size to be reviewed for a coastal use permit. This review affords ADEM the opportunity to require buildable area outside of wetlands on all proposed lots. Often, other wetlands excluded from these requirements are set aside by conservation easement or deed restriction. ADEM's Coastal Program also reviews all wells that have the capacity to pump more than 50 gallons per minute. This review allows ADEM to evaluate a well's potential impact on groundwater and the possibility for saltwater intrusion.

Mobile Bay has been accepted for inclusion into the National Estuary Program. South Baldwin County will conduct an advanced identification of wetlands that can be used by regulators from every level. ADEM continues its participation in the USEPA's Gulf of Mexico Program. Locally, an Adaptive Resource Management program has been started to support and influence the course of coastal resource management in Alabama, as well as to provide committee membership for the NEP program recently started.

Mr. Brad Gane is Coastal Programs Chief with the Alabama Department of Environmental Management. Mr. Gane has been engaged in coastal research, management, and regulatory compliance activities since receiving his B.S. degree from Louisiana State University in 1973. Mr. Gane is co-author of the Alabama Coastal Area Management Program and has been directly involved with the State's coastal management program for approximately 12 years.

COASTAL AND MARINE ISSUES: FLORIDA

Ms. Lisa Polak
Office of the Governor, Florida

Florida's 11,000 miles of tidal coastline, ownership of 6.7 million acres of offshore land, and 3 million acres of estuarine open water and wetlands make it the largest ocean-owning state in the contiguous United States. Tourism and commercial and recreational fishing associated with Florida's coasts bring billions of dollars to the state annually. In addition, most of Florida's population resides in the coastal zone. With such characteristics, it is easy to see why we in Florida who are working to preserve and protect our natural resources face a myriad of problems and issues daily. Discussed here are some current issues that may be of interest.

OUTER CONTINENTAL SHELF OIL AND GAS ACTIVITIES

Exploratory Drilling Activity

Chevron is currently drilling an exploratory well on Destin Dome Block 57, approximately 25 miles offshore Pensacola. This well, to be completed in March 1996, is being drilled to assist in accurately defining the extent of the Norphlet gas reservoir within the Destin

Dome 56 Unit. A Development and Production Plan for the Destin Dome 56 Unit, if submitted, would be the first for the Eastern Gulf of Mexico.

In June 1995, the U.S. Department of Commerce (DOC) released its decision overturning the state of Florida's finding of inconsistency for Mobil's Supplemental Plan of Exploration (SPOE) on Pensacola Block 889 on the grounds that this activity was consistent with the objectives of the Coastal Zone Management Act. Mobil had submitted a SPOE in September 1991 for one additional well added to six previously approved exploratory wells off of Pensacola. The state of Florida found the SPOE inconsistent with state laws in April 1992, and Mobil appealed the state's decision to the DOC later that month. We are not aware of plans for Mobil to pursue drilling in this area in the near future.

Five-Year Oil and Gas Program

The Minerals Management Service's 1997-2002 Draft Proposed Five-Year Program halts any new oil and gas lease sales within a 100-mile buffer zone of Florida's Gulf Coast. This decision is consistent with the Governor's long-standing position calling for a 100-mile no oil and gas activity zone to protect our coastal and marine resources, especially in areas where environmental information necessary to assess impacts accurately is lacking. We applaud MMS's decision to allow no new leasing and to address concerns regarding existing leases in the panhandle area.

South Florida Buy-Back

In July 1995, Governor Chiles joined President Clinton to announce that 73 oil and gas leases off the coast of southwest Florida and the Florida Keys were being relinquished by the industry. The landmark decision, the result of a settlement between nine oil companies and the U.S. Department of the Interior, ended a 1992 lawsuit. Conoco initially filed suit against the federal government in 1992 for breach of contract and unconstitutional taking of its OCS leases offshore southwest Florida; Bristol Bay, Alaska; and offshore North Carolina.

Sensitivity Atlases

Protection of Florida's marine and coastal resources in the event of an oil spill, regardless of the source, is a top concern of state officials. In order to be better prepared, the Department of Environmental Protection is updating the state's Marine Environmental Sensitivity Atlases to include details of biological resources present. The update of this GIS/Marine Spill Analyses System is a multi-year project with completion of the Florida Gulf coast expected by the end of this year. The Department continues work on updating the atlases for the remainder of the state. The Department is also conducting a project to compile biological resource information out further into the marine environment and make it available on CD-ROM.

State Water Oil and Gas Activity

Coastal Petroleum Company continues to try to exercise its state submerged land oil and gas lease obtained in the 1940s. In 1993, the Department of Environmental Protection (DEP), with Governor and Cabinet approval, required $515 million in security against a worst-case oil spill before permitting Coastal to drill its leases. Coastal Petroleum is the only company grandfathered in under the 1989 and 1990 statutes prohibiting drilling in state waters. Coastal appealed the state's decision, which was reversed by the First District Court of Appeals in February 1995. The state's motion for rehearing or certification to the State Supreme Court was denied in March 1995. With the DEP bond amount overturned in court, the Governor and Cabinet, sitting as the Board of Trustees of the Internal Improvement Trust Fund, set a bond amount pursuant to Chapter 253 (State Lands), Florida Statutes, of $500 million at a May 1995, Cabinet meeting. The Cabinet then requested that DEP run additional damage scenarios and reconsider the bond amount at the 27 June 1995 Cabinet meeting. The final agency action bond amount was set unanimously at $1.9 billion. The Cabinet's action is currently under appeal.

SOUTH FLORIDA ECOSYSTEM: FLORIDA KEYS NATIONAL MARINE SANCTUARY (FKNMS) / EVERGLADES / FLORIDA BAY

Restoration of the South Florida ecosystem continues to be a top priority for Governor Chiles. The state has played an active role in the development of the FKNMS Draft Management Plan through representation on the Advisory Council, CORE Committee and Water Quality Protection Committee. The FKNMS Draft Management Plan was released by NOAA in the summer of 1995. A series of public hearings was held in November with the public comment period ending on 31 December 1995. The Governor's Office staff is currently reviewing and assisting in coordinating a statewide review of the draft management plan. Adoption of the final management plan will require approval of the Florida Governor and Cabinet. Implementation of the plan to protect Sanctuary resources will be accomplished through an extensive state/federal cooperative effort.

The Governor's staff has been actively involved with federal, state and local governments, industry, and private interest groups working on restoration and protection of the Everglades and Florida Bay. The Governor's Commission for a Sustainable South Florida was created by executive order to recommend strategies for ensuring long-term compatibility of a strong South Florida economy and a healthy Everglades ecosystem. In October, the Commission presented a report to the Governor with 110 recommendations and more than 300 action steps aimed at restoring and protecting the Everglades-Florida Bay ecosystem and revitalizing south Florida's human environment. The Governor's staff is working with state and regional agencies and the Commission to set priorities for implementing the recommendations. In addition, the Governor's staff, state agencies and the South Florida Water Management District participate in the federally created South Florida Ecosystem Restoration Working Group.

FISHERIES

Over the last year, issues pertaining to Florida's saltwater fisheries have gained a great deal of attention, from the general public, as well as from state government, and from the scientific community. In November 1994 a Constitutional Amendment was approved by 72% of the voters which provided that, effective 1 July 1995, no gill nets or entangling nets can be used in state waters. In addition, no other type of net larger than 500 square feet can be used in nearshore and inshore Florida waters, and no more than two of the smaller, legal nets could be used (unconnected) per vessel. Nearshore and inshore waters are defined as within three miles of the Gulf coast and within one mile of the Atlantic coast.

Legislation passed in 1995 directed the Florida Department of Labor and Employment Security to develop a service plan to promote retraining for individuals adversely impacted by the net ban and to develop recommendations for compensation for adversely impacted persons. The legislation included $20 million for the state to purchase illegal nets from approximately 1,700 qualified fishermen. In addition, unemployment benefits of $10 to $15 million, from the Department's Unemployment Compensation Benefits Trust Fund, are expected to be paid to approximately 6,103 qualified fishermen.

Despite tremendous planning and coordination, the net buyback has not proceeded smoothly. Governor Chiles ordered a temporary suspension of the program in September 1995, when it became apparent that the $20 million buyback fund was quickly being depleted, probably because of the actions of some to defraud the state by altering nets. Although it was continued in October, the buyback program is still plagued by legal challenges.

On 29 November 1995, the Governor and Cabinet took a significant step toward protecting and replenishing many of the state's valuable saltwater fishery resources by approving a shrimp trawl rule proposed by the Marine Fisheries Commission (MFC). The rule, effective 1 January 1996, was the result of the input received over many months at dozens of statewide public meetings and workshops from fishermen, scientists, elected officials, conservationists, and other interest groups. It restricts the use of trawls to shrimp harvest. However, because of strong interest in starting a cannonball jellyfish industry and harvesting true baitfish, the MFC is working on a rule to allow the use of trawls for the direct harvest of jellyfish and baitfish, in addition to shrimp.

Two federal fishery projects that were reviewed for consistency with Florida's Coastal Management Program over the last year were found to be inconsistent with state law.

The Gulf of Mexico Fisheries Management Council Amendment 2 to the Fishery Management Plan for Coral and Coral Reefs allowed the resumption of liverock harvesting in the federal EEZ off the Florida Panhandle. This activity is banned in state waters to protect fishery habitat. The state determined that the Gulf Council's shift in policy would make enforcement of state regulations impossible and would also contribute to destruction of habitat in both state and federal waters.

The state found a Gulf of Mexico Fishery Management Council proposal to reduce the commercial size limit for harvest of red grouper to be inconsistent with state laws, goals, and policies. The proposal would allow commercial harvesting of red grouper which were below sexual maturity size and would therefore increase the risk of overfishing (increased harvest prior to reproduction). The Gulf Council's proposal was subsequently rejected by the NMFS.

OTHER COASTAL ISSUES

The state worked with MMS and the Army Corps of Engineers to draft the nation's first sand and gravel resources leasing contract for the federal OCS off of Jacksonville. In this shore protection project, OCS sand was used to restore eroded beaches in Duval County. Sand placement for the project was complete in mid-November and work is presently being conducted to revegetate the dunes. Maintenance of new vegetation (watering and fertilizing) will be conducted for 90 days after revegetation is complete.

During a Marine Turtle Nesting Workshop at Apalachicola NERR, it was announced that an endangered leatherback turtle had nested four times on St. George Island in 1994. These nestings are the most northern documented for a leatherback in the United States.

Ms. Lisa Polak serves as the Chief Analyst for Environmental Policy with the Florida Governor's Office. She works in the Environmental, Community and Economic Development Policy Unit, Office of Planning and Budgeting, Executive Office of the Governor. In this capacity she deals with many of the issues affecting Florida's marine and coastal environment, including policy regarding outer continental shelf leasing, exploration, and the potential of future development. Ms. Polak received her B.S. and J.D. degrees from Florida State University.

SESSION 3A

MAINTENANCE OF FISHERIES USING PLATFORMS AS MATERIALS OF OPPORTUNITY

Session: 3A - MAINTENANCE OF FISHERIES USING PLATFORMS AS MATERIALS OF OPPORTUNITY

Co-Chairs: Dr. Ann Scarborough Bull and Mr. Villere Reggio

Date: December 13, 1995

Presentation	Author/Affiliation
Maintenance of Fisheries Using Platforms as Materials of Opportunity	Dr. Ann Scarborough Bull Minerals Management Service Gulf of Mexico OCS Region
Offshore Platforms as Artificial Reefs	Dr. Ann Scarborough Bull Minerals Management Service Gulf of Mexico OCS Region
Recruitment of Larval and Juvenile Fish into Offshore Platform Communities	Dr. Richard F. Shaw Mr. Joseph S. Cope Mr. James G. Ditty Coastal Fisheries Institute Louisiana State University
Determination of Fishery Resources Associated with Petroleum Platforms	Dr. David R. Stanley Dr. Charles A. Wilson Coastal Fisheries Institute Center for Coastal, Energy and Environmental Resources Louisiana State University
An Assessment of Techniques for Removing Offshore Structures	Dr. William E. Evans Committee on Techniques for Removing Fixed Offshore Structures Marine Board Commission on Engineering and Technical Systems National Research Council National Academy Press Washington, D.C. 1996
Fisheries Impacts of Underwater Explosives Used in Platform Salvage	Mr. Gregg Gitschlag Galveston Laboratory Southeast Fisheries Center
Characterization of Biofouling Communities on Oil and Gas Production Platforms: Impact on Finfish Assemblage	Dr. Quenton Dokken Mr. Carl Beaver Ms. Susan Cox Ms. Christi Adams Mr. Jeff Childs Texas A&M University Mr. Jay Rooker University of Texas

Industry's Perspective on the Recycling of Platforms into Artificial Reefs	Mr. Vance Mackey Mr. Greg Schulte Offshore Facilities Services Chevron Petroleum Technology Company
Artificial Reefs off Texas: an Evaluation by Charter Fishing and Diving Boat Captains	Mr. Hal R. Osburn Ms. Leslie D. Finkelstein Dr. Robert B. Ditton Texas A&M University
Alternative Methods to Minimize Impacts to the Fisheries Resource When Donating Platforms to the Texas Artificial Reef Program	Ms. Jan C. Culbertson Texas Parks and Wildlife Department Seabrook Marine Laboratory

MAINTENANCE OF FISHERIES USING PLATFORMS AS MATERIALS OF OPPORTUNITY

Dr. Ann Scarborough Bull
Minerals Management Service
Gulf of Mexico OCS Region

INTRODUCTION

There are about 3,800 oil and gas structures in the Gulf of Mexico. About 1,800 of them are large multi-leg platforms. Hundreds of these structures have been in the north-central Gulf of Mexico for more than 30 years. It is not an exaggeration to say that offshore platforms began influencing fisheries a half century ago. Yet we have just started to investigate the connection between offshore oil and gas platforms and fisheries.

It has been in the last 10 years that we have begun actually to look at and question the role that platforms play in fisheries. No doubt part of that interest stems from the fact that there are lots of platforms out there to study and that more platforms are being taken out than are being put into the Gulf. Part of that interest must also stem from the knowledge that fisheries are collapsing world-wide.

For the most part, fisheries in the Gulf of Mexico continue to supply 20% of U.S. fish and seafood products. If the platforms are influencing the finfish resources in the Gulf, we need to find out what that influence is. If it is a good influence, then we should keep some of the platforms around. This certainly may be a positive action toward a sustainable fishery in the Gulf.

This section offers a number of presentations concerning platforms and fisheries issues. It offers information on the types, numbers, and ages of fishes at platforms; it discusses some of the consequences of platform removal and removal techniques; it addresses the effect of biofouling communities on platform fisheries and the economics of recycling platforms; it touches on Texas's Artificial Reef program, and concludes with an overview of the newest ways to make rigs to reefs.

Ann Scarborough Bull has worked as a marine biologist for the Minerals Management Service since 1988. She performed her graduate research at the Marine Biological Laboratory, Woods Hole, and her post doctoral work at Johns Hopkins in Maryland. Her research interests focus on the role of offshore platforms in the fisheries of the Gulf of Mexico.

OFFSHORE PLATFORMS AS ARTIFICIAL REEFS

Dr. Ann Scarborough Bull
Minerals Management Service
Gulf of Mexico OCS Region

ABSTRACT

Fish communities at three artificial reef sites in the Gulf of Mexico were monitored from 1989 through 1991. South Timbalier Block 86 Platform A (86-A) was toppled by a hurricane in 1985; South Timbalier Block 128 Platform A (128-A) was detonated and toppled in place in fall of 1988; and South Timbalier Block 134 Platform D (134-D) was detonated, towed, and deployed in 1991 about 30 m from 128-A. The results of a 1989 fish survey at 86-A and at 128-A suggested that the communities were more mature at 86-A. The predominance of immature fish and the paucity of adults of those same species on 128-A indicated that this artificial reef was acting as a recruitment site. Observations in 1990 at 86-A were essentially the same as those of 1989, while the communities at 128-A showed a greater diversity and maturity. Observations in 1991 at 86-A were essentially the same as those of 1989 and 1990, while the communities at 128-A continued to show further development. A large number of immature fish at 134-D were comparable to the 1989 observations made at 128-A. Further, adult reef-dependent species were observed moving freely between 128-A and 134-D. Observations made in 1989 at 86-A and 128-A suggest that differences were related to the manner by which each structure was toppled and the length of time each had remained undisturbed; differences observed between 1989 and 1990 were related to time undisturbed; and differences recorded between 1990 and 1991 were related to continued diversification and maturation of the community at 128-A. Observations made in 1991 at 128-A and 134-D suggest that 134-D acted as a recruitment reef as well as part of a reef complex for adult reef-dependent species moving between the adjacent structures.

INTRODUCTION

There are approximately 3,700 oil and gas production platforms in federal waters of the Gulf of Mexico. Production platforms are set in place by driving steel support legs (piles) deep into the seafloor. Working machinery and personnel sit above the water supported by a steel network (jacket) that is intentionally overbuilt and remarkably secure (Gallaway and Lewbel 1982). However, offshore structures are not intended to be permanent. When production ceases, they must be removed. Platforms may be relocated for re-use, removed and scrapped, or used as artificial reefs. In the last few years the practice of converting obsolete offshore structures to artificial reefs has gathered broad public and private support; both Louisiana and Texas have legislated state programs to convert obsolete offshore structures to artificial reefs.

During the summers of 1989, 1990, and 1991, the author assessed the fish communities of three artificial reefs at two locations in the Gulf of Mexico approximately seven miles apart. Both South Timbalier Block 86 Platform A (86-A) and South Timbalier Block 128 Platform A (128-A) included the entire above- and below-water sections of previously standing platforms; South Timbalier Block 134 Platform D (134-D) included only the below-water sections.

In October 1985, 86-A which had been completely shut down during the twentieth year of active production, was knocked over during Hurricane Juan. In September 1988, 128-A was retired, severed by use of explosives 5 m below the seafloor, and toppled in place. In 1991, 134-D was severed with explosives, towed, and placed within 30 m of 128-A. The objectives of this study were to evaluate, document, and compare the fish communities at these sites in order to assess qualitatively their function as artificial reefs.

METHODS

Surveys of the fish communities at 86-A, 128-A, and 134-D were conducted using a stationary visual census technique (Bohnsack and Bannerot 1986). Fish surveys were performed with the diver remaining stationary while listing and then counting the fishes within a horizontal range of vision. Although this method is customarily used to gather quantitative data, poor visibility at all study sites made quantification unreliable. Additional information noted during fish identification included depth, temperature, approximate lifestage/size, and behavior.

South Timbalier Block 86 Platform A

At least six dives per summer from 1989 through 1991 were made at the South Timbalier Block 86 Platform A site. Recordings of fish and invertebrate communities were always hampered by very poor visibility at this location. Qualitative surveys of the fishes were completed on the same day, or the following day, after the observations were completed at 128-A.

South Timbalier Block 128 Platform A

Fish distributions, densities, and diversities data were gathered during at least 12 dives per summer from 1989 through 1991 at South Timbalier Block 128 Platform A. During the first dives of any day, surveys of fishes were performed around the deck area and then from the deck along the length of the jacket towards the base of the piles. During subsequent dives, a concerted effort was made to survey the fishes along the entire length of a single inner leg. The 1989 effort was the first attempt to observe and record the biota of this artificial reef since it was toppled in place in 1988.

South Timbalier Block 134 Platform D

Fish distributions, densities, and diversities data were gathered during six dives at South Timbalier Block 134 Platform D in 1991. To assist in the logistics, a line approximately 30 m in length was attached between a central point on the eastern side of 128-A and western side of 134-D. A concerted effort was made to survey the fishes along the entire length of a single inner leg of the structure.

RESULTS

In 1989, the majority of the fish at 128-A were young of the year (YOY), immature, or young adults. All fish species observed at 86-A were adult, excluding immature cocoa damselfish (*Pomacaentrus variabilis*) and blennies, which were present at both 86-A and 128-A. The condition at 128-A was exceptional in that numerous immature groupers and snappers were present. In addition, of those few adult finfish species observed at 128-A, no immature of the same species were observed with the exception of blennies. Fewer immature blennies were observed at 86-A than at 128-A. At least one pair of adult cocoa damselfish was observed on 86-A.

The fish population at 128-A in 1990 appeared to be a mixture of species composed entirely of either adults or juveniles. The French angelfish (*Pomacanthus paru*) was the only species represented by both adults and juveniles. No YOY were observed and some species observed in 1989 were not seen in 1990 and vice versa. Comparison with 1989 data showed an increase in species richness with expansion into tropical and pelagic types as well as augmentation of reef-related species. Reef-related species such as cocoa damselfish (*P. variabilis*), red snapper (*Lutjanus campechanus*), and grouper were all juveniles. Some reef-related species such as cubera snapper (*L. cyanoptus*), scorpion fish (*Scorpaena* sp.), and nurse sharks (*Ginglymostoma cirratum*) were fully grown adults. Pelagic species included African pompano (*Alectis ciliaris*), crevalle jack (*Caranx hippos*), and Spanish mackerel (*Scomberomerus maculatus*).

The 1991 observations at 128-A suggested community maturation with a substantial increase in species richness and abundance. The fish population was a mixture of species with each composed of YOY, juveniles, young adults, or adults. Comparison with data from 1989 and 1990 showed an expansion into pelagic and reef-related types. Additional reef-related species were fully grown adults. These included bigeye (*Priacanthus arenatus*), whitespotted soapfish (*Rypticus maculatus*), spotfin butterflyfish (*Chaetodon ocellatus*), and nurse sharks (*G. cirratum*).

Except for immature cocoa damselfish (*P. varabilis*), blennies, and a small school of juvenile yellowtail reeffish (*Chromis enchrysura*) observed during the summer of 1991 on 86-A, all fish observed were adult including flamefish (*Apogon maculatus*) and red grouper (*Epinephelus morio*).

Impressions of 134-D were prominent since comparisons between 128-A and 134-D could be made during the same day and often the same dive. The 1991 fish community at 134-D initially appeared depauperate; however, closer inspection revealed conditions similar to those observed at 128-A in 1989. The majority of resident fishes at 134-D were YOY or immature. A number of grouper species, all YOY, were observed tucked away in nooks and crannies. A bundle of snagged rope about 1 m in diameter provided the necessary cover for both numerous YOY Spanish hogfish (*Bodianus rufus*) and several immature reef butterflyfish (*Chaetodon sedentarius*). At least two species of wrasse were represented by abundant immature specimens, while a single adult bluehead wrasse (*Thalassoma bifasciatum*) was observed at 128-A. A large number of two- to three-year-old red snapper (*L. campechanus*) appeared to move freely between 128-A and 134-D. The only pelagic species observed at 134-D was a school of juvenile greater amberjack (*Seriola dumerili*).

DISCUSSION AND CONCLUSIONS

High fish abundances often occur at artificial reefs. There are several factors that are important for artificial reefs to attract fish successfully and/or increase local fishery biomass. Artificial reefs must attract and retain fish from other reefs or attract settling fish larvae to increase production. It is well known that fish have an innate, positive attraction to underwater structures (thigmotropism). Pre-settlement larvae may be attracted in response to physical, chemical, and biological stimuli. Juvenile and young adult reef-dependent species (e.g., snapper, grouper, and damselfish) may recruit in response to sensory stimuli, insufficient food, or shelter. Ocean pelagic species use the vertical relief as a visual cue for their transient movements (Gallaway and Lewbel 1982).

Bohnsack (1989) concluded that the presence of artificial reefs is more important for reef-dependent species in locations more isolated from natural reef habitats. Structures 86-A, 128-A, and 134-D are over 100 miles from natural reef habitats. However, they are not far from standing platforms that are likely acting as established artificial reefs (Scarborough-Bull, 1989).

Stone *et al.* (1979) concluded that an artificial reef in proximity to an established reef initially attracts only the juveniles or young adults of reef-dependent species from the nearby structure. Further, they observed that transient species begin to key on artificial reefs as soon as the artificial structure is emplaced. They concluded that artificial reefs did not diminish the resident population of nearby natural reefs by attracting adult reef-dependent species to the new habitat.

Fishes were present for at least 20 years prior to the designation of 86-A, 128-A, and 134-D as artificial reefs. While these communities were undoubtedly beyond the initial stages of recruitment and colonization when the structures were last standing, they were in different conditions when they were designated as artificial reefs.

In the case of 86-A, sinking from the force of a hurricane was no doubt disturbing, but it was also a relatively slow process and not as disturbing as explosive removal. Initial observations suggest that fish associated with 86-A prior to its sinking may have remained with the structure after the hurricane and that this artificial reef serves less as a recruitment site than 128-A and 134-D.

The winter of 1989-1990 was exceedingly cold with coastal marsh areas freezing several times and unusually cool, brackish water extending at least 50 mi into the Gulf (USDOC, 1990). Although this probably delayed finfish spawning to some extent, whether this affected recruitment to 128-A in 1990 is unknown. One would like to hypothesize that the juvenile damselfish, snapper, and grouper observed in 1990 were the YOY's recruited to 128-A during 1989. However, without tagging and documentation this is only interesting conjecture.

The two- to three-year-old red snapper (*L. campechanus*) observed in 1991 at 128-A and 134-D may represent the year class recruited to 128-A during 1989. The lack of red snapper of any other age-group supports this opinion. It is assumed that the use of explosives and towing of 134-D removed most of the associated fish community; the predominance of immature fish suggests that 134-D acted as a recruitment reef in 1991 in much the same manner as did 128-A in 1989. The presence of several viable finfish nests and gastropod egg cases indicates that 128-A provided acceptable conditions that will likely increase biomass.

Ultimately, whether or not there will be further recruitment to, and development of, the marine communities of 86-A, 128-A, and 134-D will depend upon a number of environmental, biological, and chemical parameters acting synergistically. Site selection by the larvae, tolerance to turbidity, hypoxic events, susceptibility to predation, competition for space, and resistance to biological disturbances will have direct and indirect influences. Studies examining the relationships between these components may provide information invaluable in predicting the developmental stages, community structure, and possibly the productivity of artificial reef communities.

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RECRUITMENT OF LARVAL AND JUVENILE FISH INTO OFFSHORE PLATFORM COMMUNITIES

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INTRODUCTION

The introduction and proliferation of offshore oil and gas structures (de facto artificial reefs) in the northern Gulf of Mexico has undoubtedly affected the marine ecosystem. Subsequent research on impacts, driven mostly by environmental concerns, has focused primarily on production-based discharges and oil spills. Consequently, the effects of habitat alteration (i.e. placement of oil and gas structures/creation of hard bottom) on OCS fisheries are unknown, although speculation bordering on dogma runs rampant.

Our research has four specific objectives.

1. Provide foundational information on the role oil and gas platforms play as important nursery grounds or refugia for postlarval and juvenile fish, which could thereby contribute to and enhance overall fish production.
2. Supplement and compare a relatively new sampling technique, light trap methodology (which is capable of sampling large numbers of late stage postlarval and juvenile fishes in structurally complex environments) with traditional sampling techniques (i.e., vertical and passive horizontal plankton net collections).
3. Respond to specific fisheries management requests for basic biological information on reef fish, e.g., larval, postlarval and juvenile taxonomy, seasonality, vertical and across shelf distribution, relative abundance, and possibly otolith daily ring validation and age/ growth estimation.
4. Begin within a statistically-rigorous sampling design and program, the across-shelf characterization of the early life stages of the fish community utilizing offshore oil and gas platform habitat in central Louisiana.

If we are to begin to address the yet-unresolved, fundamental and larger question of whether offshore rigs simply attract/concentrate fish or indirectly enhance production (increase biomass = increase spawning or nursery ground habitat, growth, survivorship of young, etc.), we must begin to document the habitat *function* of rigs and the species which utilize this unique, hard-bottom habitat; to assess the role that rigs play in influencing the distribution and abundance of young fishes; and to address rigs as nursery grounds or refugia for postlarval and juvenile fishes associated with hard bottom habitat.

The adult fish communities around natural and artificial reefs are known (Seaman and Sprague 1992) and the fisheries aggregation value of oil and gas structures is well-recognized in the Gulf (CDOP 1985). Despite research efforts, biologists still disagree over the paradigm of whether rigs simply attract fish or enhance production. This debate has in fact shadowed the creation of artificial reefs in some areas and raised questions about the value of oil and gas platforms as reefs (Wilson and Stanley 1991). Existing data on adult fishes support both sides of the debate (Stone *et al.* 1979, Alevizon *et al.* 1985). Bohnsak (1989) theorized that reef effects fell along a continuum between attraction of existing organisms and production of organisms, with increased productivity occurring for reef dependent species in areas of limited hard substrate habitat. Since the northern Gulf has little natural reef habitat, it is unlikely that the introduction of 4,488 oil and gas platforms has simply attracted the fish from other areas. We believe that the contribution of artificial reefs to existing reef habitat has enhanced reef fish populations, but the extent of this augmentation is not known.

The structurally complex architecture (vertical and horizontal) associated with oil and gas platforms presents a formidable challenge to conventional sampling for early life stages of fish. A number of sampling methods are available, but all have biases in number, composition, and size of postlarvae or juveniles collected. More recently, various types of aggregation devices which passively attract fish with light into collection traps have been successfully used to sample hard bottom or reef habitat. Light traps, originally constructed to sample shallow and weedy limnetic environments (Faber 1981, 1982; Secor *et al.* 1993), have been used to sample such diverse marine environments as under Antarctic fast ice (Kawaguchi *et al.* 1986) and tropical coral reefs (Doherty 1987; Choat *et al.* 1993 and papers cited within). No single sampling gear can, however, provide a comprehensive collection of early life stages (Choat *et al.* 1993), and a program which utilizes several collection methodologies will allow for a more accurate estimation of abundance and size composition (Gregory and Powles 1988). Therefore, we augment the trap catch data with replicate vertical plankton hauls and passive horizontal plankton net collections.

COMPARATIVE RESULTS

We have built upon research experience gained from an unfunded pilot project at Mobil West Cameron (WC) 352, which allowed us to acquire preliminary experience with light traps within the submerged internal structure of rigs and to satisfactorily demonstrate that the gear effectively collects a highly diverse community of postlarval and juvenile fish (see species composition and seasonality table in appendix). WC 352 is a mid-shelf platform in approximately 20m (65 ft) of water off the Louisiana-Texas border. Two of the sampling sites for this research, Green Canyon 18 (229m) and Mobil Grand Isle 94 (61m depth) platforms, are larger, deeper platforms and the third site, Exxon South Timbalier 54 (22m) is of similar depth but all are significantly upstream and much closer to the nutrient- and food-rich waters of the Mississippi River. Site selection for the present study is based upon the work of Gallaway (1981) and Continental Shelf Associates (1982) who reported that nekton communities around platforms differed due to water depths in the northern Gulf. Three communities were characterized; coastal assemblage (water depths <27m), offshore assemblage (water depths 27 to 64 m) and a bluewater/tropical assemblage (water depths >64m). The eight-pile platforms selected for this project encompass all three zones.

As mentioned above, samples were collected at WC 352 from seven sampling periods between November 1991 to August 1992; 8,562 fish and 117 squid were collected from 1,368 minutes of sampling. This is the highest catch-per-unit-effort reported from light trap literature. The most fish caught in a single 10-minute set was 671. Significantly more fish were obtained in surface samples than in bottom samples; however, more squid were collected in bottom samples. Inshore lizardfish was by far the most abundant fish collected, making up 52% of the total catch. The largest number collected during a single set was 569, and several other sets obtained numbers over 400. Gulf menhaden was also common and made up 21% of the total catch. A number of reef species were also collected. Although these results are preliminary, they do indicate that platforms support a large biomass composed of early stages of fishes. Further work must be done to confirm the possible nursery function of platform habitat.

We have gained additional light trap experience from two small Louisiana Sea Grant-funded pilot projects. The first study was to determine the effect of trap size, and three sizes of our modified quatrefoil light trap design was used. No statistically significant effects were found among the different trap sizes and sampling locations tested; the interaction term was also not significant. The second study investigated the effect of trap design on catch and tested our trap design, a Doherty trap, and another quatrefoil-type trap. The latter study was conducted during July 1995 at Mobil's West Cameron 71-D, an oil and gas platform in approximately 11m of water. We found that catch differed among light traps, and that our modified quatrefoil light trap designs had the highest catch rates. In conclusion, light trap size did not have an effect on catch rate within the environments studied. However, trap design produced a notable effect.

METHODS FOR ONGOING STUDY

Year 1. We have begun to address all four objectives. We sample monthly for a three-night period at Green Canyon 18 (229m depth). All samplings are associated with the new moon phase, begin after sunset, and are completed before sunrise. New moon phases are associated with peak recruitment periods of many reef-dependent fishes (Johannes 1978; Robertson *et al.* 1988). In May we will also conduct three additional, two-day, sampling periods associated with 1/4, 3/4, full moon phases. The major sampling station for each rig is located in the internal central region along a stainless steel, small diameter guidewire (monorail) tethered to the first set of underwater cross-member support structures. At this central station, replicate trap collections (N = 2) are taken three times each night at near-surface and at a depth between 15 and 23m, depending upon the underwater configuration of the first set of cross-member supports. Traps are deployed for 10- minute periods. The light trap design we are using is a modified version of the "quatrefoil" design (Floyd *et al.* 1984; Conrow *et al.* 1990; Secor *et al.* 1993). We also take vertical zooplankton hauls (20-cm diameter net with 63μm mesh) and passive surface and at depth plankton collections (60-cm diameter with 333μm mesh) three times during the night at the central station. The vertical haul net, which is held rigidly to the guidewire, is lowered codend first to the bottom of the monorail, left at depth for five minutes for water column restabilization, and then hauled to the surface at approximately 1m/s via a portable davit and electric winch. The passive collections are taken for 10-15 minutes at the surface and 15-20 minutes at depth. Unlike the light traps, the plankton net collections sample zooplankton biomass, fish eggs, and yolk-sac and early stage fish larvae. In addition, three collections each night are made with a floating light trap (or a surface plankton net, depending upon the current regime) which is tethered and free drifted, 20m away from the rig on the down current side of the platform.

Samples are preserved in ethanol (for future otolith age and growth analyses) or kept alive for subsequent species identification, for marking with buffered alizarin complexone for validation of daily otolith ring formation, or for growth experiments). All fish are removed from all samples, enumerated and measured to the nearest 0.1 mm SL with an ocular micrometer. We measure temperature, salinity, conductivity, and turbidity throughout the water column, and current speed and direction (at depth only) using a Datasone III Hydrolab and two (2) Interocean S-4 current meters.

Year 2. We will continue to address all four objectives. During Year 2, we will utilize the seasonality and species composition information gained from Year 1 to tailor a more temporally-intensive (but seasonally-limited) sampling design specifically targeting the short-term temporal variability of reef fish which spawn (or, more appropriately, have larvae, postlarvae, and juveniles present) during April to August (e.g., snappers, amberjacks, spadefish, etc.) at Mobil Grand Isle 94 (61m depth). The specific sampling procedures remain the same as in Year 1. We will sample for three consecutive nights twice monthly. The second monthly sample collections will occur around the full moon phase, another peak recruitment period (Johannes 1978). The month of May dedicated to two additional sets of two-day sampling periods so that collections will be made during new, ¼, ¾, and full moon phases.

Year 3. We will continue to address all four objectives and we will conduct a similar, tailored, short-term, and intensive sampling protocol as in Year 2 only at the Exxon South Timbalier 54 (22m depth) platform.

STATISTICAL ANALYSES

The order of light trap (surface, at depth, and tethered farfield) and net samples will be randomized for each set. The ultimate statistical model implemented at the end of Year 3, when all three locations (across shelf) have been sampled, will be a randomized blocked, split-plot design with location and month as factors. Night will be blocked and the three sets of replicates per night will be a nested factor within night (gains power). Depth (surface and 15-23m depth) will be a split plot on night. The two replicates per trap set (three sets/night) will be used as sampling error (gains power). Moon phase will be considered in a separate, smaller model, run only on the three (Years 1-3) sets of May collections and will be a factor blocked on night and split or blocked on depth.

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DETERMINATION OF FISHERY RESOURCES ASSOCIATED WITH PETROLEUM PLATFORMS

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INTRODUCTION

Numerous attempts have been made using a variety of methods to document the abundance and composition of fishes associated with petroleum platforms (Sonnier *et al.* 1976; Gallaway *et al.* 1981; Continental Shelf Associates 1982; Gallaway and Lewbel 1982; Putt 1982; Stanley and Wilson 1990, 1991, 1995; Stanley 1994). With the exceptions of Putt (1982), Stanley and Wilson (1990, 1991) and Stanley (1994), earlier studies were only "snapshots" of the abundance and species composition of fishes associated with platforms. Results of these studies provided some insight into fish populations at specific sites; however, gear bias, limited visibility, diver/remotely operated underwater vehicle (ROV) avoidance and a lack of standard survey techniques make results difficult to interpret and compare.

Despite the range of methodologies, investigators found that fish abundance and species composition can change dramatically with platform size, location and time of year (Continental Shelf Associates 1982; Putt 1982, Stanley 1994). Gerlotto *et al.* (1989) found that fish densities were five to 50 times higher immediately adjacent to a platform than 50 m away, and Stanley (1994) found the near field area of influence to be 16 m with fish densities at greater distances comparable with background levels in the northern Gulf of Mexico. Long-term studies reported that fish populations at petroleum platforms were variable over time as Putt (1982) observed changes by a factor of two from month to month while Stanley (1994) found that monthly abundance may change by up to a factor of five.

Two complimentary techniques were used during this study to determine the abundance and species composition of fishes at two petroleum platforms. Stationary dual beam hydroacoustics measured *in situ* target strengths and fish densities while a remotely operated underwater vehicle (ROV) was used to determine species composition of fishes associated with two petroleum platforms.

METHODS

Research trips were conducted quarterly (August 1994 to 2 March 1995) at Mobil USA Inc.'s petroleum platforms Grand Isle 94 (GI94 (water depth 60 m, located 62 km S of Grand Isle, La.) and Green Canyon 18 (GC18) (water depth 219 m, located 110 km SW of Grand Isle, La.). Dual beam hydroacoustics was used to measure vertical and horizontal density of fishes adjacent to each side of the platform. Data were collected over 24-hour periods on each research trip. Species composition of fishes was determined using ROV visual point count surveys during each research trip.

RESULTS AND DISCUSSION

Dual beam hydroacoustics revealed several differences between the two sites. A significant near field area of influence of 18 m was detected at GI94 while at GC18 a 10 m area of influence was documented (Table 3A.1). Horizontal fish density varied between platform side, season, time of day and distance at GI94, however at GC18 differences were only noted for time of day (Table 3A.1).

Vertical fish densities differed between the two sites. We found significant differences in vertical fish densities at GI94 between sides of the platform, season, depth and an interaction of season and depth; at GC18 depth and depth by season were significant (Table 3A.2). Fish density at GI94 was fairly uniform throughout the water column, although significantly higher densities were found at 0-5, 40-45 and 50-55 m depth strata (Figure 3A.1). Fish density at the GC18 site was significantly higher in the 0-20 and 20-40 m depth strata than the rest of the water column; at depths greater than 80 m fish densities were near zero (Figure 3A.1). Fish densities in the upper 20 m at GC18 were similar to the densities found at GI94, however below 20 m densities at GC18 were dramatically lower (Figure 3A.1).

Total fish abundance estimated at GI94 (with a 18 m area of influence) averaged 28,734 and the fish there were somewhat uniformly distributed through the water column (Table 3A.3). Total fish abundance at GC18 (with a 10 m area of influence) averaged 3,287 over the study period, and 70.7% of the fishes were found in the upper 20 m. This observation challenges the general paradigm that larger structures harbor more fish.

Table 3A.1. Randomized block analysis of variance of horizontal fish densities at Grand Isle 94 and Green Canyon 18 petroleum platforms from Summer 1994, Fall 1994 and Winter 1995.

Horizontal Fish Density Green Canyon 18

Source	**DF**	**Sum of**	**Mean**	**F**	**Prob > F**
Model	399	9.3624	0.0234	7.40	0.0001
Error	1960	6.2131	0.0031		
Total	2359	15.5756			
Variables	**DF**	**Type III SS**	**Mean Square**	**F**	**Prob > F**
Platform side	3	2.1530	0.7177	39.81	0.0001
Season	2	0.0253	0.0127	0.70	0.4959
Diel	3	0.7520	0.2417	13.41	0.0001
Distance	9	0.0884	0.0100	0.55	0.8409
Season*Diel	4	0.1833	0.0458	2.54	0.0399
Season * Distance	18	0.4898	0.0272	1.51	0.0850
Diel * Distance	27	0.2960	0.0109	0.61	0.9350

Horizontal Fish Density Grand Isle 94

Source	**DF**	**Sum of Squares**	**Mean Square**	**F**	**Prob > F**
Model	479	436.10	0.91	33.31	0.0001
Error	2300	62.86	0.03		
Total	2779	498.97			
Variables	**DF**	**Type III SS**	**Mean Square**	**F**	**Prob > F**
Platform side	3	28.74	9.58	27.77	0.0001
Season	2	143.51	71.76	207.95	0.0001
Diel	3	21.22	7.08	20.50	0.0001
Distance	9	21.85	2.43	7.04	0.0001
Season*Diel	4	40.82	6.80	19.71	0.0001
Season * Distance	18	38.638	2.15	6.22	0.0001
Diel * Distance	27	1.51	0.06	0.16	1.0000

Table 3A.2. Randomized block analysis of variance of vertical fish densities at Grand Isle 94 and Green Canyon 18 petroleum platforms from Summer 1994, Fall 1994 and Winter 1995.

Vertical Fish Density Green Canyon 18

Source	DF	Sum of Squares	Mean Square	F	Prob > F
Model	479	40.749	0.085	2.98	0.0001
Error	2658	75.847	0.029		
Total	3137	116.596			
Variables	**DF**	**Type III SS**	**Mean Square**	**F**	**Prob > F**
Platform side	3	0.584	0.194	3.48	0.0161
Season	2	0.356	0.178	3.19	0.0424
Diel	3	0.409	0.136	2.44	0.0643
Depth	9	11.345	1.261	22.56	0.0001
Season*Diel	4	0.182	0.030	0.54	0.7747
Season * Depth	18	1.590	0.089	1.59	0.0605
Diel * Depth	27	3.540	0.131	2.35	0.0002

Vertical Fish Density Grand Isle 94

Source	DF	Sum of Squares	Mean Square	F	Prob > F
Model	502	100.742	0.200	33.99	0.0001
Error	2553	15.074	0.006		
Total	3055	115.817			
Variables	**DF**	**Type III SS**	**Mean Square**	**F**	**Prob > F**
Platform side	3	19.894	6.631	73.39	0.0001
Season	2	26.299	13.149	145.53	0.0001
Diel	3	0.461	0.153	1.70	0.1667
Depth	9	3.282	0.298	3.30	0.0002
Season*Diel	4	0.392	0.065	0.72	0.6312
Season * Depth	18	11.243	0.562	6.22	0.0001
Diel * Depth	27	0.706	0.021	0.24	1.0000

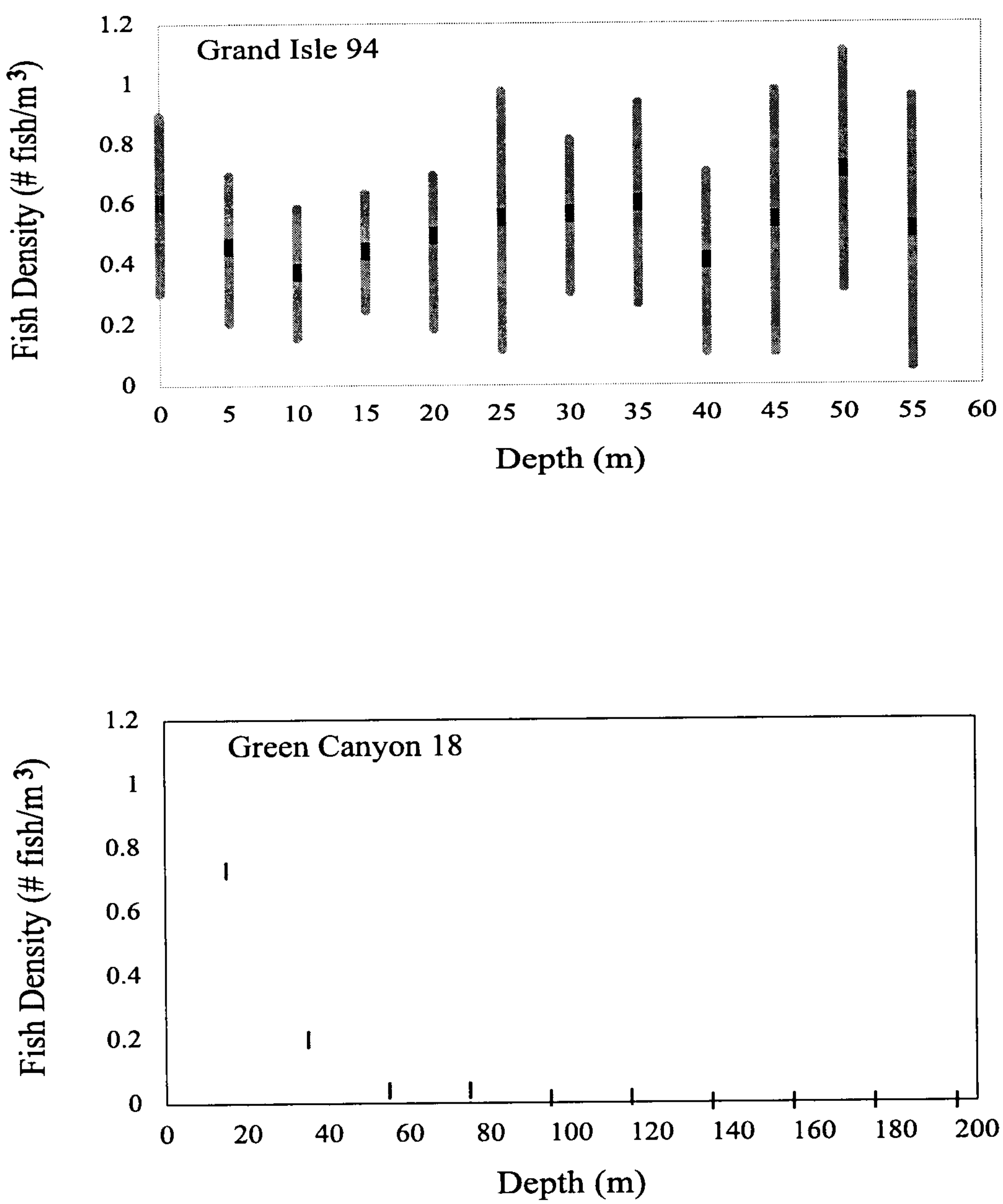

Figure 3A.1. Mean fish density and 95% confidence interval by depth strata for Grand Isle 94 and Green Canyon 18 platforms from summer 1994, fall 1994 and winter 1995.

Table 3A.3. Species composition of fishes from visual point surveys and estimated number of fish at Grand Isle 94 and Green Canyon 18 petroleum platforms from Summer 1994, Fall 1994 and Winter 1995.

Species	Grand Isle 94 Percent Frequency (Estimated Number)	Green Canyon 18 Percent Frequency (Estimated Number)
Almaco jack	0.1 (28.7)	9.1 (299.1)
Bar jack	0.2 (57.5)	3.5 (115.1)
Barracuda	0.5 (143.7)	4.4 (144.6)
Bermuda chub	1.1 (316.1)	5.3 (174.2)
Black jack	-	0.9 (29.6)
Blackfin tuna	-	5.3 (174.2)
Blue runner	86.6 (24883.4)	7.5 (246.5)
Cobia	0.1 (28.7)	-
Creole fish	0.2 (57.5)	44.4 (1459.5)
Gray triggerfish	2.5 (718.3)	1.2 (39.5)
Greater amberjack	0.7 (201.1)	9.4 (309.0)
Horse-eye jack	-	5.7 (187.4)
Jack crevalle	0.7 (201.1)	-
Lookdown	1.2 (344.8)	-
Mangrove snapper	0.9 (258.6)	-
Rainbow runner	0.1 (28.7)	0.2 (6.6)
Red snapper	4.4 (1264.3)	-
Scamp	0.7 (201.1)	1.1 (36.2)
Vermillion snapper	0.1 (28.7)	-
Yellowfin grouper	0.1 (28.7)	-
Yellowtail snapper	-	1.0 (32.9)
Total	28733.7	3287.1

Species composition also varied between the sites. Eighteen species were found at GI94 with blue runners dominating the fishes observed. At GC18 a total of 14 species was detected; Creole fish was the most common species found (Table 3A.3). The fish community surrounding GI94 had Bermuda chub, bluerunner, gray triggerfish, lookdown and red snapper constituting over 95% of the nekton (Table 3A.3). Recreational and commercially important fish species were found at both sites as red snapper, greater amberjack, gray triggerfish and scamp were common near GI94 and blackfin tuna and greater amberjack were abundant at GC18 (Table 3A.3).

Results of this study emphasize the variability in the abundance and species composition of fishes at these de facto artificial reefs which dominate the marine ecosystem in the northern Gulf of Mexico. The differences in abundance and species composition between these sites and earlier studies by Stanley (1994) and Putt (1982) can be attributed to water depth and geographical location. The species assemblage at GI94 was similar to those reported by Gallaway *et al.* (1980) for platforms in the "offshore zone." Species found at GC18 were different from other platform surveys and more indicative of those found near shelf-edge, natural, hard bottom features (Gallaway 1981). For example, yellowtail snapper, an uncommon species in the northern Gulf of Mexico, was common at the GC18 site, further evidence that the fish assemblage at this site resembles that of a tropical, natural hard

artificial reefs, estimates of abundance and species composition throughout the water column and over long time periods.

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David Stanley received his BSc. degree from University of Guelph, Ontario, Canada, and his MSc. and Ph.D. from Louisiana State University developing a new methodology accurately to quantify the number and species of fishes associated with petroleum platforms and artificial reefs. With two complementary techniques, dual beam hydroacoustics and point count visual surveys, precise estimates of the species abundance of these sites are now possible. Dr. Stanley is now employed as a post-doctoral research associate at LSU. His research is focused on how the addition of 4,000 platforms impacts the dynamics of marine fish populations in the Gulf of Mexico and is interested in the function of artificial reefs.

AN ASSESSMENT OF TECHNIQUES FOR REMOVING OFFSHORE STRUCTURES

Dr. William E. Evans
Committee on Techniques for Removing Fixed Offshore Structures
Marine Board
Commission on Engineering and Technical Systems
National Research Council
National Academy Press
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NOTICE

The project that is the subject of this report was approved by the Governing Board of the National Research Council, whose members are drawn from the councils of the National Academy of Sciences, the National Academy of Engineering, and the Institute of Medicine. The members of the panel responsible for the report were chosen for their special competencies and with regard for appropriate balance.

This report has been reviewed by a group other than the authors according to procedures approved by a Report Review Committee consisting of members of the National Academy of Sciences, the National Academy of Engineering, and the Institute of Medicine.

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BACKGROUND

Nearly 3,800 platforms populate the U.S. federal Outer Continental Shelf (OCS). Most of these are off Louisiana and Texas (MMS, 1995). The Minerals Management Service (MMS) requires removal of platforms from a lease within one year after termination of the lease. Lease operators may remove a platform when the costs of operating and maintaining a structure exceed revenues or when a structure is obsolete or damaged. The options for disposing of offshore structures include complete removal with disposal ashore, placement in an approved ocean disposal site, conversion to a fishing reef, or removal for refurbishing and replacement elsewhere. In some cases, with approvals, maintenance in place is an alternative to removal. Removal must be to a depth that safeguards ocean shipping, that does not obstruct shrimp trawling operations, or that safeguards submarine passage and minimizes the threat of encountering a seabed obstruction.

The pace of platform removals continues to accelerate as aging platforms built in the boom years of the late 1960s and 1970s are taken out of service. More than 100 platforms have been removed from service in each of the last several years (181 were removed in 1993).

The most commonly used procedure for removing fixed offshore structures is to cut them into sections and remove by lifting. The necessary submarine cutting is accomplished for the most part by explosives. The use of submarine explosives can harm fish, turtles, and marine mammals. The harm can be mitigated by careful timing and operational procedures, but the extent of harm and potential for mitigation have not been well documented. An alternative to explosives for submarine cutting is the use of jetting tools and torches or mechanical cutting devices.

Many operators prefer the explosive cutting method because of cost and operational risk considerations. Experience has shown that for most conditions, severing and retrieving structures can be accomplished explosively in one operation. Uncertainty is increased substantially if non-explosive techniques prove inadequate or unsuccessful during the removal process. Such failures may require more active intervention, such as diver cutting. Diver interaction with a structure damaged in an unknown manner is inherently dangerous and time consuming, as well as expensive. The prevailing judgment of platform owners and operators is that explosive cutting is cheaper, safer, more flexible, and more reliable than available or reasonably prospective non-explosive technologies for most platform removals.

Most of the problems with the explosive method are associated with the environmental impacts, especially mortality of marine life in the region affected by the detonation of the explosive charge. While the occurrence of turtles and marine mammals around platforms is not well documented, the National Marine Fisheries Service has identified explosive removals of offshore structures as a possible contributor to turtle and marine mammal mortality.

Fish kill associated with explosive removals is also of concern; however, only fragmentary data pertinent to fish kill are available. The range at which fish can be killed by explosives is dependent on several factors-the intensity of the explosive shock wave as determined by the type, configuration, and amount of explosive used, reflection and refraction of the shock wave due to bottom material and water conditions (temperature, salinity, etc.), and the susceptibility of specific species of fish to the various shock wave parameters

The U.S. General Accounting Office (GAO) recently reviewed offshore structure removal operations and concluded that non-explosive technologies merit further consideration and development due to concerns about the impact of explosive removal techniques on biological communities (GAO, 1994). They also concluded that the Minerals Management Service (MMS) has not adequately studied the costs and benefits of using non-explosive technology that would reduce the risk of environmental damage from removing offshore structures. Moreover, they concluded that certain actions by MMS may actually discourage the use of non-explosive platform removal measures (e.g., an MMS proposal to relax the limits on the use of explosives).

The Minerals Management Service requested that the National Research Council (NRC) address the issues raised in the GAO report by convening an expert committee to undertake a technical assessment and prepare a report that recommends alternatives for future MMS action. This report has been prepared in response to that request. The committee's tasks included the following: review the state of practice of platform removal technology, including appraising the costs of alternative techniques; examine and appraise innovative technologies and techniques under development; assess the occupational and environmental hazards of explosive and alternative removal techniques; and identify approaches for mitigating the identified hazards. During the course of the study, the committee also learned about the requirements and concerns of other users of the marine environment (including shrimpers, fishers, recreational boaters, and those concerned about environmental damage), which should be taken into account in developing federal procedures for full or partial platform removal and for site clearance, and assessed the adequacy of existing NMFS regulations governing the removal of fixed offshore structures.

Based on their findings, the committee prepared the following report, which provides a comparative assessment of offshore structure removal technologies and existing and potential mitigation strategies for decreasing the harm to living marine resources. This report is intended to provide guidance to the Minerals Management Service on the technical basis for development of offshore structure removal techniques and for updating pertinent federal rules and procedures. The report identifies alternative approaches for minimizing damage to the marine ecosystem from offshore structure removals.

COMMITTEE COMPOSITION AND SCOPE OF THE STUDY

A committee of twelve people was convened by the NRC's Marine Board. Biographies of committee members appear in Appendix A. Expertise on the committee included offshore civil engineering, geotechnical engineering, marine construction, underwater blast effects and mitigation, technical assessment, biology, ecology, and management of living marine resources. This composition provided the scientific, technical, economic, policy, and practical expertise to accomplish the assessment. The points of view of the offshore oil and gas industry and their associated service industries were included on the committee, as were those of scientists who have been involved in research on specific living marine resources (sea turtles, marine mammals, and fish) that may be affected by explosives used to remove offshore structures.

The committee was assisted by liaison representatives from the Minerals Management Service, which sponsored the study, and the National Marine Fisheries Service (NMFS), which is charged with ensuring compliance with regulations protecting living marine resources. The principle guiding the committee, consistent with NRC policy, was not to exclude any information or possible bias that might accompany input vital to the study, but to seek balance and fair treatment of all viewpoints.

The study focused on the assessment of offshore structure removal technologies and associated hazards, and the development of strategies to mitigate the environmental effects of these activities. Disposal of platforms after removal, either on site, in deeper water, or onshore, was outside the scope of this study. Although issues concerning the requalification of offshore structures for extended service and the reuse of offshore structures through state-sponsored "rigs to reefs programs" were originally excluded from the scope of the study, the committee found it necessary for a full understanding of the complexity of the issues to include a limited examination of the latter program and to present their findings concerning the role in the Gulf of Mexico ecosystem. Although the assessment may provide valuable insights concerning removal of offshore structures from state offshore lands as well as federal offshore lands, the assessment of state rules was beyond the scope of the study.

Based on findings from these activities, the committee has prepared the following report addressing technical and regulatory issues relating to the safe removal of offshore structures while protecting living marine resources from harm insofar as is possible.

HOW THE STUDY WAS CONDUCTED

The committee initiated its investigations with briefings from MMS and NMFS representatives who are involved in overseeing offshore removal activities. Experts from government, industry, and the research and environmental interest communities were invited to present information and insights on present and alternative methods of removals, their costs, reliability, safety, and measures for mitigating their effects on the environment and on regulatory issues, including possible changes in existing regulations. The committee reviewed available scientific literature on the effects of removals on living marine resources, and invited representatives of other users of the marine environment, including the fishing, shrimping, boating, and recreation communities, to present their concerns about the effects of explosive removals on their activities and on the Gulf of Mexico ecosystem. The committee also heard presentations and obtained information from private sector companies about new technologies for non-explosive removals and devices to mitigate the damage to marine animals from blasts.

A notice was issued in the *Federal Register* offering interested parties the opportunity to contribute information on all the major issue areas of the study. A copy of the notice and a list of those responding is found in Appendix B. This information was issued by the committee in its analysis.

The report is not intended to serve as a sourcebook on removal technology, but to provide an assessment of the current status of explosive, non-explosive, and mitigation techniques. The objective of the present assessment is to formulate a strategy to ensure that as little harm is inflicted on the environment and on living marine resources as is compatible with maintaining safe, cost-effective operations.

ORGANIZATION OF THE REPORT

The report represents a synthesis of information gathered by the Committee through briefings, literature review, technical presentations, analysis, and additional information gathered from interviews and articles.

- Chapter 1 provides an overview of the status of platforms at the present time and the regulations governing removals.
- Chapter 2 provides an assessment of alternative cutting techniques.
- Chapter 3 describes technical considerations relevant to the selection of particular removal methods.
- Chapter 4 presents the environmental effects of current removal activities and technologies.
- Chapter 5 provides a comparative summary of the costs and benefits of alternative approaches to removals.
- Chapter 6 presents the major conclusions and recommendations that follow from the findings of the investigation.
- The Executive Summary provides a synopsis of the report.
- Appendices provide the reader with additional background information, a list of individuals who made presentations to the committee, the respondents to the *Federal Register* notice, and biographies of committee members.

The report is intended to serve as a guide to the Minerals Management Service in making decisions about regulations governing the removal of offshore structures and about strategies for encouraging the use of techniques and approaches that will decrease the damage to the environment and to living marine resources from these activities.

ACKNOWLEDGMENTS

The committee wishes to thank the federal liaisons, Charles Smith and Mary Ann Turner of the Minerals Management Service and Gregg Gitschlag of the National Marine Fisheries service, for their invaluable information on their agencies' activities and perspectives on the issues under examination in this study. Other staff of both agencies also contributed time and information to the committee in a manner that was timely and enthusiastic. Special thanks are also extended to the individuals who spoke to the committee on behalf of professional and public interest groups presenting the concerns of their colleagues. These

presentations enabled the committee to grasp the broader context in which the technical issues are embedded.

EXECUTIVE SUMMARY

Today, in the U.S. Gulf of Mexico, there are about 3,800 platforms in Outer Continental Shelf (OCS) waters in depths ranging from under 10 feet of water to nearly 3,000 feet. These platforms vary from a simple vertical caisson supporting one well in 1 0 feet of water, to a huge structure in 1,350 feet of water supporting some 50 wells, to a tension leg platform in 2,860 feet of water. Approximately one-fourth of these platforms are older than 25 years and will soon require removal.

Platform abandonment has five steps: (1) permitting (obtaining necessary approvals), (2) well-plugging, (3) decommissioning (removing hydrocarbons from equipment), (4) platform removal (the subject of this report), and (5) site clearance.

The Minerals Management Service (MMS) requires removal (to a depth 15 feet below mudline) of all platforms within one year after production ceases. The industry currently removes about 150 structures per year, and all indications are that this figure will gradually rise as the older structures reach their economic limits. Moreover, the ratio of deeper water structures to shallow water structures removed, now quite small, will also increase as more deep water platforms reach the end of production. Since deep water platforms are much more expensive to remove, removal costs will inevitably increase. It is estimated that by the year 2000, the industry will spend over $300 million per year for platform removal.

Nearly 70 percent of the platforms removed since 1987 have been removed with explosives. Non-explosive methods used for the remaining 30 percent include mechanical cutters, abrasive cutters, and torch cuts made by divers.

A report by the General Accounting Office (GAO) raised questions about whether current MMS requirements and practices governing removals are adequate to protect living marine resources, particularly with respect to the use of explosives.

The MMS, in response to the report, requested that the National Research Council (NRC) appoint a committee to assess the state of practice of explosive and non-explosive platform removal technology.

The Committee on Techniques for Removing Fixed Offshore Structures reviewed reports and papers on the subject and developed data on comparative costs and effects of explosive removals on marine life. The committee heard presentations by industry representatives, by experts on explosive and non-explosive removal techniques, by representatives of shrimping and fishing industries, and by state and federal agencies with regulatory responsibilities for removal activities and protection of living marine resources. Representatives of environmental organizations and scientists conducting research on the ecology of the Gulf of Mexico also presented their views on these issues. The committee addressed the hazards of each removal process, how they can be mitigated, and appraised the adequacy of current regulations governing platform removal. Responses to questions posed by the MMS covering the issue, published in the *Federal Register*, were also reviewed.

While there certainly was no unanimity of opinion among the parties about what should be done, the committee found sufficient common ground to recommend a framework for a more reasonable program.

CONCLUSIONS

Regulations governing the removal of offshore structures need to be sufficiently flexible to accommodate the complex requirements of a wide variety of structures, marine life, and users in the Gulf of Mexico.

The many different platforms, the array of potential interactions with other users of the ocean, and the complexity of the biological communities associated with platforms indicate that inflexible regulations for platform removals are not efficient or equitable. The existing MMS regulations have functioned well for many years. They are prescriptive in some areas, such as establishing the depth to which a platform must be removed. In other areas, the regulations provide partial flexibility to accommodate unusual cases by requesting approval of specific procedures from the MMS. During the years that the regulations have been in place, improvements and modifications have continuously occurred. One significant change was the National Marine Fisheries Service (NMFS) Observer Program that was added to minimize the incidental takings of sea turtles and marine mammals. Another improvement made in recent years is the requirement for site clearance verification and reports.

Explosives are an economical and reliable tool for removing most structures, especially those located in deep water.

The effects of mortality from explosive removals on fish populations are not sufficiently certain at this time to warrant changes in the existing regulations and procedures that now govern their use. However, losses may be substantial and continued efforts should be made to reduce these impacts. This points out a need for research to understand these effects.

Prohibiting or further restricting the use of explosives in the platform removal process is not supported by the available evidence as to their effects on sea turtles and marine mammals. The effects on fish population dynamics are uncertain. Prohibition of explosive removals would incur risks to divers and other offshore workers. Such a prohibition would also increase substantially the cost of platform removals. Research and development efforts on techniques to remove platforms without using explosives or by using smaller amounts of explosives more effectively are progressing, as are research and development efforts on methods of mitigating the effects of explosives on marine life. Wider deployment and field testing in the Gulf are needed to evaluate the costs and benefits of these techniques.

The requirement that structures be removed to a depth of at least 15 feet below the mudline is a disincentive to develop and use non-explosive techniques as well as advanced explosive techniques using smaller charges.

The fifteen-foot depth requirement increases significantly the risks to divers and costs of non-explosive cutting, or advanced explosive cutting requiring the placing of explosives by divers. Divers are put at risk if required to work inside platform structural elements since they risk igniting gas pockets that can build inside the element. Divers with torches can work much more efficiently and safely near the mudline versus 15-20 feet below the mudline. Similarly, advanced explosives or pile severing devices can be placed and operated much more easily near the mudline.

The NMFS Observer Program has significantly improved understanding of the effects of platform removals involving explosives on sea turtles and marine mammals. However, the effects of explosives on highly valued populations offish frequently resident at platforms are not well understood.

The NMFS Observer Program is valuable from both a research and enforcement perspective. Continuance of this program can play a significant part in improving understanding of the effects of explosive removals on living marine resources and in mitigating these effects. Empirical information about the numbers, location, and variation of species of interest is too fragmentary to support conclusions about possible effects on total fish populations or population dynamics. Further research is needed to obtain a definitive understanding of these effects.

The simplest means of blast mitigation are unlikely to significantly reduce fish kill from explosive removal operations.

While there is considerable uncertainty in applying existing methods to mitigate fish kill in the platform environment, the indications are that the blast effects of multiple detonations are severe enough that the mitigation brought about by reduction in size of explosives used (e.g., 20 to 25 lb. charges in place of 50 lb. charges) or deeper detonations (e.g., 32 feet instead of 16 feet) will have at most a modest effect on fish kill.

Devices that scare fish away from platforms during explosive activity are not currently developed for open ocean water. However, this line of technological development offers promise for the future and should be encouraged.

Fish in shallow water (less than 50 feet deep) are vulnerable to explosives because of the effects of the pressure wave that is generated (high compression followed by rapid decompression). There has been some success in removing fish by acoustical means (fish scare devices) from regions such as near water intakes. If these techniques could be adapted to the fish species, water depths and distances (e.g., 200-300 feet) of concern in platform removals, the number of fish killed could be reduced significantly. Moreover, the more modest means of mitigation (charge reduction and depth increase) would then be likely to reduce further the probability and extent of fish kill.

Limiting the number of near-simultaneous explosions to eight and limiting the weight of individual charges to 50 pounds (without applying for a special permit) may have undesirable effects.

Although limitations on the number of detonations and weight of individual charges were motivated by concern over the effects of explosions on marine life, these limitations may increase rather than decrease such damage. There are no data comparing the lethality of a single explosive charge with that of a series of charges of the same size. Estimates of the fish kill from the explosive removal of an oil platform that are based solely on existing data using single charges must be assumed to seriously underestimate the fish kill in the absence of contrary information. Requiring a delay if more than eight explosions are necessary to remove the structure will expose surviving fish to subsequent explosions.

Since the 50-pound limit is approved routinely, this "limit" may well become a de facto standard and discourage more discriminatory analysis of the size of the charge needed to do the job. Such a standard could sometimes require more explosive charge than necessary, and at other times reauire too little charge, which would necessitate the use of a second charge. Both scenarios would increase the number of fish killed.

The non-lethal effects (e.g., temporary or permanent hearing loss, other physiological and neurological damage) on future reproductive performance, predator avoidance, etc., for living marine resources affected by explosive removals are not known. If species found in association with platforms represent specific year classes or are important components of the reef ecosystem, the impact could be significant.

Studies are needed to determine the non-lethal morphological and physiological effects of high-level impulse noise on fish and other marine species affected by explosive removals.

Leaving platforms in place, partial removal, toppling in place, or using platforms for artificial reefs are options that are economically and environmentally attractive to many ocean user groups. Liability and regulatory issues now limit their use.

Operators would, of course, avoid costs of removal if they were permitted to leave platforms in place, but they believe that the potential liability would be too great an economic burden. Further, coastal states are also hesitant to assume potentially unlimited liability. Partial removal solves most of the liability problems, but is only feasible in deeper waters because of the need for navigation clearance. Transportation costs may limit use of artificial reefs if the reefs are too far from the original platform sites.

RECOMMENDATIONS

Following are recommendations for action.

- *The committee recommends that the Minerals Management Service (MMS):*
  1. Change the minimum depth at which the structure or well conductors must be severed from the current depth of fifteen feet below the mudline to three feet below the mudline, provided that platform removal measures are employed that do not increase adverse environmental effects. Such measures include the use of non-explosive techniques, reduced charges, fish scare devices, or some other effective mitigating methods.
  2. Work with industry, explosive experts and other stakeholders and user groups to develop design guidelines relating to the specific size of explosive charges necessary to effectively remove the structural element to be cut.
  3. Allow partial removal of deeper water structures when non-explosive or advanced techniques are used.
  4. Remove the limit of a maximum of eight detonations at any one time, but retain the requirement of a 9/10th second delay between individual detonations.
  5. Incorporate into the permitting process the flexibility to encourage testing of removal techniques that could reduce the risks to living marine resources.

- *The committee recommends that the National Marine Fisheries Service (NMFS) in cooperation with MMS and state agencies:*
  6. Maintain the current marine mammal and sea turtle observer program, including the ban on night time detonations, but shorten the required period of observation from 48 to 24 hours prior to detonation.
  7. Systematically gather more information about the species, numbers, and age distribution of the fish killed and, so far as is practical, of fish surviving when explosives are used to remove platforms.

- *The committee recommends that the offshore industry*
  8. Develop a guidebook on recommended practice for the use of explosives in the platform removal process.

9. Sponsor and support programs to explore the effectiveness of using acoustic means to expel fish to a relatively safe distance from removal operations.
10. Investigate means of incorporating the reduction of environmental damage into the initial design process for platform removal.

- *The committee recommends that state agencies with jurisdiction:*
  11. Evaluate the potential to increase the attractiveness of artificial reefs as a disposal option (for example, by increasing the number of sites).

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William Evans has an extensive background in biological oceanography. Among other things he was the Director of the Hubbs Research Center, Sea World, San Diego; Chief Scientist for the National Marine Fisheries Service; Chairman of the Marine Mammal Commission; and, Director of the National Oceanic and Atmospheric Administration. He is now president of Texas Institute of Oceanography and a Professor in several disciplines including marine biology, wildlife and fisheries, and oceanography. In 1994, he was asked to sit on the Marine Board of the National Research Council during their Assessment of the Techniques for Removing Offshore Structure.

FISHERIES IMPACTS OF UNDERWATER EXPLOSIVES USED IN PLATFORM SALVAGE

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INTRODUCTION

More than 4,000 oil and gas structures are present in the Gulf of Mexico. A recent average showed that more than 100 removals occur each year. Sixty-six percent of these structures are salvaged with explosives. Typically, the deck of an offshore platform is cut manually with torches and lifted onto a materials barge. Explosives are lowered down the hollow pilings and conductors to a minimum depth of 5 m (15 ft) below the mudline as required by Minerals Management Service. Explosives are detonated, thereby severing the pilings and conductors which, along with the jacket, are removed from the sea bed.

One consequence of using underwater explosives is a negative impact on marine life, particularly fish. This report presents preliminary results assessing the fish mortality at six platform removals between August 1993 and September 1995. Study sites spanned the Louisiana coast from the western border to the Mississippi delta. Water depths ranged from 14-28 m (45-92 ft).

METHODS

Sampling methodology included efforts to collect all dead fish which floated to the surface after explosives were detonated. A sample of the dead fish which sank to the sea floor was collected using three techniques, all of which required SCUBA divers: line transect surveys, circular surveys, and sampling frames placed beneath the platform. Although procedural modifications occurred during the study, the final sampling protocols are described here.

Field personnel operating from inflatable boats collected dead fish at the surface using dip nets. Circular surveys measuring 3.4 m in radius and 100 m transect lines were sampled, as shown in Figure 3A.2 Divers sampled a 1 or 2 m wide area on either side of the transect line. Discrete samples were collected in 25 m increments along the transect. Sampling frames constructed of PVC pipe were placed beneath the

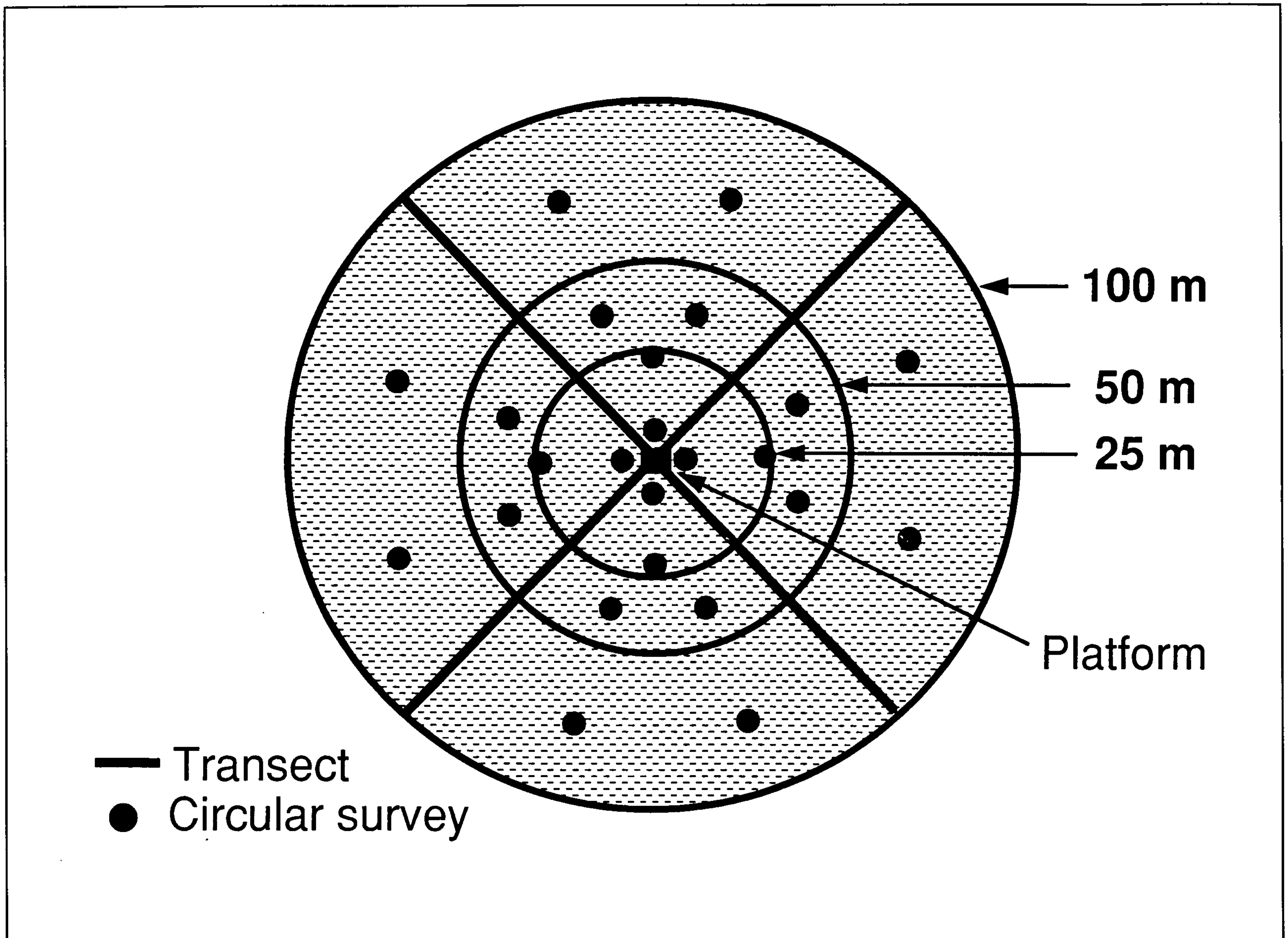

Figure 3A.2. Sampling design.

platform. Due to obstructions on the bottom, dimensions of the frames sometimes varied, although a sufficient number of frames were deployed to cover approximately 20-30% of the footprint area beneath the platform.

Fish mortality was estimated by multiplying fish density (number of fish in sample divided by area sampled) by total area for each region of interest (e.g. 0-25 m radius around the platform, 25-50 m, 50-75 m, and 75-100 m for transect line analysis). This same procedure was applied to data collected from circular surveys and sampling frames. The total estimated mortality at a study site was obtained by summing the number of dead fish collected at the surface, the estimated mortality beneath the platform and the estimated mortality in open water around the platform to a maximum distance of 100 m. The transect and circular survey techniques served as duplicate estimators for mortality in the open water area.

RESULTS

Surface mortality ranged from 100-1,300 at the six study sites. Estimated mortality ranged from 200-1,200 for the footprint area beneath the platform, from 800-2,500 for open water using transect data and 500-4,100 using circular survey data. Total estimated mortality ranged from less than 2,000 to as many as 5,000 fish at individual platforms.

Systematic collection of dead fish from the sea floor is costly compared with recovering floating fish from the surface. However, if the ratio of sinkers to floaters is consistent between platforms then it may be possible to estimate total mortality by simply determining the number of dead floating fish and multiplying this value by a constant. The ratio of sinkers to floaters at four study sites ranged between two and four. The remaining two platforms had the high and low values: less than one and 42. Future research is needed to determine if the highest ratio is an aberration and if the ratios obtained at new sites are also less than four. If so, then the surface collection of fish may serve as a crude estimator of total mortality.

Fish species with the highest estimated mortality included, in descending order, Atlantic spadefish, red snapper, blue runner, and sheepshead. Estimated mortality at the last five study sites ranged from 500-2,100 for spadefish, 0-1,200 for red snapper, 0-1500 for blue runner, and 100-900 for sheepshead. (The first site was excluded from this analysis due to the wide range in estimates between the transect and circular survey methods, which may be related to sample loss resulting from logistical problems encountered in the field.) Combining the results from these five platforms yielded a total estimated kill of 5,100 spadefish, 2,700 red snapper, 2,300 blue runner, and 2,200 sheepshead. These four species accounted for approximately 86% of the combined estimated fish mortality at these five study sites.

Prior to the detonation of explosives, a fish tag and release study was conducted. Results obtained for red snapper are presented here. No red snapper were tagged and released at one site and only four at another. At the remaining removal locations the number of tagged red snapper released alive totaled 44, 117, 132, and 172. Typical recovery rates for tag-release studies of fish are about 5%. The percentage of tagged fish recovered after detonations was 41%, 48%, 64%, and 19% at our study sites, respectively. High recovery rates indicate the large impact of underwater explosives on the fish populations at platform removals.

Data from the tag-release study were used to estimate the pre-detonation population size of red snapper. The ratio of untagged to tagged red snapper mortalities collected after the blast was multiplied by the number of live red snapper tagged and released prior to detonations to yield an estimate of the total red snapper population size. Values ranged from 550-1,900 at the four study sites. The percent of the population killed by blasting activity was calculated by dividing estimated red snapper mortality by estimated population size. Results ranged from 57-73%. However, in tag-release studies tagged fish returned to the sea generally do not survive. There is typically mortality associated with handling and tagging procedures. In addition, fish captured in deeper water tend to display higher mortality after release. Taking into account mortality associated with tag-release procedures will lower the red snapper population estimates shown here. This in turn will result in an increase in the calculated percentage of the red snapper population killed by explosives.

Predicting fish mortality at explosive platform removals is complex. A casual review of data relating to platform size, age, water depth, and the weight of explosives used in platform removal showed no consistent relationship between these parameters and the magnitude of estimated fish mortality. However, removals that occur in waters deeper than those studied

(14-28 m) are expected to have a greater impact on red snapper.

Gregg Gitschlag has worked at the National Oceanic and Atmospheric Administrations, National Marine Fisheries Service Galveston Laboratory for the past 17 years as an oceanographer and fishery biologist. He has conducted research on shrimp migration, red snapper release survival, and sea turtle migration and distribution. He was also a member of the benchmark study of the Buccaneer Oil and Gas Field study in the mid-1970s. Mr. Gitschlag completed his B.Sc. in zoology at the University of Michigan and his M.Sc. in biological oceanography at Florida State University. For the past several years Mr. Gitschlag has been investigating the impacts of explosive platform removals on fish populations.

CHARACTERIZATION OF BIOFOULING COMMUNITIES ON OIL AND GAS PRODUCTION PLATFORMS: IMPACT ON FINFISH ASSEMBLAGE

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INTRODUCTION

In the offshore waters of the northern Gulf of Mexico, all five Gulf states have implemented efforts to increase finfish productivity through the development of artificial reef habitats. In Texas and Louisiana, the most prevalent material of opportunity for artificial reef development in the northern Gulf of Mexico is the steel jacket structures of oil and gas production platforms.

The development of biologically productive ecosystems within the framework of platform structures has been recognized since the installation of the first offshore structure. Yet, although platform structures are primary offshore fishing sites in the northern Gulf of Mexico (Ditton *et al.*, 1995), little understanding of the dynamics or productivity of this artificially created reef habitat exist; so little in fact that the impact of these reefs as fishing sites cannot be factored into fishery management strategies.

For actively migratory finfish, it is not known whether platform reefs are merely functioning as fish attractant devices that congregate existing stocks or actually support/ cause increases in population densities and biomass. But, considering other recruits to platform reefs including sessile algae and invertebrates and non-migratory demersal reef fish, platform reefs do support an increase in biomass and population densities by providing additional hard substrate surfaces for colonization, and subsequently, a diversity of microhabitats that are utilized by reef fish, post settlement juveniles through adults.

This raises the question, is this enhancement of the diversity and biomass of marine plants and organisms with no commercial value contributing to increases in diversity, population densities, and biomass of finfish having economic value as recreational and commercial fishery resources? This question can only be answered when the ecosystem and biological dynamics of these unique habitats is understood.

The information reported herein is a preliminary report of work in progress for the purpose of increasing understanding of the ecosystem and biological dynamics of platform reefs in the northern Gulf of Mexico. Ultimately, this will support development of strategies for artificial reef development that maximize biological productivity, and make it possible to incorporate the impacts of platform reefs upon fishery resources in fishery management strategies.

METHOD AND MATERIALS

Results reported herein are based on data collected from two active offshore production platforms in the northwestern Gulf of Mexico, Mobil's High Island A389A (27°54'30" N, 93°35'06" W), and British Petroleum's East Breaks A165 (27° 49' N, 94° 19' W) (Figure 3A.3). Both structures are in the deep tropical waters near the outer edge of the continental shelf, and have been on location for more than ten years. HI A389A is approximately 177 km southeast of Galveston, Texas and EB A165 is approximately 145 km out, in 122 m and 243 m of water, respectively.

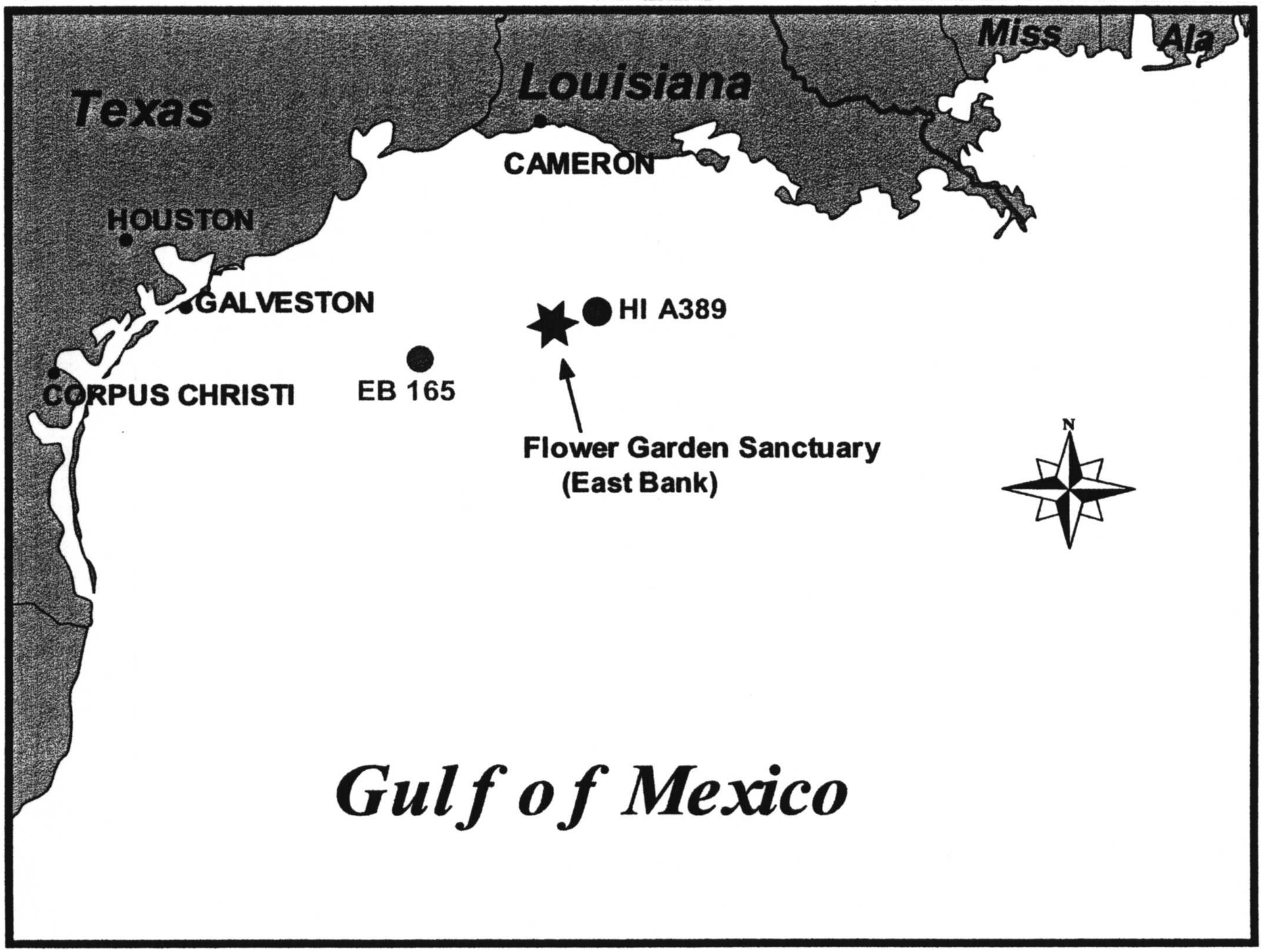

Figure 3A.3. Location of Mobil High Island A-389A and British Petroleum East Breaks A-165 platforms.

Surface water temperatures range from a winter low 18° C in February to a high of 30° C in late August and early September. The tropical nature of these waroceanic waters allows for a year-round growing season for many marine organisms. Water clarity is typically good, allowing for maximum light penetration. Currents vary, but are likely influenced primarily by the Loop Current to the east which brings tropical Caribbean water into the Gulf. It is also possible that HI-A389A is primarily affected by the Loop Current and EB-A165 is more strongly affected by nearshore currents traveling up the western shores of the Gulf from southern Mexico.

Sampling of the fouling community was conducted primarily by nondestructive means. Vertical photographic transects (Bohnsack 1979) from the surface to 53 m depth were used to describe the fouling community. All organisms were identified to the lowest possible taxonomic group. A total of 533 (369 for HI 389A and 164 for EB A165) transparencies were analyzed providing 13,325 data points.

Analysis of Variance (ANOVA) was utilized to determine significant differences in average fouling community diversity along the depth gradient. Tukey's mean separation test was used to determine differences in species diversity between depth zones. Species diversity for each depth zone was assessed using the Shannon-Wiener Diversity Index (Shannon 1948).

Rugosity measurements (linear measurements of the surface area created by fouling community organisms) were taken at 3.0 m intervals from the surface to 53 m. Rugosity was determined by measuring the relief created by the fouling community organisms between two points set 1 m apart. Three replicates were taken for each 3.0 m depth increment. Rugosity for each increment is defined as:

$$\frac{\Sigma\, 3(X+1) - 1}{3}$$

Degree of fouling was measured as the difference between the circumference measured around the surface of the fouling community and the actual circumference of the bare pipe structure on which the fouling community was attached.

In addition to phototransects and rugosity measurements, a 10 cm^3 section of the fouling community was collected, preserved and dissected to determine numbers of cryptic species inhabiting the fouling community. Methods and results of efforts to study the porifora are reported fully in Adams (1995). The sponge community was photographed *in situ*. Two photographs of each specimen were taken; one with a 28 mm lens fitted with a close-up kit at a focal length of 250 mm and one with a 35 mm lens and a 1:2 macro extension tube with a focal length of approximately 90 mm. A 5 cm^3 sample of each specimen was then collected. In the laboratory, spicules were mounted on slides and each specimen identified to the lowest possible taxon.

Using a line point intercept method, vertical transects were employed along each of the four corner legs of HI A389 to investigate abundance and zonation. The transect line was marked at 0.5 m intervals, and for analysis three depth zones was identified; upper (0-12 m), mid (12.5-25 m) and lower (25-37 m) depths. The number of sponges were compared between legs for each species, as well as for total numbers of sponges, using a heterogeneity chi-square (Zar 1984). The null hypothesis for the chi-square is that all four legs are from a homogenous population using the following equation:

$$X^2 = \frac{\Sigma\,(f-F)^2}{F}$$

where the observed frequency of a species is f and the expected frequency is represented by F. Species diversity for each depth zone was determined using the Shannon-Wiener Diversity Index.

The mean number of sponges for the dominant species for all three zones was analyzed using an ANOVA to test the null hypothesis. Species were considered dominant if the count was equal to or greater than 20 of 100 observations. For multiple comparisons, Tukey's HSD was used as an ad-hoc test for each ANOVA.

Methods and results of fish surveys are reported fully in Rooker *et al.* (*In review*). Divers conducted visual surveys during the day and night to determine spatial and temporal patterns in habitat utilization by resident finfish, swimming measured transects along diagonal sections of the platform structure to a depth of 24 m. Statistical analysis included ANOVA, Tukey's HSD test, Chi-square analysis, Shannon-Wiener diversity indices (H′) and Evenness (J′). This data has been collected from HI-A389 only.

RESULTS

At this point in the project, data analysis is adequate to compare rugosity, species diversity, and vertical zonation between Mobil's HI A389 platform and British Petroleum's EB A165 platform. Other measurements and analysis for EB A165 have not been completed.

A total of 62 species representing 8 phyla were identified during the quantitative survey of the fouling community of HI A389A. Three distinct depth zones were defined by statistical analysis of data obtained from phototransects (Figure 3A.4). The zone between the surface and a depth of 9.1 m displays a relatively low diversity of organisms being dominated by the bivalve *Isognomon radiatus*, barnacles and turf algae. A Shannon-Wiener Diversity index of 0.696 is was determined for this zone. The upper 0.6 m of this zone displays a dense growth of turf algae. Below this area dense colonies of *Isognomon radiatus* and the barnacle *Balanus tintinnabulum* form a low relief growth over the steel substrate providing habitat for a number of cryptic species. The sponge *Tedania ignis* and the hydroid *Obelia dicotoma* also grow in small low relief patches in the lower portions. Rugosity measurements in this zone show a low relief community averaging 0.25 m relief over a 1 m distance.

The depth zone between 9.1 and 36.5 m displays the greatest diversity of fouling community organisms. Shannon-Wiener Diversity indices for this zone were determined to be 0.900. A total of 23 organisms were found to be common to the fouling community in this zone. The hydroid *Obelia dicotoma* and the annelid *Filograna huxleyi* dominated phototransects in this zone. The sponges *Tedania ignis*, *Neofibularia nolitangere, Strongylacidon porticola* and several bryozoans were also common as well as the tube sponge *Callyspongia vaginalis*. Large *Neofibularia nolitangere* sponges, some measuring more than 1 m in diameter, are common on both horizontal and vertical structures at this depth. The bivalve molluscs *Spondylus americanus*, *Pinna carnea* and *Dendostrea frons* are also conspicuous parts of the fouling community assemblage, most of which are covered with several cm growth of sponges, hydroids and algae. Small dense colonies of the octocoral *Carijoa riisei* (*Telesto riisei*) are present in the mid to lower portions of the zone while small colonies of the hydroid *Bougainvillia inequalis* are common on horizontal structures in the upper portion. Broad patches of the fire coral *Millipora alcicornis* can be found throughout the zone but, are more common on the upper portions. Colonial tunicates of the genus *Clavelina* are common on horizontal structures and well casings within this zone as are encrusting colonial bryozoans. Several species of scleractinian corals are also found in this zone. The fouling community of this zone is of a relatively high relief as indicated by an average rugosity of 0.39 m across the zone. Rugosity within this zone ranged from 0.27 to 0.54 m.

A 10 cm^3 section of the fouling community was removed from a depth of approximately 21.3 m and examined to determine the numbers of cryptic species associated with the fouling community. A total of 429 organisms including 212 microcrustaceans, 113 polychaete worms and 76 brittle stars as well as small hydroids, crabs and shrimp.

From 36.5 to 53 m diversity decreases only slightly displaying a Shannon-Wiener Diversity Index of 0.807. This zone is also dominated by various sponges, *Obelia dicotoma* and *Bougainvillia inequalis* hydroids and the polychaete *Filograna huxely*. Feather hydroids and antipatharians are present in the lower portions of this zone. A horizontal template structure at 38 m provides a surface that collects organisms that have fallen from the structure above. Sediment accumulations composed mainly of shell material from barnacles, bivalves and calcareous worm tubes from the annelid *Filograna huxely* collect on the template providing a habitat for micromolluscs, polychaete worms, small crabs and brittle stars. Samples of this sediment have been collected and will be analyzed to identify infaunal organisms. Some vertical structures immediately above and below the level of the template shows a distinct reduction in density of fouling community organisms. This usually occurs on well casings that exhibit movement within the template. These areas are typically covered with a layer of red calcareous algae. The moderately high relief fouling community has an average rugosity of 0.33.

Rugosity varied significantly between HI-A389A and EB-A165 (Figure 3A.5). Although relatively close in location, two obvious differences exit between these platforms, water depth (HI-A389A = 122 m versus EB-A165 = 243 m) and the near proximity of the Flower Garden Banks coral reef to HI-A389A (approximately 2 km west). It is also possible that the two platforms are affected by different currents. HI A389A is probably most strongly effected by the Loop Current while EB A165 may be affected more by longshore or shelf influenced currents. The rugosity of EB-A165 was greatest near the surface, steadily decreasing with depth and was significantly less than that of HI-A389.

East Breaks A165 varied dramatically in terms of species composition and vertical zonation. Species

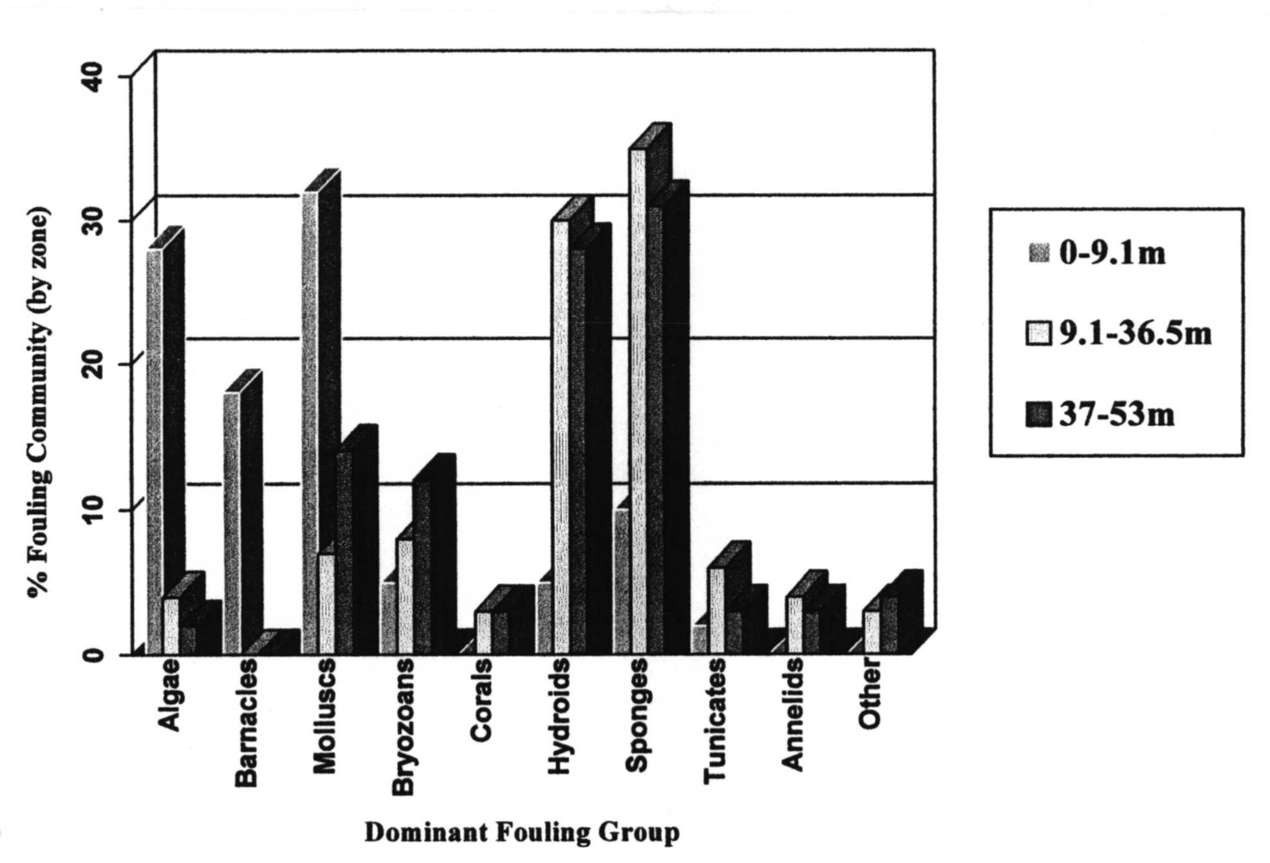

Figure 3A.4. Vertical zonation at High Island A-389A.

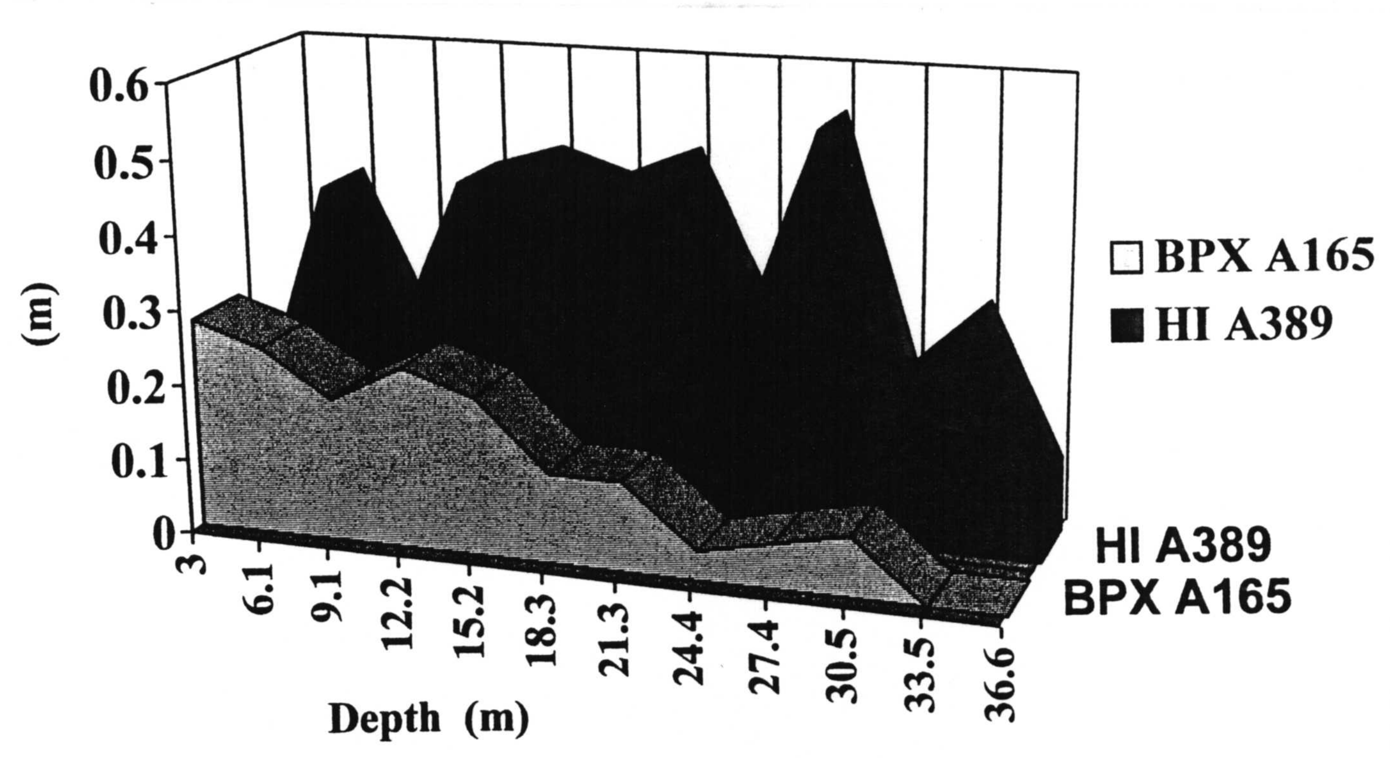

Figure 3A.5. Comparison of rugosity between High Island A-389A and East Breaks A-165.

composition of the fouling community defined five distinct zones vertically from the surface to 53 m. (Figure 3A.6). Photo transects defined 48 species representing 8 phyla as the most common components of the fouling community.

With a diversity of 0.58, the 0-1 m zone had the lowest diversity. This narrow zone is dominated by a dense growth of algae covering *Isognomon* sp. tree oysters and barnacles. A rugosity of 0.20 is fairly uniform throughout for this zone.

From 1.1-3 m the fouling community is dominated by brown and green algae, low relief encrusting orange *Tedania ignis* sponge and small acorn barnacles. This community grades into a dense growth of *Isognomon* oysters. The diversity of this zone (0.653) is somewhat reduced possibly because of temperature variability, high wave energy and exposure to produced waters. Mean rugosity in this zone was calculated at 0.20.

Between 3.1 and 23 m depth dense growths of tree oysters and barnacles interspersed with green algae and low-relief *Bouganvillia inaequallis* hydroids dominated the fouling community. Orange and red sponge overgrow the barnacle shells in the upper regions. The spiny oyster *Spondylus americanus*, dense colonies of tubiculus polycheate worms, hydroid colonies (generally *Bouganvillia inequallis*), *Filograna huxleyi*, *Carijoa reesii*, articulated bryozoans (*Crisia* sp.), tunicates and isolated cup corals (*Phylangia americana*) are common in this zone. Several large patches of the hydrocoral *Millipora alcicornis* are present as well. At 0.879, diversity in this zone was higher than any other zone in which the fouling community was sampled. Rugosity in this zone measured 0.06.

From 23.1 to 25 m fouling community diversity was calculated as 0.72 and rugosity measured 0.02. The fouling community at this depth is characterized by a distinct drop in diversity and rugosity. Low relief sponges, hydriods and brown algae dominate. This zone extends approximately 1 m above and below the horizontal template structure at 24 m. This reduction is presumed to be caused by grazing animals associated with the horizontal structure.

The fouling community between 25.1 and 53 m of depth exhibit a diversity of 0.80 and a mean rugosity of 0.07. The limited overstory of this community is dominated by the hydroids *Obelia dicotoma* and *Bouganvillia inequallis*. *Spondylus americanus* oysters, ribbon, encrusting and fan bryozoans (*Reteporellina* sp.), *Filograna huxleyi*, and *Carijoa reesii* . A low relief mat of brown algae, assorted sponges, and tunicates dominates the understory. In the deeper portions antipatharians and stalked bryozoans are common.

The sponge community of HI 389 is composed of 27 species (Adams 1995). These species comprise two classes, 10 orders and 18 families. Only 18 species were present in the transects. *Stelletta kallitetliia, Tedania ignis, Desmacella meliorata* and *Neofibularia nolitangere* were the dominant species. *Stelletta kallitetliia* and *Tedania ignis* were observed in each of the 0.5 m depth intervals along the transects. *Desmacella meliorata* was absent from 19-24 m but was present throughout the rest of the transect. *Neofibularia nolitangere* was present in all depths from 13-37 m but was absent at shallower depths, *Geodia gibberosa*, and *Suberites* sp. were confined to the upper 18 m of the water column while *Halichondria* cf. *magniconulosa*, *Dictyonella ruetzleri* and *Clathria echinata* were confined to depths between 19 and 37 m. *Clathrina coriacea*, *Callyspongia vaginalis* and *Phorbas amaranthus* showed no distinct depth preference, being irregularly distributed along the length of the transects.

Although the sponge community displayed a slight increase in species richness with depth (13 in the upper zone, 14 in the mid depth and 15 in the deeper depths to 37 m) there was no significant difference between depth zones. Diversity (H') showed similar slight but insignificant increases with depth.

Collectively the dominant sponge species composed almost one half of the fouling community along the transects. The dominant sponge species composed 38% of the fouling community in the upper zone (0-12 m), 42% in the mid zone (12.5-24.5 m) and 43% in the lower zone (25-37 m).

At depths of 45.7 and 53 m, several large specimens of the sponge *Neofibularia nolitangere* were observed to be in an advanced state of decay during the month of December. These sponges had begun to recover by the following March.

In the investigation of finfish (Rooker *et al.*, *In review*), 46 species were observed. Serranids (26.2%), labrids (25.4%), and pomacentrids (24.6%) were the dominant reef-dependent taxa. Of the three designated depth zones (upper 1.5-9.0 m; middle 9.0-16.5 m; lower 16.5-24.0 m) mean abundance and diversity were

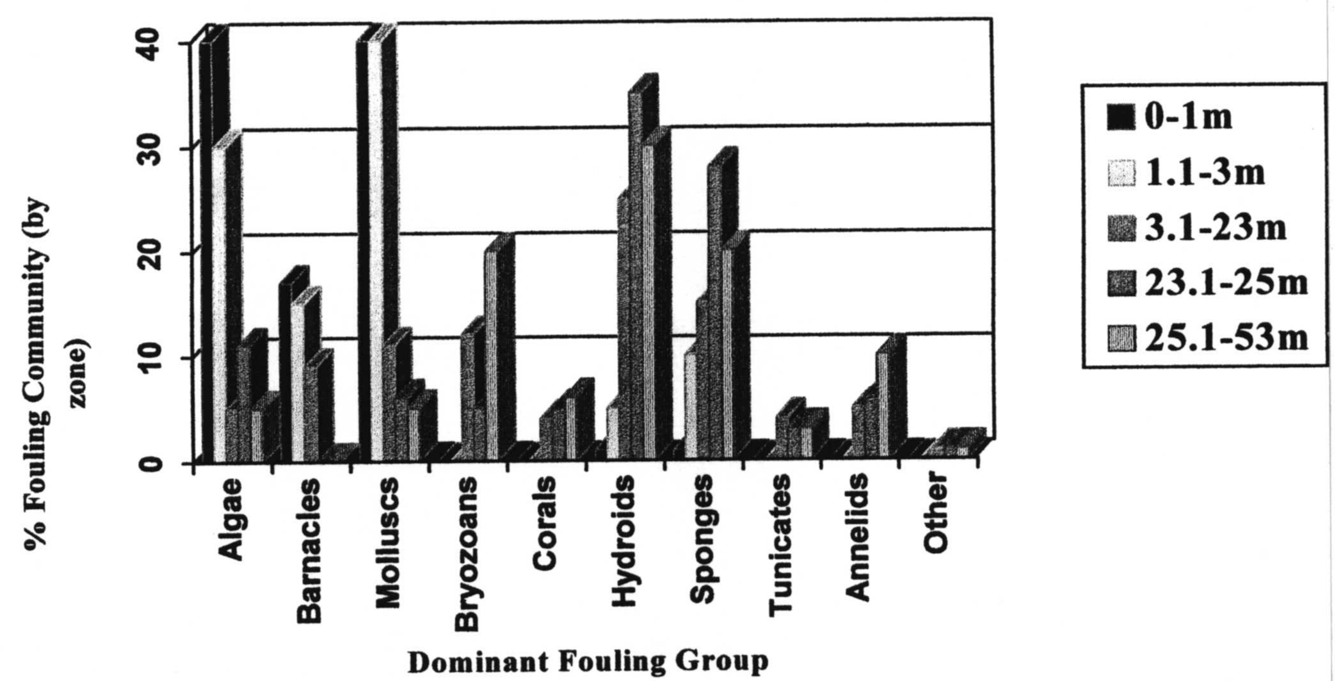

Figure 3A.6. Vertical zonation of fouling community on East Breaks 165.

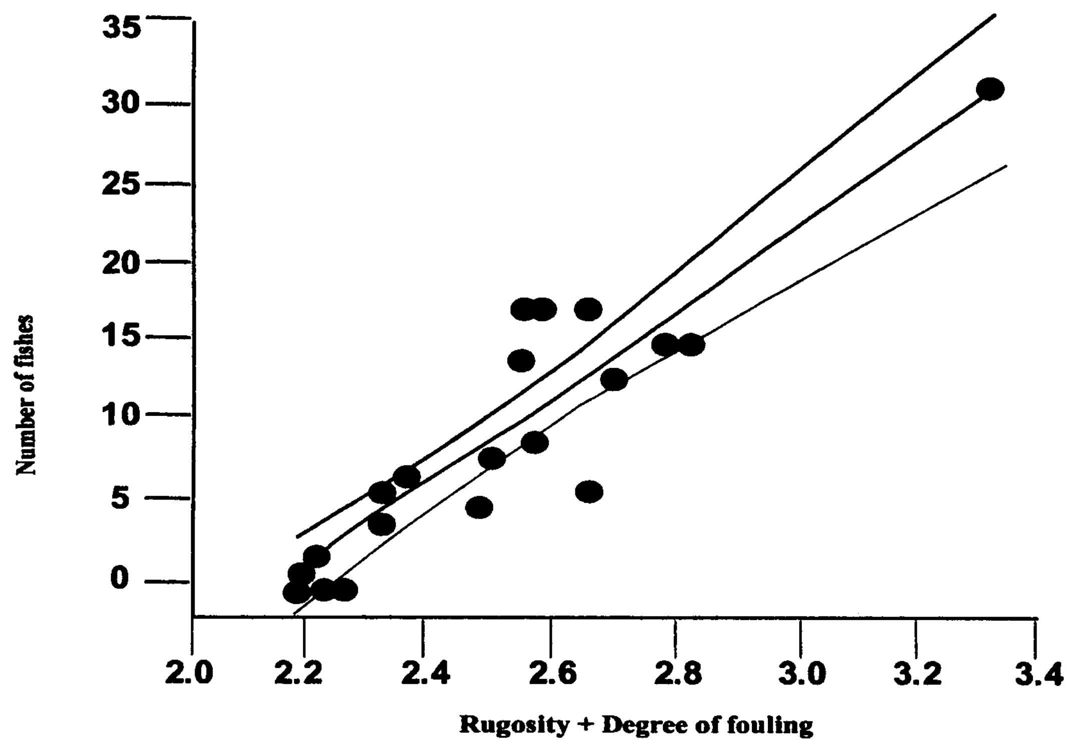

Figure 3A.7. Correlation of reef dependent finfish to rugosity and degree of fouling on High Island A-389 (after Rooker *et al.* 1995, in preparation).

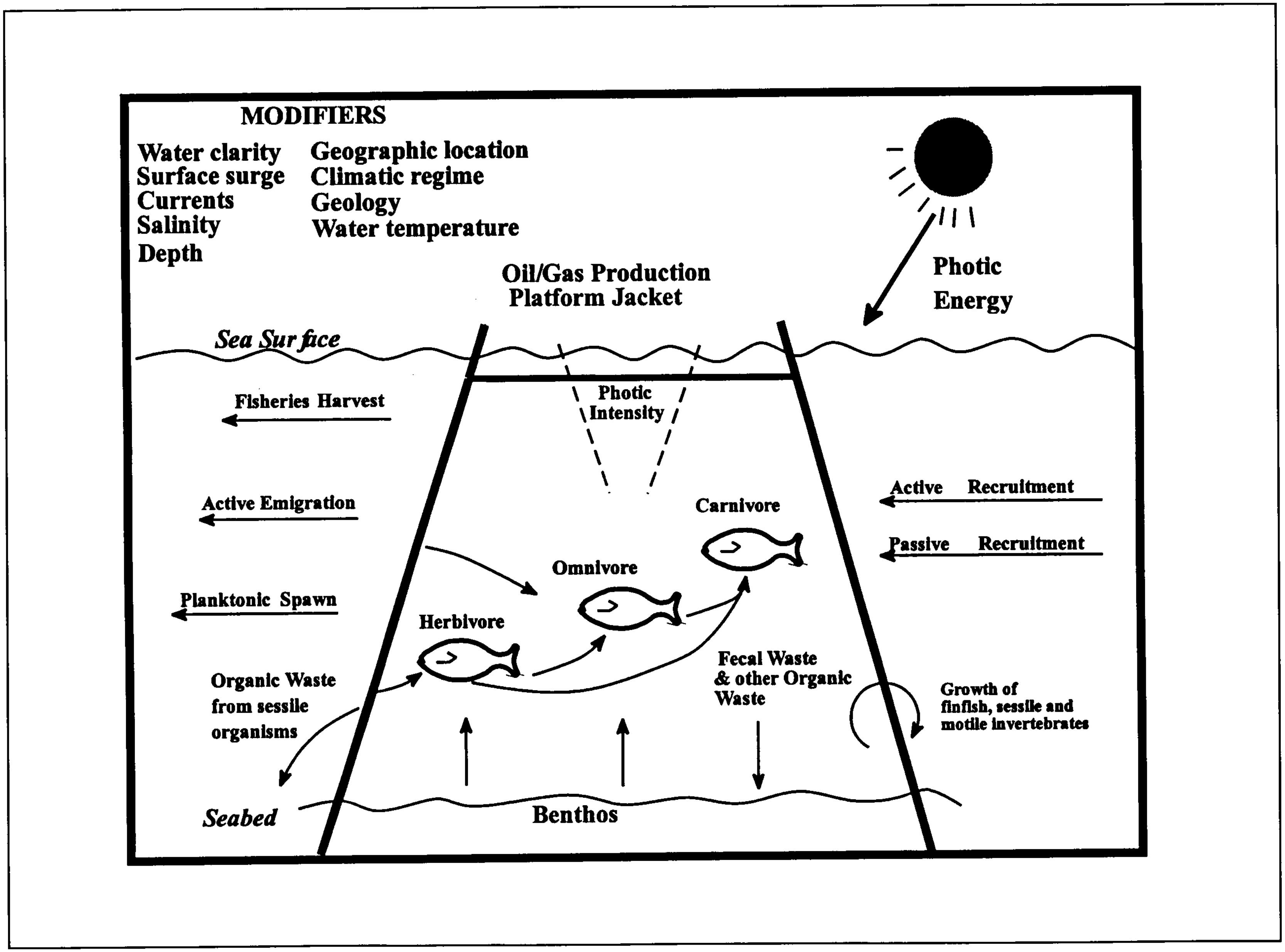

Figure 3A.8. Conceptual model of ecological productivity.

lowest in the upper zone. Night time counts were characterized by marked reduction or complete absence of several species, due in part to twilight cover-seeking and movement activities. Seasonal variations in community composition and species abundance (May vs. September) were primarily due to recruitment of juveniles (0 - age fishes) to the artificial reef in late summer. Increases in total fish abundance (all taxa combined) coincided with both increasing habitat rugosity and degree of fouling (Figure 3A.7).

DISCUSSION

As artificial reef substrate, oil and gas platforms are relatively simple: smooth rounded pipe surfaces providing maximum surface for colonization but minimal rugosity and attendant microhabitats. Rugosity is created by the sessile fouling community which, typically below approximately 3 meters is comprised predominantly of soft bodied organisms. Shallower than 3 meters, shelled molluscs, primarily barnacles, and tree oysters, dominate the sessile community. Compared to natural reefs, platform reefs are unique in that they possess vertical relief penetrating the water's surface during their operational phases. In deep waters and opaque waters this places substantial portions of the reef in the most intense area of the photic and high mechanical energy zone near the surface. Both as active and obsolete production platforms, they possess internal volume, that is the area encompassed within the framework of the structure which is habitable by resident and migratory pelagics.

Observing sessile fouling community assemblages on offshore platforms, Galloway and Lewbel (1982) described three distinct biological zones. From the shoreline seaward, distinct fauna assemblages were reported as coastal (0 - 30 m), offshore (30 - 60 m), and bluewater (>60 m). Both species composition and biomass were reported to differ between zones. From a fisheries productivity and management perspective, key questions are, what is the potential sustainable fisheries productivity of platform reefs in each zone? And, if significant differences exist between zones, what is/are the causative factor(s)? From an ecological viewpoint, one must consider the overall contribution that platform reefs make to the health, productivity, and sustainability of the Gulf ecosystem. Does the increase in the diversity and biomass of sessile algae and invertebrates have an impact on the overall well being of the Gulf of Mexico as a natural ecosystem?

Ecologically, productivity of an artificial reef occurs as: 1) an increase in biomass; 2) increase in diversity; and/or 3) increase in population densities (Figure 3A.8). Socioeconomically, productivity occurs as increased potential for fishery harvest, either by congregating and making the resource easier to harvest and/or increasing population densities, or by creating recreational opportunities. It appears that platform reefs contribute significantly to the overall biomass and diversity of the sessile fouling community in the northern Gulf of Mexico. Also, through the creation of microhabitats providing cover and concealment for mobile invertebrates and reef fish, the fouling community plays an important role in determining the holding capacity of a platform artificial reef. Assuming that platform reefs increase feeding opportunities for migratory pelagic and demersal species, it is hypothesized that by increasing the holding capacity for organisms low in the trophic hierarchy, the potential holding capacity and retention time for those finfish with commercial value is increased.

Continuation of this work will include:

1) Coverage of expanded geographical range.
2) Acoustic and visual survey of finfish populations.
3) Mark and recapture studies of pelagic seasonal migrants.
4) Age stratification analysis (otolith analysis).
5) Food preference (trophic structure).
6) Reproductive contributions (spawning).
7) Recruitment (sessile invertebrates and finfish).
8) Fouling community biomass.
9) Vertical zonation.
10) Impact of nephloid layer and suspended particulate matter.
11) Impact of photic intensity.

ACKNOWLEDGMENT

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Susan Cox is a graduate student pursuing an M.S. degree in Biology at Texas A&M University-Corpus Christi. Susan's interests range from coastal wetland marshes to bluewater platforms in the deep Gulf waters. Ms. Cox has been studying artificial reef systems for two years as a graduate research assistant for the Center for Coastal Studies She is particularly interested in the utilization of the fouling community by reef fish populations.

Christi Adams is a Pd.D. candidate with the University of London. Ms. Adams earned an M.S. degree in biology at Texas A&M University-Corpus Christi while studying the sponge community of an offshore gas platform. Her interest in sponges has continued and is currently the focus of her dissertation work.

Jeff Childs is a M.S. candidate in the Department of Wildlife and Fisheries Sciences at Texas A&M University. Mr Childs is actively involved in the study of elasmobranchs of the northwestern Gulf of Mexico.

Jay Rooker is a Ph.D. candidate with the University of Texas Marine Science Institute, where he holds a Julian C. Barton Fellowship. Mr. Rooker is an experienced tropical fisheries researcher whose current research focuses on the condition, growth, and natural mortality of larval and juvenile red drum in south Texas.

INDUSTRY'S PERSPECTIVE ON THE RECYCLING OF PLATFORMS INTO ARTIFICIAL REEFS

Mr. Vance Mackey
Mr. Greg Schulte
Offshore Facilities Services
Chevron Petroleum Technology Company

This presentation focuses on the Artificial Reef program from the perspective of the oil industry.

TYPICAL PLATFORM

This presentation discusses a "Fixed," four-pile platform in 150 ft of water (See Figure 3A.9). There are five main items associated with this type of platform:

- Jacket
- Piling
- Superstructure (Deck)
- Conductors
- Pipeline

The jacket is the portion of the platform that extends from the mud line to just above the water line. During

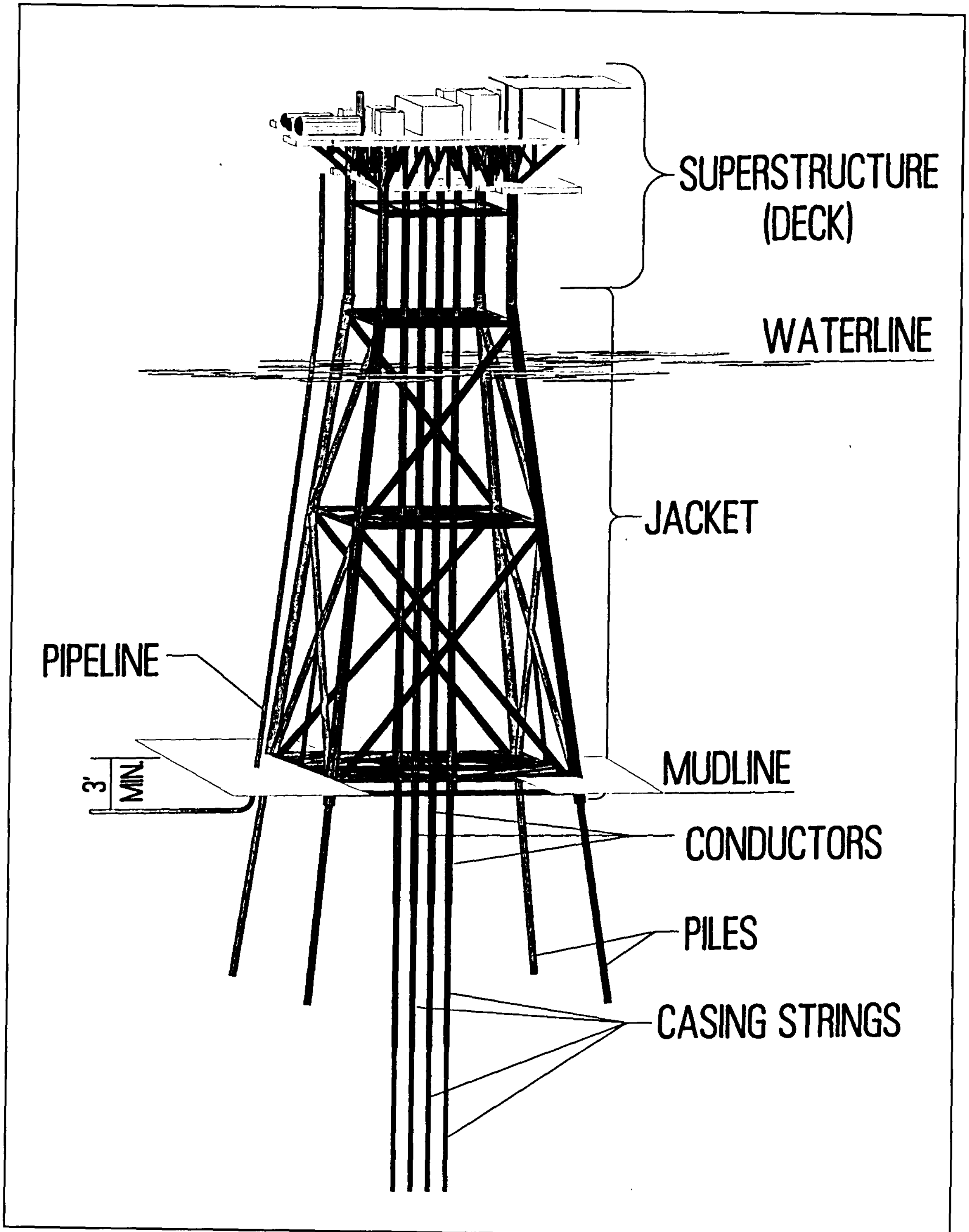

Figure 3A.9. Diagram showing major elements of a four-pile platform in 150 feet of water.

jacket installation, piles are driven through each jacket leg into the seafloor. Piles are nothing more than large diameter pipe that pin the jacket to the seafloor. Once the piles are installed they are welded to the top of the jacket. The superstructure, more commonly known as the deck, which supports the processing equipment and piping, is then set on the piles. The conductors (wells) extend up through the center of the jacket and deck and act as the conduit for oil and gas production to get to the surface. The conductors are usually made up of three to five casing strings grouted together into a single unit. The pipeline is clamped to the side of the jacket and extends from the mud line up to the deck. The pipeline is used to carry production to/from the platform.

Shown below are typical weights for a jacket, piling and superstructure for a four-pile platform in 150 ft. of water. Also shown is the weight of the same jacket after it has been installed for several years. The increase in weight is due to marine growth which accumulates on the jacket members. The marine growth can be 4 inches thick or more in some places.

Typical Four-Pile Platform in 150' of Water

Superstructure (with equipment)	500 tons
Jacket (New)	450 tons
Jacket (with Marine Growth)	600 tons
Pile (cut @ 15' BML)	60 tons ea.
Conductor (cut @ 15' BML)	125 tons ea.

Conductor and piling weights are calculated based on severing each at 15 ft. below mud line. The 15ft cutoff elevation is a Minerals Management Service (MMS) requirement.

PLATFORM REMOVAL PROCESS

The MMS requires operators to remove all platforms within one year after the lease is lost. Generally, the lease is considered lost once all production from that lease has ceased. In a lease with a number of platforms, an operator may choose to remove some platforms before loss of the lease. Safety concerns on older platforms or the economic benefits of spreading the abandonment cost over a number of years are some reasons for early removal of some platforms.

The platform removal process occurs in five distinct phases:

- Well Plug & Abandonment
- Decommissioning
- Pipeline Abandonment
- Platform Removal
- Site Clearance

Well Plug and Abandonment—Wells are plugged using mechanical plugs in combination with plugs of cement set at several elevations in the well bore (See Figure 3A.10). Each plug is tested to a predetermined test pressure to ensure no leaks are present.

Decommissioning—Decommissioning is preparing the structure for removal prior to arrival of heavy lift equipment. Decommissioning activities include conductor severing, pile jetting, equipment flushing, pipeline flushing, and preliminary equipment removal. Pile jetting is necessary to remove the mud plug from inside the pile down to the required severing depth. The mud plug is removed by jetting and either air lifting or pumping the soil slurry out of the pile. This allows the severing device to be lowered inside the pile without obstruction. To access the piles, holes are cut in the deck leg and the jetting tool lowered through the deck leg into the pile.

Pipeline Abandonment—Pipelines in less the 200 ft. of water are buried a minimum of three feet below mud line. Once they have been flushed and plugged, operators typically permit to abandon these pipelines in place. The ends of the pipelines at the platform are cut and buried a minimum of three ft. below mud line.

Platform Removal—The platform removal is typically accomplished in reverse of how the platform was installed. A heavy lift derrick barge, which could cost in upwards of $125,000/day, is contracted to lift the deck, conductors, jacket, and piles. The deck is removed first by cutting the welded connection at the pile top. The conductors are then lifted up through the jacket. The piles are then severed using explosives, mechanical cutters, or abrasive cutters. The jacket is then lifted, usually with the piles still inside Disposition of the platform will be addressed later in the presentation.

Site Clearance—If the platform has not been reefed in place, the site must be cleared of all debris for the area covered by a 1,320 ft. radius circle measured from the center of the platform location. The entire area must be

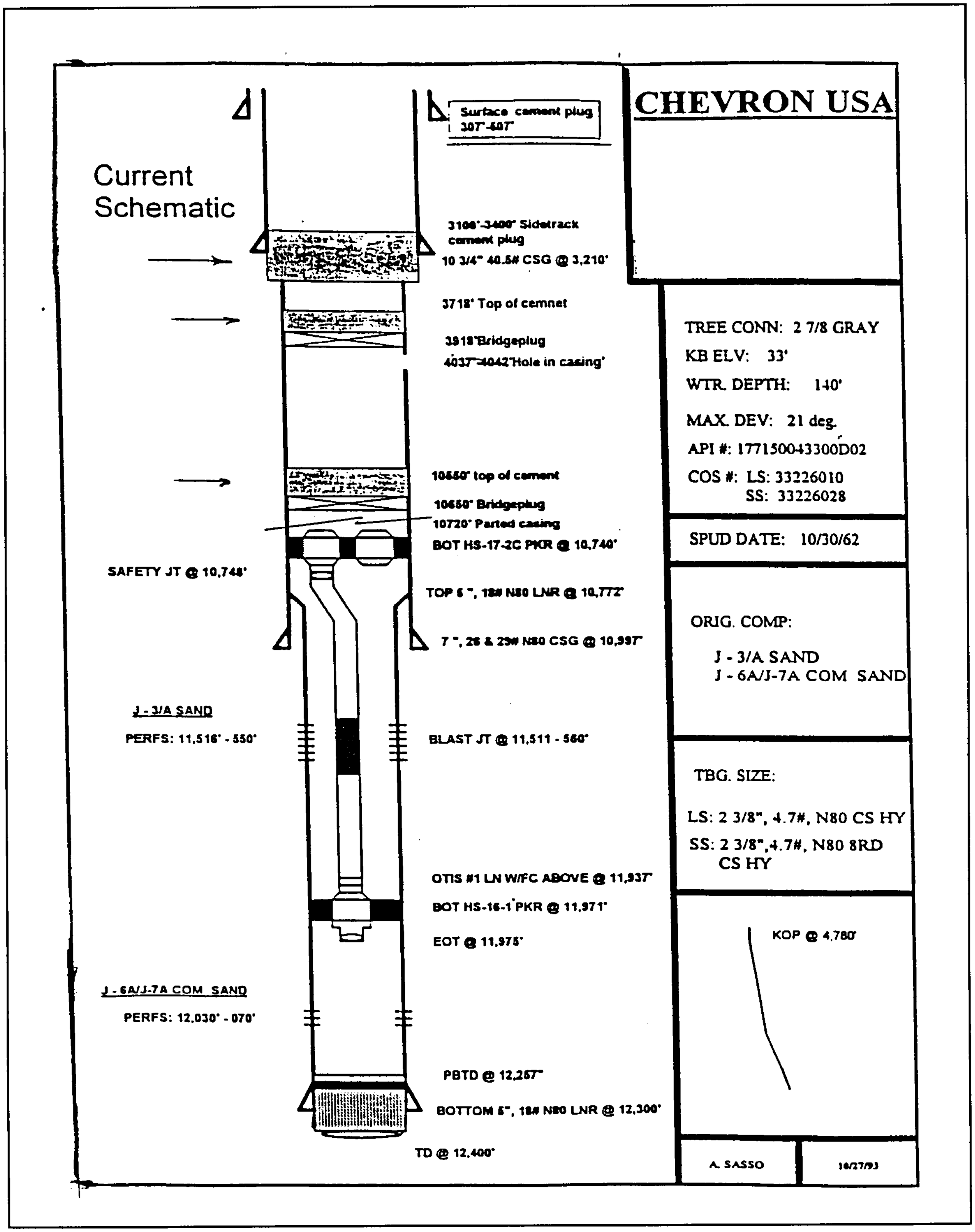

Figure 3A.10. Schematic of mechanical and cement plugs set in combinations at several elevations in a well bore during the first step in the platform removal process.

trawled in two directions. Figure 3A.11 shows a typical trawl grid required for site clearance verification.

REMOVAL COST

Below are typical removal and clean up cost for a 4-pile platform with six (6) conductors in 150 ft. of water:

Activity	Cost
Well P&A	$300,000
Decommissioning	110,000
Pipeline Abandonment	45,000
Platform Removal	570,000
Site Clearance	150,000
TOTAL	$1,175,000

Obviously, removing a platform is a very expensive activity. As described in the next section, the "Rigs to Reefs" program provides a cost effective and environmentally acceptable alternative for platform abandonment.

Once the oil and gas platform has been removed the oil company has several options on how to proceed.

RE-USE

If the abandoned platform is in relatively good condition, and the oil company has a need, they may elect to re-use the deck, jacket, and equipment or any combination thereof. The main advantages of platform re-use is cost savings. If the oil company removing the platform does not have a re-use application, it may put the deck, jacket, and equipment on the open market to other operators who may have a need. In this situation, the oil company with the surplus platform makes money on the sale, while the buyer of the abandoned platform saves money on fabrication costs and improved schedule.

SCRAP

If the abandoned platform is in poor condition, and it is not practical to turn the platform into a offshore artificial reef, the platform will be brought to shore and sold for scrap. The scrap dealer will typically pay the oil company between $50 and $90 per ton to purchase and scrap the abandoned oil platform. On a typical four-pile platform in 150 ft of water, the scrap value will amount to a mere $40,000-$72,000 on a structure costing millions to fabricate and install.

REEF

The oil company may elect to participate in one of the many artificial reef programs currently sponsored by several of the Gulf Coast states. Several factors influence the decision to participate in a reefing program such as platform location relative to a planned reefing area, water depth, re-use potential, cost saving versus reef donation amount, and platform size. Timing is also important as it can take up to six months to obtain a reefing permit. If an oil company does not plan ahead, reefing may not be an option due to the time restraints.

HISTORY OF LOUISIANA RIGS TO REEF PROGRAM

The National Fishing Enhancement Act of 1984 paved the way for the creation of several artificial reef programs in the Gulf Coast states. The National Fishing Enhancement Act established standards for the planned development of artificial reefs in state and federal waters. As a result of the 1984 Fishing Enhancement act, Louisiana formed the Louisiana Artificial Reef Initiative (LARI). LARI consisted of industry, state, federal, and university representatives committed to developing Louisiana's Artificial Reef Program. In 1986 LARI drafted and had approved the Louisiana Fishing Enhancement Act (Act 100). Act 100 outlines the guidelines necessary for the establishment of Louisiana's Artificial Reef Program.

Once the basic artificial reef guidelines were approved, pre-determined reef areas had to be established. The pre-determined reef areas had to be positioned such that they did not adversely affect the fishing industry, shipping lanes, pipeline corridors, or military zones. Nine planning areas have been established off the coast of Louisiana (see Figure 3A.12). Management of the Louisiana Artificial Reef Program currently resides with the Louisiana Department of Wildlife and Fisheries (LDW&F).

One of the primary conditions of the Louisiana Artificial Reef program is that the participating company must donate to the state 50% of the savings realized by participating in the reefing program. These donated funds are put into a protected trust, the interest of which pays the costs to manage and enhance the Artificial Reef Program.

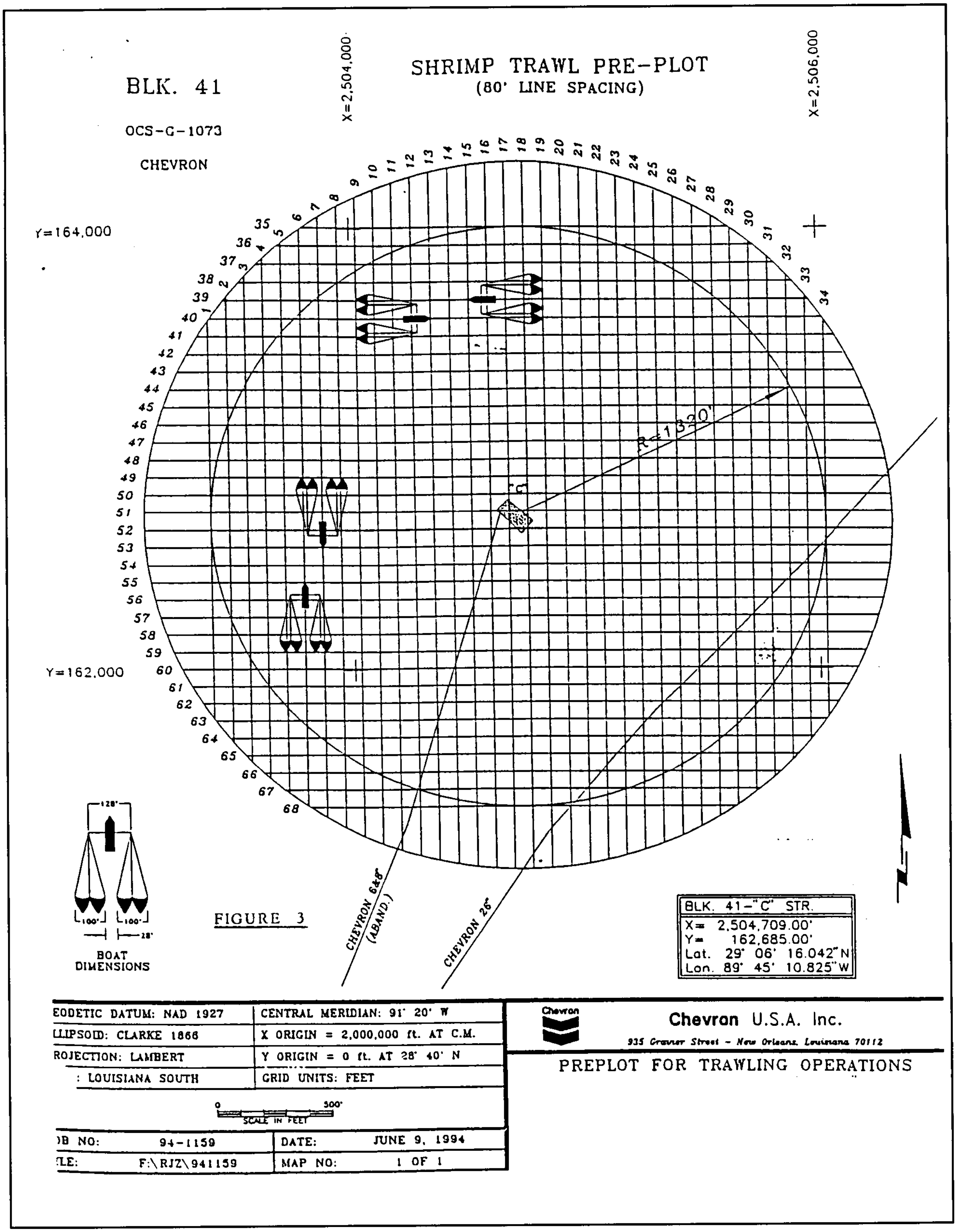

Figure 3A.11. Diagram of a typical trawl grid required for site clearance verification.

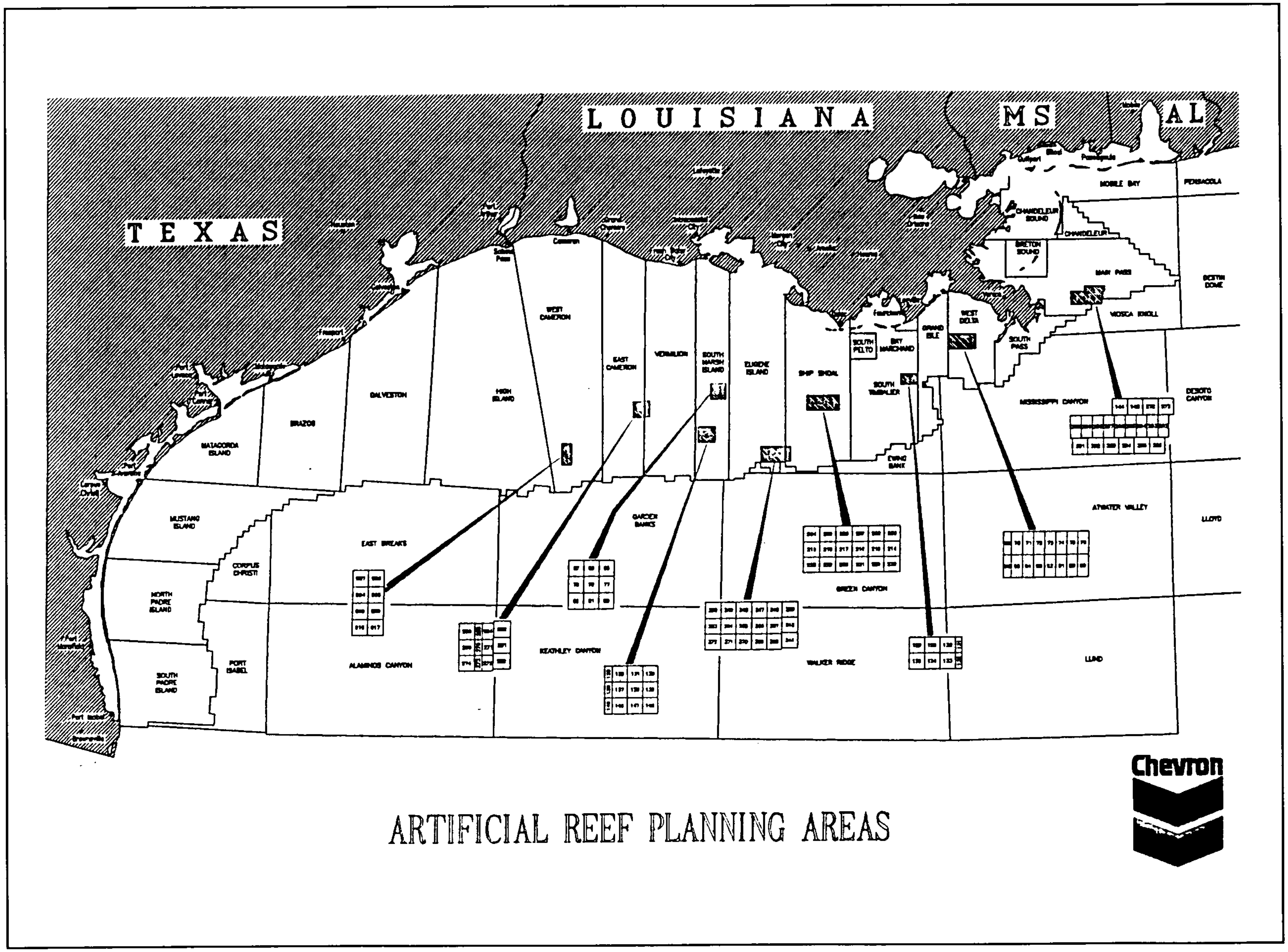

Figure 3A.12. Artificial reef planning areas.

CANDIDATE SELECTION

Once the oil company has determined that a platform must be removed, the company must then decide if the platform is a good reef candidate. As mentioned above, re-use of either the deck, jacket or both is a prime consideration. Several other factors influence the decision to reef a platform, including platform location, platform weight, and water depth. The closer the platform is to an approved reef planning area the better the chances that the platform will be reefed. The artificial reef planning areas are located in deeper water to ensure minimum clearance requirements for safe navigation. For this reason, jackets in less than 100 ft. are generally not considered good reef candidates due to the cost to tow the platform to an approved reefing zone. Platforms in less than 100 ft. of water also weigh less and are thus easier and cheaper to put on a material barge and transport to shore for scrap. Jackets in water depths greater than 150 ft. are typically heavy, expensive to remove, and thus make the best reefing candidate. Decks are rarely reefed as they can usually be brought to shore, refurbished and re-installed at a later date.

SITE SELECTION

Once the oil company has determined what will be reefed it must decide where. As mentioned, the oil company has nine pre-determined artificial reef planning areas to choose from. Each planning area is comprised of several offshore blocks. If the platform is already located in one of the planning areas, the platform will simply be "toppled in place." If the platform is not located in a artificial reef planning area, the platform will be towed to the nearest reef site and toppled. If towing a platform to a reef block, the company must consider who owns the block and what the water depth is at the reef location. If another oil company owns the block, approval from that company must be obtained prior to reefing. Water depth must also be considered for both reefing scenarios described. The Coast Guard maintains minimum "as toppled" clearance requirements. If the water depth is too shallow, the platform will have to be modified or an alternate location selected.

PERMITTING PROCESS

The next step is to obtain a reefing permit. The oil company must contact the LDW&F and provide them information identifying what will be reefed, what pre-determined artificial reef planning zone the platform will be reefed in, the configuration of the platform in the artificial reef planning area, and what minimal clearances will be after the platform is reefed. Once the oil company and LDW&F have agreed to all of the above, the LDW&F obtains a permit from the Corps of Engineers. The reef permit is obtained by LDW&F in lieu of the oil company as the LDW&F will assume ownership of the platform once is has been placed at the reef site. Receiving the reef permit includes a 60-day public notice period as well as permission from the Coast Guard on minimum clearance requirements and navigation aids to mark the reef location. The entire permitting process can take up to six months.

Once the permit has been obtained, the oil company and state must enter into an "Act of Donation" contract. The "Act of Donation" contract serves several purposes. It outlines the exact location of the proposed artificial reef, conditions for the transfer of ownership, and donation amount. Once the "Act of Donation" is executed by both parties the reefing can occur.

THE REEFING PROCESS

The oil company has two primary methods for performing the actual reefing, both of which are dependent on location.

If the platform to be reefed is located in one of the pre-determined reefing areas (see Figure 3A.12), the platform can be toppled in place. In this scenario all non-reefable material is removed, the jacket legs severed, and the platform toppled in place utilizing a derrick barge. A topple-in-place reef is typically the most economical reef method because the platform does not need to be towed to the reef site by an expensive derrick barge, conductors and piles are generally not pulled, and site clearance requirements are relaxed. The increased savings realized by a topple-in-place reef are passed on to the state in the form of a larger donation amount.

If the platform is not located in a pre-determined reefing area it can still be turned into an artificial reef. This can be accomplished by removing the platform from its present location and towing it to a pre-determined reef zone utilizing a derrick barge. Depending on the distance of the platform from an approved reefing zone, substantial towing times and costs may be incurred. Once the platform arrives at the specified reefing zone the platform is set on bottom and the platform toppled using a procedure similar to that described under topple in place. Once the platform is toppled, divers verify minimal as-toppled clearances and a LWD&F maintained buoy set to mark the artificial reef location. An "As Reefed" location plat is then provided to the LWD&F. If the reefing was done according to the conditions of permit, the state is now the owner of another offshore artificial reef. A tow-then-topple is still economically attractive, but the costs savings is substantially less than the topple-in-place reef because of the towing cost and the costs to complete site clearance requirements at the original platform location..

BENEFITS

A major benefit of the "Rigs to Reef" program is that it offers an oil company an opportunity to have a positive environmental impact. The reefed platform provides vitally important habitat for the formation of algae, coral, and other important nutrients. These nutrients provide the basic support needed to sustain a wide range of marine life. The increased marine life around an artificial reef also promotes recreational fishing which leads to increased tourism dollars for the state.

The platform removal costs are also reduced by participation in the "Rigs to Reef" program. Reefing a platform is usually much cheaper than loading the abandoned platform onto material barges and transporting to shore. Establishing a reef site also saves money on future removals. An established reef site allows the oil company to reef additional platforms on future removals.

Typical savings for a tow-then-topple four-pile jacket in 150' of water can range from $0 to over $300,000 depending on water depth, size of platform, and location relative to closest planned reefing area. Similarly, the costs for the same platform toppled in place can range from $120,000 to over $500,000 depending on the same parameters. Chevron has reefed over 15 platforms and donated over 1.2 million dollars since the inception of the Louisiana Reef program.

Vance Mackey is a design and construction engineer with Chevron Petroleum Technology Company. Vance is a core member of Chevron's platform abandonment team. Previously a facility engineer for Chevron U.S.A. Inc., he worked extensively with offshore platform production facilities and was the 1993 Abandonment Team Leader for Chevron's Lafayette, La. office. He has served on a subgroup to the API/NOIA Adhoc OCG Lease Assignment Group, which was responsible for developing a template of abandonment cost ranges to be used by the MMS for future bonding requirements. He has been a project manager and/or consultant on over 35 abandonment projects in the Gulf of Mexico. He received a B.S. degree in civil engineering from the University of Southwestern Louisiana.

Greg Schulte is a design and construction engineer with Chevron Petroleum Technology Company. Greg is also a core member of Chevron central platform abandonment team. Greg has been project manager on over 30 structure removals and served as Chevron's "Rigs to Reef" Coordinator for the last three years. He has been directly involved in seven platform reefings off the coast of Louisiana. He has been with Chevron since graduating from the University of Missouri-Rolla with a B.S. degree in civil engineering in 1991.

ARTIFICIAL REEFS OFF TEXAS: AN EVALUATION BY CHARTER FISHING AND DIVING BOAT CAPTAINS

Mr. Hal R. Osburn
Ms. Leslie D. Finkelstein
Dr. Robert B. Ditton
Texas A&M University

Artificial habitat development in the Gulf of Mexico off Texas has been significant but largely unintentional. Over 800 petroleum production structures or rigs provide several thousand acres of hard substrate habitat in the form of durable steel pipes extending throughout the water column. Although not purposefully placed as artificial reefs, these habitats allow for attachment by hard-surface-limited sessile invertebrates which, in turn, create an interactive food web supporting a host of reef fish species.

Hard substrate habitat in the Gulf is limited and so with an escalation in the early 1980's of rig removals, the need to preserve the valuable hard substrate of these offshore rigs was widely recognized. With an estimated 900,000 saltwater anglers and 250,000 divers in Texas, demand remains high for fishing and diving opportunities at these easy-to-find sites.
Along the 580 linear kilometers of Texas shoreline are situated dozens of fishing ports. These coastal communities have built up large infrastructures to

support and accrue the economic benefits of this growing demand for fishing and diving opportunities.

To realize this goal of creating and preserving these valuable habitats, the Texas Legislature in 1989 directed the Parks and Wildlife Department or TPWD to develop the artificial reef potential off Texas for enhancing fishery resources and fishing and diving opportunities. TPWD was aided in this endeavor by the creation of a dedicated Artificial Reef Fund to finance research, administration, maintenance, liability, and construction for the program and by the creation of an Artificial Reef Advisory Committee representing all major stakeholders in the optimum development of artificial reefs.

To guide future placement, TPWD produced the Texas Artificial Reef Plan, which followed an exclusion mapping approach. This technique applies geographic, hydrographic, geological, biological, ecological, social, and economic considerations as siting criteria.

In addition, TPWD has employed a user-resource planning framework for the Artificial Reef Program which includes advanced site planning, permitting requirements, location and design criteria, reef maintenance and management goals, and program evaluation.

Through mid-1995, the Texas Artificial Reef Program has sited 31 obsolete rigs as well as several other materials of opportunity at 24 sites. In addition, the Artificial Reef Fund has received $3 million in donations from petroleum companies.

Although many of the rigs donated have been toppled in place at sites over 150 kilometers from the shore, reef fish ecosystems are being preserved at these sites, and the large monetary donations have provided the funding to create a number of nearshore reef.

Following this early success, efforts are now being made to better address the program evaluation portion of the planning framework. More specifically, we want to develop appropriate methodology and begin a systematic assessment of the characteristics, impacts, and needs of major artificial reef user groups. In other words, how well is the program doing in satisfying the customers it was designed to serve? The present study is our first effort in this area and is focused on for-hire or charter fishing and diving boats.

In conjunction with Texas A&M University, an inventory of Texas offshore charter and party boats used for recreational fishing and diving was completed in early 1994. Party and charter fishing boats were identified as two segments within the charter fishing industry in which party boats were larger vessels capable of carrying more than six people.

A total of 173 captains were identified and each was sent through the mail a 12-page self-administered questionnaire. Questions were designed primarily to provide information on the frequency of reef use, characteristics of charter operations, and preferences for future artificial reef development.

Questionnaire mail-outs followed a modified version of the Dillman survey methodology, including four waves of mailings and follow-up phone calls. A total of 118 captains responded for an overall response rate of 68%.

Results of the study were very successful in providing insights into the business operations and attitudes and opinions of Texas charter boat captains. Boat captains are generally stable in their business although it tends not to be their sole household income. Survey respondents have been in the charter industry for an average of over 12 years with nearly all captains planning to be in business at least another three years. However, on average only 55% of their household income comes from the charter business. Only 16% said their household earned all its income from the charter business.

Over 180,000 paying customers were estimated to participate in over 14,000 offshore charter trips annually. Charter fishing boats accounted for 59% of the total trips offshore.

Natural and artificial hard substrate habitats offshore Texas in general, and purposefully-placed artificial reefs in particular, were identified as a critical component of both charter fishing and diving operations. Over 79% of the trips taken offshore were to natural or artificial hard substrate habitats. Over 10% of the trips were to TPWD artificial reef sites although it's likely that unfamiliarity by captains with which artificial reef sites were placed by TPWD resulted in an underestimate of trips to TPWD artificial reefs.

Dive boats had the highest ratio of trips to TPWD artificial reefs versus total trips at 1 to 9. The majority of dive boat trips, however, appear to be to rigs which are still standing.

Twenty-six percent of all charter trips were to other purposefully-placed artificial reefs. Many of these other artificial reefs may have been private reefs composed of small amounts of secretly placed materials for the purpose of enhancing fishing success, particularly by charter fishing captains.

TPWD artificial reef sites used most frequently tended to be those located closest to metropolitan areas. Over 52,000 anglers and 6,000 divers in the previous year took charter trips to TPWD artificial reefs with two-thirds originating from two locations, Port Aransas and Freeport. Summer (June-August) was the period of peak activity with 33% of party boat trips occurring then, 36% of charter boats trips, and 70% of dive boat trips. Sites used the least were those located 150 kilometers or more offshore.

Boat captains reported that one of the most important influences on charter trip plans is the distance they must travel offshore. Captains of each boat type reported maximum travel distances in the 110 kilometer range. Charter and party fishing boat captains reported about 54 kilometers average distance traveled offshore, but dive boat captains traveled almost twice that distance offshore on average. Other important influences in selecting a reef site included water depth, presence of desired fish, and diversity of marine life.

The most preferred types of materials for future artificial reefs were rigs and vessels. However, there was no coastwide consensus on preferences regarding other reef placement parameters. Boat captain preferences for reef distance from shore generally reflect differences in bathymetry along the Texas coast, with lower coast captains preferring more nearshore reefs corresponding to greater nearshore water depths in that area. Party boat and dive boat captains tended to prefer reef placement in deeper water than did charter fishing boat captains.

To gauge the opinion of boat captains regarding reef management issues, they were asked to indicate their level of agreement with specific management statements, such as "I want to see more artificial reefs placed by TPWD in the Gulf." Responses were categorized on a five-point Likert scale ranging from Strongly Agree to Strongly Disagree. There was almost unanimous agreement that TPWD does need to place more artificial reefs in the Gulf by both charter diving and fishing captains.

However, there was considerable disagreement regarding the use of marking buoys, which make the site easier to find, and mooring buoys, which make it easier to tie off vessels. Dive boat captains favored the use of these buoys by about a three to one ratio over fishing boat captains. Opposition by fishing boat captains may have been because they wish to conceal a good fishing spot.

Disagreement also existed about designating artificial reefs for specific uses only, such as sport fishing, or for specific types of fishing gear only, such as rod and reel. A plurality of captains were opposed to designating certain reefs for specific gears and/or specific uses. However, there was no clear difference between fishing and dive boat captains in support or opposition to such measures.

This study documented that enhancement of the marine aquatic environment off Texas using artificial reefs has been successful in providing substantial user opportunities to the charter fishing and diving industries. Not only are many of TPWD's artificial reef sites regularly visited by charter boat captains, there is also high demand for additional sites. However, specifics of where new sites should be and how they should be managed and maintained depends on the primary activity and geographic location of the charter boat captain.

To maximize benefits for the entire charter industry, the TPWD Artificial Reef Program should likely emphasize, where possible, diversity in future site selection and management. Artificial reefs placed in deeper, clearer water with high profile materials might better enhance diving trips while lower profile materials placed in more nearshore locations would increase opportunities for fishing trips.

While all areas of the coast can benefit from reef placement, emphasis should be given to those regions with higher availability of charter boats, extensive local tourism-infrastructure development, and large urban populations to draw upon for customers.

Diversity should also be sought in providing marking and mooring buoys as well as in designating sites for specific uses or fishing gears. Involvement of local charter boat captains in making site designations would enhance the Artificial Reef Program by producing a more optimum management approach.

The success of this study in identifying managerially-useful information can be directly attributed to the effectiveness of the mail questionnaire survey methodology. This methodology, when applied with techniques such as an extensive inventory of the target group, pre-tested questions, highly professional questionnaire format, multiple mailings and follow-up contacts, can result in a high level of confidence in the representativeness of the responses.

Managers who generally depend on public hearing formats and unsolicited comments to gauge public opinion can benefit from having a more representative and relatively inexpensive source of user-group feedback.

In conclusion, future development of artificial reefs off Texas could benefit from additional surveys of other affected user groups, including private boat anglers, scuba divers and commercial fishers. The diversity identified within the charter boat industry may well exist within these other resource user groups that are often thought of as being homogeneous. This study provides a model for surveying these user groups to continue the process of program evaluation for the Artificial Reef Program in Texas.

Hal R. Osburn received a B.A. in zoology from the University of Texas at Austin and an M.S. degree in marine biology from Texas A&M University. In 1975 he began work with the Texas Parks and Wildlife Department as a coastal fisheries field biologist. He has progressed through the ranks as an Area Leader, Program Leader, and Director of Programs focusing on fishery dependent and independent marine research surveys. He was an author of the Texas Artificial Reef Management Plan in 1990 and currently serves as the Artificial Reef Program Director as well as the Coastal Fisheries Policy Director stationed at the Department's Austin headquarters.

Leslie D. Finkelstein is a graduate assistant in the Department of Wildlife and Fisheries Sciences at Texas A&M University in College Station.

Robert B. Ditton is a professor in the Department of Wildlife and Fisheries Sciences at Texas A&M University in College Station. Professor Ditton has performed extensive research in the human dimensions of fisheries management.

ALTERNATIVE METHODS TO MINIMIZE IMPACTS TO THE FISHERIES RESOURCE WHEN DONATING PLATFORMS TO THE TEXAS ARTIFICIAL REEF PROGRAM

Ms. Jan C. Culbertson
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INTRODUCTION

Since the 1940s the search for oil and gas in the Gulf of Mexico has had a distinctly positive effect in increasing the numbers and diversity of reef fish and benthic encrusting organisms, previously limited to a few natural hard-bottom areas such as the Flower Garden Banks. Over one-quarter of the hard substrate existing offshore now has been created by the steel legs of nearly 4,000 petroleum platforms.

These reef species—Atlantic spadefish, red snapper, blue angels, french angels, reef butterfly fish, just to name a few, spend some part of their life cycle in the shadow or protection of these hard bottom structures. When a platform is removed, the fish have no place to go but seek another structure for refuge before they become dinner for larger open water species. The benthic organisms attached to the structure such as barnacles, thorny oysters, hydroids, bryozoans, gorgonians and cup corals are lost forever when the structure is salvaged.

In the 1980s the petroleum industry was beginning to remove a significant number of obsolete platform structures offshore of Louisiana and Texas. Federal and state agencies began to voice their concerns about the loss of reef fish habitat when these structures were removed. Widespread support from the general public for converting these structures into permanent artificial reefs gave Congress the motivation to pass the National Fishing Enhancement Act in 1984 (HR 6342, Title 11 Section 201-208). This federal legislation allowed the oil and gas industry to donate their structures as artificial reefs to the states in lieu of the standard salvage removal option. This legislation also gave regulatory guidance to the States for permitting and accepting the liability for these structures.

Texas legislation was passed in 1989 and is provided under the Texas Parks and Wildlife Code, Chapter 89, Section 89.001-89.0061. The Texas Parks and Wildlife Department adopted an Artificial Reef Plan in 1 990, which provides guidance to the state in selecting new reef sites and in determining acceptable donations. To support the administration, maintenance, marking and liability for these artificial reef structures, the Artificial Reef Plan requires the donor to contribute 50% of the monetary savings for not salvaging the jacket to a Texas Artificial Reef Fund. Since the Plan was approved, the Department has accepted the donation of 35 oil and gas platforms, which have been donated by 18 different petroleum companies. The OXY U.S.A. plans to donate a 36th structure, which will be piaced at the Department's 27th permitted reef site sometime in January 1996.

The Texas Artificial Reef Plan also calls for potential donations to be reviewed by acitizen's advisory committee composed of interested user groups in the Gulf of Mexico. This advisory committee allows a forum for minimizing conflicts between user groups before the permitting process begins. This ten-member Artificial Reef Advisory Committee is represented by: a salt water fishing group, the oil and gas industry, Texas Tourism, Texas General Land Office, a shrimp organization, a Texas diving club, the Attorney General's Office, a Texas University, an environmental group, and the Texas Antiquities Commission.

The primary goal of the Texas Artificial Reef Program is to provide highly durable, stable, and complex structures in a "form as close to their current form" as possible to enhance the fishery resources. An equally important goal is to determine where artificial reefs would be most beneficial to the reef fishery resource and provide unique recreational fishing and diving opportunities as well as not interfere with other user groups in the Gulf.

ALTERNATIVE PERMIT OPTIONS WHEN DONATING A PLATFORM

The Texas Artificial Reef Program offers alternative permit options when donating a platform. Texas does not have the same concentration of petroleum structures along our coast as are available to the Louisiana Program. The Galveston District Corps of Engineers (COE) does not restrict Texas reef development to a specific number of planning areas and permits individual reef sites that have met the guidelines of the Artificial Reef Plan. Each permitted reef site encompasses one quarter square mile (1,320-ft by 1,320-ft), which has the potential space for clustering at least nine jacket structures on the bottom (Figure 3A.13). The initial donor at this reef site is allowed to topple the structure in place and other jacket donations are encouraged to be transported from nearby.

Although most of the Texas artificial reef sites are individually permitted, the Texas Parks and Wildlife Department's Artificial Reef Program offers some interesting new opportunities to the petroleum industry. Ten reef sites are already established within a 2,500 square mile area authorized under a General Permit in the High Island Leasing (OCS) Area (Figure 3A.14). The Corps of Engineers has permitted this entire area so that artificial reefs may be created without a public comment period as long as the reef site meets all the special conditions of the General Permit. These special conditions require that the structure have:

1. at least five nautical miles from another reef site;
2. at least two nautical miles from any safety fairway;
3. at least 85 ft of clearance over the structure;
4. at least a distance equal to seven times the depth of water away from an active pipeline and not disturb any abandoned pipelines; and
5. at least one nautical mile away from any specific hard bottom communities (such as the Flower Garden Marine Sanctuary East and West Banks). Creation of an artificial reef closer than one nautical mile to any hard bottom area requires an individual permit from the COE and is given a public comment period.

ALTERNATIVE REMOVAL OPTIONS WHEN DONATING A PLATFORM

Once all wells are properly plugged and abandoned 15 ft below the mudline, there are several alternative removal options (Figure 3A.15) when donating a platform jacket to the Texas Artificial Reef Program.

EXPLOSIVE REMOVAL OPTION

The most common removal option involves using explosives inside the jacket legs 15 ft below the mudline, then pulling the structure over in a horizontal position on the bottom. The advantages of this removal method have been the cost and time savings of using explosives in removing deep water structures. The disadvantages include safety concerns for turtles and marine mammals, potentially negative publicity from

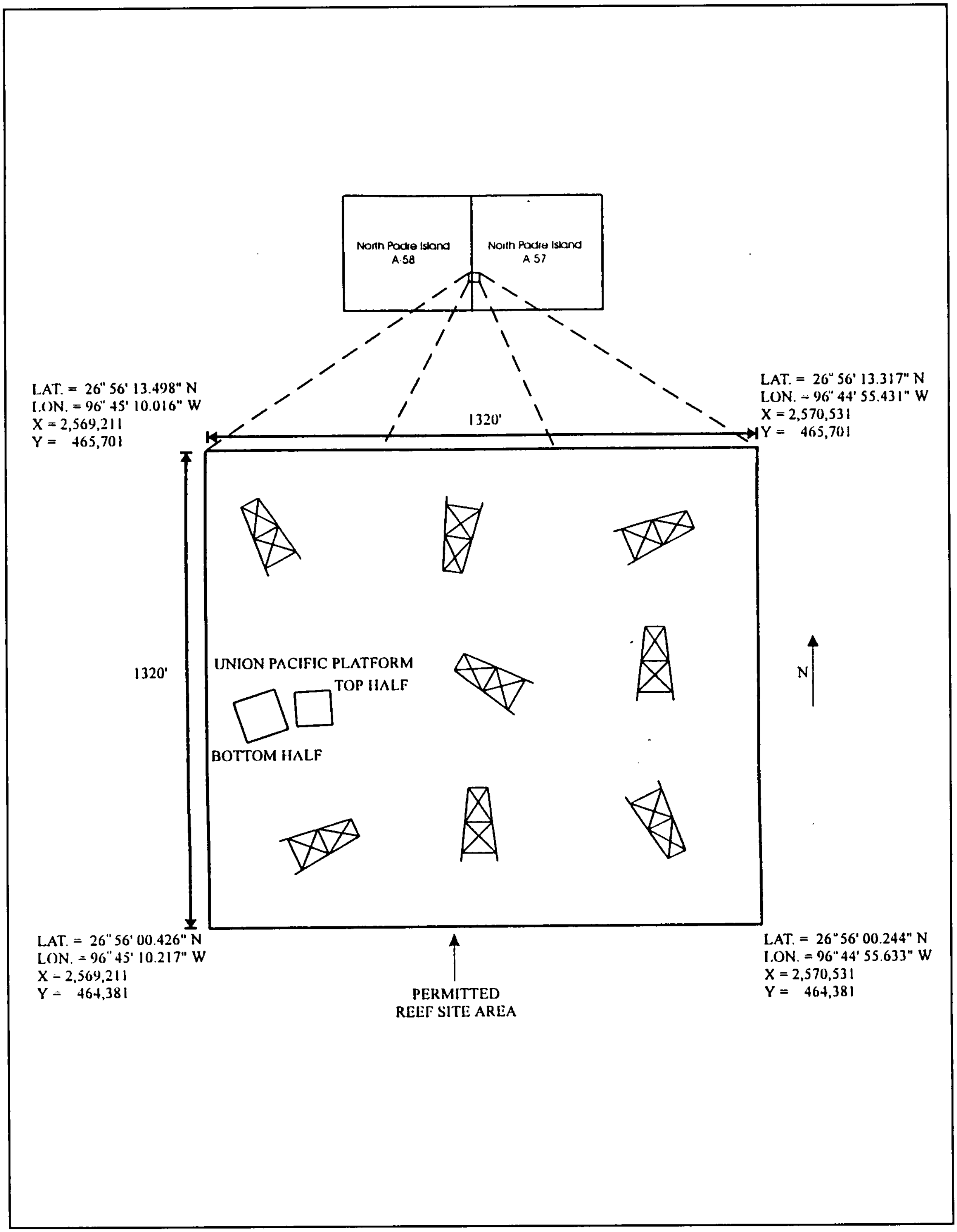

Figure 3A.13. Texas Parks & Wildlife Department Artificial Reef Program, North Padre Island A-58.

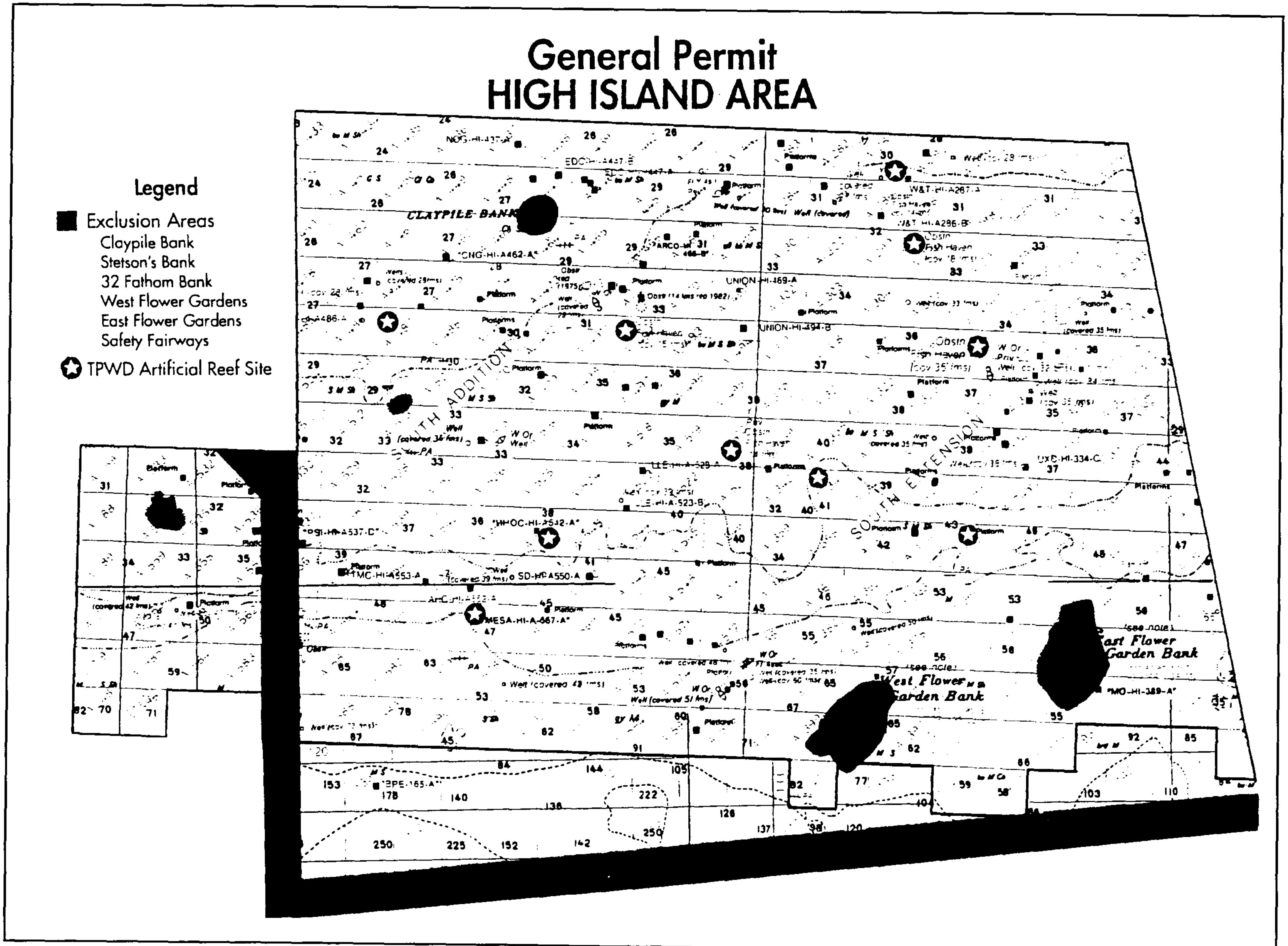

Figure 3A.14. General permit high island area.

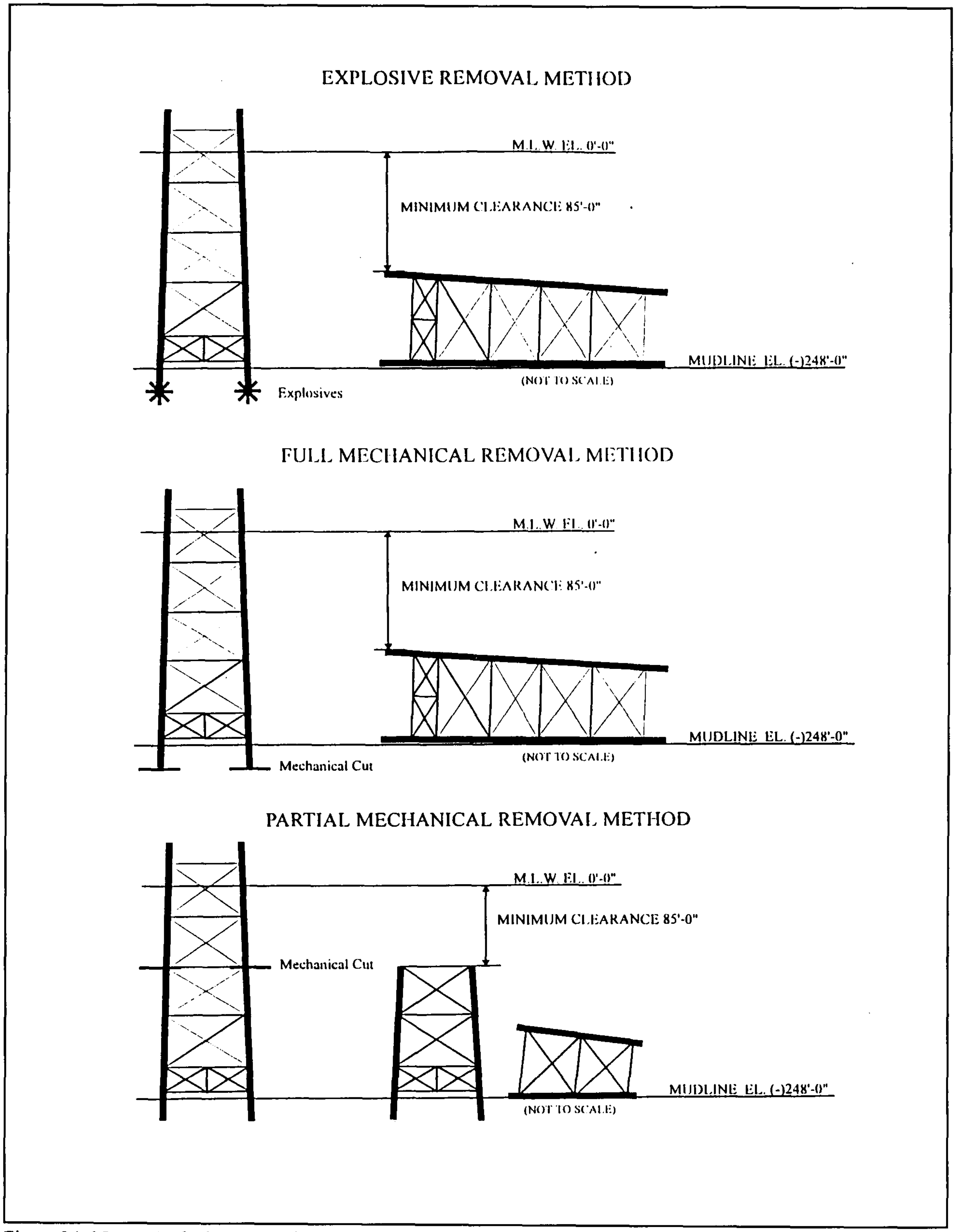

Figure 3A.15. Explosive removal method.

the fish killed from the explosion, and danger to commercial divers working in the legs of the jacket prior to setting the charge.

Most of the jackets donated to the Texas Artificial Reef Program have been removed using this method. Although some fish are lost initially, there would be greater losses to the fishery resource if the structures were salvaged on shore. The Department has been monitoring a cluster of six jackets donated by Cal Dive International and Blue Dolphin Energy. These structures were placed in the shape of a star at the Freeport Liberty Ship Reef Complex in 1994 and appear to be attracting large commercially important reef fish. Juvenile french angel fish have been observed in the openings where explosives were used. Although the original encrusting organisms were lost during the removal process, these structures appear to be quickly regrowing tunicates, hydroids, and bryozoans at this shallow water reef site.

FULL MECHANICAL REMOVAL OPTION

A second removal option involves cutting the base of the piles below the mudline with abrasive or mechanical cutters, and then placing the entire structure in a horizontal position on the bottom. The advantages of using this removal method include no risks in harming turtles, marine mammals, the fishery resource or the benthic organisms attached to the structure. A distinct disadvantage of this method is the expense of new technology, which is labor intensive and time consuming. This method may not always be an option when removing deep water structures because of the danger to divers and the limitations of the cutting equipment.

The Texas Artificial Reef Program is proud to have received six jackets mechanically removed below the mudline, transported intact to two separate reef sites, and donated by Mobil Oil Company. Although there was no monetary savings for donating these jackets using this method, this environmentally aware company protected the sea turtles, marine mammals, and the fishery resource associated with these six jackets. These jackets were removed from a relatively shallow water area (60-70-ft depth) offshore Port Mansfield and were transported to two near shore reefs (70-ft and 100-ft depth), where they are continuing to attract reef fish, divers and anglers.

PARTIAL MECHANICAL REMOVAL OPTION

The Texas Artificial Reef Program is excited by an alternative removal option, which provides the petroleum industry another avenue for donating deep water structures and also minimizes the impacts to the fishery resource. In the past year, the Department has been working closely with the U.S. Department of the Interior's Minerals Management Service to investigate alternative removal methods, where the structure is being mechanically removed and made into an artificial reef. Although the media may love explosions, the petroleum industry may not necessarily want the publicity associated with fish kills that often accompany an explosive removal operation. However, a full mechanical removal of a jacket structure may be cost prohibitive or may not be possible in some deep water applications.

MMS recently granted a waiver to Union Pacific Resources Company for the partial removal of their four-pile jacket in North Padre Island A-58. This company was able to save at least $650,000 by mechanically cutting the jacket at 86 ft and placing the upper jacket section on the bottom next to the standing portion of the jacket in 254-ft depth water.

This type of donation allows for the maximum biological profile in the water column within current Coast Guard regulations, and also allows the creation of artificial reefs without the need for explosives in a deep water removal operation. A distinct advantage of this partial removal option for the petroleum industry is that it is less costly and less time consuming than a full mechanical removal operation. The Texas Artificial Reef Program will continue to work with MMS and the petroleum industry on a case by case basis to utilize this partial removal method, which enhances the reef fishery resource and benefits the people of Texas.

Jan Culbertson received her B.A. from the University of Delaware and her M.Sc. in marine fisheries from the University of Georgia. Her primary duties are as the Artificial Reef Coordinator for the State of Texas, Parks and Wildlife Department. She works with the Army Corps of Engineers for permitting, the Coast Guard and the National Oceanic and Atmospheric Administration (NOAA) for aids to navigation, NOAA and the Minerals Management Service (MMS) for research monitoring, and MMS for pipeline avoidance and alternative removal methods.

SESSION 3B

OIL-SPILL GIS PROJECTS

Session: Session 3B - Oil-Spill GIS Projects

Co-Chairs: Dr. Norman Froomer and Dr. Shea Penland

Date: December 13, 1995

Presentation	Author/Affiliation
Introduction	Dr. Norman Froomer Minerals Management Service Gulf of Mexico OCS Region
Environmental Sensitivity Component of the Gulf Wide Information System	Ms. Joanne Halls Ms. Jacqueline Michel Mr. Jeffrey A. Dahlin Research Planning, Inc. Columbia, South Carolina
The Gulf-Wide Information System (G-WIS) for Oil Spill Contingency Planning: Pilot Study Results	Ms. Lynda Wayne Mr. Ed Vigil Ms. Karen Ramsey Dr. Shea Penland Center for Coastal Energy and Environmental Resources Louisiana State University Dr. Norman Froomer Minerals Management Service Gulf of Mexico OCS Region Ms. Barbara Yassin Mr. Steve Oivanki Mississippi Office of Geology
Manuscript not submitted	Mr. Christopher Friel Florida Marine Research Institute
Towards a Coastal and Marine Resource Assessment System	Dr. Mark E. Monaco National Oceanic and Atmospheric Administration Office of Ocean Resources Conservation and Assessment Strategic Environmental Assessments Division

INTRODUCTION

Dr. Norman Froomer
Minerals Management Service
Gulf of Mexico OCS Region

The Gulf Wide Information System (GWIS) is a cooperative effort between the Minerals Management Service and Louisiana State University to develop a geographic database to support oil spill contingency planning in the US Gulf of Mexico. The project is based on the following three principles:

GULFWIDE SUPPORT AND CONSENSUS FOR DATABASE

The objective of GWIS is to develop an authoritative database that will be used by MMS for oil-spill contingency planning, as mandated by the Oil Spill Act of 1990, and by industry and other regulatory and resource protection agencies for oil-spill planning and response. To encourage consensus, GWIS has established a Steering Committee with members from industry, Federal agencies, and each Gulf State. The Steering Committee has been involved in all major decisions concerning the design and composition of the database. Furthermore, many Steering Committee members are contributing resources to support the project.

REGIONALLY COMPLETE AND CONSISTENT DATABASE

The Gulf of Mexico coastal States are providing much of the data for the project. The MMS and LSU are compiling and augmenting the data using an enhanced environmental sensitivity index (ESI) mapping framework to ensure regional completeness and consistency. The enhanced ESI concept includes additional items in the database, expanded offshore geographic coverage, metadata for each geographic feature, information on level of effort and area covered by surveys, and procedures to assure regional consistency and completeness. GWIS has produced a Gulf Wide Information System Database Specifications Manual to assure that data deliverables will fit together in a regional context.

APPLICATION INDEPENDENT DATABASE

While the primary purpose of GWIS is to develop a database to support oil spill contingency planning, another important objective is to compile a database that can be used for other environmental and planning applications. To assure this capability, the project, to the extent that resources permit, emphasizes the robustness of the data itself, not the specific application for which the data will be used.

The GWIS data structure is based on the work done by the National Oceanic and Atmospheric Administration (NOAA) and Research Planning Inc. (RPI) to develop Environmental Sensitivity Index maps and databases for coastal areas of the United States. The first ITM presentation was by Joanne Halls from RPI who described the ESI data gathering and compilation process and the ESI enhancements that will be incorporated into GWIS.

GWIS began in July 1995. The first year of the project concentrated on developing consensus and designing the database. The broad geographic scope and complexity of this project made a pilot project prudent. Coastal Mississippi was selected for the pilot. Linda Wayne and Ed Vigil from LSU presented the results of this pilot effort in the second presentation.

The GWIS database will be large and quite complex. Users will want to be able easily to access information for a specific oil spill planning situation. In the third presentation, Chris Friel from the state of Florida demonstrated an Arcview oil spill application that they have developed with Environmental Systems Research Incorporated. This demonstration provided an example of how the GWIS database may be accessed to support oil spill planning.

The final presentation was by Dr. Mark Monaco, NOAA. NOAA has been working with MMS on GWIS to possibly develop the fisheries component of the GWIS database. Plans have been formulated to develop and enhance NOAA's Estuarine Marine Living Resources data to be used within GWIS. In addition, Dr. Monaco presented NOAA's plans for developing and distributing coastal and marine information systems in the future, and the relationship of GWIS to these plans.

ENVIRONMENTAL SENSITIVITY COMPONENT OF THE GULF WIDE INFORMATION SYSTEM

Ms. Joanne Halls
Ms. Jacqueline Michel
Mr. Jeffrey A. Dahlin
Research Planning, Inc.
Columbia, South Carolina

Environmental Sensitivity Index (ESI) maps have been an integral component of oil-spill contingency planning and response since 1979, when the first ESI maps were prepared days in advance of the arrival of the oil slicks from the IXTOC 1 well blowout in the Gulf of Mexico. Since that time, ESI atlases have been prepared for most of the U.S. shoreline and have progressed technologically from manual cartography to digital Geographic Information Systems (GIS), while increasing in spatial and attribute complexity.

As the oil-spill community moves toward development of automated sensitivity maps, it is important to inform and educate potential users of the contents of ESI data and the planned improvements to ESI in the Gulf of Mexico.

The shoreline habitats are classified using a ranking scheme from 1 (low) through 10 (high), based on potential ecological impacts, natural persistence of oil, and ease of cleanup. The biological information includes oil-sensitive animals and sensitive habitats such as submerged aquatic vegetation and coral reefs. The animals include marine and terrestrial mammals, birds, fish, and shellfish and particular attention is given to known concentration areas, critical reproduction areas, and threatened or endangered species. The geographic distributions are linked in the GIS to several relational databases which contain information on concentrations, species names, federal and state status, seasonal (by month) occurrence, and breeding activities. The human-use information includes specific features which are sensitive to oil spills due to their value of use either economically (e.g., aquaculture) or culturally (e.g., archaeological sites). Specifically, the resources include all managed lands, recreation areas, economic activities, and archaeological and historical sites.

The ESI product consists of the hardcopy atlases, which contain detailed descriptions of all data, maps for each USGS topographic quadrangle, and tabular data for each map, GIS digital data, and metadata which is compliant with the Federal Geographic Data Committee's metadata standard. The ESI atlases have progressed in complexity due to improved technology and knowledge of resources; therefore, the data structure has evolved through time. However, this evolution has maintained a vision for future uses of ESI data which results in a complex data structure that is capable of expanding to include more information and also capable of being collapsed to fit previously digitized atlases.

Some of the future goals of ESI mapping include feature-level data assessment, the inclusion of survey boundaries for many biological elements, the delineation of offshore extent, the integration of ESI data with other existing systems or projects, and the development of user interfaces to the data using desktop mapping software.

Joanne Halls is director of Research Planning, Inc.'s Geographic Information Systems (GIS) department. Ms. Halls graduated from the University of Denver with a B.S. in Geography, the University of South Carolina (USC) with a M.S. in Geography, and is currently completing her Ph.D. in Geography at USC. She is responsible for project planning, database design, quality control, metadata standards, and development of advanced spatial modeling applications. Previously, Ms. Halls worked at the University of South Carolina as a GIS Project Manager for several grants. Research involved the integration of remote sensing and GIS for the prediction of urban growth, spatial market analysis of retail centers, and temporal-demographic analysis of land use. Ms. Halls' current research efforts focus on expert systems and GIS for managing natural resources.

THE GULF-WIDE INFORMATION SYSTEM (G-WIS) FOR OIL SPILL CONTINGENCY PLANNING: PILOT STUDY RESULTS

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Mr. Ed Vigil
Ms. Karen Ramsey
Dr. Shea Penland
Center for Coastal Energy and Environmental Resources
Louisiana State University

Dr. Norman Froomer
Minerals Management Service
Gulf of Mexico OCS Region

Ms. Barbara Yassin
Mr. Steve Oivanki
Mississippi Office of Geology

INTRODUCTION

The US Minerals Management Service (MMS) established the Coastal Marine Institute (CMI) at Louisiana State University to promote environmental research related to the oil, gas, and mining industries. One of the primary initiatives of CMI is to create a Gulf-wide Information System (G-WIS) to support government and industry oil spill contingency planning needs. G-WIS is being implemented to coordinate and compile critical information about the location and character of environmental resources, infrastructure, and administrative boundaries that occur within the coastal region of the U.S. Northern Gulf of Mexico. Information needed to support the program is collected from state and federal resource agencies, industry, and other data providers.

A pilot study was initiated to test and refine proposed data standards and methods. The study focused on a small geographic region and prototyped all activities associated with data development and integration. Jackson County Mississippi was chosen as the study area. Jackson County is located in the southeast corner of the state and was selected due to its coastal environment, interstate border, and nearly completed ESI mapping.

The objectives of the study were

1. determine improvements to the proposed methodology,
2. fine data definitions,
3. identify missing or inadequate data, and
4. determine georectification, edgematching and editing procedures.

METHODS

The initial phase of the study focused on the identification of potential and existing data resources. The study team, comprised of the MMS, LSU, and the Mississippi Office of Geology (MOG), held a working session to review the listing of required data types previously determined by the G-WIS Steering committee (Table 3B1). The team developed a data specification worksheet for each data type and recorded information regarding potential data resources (Table 3B.2). Each group was given responsibility for locating and compiling specific data resources as previously outlined in the *G-WIS Data Specification Manual.* A performance schedule was determined and data collection commenced.

Data were collected at three primary scales. The Gulf-wide scale (1:2,000,000) included a generalized shoreline, state/county political boundaries, and federal data reference information which spanned the entire region. e.g., protraction zones, interstate highways, temperature zones, and federal platforms. The MMS provided most of the information collected at this scale. The regional scale (1:100,000) included a more detailed shoreline, political boundaries, intrastate highways, lease grid blocks, navigation channels, and oil/gas infrastructure (pipelines and terminals). LSU compiled most of this information from USGS Digital Line Graphs (DLG's) and other regional data sources. The state scale (1:24,000) included a highly detailed shoreline (mapped in 1995 using Global Position System technology), environmental sensitivity (ESI) maps, topography, place names, and a bathymetric surface model. The MOG collected the majority of the 1:24,000 data.

LSU was responsible for compiling the collected data into a unified GIS data base. Both geographic and attribute data were converted to the Arc/Info data format using custom and standard data translation programs. The data were reviewed as to compliance with the *G-WIS Data Specification Manual* and organized into a set of thematic view using the ArcVIew software program. Views were created for the Gulf-wide, regional, and state scales and related information such as CAD drawings and photographs were integrated and linked to their mapped representation.

Table 3B.1. G-WIS Priority Data Listing.

Level One Priority Data Layers:
- Base maps
- Shoreline Habitat Type
- Aquatic Habitat Type
- Terrestrial Biological Resources
- Regulated Endangered and Threatened Species
- Significant Commercial and Recreational Aquatic Species
- Recreational Areas

Level Two Priority Layers:
- Location of Protected Areas
- Coastal Marine Processes (temperature and salinity)
- Transportation Infrastructure
- USCG Area Contingency Plans
- Access and Staging Areas
- Modern, Historical & Prehistoric Cultural Resources
- Bathymetry

Level Three Priority Layers:
- Sources of Public/Commercial Water Supplies
- Oil & Gas Infrastructure
- Political and Administrative Boundaries & Locations
- Pre-approved Dispersant & In-situ Burning Zones & Exclusion Areas
- Navigable Shipping Routes/Channels
- Response Equipment Location
- Topography
- Place Names
- Permitted Waste Disposal Sites

Not Prioritized
- Land Use
- Database of Historical Spills
- Utilities
- Population Data

CONCLUSIONS

The data were successfully compiled into a functional GIS data base. Objectives for data collection were met or surpassed and coordination among the participating agencies was extremely good. However, several primary data management issues emerged as a result of this study:

Data Sharing and Access

Study participants experienced no data sharing problems during the study. However, data access was difficult when participants had little or no access to the Internet and data transfer via tapes and diskettes was required. It was also concluded that variability in media capabilities also impedes the data assimilation process since LSU-CCEER does not have the hardware necessary to read all forms of media. Therefore, future data sharing efforts will identify access and media capabilities early in the coordination process and include preferred media and format as part of the *G-WIS Data Specification Manual.*

Format

Most of the data were available in digital format and LSU was able to translate the data into the Arc/Info system with little difficulty. However, several information resources were in hard copy format, and

Table 3B.2. Example of G-WIS Pilot Study Data Development Form.

G-WIS Data Development Form

Priority Rank 2.7
Pilot? yes
LSU

Data Title: Bathymetry

Priority Level Ranking: II

Organization responsible for collection: LSU

Features to be included and/or level of detail:
Gulf-wide (1:2,000,000) - contour to 100 meters
Mississippi (1:100,000) - contour to 5 or 10 meters (test)
Jackson County (1:24,000) - contour to 1 meter

Does the data exist within the responsible organization? yes
digital or hardcopy? digital
digital format? NOAA converted to ArcInfo point and polygon coverages

Potential Sources for data:
Source 1
Organization: MMS-GOMR
Point of Contact (name, title, phone, fax, email):
Norman Froomer, COTR (504) 736-2782
Available information (status, scale, geographic extent, description):
available in digital format from MMS, developed by Dynalysis Corp.
Source 2 MARIS HAS POSTPONED THIS DIGITIZING EFFORT
Organization: MARIS
Point of Contact (name, title, phone, fax, email):
Barbara to provide
Available information (status, scale, geographic extent, description):
currently digitizing NOAA charts for coastal MS
Source 3
Organization: NOAA - HAZMAT
Point of Contact (name, title, phone, fax, email):
Jill Peterson, Sandy Point Washington
Available information (status, scale, geographic extent, description):
point data has been collected, processed by LSU

Notes/Comments:
- use TIN process to contour
- use to test for georeferencing problems, e.g. base map shoreline/bathymetry correlation

Issues: 9/29 NOAA Hazmat data contoured at 100 and 5 meter completed

integration into the digital environment became an issue. In particular, there was difficulty capturing much of the information included in the USCG Area Contingency Plan documents. At a minimum, LSU would like to capture the plan boundaries and provide users reference to the specific plan and a point of contact. LSU will work with Marine Safety Offices (MSO's) to locate the needed information and then solicit guidance from the Steering Committee regarding the amount of effort that should be contributed toward the extraction of these and other text-based information resources.

Edgematching

There were insufficient data to truly test issues of edgematching. Most interstate data resources, such as transportation and ESI mapping, were provided by a single source and therefore inherently matched. Other data resources were not available for all areas. As a result, the only edgematching problem encountered during the pilot was a discrepancy between the federal and state offshore lease lines. A problem beyond the scope of the G-WIS program. LSU will continue to pursue this issue and highlight those data categories where edgematch problems could present substantial problems.

Data Quality

The G-WIS data specifications were not always met. This is in great part due to the time restrictions imposed upon the pilot study. Metadata was not provided for most data sets and several data fields were incomplete. As a result, LSU will implement a more stringent data review program. Upon receipt, data will be checked to ensure compliance with the *Data Specification Manual*, complete geographic coverage, and spatial correlation with related layers. Inadequacies will be fully documented and reviewed with the contributing organization. LSU will attempt in-house corrections where feasible. In addition, LSU will revise the *Data Specification Manual* to enhance user understanding and work closely with the other participants to improve the data quality.

Data Management

During the pilot study, it became quickly apparent that the data management program must be implemented at the earliest stages of data receipt and strictly implemented. Some data resources were not adequately documented. As a result, the data may be difficult to locate and metadata documentation efforts will be hampered. Therefore, LSU will emphasize the early documentation and archive of received data in Years Two and Three.

TOWARDS A COASTAL AND MARINE RESOURCE ASSESSMENT SYSTEM

Dr. Mark E. Monaco
National Oceanic and Atmospheric Administration
Office of Ocean Resources Conservation
and Assessment
Strategic Environmental Assessments Division

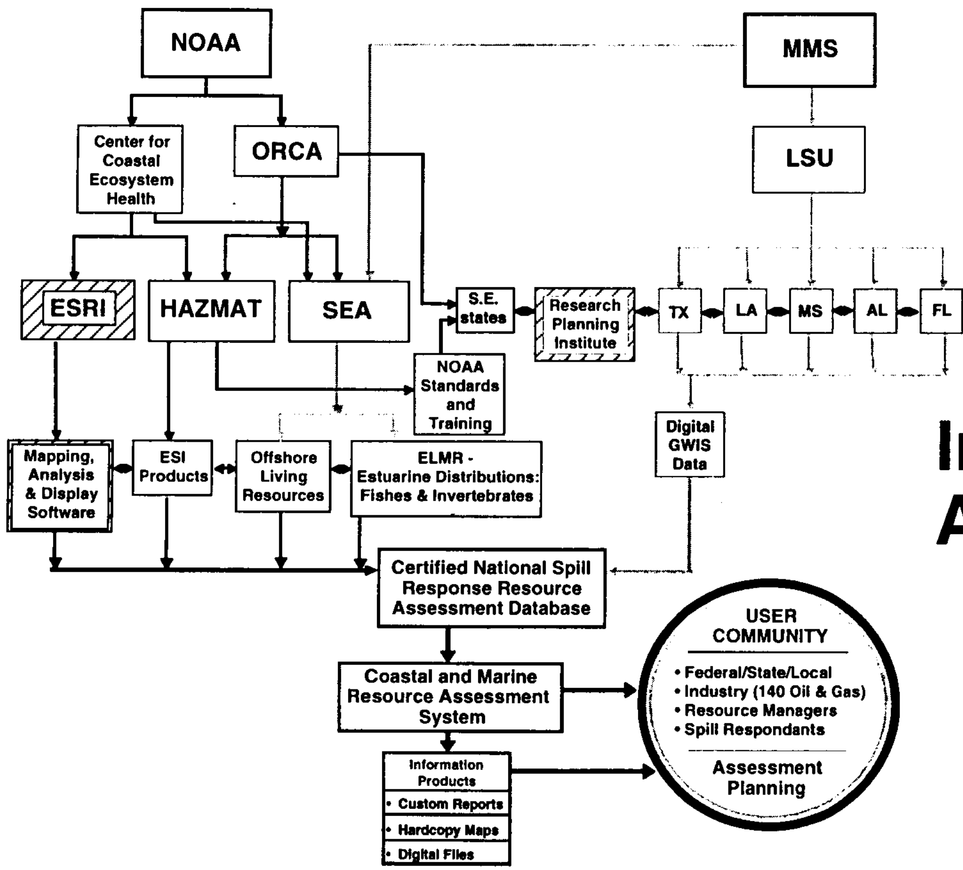
PRESENTATION SUMMARY

This presentation describes a federal, state, and private sector partnership evolving toward the development of a certified ESI database and an ArcView-based Coastal and Marine Resource Assessment System. Current partners in this effort are NOAA's Office of Ocean Resources Conservation and Assessment (ORCA) and the Coastal Services Center, DOI's Mineral Management Service (MMS), various state environmental agencies of the five Gulf of Mexico states, Environmental Systems Research Institute, Inc., and the Research Planning Inc. (Figure 3B.1). Collectively, we are formulating and testing data certification methodologies and computer-based products (including the desktop system—see Figure 3B.2) to support oil-spill environmental sensitivity index (ESI) data base development and products (e.g., maps).

Our partnership effort was initiated to support and complement MMS's Gulf Wide Information System (GWIS) project to support oil-spill contingency planning. This effort directly supports GWIS by providing estuarine, coastal, and marine species distributions and by the development of a prototype desktop information system to query and analyze biological data components of ESI products. Although our current work is primarily focused on oil-spill and ESI related activities, we envision the prototype desktop analysis system will be a fundamental step in the development of a more generic Coastal and Marine Resource Assessment System. Thus, the analysis system will have much broader application potential to address a number of marine environmental assessment needs.

The types of themes and problems the system will address include oil spill contingency and response planning, environmental impact assessment, and natural resource management. The initial data sets to be incorporated into the system include the GWIS ESI information, estuarine and marine living resource

Coastal and Marine Resource Assessment System



Institutional Arrangements

Partnership Development Team

Figure 3B.1. Institutional partners and arrangements for the development of the Coastal and Marine Resource Assessment System.

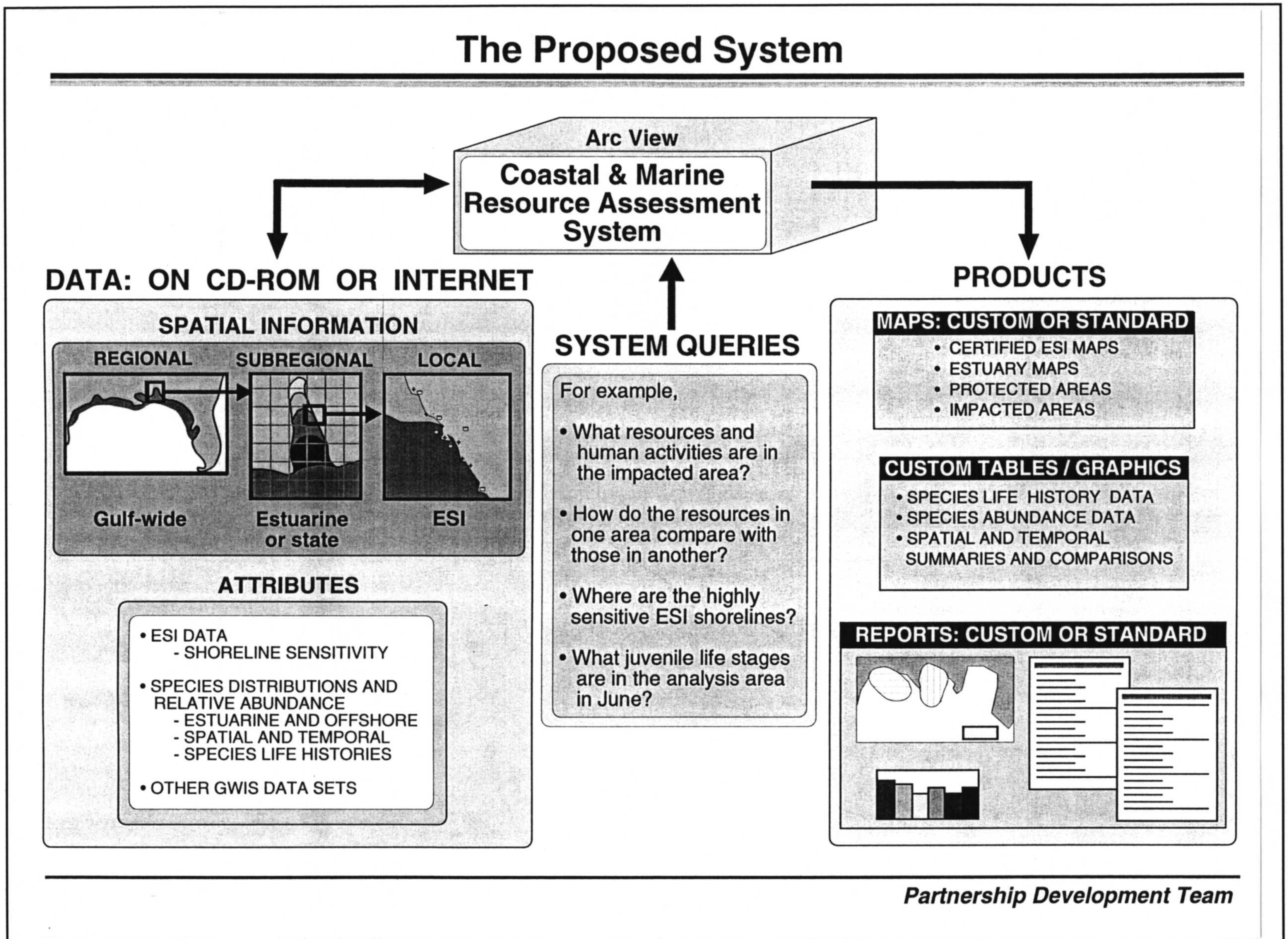


Figure 3B.2. Example structure of the desktop geographic information system: data, queries, and products.

distribution data, and estuarine physical and hydrological characteristic data. A unique aspect of this work is that our efforts build on existing ESRI ArcView development work, including the Florida Marine Research Institute's (FMRI) Marine Spill Analysis System. New significant features will include a more user-friendly front-end to ArcView for querying the data, access to offshore, ESI, and Estuarine Living Marine Resource (ELMR) data; and a complementary analytical GIS tool for GWIS data. A very important component of the partnership effort is NOAA's planned process to review and certify ESI data and maps, currently in development by many of the nation's coastal states. The certification process will initially be tested to support MMS's GWIS project. Our plans are to complete the prototype ArcView-based coastal desktop system and define the ESI certification process in early 1997.

Our project's unique multi-governmental and private sector partnership provides an opportunity to change the way we do business in coastal and marine resource management. By applying and pooling resources to develop user-defined products, we intend to develop unique and powerful synthesis, analysis, and assessment capabilities within our Coastal and Marine Resource Assessment System. Our initial development and prototype work is focused on oil-spill planning and response and will be broader in scope and capability as new partnerships are forged.

Dr. Mark Monaco has worked for NOAA for 12 years and is Chief of its Biogeographic Characterization Branch. His areas of research interest are fisheries, estuarine ecology, and biogeography. Dr. Monaco received his B.S. and M.S. in fisheries and environmental biology from The Ohio State University, and his Ph.D. in marine, estuarine, and environmental sciences from The University of Maryland.

SESSION 3C

COASTAL MARINE INSTITUTE PROGRESS REPORTS

Session: 3C - COASTAL MARINE INSTITUTE PROGRESS REPORTS

Co-Chairs: Dr. James Kendall and Dr. Robert S. Carey

Date: December 13, 1995

Presentation	Author/Affiliation
Coastal Marine Institute Progress Reports—Introduction	Dr. James J. Kendall Minerals Management Service Gulf of Mexico OCS Region Dr. Robert Carney, Director Coastal Marine Institute Louisiana State University
A Numerical Modeling Study of the Gulf of Mexico under Present and Past Environmental Conditions	Ms. Susan E. Welsh Department of Geology and Geophysics Louisiana State University Dr. Masamichi Inoue Coastal Studies Institute and Department of Oceanography & Coastal Science Louisiana State University
Digital High Resolution Acoustic Data for Improved Benthic Habitat/Geohazards Evaluations	Dr. Harry H. Roberts Coastal Studies Institute Louisiana State University
A Management Overview for Continental Slope Oil and Gas Development in the Gulf of Mexico	Dr. Robert S. Carney, Director Coastal Ecology Institute Louisiana State University
Transport and Mixing Processes in Louisiana Estuaries	Dr. Masamichi Inoue Dr. William J. Wiseman, Jr. Coastal Studies Institute and Department of Oceanography & Coastal Sciences Louisiana State University
Environmental Pollution	Dr. Maxwell H. Mayeaux Ms. Linda Heffernan Dr. Marta Vasquez Dr. Gary W. Winston Department of Biochemistry Louisiana State University

The Development of Bioremediation for Oil Spill Cleanup in Coastal Wetlands: Product Impacts and Bioremediation Potential

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Dr. Qianxin Lin[1]
Ms. Karolien Debusschere[2]
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Response of Sedimentary Bacteria in a Louisiana Salt Marsh to Contamination by Diesel Fuel

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Dr. Jay C. Means
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COASTAL MARINE INSTITUTE PROGRESS REPORTS—INTRODUCTION

Dr. James J. Kendall
Minerals Management Service
Gulf of Mexico OCS Region

Dr. Robert Carney, Director
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On 30 September 1992, the MMS and the State of Louisiana signed a Cooperative Agreement establishing the first Coastal Marine Institute (CMI). This CMI addresses the parallel OCS information needs of both parties in a timely, cost effective manner, while taking full advantage of the academic talents in the immediate OCS planning area.

Under the terms of this agreement, the MMS and the State of Louisiana provide matching funds to conduct environmental research of joint interest. The State, through Louisiana State University, provides matching funds of at least one dollar for each dollar provided by the MMS (up to $10 million over a five-year period). All funds obligated are used to support studies that fall within a general framework.

The CMI framework provides broad boundaries for guidance in the development of specific research projects. This framework was designed to include:

- technologies for extracting and transporting non-energy resources;
- environmental responses to changing energy extraction and transport technologies and spills;
- analyses and synthesis of existing data/information from previous studies;
- modeling of environmental, social, and economic processes and systems;
- new information about the structure/function of affected systems via application of descriptive and experimental means; and
- and projects that improve the application and distribution of multisource information.

The framework also fosters the continuing education and training of the academic and the regulatory communities, as well as MMS professional and management staff (e.g., short courses, workshops, seminars, etc.).

Studies proposed for support under the CMI are reviewed by the CMI Technical Steering Committee, on which MMS and LSU are equally represented. Dr. Robert Carney serves as the CMI Director and administers the daily activities of the program from LSU's Baton Rouge campus. This salient partnership provides the MMS an additional means of meeting its own information needs as well as those of one of its most important regional customers, the State of Louisiana.

This session highlighted those CMI research efforts that were well underway at this time and began the information transfer process between the CMI scientific and management personnel and decisionmakers of both the state the MMS.

Dr. James J. Kendall is the Chief of the Environmental Studies Section, MMS, Gulf of Mexico Regional Office. His research interests include the effects of contaminants on the physiology of corals, the behavior of reef animals, and procedures for aquatic toxicity testing. Dr. Kendall has conducted research and monitoring programs in the Gulf of Mexico, Galveston Bay, the Florida Keys, and the Gulf of Eilat, Red Sea. Dr. Kendall received his B.S. in biology from Old Dominion University and his Ph.D. in oceanography from Texas A&M University.

Robert Carney is a benthic ecologist who began deep-sea studies as a master's student at Texas A&M (M.S. 1971) and continued this line of research at Oregon State University (Ph.D. 1976). He served as director of LSU's Coastal Ecology Institute from 1986 to 1995 and has been director of the LSU-MMS CMI program since its inception. He is an associate professor in the LSU department of Oceanography and Coastal Studies. Prior to LSU, Dr. Carney was employed at Moss Landing Marine Labs, the National Science Foundation, and the Smithsonian Institution. Dr. Carney's published works are in the area of deep-sea ecology and environmental studies in the marine environment.

A NUMERICAL MODELING STUDY OF THE GULF OF MEXICO UNDER PRESENT AND PAST ENVIRONMENTAL CONDITIONS

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INTRODUCTION

The Gulf of Mexico (GOM) is a highly suitable domain for paleoceanographic study using an eddy-resolving, ocean circulation model. This modeling project features two distinct phases. The circulation in the GOM is first modeled under present environmental conditions to calibrate model parameters and verify model output. This part of the project is significant not only as a necessary step in creating a model for past environmental conditions, but also in providing a valuable tool in the study of Loop Current (LC) behavior and general circulation in the GOM. The next step is to lower sea level in the GOM to approximately that which occurred during the Last Glacial Maximum. New surface boundary conditions are applied that reflect the glacial environmental conditions. This pale-oceanographic model should help interpret the distribution of glacial fauna and sedimentation patterns found in the geologic record.

NUMERICAL MODEL DESCRIPTION

The bathymetry of the GOM features several broad, gently sloping shelves, steep escarpments and relatively shallow sill depths in the Yucatan and Florida Straits. The circulation in the GOM is dominated by the presence of the LC and the anticyclonic eddies that are shed from the LC. The Modular Ocean Model (MOM) is a three-dimensional primitive equation model that allows us to include the effects of bottom topography as well as adequately to resolve eddy dynamics. The Bryan/Cox/GFDL model is the precursor to MOM and was described in detail by Semtner (1986). MOM version 1.1, produced by R. Pacanowski, K. Dixon and A. Rosati (1991) at the Geophysical Fluid Dynamics Laboratory at Princeton University, is used in the study.

The model grid is derived from the ETOP05 1/12° resolution, world topography data (Figure 3C.1). The bathymetric values are interpolated to 1/8° and then smoothed using a coastline-preserving scheme to prevent topographically-induced instabilities in the numerical solution. The model grid extends outside the GOM into a synthetic return flow region that links the Straits of Florida with the Yucatan Straits. The bathymetry in this region has been altered to connect the Florida Straits with eastern portion of the Caribbean and does not represent actual bathymetry. The inflow into the GOM is achieved by forcing the flow through the western Caribbean to acquire the observed geostrophic values, thus eliminating the need to model the entire North Atlantic.

There are 15 levels in the vertical with a total depth of 3,600 meters. The upper four levels are 75-meters thick and the lower 11 levels are 300-meters thick for a total depth of 3,600 meters. These depth levels allow for higher vertical resolution on the shelf.

The initial runs of the model simulate present-day environmental conditions in order to calibrate the model. The three-dimensional annual mean temperature and salinity fields used to initialize the model have been interpolated from the Levitus Climatological Atlas of the World Ocean (Levitus, 1982). The surface temperature and salinity fields are restored to Levitus annual mean values with a relaxation time scale of six weeks. The surface wind stress field has been interpolated from the Hellerman and Rosenstein (1983) annual mean wind data.

The volume flux through the Yucatan Straits is controlled by adjusting the barotropic u-component of velocity along a longitudinal band center at 82.375°W in the Caribbean. The desired vertical shear is achieved by relaxing the temperature and salinity along this same vertical cross section to the observed values on a time scale of one week. The temperature and salinity fields used for this purpose are derived from the Levitus climatology.

RESULTS

The model has been successfully initialized with the three-dimensional temperature and salinity fields, wind forcing, quadratic friction, a five-point conjugate gradient solver, a surface boundary condition on temperature and salinity and adjustment of the flow to geostrophic values in the Caribbean. The values of viscosity and diffusivity are 200 m^2/s and 100 m^2/s

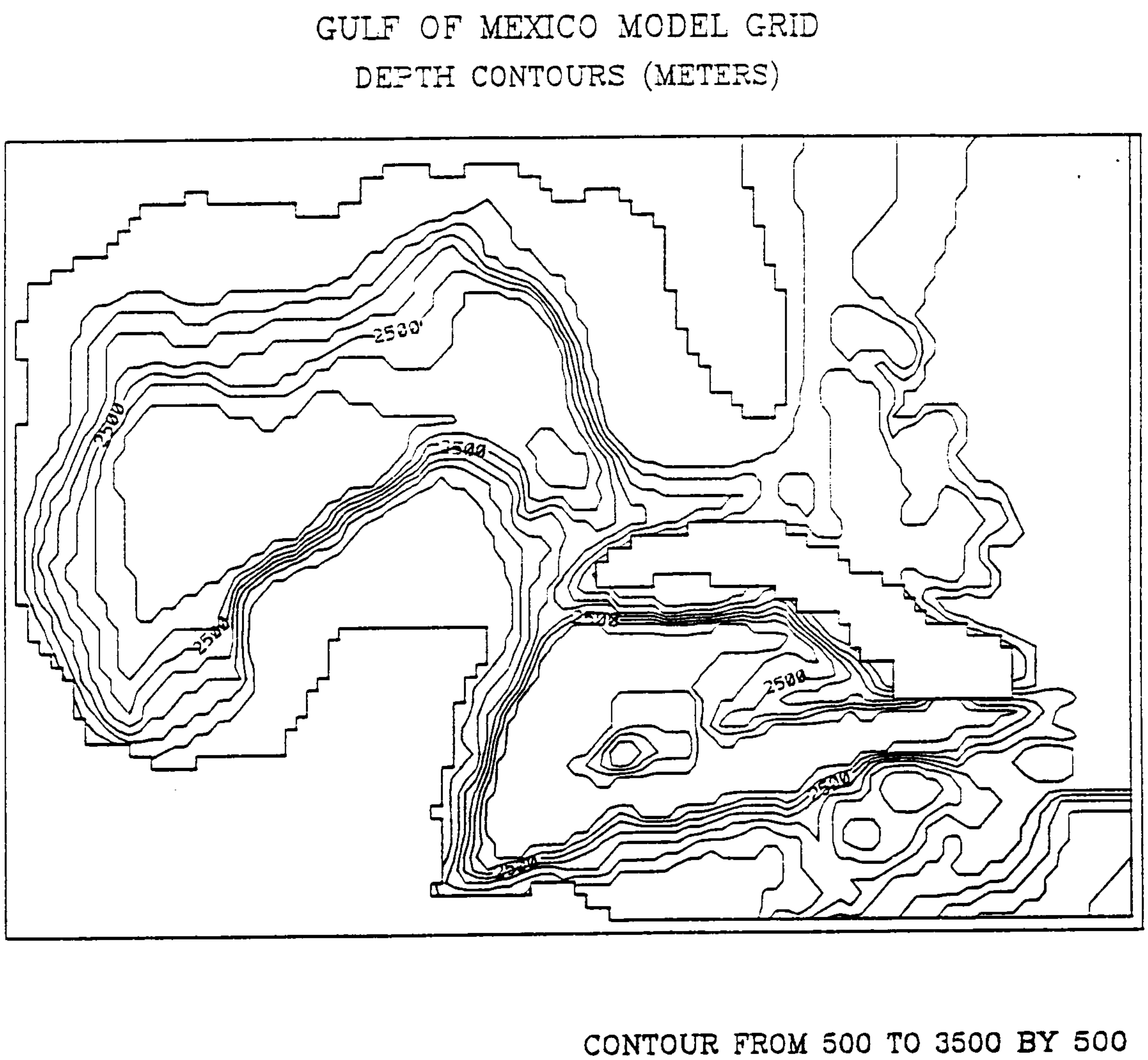

Figure 3C.1. Contour plot of model depths (meters) superimposed an on outline of gridded land values for model domain.

respectively. Bottom stress is applied with a coefficient of C_D=.001. This case was run for over ten years of model time on an IBM 3090 during which time adjustments were made in several of the parameters and the method of forcing the inflow. Additional model runs were made with this configuration to find minimum values for viscosity and diffusivity that would generate more realistic ocean processes and were found to be 75 m^2/s for each.

When the model is run with high values of viscosity and diffusivity, the process of shedding rings from the LC is very smooth and the LC rings follow the same migration path. When the friction is reduced, the eddy-shedding process becomes very unstable and the rings follow unique westward migration paths. In both the high and low friction cases, the eddy-shedding period is always approximately 30 weeks. This is a little lower that the primary eddy-shedding period of eight to nine months reported by Vukovich (1995) and Sturges (1993).

The next stage was to implement the annual cycle in the forcing. Temperature and salinity at the surface were restored to the Levitus Seasonal Climatology with a relaxation time scale of six weeks. The surface wind stress was updated every timestep to represent the Hellerman monthly mean wind stress. The inflow condition in the Caribbean also included Levitus Seasonal Climatology.

The seasonal calculations produced a realistic picture of the general circulation in the GOM (Figure 3C.2). Model transport through the Yucatan Channel ranges from 25 to 30 Sverdrups with a maximum transport occurring in summer as observed by Molinari *et al.* (1978). The weak flow over the Campeche Bank during the spring and the seasonal reversal of flow in the Campeche Bay from anticyclonic in the spring and summer to cyclonic in the fall is reproduced in the model (Molinari *et al.*, 1978). Fluctuations in the transport of the western boundary flow are reproduced in the model and have a maximum in the summer as observed by Oey (1995). There is a reversal of flow produced in the model over the Texas-Mexico shelf from northward in July to southward in October as reported by Oey (1995). An eastward shelf break current is generated in the model as described by Oey (1995) that may enter the Mississippi Canyon or possibly rejoin the LC as observed by Molinari *et al.* (1978). The formation and disappearance of the Tortugas gyre also can be observed in the model output.

The LC rings generated in the model have similar lateral size, vertical structure, migration paths, translation speeds and life spans as reported by several authors. During the last five years of model simulation with seasonal forcing, the details of eight LC rings were examined. These eight rings had a mean radius of approximately 350 km and an average life span of 366 days. The westward migration speed ranged from 3.3 to 6.3 km/day with an average of 4.1 km/day (4.8 cm/s) which is very close to the 5 cm/s reported by Sturges *et al.* (1993) and 3-6 km/day reported by Hamilton (1990).

The final stage of this project was to repeat the seasonal calculations with a bathymetry representing sea level at 124 meters below present and forcing with glacial surface boundary conditions. The new grid has 16 levels in the vertical with bimodal spacing of 80 meters for each of the upper six levels and 300 meters for each of the ten lower levels. Due to the steeper gradients in topography in the upper six levels, both the viscosity and diffusivity had to be increased to 100 m^2/s. Wind forcing was implemented using seasonal wind stress from the glacial atmospheric model of Kutzbach and Guetter (1985). The sea-surface temperature was restored to estimates made by CLIMAP (CLIMAP Project Members, 1976). The surface salinity as well as the temperature and salinity used to force the inflow were restored to the Levitus Seasonal Climatology (1982).

The greatest unknown in modeling the GOM using LGM forcing is the volume transport through the Yucatan Straits. The Sverdrup transport of the North Atlantic Gyre for the present was examined using both the Hellerman and Rosenstein wind stress and the Isemer and Hasse wind stress climatologies. Then the Sverdrup transport for the North Atlantic Gyre was computed using the Kutzbach and Guetter (1982) wind stress. It appears that the transport into the Caribbean during the LGM was as much as 37.8% less that the present. Therefore the LGM simulations were first made using approximately the same annual-mean transport as the present-day case (28 Sverdrups) to represent the maximum inflow case. Then the annual-mean transport was reduced to 18 Sverdrups to represent the minimum inflow case. Both these cases were run for four years of model time.

There are several obvious differences between the present and past circulation studies of the GOM. The greatest difference is in the circulation of the Western Gulf. The western boundary flow is a dominant process in the present GOM, as well as seasonal reversals of flow in the Campeche Basin and Northwestern Gulf. During the LGM the entire western Gulf appears to be dominated by the presence of LC Rings and not driven by the annual cycle in the windstress curl (Figure 3C.3). Flow in the Campeche Basin is mainly anticyclonic and the western boundary flow appears to be generated mainly by the addition of anticyclonic vorticity from the LC rings.

SUMMARY

The first stage of this GOM modeling project is necessary to develop and validate a model for use in paleoceanographic modeling of the GOM. The present-day simulations of the GOM will be of value to the GOM modeling community due to the increased grid resolution, a unique method of forcing that eliminates the use of open boundaries and implementation of one of the latest state-of-the-art numerical models. The model integration appears quite stable and the simulation of the LC and associated eddies is very realistic. The implementation of the annual cycle in the forcing produced even more realistic results. The goal of the second stage is to learn about the GOM

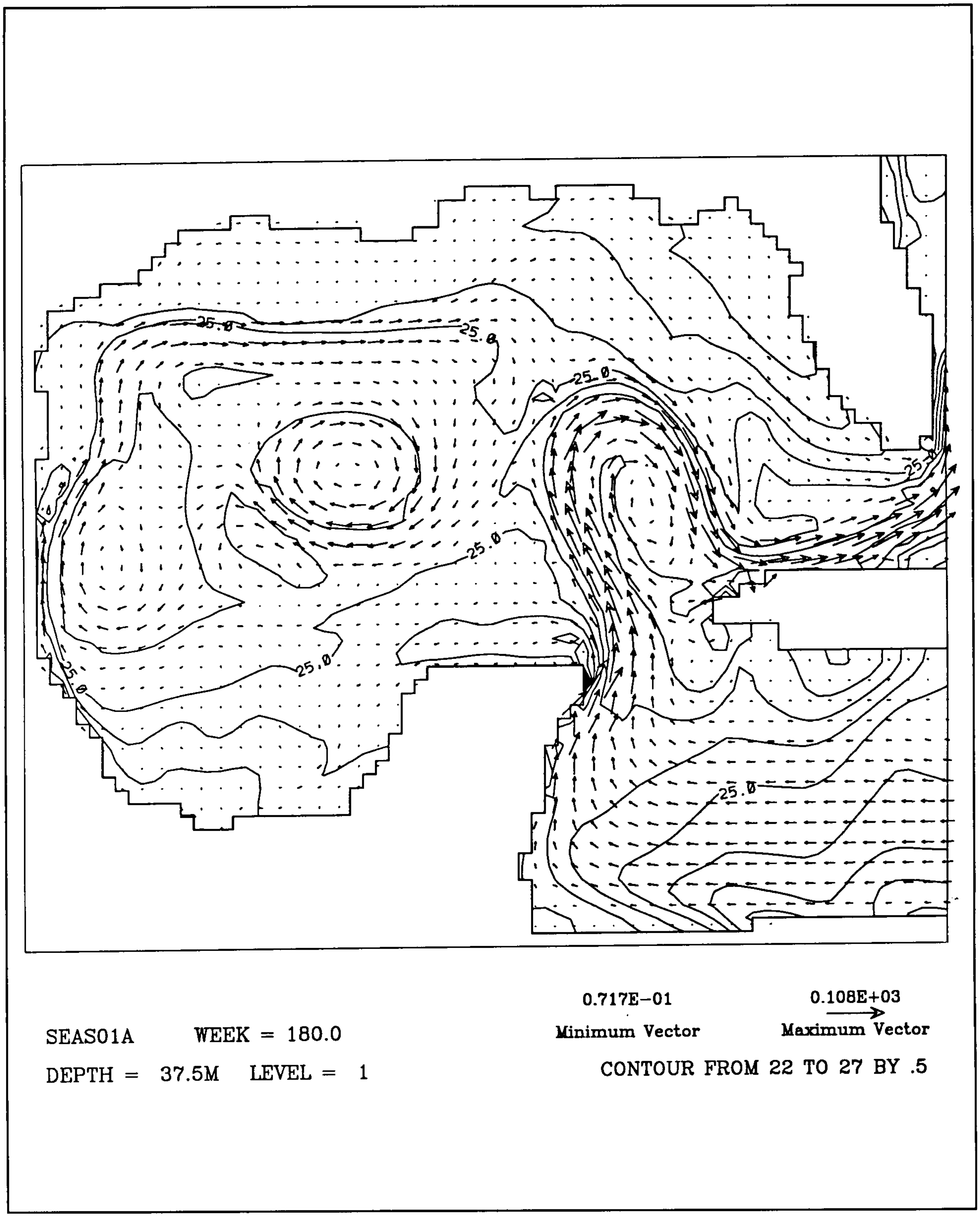

Figure 3C.2. Velocity vector plot (cm/s) superimposed on temperature contours (°C) for level 1 of the present-day model showing the Loop Current, a Loop Current Ring in the central Gulf, the western boundary flow and the eastward shelfbreak current.

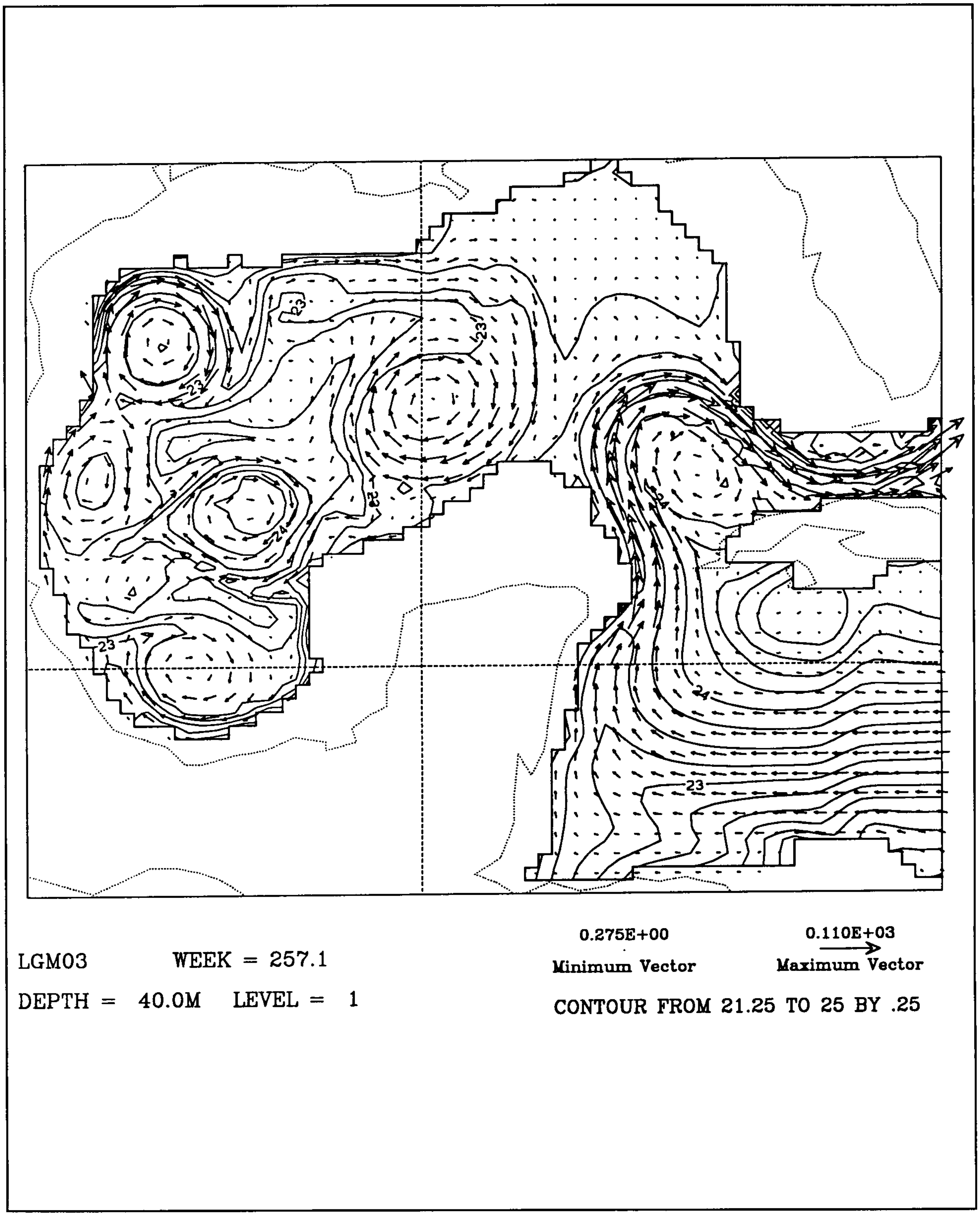

Figure 3C.3. Velocity vector plot (cm/s) superimposed on temperature contours (°C) for level 1 of the LGM model showing the Loop Current, a Loop Current Ring in the central Gulf, upwelling along the western Yucatan Coast and anticyclonic flow in the Campeche Basin.

circulation during lowered sea level and help interpret Late Quaternary sedimentological and paleontological studies of the GOM.

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Susan Welsh is a doctoral candidate in the Department of Geology and Geophysics at Louisiana State University. She received her B.A. in earth and planetary science at the Johns Hopkins University in 1983 and her M.S. in oceanography at Florida State University in 1986. Ms. Welsh has worked on numerical modeling projects as a scientific programmer at both Florida State and Louisiana State Universities.

Dr. Masamichi Inoue had worked at the Florida State University and at Australian Institute of Marine Science. He has been at Louisiana State University for the past eight years and is associate professor at the Coastal Studies Institute and in the Department of Oceanography & Coastal Sciences. His research interests include modeling ocean circulation and transport processes. Dr. Inoue received his Bachelor of Engineering in naval architecture from Tokai University in Japan, his M.S. in ocean engineering from the University of Rhode island, his Master of Engineering in civil engineering and his Ph.D. in oceanography from Texas A&M University.

DIGITAL HIGH RESOLUTION ACOUSTIC DATA FOR IMPROVED BENTHIC HABITAT/GEOHAZARDS EVALUATIONS

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INTRODUCTION

Within the northern Gulf of Mexico OCS region, which incorporates the outer continental shelf and upper continental slope, both the petroleum industry and the Minerals Management Service (MMS) must understand sea floor geology for operational and regulatory purposes. This province has the most complicated geologic framework in the Gulf and arguably is the most complex distal shelf and slope in today's oceans. In this province, regional topography is dominated by domes or knolls associated with salt in the shallow subsurface and intervening basins. Bottom slopes associated with these regional-scale features range from less than 1° on the dome tops and along the intraslope basin floors to over 20° on the side of domes and on basin flanks (Coleman *et al.* 1986). Superimposed on this large-scale geologic framework is a spectrum of smaller-scale geologic features that pose the real challenge within the OCS region regarding operations and management in deep water. Near-surface geology and topography of the upper continental slope in the northern Gulf of Mexico is highly influenced by cyclic episodes of shelf edge progradation (Suter and Berryhill 1985) and associated basin-filling on the slope (Acosta and Weimer 1994). These events, which occur primarily during periods of lowered sea level, are accompanied by contemporaneous deformation of the sedimentary sequence by salt and shale diapirism plus surface sediment redistribution by physical oceanographic processes. Rapid progradation of the shelf edge through shelf edge delta development leads to slope oversteepening. In this setting, thick wedges of metastable sediment with high pore pressures load preexisting faults at the shelf margin during period of falling-to-low sea level. These conditions promote submarine landslides, debris flows, shelf edge slumping on various scales, and even canyon formation (Coleman *et al.* 1983). During the falling-to-lowstand stage of a sea level cycle, sedimentary loading of intraslope basins, from just below the shelf edge to the Sigsbee Escarpment, mobilizes salt and shale, initiating new faults and activating old ones. Faulting creates abrupt relief and steep slopes (some near vertical) on the modern ocean floor of the slope. In many cases, faulting is accompanied by slope failure and mass movement. In addition, faults function as avenues of transport for fluids and gases that affect the present surfical geology of the slope through: (a) expulsion of large volumes of fluid mud results in mud volcanoes and mud flows (Neurauter and Roberts 1994; Kohl and Roberts, 1994), (b) development of highly populated communities of chemosynthetic organisms (Kennicutt *et al.* 1985), (c) creation of brine pools and pock marks (McDonald *et al.* 1990), (d) gas hydrate mound formation (Brooks *et al.* 1985), and (e) precipitation of carbonates and other more exotic minerals to form hardgrounds, chimneys, and mound-like buildups (Roberts and Aharon, 1994). All of these sea floor impacts are associated with the vertical flux of hydrocarbon gases, crude oil, and other formation fluids migrating along faults.

Although present conditions are those of a high sea level when fluvial system have retreated landward from the shelf edge, the modern sea floor is still highly complex, largely a remnant of responses to sedimentary loading at or near sea level lowstands. Many of the responses caused by sedimentary loading such as salt migration and fault movements are still occurring. These responses not only create a variety of geohazards, but also provide trophic resource (e.g., hydrocarbon gases and crude oil) that support lush and environmentally protected chemosynthetic communities. The MMS-supported project discussed in this document is focused on upgrading our interpretations of geohazards and the locations of sensitive benthic communities (chemosynthetic organisms). This goal is being accomplished by developing new bottom feature interpretation criteria through the combined activities of reevaluation of previously collected geohazards data sets (high resolution seismic and side-scan sonar), newly acquired digital acoustic data sets, and sea floor observations provided by use of a manned research submersible. This project also is designed to assess the best acoustic tools and acquisition strategies as well as the possible added value of using 3D-seismic surface amplitude extraction data.

METHODS AND DATA SETS

High resolution acoustic data for the continental slope are primarily acquired by the petroleum industry for engineering requirements and to meet Minerals Management Service (MMS) regulations regarding identification and assessment of geohazards and protection of sensitive benthic communities. The engineering studies for drilling/production platforms and pipeline routes require an appraisal of the slope's surface geology to determine geotechnical properties of slope sediments and potential geohazards that may be detrimental to man-made structures. These data sets consist of high resolution seismic and side-scan sonar acquired by both surface-tow and deep-tow methods. Upon request to many companies, data sets have been made available for an integrated study of surficial continental slope geology. Submersibles such as the Johnson Sea-Link (JSL) from Harbor Branch Marine Laboratory have been used for collection of direct observational data and feature-specific sampling under support from NOAA's National Underseas Research Program. These data sets provide the "ground truth" for acoustic appraisals of the sea floor. Although funded from another source, submersible-derived data are critical to the success of upgrading our interpretive capability using acoustic data alone. In essence, this project is attempting to "calibrate" acoustic images of various sea floor features important to both MMS and industry missions. Data sets from the above sources were used to assess the surficial geology of the upper and middle slope. Most research submersibles, like the JSL, readily available to scientific personnel in the Gulf of Mexico are limited to a diving depth of about 1,000 m.

During the first year of this program data sets were primarily collected from industry to derive characteristics of feature detection/interpretation from acoustic records. In addition, testing of acoustic sources and data collection systems, was carried out during Year 1. Review of previously acquired industry data continued in Year 2 but field acquisition of data from targets which had been directly observed and studied using a research submersible was the main objective. This task was carried out in the summer of 1995. Eight features, shown in Figure 3C.4, were the subjects of data collection. Three acoustic sources were used: (1) ORE Geopulse Boomer (400-14000 Hz signal with minimal reverberation and vertical resolution of > 1 m), (2) Seismic Systems model S-15 water gun (200-800 Hz signal centered around 400 Hz with vertical resolution of about 2 m), and (3) the Seismic System 50 in^3 air gun, GI gun (a lower frequency source than the Geopulse or S-15, but with a bed resolution of 2-3 in). A Model 260 EG&G digital side-scan system was used to image targets above water depths of 200 m.

All data sets were located using GPS-controlled navigation through a special survey-control software program written by the Coastal Studies Institute Field Support Group. Sound-source triggering, signal acquisition, real-time and post-survey processing, and digital data storage were controlled by the Delph 2 digital acquisition system operating on a modified PC-compatible 486 computer. With this acquisition system, two acoustic sources were operated synchronously using staggered firing and listening times, and data storage in separate files. There was no signal interference between the two sound sources, but with the more powerful Seismic Systems GI Gun remnant sound energy from the GI Gun interfered with the Geopulse and water gun return signals. Therefore, the air gun was operated as a single acoustic source.

The Delph 2 system allows real time monitoring, optimization, and basic processing of return signals. Processing of single-channel data is limited to gain optimization, high and low pass filtering, swell filtering, stacking of adjacent shots, and predictive deconvolution. Sampling frequency for the Geopulse signal was 8,000 Hz for a 250 ms sweep, and the water-gun was 4,000 Hz at 500 to 1,000 ms sweeps. Incoming data are stored on a 500 megabyte hard drive and downloaded onto 8 mm Exabyte magnetic tape at the end of each survey line. Navigation fixes are incorporated into the stored data. As backup, data were also recorded in analog format on EPC recorders.

SEA FLOOR FEATURES

Faulting is a process that occurs on many scales within the continental slope setting, from major growth faults that cut thousands of meters of sedimentary section to much smaller compensating faults related primarily to salt movement in the shallow subsurface. In addition to off-setting the sea floor and creating local topography, faults are responsible for numerous constructional sea floor features related to the vertical flux and explusion of fluids at the ocean bottom. At one end of the feature spectrum are large mud volcanoes (Neurauter and Bryant 1990; Neuranter and Roberts 1994) formed by fine-grained sediment forced up faults. Hedberg (1974) identifies the process of sediment flux by gas-filled formation fluids up faults as being responsible for creating mud diapirs as well as mud volcanoes. At the other end of the spectrum, vertical flux of gases and fluids may be very slow. Microbial degradation of both hydrocarbon gases and crude oil associated with this process can produce by-products such as calcium-magnesium carbonates that create a variety of sea floor features including hard grounds and mound-like structures of various dimensions (Roberts *et al.* 1992 a, b). This process has been described from other settings where salt tectonics is not a factor and only biogenic methane is the hydrocarbon source (Ritger *et al.* 1987; Paull *et al.* 1992).

Mud Vents and Mud Volcanoes

Transport of fluids, gases, and fine-grained sediment up fault planes is rapid and cone-shaped accumulations of mud often develop. As Neurauter and Bryant (1990) and Neurauter and Roberts (1992) point out in studies on the northern Gulf of Mexico continental slope, these features are common in this setting. Neurauter and Roberts (1992) noted that active mud volcanoes have caldera-like depressions that contain fluid mud bubbling with gas that is frequently mixed with globules of crude oil. As the pool of fluid mud upwells over the lip of the crater, sheets of sediment-rich fluid flow down slope, adding a new accetion unit to the cone's flank, and extend the diameter of the mud volcano's base. Features of this description occur on a variety of scales from small cones less than 1m diameter to large features with over 30m relief and bases of over 1km in width. Kohl and Roberts (1994) demonstrate that the process of fluid mud extrusion results in displaced microfaunas and inversion of biostratigraphic marker horizons in slope sediments. Figure 3C.5 illustrates an active mud volcano and adjacent mud diapir imaged during the Year 2 data collection period. These similar appearing features demonstrate the dilemma regarding true identification of these features from even high quality acoustic data as shown in Figure 3C.5. The mud volcano in this figure

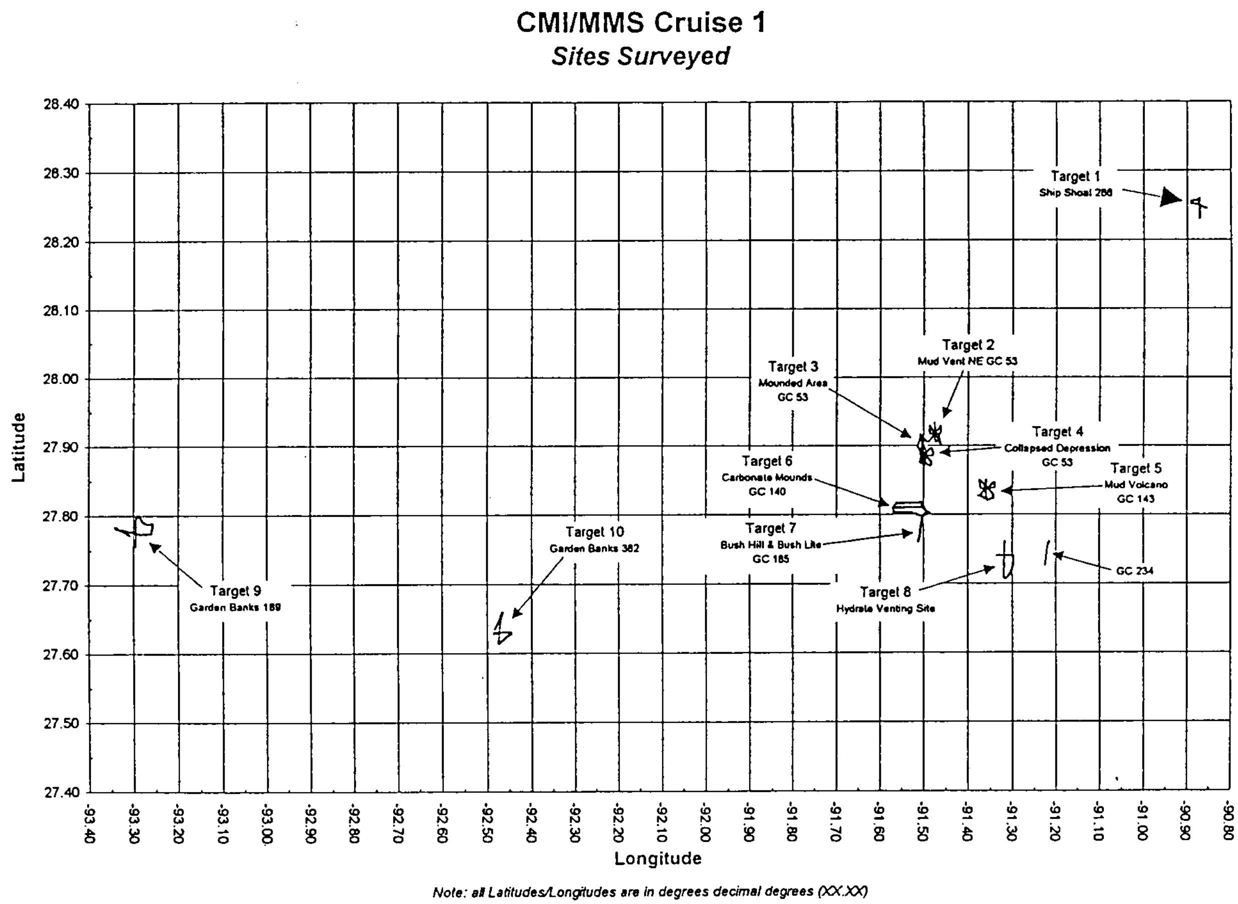

Figure 3C.4. Location map of the eight sea floor features from which acoustic data were acquired during Year 2 of this 3-year research program.

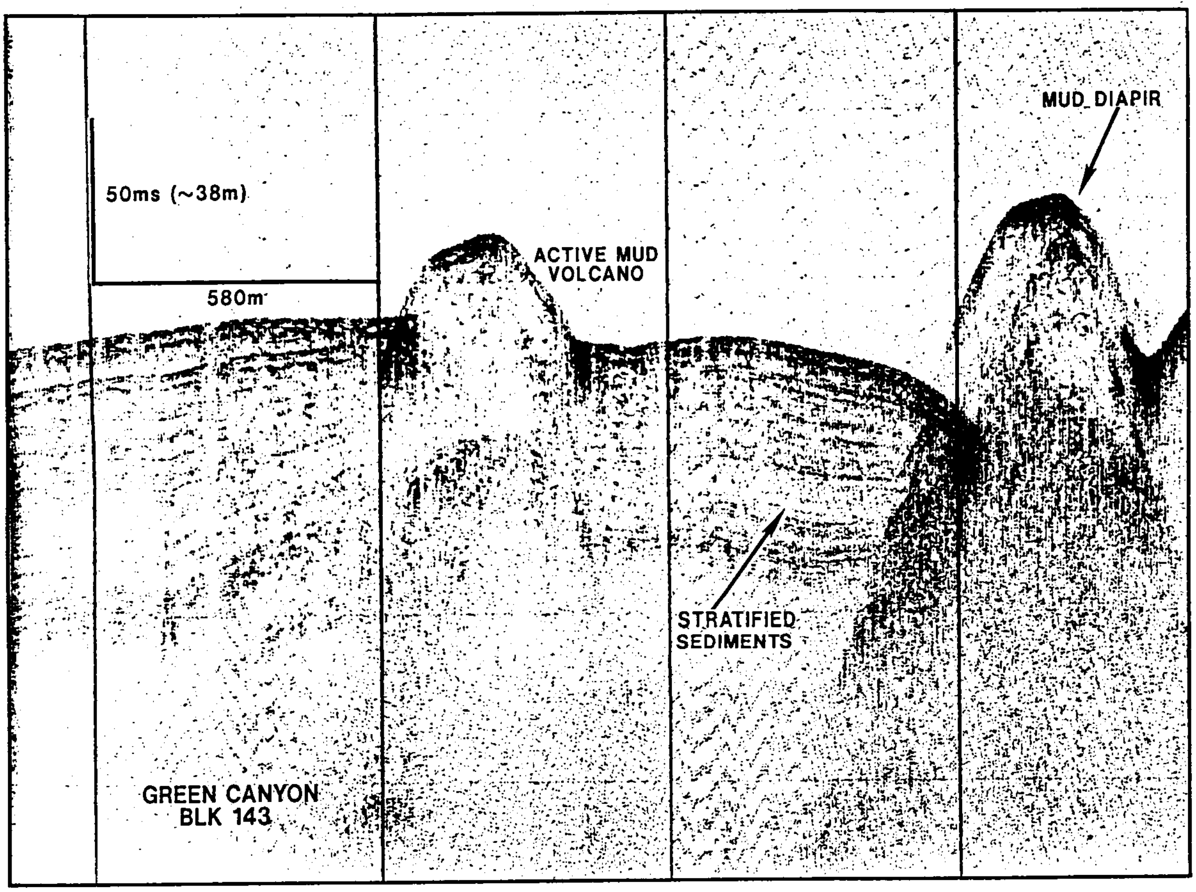

Figure 3C.5. Acoustic profile (Seismic Systems S-15 water gun) showing two similar sea floor features in Green Canyon Area, Block 143. Direct observations with research submersible confirms one is an active mud volcano and one is a mud diapir.

was initially described by Neurauter and Roberts (1992) from submersible observations. In some cases, fluid mud extrusion takes place without the formation of a cone-shaped vent. For example, small-scale sheets of mud are extruded on the surfaces of gas hydrate mounds, perhaps an expulsion product during the hydrate-forming process. In other cases, thick sheets of mud flow kilometers down slope from extrusion sites such as those in the Garden Banks, Block 382. These young mud flow deposits are in the vicinity of Shell's Auger platform. Other sea floor features related to the rapid flux of fluid mud, hydrocarbon, and formation fluids were studied in Garden Banks Block 189, Green Canyon Block 53, and Ship Shoal Block 288 (Figure 3C.4).

Gas Hydrate Mounds

Areas of moderate-to-low vertical flux of fluids and gases to the sea floor below water depths of about 500 m commonly develop into mounded regions of gas hydrates. Figure 3C.6, "Bush Hill" in the Green Canyon Area (Block 185), represents a classic example of a gas hydrate mound. In addition to affecting local topography/geology, gas hydrate mounds function as a rather constant trophic resource for chemosynthetic

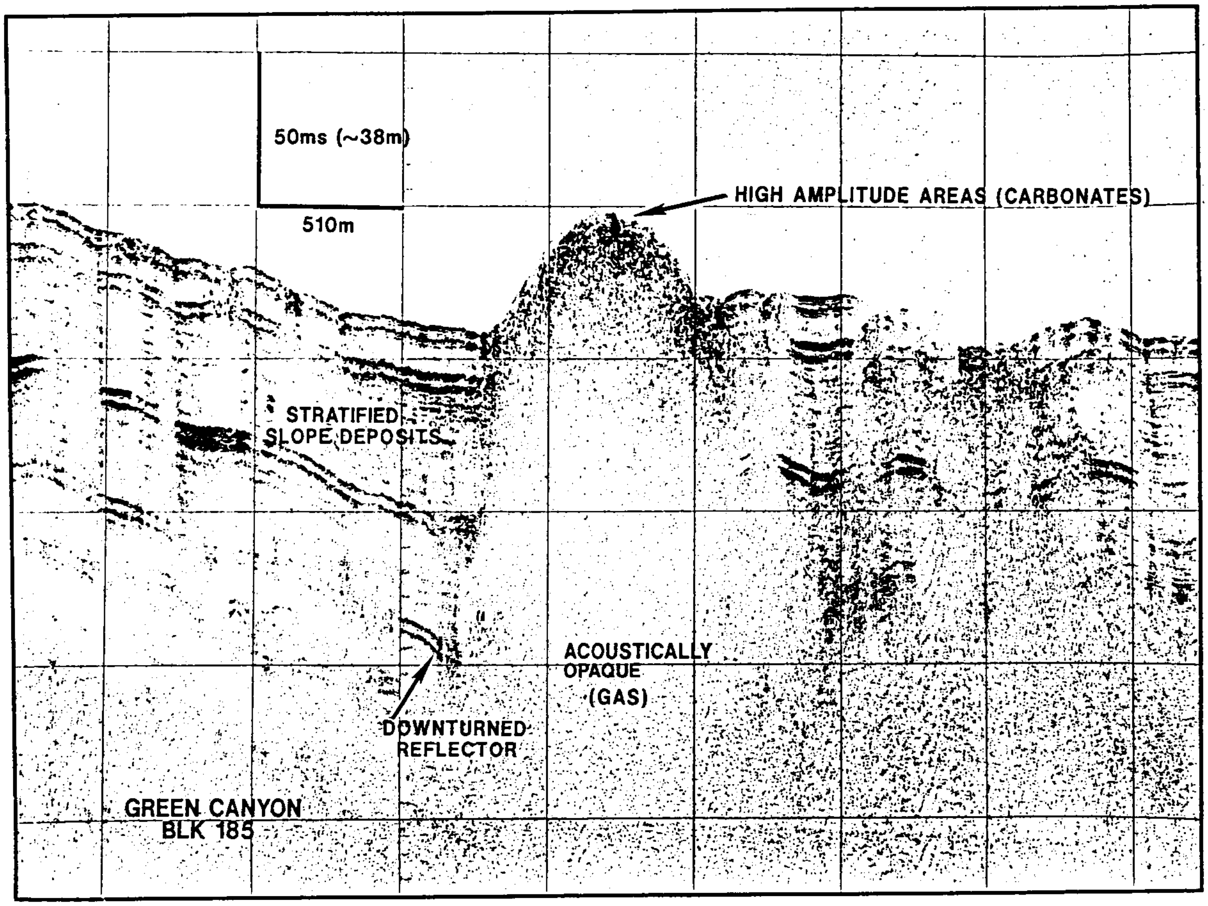

Figure 3C.6. A 50 in^3 air gun profile across Bush Hill, a gas hydrate mound in the Green Canyon Area, Block 185. This profiler was acquired during Year 2 of the project. Note the local, but highly reflective area at the top of this feature. Submersible observations indicate that his is an area of outcropping authigenic carbonates and chemosynthetic communities.

communities. Also, as interpreted from piston cores and direct submersible sampling they are probably intermeshed with authigenic carbonates. These carbonates frequently take the form of small nodular masses to ledge-like outcrops.

Gas hydrates are ice-like substances composed of rigid cages of water molecules that enclose molecules of hydrocarbon gases, primarily methane. These frozen substances are termed clathrates, gas hydrates, and methane hydrates in the scientific literature. However, the term "gas hydrate" is used most commonly in the geosciences (Kvenvolden 1988). They occur under special conditions of temperature and pressure where the supply of hydrocarbon gas is sufficient to stabilize the molecular architecture of the hydrate. Abundant deep-seated hydrocarbons, numerous and complex fault systems that function as transport pathways, nearly continuous fault adjustments related to salt tectonics, and a myriad of surface hydrocarbon seeps, makes the Louisiana continental slope an ideal setting for hydrate accumulation. However, their acoustic signatures on high resolution acoustic data are similar to those of mud volcanoes and mud diapirs. This project is attempting to develop criteria for distinguishing on typical geohazards data sets. In addition to "Bush Hill," data from two other known gas hydrate features (Green Canyon Block 232 and 234) were collected during the Year 2 field project (Figure 3C.4).

Dome-Top Mounds

In areas where the flux of fluids and gases to the sea floor is very slow, abundant authigenic carbonates usually occur. In some cases, especially on the tops of salt diapirs in the, shallow subsurface, these carbonates develop into well-defined mounds. Although almost every upper slope diapir crest thus far investigated in this study has a carbonate mound of some description, one of the best examples of a wide-spread mound complex occurs in the Green Canyon Area, Block 140 (Figure 3C.7). As previously described by Roberts *et al.* (1992 a, b), each one of these mounds is the site of slow seepage of both hydrocarbon gases and crude oil. The mounds have developed from deposits of both calcium- and magnesium-rich carbonates, a by-product of microbial activity at the seep sites. Carbonates derived from this process have been described in detail from other localities by Ritger *et al.* (1987) and Paull *et al.* (1992). The average relief of these mounds is about 10m with some greater than 20m. Details of the mound-forming process are currently being interpreted from submersible-derived data sets. At this location, the mounds have developed during several late Pleistocene cycles of sea level change (Roberts and Aharon, 1994) and occur in association with coarse sediment lags which seem to be evidence of considerable dome-top erosion. On surface amplitude data derived from 3D seismic (Roberts *et al.* 1992a), this site displays no "bright" or high amplitude zones. This response is consistent with a reflective, irregular, carbonate interface where seepage is a very slow process. On the upper slope near the shelf edge, seep-related mounds with similar amplitude signatures are veneered with biogenic carbonates developed primarily during periods of Late Pleistocene lowered sea level when the photic zone coincided with mound depths (mounded area of Green Canyon Area, Block 53; Figure 3C.4).

SUMMARY AND FUTURE ACTIVITIES

Through Year 2 of this project, both existing (industry data) and newly acquired high resolution acoustic data (1995 field project) have been analyzed with "ground truth" manned submersible data to help better understand the surficial geology of Louisiana's continental slope. These data sets clearly show that faults play a key role in producing many of the small-to-mesoscale geologic features on the slope that are considered geohazards by both MMS and industry. Faults create topography by off-setting the sea floor. This process also causes oversteepened slopes and subsequent slope failures. However, through fault-induced transport of fluid mud, formation fluids, and hydrocarbons to the ocean floor numerous small-to meso scale geologic features are developed. Many of these features are associated with sites of chemosynthetic community development. Although faults provide the avenues for vertical migration of fluids and gases to the sea floor, the rate of flux is a critical determinant of feature type and to a large extent whether that feature will support a chemosynthetic community. Rapid flux of fluid mud and gas results in both the buildup of mud volcanoes and, in the proper setting, impressive mud flow deposits. Below a water depth of about 500 m pressure and temperature conditions are suitable for development of gas hydrates in settings of moderate vertical flux rates of fluids and gases. Many areas exhibit hydrate mounds that may have over 30 m relief. Gas hydrate areas typically support the most vibrant chemosynthetic communities. In contrast, areas of low hydrocarbon flux rates favor the development of authigenic carbonates. Many of these areas exhibit broad expenses of mounded sea floor, individual mounds sometimes exceeding 20 m relief. The Year 2 field data collection program was successful in collecting high quality acoustic data from features from high flux-to-low flux settings. Additional data from other features are planned for the Year 3 field season (summer). Collection of existing data from industry will continue in Year 3 with a summary of project results planned for the end of 1996.

ACKNOWLEDGMENTS

This research has been supported by the Minerals Management Service through the Coastal Marine Institute and a Louisiana State University Cooperative Agreement (Contract No. 14-35-0001-30660), with submersible support by NOAA National Underseas Research Center, University of North Carolina at Wilmington (Grants NA 80AA-8-00081, NA88AA-D-UR004, and NA36RU0060). As parts of these projects and others, many petroleum companies have contributed high resolution acoustic data sets for submersible dive planning and for analysis of surficial geology of the slope.

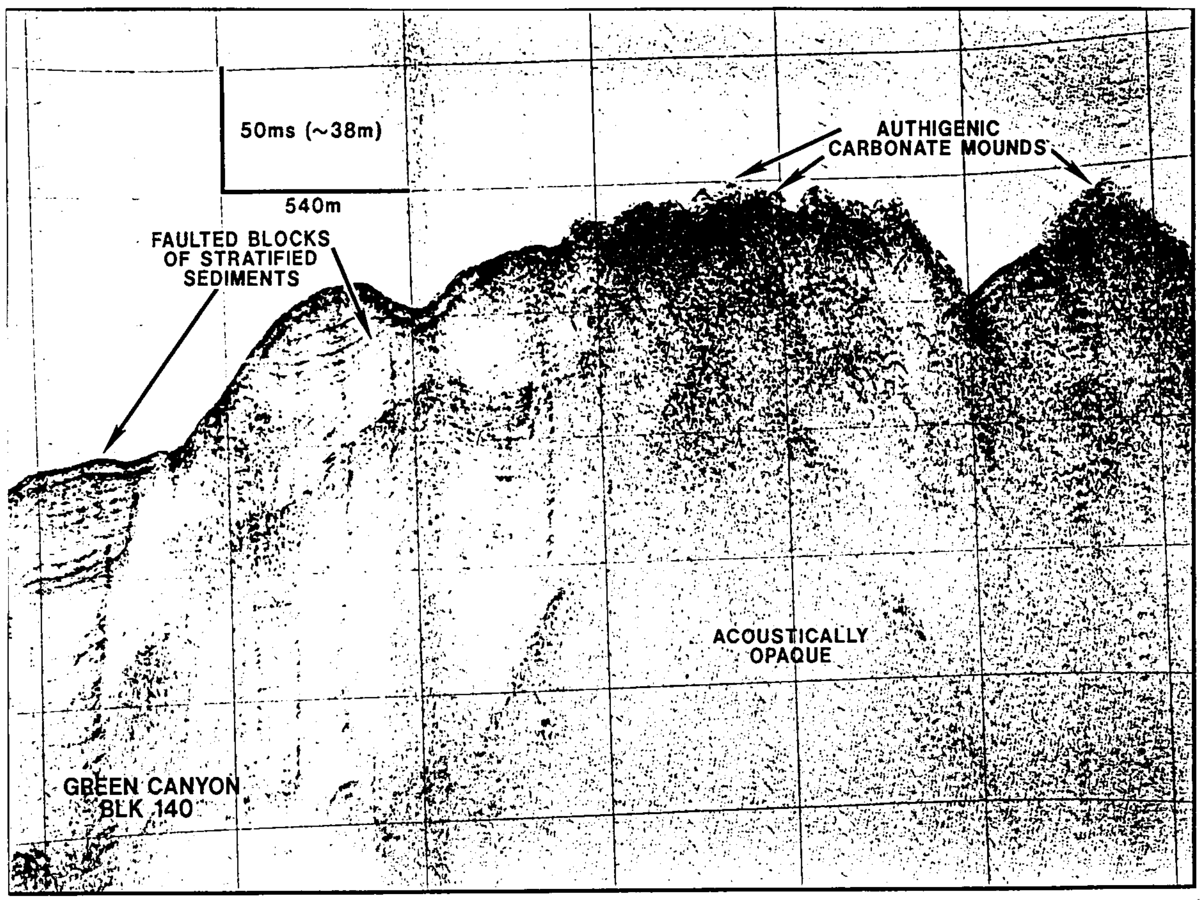

Figure 3C.7. Acoustic profile (15 in^3 water gun) across the top of the salt diapir in Green Canyon Area, Block 140. Note the highly reflective authigenic carbonate mounds over the crest of this feature.

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Dr. Roberts is a former director of the Coastal Studies Institute where he is currently a senior researcher. He is also a professor in the Department of Oceanography and Coastal Sciences. A marine geologist/sedimentologist, he has worked on both carbonate and terrigenous clastic depositional systems. His current research interests are focused on the surficial geology of the Louisiana continental slope and deltaic geology of the local Mississippi delta complex and Mahakam delta of Indonesia. Dr. Roberts received a B.S. in physics from Marshall University and an M.S. and Ph.D. from Louisiana State University.

A MANAGEMENT OVERVIEW FOR CONTINENTAL SLOPE OIL AND GAS DEVELOPMENT IN THE GULF OF MEXICO

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For those of us who like me, entered oceanography in the 60s, 70s, and even maybe the 80s, significant exploitation of the deep seafloor was futuristic fancy. During those decades, there were waste disposal programs in deepwater and varying interest in manganese nodule mining, but no real development. Lacking development, management of deep environments was not considered. Today, deep ocean disposal is banned and nodule mining has no economic incentive. Yet, here in the Gulf of Mexico deepwater oil and gas development is an exciting and challenging pioneer area. Along with the considerable engineering challenges facing industry, MMS is faced with developing the appropriate environmental management strategy. This project is intended as a step in such a development. It first reviews previous federal programs addressing deep ocean environmental concerns looking for applicable models. Then it reviews the present scientific knowledge of the Gulf of Mexico to determine the extent to which management strategies developed in shallow water may apply in deep.

The federal government through the Department of Energy (DOE), the National Oceanic and Atmospheric Administration (NOAA), and the Environmental Protection Agency (EPA) has undertaken research addressing environmental concerns surrounding nuclear waste dumping, chemical dumping, and nodule mining in the deep ocean. All such projects may be characterized as having been terminated in the preliminary stages. In the case of dumping, research findings were insufficient to challenge the prohibitions of the London Dumping Convention. In the case of nodule mining, economic incentive was lost. Therefore, none of these areas provides MMS and industry with a useful model.

While the research of these efforts is of limited utility to MMS, it is interesting to look at the restrictions which various policies anticipated.

1. General deep ocean dumping would have been permitted by EPA and monitored by NOAA. Criteria for permitting and monitoring were never established. Presumably, siting would have been based on pre-existing sites.
2. High-level nuclear waste disposal would have been carried out at sites proposed by DOE and judged by EPA using London Dumping Convention criteria.
3. Nodule mining would be permitted and presumably monitored by NOAA through a system of claim registration in international waters. Development would be forbidden in specified Stable Reference Areas (SRA's) set aside to protect some fraction of the environment.

Of these, only nodule mining bears a resemblance to oil and gas development. It was accepted that nodule mining would strip very large areas of the seafloor of nodules, impacting the fauna, and altering the environmental characteristics for millennia. This wide scale impact was viewed as acceptable if preserves were established and never exploited. Oil and gas development works on very different scales. The actual "foot print" of development may be only a few thousands of meters square, and the duration of impact much less than a half a century. On the continental shelf MMS has created "preserves," notably the Flower Gardens areas. However, these protect unique habitats, while the nodule mining plan sought to protect segments of typical habitat. MMS already limits or forbids development in deep areas of special interest and value. So far, no such restrictions exist for deep water. Chemosynthetic communities are, however, afforded protection through operational restrictions.

The primary lesson to be learned from all these terminated programs is that environmental concerns exist even for the most remote part of the deep ocean. And, in the case of nodule mining, U.S. environmental regulations may be proposed even for international waters. Thus, MMS and industry should make sure that unwarranted environmental concerns do not hinder development, and that management appropriate for the environment be adapted.

Since MMS and the oil and gas industry have arrived at a highly successful environmental program for shelf-depth development, the most expedient means of developing a deep-water program would be simply to apply the same management strategy to all environments. Oceanographers have, however, traditionally treated the deep ocean as distinctly different from the shallow. Thus, we must question how different the deep and shallow Gulf of Mexico are. Fortunately, the deep-sea biota of the Gulf of Mexico has received sufficient study to provide some guidance in policy development without additional study. In the 60s and 70s the late Willis Pequegnat of Texas A&M undertook extensive trawl sampling throughout the Gulf with Office of Naval Research support. Subsequently, MMS supported a synthesis of that work (Pequegnat 1983), a survey based on box coring (Gallaway and Pequegnat 1988, Pequegnat *et al.* 1990). This last effort was especially important in two regards. First, it provided a Gulf data base similar to that of most deep-sea work. Second, it led to the discovery of chemosynthetic communities in the northern Gulf.

The work in the Gulf has shown that there are no commercial species below 1,000m. Thus, bottom fisheries related issues should not arise. With the exception of deep hard grounds and chemosynthetic communities, the number of unique habitats appears to be limited. However, the deep Gulf does contain the same high diversity of fauna that puzzles ecologists in all oceans. Why is the deep ocean highly diverse? This stands out as the primary concern about applying shallow management to the deep sea. In most other regards, deep oil and gas development may pose fewer environmental threats than shallow.

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Robert Carney is a benthic ecologist who began deep-sea studies as a master's student at Texas A&M (M.S. 1971) and continued this line of research at Oregon State University (Ph.D. 1976). He served as director of LSU's Coastal Ecology Institute from 1986 to 1995 and has been director of the LSU-MMS CMI program since its inception. He is an associate professor in the LSU department of Oceanography and Coastal Studies. Prior to LSU, Dr. Carney was employed at Moss Landing Marine Labs, the National Science Foundation, and the Smithsonian Institution. Dr. Carney's published works are in the area of deep-sea ecology and environmental studies in the marine environment.

TRANSPORT AND MIXING PROCESSES IN LOUISIANA ESTUARIES

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INTRODUCTION

The second year of our project entitled "Coastal Marine Environmental Modeling" has focused on transport and mixing processes in Louisiana estuaries. Mixing and flushing characteristics of the Terrebonne/Timbalier Bay System were investigated by tracking numerous labeled tracer particles in our two-dimensional depth-integrated model.

METHODS

During the first year, a two-dimensional depth-integrated fully-nonlinear hydrodynamic model was applied to study circulation in the Terrebonne/Timbalier and the Four League Bay systems (Inoue and Wiseman 1994). The Terrebonne/Timbalier Bay Model includes both Terrebonne Bay and Timbalier Bay (see Figure 3C.8). The southern boundary of the model domain is open. The model is forced by the observed wind and the sea level height. An extensive model calibration had been carried out using the field data collected under an interdisciplinary field program sponsored by the USGS (Wiseman and Inoue 1993).

In order to shed light on transport and mixing processes, labeled tracer particles were released in the model and their trajectories were tracked. In carrying out those tracer particle experiments, our emphasis was on examining details of advective transport processes by realistic currents driven by the observed tides and winds. Every particle released in the model was tracked continuously until it had left the model domain.

RESULTS

In one experiment, 9,800 labeled particles were released at uniformly-separated distances along a straight line across the main deep passage (Figure 3C.9). Those particles form an interface separating the bay water from the outside Gulf water at the time of release (5/2/1990 Hour 0). Immediately after release, the interface translates northward with an incoming flood tide, while the shape of the interface undergoes complex evolutionary process. The interface continuously stretches and folds under the action of current shear and deformation fields generated due to topographic interaction with wind- and tide-driven flow. The evolution of the interface reveals complex shear flow patterns. Some initially adjacent particles end up widely separated, giving an appearance of the interface broken up into smaller units. Broken-up units undergo further stretching and folding. The combined action of stretching and folding produces exponential area growth (Ottino 1989), thus leading to mixing of two neighboring water masses. Some particles tend to stay in proximity for an extended period. After nine days, many of the particles had exited the bay, while some still remain in the vicinity of the main passage.

In another experiment, more than 5,000 particles were initially released at uniformly-separated locations (approximately 100 m apart) throughout the bay system (Figure 3C.10). Then the trajectories of the labeled particles were tracked for the next 25 simulation days. The Lagrangian movements of the labeled particles indicate the principal flow paths associated with subtidal circulation, which appears to be dominated by wind forcing. For the period of this model simulation, subtidal circulation includes strong inflow through Little Pass Timbalier, a small passage located to the east of the main passage, and weaker inflow through Whiskey Pass, a small passage located to the west. It should be noted that the winds, through variable, were predominantly from the southeast. Main outflow appears to take place through the main deep passage. Flushing time appears to be rather long in comparison to a flushing time estimate based on tidal prism. For example, after five days, 87% of the particles still remain within the bay system. This figure drops to 70%

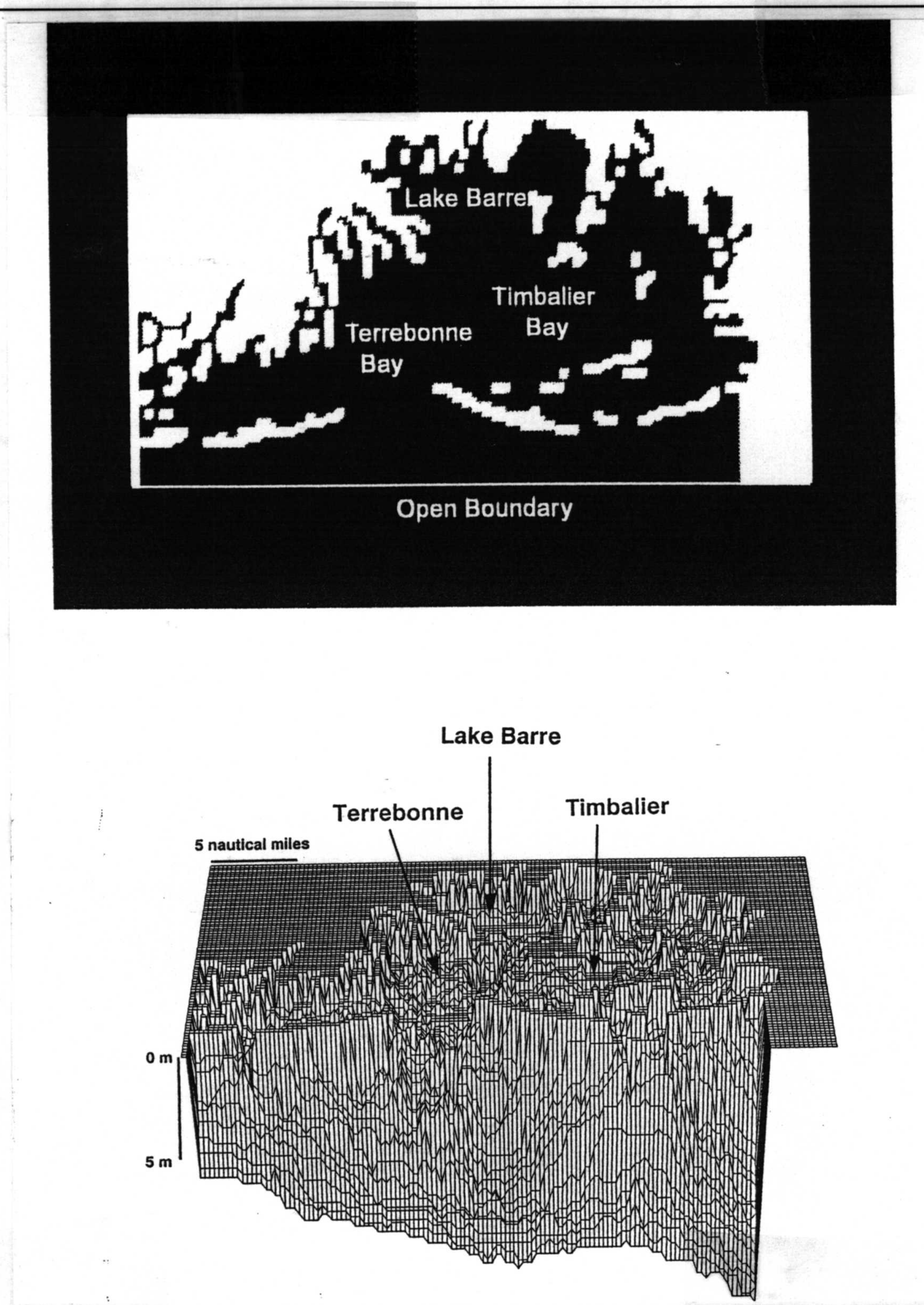

Figure 3C.8. TOP: Model geometry of the Terrebonne/Timbalier Bay Model. The southern boundary is open. BOTTOM: Model bathymetry of the Terrebonne/Timbalier Bay Model.

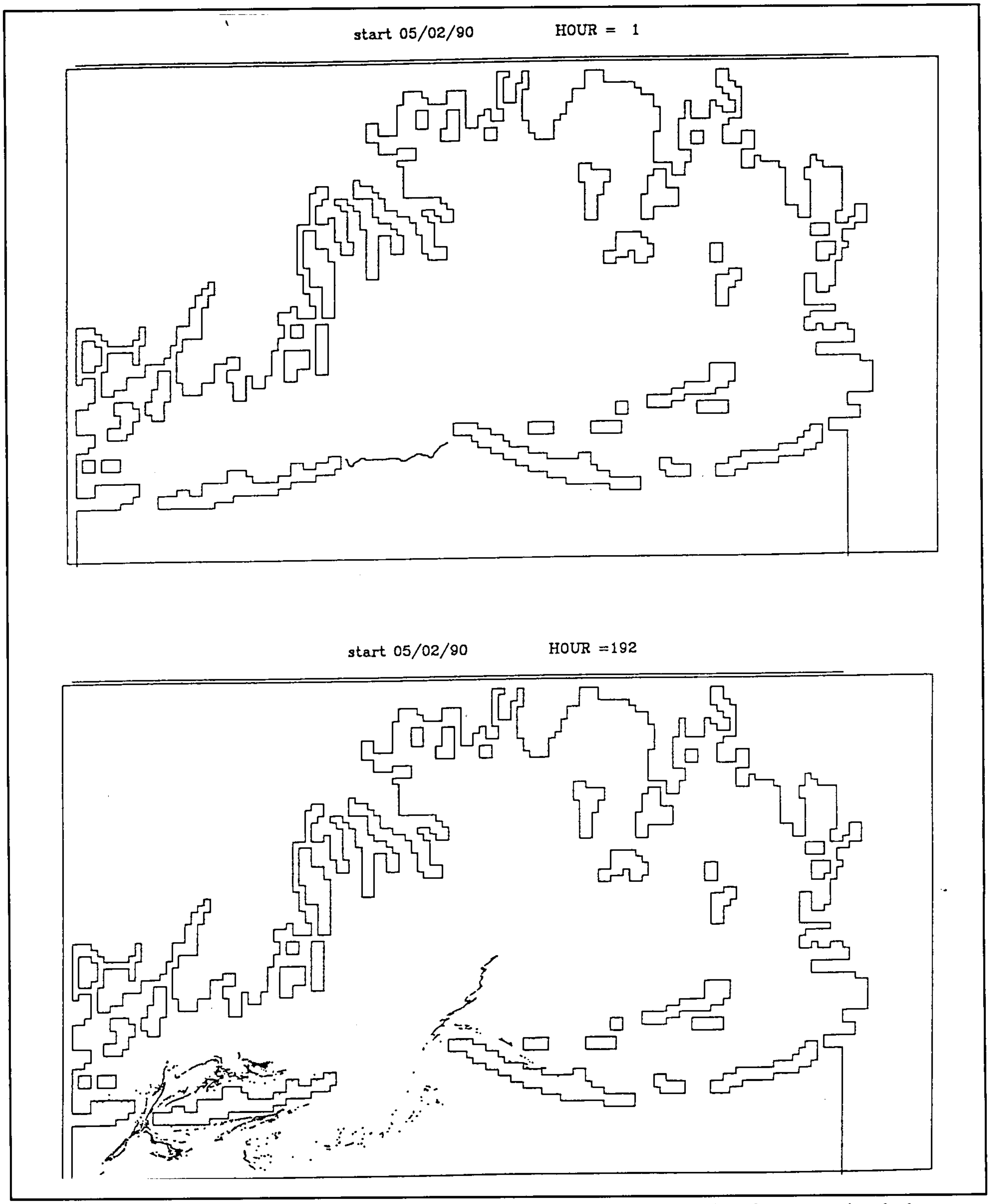

Figure 3C.9. TOP: Distribution of tracer particles at one hour after release, forming an interface separating the bay water from the outside Gulf water Tracer particles were released along a straight line across the deep Wine Island and Cat Island Passes. BOTTOM: Distribution of tracer particles after nine days. Many particles have exited the bay, while some still remain inside the bay after nine days.

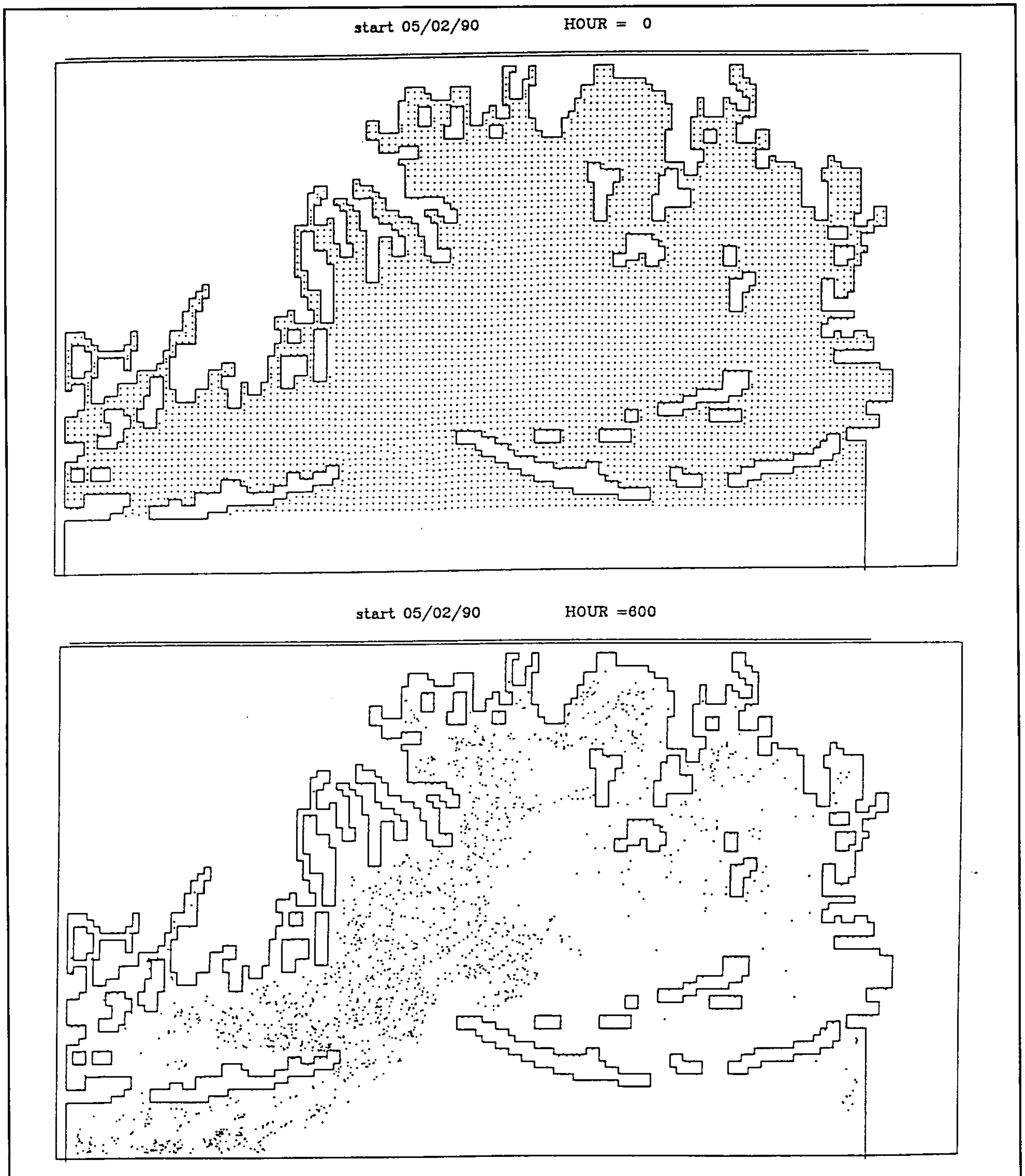

Figure 3C.10. TOP: Distribution of tracer particles at release. Tracer particles were released at uniformly-separated locations throughout the bay. BOTTOM: Distribution of tracer particles after 25 days. At this time 41% of the particles remain in the Bay. Winds were predominantly from the southeast during the simulation period. The distribution of particles suggests net inflow through the shallow eastern passage (and possibly through Whiskey Pass at the western end of the model domain) while net outflow appears to take place through the main deep passage, Wine Island and Cat Island Passes.

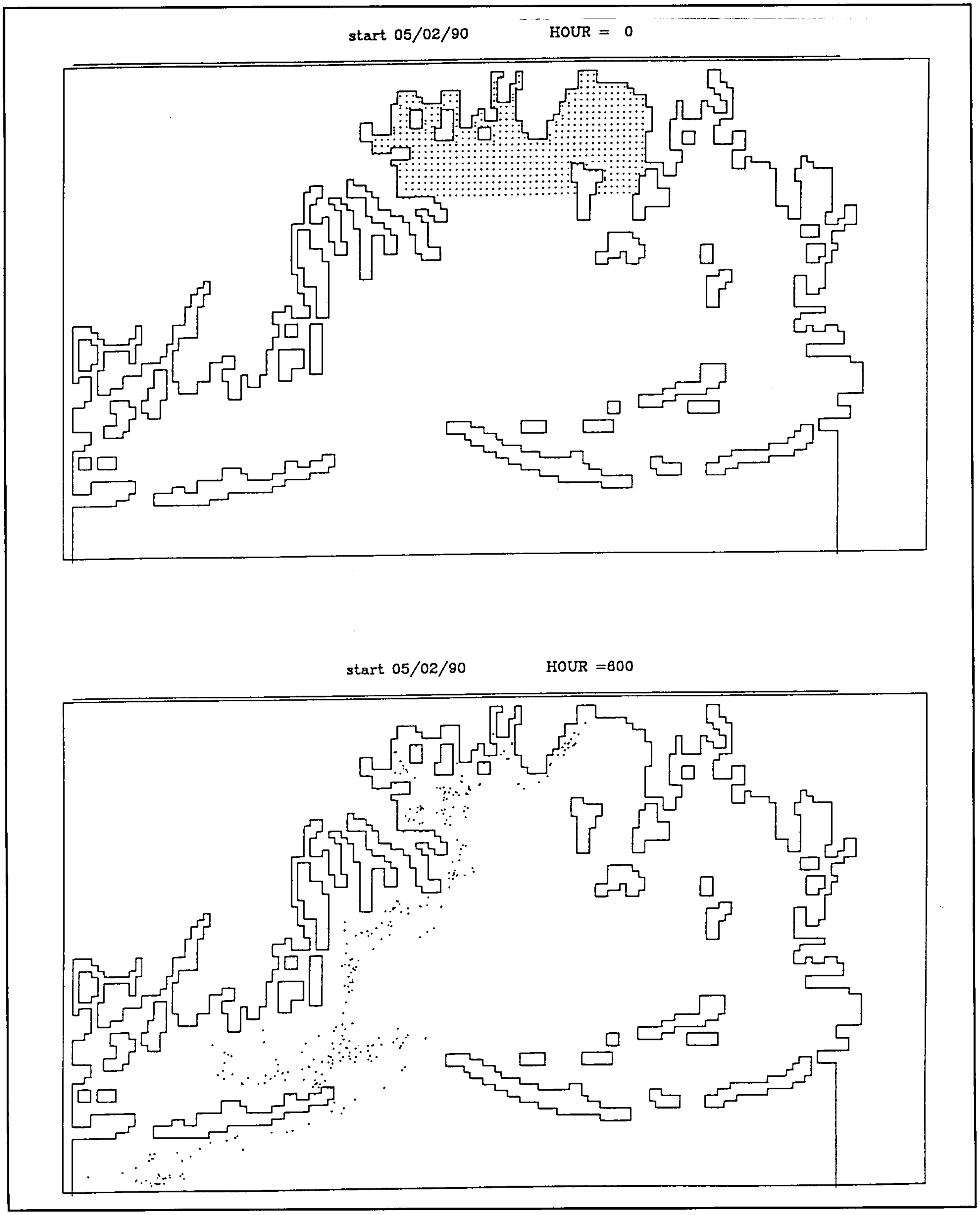

Figure 3C.11. TOP: Distribution of a subset of tracer particles at release. BOTTOM: Distribution of the same tracer particles after 25 days. Note that while many particles have exited the bay, some have remained in close proximity to each other and have accumulated immediately SSW of their release area.

after 10 days, 60% after 15 days, 51% after 20 days, and 41% after 25 days. If we use 50% as a criterion for estimating flushing time, it is close to 21 days for the entire bay system. Particle tracking reveals that some initially adjacent particles end up widely scattered within a short time period while others tend to remain in proximity for an extended period, giving rise to dispersion of particles (Figure 3C.11).

CONCLUSIONS

Based on simulation experiments by tracking tracer particles released in a 2-D hydrodynamic model forced by the observed tides and winds, the following conclusions can be drawn regarding transport and mixing processes in the Terrebonne/Timbalier Bay System: 1) mixing involves continuous stretching and folding of material interface; (2) dispersion is dominated by complex shear-flow patterns and topographic trapping; (3) flushing time of the bay system appears to be relatively long, and sub-tidal circulation appears to be dominated by wind forcing; (4) ebb flow appears to be concentrated in the main deep passage. These observations point to the need to resolve small-scale shear flow patterns, in both space and time, in order to understand dispersion, transport and mixing processes in the estuaries.

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ENVIRONMENTAL POLLUTION

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Population diversity provides an obvious index of the overall health of any ecosystem. When community structure changes are used to index and identify potential problems, it may be a moot beacon, sending a clear message that a problem exists, but often signaling after the damage is done.

Techniques used to identify potential problems include the use of community members that may be particularly sensitive and exhibit subtle, but measurable responses to various environmental conditions. With this in mind, the term "biomarker" has been defined by the NATO Advanced Workshop on Biological Markers as "a change in a biological response that can be related to an exposure to, or toxic effect of, an environmental chemical (or chemicals)" (NATO 1993). The nature of the biological response can range from: 1) a biochemical (molecular) response; 2) behavioral/social interaction changes; 3) and finally, population or community structure changes.

Methods that detect subtle physiological or biochemical changes in animals exposed to chemical pollutants or environmental stresses are particularly useful. Two classes of biochemical response induced by chemicals and detrimental environmental conditions that can provide early-warning indices of environmental impact are 1) enzymes of the microsomal mixed-function oxygenase (MFO) (Payne 1977; Goksøyr and Forlin 1992; Reily *et al.* 1992) system, especially the proteins of the cytochrome P450 1A subfamily, and 2) heavy metal-induced stress-response proteins such as heat-shock proteins (Sanders 1993; Black *et al.* 1995).

Sea anemones have several advantages as sentinels for pollution exposure: 1) they inhabit oil platforms; 2) they are relatively sessile; 3) they are ubiquitous in the Gulf of Mexico; 4) they have evolved mechanisms to deal with oxidative stress; 5) and at least three proteins associated with MFO activity are present demonstrated by immunoblotting techniques.

We collected the intertidal grey anemone (*Bunodosoma cavernata*) from rock jetties at Belle Pass, south of Port Fourchon, Louisiana. This pass is heavily-utilized by support vessels for offshore oil exploration and by commercial and recreational fishermen. We compared two gulf species to anemones from the west coast of the United States and the coral reef community; *Aiptasia pallida* and *Bunodosoma cavernata*, common in the northern Gulf of Mexico; *Condylactis gigantea*, a coral reef species from the Caribbean; and *Anthopleura elegantissima* and *Anthopleura xanthogrammica,* cold water species from the west coast of California and Alaska.

Western blots probed with anti-scup (*Stenotomus chrysops*) CYP 1A1 antibodies cross-reacted with microsomal proteins of approximately 70 kDa in all anemones except *Condylactis gigantea.* Multiple microsomal proteins of approximately 40, 55, and 65 kDa from *Aiptasia pallida* cross-reacted with these antibodies. A 30 kDa protein was recognized from all species except *Aiptasia pallida.* A 45 kDa protein was recognized by all except *B. cavernata.*

Western blots probed with anti-trout CYP 3A1 antibodies cross-reacted with microsomal proteins of 31 kDa in all species except *Aiptasia pallida.* Anti-trout 3A1 antibodies cross-reacted with 75 kDa protein in *Anthopleura xanthogrammica. Aiptasia pallida had* multiple proteins recognized of approximately 60, 55, 56, 50, and 45 kDa.

Western blots probed with anti-trout CYP 2K1 antibodies recognized proteins of 50 kDa in all species except *Aiptasia pallida.* Proteins of 90 kDa were recognized from all species except *Condylactis gigantea.* Additional proteins of 60, 70, and 80 kDa were recognized from *Aiptasia pallida.*

Evidence of MFO activity can be seen with the enzymatic production of oxidative metabolites of benzo[a]pyrene (B[a]P). Microsomes from *B. cavernata* were incubated with B[a]P. Several oxidized metabolites were detected by HPLC including: 1)B[a]P tetrols and 7,8-DHDE B[a]P; 2) B[a]P 4,5-, and 9,10-diols; 3) B[a]P diones; and 4) 3-, and 9-hydroxy derivatives of B[a]P.

B. cavernata were exposed to Cd, Cu, or Hg in concentrations of 0, 25, or 250 μg/l in glass aquaria using artificial sea water (25 ppt salinity). Incubation of Western blots of the cytosolic fraction from 250 μg/l copper exposed and unexposed *B. cavernata* with mouse monoclonal antibodies raised to anti-human 70 kDa heat-shock protein (HSP) provided evidence of induction of a 32 kDa protein homologous to HSPs of humans (Table 3C.1).

Incubation of Western blots of the cytosolic fraction from 250 μg/l copper exposed and unexposed *B. cavernata* with rat monoclonal antibodies raised to anti-mouse hsp-90 showed induction of a 70, and 90 kDa protein (Table 3C.2).

We have illustrated evidence of the presence and inducibility of proteins or biochemical systems involved in the metabolism of chemical toxins (MFO system) and heavy metals (HSPs) in sea anemones found in the Gulf of Mexico.

Future work will involve sampling sites along the upper Gulf Coast. We will collect *B. cavernata* from several sites along the Gulf Coast including: 1) rock jetties of the Calcasieu River estuary located south of Cameron, Louisiana. This estuary of the Calcasieu River in southwest Louisiana has a long history of chemical exposure including PCBs and heavy metals; 2) Sabine Pass jetties, the Gulf of Mexico outfall of the Sabine River estuary, has heavy commercial oilfield-related traffic and petrochemical plants located on the upper estuary; 3) Galveston jetties, heavily used by commercial shipping navigating the Houston Ship Channel; 4) islands off the shores of Alabama and Mississippi; and 5) locations along the gulf coast of Florida.

Table 3C.1. Evidence of a 32 kDa heat-shock protein induced by 250 μg/l copper probed with anti-human hsp 70 antibodies in *Bunodosoma cavernata**

Standards	250 μg/l Cu				Control			
	1	2	3	4	1	2	3	4
84 kDa	—	—	—	—	—	—	—	—
41.7 kDa	—	—	—	—	—	—	—	—
32 kDa	+++	+++	+++	+++	++	++	+++	++

* Relative intensity of bands from Western blots: No band (—); Band present, low intensity (+); Band present, moderate intensity (++); Band present, very intense (+++).

Table 3C.2. Evidence of a 70, and 90 kDa heat-shock protein induced by 250 μg/l copper probed with anti-mouse hsp 90 antibodies in *Bunodosoma cavernata**

Standards	250 μg/l Cu				Control			
	1	2	3	4	1	2	3	4
90 kDa	+++	+++	+++	+++	++	+	++	+
70 kDa	+++	+++	+++	+++	+++	+	+++	+
32 kDa	—	—	—	—	—	—	—	—

* Relative intensity of bands from Western blots: No band (—); Band present, low intensity (+); Band present, moderate intensity (++); Band present, very intense (+++).

MFO activity, stress-protein levels, and anti-oxidant defense capabilities of anemones from the different locations will be compared to determine differences between collection sites and to determine if correlations between these data and environmental exposure exist.

We have designed a recirculating-water culture system on the campus of LSU to 1) hold anemones collected from the different sites; 2) attempt to have a sustainable, reproducing colony for future research; 3) produce anemones that have not been exposed to toxic chemicals to use as controls for future exposure trials; 4) attempt to produce a colony of genetically-identical clones in an attempt to reduce genetic variability. These animals can then be used to monitor sites. Once we have animals with only constitutive levels of these proteins, we will place them on offshore oil rigs to determine the extent of induction.

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THE DEVELOPMENT OF BIOREMEDIATION FOR OIL SPILL CLEANUP IN COASTAL WETLANDS: PRODUCT IMPACTS AND BIOREMEDIATION POTENTIAL

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ABSTRACT

Although bioremediation for oil spill cleanup has received considerable attention in recent years, its satisfactory use in the cleanup of oil spills in the wetland environment is still questionable and generally untested. We have initiated a multi-disciplinary experimental program to evaluate the use of both microbial seeding and fertilizer as means of enhancing oil biodegradation in coastal salt marshes. We are utilizing both controlled greenhouse experiments as well as field trials to test the efficacy and ecological safety of these enhanced biodegradation methodologies. We shall report on the results of the first year of this three-year investigation. The specific objective of this paper is to summarize the overall scope of the study and to present some preliminary findings concerning marsh plant response to the bioremediation agents.

Sods of marsh (soil and vegetation intact), approximately 30 cm in diameter and 25 cm deep, collected from the inland zone of a *Spartina alterniflora* dominated salt marsh in south Louisiana were used in a greenhouse experiment to identify the effects of the following treatments, with and without oil, on plant and soil responses: (1) seeding product, (2) fertilizer product, and (3) control (no product). Mesocosms were sampled for (1) petroleum hydrocarbon chemistry to identify and quantify the degree of oil biodegradation, (2) soil microbial response to determine the effect of the bioremediation products on the microbial communities that are performing the oil biodegradation, (3) soil chemistry to determine the effect of the bioremediation products on those factors that limit the growth of microbes and plants (e.g. nutrients, soil reducing conditions and soil toxins), and (4) plant response to evaluate the effects of the oil and products on plant vigor and growth. This paper presents selected plant responses that demonstrated that the bioremediation products tested had no adverse impact on plant growth. Additionally, soil respiration was increased by fertilizer, but not microbial, application.

INTRODUCTION

The northern Gulf Coast of the United States is a region of intense oil exploration, production and transmission. Consequently, coastal states, such as Louisiana, are subject to oil spills resulting from shipping accidents, production-related incidents, and pipeline ruptures. Since these incidents often occur in the nearshore environment, coastal salt marshes are frequently the first wetland habitats to be subjected to the oil. As a result, a large number of investigations have documented the effect of petroleum hydrocarbon spills on the dominant salt marsh plant species, *Spartina alterniflora* (Hershner and Lake 1980, Lee *et al.* 1981, Alexander and Webb 1983, Ferrell *et al.* 1984, Mendelssohn *et al.* 1990 and others). In addition, some investigators (e.g., DeLaune *et al.* 1984) have evaluated the impact of oil cleanup procedures in salt marshes. Not only can petroleum hydrocarbons have detrimental impacts on coastal marshes, but additionally, the cleanup of the oil from these highly sensitive environments is often more damaging than the oil itself. Hence, it is important to develop less intrusive oil spill cleanup procedures that exert little to no impact on wetland ecosystems.

Bioremediation, the act of adding materials to contaminated environments, such as oil spill sites, to cause an acceleration of the natural biodegradation process (U.S. Congress 1991) is a promising means by which oil released into salt marshes, as well as other wetland types, can be removed with little impact to the habitat. Bacteria, cultured and selected for high rates of oil degradation, and fertilizers, which enhance native microbial activity, are two types of bioremediation products that can be added to oil contaminated wetlands. Although data in the scientific literature demonstrating the relative effectiveness of bioremediation as an oil cleanup procedure in wetlands is lacking, a number of studies have demonstrated, in general, the potential for enhanced oil degradation as a result of bioremediation, especially through nutrient additions (Tabak *et al.* 1991, Stafferman 1991, Lee and Levy 1987, Lee and Levy 1991, Bragg *et al.* 1993, Lee *et al.* 1993 and others). Specifically for wetlands, Scherrer and Mille (1990) confirmed enhanced degradation of oil in a West Indies mangrove swamp after the addition of an oleophilic fertilizer. Similarly, Lee and Levy (1991) found enhanced degradation of oil, this time in salt marsh sediments, treated with inorganic nutrients. However, critical evaluations of oil bioremediation potential, based on oil chemical analyses that can unequivocally identify enhanced biodegradation in wetland environments is lacking in the published literature.

Microbial seeding as a means of enhancing oil biodegradation has even greater uncertainties associated with it, especially in systems such as wetlands where hydrocarbon degrading bacteria are naturally prevalent. For example, microbial seeding was used in an experimental mode to test its effectiveness in cleaning up an oil spill in a marsh (Marrow Marsh) in Galveston Bay. The reported results did not indicate that the microbial seeding significantly degraded oil at this marsh site (Mearns 1991). In a recent investigation (Venosa *et al.* 1992), two microbial products, which exhibited enhanced biodegradation of Alaska North Slope crude oil in shaker flask tests, did not accelerate biodegradation in a field experiment conducted on an oiled beach in Prince William Sound, although the high variability in the data, the highly weathered nature of the oil, and a lack of sufficient time for biodegradation were cited as possible reasons for the lack of response. Regardless of these equivocal results, many microbial products have been commercialized. If added microbes, per se, are not effective in increasing oil degradation, the high costs of microbial amendments may not be warranted. Oil response agencies, both public and private, require a critical evaluation of microbial seeding in enhancing oil biodegradation. Finally, the ecological impacts of these amendments, microbial as well as fertilizer, must be identified.

A multi-disciplinary, multi-investigator research program has been initiated to address the question: Is bioremediation, via fertilization or microbial seeding, an effective and ecologically safe means of oil spill cleanup in coastal wetlands? The specific objective of this paper is to summarize the overall scope of the study and to present some preliminary findings concerning marsh plant response to the bioremediation agents.

PROJECT GOAL AND APPROACH

The overall goal of the proposed project is to determine the potential for the use of bioremediation as a oil-spill cleanup technique in wetlands. Specifically, we shall determine the effects of both fertilization and microbial seeding on (1) petroleum hydrocarbon degradation and (2) the impacts, if any, of these oil spill cleanup methods on the wetland. To accomplish the preceding goal, we have divided the project into three phases (Figure 3C.12):

Phase 1: Project Design—This component, whose objective was to design the Phase 2 efforts, was funded by Exxon and has been completed; this paper is the result of that effort.

Phase 2: Greenhouse Bioremediation Trials—The present paper describes the first experiment within the Phase 2 effort to determine the potential for oil spill bioremediation in wetland mesocosms. This phase of the research consists of four tasks described below and is being funded jointly by Exxon USA and the Minerals Management Service's Coastal Marine Institute at Louisiana State University.

Phase 3: Field Demonstration Project—If the greenhouse experiments indicate a potential for bioremediation of oil spills in wetlands, a field demonstration will be conducted.

PROJECT DESCRIPTION

Controlled greenhouse experiments, as well as field trials, are planned to test the efficacy and ecological

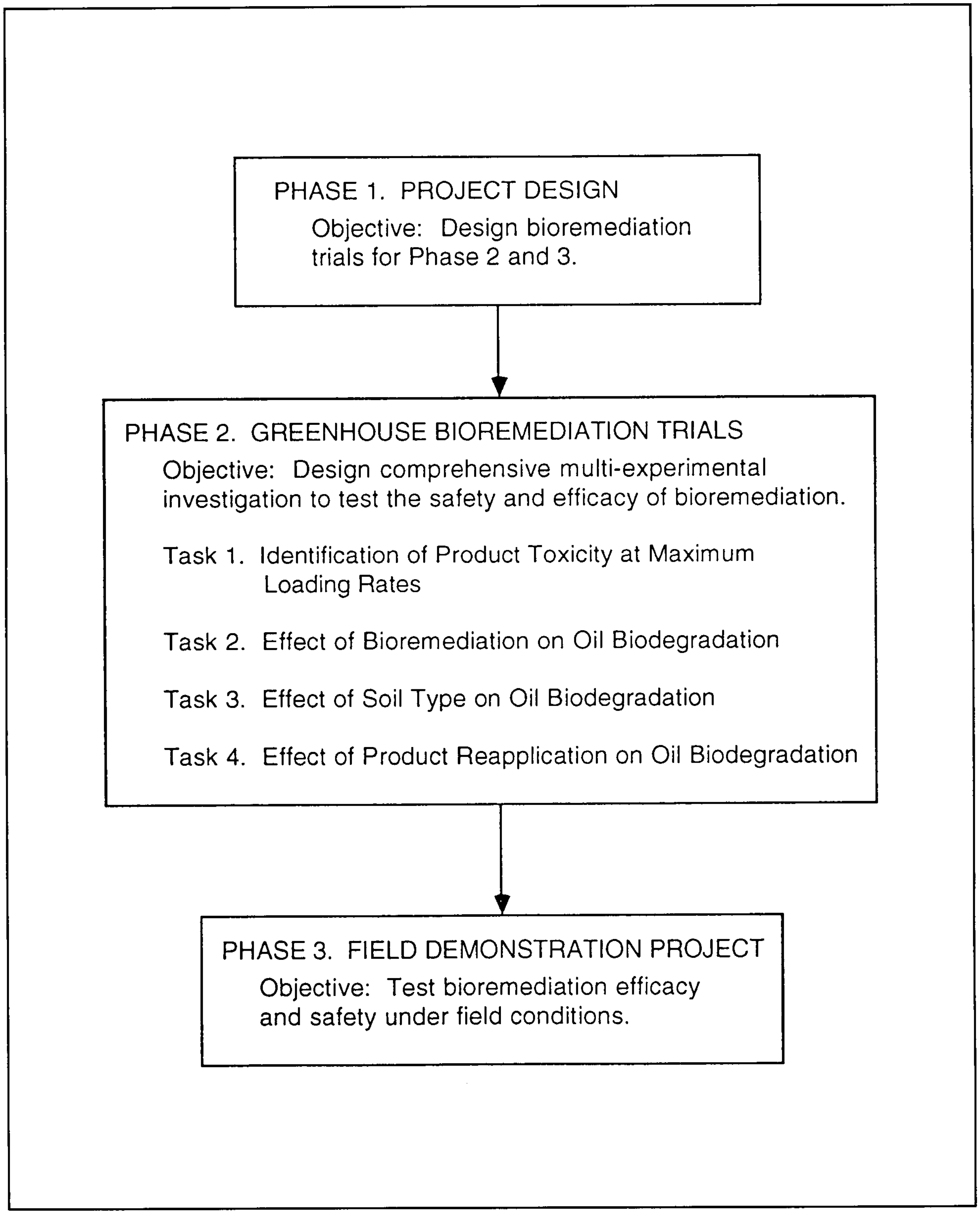

Figure 3C.12. The overall project was designed in three phases: Phase 1–Project Design has been completed; Phase 2–Greenhouse Bioremediation Trials are ongoing; Phase 3–Field Demonstration Project will be pursued if the greenhouse trails indicate a potential for bioremediation.

safety of microbial seeding and fertilization as enhanced biodegradation methodologies. This three-year study is designed to test the following aspects of bioremediation in coastal marshes:

(1) Product Toxicity: Determine if the maximum allowable loading rate (as defined by the product manufacturer) of the selected bioremediation products generates adverse impacts to wetland plants, infaunal animals and microbial communities. This experiment is required to ensure that the product loading rate suggested by the manufacturer is not toxic to wetland plants and estuarine animals. Only products on the National Contingency Plan (NCP) list with defined maximum loading rates will be used in this study.

(2) Biodegradation Potential: Determine the effect of fertilizer and microbial seeding on oil biodegradation in salt marsh soil mesocosms. This experiment is essential to determine the potential for enhanced oil biodegradation via bioremediation in salt marsh substrates and is the first step before large scale field trials.

(3) Marsh Soil Type: Determine to what extent product-enhanced oil biodegradation is modified by marsh soil type. Salt marsh soils, depending on their texture and specific microbial communities, may exhibit different capacities for bioremediation which must be quantified in order to access the variability in bioremediation potential of salt marshes.

(4) Product Reapplication: Determine (a) if product reapplication is required to maintain an enhanced rate of biodegradation and, thus, to maximize total hydrocarbon degradation and (b) whether reapplication rate is a function of the initial oil dosage. Reapplication of the fertilizer bioremediation product is likely during a real cleanup operation. Thus, the efficacy of reapplication as a means of maintaining maximum biodegradation rates at different oil dosing levels will be evaluated.

(5) Field Bioremediation Trial: Determine, under real-world conditions, the degree to which the potential for bioremediation demonstrated in the greenhouse marsh mesocosms is realized in the field. This experiment will be designed to assess bioremediation in both streamside salt marshes, where subsurface hydrology is a relatively active, and immediately adjacent inland salt marshes, where subsurface hydrology is minimal. Both bioremediation efficacy and ecological safety will be evaluated.

The effectiveness of bioremediation and its ecological safety will be assessed in the above experiments by evaluating the following: (1) petroleum hydrocarbon chemistry to identify and quantify the degree of oil biodegradation (Overton and Henry), (2) oil morphology, which will be related to oil chemistry, as an inexpensive means of evaluating oil biodegradation (Debusschere), (3) soil microbial response to determine the effect of the bioremediation products on the microbial communities that are performing the oil biodegradation (Portier and Walsh), (4) soil chemistry to determine the effect of the bioremediation products on those factors that limit the growth of microbes and plants (e.g. nutrients, soil reducing conditions and soil toxins) (Mendelssohn), and (5) plant and infaunal response to evaluate the combined effects of the oil and products on plant and animal components of the marsh system (Mendelssohn and Rabalais).

IDENTIFICATION OF PRODUCT TOXICITY AT MAXIMUM LOADING RATE

Objective and Rationale

This experiment is designed to determine if the maximum allowable loading rate of the selected bioremediation products generate adverse impacts to wetland plants, infaunal animals and microbial communities. We specifically ask the question: Can bioremediation be used for oil spill cleanup without causing negative impacts to wetland structure and function? Selected plant and soil responses are presented.

Experimental Design and Methods

Sods of marsh (soil and vegetation intact), approximately 28 cm in diameter (0.06 m^2) and 30 cm deep, were collected from the inland zone (approximately 5 m from the creekbank natural levee) of a *Spartina alterniflora* dominated salt marsh located west of Cocodrie, Louisiana and used as the experimental units. Inland sods were chosen because the inland zone comprises the largest aerial extent of most salt marshes. We recognize that soil type will likely influence bioremediation, and, thus, this factor will be examined in future research. *Spartina alterniflora* is the dominant intertidal salt marsh grass along the Atlantic and Gulf Coasts of the United States

Table 3C.3 Experimental design for Task 1. The three bioremediation treatments (fertilizer, microbial seeding and control) were applied to both oiled and unoiled marsh sods.

	Fertilizer	Microbial Seeding	Control
No Oil	5 replicates	5 replicates	5 replicates
Oil	5 replicates	5 replicates	5 replicates

and thus results from this study will be generally applicable to many other salt marshes.

In the greenhouse, the following treatments were randomly assigned to the collected sods: (1) fertilizer product, (2) seeding product, and (3) control (Table 3C.3). The experimental design was a randomized block with a 3 x 2 factorial treatment arrangement (three bioremediation types [mentioned above] and two oil dosage levels [oiled with 1 l / m^2 (1 mm of oil thickness) and control) (Table 3C.3). Each treatment combination was replicated five times for a total of 30 sods of marsh. Analysis of variance was used to test for statistically significant differences ($P<0.05$) among the treatments.

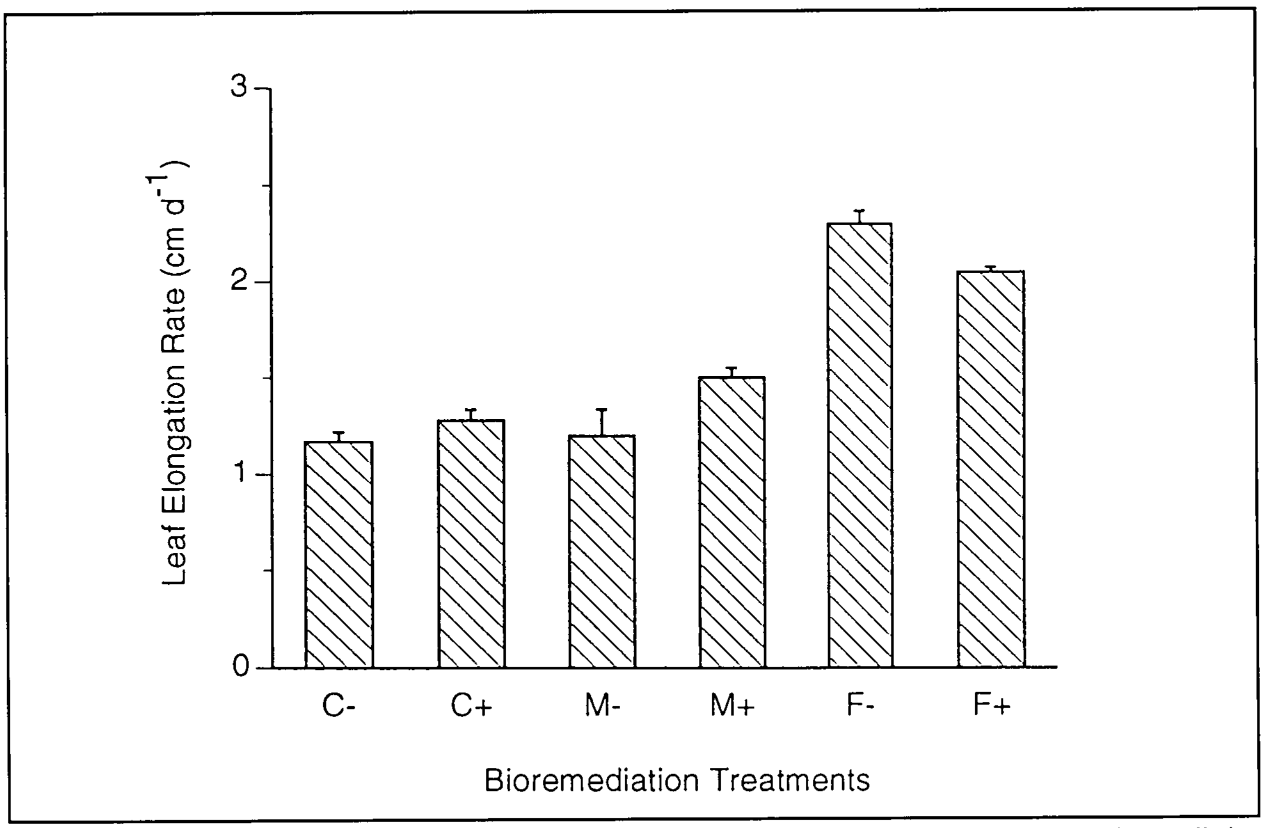

Figure 3C.13. The response of leaf elongation rate to bioremediation and oil treatments (C=no bioremediation product, M=microbial product, F=fertilizer product; +oil, -oil). Means of 5 replicates and standard error bars are presented.

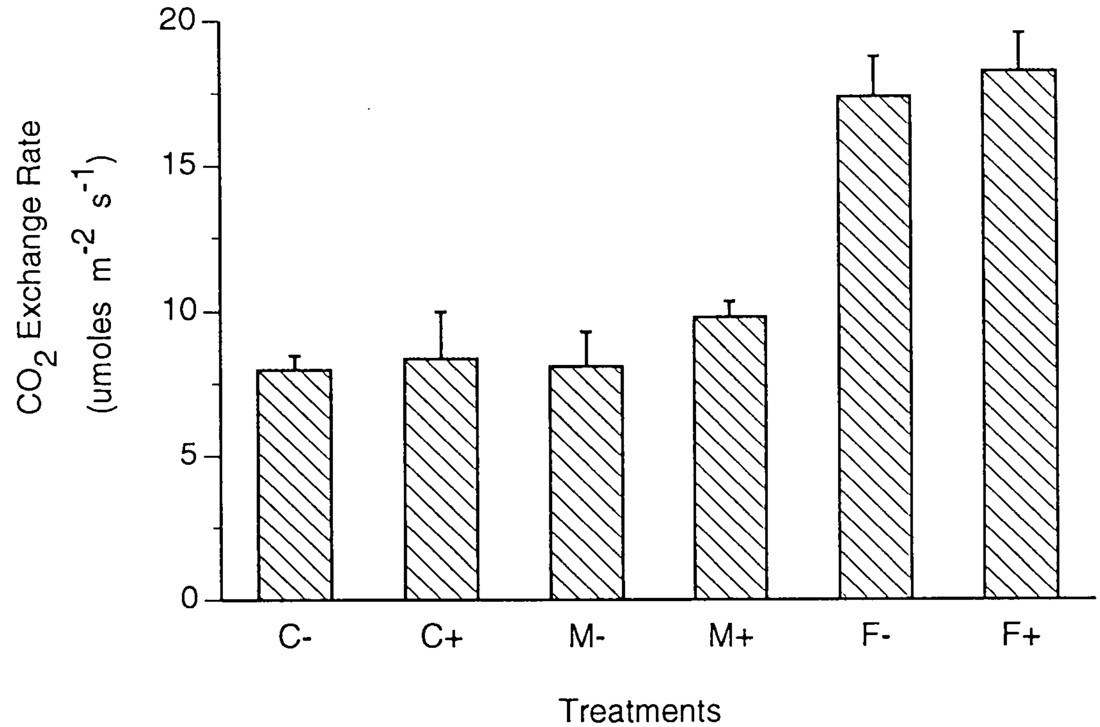

Figure 3C.14. The effect of bioremediation and oil treatments on net leaf CO_2 exchange rate (C=no bioremediation product, M=microbial product, F=fertilizer product; +oil, -oil). Means of 5 replicates and standard error bars are presented.

A reduced crude with nC-13 and below removed in order to simulate oil spilled in open water and subsequently transported into a salt marsh by winds or tides was added to the surface water of the mesocosms. The water was then drained from the bottom of the pots to allow the oil to come in contact with the surface of the sods. The bioremediation products utilized were those proven to be most successful in enhancing oil biodegradation from marsh sediment-microcosm experiments performed by Ms. Sara McMillen of Exxon Production Research, Houston as part of Phase I of this project. This work employed both respirometry and oil chemistry (GC-FID) to identify enhanced oil biodegradation, The results indicated that Customblen, a fertilizer product used during the Valdez Spill and Petrobac, a microbial product, show promise as bioremediation agents. Thus, we used these two products in the present experiment.

The Costomblen used in this study contained 28% N and 8% P as ammonium nitrate, calcium phosphate and ammonium phosphate (Bragg *et al.* 1992). Petrobac contains microbes, without any fertilizer, selected for hydrocarbon degradation in a saline medium (R. Drake, Polybac Corp., personal communication). The products were applied to the soil surface in a manner similar to that during a field application and following the manufacturer's specifications (Customblen: 93 g m^{-2}; Petrobac: 0.833 l m^{-2} of inoculum [46 g of Petrobac l^{-1}of deionized water]). The sod-mesocosms were kept moist, but drained by maintaining an average water level at 5 cm below the soil surface. Water levels were allowed to fluctuate due to evapo-transpiration, but they were reflooded daily with deionized water to 5 cm below the soil surface to maintain relatively constant salinities.

Plant responses were measured during a three-month period (at 0, 1, 2, 4, 8 and 12 weeks after product addition) to determine the effect, if any, of product addition on plant growth and photosynthesis (a highly sensitive indicator of plant response to stress). Soil respiration was determined with an infra-red gas analyzer by measuring carbon dioxide production in a

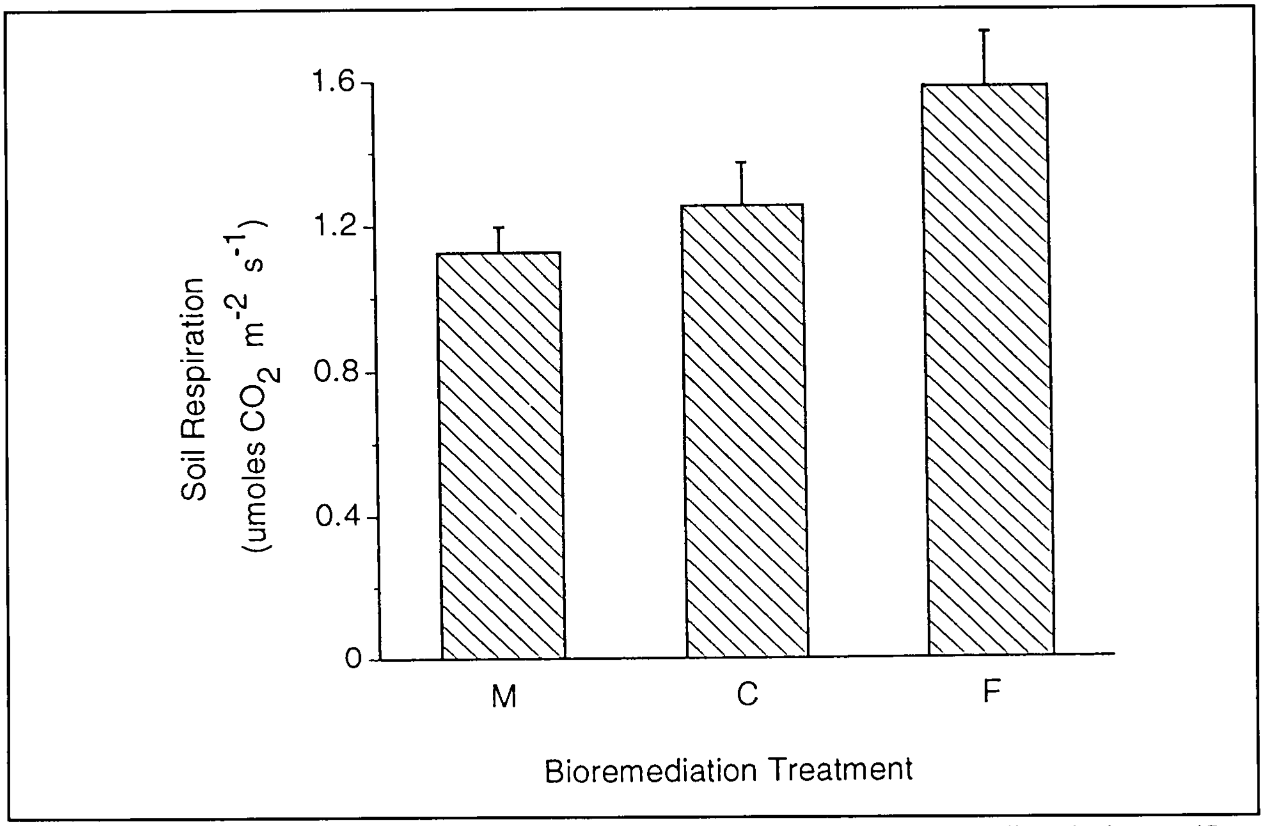

Figure 3C.15. The effect of the bioremediation products, averaged over oil treatments, on soil respiration rate (C=no bioremediation product, M=microbial product, F=fertilizer product). Means of 10 replicates and standard error bars are presented.

flow through respiration chamber placed over the soil surface. Microbial, infaunal, and soil chemical responses were also evaluated and will be presented in future publications.

Results

The effect of the bioremediation products and oil on the growth response of *Spartina alterniflora* was assessed by determining leaf elongation and photosynthetic (leaf CO_2 exchange) rates. Bioremediation had a significant positive effect on both leaf elongation (Figure 3C.13) and photosynthesis (Figure 3C.14). The bioremediation effect was due to the fertilizer product which significantly increased leaf elongation and net CO_2 exchange rates (photosynthesis) above the control, regardless of the presence of oil (Figures 3C.13 and 3C.14). The addition of the microbial product had no significant effect on the plant growth responses (Figures 3C.13 and 3C.14). These results demonstrate that the bioremediation agents tested were not toxic to the vegetation. In fact, the fertilizer product, Customblen, stimulated plant growth, a response that was not unexpected. The addition of a reduced crude oil to the marsh mesocosms had no significant impact on plant response (Figures 3C.13 and 3C.14), and there was no significant interaction between bioremediation products and the oil.

In-situ soil respiration was measured to determine if the bioremediation agents and oil were affecting the metabolism of the soil community. The living soil community is composed of bacteria, fungi, invertebrates and roots of *Spartina alterniflora*. The fertilizer treatment had a significant positive effect on soil respiration compared to both the control and the microbial treatments (Figure 3C.15). The soil respiration of the microbial treatment, however, was not significantly different from that of the control (Figure 3C.15). Oil addition also had a significant effect on soil respiration, with the oiled mesocosms exhibiting significantly higher soil respiration than the unoiled mesocosms (Figure 3C.16). The increase in soil respiration due to the fertilizer and oil treatments could be a response to either increased microbial activity or to greater root density within the soil. Although we presently cannot separate the two, soil cores have been collected from the sods and root density will be evaluated in an attempt to separate these factors.

SUMMARY AND CONCLUSIONS

1. The fertilizer product significantly increased the growth response of *Spartina alterniflora* and the rate of soil respiration, while the microbial product did not significantly affect either of these processes.
2. Oil significantly increased soil respiration, but had no influence on plant growth.
3. The bioremediation products tested did not negatively impact plant growth response; therefore, they appear to have no toxic affect at the application rates used in this investigation.
4. The results of this investigation, in conjunction with our findings from ongoing bioremediation experiments, will help to determine if bioremediation is a suitable oil spill cleanup technique in the wetland environment.

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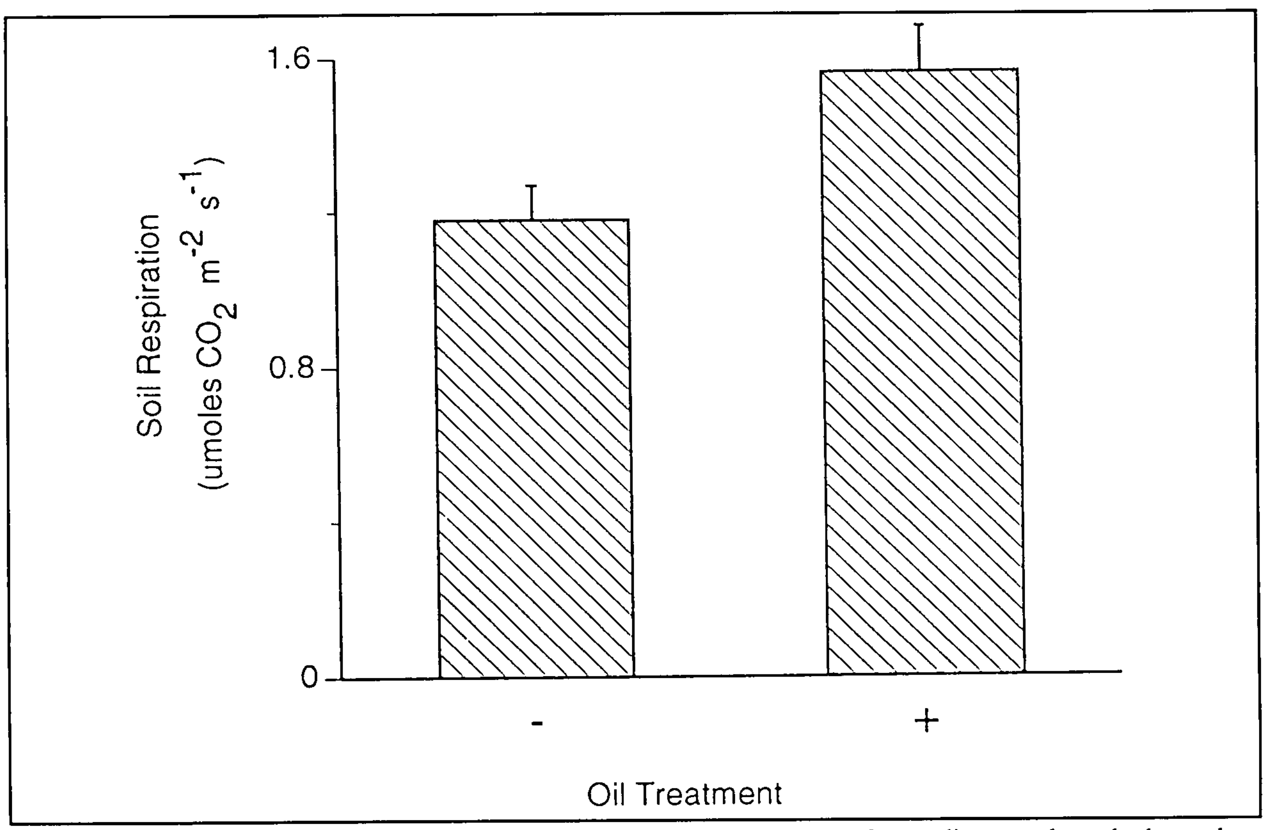

Figure 3C.16. Soil respiration as a function of oil addition (+oil, -oil). Means of 15 replicates and standard error bars are presented.

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RESPONSE OF SEDIMENTARY BACTERIA IN A LOUISIANA SALT MARSH TO CONTAMINATION BY DIESEL FUEL

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INTRODUCTION

It is estimated that 1.7-8.8 x 10^6 tons of petroleum hydrocarbons are released into the marine environment annually; 10% or more of this input may be from refined petroleum such as fuel oils (National Research Council 1985a). Among the various refined petroleum products, diesel fuel is considered to be highly toxic because it is enriched in polycyclic aromatic hydrocarbons (PAH; approximately 30-40%, (National Toxicology Program 1986)), the most toxic component of petroleum hydrocarbons (Kennish 1992; Clark 1989). Because of its toxicity and widespread use in military, commercial, and recreational vessels, diesel fuel represents a potentially significant contaminant to aquatic environments. Most of the PAH released into aquatic environments (approximately 1.7 x 10^5 tons per year) accumulates in estuaries (Kennish 1992). As opposed to lighter fuels such as gasoline, many of the PAH in diesel are of a sufficiently high molecular weight that they do not readily evaporate (Clark 1989), but become associated with fine hydrophobic particles and are ultimately transported to the benthos (Connell & Miller 1984). Salt marshes are low-energy environments where these particles are likely to accumulate (Little 1987). Salt marshes are also highly productive and serve as nursery grounds for many commercially and economically important species. Because of these physical and biological characteristics, salt marshes are considered to be particularly susceptible to chronic and/or catastrophic inputs of petroleum hydrocarbons (National Research Council 1985b, Samiullah 1985) .

This report is part of a study in which microcosm experiments were performed to examine the effects of diesel fuel on the benthic food web of a coastal salt marsh. Future papers will consider the impact of diesel on microalgal activity and abundance, meiofaunal grazing, and meiofaunal community structure. Here, we examine the influence of diesel-contaminated sediments on the benthic bacterial assemblage in terms of abundance, metabolic activity, and capacity to degrade PAH.

METHODS AND RESULTS

The research was performed using sediments from Terrebonne Bay estuary (29^0 15' N; 91° 21'W) near the Louisiana Universities Marine Consortium Laboratory (LUMCON). The study site is located in a region of intense hydrocarbon production and drilling activity, and commercial and recreational boat traffic is high. These combined factors lead to a high probability that the marsh experiences chronic exposure to both refined and crude hydrocarbons.

The effects of diesel fuel on sedimentary bacteria were examined using intact, natural sediment collected in cylindrical microcosms from the study site. Microcosms were maintained in the LUMCON laboratory under controlled temperature and light conditions. Experimental treatments consisted of the daily addition to microcosms of small doses of diesel-contaminated, and bacterial responses were determined over a 28-day period.

Microcosm experiments were performed with a 2 x 4 x 5 factorial design, with two wet tables (as blocks), four exposure times, and five diesel treatments as factors. Each diesel x time combination was replicated twice in both wet tables. Microcosms were constructed of 15.2 cm i.d. PVC pipe with windows covered with Nitex mesh (62 μm) to allow exchange of water. At low tide on 22 May 1994, 80 microcosms of exposed unvegetated sediment were collected by hand from mud flats surrounded by *Spartina alterniflora* marsh. Intact microcosms were removed from the mud flat and transported to the Louisiana Universities Marine Consortium (LUMCON) facility at Cocodrie, Louisiana. Forty microcosms were randomly assigned to both of two wet tables. Microcosms were irrigated individually using a drip system. Ambient marsh water was filtered (5 μm) and pumped into a 1,200 l holding tank. Water was aerated by continuous recirculation. Water was pumped from the holding tank to a 60-l head tank, which fed the drip system.

The treatments consisted of the addition to microcosms of sediment spiked with three levels of diesel (High, Medium, and Low), and two types of controls; in one control (Cont1), no sediment was added to microcosms, in the second control (Cont2) "uncontaminated" sediment was added to microcosms. Four replicate microcosms (two from each wet table) of each of the five treatment levels (20 total microcosms) were harvested at each of four time intervals (0, 7, 14, and 28 days) following a previously determined randomization schedule

Surficial sediments (top 2 cm) were collected from the marsh and processed following the procedure of Chandler (1986). This procedure results in sterile sediment consisting of particles < 62 μm. Diesel fuel was obtained from a commercial vendor. Two liters of processed sediments and 600 ml of diesel were placed in an amber 4-l bottle and tumbled for 10 days. The bottle was then removed from the tumbler and sediment allowed to settle overnight. Diesel was aspirated from the bottle and sediment was washed repeatedly with 15 ppt artificial seawater (ASW). A sediment sample was removed from the batch, and total PAH was determined to be 687 ppm (dry weight). Contaminated sediment was then diluted with ambient sediment (processed as described above) to achieve PAH concentrations of 550, 55, and 5.5 ppm (dry weight). Diluted contaminated sediments were added to microcosms as described below with the objective of achieving final added concentrations in the top 1 cm of sediment of 55 (High), 5.5 (Medium), and 0.55 (Low) ppm.

At the beginning of the experiment, microcosms were dosed by adding sediment sufficient to create a 1-mm-thick layer of sediment on the microcosm's surface. On each subsequent day, microcosms were dosed with 1.8 ml of sediment, sufficient to create a 0.1-mm sediment layer on the surface of microcosms.

Total PAH in sediment used to dose High treatments, as well as sediment in the top 1 cm of Day-0 and Day-28 High and Medium treatments, were determined with an Iatroscan (Ackman *et al.* 1990). On Day 0 and Day 28 all treatments were analyzed for PAH composition by GC/MS (Means & McMillin 1993).

Bacterial abundance in the top 1 cm of sediment was determined from acridine orange direct counts (AODC, Carman 1993). Bacterial activity was measured by administering ^{14}C-acetate into sediment cores (1.7 cm i.d.) and following the label into bacterial membrane lipids (phospholipids) and lipid storage products (poly-ß-hydroxyalkanoates - PHA; (Findlay & White 1987). Bacterial activity on Day 28 was also determined by determining ^{3}H-leucine incorporation into protein.

Table 3C.4. Concentrations of parent and alkylated PAH as determined by GC/MS analysis. "Diesel" represents sediment that was contaminated with diesel and added to microcosms in various dilutions (see text for further details). "Control" represents the average of both types of control microcosms (two samples each from Cont1 and Cont2). "Low," "Medium," and "High" represent the three diesel treatments. Values are ppm (dry weight), and are the average of two replicates. "Nap" = naphthalene; "Phen" = phenanthrene; "DBT" = dibenzothiophene. "%Alkylated" = the proportion of total PAH that contained one or more alkyl side chains.

		Control		Low		Medium		High	
Compound	Diesel	Day-0	Day-28	Day-0	Day-28	Day-0	Day-28	Day-0	Day-28
Nap	2601	3	4	0	2	12	0	2	8
C1-Nap	44054	2	2	0	2	90	0	47	5
C2-Nap	143537	2	1	0	1	395	0	186	8
C3-Nap	141640	7	6	0	10	1412	0	944	132
C4-Nap	84171	7	5	0	8	3717	0	3274	609
Fluorene	6843	0	3	1	0	8	0	2	1
Phen	17321	7	9	19	2	54	18	39	614
C1-Phen	53680	5	8	41	3	209	49	280	581
C2-Phen	56659	5	10	85	3	420	68	1314	1189
C3-Phen	38957	6	13	95	5	346	83	1210	1535
DBT	5169	0	1	0	0	12	0	17	26
C1-DBT	23930	1	52	2	0	105	0	155	210
C2-DBT	52212	6	12	46	6	427	15	1693	1175
Fluoranthene	825	49	25	37	18	87	61	41	46
Pyrene	3839	52	26	93	29	97	97	169	212
Benzanthracene	105	11	98	19	34	37	43	11	34
Chrysene	26	39	32	52	12	55	22	31	15
Benzo(b)fluoranthene	7	41	29	45	44	66	59	25	18
Benzo(k)fluoranthene	2	5	20	30	40	26	39	2	12
Benzo(a)pyrene	5	13	14	21	13	34	37	6	12
Total Parent	48548	228	287	323	210	549	374	349	1000
Total Alkylated	638841	36	67	269	38	7119	214	9101	5442
%Alkylated	92.9	13.5	18.8	45.5	15.3	92.8	36.4	96.3	84.5
Total PAH	687389	264	354	592	248	7668	587	9450	6442

Bacterial metabolism of PAH was examined with a modified version of the procedure described by MacGillivray & Shiaris (MacGillivray & Shiaris 1994), in which degradation [9-^{14}C]phenanthrene was determined.

Concentrations of major PAH classes are summarized in Table 3C.4. The most abundant classes of PAH in diesel-contaminated sediment were naphthalenes, phenanthrenes, and dibenzothiophenes (DBT). Alkylated PAH made up 93% of the total PAH. The high proportions of naphthalenes, phenanthrenes, DBT and alkylated PAH are typical of refined petroleum hydrocarbons. In comparison to diesel-contaminated sediment, ambient sediment was relatively depleted in 2- and 3-ring PAH, and most PAH was in the form of 4- and 5-ring compounds (Figure 3C.17).

Composition of PAH in Day-0 microcosms was variable, but generally reflected that of the added diesel-contaminated sediment (Table 3C.4, Figure 3C.18). In High (Figure 3C.18C) and Medium (Figure 3C.18B)

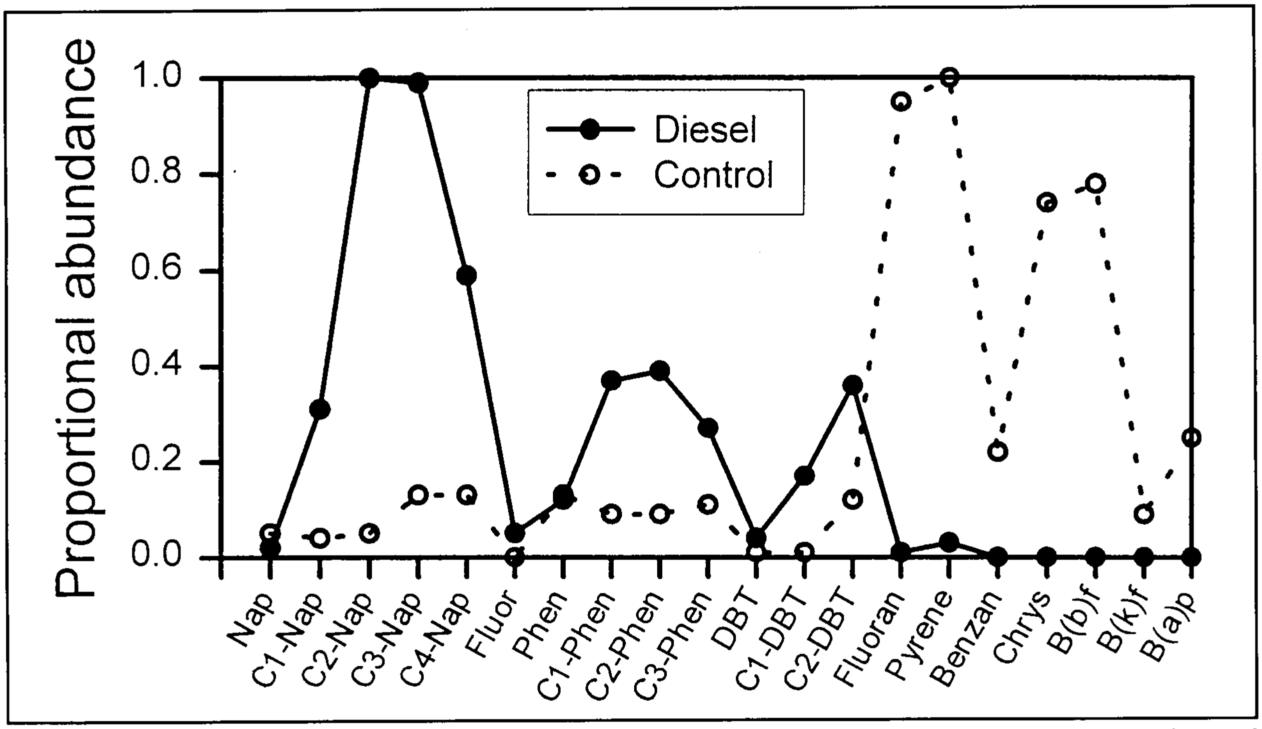

Figure 3C.17. Proportional abundance of major groups of PAH in diesel-contaminated (closed circles) and control (ambient) sediment (open circles). Nap = Naphthalene, Fluor = Fluorene, Phen = Phenanthrene, DBT = Dibenzothiophene, Fluoran = Fluoranthene, Benzan = Benzanthracene, Chrys = Chrysene, B(b)f = Benzo(b)fluoranthene, B(k)f = Benzo(k)fluoranthene, B(a)P = Benzo(a)pyrene. "C1", "C2", "C3", and "C4" represent alkylated homologs of parent compounds containing from 1 to 4 methyl side chains, respectively. Values are averages of two replicates.

treatments, naphthalene and C1-, C2, and C3 naphthalenes were proportionately less abundant than they were in diesel-contaminated sediments (Figure 3C.17). Low treatments (Figure 3C.18A) consisted of only a minor PAH addition to microcosms, and thus the proportional abundances of PAH were similar to those of controls, i.e., very little naphthalene (parent or alkylated) and relatively high abundances of 4- and 5-ring compounds. The relatively high concentration of phenanthrenes and C2-DBT were, however, evidence of the addition of diesel-contaminated sediments.

PAH composition in Day-28 microcosms differed substantially from Day-0 samples, and the degree of change differed among treatments (Figure 3C.18). PAH in Day-28 Medium and Low treatments resembled that of controls, while PAH in High treatments clearly indicated hydrocarbon contamination.

Average total PAH in control microcosms was 0.26 ppm on Day-0, and 0.35 ppm on Day-28. GC/MS measurements of total PAH in Day-0 Low, Medium, and High treatments were 0.59, 7.7, and 9.4 ppm respectively (Table 3C.4).

Iatroscan data indicated that PAH in High treatments accumulated over the first week, and then decreased by approximately one half by Day-14, and again decreased by one half by Day-28 (Figure 3C.19). Total PAH in Medium treatments decreased by a factor of approximately seven by Day-7 and then remained relatively constant thereafter (Figure 3C.19). Thus, the removal rate of PAH in Medium (and Low) treatments was equal to or exceeded the rate of addition. The removal rate of PAH from High treatments, however, was not sufficient to reduce PAH concentrations to background levels.

Bacterial abundance in microcosms ranged from 0.27 to 2.8 x 10^9 cells/gdw throughout the experiment (Figure 3C.20). Bacterial abundance was not significantly affected by diesel-contaminated sediment ($p = 0.178$), and there was no trend that was even suggestive of an effect. Bacterial abundance did vary significantly

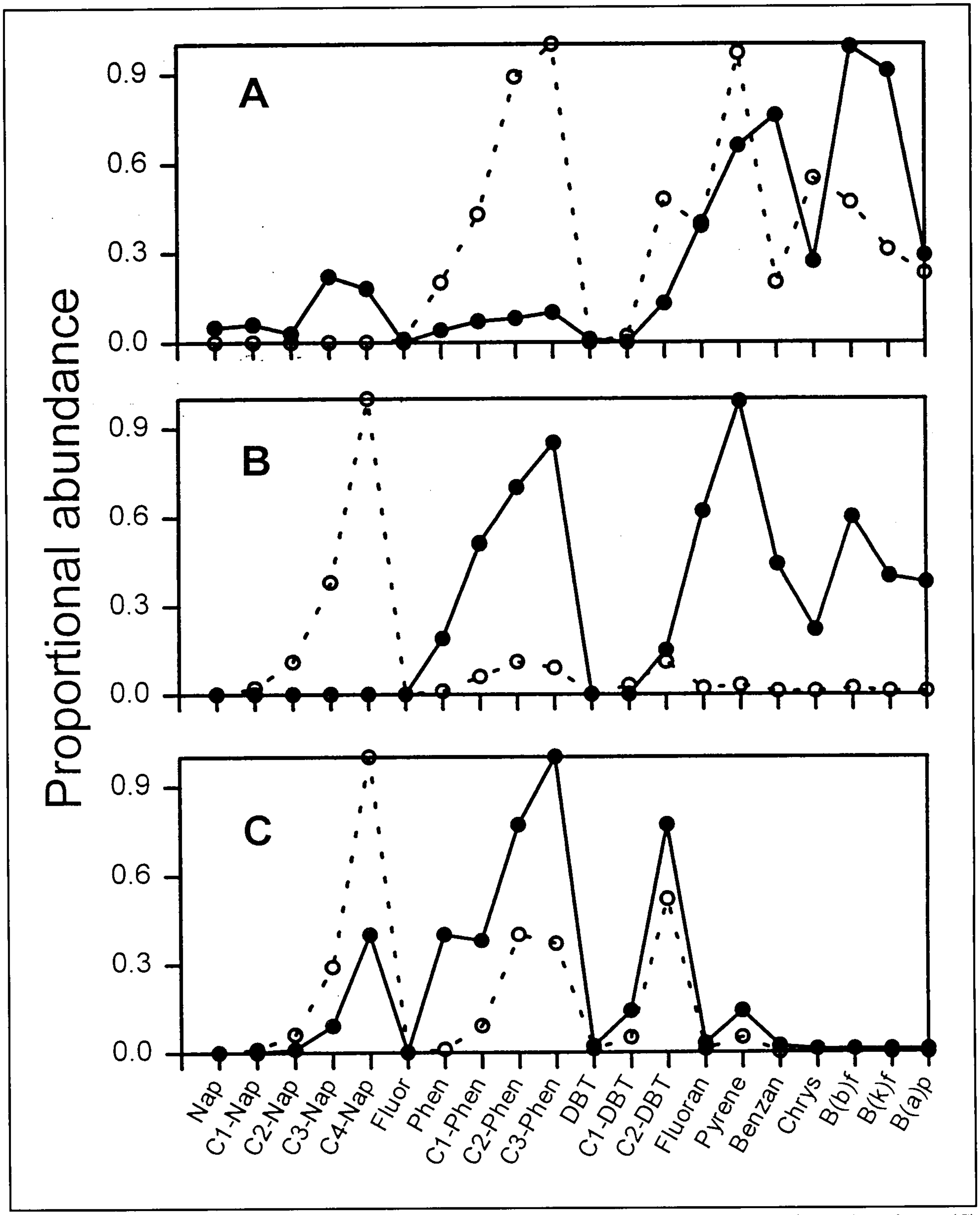

Figure 3C.18. Change in proportional abundance of major groups of PAH in Low (A), Medium (B), and Low (C) treatments over the 28-day study period. Closed circles = Day-28, Open circles = Day-0. Abbreviations as in Figure 3C.17. Values are averages of two replicates.

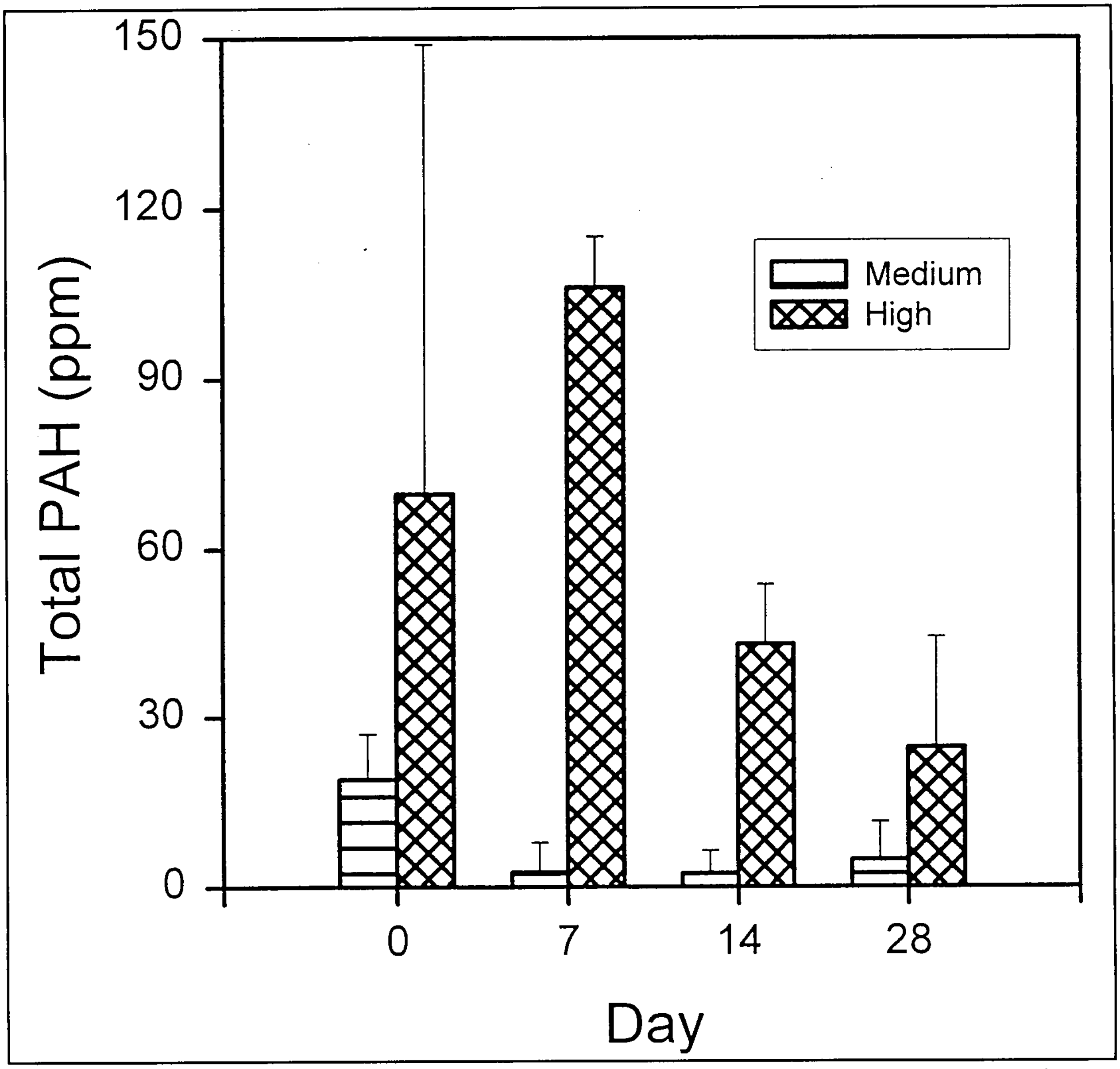

Figure 3C.19. Total PAH concentration in High and Medium treatments as determined by Iatroscan. Values are means ± 1 S.D. (n = 4).

among days ($p < 0.0001$), with greatest numbers being detected on Day 7.

As with bacterial abundance, bacterial activity as determined by ^{14}C-acetate incorporation into phospholipids (Figure 3C.21a), or the phospholipid:PHA (poly-ß-hydroxyalkanoates) ratio of ^{14}C-acetate incorporation (Findlay & White 1987) were not significantly influenced by diesel-contaminated sediment (p = 0.674 and 0.739, respectively; Figure 3C.21b). Similarly, ^{3}H-leucine incorporation into protein (measured on Day-28 only) was remarkably consistent among treatments (Figure 3C.22, p = 0.742).

In contrast to bacterial abundance and assays of bacterial activity, bacterial degradation of ^{14}C-phenanthrene was sensitive to diesel-contaminated sediment (Figure 3C.23). In Day-0 microcosms, degradation of ^{14}C-phenanthrene was low but detectable (0.9 to 1.3% of total available over a 72-h period), and did not differ among treatments. Degradation rates of ^{14}C-phenanthrene remained relatively low in both

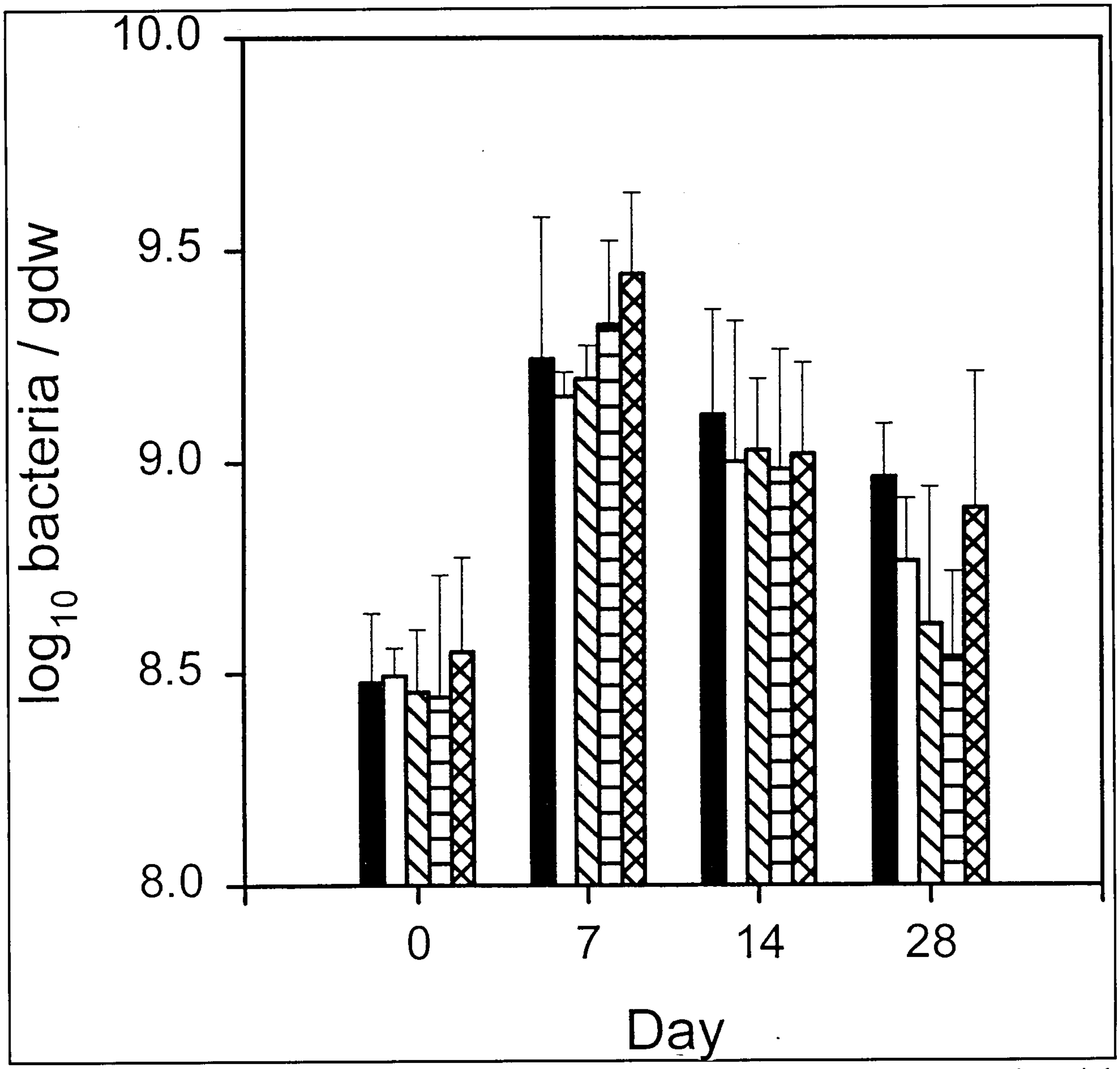

Figure 3C.20. Bacterial abundance in sediments exposed to a range of diesel contamination over a 28-day period. Solid bars = Contl; Open bars = Cont2; Diagonally hatched bars = Low; Horizontally hatched bars = Medium; Cross-hatched bars = High. Values are means $\pm$ 1 S.D. (n = 4).

controls over the entire course of the experiment (range 0.8 to 2.0%). Dose-dependent enhancement of phenanthrene degradation in all diesel treatments (Low, Medium, and High) occurred from Day 7 through Day 28. The enhancement of ^{14}C-phenanthrene degradation was statistically significant in Medium and High treatments when performing ANOVA on the entire data set, and when considering Days 7 through 28 individually ($p < 0.0001$). Degradation of ^{14}C-phenanthrene in Low treatments was significantly higher than in controls only on Day 28. When comparing only Low treatments and controls from Day 7 through Day 28, ^{14}C-phenanthrene degradation was significantly elevated in Low treatments ($p < 0.05$). The latter test is less conservative (and more sensitive) than a complete ANOVA, but serves to confirm what appeared to be enhanced PAH degradation even in Low treatments. After Day 7, the enhancement of ^{14}C-phenanthrene degradation in Low and Medium treatments remained constant or was slightly

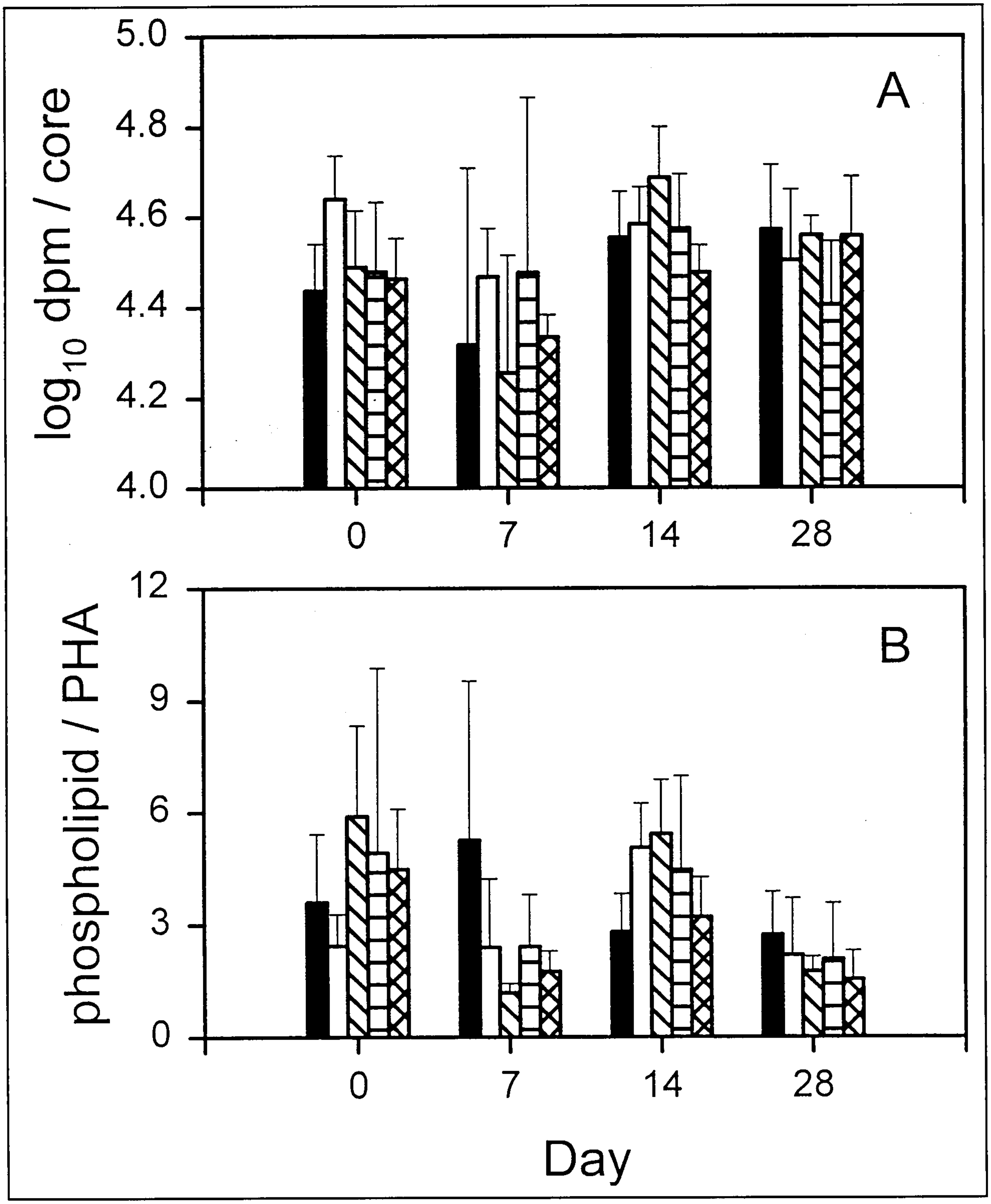

Figure 3C.21. ^{14}C-acetate metabolism in sediments exposed to a range of diesel contamination over a 28-day period. (A) Incorporation of ^{14}C into polar lipids. (B) Phospholipid/PHA ratio of ^{14}C incorporation. Solid bars = Cont1; Open bars = Cont2; Diagonally hatched bars = Low; Horizontally hatched bars = Medium; Cross-hatched bars = High. Values are means $\pm$ 1 S.D. (n = 4).

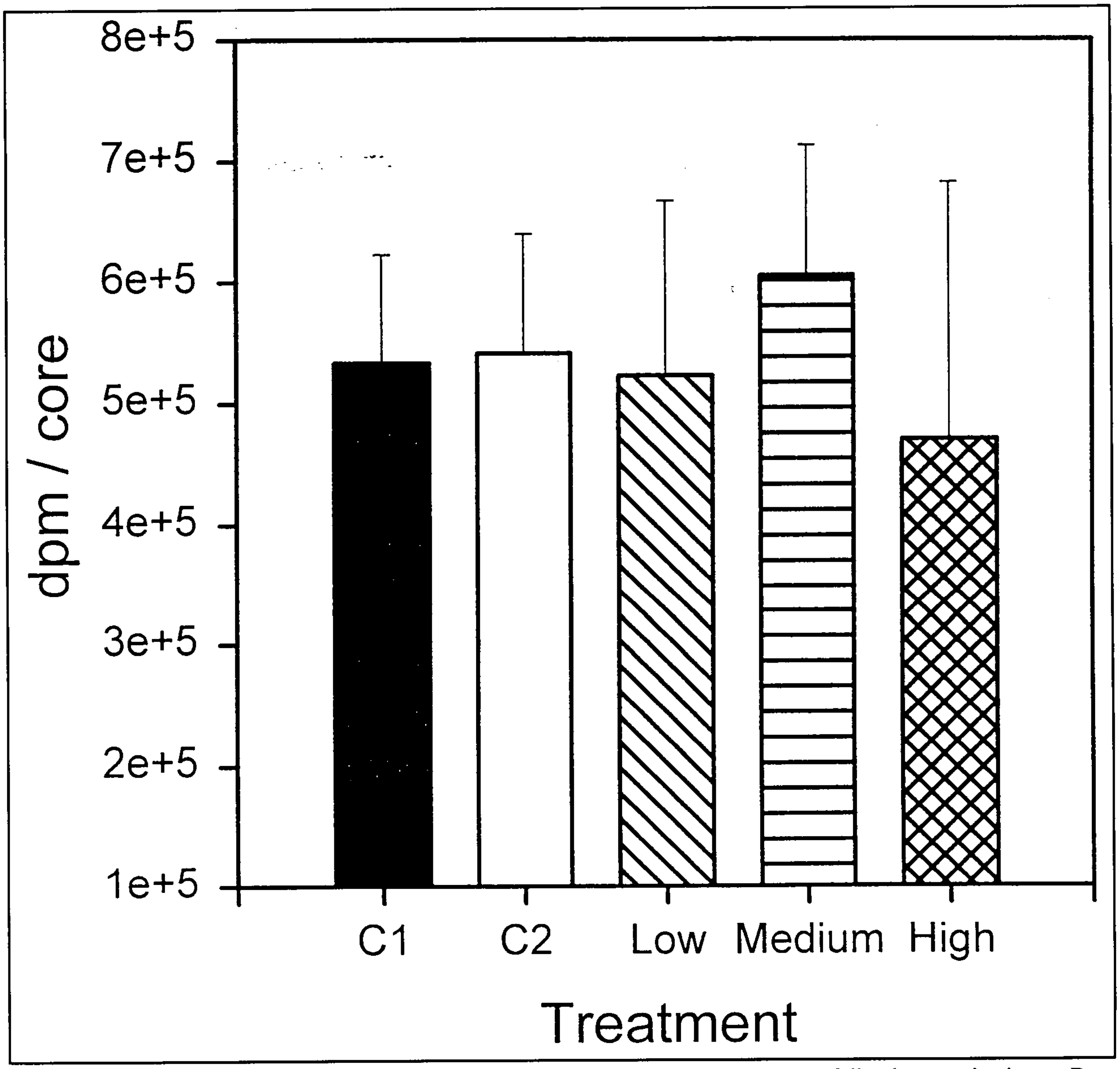

Figure 3C.22. ^{3}H-leucine incorporation into protein in sediments exposed to a range of diesel contamination on Day-28 of experiment. Solid bars = Cont1; Open bars = Cont2; Diagonally hatched bars = Low; Horizontally hatched bars = Medium; Cross-hatched bars = High. Values are means ± 1 S.D. (n = 4).

diminished. ^{14}C-phenanthrene degradation in High treatments continued to increase throughout the experimental period.

DISCUSSION

Our observations on the effects of diesel on Gulf of Mexico sedimentary bacteria appear to be generally consistent with the previous studies of individual PAH or crude oils. Even at the highest doses (ca. 55 ppm PAH), diesel-contaminated sediment had no detectable influence on bacterial incorporation of ^{14}C-acetate or ^{3}H-leucine, or on bacterial abundance. Nor did diesel-contaminated sediments have an influence on the physiological condition of the bacterial community as indicated by the relative incorporation of ^{14}C-acetate into phospholipids.

Failure to detect changes in bacterial abundance or metabolic activity, however, does not mean that the

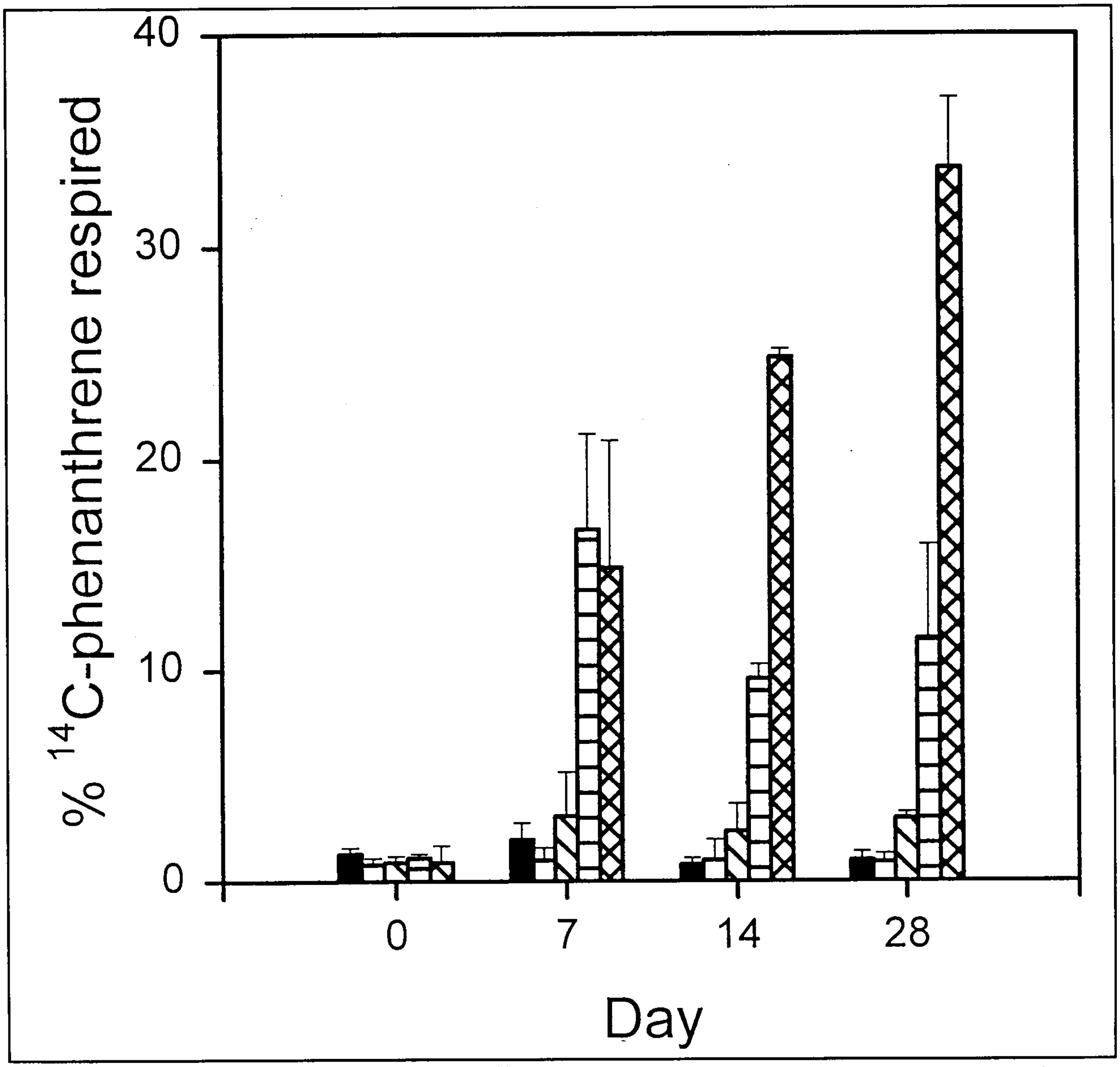

Figure 3C.23. Conversion of ^{14}C-phenanthrene to $^{14}CO_2$ in sediments exposed to a range of diesel contamination over a 28-day period. Sediments were incubated for 72 h at 27 °C. Solid bars = Cont1; Open bars = Cont2; Diagonally hatched bars = Low; Horizontally hatched bars = Medium; Cross-hatched bars = High. Values are means ± 1 S.D. (n = 4).

bacterial community was unaffected by addition of hydrocarbons. Indeed, Baker & Griffiths (1984) proposed that evolved resistance to environmental contaminants may be responsible for variability in responses of sedimentary microorganisms to petroleum hydrocarbons. Further, Griffiths *et al.* (1981) proposed that insensitivity of Gulf of Mexico bacteria to petroleum hydrocarbons is the result of adaptation to chronic exposure from years of oil-production activities.

Although ^{14}C-phenanthrene degradation rates were relatively low at Day 0, degradation was nevertheless detectable (0.30 to 0.43% day^{-1}). Thus, it would appear that ambient bacteria in this Louisiana salt marsh exhibit some significant level of preadaptation to PAH. Nevertheless, even modest (0.55 ppm) additions of diesel elicited significant elevations of phenanthrene degradation. In the Low and Medium treatments, the rate of ^{14}C-phenanthrene degradation peaked by one week, and remained constant thereafter. ^{14}C-phenanthrene degradation in High treatments, however, continued to increase throughout the experiment, and reached a rate of 11.2% day^{-1} by Day-28. The continued acceleration of phenanthrene degradation in High treatments apparently occurred because the supply of hydrocarbons outpaced the rate at which they were metabolized.

We also observed that alkylated PAH, which are generally diagnostic of petroleum hydrocarbons, were readily removed from sediments. In Low and Medium treatments, parent and alkylated naphthalenes, phenanthrenes, and DBT were removed completely or almost completely over the 28-day study period. The rate of decrease in parent phenanthrene and DBT in Low and Medium treatments was lower than the rates of decrease in alkylated forms. This implies that the removal of PAH was not simply a desorption phenomenon; if such were the case, higher molecular weight (alkylated) compounds would have been removed more slowly. Thus, microbial degradation must have contributed significantly to the removal of two- and three-ring parent and alkylated PAH, and alkylated PAH showed no evidence of being disproportionately resistant to microbial degradation.

Previous studies have suggested that DBT may provide a reliable marker for petroleum-hydrocarbon contamination because they are found in all types of petroleum (Seinhauer *et al.* 1994, Clark 1989), including diesel (Williams *et al.* 1986), and they are considered to be resistant to photochemical (Andersson 1993) and microbial (Sinkkonen 1989) degradation. In the present study, however, DBT were at least as susceptible to microbial degradation as were phenanthrenes. Fayad & Overton (1995) also observed high rates of DBT degradation in sediments contaminated during the 1991 Gulf War. Thus, our data indicate that DBT were metabolized by sedimentary bacteria at a high rate, and that DBT would not accumulate in these sediments unless very high rates of input were maintained.

Collectively, our data indicate that the Louisiana salt marsh bacterial community studied here is symptomatic of one that has been chronically exposed to petroleum hydrocarbons: bacterial abundance and general assays of bacterial metabolism are insensitive to additions of diesel, ambient bacteria can metabolize PAH at substantial rates, and the PAH-degrading portion of the community responds quickly to additions of petroleum hydrocarbons. It is possible that the PAH-degrading bacterial community maintains ambient sedimentary PAH concentrations at relatively low levels. In Low and Medium treatments, no significant accumulation of PAH could be detected over the 28-day period relative to ambient sediment. Further, PAH concentration in High treatments were reduced by approximately 43% over the 28-day experiment, despite the daily addition of diesel-contaminated sediment.

These observations of the bacterial response to diesel contamination have implications for understanding how ecosystems respond to contamination by crude or refined petroleum hydrocarbons. One possibility is that rapid bacterial metabolism of petroleum hydrocarbons could ultimately reduce exposure of other benthic organisms to potentially toxic compounds. We have observed that the meiofaunal/microbial foodweb in this salt marsh is relatively resistant to petroleum-hydrocarbon contamination from produced water (Carman *et al.* 1995), or diesel (Carman, unpublished). Further study will be required to determine if the apparent insensitivity of this benthic food web is because the fauna themselves are resistant to hydrocarbons, or if they rely on bacterial detoxification of petroleum contaminants.

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Dr. Kevin Carman is an associate professor in the Department of Zoology and Physiology at LSU. Dr. Carman began postdoctoral research at LSU in 1989 upon completion of his Ph.D. in biological oceanography at Florida State University. His undergraduate education was at McPherson College. Dr. Carman's research is characterized by innovative investigation of maine meiofaunal ecology. MMS and ONR supported work addresses the effects of polynuclear aromatic hydrocarbons on an estuarine sediment foodweb. His other interest include meiofaunal feeding and the epibiology of meiofauna. Both areas focus upon metazoa-bacteria-environment interactions.

Dr. Steven Pomarico is a post doctoral student working in close conjunction with Dr. Kevin Carman in LSU's

Department of Zoology and Physiology. Dr. Pomarico received his Ph.D. in Biochemistry from LSU in 1990. Drawing upon his molecular background, in Dr. Carman's lab he is looking at hydrocarbon effects upon metazoan fauna.

Dr. Jay C. Means, Professor of Environmental Chemistry and Aquatic Toxicology at LSU School of Veterinary Medicine, is recognized nationally for his work on the fate and transport of hydrocarbons and other hydrophobic contaminants such as ploychlorinated biphenols and chlorinated hydrocarbons in aquatic environments, including estuarine and coastal marine systems. His laboratory group pioneered the research on the predictive modeling of sorption/desorption processes on sediments and also on estuarine colloids.

SESSION 3D

LATEX PHYSICAL OCEANOGRAPHY PRELIMINARY RESULTS, PART I

Session: 3D - LATEX PHYSICAL OCEANOGRAPHY PRELIMINARY RESULTS, PART I

Co-Chairs: Dr. Alexis Lugo-Fernández and Dr. Worth D. Nowlin

Date: December 13, 1995

Presentation	Author/Affiliation
Latex Physical Oceanography Preliminary Results, Part I	Dr. Alexis Lugo-Fernández Environmental Studies Section Minerals Management Service Gulf of Mexico OCS Region
Circulation of the Louisiana-Texas Coastal Current in Spring (1992) and Summer (1993) from ADCP and Hydrography Results	Dr. S. Murray Dr. N. Pettigrew Coastal Studies Institute Louisiana State University Dr. C. Ebbesmeyer EVANS, Hamilton, Inc.
General Shelf-Wide Circulation over the LATEX Region	Dr. Worth D. Nowlin, Jr. Dr. Robert O. Reid Mr. Yongxiang Li Ms. Wensu Wang Department of Oceanography Texas A&M University
Secondary Eddies on the Latex Slope from Drifter and Hydrographic Data	Dr. Peter Hamilton Science Applications International Corporation Dr. D. C. Briggs Department of Oceanography Texas A&M University Dr. G. S. Fargion Department of Marine Biology Texas A&M University, Galveston
Summer Upwelling and Related Currents off South Texas	Dr. Matthew K. Howard Department of Oceanography Texas A&M University
Observations of Circulation in the Near-Field Plume of the Mississippi River and Adjacent Louisiana Bight	Dr. Lawrence J. Rouse Coastal Studies Institute Louisiana State University
Circulation Associated with LATEX Fronts and Squirts	Dr. Nan D. Walker Coastal Studies Institute Louisiana State University

LATEX PHYSICAL OCEANOGRAPHY PRELIMINARY RESULTS, PART I

Dr. Alexis Lugo-Fernández
Environmental Studies Section
Minerals Management Service
Gulf of Mexico OCS Region

All components of the Louisiana-Texas Shelf (LATEX) program are at present concentrated in data reduction and analyses. Many previous ideas are being corroborated and new insights into the dynamics and oceanographic processes operating in the shelf are emerging. This session, Part I of Preliminary Results of LATEX, focuses on the general shelf circulation and physical processes. The program has been able to document the importance of the wind field, Mississippi River outflow, and the effects of offshore Loop Current Eddies. The mean circulation paradigm of Cochrane-Kelly has been confirmed. The mean circulation is primarily driven by winds and buoyancy up to mid-shelf. Surprisingly, the outer shelf circulation is driven mainly by offshore eddies. Oceanographic phenomena such as nearshore upwelling and circulation in the Louisiana Bight are discussed with new insights reveal by this program. Also, a poster presentation summarizes findings and results of Loop Current eddies made during the 1991-95 period.

Dr. Alexis Lugo-Fernández has been an oceanographer with the Minerals Management Service, Gulf of Mexico OCS Region since 1989. At the MMS, Dr. Lugo-Fernández's experience includes preparation of NEPA Documents and management of physical oceanographic studies in the Environmental Studies Section. His primary interests are physical processes on coral reefs and circulation in the shelf. Dr. Lugo-Fernández obtained his B.S. in physics and M.S. in marine sciences from the University of Puerto Rico, and Ph.D. in marine sciences (physical oceanography) from Louisiana State University.

CIRCULATION OF THE LOUISIANA-TEXAS COASTAL CURRENT IN SPRING (1992) AND SUMMER (1993) FROM ADCP AND HYDROGRAPHY RESULTS

Dr. S. Murray
Dr. N. Pettigrew
Coastal Studies Institute
Louisiana State University

Dr. C. Ebbesmeyer
EVANS, Hamilton, Inc.

This note describes the results of two cruises from the LATEX B program, which has the overall objective to determine fundamental aspects of the velocity and thermohaline structure of the coastal plume arising from the fresh water discharge of the Atchafalaya-Mississippi River complex. Additional elements of LATEX B focus on sediment flux and the pollutant chemistry, satellite remote sensing, and biological characteristics of the plume. There were five cruises of 10-day duration in the coastal plume (April 1992, October 1992, April 1993, July 1993 and July-August 1995) and one cruise (April 1994) focused entirely on the near-field plume of the Mississippi River. Cruises were run in different seasons to evaluate differences in the dynamic and thermohaline regimes of the coastal plume under seasonally varying buoyancy and wind forcing. Discharge data (Figure 3D.1) indicates that Cruise I occurred during anomalously low spring flow conditions in April 1992, and Cruise IV occurred during anomalously high summer flow conditions of July 1993.

CRUISE I

Winds during Cruise I were typical of late winter-early spring. Three C-MAN stations (Figure 3D.2) indicate that there were five distinct alternating phases of northerly and southerly flow associated with the migration of high and low pressure systems and the abrupt wind shifts associated with frontal passages. The near surface salinity distribution (Figure 3D.3) clearly shows a westward drift of the fresh water from the Atchafalaya and Mississippi River mouths in accord with both the geostrophic adjustment of the elevated surface through to freshwater input and the easterly wind components. Figure 3D.4 illustrates the westward currents south of Sabine Pass as a result of the frontal

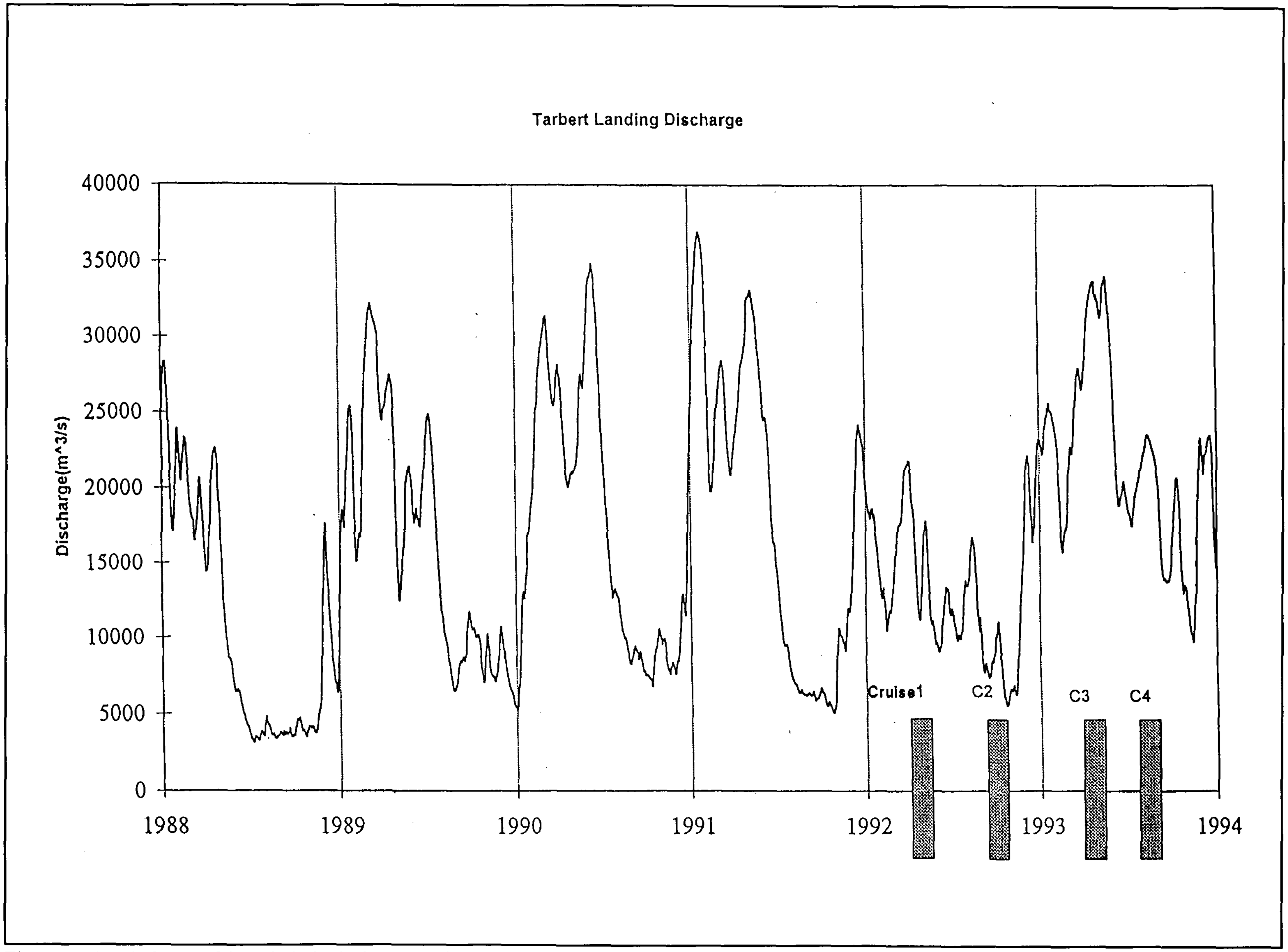

Figure 3D.1. Discharge of the Mississippi River at Tarbert Landing, 1988-1993, highlighting occurrence of the first four LATEX B cruises.

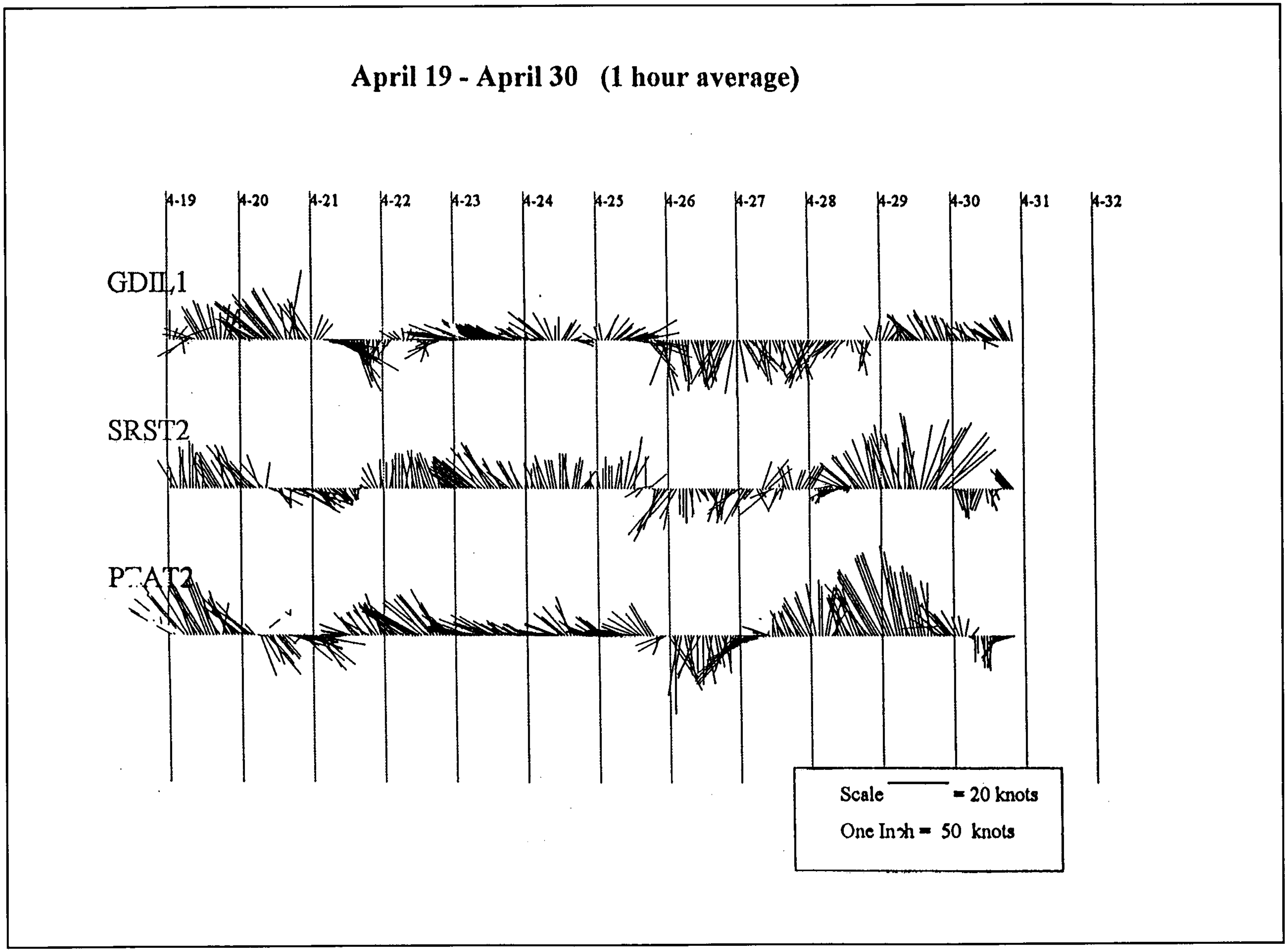

Figure 3D.2. Time series of three coastal wind stations (C-MAN).

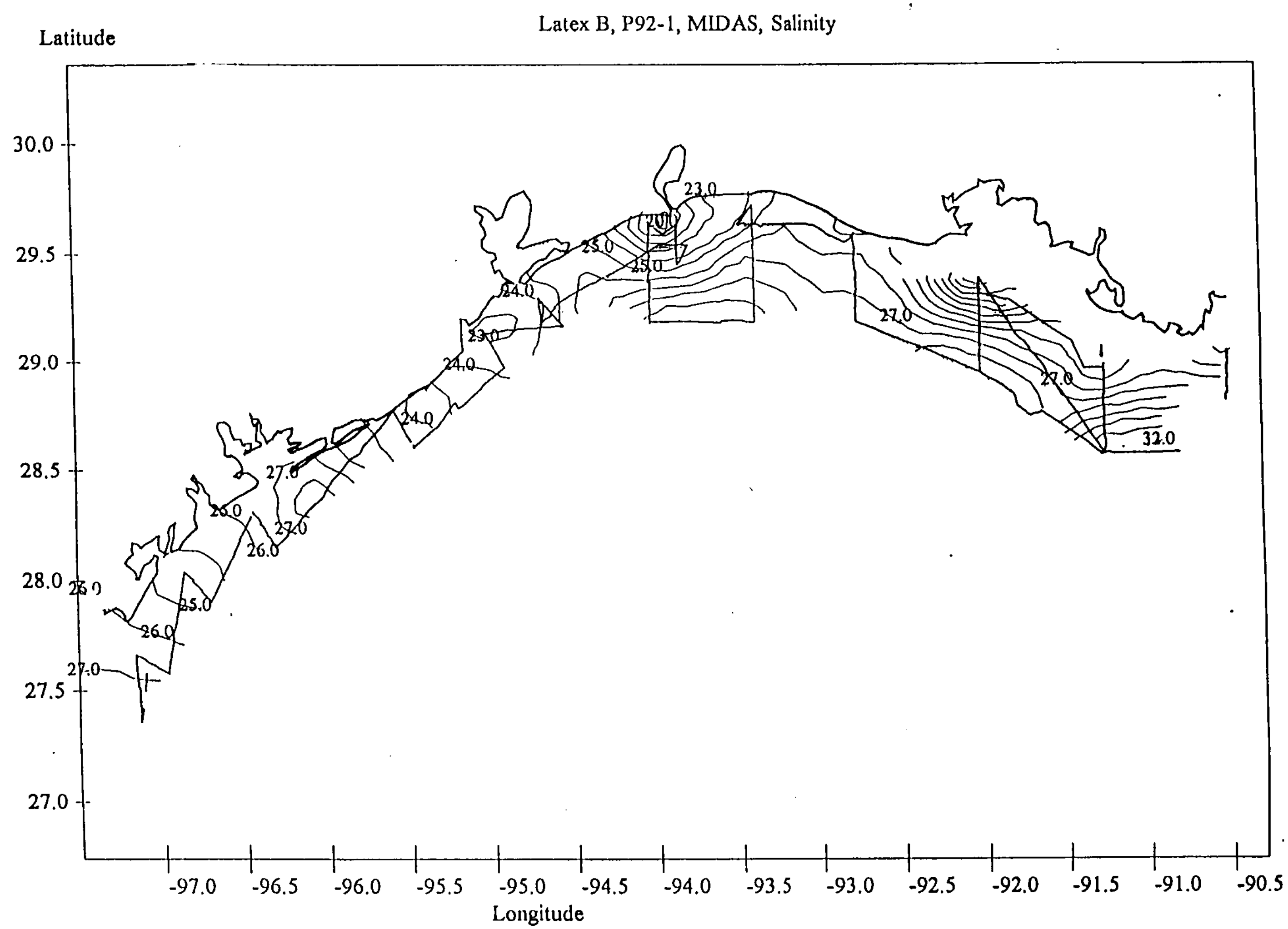

Figure 3D.3. MIDAS surface salinity (psu).

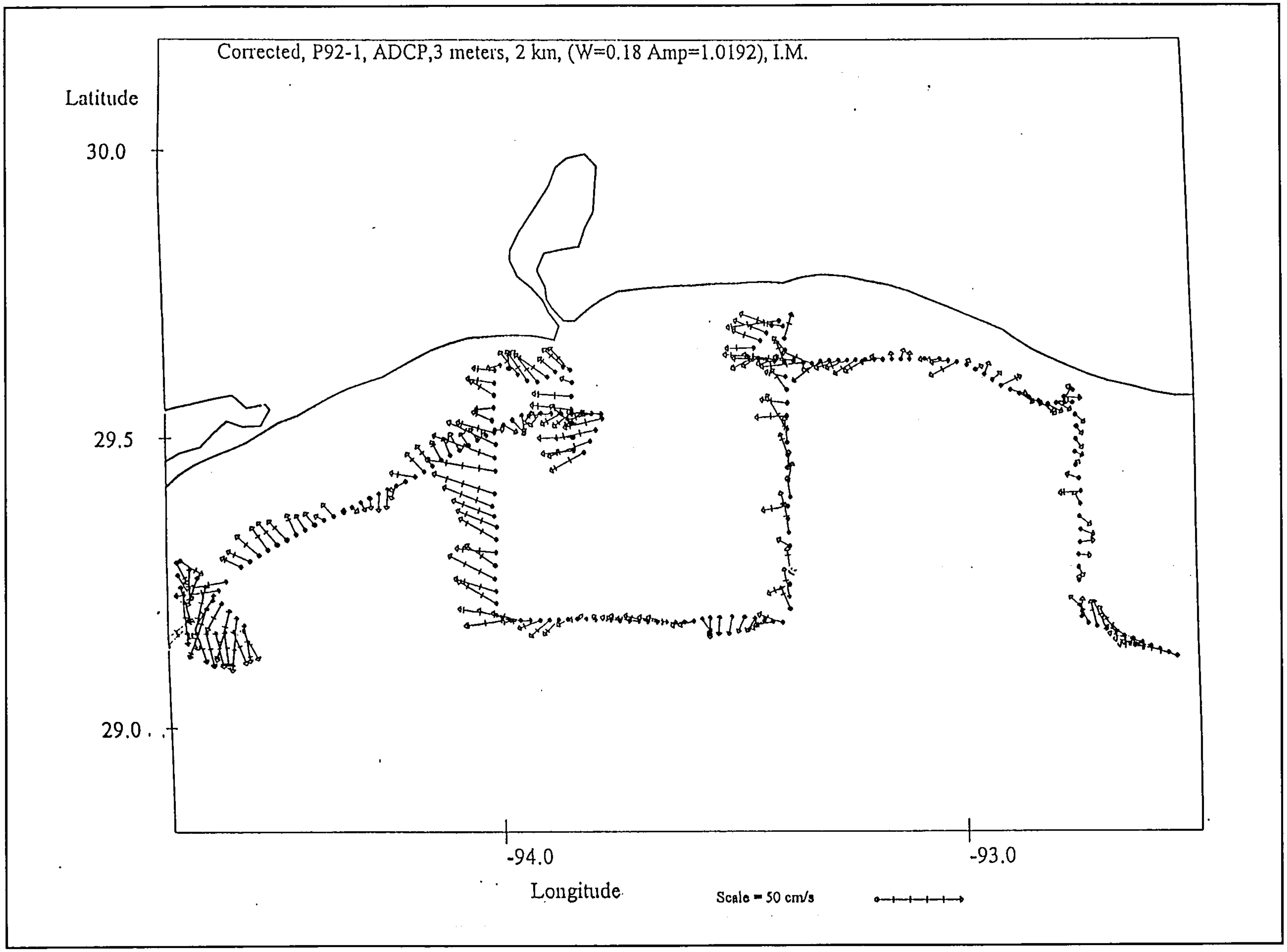

Figure 3D.4. ADCP, 3-meter level, Sector 2.

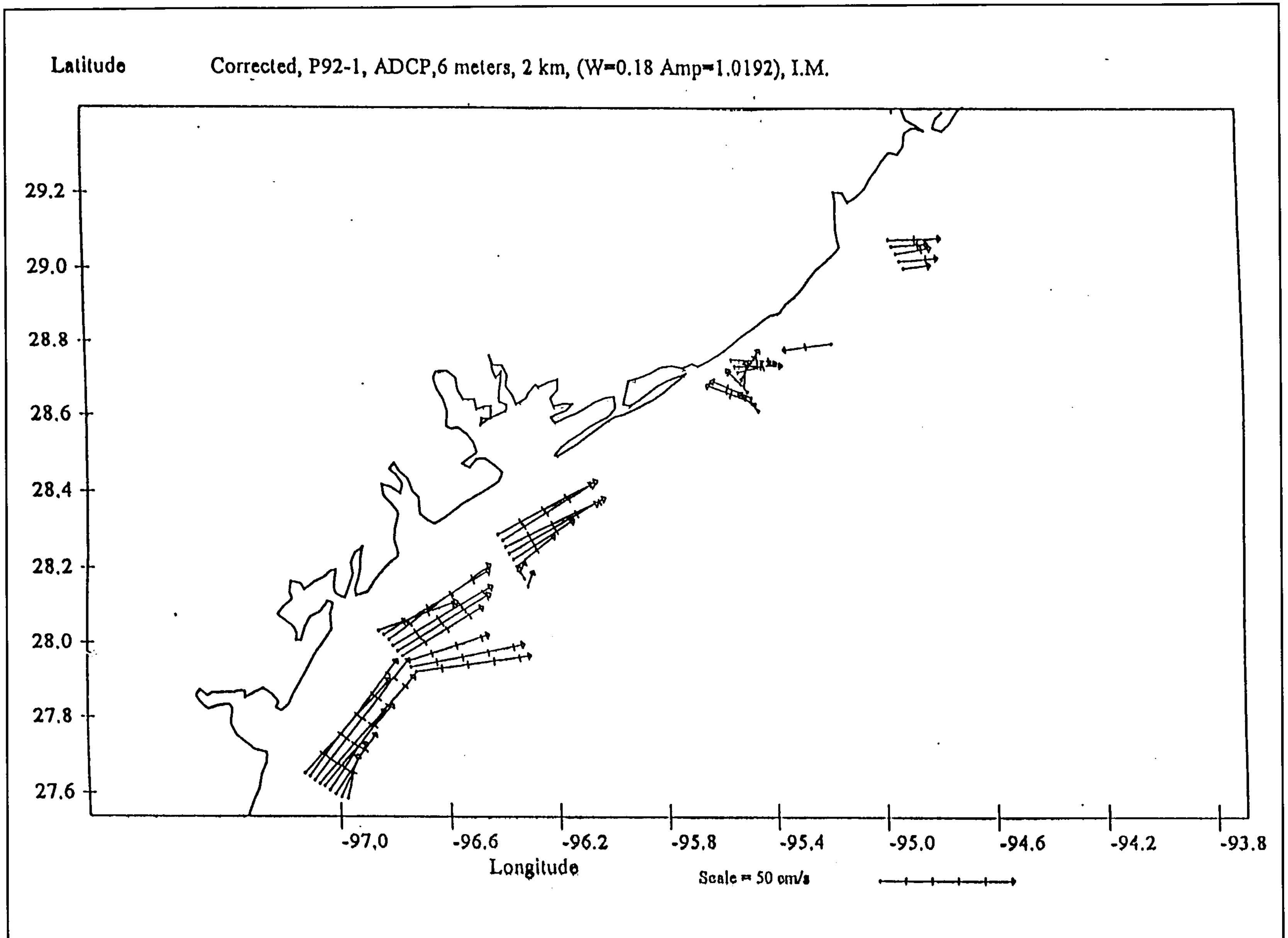

Figure 3D.5. ADCP, 6-meter level, Sector 3.

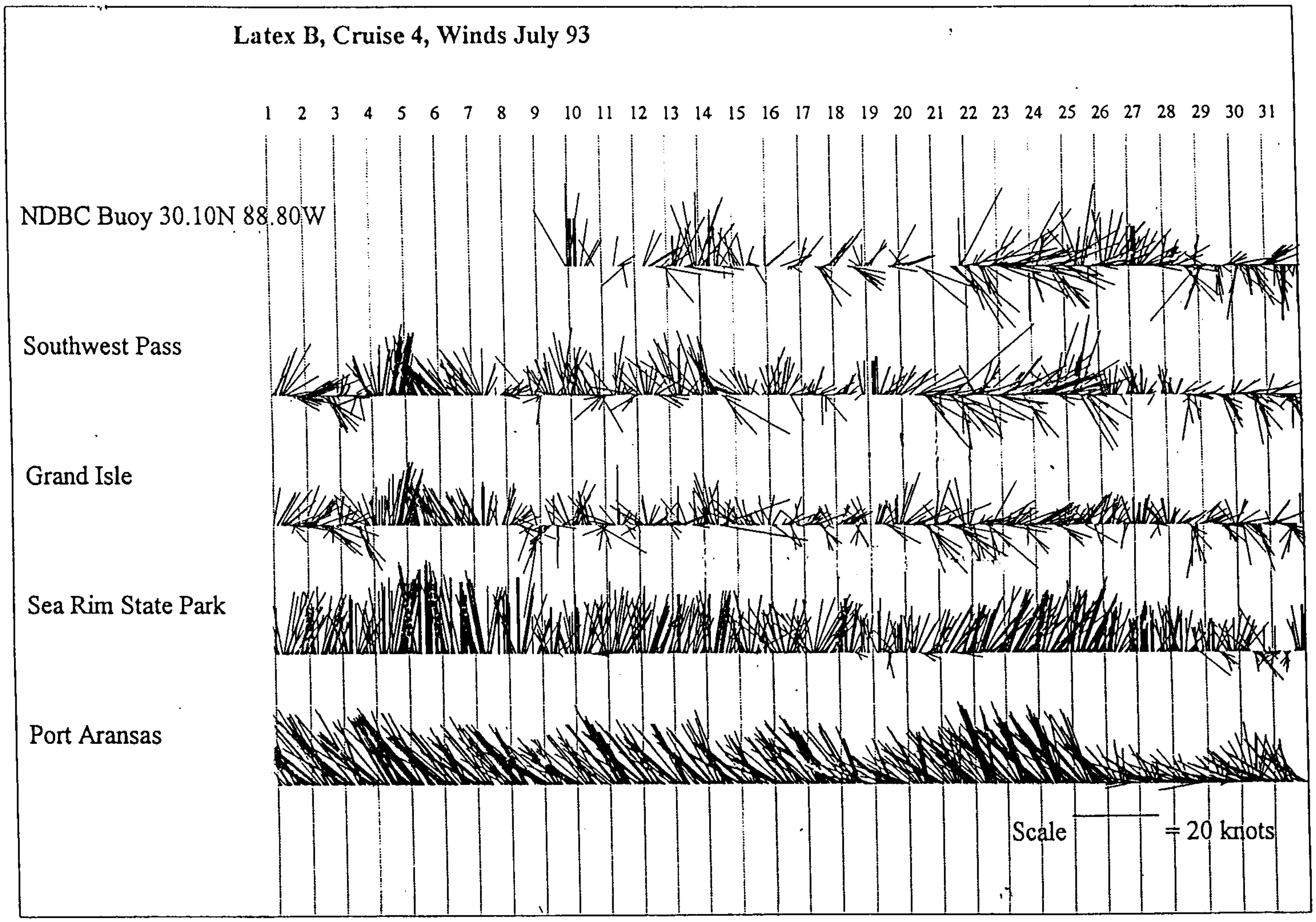

Figure 3D.6. Wind vectors from four C-MAN stations and the NDCB buoy just east of the Mississippi delta, July 1993.

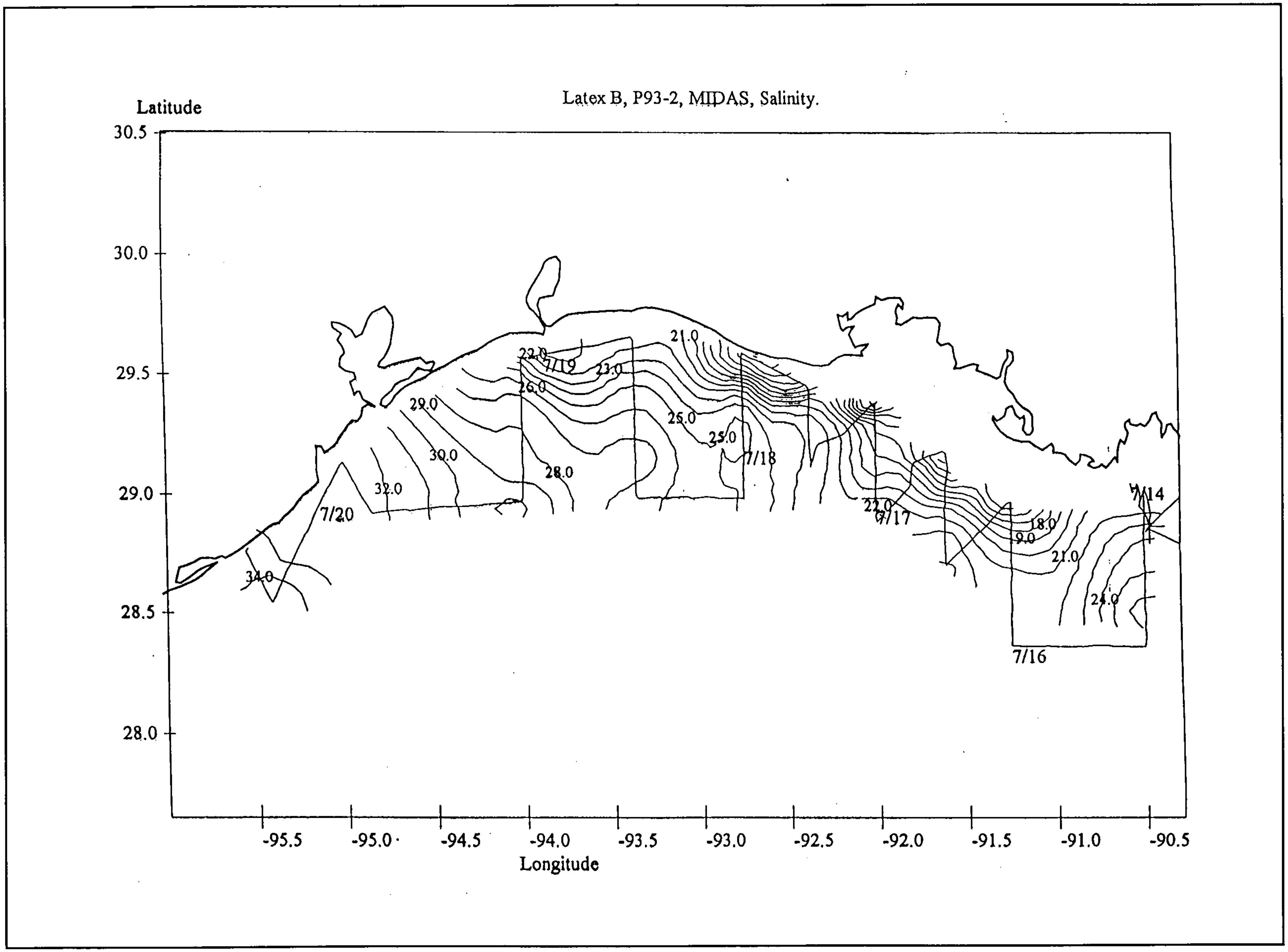

Figure 3D.7. Near-surface salinity along the track of Cruise IV.

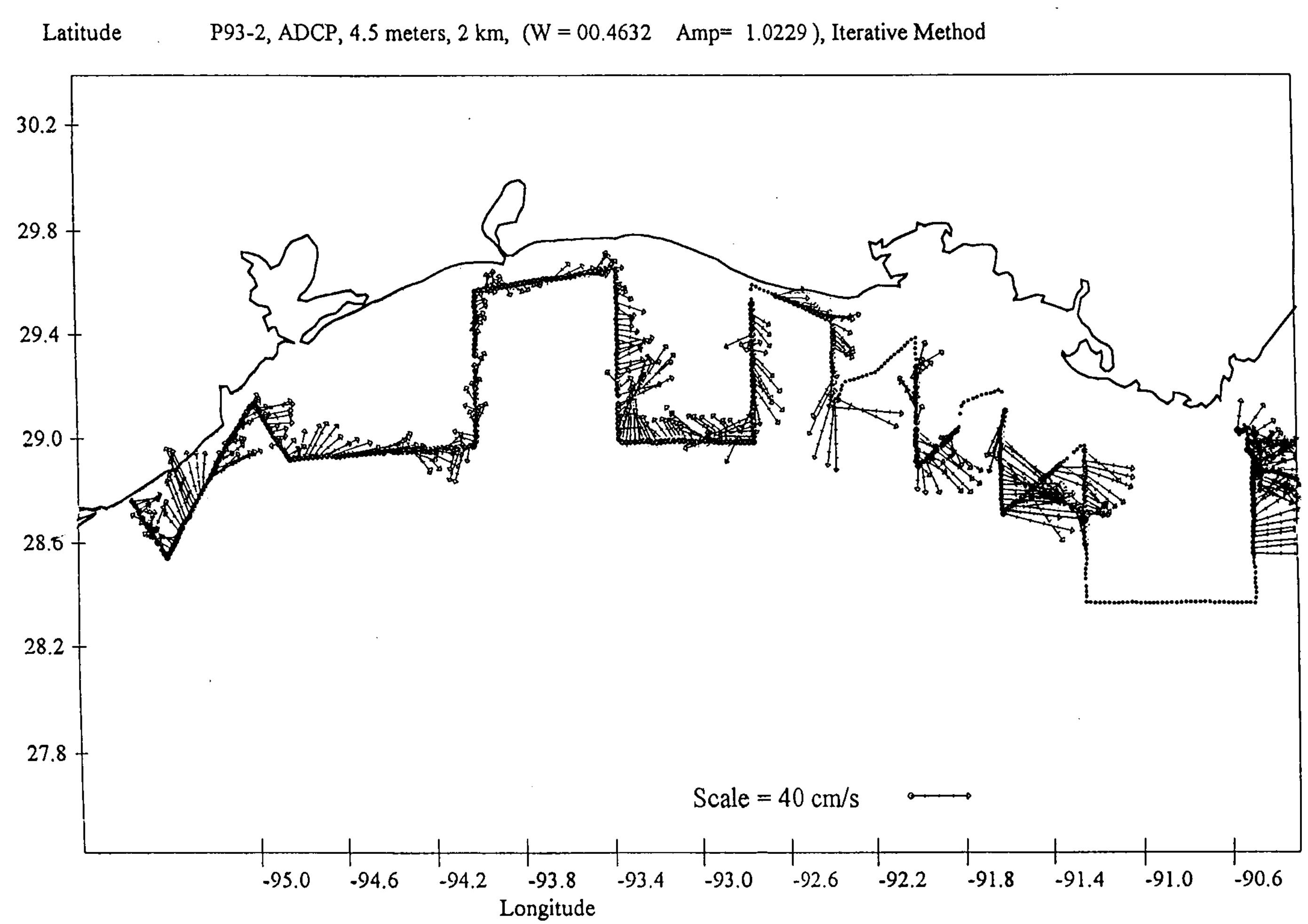

Figure 3D.8. Current vectors along the Cruise IV track at the bin centered at 4.5 m depth (2-m bins).

passage and northerly winds of 26 April. A strong upcoast return flow was measured off south Texas (Figure 3D.5), resulting from the sustained strong southeasterly winds along the entire Texas coast (c.f. Figure 3D.3).

CRUISE IV

Prior to Cruise IV, the Mississippi Atchafalaya discharge was much higher than during Cruise I, but summer wind conditions prevailed. Figure 3D.6 shows weak variable wind off east-central Louisiana with frequent westerly components. Winds at the Texas-Louisiana border (Sea Rim) were strong from the south and south-southwest. Very strong winds in south Texas-Port Aransas then are capable of driving the coastal water upcoast to the north and east. The salinity distribution (Figure 3D.7) agrees with the expectation clearly showing higher salinity south Texas water flowing northeast upcoast toward Louisiana where it converges and collides with the low salinity Atchafalaya outflow. The near surface ADCP maps (Figure 3D.8), though showing shorter wave length features than the hydrography, clearly show the strong eastward summer regime flow.

CONCLUSIONS

In the spring-winter regime, the Mississippi Atchafalaya rivers establish a downcoast coastal plume as we would expect from the geostrophic adjustment. The cross-shore length scale of the coastal plume is 50-80 km. Frontal passages interrupt the coastal plume and turn off the downcoast transport but only temporarily (12-18 hours). The downcoast baroclinic coastal jets we observed off Louisiana are associated with the coastal hydrographic structure. We have also observed upcoast wind-driven jets off the Texas coast in the upper layer. The convergence zone of longstanding folklore (and Cochrane and Kelly 1986) is present but on an intermittent basis.

In early June 1993, an array of near surface drifters showed a zone of strong cross-shore (on-shore) motion at about 93° W and approximately 100 km wide. The last gasp of the winter regime, the easterly winds drove the drifters westward. During our observation period, Tropical Storm Arlene drove the coastal current strongly downcoast to Mexico in three days (1-2 knots). When the summer regime set in, the drifters moved slowly upcoast after June 26 (.50-.75 knots). Cruise IV ADCP/CTD showed eastward summer regime current with a salinity front southwest of Sabine Pass. Again, the ADCO showed strong cross-shore (off-shore) flow southeast of Galveston. Even summer fluctuations in wind cause significant perturbations in the coastal current, i.e., the Atchafalaya plume jet.

Dr. Stephen P. Murray has 25 years of research experience in coastal and shelf waters. He is past director of the Coastal Studies Institute at Louisiana State University, where he is presently employed working on research projects on the physical oceanography of shelf, sea straits, and coastal waters. Dr. Murray received his Ph.D. in dynamical oceanography from the Department of Geophysical Sciences, University of Chicago in 1966.

GENERAL SHELF-WIDE CIRCULATION OVER THE LATEX REGION

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Dr. Robert O. Reid
Mr. Yongxiang Li
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INTRODUCTION

The principal external forcing mechanisms for the general circulation over the Texas-Louisiana continental shelf are assumed to be wind stress, buoyancy effects due to river discharge, and effects of the offshore circulation, i.e., the anticyclonic and cyclonic current rings found over the continental slope. Cochrane and Kelly (1986) suggested an annual cycle for the shelf-wide circulation. Cochrane and Kelly (hereinafter referred to as CK) attributed the circulation over the inner and mid shelf principally to the effects of wind stress. When the wind has an alongshore component directed downcoast (from the Mississippi toward Brownsville), the nearshore flow was likewise directed, and the flow is upcoast in response to wind with an upcoast component.

In Figure 3D.9 we show the daily alongshore component of 10-m wind from Victoria, Texas. This was produced by averaging the 30-year record of winds at that location. It is seen that the alongshore component is generally downcoast except for a period

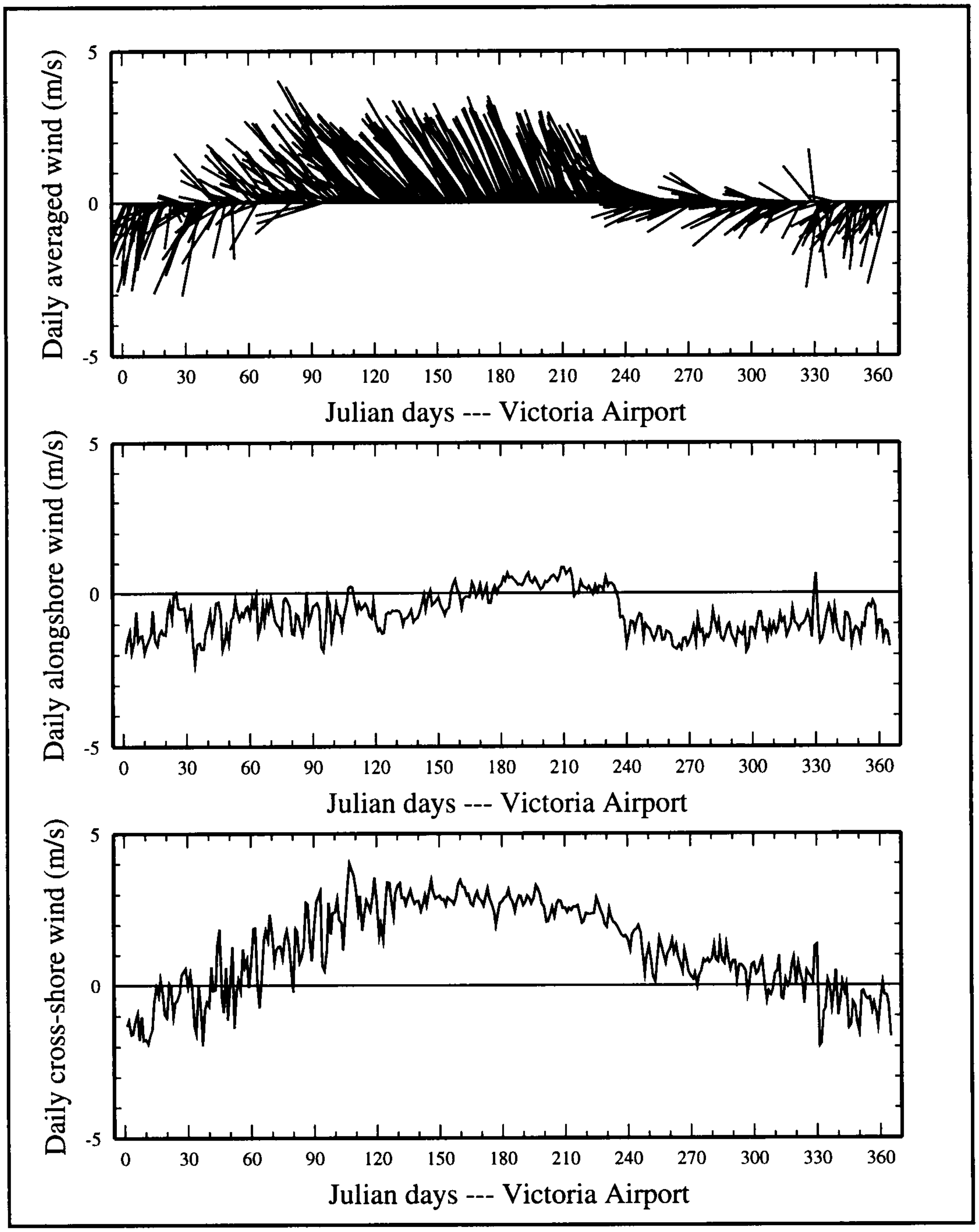

Figure 3D.9. 30-year average daily wind stick vectors (upper) with north oriented up, alongshore wind component (middle), and cross-shore component (lower) at Victoria airport.

in summer when it is upcoast. The early summer transition from downcoast to upcoast is characterized by numerous episodic reversals and generally occurs during June. Typically (based on 30-year records from coastal stations that we have examined) winds are upcoast during July and August, and shift abruptly downcoast at the end of August. On average, they then remain downcoast from September through May. It should be noted that there are numerous short periods during which the alongcoast direction of the wind stress is reversed for several days relative to its average direction, and we have found that the response of the coastal flow to such reversals is quite rapid (less than 24 hours).

In response to this temporal pattern of alongshore wind stress, CK proposed that the nearshore ocean flow should be downcoast from September through May, transition to upcoast in June and remain upcoast during July and August. This pattern was substantiated by their 3-year monthly mean fields of surface geopotential anomaly relative to 70 db, calculated from hydrographic data collected in 1963–1965 aboard the R/V GUS III and surface salinity patterns from 1964 cruises. Based on direct current measurements made as part of the LATEX study, we have substantiated this wind effect and subsequent flow pattern over the Texas-Louisiana shelf. Fields of LATEX current and wind stress are presented to illustrate the bimodal pattern of shelf circulation and the transition between the two regimes. We also present the average geopotential anomaly patterns based on seven LATEX non-summer cruises and on three summer cruises; in each case average current vectors for the corresponding periods are shown.

Although the effects of offshore rings can be seen in the monthly current meter fields and in the averages, we further illustrate such effects by showing results from one LATEX cruise period when large anticyclonic and cyclonic rings were present at the shelf edge.

Finally, the buoyancy effects of river discharge on the shelf circulation are illustrated by comparison of mean distributions of surface salinity and geopotential anomaly for fall, spring, and summer.

LATEX 10-m, SHELF-WIDE CURRENT REGIME

Current vectors for May, June, August, and September 1992 are shown in Figures 3D.10–14. They were produced by objective analysis of monthly averaged current measurements from 31 LATEX meters suspended approximately 10 m below the sea surface. The fields of current vectors shown were obtained by objective analysis from those averages at a 15-minute grid. We think that the analyzed fields are reasonable representations of the observed current fields.

Also shown in Figures 3D.10–14 are the corresponding monthly averages of objectively analyzed fields of surface wind stress. In May 1992 the average wind stress over the inner shelf had a downcoast component everywhere north of about 27.5°N. The flow over the inner shelf was likewise downcoast. The flow over the outer shelf was generally eastward, giving rise to a pattern of cyclonic circulation over the shelf, as proposed by CK. This eastward flow was strongest between about 95° to 96°W due to the presence of an anticyclonic ring situated over the continental slope. Note the tendency for offshore flow northeast of the ring and onshore flow between 91° and 93°W.

In June the monthly average wind stress (Figure 3D.11) had an upcoast component over the entire inner shelf. The flow over the inner shelf was likewise upcoast. The situation in July 1992 (not shown) was essentially the same as for June. During August the wind stress over the inner shelf shifted from upcoast to downcoast. The resulting monthly average current field (Figure 3D.12) showed upcoast flow off Louisiana and downcoast flow off Texas. After the transition in alongshore wind stress direction during August, wind stress over the inner shelf during September (Figure 3D.13) was all downcoast north of about 27°N, and the coastal flow was all downcoast. Thus, the non-summer circulation regime had been fully restored by September 1992. It is worth mention that the anticyclonic ring seen in May remained over the continental slope and continued to influence the outer shelf circulation through August. In September, its effects are not evidenced in the monthly average current field.

SEASONAL PATTERNS OF GEOPOTENTIAL ANOMALY AND SURFACE SALINITY

The surface geopotential anomaly relative to 200 db for LATEX cruise H05 (26 April–10 May 1993) is shown in Figure 3D.14. Also shown are current vectors at approximately 10-m depth averaged over the period starting two weeks before and extending through the cruise. The agreement between the direction and relative speed of the surface currents as inferred from the geopotential anomaly and the directly-measured currents is quite good. Pictured is downcoast nearshore

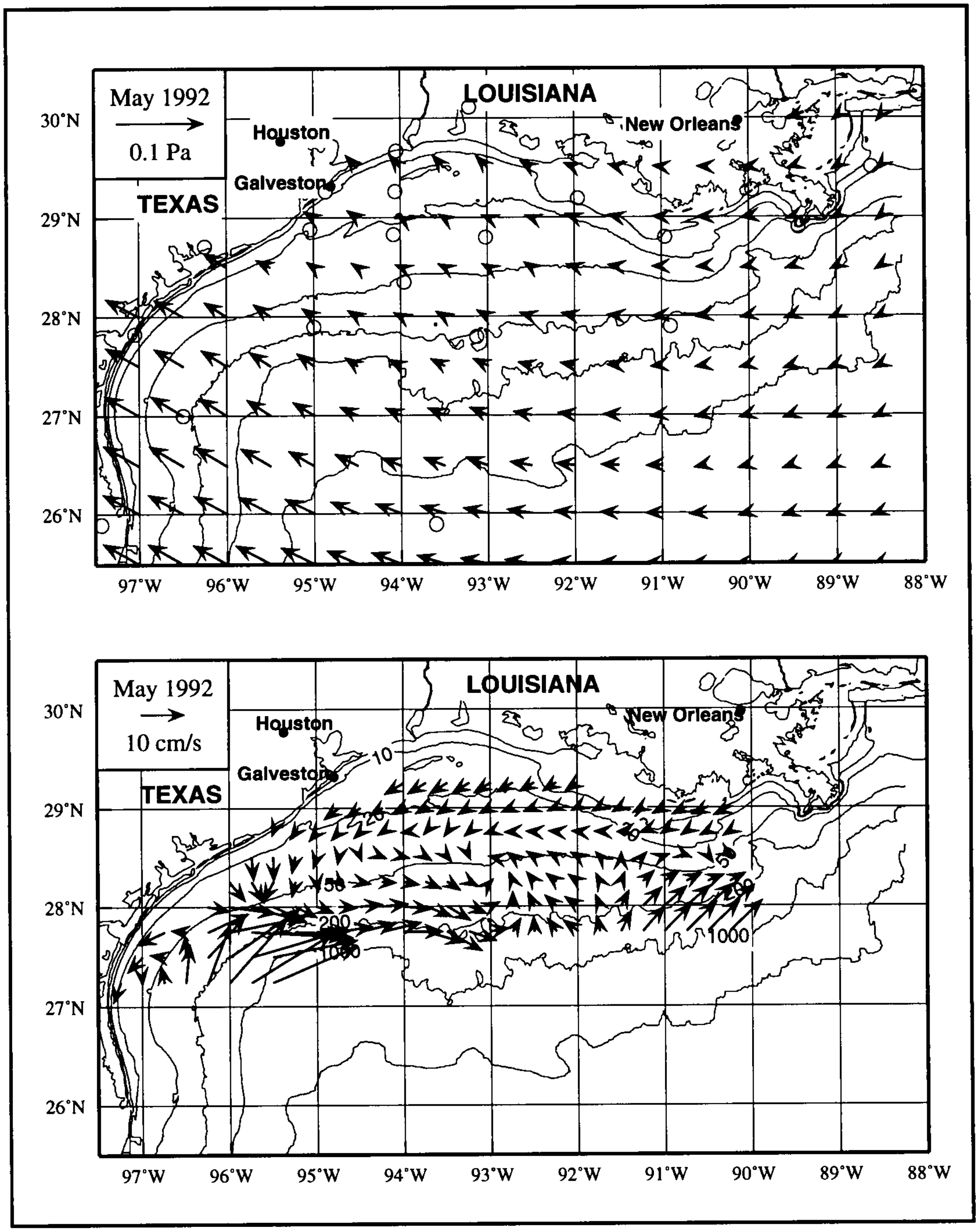

Figure 3D.10. Objectively-analyzed surface wind stress (upper) and 10-m currents (lower) from monthly-averaged observations (May 1992).

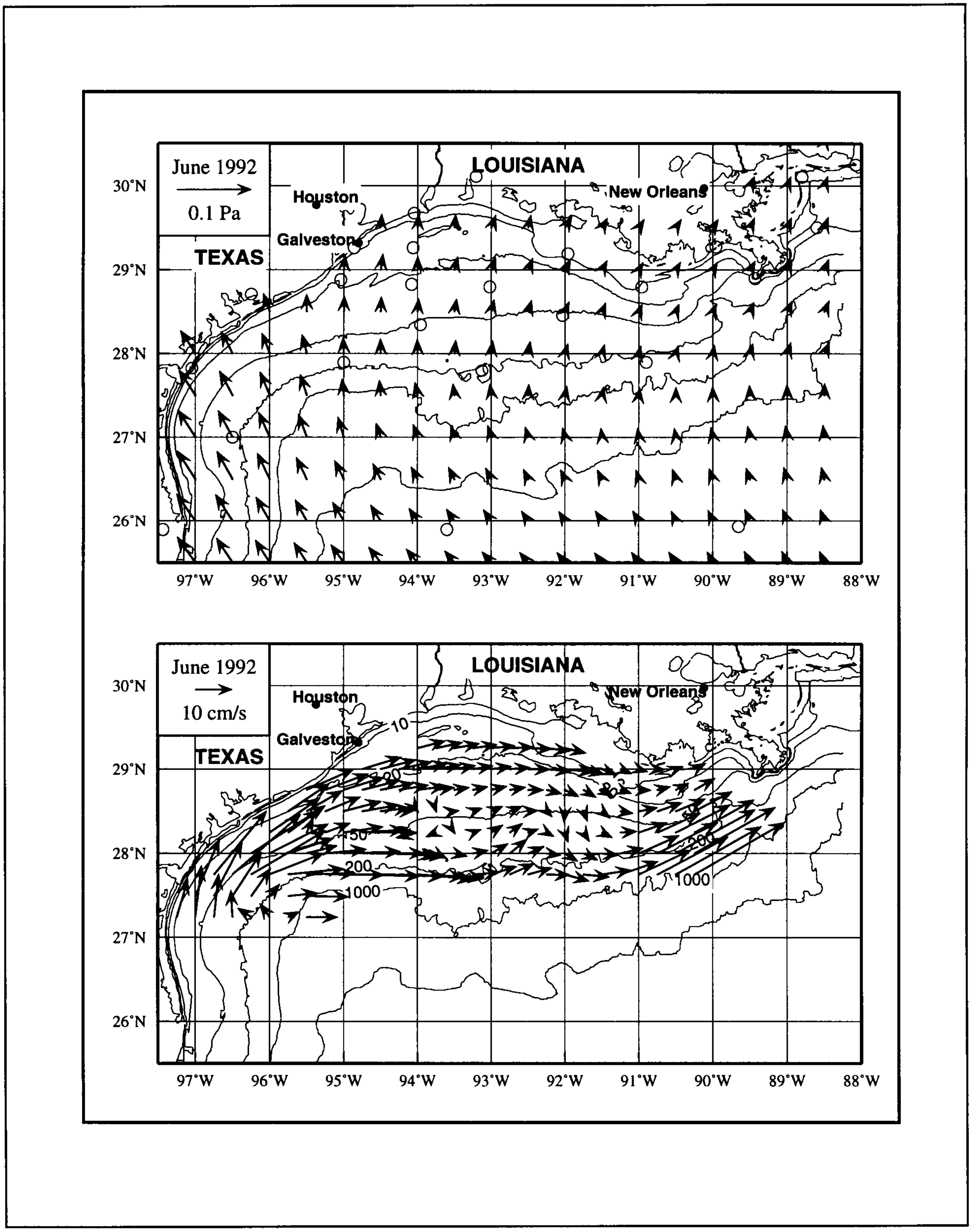

Figure 3D.11. Objectively-analyzed surface wind stress (upper) and 10-m currents (lower) from monthly-averaged observations (June 1992).

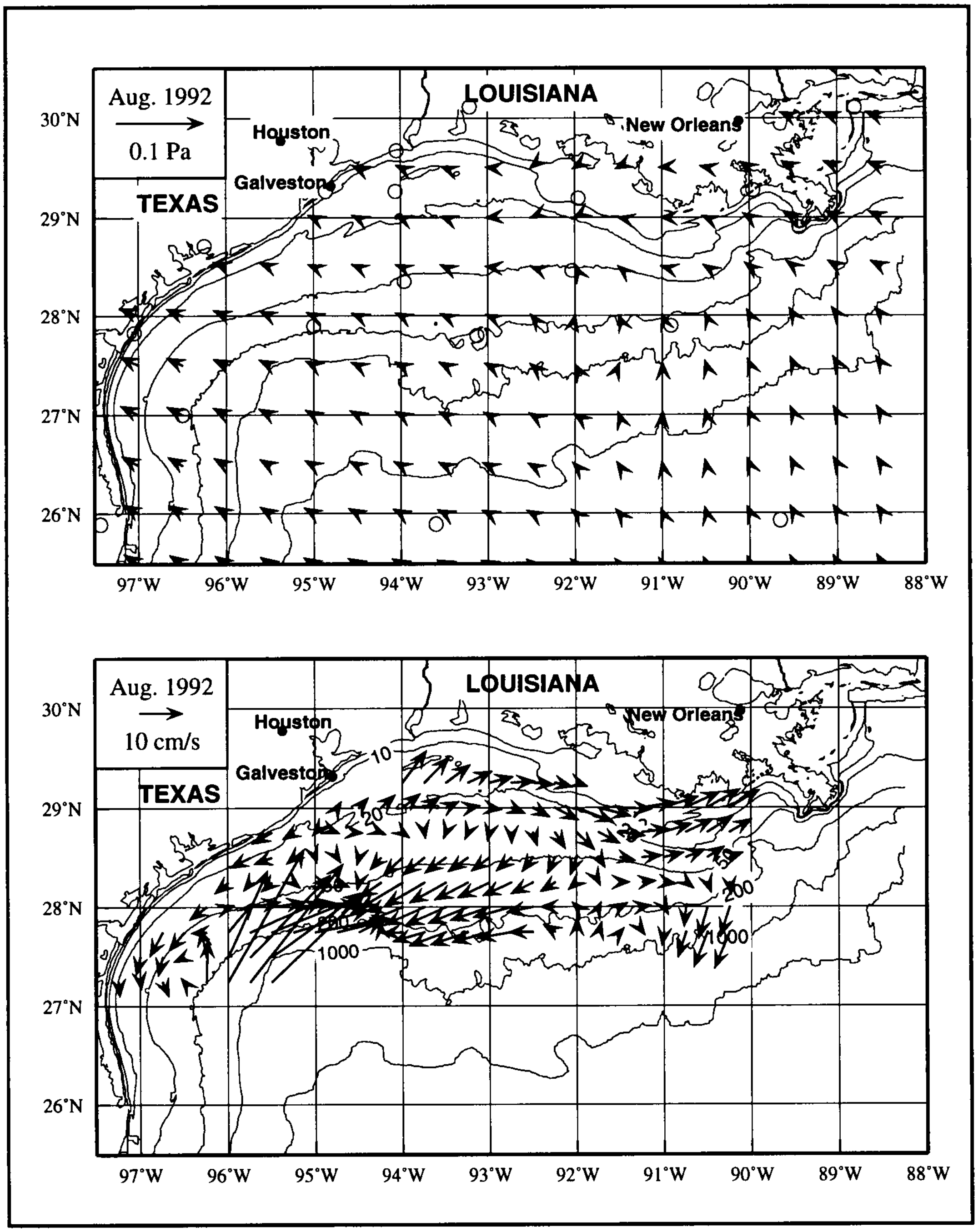

Figure 3D.12. Objectively-analyzed surface wind stress (upper) and 10-m currents (lower) from monthly-averaged observations (August 1992).

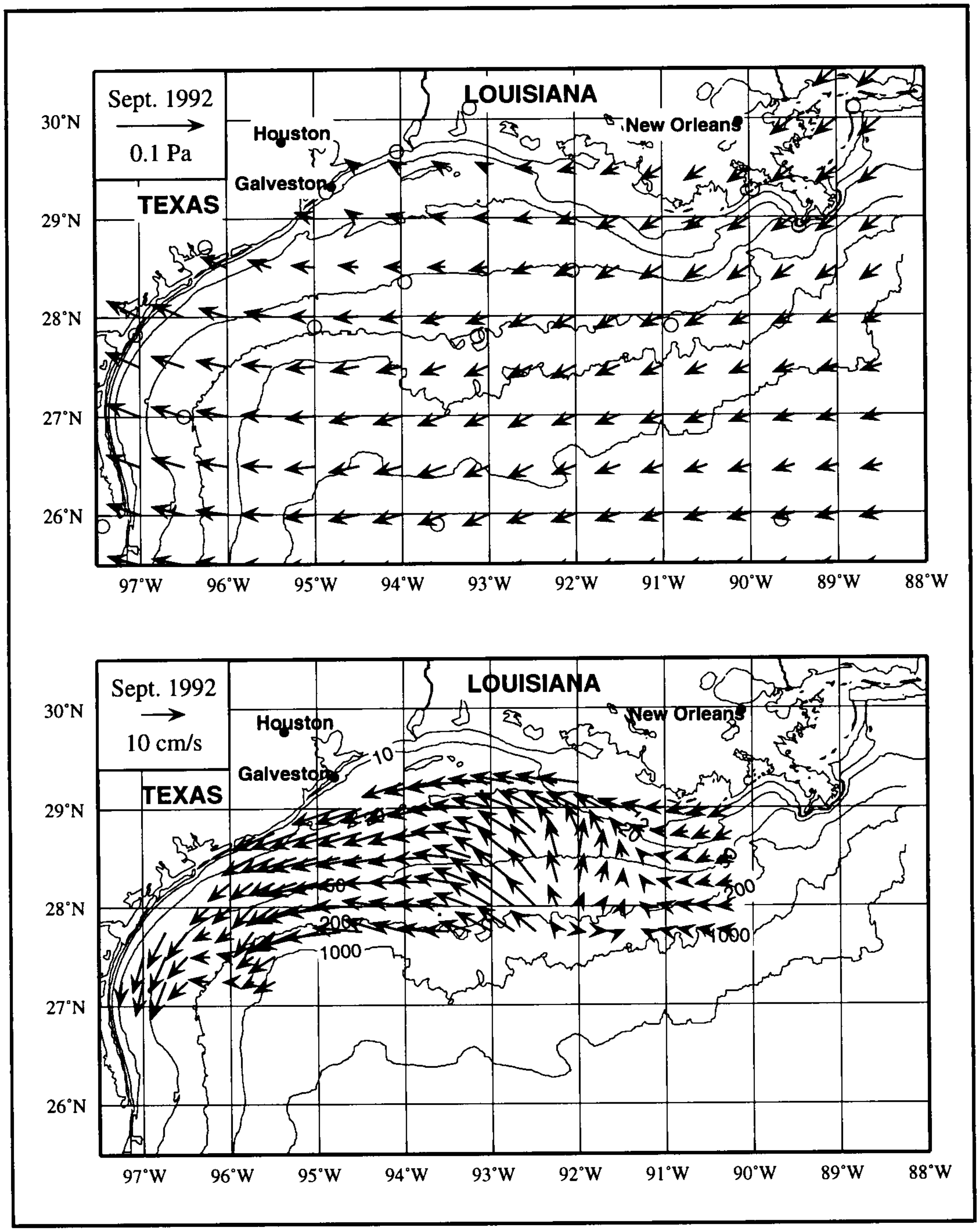

Figure 3D.13. Objectively-analyzed surface wind stress (upper) and 10-m currents (lower) from monthly-averaged observations (September 1992).

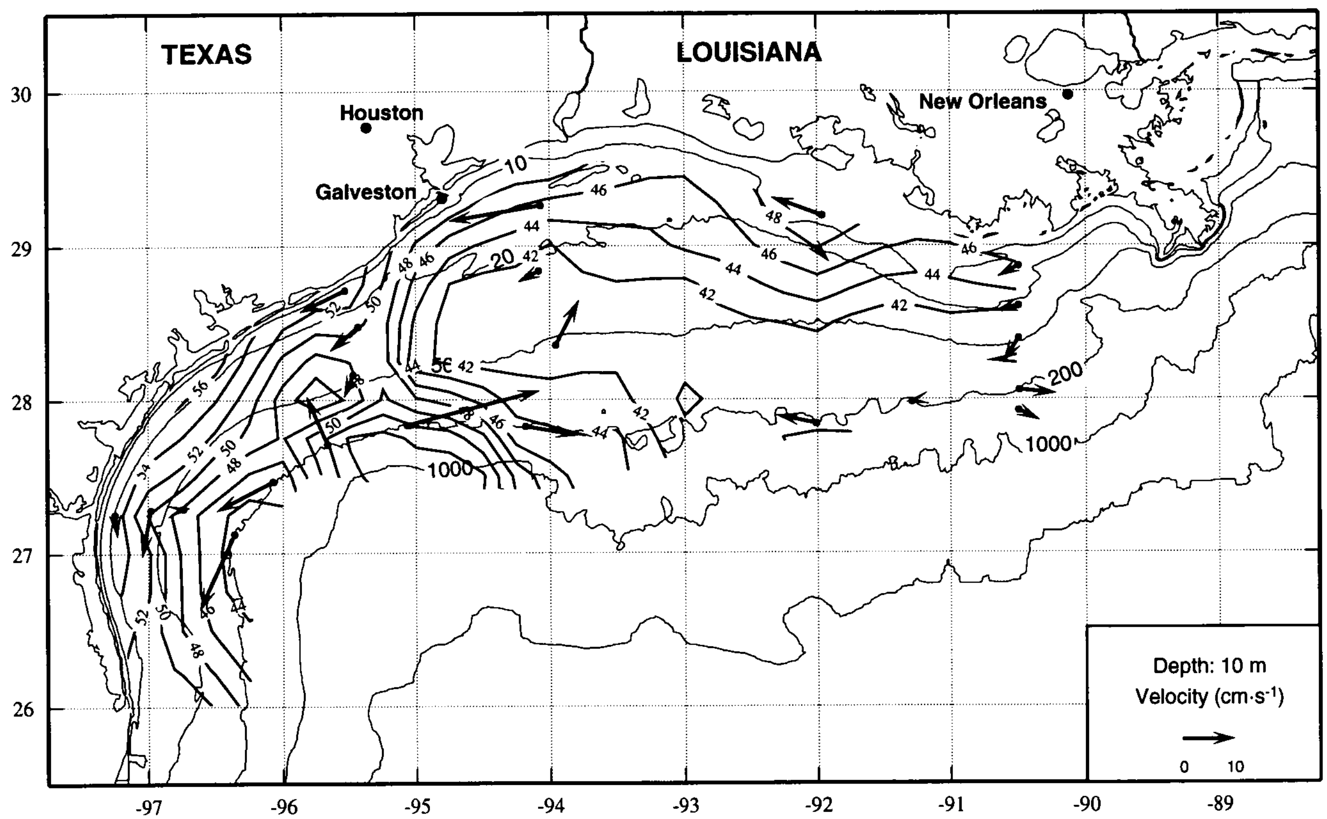

Figure 3D.14. Surface geopotential anomaly (dyn cm) relative to 200 db for LATEX H05 cruise (26 April - 10 May 1993) and 10-m currents (cm/s) averaged for two weeks before and during the cruise period.

flow, as expected for April or May. Over the eastern shelf (east of about 95°W) there exists a cyclonic circulation which may not be closed to the southeast—again as expected from the CK averages and those of Li *et al.* (1995). Over the outer shelf and slope in the southwest are seen the on-shelf circulations of a large anticyclonic ring between 94° and 96°W and a cyclonic ring between 26° and 27.5°N. The consequence of those rings is considerable on-shelf flow near 95.5° to 96°W and major off-shelf flows between 94° and 95°W and south of 26.5°N. The entire circulation pattern of the outer lower Texas shelf is seen to have been dominated by the effects of these rings. The flow on the shelf and off the shelf is considerably more prominent than shown in the monthly circulation averages of CK.

In Figure 3D.15 is shown the average surface geopotential anomaly relative to 200 db based on the seven LATEX non-summer cruises and on the three summer cruises. The 10-m current vectors averaged over the months September-May and June-August, of the period April 1992 through November 1994, are shown with the non-summer and the summer geopotential anomaly patterns, respectively. The directly measured currents qualitatively confirm the circulation inferred from the geopotential anomaly in both summer and non-summer periods.

The distribution of geopotential anomaly and average currents for the average non-summer period indicate downcoast flow over the inner shelf. The cyclonic circulation feature depicted by CK can be seen east of 95°W over the mid and outer shelf. Further to the west, the long-term presence of anticyclonic and cyclonic rings offshore resulted in average on-shelf flow between 95.5° and 96°W and off-shelf flow between 93° and 95°W. The currents over the outer shelf are likewise upcoast, which, at least in part, results from the presence of anticyclonic rings at the western shelf edge. A component of inshore flow is seen over the most of the mid shelf.

The 64-year average and the 1992, 1993, and 1994 daily discharge rates for the Mississippi-Atchafalaya river system are shown in Figure 3D.16. The large year-to-year variability is illustrated by comparing discharge rates for the three LATEX field years (shown) with one another and with the long-term mean. For comparison, the average daily discharges of 11 Texas rivers, based on data series of length ranging from 20 to 77 year, are also shown. Note the scale change to allow details of the Texas discharge to be seen. Clearly, the Texas rivers can have only a minor effect on the general shelf circulation relative to the Mississippi-Atchafalaya system. Very near the mouths of the Texas rivers the situation may be different, of course. The average Mississippi-Atchafalaya discharge peaks in April, but is still near its maximum in May. It reaches a minimum in September. The August-September period and November appear to have comparable daily discharge rates.

For hydrographic cruises with good quality data and covering major portions of the Texas-Louisiana shelf, Li *et al.* (1995) constructed mean distributions of temperature, salinity, and geopotential anomaly relative to 70 db. To illustrate the relative effects of river discharge and wind stress on the distribution of salinity, and consequently on geopotential anomaly patterns, we show in Figure 3D.17 mean surface salinity distributions for November, May, and July-August.

In May the mean salinity is seen to be much lower than in November both near the source of the fresh water and also over the entire inner shelf. Remembering from Figure 3D.16 that river discharge is much larger before and during May than November, and that the alongshore wind components are downcoast in both seasons, we conclude that the distributions differ principally because of the river discharge difference. The buoyancy effect of the larger amount of fresh water over the inner shelf during May than during November leads to greater values of geopotential anomaly during May (not shown) and thus enhanced downcoast geostrophic shear.

The surface salinity pattern for July-August is completely different from that for May though separated in time by only one month. Salinities greater than 36 extend halfway up the Texas coast in July-August. This is indicative of the upcoast flow under the action of upcoast alongshore wind stress component. As noted earlier, river discharge rates are about the same in July-August and November. However, we see that the fresh water discharge of November is distributed along the inner shelf by downcoast flow, while the discharge is held near the mouth of the river system by the upcoast flow in summer.

CONCLUDING HYPOTHESES

Our principal conclusions may be framed as hypotheses related to the previous descriptive circulation schema proposed for the Texas-Louisiana shelf:

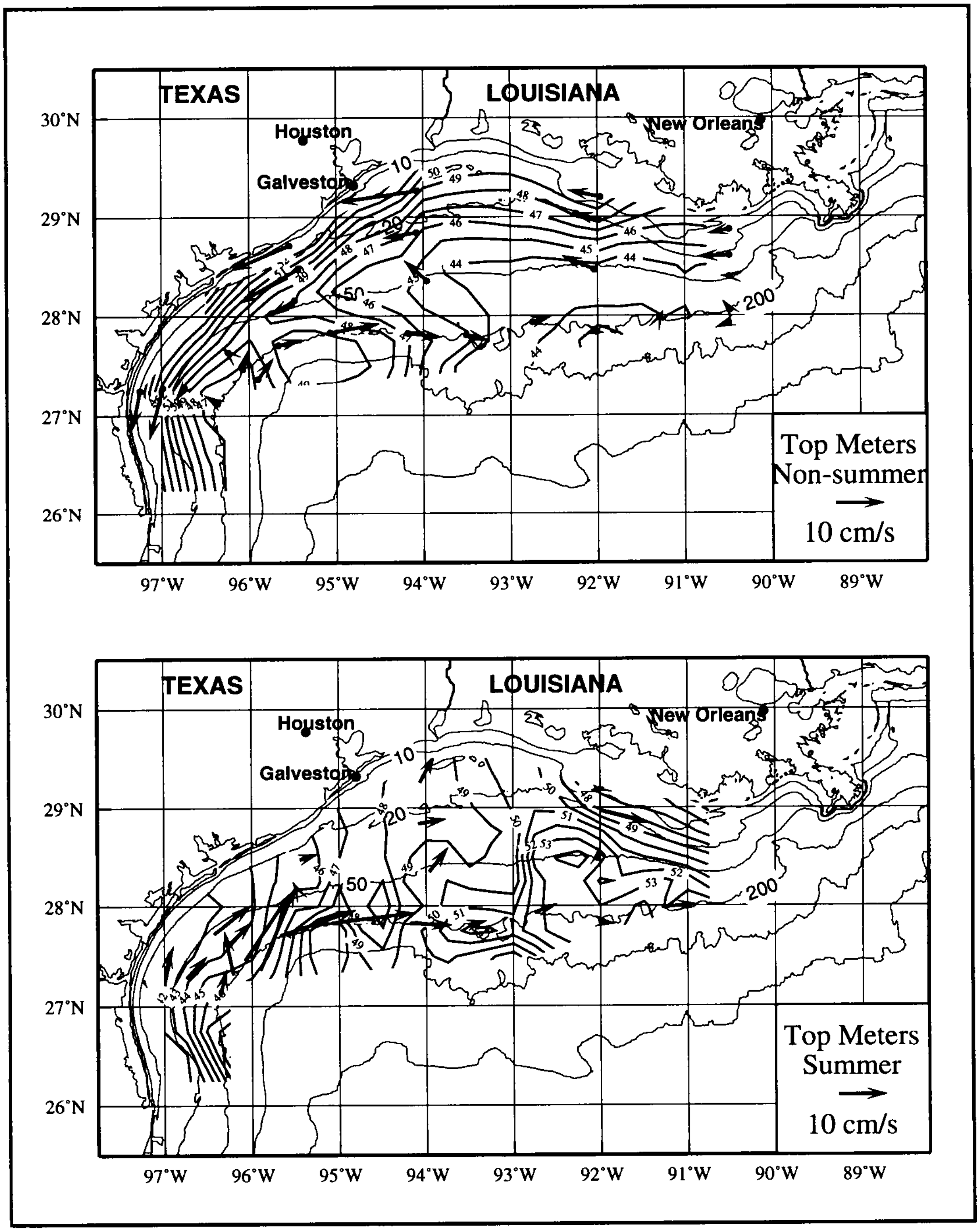

Figure 3D.15. Geopotential anomaly of sea surface relative to 200db averaged for 7 non-summer (upper) and 3 summer (lower) LATEX hydrographic cruises. Also shown are 10-m currents averaged for non-summer and summer during the period from April 1992 through November 1994.

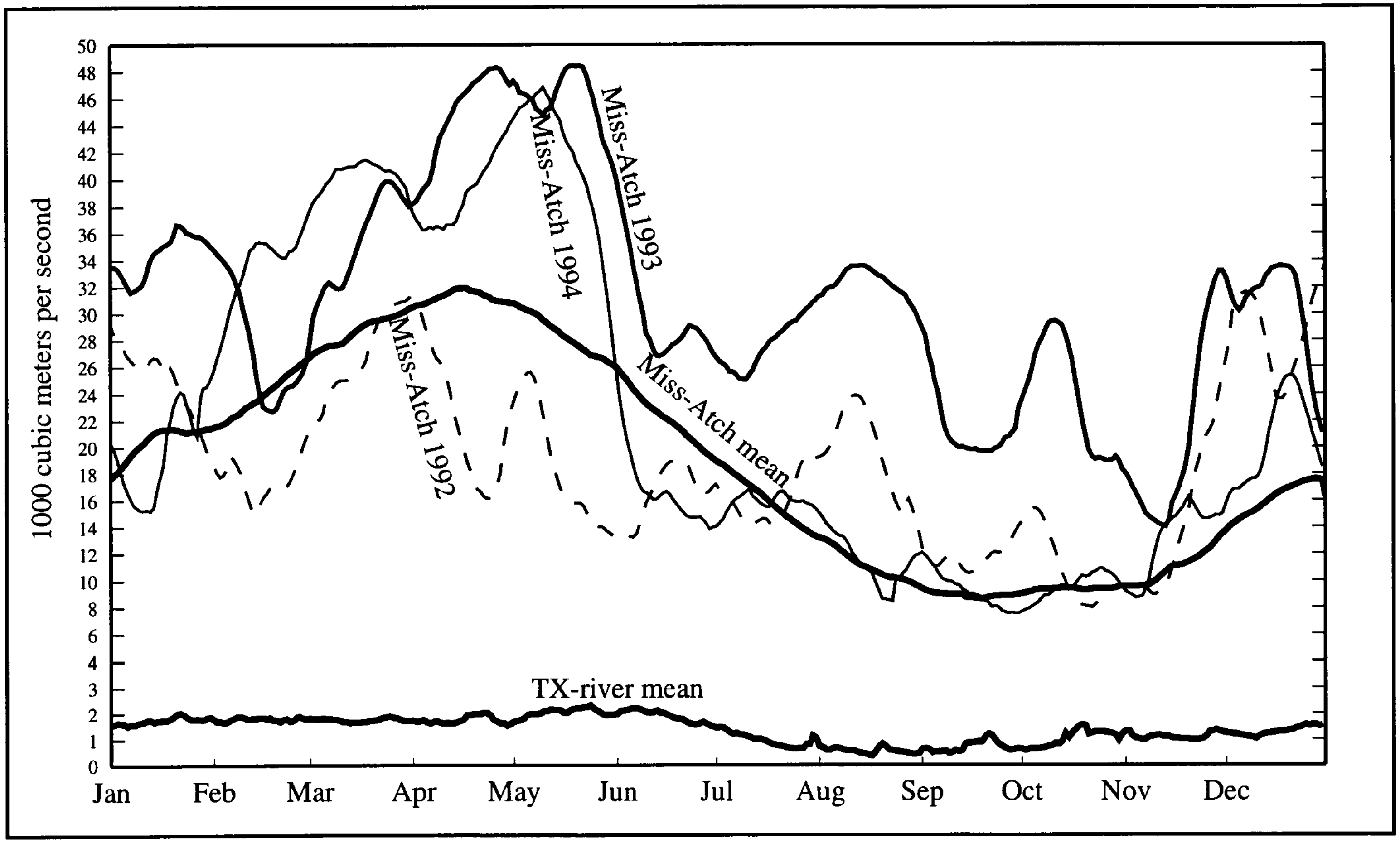

Figure 3D.16. 64-year average and the 1992, 1993, and 1994 daily river discharge for the Mississippi and Atchafalaya Rivers combined and average daily discharge from 11 rivers in Texas based on 20 to 77 years of data for individual rivers.

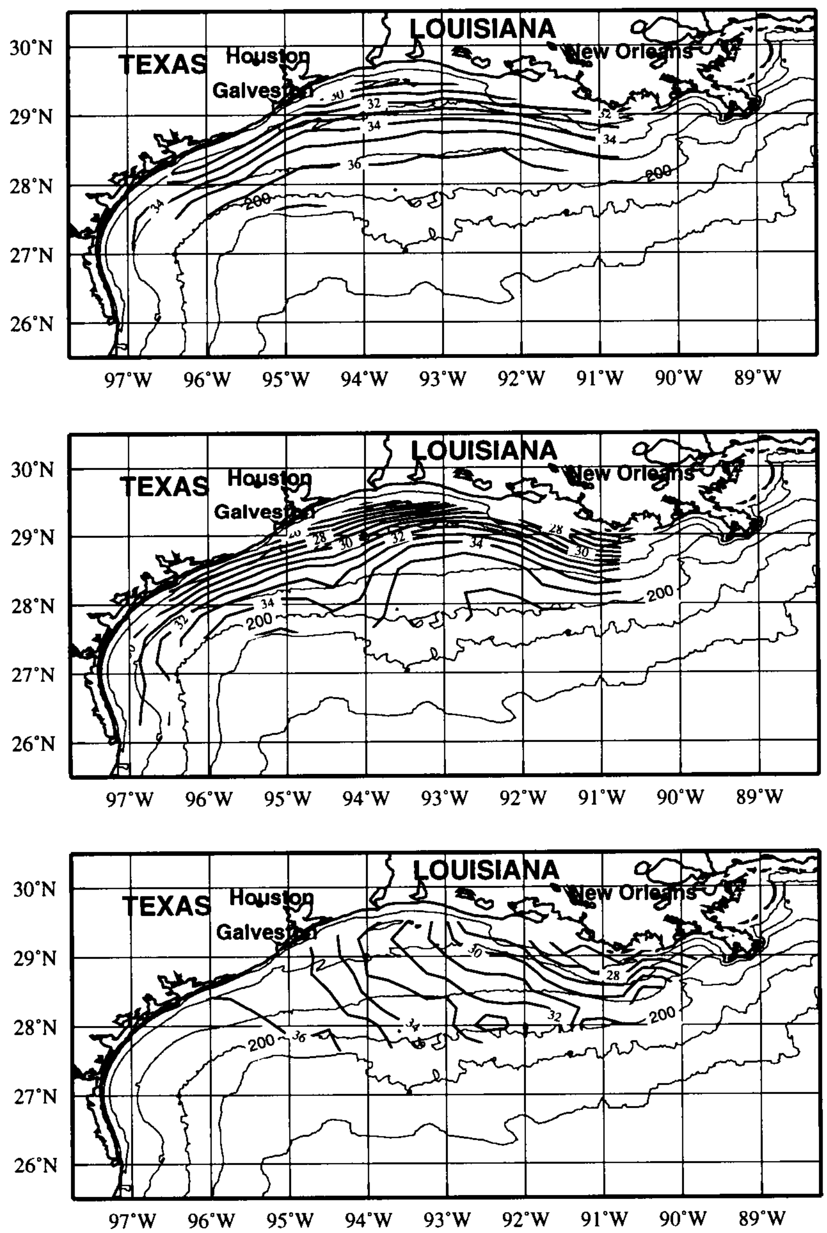

Figure 3D.17. Average sea surface salinity in fall (upper) for 6 November cruises, in spring (middle) for 10 May cruises, and in summer (lower) for 9 July-August cruises.

- The summer transition to downcoast flow over the inner shelf (<50 m depth) is a direct result of the wind regime.
- The Cochrane-Kelly schema for the low frequency circulation is essentially correct for the inner and mid-shelf regions.
- Forcing for the inner and mid-shelf regions is essentially by wind and buoyancy contrast.
- There is more on- and off-shelf exchange than pictured by the Cochrane-Kelly schema.
- The upcoast (eastward) flow at the shelf edge envisioned in the Cochrane-Kelly schema may well be the result of integrated effects of anti-cyclonic eddies impinging on the shelf edge. (Oey's 1995 model study provides confirmation.)

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Robert O. Reid is Distinguished Professor Emeritus of the Department of Oceanography, Texas A&M University. He is a member of the National Academy of Engineering and a Fellow of both the American Meteorological Society and the American Geophysical Union. His research interests, as reflected by about 80 publications, range from analytical and numerical studies of ocean circulation, storm surges, tides, and tsunamis through surface wave dynamics, estuarine circulation, modeling of dense plumes, wave forces or structures, and stochastic modeling. His present interest is in the application of spectral modeling techniques in shelf wave dynamics and in mesoscale circulation, as well as in certain aspects of data synthesis.

Yongxiang Li received a B.S. in mechanics from Peking University and a M.S. in physical oceanography from the Institute of Oceanology, Chinese Academy of Sciences. Prior to coming to Texas A&M University in 1993, he carried out research on ocean circulation and air-sea interaction in the west Pacific and East China Sea at the Institute of Oceanology. At A&M he has been studying and researching the circulation and property distributions over the Texas-Louisiana shelf.

Wensu Wang earned a B.E. in mechanics from Tsinghua University and M.S. in physical oceanography from the Institute of Oceanology, Chinese Academy of Sciences. As a doctoral student in oceanography at Texas A&M University, her professional interests are in data analysis techniques and numerical modeling as applied to the marine boundary layer, air-sea interactions, and ocean circulation.

SECONDARY EDDIES ON THE LATEX SLOPE FROM DRIFTER AND HYDROGRAPHIC DATA

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Department of Oceanography
Texas A&M University

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INTRODUCTION

Between May 1992 and November 1994, the LATEX C program conducted 21 aerial XBT/XCP surveys of the Louisiana-Texas continental slope. Some surveys had general coverage of large areas of the slope, whereas others were designed to survey specific Loop Current (LC) or slope eddies. In addition there were seven seasonal surveys of the slope obtained from the GULFCET hydrographic program and numerous ship-of-opportunity (SOOP) transits across the slope. This database has been used to document the occurrence on the slope of smaller secondary eddies that are distinct from LC eddies proper, though they may be related to or derived from them.

RESULTS

The existence of 30-100 km diameter cyclones and anticyclones on the Louisiana-Texas slope has been known for some time (Hamilton 1992). Examples are shown from the drifter track in Figure 3D.18, where the drifter moves from west to east along the slope, moving alternately around cyclones and anticyclones that occupy much of the region between the 200 and 2000m isobaths. The cyclone at 92° W was shown to originate in the central deep basin of the Gulf. It was advected north onto the slope by the approach of a large LC eddy from the east. This cyclone was surveyed a number of times and it remained on the slope at approximately 92° W for more than six months.

Another example of an eddy moving onto the slope from the deeper water is the anticyclonic eddy V (Hamilton *et al*, 1993). Eddy V separated from the large LC eddy U in August 1992. It then moved rapidly westward along the 2,000m isobath until it reached the NW corner of the slope in December 1992. Eddy V remained in the NW corner for about six months,

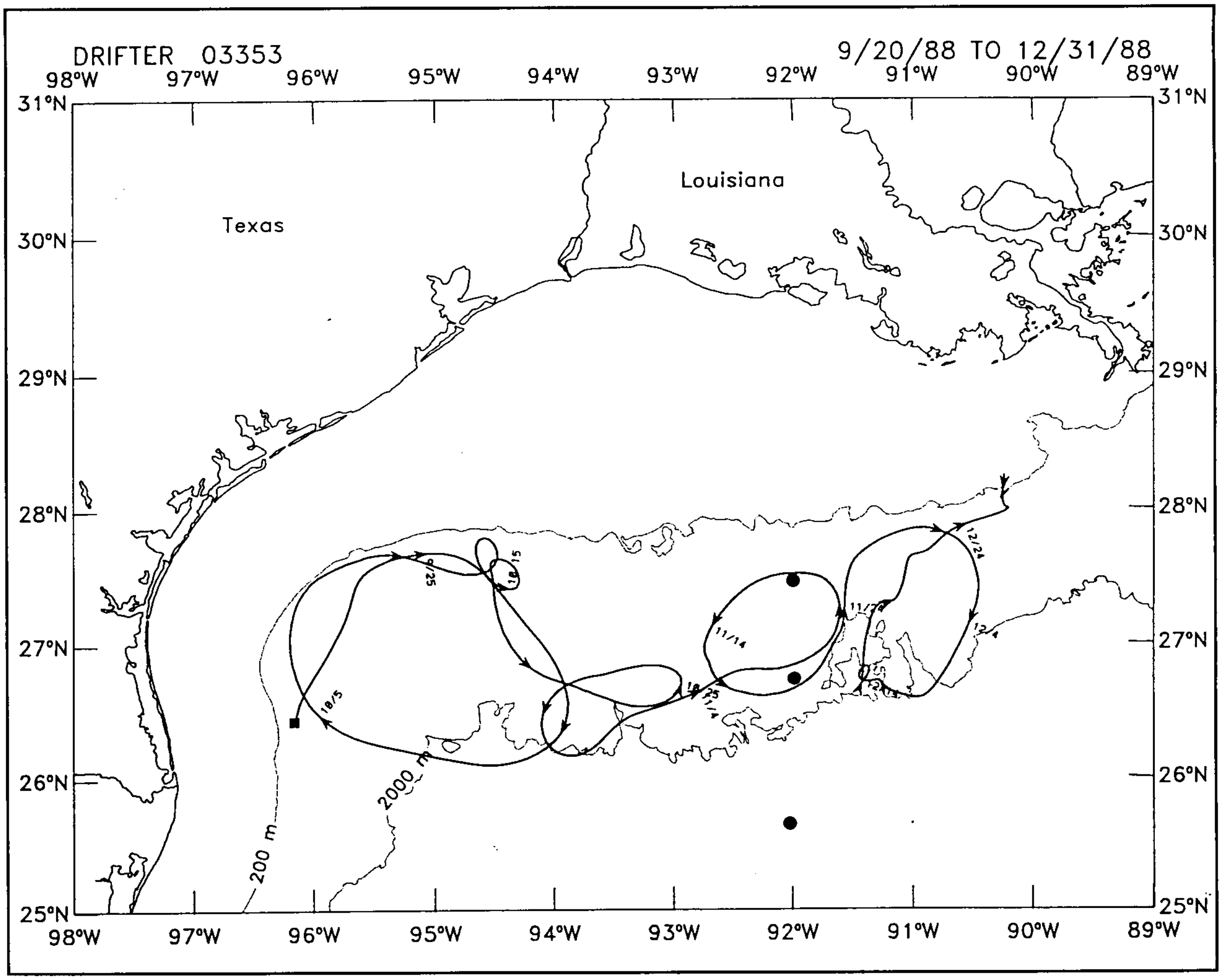

Figure 3D.18. Smoothed tracks for drifter 03353. Arrow heads are positioned every 5 days and alternate arrows are marked with month and day (00 hours GMT). Solid dots mark positions of moorings from the Gulf of Mexico, Year 5 Physical Oceanography Program.

making at least one excursion onto the middle of the slope (January 1993), and eventually permanently moving onto the slope as the circulation weakened in April and May 1993. Excursions onto the slope from the 2000m isobath were probably caused by interactions with LC eddies further south along the Mexican slope. Also, interaction with an anticyclone in early spring 1993 invigorated Eddy V's circulation.

Eddies can move north onto the slope, and there have been observations of slope eddies moving south off into deeper water. An example for a lower slope cyclone is given by drifter 12372 in Figure 3D.19. Velocities from XCP's from a flight in May 1994 (Figure 3D.20) show concentrated flows between the cyclone and a smaller vigorous anticyclone to the northeast (drifter 12373 in Figure 3D.19). There is also an upper slope anticyclone to the north that is skirted by drifters 12374 and 07842 (Figure 3D.19), which is only weakly present in the 15° C surface (Figure 3D.20) but has a large depression of the 8° C surface (not shown). The northwestern warm slope eddy, on the other hand, shows only small

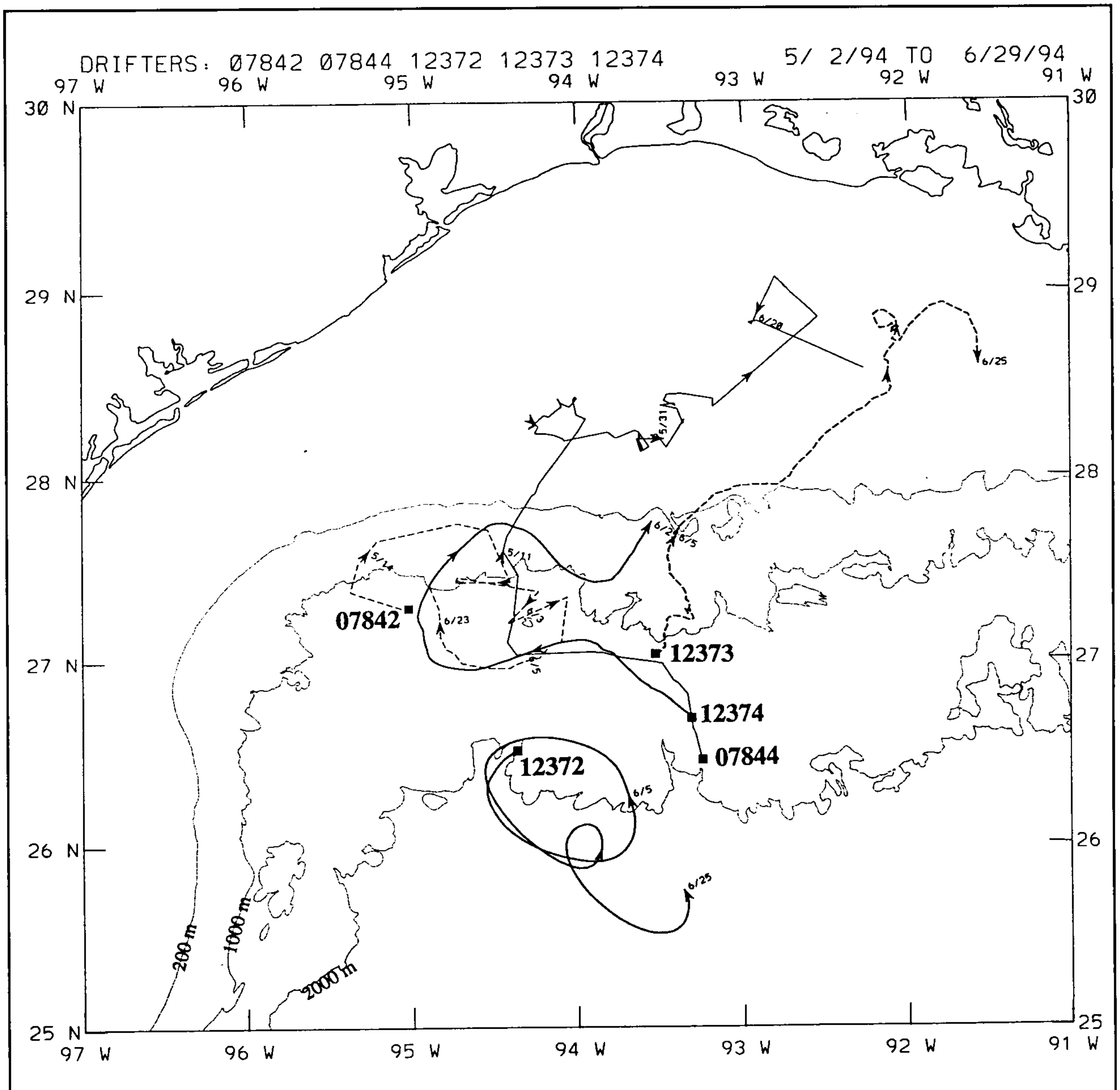

Figure 3D.19. Smoothed (except 07844 and 07842) tracks for the indicated drifters.

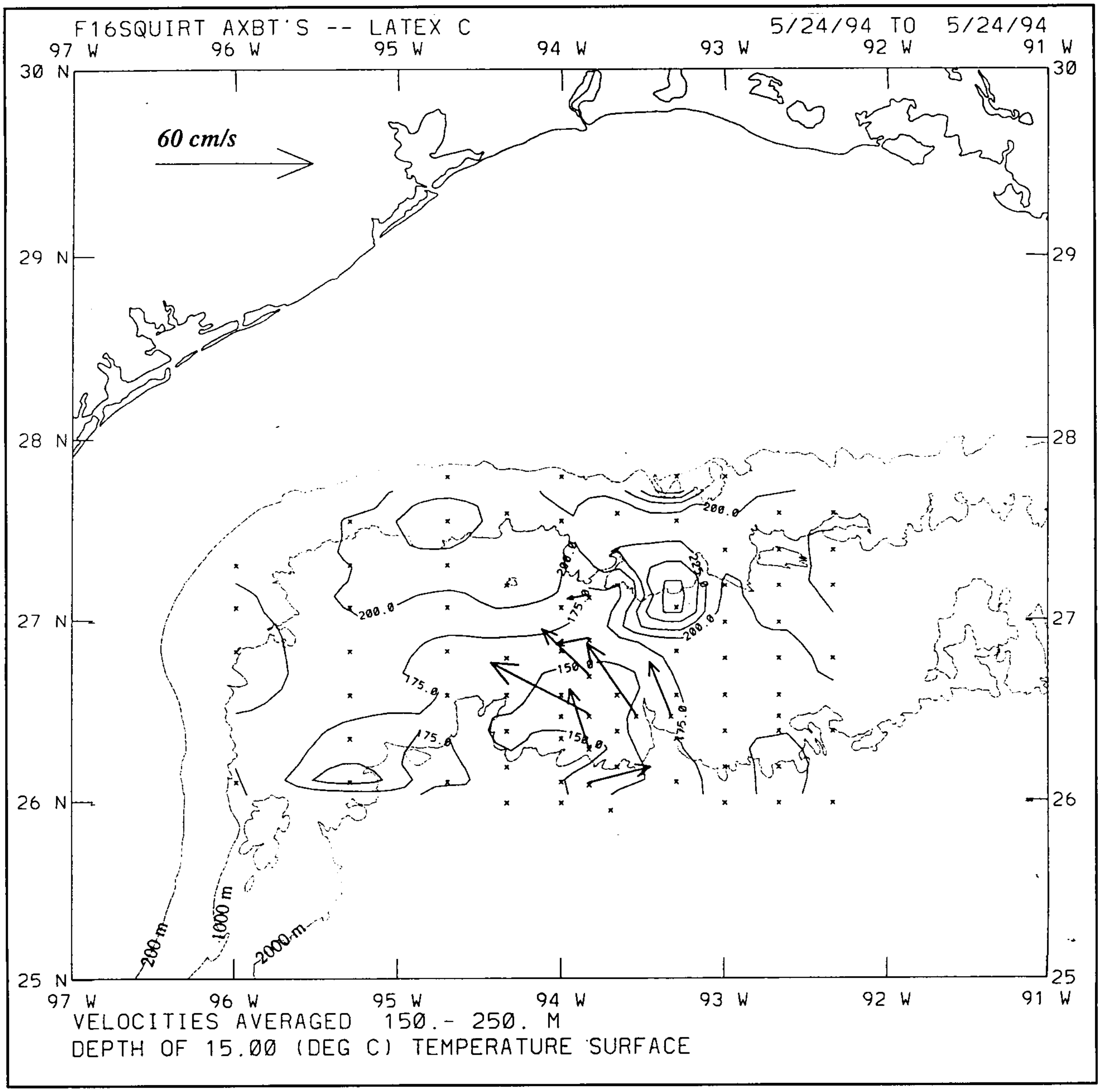

Figure 3D.20. Depth of 15° C isotherm surface from the AXBT/AXCP survey F16 SQUIRT. Velocities are from smoothed AXCP profiles, averaged between the indicated depths.

depressions of the 8° C surface. The presence of small eddies on the upper slope provides a means of transporting water parcels from the lower slope to the LATEX shelf and vice-versa. At present there is not enough data to determine the origin of, or how long-lasting are, these smaller (~30 to 50 km diameter) upper slope eddies. There are more examples in the LATEX C data of the movement of drifters onto the shelf being associated with smaller eddies on the slope.

A further example of strong flows, perpendicular to the isobaths, that can occur between eddies was observed in November 1994. Figure 3D.21 shows the depth of the 8° C isotherm for eddy Y, centered at about 26° N, 91° W in deep water, and a vigorous cyclone on the lower slope at 93° W. Current velocities are as strong (~25-30 cm/s) on the east of the cyclone as in the major LC eddy. The center of the cyclone is being advected northwards further onto the slope as eddy Y moves

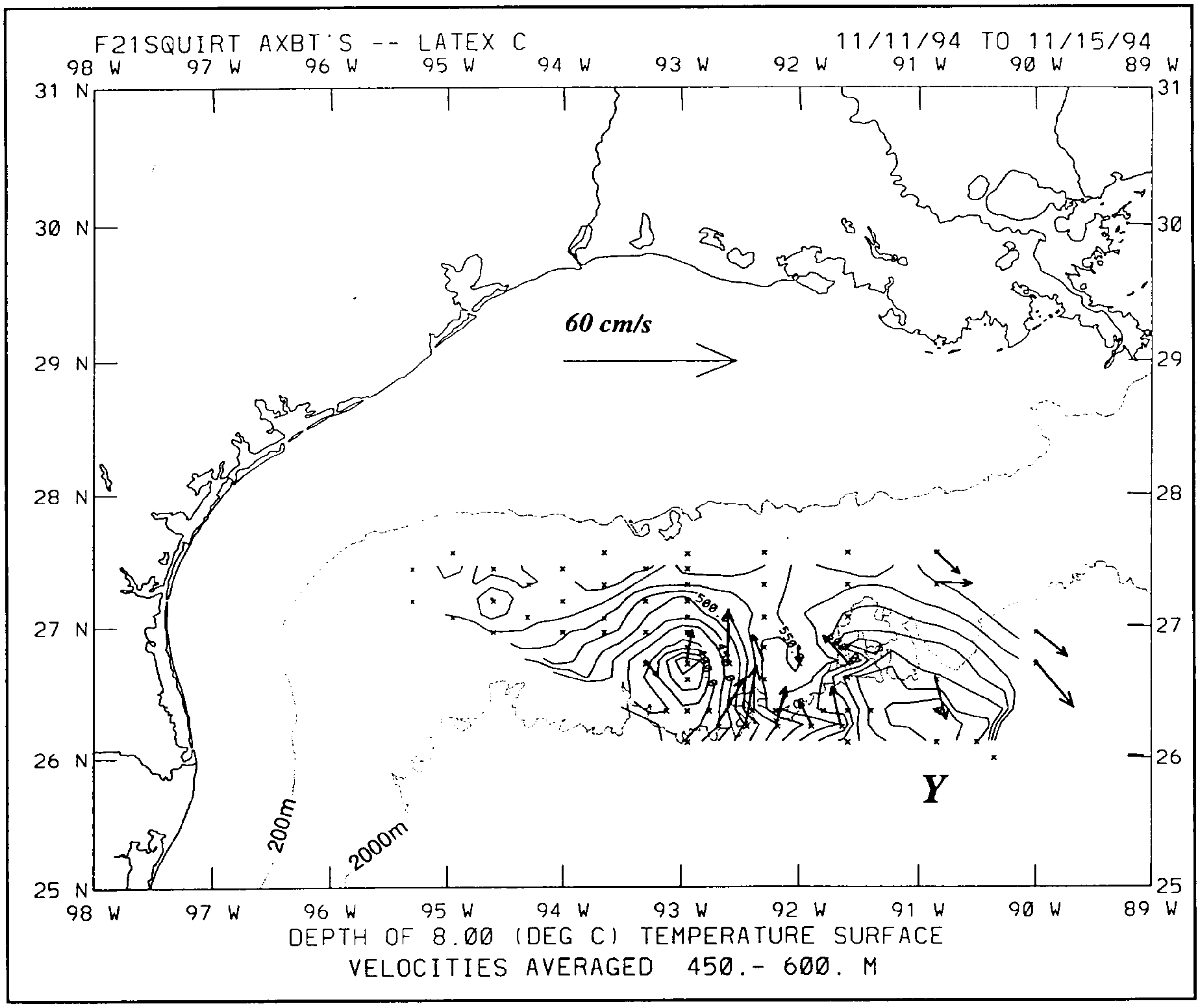

Figure 3D.21. Depth of 8° C isotherm surface from the AXBT/AXCP survey F21 SQUIRT. Velocities are from smoothed AXCP profiles, averaged between the indicated depths.

westward. A survey taken 10 days before that of Figure 3D.21 showed the center of the cyclone over the 2000m isobath, about 50 km to the south.

SUMMARY

Hydrographic surveys and drifter deployments from LATEX C and the GULFCET program have shown the existence of many secondary cyclones and anticyclones over the Louisiana and Texas slopes. Some characteristics are diameters on the order of 30-100 km, and swirl velocities on the order of 30-60 cm/s. The smaller upper slope anticyclones can have differing depth structures, and flows between anticyclone-cyclone pairs can transport drifters onto the shelf. Lower slope eddies have been observed to migrate on and off the slope, from and towards the deep central basin, respectively. The larger eddies can have quite long lifetimes (~6 months) on the slope and they can be moved around to some extent by the passage of LC eddies to the south.

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SUMMER UPWELLING AND RELATED CURRENTS OFF SOUTH TEXAS

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INTRODUCTION

This contribution is derived from work done with Professor John Cochrane (Department of Oceanography, Texas A&M University) and by Dr. Nan Walker (Coastal Studies Institute, Louisiana State University) and is the subject of a more extensive publication currently in progress.

Wind-driven coastal upwelling probably occurs each year along the south Texas coast and presumably is an important factor contributing to and perhaps even limiting the biological productivity of Texas coastal waters, yet little has been published on this topic. Using suitable averages of meteorological and oceanographic station data and discrete infrared satellite imagery, we will present evidence of seasonal upwelling along the Texas coast and describe its spatial and temporal extent in broad descriptive terms. The episodic nature of upwelling will be shown through an examination of selected time series of winds and currents collected during the Louisiana-Texas Shelf Physical Oceanography Program (LATEX).

METHODS AND RESULTS

The data used in this analysis are summarized in Figure 3D.22, which shows a map of the study area and the measurement locations. Much of the meteorological and hydrographic data were collected in differing years over several decades; however, it is noteworthy that one data set, that of the LATEX A field program, provides nearly comprehensive coverage of the region during 1992, 1993, and 1994.

Meteorological data supplied in this analysis are from the climatology by Hellerman and Rosenstein (1983), from airport weather stations at Brownsville and Corpus Christi, Texas (1951-1960), and from National Data Buoy Center (NDBC) buoy 42008 off Freeport, Texas (1978-1983) (discussed in Cochrane and Kelly 1986). Data from PTAT2 at Port Aransas (1992-1994) were obtained from the National Data Buoy Office (NDBC).

Near-shore temperature and salinity were recorded at the Brazos Santiago Tide station near Brownsville from 1958 to 1971. In somewhat deeper water, temperature and salinity data were collected at two GUS III stations during repeated visits in 1963 through 1965. Near-surface temperature and salinity data collected across the entire south Texas shelf during LATEX A hydrography cruises in May and August of both 1993 and 1994 were used to generate the horizontal contours of those parameters. The full vertical profiles of the CTD data and nitrate values from bottle samples taken along line 7 during the same LATEX cruises were used to produce vertical sections. Currents, temperature and salinity were measured continuously from April 1992 to December 1994 at moorings labeled 1 through 4. In this work, however, we only show results from the near-surface meters at moorings 1-3, and mainly from the top meter at mooring 1. Offshore temperature conditions are characterized by the bathythermograph data were analyzed by Etter and Cochrane (1975). Infrared imagery from the NOAA/NOS Ocean Products

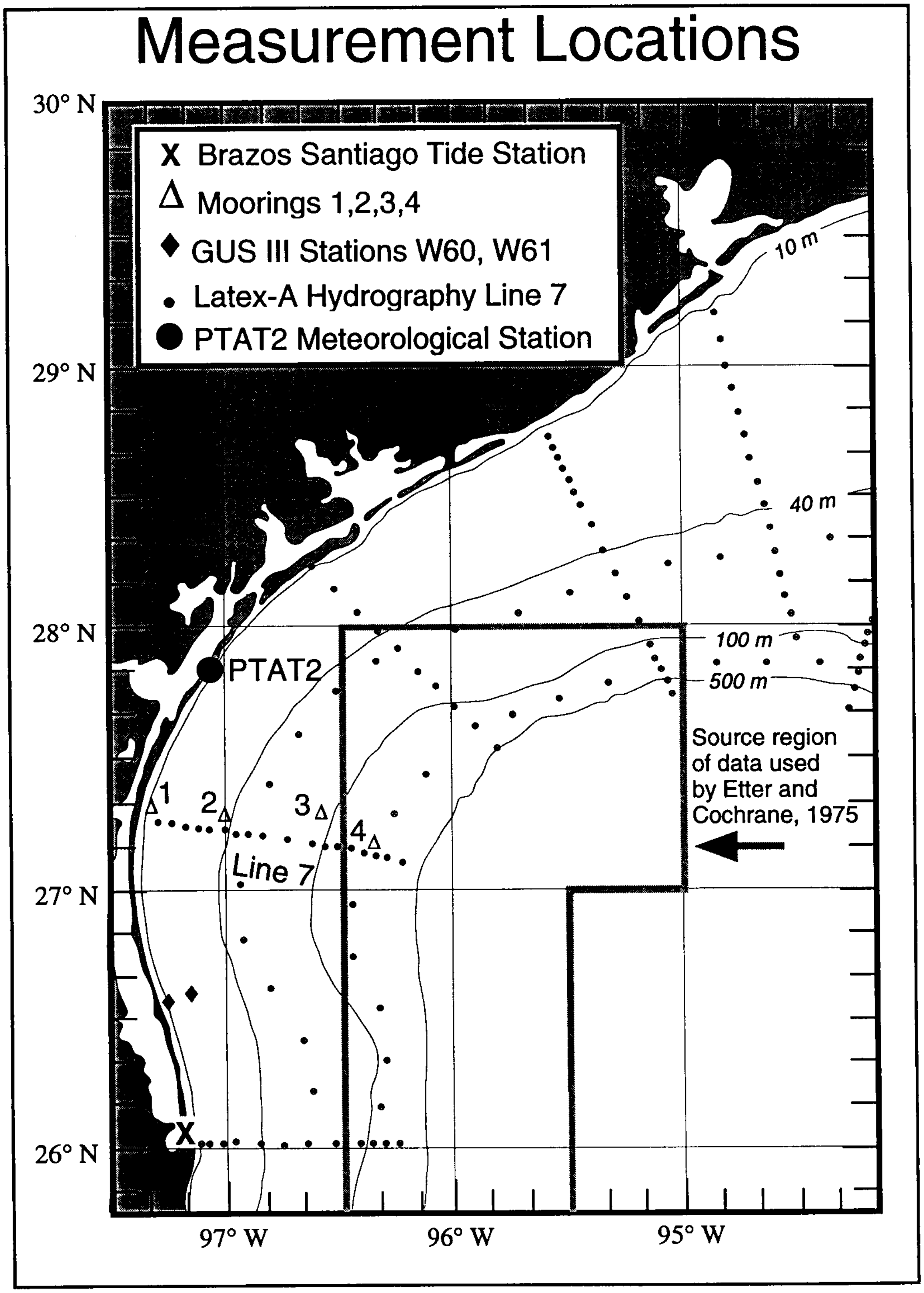

Figure 3D.22. Base map of the south Texas shelf showing the locations where data discussed were measured.

division and from the Coastal Studies Institute at Louisiana State University complete the data set.

One consequence of the earth's rotation is that marine winds produce a net transport in the upper water column (Ekman layer) that in the northern hemisphere is 90 degrees to the right of the wind direction. When winds blow upcoast with land to the left and water to the right, the water transported offshore must ultimately be replaced by upwelled water from below. This water is usually cooler, more saline, and often has higher concentrations of nutrients and dissolved oxygen than the water it replaces. Winds that favor upwelling along the Texas shore are those that have an upcoast component, which in the present work means along the coast from Brownsville toward New Orleans. As a first step, we examine the meteorological record looking for times when the alongshore component of the wind is conducive to upwelling.

Monthly mean alongshore wind stress, from a climatology prepared by Hellerman and Rosenstein (1983), for 26°, 27°, and 28°N along the Texas coast (Figure 3D.23) shows alongshore components are stronger in the south than in the north. This is primarily a consequence of a coastline orientation that is nearly meridional at 26° and 27° and turns toward a more zonal orientation at 28°N. In the south, the alongshore stress becomes upcoast between March and April, reaches maximum strength in late May to early June, and persists until September-October. In the north, near 28°N, upcoast stress begins mid-May, peaks in July,

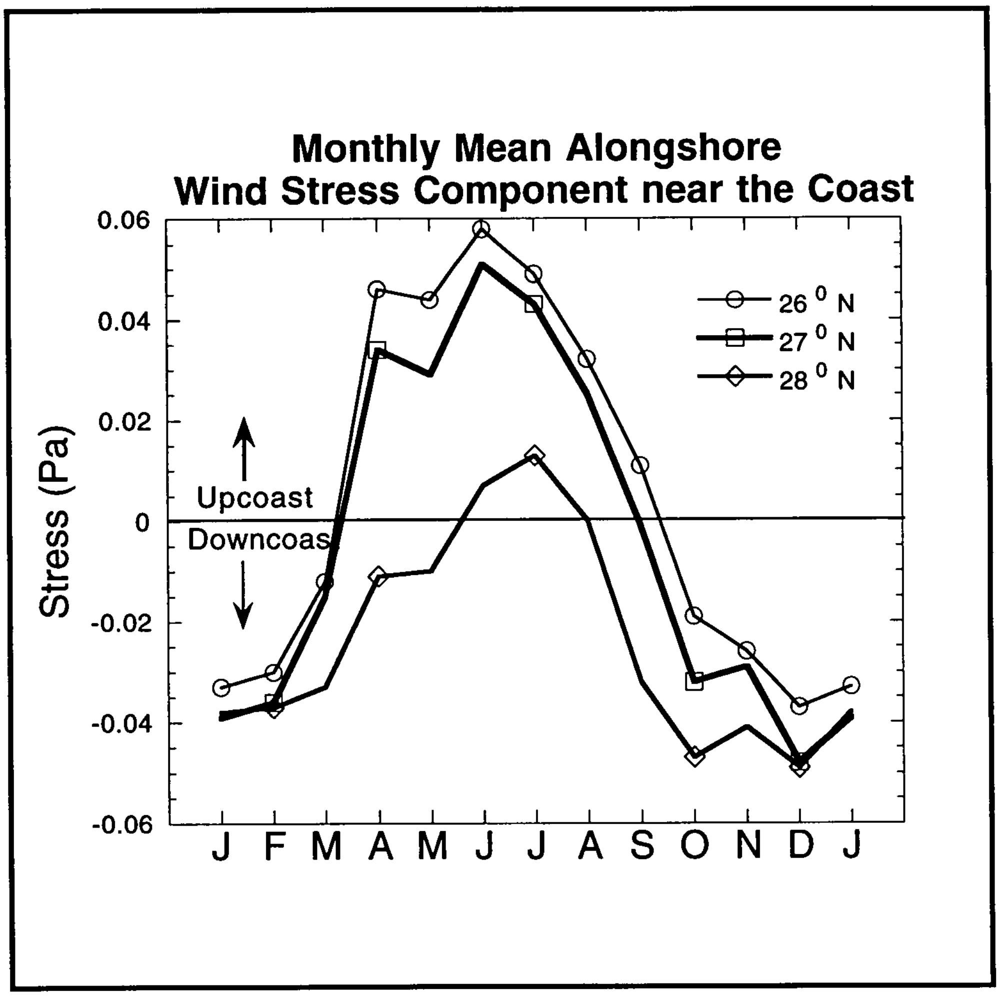

Figure 3D.23. Monthly mean alongshore wind stress component near the coast based on Hellerman and Rosenstein (1983).

and becomes downcoast after August. Examination of the monthly mean alongshore wind stress from station data at Brownsville, Corpus Christi, and off Freeport are in good agreement with the Hellerman-Rosenstein climatology.

Next we examine the oceanographic record for evidence of coastal upwelling. Near-surface mean temperatures for the outer and off-shelf regions are compared to inner shelf stations in Figure 3D.24. Off-shelf stations show an annual cycle with a temperature maximum occurring in August. Near- shore stations follow the offshore warming trend closely until June when temperatures at the inshore stations decrease to a local minimum in July. After July the inner station temperatures gradually increase but do not reach the offshore temperatures until mid-September. Because the current meters are located 10 to 14 m below the surface they record temperatures lower than those found at the surface throughout the year but they also exhibit a decrease in temperature in June or July. Although the winds are favorable to upwelling in

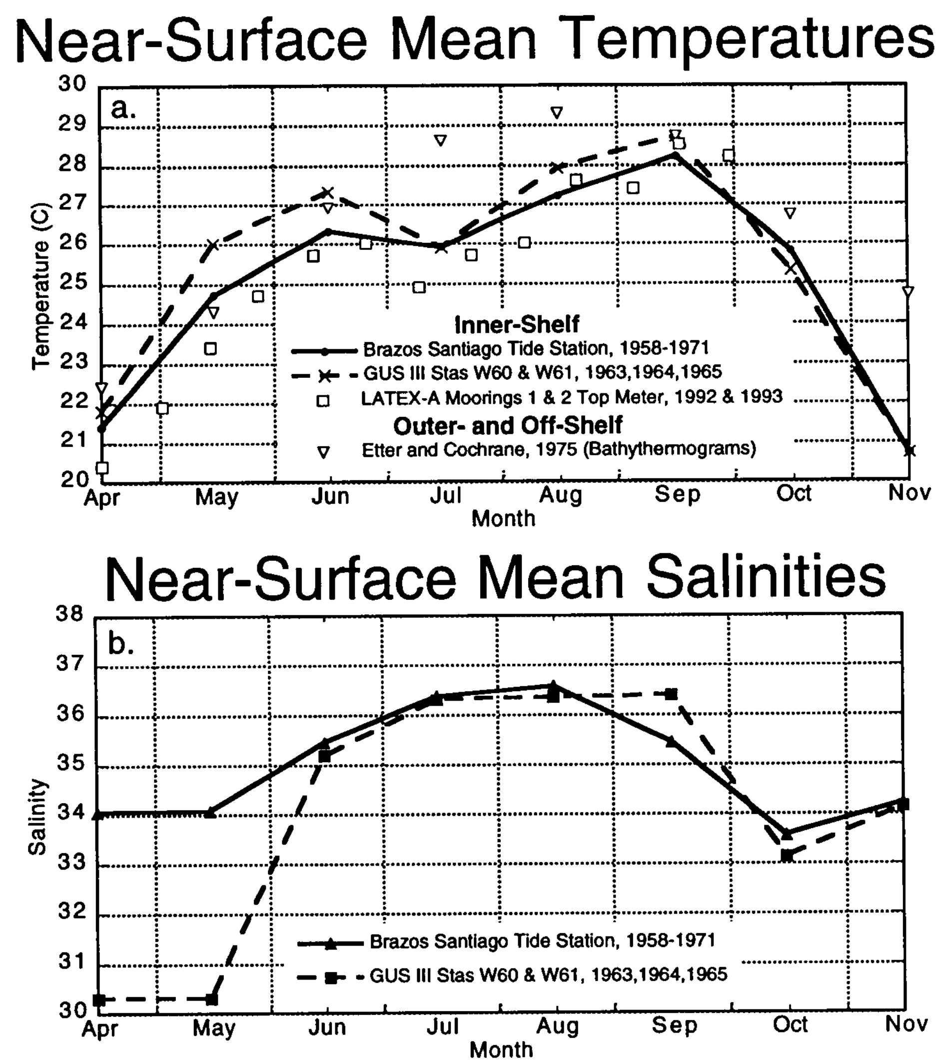

Figure 3D.24. Near surface mean temperatures and salinities from various inner-shelf and outer and off-shelf locations.

Table 3D.1. Relative frequency of coastal cool bands which are cooler by 2° C or more than the adjacent open Gulf and extent 4° or more in latitude along the western boundary. Based on NOAA/NOS/OPC Oceanographic Feature Analyses.

	June	July	Aug	Sep
1992	0.33	0.78	0.33	<0.11
1993	<0.11	0.89	0.44	0.22
1994	0.33	0.89	0.89	0.44
Mean	0.22	0.85	0.56	0.22

April-May, cooling in the nearshore waters is not apparent in the monthly averages during these months.

Compelling evidence of upwelling along the Texas coast is seen in a sequence of AVHRR infrared satellite images received at the Coastal Studies Institute for 7 July, 01 August and 18 August 1993. They show a coastal cool band of water extending from 24° to 28°N inshore of the 50-m isobath, strongest in July, waning in early August but still evident in the mid-August image. Table 3D.1 shows the relative frequency of coastal cool bands based on the subjective analysis of the infrared imagery charts supplied by NOAA/NOS for the months June-September of 1992-1994 (nine charts per month). There is a significant increase in the relative frequency of the occurrence of coastal cool bands in July, decreasing in August in some years but definitely less frequent in September. Contour plots of surface temperature taken from the LATEX hydrography cruises conducted in early August 1993 and 1994 confirm that the low temperatures exist just below the surface along the coast and range from 26-27°C in the south to the 29-30°C upcoast.

Subsurface indications of upwelling can be seen in the vertical sections of potential density and temperature in Figure 3D.25. In May 1993, isopycnals of the anomaly of potential density (σ_θ) slope downward indicating that upwelling is not occurring. In August, the isopycnals and isotherms slope upward, consistent with that expected when upwelling is occurring. A vertical section of nitrate concentrations along line 7 shows very low values in both months with August being the lower of the two. This is contrary to the expectation that nutrients are enhanced by upwelling. We speculate that this non-conservative tracer may have been depleted by phytoplankton uptake. Chlorophyll and oxygen data will be examined in future work.

In Figure 3D.26, a six-month time series for April-September 1992 of 40-hour low-passed alongshore wind stress from PTAT2 and alongshore currents from the top meter on mooring 1 are plotted with unfiltered temperature and salinity series from the same current meter. One sees that some but not all of the upcoast wind events correlate with the episodes of upcoast currents. The most interesting effect occurs in the temperature, which after gradually increasing until mid-June when drops sharply by 4-5°C and stays low for about a month. During the same period, salinity increases 4-5 PSU and remains relatively constant for some time. A similar behavior is seen to occur in 1993, although it occurs later, near the beginning of July. In 1994, conductivity data were not available; however,

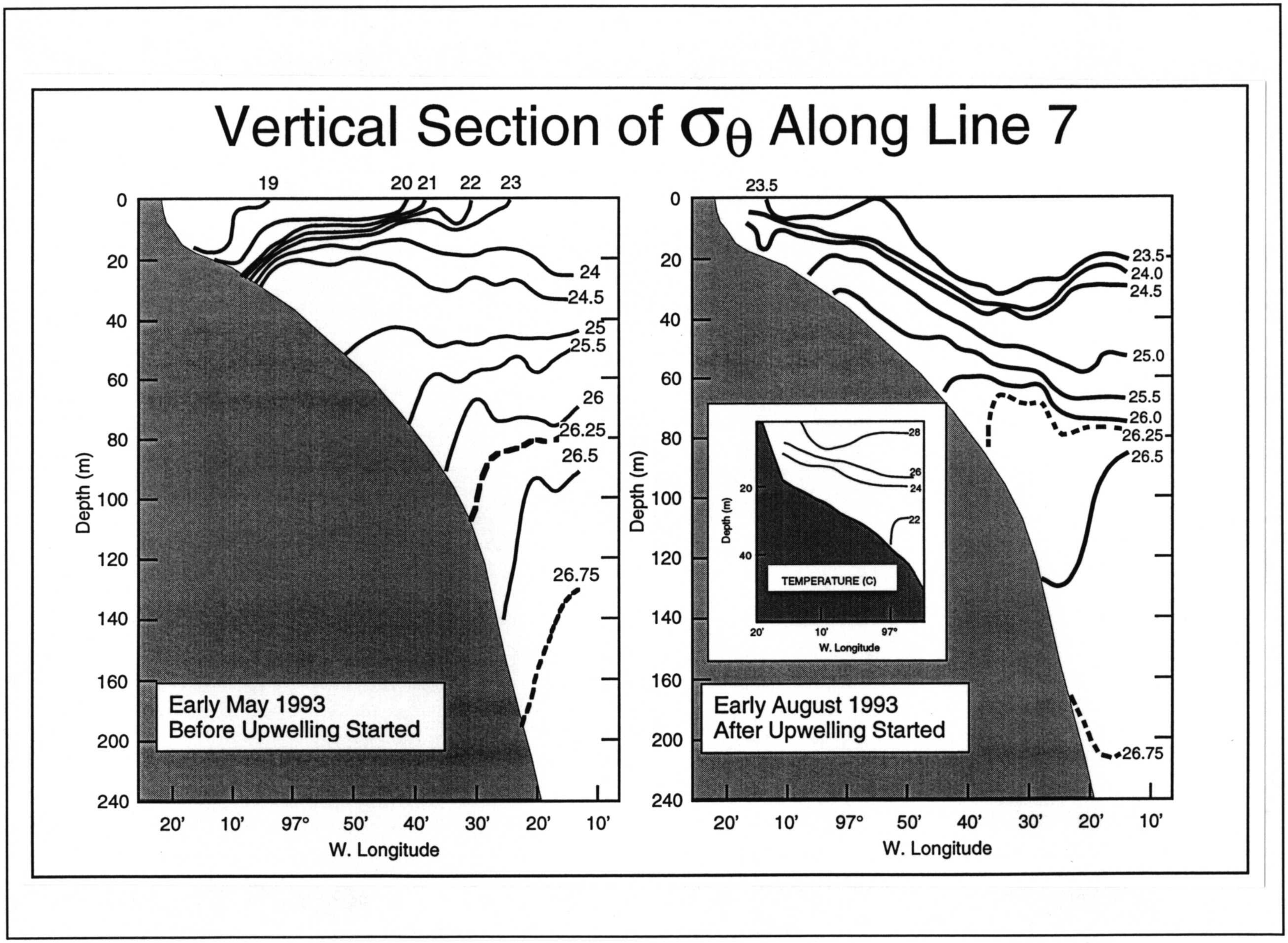

Figure 3D.25. Vertical section of σ_θ of along line 7 in early May and early August 1993 and temperature in August 1993.

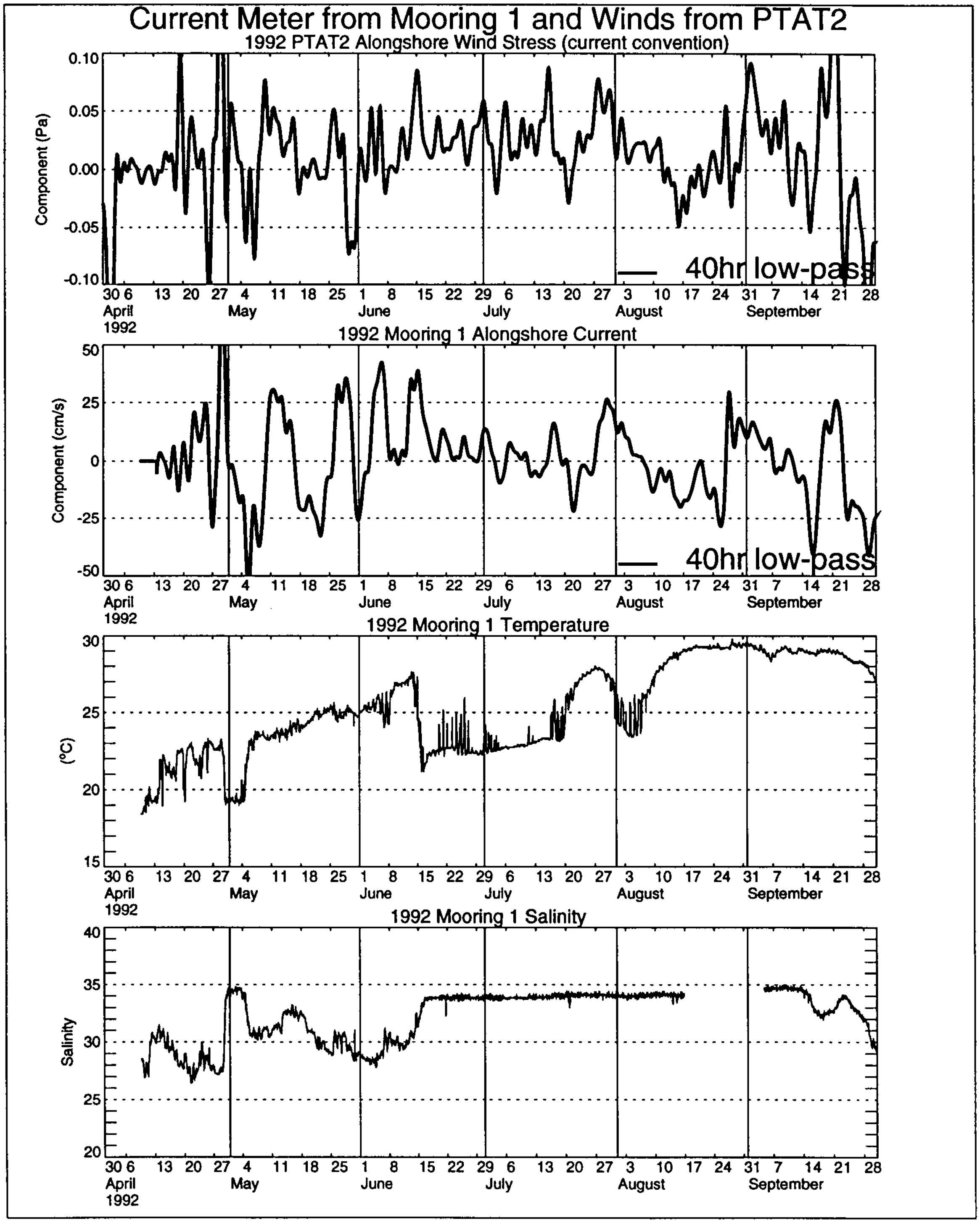

Figure 3D.26. Filtered alongshore wind stress and currents with unfiltered.

Table 3D.2. Six-week means of the alongshore component of currents at top current meters (10-14 m depth) of moorings 1, 2, and 3 combined (cm/s).

	1992	1993	1994	Mean
08 Apr - 19 May	-0.65	-1.08	-8.09	-3.27
20 May - 30 Jun	$<5.52>_{3}$	-4.44	2.57	1.22
01 Jul - 11 Aug	$<4.80>_{3}$	$<4.76>_{2}$	6.72*	5.43
12 Aug - 23 Sep	-5.11	$<5.62>_{2}$	-	0.26

< > Indicates that a six-week mean for one of the moorings is missing. The subscript indicates which mooring was missing.

* Indicates that the records ended with 27 July.

All entries in the table have been given equal weight in computing the multiyear means.

the temperature record showed an analogous drop in late June.

To decrease the variability in the current meter time series, four six-week block averages in each of the years 1992-1994 were made of the alongshore current at moorings 1, 2, and 3 top and the interannual mean computed. These averages are shown in Table 3D.2. Even though the winds at PTAT2 were upcoast in May, a mean downcoast current flow existed. It is not until the strong upcoast winds appear in July and August that a strong upcoast current develops.

CONCLUSION

Mean wind stress is favorable for upwelling along much of the western boundary of the Gulf of Mexico between 20°N and 28°N from April through August. Readily available near-surface temperature records, however, indicate that the episodic upwelling that surely occurs in April and May is too infrequent or weak to be discerned in the mean temperature records for those months. Available current measurements suggest a downcoast mean current for April and May, consistent with weak upwelling. Since the mean near-surface salinity for June is markedly above the April and May means, and the mean alongshore current then is weakly upcoast, June appears to be a transition month. Marked upwelling and an upcoast current are mean conditions for July and August on the basis of all types of data available. However, no significantly high nitrate concentrations were found in the upper layers. In the latter half of June or in July of 1992, 1993, and 1994, the inner-shelf mooring near 27°N, after a moderate upcoast wind fluctuation, experienced a rapid 4° or 5°C drop in temperature that persisted for a more than a month in both 1992 and 1993, and except for some short interruptions, also in 1994. Further investigation is needed on the wind-current interrelation during 1992, 1993, and 1994, and on the cessation of sustained upwelling in late August or early September.

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OBSERVATIONS OF CIRCULATION IN THE NEAR-FIELD PLUME OF THE MISSISSIPPI RIVER AND ADJACENT LOUISIANA BIGHT

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Coastal Studies Institute
Louisiana State University

In April of 1994 a nine-day cruise was conducted to survey the Louisiana shelf from the coast to the shelf edge and from Timbalier Bay to just east of the Mississippi River (Figure 3D.27). The area was surveyed twice during this period with a total of 189

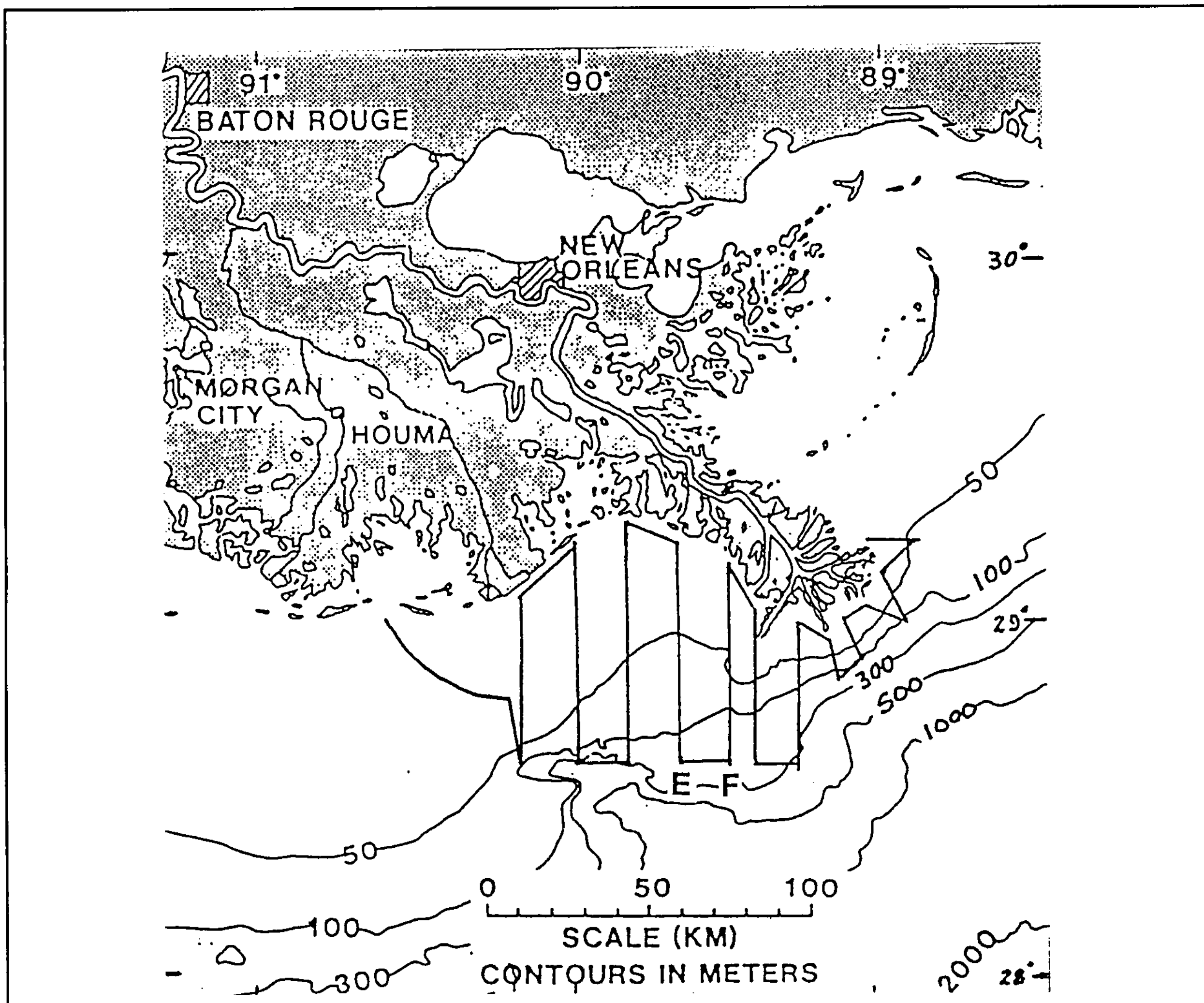

Figure 3D.27. Site map with the cruise track for phase one of the survey.

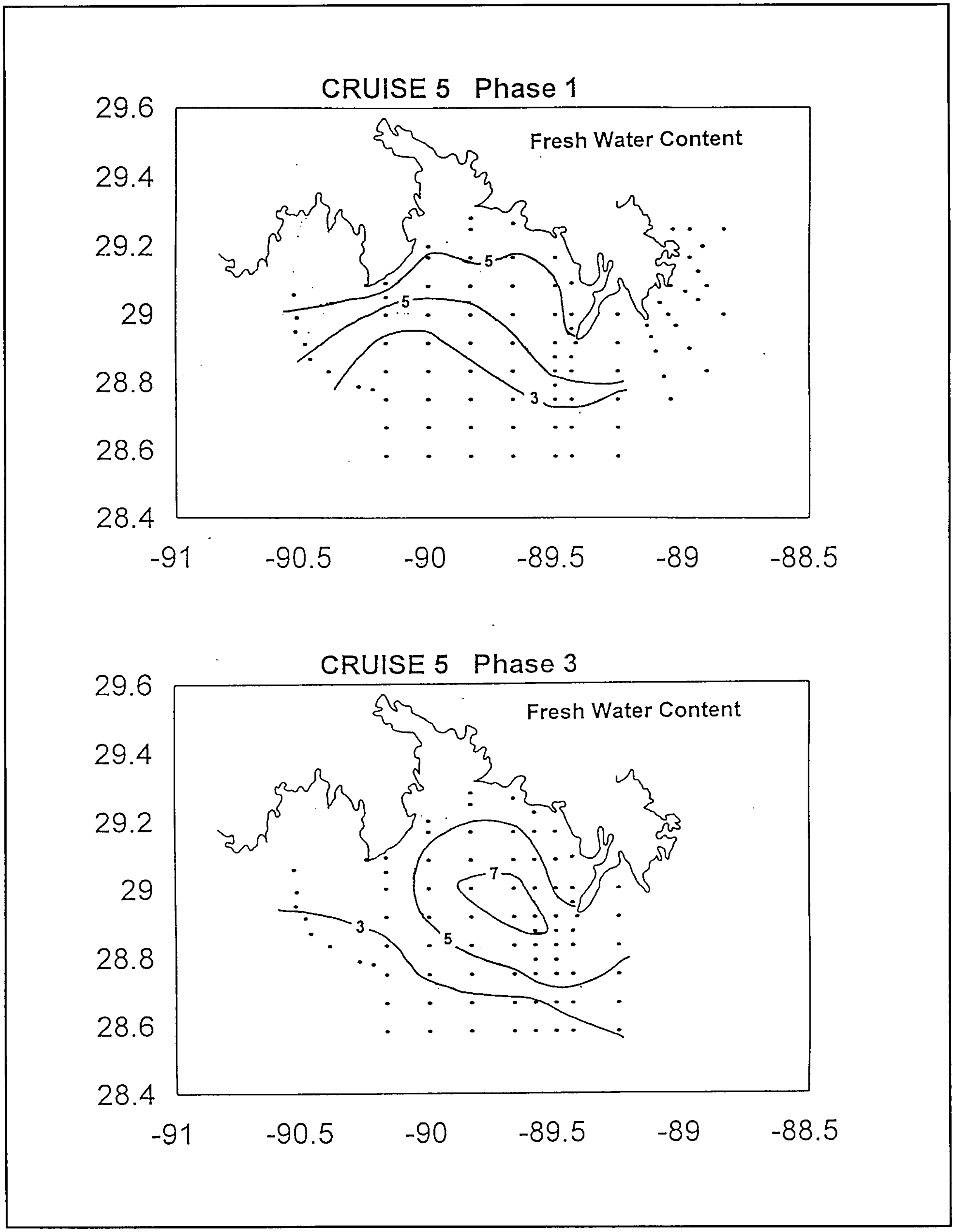

Figure 3D.28. Contours of the freshwater content of the shelf (contours in meters).

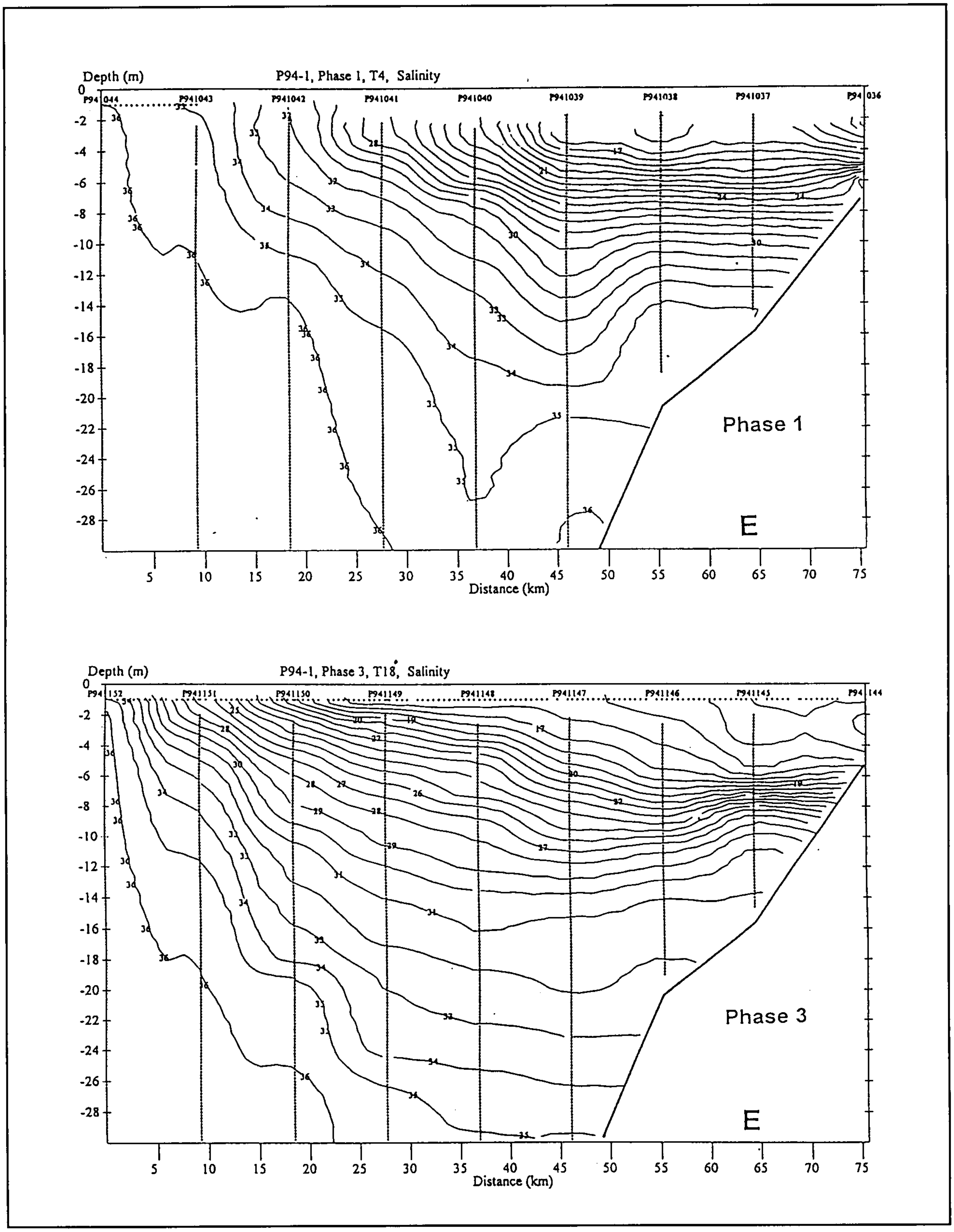

Figure 3D.29. Salinity cross sections from transect E (see Figure 3D.27).

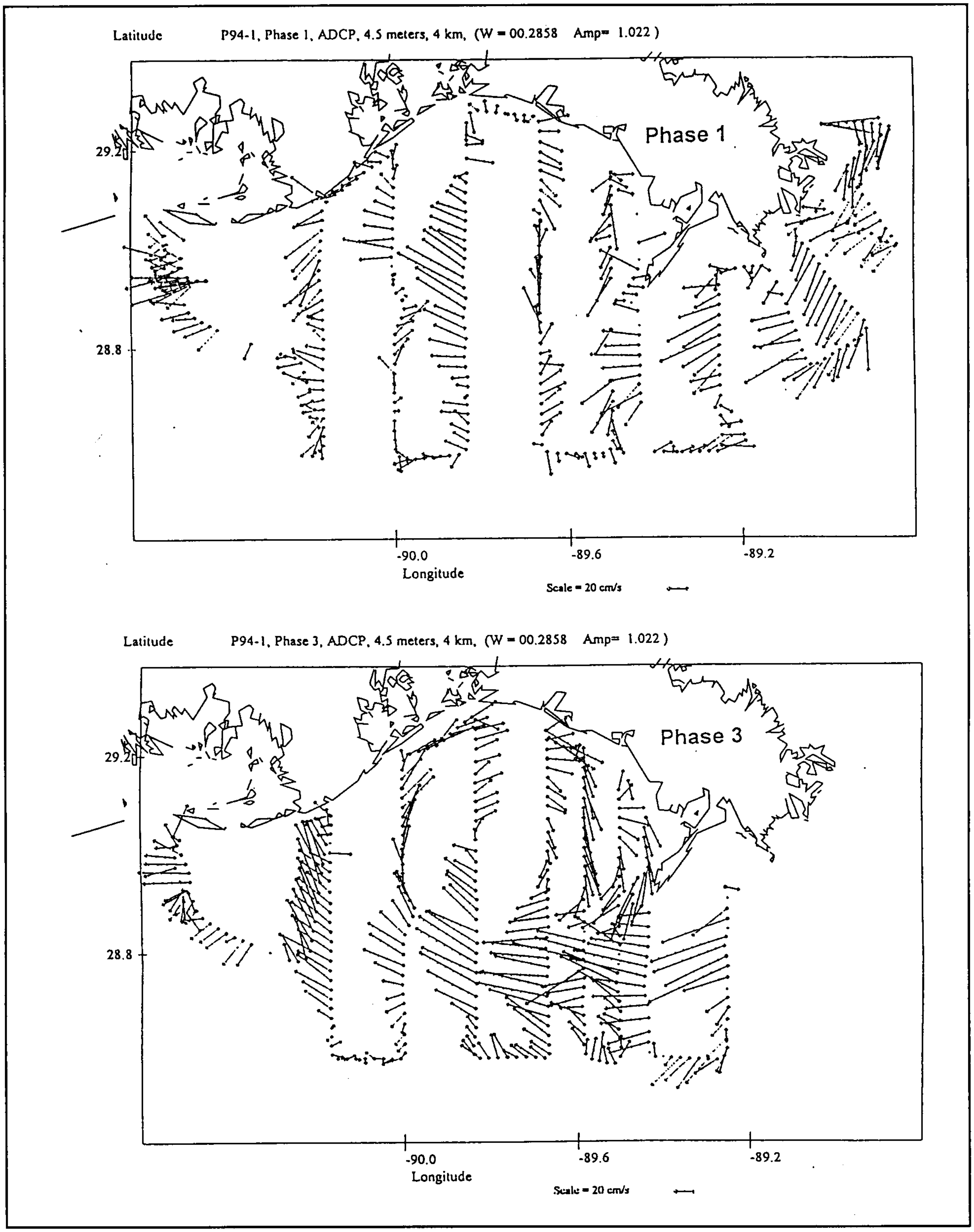

Figure 3D.30. Horizontal currents at 4.5 meters below the surface as measured by the shipboard ADCP. The current vectors are 4 km averages.

CTD stations. Approximately 2,200 km of continuous sea surface observations (from a flow-through data acquisition system) and Acoustic Doppler Current Profiler (ADCP) data were obtained. In addition to the physical measurements, samples were acquired for the determination of biological and chemical properties at about half the stations. The goals of the cruise were to investigate the synoptic distribution of freshwater, sediment, nutrients, and pollutants and the variability of these distributions at time scales of five to 10 days; to investigate the role of the wind in the variability; and to describe the circulation in the Louisiana Bight.

The cruise was divided into three phases: a west to east survey (90 stations) of the area (survey track in Figure 3D.27), a survey of fronts associated with the plume discharging from Southwest Pass, and a resurvey from east to west of most of the area covered in the first phase (the area to the east of south pass was not included). Eighty stations were occupied in the third phase, including 11 stations on a line added between lines E and F in Figure 3D.27. The difference in water properties between the first and third phases will be used to provide an indication of the temporal changes over the large area immediately to the west of the Mississippi River Delta.

During April of 1994 the discharge of the Mississippi River was rising to the 1994 peak discharge of slightly more than 32,500 m^3/s in early May. During the cruise (11 to 21 April) the discharge averaged about 26,500 m^3/s. For several days prior to the cruise, winds were 10 to 13 m/s from the southeast. These southeast winds continued, though at lower speeds, for the duration of the first phase. Near the end of the first phase, a wind shift occurred with the movement of a cold front through the area. Winds shifted to the northeast and east; strong (7 to 10 m/s) at first, but dropping to 3 to 6 m/s for the remainder of the cruise. These two wind regimes provided an opportunity to observe the variability of hydrographic properties in the area.

The southeast winds of the first phase drove the freshwater discharge plume of Southwest Pass sharply into the Louisiana Bight to the west of the delta. The contours of freshwater content (Ketchum and Keen 1955) for this phase show that the maximum freshwater content of greater than five meters bends toward the coast approaching it in the vicinity of the mouth of Bayou Lafourche and extending along the coast to the west (Figure 3D.28). The northeast winds of the second phase produced a different distribution of freshwater. The plume of freshwater is seen as a mound with a maximum freshwater content in excess of seven meters (Figure 3D.28). The five meter contour extends further offshore in the Louisiana Bight and is not seen to extend along the coast to the west. The salinity cross sections for line E (Figure 3D.29) also illustrate the movement of the freshwater plume in response to the different wind regimes. In the first phase the 20 psu isohaline comes to the surface at a distance of about 40 km from the seaward end of the line (28° 35' N). In the third phase the 20 psu isohaline surfaces about 20 km further offshore. The cross sectional area enclosed by the 34 psu isohaline is much greater in phase three than in phase one. In both phases, the rising of the isohalines near the coast is an indication that seawater is upwelling along inner portion of the bight.

During both phases a clockwise gyre was observed in the bight (Figure 3D.30). ADCP data show that the gyre was pushed closer to the coast by the southeast winds of the first survey. Current speeds on the offshore side of the gyre during this phase were as great as 50 cm/s whereas the inshore current speeds were less than 30 cm/s. During the second survey, the center of the gyre was further offshore and the speeds were higher (70-80 cm/s offshore and 30-40 cm/s inshore). ADCP sections indicate that these gyres extended more than 10 meters below the surface.

ACKNOWLEDGMENTS

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CIRCULATION ASSOCIATED WITH LATEX FRONTS AND SQUIRTS

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INTRODUCTION

Surface temperature structure across the Louisiana and Texas continental shelves changes substantially throughout the year. During winter, surface temperature variability is maximized as winter storms move over the northern Gulf of Mexico and remove heat from shelf water masses. Inner shelf waters cool most rapidly as a result of their depth-limited heat storage capacity. This results in a range of temperatures across the shelf with coolest waters close to the coast and warmest waters offshore. In contrast, during summer, almost no surface temperature structure is discernible over the continental shelves of the Louisiana and Texas. An exception is the southeast Texas coastline where relatively cool upwelled waters contrast in temperature to ambient Gulf of Mexico waters during the summer months.

The presence of thermal structure on the shelf enables detection of water masses and tracking of water mass movements over large areas. The first section of this paper presents a synthesis of information on frontal locations, variability, and intensity over the LATEX shelf based on analyses performed on a multi-year archive of NOAA satellite data. In the second section, satellite image data is analyzed in tandem with in-situ current measurements in an attempt to reach a better understanding of circulation associated with fronts and squirts.

FRONTAL ANALYSES

For this study, surface temperatures were extracted from 5 profile lines corresponding to the LATEX-A mooring lines (Locations, Figure 3D.31). The year isdefined here as beginning in September and ending in August to focus on the winter season and to facilitate

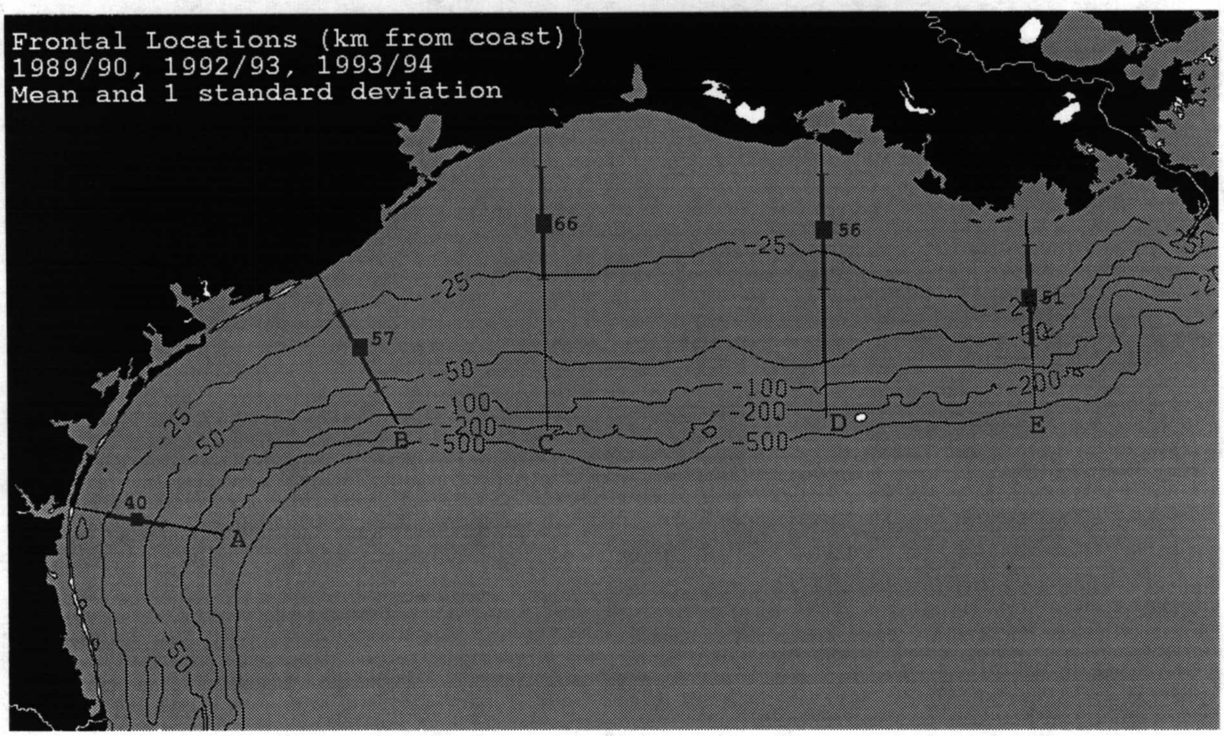


Figure 3D.31. Schematic depicting the average positions of sea surface temperature (SST) fronts along lines A through E as well as 1 standard deviation for the 1989/90, 1992/93 and 1993/94 autumn, winter and spring periods.

the investigation of autumn cooling and spring warming on the shelf. An attempt was made to locate at least 2 cloud-free images across the entire LATEX region for each month. The three years investigated were 1989/90, 1992/93 and 1993/94. A schematic summarizing the average position of shelf fronts along each line and their variability (one standard deviation from the mean) is shown in Figure 3D.31. The fronts along line A are closest to the coast, however, as a result of the shelf narrowing they lie in deeper water than those of lines C, D, and E. The fronts along Line C were furthest from the coast, however, in terms of bathymetry the fronts were in shallower water than those across the rest of the shelf. What is also noteworthy is that the average position of fronts along Line B was in considerably deeper water than that of Line C, perhaps indicating a preferential site for seaward movement of shelf waters, either due to convergences or wind-forced flow. Indeed, the 1989/90 image data showed this region to be a preferential site for mini-squirt formation. The fronts along line A may lie closer to the coast as a result of the frequent occurrence of anticyclonic eddy activity along the seaward end of this line. Warm eddy filaments are often observed spilling onto the shelf in this region, a process which would inhibit the offshore movement of coastal waters. However, just north of Line A where the depth contours curve sharply to the east, a preferential region for squirt formation has been observed. This region lies along the northern flank of the detached anticyclonic eddy zone and thus eastward currents associated with the north side of the eddy would enhance offshore movement of shelf water. It is

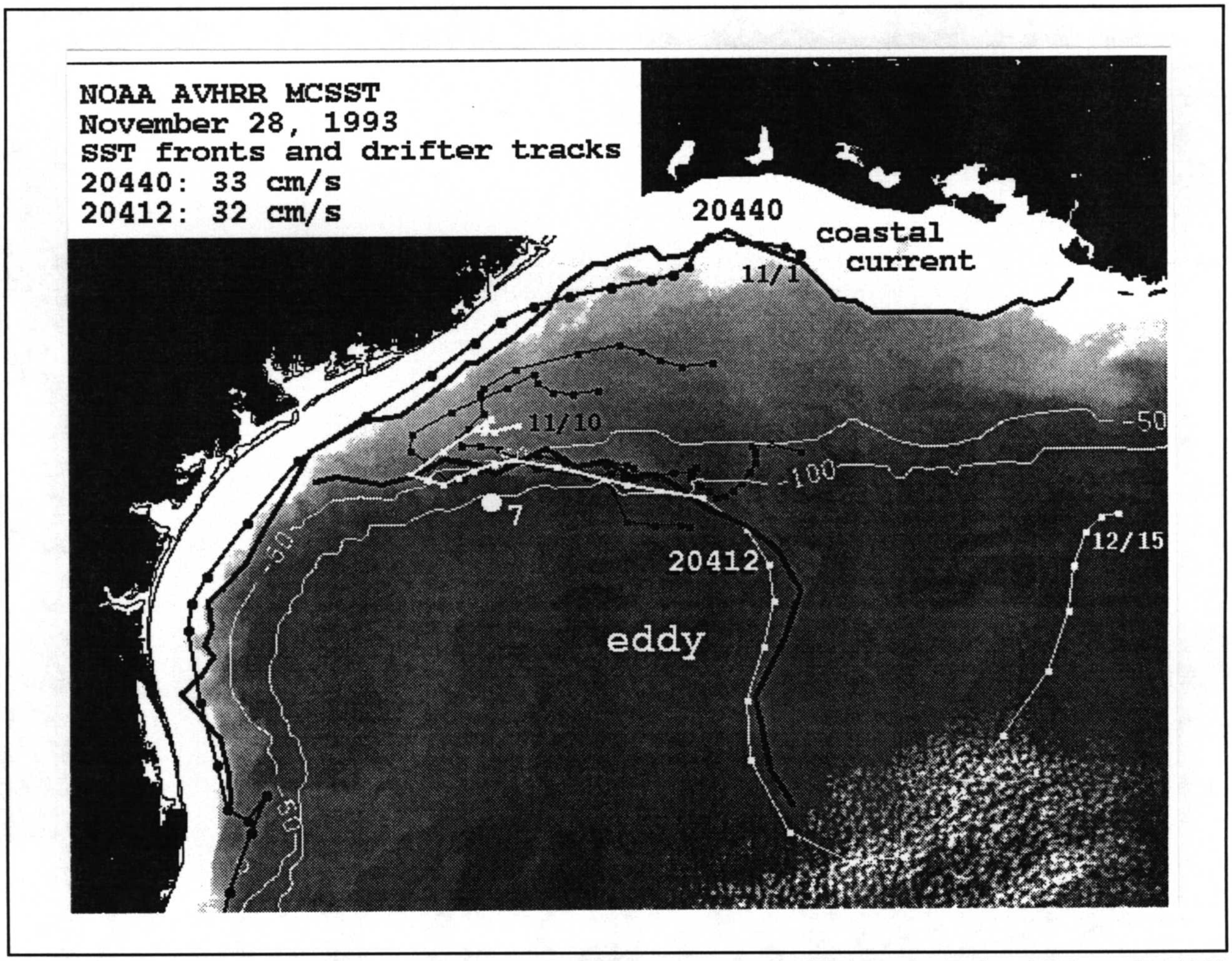


Figure 3D.32. NOAA AVHRR satellite image of surface temperature distributions obtained on 28 November 1993 (1422 UTC) with cool water depicted in light gray shades and warm waters depicted in dark shades of gray. Temperature range is 10 to 28° C. Tracks of surface drifters are displayed with thin solid lines and the dots indicate the start of a new day. The major SST fronts are depicted with the heavier black solid lines.

important to note that the standard deviations of the frontal positions is very high on all the lines except A. The frequent occurrence of multiple fronts along these lines and the movement of fronts with major east to west wind shifts can explain a large part of this variability. The frontal intensity averaged 1.6-2.3° C with little year to year variability in these averages. The strongest fronts (8° C) were observed subsequent to cold air outbreak episodes.

CASE STUDIES

In this section, in-situ measurements are combined with satellite image data to obtain a better understanding of how surface circulation relates to frontal configuration and the development of squirts. Drifter data were obtained from Walter Johnson and Peter Niiler and current measurements were obtained from the LATEX-A program. Figure 3D.32 shows the satellite-observed surface temperatures on 28 November 1993 (14 UTC) with the tracks of several drifting buoys overlain. In addition, the two major SST fronts are depicted solid black lines. The cooler coastal current waters were separated from the warmer offshore waters by a front of 3-4° C. A distinct front (running west to east along the 50-100m isobath) was also detected on the north side of a warm feature associated with a detached Loop Current eddy.

The drifters followed two distinctly different paths. One group (represented by 20440) flowed approximately parallel to the coastal front from just west of Atchafalaya Bay to the Mexican shelf. The other group (represented by 20412 and others) turned offshore near 28° N, 95-96° W and traveled along the 50 m isobath. Although the trajectories of the surface drifters were often rapidly effected by major wind direction shifts, the seaward movement observed in late November was not obviously wind-related It is hypothesized that this offshore movement was caused by a convergence of surface flow fields associated with the detached Loop Eddy and also perhaps a cyclonic eddy to its north. Current speeds within the coastal current and within the squirt averaged about 30 cm/s. Many of the drifting buoys which traveled in the coastal current to the Mexican shelf were advected offshore within a 2nd squirt associated with another detached Loop eddy (not shown). Unfortunately, current measurements were not available in the vicinity of the offshelf flow field depicted in Figure 3D.32, however, records at LATEX-A mooring 7 (Location, Figure 3D.32) on the 100 m contour demonstrated continuous flow to the northeast and east from mid-December to mid-January in opposition to the prevailing downcoast flow within the coastal current (at Mooring 24, Location, Figure 3D.32).

Another prominent site of offshelf flow is the Atchafalaya plume region the SST fronts move landward with winds blowing to the west and seaward with winds blowing to the east. An episode in December 1993 (14-15) was identified when clear sky imagery was obtained simultaneously with current meter measurements at three LATEX-A current meter moorings. Passage of a cold front rapidly reversed the wind field from strong southerly winds to strong westerly and northwesterly winds. The major thermal front of the Atchafalaya plume front moved 40-60 km seaward over the course of 34 hours (the time between clear images). This displacement equated to current speeds of 33-47 cm/s. At the three mooring sites (17, 18, and 19) current reversals occurred almost simultaneously with one another and with the wind direction change. Current speeds ranged from 30-38 cm/s at directions ranging from 103° to 138° T. Thus, the westerly winds (blowing to the east) rapidly forced a current direction change of approximately 180 degrees with the resultant currents traveling in the of the wind and at the deeper depths (10 meters) slightly to the right of the wind direction. The data indicate that a reversal of flow occurred within the water column to a depth of at least 10 meters. When the easterly winds (blowing to the west) resumed the "normal" downcoast coastal current structure was re-established.

These case studies (and others) have enhanced our understanding of circulation associated with fronts and squirts on the LATEX shelf. In addition, they have shown that the satellite-observed thermal features and their movements are usually indicative of the structure and movement of the surface mixed layer.

Dr. Nan Walker is an assistant professor in the Department of Oceanography and Coastal Sciences and the Coastal Studies Institute, Louisiana State University. Her research interests include satellite oceanography, physical oceanography, air-sea interactions and ocean climatology. She obtained her Ph.D. from the Department of Oceanography at the University of Cape Town, South Africa in 1989, her M.S. from the Dept of Marine Sciences, LSU in 1982 and her B.S. from Duke University in marine zoology in 1976.

SESSION 4AB

OCS INDUSTRY ISSUES, PART I: INDUSTRY'S OUTLOOK FOR GULF OF MEXICO OIL AND GAS DEVELOPMENT

Session: 4AB - OCS INDUSTRY ISSUES, PART I: INDUSTRY'S OUTLOOK FOR GULF OF MEXICO OIL AND GAS DEVELOPMENT

Co-Chairs: Mr. Paul L. Kelly and Ms. Carla M. Langley

Date: December 13, 1995

Presentation	Author/Affiliation
Industry's Outlook for GOM Oil and Gas Development	Ms. Carla M. Langley Office of the Regional Director Minerals Management Service Gulf of Mexico OCS Region
Opening Remarks	Mr. Paul L. Kelly Vice President, Rowan Companies, Inc. Chairman, OCS Policy Committee
Future Issues and Policies Affecting the Gulf of Mexico's Capital Investment and Development	Dr. Bruce Appelbaum Division Manager Offshore Division, Texaco, Inc.
Future Industry Research and Technology Needs	Dr. Arnold M. Schaffer Phillips Petroleum Company
The Gulf of Mexico from the Viewpoint of an Independent Operator	Mr. Joe B. Foster Newfield Exploration Company
Legislative and Regulatory Issues Pertinent to the Oil and Natural Gas Industry in the Gulf of Mexico	Ms. Genevieve Laffly Murphy Exploration Coordinator American Petroleum Institute
Gulf of Mexico Program	Mr. R. Michael Lyons Manager of Environmental Affairs Louisiana Mid-Continent Oil and Gas Association

INDUSTRY'S OUTLOOK FOR GOM OIL AND GAS DEVELOPMENT

Ms. Carla M. Langley
Office of the Regional Director
Minerals Management Service
Gulf of Mexico OCS Region

Two half-day sessions, Outer Continental Shelf (OCS) Industry Issues: Part I and Part II, were developed and coordinated using an informal customer-partnership arrangement between MMS and OCS Industry representatives. The first of the two sessions, OCS Industry Issues, Part I: Industry's Outlook for Gulf of Mexico Oil and Gas Development, addresses current and future issues of concern to the region's OCS oil and natural gas industry. Presentation summaries from OCS Industry Issues, Part II: Industry/Agency Cooperative GOM Oil and Gas Regulatory Activities can be found in Session 5A&B.

Mr. Paul L. Kelly, OCS Policy Committee Chairman and Vice President of Rowan Companies developed this session's theme, invited speakers, moderated the session, and coordinated meeting logistics through Ms. Carla M. Langley, the MMS ITM Coordinator. Following Mr. Kelly's opening remarks are presentation summaries from the panel of speakers. Topics include: long-term corporate technology research and industry needs; future issues and policies affecting the Gulf of Mexico's capital investment; the future from the perspective of an independent operator, future OCS legislative and regulatory issues; and an overview of the Gulf of Mexico Program.

Special appreciation is extended to the session Co-Chair, Mr. Kelly, for his time and effort spent creating the session agenda as well as to the panel of speakers for their time spent addressing current and future issues of concern to the OCS oil and gas industry.

Carla Langley is a staff assistant in the Regional Director's Office with the Gulf of Mexico OCS Region of the Minerals Management Service. She joined MMS in 1982 and presently coordinates outreach efforts and special projects. In 1995 she was the Agenda and Logistics coordinator for the Region's Information Transfer Meeting. From 1985 to 1991, Ms. Langley was a physical scientist with the Department of Defense. In this capacity, half of her time was spent overseas aboard U.S. Naval research vessels collecting and analyzing oceanographic and GPS data and monitoring bathymetric subsystem performance for application in the U.S. Fleet Ballistic Missile Program. She is a graduate of the University of New Orleans.

OPENING REMARKS

Mr. Paul L. Kelly
Vice President, Rowan Companies, Inc.
Chairman, OCS Policy Committee

Looking ahead to 1996, one of the most significant events for the U.S. offshore industry will be the final approval of the federal government's Five-Year OCS Leasing Program covering the years 1997 to 2002. The Draft Proposed Five-Year Program announced on 9 August 1995 includes up to 16 lease sales in eight offshore planning areas located exclusively in the Gulf of Mexico and offshore Alaska. Compared to the current program, which itself is very modest, the proposed 1997-2002 program considers three fewer planning areas (8 vs. 11), less acreage (144.2 vs. 207.9 million acres) and fewer sales (16 vs. 18).

Comments on the proposed Five-Year Plan were due last 9 October. The next step in the process will be the issuance of a Proposed Program and Draft Environmental Impact Statement to be issued in January 1996 for a 90-day comment period. Congress, the U.S. Attorney General and the Governors of affected states will receive the proposed Program at this time along with other interested and affected parties. The Proposed Final Program and Final EIS are scheduled for release in August 1996. Final Approval of the Five-Year Program (July 1997-July 2002) is expected to be in October 1996.

The Proposed Five-Year Program makes it clear that the Gulf of Mexico is and will continue to be, for the foreseeable future, America's primary offshore oil and natural gas resource. And, while we may disagree with the Interior Department about overall OCS leasing policy, recent policy initiatives concerning the Gulf implemented or under consideration by Interior's Minerals Management Service recognize growing competition for oil and gas investment capital throughout the world and build confidence on the part

Table 4AB.1. Proposed Five-Year Program, 1997-2002.

High Number of Deepwater Blocks Proposed for Leasing in the Gulf of Mexico		
Planning Areas	No. of Blocks	
	Shallow (< 400m)	Deep (> 400m)
Western Gulf	2,864	3,650
Central Gulf	3,971	5,137
Eastern Gulf	113	559

Source: Minerals Management Service

of industry that the Gulf of Mexico will be a reliable oil and natural gas province in which to invest in the next century. MMS wants to spur new activity in the ultra deep waters of the Gulf. At the same time the agency wants to see as many leases in the shallow waters drilled and resources in existing fields fully exploited, all to assure fair return to American taxpayers. MMS seems to be willing to use leasing policies, royalty policies and regulatory reform to achieve these objectives in a positive way.

The OCS currently accounts for about 14% of U.S. oil production and 23% of natural gas production. All OCS production comes from the Central and Western Gulf of Mexico, with the exception of a limited portion coming from the southern California Planning Area. The percentages attributable to the Gulf are certainly bound to increase. In fact, this year's report from the National Petroleum Council entitled *Research, Development and Demonstration Needs of the Oil and Gas Industry* states that "Deepwater exploration and production in the Gulf of Mexico will progress rapidly during the next 10 to 20 years, primarily due to the advancements in technology and the high per-well producing rates recently confirmed. It is highly probable that the Deepwater Gulf will become the primary supplier of domestic oil and gas in the near future."

Reflecting this industry assessment, the Proposed Five-Year Program, 1997-2002 (Table 4AB.1), shows a high number of deepwater (>400 m) blocks proposed for leasing in the Gulf of Mexico.
At the same time, results of federal lease sales in the Central and Western Gulf of Mexico and state lease sales in Texas and Louisiana in 1995 show continuing high interest in shallower water areas by major companies and independents. Overall the Gulf of Mexico looks good to the industry in terms of both geological prospects and the regulatory regime. Extended reach drilling, 3-D seismic technology, super-computing and leading-edge graphics imaging are all tools which are helping industry reinvent the remarkable Gulf once again. These new tools, sub-salt plays and deepwater prospects, plus some false starts in foreign provinces, are all factors which will continue to cause operators to increase the role of the Gulf in their global exploration strategies in 1996.

Our panel this afternoon is going to look at the Gulf of Mexico from various industry viewpoints, including future issues and policies affecting capital investment and development; future industry research and technology needs; the future from the perspective of a small independent oil and gas company; legislative and regulatory issues pertinent to the Gulf of Mexico; and finally, the petroleum industry's views on the Gulf of Mexico Program, a regional management effort coordinated by the Environmental Protection Agency.

Many of you in the audience are researchers involved in the OCS program. You are scientists, contractors, managers, representatives from government, academia, industry, environmental groups, and the general public. All of our institutions are facing reduced budgets for research and a growing demand for increased efficiency in the way we do our work. From industry's perspective we see a growing need for more collaboration and cooperation among our researchers in industry, government and academia; and I might add, more focus on *real* problems and issues. We all need to look into the same crystal ball, so to speak, and this is what we hope to achieve with our panel this afternoon.

Paul L. Kelly received his B.A. in political science and his J.D. from Yale University. He is vice president of Rowan Companies, Inc. with responsibility for special

projects and government and industry affairs. Mr. Kelly represents the oil service/supply industry on the U.S. Secretary of Interior's Outer Continental Shelf Policy Committee, and in April 1994 he was elected to a two-year term as chairman of that Committee. He also serves as a member of the National Offshore Safety Advisory Committee (NOSAC), sponsored by the U.S. Coast Guard, which provides advice to the U.S. Department of Transportation on offshore mineral and energy issues. Mr. Kelly is also a director of the Alaska Oil and Gas Association, the International Association of Drilling Contractors and Rowan Drilling de Venezuela, C.A., as well as an advisory member of the Executive Committee on the Gulf of Mexico Offshore Operators Committee.

From 1985 to 1987 Mr. Kelly served as managing director of British American Offshore Ltd., London, Rowan's main contracting entity in the North Sea. From 1988 to 1990 he was a director of the British American Business Association in Houston, serving as president of the association in 1989.

FUTURE ISSUES AND POLICIES AFFECTING THE GULF OF MEXICO'S CAPITAL INVESTMENT AND DEVELOPMENT

Dr. Bruce Appelbaum
Division Manager
Offshore Division, Texaco, Inc.

The following remarks are based on a report released in August 1995 by the National Petroleum Council. The slide show that accompanied the presentation is also included here.

Future Issues Affecting the GOM's Capital Investment: These issues apply to the domestic industry as well as directly to the Gulf of Mexico (GOM) and include the following: the present and future state of U.S. energy security; improving dialogue and credibility between industry and its stakeholders; increasing efficiency of exploration and development hydrocarbons; and expediting a deepwater infrastructure and exploitation of marginal/high cost discoveries in both shallow and deepwater.

Trends in U.S. Oil Production and Demand: The U.S. demand for petroleum products has grown by 1 to 2% per year since 1990 while production has declined by about 2% per year during the same period.

Growth of Oil and Gas Imports: In 1993, the U.S. was importing 7.6 MMB/D of oil. In 1994, that number exceeded 9.0 MMB/D, representing over 50% of our oil requirements. If current trends continue, we will reach a level of 12.2 MMB/D before 2010. Natural gas imports in 1985 made up just over 5% of demand. Consumption of natural gas has been increasing by 3% per year since 1991, while production of natural gas has increased by approximately 2% per year for the same period. Imports are projected to account of 15% of demand natural gas.

Oil & Gas Consumption: The oil and gas industry plays a broader role in the U.S. economy than most industry employees and government policy makers realize. Basically, oil and gas are fundamental enablers of the domestic economy. More oil and gas are consumed indirectly via goods and services people buy than through direct sales of fuel to individual consumers.

Oil & Gas vs Other Industries Total Dollar Revenue: The total output of our industry includes many sectors: exploration and production, service and supply, refining, gas processing, transportation and retail sales, yielding about $380 billion yearly generated by over one and a half million people working for more than 40,000 companies. This is about 4.7% of U.S. gross output and does not includes the petro-chemical industry.

The Oil & Gas Industry Provides: Our industry is of major importance to the U.S. economy, providing 4.7% of gross output; 3% of private, nonresidential domestic investment; 2.9% of all industrial research and development funded by U.S. companies; 4.3% of all federal, state, and local taxes; 84.4% of all federal mineral lease royalties; 20.8% of U.S. spending on pollution abatement in manufacturing; wages 14.2% higher than the U.S. average.

Offshore Production as a Percentage of U.S. Production: While offshore production of natural gas has accounted for between 25% and 30% of U.S. production since the late 1970s, offshore oil production has risen rapidly from 15% in 1990 to nearly 25% in 1994. This trend has continued through 1995, with 74% of this production related to the Outer Continental Shelf.

Onshore vs. Offshore Production Crude Oil: Offshore oil production has been growing slowly since 1990. On the other hand Onshore production has been falling rapidly since 1985. This drop includes the decline in Alaskan production.

U.S. GOM Percent of Development Drilling Wells: Much of the growth in offshore production has derived from the significant increase in development drilling in older fields. Three-dimensional seismic and horizontal drilling technology have provided a tremendous opportunity to revitalize many older fields. However, this is not a long term solution to the production declines in the U.S. Accelerating exploration is a vital component to growing offshore production.

GOM Industry 3-D Seismic Coverage: The availability of three-dimensional seismic technology has set the foundation for a number of events. It has set up both the opportunity for field revitalization programs as well as enhancing our ability to evaluate our shelf and deepwater lease inventories. 3-D has become an exploratory as well as development tool.

U.S. Undiscovered Reserves Billion BOE: 30% of the undiscovered hydrocarbons to which we have access are in the GOM. It is up to industry and government to meet the increasing demand for further domestic production.

Industry–Government Relations: Before we can address specific long-term issues, we need to address fundamental issues about how we conduct our business.

Recent Successes of Industry & Government Working Together: Industry and government have successfully worked together include deepwater royalty relief; deepwater workgroup drafting of new production regulations; a workshop on produced fluid issues; a pre/post stack depth migration seismic workgroup for lease sales; a workshop on exploratory unitization; and an ongoing workgroup addressing testing of BOP. These are issues where the desired outcome of interested stakeholders will be achieved through cooperation.

Congressional Oil & Gas Forum: The formation of the Oil and Gas Forum will help industry and government achieve joint results through the opportunity to enhance both communications and understanding. The forum is an educational vehicle consisting of 61 U.S. Representatives and Senators that will provide a more singular voice for our industry.

Perception Is Everything: We are a diversified industry and as such lack a unified vision and a single voice. While achieving a single voice may not be possible, we must take advantage of every opportunity to enhance communications and understanding with a focused position relative to our stakeholders.

Issues Viewed as Critical by Congress: This recent report should help us understand where energy stands relative to other issues in Congress. Interestingly enough, for the quarter ending 30 June 1995, imported oil represented approximately 26% of the U.S. deficit.

Worldwide Competitive Semi Submersible Utilization: A few other issues are relevant here. First is the 100% utilization of deepwater drilling rigs. Clearly, this is a strategic and long-term issue for many of us operating in the GOM. Presently, there are in excess of 1,500 oil and gas leases in water depths greater than 400 meters. The evaluation of these leases will be an issue for years to come. As a matter of information, the third and fourth generation semis are those that can work in water depths greater than 1,500'. In the GOM we presently have 18 second generation, 3 third generation and 4 fourth generation semis in the GOM. We have only one drill ship in the GOM.

Offshore GOM Industry Leasehole & Infrastructure Development as of 1995: The need to foster the development of a deepwater infrastructure is essential. Considering the limited number of rigs and the need to realize a return on capital, this is a major issue for industry.

Capital Comparison: In a generic look at what is at stake from a capital investment point of view, exponential deepwater investment far exceed that of a typical shelf development.

Paradigm Shift for Development Options: Marginal and/or remote discoveries need viable economic options. As we develop new regulations for the deepwater, clearly tankering is a topic that needs to be addressed.

Distribution of Offshore Oil & Gas Platforms Worldwide: 60% of the world's oil and gas platforms are located in the Gulf Coast area.

Disposal of Offshore Oil & Gas Platforms at Sea: The issue of platform abandonment is critically important to the international community. Of concern is the consideration by the London Convention, the global

Information Transfer Meeting
Minerals Management Service

Future Issues and Policies Affecting Gulf of Mexico Capital Investment and Development

December 13, 1995

Dr. Bruce S. Appelbaum
Texaco Exploration and Production Inc.

Future Issues Affecting the GOM's Capital Investment

Offshore Division

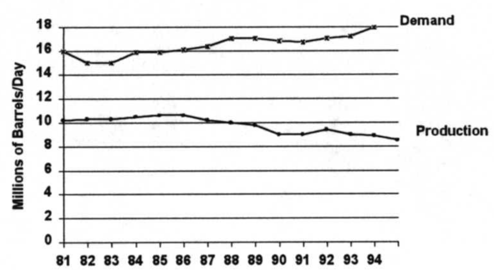
General Themes:

- **Present and future state of U.S. energy security.**
- **Improving dialogue and credibility between industry and its stakeholders.**
- **Increase efficiency of exploration and development hydrocarbons.**
- **Expediting a deep water infrastructure and exploitation of marginal/high cost discoveries in both shallow and deep water.**

Source: Texaco Exploration and Production Inc.

Trends in U.S. Oil Production and Demand

Offshore Division



Source: U.S. DOE

Growth of Oil and Gas Imports

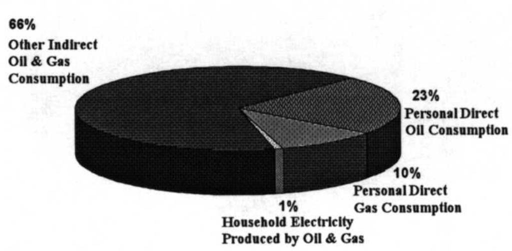
Offshore Division

	1993	2010
Oil (MMB/D)		
Domestic Demand	17.2	20.9
Crude Oil Imports	6.7	8.9
Oil Product Imports	0.9	3.3
Total Imports	7.6	12.2
Oil Import Share of Demand	44%	58%
Gas (TCF)		
Domestic Demand	20.2	24.6
Natural Gas Imports	2.1	3.6
Gas Import Share of Demand	11%	15%

Source: Energy Information Agency, 1995

Oil and Gas Consumption

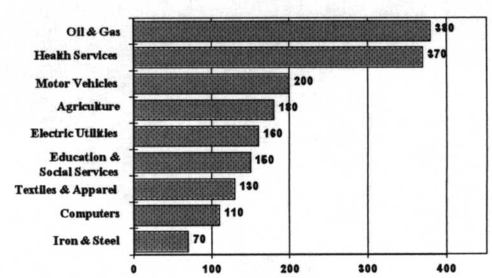
Offshore Division



Source: NPC Future Issues, Aug. 1995

Oil & Gas vs Other Industries Total $ Revenue

Offshore Division



Source: NPC Future Issues, Aug. 1995

The Oil & Gas Industry Provides:

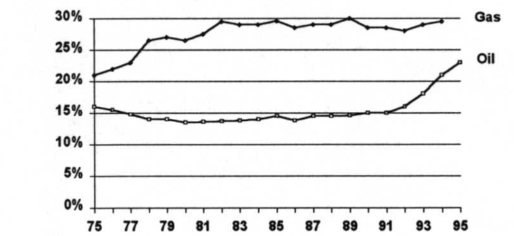
Offshore Division

- 4.7% of U.S. gross out put ($380 billion in 1987)
- 3.0% of private, nonresidential U.S. domestic investment ($22.5 billion in 1987)
- 2.9% of all industrial research and development funded by U.S. companies ($2.2 billion in 1991)
- 4.3% of all federal, state, and local taxes ($91.9 billion in 1991)
- 84.4% of federal mineral lease royalties ($3.1 billion in 1993)
- 20.8% of U.S. spending on pollution abatement in manufacturing ($5.3 billion in 1992)
- Wages 14.2% higher than U.S. average ($30,117 vs $26,361 in 1993)

Source: NPC Future Issues, Aug. 1995

Offshore Production as a Percentage of U.S. Production

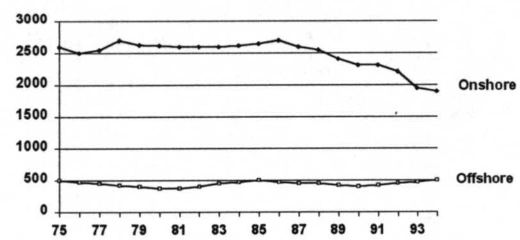
Offshore Division



Source: U.S. DOE

Onshore vs Offshore Production Crude Oil

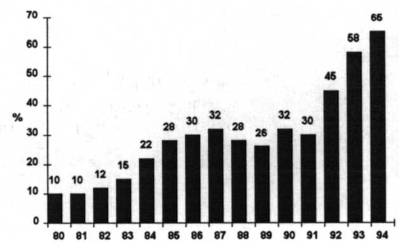
Offshore Division



Source: U.S. DOE

U.S. Gulf of Mexico Percent of Development Wells drilled from Fields/ Platforms older than 5 years

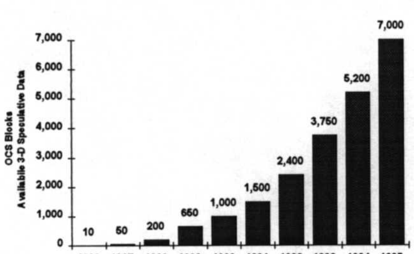
Offshore Division



Source: LL&E

Gulf of Mexico Industry 3-D Seismic Coverage

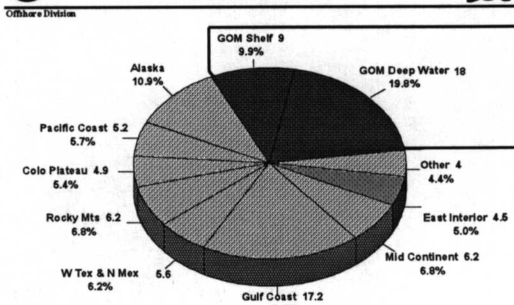
Offshore Division



Source: LL&E

U. S. Undiscovered Reserves Billion BOE

Offshore Division



Source: Incentives to deep water drilling (MMS), Undiscovered oil & gas resources (MMS), GOM Deep Water Article (Howard, Weil)

Source: Texaco Exploration and Production Inc.

Industry - Government Relations

Offshore Division

- Focus on maintaining and improving U.S. oil and gas industry's ability to compete in world markets.
- Encourage science, economic, and energy education.
- Focus on economically efficient environmental protection that weighs the cost of protection against the benefits.
- Foster efficiency increases of technological development (Deep Star).

Source: Texaco Exploration and Production Inc.

Recent Successes of Industry and Government Working Together

Offshore Division

- Deep Water Royalty Relief
- Deep Water Workgroup Drafting New Production Regulations
- Workshop on Produced Fluid Issues
- Pre/Post Stack Depth Migration Seismic Workgroup for Lease Sales
- Workshop on Exploratory Unitization
- Ongoing Workgroup Addressing Testing of BOP

Source: Texaco Exploration and Production Inc.

Congressional Oil & Gas Forum

Offshore Division

Objectives:

- To promote greater understanding on the part of the public and policy-makers of the benefits that a strong domestic oil and gas industry provides to the U.S. economy as a whole and to millions of American consumers;
- To educate policy-makers about the impact of existing and proposed laws and regulations on the domestic oil and gas industry;
- To provide a forum for discussion and action by members of the Forum on issues of common interest affecting the domestic oil and gas industry.

Source: Congressional Oil & Gas Forum

Perception is Everything

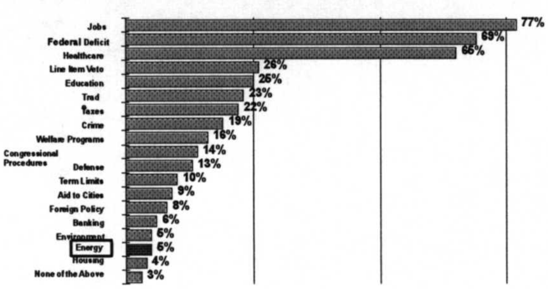
Offshore Division

- The Oil and Gas industry cannot ignore the evidence of its negative public image.
- Stakeholders' understanding and opinions of our industry will effect future policy.
- Recognition of the importance of public policy.
- Acrimony need correction.

Source: Texaco Exploration and Production Inc.

Issues Viewed as Critical by Congress

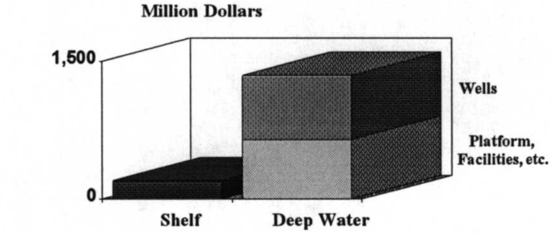
Offshore Division



Source: Bonner & Associates/Gallop Poll

Capital Comparison

Offshore Division



Source: Texaco Exploration and Production Inc.

Paradigm Shift for Development Options

Offshore Division

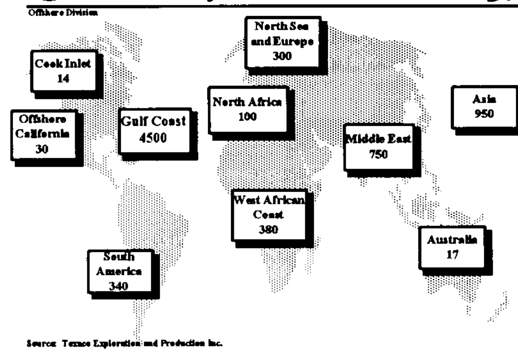
OFFSHORE TANKERING

- Utilized in North Sea
- Presently Barging in GOM
- USCG Approved Lightering Zones

Source: Texaco Exploration and Production Inc.

Distribution of Offshore Oil and Gas Platforms Worldwide

Offshore Division



Source: Texaco Exploration and Production Inc.

Disposal of Offshore Oil and Gas Platforms at Sea

Offshore Division

- Current guidelines of the International Maritime Organization require all platforms in less than 75 meters be removed (except approved artificial reef programs)
- Beginning in 1998, IMO requirements for complete removal will extend to all platforms installed in less than 100 meters.
- Potential worldwide ban on disposal of platforms at sea (London Convention proposal).
- Of the 181 platforms in water depths of 75 meters or greater off the U.S. coast it is estimated that incremental costs could range from $600 MM to $1.75 billion.

Source: ICF Resources Inc., Nov. 1995

Stable and Predictable Regulatory Practices

Offshore Division

- Must continue to have a single regulatory agency which understands our industry if we are going to grow investment capital.
- Require cost benefit analysis for regulatory intervention.
- Use goal-oriented regulatory mechanisms where regulatory intervention is necessary.

Source: Texaco Exploration and Production Inc.

Access Beyond Central and Western GOM

Offshore Division

- Need to test consensus building as a prelude to conducting an entire Eastern Planning Area lease sale
- Change the prevailing attitude of "Whether to Proceed" to one of "How to Proceed"
- Examine cost/benefit analysis of keeping certain areas "off limits"

Source: Texaco Exploration and Production Inc.

Conclusion

Offshore Division

- Gulf of Mexico is critical to energy security of our nation.
- Must maintain an efficient and viable OCS (Shelf) exploration and development program.
- Need to grow a profitable deep water business in the GOM.
- Apply cost/benefit analysis on regulatory issues.
- Encourage cooperation between industry and government.

Source: Texaco Exploration and Exploration Inc.

authority to regulate offshore E & P discharges, emissions and safety, of the possible worldwide ban on abandonment in place or by scuttling in deeper waters.

Stable and Predictable Regulatory Practices: Consistent with industry arguments relative to the devolution of the MMS, our ability to risk and invest capital is rooted in a stable and predictable regulatory arena. As such, we must have one central regulatory agency to deal with E & P functions in the GOM. Also, industry and government must understand the trade-off between costs and benefits of our regulatory requirements.

Access Beyond Central and Western GOM: We appreciate the MMS's scheduling of an Eastern Planning Lease Sale in the next five-year leasing program. Especially, since we have not had a lease sale in the Eastern GOM since 1988. However, we would urge the MMS to conduct multiple sales in this area as well as to expand the area available for leasing to the east and south to include areas with existing leases in the Eastern GOM. The question remains as to how we proceed elsewhere in the Eastern GOM.

Conclusion: The mission of Texaco's Offshore Division is to increase the value of its traditional shelf business while growing a new, profitable business in the deepwater Gulf. In some measure this is also the mission of our industry in the Gulf, as this area becomes increasingly critical in supplying the energy needs of our country for the foreseeable future. The technology and regulatory environment for this work are being supplied by an industry and government that are growing more aware that cooperation on our common agendas is the only way that the growing expense and increasing complexity of our business can be managed. Now we need to be more diligent in emplacing policy and procedures that recognize that win-win for industry and government is also a big win for the American people.

Dr. Bruce S. Appelbaum, Division Manager of the Offshore Division of TEPI's East Region in 1995, was responsible for exploration and producing operations in all Federal waters and the Texas State waters in the Gulf of Mexico. Since that time he has been promoted to President of Texaco's International Exploration Division located in Houston. Dr. Appelbaum joined Texaco in 1990 as Division Manger of the Offshore Exploration Division. The Division became increasingly focused and profitable subsequent to his arrival and is being benchmarked by several organizations. His work with the Exploration Planning Group facilitated rightsizing and overhead reduction. He also championed the integration of exploration and producing operations which is the core of the East Region organization. He is a member of the Technical Advisory Council Board of EPTD and Upstream Planning Group. Prior to his arrival at Texaco, Dr. Appelbaum worked at several independent oil companies where he was instrumental in developing successful exploration programs primarily in the Gulf of Mexico, but also including international arenas such as the North Sea and Gulf of Suez. Dr. Appelbaum received a bachelor of arts degree in geology in 1969 from State University of New York, a master's degree in geology oceanography in 1971, and a Ph.D. in geological oceanography in 1974 from Texas A&M University.

FUTURE INDUSTRY RESEARCH AND TECHNOLOGY NEEDS

Dr. Arnold M. Schaffer
Phillips Petroleum Company

The presentation focuses on the results of a recent report of the National Petroleum Council that analyzes the near- and long-term technology needs of the oil and gas industry. In her letter of 27 July 1994 to the National Petroleum Council, Secretary O'Leary asked the NPC to conduct a study of the research, development, and demonstration needs of the natural gas and oil industry. The scope includes both the upstream and downstream sectors and encompasses natural resource identification through the output of the refinery and the gas processing facilities. The context for reporting these needs is the importance of oil and gas to the vitality of the American economy. In addition, the study examines the relevant capabilities and role that the nine major national laboratories and the National Institute for Petroleum and Energy Research (NIPER) could play in providing technical and scientific support to the industry. (The national laboratories included are Argonne, Brookhaven, Idaho National Engineering Laboratory, Lawrence Berkeley, Lawrence Livermore, Los Alamos, Oak Ridge, Pacific Northwest, and Sandia). The role of other public and private labs in meeting the needs of industry also is discussed. Finally, the issues of collaboration and barriers to working with the government laboratories are discussed.

The National Petroleum Council, a federally chartered and privately funded advisory committee, was established by the Secretary of the Interior in 1946 at the request of President Harry S. Truman. In 1977, the NPC's functions were transferred to the U.S. Department of Energy. The purpose of the NPC is solely to advise, inform, and to make recommendations to the Secretary of Energy with respect to any matter relating to oil and natural gas submitted to it or approved by the Secretary of Energy. The NPC's response is provided to the Secretary in the form of written reports approved by its membership.

Wayne Allen, CEO of Phillips Petroleum, chaired the NPC committee responsible for the report. Patricia Godley, Assistant Secretary, Fossil Energy, was co-chair. A subcommittee co-chaired by Charlie Bowerman of Phillips and Sandra Waisley of DOE drafted the report with assistance from a Task Group on Industry Needs chaired by Ken Cuccinelli of Consolidated Natural Gas and a Laboratory Capabilities Task Group chaired by Barry Coon of Conoco. Given the budget and policy debates occurring in Washington—particularly the debate on the future of DOE and the National Laboratories, the Committee adopted an ambitious schedule which resulted in the final report being presented to the NPC membership on 9 August 1995.

While planning the scope of the report, the NPC participants agreed that the Secretary's request could best be met by undertaking a detailed study; i.e., there was perceived to be value to the industry in going through the process. For example, it is important for the industry to understand common needs and opportunities for reducing the cost of satisfying these needs through cooperation/collaboration. In addition, preparation of a "technology roadmap" would serve both industry's and the DOE's needs by not only summarizing the direction that industry is taking but serving as an important tool for the allocation of government research funding and laboratory resources. A summary of the R&D needs would also be an opportunity to point out the importance of the oil and gas industry—both to the economy of the nation and in comparison to other energy programs.

The report was divided into four sections. The first summarizes the current role and vision of the future of the oil and gas industry. The second part describes the industry's technology needs of the industry, both in the near- and long-term. The information in this chapter was developed from a detailed technology needs survey. The third section describes the capabilities of the national laboratories and NIPER relevant to the oil and gas industry. Finally, the report summarizes how industry needs can be met by collaboration and the role of the DOE laboratories in this process.

The conclusions of the NPC, presented in the final report, Volume I, are that oil and gas are essential to maintain economic growth, a high standard of living and the national security of the United States. Oil and gas supplied nearly 65% of the total energy demands in 1993. Although alternative energy sources are important, oil and gas will continue to be the major source of energy for many years to come. The U.S. economy continues to grow based on energy from oil and gas, priced in some cases in real terms at pre-1980 levels. The industry faces significant challenges efficiently to find, produce, process, and convert into products new energy reserves at acceptable costs while complying with regulation. The report concludes that achievement of the necessary technological advancements is a strategic imperative for industry and the nation.

Industry's technology needs were determined by combining information from a comprehensive survey sent to a large cross-section of the industry and other pertinent information from studies completed in the last several years. The survey was sent to 130 members of the National Petroleum Council with 89 responding. Responses include information on 250 technologies in 11 key technology areas. The responses identified highest priority technologies based on business impact and likelihood of not being met under a business-as-usual scenario. (The 11 key technology areas include exploration, development, drilling and completion, production, deepwater offshore, Arctic Region activities, oil processing and refining, gas processing, gas gathering, gas storage, environmental and regulatory).

The industry survey revealed technical capabilities that are expected to have high impact, though some of them may not be available when needed given the current stage and mode of technology development. These are different depending on size of company, type of the business, etc. The upstream needs having the highest impact and least likelihood of availability include: high resolution depth imaging, improved well productivity, hydrate control and prevention, paraffin control, and horizontal well technology. The downstream needs identified in the report include such areas as catalysts with improved selectivities, yields, and lifetimes, new approaches to refining heavy feeds, improved energy efficiency of processes and equipment, improved plant and process reliability, and separations technology.

The section on laboratories describes the specific capabilities of the nine DOE national laboratories plus NIPER related to the specific technical areas surveyed. The laboratories prepared one-page summaries of projects, which reflect current possibilities of application in areas of direct interest to the oil and gas industry. The laboratories also provided a description of their potentially valuable enabling capabilities and technical strengths that are not now necessarily being applied. The laboratories have significant funding and a large number of projects in the three technology needs categories of environmental and regulatory, oil processing and refining, and development. The laboratories participate at a modest level in the technology needs categories of exploration, drilling and completion, and production. They participate at a low level in the other broad technology needs categories.

The report describes "a new paradigm for oil and gas research" which calls for gaining advantage from using technology rather than from owning it. The survey found industry strongly willing to collaborate which contrasts sharply with earlier NPC studies suggesting oil and gas industry reluctance toward DOE involvement. In contrast, the current report states where industry wants DOE's help—and where they don't.

Dr. Arnold M. Schaffer has worked at Phillips Petroleum Company for the past 21 years. His current position is Manager of the Environment and Technical Information Division in Corporate Technology. Previously, he has held management positions in such areas Fundamental Catalysis, Refining Research, and Analytical Chemistry. Dr. Schaffer received his B.S. in chemistry from Polytechnic University and his Ph.D. in physical chemistry from the University of Washington.

THE GULF OF MEXICO FROM THE VIEWPOINT OF AN INDEPENDENT OPERATOR

Mr. Joe B. Foster
Newfield Exploration Company

The slide show that accompanied this presentation is included with the text.

Independent operators are playing an increasingly important role in the drilling for and production of oil and gas in the Gulf of Mexico.

During the second quarter of 1995, non-integrated, non-affiliated independents operated 18.8% of total Gulf of Mexico oil and gas production, as compared with 9.4% in 1986. Further, independents owned 33.1% of the primary term acreage in water depths less than 600 feet, as compared to 31.6% owned by majors and 28.5% owned by other integrated or affiliated companies. Since this is largely exploration acreage, these figures would indicate an even greater role for independents in the future.

Since the oil price collapse of 1986, lower prices and deregulated markets have led to downsizing of the majors, dramatic efficiency improvements, and widespread sharing of technology and costs. These changes have given more independents the capability to enter the Gulf of Mexico.

Further, barriers to entry into the Gulf by independents have been lowered as geophysical data costs have come down, area wide lease sales have been held, infrastructure has been made available to independents on a rental or fee basis, reuse of used platforms has become commonplace, and lag times between discovery and first production have dropped from three to five years to six months to a year and a half.

Independents have been found to add value in the Gulf of Mexico by achieving lower unit costs and lower economic limits as many oil/gas fields near the end of their life. Independents also have the continuity and diversity of viewpoint to be persistent drillers, testing smaller targets than the majors might, intensely developing old fields, and sometimes making large discoveries.

Concerns have been expressed about the financial capability of independents and about their ability to

MMS ITM

THE GULF OF MEXICO FROM THE VIEWPOINT OF AN INDEPENDENT OPERATOR

PRESENTATION SLIDES

JOE B. FOSTER
NEWFIELD EXPLORATION COMPANY
DECEMBER 13, 1995

NEWFIELD

Gulf of Mexico OCS Gross Operated Production

Million Cubic Feet of Natural Gas Equivalent Daily
(MMCFGE/D)

Second Quarter 1995

	MMCFGE/D	PERCENT
14 Majors	11,707	60.8
16 Other Integrateds/Affiliate	3,139	16.3
20 Independents	3,614	18.8
All Others	784	4.1
	19,244	100.0

NEWFIELD

Gulf of Mexico OCS
Primary Term Gross Acreage Holdings

600' Water Depth or Less - Thousands of Acres

July, 1995

	ACRES	PERCENT
12 Majors	2,599	31.6
22 Other Integrateds/Affiliates	2,342	28.5
31 Independents	2,717	33.1
All Other	561	6.8
	8,219	100.0

NEWFIELD

Gulf of Mexico OCS
Gross Operated Production

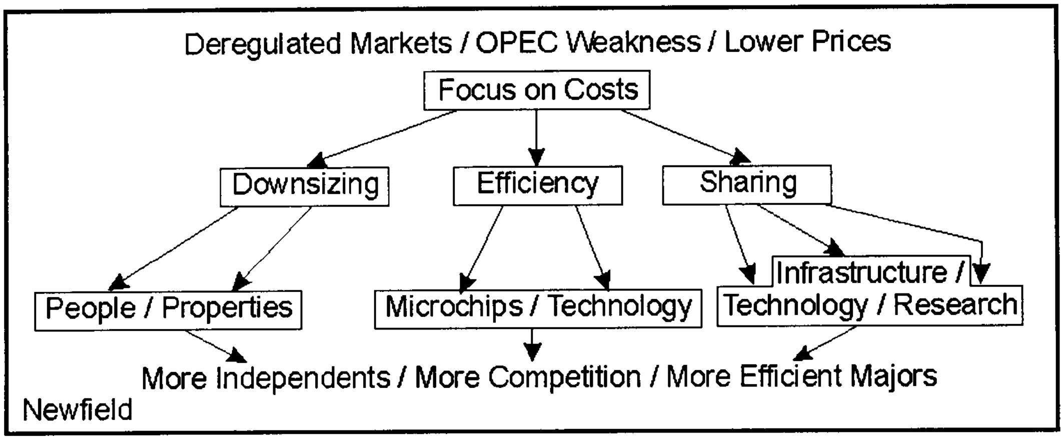
Million Cubic Feet of Natural Gas Equivalent Daily (MMCFGE/D)

1986			SECOND QUARTER 1995		
	MMCFGE/D	PERCENT		MMCFGE/D	PERCENT
13 Majors	11,466	67.7	14 Majors	11,707	60.8
15 Other Integrateds/ Affiliates	3,778	22.3	16 Other Integrateds/ Affiliates	3,139	16.3
20 Independents	1,586	9.4	20 Independents	3,614	18.8
All Others	108	0.6	All Others	784	4.1
Total	**16,938**	**100.0**	**Total**	**19,244**	**100.0**

NEWFIELD

Revolution / Evolution in E&P

Since 1986



Gulf of Mexico OCS
Gross Operated Production Ranked by Operator

Million Cubic Feet of Natural Gas Equivalent Daily (MMCFGE/D)

1986

Rank	Operator	MMCFGE/D
1	Shell	2,241
2	Chevron	1,969
3	Exxon	1,287
4	*Tenneco*	1,046
5	Arco	1,038
6	Conoco	1,032
7	Texaco	980
8	Mobil	814
9	Marathon	737
10	Pennzoil	634
	Total Top 10	11,778
11	Unocal	575
12	Amoco	524
13	*Transco*	402
14	Odeco	352
15	CNG	323
16	*McMoran*	291
17	*Placid*	271
18	Kerr-McGee	232
19	ORYX	211
20	Phillips	194
21	OXY	180
22	Samedan	151
23	*Mesa*	143
24	*Forest*	129
25	*Superior*	101
	Total Top 25	15,857
	Total OCS	16,938
	Percent Top 10	70%
	Percent Top 25	94%

Italics = *Gone*

Second Quarter 1995

Rank	Operator	MMCFGE/D
1	Shell	2,510
2	Chevron	2,052
3	Mobil	1,113
4	Unocal	1,039
5	Exxon	954
6	Texaco	861
7	Pennzoil	693
8	Vastar	609
9	Conoco	606
10	Marathon	596
	Total Top 10	11,033
11	Amoco	593
12	*Walter*	457
13	Murphy	362
14	*BP*	345
15	Samedan	331
16	*Norcen*	322
17	Kerr-McGee	303
18	*Apache*	301
19	*Newfield*	292
20	CNG	284
21	ORYX	278
22	*Amerada Hess*	232
23	OXY	228
24	*Zilkha*	213
25	Phillips	196
	Total Top 25	15,770
	Total OCS	19,244
	Percent Top 10	57%
	Percent Top 25	82%

Italics = *New*

Newfield

Changed Circumstances on the Gulf of Mexico Shelf to About 600' Water Depth

	1950's to Early 80's	Late 80's to Now
Perceived Potential	Highly attractive province with hugh reserve potential.	Mature province with good potential in smaller, deeper fields and in exploitation.
Technology	Expensive; proprietary; limited availability.	Lower cost; shared data, wide-spread availability.
New Leases	Vey expensive; limited offerings.	Less expensive; areawide lease sales.
Farmouts	Infrequent.	Common following areawide sales.
Producing Property Acquisitions	Rare except in mergers and company acquisitions.	Available due to downsizing and more marginal fields.
Operations	Large staffs, propietary infra-structure required.	Turnkeys, outsourcing, partnering, shared or rented facilities common.
Lag Time- Discovery to First Production	3-5 years; pipeline and market limitations.	0.5 - 1.5 years; many pipelines; open acess; common carriers.
Barriers to Entry	High - daunting to independents.	Low -. attractive to independents

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How the Independents Add Value in the Gulf of Mexico

- Economy in Operations
  - Lower unit costs in small operations
  - Lower economic limits
- Continuity and Focus
- Diverse Viewponts
- Persistence in Drilling
  - Smaller exploration targets
  - Intense development/exploitation
  - Finding the occasional big one
- Financial Incentives for Top Oil Finders/Operators

NEWFIELD

Concerns About Independents in the Gulf

- Financial Capability
  - Initially
  - To dismantle and abandon
- Technical/Operating Capability
- Safety and Environmental Capability
  - Compliance
  - Ability to deal with a disaster

NEWFIELD

Concerns Of Independents in the Gulf

- Continued Ability to Participate
  - Bonding - OPA 90 - Availability of Insurance
- Availability of Exploration Acreage -
  Areawide Leasing - Acreage Turnover
- Handling of Dismantlement/ Abandonment Liabilities in Property Acquisitions
- Implementation of Saftey and Environmental Management Program (SEMP)
- Actions of Irresponsible Operators
- Appropriate Level of Regulation/Inspection

NEWFIELD

deal with the higher cost structure in the Gulf of Mexico, as well as their ability properly to dismantle and abandon properties they acquire from others. Concerns also exist about the technical and operating capability of some independents, about their willingness and ability to comply with all safety and environmental regulations, and about ability to deal with a disaster. But Minerals Management Service (MMS) has implemented many regulations and guidelines for adequately dealing with these concerns, and this author concludes that the value added by independents far exceeds the relatively minor costs of their presence.

On the other hand, independents have some concerns about operating in the Gulf of Mexico. Will regulations, such as required in the Oil Pollution Act of 1990, become too stringent to allow their continued participation? Will there be inhibitions against the turnover of exploration acreage? Will transfers of producing properties from large companies to independents become more difficult? Will the implementation of a voluntary Safety and Environmental Management Program (SEMP) be adequate to prevent an irresponsible or "rogue" operator from giving independents a black eye? Can SEMP be implemented in a cost effective manner? Will MMS find the level of regulation/inspection to encourage safe, environmentally acceptable operations, yet still promote production growth?

The migration of independents to the Gulf of Mexico is likely to continue, and it is in the public interest for it to do so. Industry and government must continue their efforts to increase their knowledge of the Gulf of Mexico, to understand one another better, and to communicate with one another more effectively.

Joe B. Foster is Chairman and Chief Executive Officer of Newfield Exploration Company, which he founded in January 1989. He is an independent oil producer, exploring for and acquiring oil and gas reserves in the central Gulf of Mexico. Previously, Foster was Chairman of Tenneco Oil Company and Executive Vice President and director of Tenneco, Inc. He serves on the National Petroleum Council and is Chairman of the Offshore Committee of the Independent Petroleum Association of America. Foster has as B.S. in petroleum engineering and a B.B.A. degree in general business from Texas A&M University . He is a member of the Board of Trustees of the Texas A&M University Development Foundation and a Distinguished Alumnus of the Colleges of Engineering and Geosciences at Texas A&M.

LEGISLATIVE AND REGULATORY ISSUES PERTINENT TO THE OIL AND NATURAL GAS INDUSTRY IN THE GULF OF MEXICO

Ms. Genevieve Laffly Murphy
Exploration Coordinator
American Petroleum Institute

As the petroleum industry's primary trade association, the American Petroleum Institute (API) is called upon to:

- advocate government-decision making that encourages efficient and economic oil and natural gas development, refining, transportation and use,
- promote improved public understanding of the industry's value to society, and
- serve as a forum for the exchange of views on issues affecting the industry.

We do this by participating in the regulatory and the legislative process, sponsoring public education programs, conducting research, developing standards, and responding to public expectations regarding the environment and our activities.

This is a big job when one considers the industry we are representing. API's more than 300 member companies produce approximately 85% of the oil and 75% of the natural gas extracted from the Gulf of Mexico. Despite massive restructuring to respond to global competition and change, cost cutting and re-engineering, the industry still employs 1.5 million people, contributes approximately 5% of the U.S. economic output and 5% of all federal, state and local taxes.

REGULATORY REFORM

This year, API's number one legislative priority has been building support for the enactment of meaningful regulatory reform. Regulatory reform means using sound science rather than worst-case scenarios to assess risks—and using common sense and cost-benefit analysis to shape regulations. It means making the laws already on the books more effective and providing the same protection for less money.

A comprehensive reform bill took center stage in the 104th Congress, overwhelmingly passed the House of

Representatives but was slowed in the Senate, complicated by presidential politics. While great progress was made in the first session, API intends to continue to work for regulatory reform by either supporting a single comprehensive bill or piecemeal as part of individual reauthorization bills, such as Clean Water or Clean Air Act reauthorizations. (Some statutes expressly prohibit agencies from weighing the cost of regulation against its benefits.)

This is an issue that should concern all businesses and all Americans. Federal regulations and red tape cost the economy more than $600 billion per year, $6,000 per household. Americans pay more in regulatory costs than personal income tax—$543 billion. API is working through a broad-based coalition—the Alliance for Reasonable Regulation (ARR)—to achieve meaningful regulatory reform.

LONG-TERM COMMUNICATIONS

API has also undertaken a long-term program to better inform opinion leaders, the media, various constituencies, and the public about the role of oil in the U.S. economy and the harmful effects of proposals to force reduced oil use regardless of cost. We believe we must as an industry do even more to tell our story and inform government decision makers and the public on our issues.

This spring, for instance, we commissioned an extensive study on the cumulative impact of certain new regulations on exploration and production activities. ("Potential Impacts of Environmental Regulations on the Oil and Natural Gas Industry.")

The report found that the many compliance requirements currently under consideration could cause industry to triple environmental spending. The impact would cause operators to abandon over 200,000 wells, resulting in a decline of 7-11% in domestic production, a loss of 54,000 jobs (19,000 in the petroleum industry); a decline in federal and state revenues of $8.5 billion and a loss of $500 million in federal offshore royalties. This would be on top of the $10.6 billion the U.S. petroleum industry already spends on environmental protection—$46 for every man, woman and child in America.

Yet concern about the state of the environment remains the driving force behind the legislative and regulatory issues confronting our industry. The public's perception that the environment is deteriorating and the reality that it is improving has caused API to address this problem in several ways.

STRATEGIES FOR TODAY'S ENVIRONMENTAL PARTNERSHIP

In the late 1980s, API laid the foundation for a program we call "STEP" or "Strategies for Today's Environmental Partnership." Through STEP, API and our members aim to address the public concern about how our products and operations affect human health and the environment and what we're doing to improve performance in these areas. So we are making improvements in our performance, documenting those improvements and communicating them to the public.

As part of the STEP program, in May API published its third annual environmental performance report. The report tracks the industry's health, safety and environmental performance in eight areas:

- chemical releases
- oil spills
- work place safety
- underground storage tank upgrades
- used oil collection and recycling
- gasoline stations vapor recovery
- dollars spent on environmental protection.

In another important initiative, API and the *National Science Teachers Association* have been engaged in a partnership to help improve science education nationwide. This effort has produced six new science curriculum units for grades 6-12 which use real-life, hands-on examples from the petroleum industry to illustrate scientific concepts. Included is a unit which focuses on the discovery and extraction of offshore oil. It is being pilot-tested in 200 California schools with 44,000 9th and 35,000 10th graders before being used nationwide.

USED OIL PROGRAM

Another example of partnership and a common sense approach to regulation involving industry/public/government is API's *Used Oil Program*. It may come as a surprise, but surveys show that fully one-half of all U.S. motorists change their own oil. As a result, too much of it ends up in sewers and garbage cans and ultimately threatens soil and water - including the Gulf. Several years ago API joined grassroots groups and government agencies to reduce those risks. The results are a dramatic success story. Less than 200 collection points existed in 1991. There are over 10,000 today. Less than 1 million gallons of used oil were collected in 1991 compared to over 16 million gallons today.

In a partnership with American Oceans Campaign. Together, API has television public service announcements to be shown around the country to encourage used oil recycling.

SAFETY AND ENVIRONMENT MANAGEMENT PROGRAM

Other partnerships include the Safety and Environment Management Program, which provides offshore operators with an alternative to costly command and control regulations. This voluntary program seeks to improve safety and environmental performance on offshore rigs with full government cooperation. It recognizes that government and industry have a common goal of improving safety and environmental performance.

ACCESS

Every five years we are given the opportunity to help shape the future of offshore leasing. We are in the midst of that process, which began in November 1994 when MMS published a Request for Comments. The process will end in August 1996.

Our general reaction to the proposed five-year program is disappointment. Its proposed 16 sales in eight planning areas is said to contain a "politically feasible" schedule. We say that it is not ambitious enough; that it ignores the long lead time to develop projects and infrastructure; that it emphasizes one geographic region for sustaining the U.S. energy needs; and, that it emphasizes production, not reserve replacement.

The proposed program gives industry access to areas that represent the core of its domestic business: Alaska and the Central and Western GOM. However, the wealth of the OCS can only benefit this country if its resources are more fully developed. Development thus far has generated over $105 billion to the federal treasury in cumulative mineral revenue. Over 80% has gone to the general fund allowing Congress to fund $85 billion worth of programs without having to raise a single tax dollar. But even greater benefits can be achieved through a more ambitious five-year leasing program.

The industry's OCS environmental record is laudable, proven by more than $500 million dollars in studies over the last 20 years. Risk of accidents is low. Production from the OCS contributes less than one-tenth of 1% of the oil in oceans. Industry's operational record and MMS's inspection and enforcement efforts are notable.

We must be prepared to communicate this record in areas outside the Central and Western Gulf. Between now and the next five-year program, beginning in 2003, industry and government must work together to get the message through. We would suggest starting with the Eastern Gulf of Mexico.

API would like to see more of the Eastern Gulf Planning area considered under five-year leasing program. We endorse inclusion of areas off Alabama and deepwater blocks. MMS has proposed a small sale in 2001. Cognizant of Florida's asserted 100 mile buffer, API is suggesting that MMS establish a task force and request Florida's participation to open communications. API also would like MMS to fund studies called for under the executive directive that removed many Eastern Gulf areas from leasing.

OCS MORATORIA

Since 1982, Congress has adopted restrictions on OCS leasing. This year industry lobbied for elimination of those restrictions from the Department of the Interior's fiscal year 1996 appropriations. We were not successful, and the restrictions remain in place.

DEEPWATER ROYALTY INCENTIVES

As you know, the President signed deepwater royalty incentives into law on November 28. MMS is called on to implement the law within 180 days to allow operators to petition for royalty relief from existing leases and offer new leases in deepwater with new royalty terms. API is anxious to work with MMS as it promulgates these new policies and regulations for the Central and Western Gulf.

ROYALTY SIMPLIFICATION & FAIRNESS

A number of industry groups have crafted legislation to simplify the royalty collection system and make it more equitable. API supports legislation, passed by both Houses of Congress as part of budget reconciliation, that would, among other things, establish a six-year statute of limitation on royalty payments and records retention and permit the government to pay interest on overpayments of royalty.

AIR REGULATIONS

As you know, MMS has just completed a study that clearly demonstrates that emissions from offshore platforms do not play a significant role in the air pollution episodes that occur along the Gulf Coast in Houston and Beaumont, Texas and Baton Rouge, Louisiana. API is working to ensure that the DOI retains authority to regulate air emissions from OCS platforms. The question of jurisdiction over offshore air emissions has surfaced as EPA develops new air regulations for oil and natural gas production facilities. We will continue our efforts to ensure that a second government agency does not begin regulating offshore platforms.

TOXIC RELEASE INVENTORY

EPA is considering greatly expanding its Community-Right-to-Know reporting program. The exploration and production industry, including offshore platforms, are on EPA's list for new regulations. The program was designed to provide information to communities around manufacturing sites. API has argued that this new major reporting burden makes no sense for the exploration and production industry, both offshore and onshore, and provides no environmental benefits.

OFFSHORE PLATFORM DECOMMISSIONING

An international ban on the disposal of offshore structures at sea is currently under consideration by the contracting parties to the London Convention. API opposes the ban and has worked with the U.S. State Department, the MMS and the EPA to ensure that the U.S. delegation is fully informed regarding the impact to U.S. companies and internationally. API has just completed a report which estimates that the potential impact to U.S. companies from the proposed ban is in the range of $1.9 billion -$5 billion in U.S. waters and the North Sea. API also will be co-sponsoring MMS's international workshop on platform decommissioning in April 1996 in New Orleans.

CERTIFICATES OF FINANCIAL RESPONSIBILITY

The implementation of the Oil Pollution Act, passed by Congress in 1990, has proved problematic. Congress is again attempting to clarify reasonable financial responsibility requirements for offshore facility. API has urged that only offshore OCS facilities be subject to new financial responsibility requirements that the level be based on risk.

UNITIZATION AND SUSPENSIONS

As exploration ventures into the deeper waters, the industry needs a continuation of policies that govern offshore leases and the administration of those policies in a flexible and predictable manner. The stability of these policies is crucial to fostering deepwater exploration. MMS's recent workshop on this matter and its outreach efforts, as well as others such as the Blowout Prevention regulations, is viewed by industry as very constructive, and we encourage MMS to continue the dialogue.

GULF OF MEXICO PROGRAM

High visibility of industry operations in the Gulf makes us a target for the public's concerns about water quality and other environmental issues. Because some groups have targeted the industry as a source of pollution in the Gulf, often with little evidence, API is undertaking to communicate to policy makers and the public the substantial body of literature that exists on the impact of industry operations in the Gulf of Mexico. We will provide input to the legislative and regulatory process to avoid additional requirements not based on science and to educate the public about the benefits of offshore operations.

CONCLUSION

Gaining the public's confidence is key to ending offshore moratoria, as well as tempering regulatory and legislative proposals that block or delay exploration and production. The resolution of these regulatory and legislative issues in a sound manner is very important to the industry if we are to reverse a trend of declining domestic energy production, increase reserves, spur technological development and deliver energy to the American people.

During her employment at the American Petroleum Institute, Genevieve Laffly has worked on issues as diverse as the transportation and regulation of hazardous materials to the breakup of AT&T. She recently served as environmental coordinator for API's refining committee on matters dealing with air, water, and waste regulations and is currently API's exploration coordinator in the Exploration & Production

Department. Her responsibilities include addressing government policies that impact energy company's ability to explore, develop, and produce oil and gas onshore and offshore. Ms. Laffly is a graduate of Georgetown University and the Graduate School of the George Washington University. Prior to joining the API in 1978, she served as a legislative assistant to an Illinois Congressman.

GULF OF MEXICO PROGRAM

Mr. R. Michael Lyons
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INTRODUCTION

The Gulf of Mexico Program (GOMP) was created in 1988 by the EPA to develop and implement a management strategy aimed at protecting, restoring and maintaining the health and productivity of the Gulf. The program describes itself as an intergovernmental partnership involving federal, state, and local environmental agencies, citizens and representatives of business and industry (Figure 4AB.1).

The GOMP budget is $4 million annually. This figure includes approximately $2 million for program operations and $2 million for the funding of projects recommended in the program process. The EPA currently provides the entire $4 million from discretionary funds.

The first five years of the program focused on better characterizing eight fundamental environmental issues affecting the Gulf of Mexico. Issue committees were established to develop these characterizations and formulate action plans to address these issues. The issues identified were:

- habitat degradation
- freshwater inflow
- nutrient enrichment
- toxic substances and pesticides
- coastal and shoreline erosion
- public health, marine debris
- living aquatic resources.

Action plans have been developed to address each of these issue areas.

In recent years, the program has focused its attention on strategic implementation of action plans designed to address each of these issues. The GOMP has narrowed its focus from an original 400+ action items to 80 action items. It has further narrowed its immediate focus from eight issue areas to three and has begun a process of formulating goals and objectives for each of these three areas. The current focus of the program is on:

(1) enhancing the sustainability of Gulf commercial and recreational fisheries,
(2) improving and expanding coastal habitats for birds, fish, and other living resources, and
(3) protecting human health and the food supply by reducing the input of nutrients, toxic substances, and pathogens to the Gulf.

PRESENTATION SUMMARY

The Gulf of Mexico Program (GOMP) was established in 1988 "in response to signs of serious long-term environmental damage to the resources of the Gulf of Mexico." Its purpose was to develop and implement a management strategy designed to protect, restore, and maintain the health and productivity of the Gulf.

The GOMP was designed to be a partnership of government agencies, the public, and business and industry. While the operational budget ($2 million annually) of the program comes entirely from the EPA discretionary budget, it does receive in-kind contributions from other federal agencies and, in some cases, matching funds for specific projects from these other federal agencies. Policy for the program is set by the program's Policy Review Board, comprised of the following membership: the EPA, U.S. Soil Conservation Service, U.S. Navy, NOAA/National Ocean Service, NOAA/NMFS, U.S. Coast Guard, U.S. Army Corps of Engineers, Texas, Louisiana, Mississippi, Alabama, Florida, and two citizen representatives.

The GOMP is based at the Stennis Space Center in Stennis, Mississippi, near the Mississippi-Louisiana boarder at Interstate-10. The program office is staffed by 11 full-time equivalent employees of the EPA or other partner federal agencies.

Reporting to the Policy Review Board are a number of working and advisory committees. These include a Citizens Advisory Committee, a Technical Advisory Committee, a Management Committee, eight individual Issue Committees, and two operating committees.

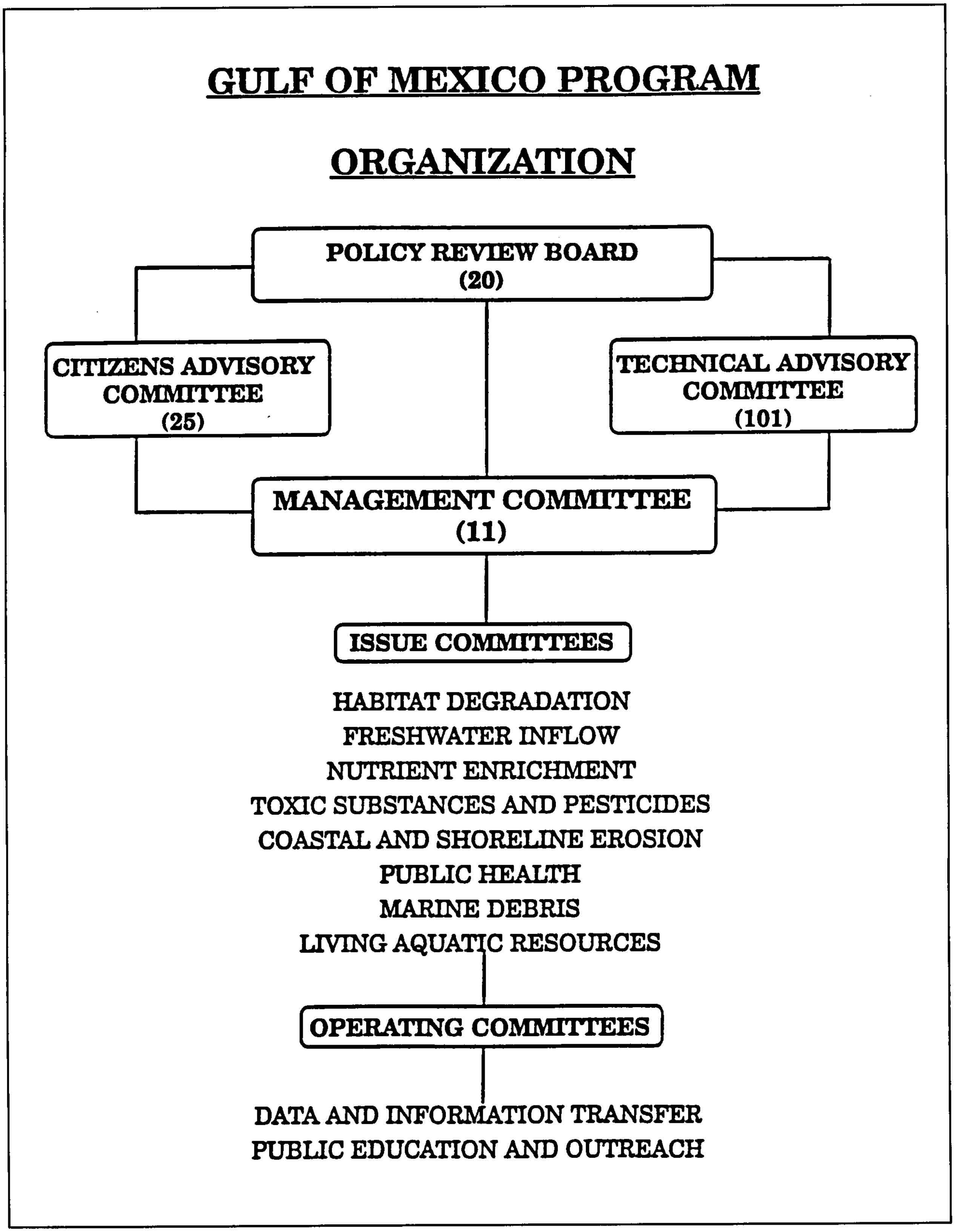

Figure 4AB.1. Gulf of Mexico Program Organization.

Through these committees, hundreds of individuals have been involved, for the most part on a volunteer basis, in the GOMP planning process.

The Citizens Advisory Committee is appointed by the GOMP staff and currently includes 101 scientists, government employees, and other. The purpose of the TAC is to advise the Policy Review Board and Management Committee on scientific and technical issues. Most of these individuals also serve on the various Issue Committees of the GOMP. In fact, when the program was initiated, there were no Issue Committees—these functions were served by the TAC.

The eight Issue Committees evolved form the original TAC as the program began to characterize and develop action plans for the eight identified priority environmental issues for the Gulf. Action plans have now been developed for each of the identified issues. These documents are continuously being updated and revised.

The eight Issue Committees are as follows:

- Habitat Degradation
- Freshwater Inflow
- Nutrient Enrichment
- Toxic Substances and Pesticides
- Coastal and Shoreline Erosion
- Public Health
- Marine Debris
- Living Aquatic Resources.

The primary purpose of these Issue Committees is to develop, maintain, and implement an Action Plan for their issue area. These action plans are intended to: (1) identify goals, objectives, and activities necessary to address issue area; (2) provide a basis for each action; (3) effectively direct limited resources, and; (4) provide the rationale for budget requests and agency plans.

The program has effectively completed the second phase of their mission. Action plans have been developed and published in each issue area. As a result of this effort, 418 individual action items were identified. Many of these action items fall into one of three categories:

(1) additional data/information/research,
(2) public education and outreach projects, and
(3) small demonstration projects (e.g. innovative sewerage disposal technology, wetlands creation projects, erosion control projects).

Some deal with potential regulatory controls (e.g. development of stormwater controls, creation of sediment criteria, evaluation of federal, state, and local wetland regulatory programs, development of a toxic substances management plan).

While the GOMP is not a regulatory program and has no authority to adopt regulations, it also makes it clear that, as part of this management plan development, it could recommend additional controls and regulations. It would be not the program's responsibility to adopt and enforce these rules, it would be the responsibility of the participating federal and state agencies involved in the program.

Since the adoption of the eight Action Plans and the identification of the 418 action items pursuant to these plans, the GOMP has begun to prioritize these action items. In 1994 and 1995, each Issue Committee was asked to designate its top ten priority action items. These have published by the GOMP program office. The GOMP then funded, to the extent money was available, these priority projects. In addition to the $2 million budgeted for these projects, the GOMP sought matching funds or in-kind contributions from the federal and state agencies involved in the program.

The GOMP has also published a report on research needs identified by the various Issue Committees. This report was published pursuant to a GOMP Workshop in March of 1995.

There are two Operating Committees in the GOMP. The most active to date has been the Public Education and Outreach Committee. The program from the beginning has put a strong emphasis on public relations and public education projects. Each of the eight Issue Committees has sponsored at least one public education project dealing with its particular issue area. These projects have included videos, written materials, seminars, and materials for school age children. In fact, the program has placed particular emphasis on projects for school children. Every other year the GOMP conducts a large symposium and dedicates a significant portion of the meeting to school children from each of the Gulf states.

The other operating committee is the Data and Information Transfer Committee. As you might imagine in this age of information and computers, this committee is beginning to attract a lot of attention. The group is grappling with the many issues involved with obtaining and distributing environmental studies and information on the Gulf to the general public. This is an area that bears watching closely: how much data is released to the public? Which studies are to be made available? How are the studies and data screened before being released? These are but some of the questions that must be answered by the program.

In 1992, participating federal agencies and states adopted ten environmental challenges, or overall goals, for the GOMP. Since that time, the program has focused on addressing these goals. They are to :

- Significantly reduce the rate of loss of coastal wetlands
- Achieve an increase in Gulf Coast seagrass beds
- Enhance the sustainability of Gulf commercial and recreational fisheries
- Protect human health and food supply by reducing input from nutrients, toxic substances, and pathogens to the Gulf
- Increase Gulf shellfish beds available for safe harvesting by 10%
- Ensure that all Gulf beaches are safe for swimming and recreational uses
- Reduce by at least 10% the amount of trash on beaches
- Improve and expand coastal habitats that support migratory birds, fish, and other living resources
- Expand public education/outreach tailored for each Gulf Coast count or parish
- Reduce critical coastal and shoreline erosion

STRATEGIC ASSESSMENT

In 1994, the GOMP began to develop a "strategic assessment" process designed to identify a plan of action appropriate to accomplish each of the ten environmental challenges. As a pilot, the program has begun to develop a strategic plan for challenge five which seeks to increase Gulf shellfish beds available for safe harvesting by 10%. Upon completion, the program intends to address each challenge in a similar manner.

In the strategic assessment process the strategic assessment team will review all of the action plans and individually identified projects within those plans and evaluate the applicability of each to the challenge in question. A plant will then be developed which includes previously identified projects as well as any new projects which the team deems necessary and appropriate to accomplish the challenge.

FEDERAL AGENCY PARTNERSHIP AGREEMENT

Earlier this year, the federal agency participants in the program signed a federal agency partnership agreement which commits each to supporting the GOMP process and sets forth goals and responsibilities of the partners and of the overall program. This document confirms the EPA as the agency with administrative responsibilities for the GOMP. It also, however, provides for the creation of a new GOMP structure involving the federal agencies as equal partners in a Program Directorate and providing for the chairmanship of this body to rotate among these federal partners.

The agreement sets forth a timeline for federal agencies to confirm their level of commitment, to develop a regional communications network for program participants, to develop a program strategy, and to develop ecological baselines. Each participating federal agency is invited to participate on the Policy Review Board, the new Program Directorate, and the various technical and issue committees.

ENVIRONMENTAL BASELINE

The most recent development in the GOMP is an effort to develop environmental baselines. At the last major meeting of the GOMP (6/95), the program narrowed its focus to the following three "program outcomes," or goals, for the purpose of baseline development:

(1) Enhance the sustainability of Gulf commercial and recreational fisheries;
(2) Improve and expand coastal habitats that support migratory birds, fish and other living resources; and;
(3) Protect the human health and food supply by reducing input of nutrients, toxic substances, and pathogens to the Gulf.

For each of these program outcomes the GOMP attempted to develop two or three measurable goals. The initial drafts of these goals attempted to include percentages (e.g. Reduce human exposure to food-borne pathogens and toxics, as reflected by the number of pollution/pathogen-related harvest restriction and consumption advisories, by ___% in five years). The program has been unable as of yet to identify appropriate percentage reductions/designations. At this time, however, the program is continuing attempts to designate appropriate percentages for each program outcome goal.

BUSINESS AND INDUSTRY RESPONSE

While the GOMP has billed itself as a partnership which includes a wide range of Gulf interest groups, including business and industry, the business community was largely left out of the program until 1994. The catalyst for change has been the Gulf of Mexico Coalition (GOMC).

The Gulf of Mexico Coalition was created in 1994 following a business and industry symposium on the GOMP in New Orleans. The symposium was sponsored by a large number of trade associations representing business interests in the area of the Gulf coast. Some 200 attendees met with GOMP staffers and learned the details of the program, many for the first time.

Following this session, business leaders decided to create the GOMC. The GOMC is a voluntary coalition of business and industry representatives representing interests in the Gulf coast area. It is currently comprised of several hundred individuals representing hundreds of companies and industry trade organizations. The coalition has no paid staff or dues structure. It is run entirely by volunteers from the member companies.

The GOMC is comprised of a Steering Committee and four Standing Committees. General direction is developed by the Steering Committee and approved by GOMC. The four standing committees are the Technical Committee, the Information Committee, the Legislative Committee, and the State Work Group Committee. The Technical Committee is comprised of ten subcommittees which correspond directly to the GOMP Issue and Operating Committee.

The GOMC has also created a GOMC Business Council to interface with the GOMP Policy Review Board and Management Committee. The Business Council consists of representatives from general business organizations in each of the five Gulf states and representatives from the following business sectors: oil and gas, chemicals, utilities, forest and paper products, and agriculture. This ten-member council annually elects a chairman and vice-chairman. The chairman has been granted a voting seat on the GOMP Management Committee and a non-voting seat on the Policy Review Board.

In addition to these two policy positions granted to the business community, the GOMP has also placed GOMC members on each on the GOMP Issue Committees and allowed general participation by business and industry representatives in all GOMP meetings.

Meetings of the GOMC are currently held in conjunction with the regular meetings of the GOMP.

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SESSION 4C

SOCIOECONOMIC RESEARCH IN THE GULF OF MEXICO REGION

Session: 4C - SOCIOECONOMIC RESEARCH IN THE GULF OF MEXICO REGION

Co-Chairs: Mr. John R. Greene and Dr. Harry Luton

Date: December 13, 1995

Presentation	Author/Affiliation
Exploration and Production Companies in the Gulf of Mexico	Dr. Ruth Seydlitz Mr. John W. Sutherlin Ms. Samantha T. Smith University of New Orleans
The Shift in the Oil and Gas Industry in the Gulf of Mexico	Dr. Ruth Seydlitz Mr. John W. Sutherlin Ms. Samantha T. Smith University of New Orleans
Comparing the Safety and Environmental Performance of Offshore Oil and Gas Operators	Dr. Allan Pulsipher Dr. Omowumi Iledare Dr. David Dismukes Mr. Dimitry Mesyanzhinov Mr. Robert H. Baumann Mr. William Daniel, IV Center for Energy Studies Louisiana State University
Outer Continental Shelf Issues: Central Gulf of Mexico	Dr. Robert Gramling University of Southwestern Louisiana
A Historic Socioeconomic Database for the Gulf of Mexico	Dr. Natsumi Aratame Louisiana State University
Phase One Socioeconomic Baseline Study for the Gulf of Mexico: a Preliminary Analysis	Dr. Joachim Singelmann Dr. Forrest Deseran Dr. Charles M. Tolbert Louisiana Population Data Center Departments of Sociology and Rural Sociology Louisiana State University
Income Inequality at the Place Level: A Comparative Analysis—Preliminary Results	Dr. Charles M. Tolbert Dr. Edward S. Shihadeh Louisiana Population Data Center Departments of Sociology and Rural Sociology Louisiana State University

EXPLORATION AND PRODUCTION COMPANIES IN THE GULF OF MEXICO

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BACKGROUND AND PURPOSE

A restructuring of the offshore oil and gas industry in the Gulf of Mexico began in the mid-1980s. Since that time, major companies have reduced their presence while independent firms have been more aggressive. The resource base now is substantially different from that of half a century ago, when the major corporations began operations. Extraction of oil and gas is increasingly difficult and capital intensive, as new sources are found in subsalt regions and deep water. In addition, the infrastructure is aging. Hence, operating conditions in the Gulf create different challenges and place different pressure for today's independent firms than those experienced by the major corporations in the past. The purpose of this project was to examine the characteristics, environment, and practices of companies currently active in the Gulf and to determine how these aspects of the companies have changed since 1986.

DATA AND METHODS

Telephone interviews were conducted with upper-level executives from companies active in the offshore Gulf of Mexico. The companies were selected by random sampling within each of five types of firms. The sample consisted of 11 major corporations, 13 large and 4 small integrated independent companies, and 9 large and 11 small nonintegrated independent businesses. These numbers represent relatively large percentages of each of the five types of companies. The interview instrument consisted of open-ended questions concerning companies' characteristics and use of service firms in the fall of 1994 and in 1986; the executives' predictions about the future of the oil and gas industry in the offshore Gulf; and the influence of leasing policies, technological developments, federal agencies, and environmental regulations on the companies' practices in the Gulf. Frequency and percentage distributions were calculated for questions whose answers could be quantitatively coded. Content analysis was used for the responses that could not be quantitatively coded.

SIGNIFICANT CONCLUSIONS

The results revealed that five distinct types of companies are operating in the Gulf:

1) major corporations
2) large integrated independent firms
3) small integrated independent firms
4) large nonintegrated independent companies
5) small nonintegrated independent companies

The findings also revealed that there were more differences among the five types of companies by integration (integrated vs. nonintegrated firms) than by size or the usual categorization scheme of major vs. independent businesses. Thus integration appears to be the most important defining characteristic of companies operating in the Gulf.

The findings also suggested that six trends are occurring in exploration and production companies in the Gulf. First, there was an increase in the number of companies operating in the Gulf between 1986 and the fall of 1994. Twelve companies obtained neither oil nor gas from the offshore Gulf in 1986 but derived at least one of these resources in 1993. Seven of these 12 firms were small nonintegrated ones and four of these could be new companies because they had no headquarters in 1986. Second, most of the companies obtained more oil and gas in 1993 than in 1986. Two-thirds of the executives reported that their company obtained more oil in 1993, while three-fourths of them declared that they extracted more gas. Third, most of the firms were more involved in exploration in the Gulf in 1994 than in 1986. Over two-thirds of the officials claimed that their companies were doing more exploring in 1994. Fourth, participation in joint ventures increased between 1986 and the fall of 1994. Almost two-thirds of the companies were more involved in joint ventures in 1994. Fifth, changes in the companies' activities suggested a tendency toward becoming involved in downstream integration operations. Executives from three integrated firms indicated that their companies were not involved in such activities in 1986, but were in 1994. In addition, officials from four large nonintegrated firms stated that their businesses were involved in at least one downstream activity. Sixth, changes in characteristics, views of the business environment, and practices implied that a shift is occurring in activity in the Gulf: the nonintegrated independent businesses are becoming more involved while the major and integrated independent companies are maintaining a steady rate of activity or reducing their involvement.

STUDY RESULTS

The first objective of the study was to examine the characteristics of major and independent operators currently active in oil and gas exploration and production in the offshore Gulf and to determine how these characteristics have changed since 1986. The findings showed that most of the companies extract both petroleum and gas. Also, most of the firms obtained more of both substances in 1993 than in 1986, especially the nonintegrated firms. Moreover, the majority of the firms had their headquarters in the Gulf region, particularly the independent companies, while only about half of the other offices were in this region, mainly those of the nonintegrated companies. Further, the bulk of the companies increased their staffs between 1986 and 1994, particularly the nonintegrated businesses. Finally, there were three key areas of employment: production/platform maintenance and operation, exploration, and administration.

The second objective of the study was to investigate the business environment and to see how this has changed since 1986. The responses to these questions revealed widespread support for areawide leasing and the reduction in the minimum bid. In addition, there was widespread dislike for four possible regulations (in descending order of influence): the Clean Water Act, as written in the fall of 1994, the financial responsibility provisions of OPA '90, the Clean Air Act, and the increases in lease bonding to cover plug-and-abandon liabilities. Also, almost all of the companies used 3D seismic data, about half did horizontal drilling, and very few, mainly major corporations, were involved in deepwater or subsalt exploration. Moreover, almost all of the companies were involved in joint ventures and most of the firms increased their involvement in such projects between 1986 and 1994. In addition, the use of service companies was ubiquitous, and most of the firms made greater use of these companies in 1994 than in 1986. Finally, the majority of the officials were optimistic about the future of oil and gas extraction in the Gulf.

The third objective of the study was to explore how the characteristics of the companies affect their operations. The findings are as follows. Major corporations extracted the most oil and gas, had their headquarters out of the Gulf region, and had the largest staffs. Independent firms, particularly nonintegrated ones, were more involved in exploring in 1994 than in 1986 and had their headquarters in the Gulf area. Integrated businesses had more of their other offices outside of the Gulf region while nonintegrated ones had more of their other offices in the Gulf zone. In addition, integrated firms tended to close their offices in this area between 1986 and 1994, while nonintegrated ones tended to open other offices in this area. Moreover, integrated companies had larger staffs than did nonintegrated ones and integrated concerns tended to reduce their workforces between 1986 and 1994 while nonintegrated ones tended to enlarge their staffs.

The fourth objective of the study was to examine how the business environment influences the practice of companies. Almost all of the executives felt that the prices of oil and gas influence operations, over two-thirds of them were negative about the prices in the fall of 1994 and almost half were not optimistic about future prices. In addition, the executives felt that areawide leasing and the reduction of the minimum bid increased activity in the Gulf. Moreover, the executives viewed 3D seismic data and horizontal drilling positively while deepwater and subsalt exploration were too new for the executives to have an opinion on how these two technologies would affect their firms' operations. Finally, the executives were concerned that the four possible regulations would have adverse effects on the business environment and thus on oil and gas activity in the offshore Gulf.

Dr. Ruth Seydlitz is an Associate Professor of Sociology at the University of New Orleans. She has worked at the university for eight years. Her research interests include social impact analysis, particularly in the oil and gas industry in the Gulf of Mexico. She has conducted research on this topic since 1991 and has published three articles (*Rural Sociology* 1993, *Impact Assessment*, 1995 and *Society & Natural Resources* 1995), two research reports, and two chapters in another report in this field. She received her B.S. in sociology and psychology from the University of Tulsa in 1979 and her Ph.D. in sociology from Washington University in St. Louis in 1986.

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Science. For two years, he was a Project Manager in the Environmental Social Science Research Institute at the University of New Orleans. Mr. Sutherlin received his B.A. from Louisiana Tech University in 1990 and his M.A. in political science from the University of New Orleans in 1995.

Ms. Samantha T. Smith is a Research Assistant in the Environmental Social Science Research Institute at the University of New Orleans where she is currently pursuing an M.A. in sociology. She has been involved in environmental research for three years and interned with the Tulane Environmental Law Clinic for a year. In 1993, Ms. Smith received her B.A. from Loyola University of New Orleans in sociology with a minor in environmental studies.

THE SHIFT IN THE OIL AND GAS INDUSTRY IN THE GULF OF MEXICO

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This presentation discusses the five types of oil and gas exploration and production companies active in the Gulf of Mexico and the shift in activity among these five types of companies. The first section explores which businesses are active in the Gulf and the five types of firms. The second portion focuses on the shift in activity.

COMPANIES ACTIVE IN THE GULF

To be considered an oil and gas exploration and production company active in the Gulf of Mexico, the firm had to have participated in MMS lease sales in the Gulf since 1988, the earliest year for which the data could be obtained feasibly. One hundred thirty companies met this criterion; however, not all 130 are appropriate candidates for current studies. Five of the independent businesses could not be included because they are subsidiaries of firms already included in the list of 130 companies. Another five were excluded because they are partnerships or temporary ventures. Eight additional firms were omitted because they lost their leases in the Gulf. Another enterprise was not actively working on its leases in the Gulf and still another was no longer involved in offshore extraction. Therefore, these 20 companies were not included in the list. An additional nine companies were excluded because published information on them (Crandell *et al.* 1993; Moore 1993; Staff 1993) was insufficient and they had no phones. Having a phone was important because the interviews were conducted over the phone. Therefore, of the 130 companies on the list, 101 companies were eligible for inclusion in this study.

When oil and gas exploration and production companies in the Gulf of Mexico are discussed, they are usually classified as either major corporations or independent companies. Although this categorization scheme is typical, it was considered inadequate because the independent firms are too diverse to be included in one group. Another factor sometimes used when discussing oil and gas companies is the firms' involvement in downstream integration activities such as oil and gas refining and processing, wholesale trade, and retail trade. However, a categorization scheme that only classifies firms as major, integrated independent and nonintegrated independent firms is incomplete. Within both categories of independent firms, there is still a large degree of diversity.

The Crandell *et al.* (1993) study examined levels of exploration and production expenditures, reserves and assets, and numbers of employees to identify 17 companies as major corporations. The worldwide exploration and development funds, rankings on worldwide assets, rankings on worldwide revenues, rankings on worldwide reserves and the total number of employees (Crandell *et al.* 1993; Moore 1993, Staff 1993) are available for a large number of companies and were used to determine the size of the firms. Therefore, the companies are categorized into five groups: major corporations, large integrated enterprises, large nonintegrated businesses, small integrated firms and small nonintegrated endeavors. Of the 101 firms, 17 are major corporations, 19 are large integrated firms, 5 are small integrated businesses, 14 are large nonintegrated operators, and 46 are small nonintegrated enterprises. The sample for this study consisted of 11 major corporations, 13 large and 4 small integrated independent firms, and 9 large and 11 small nonintegrated independent businesses.

THE SHIFT IN THE GULF

People speak of a shift in activity in the Gulf of Mexico in which major corporations are becoming less active, particularly in exploration, while independent firms are becoming more active. However, the results of this study concerning business characteristics and the business environment did not support this view of the shift. Rather, the outcome suggested that the nonintegrated independent businesses are becoming more involved in the offshore Gulf while the major and integrated independent companies are maintaining a steady rate of activity or reducing their involvement in the Gulf. The results to be discussed first in this section support the idea that there has been a change in activity levels of the companies in the Gulf.

Some of the changes between 1986 and 1994 in the business characteristics of the five types of companies suggest that the nonintegrated firms may be the most committed to oil and gas extraction in the Gulf of Mexico. These changes are the ones concerning the amount of oil extracted, the involvement in exploring, the location of headquarters and other offices, and the numbers of employees. First, the changes in the amount of oil extracted suggest that the nonintegrated enterprises are becoming more active. The overwhelming majority of the large and small nonintegrated operators were extracting more oil in 1993 than in 1986 while approximately equal numbers of the major corporations and small integrated companies were obtaining more oil and less oil and the majority of the large integrated firms were deriving less oil. Second, the results concerning the difference in exploring imply that the nonintegrated firms are becoming more involved in offshore extraction in the Gulf. Large majorities of both the large and small nonintegrated endeavors were doing more exploring in 1994 than in 1986. In contrast, about equal numbers of the major corporations were doing more and less exploring in 1994 while over half of the large integrated firms were doing more exploring in 1994.

Third, the location of headquarters and other offices also connotes a greater commitment to the Gulf of Mexico on the part of the independent businesses, particularly the nonintegrated ones. Most of the major corporations had their headquarters in cities outside the Gulf region while most of the independent operators had theirs in this area. In addition, the integrated companies had a large number of their other offices outside the Gulf territory, but most of the other offices of the nonintegrated firms were in the Gulf region. Further, between 1986 and 1994, the integrated companies closed some of their offices in the Gulf area while the nonintegrated businesses opened some offices in this region. Fourth, the pattern of changes in the numbers of employees hints that the nonintegrated endeavors are the most committed to Gulf extraction. The nonintegrated companies displayed an increase in workers, especially in the small nonintegrated firms. On the other hand, the integrated concerns showed overall decreases in the number of employees.

Some changes in the business environment between 1986 and 1994 suggest that the independent companies are becoming more important players in Gulf extraction. These changes consist of those concerning: joint ventures, service company use and the companies' views of the future of oil and gas extraction in the Gulf. In addition, the answers to the questions concerning how the change in leasing policies affected the firms' operations suggest that a shift in the players is occurring. First, the differences in participation in joint ventures imply that the nonintegrated independent companies are doing everything they can to increase their activity in the Gulf. Majorities of the large and small nonintegrated endeavors increased their participation in joint ventures. On the contrary, only half of the large integrated concerns took part in more joint ventures in 1994 while about equal numbers of major corporations did more and did fewer of these in 1994.

Second, the changes in the use of service companies hint that the major companies may be reducing their presence in the Gulf. Although the bulk of the major corporations hired outside contractors more in 1994, four companies used service companies less in 1994. Only five of the firms examined decreased their use of service companies between 1986 and 1994—four major and one large integrated companies. However, the unknown issue is whether the four companies are doing more activities themselves or are less involved in the Gulf. Also, it is possible that outsourcing on the part of the seven major companies that increased their use of service companies is a way to reduce their presence in and commitment to extraction in the Gulf.

Third, the major corporations and large integrated independent firms seem less optimistic about the future of operations in the Gulf. Major and large integrated companies were less hopeful about their businesses' involvement in exploration in 1998. Although the majority of all five types of companies reported that their firm would be more engaged in exploring, representatives of four major and four large integrated concerns disagreed. In addition, the results were similar concerning the size of the workforce in the Gulf in 1998. Again, the bulk of all five types of firms predicted that the workforce would be larger in 1998. Yet, eight officials disagreed—four from major corporations, three from large integrated businesses, and one from a small nonintegrated enterprise who was concerned about regulations. The explanations employed exclusively by officers from major corporations suggest that the major firms may be planning to reduce their presence in the Gulf. These reasons included disposition of properties, reduced exploration and production, and outsourcing. Moreover, almost all of the respondents predicted that the independent companies' share of activity in the Gulf would be larger in 1998 than in 1994. Once again, the reasons imply that the major corporations will have a reduced presence in the Gulf. These explanations consisted of the general trend toward a smaller presence by the major corporations, the marginal/mature nature of the Gulf, which precludes "elephant hunting," and the exit from the Gulf by the major corporations. A few people qualified their predictions by stating that the independent firms' share of activity on the shelf would be greater in 1998, but the major corporations' proportion of operations in deepwater would be greater than that of the independent businesses.

The respondents' answers concerning how changes in the two leasing policies—areawide leasing and the reduced minimum bid—influenced their companies' operations in the Gulf provided more evidence for the idea that a shift in activity is occurring. This evidence can be summarized as follows: 1) the changes allowed independent companies to begin activities in the Gulf, 2) the new policies increased competition in the Gulf, and 3) the changes in the policies increased activity by independents in the Gulf.

Three nonintegrated companies claimed that the change in one or both of these policies allowed their company to enter into Gulf extraction. One executive from a large nonintegrated concern stated, "We have been active in the Gulf only since 1990. However, without areawide leasing, we would not have become active in the Gulf at all" and "...without the lower minimum bid, the decision to become active in the Gulf would have been more difficult." An officer from a small nonintegrated company, in answer to both questions, said, "...it has paved the way for us to enter the Gulf of Mexico...." Other similar comments were "Allowed us to compete; without this we couldn't exist" (large nonintegrated firm), "Enormously, this is what put us in business. This drives GOM activity" (small nonintegrated enterprise), and "Company began..." (small nonintegrated firm).

In addition, several statements made by the respondents demonstrate that the changes in the leasing policies increased competition in the Gulf. For example, two representatives of major corporations responded, "More companies are competing for properties..." and "...allowed more independents, thus more competition." Executives of independent businesses made the following statements: "Allowed us to compete on more prospects—more competitive" (large integrated firm), "... More competitive..." (large nonintegrated business) and "Allowed us to compete, without this we couldn't exist" (large nonintegrated).

Moreover, these policies were credited by representatives of many independent companies with increasing their firms' activity in the Gulf. Four people from large integrated businesses stated that areawide leasing increased their activity, four respondents from large independent firms responded that areawide leasing increased their potential for finding oil and gas, and seven executives from independent concerns claimed that areawide leasing enabled them to get more leases. Also, three people from nonintegrated enterprises asserted that the reduced minimum bid increased their activity, and eleven officials from independent endeavors declared that the reduced minimum bid increased their ability to make bids, get leases, and obtain more acreage. A member of a small nonintegrated firm stated that areawide leasing, "Caused significant growth for us." Another executive declared that the reduced minimum bid "increased the number of bids by smaller independent companies" (large integrated firm). Yet another official from a large nonintegrated business asserted that the reduced minimum bid, "began more activity, decreased farmouts and increased our activity" and an official from a small integrated concern, in response to both policies said, "Helped independents."

Additional evidence for a shift from integrated corporations to nonintegrated companies comes from the fact that some of the integrated businesses are only doing marketing and have foregone exploration and production in the Gulf.

On the other hand, some results suggest that the major corporations are firmly committed to extraction in the Gulf. Part of this evidence concerns business characteristics and part pertains to the business environment. First, almost all of the major corporations, as well as the nonintegrated companies, obtained more gas from the Gulf in 1993 than in 1986. The majority of the large integrated firms derived more gas in 1993, but a third of this group of businesses extracted less gas in 1993.

Second, major corporations' use of new technology and their participation in joint ventures suggest that they plan to be in the Gulf for the near future. Regardless of the type of technology (3D seismic, deepwater projects, subsalt exploration, horizontal drilling), the majority of the major corporations either were already involved or currently planned to become involved with it. This statement could not be made for any of the four types of independent companies. Also, nine of the eleven major companies either engaged in or planned to engage in subsalt exploration, and six were either involved in or were currently planning deepwater projects.

The major companies were the most involved in joint ventures in terms of both the number of these operations and the fact that all of the major corporations were participating in these projects. However, this participation in joint ventures might be a way for the major corporations to continue operating in the Gulf while reducing their commitment to extraction from the Gulf or it might be a way to increase operations in the Gulf. No questions were asked to ascertain why the companies took part in joint ventures; thus the meaning of this participation is unknown.

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COMPARING THE SAFETY AND ENVIRONMENTAL PERFORMANCE OF OFFSHORE OIL AND GAS OPERATORS

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BACKGROUND

Accidents on offshore oil and gas platforms have declined by an order of magnitude during the past decade. At the same time, however, concerns about environmental damages from offshore oil and gas operations—as reflected in a variety of state and federal moratoria on offshore leasing in legislation such as the Oil Pollution Control Act of 1990 and in studies by the National Research Council (1990) and General Accounting Office 1995—seem to have intensified.

Underlying these concerns is a premise, popular in both industry and regulatory circles, that as major oil companies shift their E&P investments abroad, relatively more domestic E&P will fall to smaller independent companies. These independents have neither the technical, scientific or regulatory experience of the majors, nor their financial resources. Thus in the future:

(1) U.S. petroleum reserves would be less aggressively and efficiently developed, and
(2) safety and environmental risks inherent in the development of those reserves would also grow.

We have found little empirical evidence to support these concerns in the historical data available for the federal OCS.

Our analysis of the economic factors suggests that the investment strategies of independents have mirrored the majors' shift toward foreign prospects, with the rate of substitution of domestic for foreign E&P investment about the same for majors and large independents. It also suggests that independents were more aggressive and more successful than the majors in developing domestic oil and gas reserves (Iledare *et al.* 1995; Pulsipher *et al.* 1995b). In this article we deal only with safety and environmental concerns and our empirical results indicate that independents have, at least marginally, a better safety record than the majors.

A serious obstacle to the analysis of offshore safety has been the data. To date, no comprehensive, consistent and accessible data base records operator-specific safety performance. While far from perfect, the compilation of data used here allows testable empirical inferences to be drawn from past operator performance, and the operator-specific characteristics conditioning that performance, in the federal Gulf of Mexico OCS.

We have not measured or compared the environmental records (i.e., environmental damages resulting from accidents on offshore platforms) because damage data are neither defined nor available. However, we believe that our safety index is a better measure of environmental risk than oil spilled as reported to MMS. Geographic isolation of many offshore platforms makes self-reporting a questionable strategy and inspections difficult and expensive. Further, vast improvements in spill prevention technology have made major oil spills rare and spasmodic events. (One analyst calculated that the probability of a blowout (the event most likely to result in a major oil release) involving a well subject to MMS regulations releasing more than 1,000 barrels was 0.00—with an upper limit of 0.04 (Martin 1986). Although this may seem extreme, MMS data show that the *total* amount of oil spilled during blowout over the 1971 to 1986 period was 840 barrels (1989).

More importantly, the environmental risk of primary concern to the public is the ecological catastrophe, not the relatively minor spills that dominate the MMS data. Safety data, especially when injuries or fatalities are involved, are much less likely to be under- or unreported, and serious accidents involving injuries or fatalities are more likely to be associated with potentially catastrophic environmental consequences. Thus in our view it may be more accurate to base inferences about the potential environmental risk from the operator's safety record—the poorer the safety record the greater the potential environmental risk. (The simple correlation between the total amount of oil reported to MMS as spilled by each operator and individual operator safety scores was 0.68 for the entire period and 0.60 and 0.42 for the earlier and later periods.)

METHODS

Data

For this paper we assembled a consistent data base from published and unpublished MMS data for each OCS operator and cross checked it with data from Offshore Data Services. The data are organized on a platform as well as an operator or a production basis and cover the 1980 to 1994 period.

Accidents and Safety Scores: Since accidents vary greatly in their seriousness or consequences, we differentiated among them with the following crude weighting scheme. Accidents in which no injuries or fatalities were reported were assigned a weight of one, accidents with injuries but no fatalities were weighted as five, and accidents resulting in fatalities were counted as twenty-five. Admittedly this (1-5-25) scheme is as subjective as it is simple, but experimentation with other schemes suggests to us that the results are not very sensitive to the particular weights chosen. An individual operator's safety score is simply the sum of these weighted values for the period.

There has been rather extreme variation in the cumulative safety score for all operators over the study period as illustrated in Figure 4C.1. At the crest of the domestic oil boom in the early 1980s when in expectation of $50/barrel-oil-forever, 200 or more new platforms were being installed annually on the OCS (with inexperienced workers on rush schedules);

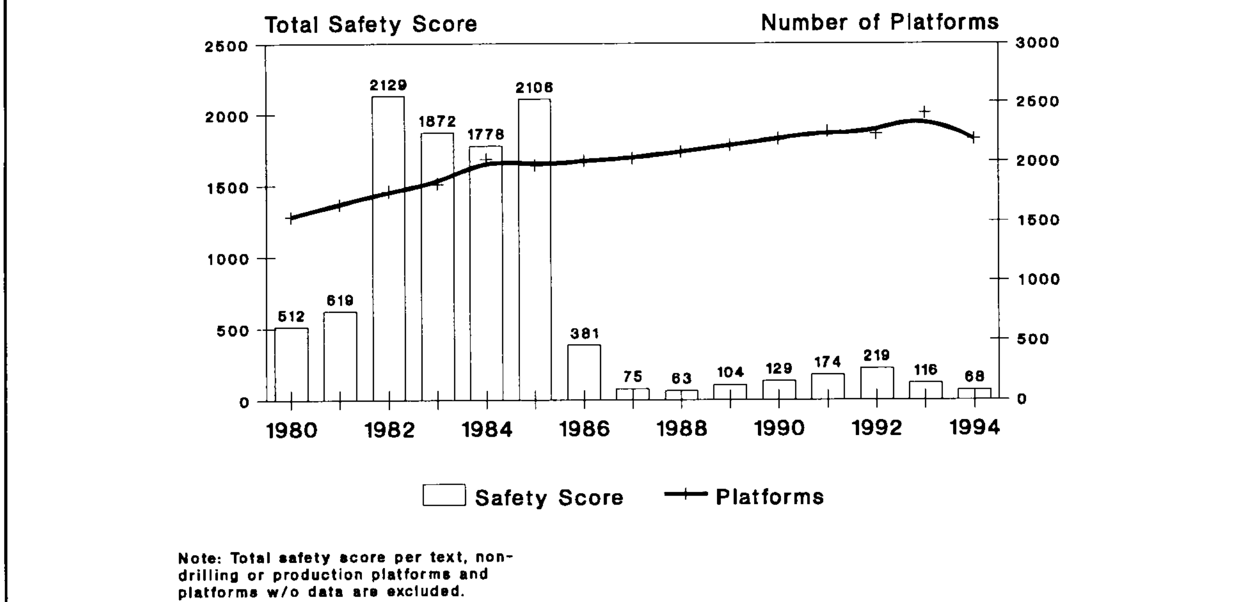

Figure 4C.1. Total safety score compared with total number of operating drilling and production platforms, 1980 to 1994.

accidents soared. The cumulative safety score as we have defined it jumped from about 500 in 1980 to around 2,000 between 1982 to 1985. When the world oil price dropped, so did OCS activity and so did OCS accidents—with the industry's annual safety score falling from 2,100 in 1985 to less than 400 in 1986. Less dramatic but perhaps more significant is the fact that the offshore industry's safety score remained at very low levels after OCS activity revived in the later 1980s and. Figure 4C.1 shows about an order of magnitude difference between the accident-scarred early 1980s and the post-price-collapse period—despite, as measured on the left axis, a steadily growing number of operating platforms.

Explanatory Variables: The individual operator's safety score would be expected to vary with a number of factors such as the number, type and age of the platforms operated. To account for, or "hold constant," such factors, we have used multiple regression analysis. This allows us to 1) estimate the association between accidents and several hypothesized explanatory variables, as well as; 2) predict a safety score for an individual operator, or group of operators, which reflects their own unique circumstances; and then 3) compare such predicted values to the measured value to statistically identify "better" or "worse" (than expected) safety records.

The variables we have included in the regression equation are the dependent variable (I), which is the safety score for each operator and the following independent or explanatory variables:

- LPLTY – Platform years as the summation of the number of platforms operated in each year by the operator over the study period—the hypothesis being that more platform years provide more opportunity for accidents.
- LAVAGE – Average age of operator's platforms—the hypothesis being that older platforms are less safe.
- LWELLS – Number of wells drilled—the hypothesized relationship being that drilling provides more opportunity for accidents than production.
- LGPLT – Percent of platforms producing gas—the hypothesis is that gas production is more accident prone than oil production.
- LINCS – Cumulative number of INCs (instances of noncompliance recorded against the operator during the MMS inspection process)—the hypothesis being the larger the number of INCs the more likely accidents are to occur.

To test directly for differences among the safety records of majors and independents considered as groups, we also classified each operator either as a major (18 firms as usually identified), large independent (35 firms with total assets world-wide in excess of $500 million) or smaller independent (90 firms including all other operators active on the OCS during the study period). Groups were assigned "dummy variables" to measure the association between group membership and safety scores. Large independents were designated in the regression equations as LARGEI and smaller independents as SMALLI. (The hypothesized relationship being positive according to the conventional wisdom but a central research question for us.)

RESULTS

Analysis of the data indicated the presence of heteroskedasticity in the residuals. Specifically, the errors tended to grow with increases in the number of operator platform years. Thus, weighted least squares (WLS) was applied to both sets of regressions with the variance of platform years (LPLTY) being used as weights in order to correct for this problem and yield more reliable estimates. The R^2 and adjusted R^2 are both reasonably high and indicate that the hypothesized model captures some 70 to 71% of the variation in the safety scores. During the 1980-1986 period, three of the six variables were significantly different from zero at the 99%level as evidenced by t-ratios that exceed an absolute value of 2. The three variables which proved to be statistically significant included the indicator for large independent operators (LARGEI); the indicator variable for small independent operators (SMALLI), and the number of platform years (LPLTY).

Majors' and Independents' Safety Performance

The regression indicates that during the period 1980 to 1986, both large and small independents tended to have better safety records than the majors. Some algebraic manipulation of the results (elasticities—or the percentage change in accidents resulting from a change in operator classification—can be generated using the following formula: $\xi = e^{\beta} - 1$) also tells us that, holding other things constant, a shift of operator classification from a major to a small independent would result in 0.96 percent reduction in the operator's expected safety score. A shift from the major classification to large independent would result in a 0.90 percent reduction.

The analogous empirical determinants of accidents during the 1987-1994 time period are shown in the last two columns of Table 4C.1. The summary statistics (R^2 and adjusted R^2) are both relatively high, explaining some 70 to 72% of the variation in operator safety scores. The parameter estimates presented in Model 2 are generally consistent with the results found in the 1980-1986 model. In this model, however, we found five of the seven explanatory variables to be statistically significant at the 95% level. The estimates for the two classifications of independents are similar to those of the 1980-1986 period, as is the estimate of the platform-years variable.

Oil Spilled by Majors and Independents

Cumulative barrels of oil spilled, as reported to MMS, is computationally analogous to our safety score measure. Since circumstances we hypothesized as being associated with our safety score should also be associated with oil spilled, we repeated the procedure summarized in the preceding section using barrels of oil spilled as the dependent variable. Although the model explained only about 60% of the variation among operators in oil spilled—as opposed to 70% in the previous safety score model—the significance levels and relative magnitudes of the explanatory variables retain the same pattern and support the same inferences. (The only exception was the variable measuring the percentage of gas wells. In the safety score case we anticipated a positive association (because of a higher potential for explosions and compressor accidents) and in the oil spill case a negative association. We found negative associations in both cases but in neither case was the association statistically significant.)

Outlier Analysis

We also analyzed the residuals from our model to identify operators whose safety score differed significantly from our predictions. These residual "outliers" were identified via the use of studentized (or standardized) residuals as outlined in Belsley (1980). These studentized residuals are closely related to the t-distribution.

Probably the most significant result is the relatively small number of outliers. Using a 90% significance level, in the 1987-1994 period there were eight (5.8% of total) in the "significantly-better-than-expected" group and seven (5.1% of total) in the "significantly-worse-than-expected" group. This leaves 89% in the "not-significantly-different-than-expected" category.

Table 4C.1. Empirical results—index of operator accidents.

Variable	1980-86 Parameter Estimate (Std Errors)	1980-86 T-Ratios	1987-1994 Parameter Estimates (Std. Errors)	1987-1994 T-Ratios
INTERCEPT	1.804269 (0.89109841)	2.025	0.515357 (0.49028377)	1.051
LARGEI	-2.312938 (0.46252361)	-5.001	-1.447334 (0.24113063)	-6.002
SMALLI	-3.288777 (0.53819132)	-6.111	-1.362809 (0.26875779)	-5.071
LPLTY	0.482109 (0.17346319)	2.779	0.204935 (0.09598936)	2.135
LGPLT	-0.084118 (0.11660727)	-0.721	-0.084200 (0.06165584)	-1.366
LWELLS	0.161634 (0.12554486)	1.287	0.246714 (0.08053146)	3.064
LAVAGE	0.145651 (0.22146305)	0.658	0.219109 (0.10983526)	1.995
LINCS	NA	NA	0.038510 (0.07515702)	0.512
R^2	0.7144		0.7233	
Adjusted R^2	0.6981		0.7079	
n =	115		136	

However, the composition of both groups is equally important. The eight operators in the "significantly-worse-than-expected" group include one major operating more than 100 platforms and one major with slightly fewer than 100 platforms. Thus it may be somewhat misleading to visualize the situation on an operator-by-operator scale. That is, if the number of platforms operated by the "worse-than-expected" operators were used, rather than the number of operators, *per se*, about 26% of the total number of platforms (as contrasted with 5.8% of total on an operator basis) would fall into this category.

CONCLUSIONS

The statistical evidence we have discussed shows that independents had a marginally better safety record than the majors during the two periods we analyzed—when intervening variables such as the number of platform years, the number of wells drilled, and the age of platforms operated were held constant. The independents' superiority is modest but consistent and statistically significant. This result is contrary to the conventional thinking in both industry and regulatory circles.

We also found only a very small number of "outliers," i.e., operators with either much better or much worse records than one would expect given the number, age, etc. of the platforms they operated, with no predominance by either independents or majors.

Two somewhat contradictory caveats might be attached to this conclusion. The first is that three of the outliers in the "worse-than-expected" end of the distributions were majors operating a relatively large number of platforms, about 26% of the total number of platforms during the 1987-1994. Second, given the dramatic drop in the safety score shown in Figure 4C.1, "worse-than-expected" in the 1987-1994 period may not be "so bad"—at least compared to the earlier (1980-1986) period.

Finally, when comparing independents and majors, it is important not to lose sight of the remarkable decline in the offshore industry's accident rate depicted in Figure 4C.1. Others have shown that workers on offshore platforms today face risks comparable to such occupations as flight attendants or roofers—an equivalence that many would find most surprising (Arnold and Koszela 1990). Our own comparisons of majors and independents admittedly are broad, but they certainly do not suggest that history provides much of an argument for tighter OCS regulations if more work offshore were to fall to independent operators.

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OUTER CONTINENTAL SHELF ISSUES: CENTRAL GULF OF MEXICO

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BACKGROUND

This report summarizes the research effort and findings of an investigation of the issues associated with Outer Continental Shelf (OCS) oil and gas activities in the Central Gulf of Mexico. Stakeholders assessed for the delineation of the issues associated with OCS oil and gas activities ranged across the offshore oil and gas industry; the offshore support sector; other direct and indirect coastal users; stakeholders that benefited from economic growth in general; concerned citizen groups; and public and governmental organizations.

OBJECTIVES

(1) To identify and describe the various stakeholder groups in the coastal central Gulf of Mexico, define their interests, and the degree of their concerns about Outer Continental Shelf oil and gas activities.

(2) To identify the specific social and economic issues and concerns related to the central Gulf of Mexico oil and gas activity that are seen as being important by different major stakeholders and other knowledgeable individuals.

(3) To identify the underlying assumptions held by various stakeholders concerning the effects of Outer Continental Shelf activities, which determine the positions they take on the social and economic issues.

DESCRIPTION

Throughout the course of the study 131 individuals in coastal communities in Alabama, Mississippi and Louisiana were interviewed concerning their perspectives on offshore oil and gas development. Selection of the sample communities occurred in May of 1993 in conjunction with MMS representatives. We examined census data at the county and community level, but in the end relied most heavily on our combined knowledge of coastal communities in Louisiana, Mississippi, and Alabama. Initially we selected four Louisiana communities. Cameron,

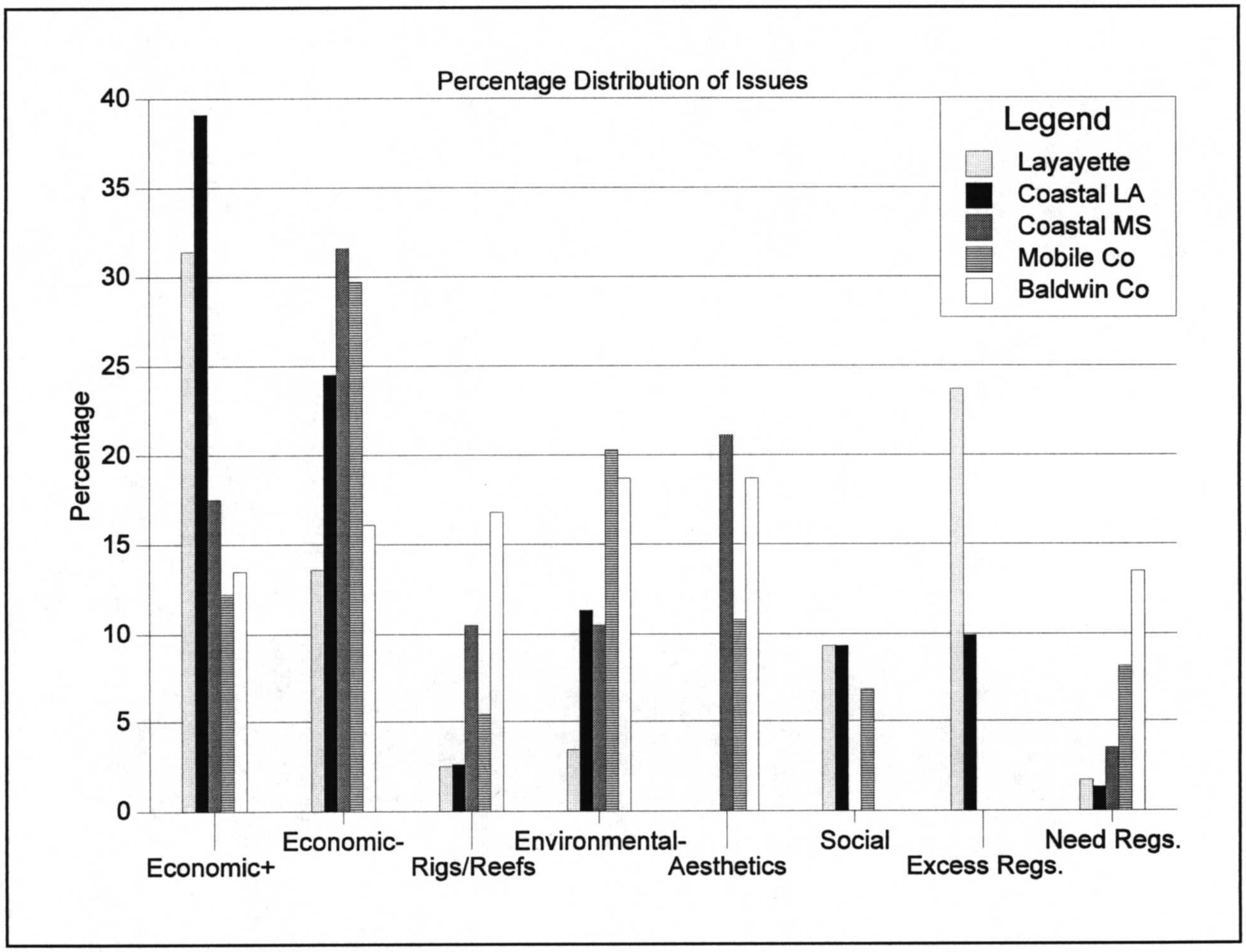

Figure 4C.2. Major issues across the region.

Morgan City and Grand Isle were selected for their location on the coast, and their primarily blue collar association with the offshore oil sector. Grand Isle was also selected for its concentration of other direct and indirect coastal users, primarily concentrated around shrimping and tourism. Lafayette was selected for its white collar association with the offshore oil sector, having long been a regional center for offshore activity. We selected Gulfport, Biloxi and Pascagoula in Mississippi because they represented the overwhelming majority of the coastal Mississippi population, and a wide diversity of coastal uses and occupations. In Alabama we selected Mobile because it was a major port city, Dauphin Island for its other coastal users, and Gulf Shores and Fairhope primarily for their coastal tourism and retirement sites.

Because the key informants constituted a previously unidentified and thus unknown population, a technique known as snowballing was utilized. This technique is specifically appropriate to field research. Snowball sampling is a method through which the researcher develops an ever-increasing set of sample observations. One respondent in the sample under study is asked to recommend others for interviewing, and each of the subsequently interviewed participants is asked for further recommendations. This is the only feasible type of sampling procedure which fit the requirements of the project to 1) identify various stakeholder groups through a referral process and, 2) retain flexibility in the field to identify and sample stakeholder groups as they are "discovered" through the sampling process.

All of the interviews in the coastal communities were recorded. The tapes of the interview were transcribed during the fall of 1993 and spring of 1994. The transcripts were then content analyzed for the emergence of issues across five locations, Lafayette, LA and vicinity, coastal Louisiana, coastal Mississippi, Mobile County Alabama and Baldwin County Alabama.

Table 4C.2 Percentage distribution of issues across each region.

		Lafay	C LA	C MS	Mobile	Bladw
Economic +	Jobs	6.8	15.0	12.3	2.7	2.6
	Support sector	4.2	2.0	1.8	0.0	0.6
	Spinoffs	14.4	20.3	3.5	5.4	3.2
	Need oil	5.9	1.3	0.0	4.1	7.7
Economic -	Tourism	0.0	0.0	5.3	0.0	5.8
	Property values	0.0	0.0	3.5	0.0	0.6
	Accident	0.0	0.0	5.3	1.4	8.4
	Cyclical	12.7	16.3	1.8	0.0	0.0
	Trash on bottom	0.8	4.6	14.0	20.3	1.3
	Migration $ & jobs	0.0	2.0	0.0	5.4	0.0
	Displaces other	0.0	0.7	1.8	2.7	0.0
Environmental +	Rigs as reefs	2.5	2.6	10.5	5.4	16.8
Environmental -	Offshore pollution	1.7	2.6	7.0	6.8	7.1
	Onshore pollution	0.0	2.6	1.8	4.1	1.3
	Damage to wetlands	0.0	3.3	0.0	2.7	0.6
	General	1.7	2.6	1.8	6.8	9.7
Aesthetics	Visual	0.0	0.0	12.3	4.1	14.8
	Noise	0.0	0.0	3.5	4.1	1.9
	Marine trash	0.0	0.0	5.3	2.7	1.9
Social	Boomtown	1.7	5.2	0.0	1.4	0.0
	Overadaptation	7.6	3.9	0.0	4.1	0.0
Policy	Too many regs.	23.7	9.8	0.0	0.0	0.0
	Careful regs.	1.7	1.3	3.5	8.1	11.6
	Need more regs.	0.0	0.0	0.0	0.0	1.9
	Planning	9.3	0.7	0.0	0.0	0.0
	Safety	5.1	0.0	0.0	0.0	0.0
Navigation	Hazards	0.0	0.7	1.8	5.4	1.9
	Aids	0.0	0.0	3.5	1.4	0.6
Other	Cost of living	0.0	0.7	0.0	0.0	0.0
	Family impacts	0.0	0.0	0.0	1.4	0.0
	Oil cos. publicity	0.0	0.7	0.0	0.0	0.0
	Improve genetic pool	0.7	0.0	0.0	0.0	0.0
	Career opportunities	0.7	0.0	0.0	0.0	0.0
Total		00.0	100.0	100.0	100.0	100.0

Legend: Lafay = Lafayette Parish, Louisiana
C LA = Coastal Louisiana
C MS = Coastal Mississippi
Mobile = Mobile County, Alabama
Baldw = Baldwin County, Alabama

SIGNIFICANT CONCLUSIONS

Both positive and negative economic and environmental issues emerged across the three states (Louisiana, Mississippi and Alabama) surveyed. While jobs and economic spinoffs emerged as issues in all regions they were more frequently mentioned in Louisiana. Negative economic impacts also came out as issues across the three states, but were more closely associated with the coastal tourism region of Alabama. There were marked differences in the issues associated with regulating OCS activities with Louisiana respondents maintaining that the activity was too heavily regulated and Mississippi and Alabama respondents maintaining that careful regulation was necessary. There were also marked differences in the extent to which aesthetic considerations emerged as issues. In Louisiana aesthetic considerations did not emerge as an issue, while in Mississippi and Alabama they did (see Figure 4C.2 and Table 4C.2).

STUDY RESULTS

Several general trends can be seen although exceptions to these are also evident. In general, in Louisiana, where offshore activities have been ongoing for almost five decades, respondents generally focused on the issues of jobs and economic spinoffs and felt that the current offshore regulatory structure was burdensome and too restrictive. In contrast in Mississippi and Alabama, where coastal tourism was more important, the issues of potential aesthetic and environmental impacts were more evident, and respondents overwhelmingly agreed that careful regulation of the offshore industry was necessary if offshore development was to go forward. A fair amount of environmental concern associated with a number of specific issues was evident in all the sample areas except the Lafayette vicinity sample, and both individuals who expressed support for and opposition to offshore development expressed environmental concerns. This led to the conclusion that, at least in this case, stakeholders could not be characterized by neat mutually exclusive sets of issues, but had more complex mixes of stakes associated with the potential impacts of offshore development. Two groups (offshore fishermen, including commercial fishermen and shrimpers) focused on single issues (rigs as reefs and trash on the bottom respectively), and these groups were spread geographically across the survey regions.

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A HISTORIC SOCIOECONOMIC DATABASE FOR THE GULF OF MEXICO

Dr. Natsumi Aratame
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Introduction

The purpose of this project in this phase is to build the longitudinal database that helps us carry out sociological analyses of the impacts of offshore drilling activities. Despite a long history of OCS activities in the Gulf of Mexico, little information is available on the socioeconomic impact of offshore drilling in this region in general, and their coastal areas in particular. Therefore, we have spent the past year probing into various data sources collecting a wide range of socioeconomic information for the Gulf of Mexico (GOM) states of Alabama, Mississippi, Louisiana, Texas and Florida for the period 1930-1990 (see Table 4C.3).

Table 4C.3 Major data sources used.

Population, Civil Employment, Income

1930-1960 Censuses	-	ICPSR* 0003
	-	Census of population 1960: General Social and Economic Characteristics
1970 Census	-	ICPSR 9694
1980 Census	-	ICPSR 8038/8107
1990 Census	-	ICPSR 6054

County and City Data Book Consolidated File - ICPSR 7736
County Statistics File (Co-Stat 4) - ICPSR 9806

Government Employment

Census of Government 1962, 1972, 1977, 1982, 1988
ICPSR 0017, 0069, 8117, 8395, 6069

Government Finance

Census of Government 1962, 1972, 1977, 1982, 1988
ICPSR 0017, 0069, 8118, 8394, 9484

Establishment statistics

County and City Data Book Consolidated File - ICPSR 7736
County Statistics File (Co-Stat 4) - ICPSR 9806

*ICPSR: Inter-University Consortium for Political and Social Research

The dataset is compiled at the county or parish level and includes demographic, civilian employment, establishments, and government finance and employment data. The benefit of collecting data at smaller units is that we can easily aggregate the data to higher levels if necessary. Some datasets already exist that include a particular aspect of socioeconomic information for certain geographic units and for particular years; however, this dataset will be the first to assemble a wide range of socioeconomic information over 50 years at the county/parish level.

The database will also include several measures of oil and gas dependency of a county, as well as measures of occupational change as related to the oil and gas industry. These measures are being developed from a detailed matrix of industry by occupation at the county level for the five GOM states for 1980 and 1990.

SUBJECT AREAS

The selection of subject matters that enter into the database was guided by the following conceptual scheme. It is assumed that there are direct economic and (indirect) socioeconomic impacts of OCS activities. The direct economic impact refers to the effects of such activities on the pattern of employment related to oil/gas production. The extent of the impact is expected to be different from county to county, depending on differences in the infrastructure of coastal counties and on differences in human capital and industrial specialization. The impact, however, goes beyond changes in the employment structure as related to oil and gas extraction.

For example, counties with an increased oil/gas dependency may experience a change in the demographic structure, an increase in labor demand in other economic activities, increased needs for public services due to population growth, and changes in the structure of revenues and expenditures. Often during the period of expansion and decline, a gap arises between increasing or declining demand for public services, on the one hand, and capacity to supply by the local government concerned, on the other hand. The impact, however, might also be affected by the initial

Table 4C.4. Variable names: civilian employment 1980-90.

FIPS	Char	5-DIGIT COUNTY FIPS CD
STATE	Char	STATE CODE (FIPS)
REG	Char	U.S. REGION
DIV	Char	U.S. DIVISION
SMSA	Char	1980 CLASSIFICATION
SCSA	Char	1980 CLASSIFICATION
AREANAME	Char	NAME OF AREA SUMMARIZED
MSACMSA	Char	MSA OR CMSA: 1990
PMSA	Char	PRIMARY METRO STATISTICAL AREA: 1990
CNTYSC	Char	COUNTY SIZE CODE: 1990
CMSA2	Char	2-DIGIT CMSA CODE: 1990
E8065001	Num	INDUSTRY (EMPLOYED PERSONS 16 YEARS AND OVER): AGRICULTURE,FORESTRY,FISHERIES & MINING
E8065002	Num	INDUSTRY (EMPLOYED PERSONS 16 YEARS AND OVER): CONSTRUCTION
E8065003	Num	INDUSTRY (EMPLOYED PERSONS 16 YEARS AND OVER): MANUFACTURING (NONDURABLE GOODS)
E8065004	Num	INDUSTRY (EMPLOYED PERSONS 16 YEARS AND OVER): MANUFACTURING (DURABLE GOODS)
E8065005	Num	INDUSTRY (EMPLOYED PERSONS 16 YEARS AND OVER): TRANSPORTATION
E8065006	Num	INDUSTRY (EMPLOYED PERSONS 16 YEARS AND OVER): COMMUNICATIONS & OTHER PUBLIC UTILITIES
E8065007	Num	INDUSTRY (EMPLOYED PERSONS 16 YEARS AND OVER): WHOLESALE TRADE
E8065008	Num	INDUSTRY (EMPLOYED PERSONS 16 YEARS AND OVER): RETAIL TRADE
E8065009	Num	INDUSTRY (EMPLOYED PERSONS 16 YEARS AND OVER): FINANCE, INSURANCE & REAL ESTATE
E8065010	Num	INDUSTRY (EMPLOYED PERSONS 16 YEARS AND OVER): BUSINESS & REPAIR SERVICES
E8065011	Num	INDUSTRY (EMPLOYED PERSONS 16 YEARS AND OVER): PERSONAL, ENTERTAINMENT & RECREATIONAL SERVICES
E8065012	Num	INDUSTRY (EMPLOYED PERSONS 16 YEARS AND OVER): PROFESSIONAL & RELATED SERVICES-HEALTH SERVICES
E8065013	Num	INDUSTRY (EMPLOYED PERSONS 16 YEARS AND OVER): PROFESSIONAL & RELATED SERVICESPROFESS-EDUCATIONAL SERVICES
E8065014	Num	INDUSTRY (EMPLOYED PERSONS 16 YEARS AND OVER): PROFESSIONAL & RELATED SERVICESPROFESS-OTHERS
E8065015	Num	INDUSTRY (EMPLOYED PERSONS 16 YEARS AND OVER): PUBLIC ADMINISTRATION

level of oil and gas dependency. Thus, to assess both the direct and indirect effects of OCS activities, the database in this project includes the following areas: demographic, civil employment, establishment, government employment and finances.

DATA SOURCES

Demography, Income and Civil Employment

The best source of demographic and labor force information is found in the population census in respective years. Therefore, we have extracted demographic and labor force information from the 1930-1990 census computer tapes. Concerning the 1960 employment information, the data were entered manually since they are not available in machine-readable form.

Establishments

Information on establishments is available from the City and County Data Book for the period 1930-70 and from CO-STAT4 for the subsequent years. Therefore, we have extracted and combined data from these two datasets.

Government Employment

The data on government employment are available from the 1957, 62, 72, 77, 82, and 88 Census of Governments. The compilation of government employment data proved more time consuming than anticipated. For example, the 1957 employment (and finance) data are not available in computer tapes. Thus, for this period, we entered the data manually based on the data in census reports.

Government Finance

While some data are from the City and County Data Book and the COSTAT4 computer datasets, more detailed information is available from the original Census of Governments. Thus, as in the data on government employment, we have compiled data on government revenue and expenditure from respective government censuses.

All variables names in these data files were renamed so that every variable name is unique; the names indicate both the year of data collection or publication and the sequence in a dataset.

COMPARABILITY

Two main problems exists regarding the comparability of data across time and space. First, the definition of some variables has changed, and second, the geographical coverage has also undergone some changes.

Regarding the issue of definition, for example, industrial and occupational classifications in each period are slightly different and the definition of the labor force has also changed. Prior to 1940, employment data are based on the concept of gainful workers, whereas since and including 1940, the labor force concept has been used.
For the 1980 and 1990 occupational and industrial classification, we were able to reclassify the 1980 categories to the 1990 categories using the conversion table and the detailed three digit level industry and occupation data provided by the Census office. No such conversion of categories is possible for earlier years, since neither the information for detailed occupations and industries nor the conversion tables are available at the county level.

The lower age limit also changed during the period 1940-1990. For the period 1940-60, all persons aged 14 years and over are included, but this age limit was raised to 16 years since the 1970 census. However, it is not possible to adjust these data, because labor force data for the period 1940-1960 are not available by age in such a manner that we could exclude 14- and 15-year old workers. These inconsistencies will be noted in the codebook as much as possible, but one always needs to be careful when comparing data over longer time periods.

We are also concerned with the addition and disappearance of counties and change of county boundaries. In general, the choice of county as a unit of data collection presents fewer problems than if we were using other administrative categories such as city, since counties as a geographic unit have remained quite stable over many years in terms of numbers and land area.

For example, there were 3100 counties in the U.S. in 1930, and this number remained basically the same until the late 1950s. The number increased to about 3140 due mostly to the addition of counties in Alaska and Hawaii in the late 1950s, but it has remained stable until today. The change in land area might be more significant for the purpose of statistical analysis, but the effect is probably very small. In our study area, there are only 6 counties whose land area changed by more than 10%. Ninety-three percent of counties either did not change their boundaries, or the change resulted in an increase or decease of land area by less than 5%.

STRUCTURE OF DATABASE

The compiled dataset includes approximately 2500 variables, amounting to about 15MB. The database includes various geographic codes, such as States, Metropolitan Areas, Labor Market Areas, to allow researchers to aggregate the county-level data to other geographic levels. Table 4C.4 shows the preliminary organization of the database in terms of subject areas by the year for which data are available. Each major category is further broken down into many more subject areas. In general, more data are available for 1980 and 1990 than for earlier periods. The problem for the most recent period was more one of deciding which of the many variables to exclude.

An example of the actual variable names is shown in Table 4C.4. The first letter ("E") indicates the broad category to which the variable belongs, and the second and third digits generally show the year of data collection. The remaining digits shows a sequence number, though they may not be in sequential manner. These digits refer to the variable number in the original dataset so that a researcher can go back to the original data sources if desired.

DATA FORMAT

The database currently exists on an IBM mainframe at LSU in a SAS data format. The database will be made available in several mainframe formats such as SAS and SPSS system files, SAS transport or SPSS export file, and ASCII data with SAS or SPSS data definition files. Since export or transport files are also compatible with SPSS/PC and SAS/PC, they can be download for analysis on PCs. Since these formats can be converted to popular spreadsheet formats using conversion software, we should be able to provide data in Lotus 123 and Microsoft Excel format as well.

PHASE ONE SOCIOECONOMIC BASELINE STUDY FOR THE GULF OF MEXICO: A PRELIMINARY ANALYSIS

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OVERVIEW

This summary of preliminary research is based on unique occupational and industrial data acquired through the LSU/MMS Coastal Marine Institute. The U.S. Bureau of the Census was commissioned to develop county- and parish-level industry by occupation matrices for all counties for the gulf-coast states of Texas, Louisiana, Mississippi, Alabama, and Florida. These data will permit us to follow shifts in employment within and between occupations and industries at key times in the development of the U.S. oil and gas industry. The Bureau extracted these matrices from its databases for the 1980 and 1990 decennial censuses. The data were recently received and contain detailed occupational and industrial information for 534 counties. Though we will work with these data for some time, we present some initial analyses below.

TECHNICAL CONSIDERATIONS

The occupation by industry matrices employ codes from the respective 1980 and 1990 censuses of population and housing. The Census codes are derived from the Standard Industrial Classification and from the Standard Occupational Classification. Because these coding conventions are modified between decennial censuses, it has been necessary for us to undertake a moderate amount of recoding to ensure that the data for 1980 and 1990 correspond. We have developed an equivalency template that facilitates the reclassification of occupations and industries.

OIL AND GAS DEPENDENCY, INDUSTRY, AND OCCUPATION: A CONCEPTUAL FRAMEWORK

In our CMI project, our primary interest is the extent to which a county is dependent on oil/gas extraction. One important consequence of changes in the industrial structure is occupational change. To clarify the two concepts: *industry* refers to the kind of product or service produced; *occupation* refers to kind of work carried out.

From a sociological perspective, the interplay between industry and occupation is of utmost importance. While sociologists tend to focus much more on occupations (which, after all, yield information about status, income, and social mobility), it is equally clear that industry plays an important role in these matters. We know, for example, that much of the upward social mobility of the postwar period in the United came about from an upgrading of the labor force, i.e. during this period, higher-status jobs grew faster than lower-status jobs. We further know that this upgrading was largely the result of changes in the industrial structure towards industries that tend to require higher-status positions.

It is for these reasons, that we have begun with an analysis of the way industry and occupation interact, with special emphasis on the role of the oil/gas extractive industry in this process. In the following, we present some preliminary findings about changes in industry and occupation as related to oil/gas extraction.

Our data indicated that the industry of oil/gas extraction accounted for a substantial share of total employment only in Louisiana and Texas (4.2% and 2.76% in 1980, respectively). Oil/and gas in 1980 employed 1.4% of total employment in Mississippi and less than 2/10th of a percent in Alabama and Florida. The relative employment share of oil/gas extraction went down during the 1980s in all five coastal states, decreasing to 2.8% in Louisiana and 1.8% in Texas. These state totals, however, average substantial variation in the importance of oil/gas employment by county and parish. Information about the relative share of oil/gas production is shown in Figures 4C.3 and 4C.4.

The figures show the importance of employment in oil/gas extraction for Louisiana's parishes. In 1980, La Salle had the highest employment share in oil/gas extraction with 14.6% of total employment. Oil/gas employment is also very important in the coastal parishes of Cameron, Vermillion, and Iberia, and in their northern neighbors (Jefferson Davis, Acadia, and Lafayette). Terrebonne also falls into the category with the highest oil/gas employment.

A comparison of the 1980 and 1990 employment shares in oil/gas show that almost all parishes experienced a decline in the percent of total employment accounted for by this industry. Oil/gas employed more than 10% of the workforce in only La Salle, Vermillion, and Terrebonne. The 1980-90 comparison also shows, however, that oil/gas employment remained more important in the coastal parishes than in any other region of Louisiana. While oil/gas employment declined throughout the state, the decline was less in the coastal parishes than elsewhere. This clearly indicates a growing concentration of oil/gas employment in Louisiana's coastal parishes.

We now briefly discuss some preliminary findings about the relationship between industry and occupation. We have started the analysis with an examination of the occupational structure in the oil/gas industry. Our expectation was that parishes that experienced a substantial relative decline in oil/gas employment would also experience more occupational change than parishes where oil/gas employment remained more stable. This expectation was based on the assumption that when organizations change in size, the relative size of the various units (and hence the occupational composition of the organization) changes as well. Thus, whatever might induce overall occupational change in Louisiana's economy, this change should be exacerbated by changes in the oil/gas industry. As a first approximation, we measured occupational change in terms of the index of dissimilarity, i.e. without concern for the direction of this change (upgrading or downgrading of the labor force). Our initial findings show that while change in the oil/gas employment tended to increase change in the occupational composition of the oil/gas industry, this positive effect was counteracted by the relative size of employment in the oil/gas industry. In order words, among parishes, the greater the proportion of total employment in oil/gas extraction in 1980, the smaller the occupational change during the period 1980-90. While we are not yet entirely clear about the process of this effect, we hypothesize that parishes with large employment shares in oil/gas extraction have much larger companies in this industry than parishes with lower employment shares. Larger companies tend to have a more stable organizational structure than smaller companies which could account for the change differential of the occupational structure in the oil/gas industry.

Our work on the relationship between industry and occupation in the contact of change in oil/gas extraction will focus on the direction of occupational change and on a decomposition of the various structural effects. For this purpose, we will apply the shift-share analysis method to occupational change. This method makes use of our detailed industry-occupation matrix. It allows us

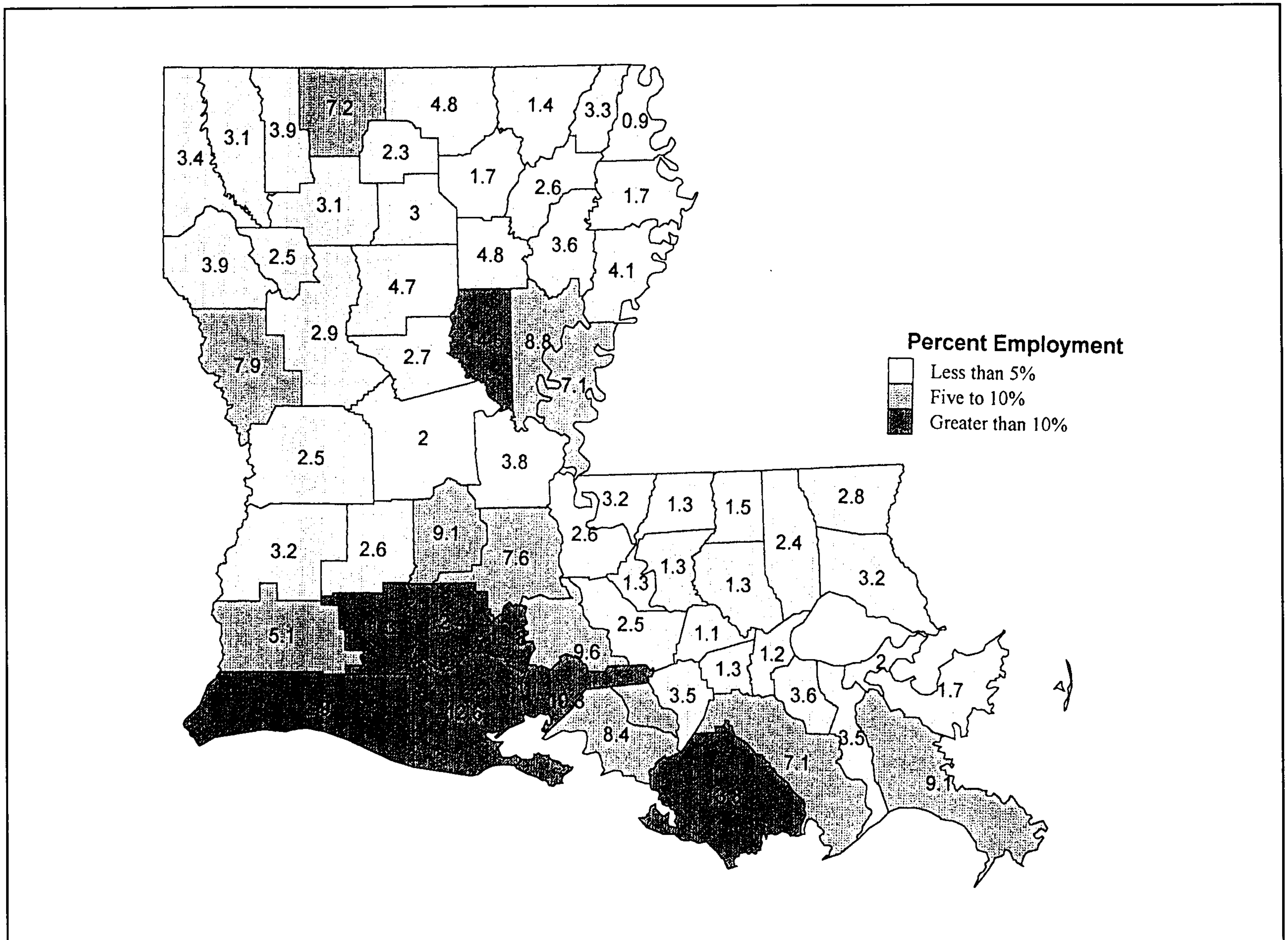

Figure 4C.3. Percent employed in oil/gas extraction, Louisiana, 1980.

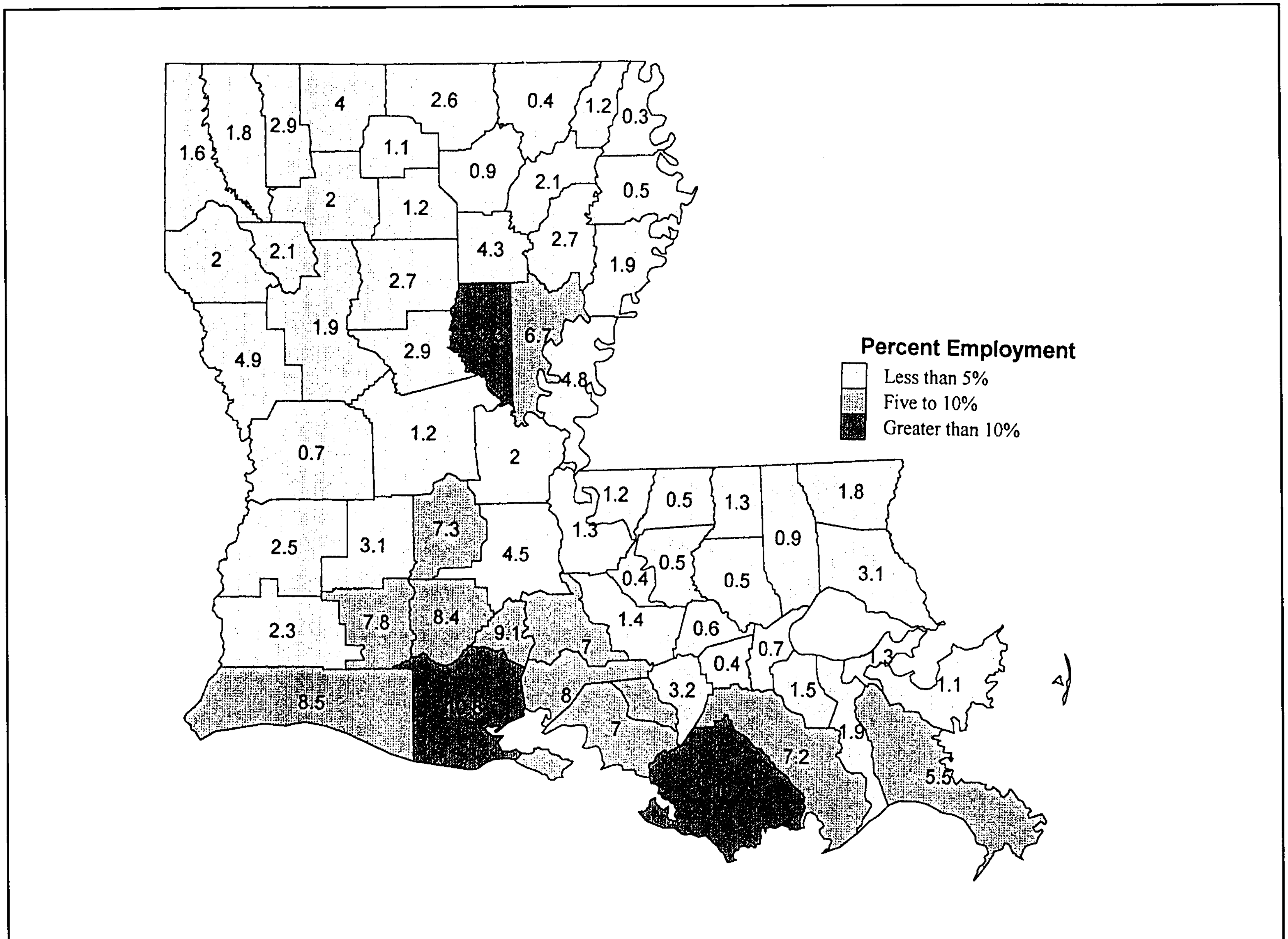

Figure 4C.4. Percent employed in oil/gas extraction, Louisiana, 1990.

to identify the components of occupational change that are due to changes in the industrial structure, to changes in the occupational mix within industries, and the interaction between these two structural changes. Shift-share analysis, moreover, makes it possible to identify the contributions of specific industries for both the industry shift effect and the occupational mix effect, thus enabling us to pinpoint the role played by the oil/gas industry in this process. We hope to have the opportunity to present that analysis at next year's technology transfer meeting.

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INCOME INEQUALITY AT THE PLACE LEVEL: A COMPARATIVE ANALYSIS—PRELIMINARY RESULTS

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OVERVIEW

This summary of preliminary research is based on our ongoing study of income inequality in coastal communities. The analysis is designed to gain an understanding of the effects of onshore and offshore oil and gas development on income inequality in coastal areas. These place-level case studies of family income inequality build on recently completed work at the parish level (Tolbert 1995). The parish-level research has generated useful results and considerable interest among representatives of various federal and state agencies. Yet, the research is obviously limited by the size and diversity of parishes which can mask important variation *within* parishes. The new research improves on the parish-level inequality analysis by employing data on coastal places (urbanized areas of 2,500 or more persons). We also add decennial census data for 1950 and 1960 to the 1970, 1980, and 1990 data employed in the parish-level analysis. This improves on the parish-level by providing a much broader temporal context within which inequality patterns can be analyzed.

RATIONALE FOR ANALYSIS AT THE PLACE LEVEL

Most inequality studies make spatial comparisons at very high levels of aggregation (e.g., national, state, or major metropolitan areas). Our analysis at the place level has a number of advantages. First, as units of analysis, towns and cities are more spatially homogeneous than larger units. In contrast, metropolitan areas, counties, and states are aggregations of units that comprise anything from densely populated urban areas to sparse rural communities. Since similarity is basic to the process of aggregation, it is advisable to select units of observation that are as theoretically homogeneous as possible. Second, social problems such as poverty, unemployment, and marital disruption are more prevalent in the central cities of metropolitan areas. Given our focus on family income inequality,

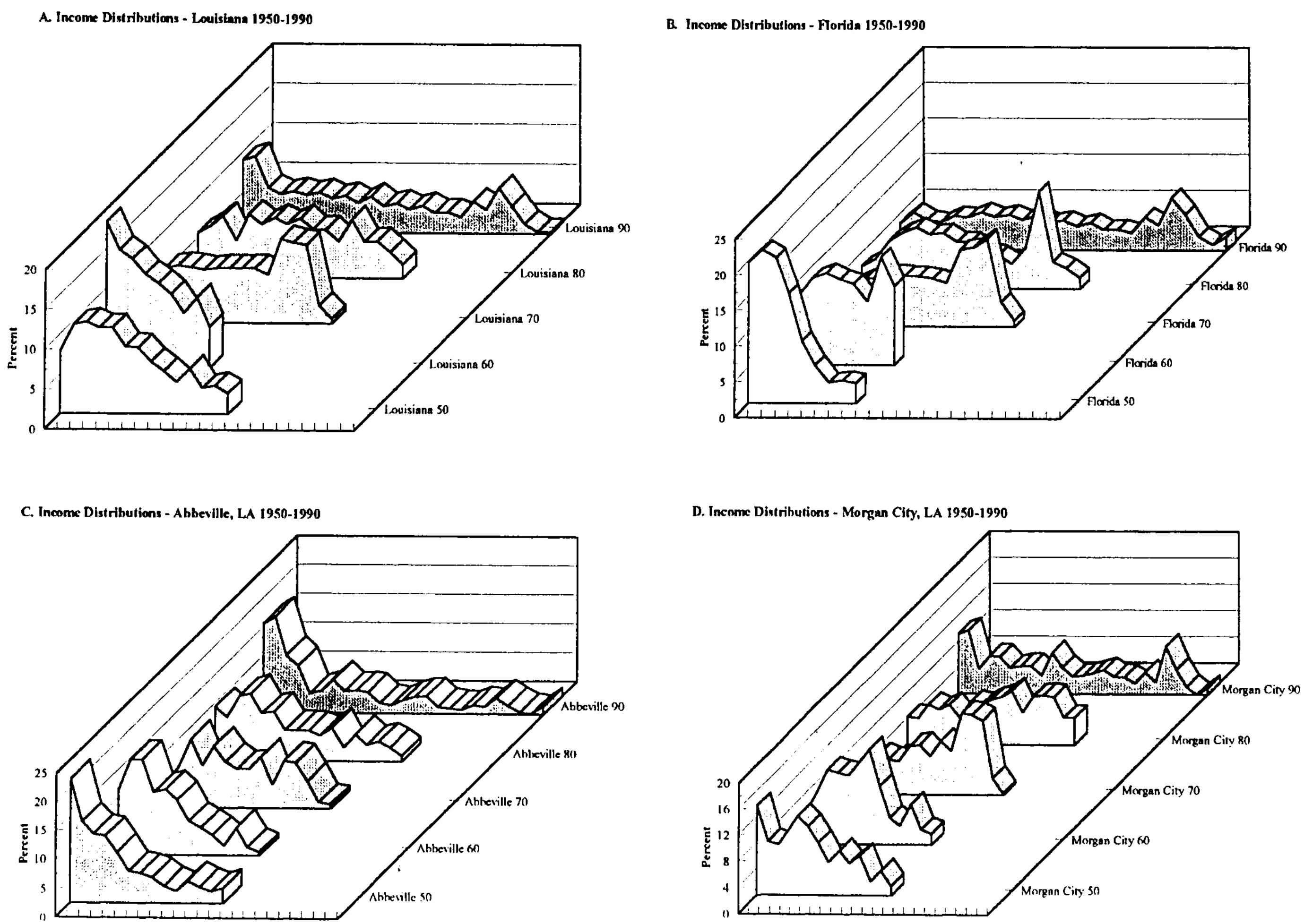

Figure 4C.5. Income distribution for Louisiana, Florida, Abbeville, and Morgan City 1950 - 1990.

results from our place-level analysis would not be confounded by the widely-acknowledged socio-economic differences between central city and suburban residents. Third, in contrast to a parish-level analysis, a place analysis yields many more spatial units and, hence, lends considerably more power to statistical tests that we will use to identify relatively stable and relatively volatile inequality patterns.

SELECTION OF PLACES

To maximize the utility and validity of comparisons, efforts are being made to pair and/or match places as closely as possible on inequality trends. At this time, the final selection of communities has not been made. We plan to select a Louisiana community and a Florida community that exhibit relatively little change in family income inequality across the 30 year period. We will also identify a pair of Louisiana and Florida locales that exhibits substantial volatility in income inequality. The matrix that follows outlines this strategy for our case studies:

	Extent of Change in Inequality Over Time	
	Little or No Change	Substantial Change
Louisiana	$La._1$	$La._2$
Florida	$Fl._1$	$Fl._2$

Our previous parish-level analysis suggests the possibility that the upper left and lower right cells ($La._1$ and $Fl._2$) may be empty. That is, there may be no Louisiana coastal places that exhibit stability and no Florida communities that exhibit volatility in income inequality trends. We suspect, however, that a place-level analysis may reveal substantial within-parish differences in which some locales are stable and others are volatile. We are making efforts to identify reasonably matched pairs of Florida and Louisiana communities that fill each cell of the above matrix.

PRELIMINARY FINDINGS

The preliminary results in Figure 4C.5 suggest that there have been major changes in the income distribution at both the state level in Louisiana and at the place level as well. At the state level in Louisiana, Figure 4C.5A shows that over the last four decades there was a growing polarization of income groups, though the trend is far from monotonic. In 1950 and 1960, earners were concentrated in the low and low-middle income categories. In 1970 and 1980, the distribution became more uniform, suggesting more equality in the distribution of income. By 1990, however, there was clear polarization of earners in the lowest and highest income categories and disproportionately fewer earners in the middle income groups. We note that the income distributions at this stage are preliminary and are not yet expressed as constant dollars, nor do the distributions have the same number of income categories from year-to-year. Nonetheless the trends for Louisiana appear to be real and distinct since Figure 4C.5B reveals a very different story for Florida, where there was considerably less change in the income distribution and less evidence of income polarization.

Interestingly, the state-level trends in income distribution for Louisiana are not necessarily the same as those at the place level. Morgan City, for instance, does have a similar as that observed at the state level (Figure 4C.5C). In contrast, changes in the income distribution for Abbeville do not conform to those at the state level nor to Morgan City, despite the fact that it too is located in a coastal parish. Figure 4C.5D indicates that the income distribution in Abbeville has resisted changes over the last four decades. Both the 1950 and 1990 income distributions are very similar, though in the latter year there were proportionately fewer earners in the low-income categories. These important differences confirm our earlier suspicion that place-level income distributions must be examined separately since they are potentially distinct from one another and from those at higher units of analysis.

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SESSION 4D

LATEX PHYSICAL OCEANOGRAPHY PRELIMINARY RESULTS, PART II

Session: 4D - LATEX PHYSICAL OCEANOGRAPHY PRELIMINARY RESULTS, PART II

Co-Chairs: Dr. Alexis Lugo-Fernández and Dr. Thomas Berger

Date: December 13, 1995

Presentation	Author/Affiliation
LATEX Physical Oceanography Preliminary Results, Part II	Dr. Alexis Lugo-Fernández Environmental Studies Section Minerals Management Service Gulf of Mexico OCS Region
Results of the Sculp Drifting Buoy program	Dr. Walter R. Johnson Mr. Robert P. LaBelle Minerals Management Service Herndon, Virginia Dr. Pearn P. Niiler Scripps Institution of Oceanography
An Updated Climatology of Loop Current Eddies from GEOSAT Altimetry	Dr. Robert R. Leben Dr. George H. Born Colorado Center for Astrodynamics Research University of Colorado, Boulder
Effect of River Flow and Circulation on Nutrient Distributions on the Texas-Louisiana Continental Shelf	Dr. Denis A. Wiesenburg Ms. Kelly R. Thornton Center for Marine Sciences University of Southern Mississippi
Phytoplankton Distributions on the Louisiana Continental Shelf: A Comparison of Results from Microscopic Identification and Phytoplankton Pigments Measurements	Ms. Paula S. Bontempi Dr. Denis A. Wiesenburg Center for Marine Sciences University of Southern Mississippi Ms. Carrie A. Neuhard Lyons Department of Oceanography Texas A&M University Mr. Michael L. Parsons Department of Oceanography and Coastal Studies Louisiana State University Dr. Quay Dortch Louisiana Universities Marine Consortium (LUMCON)
Ichthyoplankton Distributions and Abundances in the Coastal Current of Louisiana and Texas	Dr. Richard F. Shaw Mr. Joseph S. Cope Mr. James G. Ditty Coastal Fisheries Institute Louisiana State University

Fate of Chemicals in the Mississippi River Plume: Transport and Three-phase Partitioning in the Shallow Coastal Shelf of the Gulf of Mexico

Ms. Debra J. McMillin
Dr. Jay C. Means
Aquatic Toxicology Laboratory
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LATEX PHYSICAL OCEANOGRAPHY PRELIMINARY RESULTS, PART II

Dr. Alexis Lugo-Fernández
Environmental Studies Section
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The presentations from the morning session, Part I, provided an oceanographic framework for the presentations of this afternoon. Specifically, the cyclonic mean circulation over the shelf was confirmed. This pattern consists of westerly flow from September through May, driven primarily by winds and Mississippi River outflow, and easterly flow over the outer shelf resulting from the average effect of offshore Loop Current eddies. The summer shift, June transition and easterly flow from July to August is essentially a wind driven phenomenon. We also saw evidence of upwelling at some inshore areas which may be driving areas of high biological productivity. This afternoon's talks present how the biological shelf processes and chemical dispersion or advection are affected by the freshwater input, the general circulation, water temperature, salinity, and stability.

Dr. Alexis Lugo-Fernández has been an oceanographer with the Minerals Management Service, Gulf of Mexico OCS Region since 1989. At the MMS, Dr. Lugo-Fernández's experience includes preparation of NEPA Documents and management of physical oceanographic studies in the Environmental Studies Section. His primary interests are physical processes on coral reefs and circulation in the shelf. Dr. Lugo-Fernández obtained his B.S. in physics and M.S. in marine sciences from the University of Puerto Rico, and Ph.D. in marine sciences (physical oceanography) from Louisiana State University.

RESULTS OF THE SCULP DRIFTING BUOY PROGRAM

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Mr. Robert P. LaBelle
Minerals Management Service
Herndon, Virginia

Dr. Pearn P. Niiler
Scripps Institution of Oceanography

ABSTRACT

MMS and Scripps Institution of Oceanography deployed over 340 drifting buoys in the western Gulf of Mexico over a one-year period during 1993-94. The buoys were satellite-tracked, Lagrangian surface drifters that floated in the top meter of the water column and reported positional information several times a day for up to several months. The data from these drifters have characterized the surface flow in the western Gulf, concentrating on shelf waters. The emerging picture of surface circulation from the drifter data is being compared with results from oil-spill trajectory model runs driven by a numerical ocean circulation model with a high-resolution curvilinear grid.

INTRODUCTION

A large field program of Lagrangian measurements to support and skill assess numerical ocean circulation models was begun in 1993 through a cooperative effort between the MMS and Scripps Institution of Oceanography (Niiler and Davis 1992). Preliminary results from the Surface Current Lagrangian Program (SCULP) study are now being used as inputs to the MMS Oil-Spill Risk Analysis (OSRA) model runs in the western Gulf of Mexico.

The results of OSRA model runs using surface currents generated by a numerical ocean model are compared to model runs using Lagrangian drifter data as a supplement to the numerical surface current field. Both model runs are also used to hindcast a recent actual oil spill in a tanker lightering zone south of Galveston, Texas.

SURFACE CURRENT LAGRANGIAN PROGRAM (SCULP)

Approximately 340 drifting buoys were deployed in a repeated array from aircraft and from three production platforms located offshore Louisiana and Texas. The drifters were designed to float in the top 1 meter of the water column and to report their positions several times a day for up to several months. Weekly deployments were made from mid-October 1993 through January 1994, followed by monthly deployments from February 1994 through September 1994. Calculations derived from these buoy positions provided not only individual buoy tracks, but also averaged surface currents (Figure 4D.1).

During September through May, the averaged surface currents from the drifters show westward and southwestward flow, following the coastline (Figure 4D.1). The coastal current forms a jet structure, and the drifters are transported by this current at as much as 75 to 100 cm/s. At approximately the U.S.-Mexican border, most of the drifters move offshore (eastward), influenced by eddies at the shelfbreak and further offshore. The drifters continue eastward, with large north-south excursions caused by the eddies. A fraction of the drifters return to the shelf during these excursions. The large-scale wind forcing of the Louisiana/Texas shelf can be observed in the drifters' response to wind events.

Approximately June through August, the seasonal wind regime reverses, and the drifter tracks also reverse, moving northward and northeastward off Texas and eastward off Louisiana. Many of the drifters move close to the coast and then move offshore again. Large inertial motions can be observed in the drifter tracks, particularly during July and August.

As an initial analysis, the daily averaged velocities derived from the drifter motion were averaged into 0.25 degree bins for several time intervals (seasonal, monthly, etc.). Maps of these velocities give the vector velocity representation of the drifter track behaviors discussed above. Seasonal averaged current estimates from these maps were used in the OSRA analysis discussed below.

OIL-SPILL RISK ANALYSIS MODEL

The OSRA model uses a stochastic approach to characterize the risk of oil-spill contacts to resources over large spatial and temporal dimensions (LaBelle and Anderson 1985). In estimating average contacts to coastal resources, the OSRA model uses climatological inputs from available wind and ocean data and models to drive multiple simulated trajectories from potential offshore oil-spill sites. Figure 4D.2 shows a simulated spill launch point and the resource area representing the Texas coastal waters. The spill launch point represents the approximate location of an oil spill that occurred on 5 February 1995, caused by the collision of two tankers about 105 km south of Galveston Bay. Bunker C oil came ashore at the Matagorda National Wildlife Refuge and along the Padre Island National Seashore within about three weeks of the accident.

OIL-SPILL TRAJECTORY SIMULATIONS

The OSRA model was run using a combination of observed and numerically computed ocean currents and winds. Most of the ocean currents used were generated by a numerical model. They were supplemented with many direct observations of the currents in the western Gulf resulting from repetitive deployments of SCULP surface drifting buoys. Climatologically representative monthly mean surface currents were provided using the Princeton-Dynalysis Ocean Model (PDOM), (Dynalysis 1994). The PDOM, an enhanced version of the Mellor-Blumberg Model, is a three-dimensional, time dependent, primitive equation model using orthogonal curvilinear coordinates in the horizontal and a topographically conformal coordinate in the vertical. The use of these coordinates allows for a realistic coastline and bottom topography, including a sloping shelf, to be represented in the model simulation. The PDOM incorporates the Mellor-Yamada turbulence closure algorithm to provide a parameterization of the vertical mixing process through the water column.

The PDOM model was driven by monthly climatological wind stress, heat flux, river flow, and inflow transport boundary conditions. From a 12-year simulation, a climatologically representative year was selected. Monthly averaged surface currents were then computed from that year and constitute the background ocean currents used in the oil-spill trajectory simulations.

In the second set of OSRA trajectory simulations, the drifting buoy mean velocities were substituted for the PDOM model currents in the appropriate geographical areas. In addition to the ocean currents, a wind field was employed to add the effect of the direct sea surface winds on the hypothetical spills. This wind field was the Naval Research Lab's geostrophic sea surface wind sets derived from analyzed atmospheric pressure maps at 12-hour intervals for the 27-year period extending from January 1967 through December 1993 (Rhodes, Thompson, and Wallcraft 1989). The direct wind drift on a hypothetical oil spill is modeled using an empirical "3.5% rule" with a speed-dependent wind deflection angle (Samuels, Huang, and Amstutz 1982).

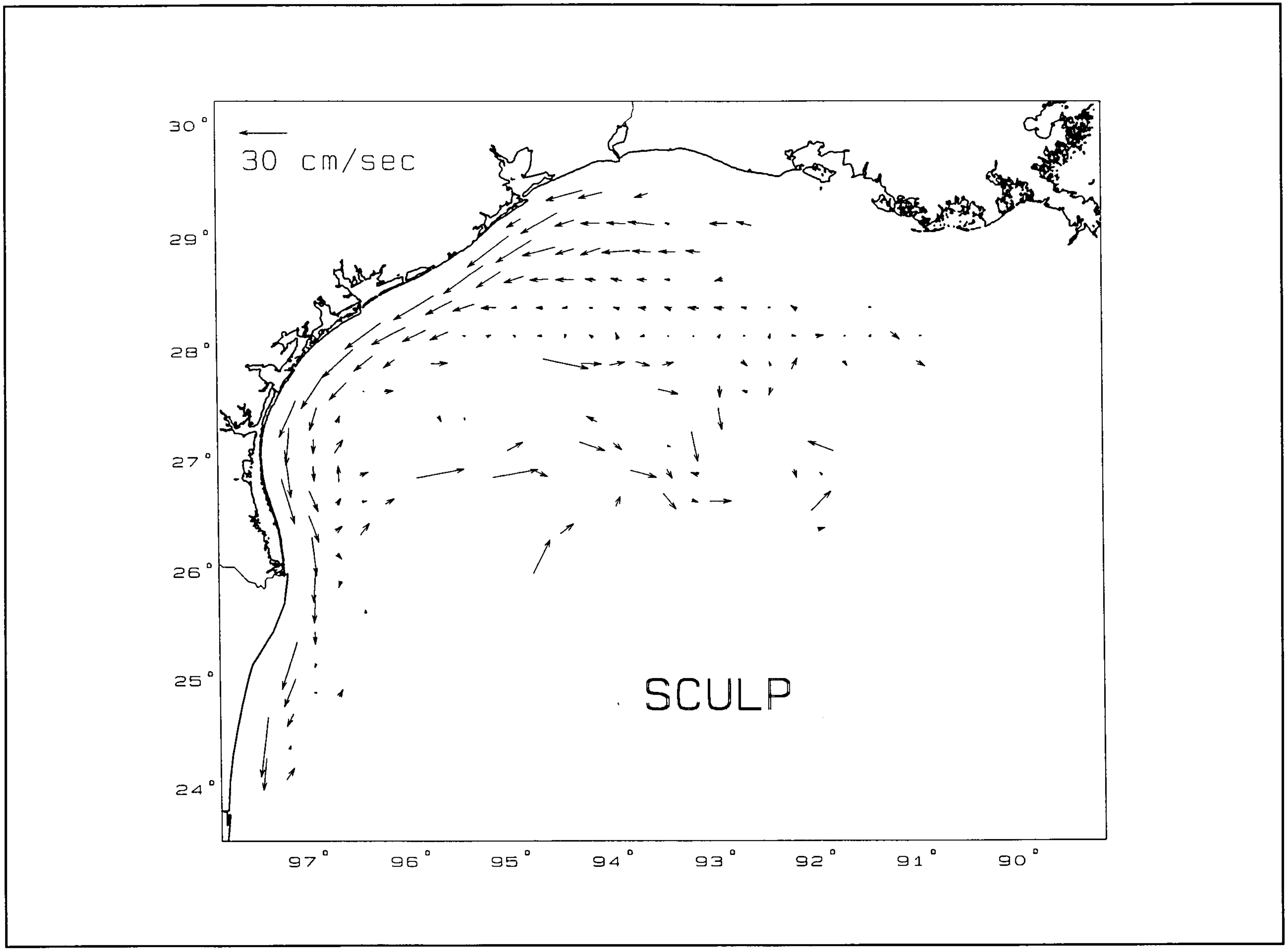

Figure 4D.1. Winter season averaged velocity.

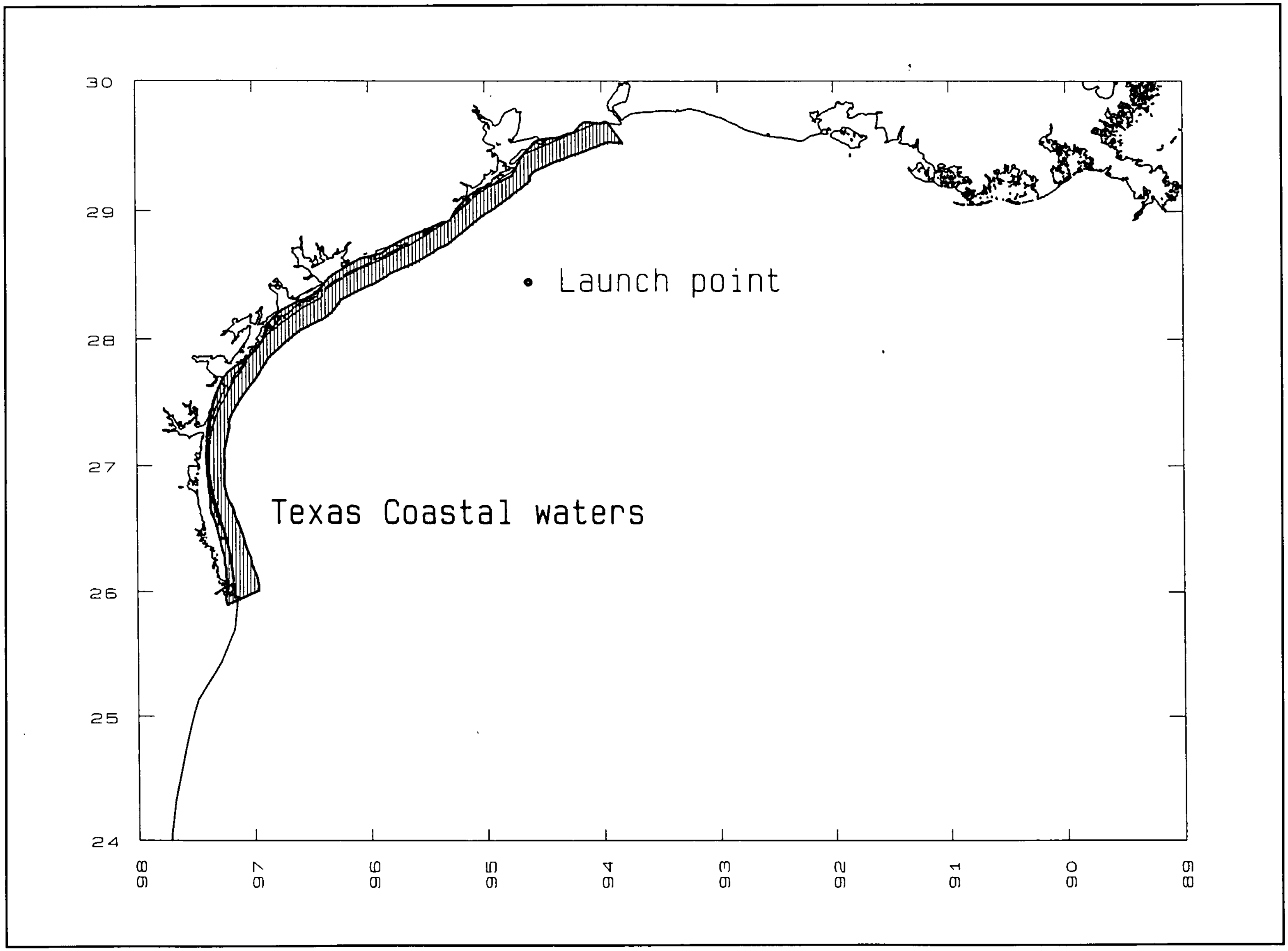

Figure 4D.2. Launch point and Texas coastal waters.

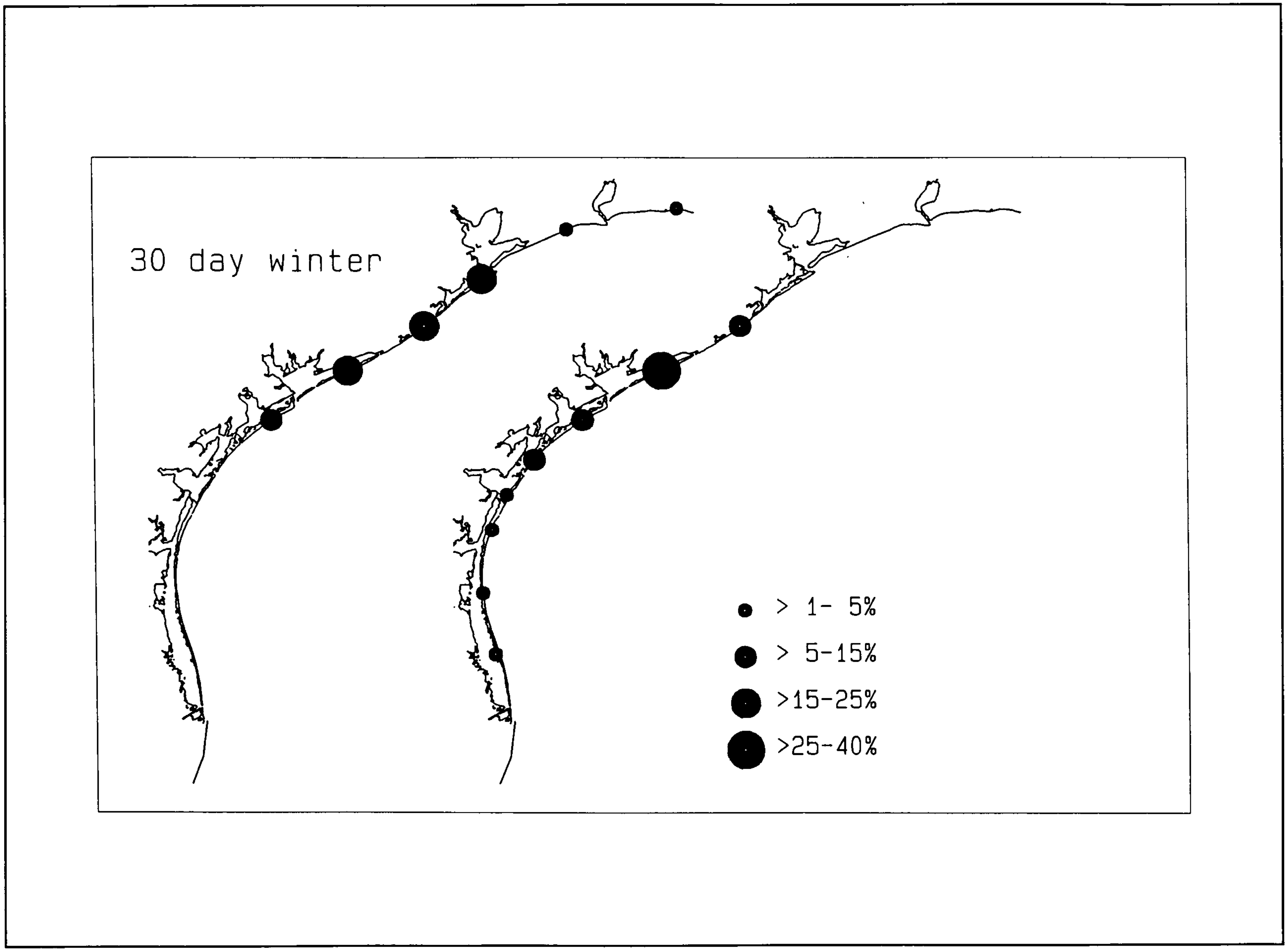

Figure 4D.3. Contacts with (right) and without (left) SCULP data.

RESULTS OF THE COMPARISON

The primary purpose of the SCULP study was to use drifter observations directly in defining a horizontal and time-evolving surface current field to improve oil-spill trajectory analysis. As a first step, the SCULP data have been averaged as seasonal mean surface currents and were input to the OSRA model.

The OSRA model was run with and without the SCULP averaged velocity data from multiple spill launch sites in the western Gulf of Mexico. The results shown in Figure 4D.3 are from a single launch point, the site of the tanker collision (Figure 4D.2).

Figure 4D.3 compares oil-spill contact probabilities when the OSRA model was run with and without the drifter data. The probabilities shown are for the winter season (January-March) within 30 days spill travel times from the launch point. (Five hundred trajectories were simulated for each season.) Use of the drifter data as supplement to the model run resulted in contacts more along the southwest coast than did use of the climatological model results alone. These results are consistent with other measurements and observations of the flow in this region, including the February 1995 oil spill.

Similar patterns were seen in the spring and fall seasons when comparing results of the two current fields. However, the drifters showed markedly different behavior in the summer (July-September), moving generally northeastward. The incorporation of the averaged current from the drifters did not make as large a change in the hypothetical trajectories in the summer run.

The model hindcast of the tanker spill south of Galveston showed 30-day winter contact probabilities to the Matagorda coastline at a 15% chance when drifter data was used and 6% when not used. The Padre Island contacts ranged from 1 to 5% with drifters, zero without. However, since the simulated spills were modeled with no areal dimension, it is more realistic to record contacts to the nearshore waters (i.e., the Texas coastal waters shown in Figure 4D.2). When the drifter data were used, contacts to this resource (30-day winter trajectories) were estimated at a 90% probability, and at a 78% probability without drifters.

Although a single spill event may not reflect the characteristic nature of the surface flow, the southwestward flow for this area has been observed and measured. Therefore, although the numerical model results are a large improvement over previous oil-spill model inputs, the judicious use of drifter data in conjunction with the numerical model surface flow provides a significant improvement to surface oil-spill modeling in the western Gulf of Mexico.

ACKNOWLEDGMENTS

The buoys were deployed from platforms with the generous assistance of personnel from BT Operations (Vermillion 119D), Shell Oil (West Cameron 565), and UNOCAL (West Cameron 280).

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AN UPDATED CLIMATOLOGY OF LOOP CURRENT EDDIES FROM GEOSAT ALTIMETRY

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ABSTRACT

An updated climatology of Gulf of Mexico sea surface height has been produced using the complete GEOSAT altimeter time series, including declassified along track data from the Geodetic Mission released in the summer of 1995. All alongtrack data are referenced relative to an accurate high resolution mean surface based on altimeter data collected from the TOPEX/Poseidon, ERS-1 and GEOSAT Exact Repeat missions. By referencing the data with respect to an independent altimetric mean, the climatology can be extended to include present and future altimeter data in a consistent reference frame. Referencing of the GEOSAT climatology can also be achieved with a minimum of effort when more altimeter observations, such as those from the GEOSAT Geodetic Mission, are added to improve estimates of the mean sea surface topography. The dominant oceanographic signal observed by an altimeter over the Gulf of Mexico is the sea surface height variability associated the shedding of large anticyclonic eddies from the Loop Current. During the GEOSAT time period, April 1985 to December 1989, six major Loop Current eddies were observed. The updated climatology provides a benchmark for intercomparison of the surface topography of these eddies and will allow comparisons with Loop Current eddies observed in the 1990s by altimeters aboard the ongoing TOPEX/Poseidon, ERS-1 and ERS-2 missions.

INTRODUCTION

The U.S. Navy's first altimeter satellite mission began with the launch of the GEOdetic SATellite (GEOSAT) in March 1985 and continued until late 1989. The goal of the primary mission, the so-called Geodetic Mission (GM), was to map the global ocean mean sea surface topography by altimetric sampling along a high spatial resolution nonrepeating ground track. This mission lasted from 30 March 1985 to 30 September 1986. Absolute height measurements from this data were originally classified. The Exact Repeat Mission (ERM) began on 8 November 1986 when the satellite was placed into a 17 day exact repeat ground track pattern. As long as the subsatellite point remained within 1 km of this ground track the data was unclassified. The altimeter continued repeat track sampling of the ocean topography until the satellite ultimately failed in January 1990.

The absolute sea surface height data from the GM mission were classified because the shape of the mean sea surface can be used to accurately determine the deviation of gravity from vertical, a quantity useful for the accurate targeting of submarine launched intercontinental ballistic missiles. In the summer of 1995, the GEOSAT GM data was declassified, presumably, because of the cessation of the Cold War and the public availability of altimeter observations from the European Space Agency satellite ERS-1. The ERS-1 altimeter had just completed the geodetic phase of its mission in March 1995, completing two cycles of an 168 day repeat mapping of the ocean topography. The declassified GEOSAT data were processed into a standard GEOSAT altimeter geophysical data record (GDR) format and released by the National Oceanographic Data Center on CD-ROMs in October 1995.

Initial altimetric studies of the Loop Current eddies in the Gulf of Mexico using the geodetic data have had to rely on crossover analysis techniques (Johnson *et al.* 1992, Leben and Born, 1993). Crossovers from the GM were not classified because they contain no absolute height information from which to construct the ocean surface. Unfortunately, this lack of an absolute reference system also makes consistent referencing of data between the Geodetic mission and other altimeter missions difficult, especially in areas with large inter-annual variability such as the Gulf of Mexico. With the release of the declassified along track data, it was hoped that the non-repeat GEOSAT GM could be referenced to an existing mean sea surface. Accurate surfaces based on the TOPEX/Poseidon, ERS-1 and GEOSAT (non geodetic) data first became available in the spring of 1995. An evaluation of these surfaces to select a mean reference surface for reprocessing of TOPEX/Poseidon GDRs was performed in the early summer of 1995 by the TOPEX Science Working Team. A mean surface (OSUMSS95) produced by the Ohio State University (Yi 1995) was recommended and accepted as the best candidate. This paper presents preliminary results of along track processing of GEOSAT data with respect to this surface in the Gulf of Mexico.

METHODS AND RESULTS

In this study, both the GEOSAT GM and ERM once per second along track altimeter data were referenced to the OSU mean sea surface. This mean surface is based on one year means of sea surface height from the exact repeat TOPEX, ERS-1 and GEOSAT data, and the first cycle of 168 day repeat ERS-1 data (Yi 1995). The precision of the GEOSAT orbits required an empirical correction of the data after standard pathlength corrections were applied. We elected to use classical along-track orbit error reduction by fitting and removing a tilt and bias to the sea surface anomaly along each track based on the criterion of least absolute deviation. Objective analyses were performed to produce maps of the sea surface height anomaly fields using a 100 km decorrelation scale and data from each repeat period. Maps produced from the GM data are produced at 23 day intervals, the near repeat period of the GM orbit. Maps from the Exact Repeat mission are produced at 17 day intervals, the exact repeat period of the ERM orbit.

The along track sea surface height anomalies from representative cycles of GEOSAT GM and ERM altimeter data, GEOSAT GM cycle nine and GEOSAT ERM cycle two, are shown in a wiggle plot format (Figure 4D.4). This format plots the sea surface height anomaly along track so that the ground track width is proportional the absolute anomaly. The track is colored black or white to indicate positive and negative anomalies. The width scale is shown in the lower right hand corner of each plot. These plots show that the GM data is noticeably noisier along track than the ERM data, a result of contamination by residual geoid signal in the mean surface. Systematic errors in the OSU mean reference surface are larger along the GM ground tracks. This is primarily a result of using only GEOSAT ERM data in the estimation of the OSU mean surface, since the GM data was classified at the time. Fortunately, the contamination is quite small, well below the level which would affect the accuracy analysis fields and estimation of Loop Current eddy statistics.

Analysis maps of sea surface height anomaly for the same two cycles have been contoured (Figure 4D.5). The drifter locations are plotted for the 10 days centered on the midpoint date of the GM analysis with a cross marking the initial drifter location. Two Loop Current eddies were sampled by the altimeter during GM cycle nine, Fast Eddy (25N, 93W) and Ghost Eddy (22N, 96W). The drifters provide an independent verification of the eddy centers and the apparent accuracy of the GEOSAT along track analysis with respect to the OSU mean surface. Initial qualitative comparisons of the drifter locations and the altimeter maps show very good correlation. MPEG animations which were used for these comparisons can be viewed on the World Wide Web (WWW) at http://www-ccar.colorado.edu/gom.html. Links to other animations presented at the 1995 MMS Information Transfer Meeting may also be found at the site.

CONCLUSIONS

This work represents another milestone in the preparation of a complete GEOSAT altimeter climatology for the Gulf of Mexico. The declassification of along track Geodetic Mission data has made it possible to reference GEOSAT relative to an existing mean surface, allowing consistent analysis and comparison of the sea surface height variability in the Gulf over the time period, 1985-1989. A climatology of Loop Current eddy statistics during the GEOSAT period is in preparation.

ACKNOWLEDGMENTS

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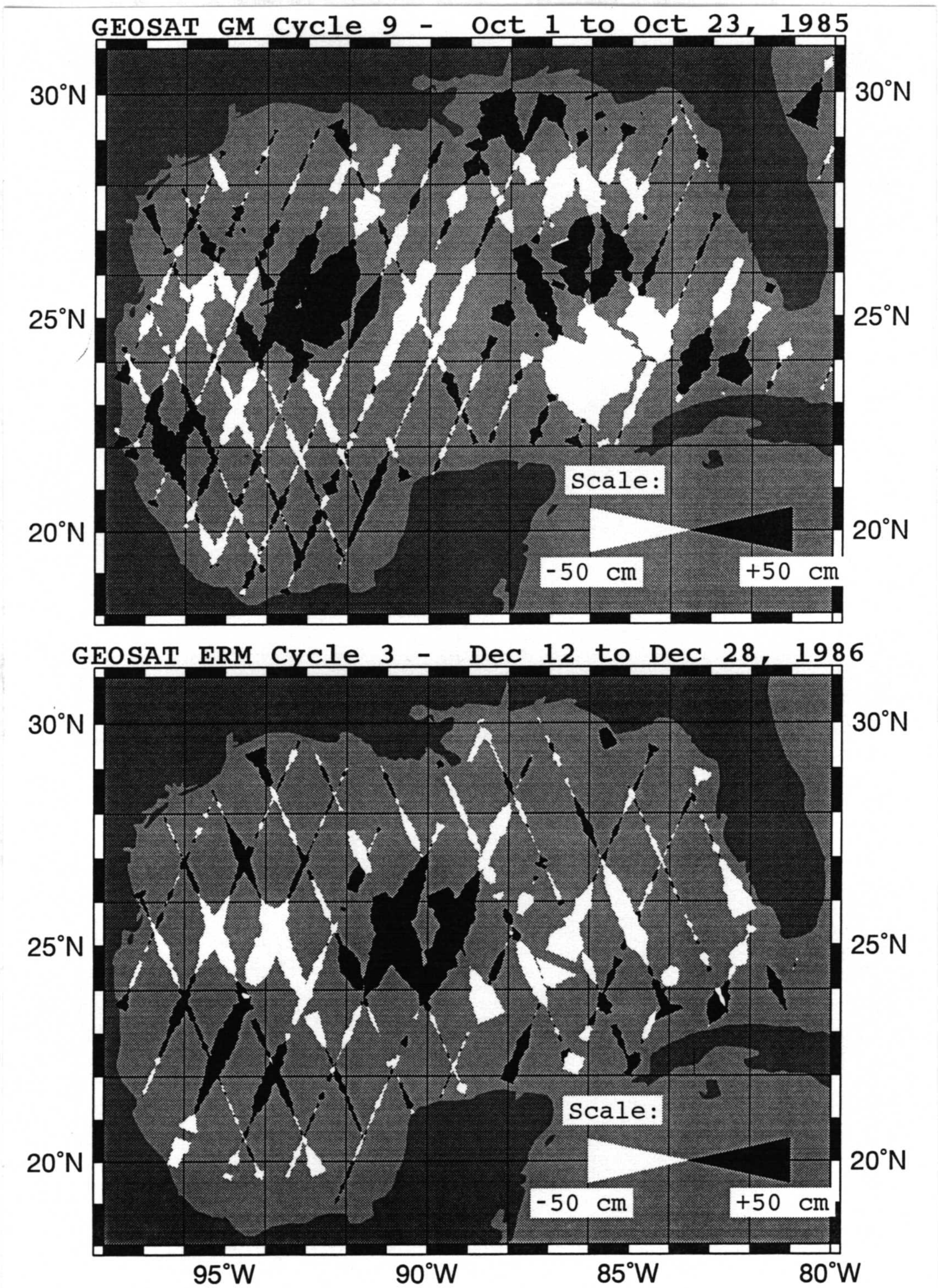

Figure 4D.4. Sample along track ground tracks from the GEOSAT Geodetic Mission and GEOSAT Exact Repeat Mission. Ground track widths are proportional to the sea surface height anomaly. Black (white) tracks indicate positive (negative) values. The scale is shown in the lower right hand corner.

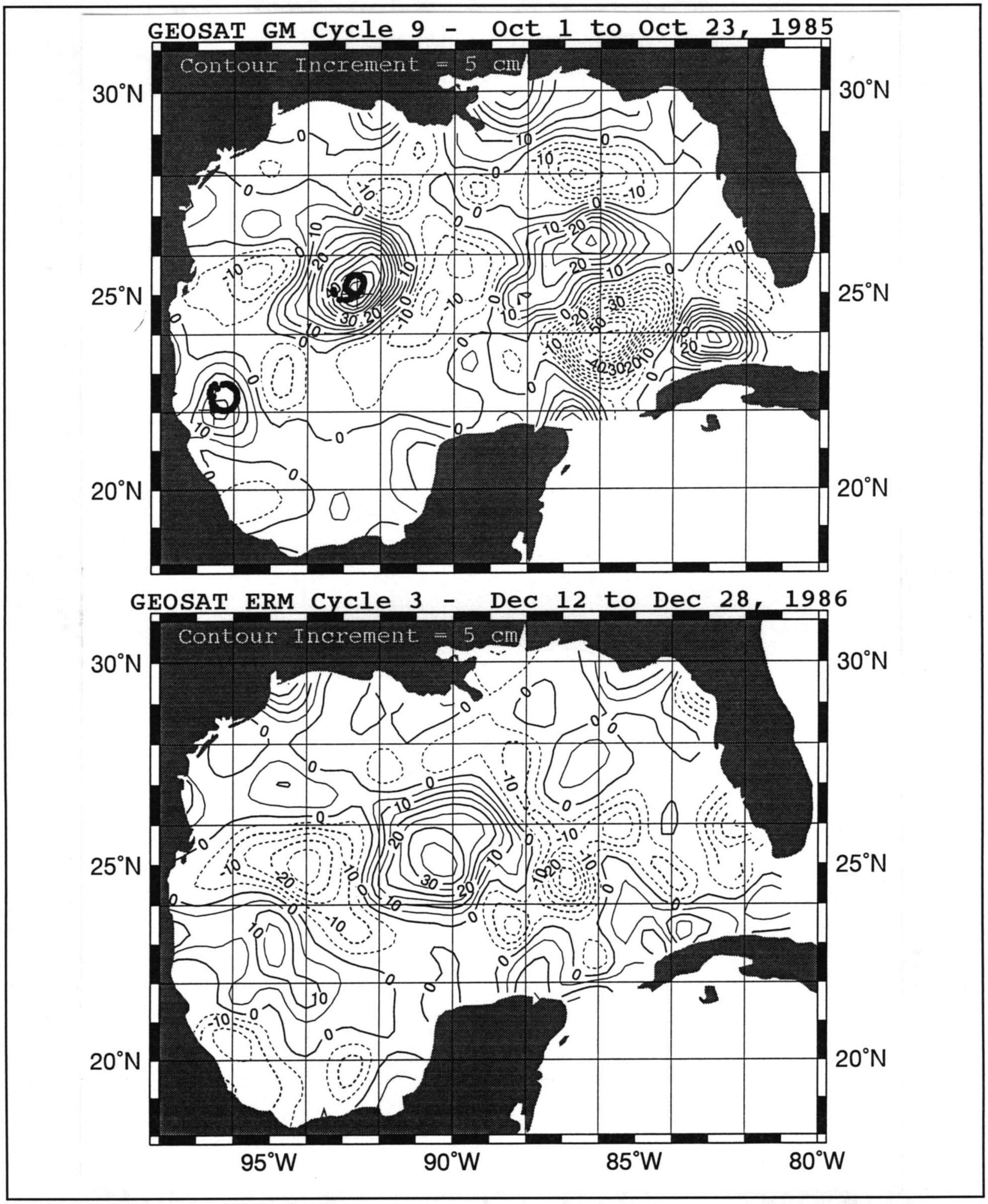

Figure 4D.5. Maps of sea surface height anomalies with respect to the OSU mean sea surface estimated from the along track data shown in Figure 4D.4. Positive contours are solid and negative contours are dashed. The contour increment is 5 cm. Locations of two coincident satellite tracked drifting buoys are plotted for the 10 days centered on the midpoint date of the analysis. A cross marks the initial drifter location.

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EFFECT OF RIVER FLOW AND CIRCULATION ON NUTRIENT DISTRIBUTIONS ON THE TEXAS-LOUISIANA CONTINENTAL SHELF

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One of the objectives of the Texas-Louisiana Shelf Circulation and Transport Processes Study (LATEX A) was to assess the processes that control the distribution of nutrients on the Texas and Louisiana shelves. A full understanding of processes influencing nutrient distributions on the Texas and Louisiana shelves is important, because the high level of nutrient input and consumption is partially responsible for increased primary production in this region of the Gulf of Mexico. Each summer on the Louisiana shelf, the flux of biogenic organic material and its subsequent decomposition along with other factors result in the formation of a region of hypoxia. The consequences of hypoxia on the Louisiana shelf have received recent national attention. Organic material from primary production is also a food source for higher trophic levels, including zooplankton and fish. The 628,000 metric tons of fish and shellfish landed in Texas and Louisiana during 1993 was a significant percentage of the total U.S. catch.

To assess the processes affecting shelf nutrient distributions, measurements were made of dissolved silicate, phosphate, nitrate, nitrite, ammonia and urea at over 13,000 locations during ten LATEX A hydrographic surveys. These nutrient data are being used to evaluate the relative importance of riverine input, shelf-edge upwelling, and benthic flux of nutrients on the shelf. The ten LATEX A hydrographic cruises (designated H01 to H10) were conducted during May (H01, H05, H08), August (H02, H06, H09), and November (H03, H07, H10) 1992, 1993, and 1994, as well as one cruise during February 1993 (H04). The first four cruises covered only the Louisiana shelf, while the last six cruises covered both the Louisiana and Texas shelves. The number of stations occupied on each cruise varied from 114 (H01) to 238 (H07). The 212 station locations occupied on cruise H05 are shown in Figure 4D.6.

Of the processes likely to influence nutrient distributions, benthic flux of nutrients should be the most constant. Shelf edge upwelling is dependent on current flow along the shelf edge and on wind forcing. Nutrient input onto the shelf from deep-water upwelling probably occurs most significantly when Loop Current eddies impinge upon the shelf edge and affect local circulation. These eddies are important for understanding nutrient distributions observed for several cruises, especially H01 and H05. Riverine input of nutrients is the most variable, since riverine nutrient flux is correlated to the amount of water entering the Gulf of Mexico from local rivers. The flows from the Mississippi and Atchafalaya rivers are dominant, with Texas rivers contributing less than 5% of the fresh water present on the Texas-Louisiana shelf. During the study period, the flow of the Mississippi and Atchafalaya rivers varied widely. Total river discharge during 1992 was near the 64 year average, while 1993 total discharge was the highest in the last 64 years. Daily flows during 1993 and 1994 were well above the average in spring, while 1992 spring flows were below

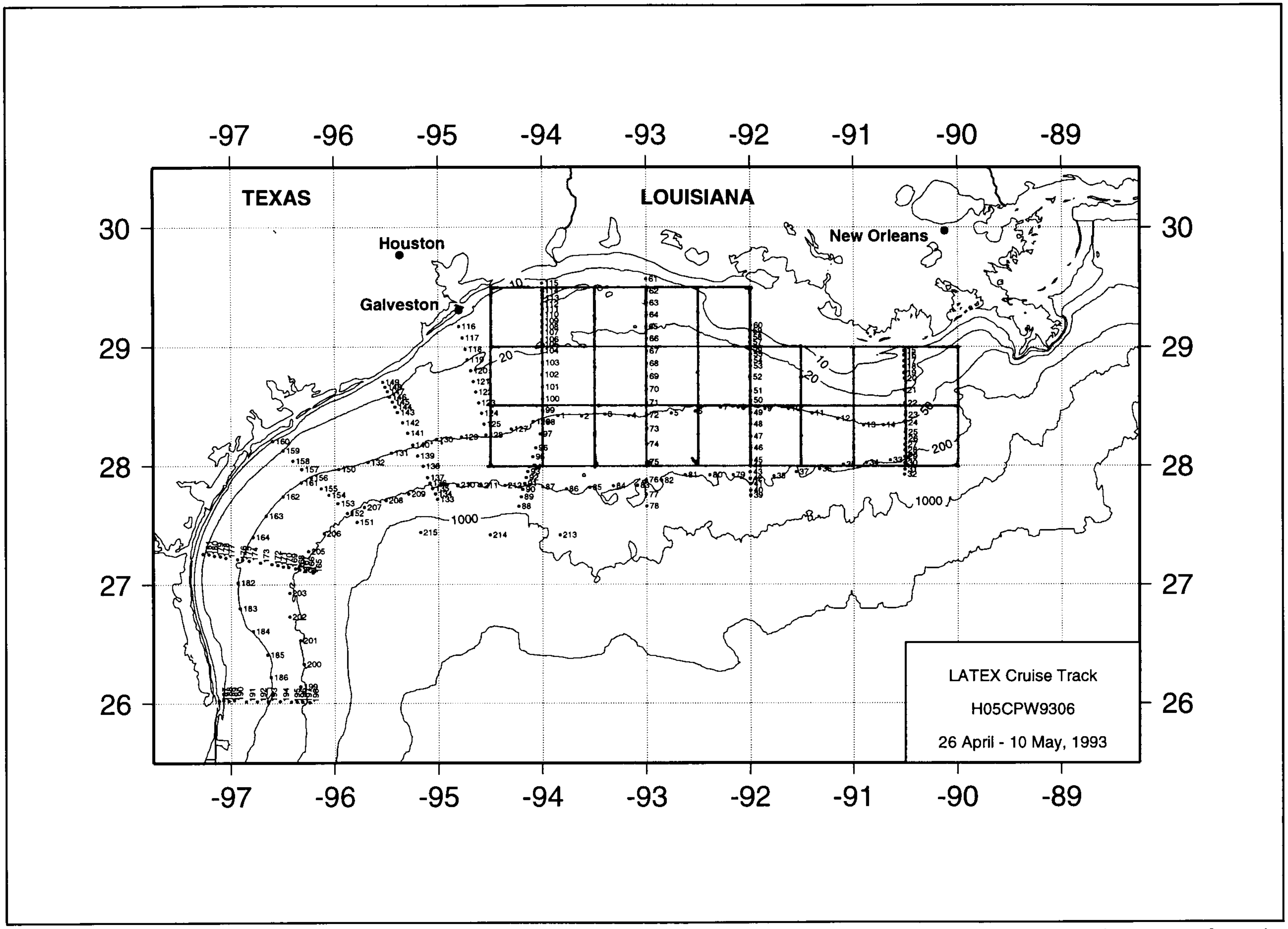

Figure 4D.6. CTD station locations occupied during LATEX A cruise H05. Boxes indicate areas that were used to calculate nutrient masses for cruise comparisons.

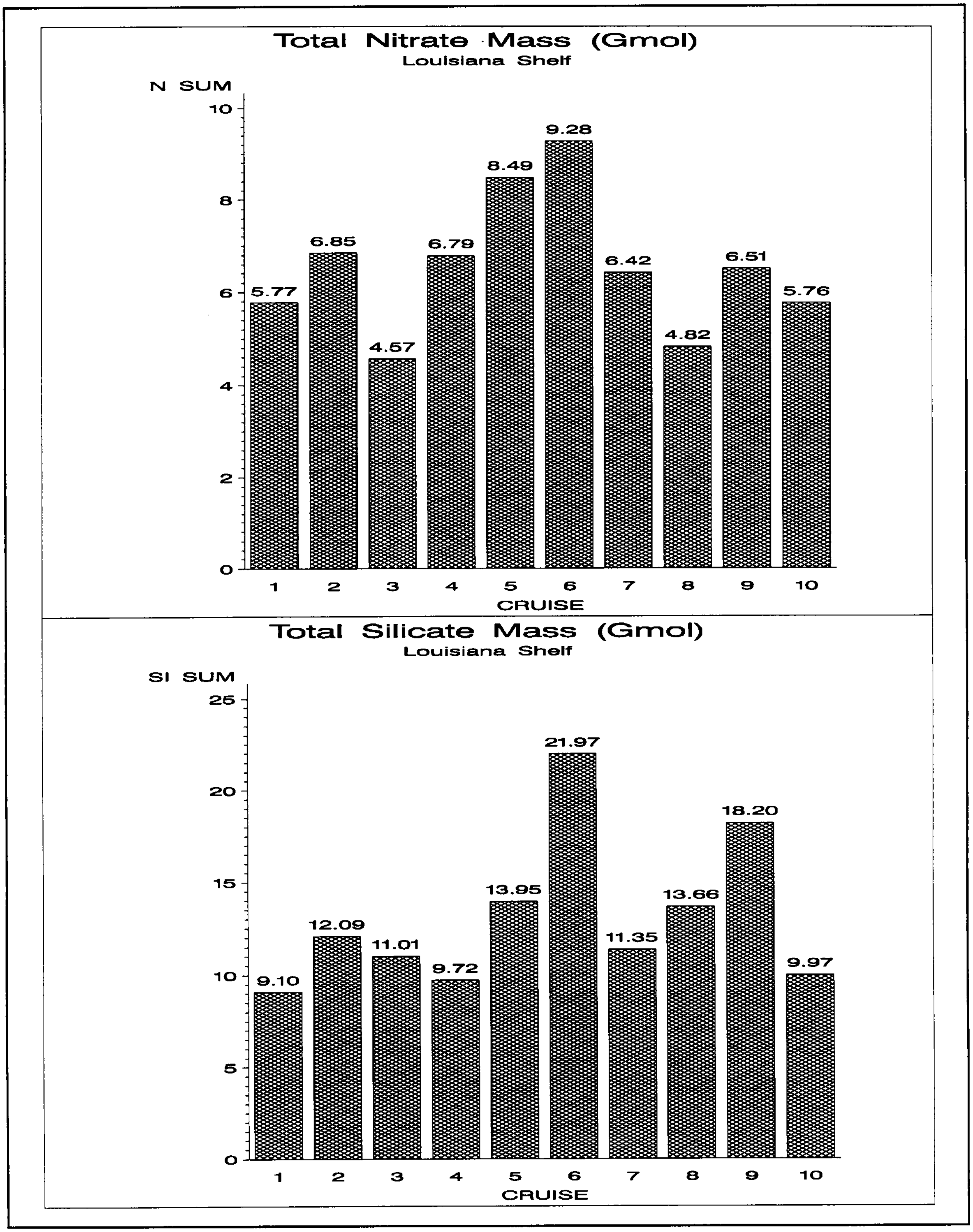

Figure 4D.7. Total mass in gigamoles (Gmol) of dissolved nitrate and silicate on the Louisiana shelf during each of the ten LATEX A standard grid hydrography cruises.

average. Flows in November and December were above average all three years. The most spectacular anomaly occurred during summer 1993, when river flows were significantly above average from July through November and attained record status during August.

Surface nutrient distributions on both shelves generally reflected the distribution of fresh water on the shelf. The inner shelf had more fresh water and higher surface nutrients, while the outer shelf had higher surface salinities and lower overall nutrient concentrations. The average surface salinity during the 1992 cruises (normal flow year) was 32.6, and the average surface nitrate concentration was 0.7 μM. During 1993 (record flow year), the average surface salinity was 31.5, and the nitrate levels averaged 1.3 μM.

To evaluate the total nutrient distributions from this region relative to the river flows, the Louisiana and Texas shelf was divided into 49 boxes with sides of 30 minutes of latitude and of longitude. The average area of these boxes was 2724 km^2. The 23 boxes used in this analysis of the Louisiana shelf are shown in Figure 4D.6. For every cruise, station nutrient data were interpolated vertically to produce average values in each five-meter depth interval. These five-meter interpolated values were then averaged to the center location of each of the boxes using a weighted averaging technique which valued measurements closest to the box center more than those further away. Using the average concentration at the box center of each of the five-meter bins, a nutrient mass was calculated for every five-meter slab. The masses were vertically summed (surface to bottom) for the boxes individually to allow evaluation of the changes in total mass for each box per cruise. Also, the total mass of every nutrient was calculated for the Louisiana shelf for each of the cruises. Total nitrate mass and total silicate mass (in gigamoles) on the Louisiana shelf for all LATEX A hydrography cruises are shown in Figure 4D.7.

In general, the total nitrate and silicate masses on the Louisiana shelf during hydrographic surveys reflected the amount of river water discharged to the shelf in the months prior to the cruise. The highest masses of nitrate and silicate were observed during cruise H06 (August 1993), when the Mississippi River was flowing at its highest August rate in 63 years. Nutrient levels were highest in the easternmost boxes, near the Mississippi and Atchafalaya river outflows. The silicate to nitrate ratio for the cruise varied from a low of 1.58 in May 1992 (H01) to a high of 2.80 in August 1994 (H09). The different ratios could indicate a shift in phytoplankton population on the shelf during the study period. All phytoplankton use nitrate, but predominantly diatoms use silicate during primary production.

The inflow of riverine nutrients and biological consumption over time was consistent with changes in nitrate and silicate from all three years. Examination of nutrient mass patterns on the Louisiana shelf revealed lower nutrient mass during May (H01, H05, H08), higher levels during August (H02, H06, H09), and lower levels during November (H03, H07, H10). These nutrient masses were consistent with an influx of nutrients to the shelf in May and June (with a six-week lag time from the river flows), which led to high nutrient levels during the summer. During the long summer photic periods, nutrients were consumed by phytoplankton and converted to higher level biomass, resulting in lower water column nutrient levels in November. This general pattern was observed each year for both nitrate and silicate. The difference in absolute levels probably reflected the different amounts of river water input to the Louisiana shelf each year.

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PHYTOPLANKTON DISTRIBUTIONS ON THE LOUISIANA CONTINENTAL SHELF: A COMPARISON OF RESULTS FROM MICROSCOPIC IDENTIFICATION AND PHYTOPLANKTON PIGMENTS MEASUREMENTS

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Complementary analyses of phytoplankton pigment data and phytoplankton count data were assessed for the Louisiana continental shelf in the northern Gulf of Mexico during spring 1992. This research was conducted as part of the Texas-Louisiana Shelf Circulation and Transport Processes Study (LATEX A), the Mississippi River Plume Hydrography Study (LATEX B), and a phytoplankton study funded by the Office of Naval Research (ONR). Comparisons were made between the phytoplankton pigment data and phytoplankton count (>3 µm size class) data for different algal groups for the LATEX and ONR data sets. Surface cyanobacterial counts from LATEX B were compared to the surface distribution of zeaxanthin, the marker pigment for cyanobacteria, from the LATEX A analyses. The May 1992 (H01) LATEX A hydrographic cruise took place from 30 April to 9 May 1992, covering the Louisiana continental shelf in four cross-shelf transects from 90.5° to 94.0°W longitude (Figure 4D.8). These transects stretched from the 10-m to the 500-m isobath, and occupied 114 stations shelf-wide. Discrete duplicate 1 L water samples for pigments were taken from 10 liter Lever-Action Niskin bottles mounted on a Sea-Bird SBE911+ CTD, attached to a 12-place Rosette frame. Sampling locations in the water column at 81 of the 114 stations were chosen from vertical fluorescence profiles on the CTD downcasts. Pigment samples were taken in amber Nalgene bottles, immediately filtered onto 47 mm Whatman GF/F filters in the lab on board the ship, and frozen in liquid nitrogen until laboratory analysis by high-performance liquid chromatography (HPLC) (Mantoura and Llewellyn 1983). HPLC was performed in the laboratory at Texas A&M University following the methods of Bidigare (1991).

Whole water samples for phytoplankton counts were collected at the surface and chlorophyll maximum at each station where pigment samples were taken. Phytoplankton samples were also collected from the Niskin bottles attached to the CTD mounted on the Rosette. These were 250 ml water samples, preserved in a 1% glutaraldehyde solution, and stored at 5° Celsius until enumerated according to the Utermöhl method (Utermöhl 1958). The Utermöhl method utilizes settling chambers for concentration of the phytoplankton material. The inverted microscope technique (Zeiss IM-35) was used for enumeration (Utermöhl 1958; Hasle 1978). Twenty-two of the 114 stations were chosen for microscopic analysis on the basis of chlorophyll *a*, *b*, and *c* biomass contours and vertical fluorescence profiles. From each transect, one station was chosen on the inner part of the shelf, two to three on the middle shelf, and one on the outer part of the shelf (Figure 4D.8).

The LATEX B 92-1 cruise took place from 22-30 April 1992 and covered the Louisiana shelf on approximately nine cross-shelf transects. One transect due south of Terrebonne Bay was located in the same area as Line 1 of the H01 LATEX A cruise (Figure 4D.8). The 92-1 cruise occupied 39 stations shelf-wide. At each of these stations whole water samples were taken and preserved in 0.5% glutaraldehyde and refrigerated for 1-24 hours. They were then size fractioned by filtration onto 0.2, 3, and 8 µm polycarbonate filters, with 0.03% proflavine hemisulfate used to stain the latter two fractions, and then the filters were mounted in immersion oil (Murphy and Haugen 1985; Shapiro *et al.* 1989). The 0.2-3.0 µm fractions were counted immediately on shipboard; the 3-8 µm fractions were counted immediately if possible and, if not, refrigerated and counted within days of returning. The >8 µm fractions were frozen and counted later. All samples were counted using an Olympus BH2-RFCA epifluorescence microscope with blue and green excitation light and, as necessary, transmitted light. The autotrophic cells were identified to the nearest possible taxon. Small, coccoid cyanobacteria (1-2 µm) appeared in all size fractions because of their

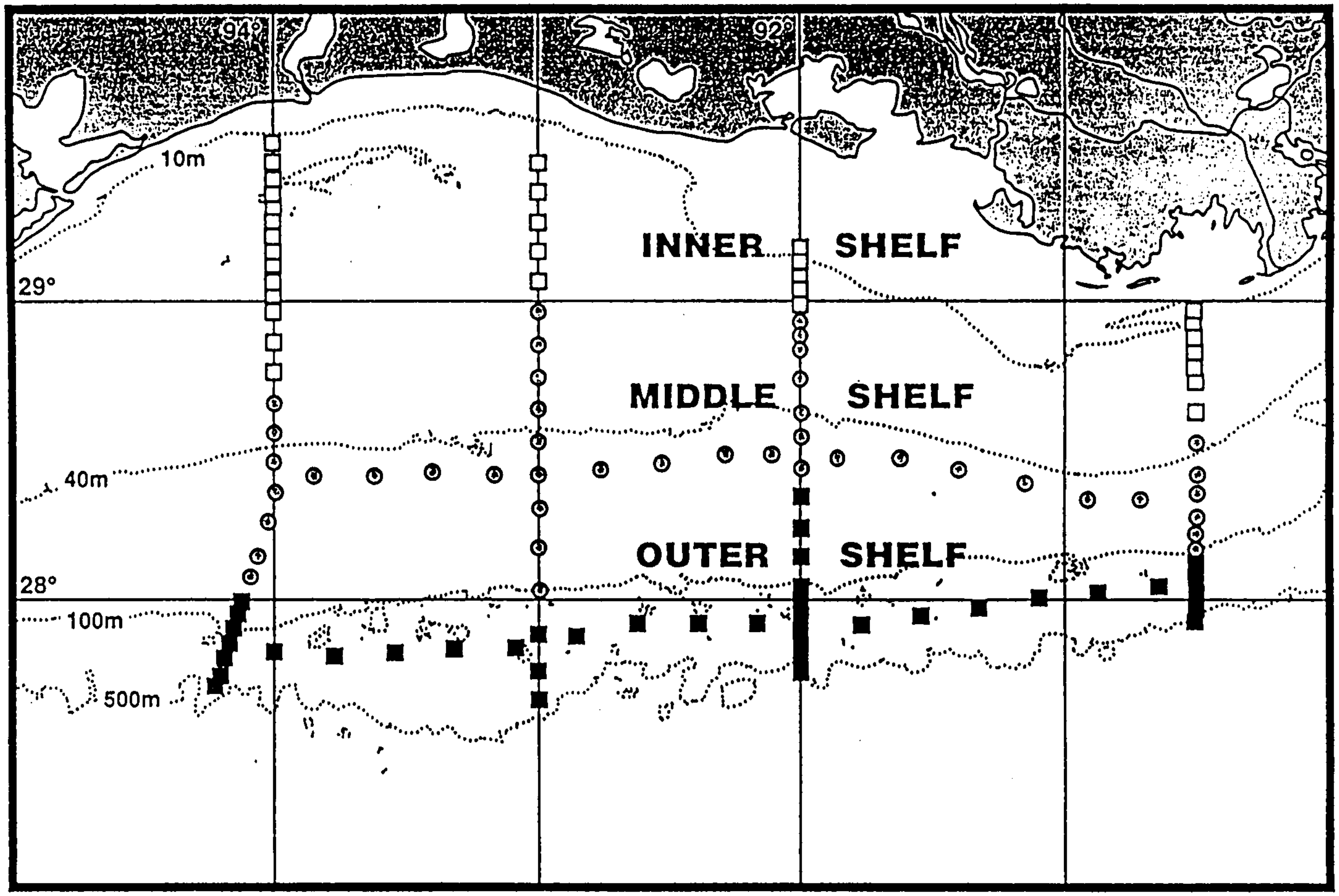

Figure 4D.8. Cruise H01 LATEX A station distribution. The four cross-shelf transects cover from 90.5° to 94.0°W, with Line 1 to the east and Line 4 to the west of the study area. Note the inner, middle, and outer shelf breakdown by station in geometric shapes.

association with larger aggregate particles, so the numbers in all size fractions are summed. The LATEX B cruise cyanobacteria count data (0-3 μm size class) was compared to zeaxanthin pigment data. Zeaxanthin is sometimes used as a marker pigment for cyanobacteria (Hooks *et al.* 1988).

The Louisiana shelf can be divided into three distinct regions, the inner, middle, and outer shelf, on the basis of their distinct hydrographic characteristics, physical processes, and phytoplankton distributions (Figure 4D.8) (Neuhard 1994; Bontempi 1995). The data will be discussed by reference to these areas.

Initially, phytoplankton pigment and phytoplankton count data from cruise H01 of LATEX πA were compared at the surface and chlorophyll maximum across the Louisiana shelf to see how representative the pigments were of the distinct phytoplankton groups. Diatoms were found to be dominant on the inner shelf (40,000-16 million cells/L) at the surface and chlorophyll maximum (Bontempi 1995). The indicator pigment for diatoms, fucoxanthin (Hooks *et al.* 1988), correlated with the diatom dominance showing the highest level of fucoxanthin on the inner shelf (100 to about 18,000 ng/L) (Neuhard 1994).

Dinoflagellates were found to be higher in number on the inner shelf (7200-155,900 cells/L, or about 0.5-6.0% of the phytoplankton) at the surface and chlorophyll maximum, but composed more of the phytoplankton population on the outer shelf even though overall abundances were lower (6000-19,800 cells/L, or 6.5-35.5% of the phytoplankton). The marker pigment for dinoflagellates, peridinin (Hooks et al. 1988), indicated that dinoflagellates were present on the outer shelf (0 to about 30 ng/L maximum out of 0-700 ng/L of chlorophyll *a* total (Neuhard 1994)), but did not accurately give an estimation of the dinoflagellate contribution to the phytoplankton population. This vagueness of the pigment data in reflecting the role of dinoflagellates in the outer shelf phytoplankton population may be because phytoplankton are very concentrated in the inner shelf waters as evidenced from the phytoplankton counts (Bontempi 1995), and are more dispersed in the water column on the outer shelf. Therefore, the pigments show dinoflagellates as present in the phytoplankton, but their true role in the phytoplankton community is not clearly defined. Phytoplankton counts resolve this part of the phytoplankton community in detail.

19' hexanoyloxyfucoxanthin, the marker pigment in Prymnesiophytes (Hooks et al. 1988), showed an increase on the middle and outer shelf when compared to the inner shelf (10-230 ng/L versus 5-60 ng/L on the inner shelf). The phytoplankton counts of Prymnesiophytes were supported by the pigment data. There was a shift in the phytoplankton population from the percentage of Prymnesiophytes or coccolithophorids on the inner shelf (0.0-6.0%), which increased to 0.0-23.5% Prymnesiophytes on the middle and outer shelf at the surface and chlorophyll maximum.

Cyanobacteria data at the surface of the LATEX B cruise area were compared with surface zeaxanthin concentrations from the week following the LATEX B cruise. The percentage of cyanobacteria as part of the total autotrophs increased moving from the inner shelf towards the middle shelf, composing 40-85% of the total autotrophs on the inner part of the shelf, and greater than 85% on the middle part of the Louisiana shelf. Zeaxanthin concentrations were low on the inner shelf (about 20 ng/L), and levels were much lower than total chlorophyll *a* (200-7500 ng/L). On the middle shelf at the surface, zeaxanthin levels were varied between about 20 to 60 ng/L, and cyanobacteria numbers increased to compose the majority of the autotrophic phytoplankton population. These data support the need for both phytoplankton pigment and phytoplankton count data.

Analysis of phytoplankton pigments by high-performance liquid chromatography is less time consuming than phytoplankton taxonomic counts. HPLC pigment analyses can be used as a rapid means of analyzing a greater number of samples over large study areas. This kind of sampling provides good resolution of the vertical and horizontal distributions of phytoplankton pigments. Phytoplankton pigments are useful in identifying phytoplankton at the class level, and are helpful in the identification of small cells that may be overlooked or are too small to be seen with the inverted microscope (Neuhard 1994). However, phytoplankton taxonomic counts allow proper estimations of the contribution each phytoplankton species to the existing population. This information cannot be easily determined from HPLC data. The taxonomic structure of the community can be summarized with species identification, giving insight into strategies for species and possibly ecosystem succession (Bontempi 1995). Even though taxonomy is a more labor-intensive and time consuming procedure, phytoplankton count data delineate the phytoplankton gradients (as in the dinoflagellate number versus peridinin levels) which may have implications in higher trophic levels, as in determining the number of autotrophs versus heterotrophs present in an area. Pigment analyses and phytoplankton counts individually give insight into the structure of the phytoplankton regimes. When coupled together they provide an unequaled view of the primary trophic level structure which may be used to assess biomass, carbon fluxes, energy transfer, and primary production in an ecosystem.

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ICHTHYOPLANKTON DISTRIBUTIONS AND ABUNDANCES IN THE COASTAL CURRENT OF LOUISIANA AND TEXAS

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INTRODUCTION

The purpose of this limited-scaled survey of ichthyoplankton and macrozooplankton is to support the other disciplines (mainly physical oceanography) in their characterization of the across and along shelf water masses of the Mississippi/Atchafalaya extended plume (i.e., the Louisiana-Texas coastal current) as specified within the Mississippi River Plume Hydrography (Task B) in the Louisiana/Texas Physical Oceanography Program funded by MMS.

METHODS

Oblique plankton tows were made with a 60-cm diameter paired-bongo frame modified to accommodate a 20-cm ring. Bongo-net meshes were 153 and 335 µm, while a 63-µm mesh net was lashed to the 20-cm ring. Nets were lowered to the bottom as rapidly as possible before retrieving at a ship speed of 1 knot and an ascent of approximately 1 m/s. The 153- and 335-µm nets were fitted with a torpedo-type flowmeter for volume-filtered estimates. Volume-filtered estimates were not determined for the 63-µm net because of the potential of clogging (Taylor 1976, Tranter and Smith 1968). The 63- and 153-µm samples were initially preserved in 4% formaldehyde and transferred to 70% ethanol after 24 h. The 335-µm samples were preserved in 70% non-denatured buffered ethanol, placed on ice, and transferred to fresh 70% ethanol 24 h later. This method is suitable for larval fish otolith and growth analysis (Butler 1992, Methot and Kramer 1979).

Biomass estimates were performed on one-half of all samples. All plankton splits were made with a Folsom plankton splitter (McEwen *et al.* 1954). Halves were randomly selected for analysis. The three mesh sizes used in the study were analyzed in order to evaluate differences in zooplankton biomass estimates by size fractions. To determine the relationship between volumetric and gravimetric techniques, volume displacements (Yentsch and Hebard 1957) were conducted on a randomly-selected third of the stations from each cruise prior to dry weight determination. Dry weights were determined for all samples by oven-drying at 60° C to constant weight (Lovegrove 1966). Zooplankton biomass was calculated for both gravimetric (mg/m^3) and volumetric (ml/m^3) biomass estimates for the 153- and 335µm samples as:

Zooplankton Biomass = Weight or Volume Displacement / Volume Filtered,

where volume filtered=volume filtered (m^3) by the net. Volume filtered was calculated as:

Volume Filtered = Net Area x Δ Counts x Rotor Constant,

where Net Area=area of net's mouth (m^2), Δ Counts= number of flowmeter rotor revolutions, and Rotor Constant=0.5102. Zooplankton biomass was not determined for the 63-µm (20-cm net) samples, since volume filtered estimates would not be reliable for these samples.

Larval fish and squid were removed from halves of all 335-µm samples and identified to the lowest taxonomic level possible. If a 335-µm mesh sample was not available at a particular station, the 153-µm sample was sorted if available. If the number of fish sorted from a half sample was less than 5, the other half of the sample was sorted if available. For each station, larval density (#/100m^3) was calculated for each species as:

Density = (# Species $_x$ / Volume Filtered x 100),

where # species $_x$ = the number of larvae of the xth species at that station. For each cruise, percent catch was calculated for each species as:

% Catch = (# Species $_x$ / $\sum$(# Species $_x$)) X 100.

All half splits (minus the fraction used in the zooplankton analysis for the 153-µm samples and larval fish and squid for the 335-µm samples) not used for biomass estimates were archived in 70% ethanol for future ecological studies.

RESULTS

Two hundred twenty samples were obtained from 76 biological stations during April and October 1992. The total number of larval fish collected was 8,773 and the number of squid was 18 within a maximum depth of 40 m. Twenty-eight families, composed of 45 larval fish and 2 squid genera, were identified collectively.

Mean biomass estimates were higher in April than in October for both the 153- and 335-µm samples. The correlation between zooplankton dry weight and volume displacement was highly significant for both the 153- (N=27) and 335-µm (N=28) samples. The regression intercepts were not significantly different from zero (ANOVA, p=0.528). Thus the two biomass determinations appear to be linearly related; however, dry weight estimates tend to be less variable, and more reproducible.

CRUISE I, APRIL 1992

Ninety-five samples from 34 biological stations were obtained during the April 1992 cruise, a high-river period. Samples were collected from the Mississippi Delta to nearly Corpus Christi, the southwestern-most portion of the plumes range. Temperature ranged from 22 to 24 °C, while salinity ranged from 18 to 34 ‰.

Zooplankton biomass tended to be high in the western portion of the study area for both the 153- and 335-µm samples during Cruise I. Zooplankton dry-weight biomass estimates for the 153-µm samples ranged from 0.002 to 0.112 g/m^3 ($\bar{x}$=0.014, s.d.=0.020), while the 335-µm samples ranged from less than 0.001 to 0.015 g/m^3 ($\bar{x}$=0.004, s.d.=0.004). Dry-weight biomass estimates were highly correlated between the 153- and 335-µm samples.

During Cruise I (April 1992), 6,396 larval fish and 12 squid were collected. Larval fish densities were highest off Atchafalaya Bay and westward to Sabine Lake, ranging from 2 to 695 larvae/100 m^3 ($\bar{x}$=94.7, s.d.=123.6). No significant correlation was seen between larval density and both the 153- and 335-µm biomass estimates; however, high larval densities were significantly correlated with warm, mean water column temperature. April samples were dominated by *Anchoa* spp. (% Catch=61.5 %), although *Cynoscion arenarius* (14.4 %), unidentified engraulids (8.4 %), *Etropus crossotus* (3.8 %), and *Symphurus* spp. (3.7 %) were also abundant. Including all genera, the family Engraulidae made up 74% of the total catch.

CRUISE II, OCTOBER 1992

One hundred twenty-five samples were collected from 42 stations during October 1992, a low-river period. Samples were collected from Mississippi Delta to Galveston Bay. Temperature ranged from 23 to 26 °C and salinity ranged from 20 to 34 ‰.

Zooplankton biomass for the 153-µm mesh tended to be high west of Atchafalaya Bay, while 335-µm samples were highest between Atchafalaya Bay and Sabine Lake. Biomass for the 153-µm samples ranged from 0.001 to 0.074 g/m^3 ($\bar{x}$=0.009, s.d.=0.012) and 335-µm samples ranged from less than 0.001 to 0.008 g/m^3 ($\bar{x}$=0.002, s.d.=0.002). As before both mesh dry-weight biomass estimates were highly correlated; however negative correlations were noted between biomass for the 153- and 335-µm samples and both mean water column salinity and temperature.

During Cruise II (October 1992), 2,377 larvae and 6 squid were obtained. Larval fish densities were highest off Sabine Lake and at offshore stations, ranging from 0 to 130 larvae/100 m^3 ($\bar{x}$=18.7, s.d.=25.3). Again, no significant correlation was noted between larval density and zooplankton biomass. Larval density was positively correlated with both mean water column temperature and salinity; however, an inverse relationship existed between larval fish density and chlorophyll concentration ([chl a]=0.52-15.43 µg/l). *Micropogonias undulatus* was the dominate species (% Catch=48.3 %) collected. *Anchoa* spp. (17.3 %), *Symphurus* spp. (6.6 %), *Etropus crossotus* (6.4 %), *Sciaenops ocellatus* (2.6 %), and unidentified gobiids (2.4 %) were also common in October samples.

CRUISE III - APRIL 1993

One hundred thirty-one samples from 44 biological stations were obtained during the April 1993 cruise, a high-river discharge period. Samples were collected from the Mississippi Delta to Corpus Christi, Texas, the southwestern-most portion of the plume's range.

Zooplankton biomass tended to be high in the central portion of the study area, from Atchafalaya Bay to slightly west of Sabine Lake, for both the 153- and 335-µm samples. Zooplankton dry-weight biomass estimates for the 153-µm samples ranged from 16.77 to

1213.70 mg/m^3 ($\bar{x}$=149.21, s.d.=201.89), while the 335-µm samples ranged from 6.91 to 400.69 mg/m^3 ($\bar{x}$=40.07, s.d.=61.37).

An estimated 1,596 larval and juvenile fish and 38 squid were collected during the April cruise. Larval fish densities were highest off Atchafalaya Bay and along the Texas coast, ranging from 5 to 936 larvae/100m^3 ($\bar{x}$=191, s.d.=195). April samples were dominated by the unidentified engraulids (%Catch = 36.34 %), although *Cynoscion arenarius* (14.79 %), *Anchoa* spp. (11.66 %), and *Brevoortia patronus* (8.90 %) were also abundant. These percentages are similar to LATEX B April 1992 results, where engraulids (74%) and *Cynoscion arenarius* (14.4 %) dominated the catch.

CRUISE IV - JULY 1993

One hundred fifty-six samples were collected from 52 stations during July 1993, typically, a period of high biological activity. Samples were collected from the Mississippi Delta to south of Galveston Bay, Texas, as well as during the Plume and Convergence surveys.

High zooplankton biomass estimates for both the 153- and 335-µm mesh samples were found scattered throughout the central and eastern portion of the cruise. Biomass for the 153-µm samples ranged from 16.19 to 261.11 mg/m^3 ($\bar{x}$=79.72, s.d.=57.13) and 335-µm samples ranged from 0 to 108.11 mg/m^3 ($\bar{x}$=28.18, s.d.=25.53).

An estimated 2,899 larval and juvenile fish were obtained during the July 1993 cruise. Larval fish densities were highest west of Sabine Lake, ranging from 0 to 1685 larvae/100m^3 ($\bar{x}$=285, s.d.=325.) Again, unidentified engraulids made up the bulk of the catch (%Catch = 50.78 %). *Symphurus* spp. (6.21 %), *Cynoscion arenarius* (5.14 %), *Chloroscombrus chrysurus* (4.48 %), *Opisthonema oglinum* (4.35 %), and *Anchoviella perfasciata* (4.28 %) were also common in July samples.

PLUME SURVEY

Dry-weight biomass estimates for the 153-µm samples showed no trend associated with Galveston Bay's plume, which ranged from 17.89 - 143.35 mg/m^3. The 335-µm biomass estimates were higher outside of the plume's influence, ranging from 6.60 - 63.56 mg/m^3. Larval fish density increased as the distance from the bay increased and ranged from 0 - 737 larvae/100m^3.

CONVERGENCE SURVEY

For the 153- and 335-µm biomass estimates, no trend was associated with the convergence zone; however, higher densities were noted on the shoreward side of both water masses. Dry-weight biomass estimates ranged from 30.33 - 171.45 mg/m^3 for the 153-µm fractions and from 8.62 - 88.21 mg/m^3 for the 335-µm size fractions. Larval fish density was higher on the Louisiana side of the convergence. This contrasts the overall picture of ichthyoplankton densities, where the highest densities were found along the Texas shelf. Larval fish densities ranged from 57 - 673 larvae/100m^3.

OVERVIEW FOR CRUISE 3 AND 4

Two hundred eighty-seven samples were obtained from 96 biological stations during April and July 1993 LATEX B cruises at station depths ranging between 2.9 and 57.7 m. Forty-four genera of larval and juvenile fish, from 30 families, and 2 squid genera were identified collectively. Four thousand four hundred ninety-five larval and juvenile fish and 38 squid were taken. Curiously, squid were only present during the April cruise.

Zooplankton dry-weight biomass estimates were significantly higher in April than in July within the 153-size fraction; however no difference was found between the cruises for the 335-size fraction (t-test, α=0.05). Since the data violated the assumptions for parametric regression even after appropriate transformations, the relationship between zooplankton dry weight and volume displacement was evaluated by Kendall Partial Rank-Order Correlation Coefficient ($T_{xy.z}$; Siegel and Castellan, 1988). Analysis revealed a strong positive relationship (τ=0.81, p<0.001) between the two biomass determinations. Thus the two biomass estimates are linearly related with little variability. However, dry weight may lead to the best estimate since it tends to be less variable and more reproducible statistically, and more useful for ecological studies from an energetic standpoint, than volume displacement estimates (Laurence 1976).

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FATE OF CHEMICALS IN THE MISSISSIPPI RIVER PLUME: TRANSPORT AND THREE-PHASE PARTITIONING IN THE SHALLOW COASTAL SHELF OF THE GULF OF MEXICO

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INTRODUCTION

To investigate the potential fate of chemicals discharged into Gulf of Mexico waters, a fairly complex set of physical and chemical oceanographic processes must be elucidated and understood. Among these are the bulk transport or advective processes of the water masses themselves. This includes mixing of fresh and saline waters, current direction and velocities, and temperature and salinity gradients and stratification. All of these forcing functions drive the dilution of chemical species in discharges. Along with these bulk phase physical processes, pollutant chemicals may undergo partitioning processes with suspended particulates (Means *et al.*, 1980) which may have their origins in either allocthonous (riverine) or autochthonous (resuspension/biological production) sources. The partitioning of both metals and organic compounds that occurs in this dynamic hydrologic environment is a function of compound/metal solubility and changes in salinity, temperature and redox potential. Sedimentation of particulates to the sediment bed is the major removal process of chemicals that may be introduced in discharges. Resuspension and bed load transport of materials may also occur in tidally energetic areas or as the result of strong weather events. Photolysis and hydrolysis reactions resulting in the decomposition of the chemical may be important for some chemical classes.

In recent years, a competing partitioning process with colloidal-sized, organic-rich micro-particulates has been recognized as a potential factor in the facilitation of transport processes in aquatic systems (Sigleo and Means 1990). Because these colloidal solids can bind both metals and organic compounds, and because they are relatively stable in the water column, they result in increasing the apparent "dissolved phase" transport of bound substances. The present study represents the first large geographic scale evaluation of the three-phase partitioning model that was developed in the laboratory.

Previous attempts to study such a complex array of transport processes using the low level chronic discharges from single sources in the Gulf of Mexico have been only partially successful in determining the fate of chemicals. At most the range of reliable information has extended only a few hundred meters from the discharge source (Rabalais *et al.* 1991). In the present study, the large and relatively intense chemical signatures of the Mississippi River and Atchafalaya River plumes as well as other smaller riverine inputs to the Gulf of Mexico from the Calcasieu, Sabine and Galveston estuaries have been used to investigate transport processes over much greater distances and may provide the necessary information to develop long-range fate and transport models for the Gulf of Mexico that can be used by MMS in fulfilling their mandate to assess real and potential environmental impacts of chronic and catastrophic chemical releases during oil and gas production.

ORGANICS

The organic pollutants measured include parent and alkylated PAH, PCB's, and several chlorinated pesticides. Methodology utilizing gas chromatography/mass spectrometry was developed which allowed for detection limits in the dissolved and colloidal phases in the parts-per-trillion range (pg/ml). A summary of organics data for three phases of water from six cruises is presented in Table 4D.1. It can be seen from the table that the herbicides (especially Atrazine) were by far the most ubiquitous and abundant of the organics. Thus, we chose to focus data interpretation efforts on the herbicides and pesticides data due to their potential for hazardous impacts upon aquatic life and for use in modeling transport processes in the coastal current. A detailed discussion of both the methodology and results can be found in McMillin and Means (1996).

Table 4D.2 shows a summary of dissolved phase water data by cruise for herbicides and pesticides. A brief summary of trends that were observed follows. Atrazine was chosen for detailed study due to its ubiquitous nature and high concentrations. The relative absence of "not detected" results for this chemical will make it useful for modeling of transport processes.

Phase Distribution

Pesticides and PCBs were detected infrequently and only in the suspended particulate phase, while herbicides, with the exception of Trifluralin, were detected in both the dissolved and colloidal phases, and rarely in the particulate phase. Distribution of Atrazine between dissolved and colloidal phases was uniform among river samples, but varied with distance from shore (increasing salinity) in the Gulf. Generally, Atrazine was most concentrated in the dissolved compared to colloidal phase; however, this trend was reversed in samples taken April 1994 immediately west of the Mississippi River outfall (Plume Cruise). This is probably the result of lower salinity water allowing increased Atrazine binding to colloidal material (Means *et al.* 1983, and Sigleo and Means 1990).

Spatial Distribution

Herbicide concentrations were generally highest toward shore along all transects and were inversely correlated with salinity gradients. Maximum concentrations tended to occur in transects off the Atchafalaya Basin.

Temporal Distribution

Figure 4D.9 shows mean concentrations by cruise for the dissolved phase herbicide data. Dissolved phase Atrazine and most other herbicides concentrations were highest during the low discharge volume periods (July and October cruises), while Alachlor was only detected in samples collected in April. Figure 4D.10 shows Atrazine concentrations in dissolved phase

Table 4D.1. Mean concentrations of organic pollutants in three phases of water sampled collected on 6 cruises from 1992–1994. Abbreviations: M-, E-, DM-, IP-, and TM-N = methyl-, dimethyl-, isopropyl-, and trimethyl-naphthalene; M- or DM-DBT = methyl or dimethyldibenzothiophene; M-, DM-, or TM-P = methyl-, dimethyl-, or trimethyl-phenanthrene.

	DISSOLVED PHASE				COLLOIDAL PHASE				PARTICULATE PHASE			
	Mean	RANGE		FREQ	Mean	RANGE		FREQ	Mean	RANGE		FREQ
ANALYTE	pg/ml	MIN	MAX	(of 293)	pg/ml	MIN	MAX	(of 272)	ng/g	MIN	MAX	(of 266)
Sample Vol (ml) or wt (g-dry)	**4000ml**	4000ml	4000ml	293	**567ml**	150ml	1000ml	272	**0.54g**	0.010g	15.71g	266
Naphthalene	**123**	0.0094	1673	272	**150**	0.28	1346	128	**417**	1.7	8022	216
Hexachlorobutadiene	**nd**	0	0	0	**nd**	0	0	0	**4.0**	0.56	23	6
2-MN	**164**	1.4	1468	281	**86**	0.16	1490	146	**228**	1.1	4466	257
1-MN	**106**	0.14	939	287	**62**	1.2	1097	138	**105**	1.1	1357	254
2-EN	**31**	0.53	303	290	**20**	0.31	309	116	**81**	0.56	3392	249
1-EN	**9.2**	0.31	94	274	**6.5**	0.14	62	86	**16**	0.14	589	188
2,6/2,7-DMN	**88**	0.64	934	292	**57**	0.11	1208	108	**238**	1.3	9641	263
1,3/1,7-DMN	**69**	0.79	696	293	**41**	0.41	970	148	**122**	0.15	4717	264
1,6-DMN	**48**	0.45	513	288	**29**	0.017	653	136	**103**	0.90	3802	263
1,4/2,3-DMN	**30**	0.53	278	290	**21**	0.18	507	121	**60**	0.15	2373	258
1,5-DMN	**22**	0.36	276	290	**16**	0.51	216	103	**21**	0.18	684	223
Acenaphthylene	**2.3**	0.11	23	216	**4.1**	0.028	38	70	**2.4**	0.019	16	113
1,2-DMN	**14**	0.33	118	290	**12**	0.028	188	108	**27**	0.0091	1044	240
2-IPN	**7.7**	0.80	36	199	**7.1**	1.6	32	39	**16**	0.10	302	88
1,8-DMN	**3.1**	0.0012	16	57	**10**	2.9	59	29	**2.0**	0.43	5.7	7
Acenaphthene	**13**	0.69	82	288	**116**	0.13	3603	126	**11**	0.074	336	154
1,6,7-TMN	**22**	0.61	155	289	**32**	0.42	541	82	**66**	0.34	2372	218
Fluorene	**19**	0.25	138	292	**57**	0.49	2412	120	**36**	0.18	1045	194
Trifluralin	**1.8**	0.96	2.8	4	**2.0**	0.84	3.4	5	**4.4**	0.088	22	13
CL2-PCB	**6.5**	2.4	22	5	**17**	0.64	70	27	**5.8**	0.58	111	28
Hexachlorobenzene	**nd**	0	0	0	**3.1**	0.81	6.0	4	**3.3**	0.23	7.1	14
Simazine	**19**	0.010	160	128	**17**	1.1	50	75	**18**	17	19	2
Dibenzothiophene	**9.4**	0.018	108	286	**12**	0.19	169	101	**14**	0.23	120	62
Atrazine	**199**	1.1	1682	289	**109**	4.0	822	243	**16**	16	16	1
Phenanthrene	**24**	0.054	221	286	**54**	0.020	669	102	**102**	9.7	2132	44
Anthracene	**3.7**	0.00074	55	190	**6.8**	0.58	74	71	**2.9**	0.017	30	40
CL3-PCB	**33**	0.45	209	21	**33**	3.6	196	33	**73**	0.37	946	41
4-MDBT	**4.7**	0.36	73	242	**6.6**	0.028	78	83	**9.8**	0.68	66	34
2/3-MDBT	**3.1**	0.18	55	204	**5.4**	0.086	42	72	**6.1**	0.068	53	31
CL4-PCB	**78**	1.8	324	20	**51**	8.7	313	32	**53**	0.11	523	38
3-MP	**5.6**	0.14	102	269	**8.9**	0.052	116	103	**19**	0.91	121	25
1-MDBT	**1.5**	0.00029	14	118	**3.9**	1.1	19	55	**4.8**	0.034	61	61
2-MP	**4.3**	0.10	99	262	**8.3**	0.11	137	99	**18**	1.0	169	30
Alachlor	**23**	4.6	68	11	**nd**	0	0	0	**1.4**	1.4	1.4	1
4/9-MP	**3.5**	0.016	62	238	**7.1**	0.097	86	93	**19**	0.37	51	23
1-MP	**4.9**	0.059	49	147	**7.2**	0.089	57	76	**8.8**	0.25	76	37
Metolachlor	**24**	1.6	147	276	**26**	2.0	155	199	**8.6**	3.6	33	11
Cyanazine	**93**	0.60	523	102	**77**	5.6	460	49	**88**	45	181	3
3,6-DMP	**3.7**	0.034	48	19	**4.6**	0.94	17	33	**10**	0.034	120	71
3,5-DMP	**nd**	0	0	0	**12**	5.3	16	3	**4.8**	0.19	15	5
2,6-DMP	**11**	0.0030	32	6	**33**	0.022	83	19	**6.9**	0.071	65	47
2,7-DMP	**102**	2.0	347	102	**12**	0.51	35	60	**11**	0.70	54	59
3,9-DMP	**2.5**	0.024	66	192	**6.1**	0.27	62	90	**35**	2.9	244	80
1,6/2,5/2,9-DMP	**1.8**	0.019	27	134	**5.2**	0.48	40	55	**21**	0.19	167	84
1,7-DMP	**1.8**	0.022	31	89	**3.0**	0.41	21	50	**10**	0.37	115	79
1,9/4,9-DMP	**1.6**	0.036	17	32	**2.4**	0.40	9.5	23	**5.9**	0.20	28	77
1,2-DMDBT	**2.5**	0.63	8.4	4	**nd**	0	0	0	**4.6**	0.052	12	24
Fluoranthene	**2.7**	0.024	14	233	**9.4**	0.036	194	161	**22**	0.27	156	22
1,5-DMP	**2.7**	2.7	2.7	1	**5.9**	5.9	5.9	1	**9.3**	0.53	29	14
1,8-DMP	**1.5**	0.44	4.1	11	**1.8**	0.82	4.2	9	**3.4**	0.058	23	39
1,2-DMP	**4.0**	1.2	8.8	9	**2.9**	1.7	4.7	5	**3.1**	0.35	7.9	26
9,10-DMP	**2.4**	0.41	5.6	10	**2.3**	2.2	2.4	2	**5.6**	0.040	46	23

Table 4D.1 (continued from previous page)

	DISSOLVED PHASE				COLLOIDAL PHASE				PARTICULATE PHASE			
	Mean	RANGE		FREQ	Mean	RANGE		FREQ	Mean	RANGE		FREQ
ANALYTE	pg/ml	MIN	MAX	(of 293)	pg/ml	MIN	MAX	(of 272)	ng/g	MIN	MAX	(of 266)
Pyrene	2.2	0.048	20	251	8.1	0.025	657	189	23	0.57	204	39
o,p'-DDE	2.1	0.33	5.4	3	nd	0	0	0	6.0	6.0	6.0	1
Chlordane	9.4	2.6	17	5	2.3	1.1	5.7	9	0.81	0.26	2.6	8
trans-Nonachlor	0.50	0.50	0.50	1	1.7	0.74	4.3	5	0.46	0.27	0.9	4
CL5-PCB	nd	0.0	0	0	22	3.6	130	34	30	0.059	149	28
Dieldrin	11	11	11	1	19	2.3	62	9	nd	na	na	0
p,p'-DDE	3.5	2.0	8.3	9	8.1	1.9	13	5	nd	na	na	0
o,p'-DDD	nd	0	0	0	nd	0	0	0	1.7	0.011	2.7	3
CL6-PCB	nd	0	0	0	6.4	1.0	22	11	4.9	0.13	54	43
1,2,8-TMP	1.7	0.063	6.9	40	3.3	0.41	12	37	19	0.048	102	80
p,p'-DDD/o,p'-DDT	nd	0	0	0	nd	0	0	0	nd	na	na	0
CL7-PCB	nd	0	0	0	nd	0	0	0	4.8	0.90	9.9	3
p,p'-DDT	nd	0	0	0	3.8	3.8	3.8	1	10	10	10	1
Benzanthracene	1.0	0.010	8.2	58	3.6	0.039	38	50	8.3	0.039	77	66
Chrysene	0.9	0.016	6.8	124	6.0	0.00095	49	108	8.4	0.084	172	105
Benzo(b)fluor	1.7	0.87	3.1	7	11	0.22	53	45	34	0.030	1297	77
Benzo(k)fluor	0.8	0.40	1.5	4	5.1	0.22	16	17	12	0.20	97	22
Benzo(a)pyrene	6.5	2.7	10	10	13	1.1	61	23	25	0.061	381	53
Indenopyrene	3.2	1.4	7.1	9	25	4.5	71	7	84	0.041	418	22
Dibenzanthracene	12	3.2	33	7	12	12	12	1	70	14	124	3
Benzoperylene	11	0.46	19	9	32	3.4	339	16	44	0.11	170	35
Estimated Totals												
C1-Naphthalenes	266	0.14	2362	287	145	0.16	2587	148	331	3.8	5823	257
C2-Naphthalenes	310	1.2	3095	293	172	0.41	4126	151	656	0.16	26242	264
C3-Naphthalenes	186	3.0	1836	289	217	0.98	3432	92	380	1.6	14320	229
C4-Naphthalenes	50	2.1	398	230	231	7.7	1794	64	144	0.35	4382	172
C1-Dibenzothiophenes	8.0	0.36	141	243	12	0.25	139	83	14	0.068	128	68
C2-Dibenzothiophenes	20	0.16	295	168	38	1.9	236	78	98	2.6	876	42
C1-Phenanthrenes	15	0.39	306	272	24	0.43	396	120	38	0.25	398	41
C2-Phenanthrenes	13	0.45	510	212	14	0.51	250	126	62	0.38	769	114
C3-Phenanthrenes	7.2	0.43	88	75	29	0.59	90	60	90	0.95	566	64

samples taken along transect S1 for each cruise. It can be seen in this figure that the high concentrations of Atrazine were carried further distances from shore during July cruises as compared to April. These data correlate inversely with salinity data. These trends were most apparent at transect S1 where concentrations tended to be highest, but were similar for other transects and other herbicides as well.

Depth Distribution

Surface samples showed highest herbicide concentrations in the April and July samples, while bottom samples showed the highest concentrations in October. The reason for this reversal is unknown, but was consistent among the herbicides.

Mass Transport

Results for transport across 5 transects were calculated for the October cruise using average net volume transport values calculated from ADCP data. Values for Atrazine ranged from 640-3,400 kg/day, averaging 2400±730 kg/day excluding the lowest value. The low value for the transect at longitude 92.0 was attributed to a wind shift from predominantly east-west to north-south during sampling at this transect only (Murray 1994). These values compare to 2,000 kg/day for April 1992 reported for the Mississippi River at Belle Chase, Louisiana (USGS 1994).

INORGANICS

The fate of 55 trace and rare earth elements in the Mississippi River plume and coastal waters of the Northwestern Gulf of Mexico is being investigated. A three-phase model was applied in which samples from both surface and bottom depths are separated into a particulate (>400 nm), colloidal (1-400 nm) and dissolved phases (<1 nm) prior to elemental analysis by ICP/MS. Detection limits achieved were 0.1 ng/ml for the dissolved and colloidal phases and ~1 ng/g for

Table 4D.2. Dissolved phase data for herbicides and pesticides from six LATEX cruises. (nd = not detected, na = not available).

ANALYTE	CRS 1: April 1992				CRS 2: Oct. 1992				CRS 3: April 1993				CRS 4: July 1993				CRS 5: April 1994				CRS 6: July 1994			
	MEAN	RANGE		FREQ	MEAN	RANGE		FREQ.	MEAN	RANGE		FREQ	MEAN	RANGE		FREQ	MEAN	RANGE		FREQ	MEAN	RANGE		FREQ
	pg/ml	MIN	MAX	(of 68)	pg/ml	MIN	MAX	(of 59)	pg/ml	MIN	MAX	(of 70)	pg/ml	MIN	MAX	(of 34)	pg/ml	MIN	MAX	(of 32)	pg/ml	MIN	MAX	(of 30)
Herbicides																								
Trifluralin	**nd**	na	na	0	**nd**	na	na	0	**1.8**	0.96	2.8	4	**nd**	na	na	0	**nd**	na	na	0	**nd**	na	na	0
Simazine	**17**	11	26	20	**23**	2.5	91	34	**11**	4.5	32	34	**30**	7.0	84	17	**5.3**	0.010	11	12	**30**	6.2	160	11
Atrazine	**110**	21	283	68	**407**	79	1682	56	**98**	6.9	514	69	**302**	13	1570	34	**33**	1.1	148	32	**246**	8.4	1033	30
Alachlor	**38**	11	68	6	**nd**	na	na	0	**25**	14	37	2	**nd**	na	na	0	**5.4**	4.6	6.3	3	**nd**	na	na	0
Metolachlor	**22**	7.1	117	58	**30**	4.0	120	58	**18**	1.6	123	67	**29**	2.8	147	34	**18**	3.0	79	30	**24**	3.7	73	29
Cyanazine	**87**	8.8	271	29	**140**	8.9	523	34	**34**	13	69	11	**156**	12	401	13	**8.6**	8.6	8.6	1	**135**	0.60	381	14
Chlorinated Pesticides																								
Hexachlorobutadiene	**nd**	na	na	0	**nd**	na	na	0	**nd**	na	na	0	**nd**	na	na	0	**nd**	na	na	0	**nd**	na	na	0
Hexachlorobenzene	**nd**	na	na	0	**nd**	na	na	0	**nd**	na	na	0	**nd**	na	na	0	**nd**	na	na	0	**nd**	na	na	0
Chlordane	**nd**	na	na	0	**9.4**	2.6	17	5	**nd**	na	na	0	**nd**	na	na	0	**nd**	na	na	0	**nd**	na	na	0
trans-Nonachlor	**nd**	na	na	0	**nd**	na	na	0	**0.50**	0.50	0.50	1	**nd**	na	na	0	**nd**	na	na	0	**nd**	na	na	0
Dieldrin	**nd**	na	na	0	**nd**	na	na	0	**nd**	na	na	0	**11**	11	11	1	**nd**	na	na	0	**nd**	na	na	0
o,p'-DDE	**nd**	na	na	0	**nd**	na	na	0	**nd**	na	na	0	**1.3**	1.3	1.3	1	**nd**	na	na	0	**2.9**	0.33	5.4	2
p,p'-DDE	**nd**	na	na	0	**nd**	na	na	0	**2.8**	2.8	2.8	1	**nd**	na	na	0	**nd**	na	na	0	**4.2**	2.0	8.3	8
o,p'-DDD	**nd**	na	na	0	**nd**	na	na	0	**nd**	na	na	0	**nd**	na	na	0	**nd**	na	na	0	**nd**	na	na	0
p,p'-DDD/o,p'-DDT	**nd**	na	na	0	**nd**	na	na	0	**nd**	na	na	0	**nd**	na	na	0	**nd**	na	na	0	**nd**	na	na	0
p,p'-DDT	**nd**	na	na	0	**nd**	na	na	0	**nd**	na	na	0	**nd**	na	na	0	**nd**	na	na	0	**nd**	na	na	0
Polychlorinated Biphenyls																								
CL2-PCB	**nd**	na	na	0	**nd**	na	na	0	**3.9**	2.5	5.3	2	**2.4**	2.4	2.4	1	**nd**	na	na	0	**13**	4.0	22	2
CL3-PCB	**nd**	na	na	0	**55**	4.5	209	14	**6.3**	0.45	16	4	**4.0**	1.6	6.5	2	**nd**	na	na	0	**65**	65	65	1
CL4-PCB	**nd**	na	na	0	**78**	1.8	324	20	**nd**	na	na	0	**nd**	na	na	0	**nd**	na	na	0	**nd**	na	na	0
CL5-PCB	**nd**	na	na	0	**nd**	na	na	0	**nd**	na	na	0	**nd**	na	na	0	**nd**	na	na	0	**nd**	na	na	0
CL6-PCB	**nd**	na	na	0	**nd**	na	na	0	**nd**	na	na	0	**nd**	na	na	0	**nd**	na	na	0	**nd**	na	na	0
CL7-PCB	**nd**	na	na	0	**nd**	na	na	0	**nd**	na	na	0	**nd**	na	na	0	**nd**	na	na	0	**nd**	na	na	0

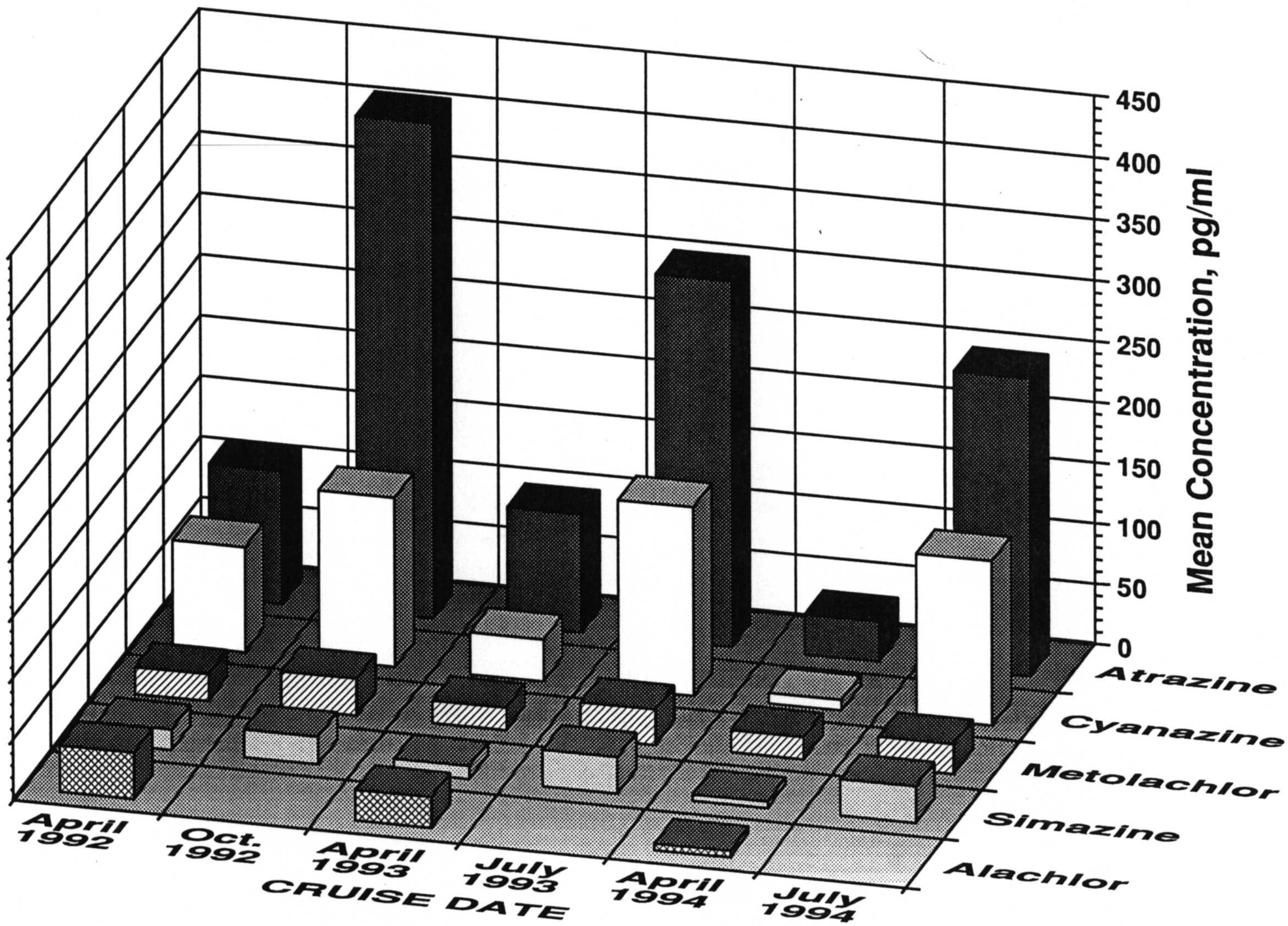

Figure 4D.9. Mean dissolved phase water herbicides concentrations (pg/ml) for six sampling cruises spanning three years (1992-1994).

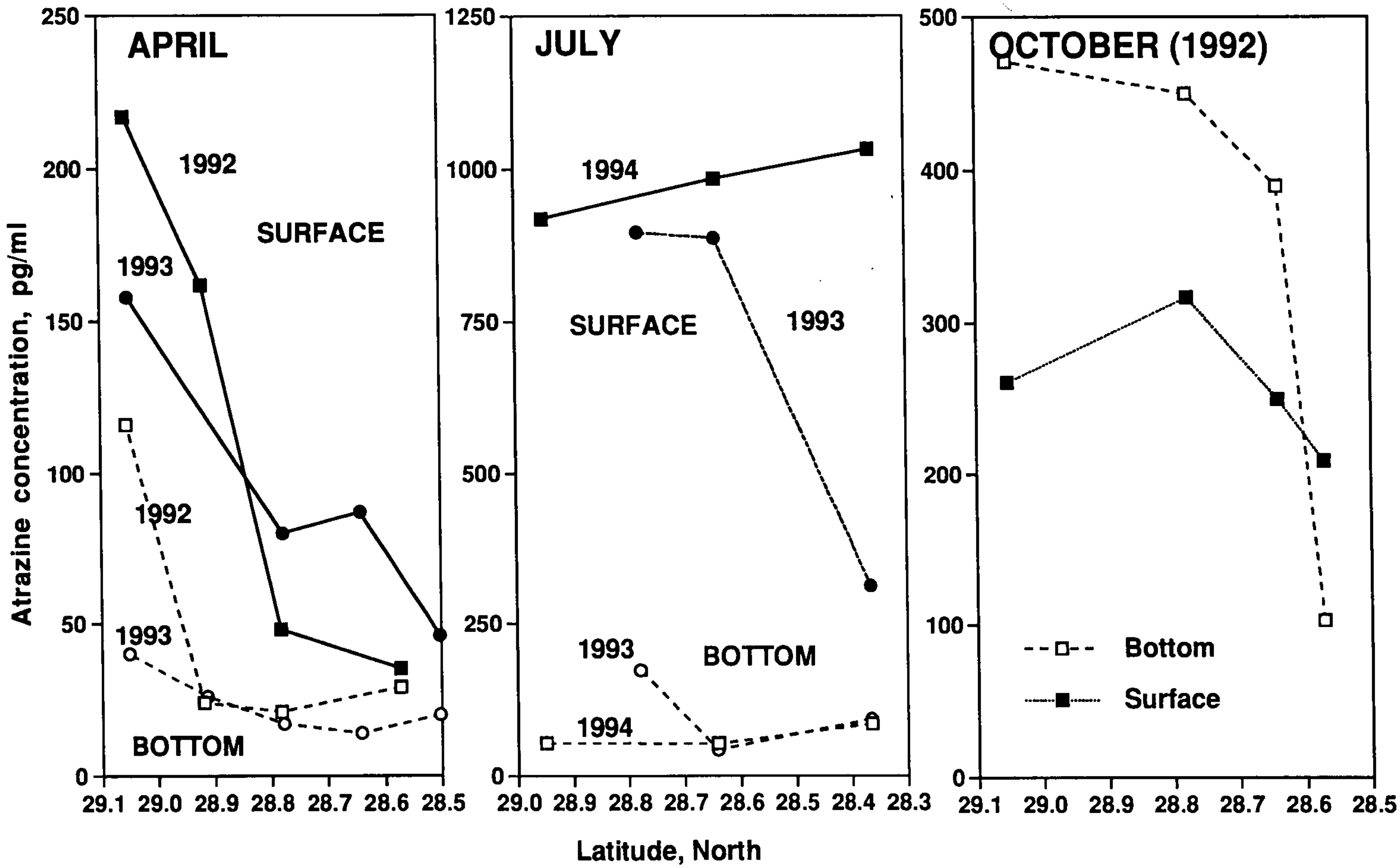

Figure 4D.10. Seasonal Atrazine concentrations (pg/ml) in dissolved phase of water samples collected at two depths along transect S1.

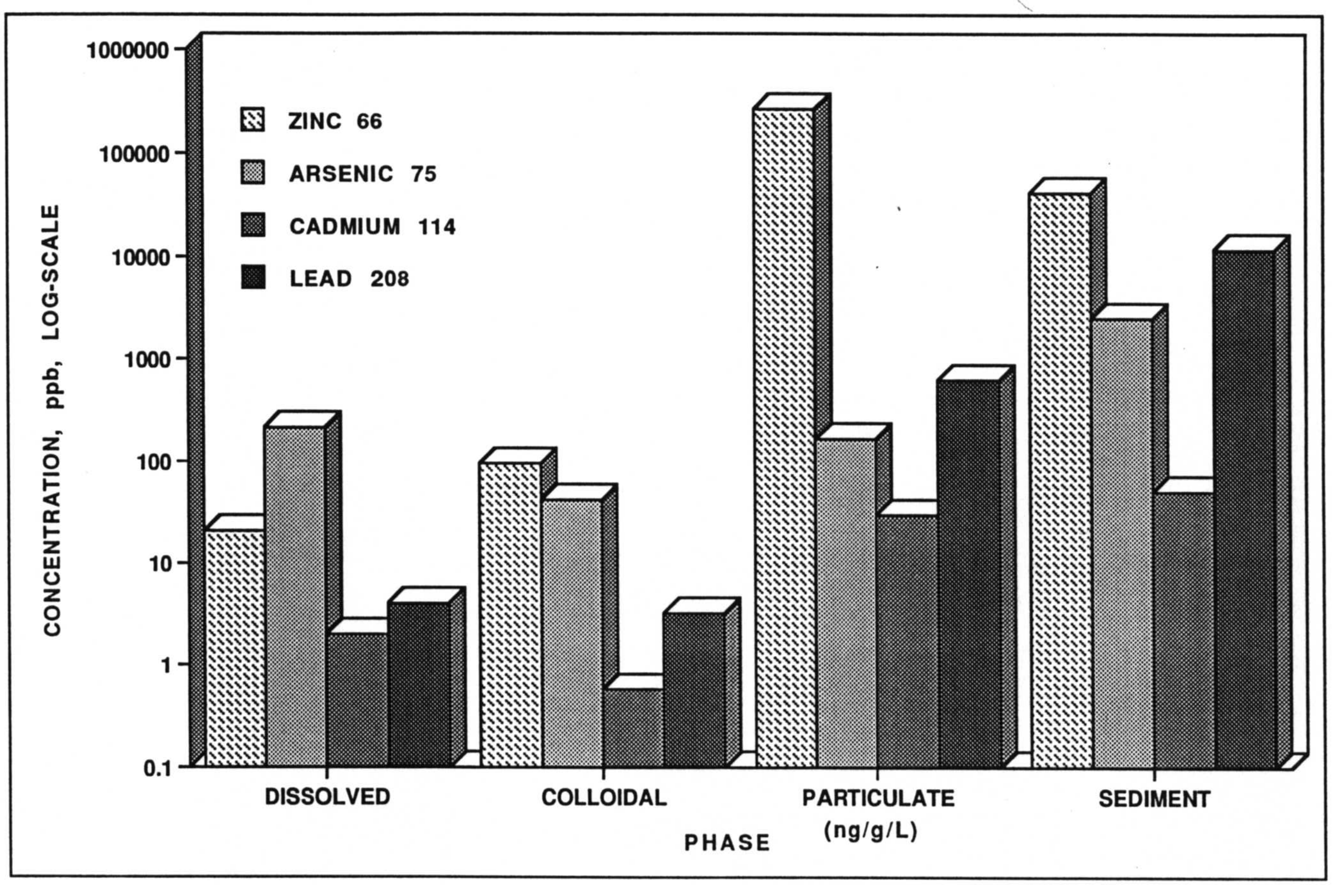

Figure 4D.11. Distribution of selected trace elements between three phases of water and bedded sediments.

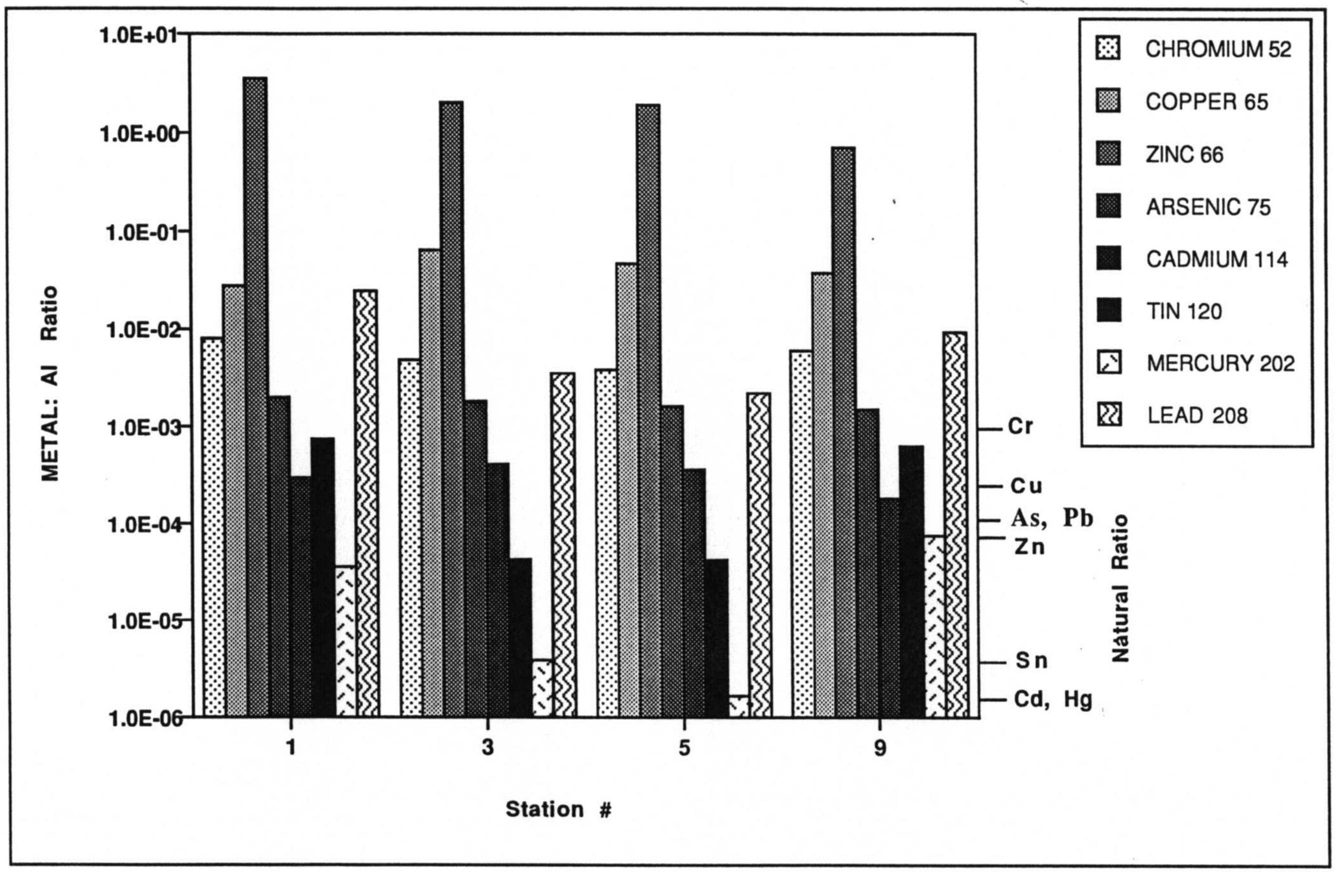

Figure 4D.12. Comparison of selected trace elements: Aluminum ratios in suspended particulate fraction of surface water with published ratios for coastal sediments.

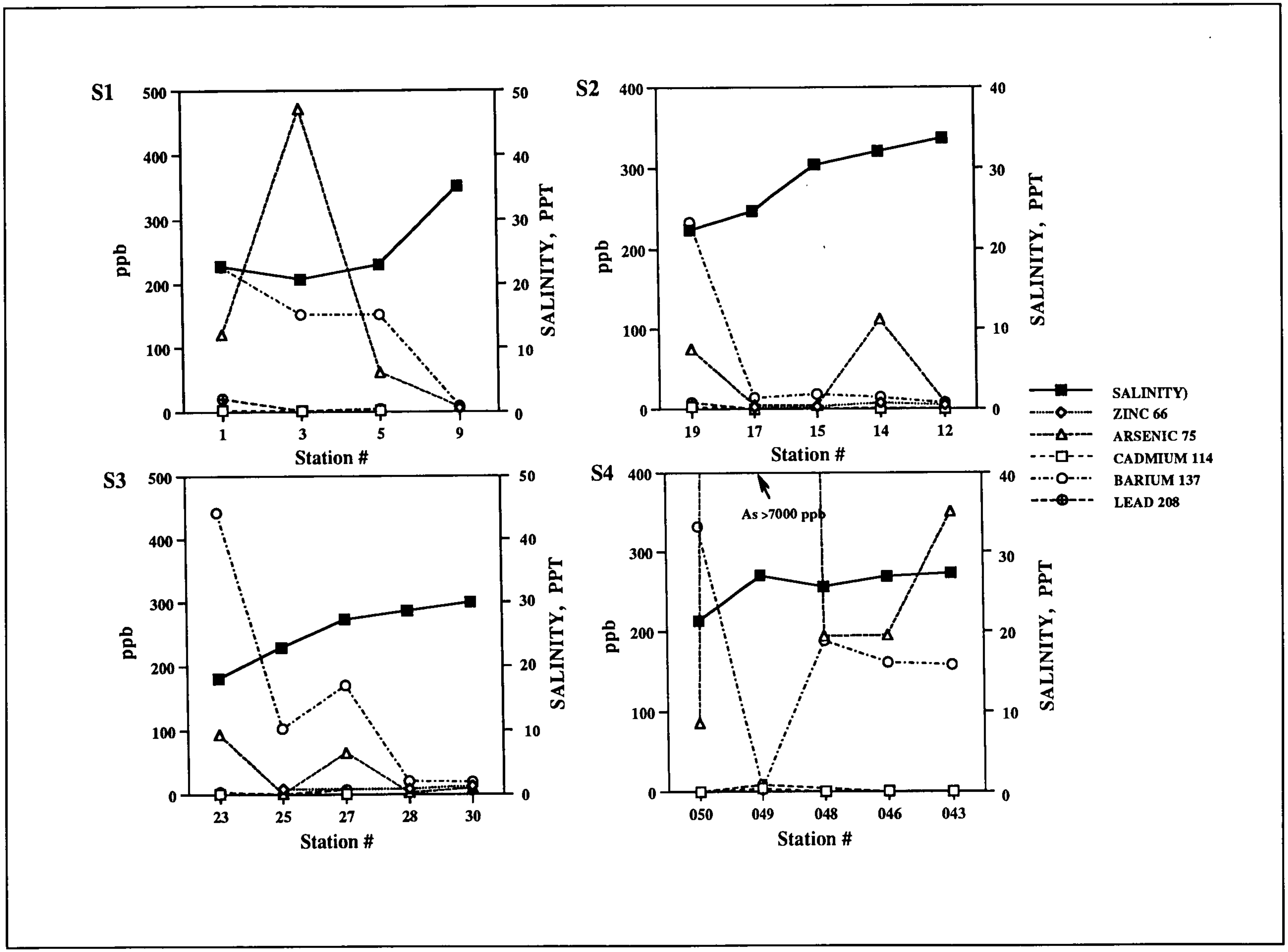

Figure 4D.13. Selected trace element concentrations and salinity values for dissolved phase water samples from four transects.

suspended particulates and bedded sediment samples. All analysis data were corrected for blanks and isotopic interferences. All elements were detected in all samples at trace levels or above. Riverine inputs from the Mississippi and Atchafalaya Rivers were identified in coastal waters. Inputs from the Calcasieu, Sabine and Galveston Rivers were also detected. Suspended particulate concentrations were highly correlated with surficial bedded sediment concentrations. Element ratioing techniques demonstrated that several elements were preferentially bound to colloidal phase fraction. Dilution of dissolved phase riverine sources using salinity data yielded good correlations. Estimates of the flux of each element are presented in a simple box model of the northwestern Gulf waters.

Figure 4D.11 shows the relative distribution of selected trace elements between the four sample matrices studied. Selected elements, such as Zn, Pb, Sr, Hg, and Ba were found to be enriched in the colloidal phase. Examination of the April 1992 suspended particulate phase data for transect S1 (Figure 4D.12) showed that Cd, Sn, Cu, and As were enriched, by more than two orders of magnitude for all except As, in both suspended and bedded phase sediments based upon published aluminum ratios in coastal sediments.

Figure 4D.13 shows the inverse relationship of several trace elements in the dissolved phases with salinity in four transects. Similar to data for organics, highest concentrations of trace elements occurred in stations nearest to the shore.

CONCLUSIONS

Sensitive methodology for the analysis of 76 individual and class estimated organic pollutants and 55 trace elements was developed and allowed for determination in almost 300 samples collected over a three-year period in the northwestern Gulf of Mexico along the coastal plume. This massive dataset shows reproducible trends between seasons from separate years, and will allow elucidation and modelling of transport processes as affected by riverine and estuarine inputs, variations in discharge volume, salinity, and depth, as well as effects of colloidal and suspended particulates. The ubiquitous nature, relatively high concentrations, and high and ongoing (year-round) mass transport of herbicides such as Atrazine raise questions of concern for impacts on aquatic life in this environment.

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Debra J. McMillin is a research associate at the School of Veterinary Medicine, Department of Veterinary Physiology, Pharmacology and Toxicology. She received her M.S. in animal science from Iowa State University. She has been doing environmental chemistry since 1984, specializing in mass spectral analysis for the last 10 years.

Dr. Jay C. Means is a professor of chemistry at the School of Veterinary Medicine, Department of Veterinary Physiology, Pharmacology and Toxicology. He received his Ph.D. in chemistry from the University of Illinois. His research interests include sediment transport as related to pollutant chemistry, pollutants in soils, sediments, and estuarine environments, as well as benthic-water contamination processes.

SESSION 5AB

OCS INDUSTRY ISSUES, PART II: INDUSTRY/AGENCY COOPERATIVE GOM OIL AND GAS REGULATORY ACTIVITIES

Session: 5AB - OCS INDUSTRY ISSUES, PART II: INDUSTRY/AGENCY COOPERATIVE GOM OIL AND GAS REGULATORY ACTIVITIES

Co-Chairs: Ms. Carla M. Langley and Mr. John D. Rullman

Date: December 14, 1995

Presentation	Author/Affiliation
Introduction and Session Moderator (no manuscript)	Mr. John D. Rullman Government & Regulatory Liaison Exxon, U.S.A.
Industry/Agency Cooperative GOM Oil and Gas Regulatory Activity	Ms. Carla M. Langley Office of the Regional Director Minerals Management Service Gulf of Mexico OCS Region
Clean Gulf Associates Update, 1991–1995	Mr. Richard W. Armstrong, Jr. Executive Director Clean Gulf Associates Mr. Russell Golson Mobil E & P, U.S., Inc.
Deepstar Regulatory Issues	Mr. Allen Verrett Texaco Exploration and Productions, Inc.
Offshore Operators Committee Bioaccumulation Study	Dr. J. P. Ray Program Manager Shell Oil Company
Preliminary Results of a Safety and Environmental Management Program (SEMP) Case Study Sponsored by the DOE and MMS	Mr. Richard A. Bresler Paragon Engineering Services, Inc. Houston, Texas Mr. Gerald Von Antz Taylor Energy Company New Orleans, Louisiana
National Offshore Safety Advisory Committee Issues	Mr. Peter Velez Manager Regulatory Affairs Shell Offshore

INDUSTRY/AGENCY COOPERATIVE GOM OIL AND GAS REGULATORY ACTIVITY

Ms. Carla M. Langley
Office of the Regional Director
Minerals Management Service
Gulf of Mexico OCS Region

Two half-day sessions, Outer Continental Shelf (OCS) Industry Issues: Part I and Part II, were developed and coordinated using an informal customer-partnership arrangement between the Minerals Management Service (MMS) and OCS industry representatives. This session, OCS Industry Issues, Part II: Industry/Agency Cooperative GOM Oil and Gas Regulatory Activities, addresses operational issues facing offshore operators. The first of the two sessions, OCS Industry Issues, Part I: Industry's Outlook for Gulf of Mexico Oil and Gas Development, addressed current and future issues of concern to the region's OCS natural gas and oil industry. Part I presentation summaries can be found in Sessions 4A&B.

Mr. John D. Rullman, Offshore Operator Committee (OOC) Technical Subcommittee Chairman and Government and Regulatory Liaison for Exxon Company U.S.A. developed this session's theme, invited speakers, moderated the session and coordinated meeting logistics through Ms. Carla Langley, the ITM Coordinator. Presented in this session are a series of papers given by oil and gas industry representatives directly involved in Gulf of Mexico offshore operations.

Operational issues presented include Clean Gulf's oil-spill cleanup efforts; DeepStar regulatory issues; OOC's bioaccumulation study (with underwater video footage); the Safety and Environmental Management Plan; and the National Offshore Safety Advisory Committee. The OOC's underwater footage provided scientific documentation highlighting abundant ecosystems (fisheries and corals) that flourish in harmony with offshore production platforms.

Special appreciation is extended to the session Co-chair, Mr. Rullman, for his time and effort in creating the session agenda and to the panel of speakers for their time spent addressing current and future issues of concern to the OCS oil and gas industry.

Carla Langley is a staff assistant in the Regional Director's Office with the Gulf of Mexico OCS Region of the Minerals Management Service. She joined MMS in 1982 and presently coordinates outreach efforts and special projects. In 1995 she was the Agenda and Logistics coordinator for the Region's Information Transfer Meeting.

From 1985 to 1991, Ms. Langley was a physical scientist with the Department of Defense. In this capacity, half of her time was spent overseas aboard U.S. Naval research vessels collecting and analyzing oceanographic and GPS data and monitoring bathymetric subsystem performance for application in the U.S. Fleet Ballistic Missile Program. She is a graduate of the University of New Orleans.

CLEAN GULF ASSOCIATES UPDATE, 1991–1995

Mr. Richard W. Armstrong, Jr.
Executive Director
Clean Gulf Associates

Mr. Russell Golson
Mobil E & P, U.S., Inc.

Clean Gulf Associates (CGA) has historically stockpiled oil spill cleanup equipment based on the needs of its membership. Several additions to the CGA stockpile have been made recently, which include two shallow water skimmers, a communications system trailer and a state-of-the-art wildlife rehabilitation trailer. But CGA has also taken recent steps to secure a number of contracted services that greatly enhance its capabilities in the areas of contingency planning and dispersant application.

BACKGROUND OF CGA

The CGA is a spill cooperative established in 1972 by 33 oil and gas exploration and production companies then operating in the Gulf of Mexico. Current membership includes 131 offshore operators. The purpose of the organization is to establish a plan for containing and cleaning up oil spills of member companies. In 1994 this purpose was broadened by the adoption of a Mission Statement that provided for material and services in addition to the traditional role of equipment resource. A copy of the Mission Statement is attached to this paper.

The organization has purchased and maintains a stockpile of oil spill cleanup equipment is stored at nine strategic locations along the Gulf Coast. Operations manuals and training on the use of all equipment are provided for each member company and contract cleanup personnel. Funds needed to maintain CGA are divided between the member companies based on a formula that takes into consideration each member's liquid hydrocarbon production. The amount and type of equipment stockpiled are predicated on the potential needs of the membership. The equipment is intended to handle various drilling and production spills, with the worst case being a blowout situation.

Membership in CGA is limited to oil and gas operators in the Gulf of Mexico Region. Only companies engaged in the exploration and production of oil and gas within the Gulf, its bays and estuaries, and the wetlands as far north as the Intracoastal Canal, are allowed to be members. Oil and gas transmission companies are allowed as associate members (but have no voting rights). Marine transportation companies and other users of the Gulf are not members of CGA but may have access to CGA equipment through their oil and gas affiliate companies. In fact, the largest spill response in which CGA equipment has ever been utilized involved the member-owned cargo on board the tank ship *Mega Borg* in 1990. Non-members may use CGA equipment upon approval by the Executive Committee. Examples of this are the Apex barge spill in the Houston Ship Channel, where private industry and the Coast Guard used the equipment, and the unidentified spill in Pascagoula where the Waterfowl Rehabilitation Station was mobilized by the Coast Guard.

CGA is managed by a nine member Executive Committee, elected from and by the Board of Directors, and a full-time Executive Director. The Executive Committee is advised and assisted by the 22 professionals that make up the Legal, Accounting, Operations and Technical Subcommittees. Ad-hoc committees are formed and staffed by experts as needed. Halliburton Energy Services, Inc. serves as the primary contractor to purchase and maintain the CGA equipment and to provide training and various administrative functions. Fourteen full-time Halliburton employees are engaged in CGA activities. This group consists of one engineer, an operations superintendent, eleven operations supervisors who also perform as spill clean up advisors, and a secretary.

The initial equipment inventory in 1972 included one High Volume Open-Sea Skimmer (HOSS Barge), one fast-response, over-the-side skimmer (FRU), one shallow water skimmer, 1,000 ft. of boom and miscellaneous smaller items. The current $15 million plus CGA stockpile includes various types of skimming equipment, boom, an inventory of dispersant and spraying equipment, a wildlife rehabilitation trailer, a biological sampling trailer, a communications system trailer and miscellaneous accessory equipment.

NEW EQUIPMENT

Belinda Breaux presented a paper entitled "Update of Clean Gulf Associates' Spill Response Planning" at the 1990 MMS ITM. At that time several CGA projects were in progress. These projects have now been completed and are worth noting. They include the four ID Boats working along the Louisiana and Texas coasts, 18,000 ft. of Expandi 4,300 open ocean boom, 10,000 ft. of shoreline protection boom and an additional trailer for ID Boat parts. ID Boats are utility boats working in member operations that have had small skimming packages installed and can be released to other members for immediate response to an oil spill.

EGMOPOL Shallow Water Skimmers

In 1991, CGA performed a study of its shallow water skimming capabilities and reviewed the experiences associated with the *Valdez* cleanup. As a result, CGA purchased two EGMOPOL skimmers for $800,000 to enhance its capabilities. These skimmers are trailer mounted, as is much of the CGA equipment, to enhance the deployment of this equipment.

Communications System Equipment

During 1992, CGA also evaluated the need for a comprehensive communications system. As a result of this study, CGA doubled the number of repeaters and portable radios in the inventory and installed radios on shallow water skimmers and boats. The radio systems are now housed and transported in a Communications Trailer and are maintained and tested by Halliburton. Communications on the HOSS Barge were upgraded by the installation of a cellular telephone and fax system, aviation base station, radio system and GPS equipment.

Wildlife Rehabilitation Trailer

During 1994, CGA designed and constructed a "state-of-the-art" wildlife rehabilitation trailer for the primary purpose of cleaning and assisting oiled waterfowl. In 1995 this unit was called out by a member and the

Coast Guard, and has proven to be a very practical and useful tool. CGA recently purchased additional equipment for this trailer based on suggestions from the two rehabilitation groups that used it.

CONTRACTED SERVICES AND CURRENT PROJECTS

SpillNet Inc.

In August, 1994, CGA secured the services of SpillNet, Inc. in order to meet the membership's contingency planning needs related to the Oil Pollution Act of 1990 (OPA-90). SpillNet is a 24-hour computer database service that provides information critical to helping a response team manage a spill effectively. SpillNet provides CGA members with access to a spill trajectory and fates module, digitized GOM coastline maps which have been updated in 1994 and 1995 using aerial photographs, an environmental database, response equipment and logistics databases, electronic status boards, and a color graphics module to improve communications. SpillNet also has prepared spill response strategies for sensitive areas along the Gulf Coast that can be modified to meet member needs.

Graphical Information System (GIS) Database

CGA supports the Coastal Marine Institute's (CMI's) project to develop a GIS database for the Gulf Coast Region through financial contributions and personnel for the steering and other committees. This project consists of data assessment, creation of a base map for the Gulf Coast and characterization of the shoreline. The data will be importable into the SpillNet database, ensuring that CGA members will have the most current data for the development of spill response plans.

Dispersant Application Capabilities

In January 1995, the Region 6 Regional Response Team granted pre-authorization to the Federal On-Scene Coordinator for the application of dispersant in certain areas of the Gulf. CGA has formed an ad-hoc committee to address various issues related to the application of dispersant. CGA has developed specifications for its desired aerial dispersant application program and contracted the services of Airborne Support, Inc. (ASI) to meet its needs. Through ASI, CGA members have 24-hour access to aircraft with appropriate spraying capabilities, spotter planes and properly trained personnel.

CGA is also investigating alternative boat spray systems, one of which incorporates the use of fire monitors instead of the typical spray bar methods.

HOSS Barge Modifications

CGA is currently investigating the possibility of installing a living quarters package on the HOSS barge. A detailed engineering design of the 16-man quarters has been completed and recently approved by the USCG. We are now preparing bid solicitation packages for this project. A final decision on this project will be made in early 1996.

FRU Modifications

The primary oil skimmer for CGA members is the self-contained Fast Response Unit (FRU), which can be quickly installed on the deck of a vessel of opportunity. Thirteen of these skimmers in the form of three models are in our inventory Tentative plans have been made to develop a fourth model for use in heavy oil skimming operations.

CONTACT WITH REGULATORY AGENCIES

CGA has assumed a very limited role as an industry spokesman on oil spill response matters in the Gulf Of Mexico. For several years the CGA Chairman has presented informal briefings on CGA activities and plans to the MMS Regional Director and his staff. More recently, committee chairs have discussed CGA matters with MMS staff supervisors. CGA has also been invited to present testimony to a Congressional committee and to a Department of Energy committee. In these cases, the Chairman speaks for the Association.

In 1994 CGA abandoned the long-standing rule of "members only" and invited state and federal regulatory agencies to their annual meeting in New Orleans. Representatives have accepted an invitation to make informal remarks at those meetings.

CONFERENCE SPONSORSHIP

CGA responded to a request from Tri-State Bird Rescue and Research, Inc. for a grant to present the Third International Conference on The Effects Of Oil On Wildlife by funding all of the basic costs of the conference. This conference was held in New Orleans in January 1993.

CONTACT WITH OTHER INDUSTRY ORGANIZATIONS

CGA has joined the Association Of Petroleum Industry CoOp Managers (APICOM), a group of industry funded oil spill clean-up organizations representing every major CoOp in the United States and Canada. Through contact with this group CGA stays informed on all oil spill response community developments.

CGA has representatives on Offshore Operators Committee (OOC) committees; the executive directors of both organizations are invited to all general meetings.

SUMMARY

In summary, CGA continues to assess its members' needs and work with various government agencies to ensure adequate spill response capabilities for the oil and gas industry in the Gulf of Mexico. Additional equipment and services will be secured as deemed appropriate to fill these needs as well as future regulatory requirements.

CLEAN GULF ASSOCIATES MISSION STATEMENT

Clean Gulf Associates (CGA) is a non-profit cooperative whose primary mission is to provide availability to oil spill response equipment, material and services for its members to respond to hydrocarbon spills and to meet regulatory requirements. This will assist the member in minimizing the impact on the environment by providing access to such equipment, materials and services which may be uneconomical or impractical for individual members to own or maintain.

Members and associate members of CGA are exploration, production and oil and gas transmission companies operating in the U.S. economic zone (area of interest) in the Gulf of Mexico (GOM), its bays and estuaries.

CGA will provide information related to CGA's needs and/or capabilities to certain organizations including but not limited to industry associations, equipment manufacturers, regulatory agencies and the general public, or when requested by an agency.

CGA will respond to regulatory agencies when the topic is law and/or a regulation related to oil spill response needs and capabilities of CGA.

Mr. Richard W. Armstrong, Jr., has served as Executive Director of Clean Gulf Associates since the position was created in April 1987. Prior to that time he was employed by Conoco Inc. for thirty years in engineering, operating, safety and training positions in Texas, New Mexico, and Louisiana, retiring in December 1986. He served as Conoco's representative on the CGA Technical Subcommittee and chaired the committee from 1982 until his retirement. Mr. Armstrong received a B.S. in petroleum engineering from Marietta College in 1957 and a B.S. in education from Ohio State University in 1953.

Mr. Russell F. Golson has been employed by Mobil Oil Corporation for fifteen years and is presently the supervisor of a group addressing the current organization and work processes within Mobil. Prior to this assignment, he worked in various production engineering, reservoir engineering, and environmental, health and safety positions, all in the South Louisiana area. He has served as chairman of the Technical Subcommittee of Clean Gulf Associates since 1993. Mr. Golson received a B.S. degree in mechanical engineering from Louisiana Tech University in 1979.

DEEPSTAR REGULATORY ISSUES

Mr. Allen Verrett
Texaco Exploration and Productions, Inc.

Mr. Verett's presentation consisted of the slide show represented on the following pages.

Allen Verrett, P.E. is a graduate of the University of Southwestern Louisiana where he received a B.S. in civil engineering. Allen joined Texaco's Offshore District offices in Morgan City, Louisiana in that same year and was assigned to the then Civil Engineering department. Allen held various positions in that district office until he was transferred as a supervisor to the Offshore Division Civil Engineering department in New Orleans, Louisiana. He was promoted to District Civil Engineer of the Morgan City offices in 1977 and in 1981 was promoted to Assistant District Manager. In 1989 he was named Offshore Division Process Manager and is currently an engineering resource advisor for the Offshore Division and serves as Texaco's E&P senior technical advisor on the DeepStar Project.

The DeepStar Project

An Industry Wide Cooperative Effort Focused On Identification and Development of Economically Viable, Low Risk Methods to Produce Hydrocarbons from Deepwater Tracts in the Gulf of Mexico.

The DeepStar Concept

DeepStar Provides:

* A Development Strategy
* Risk Management
* Capital Cost Control
* Cooperative Working Relationship With Industry

An Industry Solution To a Problem

* Oil Companies
* Vendors/Manufacturers
* Engineering Contractors
* Regulatory Agencies

An Industry Solution To a Problem

Common Direction Among Oil Companies
- Focus Technology Development Needs
- Share Technology Development Costs

* Feed-Back Loop to Vendors
    - Equipment Development

* Standardized Interfaces
    - Don't Re-invent the Wheel Every Time
    - Reduces Development Costs/Schedules
    - Potential for Equipment Sharing/Rental

DeepStar Technical Groups

Senior Advisory Panel			-	All Participants
100	-	Regulatory	-	Exxon/Texaco
200	-	Multi-phase Flow	-	Texaco
300	-	Control Systems	-	Exxon
400	-	Production Risers	-	Mobil
500	-	MODU/Moorings	-	Elf/Texaco
600	-	Pipelines/Flowlines	-	Shell
700	-	Reservoir	-	Texaco
800	-	Subsea Components	-	Mobil
900	-	Produced Fluids	-	Exxon
1000	-	Drilling	-	Shell

DEEPSTAR II-A CTR TECHNICAL COMMITTEE

CTR GROUP NO.	DATE:	TITLE:
500 DPII REV 1	11/1/95	MODU & Mooring Issues

		COMPANY:	PHONE:	FAX:
CHAIRMAN:				
	Paul Devlin	Texaco COE	(713) 432-3160	(713) 432-3290
Co-Chairman:				
	Mitchell Winkler	E&P Technology	(713) 245-7779	(713) 245-7233
	MEMBERS:			
1.	Andrea Desimoni	Agip	(713) 688-6281	(713) 680-4477
2.	Pierre Beynet	Amoco	(713) 870-5357	(713) 870-5045
3.	Frank Tiedemann	Amoco	(713) 212-7276	(713) 212-1616
4.	James Faulkner	ARCO	(214) 509-4390	(214) 509-4318
5.	Robert E. Smith	ARCO	(214) 509-3072	(214) 509-3920
6.	Thyl E. Kint	BHP	(713) 961-8313	(713) 961-8465
7.	Gail Baxter	BP	(713) 560-3423	(713) 560-8866
8.	Irv H. Brooks	Chevron	(510) 842-8204	(510) 842-2956
9.	Mike Moorehead	Conoco	(713) 293-6537	(713) 293-5529
10.	Paul R. Hilton	Elf Expl.	(713) 739-2058	(713) 650-1851
11.	Kristin Kragseth	EPR Co.	(713) 966-6139	(713) 966-6194
12.	Tom Kwan	EPR Co.	(713) 965-7867	(713) 966-6194
13.	Jim Thibodeaux	Kerr-McGee	(318) 988-7994	(318) 988-7944
14.	C. E. Arney	Marathon	(713) 296-3101	(713) 296-3190
15.	Rick Palmer	Mobil E&P	(504) 566-5878	(504) 566-5399
16.	Bert Sweetman	Mobil R&D	(214) 851-8781	(214) 851-8349
17.	Cesar Del Vecchio	Petrobras	5521 598-6332	5521 598-6790
18.	Alex Lou	Phillips	(918) 661-7961	(918) 662-2047
19.	Anders Ekvall	Shell Dev.	(713) 544-7352	(713) 544-8826
20.	Steve Homer	Texaco COE	(713) 432-3567	(713) 432-3290
21.	Peter Norris	Texaco COE	(713) 432-6222	(713) 432-3290
22.	J. A. Abadin	Texaco E&P	(504) 595-1963	(504) 595-1472
	VENDORS:			
1.	Phil Abbott	Aker Omega	(713) 588-7550	(713) 870-8008
2.	Patricia R. Blandford	Atlantia	(713) 850-8885	(713) 622-4236
3.	Jim O'Sullivan	B&R Seaflo	(713) 575-4112	(713) 575-4126
4.	Denis Graham	Diamond Off.	(713) 492-5320	(713) 647-2108
5.	John Vecchio	Diamond Off.	(713) 647-2178	(713) 647-2108
6.	Pharr Smith	Friede& Goldman	(504) 523-4621	(504) 529-5135
7.	Per Ekehorn	GVA	44181 9951333	44181 7423211
9.	Jack Pollack	Imodco	(818) 880-0300	(818) 880-0333
10.	Malcolm Sharples	Noble Denton	(713) 558-7180	(713) 558-2098
11.	Bill Hunter	Reading& Bates	(713) 589-5151	(713) 496-0186
12.	Frank Williford	Sedco Forex	(409) 696-7955	(409) 693-3482

MMS Regulatory Background Data

* Evolutionary in Nature
* Prescriptive in Nature
* Based on "Bad" Industry Experiences

MAJOR OFFSHORE EVENTS AND CONSEQUENCES

LOCATION	DATES	STATUS	CAUSE	CONSEQUENCE	IMPACT
GULF OF MEXICO PLATFORMS	1964 & 1965	WELLS SHUT IN PLATFORM UNMANNED FOR STORM	STRUCTURAL UNDER-DESIGN FOR LOADING	PLATFORM LOSS STRUCTURAL DAMAGE WELL LOSS	API RP 2A STANDARDS VERIFICATION PROGRAMME
SANTA BARBARA CALIFORNIA	1969	DEVELOPMENT DRILLING ACTIVITIES ON PLATFORM	INADEQUATE CASING DESIGN	BLOWOUTS, POLLUTION DAMAGE TO COMPLEX INJURIES TO PERSONNEL	DRILLING MORATORIUM OCS ORDERS
NORTH SEA EKOOFISK-BRAVO	1977	WORKOVER AND PRODUCING OPERATIONS	INADEQUATE OR INCOMPLETE OPERATING PROCEDURES FOR SIMULTANEOUS OPERATIONS	BLOWOUT, LARGE SPILL AND POLLUTION	NPD ISSUES GUIDELINES FOR SIMULTANEOUS OPERATIONS
NORTH SEA, ALEXANDER KIELLAND	1980	FLOATEL FOR OPERATIONS SUPPORT	INADEQUATE FATIGUE DESIGN AND MATERIAL SELECTION	CAPSIZED, LARGE LOSS OF LIFE AND LOSS OF FACILITY	NPD CONCEPT SAFETY EVALUATION
NORTH SEA PIPER ALPHA PLATFORM	1988	CONSTRUCTION, DRILLING AND PRODUCTION OPERATIONS	INADEQUATE OR INCOMPLETE OPERATING PROCEDURES FOR SIMULTANEOUS OPERATIONS	EXPLOSION, FIRE AND SIGNIFICANT LOSS OF LIFE, POLLUTION AND LOSS OF FACILITY	FORMAL SAFETY ASSESSMENT CASE CULLEN REPORT

Existing OCS Regulations Were Promulgated Based On The Expansion Of Successful Bay And Inland Estuary Production Operations And Reflect Mostly Surface Operations Where Daily Access To Wellheads Were Possible.

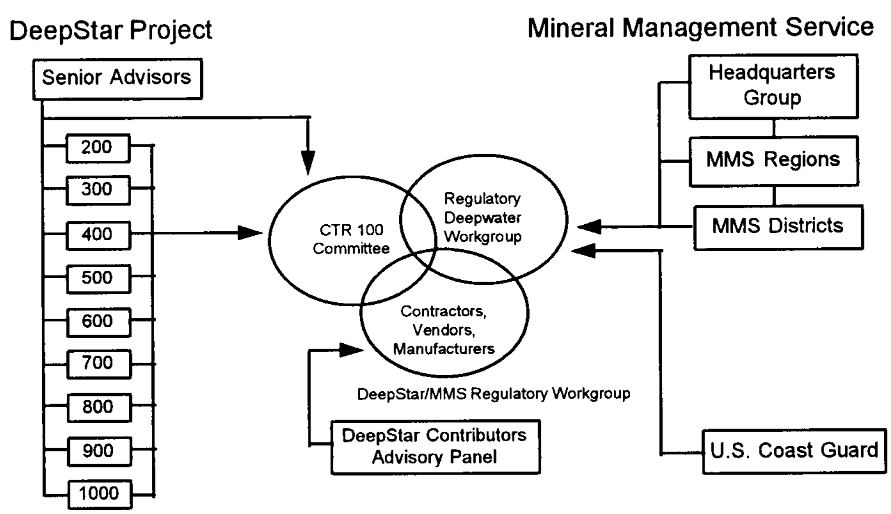
Existing Regulations Were Found To Lack The Flexibility To Address The Technology Developments Achieved In Deepwater Environments.

Guidelines Did Not Account For The Advances Made In Hardware And Control Systems That Made Remote Monitoring And Control As Safe As Conventional Surface Operational Practices.

April 1992 - MMS Headquarters Establishes Need To Study Deepwater Developments And Review Current Regulations.

April 1992 - DeepStar Program Is Initiated And MMS Joins Program To Monitor Consortiums Work.

Regulatory Workgroup Organization



Regulatory Issues Submitted to CTR 100 For Workgroup Discussion

The Evolution of MMS Deepwater Regulations Review

April 1992	MMS Engineering and Technology Division in Headquarters convenes MMS Internal Workgroup to study deepwater development and current regulations.
September 1992	Internal MMS Workgroup recommends formation of "Deepwater Workgroup" and preparation of a report that will analyze the effectiveness of the current regulations and processes used to carry them out.
November 1992	GOM Region MMS internal memo to MMS Associate Director regarding need to review policy and potential changes to encourage deepwater development.

The Evolution of MMS Deepwater Regulations Review

November 1993	Deepwater Workgroup meetings to review regulatory issues raised by DeepStar. Reviewed departures granted for existing developments and raised conservation issues.
	Semp concept discussed and evolved to a White Paper report to group. White Paper forms basis of operations plan. Several other issues raised and addressed by Workgroup.

The Evolution of MMS Deepwater Regulations Review

April 1994	Initial draft of Deepwater Workgroup report including discussion of deepwater operations plan concept (an issue paper) deepwater plan to address departures (alternative compliance) and deepwater issues. Concept of full system integration and review discussed.
July 1994	MMS Deepwater Workgroup makes recommendation to MMS Executive Steering Committee to address issue of prudent deepwater development (conservation) policy under quality improvement process.
October 1994	Development of deepwater operations plan "Straw Model" proposed by CTR 100 committee. Proposal to use Exxon "Zinc" as "go by".

The Evolution of MMS Deepwater Regulations Review

January 1995	Deepwater operations plan "Straw Model" approach is presented in open meeting. Mark Stair is identified as contractor for model.
April 1995	CTR 100 committee meeting to review progress on "Straw Model" and discuss timing and content of information necessary for plan.
April 1995	MMS comments on "Straw Model" sent to CTR 100 committee.
July 1995	CTR 100 meeting to review comments and discuss alternatives by other operators. BP example document Shell review and comments.

DEEPWATER WORKGROUP

Final Report

April 17, 1995

DEEPWATER Regulatory Issues

Operations & Safety Management
Minerals Management Service
Department of the Interior

Table Of Contents For Deepwater Workgroup Final Report

GAS FLARING AND LIQUID HYDROCARBON BURNING

DURING EXTENDED WELL TESTING

* Do not revise the regulations for gas flaring
* Formulate regional policy for the approval of mid- and long-term well testing for deepwater reservoirs
* Continue require barging of all produced liquids

BOTTOMHOLE PRESSURE SURVEY REQUIREMENTS

* Allow use of calculated bottomhole pressure surveys for subsea wells
* Develop guidelines for calculating bottomhole pressures
* Encourage development of technology to monitor bottomhole pressures

STRUCTURAL REQUIREMENTS FOR DEEPWATER FACILITIES

* Incorporate American Petroleum Institutes Recommended Practice for Planning, Designing and Constructing Tension Leg Platforms (API RP 2T) into the regulations

GAS FLARING AND LIQUID HYDROCARBON BURNING

DEEPWATER PIPELINES REQUIREMENTS

* Revise regulations to consider hydrostatic head pressure in pipeline design calculations
* Revise regulations to include design criteria for collapse
* Do not revise regulations on safety valves for subsea tie-ins

DEEPWATER OPERATIONS PLAN

* Require lessees to submit deepwater operations plan
* Recommend use of API RP 75 in preparation of the deepwater operations plan
* Identify alternative compliance to the current regulatory requirements with the appropriate justifications
* Provide documentation for conservation issues

SUMMARY OF WORKGROUP RECOMMENDATIONS

UNDERWATER SAFETY VALVES (USV) AND SHUTDOWN VALVES (SDV)

* Require quarterly testing of USV's
* Require monthly testing of SDV's with no leakage allowed
* Revise leakage criteria for USV's
* Revise closure time for USV's
* Require SDV's to close within 45 seconds
* Allow tiered emergency shutdown system (ESD) for subsea wells
* Require lessee to install USV's in vertical run of the tree
* Require lessee to address USV's and SDV's operation in Deepwater Operations Plan

SUBSURFACE SAFETY VALVES (SSSV) FOR SUBSEA WELLS

* Revise the ESD closure time for SSSV's in subsea wells
* Allow tiered ESD for subsea wells
* Revise leakage criteria for SSSV's installed in subsea wells
* Require lessee to address SSSV operation in Deepwater Operations Plan

SUMMARY OF WORKGROUP RECOMMENDATIONS

CASING ANNULUS PRESSURE MONITORING
REQUIREMENTS FOR SUBSEA WELLS

* Do not revise requirement for monitoring casing annulus pressures in subsea wells
* Conduct additional review of the casing pressure problems
* Consider casing annulus concerns during the review of applications for permit to drill for subsea wells
* Work with industry to promote technological advancements in ability to monitor pressures on multiple casing annuli
* Require lessee to describe in the Deepwater Operations Plan how drilling, cementing and design procedure negate concerns about sustained casinghead pressures

DEEPSTAR II-A CTR NO. A101

DEEPWATER OPERATIONS PLAN "STRAW MAN" - PHASE I

* Phase I of Three Phase Process
  - Phase I document provided for 100 Committee membership review and comment;
  - Phase II document provided for DeepStar Membership review and comment; and
  - Phase III document provided for MMS review and comment.

DEEPSTAR II-A CTR NO. A101

DEEPWATER OPERATIONS PLAN "STRAW MAN" - PHASE I

* Will address production system from the wellbore through the host facility boarding SDV's
  - Will not address (1) TLPs, FPSs, or templates and other supporting structures; (2) host facility; and (3) pipelines
* Will be based on the Exxon Zinc Project Departures and Design Plan document dated November 27, 1991, with additional information as available.
* Will address HAZOP analysis requirements for broad categories of system configurations:
  - Underwater single satellite wellhead depicted in API RP 14C;
  - Multi-well manifolded systems - WP > SITP, no multi-phase subsea metering; and
  - Other systems - Pipeline WP < SITP, multi-phase subsea metering, others.

DEEPWATER OPERATIONS PLAN

EXAMPLE INFORMATION AND PLAN DOCUMENT CONTENT

I. SYSTEM OVERVIEW

A. OCS Blocks to be developed

B. Brief system description (single wells, multi-well template, host platform, offset distances, number of pipelines, number of umbilicals, etc.) - Area map showing subsea and host locations and pipeline/umbilical corridor.

C. Drilling plans - Well surface and bottom hole locations

DEEPWATER OPERATIONS PLAN

EXAMPLE INFORMATION AND PLAN DOCUMENT CONTENT

II. SUBSEA EQUIPMENT DESCRIPTION

A. Subsea equipment and any special features (removable components, pipeline utilization and pressure capacity, pigging capability, chemical injection capability - Plan/side/end views of subsea template showing well slots, pipeline connection, umbilical connections, other components.

B. Wellbore, casing, tubing and completion including any unique design requirements (soft bottom, shallow gas flow potential, water flow potential); description of corrosion inhibitor, hydrate inhibition, and paraffin/asphaltine inhibitor plans - Wellbore schematic.

C. X-mas tree (vertical/horizontal, bores size, valve arrangement, header valve configuration, pressure sense points, valve override capavility, tree cap configuration, control pod location, template manifold connector configuration) - Single lineschematic of X-mas tree.

D. Completion, concentric workover, and conventional workover riser/BOP system

E. Control system (direct, piloted, sequenced, electrical/hydraulic or electrohydraulic multiplexed; pod locations; hydraulic fluid type; other chemicals injection provisions; pressure sense capability; hydraulic power unit; chemical injection unit) - Block diagram of control system components, single line schematic of hydraulic and chemical circuits from the host platform through the subsea components including the X-mas tree, single line schematic of the HPU, and single lint schematic of the CIU showing all pressure sense points, SCSSVs, USVs and SDVs

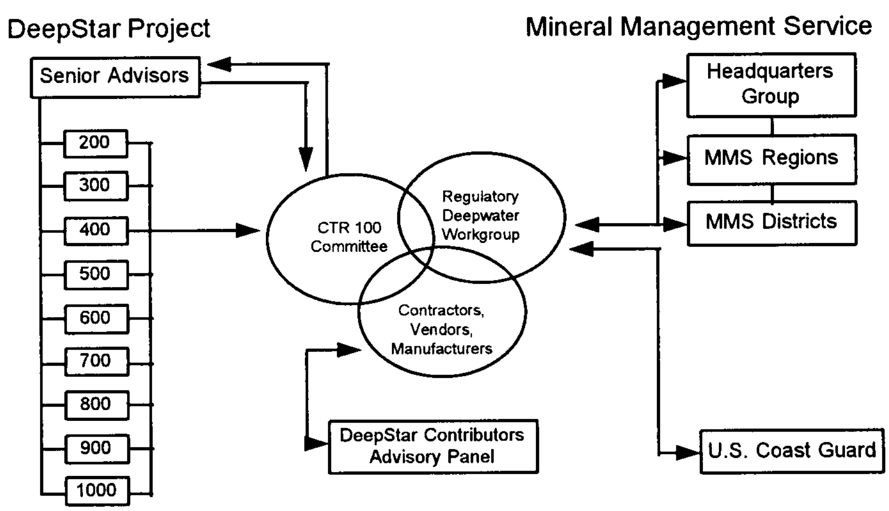
DEEPWATER OPERATIONS PLAN

EXAMPLE INFORMATION AND PLAN DOCUMENT CONTENT

III. SAFETY SYSTEM FUNCTION DESCRIPTION

A. Premise of design - system responsible for providing for safety of the host platform.
B. Interface philosophy between the host platform and subsea control system.
C. Declaration of primary and secondary shutdown systems and methods of operation - Depiction of the shutdown system functional interfaces.
D. Shutdown time expectations for primary and secondary shutdown systems - SCSSVs, USVs and SDVs.
E. Safety responses which result from potential events - Events/Response Chart (or Functional SAFE Chart).
F. Erosion detection plan.
G. Subsea safety system test method and frequency.
H. HPU, CIU and Pipeline SDV test method and frequency.

Regulatory Workgroup



Workteam Generated "Straw" Model And Received Comments Through Respective Groups

Cooperation Not Only Fostered Work In The Regulatory/Operational Area But Also Carried Over To The Joint Sponsoring Of A Produced Fluids Workshop Held At OTC In 1995 With MMS And DeepStar Sponsoring A Special Session On Produced Fluids.

WORKSHOP ON PRODUCED FLUID ISSUES
AND POSTER DISPLAYS

May 4, 1995 in Houston, Texas

Sponsored by:
* DeepStar Project
* Minerals Management Service
* Offshore Technology Conference

Presentations by Industry Experts and Researchers on:
* An Introduction to Produced Fluid Issues
* Identifying Paraffin Problems
* Paraffin Remediation Technology and Industry Initiatives
* Hydrate Production Technology and Industry Initiatives

OFFSHORE OPERATORS COMMITTEE BIOACCUMULATION STUDY

Dr. J.P. Ray
Program Manager
Shell Oil Company

INTRODUCTION

As part of the 1993 Gulf of Mexico General Permit, issued under the NPDES permitting authority of Region VI EPA, all operators in the Gulf of Mexico discharging in excess of 4,600 barrels per day (bpd) of produced water were required to conduct site specific bioaccumulation studies. The intent was to determine whether specified organic and inorganic (including radium 226 and 228) components were being bioaccumulated into edible flesh of marine organisms living near the platforms.

The permit allowed the industry to propose an optional study that would provide more specific information on the bioaccumulation issue. EPA accepted the more intensive Offshore Operators Committee (OOC) study design, but required that 12-platform pairs (discharging vs. non-discharging) be surveyed as part of the program. This modified program allowed the industry to work together cooperatively to provide the data required in the permit, and to focus their efforts on a smaller number of platforms.

SPONSORS

The OOC Bioaccumulation Study is sponsored by a consortium of Gulf of Mexico operators. These include 22 operators with discharges over 4,600 bpd (89 platforms), and 54 operators with less than 4,600 bpd.

RESEARCH TEAM

Following a competitive bidding process, the contract for this two year, $3 million project was awarded to Continental Shelf Associates of Jupiter, FL. Because of the diversity of this project, several additional subcontractors were part of the team. These included Battelle Ocean Sciences who are conducting organic analyses and providing the literature review. Arthur D. Little, Inc. who are also conducting organic analyses. Florida Institute of Technology is conducting the metals analyses. CORE Laboratories are conducting the radionuclide analyses (Analytical Technologies, Inc. are the radionuclide quality control lab).

Statistical support for the program is provided by Dr. Wolcott Smith at Temple University.

STUDY DESIGN

The OOC bioaccumulation project has two major components. The first is the Biological Survey program required by EPA. This program comprises platform pairs (discharging vs. non-discharging) from different geographical regions in the Gulf of Mexico. Two platform pairs were required near the Mississippi River, two off the coast of Texas, two in high industry activity areas, and two in water depths of less than 10 m.

The design requires that two species be collected at each platform pair with five specimens of each species. For example, if the two species were rockhind and gray triggerfish, five of each would be collected at the discharging platform, and five of each at the non-discharging platform. This would mean a total of twenty specimens to analyze for that platform pair.

The analyses are for the target analytes listed in the General Permit (e.g., barium, mercury, cadmium, arsenic, benzene, phthalates, etc.)

In addition, one platform was designated as Biological Survey Intensive. This platform pair must include specimens representing a fish, crustacean, and mollusc.

The OOC-designed portion of the study is based on an in-depth analysis of resident organisms from two platform pairs. This is known as the Definitive Study. A preliminary screening cruise was conducted to evaluate four potential platform pairs for the definitive study. Based on the results of this cruise, two platform pairs were chosen that had minimal influence from outside sources of contamination and adequate biomass to support the intensive sampling of two more cruises. These were EB 165 (> 10,000 bpd) and GC 19 (> 6,000 bpd).

At the definitive platform pairs, large sample sizes have been collected to improve the statistical power of the analyses being conducted. A compositing strategy designed by CSA and their statistical advisor is being used to minimize uncertainty in the data. The primary goal of this portion of the study is to detect whether or not produced water components can be detected in the edible flesh of near-platform residents.

In addition to several species of fish, two species of molluscs are being collected from the platform biofouling community.

OOC conducted dispersion model runs, using both the OOC produced water dispersion model and the COREMIX 1 model, to predict the approximate produced water plume position in the water column beneath each platform. These data were used conservatively to ensure that specimens collected would and do occur in the water column and on the platform structure in the zone where produced water would occur.

Field Program

The program was designed to encompass three cruises. The first, conducted in the fall of 1994, was a screening cruise to evaluate candidates for the definitive study. The definitive program was divided into two cruises, representing the spring and fall of 1995.

Field sampling was completed in December of 1995. The combination of 12 platform pairs (i.e., 24 platforms) extending from the Mississippi delta to offshore Texas, and an unusually rough weather year, has lead to an unusually long field program. Total at-sea work days for this project now stand at 100, plus another 65 weather standby days.

Sample Preparation

Fish, molluscs, and crustaceans collected in this program were frozen at sea for trans-shipment to the analytical laboratory. Fish were weighed, measured, and externally examined for abnormalities. They were then wrapped in "lab cleaned" foil, labeled, and frozen. Molluscs were frozen in shell for shipment.

The freezers were transferred to a truck onshore and shipped to Battelle Ocean Sciences in Duxbury, Massachusetts. Sample prep was conducted by Battelle with subsequent shipment to the participating laboratories.

Analytical

A detailed QA/QC program was required of all laboratories, and SOP's used by each laboratory were reviewed by industry chemists. Each laboratory was required to send a percentage of their samples to an outside laboratory for calibration analyses. In addition, industry chemists have conducted audit visits to the analytical laboratories.

Data quality objectives have been set for all analyses. For organic analyses, the method detection limits (MDLs) are in the low part per billion range. Similarly, the metals MDLs are very low.

For comparative purposes, the definitive program-produced water samples are being analyzed. Upstream ambient water samples are also being analyzed to determine background concentrations of the target analytes.

Data

The analyses of samples from cruises 1 and 2 are now completed. They are still awaiting a final quality assurance review. Data from cruise #3 will be completed in the third quarter of 1996. No data will be released from this study until the final report is submitted to EPA.

Literature Review

Battelle Ocean Sciences is conducting a thorough literature review on the marine bioaccumulation of organics and inorganics. This synthesis review will be international in scope, with a Gulf of Mexico focal point. The information will be important in interpreting the final data generated in this study. It will be important to review the OOC data in the context of previous information.

Final Report

Because of the loss of over 50 at-sea days during the fall cruise (1995) due to bad weather, the project has fallen behind by approximately two months. Initially scheduled for a June 1996 submittal to EPA, the final report will probably be submitted during the third quarter of 1996.

Jim Ray graduated from Texas A&M in 1974 with a degree in biological oceanography. He has been with Shell Oil in Houston, Texas since that time and is currently Manager of Environmental Sciences. He is Chairman of the Offshore Operators Committee's "Environmental Sciences Subcommittee," and serves as Program Manager for the bioaccumulation study. He also is chairman of the API Production Effluent

Guidelines Task Force which is responsible for offshore discharge related environmental research. He is a member of the new MMS subcommittee that is reviewing environmental study needs and priorities in OCS moratoria areas. He was recently appointed to the National Research Council's Ocean Studies Board.

PRELIMINARY RESULTS OF A SAFETY AND ENVIRONMENTAL MANAGEMENT PROGRAM (SEMP) CASE STUDY SPONSORED BY THE DOE AND MMS

Mr. Richard A. Bresler
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Houston, Texas

Mr. Gerald Von Antz
Taylor Energy Company
New Orleans, Louisiana

INTRODUCTION

On 30 June 1994, the MMS published a *Federal Register* notice requesting that industry voluntarily adopt API RP 75 (SEMP). Under the SEMP program, offshore producers would be responsible for identifying potential hazards in the design, construction and operation of drilling and production rigs and developing specific approaches to reduce occurrences of accidents.

Many smaller and mid-size independent producers, however, have raised questions over the costs and methods for implementing SEMP. The DOE and MMS determined that a carefully documented case study would answer many of the smaller producers questions. With results of the study oriented specifically to small- and mid-size companies, independent producers would be much more willing to invest the time and resources to adapt the RP 75 procedures to their own operations. As a result, the DOE and MMS have entered into a 30-month study with Taylor Energy Company (TEC) and Paragon Engineering Services (Paragon) to develop a Safety and Environmental Management Plan (SEMP). This program is intended to demonstrate how small-to mid-size companies can effectively and inexpensively develop a SEMP fashioned around API RP 75.

This paper discusses the preliminary findings during the first six months of the case study, specifically the development of a SEMP Implementation Plan and the development of Safety and Environmental Information in support of the SEMP.

SEMP IMPLEMENTATION PLAN

The SEMP Implementation Plan is contained in a SEMP Manual which was developed to take the words and intent of API RP 75 and to reduce them into specific statements about how to implement the elements.

The essential elements of the SEMP are:

- Safety and Environmental Information
- Hazards Analysis
- Management of Change
- Operating Procedures
- Safe Work Practices
- Training
- Assurance of Quality and Mechanical Integrity of Critical Equipment
- Pre-Start-up Review
- Emergency Response and Control
- Investigation of Incidents
- Audit of Safety and Environmental Management Program Elements

Paragon developed a TEC SEMP Manual which describes a company-wide philosophy to interpret the RP 75 guidelines for each element of SEMP, specifically delineating how each element is to be implemented, and listing responsibilities for documentation and archiving.

Discussed below are some highlights of the company-wide SEMP Manual developed for TEC.

Hazards Analysis

A hazards analysis alone does not ensure the facilities are safe; this is only a small part of the overall safety program. Many accidents are the result of, or are attributable to the following: poor operating procedures, deficient management of change procedures, lack of maintenance and testing of safety devices, management pressures to achieve production rates, and so forth.

The first order of business regarding the hazards analysis is to determine the methodology appropriate for the facilities being analyzed. Our philosophy is that the majority of production facilities, compressor stations and gas plants employ gravity separation (for gas/liquid separation, oil treating, and water treating), distillation (for LPG recovery), and simple absorption (for gas dehydration and removing acid gases with amine). Typically they are open and not enclosed modules, have zero to fifty persons on-site, and are limited in size. There are no complex chemical reactions which are sensitive to small changes in temperature, pressure, or feedstock. The processes are well known and easy to understand. If the facilities have been designed, built, operated, and maintained in accordance with good practices, uncontrolled releases of hydrocarbons can be successfully avoided.

For these facilities, Paragon and TEC are using a generic computer-based checklist procedure for the hazards analysis. This methodology is based on a procedure which has been used and continuously modified since the early 1980s. The analysis contains the following specific reviews: general process, process components, electrical system, fire detection and protection, quarters, and mechanical equipment.

It should be possible to complete the hazards analysis for each of TEC's facilities in one to four man-weeks, depending on the complexity of the facility. The documentation is easy to audit, and conclusions are straightforward.

In contrast, a formal HAZOP would take an estimated five to ten times the staff time and would require more experienced engineers. Even with the greater effort expended in a formal HAZOP review, it is unlikely that additional problems of significance would be uncovered for these facilities.

As required by RP 75, the initial hazards will be performed in an order of priority. This order will be established in accordance with various factors, such as: facilities with living quarters, production rates, simultaneous operations, sour gas, severe operating conditions (high pressures, highly corrosive fluids, etc.), and locations near environmentally sensitive areas.

The operating procedures should be completed prior to the start of the hazards analysis. This arrangement will allow the hazards analysis team to review the procedures along with the facilities.

Management of Change

A sound management of change procedure is imperative for safe operations. Changes happen almost continuously to improve efficiencies, to improve operability and safety, and sometimes just to keep the facilities running. Any change not carefully thought out can cause a new hazard or compromise existing safeguards.

The TEC management of change procedure involves three categories of change, each of which requires a different level of review. The first level is replacement in kind, which does not require a formal management of change review. The second level is a minor change (Type A), which requires a review by the lead operator and the platform foreman. The third level is considered a major change (Type B), which requires an additional review by the Engineering Department, the Safety Manager, and the Operations Manager. For both Type A and B changes, a Management of Change Form has been developed.

The management of change procedures should be implemented concurrently with the adaption of the SEMP implementation plan.

Operating Procedures

Operating procedures can compromise one of the most effective tools available to improve safety. Various sources have stated that between two-thirds and 90% of all accidents are caused by human error. Thus, operating procedures, if properly written and used, should reduce the frequency of accidents and near-misses in the course of daily operations.

We believe that in order for operating procedures to be accepted and used, operating personnel must be involved in the development of the procedures. This involvement encourages these personnel to take ownership of the procedures. Additionally, the procedures must be written in a simple and logical manner that is easy to follow. Complicated, wordy, and lengthy procedures will not be used by operators and therefore will not contribute to safe and environmentally sound facility operation.

The operating procedures for each facility shall address the following: a brief facilities description, start-up, normal operation, temporary operations, emergency shutdown, normal shutdown and isolation, and the course of action required by the operator for each process alarm.

Environmental and occupational safety and health considerations can be noted when applicable.

Table 5AB.1. Manuals.

SAFETY MANUAL

Management Commitment
- Safety Policy Statement
- Policy Memorandum

Introduction

Incident and Emergency Plans
- Emergency Action Plan
- Accident Reporting and Investigations

General Safety Programs
- Responsibilities
- Substance Abuse Policy
- Employee Safety Orientation
- Access to Employee Exposure and Medical Records
- Safety Incentive Program
- Safety Meetings
- Safety Program Videos
- Bulletin Boards
- Contractor Safety
- Visitor Safety
- OSHA Inspections
- Record Keeping

General Safety Measures
- General Housekeeping
- Safety Surveys
- Safety in the Office

Fire Prevention and Control

First Aid

Offshore Safety

Hazard Communication Program

Safe Work Practices
- Personal Protective Equipment
- Hearing Conservation
- Safety Signs & Color Coding
- Blinding and Equip. Isolation
- Confined Space Entry
- Hot Work Program
- Lockout/Tagout Procedures
- Hydrogen Sulfide Safety
- Transporting Hazardous Material
- Asbestos Operations

Operations Procedures
- Calibration Schedules for Monitoring Inst./Equip.
- Crane Operations
- Electrical Safety
- Equipment Abandonment
- Gas and Gaseous Conditions
- Grounding and Bonding
- Ladders
- Leak Checking
- Lifting and Moving
- Motor Vehicles
- Oxygen and Acetylene Safety
- Hot Taps
- Rope and Slings
- Small Tools Safety
- Stairways and Walkways
- Storage and Handling of Compressed Gas Cylinders
- Tank Cleaning Procedures
- Tagging and Flagging
- Welding and Cutting

SAFE DRILLING AND WORKOVER PRACTICES MANUAL

Introduction
- Corp. Health, Safety, and Envir. Policy
- Purpose, Intent and App.
- Taylor Safety Contacts

General Safety Rules

Safety Requirements
- General
- Personal Prot. Equip. and Clothing
- Environmental Protection
- Fire Prevention
- Confined Space Entry
- Hot Work Operations
- Lockout Procedures
- Hydrogen Sulfide (H_2S)

Training and Qualifications
- General
- Initial Training
- Periodic Training
- Communication of Change
- Qual. of Instr. and Certifying Agency
- H_2S Certification
- Blowout Prevention Certification
- First Aid Certification Documentation

Operating Procedures
- General
- Mechanical Hazards
- Electrical Hazards
- High-Pressure Systems
- Tubulars Handling
- Well Control
- Drilling Mud/Chemical Hazards
- Inclement Weather Operations
- Offshore Operations
- Workover Operations
- Rigup/Rigdown
- Vehicular Operations

Emergency Drills
- General
- Fire/Explosion
- Blowouts and Kicks
- Toxic Gas Releases
- Evacuation
- First Aid/Medical Response
- Oil Spills and Pollution

First Aid
- Quick Reference Index
- Basic First Aid Facts

Industry Standards and References

SAFETY HANDBOOK

General Safety Rules

Safe Work Practices
- Personal Protective Equipment
- Hearing Conservation
- Safety Signs & Color Coding
- Blinding and Equip. Isolation
- Confined Space Entry
- Hot Work Program
- Lockout/Tagout Procedures
- Hydrogen Sulfide Safety
- Transporting Hazardous Material
- Asbestos Operations

First Aid

Safe Work Practices

Three manuals comprise management's safe work practices philosophy: The *Safe Operating Practices Manual*, the *Safe Drilling and Workover Practices Manual* and the *Safety Handbook*. Table 5AB.1 outlines the tables of contents for each manual.

Safe Operating Practices Manual

In the oil and gas industry, there are many common activities for which generic safe operating practices can be developed. The procedures can be developed within a company or division and used at all sites. *The Safe Operating Practices Manual* is available for reference at each manned location.

It is not practical to expect operators to read and remember a lengthy list of procedures. Rather, we believe the manual should be organized into an overview section of General Safety rules, a section of specific Safety Procedures for certain operators, and reference materials regarding API Standards and Basic First Aid Facts.

Operating personnel can be expected to read and learn the general safety rules. The safety procedures should be written so that each procedure is preferably no more than two to three pages in length and the procedures can be used as a texts for safety meetings. More detailed information contained in API Standards on proper operating and maintenance practices is included in the manual for reference purposes. API standards exist for Safe Welding and Cutting Practices, Confined Space Work, Inspection for Fire Protection, etc. Similarly, a section on basic first aid facts in included for reference to assure that first aid information is readily available at every manned facility.

Safe Drilling and Workover Practices Manual

Some oil companies have found that increases in safety are possible if the techniques of management commitment, communication, and training that are applied to producing operations are also applied to drilling and workover operations.

The generic *Safe Drilling and Workover Practices Manual* is organized using the same philosophy as that used for the generic *Safe Operating Practices Manual*. The major difference is that, because of the nature of the work, the manual is addressed to the company representative who is in charge of the contract rig. Each contract company will have its own safety program. The purpose of this manual is to provide the company representative with information he needs to review the contractor's safety program for adequacy and to provide a backup source of reference material.

Safety Handbook

A pocket-size handbook summarizing important safety rules and emergency first aid information is provided to employees, visitors, and contract workers. The contents of the handbook are essentially the same as the *Safe Operating Practices Manual,* with a few modifications.

Training

Training is an ongoing effort at TEC. The SEMP manual presents an employee training plan that includes the training schedule, describes the method by which the training will be documented, and names the people responsible for implementing and documenting the training. Required subject matter for training is contained in the *Safe Operating Practices Manual* and the Site-Specific Operating Procedures. Table 5AB.2 outlines the TEC training topics to be implemented during the course of this project.

Assurance of Quality and Mechanical Integrity of Critical Equipment

This element of SEMP, like hazards analysis, is an ongoing process. There must be a balance between incremental effort and incremental benefits. Therefore, it is important to prioritize the areas that have the greatest impact on safety.

This element addresses procurement, fabrication, installation, maintenance, inspection and testing of new and existing equipment; corrosion; erosion caused by sand production; packings and seals; electrical components; fire fighting systems and equipment; pollution control equipment; and documentation.

Pre-Start-Up Review

A checklist is included in the TEC *SEMP Manual* for review prior to start-up of new and modified facilities. The SEMP Manual describes responsibilities and procedures for assuring that the checklist is implemented prior to start-up.

Table 5AB.2. Training program topics.

Presentation of the SEMP Plan	New Employee Orientation
Operating Procedures	Lockout/Tagout
Mechanical Integrity	Hearing Conservation
Safe Work Practices	Medic First Aid
Simultaneous Operations	H_2S Safety
Hazards Communication	Offshore Water Survival
Hazardous Waste Operations and Emergency Response	Bloodborne Pathogens
Crane Operation and Maintenance	Fire Safe Work Permits
Well Control	Basic Firefighting
Environmental Protection and Pollution Control	Personal Protective Equipment
Emergency Response and Control	Respiratory Protection
Contractor Training	Confined Space Entry

Emergency Response and Control

TEC already had an oil spill contingency plan, emergency action plan, and hurricane evacuation plan, as should all producers operating in OCS waters. The *SEMP Manual* incorporates these plans by reference and details responsibilities to ensure that the plans are reviewed periodically, that announced and unannounced drills are conducted, and that the results are documented. Some of the drills that will be performed are: abandon platform (monthly for each crew), spill (one announced and one unannounced annually), blowout, explosion, and handling and care of severe injuries.

Investigation of Incidents

TEC already had this element covered in its *Safety Manual*. An investigation will be required for any incident leading to—or which could reasonably have led to—a fatality, hospitalization, lost work day, medical treatment, job transfer or termination, loss of consciousness, or a major uncontrolled release of materials to the environment.

Audit of Safety and Environmental Management Program Elements

The first audits will be conducted within two years of the initial implementation of SEMP. The amount of time between audits should not exceed four years. The audits will review documentation, conduct private interviews of various levels and disciplines of personnel and make facility inspections.

SAFETY AND ENVIRONMENTAL INFORMATION

The purpose of this information is to provide the basis for the hazards analysis, operating procedures, and training personnel. This section can be one of the most expensive elements of SEMP if one is starting from "scratch". The challenge is determining what information is needed and how to acquire this information in the most cost-effective manner. Remember, at this point, we are not re-designing the facilities. The focus is on obtaining the information necessary for the operator to protect people, the environment, and the equipment.

Typically, when a platform is designed, the following information is developed (along with many more items) and kept in job books and drawing books:

- Safety Analysis Flow Diagrams (SAFDs)—required by MMS
- SAFE Charts—required by MMS
- Process Flow Diagrams (PFDs)
- Detailed Process and Instrument Drawings (P&IDs)
- Layout Drawings
- Fire Protection and Safety Equipment Layouts
- Electrical Classification Drawings
- Instrument Data Sheets
- Instrument Hookup Details
- Specifications and Vendor Data (On vessels, piping, equipment, electrical, etc.)

If the original information is still available, it is well worth the effort and much less expensive in the long run to keep the information updated and current. But

Table 5AB.3. Essential and optional information to be shown on simplified P&IDs.

Essential P&ID Information	Optional Information
Equipment Tag Number	Bridle Details
Equipment Name	Instrument Tag Numbers
Equipment Size	Line Numbers
Equipment Design Pres. & Temp.	Instrument Hookup Details
Equipment Capacity (Flow rates)	Skid Boundaries
Normal Operating Conditions	Specialty Item Callouts
Line Size and Rating	TOL Connections
Reducers	Solenoid Valves
Spec. Breaks	Set Points for Controllers
Valve Types	Shutdown Set Points
Relief Valve	Alarm Set Points
Instrument Symbols	
Heat Trace	
Insulation	
Instrument Alarms	
Instrument Shutdowns	
CSO/CSC Valves	

what if the information is not available, or in other words, what do you do if you are starting from "scratch" as was the case with most of TEC's facilities. The following sections outline what was done and why.

Simplified Process and Instrument Drawings

We determined that, for TEC's existing facilities, a PFD and a detailed P&ID could be consolidated into a simplified P&ID, as long as it provided all the information required for the hazards analysis, operating procedures and training. It can be difficult to define exactly what a simplified P&ID is and exactly what information is required for SEMP. However, a good rule is that it is better to show too much than not enough.

Should the simplified P&IDs show tag numbers, line numbers, incoming/outgoing process and shutdown signals, package skid limits, valve types, vessel trim (i.e., bridles, bleeds, isolation valves, etc.), and so forth? The answer is: it depends. One has to work backwards from the hazards analysis requirements, operating procedure requirements and items that the client wants shown.

The hazards analysis methodology utilized for this project will incorporate a "modified" checklist. The term "modified" means that the hazards analysis used for an existing facility is less comprehensive than that for a new design. The information that we determined as "essential" and as "optional" on the simplified P&IDs is listed in Table 5AB.3.

For operating procedures, the only significant issues were whether or not instrument tag numbers were required and whether or not all manual valves should be shown by one valve symbol or by different symbols for ball valves, gate valves, globe valves, butterfly valves, etc. We determined that tag numbers would be included on only the safety devices that were tagged on the SAFE Charts. It would be nice to have all the instruments tagged, but it is not essential; therefore, we were not going to invest time tagging all instruments. This situation isn't always the case, because, for many facilities, tag numbers are essential for operating procedures. We decided to differentiate among various valve types since this job was a rather effortless task.

We choose to leave off alarm and shutdown set points to minimize future drawing revisions. These set points are documented on a report sent to the MMS monthly and will change frequently as production conditions change.

Layout Drawings

We combined the information on the Layout drawing and the Fire Protection and Safety Equipment drawing into one drawing. In some instances, depending on the complexity of the facilities, consolidation of these drawings may not be practical.

Flare and Vent Systems

Flare and vent system information is very important, because in some cases, these systems were poorly designed or modifications were made without consideration of the overall design. An isometric sketch is made noting the line size and approximate lengths of all piping runs. This information is used later in the hazards analysis to calculate pressure drops to assure compliance with API RP 520 and 521. In addition, this information is used for radiation exposure calculations for various continuous or instantaneous flow conditions. The most difficult information to obtain is the orifice size of the relief valve when the data sheets are no longer available. It is not practical to remove the relief valves from service to obtain the orifice size in all instances. In this case, careful assumptions must be made during the analysis based on current conditions. Sometimes, however, when the orifice size is not known, the flare and vent system analysis must be postponed.

Open and Closed Drains

Open and closed drain systems must be checked carefully. The closed drain system must be checked to assure that the valves have the proper pressure ratings. The gravity or open drain system is checked because of the critical nature of the liquid seal locations and elevation differences.

Specifications

If piping specifications are not available, it is assumed that the piping is compatible with the flange ratings. It is typically not economical to verify line thicknesses and other piping material information unless there has been a history of line failures due to sand production or corrosive fluids. Typically, the flow lines and headers up to the production separators are the biggest concern. This issue is further addressed in the mechanical integrity section of the SEMP program.

Vessel and equipment information is often lost, and the only available information is on the name-plate. The design pressure and temperature are usually provided, but all other information, such as design capacities, wall thickness, corrosion allowance, etc., are lost. If the equipment has been operating satisfactorily for a significant period of time and adequately sized pressure relief valves are in place, additional information is probably not that important. However, exceptions occur if (1) there is no nameplate or design pressure information or (2) if significant volume increases or changes in operating conditions are expected. In these cases, further action is required to ensure that the equipment is suitable for the intended service.

Electrical Classification

Electrical classification drawings should be developed. Special electrical considerations exist offshore due to the electrical shock probability inherent with steel decks and the marine environment and the space limitations that require equipment to be installed near classified areas.

As a final note regarding process safety information, it is very beneficial for the hazards analysis team leader and the operating procedure coordinator to be involved with drawing development. A lot of synergy results when the same people are involved from start to finish.

CONCLUSION

A SEMP Manual that can easily be adapted for other companies has been developed and is available upon request, as the other products of this case study will be. During the first six months of program development, Paragon has also compiled process safety information as part of meeting API RP 75's requirements. The work to date represents the minimum amount of effort that a small to mid-size producer should expect to perform and still adequately cover the major areas of hazards analysis, operating procedures and training.

Our belief is that by carefully designing a program to meet the intent of RP 75, a company can guard against needless complexity and cost. If such programs are developed and conscientiously applied, increased safety and reduced maintenance, together with less downtime and lower operating costs, can result. Although the cost of the accident that didn't happen, the employee injuries and deaths that occur, or the property damage and pollution that did not occur can never be measured, there is no doubt that the cost of implementing a SEMP program will be repaid may times if even one such catastrophe is avoided.

Rick Bresler is a project manager for Paragon Engineering Services in Houston. Rick has over 16 years of experience in the oil and gas business, primarily with gas plants, gathering systems, and offshore production facilities. He holds a B.S. in chemical engineering from the University of Kansas.

CDR Gerald Von Antz is the Special Projects, Safety, and Purchasing Manager for Taylor Energy Company, an independent oil and gas development and exploration corporation. He joined TEC after serving 24 years as both a fixed-wing and helicopter search-and-rescue pilot for the U.S. Coast Guard. CDR Von Antz is the project manager for the Taylor/DOE Safety and Environmental Management Plan (SEMP)/API RP75 Study. He graduated from the University of Southern Mississippi and holds a B.A. and M.B.A.

NATIONAL OFFSHORE SAFETY ADVISORY COMMITTEE ISSUES

Mr. Peter Velez
Manager Regulatory Affairs
Shell Offshore

Mr. Velez's presentation consisted of the slide show represented on the following pages.

P.K. (Peter) Velez is Manager Regulatory Affairs for Shell Offshore Inc., a subsidiary of Shell Oil Company. Peter received a B.S. and M.S. in Civil Engineering from Rensselaer Polytechnic Institute in Troy, New York. He joined Shell's Midland, Texas office in 1975. His assignments have included Civil Engineering, operations Superintendent, Manager Production Engineering, and Manager Health, Safety and Environment. He has served trade association groups as Chairman of the Louisiana Mid-Continent Oil and Gas Environmental Conservation Council, and Chairman of the RP 75 Development Task Force. He has also served as API CEC – Water Issue Manager, and on the USCG National Offshore Safety Advisory Committee.

WHAT IS NOSAC ?

N ATIONAL
O FFSHORE
S AFETY
A DVISORY
C OMMITTEE

NOSAC SCOPE AND OBJECTIVES

THE COMMITTEE WILL ACT SOLELY IN AN ADVISORY CAPACITY TO THE USCG COMMANDANT ON MATTERS RELATING TO OFFSHORE MINERAL AND ENERGY INDUSTRIES. THE COMMITTEE WILL ADVISE, CONSULT WITH, AND MAKE RECOMMENDATIONS REFLECTING THE COMMITTEE'S INDEPENDENT JUDGMENT TO THE COMMANDANT ON MATTERS AND ACTIONS CONCERNING ACTIVITIES DIRECTLY INVOLVED WITH OR IN SUPPORT OF EXPLORATION OF OFFSHORE MINERAL AND ENERGY RESOURCES INSOFAR AS THEY RELATE TO MATTERS WITHIN USCG JURISDICTION.

NOSAC BACKGROUND

- ESTABLISHED 1988
- PURSUANT TO FEDERAL ADVISORY COMMITTEE ACT
- SPONSOR: CHIEF, OFFICE OF MARINE SAFETY, SECURITY, AND ENVIRONMENTAL PROTECTION
- THREE-YEAR APPOINTMENT
- MMS, EPA, AND OSHA MAY DESIGNATE AN OBSERVER
- CHAIRMAN AND VICE-CHAIRMAN APPOINTED BY USCG COMMANDANT

NOSAC MAKEUP

■	PRODUCTION OPERATORS	2
■	OFFSHORE DRILLING	2
■	OFFSHORE OPERATIONS	2
■	OSV/GEOPHYSICAL	2
■	DIVING SERVICES	1
■	SAFETY TRAINING	1
■	PIPE LAYING	1
■	CONSTRUCTION	1
■	ENVIRONMENT	1
■	GENERAL PUBLIC	1
		14

NOSAC MEMBERS (11/95)

■ DENISE BODE	IPAA
■ MINOR CHERAMIE	L&M BOTRUC RENTALS
■ LANEY CHOUEST	EDISON CHOUEST OFFSHORE INC.
■ PATRICIA CLARK	TEXAS GENERAL LAND OFFICE
■ RICHARD CURRENCE	TIDEWATER MARINE SERVICES
■ WILLIAM GUIDRY	HOPEMAN BROTHERS INC.
■ PAUL KELLY	ROWAN COMPANIES INC.
■ MARGARET MC MILLAN	MC MILLAN OFFSHORE SURVIVAL TECH.
■ DON RAY	SONAT OFFSHORE DRILLING
■ JOHN RYAN	ALEXANDER-RYAN MARINE & SAFETY CO.
■ ROSS SAXON	ASSOCIATION OF DIVING CONTRACTORS
■ PETER SEIDEL	GECO-PRAKLA INC.
■ PETER VELEZ	SHELL OFFSHORE INC.
■ MANDY WILLIAMS	GLOBAL INDUSTRIES

NOSAC MEETINGS

- NOSAC COMMITTEE
  - TWICE PER YEAR
    1) MARCH/APRIL IN WASHINGTON (MARCH 30,1996)
    2) OCTOBER/NOVEMBER IN HOUSTON/NEW ORLEANS
  - OPEN TO THE PUBLIC
  - FEDERAL REGISTER NOTICE PUBLISHED
- SUBCOMMITTEES AND WORK GROUPS
  - MEET AS REQUIRED
  - NOT LIMITED TO COMMITTEE MEMBERS

NOSAC ISSUES

- INTERNATIONAL SAFETY MANAGEMENT (ISM) CODE IMPLEMENTATION
- INTERNATIONAL MARITIME ORGANIZATION (IMO) INTERNATIONAL STANDARDS OF ORGANIZATION (ISO) ISSUES
- SURVEY OF USCG SELF-INSPECTION OF FIXED OCS FACILITIES
- 33 CFR SUBCHAPTER N OCS ACTIVITIES
- SUBCHAPTER L OFFSHORE LIFTBOATS
- MARINE INVESTIGATION - SUSPENSIONS AND REVOCATIONS (46 CFR PARTS 5 AND 20)
- GOM OCS AIR QUALITY STUDY
- PIPELINE-FREE ANCHORAGE AREAS FOR MODUs, LIFTBOATS, & VESSELS
- PREVENTION THROUGH PEOPLE, STRATEGY, AND INITIATIVE

SUBCHAPTER N OCS ACTIVITIES

- ISSUED ORIGINALLY IN 1956, LAST MAJOR REVISION IN 1982
- REVISION TO 33 CFR PARTS 140-147
  - WORKPLACE SAFETY
  - LIFESAVING EQUIPMENT
  - FIRE PROTECTION STANDARDS
  - ACCOMMODATION REQUIREMENTS
  - SURVIVAL TRAINING AND DRILLS
  - FOREIGN VESSELS
  - MIDUs, FIXED PLATFORMS, AND TLPs
- MAJOR UPGRADING AND REVISIONS
- TO BE ISSUED AS PROPOSED RULE DURING 1996
- MMS AND OOC HAVE PARTICIPATED
- MAY BE A SIGNIFICANT RULEMAKING BASED ON COST IMPACT CRITERIA

SELF-INSPECTION OF FIXED OCS FACILITIES

- PURPOSE: EDUCATE OFFSHORE COMMUNITY ABOUT ANNUAL USCG SELF-INSPECTION REQUIREMENTS
  - 33 CFR PARTS 140-143 REGULATIONS
  - USCG FORM CG-5432 TO REPORT RESULTS
- DEVELOPED SURVEY TO REPORT ON STATUS OF SELF-INSPECTION OF FIXED OCS FACILITIES
- IPAA, OOC, AND USCG COORDINATED EFFORT
- SURVEY RESPONSE: 89% BY COMPANIES, 92% BY FACILITIES
- 97% AWARE OF SELF-INSPECTION REQUIREMENTS
  - 90% AWARE THAT FAILURE TO REPORT WAS REGULATION VIOLATION

PIPELINE-FREE ANCHORAGE AREAS

- PURPOSE: REVIEW NATIONAL TRANSPORTATION SAFETY BOARD'S RECOMMENDATION OF THE DECEMBER 1994 ROWAN RIG ODESSA ACCIDENT NEAR BAY MARCHAND

  "IN CONSULTATION WITH MMS, DOT'S OFFICE OF PIPELINE SAFETY, NOAA, AND THE OFFSHORE OIL AND GAS INDUSTRY, IDENTIFY AND DESIGNATE, NEAR OFFSHORE INDUSTRY GOM STAGING PORTS, PIPELINE-FREE ANCHORAGE AREAS FOR MODUs, LIFTBOATS, AND OTHER INDUSTRY VESSELS."

- WORK GROUP ESTABLISHED TO MAKE IMPLEMENTATION RECOMMENDATIONS TO USCG

PREVENTION THOUGH PEOPLE

- RE-FOCUS USCG EFFORTS THROUGH A PARTICIPATORY SYSTEMATIC APPROACH TO REDUCE HUMAN FACTOR-RELATED LOSS OF LIFE, INJURY, AND POLLUTION
- USCG ANALYSIS IDENTIFIED HUMAN ELEMENTS AS KEY FACTOR IN ALL HIGH-CONSEQUENCE MARINE CASUALTIES
  - 80% ARE DIRECTLY OR INDIRECTLY "HUMAN ERROR"
- USCG STRATEGY TO RECOGNIZE/INCORPORATE A PEOPLE-ORIENTED SYSTEMS APPROACH IN ADDRESSING CRITICAL MARITIME SAFETY CONCERNS
  - PRIOR EFFORTS (80%) FOCUSED ON EQUIPMENT, DESIGN, ENGINEERING, AND SIMILAR STANDARDS, AND ONLY 20% ON "HUMAN FACTORS"
- SAFETY PARTNERSHIPS FORMED BETWEEN USCG AND INDUSTRY

IMO/ISO ISSUES

BETTER COORDINATION NEEDED TO RESPOND TO NUMEROUS IMO/ISO INITIATIVES

- BETTER INDUSTRY GROUPS
- WITH/BETWEEN GOVERNMENT AGENCIES

API, OOC, IADC, OMSA, PESA, ADC, ETC., PARTICIPATING

- PRELIMINARY RECOMMENDATIONS
- NEED LONG-TERM U.S. STRATEGY CONCERNING IMO/ISO
- STABILIZE U.S. GOVERNMENT REPRESENTATION BETTER COORDINATION, RESPONSES, AND PARTICIPATION BY U.S. INDUSTRY
- NEED ELECTRONIC INFORMATION DISSEMINATION
- NEED TO PROMOTE COST/BENEFIT ANALYSIS AND SOUND SCIENCE IN INTERNATIONAL RULEMAKING AND STANDARDIZATION

SESSION 5C

THE MINERALS MANAGEMENT SERVICE'S MARINE MINERALS PROGRAM: STATUS AND TRENDS, REGULATORY CLIMATE, AND ENVIRONMENTAL STUDIES

Session: 5C - THE MINERALS MANAGEMENT SERVICE'S MARINE MINERALS PROGRAM: STATUS AND TRENDS, REGULATORY CLIMATE, AND ENVIRONMENTAL STUDIES

Co-Chairs: Mr. Barry S. Drucker and Mr. Don Hill

Date: December 14, 1995

Presentation	Author/Affiliation
Session Overview: Relevant Environmental and Other Issues	Mr. Barry S. Drucker Physical Scientist Minerals Management Service Office of International Activities and Marine Minerals
MMS Marine Mining Literature Search and Synthesis Study	Dr. Richard M. Hammer Continental Shelf Associates, Inc. Jupiter, Florida
Impacts and Direct Effects of Sand Mining for Beach Renourishment on the Benthic Organisms and Geology of the West Florida Shelf	Dr. Norman J. Blake Dr. Larry J. Doyle Department of Marine Science University of South Florida Mr. James K. Culter Mote Marine Laboratory
Manuscript not submitted	Mr. Steve Traxler U.S. Army Corps of Engineers Jacksonville, Florida
Report on Status of Ship Shoal Environmental Impact Statement and Louisiana Coastal Barrier Island Restoration Efforts	Mr. Barry S. Drucker Physical Scientist Minerals Management Service Office of International Activities and Marine Minerals
Barrier Island Restoration	Mr. Jeff Harris Louisiana Department of Natural Resources

SESSION OVERVIEW: RELEVANT ENVIRONMENTAL AND OTHER ISSUES

Mr. Barry S. Drucker
Physical Scientist
Minerals Management Service
Office of International Activities and Marine Minerals

INTRODUCTION

As the potential for exploration and development of offshore minerals on the United States Outer Continental Shelf (OCS) increases, environmental considerations have generated and will continue to generate a need for technical information and studies. Such information will aid the Minerals Management Service (MMS) in making leasing decisions and will ensure that offshore minerals are developed in a safe and environmentally sound manner. The MMS Office of International Activities and Marine Minerals (INTERMAR) has developed and procured contracts to provide some of this needed information. The strategy with respect to environmental issues is to operate in a forward-thinking manner and to use the time available now better to understand the environmental implications of marine mineral development. This strategy should facilitate better decisions and help us develop solutions to environmental problems that may confront us. The current efforts of several of the existing federal-state mineral task forces are being redirected towards identification of environmental issues, as well as to developing action plans that address issues of concern to federal and state governments and the public. In addition, studies to provide needed environmental information are being conducted using funds provided by the MMS Environmental Studies Program (ESP). Realizing that the current subject content of the MMS ESP oil and gas information database cannot provide all of the information required, beginning in Fiscal Year 1991, INTERMAR began using ESP funds to support the agency's Marine Minerals Program.

Two general categories of studies have been and are being developed, carried out and managed by INTERMAR:

- Generic field or literature studies and technology assessments to examine the effects of types of mining operations on various aspects of the physical, chemical, and biological environments.
- Site-specific environmental studies in areas where offshore mineral activity is proposed or where offshore mineral development appears feasible in the near future.

At this session, information concerning completed and ongoing environmental studies will be presented, as well as existing conditions and regulations which will continue to generate the need for additional information.

NEW NEGOTIATED AGREEMENT PROVISIONS

In October 1994, Public Law 103-426 authorized the Secretary of the Interior to negotiate agreements for the use of Outer Continental Shelf (OCS) sand, gravel, and shell resources for programs undertaken by Federal, State, or local governments which involve shore protection, beach restoration, or coastal wetlands restoration. Agreements may also be pursued by State or local governments or the private sector for construction projects that are funded in whole or in part by, or are authorized by, the Federal government. Prior to enactment of the law, these resources could only be obtained through a competitive lease sale process. To clear up some lingering jurisdictional uncertainties, the new law also provides that any Federal agency proposing to use OCS sand for any purpose shall enter into a Memorandum of Agreement (MOA) with the Department of the Interior for such use. Public Law 103-426 also amended Section 20(a) of the OCS Land Act and requires that environmental studies be commenced not later than six months prior to commencing negotiations for an agreement or entering into an MOA.

The responsibility for negotiating the MOAs and agreements for the use of this material, as well as ensuring protection of the environment during any OCS dredging or mining operation, falls on the Minerals Management Service. Within the MMS, INTERMAR has been delegated the lead with respect to the sand and gravel program, including ensuring that all National Environmental Policy Act mandates, NEPA implementing regulations of the Council on Environmental Quality (40 CFR, Section 1500 *et. seq.*), and other appropriate laws and executive orders are considered before such agreements are executed.

Coastal States and local communities are very supportive of the program and, in light of diminishing coastal and nearshore resources, recognize the need for access to OCS sand for beach nourishment and coastal restoration. To date, several agreements have been pursued by coastal states and by the Department of the Navy:

- A negotiated agreement was completed with the City of Jacksonville/Duval County, Florida to use sand from a borrow site 7 miles offshore to renourish several local beaches. A stipulation was attached to that agreement which requires that a benthic repopulation study be conducted for the actual borrow area.
- In April, the Governor of Louisiana sent a letter to MMS Director Quarterman requesting that the negotiated agreement process to allow for the use of sand from Ship Shoal for barrier island restoration be initiated. INTERMAR and the State of Louisiana are currently examining the various options regarding preparation of required NEPA documents, specifically an environmental impact statement.
- The Navy is seeking a Memoranda of Agreement to use sand from Sandbridge Shoal, offshore Virginia, to renourish a portion of Federal beach at the Fleet Combat Training Center at Dam Neck, near Virginia Beach. The amount of sand to be requested is about 760,000 cubic yards and would provide protection for some existing buildings and structures which lie just off the beachfront. The MMS has agreed to enter into negotiations for an agreement provided that the Navy's Environmental Assessment prepared for the proposed project is revised to the extent that MMS is confident that NEPA requirements have been satisfied and that the operation can be conducted in a sound environmental manner.
- A negotiated agreement is being sought to use OCS sand to renourish Surfside and Garden City beaches, just south of Myrtle Beach in South Carolina.

IMPLICATIONS FOR THE FUTURE AND THE ENVIRONMENTAL STUDIES PROGRAM (ESP)

The MMS sand and gravel program offers new opportunities, but also definite challenges, particularly to the ESP. Efforts are being made to keep the program flexible and responsive to the requests from onshore communities. On environmental issues, the MMS would like to focus analyses on those issues that are truly significant, streamlining the NEPA process perhaps more than the agency's practice for the oil and gas program. This is particularly relevant in view of diminishing funds available within the ESP. The MMS must ensure that the correct issues are being addressed, that information is available to support all analyses and decisions, and that ESP funds that become available for sand and gravel environmental studies are used in the most efficient manner possible.

INFORMATION NEEDS AND QUESTIONS FOR DECISION MAKING

What environmental information strategy should MMS follow to make sure the sand and gravel program is properly administered? For what issues do we need "rigorous" information? For what issues is "less information" acceptable? How much information from our oil and gas studies can be used for sand and gravel decision purposes? From an environmental risk standpoint, what is the relative importance of gathering information for sand and gravel decisions versus oil and gas decisions?

MODEL FOR THE FUTURE?

MMS, in conjunction with the Virginia Institute of Marine Science (VIMS), recently developed and entered into a cooperative agreement to conduct a multidisciplinary biological/physical environmental study to provide information for decisions relative to the use of OCS sand off the coast of Virginia to renourish beaches in the vicinity of Virginia Beach. Although no requests from the state or local coastal communities for negotiated agreements have been received, it is expected that one, and probably two, such requests will be forthcoming relatively soon. The design of this study may provide a "blueprint" to follow for future studies. The MMS would like the Committee to review the design of this study and offer advice on whether or not it could serve as a model for future ESP efforts. What additional information, if any, needs to be collected?

The VIMS study is comprised of six specific topics of investigation:

- *Benthic resource and habitat mapping using a sediment profile camera*—The primary objective of this task is to assess baseline benthic ecological conditions in and around the potential sand borrow areas. This information will be used to assess the potential for biological impacts from sand dredging.

- *Nearshore wave and current observations and modeling*—The objective of this task is to study the potential of bathymetric modifications induced by sand mining to waves as they cross the study area.
- *Bathymetric data gathering for model use*—Provides supplemental bathymetric information for the modeling effort described above.
- *Shoreline processes, sediment, and sediment transport evaluation*—This task will evaluate the impacts of offshore dredging and consequent beach nourishment in terms of the potential alteration in sediment transport patterns, sedimentary environments, and impacts to local shoreline processes.
- *Acoustic Doppler Current Profiler (ADCP) current measurements /observations /modeling*—(to be undertaken by Old Dominion University)—An ADCP will be used to define the currents at the potential sand mining sites and to define the physical regime between these sites and the shoreline. A numerical model will then be used to predict the effects resulting from alterations to the local bathymetry on the local current field.
- *Microfaunal ecology and impact assessment*—USGS will investigate the ecology of benthic foraminifera and ostracods (Crustacea) from the Virginia continental shelf habitats identified as potential sites for offshore sand dredging. This information will be used to evaluate the recolonization potential of these sites on the basis of species ecology and wider zoogeographic distribution in adjacent areas.

Mr. Drucker has served as a Physical Scientist since 1988 in the Minerals Management Service's (MMS) Office of International Activities and Marine Minerals (INTERMAR). His duties are to formulate and recommend environmental studies in support of the MMS's marine minerals program, to develop statements of work for funded studies and to oversee projects as MMS Contracting Officer's Technical Representative. Prior to joining MMS, he worked as an oceanographer with the U.S. Naval Oceanographic Office. Mr. Drucker holds B.A. degrees in geology and oceanography from City University of New York and a M.S. degree in marine geology and physical oceanography from C.W. Post College of Island University.

MMS MARINE MINING LITERATURE SEARCH AND SYNTHESIS STUDY

Dr. Richard M. Hammer
Continental Shelf Associates, Inc.
Jupiter, Florida

INTRODUCTION

There are approximately 90 different non-fuel mineral commodities available in the marine environment in addition to the fuel minerals of oil and gas. Industry interest in the mining of marine non-fuel minerals in the United States has focused on sand and gravel, precious and heavy metal placers, cobalt-rich manganese crusts, polymetallic sulfides, and phosphorites. International interest has also been oriented towards a wide array of prospects, including sand and gravel in Denmark, France, Japan, the Netherlands, and the United Kingdom; tin in Burma, Indonesia, and Thailand; diamonds off southwest Africa; phosphorites off New Zealand; and metalliferous muds containing copper, silver, and zinc in the Red Sea.

The United States government recognizes the strategic importance and potential economic benefits of marine mining, as well as the potential for environmental impacts associated with marine mining activities. The U.S. Department of the Interior, Minerals Management Service (MMS) is responsible for managing the exploration and development of mineral resources on submerged federal lands on the Outer Continental Shelf (OCS) seaward of state boundaries. The MMS has a strong environmental mandate and is required to conduct environmental studies to obtain information useful for decisions related to marine mineral activities. The MMS Office of International Activities and Marine Minerals (INTERMAR) functions as a liaison for MMS involvement in international activities and provides policy direction for management and regulation of marine mineral resource activities on the OCS for minerals other than oil, gas, and sulfur.

Although many studies have been funded by the MMS concerning potential environmental impacts of oil and gas activities, there was a need to initiate similar studies concerning effects from non-fuel mineral mining operations. The study which is the topic of this paper was formally titled "Synthesis and Analysis of Existing Information Regarding Environmental Effects of Marine Mining." The 18-month effort, which was initiated in October 1991 and completed in March

1993, was the first environmental program concerning non-fuel minerals to be administered through the MMS INTERMAR using funds from the MMS Environmental Studies Program.

STUDY OBJECTIVES

The primary objectives of this study were as follows:

- Survey and analyze existing literature regarding the environmental impacts of marine mining; and
- Summarize this literature in a monograph-style manuscript.

In addition to addressing the environmental impacts of marine mining, the secondary objectives of this study were as follows:

- Summarize the respective target minerals and/or deposits of interest and the various marine mining technologies currently available;
- Discuss viable mitigation measures;
- Evaluate models designed to predict the fate of mining-related discharges and determine the biological impacts of mining operations;
- Identify data gaps and research needs; and
- Annotate and compile select environmental documents consulted during the study in both printed form and electronic format for incorporation into the Minerals/Mining Reference Database administered by INTERMAR.

METHODS

Information identification and collection consisted of computer and library searches supplemented by telephone contacts. Documents of interest were secured and evaluated to determine the quantity and quality of information available. Applicable information was analyzed to summarize mineral groups, operational methods and technology, affected environments, mitigation measures, predictive models, and data gaps and research needs.

Based upon the literature collected and reviewed, citations were selected for annotation. Each annotation was completed on a standard reference description form and included a complete citation, type(s) of study, geographic location(s), applicable OCS Planning Area(s), type(s) of environment(s), mineral(s) of interest, type(s) of mining operation(s), environmental resource(s) affected, date(s) of study, study technique(s), conclusion(s), and key words. A Reference Database was developed for the selected citations and annotations in dBASE III PLUS format.

RESULTS

Four deliverables resulted from the study. The deliverables included an Executive Summary, Final Report, Technical Summary, and Reference Database.

Six mineral resource groups were examined, including industrial minerals, mineral sands, phosphorites, metalliferous oxides, hydrothermal deposits, and dissolved minerals. For the most part, marine ores do not differ from those on land and require conventional methods for treatment.

Operational methods and technology covered mining techniques, processing, transportation, and cycling of materials. There are four basic methods of mineral extraction on land or at sea (scraping, excavating, tunneling, and fluidizing).

Deep ocean, continental shelf (i.e., beyond the three-mile boundary or beyond the seaward extent of territorial waters), coastal (including estuarine and coastal waters within three miles), and onshore environments were described. The anticipated effects of mining operations on those environments were summarized in terms of atmospheric, oceanic or aquatic, geological, biological, and socioeconomic resources.

Direct or primary effects of marine mining on the environment may result from (1) removal of the mined material; (2) introduction of new materials as procesing wastes, tailings, and discharges, or of energy as heat, light, or seismic and acoustic waves; (3) perturbation or mixing at the seafloor due to the mining operation; and (4) subsequent replacement of mined material as waste, tailings, or discharges. These factors may result in physical, chemical, and biological changes such as alteration of the shape or character of the seabed; changes in the quality of the air and water in the vicinity of the operation; and impacts on biological and socioeconomic resources. The key environmental concerns expressed in the literature have focused on perturbations to the seabed, air quality, water quality, biological resources, and socioeconomic resources (including commercial and recreational fisheries). These aspects form the basis of the summary discussion, but it was stressed that a reliable analysis of environmental impacts of any mining operation must be based on commodity-specific, technology-specific, and site-specific information.

The analysis of mitigation measures and techniques was grouped by resource to which the mitigation measure applied. Strengths and weaknesses of each mitigation measure were discussed based on evaluations of technical and socioeconomic factors.

An analysis of available computer simulation models was completed with an emphasis on strengths and weaknesses. The evaluation of models was limited to those that simulate the physical dispersion of particles through the water column and sedimentation on the seabed. Air emissions, chemical transformations, and demographic processes were considered too site-specific to warrant consideration in the analysis. The predictive capabilities of the present generation of dispersion models are still limited, due to insufficient field testing/tuning and the inability to include enough important parameters in sufficient detail to afford accurate predictive results. Near-field predictive capability is relatively good, with predictive capability degrading with increasing distance from the source.

There are significant data gaps in the U.S. knowledge base in the areas of (1) water quality modeling (i.e., the generation and dispersion of particulate and dissolved materials in the water column based on, or at least confirmed by, empirical data acquired from marine mining operations); (2) effects of significant alterations of the seabed on adjacent coastlines; (3) understanding the characteristics, behavior, and recolonization response of organisms in various mine site areas (e.g., deep seabed, seamounts, guyots, OCS, and coastal) under the stress of production operations; (4) impacts of processing discharges from onshore mines on coastal biota; and (5) understanding the realities of mining in perspective with other natural processes and man-induced activities.

SUMMARY AND CONCLUSIONS

The primary purpose of the study was to collect, examine, analyze, and summarize the existing literature regarding the potential environmental impacts of marine mining. Deliverables resulting from the study included an Executive Summary (OCS Study MMS 93-0005), Final Report (OCS Study MMS 93-0006), Technical Summary, and Reference Database.

To determine the environmental impacts of marine mining, one must first understand the specific mineral of interest and the technology that will be used for a specific mining operation. The type of mineral and the technological operations determine the impact-producing factors that will need to be considered in the assessment. Once the impact-producing factors are known, the factors can be translated into statements concerning the potential impacts that might occur to the full suite of potentially affected environmental resources including geology, chemical and physical oceanography, air quality, biology, and socioeconomics. Finally, decisions can then be made regarding the type of mitigation necessary to determine the preferred alternative for acquiring project approval on that specific marine mining operation.

Dr. Richard M. Hammer was Program Manager for the study described in this paper. Since 1980 he has worked as Senior Scientist with the environmental consulting firm of Continental Shelf Associates, Inc. since 1980. Dr. Hammer has served as a consultant for numerous industry clients and federal and state agencies concerning marine mining, beach renourishment, dredged material disposal, power plants, ocean incineration, and oil and gas activities in the Gulf of Mexico, Atlantic and Pacific Oceans, Caribbean and Caspian Seas, and Alaska waters. He received his B.S. degree in fisheries and wildlife from Michigan State University, his M.S. degree in oceanography from Texas A&M University, and his Ph.D. degree in marine biology from the University of Southern California.

IMPACTS AND DIRECT EFFECTS OF SAND MINING FOR BEACH RENOURISHMENT ON THE BENTHIC ORGANISMS AND GEOLOGY OF THE WEST FLORIDA SHELF

Dr. Norman J. Blake
Dr. Larry J. Doyle
Department of Marine Science
University of South Florida

Mr. James K. Culter
Mote Marine Laboratory

The main purpose of this study was to evaluate and gain insight into the long-term effects of seabed mining operations and the degree to which benthic organisms may repopulate the area after a mining activity takes place in a coastal or shallow open ocean area such as near the mouth of Tampa Bay on the west coast of Florida. This information is necessary to provide at least a preliminary assessment of the impacts of mining activities. Specifically the objectives were as follows:

1. To evaluate and assess the possible impacts of sand mining operations on the benthic communities (epifaunal and infaunal) before, during and after dredging operations.
2. To evaluate and assess the possible changes to the geology and topography as a result of the dredging operations.

The information produced by this study can be used to assess the level of mining or dredging impacts to the benthic communities and the suitability of a proposed area of development in relation to the ability of the biota to survive a mining operation or to repopulate after completion of mining activity.

The sampling program was conducted at each of four sites selected. The general station locations in latitude and longitude locations, site designations, and number of samplings are as follows:

Egmont Key, Site I, 27°37°N, 82°49°W, 1-pre- 3-post
Sarasota, Site II, 27°15°N, 82°35°W, 3-pre, never dredged
Venice, Site III, 26°29°N, 82°27°W, 1-pre, never dredged
Longboat, Site IV, 27°14°N, 82°36°W, 1-post

Prior to each benthic sampling event a geophysical survey was conducted at each site. A maximum of 12 nautical miles of high resolution seismic reflection profiling, side scan sonar data, and continuous video tape of the bottom was collected simultaneously.

A video camera mounted on a PHANTOM 500 ROV was towed a few feet above the bottom behind a torpedo-like weight that helps maintain depth control. The system was remotely flown from the vessel laboratory. Video camera output was recorded on VCR tape. Observations of bottom type and biology were logged in real time aboard ship every 10 minutes or as specific features or changes in bottom type or epibenthos were encountered.

The benthic infaunal and sediment sampling programs were conducted at each of the four sites. A total of three stations at each site (two in the dredge area and one outside) were sampled by box corer. The control station was outside the dredge area and approximately 1 mile removed from the limits of the disposal area, but in a sediment environment similar to the dredge area. Although an attempt was made for the first sampling period to be prior to any dredging operation and the remaining three periods after dredging, this was not possible for all four locations.

The side scan and seismic data showed no major changes attributable to dredging. The precision depth recorder data, however, showed dredge holes that had not completely filled in, even after the passage of a major storm. This was particularly true at study area I–Egmont Key where a clamshell dredge was used. The bottom at the Longboat Key site, where a modified dustpan dredge was employed, showed very little residual physical change to the topography due to the dredging, except for the overall and relatively constant deepening of the dredged areas. This indicates that traditional dredging methods (clamshell and possibly hopper dredges) may leave pits or holes in the seabed which may persist indefinitely and which could result in eventual benthic community or sediment changes in the long term. Newer, more innovative dredging techniques do not appear to create these types of features.

There were no significant changes in grain size, carbonate content, or mineralogy at any of the study sites. Each replicate at each station was analyzed for grain size at whole phi intervals, carbonate content, and total organic carbon for each sampling period. Sediments were composed of fine (125 to 250 microns) to very fine (62 to 125 microns) quartz sands with varying amounts of carbonate making up the coarser fractions of the sediment. Organic content was every where less than 1%. No clear trends in standard sediment parameters were apparent following the dredging. Replicate variation and variations among sediments were as great or greater than station variation with time. There is very little silt or clay-sized material in the West Florida shelf sediments, so it is not surprising that there were no discernible differences in grain size during any of the pre or post-dredging cruises.

Underwater video was recorded over each transect at each location for each sampling cruise. This represents a total of approximately 120 hours of video recorded during the course of the study. There was little variability observed between locations or between sampling dates. Observations of flora and fauna were rare. The flora observed was unattached, drifting macroalgae and not seagrass. Occasional worm tubes belonging to the infaunal species, Chaetopterus variopedatus were observed protruding above the sediment.

After each video camera/side scan/seismic site survey, three 30 foot otter trawls were taken for epibenthic species verification. The location of each 20 minute trawl was determined by the chief-scientist and depended upon the on-board observations with the video camera. A total of 41 different taxa were observed during the epibenthic trawling study, a low species richness reflecting the constancy of the habitat in this area. The crab, Portunus gibbesii, and the sand dollar, Mellita tenuis were by far the most dominant species present during the study. The smallest number of epibenthic species and the smallest number of individuals were collected on the last cruise in May 1994, reflecting seasonal changes and not a result of dredging since on this date only stations I and II were sampled and only station I had been dredged. The combined results of the video surveys and the trawls demonstrate the constancy of this very dynamic sand habitat and the low epibenthic diversity of the area.

In contrast, a total of 620 taxa and 52,295 individuals were identified during the infaunal study, representing a very rich infaunal community with a diversity higher than anticipated. Annelids (segmented worms) contributed 44 and 49% of the taxa and individuals, respectively. Molluscan fauna represented 22% of the taxa and 29% of the total fauna, while arthropods comprised 27% of the taxa and 11% of the individuals. These three taxonomic groups represented 93% of the taxa and 89% of all fauna. The high diversity in these samples made determining significant differences between similarities of replicates, sites or seasons difficult and masked any possible effects of dredging. Possible explanations for the high diversity are that this is a very dynamic, sand environment and that its proximity to Tampa Bay make for a mix of estuarine and Gulf of Mexico species. These factors combined with the infaunal resiliency may allow for the rapid recovery of the area after any disturbance, either man-made or natural.

Dr. Blake is a professor in the Department of Marine Science at the University of South Florida. He has worked on the West Florida Shelf for 23 years and participated in the original BLM Outer Continental Shelf Study of the eastern Gulf of Mexico. His research interests include the effects of environmental changes on populations, particularly bivalves and crustaceans. Dr. Blake received his B.S. in biology from Florida Presbyterian College and his M.S. and Ph.D. in biological oceanography from the University of Rhode Island.

Dr. Doyle is a sedimentary geologist in the Department of Marine Science at the University of South Florida. He and his students have worked on the West Florida Shelf for over 20 years and his research has helped define the facies of the sand sheet of the Continental Shelf of the Eastern Gulf of Mexico. Dr. Doyle received his B.S. and M.S. in geology from Duke University and his Ph.D. in geology from the University of Southern California.

Mr. Culter is the program manager for the Environmental Assessment, Benthic Studies Program of Mote Marine Laboratory where he as worked since 1976. He has specialized in marine ecological environmental assessments and has worked extensively with nearshore infaunal benthic communities Mr. Culter received his B.A. and M.A. degrees in biology from the University of South Florida.

REPORT ON STATUS OF SHIP SHOAL ENVIRONMENTAL IMPACT STATEMENT AND LOUISIANA COASTAL BARRIER ISLAND RESTORATION EFFORTS

Mr. Barry S. Drucker
Physical Scientist
Minerals Management Service
Office of International Activities and Marine Minerals

INTRODUCTION

Under the auspices of the Coastal Wetlands Planning, Protection, and Restoration Act (CWPPRA), the feasibility and benefits of restoring the barrier islands of coastal Louisiana are presently being evaluated with respect to their role in wetlands protection and enhancement. The feasibility study's specific purpose, as stated in the scope of services for the Barrier Shoreline Plan, is to assess and quantify wetland loss problems linked to diminishing protection from barrier formations along the Louisiana coast, to identify solutions to these problems, and to determine the barrier configuration that will best protect Louisiana's coastal resources from environmental degradation. The feasibility study is being conducted in three phases: Phase 1, presently ongoing, encompasses the Barataria-Terrebonne island chain; Phase 2 will focus on the Chenier Plain coast; Phase 3 will focus on the Chandeleur Islands.

Within the Phase 1 study area, the state of Louisiana, in the near-term, is proposing to renourish Isles Dernieres and Timbalier Islands using federal offshore sand deposits. In addition to renourishment, other coastal restoration methods, such as dune building, vegetation planting, hard structures, and related actions may be employed. On 19 April 1995, the Governor of Louisiana formally requested a lease to use federal sand resources from Ship Shoal for restoration of the Louisiana barrier islands. This request was made under the procedure established by public law 103-426 which allows for a negotiated agreement, rather than a competitive lease sale, for qualifying public works projects. The Minerals Management Service (MMS) has determined that the use of federal sand from Ship Shoal for barrier island restoration and consequent wetlands protection meets the new negotiated agreement requirements (letter from MMS Director Quarterman to Governor Edwards dated 8 June 1995).

The National Environmental Policy Act (NEPA) process is initiated when Federal agencies must consider major actions that may significantly affect the environment. Because the environmental consequences of barrier island restoration are not adequately understood and the extraction of Federal sand for the purposes of barrier island and wetlands restoration is considered a major Federal action, it was deemed necessary to prepare environmental impact statements (EIS). Preparation of an EIS to support the Phase 1 portion of the feasibility study began in early December 1995. Impacts associated with Phases 2 and 3 will need to be evaluated in future NEPA documents. The EIS will be used to assist CWPPRA Task Force funding decisions regarding recommended Phase 1 restoration methods, as well as to aid the MMS in the issuance of a noncompetitive lease to the state of Louisiana for the use of Federal sand. The EIS is considering all reasonable restoration methods, the environmental consequences, any alternatives to Federal borrow areas, and possible mitigation measures or stipulations to ensure that a balance between orderly resource development and protection of the human, marine, and coastal environments is maintained. Alternatives not recommended in the feasibility study, but identified by the various involved parties during the EIS process, will also be included for analysis.

The EIS for the project is being prepared in conformance with all applicable requirements of NEPA, the Environmental Quality Improvement Act of 1970, the NEPA implementing regulations of the Council on Environmental Quality (40 CFR, Section 1500 *et seq.*) and other appropriate laws and executive orders. Various aspects related to the EIS cannot be definitively determined until a scoping meeting, required under 40 CFR 1501.7, is conducted in the state.

PURPOSE AND PROPOSED ACTION FOR THE EIS

The purpose to which the Federal agencies are responding (40 CFR 1502.13) in the barrier island project and the proposed major Federal action (40 CFR 1502.14, 1508.18) being considered are as follows:

- Purpose: The Restoration, Protection, and Enhancement of Louisiana coastal wetlands, and for other purposes.

- Proposed Action: Restoration of the Louisiana Barrier Shoreline as Identified in Phase 1 of the Louisiana Barrier Shoreline Feasibility Study (Barataria and Terrebonne Basins)

AGENCY DESIGNATIONS AND RESPONSIBILITIES

As agreed to by the parties involved in the EIS process, the following agency designations and responsibilities were established prior to initiation of the document:

- Federal Co-lead Agencies: The Minerals Management Service (MMS), U.S. Department of the Interior, and the National Marine Fisheries Service (NMFS), National Oceanic and Atmospheric Administration, U.S. Department of Commerce.
- Primary Cooperating Agency: The State of Louisiana Department of Natural Resources (LDNR).

The MMS assumed primary contractual responsibility for preparing the EIS. However, the three primary Agencies (MMS, NMFS, LDNR) have lead responsibility for the following material and information:

- The MMS is determining the environmental information that is needed to make an informed decision on a possible noncompetitive lease for the conveyance of Federal OCS borrow material to Louisiana for restoring certain barrier islands off the state's coast, should this initiative be recommended in the feasibility study;
- NMFS, working closely with the LDNR and other appropriate Federal cooperating agencies, has primary responsibility for determining the environmental information needed for decisions related to impacts to the onshore, coastal wetlands and upland areas that may result from any restoration initiatives recommended in the feasibility study;
- The LDNR has assumed primary responsibility for decisions relating to the use of borrow material in state waters for barrier island restoration, should this initiative be recommended in the feasibility study.

The MMS and the NMFS, in consultation with LDNR, are working closely to integrate the offshore and onshore dimensions of the EIS into a comprehensive document. The co-lead agencies are also working with the cooperating agencies that have expertise and certain formal authorities over various activities related to the actions described in the EIS. Other cooperating agencies include the U.S. Army Corps of Engineers, the U.S. Fish and Wildlife Service (FWS), the U.S. Geological Survey, the U.S. Environmental Protection Agency, and the U.S. Soil Conservation Service.

TIMETABLE FOR EIS DEVELOPMENT

The following represents the timetable by which the EIS process is proceeding:

1. Request for Comments and Notice of Intent to Prepare an EIS: A Request for Comments and Notice of Intent (NOI) will be placed by MMS, after consultation with the NMFS and LDNR, in the Federal Register in January 1996. The NOI will identify the proposed action, solicit comments from government agencies, environmental groups, and the general public, and discuss preparations for a scoping meeting.
2. EIS Proposal Review: The MMS, having already submitted an EIS Statement of Requirements and requested a formal proposal and cost breakdown from the Louisiana State University's Coastal Studies Institute (LSU/CSI), transmitted the proposal for review and comment to the NMFS and LDNR, and to all appropriate reviewing authorities. The agreement was due to be finalized in December 1995. LSU/CSI will be managing the project and providing the vital link between the EIS and the feasibility study. Two subcontractors will be involved in the actual EIS analysis: Continental Shelf Associates of Jupiter, Florida and CK Associates of Baton Rouge, Louisiana.
3. Designation of Key Individuals: The MMS, NMFS, and LDNR are to designate key individuals to serve as contract inspectors prior to finalizing the cooperative agreement. All other federal cooperating agencies will also designate key agency contacts.
4. Coordination with FWS and NMFS: After finalizing the agreement, the MMS will submit a request to the FWS and NMFS for a list of any proposed, threatened, or endangered species that occur in the study area. This information will be used during preparation of the biological impact sections of the EIS.

5. Scoping Meeting: A scoping meeting was to be held in January 1996, most likely in Terrebonne Parish. This meeting will give all concerned individuals or groups the opportunity to voice their concern or support of the proposed action and provide information which needs to be addressed in the EIS.
6. Draft Environmental Impact Statement (DEIS) Preparation: Preparation of initial sections describing the proposed action and development scenarios began immediately after the cooperative agreement was finalized. The scoping meeting will largely determine the major environmental issues to be considered within the DEIS, although it is expected that Coastal Barriers Resources Act consultation determinations will be included. The completion of the final DEIS is dependent on the completion of the feasibility study, but will likely be completed by October 1996.
7. Public Meetings: Public meetings to solicit comments on the DEIS will be held no earlier than 15 days following publication and distribution of the DEIS. The MMS, in consultation with the EIS preparer, will arrange the meetings, one of which will be held in the same location as the scoping meeting mentioned above.
8. Final Environmental Impact Statement (FEIS) Preparation: The Final EIS should be completed, allowing time for public meetings and a 45-day comment period for the DEIS, as well as 30 days to respond to those comments, by mid- to late January 1997.

Mr. Drucker has served as a physical scientist since 1988 in the Minerals Management Service's (MMS) Office of International Activities and Marine Minerals (INTERMAR). His duties are to formulate and recommend environmental studies in support of the MMS's marine minerals program, to develop statements of work for funded studies and to oversee projects as MMS Contracting Officer's Technical Representative. Prior to joining MMS, he worked as an oceanographer with the U.S. Naval Oceanographic Office. Mr. Drucker holds B.A. degrees in geology and oceanography from City University of New York and a M.S. degree in marine geology and physical oceanography from C.W. Post College of Island University.

BARRIER ISLAND RESTORATION

Mr. Jeff Harris
Louisiana Department of Natural Resources

The Louisiana Department of Natural Resources has undertaken a major project to restore the deteriorating Isles Dernieres and Timbalier Islands barrier island chains. This project is being undertaken with the cooperation of the Minerals Management Service (MMS) and the Coastal Wetlands Planning, Protection and Restoration Act (CWPPRA) Task Force, which is made up of the Louisiana Department of Natural Resources, the U.S. Fish and Wildlife Service, the National Marine Fisheries, the Army Corps of Engineers, the National Resources Conservation Service, and the Environmental Protection Agency.

The immediate goal is to restore the Isles Dernieres and Timbalier Islands as part of a larger plan to slow coastal land loss in Louisiana through the restoration of other barrier islands and the shore of the chenier plain, as well as the diversion of significant volumes of fresh water and sediment to help replenish our coastal marshes.

The Isles Dernieres and Timbalier Islands are located across the Lafourche and Fourchon headlands and the Terrebonne and Timbalier Bay estuary, on the Louisiana Deltaic Plain.

Barrier islands, and in particular Louisiana barrier islands, are extremely important in the protection of the adjacent mainland. They help obstruct the winds, waves and storm surge of hurricanes, protect fragile coastal wetlands from the erosive action of the surf zone, and help control salinity in coastal marshes. In turn, Louisiana's coastal wetlands provide vital support to the nation's second largest fishery industry and serve as important hurricane buffers for the extensive oil and gas infrastructure as well as for communities, transportation, and port facilities.

Louisiana is suffering an extremely high rate of coastal land loss, estimated at about 25 square miles per year. This loss rate is the result of many causes. The subsidence and compaction of wetland soils and the global rise in sea level are natural processes on this type of environment. Human impacts to the coastal zone include access canals for oil and gas production, navigation channels, and leveeing for development purposes. In addition, channelization of the Mississippi

River for flood control and navigation has contributed significantly to the loss of coastal wetlands. Sediments and fresh water are now diverted far out into the Gulf of Mexico rather than being distributed throughout the marshes for nourishment. In addition, the Mississippi is prevented from abandoning its present delta in favor of creating new land along another part of the coast. This process of "delta switching" is the mechanism by which coastal Louisiana was created, with delta lobes building outward over time back and forth along the coast.

With greatly reduced nourishment of the wetlands, the marsh subsides more rapidly and simultaneously is less able to resist the stresses of higher salinity. Because delta sediments are shunted to deep water, they are not available to replenish the barrier shorelines. Storms and waves can then erode and break up the island chain, exposing the mainland to greater wave action and greater influx of saline water. Left unchecked, one estimate indicates that in 45 years the coastline of the state may be pushed inland in places by as much as 40 miles.

Louisiana's response to this impending crisis is to attempt to restore the barrier shoreline and divert water and sediment into the marshes. The most immediate need is in the Terrebonne and Timbalier Bay area. By rebuilding the Isles Dernieres and Timbalier Islands to a configuration similar to their state in the mid-1800s, we will restore the hurricane buffer, decrease wave activity against the mainland marshes, and reduce the penetration of tidal waters, thereby slowing the rate of coastal land loss. In conjunction with water and sediment diversions and other restoration projects, we believe that we will be able to regain and maintain healthy coastal wetlands.

At this time, the most feasible method to rebuild the island chains appears to be through placement of dredged sands, although other alternatives, including the use of protective breakwaters or other hard structures, are also being considered. The process will also include rebuilding the marshes on the landward side of the islands, using fine-grained material dredged from the nearby bay floor. Potential sources of sand include the nearshore areas around the islands and onshore sand pits, but the most attractive source in terms of sand quality and volume appears to be the Ship Shoal, a relict ancient barrier island system now lying submerged about 10 miles south of the Isles Dernieres. If mining this shoal is environmentally and economically feasible, as much as 1.5 billion cubic yards of sand are available for island restoration.

Because of the urgency of protecting the Terrebonne and Timbalier Bay area, the agencies involved have placed the Isles Dernieres/Timbalier Islands restoration on a fast track. A project feasibility study was initiated in June of this year, with completion targeted for October 1996. Simultaneously, work will begin shortly on the environmental impact statement for mining Ship Shoal and rebuilding of the islands, with completion of the final report anticipated within about one year. If all goes well, restoration operations should begin sometime in early 1997.

Jeff Harris has been employed at Louisiana Department of Natural Resources, Coastal Management Division, for four years, and presently is Coastal Resources Coordinator for the Federal Consistency Section. Prior to this, he worked for nine years as an exploration geophysicist in the oil industry, primarily in the Gulf of Mexico Outer Continental Shelf. Mr. Harris received his B.S. in geology from the University of Wisconsin-Green Bay and his M.S. in marine geology from the University of Rhode Island Graduate School of Oceanography.

SESSION 5D

GULF OF MEXICO OFFSHORE OPERATION MONITORING EXPERIMENT PROGRESS REPORT

Session: 5D - GULF OF MEXICO OFFSHORE OPERATION MONITORING EXPERIMENT PROGRESS REPORT

Co-Chairs: Dr. Pasquale F. Roscigno and Dr. Mahlon C. Kennicutt II

Date: December 14, 1995

Presentation	Author/Affiliation
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The GOOMEX: Phase I Study Design and Progress to Date	Dr. Mahlon C. Kennicutt II Geochemical and Environmental Research Group Texas A&M University
Geochemical Patterns in Sediments near Offshore Production Platforms	Dr. James M. Brooks Dr. Mahlon C. Kennicutt II Geochemical and Environmental Research Group Texas A&M University
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INTRODUCTION: FINAL PROGRESS REPORTS ON GOOMEX

Dr. Pasquale F. Roscigno
Environmental Studies Section
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The aim of the MMS Outer Continental Shelf (OCS) Environmental Studies Program is to characterize the effects of offshore oil and gas development. Historically, this characterization has been done either through a comparison of current ecosystem data with earlier benchmark data or through special studies oriented toward monitoring specific parameters. While these studies have shown that the acute impacts of OCS development are localized and ephemeral, there is less certainty regarding the nature and consequences of the subtle, chronic, long-term stresses that may be associated with OCS development, particularly in areas with a long history of activity.

The Gulf of Mexico Offshore Operations Monitoring Experiment (GOOMEX) Phase I is a complex, closely-integrated series of multidisciplinary investigations to examine the impacts of sublethal, chronic exposure to discharges from oil and gas production facilities on marine ecosystems.

GOOMEX is intended to develop environmental indicators of contaminant stress that will be useful in the preparation of Environmental Impact Statements and provide future guidance for stipulated activity on the OCS. GOOMEX can lead to the creation of mitigation measures and the modification of the scope of proposed lease sales in the Gulf of Mexico. GOOMEX will feed directly into the operational aspects of regulating the leasing activities in the Gulf of Mexico. Mitigation measures which have affected many operational aspects of OCS activities, such as the discharge of effluents, site clearance, mandated sea-bottom surveys, and archaeological surveys, have resulted from previous studies.

The Geochemical and Environmental Group (GERG) of Texas A&M University won a competitive contract procurement from the MMS to implement this study. GOOMEX study sites are all off the coast of Texas. These are Matagorda Island Field Block 686, Mustang Island Area East Addition Block A-85, and High Island Block A389 (which includes the East Flower Gardens).

By developing techniques to measure responses of resident fauna that are chronically exposed to discharges from long-term OCS production platforms, indicators can be developed to monitor oil and gas operations so that damages to marine ecosystems can be minimized. The environmental benefits that will result from the incorporation of knowledge learned from GOOMEX will improve the daily operations on the OCS.

Presented in this session are a series of papers that report on the final results of this study.

Dr. Pasquale F. Roscigno is a Program Manager for the MMS' Environmental Studies Program. Previously, he held several different research and program management positions in the Department of Interior's Fish and Wildlife Service and Minerals Management Service. Dr. Roscigno has interests in estuarine and marine ecotoxicology, environmental risk assessment, and marine process ecology.

THE GOOMEX: PHASE I STUDY DESIGN AND PROGRESS TO DATE

Dr. Mahlon C. Kennicutt II
Geochemical and Environmental Research Group
Texas A&M University

The objective of GOOMEX: Phase I was to assess sublethal effects associated with chronic exposure of marine organisms to contaminants derived from offshore oil/gas exploration and development activities. A chronic impact is defined as an effect on the biota that is caused by exposure to the "long-term" accumulation of chemicals in the environment. "Long-term" was defined as locations with a ten-year or longer history of production after exploration. Sedimentology, chemistry, and oceanographic work elements described the areal and temporal distribution of contaminants, sediment characteristics, and water quality. Biological work elements identified responses to chronic chemical contamination as reflected in induction of detoxification enzymes, life history, reproductive success, reproductive effort, community structure and genetic diversity. The sampling plan was designed to detect and describe nearfield impacts and contaminant gradients extending out from each site. All study components were linked by a common statistical design.

The field program included four sampling activities conducted over a one-and-one-half year period. The study initially evaluated five test sites and narrowed the longer-term study to the three most appropriate sites. The sampling design included a radial pattern with sample stations at 30-50, 100, 200, 500, and ≥3,000 m. Station locations were chosen based on a dose-response model and were used to test the hypothesis that chemical and biological parameters vary with distance from the platform. Comparisons of data from stations close to platforms (≤2,000 m) to stations distant from platforms (≥2,000 m) were used to evaluate the significance of the observed variations. Sediment collection was by boxcore and megafauna were collected by otter trawl.

The study included the analysis of contaminants in sediments, pore waters, and biological tissues (trace metals and hydrocarbons). All trace metal and hydrocarbon analytical protocols were those used in the NOAA National Status and Trends (NS&T) program. The associated QA activities were similar in scope to those of the NS&T program.

Biological effects were monitored in a wide range of important species from meiofauna to megafauna. These species included infauna, epifauna, mobile invertebrates and demersal fish. The biological measurements cover a range of potential markers of impact from induction of detoxification enzymes to traditional assemblage analysis. Assemblage information was collected for meiofauna and macroinfauna. Reproduction and life history studies for meiofauna emphasized harpacticoids. Megafauna (invertebrate) reproductive effort and health was also assessed. All biological studies were coordinated with measurements of tissue contaminants. Demersal fish were examined for chronic impacts at several levels of detail including necropsies (gross pathology), histopathology of representative tissues, stomach content analysis, liver and stomach content contaminant analysis, and biliary PAH metabolites. Megafauna (invertebrates) were also examined for histopathologies.

Biological exposure to contaminants was evaluated using a series of biochemical biomarkers that measure P4501A induction. *In vivo* biomarkers included enzyme assays for ethoxyresorufin-O-deethylase (EROD) and aryl hydrocarbon hydroxylase (AHH) activities. Levels of P4501A mRNA in fish livers were also assessed. PAH metabolites were measured in the bile of demersal fish as an indicator of PAH exposure. Highly Ah-responsive *in vitro* cell bioassays (i.e., rat hepatoma H4IIE cells) were also used to determine the inductive potency (as measured by EROD activity) of extracts from invertebrates.

Additional work elements were added to the core program to (1) assess pore water toxicity based on sea urchin embryological development tests and (2) develop an immunological probe to estimate reproductive effort in megainvertebrates. A series of other techniques were also developed including measures of meiofauna genetic diversity, utilization of more appropriate organisms for bioassays, and evaluation of various *in vitro* toxicological assays presently utilized for mammalian systems.

Data synthesis included contour maps of important physical, chemical, and faunal characteristics, correlations, regressions, and plots of dependent versus independent variables. Variations in benthic faunal assemblages were described by power diversity (rare fraction curves) and multivariate analysis. Principal component analysis (PCA), analysis of variance (ANOVA), multivariate analysis (MANOVA), covariate analysis (ANCOVA) and general linear modeling (GLM) formed the basis of statistical interpretations.

Dr. Mahlon C. Kennicutt II, Senior Research Scientist, is Chief Chemist of the Geochemical and Environmental Research Group with the College of Geosciences and Maritime Studies at Texas A&M University. Dr. Kennicutt has expertise and research interests in marine chemistry, environmental chemistry, and organic geochemistry. He received a B.S. in chemistry in 1974 from Union College and a Ph.D. in oceanography from Texas A&M University in 1980. Dr. Kennicutt has published over 110 peer-reviewed papers, numerous book chapters, and has made scientific presentations world-wide.

GEOCHEMICAL PATTERNS IN SEDIMENTS NEAR OFFSHORE PRODUCTION PLATFORMS

Dr. James M. Brooks
Dr. Mahlon C. Kennicutt II
Geochemical and Environmental Research Group
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Patterns of the geochemical characteristics of sediments adjacent to three production platforms (29-150 m water depths) in the northwestern Gulf of Mexico were determined by the presence of the structure, the amount and type of materials discharged from the structure, and the local hydrographic setting. Sediments close to platforms (< 500 m) were enhanced in coarse-grain materials primarily derived from discharged muds and cuttings. Hydrocarbon and trace metal (silver, barium, cadmium, mercury, lead, and zinc) contaminants were associated with these coarse-grain sediments. Contaminants were asymmetrically distributed around each platform in response to the prevailing currents. Contaminant concentrations at most locations were below levels thought to induce biological responses. At a few locations close to one platform, trace metal (i.e., Cd, Hg) concentrations exceeded levels thought to induce biological effects. In deep water (> 80 m) sediment trace metal contaminant patterns were stable over time frames of years. A few metals (lead, cadmium) exhibited evidence of continued accumulation in sediments over the history of the platform.

Dr. James M. Brooks is a Senior Research Scientist of the Geochemical and Environmental Research Group in the College of Geosciences and Maritime Studies at Texas A&M University. His expertise is in trace contaminant analysis and marine chemistry. Dr. Brooks received his B.S. in chemistry from Abilene Christian University in 1969, a M.S. in oceanography from Texas A&M University in 1970, and a Ph.D. in oceanography from Texas A&M University in 1975. Dr. Brooks has published over 200 peer-reviewed papers and directed GERG from 1977 to 1995.

Dr. Mahlon C. Kennicutt II, Senior Research Scientist, is Chief Chemist of the Geochemical and Environmental Research Group with the College of Geosciences and Maritime Studies at Texas A&M University. Dr. Kennicutt has expertise and research interests in marine chemistry, environmental chemistry, and organic geochemistry. He received a B.S. in chemistry in 1974 from Union College and a Ph.D. in oceanography from Texas A&M University in 1980. Dr. Kennicutt has published over 110 peer-reviewed papers, numerous book chapters, and has made scientific presentations world-wide.

BENTHIC ECOLOGICAL PATTERNS ASSOCIATED WITH OFFSHORE PRODUCTION PLATFORMS

Dr. Paul A. Montagna
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Meio- and macro-infaunal communities around three offshore (29–150 m) production platforms in the Gulf of Mexico were studied to determine if sublethal or persistent effects of chronic exposure to contaminants associated with production could be detected. Exploratory and production drilling of wells at these platforms had occurred during a period from the mid 1970s to the early to mid 1980s providing a one-to-two decade history of exposure to and potential recovery from effects of a variety of contaminants. Samples were taken by subsampling boxcores taken in a radial pattern around each platform with five directional radii from five distances (30–50, 100, 200, 500, and 3,000 m) from the platforms. Winter and spring samples were taken during each of two years. The resulting data were analyzed in two ways: univariate analyses using distance from platforms as a categorical variable and multivariate analysis of correlation with the contamination gradient. Total polychaetes and non-selective deposit feeding nematodes exhibited increases in density near platforms. Amphipod abundance and harpacticoid abundance, diversity, and genetic variance declined near platforms. The number of gravid female harpacticoids and their egg sizes were higher near platforms, but reduced naupliar survival in pore water toxicity tests and lower densities of copepodites and adults imply a net decrease of reproductive success. Like many other studies of pollution gradients, organic enrichment, contamination by toxicants (e.g., heavy metals and hydrocarbons), and changes in sediment granulometry are confounded with distance from the platform. However, the pattern of community change in both macroinfauna and meiofauna around these production platforms follows an emerging paradigm of response in which the density of polychaetes and nematodes increases indicating organic enrichment while harpacticoid and amphipod density decreases indicating toxic response.

Dr. Paul A. Montagna is a benthic ecologist with more than 20 years' experience. He has worked at the University of Texas at Austin since 1986 and is presently an Associate Professor in the Department of Marine Science and Research Scientist at the Marine Science Institute in Port Aransas, Texas. Dr. Montagna received his B.S. in biology from State University of New York at Stony Brook, a M.S. in biology from Northeastern University, and a Ph.D. in biology from the University of South Carolina.

DIFFERENCES IN MACROEPIFAUNAL SIZE STRUCTURE AND CATCH PER UNIT EFFORT NEAR PRODUCTION PLATFORMS IN THE NORTHWESTERN GULF OF MEXICO

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Macroepifaunal populations near three active producing platforms were studied as part of the Gulf of Mexico Offshore Operations Monitoring Experiment (GOOMEX) using a near-field, far-field collection strategy. The purpose of GOOMEX was to examine possible impacts of chronic exposure to chemical contaminants on populations living in close proximity to production platforms in the Gulf of Mexico. Three sites were chosen: MAI-686 (Matagorda Island), MU-A85 (Mustang Island), and HI-A389 (High Island) in 29, 75, and 150 m, respectively.

One component of GOOMEX examined the population structure of mobile epifauna. In this study, differences in size frequency, sex ratio, and catch per unit effort (CPUE) were used as indicators of possible sublethal effects of exposure to chemical contaminants or other platform-associated factors in target species of penaeid shrimp, portunid crabs, stomatopods, scallops, and starfish. Animals were collected by trawl on four cruises (two winter, two late spring/early summer) from near-field (50–100 m) and far-field (3 km) stations and sorted and measured onboard ship. Where possible, sex was determined from external characteristics. Data were analyzed by MANOVA to determine the effect of cruise, distance, and platform.

The most common species collected were the shrimp *Penaeus aztecus, Trachypenaeus similis,* and *Solonocera atlanditis*; the portunid crabs *Callinectes similis, Portunus spinicarpus*, and *Portunus gibbesii*, two species of starfish (*Astropecten*); the scallop (Amusium papyraceum); and three species of stomatopods (*Squilla*). When differences existed, CPUE generally was higher at the far-field station, although stomatopods were consistently higher at the near-field station. Larger individuals of most species tended to be collected at the far-field station. CPUE tended to increase at night, indicating a higher collection efficiency, but larger individuals were collected during the day. Sexual dimorphism was present in many species; however, differences in size occurred within sexes. Thus size effects were not solely due to sexual dimorphism and near-field/far-field differences in sex ratios. Differences in size and CPUE were site (platform) specific indicating that epifauna responded to the unique physical and chemical characteristics of each platform. Species showing significant differences in CPUE did not necessarily show significant differences in size. Thus, the two factors, size and abundance, did not covary.

General responses to the presence of platform structure or other characteristics in common to production platforms were not observed. Thus, the single most significant generality from this portion of the GOOMEX study was the platform-specificity observed. Each platform produced a distinctive effect on the shelf epibiota. However, the frequency of significant near-field/far-field differences declined with increasing water depth as did the frequency of significant seasonal differences in size and CPUE, suggesting that platforms affect adjacent community structure more strongly in shallow water and that seasonality may be an important promoter of this effect.

Significant differences were frequently observed even in the most mobile species, the penaeid shrimp, indicating that discrete populations maintain their coherence for significant periods of time. Significant differences occurred no less frequently than they occurred in the much less mobile starfish and scallops. Accordingly, migration between populations of mobile epifauna must occur relatively infrequently. This coherence permits differential effects produced by nearness to platforms to be expressed and observed in some of the most mobile invertebrates on the shelf.

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SUBLETHAL DETOXIFICATION RESPONSES TO CONTAMINANT EXPOSURE ASSOCIATED WITH OFFSHORE PRODUCTION PLATFORMS

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The detoxification work element was designed to the meet the primary objective of the GOOMEX project, namely, to assess the sublethal effects of potential chronic exposure of marine organisms to organic contaminants derived from offshore oil/gas exploration and development activities.

Polynuclear aromatic hydrocarbon (PAHs) mixtures are a major class of organic contaminants in the marine environment. PAHs released as the result of drilling activities are considered to be a likely contaminant in the Gulf of Mexico. PAHs are typically derived from spills of crude oil and refined petroleum, runoff, and combustion sources (Boucart *et al.* 1961; Hites *et al.* 1977; Suess 1970; and Huggett *et al.* 1987). PAHs are susceptible to biodegradation and their presence in water, sediment, and organisms is usually due to relatively recent petroleum spills and/or chronic exposure from non-point sources. Numerous studies have demonstrated that organic contaminants, such as PAHs, are probable etiologic agents (Tanabe 1989; Tanabe *et al.* 1989; Kannan *et al.* 1989; and Tillitt *et al.* 1992). Historically, hydrocarbon contaminant studies measured ambient concentrations in water, sediments, and tissues using highly sensitive analytical methods to quantify these chemicals. However, these mixtures are invariably complex and it is difficult to identify and quantify all components. Even if the concentrations of all components of these mixtures are obtained, the extrapolation of this data in terms of potential adverse effects is difficult. Thus, the use of biomarkers and bioassays for evaluating environmental contamination are powerful alternatives to historical analytical (chemical) approaches.

Table 5D.1. Species collected at both near and far stations for at least one platform.

Scientific Name	Common Name	Scientific Name	Common Name
Ancyclopsetta dilecta	3-eyed founder	*Caulolatilus intermedius*	tile fish
Centropristis philadelphica	rock sea bass	*Cynoscion arenarius*	sand sea trout
Cyclopsetta chittendeni	Mexican flounder	*Lagodon rhomboides*	pin fish
Ogcocephalus declivirostris	bat fish	*Paralichthys lethostigma*	southern flounder
Pontinus longispinis	scorpion fish	*Pristipomoides aquilonaris*	wenchman
Syacium gunteri	shoal flounder	*Synodus foetens*	lizard fish
Trichopsetta ventralis	sash flounder	*Urophycis spp.*	hake

The biomarkers utilized in this study include CYPIA-dependent enzyme activities [ethoxyresorufin O-deethylase (EROD) and aryl hydrocarbon hydroxylase (AHH)], CYPIA mRNA levels, *in vitro* cell bioassay responses (rat hepatoma H4IIE), and the production of biliary PAH metabolites. This report presents data from four (4) cruises conducted as part of the GOOMEX project at three (3) platforms (MAI-686, MU-A85, and HI-A389).

Both fish and invertebrates were collected by trawling. All specimens were maintained live until dissection. After dissection, fish livers were immediately frozen in liquid nitrogen until analysis. Invertebrate tissues were frozen at -20°C until extraction. Bile was frozen at -20°C until analysis.

Microsomes were prepared from fish livers by homogenization followed by differential centrifugation. EROD and AHH activities were determined fluorometrically from hepatic microsomal preparations. Total RNA was isolated from hepatic samples by subcellular fractionation and extraction. CYPIA mRNA was determined by Northern Blot analysis using a cDNA probe for rainbow trout CYPIA. Naphthalene, phenanthrene, and benzo[a]pyrene (BaP) equivalent metabolites were measured in bile by high performance liquid chromatography (HPLC) and fluorescence detection.

Invertebrate tissues were extracted with methylene chloride and purified by column chromatography and HPLC. Methylene chloride extracts were transferred to DMSO. Subsequently, rat hepatoma H4IIE cells were treated with aliquots of tissue extracts and the induction of EROD activity was measured and used to determine 2,3,7,8-tetrachlorodibenzo-r-dioxin (TCDD) induction toxic equivalents (I-TEQs; Safe, 1990).

Study results are based on those species of fish captured at both the near and far stations. The fourteen species in Table 5D.1 were collected at both near and far stations for at least one platform.

Table 5D.2. Invertebrate species collected and analyzed from Cruises 2, 3, and 4.

Scientific name	Common name
Trachypenaeus similis	shrimp
Squilla empusa	mantis shrimp
Penaeus aztecus	brown shrimp
Callinectes similis	crab
Amusium papyraceum	scallop
Solencera atlantidis	shrimp
Portunus spinicarpus	crab

Biliary PAH metabolite concentrations were determined on 376 samples and EROD and AHH activities were determined for 543 and 268 fish livers, respectively. Additionally, approximately 150 CYPIA mRNA analyses were completed on fish hepatic samples. Eighty-one AHH assays were conducted on invertebrate digestive tissues from Cruise 1. Although *in vitro* assay were conducted using samples collected on Cruise 1, the data was not used for the final analyses because of analytical problems associated with small sample sizes. For subsequent cruises *in vitro* assays were conducted using extracts of 99 invertebrates to assess potential contaminant exposure.

The levels of biliary BaP equivalent metabolites were typically low and no significant differences in near/far station comparisons were observed. The presence of BaP metabolites indicates exposure to pyrogenic PAH, and the low levels of BaP metabolites observed in this study are consistent with analytical data in which pyrogenic PAH levels were typically below method detection limits. The presence of naphthalene and phenanthrene equivalent metabolites in bile indicates exposure to low molecular weight PAHs. Although naphthalene and phenanthrene metabolites were detected, no consistent significant near/far station comparisons were observed. However, species differences were observed in biliary PAH metabolite concentrations which indicate intrinsic species variations.

AHH activity was only measured in fish hepatic samples collected on cruises I and II; whereas, EROD activity was measured in all hepatic fish samples. AHH activity was not measured in fish collected on subsequent cruises because a good correlation between the two assays had been established for most species and the EROD assay was found to be more sensitive. However, a few species of fish (i.e., *Lagodon rhomboides* and *Synodus foetens)* did not exhibit a coordinated induction of both AHH and EROD activities which suggests that these species may express an altered CYPIA protein compared to most other fish species. No significant cruise, platform, or near/far station differences in EROD and AHH activities were observed for any species of fish. However, significant species differences were detected. The highest mean EROD activity was measured in pin fish (145 pmol/min/mg).

Extracts of invertebrate tissues collected on Cruises 2, 3, and 4 were analyzed using an *in vitro* cell bioassay (i.e., rat hepatoma H4IIE cells) to determine their CYPIAI induction potency as measured by EROD activity and to derive I-TEQs. Extracts from the invertebrate species in Table 5D.2 were used in these assays.

The bioassay-derived I-TEQ values for brown shrimp captured at MAI-686 near were significantly higher than the I-TEQ values for brown shrimp collected at MAI-686 far. No other significant near/far station differences were noted; however, species differences were observed. The I-TEQs for scallops (1.36 ng/g) were significantly higher than those for any other species (<0.37 ng/g). This is consistent with the expected higher levels of contaminant bioaccumulation in bivalves.

In summary, the biomarker data showed few significant differences in near/far station comparisons and indicate that fish and invertebrates are only minimally exposed to PAH's which is consistent with chemical data.

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IMPLICATIONS FOR MONITORING: STUDY DESIGNS AND INTERPRETATION OF RESULTS

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The use of multivariate techniques to evaluate community responses to environmental gradients has been shown to be especially sensitive in detecting significant biological responses. A Sediment Quality Triad (SQT) was used to integrate concurrently obtained toxicological, contaminant distributions and benthic ecological data in a test of coherence of responses. Statistical testing demonstrated that the biological community responded to increased exposure by increases in the ratio of the "more tolerant taxon" to "the more sensitive taxon." In this case, polychaete to amphipod and nematode to harpacticoid ratios were responsive to exposure. The meiofaunal community in general also showed a negative response in total abundance while the macroinfaunal community exhibited an enhancement of total abundance due to organic enrichment near the platform. An integrated approach at several levels of biological organization is needed to assess the "health" of an ecosystem. Rigorous statistical design, objective site selection, and high-quality data generation are essential to successful evaluation of effects.

Dr. Roger Green is a Professor of Zoology at the University of Western Ontario, Canada. He has over 25 years' experience in the biological sciences. His specialty is environmental biology/ecology and biostatistics. He has written a total of 49 refereed papers on the subject and one book entitled, *Sampling Design and Statistical Methods for Environmental Biologists*. He has been invited to participate in numerous technical conferences and workshops concentrating on the design and analysis for environmental monitoring and study. He is currently consulting with seven governmental and/or industrial agencies on the environmental effects of chemical, noise, and nuclear pollution.

GOOMEX PHASE I: SUMMARY OF CROSS-WORK ELEMENT RESULTS AND RECOMMENDATIONS FOR FOLLOW-ON STUDIES

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One of the strengths of the GOOMEX Phase I program was the adherence to a statistically rigorous study design supported by a coordinated sample collection plan. In order to verify the soundness of the scientific interpretations, concordance across diverse elements was closely examined. In general, multiple lines of evidence were available to support the conclusions.

In summary,

- Covariation in environmental variables with distance from platforms could be reduced to four categories of potential importance in driving biological responses near platforms: sand enrichment, hydrocarbon contamination, metal contamination, and organic enrichment.
- The observed increase in the abundance of polychaetes, (especially intense among deposit feeders), an increase in nematodes relative to harpacticoids and an absolute increase in the density of non-selective deposit-feeding nematodes is consistent with species-specific effects on benthic communities.
- The pattern of increase in deposit-feeding polychaetes and non-selective deposit-feeding nematodes in the near-field around platforms was contrary to the trend expected to accompany an increase in sediment-size.
- A decrease in abundance of amphipods and harpacticoid copepods was best explained as a consequence of sediment toxicity near platforms.
- The relatively low levels of substantially degraded hydrocarbons suggested that hydrocarbons are not the primary source of toxicity in the benthos.
- The lack of an enhanced induction of the CYP1A detoxification systems in the near-field supported the conclusion that hydrocarbon exposure was low.
- Increased metal concentrations near one platform were at levels at which toxic effects may

be expected. Bioassays using sea urchin development and harpacticoid survival showed porewater from these stations was toxic.

- An evaluation of sediment contaminant levels, benthic community data, and results of porewater toxicity tests demonstrated a high degree of concordance among the three variables.
- Hypoxia in bottom waters near shallow platforms was tightly coupled with enhanced nutrient regeneration and interpreted to be a consequence of organic enrichment.
- The use of multivariate techniques to evaluate community response of either macroinfauna or meiofauna to environmental gradients has been shown an especially sensitive tool for detection of significant biological responses.
- The overall biological impact at these study sites was low compared to impacts near platforms in the North Sea. Compared to other anthropogenic discharges of treated municipal wastewater and industrial discharges, responses at the study sites were low.
- Variance in response variables was higher near platforms due to small scale heterogeneity and provided an additional indication of impact.
- Comparisons of genetic variability may be a useful technique to identify sublethal chronic impacts that occur as a result of environmental disturbance.
- Analysis of benthic fauna at the family level should be undertaken with caution and may not be generally applicable due to loss of information provided at the species level of identification.

From a close evaluation of the study design, the variables measured, the trends observed, and the information gained in GOOMEX Phase I, a number of recommendations and conclusions are provided. These observations set the stage for developing the follow-on phases of the GOOMEX Program.

In summary,

- An integrated approach at several levels of biological organization (molecular to community) and organism size (bacteria to fish) is needed to assess the state of a system.
- Rigorous statistical design, objective site selection, and high quality data generation are the underpinnings of a successful program.
- The major discontinuity at the seawater/sediment requires that very different approaches and interpretations be applied to results based on benthic and epibenthic indicators of exposure and response. Interactions across this discontinuity are also important.
- A threshold response in organisms leading to rapid deterioration may be a more appropriate model than a gradual and continuous dose-response model.
- Contaminants are not regularly distributed in sediments and are heterogeneous (small scale variability) in impacted areas. Steep and abrupt gradients are often observed and distance is not always an adequate surrogate for distance.
- "Control" type comparisons may not be optimal. Incidence, prevalence, and intensity of indicators of impact over a range of exposures may more accurately predict impact. The spatial and temporal scales of populations are not well-defined, particularly in mobile megafaunal communities.
- Strong covariation of multiple environmental variables may make it difficult if not impossible to identify cause and effect from field observations alone. Manipulative field and laboratory studies are needed to more directly address questions of causation.
- Comparison of field observations with laboratory and other controlled exposure experiments is necessary to assess the relative importance of the observed responses (i.e., the dynamic range of indicators must be established).
- Integrated, multidisciplinary approaches imply that appropriate multivariate statistical analyses be developed to provide optimal utilization of the data produced.

The results from Phase I lay the groundwork for continuing studies directed at determining the mechanistic explanations for the patterns observed. A series of recommendations are made for the structure and content of follow-on studies. Definitive testing of the patterns associated with platforms and development of a sound scientific basis for identifying the most appropriate and sensitive variables for future monitoring and management of activities associated with offshore oil and gas exploration and development are a primary goal for Phase II. A variety of design approaches will be needed to provide for the multiple goals of Phase II including: tests of generality of trends and patterns, continued development of promising Phase I indicators, introduction and testing of new more appropriate indicators, laboratory verification of causation, measurement of process variables (i.e., fluxes measured by benthic chambers, pore water profiles, and sediment trays), and in-field sampling to verify responses under well-characterized contaminant settings (including manipulative experiments, i.e., transplants, sediment trays, etc.).

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SESSION 6B

TRASH OR TREASURE? MMS GUIDELINES AND METHODOLOGICAL PROCEDURES FOR IDENTIFICATION OF SUBMERGED MAGNETIC ANOMALIES BY THE COMMERCIAL DIVING INDUSTRY

Session: 6B - TRASH OR TREASURE? MMS GUIDELINES AND METHODOLOGICAL PROCEDURES FOR IDENTIFICATION OF SUBMERGED MAGNETIC ANOMALIES BY THE COMMERCIAL DIVING INDUSTRY

Co-Chairs: Dr. Richard J. Anuskiewicz and Dr. Jack B. Irion

Date: December 14, 1995

Presentation	Author/Affiliation
Trash or Treasure? MMS Guidelines and Methodological Procedures for Identification of Submerged Magnetic Anomalies by the Commercial Diving Industry	Dr. Richard J. Anuskiewicz Dr. Jack B. Irion Minerals Management Service Gulf of Mexico OCS Region

TRASH OR TREASURE? MMS GUIDELINES AND METHODOLOGICAL PROCEDURES FOR IDENTIFICATION OF SUBMERGED MAGNETIC ANOMALIES BY THE COMMERCIAL DIVING INDUSTRY

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INTRODUCTION

Why Are We Here This Afternoon?

This session was formed to address several issues and problems related to the current methodological procedures that commercial diving companies are using to locate submerged magnetic anomalies in the Gulf of Mexico. Let us begin with a brief background as to why the oil and gas industry is required to conduct archaeological surveys and subsequent investigations on the Outer Continental Shelf (OCS).

National Historic Preservation Act of 1966, As Amended

The National Historic Preservation Act of 1966, as amended, states that the Minerals Management Service (MMS) as a Federal Bureau is required to ensure that the activities it funds (e.g., environmental studies) and the activities it permits (i.e., lease sales, plans of exploration and development, and lease term and right-of-way pipelines) do not adversely affect *significant* archaeological resources.

What Constitutes Archaeological or Historic Significance

Section 106 of The National Historic Preservation Act is a project review process that ensures that the MMS weighs preservation into the balance with the projected benefit, cost and other factors of a completed undertaking. Section 106 extends only to National Register-listed or eligible resources. Section 60.4 of the Act defines a "significant" resource as one that possesses qualities that will yield important information in American history, architecture, archaeology, and engineering. There are four specific "qualities" defined in Section 60.4 and the area we are interested in is Section 60.4, Part (d). Part (d) says that the type of archaeological information we are seeking should yield or be likely to yield information important in history or prehistory.

How Does this Law Specifically Pertain to MMS Activities?

I mentioned earlier that the MMS permits exploration, development, and pipeline construction. To facilitate this process, the MMS has conducted a series of archaeological baseline studies to determine where on the OSC archaeological resources may occur. Therefore, prior to permitting any of these activities, the MMS requires a lease operator to conduct a remote-sensing survey, prepare an archaeological review of the geophysical data, and submit this information in report form to the MMS.

MMS's Written Guidelines for Compliance, NTL 91-02, and 30 CRF 250.26

The MMS Gulf of Mexico Region has prepared sets of report writing guidelines and archaeological compliance procedures for operators, geophysical companies, and archaeologists. In December 1991, I wrote Notice to Lessees 91-02 entitled, "Outer Continental Shelf Archaeological Resource Requirements for the Gulf of Mexico OCS Region," and this NTL was issued to the oil and gas industry. About three years later, our Headquarters office formalized NTL 91-02 by publishing an new archaeological rule in the Federal Register as 30 CRF 250, 256, 280, and 281, titled "Archaeological Resources Surveys and Reports on the Outer Continental Shelf Lease Tracts."

FEDERAL LAW REQUIRES THAT SIGNIFICANT ARCHAEOLOGICAL SITES NOT BE ADVERSELY AFFECTED BY A FEDERALLY PERMITTED ACTION

So, what does all this NTL business and/or archaeological regulation mean to the operator? Remember the reports that have to be submitted to the MMS? The Archaeological Resource Management Program uses these remote-sensing surveys and report evaluations either to clear a lease block of resource potential or to provide information to require additional archaeological survey and testing. If the survey identifies an area of high archaeological potential within a lease block, the lease operator must either avoid these areas during development, or they must conduct additional surveys and testing if they choose not avoid the potential resource areas. If the archaeological testing indicates that proposed exploration or development will impact significant archaeological resources the lease operators must begin a consultation process with state and federal agencies. This consultation process includes meeting with the State Historic Preservation Office (SHPO) of the affected State, and meetings and discussions with the President's "Advisory Council on Historic Preservation" (ACHP). Both agencies have an opportunity to comment on the proposed undertaking and may provide mitigative guidelines and a Memorandum of Agreement on how to proceed prior to any type of seafloor disturbance. All parties involved (the lease operator, the MMS, the SHPO, and ACHP), must come to an agreement *before* the operator construction can proceed.

WHAT ARE SUBMERGED MAGNETIC ANOMALIES?

There is no way to know if a significant archaeological resource exists in a lease block if you don't look. Historical studies are limited in their usefulness. If the locations of historic shipwrecks are known at all, their positions are only accurate to within miles of their true location. As a result, electronic search techniques are required to locate potential archaeological resources. One of the principal instruments employed for this use is the proton magnetometer, which registers magnetic anomalies in the survey area. Magnetic anomalies are localized disturbances in the earth's magnetic field measured in units of nanoTeslas (nT) or, more commonly, gammas (γ). In Gulf waters, the normal, ambient field measures around 50,000 γ. Magnetic anomalies may be negative, indicated by a drop in the gamma count, positive, with a rise in the gamma count, or bipolar, indicated by both a rise and fall in the gamma count. The signature characteristics relate to the orientation of the object's magnetic pole to the sensor.

Magnetic Anomalies May Be Caused by a Variety of Sources, Both Natural and Man-Made

On the Outer Continental Shelf (OCS), broad, low-amplitude magnetic anomalies may result from buried fluvial channels whose fill exhibits magnetic properties different from the surrounding strata. *Methane seeps* also have been demonstrated to produce magnetic anomalies. Accumulations of pyhhrite and magnetite associated with these seeps have been shown to produce anomalies measuring 100 γ or more (Irion and Heinrich 1994).

By far the most common cause of magnetic anomalies on the OCS is *"modern marine debris,"* a fancy term for trash. A considerable amount of ferrous junk has wound up on the seafloor: steel cable, machine parts, steel belted radial tires, crab traps, refrigerators, and outboard motors to name just a few.

Why go to the trouble of looking for magnetic anomalies, then? As my colleague, Dr. Anuskiewicz, has pointed out, Federal law requires that the MMS consider the effect of any permit action on significant archaeological resources. One other possible cause of magnetic anomalies on the seafloor is *historic shipwrecks*. Historic shipwrecks can be a significant archaeological resource.

What makes historic shipwrecks important? The United States, as we know it today, would not have been possible without ships. Ships carried European explorers to our shores and provided the connective links of a developing nation. Over more than 200 years, they have fought our wars, carried our settlers, and transported our commerce. Now, most of our maritime traditions are lost and our historic ships have gone to the shipwreckers or sunk to the bottom of the sea. By preserving and studying shipwrecks, marine archaeologists hope to be able to reconstruct history and to understand better what life was like during the Age of Sail and the Age of Steam. Skillfully excavated, they tell us how our ancestors lived, how we came to be who we are today, and who we may become tomorrow. Our submerged cultural heritage is a national treasure we must protect so that we, in turn, can pass these resources to future generations for their enjoyment and education. By identifying historic shipwrecks in the remote sensing record, we are taking the first step, in conjunction with industry, towards preserving our national heritage.

Unfortunately, the magnetometer doesn't scream out "shipwreck!" Instead, it records numbers and squiggly lines; the job of the archaeologist is to interpret those numbers. Many attempts have been made to characterize the types of magnetic signatures made by shipwrecks. Clausen (1966) and Clausen and Arnold (1975:169) suggested, in an examination of early sailing vessels in Florida and Texas, that their signature consisted of "a central area of magnetic distortion characterized by a number of intense and generally localized anomalies surrounded and, depending upon the depth and dispersion of the wreck, sometimes, interspersed by scattered, smaller magnetic disturbances." Later work by Watts (1980) demonstrated that shipwreck sites can generate minimal signatures, producing broad-based, 20-gamma anomalies. A magnetic survey of known eighteenth-century ferries in the Cape Fear River near Wilmington, North Carolina, produced no reliably detected signature (Watts 1983).

Studies conducted on vessels dating after 1850 suggest that large ships of this period generate magnetic disturbances in excess of several hundred gammas. Work on iron or steel hulled ships of the Civil War period by Watts (1975), Cussler (1981), Irion (1986), Garrison and Anuskiewicz (1987), and Arnold and Anuskiewicz (1995) indicate that such vessels produce a signature that is bi-polar or multi-component in excess of 1,000 gammas. Efforts directed at groundtruthing similar anomalies in Mobile Bay revealed that modern debris can generate virtually identical signatures (Irion and Bond 1984, Irion 1986). Archaeological groundtruthing on the Tombigbee River (Saltus 1976, Murphy and Saltus 1981); on the Elizabeth River, Virginia (Watts 1982); in Mobile Bay (Irion and Bond 1984, Irion 1986); and in Matagorda Bay, Texas (Arnold 1982) established that, while there are characteristics that can be associated with various types of shipwreck sites, it is impossible to identify them on the basis of magnetic signature alone. Watts (1986:14) observed that "the remains of vessels can be demonstrated to generate every type of signature and virtually any combination of duration and intensity." Given our inability positively to identify shipwrecks from magnetometer records, industry is left with several options in order to comply with the National Historic Preservation Act.

OBJECTIVES

Should the Oil and Gas Industry Avoid or Test Unidentified Magnetic Anomalies?

This is very interesting question. First of all, when Dr. Irion and I do our archaeological review and make a mitigative recommendation, these recommendations are always posed by us to provide options. The archaeological resource management program at the MMS never makes a decision "for" the operator. We provide options. These options are (1) avoid the anomalies by re-engineering, (2) groundtruth the anomalies by using divers, or (3) don't construct the project.

Relocate Anomalies on the Seafloor

Relocating unidentified magnetic anomalies recorded on or below the seafloor can be a difficult task. However, with the present state of technology transfer, high-tech magnetometer surveys are becoming commonplace and the use of Differential Global Positioning Systems technology is becoming the rule rather than the exception. Geophysical companies are able to navigate and produce a post-plot map accurately, and when called upon, go back into the field to relocate targets.

Determine If Seafloor Magnetic Anomalies Are "Significant" Archaeological Site

The ultimate goal of an MMS mitigative recommendation is to have the operator or his representative determine if the unidentified magnetic anomaly is a significant archaeological site. The very over-simplified answer to this question is two-fold: (1) put your hands-on the anomaly and tell the MMS what it is, or (2) explain away why you can not find the anomaly.

Once a determination has been made as to the source of magnetic disturbance, an intelligent and cost-effective solution can be made on how to proceed. If the anomaly or cluster of anomalies are modern marine debris, this site is cleared archaeologically. However, if the divers determine the anomalies are suggestive of a historic period shipwreck and the operator wants to proceed, additional surveying and testing will be required. If this site is determined to be significant, the consultation process must begin between the SHPO, ACHP, the MMS and the operator along with an memorandum of agreement to how to proceed signed by all parties. This process and site clearance is very expensive and could take 12 to 18 months.

TODAY'S SITUATION

Engineering Completed Prior to Groundtruthing May Preclude Avoidance

Looking at today's situation with respect to Dr. Irion's and my observations of commercial divers trying to do archaeology under water, we see several problems and we can offers a few solutions. When the MMS archaeologists get the archaeological report and a copy of the proposed pipeline construction route, the project is already designed. Our review and recommendations are based the geophysical report. There is generally no lead time for consultation if a potential problem is identified. I don't know how many times I have been told that the operator has a pipeline construction barge on site standing by "ready to go." There is no additional time built into this scenario to do anything except construct. Solution: get the archaeological survey reports to us as soon as they are completed and written. Therefore, if a problem develops the operator will have time to re-engineer or spend the appropriate amount of time, technology, and man-power to clear or mitigate a site.

Anomalies Aren't Being Found

Once we make mitigative recommendations and the operator or his representative hires a commercial diving company, the majority of the unidentified magnetic anomalies recorded during the survey are simply not being found. It has been my personal observation that there are serious problems with the current state of the art used by some commercial diving companies when it comes to the search methodology deployed groundtruthing operations.

Projects Are Not Proving "No Adverse Effect"

When these anomalies are not found another problem arises. There can not be a determination of "No Adverse Effect" issued to clear to site. The compliance process breaks down.

Federal Obligations Are Not Being Met

What Happens When the Compliance Process Breaks down? Federal obligation are not met. If "significant," and the key word here is "significant," archaeological resources are injured or destroyed because of construction, and there is the potential for law suits and heavy fines by the Federal Government.

Construction Is Being Delayed and Money Is Being Wasted

What else would happen? Well, construction would be delayed and project costs would go up or, in the worst case, the project could be canceled. The bottom line is that lots of time and money would be wasted paying lawyers and federal fines.

WHY AREN'T ANOMALIES BEING FOUND?

Given the present situation and the available technology, why aren't anomalies being found? To try to come up with an answer, let's look at a worst case scenario. Brand X Oil Company wants to lay a pipeline from Well A to shore. They contracted the Acme Survey Company to run a shallow hazards and archaeology survey. After reviewing Acme's report, the MMS recommended that they avoid or test a cluster of five anomalies on or near the centerline of Brand X's proposed pipeline. Months later, Brand X has completed its engineering and is ready to lay pipe when they call their diving contractor to tell them to jump divers on the five anomalies. Acme Survey is no longer doing Brand X's positioning, so they call Big Easy Survey to position the dive boat. They, in turn, call a contract archaeologist to meet the diveboat at Fourchon at dawn. As the diveboat steams out to the site, the dive master learns for the first time that his crew is doing archaeological, not hazards, testing and the Big Easy Surveyor scrambles to scale off a coordinate from the Anomaly Map provided in Acme's report. By the end of the day, the divers have gotten one hit on their gradiometer, but could not tell what caused it because the bottom was too hard to drive in their rebar probe. Despite a good effort by the divers, they have found no evidence of the other four anomalies at all. What went wrong?

Positioning Errors

We suspect that positioning errors may account for some, if not most, of the problem. Most survey companies are using DGPS for their positioning, which is accurate to within 5 m. However, that position is good for the location of the antenna mounted on the ship. While positions are corrected for sensor layback, there are bound to be some inaccuracies that creep in from the scope of the cable, the effects of current, etc. In addition, survey is conducted *at most* at 50 m intervals. The actual location of the source of the anomaly easily could be 75 feet away. Complicating the picture even further, in the example cited above, the survey company only had a map to go by and had to scale off a position. With the map scale at 1 inch = 1,000 feet, it would be very easy to be off by several tens of feet. To overcome this deficiency, MMS will soon be requiring that Lat/Long positions of magnetic anomalies be supplied in reports. Also, when the Big Easy Survey Co. returned to the position, their DGPS position also was accurate to within 5 m, but it could have been 5 m in the opposite direction from Acme's unit. I think you can begin to see that all these slight inaccuracies add up to the point that when the diver jumps into the water, it would be nothing short of a miracle if he landed anywhere close to the target.

Search Methods

Positioning problems are complicated further by the search methods employed on the seafloor. Because most commercial dive companies practice liveboating, and all commercial divers are on surface supplied air with an umbilical from the dive platform, their search pattern has generally consisted of a "spoke" pattern rather than the circle search recommended by the MMS. The circle search admittedly was designed for implementation by two divers on SCUBA and did not take into account the problems that created for commercial divers. The problem with the spoke pattern, however, is that there are huge gaps in the coverage of the seafloor, particularly towards the outer ends of the "spokes." The circle search pattern offers better coverage, but is difficult for one diver to do on an umbilical, dangerous when liveboating, and creates problems in using a gradiometer to detect the anomaly source on the bottom by inducing false anomalies when the sensor changes orientation.

Detection Equipment

This leads to another potential problem, which is that of equipment selection. We frequently have found that poor communication between all the different parties has resulted in the dive company being ill prepared when they go into the field. They often may not be aware of the day's task until some unsuspecting archaeologist shows up at the dock or is picked up off a rig. As a result, they probably don't have the specialized equipment to do the job. Who can blame them for being less than pleased? It's embarrassing to the divers, wastes time and money, and creates resentment all around. At a minimum, the following equipment should be on board:

- DGPS positioning
- a magnetometer
- a gradiometer
- a metal detector
- a ten-foot steel probe
- a water jet, airlift, or hand-held dredge
- a non-ferrous weight for the anomaly buoy anchor

Not Enough Bottom Time

A fourth problem may result from the amount of time spent looking for anomalies. The assumption has been in the past that it should take no more than an hour to an hour and a half to locate an anomaly source. If the diver drops on the position and spends this much time probing the spoke pattern and nothing is found, the target is written off. We expect that some anomalies may be found in an hour; others may take longer.

Procedures Not Being Followed

One major problem we have observed is that MMS procedures for locating anomalies are not being followed. These procedures were developed over the course of hundreds of hours under water refining techniques to locate and test magnetic anomalies, and have proven to be effective under the conditions prevalent on the OCS. The bottom line is that diving projects that fail to locate the source of a recommended anomaly and cannot:

a prove that the anomaly no long exists,
b. prove that the anomaly is too deeply buried to be disturbed, or
c. prove that the anomaly is an isolated point source too small to be significant have not complied fully with recommended MMS procedures and are not in compliance with MMS permit requirements.

Original Assumptions That Are No Longer Valid

As it presently stands, certain invalid assumptions have guided the testing of anomalies by commercial diving companies. These are:

1. The position provided in the report is the precise location of the anomaly source.
2. Any piece of metal, no matter how small, found on the seafloor caused the anomaly, no matter how big.
3. If we can't find the anomaly in an hour, its not worth finding.

Much of the problem can be summarized in the adage: "*You Can Teach an Archaeologist to Dive Quicker Than You Can Train a Diver to be an Archaeologist.*" This is by no means meant to put down the efforts of commercial divers, but rather to reflect a difference in training, orientation and approach to this particular, specialized mission. Where commercial divers are trained to perform complex tasks under water, underwater archaeologists are taught to solve a problem. Grounded in the issues of what constitutes an historic site, how magnetic amplitudes relate to physical mass, how clusters of anomalies may relate to one another and what patterns have been observed on other shipwrecks, archaeologists are better prepared to direct this effort than dive supervisors.

AVAILABLE OPTIONS

What Then Are the Available Options for Operators on the OCS?

Commercial diving companies: They clearly have a long and successful record of working with the oil and gas industry and are experienced in oilfield conditions. They generally are on site for other inspection or construction purposes and can *mobilize quickly*. However, they generally are *inexperienced in archaeological methods* of search and excavation, and simply don't know what to look for when it comes to distinguishing a significant archaeological site.

Consulting Archaeologists: These individuals are trained archaeologists who are *experienced in identifying archaeological resources* and are *experienced in methods of search and excavation*. To employ these firms, however, probably would require more pre-planning on the part of the operator. They would require *more advance notification* to mobilize and schedule, they may be *more restricted by weather* or environmental conditions and they probably are *limited by vessel availability*, since none of these firms is large enough to own their own ship for offshore work.

Based on our analysis, the costs should be about the same between the two groups.

RECOMMENDATIONS

Work More Closely with Archaeologists

This would include better pre-dive coordination between the operator, the survey company, the consulting archaeologists, and the MMS. The MMS requires a two-week notification to the Field Operations coordinator prior to initiating diving operations. We also encourage pre-dive coordination between the consulting archaeologist and the MMS archaeologists and also welcome calls from the field over developing issues or concurrence with findings.

Improve Positioning

One problem in the past has been that anomaly locations were provided to the MMS in the form of line numbers and shot points. Many survey companies now are providing us real world coordinates. Soon, we will begin requiring these data so that there is no question about the starting point for the search.

Use a Stable Work Platform

If possible, we encourage the use of an anchored vessel or barge. Liveboating procedures are not really appropriate to this mission and hamper search methods.

Improve Search Procedures

Alternatives to the spoke search pattern should be employed. Earlier, we reviewed the effectiveness of the spoke method versus the circle search method. Other methods could be tried including the square search and the sweep method.

Make Sure You Have the Proper Equipment

Again, coordination is the key to a successful mission. The proper search equipment must be on board. You MUST be able to re-find the anomaly location on the seafloor and I think it is safe to assume that the coordinate you have in front of you probably is NOT the precise location of the target. Before putting divers in the water, it is a good idea to run a mini-magnetometer survey over the area to refine the target location. You may even find that the anomaly has been moved by storms or shrimp trawlers and is no longer a concern. When the divers go in the water, they must have some sort of detecting device, either a gradiometer or metal detector to guide the probing effort. You should all also be aware of a new diver-held cesium magnetometer leased and sold by Geometrics, Inc. We hope to test the effectiveness of this device for use on the OCS. In addition, the divers should have access to some sort of hand-held excavation device, either a water jet, air lift, or dredge, in the event that the anomaly is buried and can not be delineated with a probe.

Take the Time Necessary to Do the Job

Finally, it is absolutely necessary to take the time to complete the mission and to take a flexible approach in re-locating and testing the anomalies.

WHEN IS THE JOB FINISHED?

The Job is Finished When the Archaeologist has determined that the proposed project will have: "*No Adverse Effect!*"

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Richard (Rik) J. Anuskiewicz was awarded his B.A. in 1972 and his M.A. in 1974 in Anthropology, with specialization is archaeology from California State University at Hayward. He was employed with the U.S. Army Corps of Engineer Districts of San Francisco, Savannah, and New England Division from 1974 to 1984, as a terrestrial and underwater archaeologist. Since 1984 he has worked at his present position with Department of the Interior, Minerals Management Service, Gulf of Mexico Region as a marine archaeologist. Dr. Anuskiewicz received his Ph.D. in 1989 in anthropology, with specialization in marine remote-sensing and archaeology from the University of

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Dr. Jack B. Irion joined the Minerals Management Service, U.S. Department of the Interior, in August, 1995, with the title of marine archaeologist. He received his B.A. (1974) and M.A. (1977) in archaeological studies from The University of Texas at Austin. He was awarded his Ph.D. from the Institute of Latin American Studies of the University of Texas in 1991. During his career, Dr. Irion has specialized in conducting remote sensing surveys for shipwrecks, which succeeded in locating such historically significant vessels as the C.S.S. *Louisiana*, the sailing barque *Maxwell*, and the steamboats *Princess*, and *Kentucky*. In addition, he has directed numerous diving investigations on historic shipwrecks, including most recently the steamship *Columbus* and the Civil War gunboats *Tawah* and *Key West*.

SESSION 6C

THE MINERALS MANAGEMENT SERVICE'S MARINE MINERALS PROGRAM: STATUS AND TRENDS, REGULATORY CLIMATE, AND ENVIRONMENTAL STUDIES, PART II

Session: 6C - THE MINERALS MANAGEMENT SERVICE'S MARINE MINERALS PROGRAM: STATUS AND TRENDS, REGULATORY CLIMATE, AND ENVIRONMENTAL STUDIES, PART II

Co-Chairs: Mr. Barry Drucker and Mr. Don Hill

Date: December 14, 1995

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Northeast Gulf of Mexico Hard Mineral Resources Study	Dr. Mark R. Byrnes Mr. Randolph A. McBride Coastal Studies Institute Louisiana State University
Investigation of Benthic and Surface Plumes Associated with Marine Aggregate Production on the United Kingdom: Overview of year One	Mr. David R. Hitchcock Coastline Surveys Ltd, Bridgend, England Dr. Mike P. Dearnaley HR Wallingford Ltd, Wallingford, England
Marine Mining Technology and Mitigation Study	Dr. Derek Ellis University of Victoria Victoria, B.C., Canada
Living with a New Law	Mr. LeRon E. Bielak Minerals Management Service Office of International Activities and Marine Minerals Herndon, Virginia
The Permitting Process for Minerals Other than Oil, Gas and Sulphur in the OCS	Mr. Jerry Brashier Mr. G. Ed Richardson Mr. Ronald J. Brinkman Minerals Management Service Gulf of Mexico OCS Region

SHIP SHOAL WAVE CLIMATE MODELING AND EVALUATION

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INTRODUCTION

Recently there has been significant interest in the potential use of clean quartz sand comprising Ship Shoal off the Louisiana coast as a source for beach replenishment along the rapidly eroding Isles Dernieres barrier system (Figure 6C.1). Preliminary work (Byrnes and Groat 1981) contracted by the U.S. Minerals Management Service demonstrates that such an undertaking is both technically and economically feasible.

The degree to which Ship Shoal mitigates the wave climate along the Isles Dernieres has not yet been established. Consequently, the potential impacts associated with large scale extraction of sediment from Ship Shoal should not be attempted prior to a detailed evaluation of the wave and current field in this area. Specifically, a combination of wave and current data obtained from *in situ* measurement and numerical modeling is necessary to understand more completely the effects of Ship Shoal on the wave and current field. In this paper we present preliminary data obtained from the first phase of this project which concentrates on numerical modeling of wave propagation across the section of shelf incorporating Ship Shoal and the nearshore region flanking the Isles Dernieres.

CONCEPTUAL FRAMEWORK

It is now well established in the literature that the barrier islands comprising the Isles Dernieres have been experiencing among the highest rates of shoreline retreat in the United States (McBride *et al.* 1992; Stone and Penland 1992; Williams *et al.* 1992). As summarized in Figure 6C.2, the primary factors responsible for deterioration of these islands includes (1) eustatic sea-level rise; (2) compactional and geological subsidence; (3) wave erosion; (4) wind deflation; (5) reduction in sediment supply and (6) anthropogenic activity. Historical erosion rates along the Isles Dernieres ranged from 4.8 m/yr. (East Island) to 22.9 m/yr. (Wine Island) over the last century or so (McBride *et al.* 1992). Recent evidence indicates an apparent acceleration in erosion, approximating 213% over the last decade (Williams *et al.* 1992). Based on these data, it is estimated that several of the islands will disappear within the next decade or two (McBride *et al.* 1992). Given the recent impact of Hurricane Andrew along this coast (Stone *et al.* 1993; Stone *et al.* 1995; Grymes and Stone 1995), it is highly probable that this time period is less.

With the denudation of barrier systems, it is likely that mainland shoreline erosion and wetland loss will occur in response to a more energetic, local wave field (Penland and Suter 1988; McBride *et al.* 1992)—although the critical links have not yet been fully investigated (List and Hansen 1992). Recent data indicate that land loss in the Terrebonne Bay area averaged 0.86 km^2/yr. between 1932 and 1990 (Britsch and Dunbar 1993). Although preliminary, work carried out by van Heerden *et al.* (1993) indicates a large scale relationship between degradation of the Isles Dernieres, increasing tidal prism, and, subsequently, enhancement of wetland loss.

The work of van Heerden *et al.* (1993) indicates that approximately 15.3 million cubic yards of sand would be required to restore the Isles Dernieres to a configuration similar to that of the mid 1800s. Their work indicates that with such a configuration, there will be an increase in wetlands of 30,000 acres, in addition to reductions in salinity, tidal current velocity and shoreline erosion. Several studies, funded largely by MMS' Continental Margins Program, have indicated the potential use of Ship Shoal (Figure 6C.1) as a source of clean quartz sand (approximately 1.2 billion cubic meters) for beach nourishment along Isles Dernieres (Mossa 1988; Suter *et al.* 1989). Although dredging of the material appears both technically and economically feasible (Byrnes and Groat 1991), a detailed evaluation of the potential impacts associated with such an undertaking has not yet been undertaken. The preliminary data presented here builds on the findings of Mossa (1988) and Byrnes and Groat (1991) concerning the impact of dredging portions of Ship Shoal on wave refraction patterns and qualitative assessments of the resultant wave energy distribution along the Isles Dernieres.

METHODOLOGICAL APPROACH

Wave Models

Models of two different scales are used to provide the wave characteristics in this study. Firstly, a large-scale

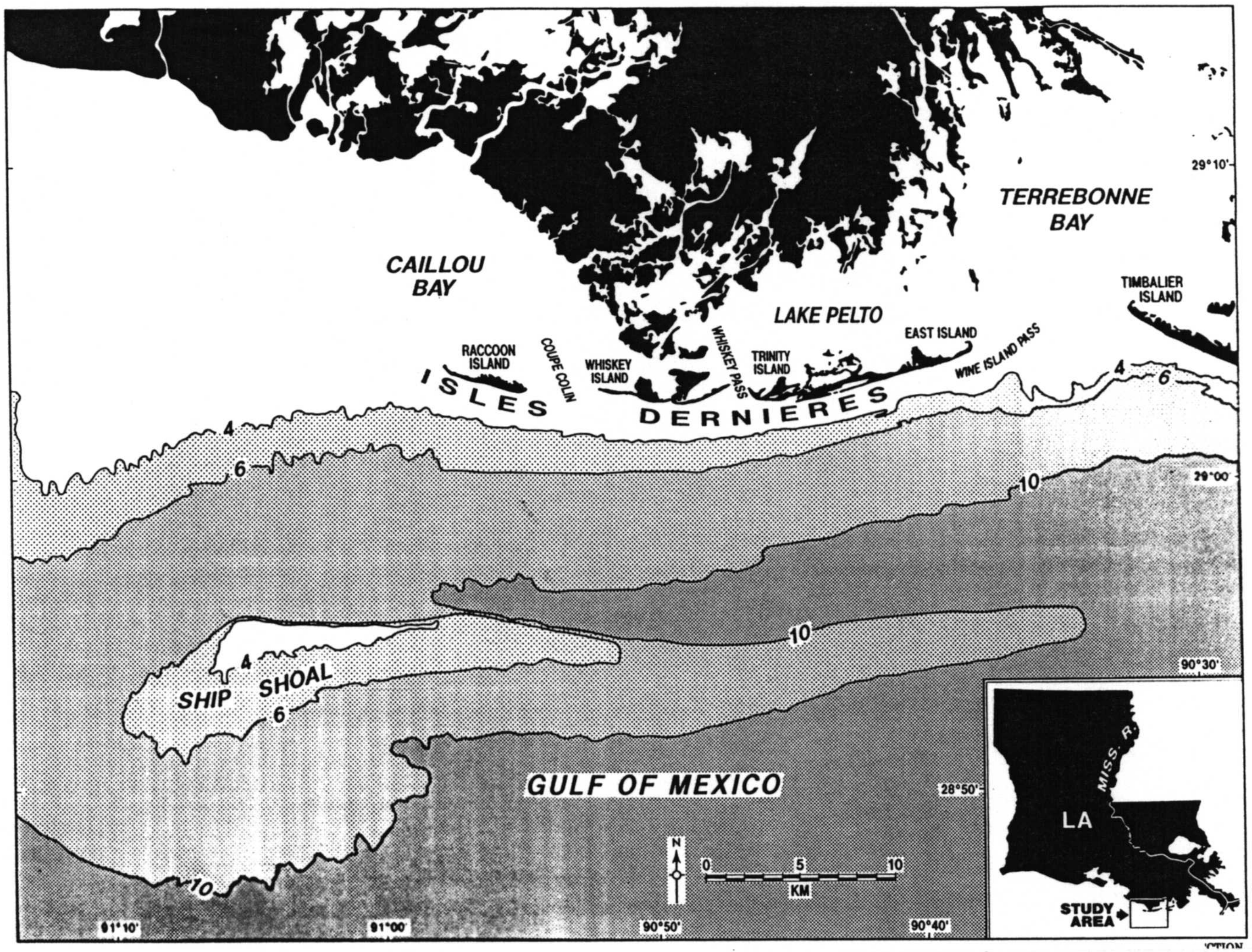

Figure 6C.1. Map of the study site with Ship Shoal outlined by the 4-, 6- and 10-m isobaths.

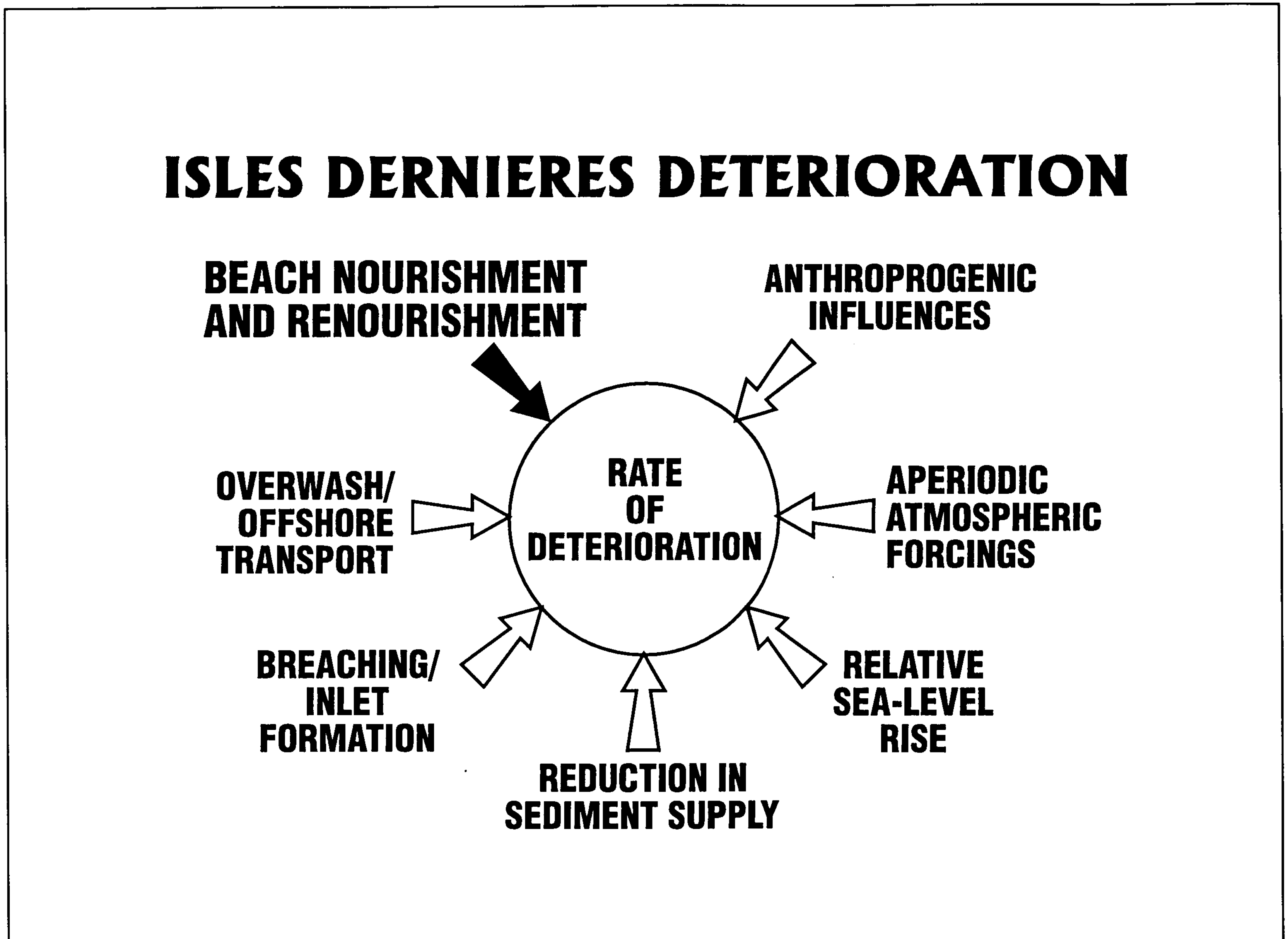

Figure 6C.2. Significant factors associated with deterioration of the Isles Dernieres, Louisiana.

Table 6C.1. Characteristics of the two wave models.

	STWAVE	REF/DIF S
Representation	Global	Local
Efficiency	High	Moderate
Accuracy	Documented Yes[1]	Documented Yes[2]
Spectral Capability	Yes	Yes
Grid Size Requirement	Δx<0.5 L Recommended[3]	Δx<0.2 L Required[4]
Breaking Criteria	Resio(1987)	Thornton and Guza(1983)
Wind-Wave Generating	Yes	No

1 - Kraus *et al.* 1994
2 - Vincent and Briggs, 1989; Berkhoff *et al.* 1982
3 - Dr. Don Resio, personal communication, 1995
4 - Kirby and Ozkan, 1994

(or global scale) wave model (STWAVE) propagates deepwater waves across the south-central Louisiana shelf into shallow water. A local wave model (REF/DIF S) is then applied to provide higher resolution information (e.g. wave breaking) that enables calculation of nearshore wave statistics at a scale useful for smaller scale problems. The two models introduced below are the representatives of the large scale and local scale wave models respectively. Their major characteristics are listed in Table 6C.1.

STWAVE Model

STWAVE is a finite-difference model for near-coast time-independent spectral wave energy propagation simulations (Cialone *et al.* 1992). It is based on a simplified spectral balance equation

$$\frac{\partial}{\partial x}\left(CC_g E(f,\theta)\right) + \frac{\partial}{\partial y}\left(CC_g E(f,\theta)\right) + \Sigma S_i = 0$$

where

$E(f,\theta)$ = spectral energy density
f = frequency of the spectral component
θ = propagation direction of the spectral component
S_i = Sources or Sinks

STWAVE simulations require a wave energy spectrum specified for the input boundary of the computational grid. The model transforms the spectrum across the grid, including refraction and shoaling effects. The spectrum is modified to include the effects of diffraction and the convergence/divergence of energy influenced by the local bathymetry. Wind-wave generation, nonlinear energy transfer, wave field, wave-bottom dissipation and wave breaking are considered. The model is computationally efficient because of its relaxing requirement of the grid size (relative to the wave length) and assumption that only wave energy directed into the computational grid is significant, i.e., wave energy not directed into the grid is neglected. STWAVE has been successfully used in several projects (Kraus *et al.* 1994; Dr. Resio, personal communication, 1995).

REF/DIF S Model

REF/DIF S (Kirby and Ozkan 1994) is a weakly nonlinear combined refraction and diffraction model that simulates the behavior of a random sea over irregular bottom bathymetry, incorporating the effects of shoaling, refraction, energy dissipation and diffraction. It includes most features presented in the model REF/DIF 1 (Kirby and Dalrymple 1993) and can, therefore, be used to model the behavior of monochromatic waves.

REF/DIF S is used with two-dimensional wave spectra. The input frequency spectrum in conjunction with a directional spreading function are divided into discrete wave components characterized by a certain frequency and direction. REF/DIF S has the ability to stack parabolic models for the individual wave components, propagating them simultaneously through the domain by solving the governing parabolic equation:

$$+2k(k\,k_0)CC_gA+i(kCC_g)_xA+(CC_gA_y)_y-k(CC_g)$$

where (x,y) are horizontal coordinates, A is the wave amplitude, k_0 is a reference wavenumber related to the initial conditions of the incident wave, C is phase speed, C_g is group velocity, and

$$K'=k^3\left(\frac{C}{C_g}\right)\frac{\cosh 4kh+8-2\tanh^2 kh}{8\sinh^4 kh}$$

After each step, the complex amplitudes for all wave components are known and the significant wave height ($H_{1/3}$) can then be computed in the following manner

$$H_{1/3}(x,y)=\sqrt{8\sum_{n=1}^{N}|A(x,y)_n|^2} \qquad (4)$$

where N is the total number of wave components and $A(x,y)_n$ is the amplitude of the wave component *n*.

Wave Energy Dissipation Across the Shelf

A wave-energy dissipation model (WAVENRG) was used in this study to simulate wave propagation and decay across the Louisiana shelf during Hurricane Andrew. The model, written by May (1973) and modified by Stone (1991), applies linear wave theory to simulate the first order wave field across a bottom slope by computing wave refraction, shoaling and bottom friction. The theoretical derivation of the approach is discussed in Stone et al (1995).

INPUT DATA TO THE MODELS

Bathymetric Matrices

In order for the wave models to be appropriately used, bathymetric grid data and offshore wave input data are required. The computational grid was derived from digitizing nautical charts (National Oceanic and Atmospheric Administration charts) and field surveys conducted by the United States Geological Survey in 1984 and 1986 (List *et al.* 1994). The resolution of the grid depends on both the scale of the model and the resolution requirement of the project. In general, the grid size for STWAVE (global scale) is much larger than the grid size for REF/DIF S (local scale). The large grid used in STWAVE and WAVENRG has a dimension of 910 x 432 and grid size of 100 meters in both longitudinal and latitudinal directions. A smaller grid which is embedded in the large grid has a dimension of 390 x 270 and grid size of 22.5 meters in latitudinal direction and 125 meters in longitudinal direction. This smaller grid is used in REF/DIF S.

To quantify numerically the influence of Ship Shoal on the wave field, several simulations were conducted using bathymetric matrices with and without the shoal complex. Both computational grids were generated using Intergraph's Terrain Model. Based on the grid size requirement for the wave models, the Terrain Model provided a rectangular grid of variable size, ranging from meters (for local wave modeling) to kilometers (for global wave modeling).

Deepwater Wave Field

A second input to the wave models is the incident wave conditions at the offshore boundary. These input conditions include wave height, wave period, wave direction and the speed and direction of wind. A useful offshore wave and wind data source is the field measurements from NOAA's National Data Buoy Center's buoy array (Figure 6C.3). An example of NDBC buoy wave records is shown in Figures 6C.4 and 6C.5. The initial input data used in this paper are summarized in Figure 6C.6 and include significant wave heights of 2, 4 and 6 m, coupled with wave periods of 6, 9 and 11 seconds respectively. Deepwater wave conditions representative of Hurricane Andrew, which impacted the area in 1992, were used to examine abnormally high wave conditions. Significant deep-water wave heights ranged from 11 to 13 m and wave periods approximated 14 seconds (Stone *et al.* 1995).

RESULTS AND DISCUSSION

Output from the models indicate that on removing Ship Shoal from the inner shelf, no significant impact occurred on the nearshore wave climate along the Isles Dernieres. However, marked increases in significant wave height occurred in the shoal region after shoal removal, with wave heights increasing by 80% during

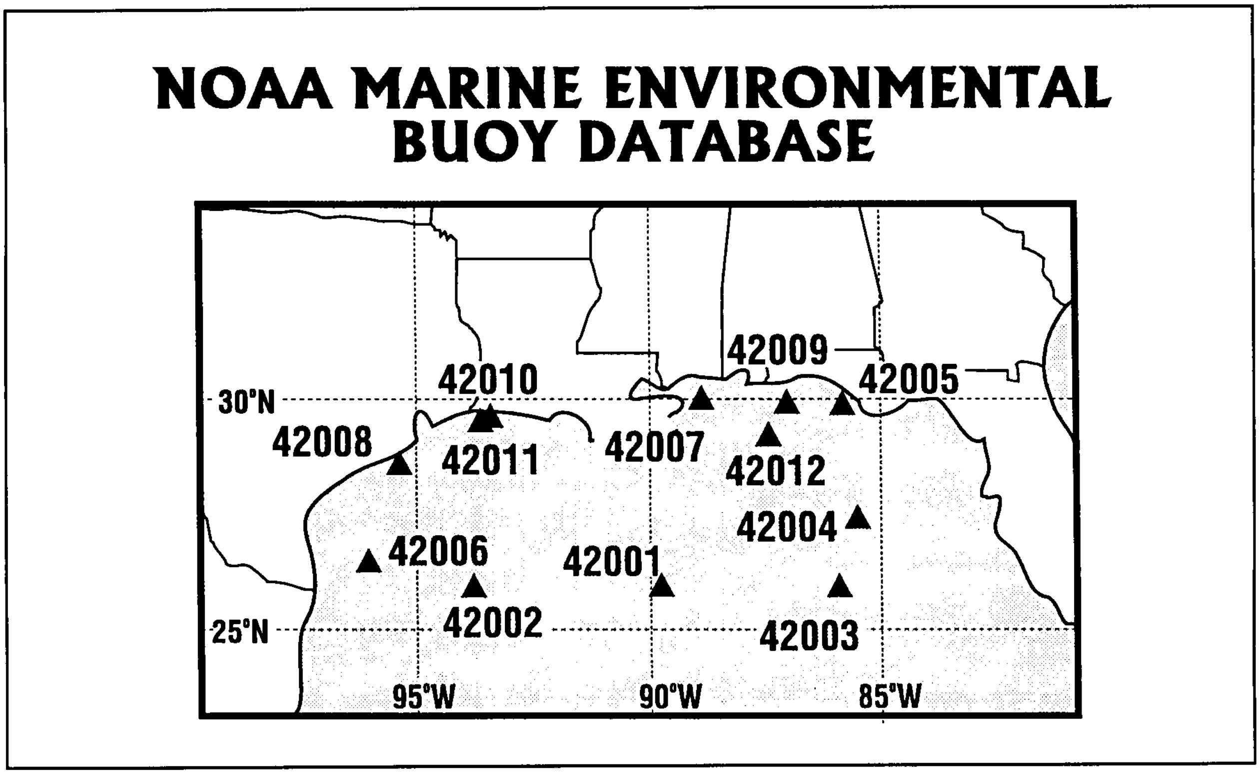

Figure 6C.3. Map of the Gulf of Mexico showing the distribution of buoys comprising the National Oceanic and Atmospheric Administration's environmental buoy database.

6 m deepwater wave heights, 40% for 4 m deepwater waves and <10% for 2 m waves. This trend did not differ for changes in deepwater wave approaches (southeast, south and southwest).

A two-dimensional distribution of wave energy dissipation across the shelf is shown in Figure 6C.7 for conditions representative of Hurricane Andrew. Wave energy dissipation became apparent in water depths of approximately 150 - 200m. The rate of wave energy decay (dE/dR) varied considerably across the shelf due to differential bottom slope-wave height effects. Given the significance of wave height in computing dE/dR, the distribution of both are plotted in Figure 6C.7 for two locations across the shelf; Ship Shoal and east of the Mississippi Canyon. Along the Ship Shoal transect, a large proportion of wave energy dissipation occurred approximately 100 km offshore reaching a peak near 5 jl m^{-3} in water depths between 25-30 m. Waves decreased in height to approximately 7 m and with additional shoreward propagation, continued to loose energy at a significantly slower rate. On moving across the Ship Shoal complex, the rate of energy decay increased from <0.5 jl m^{-3} to 2 jl m^{-3} before final peaking during breaking. East of the Canyon, the shorter, steeper nature of the shelf reduced its ability to absorb wave energy during shoreward propagation. Consequently, although the decay gradient is similar to that west of the Canyon, the peak decay value of 3 jl m^{-3} was significantly less and located considerably closer to shore—approximately 20 km offshore in 25-30 m of water. Prior to breaking, the energy dissipation rate decreased only slightly, resulting in considerably higher wave energy conditions along this portion of the coast than further to the west. Off the Isles Dernieres at Ship Shoal, total wave energy dissipation occurred although some lower amplitude waves crossed the complex and broke in water depths of approximately 1 m off Point Au Fer Island. Depth limited breaking of the long waves occurred in water depths between 1 and 4 m across the entire study area.

PRELIMINARY CONCLUSIONS

The data presented here are preliminary, and additional work is being conducted to refine the numerical models and input data. The data indicate that although the removal of Ship Shoal from the shelf results in a

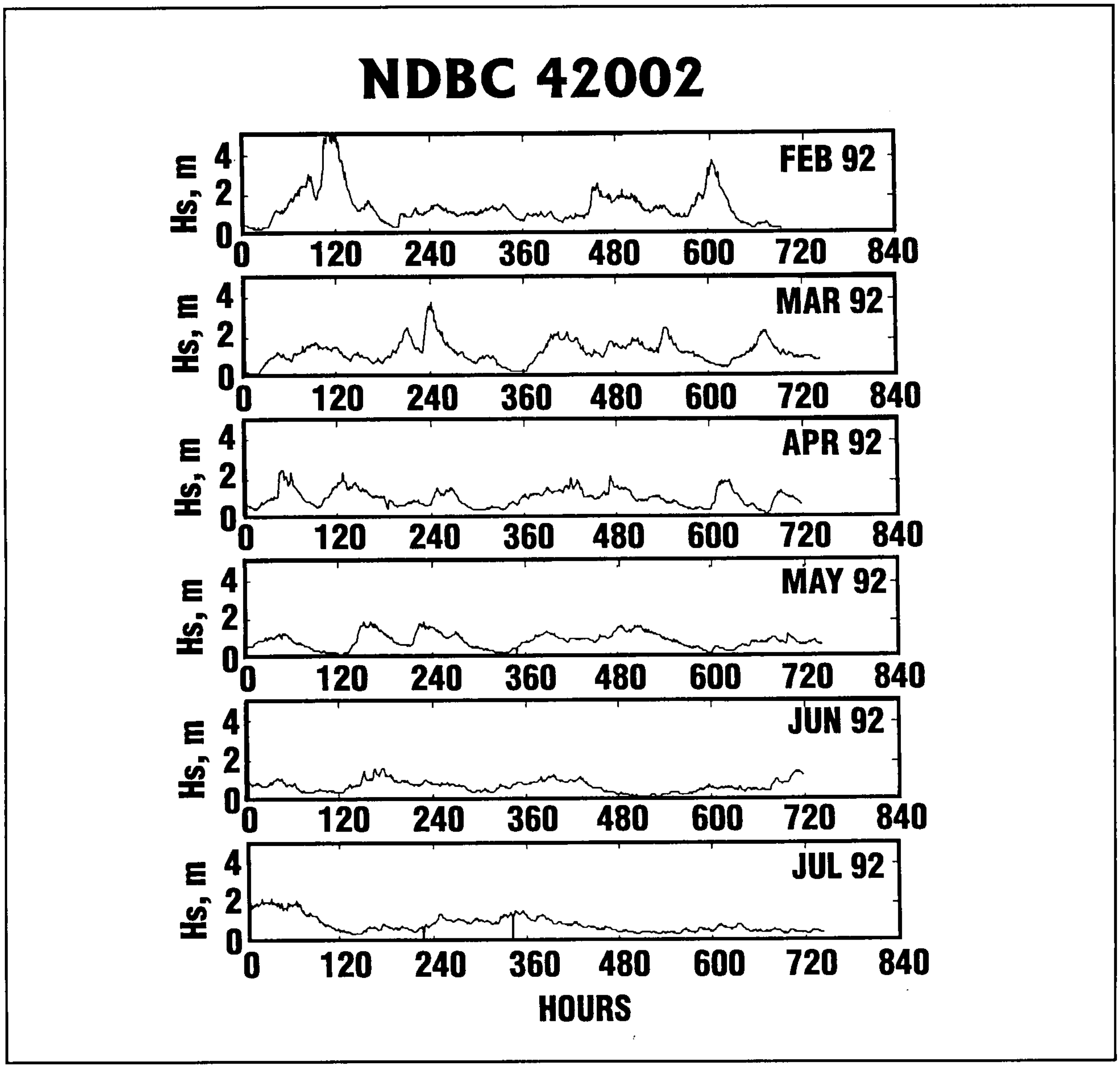

Figure 6C.4. Example 1: Time series of significant wave height (m) for a six-month period obtained from NDBC buoy 42002 used in this study as deepwater wave boundary conditions.

substantial increase in wave height of up to 80% during storm wave simulations (H_s = 6 m), this effect is localized to the shoal region and is not evident in the nearshore fronting the Isles Dernieres. This increase is reduced to <10% during less intense winter storms (Hs = 2 m). Model runs incorporating waves generated during Hurricane Andrew indicate that over 70% of the long wave dissipation initially occurred seaward of Ship Shoal in water depths ranging from 150-200 m. Wave energy dissipation rates peaked in water depths ranging from 25-30 m (100 km offshore) seaward of Ship Shoal.

ACKNOWLEDGMENTS

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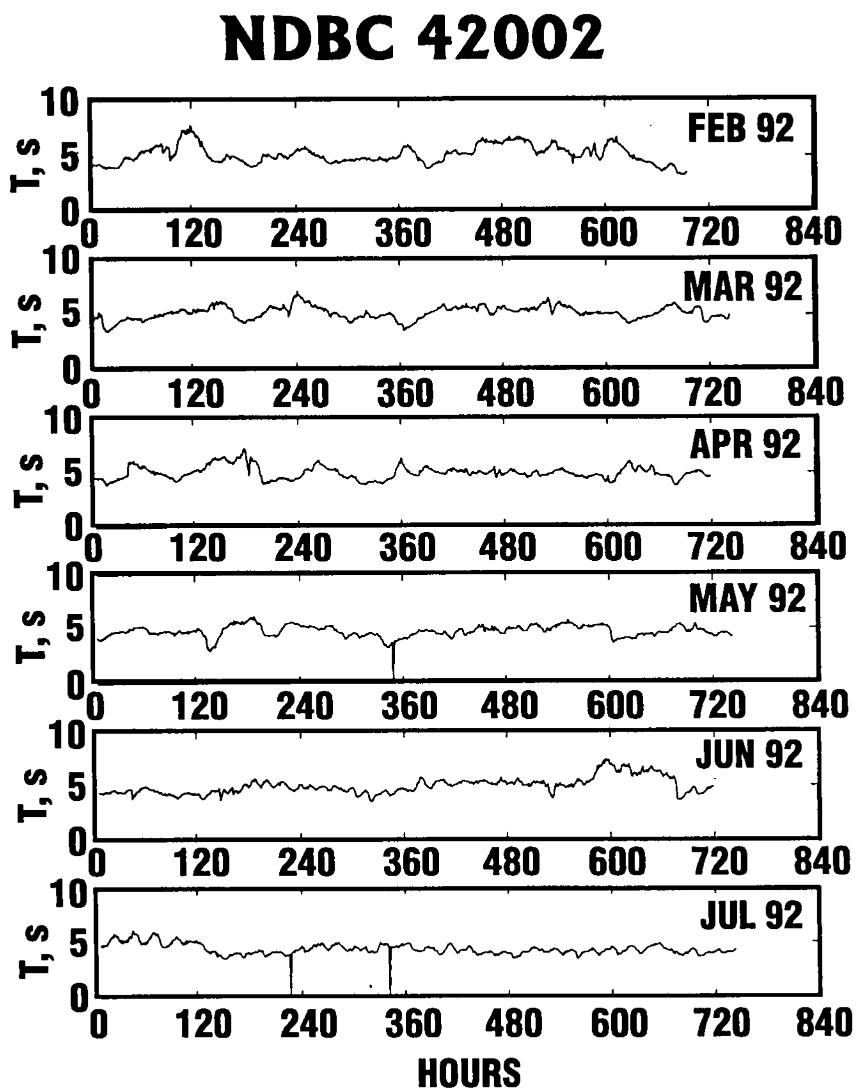

Figure 6C.5. Example 2: Time series of significant wave height (m) for a six-month period obtained from NDBC buoy 42002 used in this study as deepwater wave boundary conditions.

the U.S. Minerals Management Service (#14-35-0001-30660). Cartographic assistance was provided by Mary Lee Eggart, Clifford Duplechin and James Kennedy at LSU.

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DEEP WATER STORM WAVE CLIMATE		
H_s(m)	T_s(secs)	WAVE APPROACH DIRECTION
2	6	0 - FROM SOUTH
4	9	45 - FROM SOUTHEAST
6	11	-45 - FROM SOUTHWEST

BATHYMETRIC GRID
320 x 450 dx = dy = 100m

SHOAL REMOVAL
1.3×10^9 m^3 MEDIUM TO FINE SAND

Figure 6C.6. Deepwater storm wave climate used as input to numerical models.

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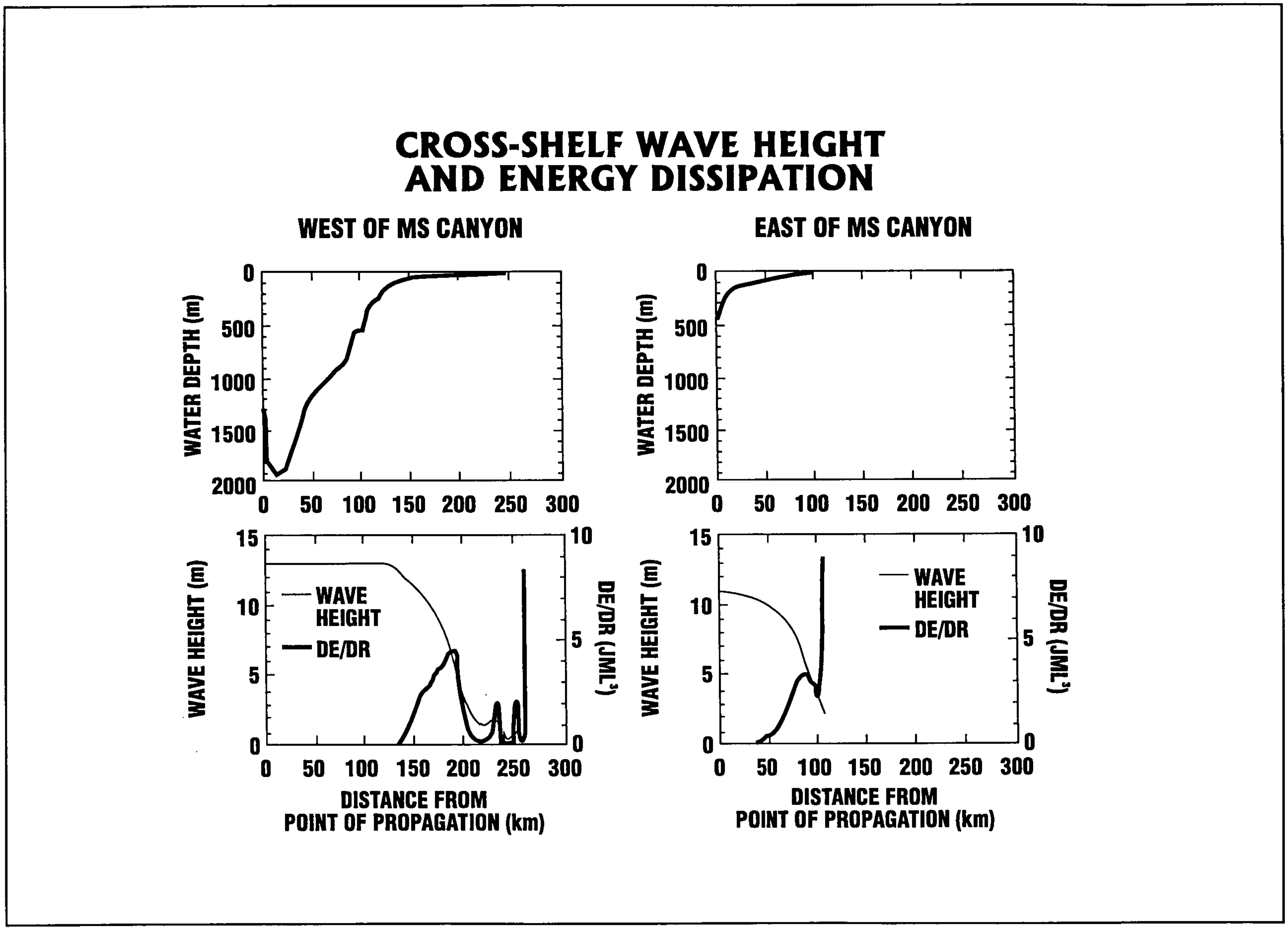

Figure 6C.7. Wave height energy relationships west of the Mississippi Canyon at Ship Shoal and east of the canyon adjacent the Caminada Moreau headland. The respective shelf profiles are shown for comparison.

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NORTHEAST GULF OF MEXICO HARD MINERAL RESOURCES STUDY

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INTRODUCTION

Coastal erosion is a serious and widespread problem of national importance with long-term economic and social consequences. Most shorelines around the United States are experiencing erosion in response to the latest rise in relative sea level (see Williams *et al.* 1991). Currently, 50% of the U.S. population lives within 75 km of the coast, and this is expected to increase to 75% by the year 2010. As the coastal population grows, so does the need for additional facilities related to community development and recreational activities, established within the framework of informed management and design decisions. This is especially true along the Gulf coast as our coastal population continues to grow and becomes increasingly dependent on the coastal zone. As such, government and industry interest in marine resource assessment and utilization has increased to address these concerns (Byrnes *et al.* 1991), and a critical need has developed for assessing the occurrence, quality, distribution, and geometry of hard mineral resources in coastal and continental shelf areas. To mitigate or control coastal land loss, nearshore hard mineral resources (sand, gravel, shell) are vital and a detailed inventory of these resources in the northeastern Gulf of Mexico is critical to meet the needs of Gulf states.

The northeastern Gulf of Mexico is faced not only with coastal erosion issues but also with the possibility of offshore lease areas on the Florida Panhandle continental shelf for oil and gas activities in the near future. As a result, the U.S. Minerals Management Service (MMS) requires environmental baseline information to make sound management decisions about this shelf region. This project specifically addresses hard mineral resource deposits located in the northeastern Gulf of Mexico. An understanding of the spatial distribution, geometry, quantity, and sediment dynamics associated with these deposits is critical to mitigating shoreline erosion, addressing industry needs for high-quality silica, and providing seafloor foundation information for placement of an offshore oil and gas infrastructure.

In order to develop a consistent regional understanding of hard mineral resources for the northern Gulf of Mexico, the LSU Coastal Studies Institute (CSI) has worked in the past with the Marine Minerals Technology Center (MMTC), the U.S. Geological Survey Marine and Coastal Geology Program (USGS), and others to test new exploration technologies, delineate surficial sediment distributions, and develop predictive depositional models for hard mineral resources (McBride *et al.* 1991; McBride and Moslow, 1991). As a result of funding from the MMTC and USGS, a large amount of geologic data was collected for the northeastern Gulf of Mexico including 130 vibracores (≤6 m long) and about 5,000 line-km of high resolution seismic reflection data (Figure 6C.8). This regional geologic data set was collected between 1981 and 1993 and covers coastal and shelf areas between the Chandeleur Islands, Louisiana and the Apalachicola Delta, Florida. The proposed study will further evaluate and synthesize these data with respect to hard mineral resource abundance, content, and geometry. Furthermore, to better understand the distribution of hard mineral resource deposits, an evaluation of historical shelf sediment transport processes will be assessed to develop a sediment budget. Where possible, identified data gaps will be filled using other existing geologic data collected in the study area, thus producing a comprehensive hard mineral resource assessment.

The proposed hard mineral resource assessment is expected to involve a three-year multi-disciplinary approach consisting of three primary scientific components: 1) marine geology, 2) benthic paleo-ecology (mollusks, foraminifera), and 3) physical oceanography. Specific application of data and results for this study can be tied to beach replenishment for shore erosion control, industrial uses of high quality quartz sand (e.g., glass, computer chips), baseline data for incorporation with the MMS physical oceanography initiative in the northeastern Gulf of Mexico, and potential placement of offshore oil and gas infrastructure relative to geologic hazards such as liquefaction and bedform migration.

PROPOSED PROJECT: PHASE I

The principal research goal of Phase I of this project is to produce regional baseline information about the hard mineral resources, geologic framework, and long-term sediment dynamics of the Florida Panhandle shelf (Mobile Bay, AL to Choctawhatchee, Florida). Specific research questions related to this goal include: 1) What are the primary sedimentary environments associated with hard mineral resource accumulation? 2) What are the main sediment transport pathways? 3) What processes control the spatial distribution, concentration, and geometry of hard mineral resources? 4) What is the role of long-term sea level change in controlling the occurrence of hard mineral resources? and 5) Do suitable quantities of economically viable hard mineral reserves exist for beach replenishment and other uses in the study area? To answer these questions, the following objectives will be addressed:

1. Quantify hard mineral resource deposits (i.e., grain size statistics, thickness, content, quality) using existing subsurface vibracores;
2. Establish the regional three-dimensional architecture of hard mineral resource deposits (i.e., geometry and spatial distribution) using existing high-resolution seismic reflection data, calibrated against the vibracore data set;
3. Produce seafloor elevation models (i.e., bathymetric surfaces) to determine volume change using historical hydrographic data;

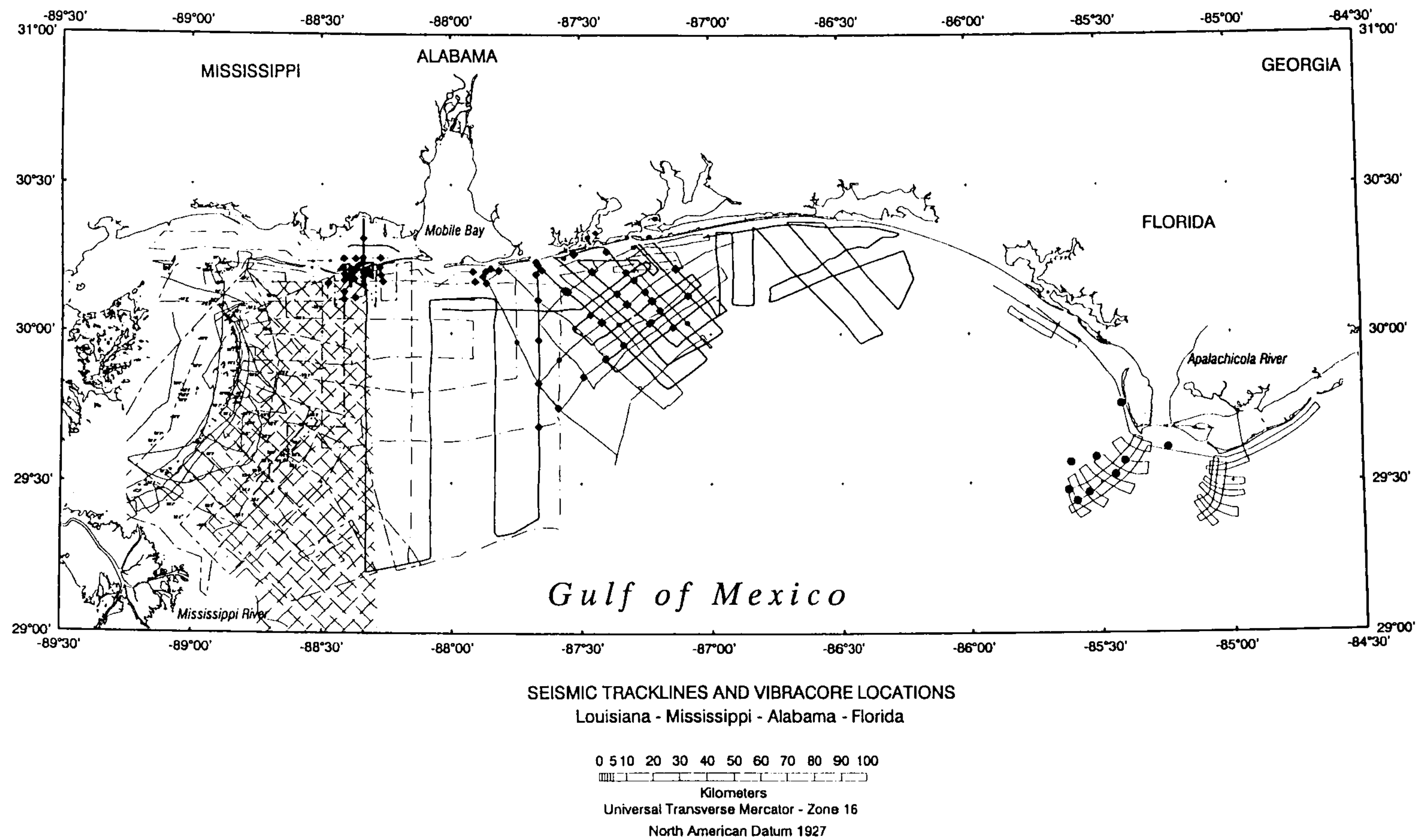

Figure 6C.8. Seismic and vibracore data collected between 1981 and 1993 for use on the proposed project.

4. Determine patterns and processes of long-term shelf sediment transport using bathymetric change data;
5. Integrate seafloor elevation models with geologic data to establish form-process relationships for continental shelf sediment deposits;
6. Disseminate research results in the form of professional presentations and journal articles;
7. Incorporate appropriate hard mineral resource data into CMI Gulfwide Information System.

METHODS

Developing a comprehensive understanding of form-process relationships in coastal and shelf depositional systems requires synthesizing geologic and geomorphic response data to evaluate the influence of dynamic controls versus inherited geologic framework (Riggs and Cleary 1993). The proposed research initiative is designed following this procedure. It is recognized that the information gained by analyzing seafloor elevation on the continental shelf can benefit greatly by incorporating knowledge of seafloor sediment characteristics and underlying geology. The most efficient and accurate way to approach this task is to adopt a strategy that utilizes computer mapping/GIS technology. GIS software will be used to integrate geologic and hydrographic data sets for evaluating the stratigraphy, evolution, and sediment budget of the shelf sedimentary system.

Geologic Data

Primary geologic data that will be used to evaluate hard mineral resources include existing marine-based vibracores and high-resolution seismic reflection data. One hundred and thirty vibracores were collected between 1987 and 1993 to calibrate acquired seismic data and provide sedimentologic samples for characterizing the stratigraphic signature of late Quaternary deposits. Six-meter-long vibracores (7.5-cm diameter) were drilled using a pneumatic vibrator attached to a submersible seven-meter-high steel tripod. The tripod was lowered to the seafloor and core tubes were vibrated into subsurface deposits the full six meters or until refusal. Refusal normally resulted when the bottom of the core barrel encountered shell beds or pre-Holocene deposits. Vibracores were collected in water depths ranging from 3 to 45 m.

Vibracore Analysis: Typical methods involved in vibracore analyses include core description, grain size analysis, biostratigraphic analysis (i.e., macrofossils), radiocarbon dating, isotope analysis, x-ray radiography, and sediment peels. Geologic cross-sections are constructed using core and seismic reflection data. Once calibrated using the core data, seismic profiles are interpreted to provide regional stratigraphic information on the geometry and spatial distribution of hard mineral resources. The incorporation of geologic data within a GIS using core and seismic interpretation software provides a four-dimensional perspective (time and space) of factors affecting erosion and deposition of the shelf surface. Grain size samples are typically collected at 25 cm intervals unless stratigraphic variability requires more sampling. Detailed grain size analyses (1.5 to 800 microns) will be performed using an AccuSizer 770 optical particle sizer. For grain sizes larger than 800 microns, a sonic siever by Gilson Instruments will be used. Size statistics (moment measures) will be computed using a PC-based computer program. Macrofaunal analyses will focus on shell beds and will provide information on sediment sources and processes of accumulation for hard mineral resources (i.e., sands). Radiocarbon dating and stable oxygen isotope analyses of pristine shells provide critical information on the absolute timing and duration of sand body accumulation.

Seismic Data Analysis: Approximately 3,500 line km of single-channel, high-resolution seismic reflection data were collected in the Phase I study area. Seismic coverage extends seaward from estuarine environments (3 m water depth) to the upper slope (~500 m water depth) (Figure 6C.8). The four seismic surveys utilized one or more of the following sound sources: sub-bottom profiler, uniboom, and bubble pulser. Seismic data will be interpreted based on the existing vibracore dataset as well as seismic stratigraphy principles based on techniques presented by Mitchum *et al.* (1977). Once calibrated, seismic data can be used to extrapolate between cores thus producing a three-dimensional architecture of the shelf depositional system. As a result, the geometry, thickness, and spatial distribution of hard mineral resources (e.g., relict fluvial channels, deltas, shore-oblique sand ridges, tidal inlet shoals, shelfbreak-parallel shoals) can be delineated.

Bathymetric Analysis: Three primary data sources are available for assessing changes in nearshore bathymetry. These include National Ocean Survey (NOS) hydrographic maps (H-sheets), digital bathymetric data from the National Geophysical Data Center (NGDC) which are derived from NOS surveys, and digital bathymetric data from other Federal agencies such as the US Army Corps of Engineers (USACE) and the US Navy. Primary data sources for the proposed study will be metric-quality maps from NOS to ensure data quality. However, other information will be considered when appropriate to meet the goal of the study.

Historical nearshore bathymetry data provide a means of analyzing local and regional sediment transport patterns associated with shoreline change and shoal movement on the inner shelf. Until recently, descriptions of temporal bathymetric change using contour overlays was the principal method for assessing change. However, modern computational techniques for digital representation of earth surface characteristics are accomplished using surface modeling routines or gridding algorithms (e.g., Byrnes and Hiland 1994). Digital elevation modeling software will be used to compare spatial and temporal changes in shelf bathymetry and to produce volumetric changes. This analysis provides a mechanism for evaluating the sediment budget in the study area and documenting historical shelf sediment dynamics (Byrnes and Hiland 1995).

RELEVANCE

Information produced by this project will include a geologic characterization of shelf sediment deposits and their relationship to shelf and shoreline sediment dynamics, all within the context of the regional sediment budget (i.e., assessing sediment source). The procedures used and purpose for the study are very similar to those applied at Ship Shoal, offshore Louisiana (see Byrnes *et al.* 1991). However, greater emphasis will be placed on linking shelf sediment dynamics with shallow subsurface data for developing an understanding of long-term sediment transport patterns associated with hard mineral resource deposits. Ultimately, a hard mineral resource inventory will be produced for incorporation within the CMI Gulfwide Information System for government and industry needs (see Congressional resolution PL-103-426, OCS sand, gravel, and shell resources). Specific application of data and results from this study can be tied to beach replenishment for shore erosion control, industrial uses of high quality quartz sand (e.g., glass, computer chips), baseline data for incorporation with the MMS physical oceanography initiative in the northeastern Gulf of Mexico (see Clark 1994), and potential placement of offshore oil and gas infrastructure relative to geologic hazards such as liquefaction and bedform migration (derived from evaluation of seafloor dynamics and subsurface geologic characteristics).

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INVESTIGATION OF BENTHIC AND SURFACE PLUMES ASSOCIATED WITH MARINE AGGREGATE PRODUCTION ON THE UNITED KINGDOM: OVERVIEW OF YEAR ONE

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HR Wallingford Ltd, Wallingford, England

BACKGROUND

Sponsored by the Minerals Management Service (MMS) over a 24-month period, UK-based marine research and survey company Coastline Surveys Ltd has successfully completed the first half of a research project investigating aspects of benthic and surface plumes associated with marine aggregate production in the United Kingdom. The research initiative is being conducted in co-operation with the internationally acknowledged research organization HR Wallingford Ltd (HR), formerly Hydraulics Research Ltd, and is widely supported by the UK dredging industry. ARC Marine Ltd, one of the United Kingdom's largest marine aggregate suppliers, has promoted the project from inception, providing financial support and unrestricted dredge vessel access during normal dredging operations. The project has also received valuable assistance from the three other main UK marine aggregate suppliers, Civil & Marine Ltd, South Coast Shipping Ltd and United Marine Dredging Ltd.

INTRODUCTION

The marine mining industry for sand and gravel aggregate within the United Kingdom is second only to Japan with some 50 vessels currently in use directly employing some 2,500 people (BMAPA 1994). In 1994 some 22 million tons were extracted, with a permitted removal of 37.8 million tons, which represents an increase of some 6% since 1992 and 46% since 1986 (Crown Estate 1994) (Figure 6C.9). Slightly over half of this resource is landed on the south and east coasts of the UK (Figure 6C.10), representing a third of construction sand and gravel regional requirements, with nearly one-third of the dredged quantity exported to the near continent. In South Wales alone, marine dredging in the Bristol Channel contributes 95% of the total regional requirement for sand.

The United Kingdom Department of the Environment (DOE) draft document "Guidance On Environmental Assessment for Marine Aggregate Dredging Proposals" prepared by the ICES Marine Environmental Quality Committee Working Group (ICES 1993) has become a *proforma* by which environmental assessments in the UK for such activities are prepared (with a lack of any real alternative so far). Items 1.2.1 (vi & vii) summarize pertinent topics requiring investigation as:

vi. transport and settlement of fine outwash sediment suspended by the dredging activity or from an outwash plume;

vii. effects of onboard screening/grading.

Also prepared by the ICES Marine Environmental Quality Committee (ICES 1993) is a study scoping document which complements the DOE guidelines. Again, this highlights the need for establishing data on "(2a)...stability, mobility and turbidity of bottom sediments and natural suspended loads," and "(3a)...information on predicted transport and settlement of fines suspended by the dredging activity, from an outwash plume or from onboard screening/grading."

PREVIOUS STUDIES IN UK

HR Wallingford Ltd have carried out a number of numerical analysis studies on the behavior of plumes

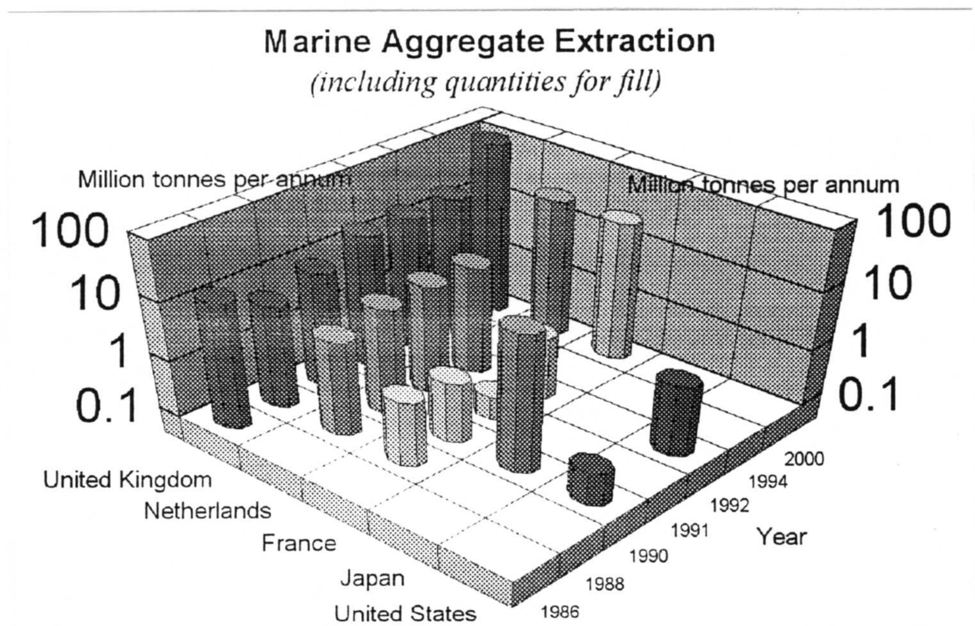


Figure 6C.9. Marine aggregate production (1994) including extracted for fill. (Data for some countries not obtainable.)

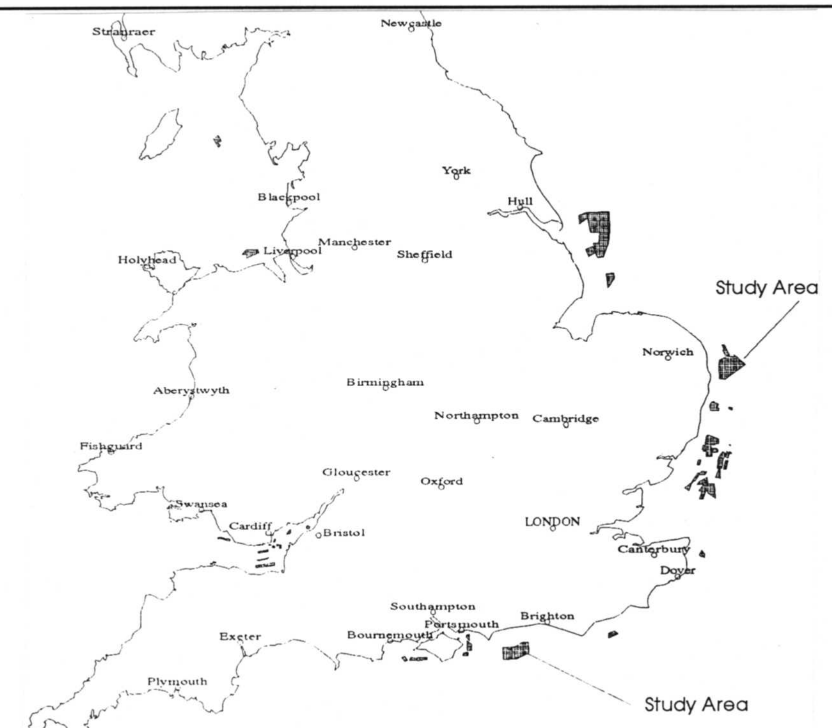


Figure 6C.10. Location of major UK marine aggregate license areas.

generated by marine aggregate dredging over recent years. These have necessarily included some broad assumptions for providing the input criteria based on manufacturers claims for dredge vessel equipment performances, such as pump capacities, and reasonable expectations and experiences of the dredging contractors, for example, solids concentrations dredged, fines contents in seabed sediments, etc.

In 1992-3 some preliminary field measurements were made by the dredging contractors during normal dredging at a site on the south coast of the UK. Various locations within the hopper were sampled to determine the sediment/water mixtures that were likely to be overspilled from the hopper. This study concluded that some 11kg total dry solids per m^3 of overspill would pass over the spillways, with slightly more than 50% being of silt/clay particle size (less than 0.063mm). During the loading of one non-screened 4,150 ton cargo, 130 tons of silt/clay and 120 tons of sand would consequently re-enter the water column over a period of 2.5 hours via the spillways (HR Wallingford Ltd 1993).

PREVIOUS STUDIES IN HONG KONG

Hong Kong is in the middle of a very large program of reclamation development. These developments have resulted in a requirement for large quantities of marine sand for reclamation fill, which is estimated to be about 210 million tons since 1990 (Whiteside *et al.* 1995). There has been an increasing requirement in Hong Kong to undertake environmental impact assessments associated with marine mining, and because of the scale of the operations, this has promoted a number of studies directed at establishing the losses during the dredging operation and the subsequent advection and dispersion of the plumes of fine material so generated. HR have multilayer flow models of Hong Kong waters and are able to use this hydrodynamic data as the driving forces for examining the fate of plumes of fine material (for example, HWR (Asia) 1993).

Recently, through field measurements using acoustic Doppler current profiling techniques (Land *et al.* 1994), it has become apparent that the processes occurring during the first few minutes of the plume generation are responsible for the loss of a considerable proportion of the fine material initially released into the water column (Whiteside *et al.* 1995). HR have investigated the processes that may be occurring during this initial phase of the development of a plume (HR Wallingford 1995) and have concluded that, for the vessels operating in Hong Kong with a single sub-surface spillway, the initial momentum of the discharge from the vessel is a significant factor, resulting in much of the material descending directly to the seabed. Additionally it has been postulated that the disaggregation of fine muddy material during the dredging process is not complete and that a further significant proportion of the muddy material released into the water column is in the form of fine clay balls, or adhered to coarser grains. These aspects are discussed further in the final section of this paper.

PROJECT PROGRAM

This project has three main phases:

- Phase One: determination of surface overspill and screening/rejection source terms and contributions to plume development;
- Phase Two: evaluation of plume survey, monitoring and representation techniques;
- Phase Three: determination of benthic plume source terms generated by action of the draghead on the seabed.

During the first year of study, the project has achieved significant progress in two key areas; first undertaking an extensive program of sampling of the surface plume source terms; and second developing a reliable and rigorous plume monitoring procedure making use of traditional water sampling and testing techniques. These were enhanced by state-of-the-art acoustic Doppler current profiling equipment displaying real-time backscatter readings for graphical representation of the plume. It is proposed to term this survey method as "continuous backscatter profiling." This approach allowed informed placement of the sampling equipment within the backscatter maxima and mimima of the plume. All fieldwork has taken place during normal dredging operations without modification of dredging practices.

Phase One: Surface Plume Source Terms

Extensive sampling of overspill from the spillways has been carried out during a number of separate field campaigns in 1994-5 aboard variously sized vessels and in different geographical areas. Results of the most recent sampling programs are presently being analyzed. Preliminary results indicate that some 35kg of total dry solids per m^3 of overspill will be returned to the water column, comprising some 38% silt/clay material (less than 0.063mm diameter). During loading of a screened 4,200 ton cargo, 285 tons of silt/clay and 465 tons of sand would enter the water column via the spillways over a loading period of almost five hours. Note when comparing this data with that of the 1992-3 study mentioned above that the surveys were conducted in areas of significantly different geology with varying proportions of fines.

The screening and rejection process is an important contributor of sediment to the surface plume. During loading of a screened cargo, up to three times the retained load can be dredged from the seabed compared with less than twice the retained cargo during an all-in load. It is postulated that more material will be discharged into the water column via the reject chute compared to the spillways, although only a very small proportion of this is of silt/clay material. During the same five-hour loading period as above, less than 1% of the rejected material is silt or clay sized, amounting to a source term input of some 700 tons. More samples of the rejected material will be obtained to test this.

Phase Two: Evaluation of Survey, Monitoring and Representation Techniques

During the second half of the year an opportunity arose for detailed monitoring of normal dredging operations on a currently licensed aggregate extraction site along the south coast of the UK. Although not timetabled to be investigated until the second year of the project, this provided an early opportunity to gather important field data for consideration in connection with an application for a further licence area. Subsequent detailed analysis will be performed during the second year of the project. The opportunity also coincided with an unusually fair weather summer period. While recording continuous backscatter profiles, it has not been an objective of this study to attempt to correlate Doppler current profiler acoustic backscatter amplitudes with the concentration of suspended solids sampled, a matter attracting considerable debate at present (see for example Land *et al.* 1994, and Weirgang 1995)

Four dredge vessels ranging in capacity from 2,000 to 5,000 tons were timetabled to load a combination of all-in (as dredged) and screened (stone-only) cargoes by trailing and anchor dredge techniques over a three-day period during which extensive monitoring and sampling would be undertaken. A 15m survey vessel was equipped with water sampling equipment, optical transmissometers, temperature/salinity probes, and an MMS-owned RDI 1200kHz BroadBand Vessel Mounted Acoustic Doppler Current Profiler (ADCP™). Over three days in August 1995, in exceptionally calm conditions, 140 background and through plume transects were made using the ADCP™ equipment to generate real-time continuous backscatter profiles. While remaining stationary in the water adjacent to a midwater drogue marker buoy, twenty vertical profiles were also recorded at various locations by ADCP™ with simultaneous water sampling and optical measurement of suspended sediment concentrations. A further 26 hours of continuous current information was also collected to prepare a detailed tidal atlas of the site.

In this UK study, peak concentrations of total suspended sediment were found to be below 2,500ppm. However, the majority of this material was sandy, and the maximum concentration of muddy material (<0.063mm) was less than 30ppm. Concentrations of sand were found to decay to background levels over a distance of 200m to 500m from the point of release into the water column. Concentrations of suspended muddy material were found to decay to background levels of 2 to 5ppm over similar distances (Figures 6C.11 and 6C.12). Figures 6C.13, 6C.14, and 6C.15 (Transects 21AU022-21AU034) represent the decay of the plume associated with a small stationary suction dredger (City of Rochester). The track chart (Figure 6C.16) of the survey vessel indicates distance away from the dredger. Multiple plumes were observed about the Geopotes XIV, an 8,000m^3 twin pipe trailing suction dredger (see Figure 6C.17,Transects 20AU037 and 20AU038).

The work has clearly demonstrated a very rapid reduction in suspended sediment concentrations away from the dredging operation as reported by Whiteside *et al.* (1995). An interesting observation was that it was possible to track the plume with the ADCP™ over a distance of 3.5km even though for 3km of that distance the concentrations in the plume were not significantly different to background levels. This effect might be attributed to the presence of minute bubbles entrained into the water column during the dredging operation and ought to be investigated at a future date.

The results of this monitoring have further demonstrated the need to consider the initial phases of plume formation and dispersion. It is clear that the reductions in sediment concentrations within the plume during the first minutes of the plume dispersion are not only associated with the increasing dimensions of the plume but also with loss of fine material from the water column onto the seabed.

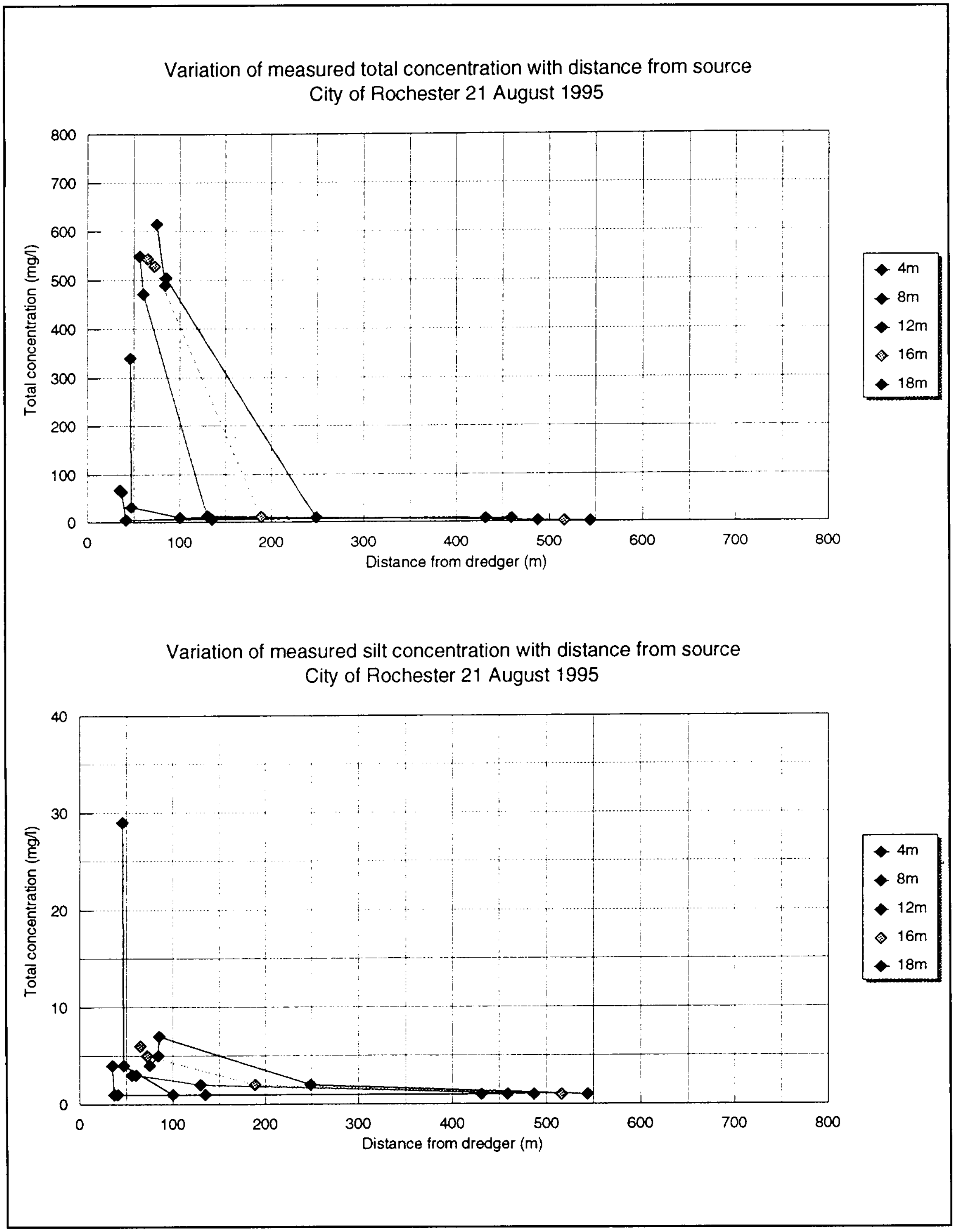


Figure 6C.11. City of Rochester, 21 August 1995.

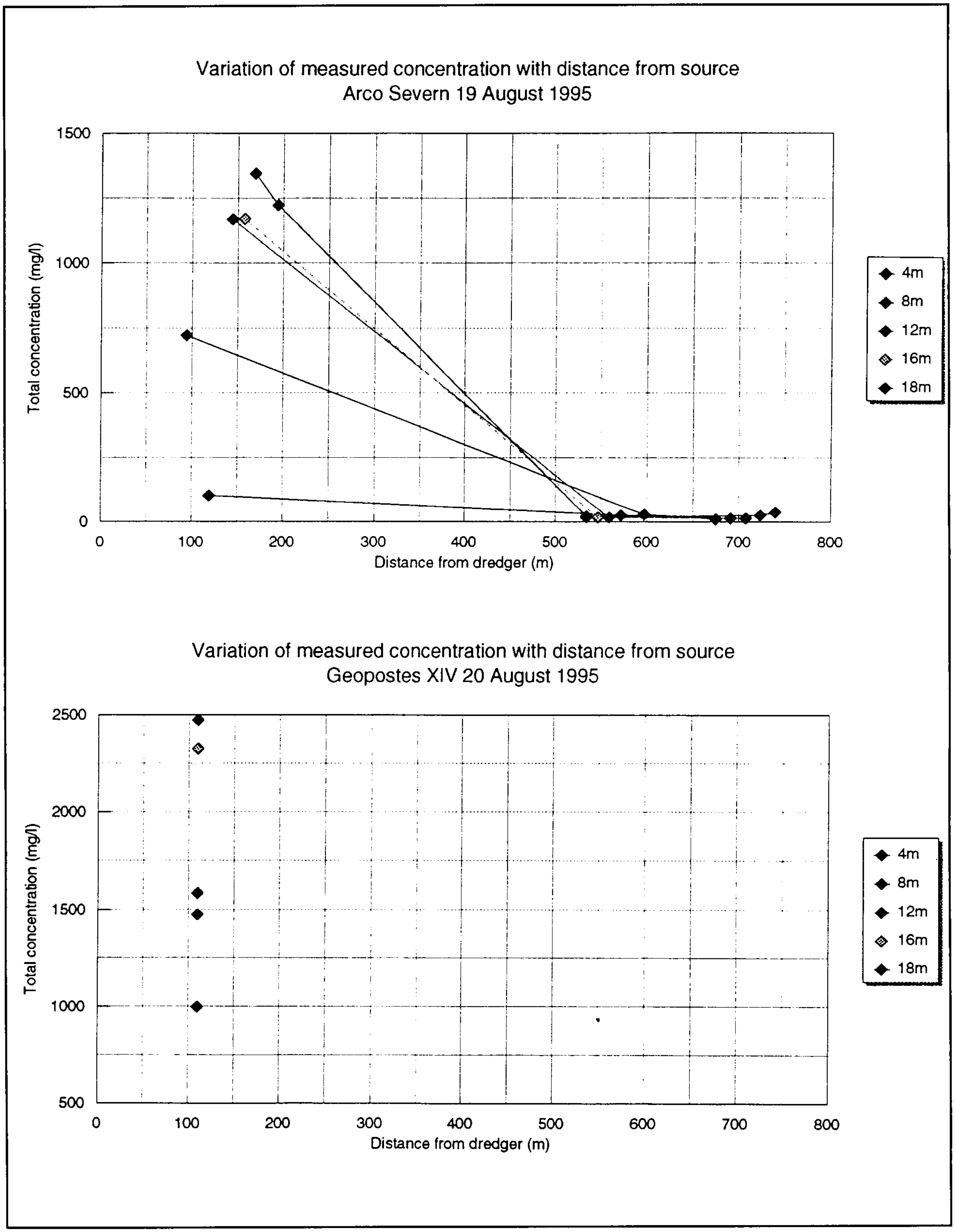
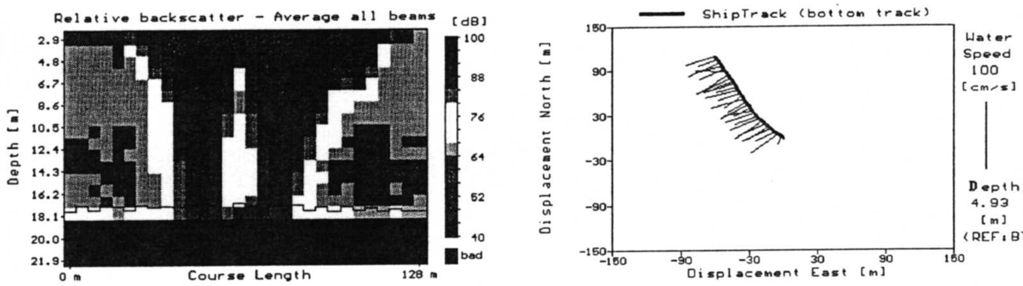
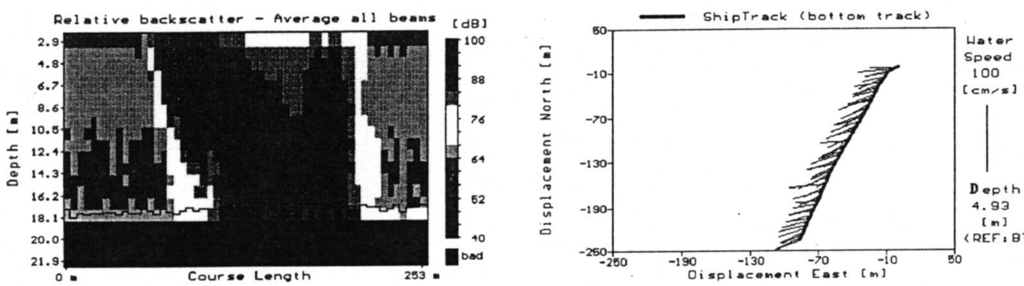


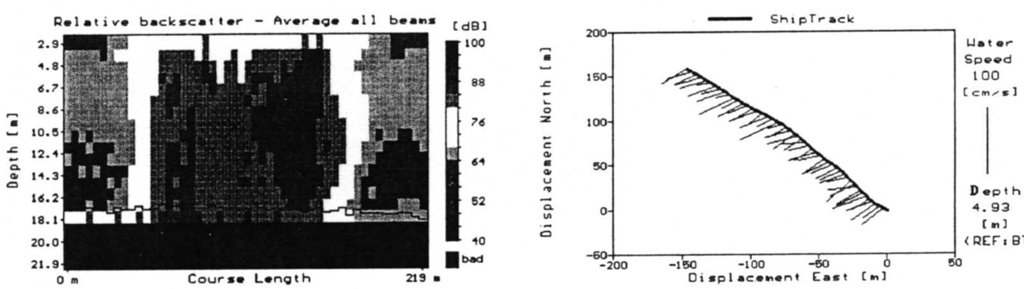
Figure 6C.12. Arco Severn, 19 August 1995.



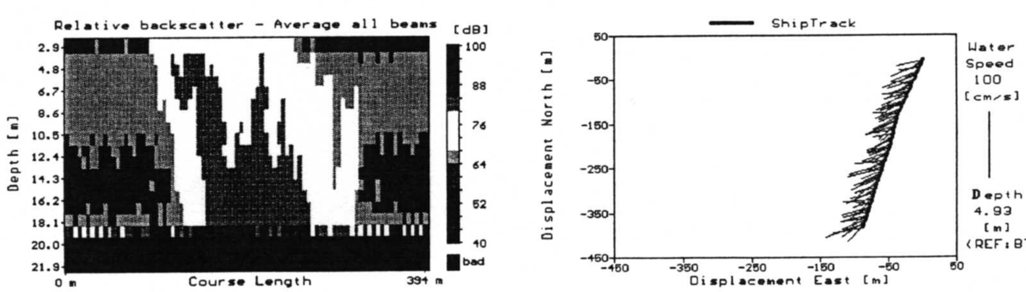
Transect 21AU022
NW transect across plume 80m away from dredger



Transect 21AU023
SW transect across plume 205m away from dredger

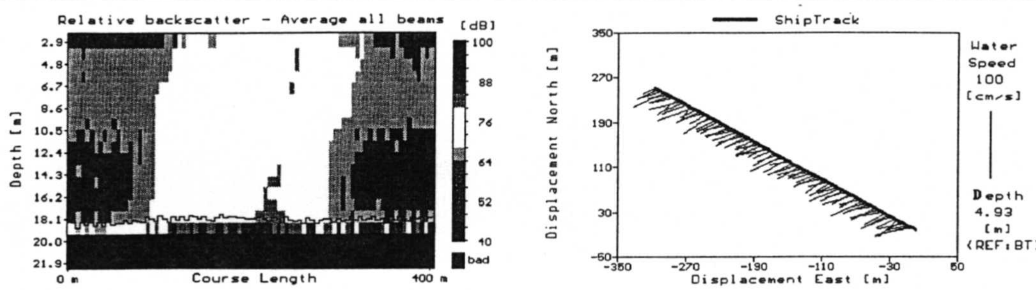


Transect 21AU024
NW transect across plume 365m away from dredger

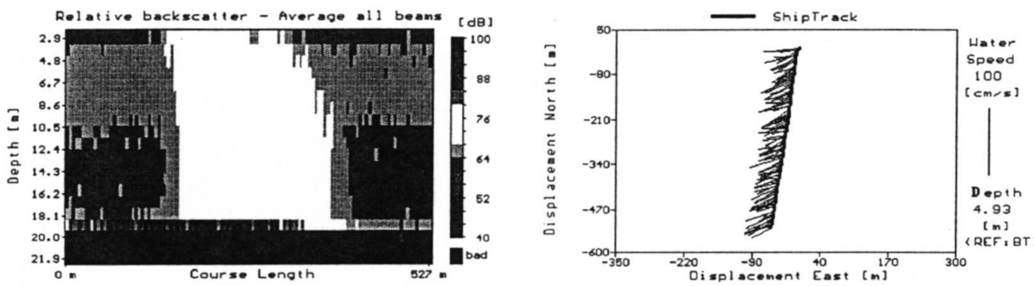


Transect 21AU025
SW transect across plume 590m away from dredger

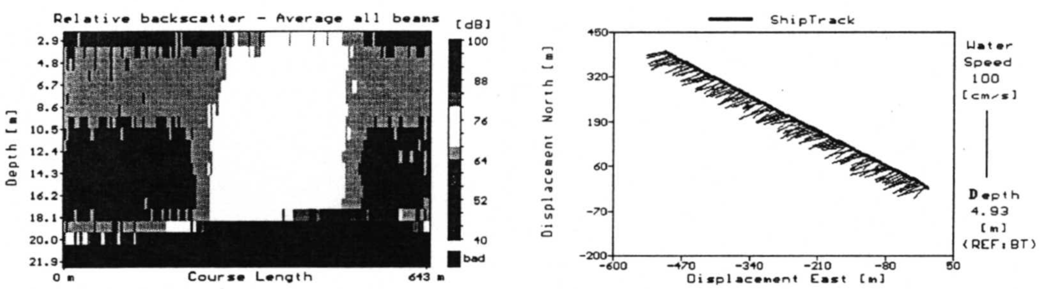
Figure 6C.13. Transects showing decaying plume generated by City of Rochester (Page 1).



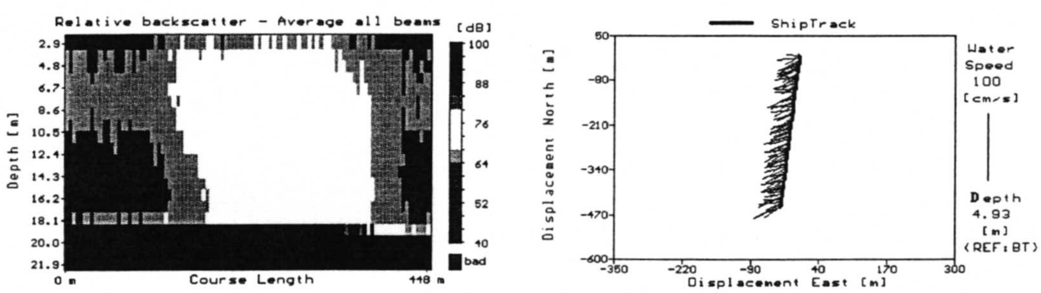
Transect 21AU026
NW transect across plume 880m away from dredger



Transect 21AU027
SW transect across plume 1160m away from dredger

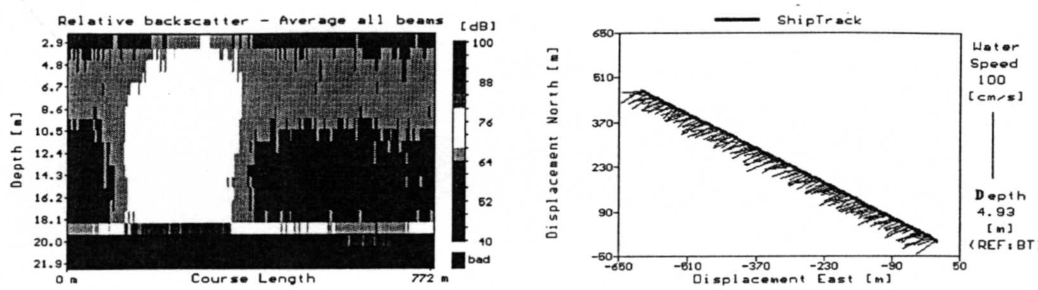


Transect 21AU028
NW transect across plume 1540m away from dredger

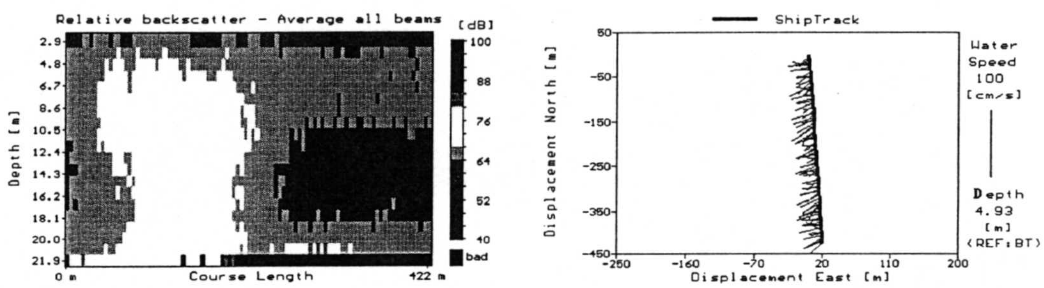


Transect 21AU029
SW transect across plume 1835m away from dredger

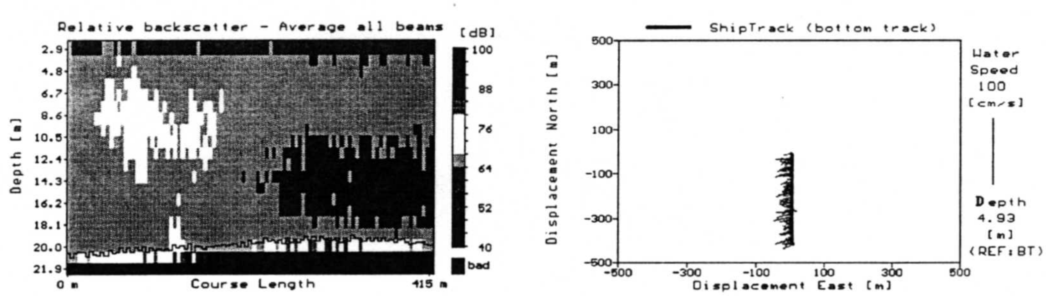
Figure 6C.14. Transects showing decaying plume generated by City of Rochester (Page 2).



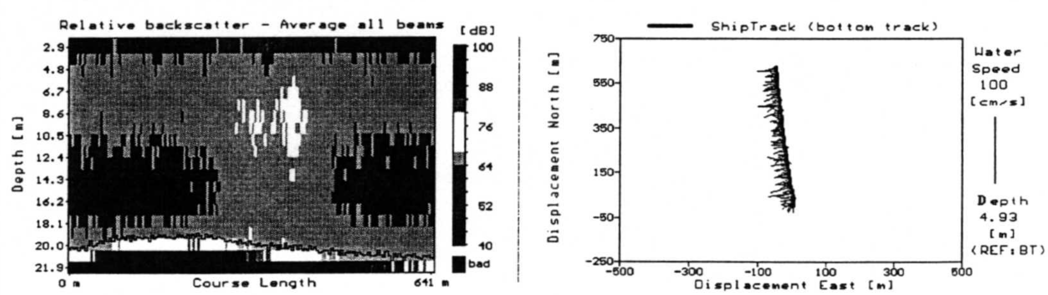
Transect 21AU030
NW transect across plume 2215m away from dredger



Transect 21AU031
S transect across plume 2640m away from dredger



Transect 21AU033
S transect across plume 3380m away from dredger



Transect 21AU034
N transect across plume 3335m away from dredger

Figure 6C.15. Transects showing decaying plume generated by City of Rochester (Page 3).

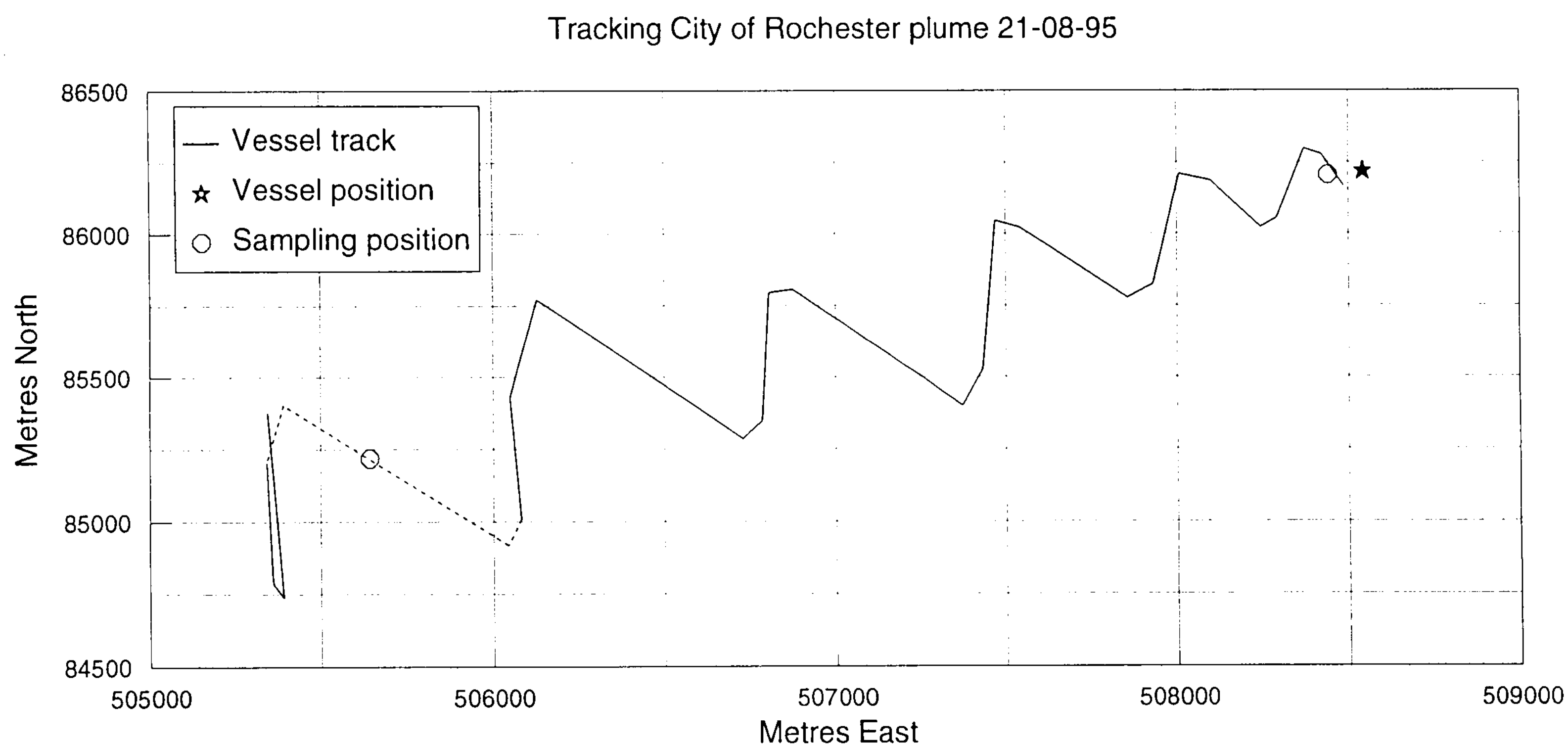
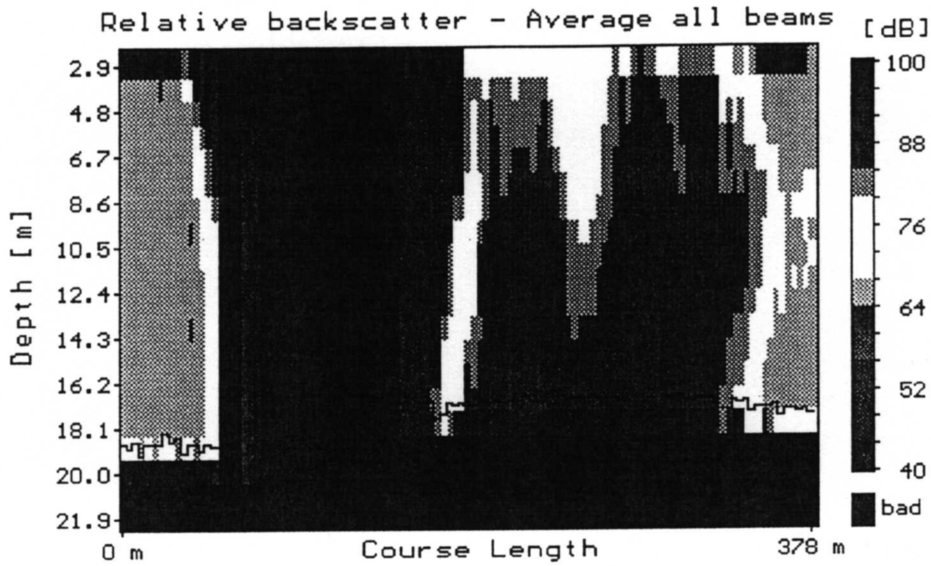
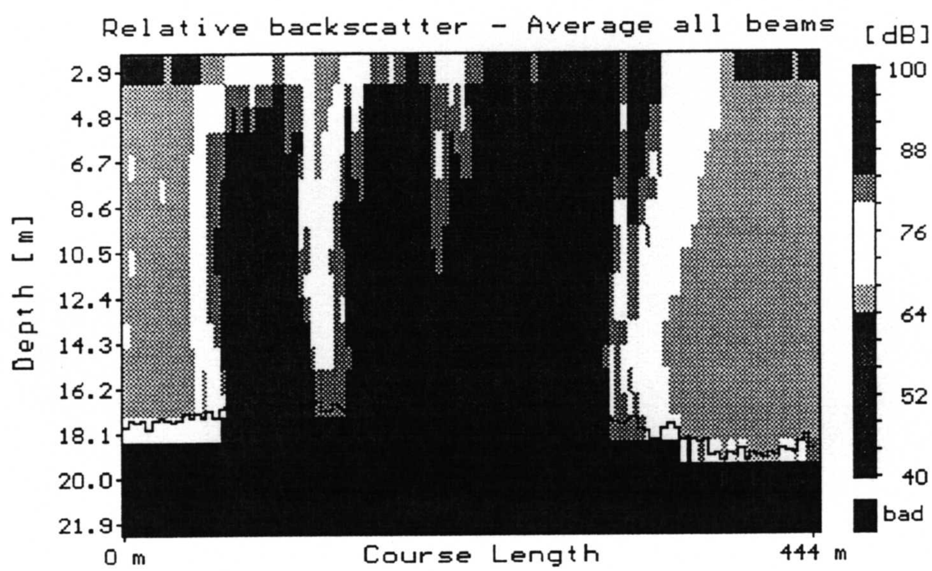


Figure 6C.16. Tracking City of Rochester plume 21-08-95.

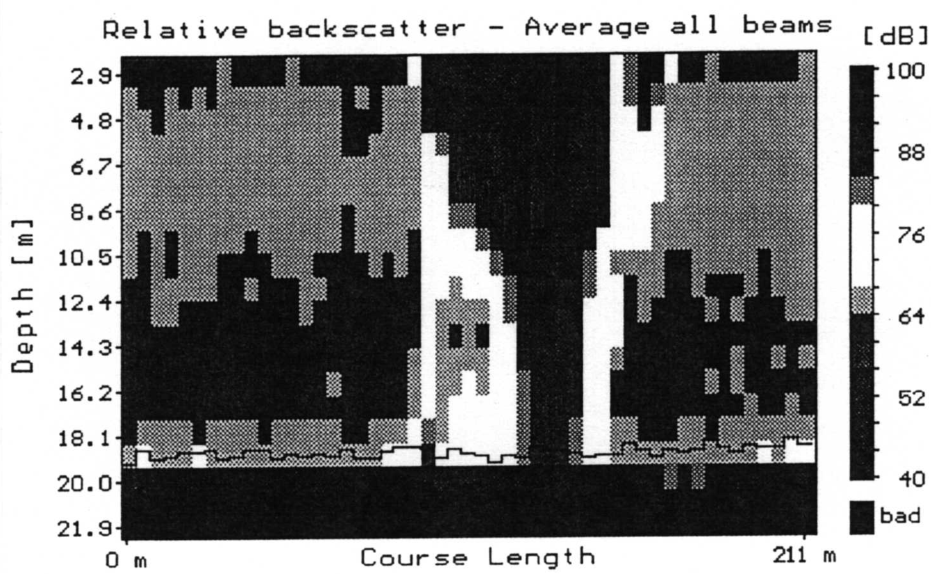


Transect 20AU037 (1344-1348)
SE transect showing multiple plumes from Geopotes XIV

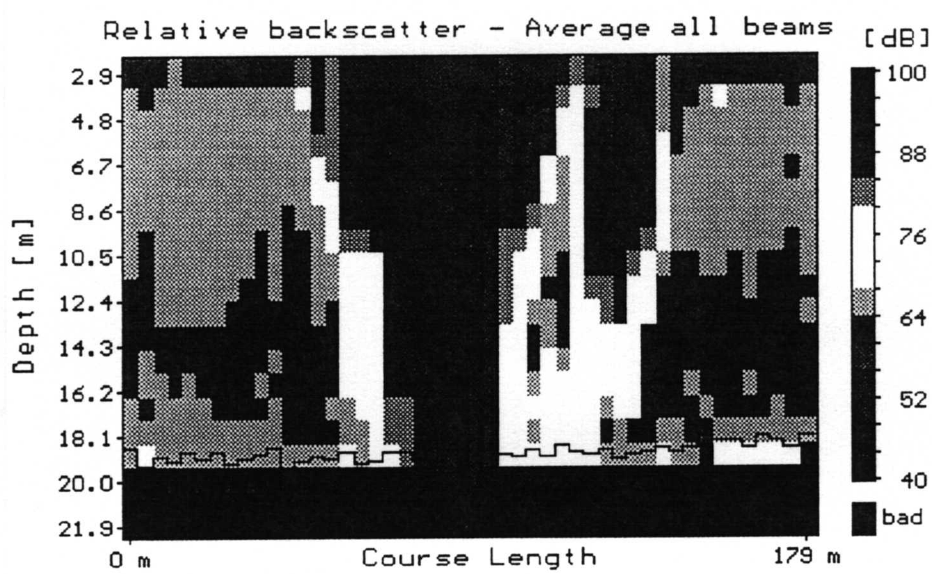


Transect 20AU038 (1348-1352)
NW transect showing multiple plumes from Geopotes XIV

Figure 6C.17. Transects 20AU037 (1344–1348) and 20AU038 (1348–1352).

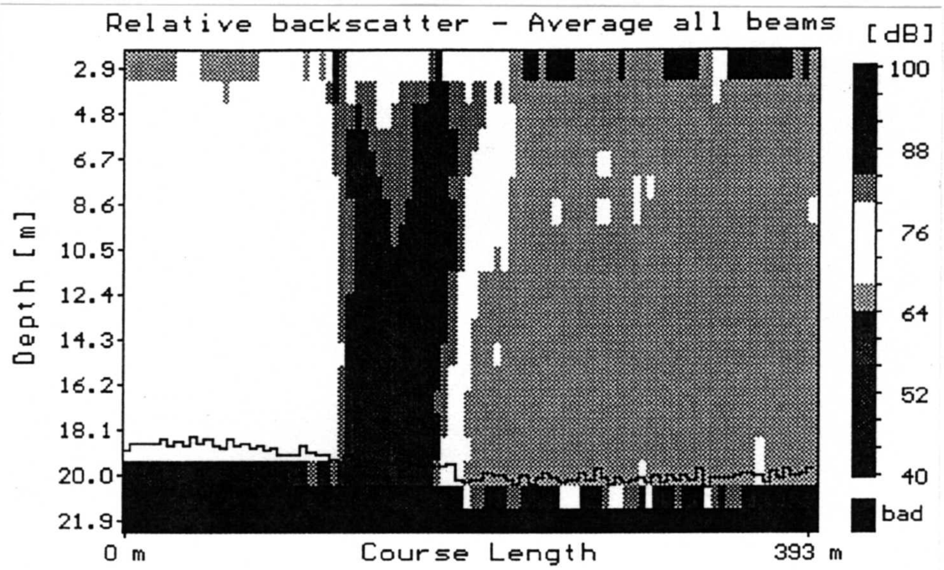


Transect 20AU004 (0950-0952)
W transect showing plume from draghead of Arco Severn

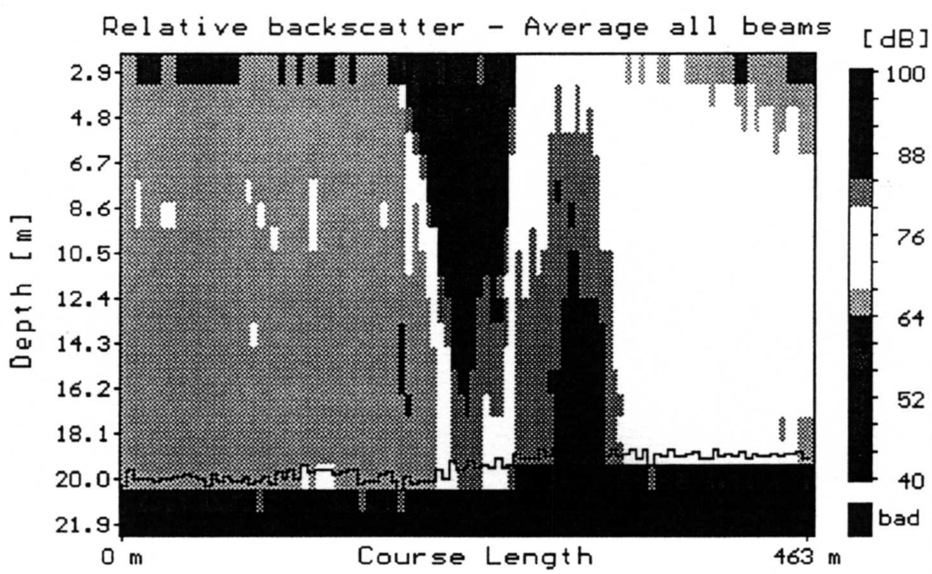


Transect 20AU005 (0955-0956)
SE transect showing two plumes from Arco Severn

Figure 6C.18. Transects 20AU004 (0950–0952) and 20AU005 (0955–0956).



Transect 19AU031 (1554-1557)
SE transect showing multiple plumes from Arco Severn



Transect 19AU032 (1559-1602)
NW transect showing multiple plumes from Arco Severn

Figure 6C.19. Transects19AU031 (1554–1557) and 19AU032 (1559–1602).

Phase Three: Benthic Plume Source Terms

Although initially planned for study during Year One, the opportunity to conduct the continuous backscatter profiling field study was intentionally allowed to override the original program. Phase Three involves mounting an array of low light intensity video cameras on the draghead to record the hydrodynamic processes visible during the dredging operation. Transect 20AU004 (ARCO Severn, Figures 6C.18 and 6C.19) successfully recorded what is believed to be the plume issuing from the draghead. Earlier work in which the primary author participated has proven the suitability of state-of-the-art underwater cameras in conditions of low background levels of suspended sediments and plankton. Pump sampling equipment will also be placed on the draghead to enable sampling of the benthic plume as it is generated and thus determine the source terms.

FUTURE MARINE AGGREGATES MINING RESEARCH

Detailed as the present project is, this study addresses only a number of aspects of the dredge plume scenario and has already raised its own questions on the present understanding of dredge plume surveying, modeling and prediction. Future proposals for research are, in no specific order:

- disaggregation of fines and role of clay balls during overspill and especially screen rejection affecting settling velocities and mechanisms of resuspension;
- settling function and resuspension aspects of density plumes and importance of entry velocity within initial discharges;
- settling function and resuspension aspects caused by air entrainment, role of anti-air entrainment systems;
- availability of dredge deposited sediments with modified size distributions for natural sediment transport and deposition processes.

SUMMARY

The first year of a 24-month research project to investigate aspects of benthic and surface plumes created by marine aggregate dredging in the United Kingdom has been completed. Extensive field work to first determine the source term data on the character of overboard returns prior to modeling, and then to monitor *in situ* the generation and decay of plumes by traditional water sampling and novel acoustic Doppler current profiling techniques, have both successfully been used to characterize dredge plumes. Analysis of the results is ongoing.

Further work within the project remit over the next 12 months will assess the contribution of the benthic plume to the gross plume generated, develop the survey and representation techniques, and appraise the implications of sediment redistribution on gross seabed morphology changes and basis for continued exploitation of the resource.

ACKNOWLEDGMENT

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MARINE MINING TECHNOLOGY AND MITIGATION STUDY

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INTRODUCTION

The marine mining mitigation and technology study was commissioned by the Minerals Management Service (MMS), U.S. Department of Interior. The MMS is responsible for the regulation of mineral exploration and development on submerged federal lands of the U.S. Outer Continental Shelf (OCS). Environmental protection is an integral part of the mandate of the MMS, and regulatory requirements exist for the enactment of mitigation measures during the conduct of all offshore mineral exploration and development activities. In keeping with the requirements of the National Environmental Policy Act (NEPA) and Council of Environmental Quality (CEQ) regulations, the MMS performs environmental analysis and assessment of proposed offshore mineral developments on a case-by-case basis. This study will provide the MMS with practical guidance in prescribing mitigation measures for future marine mining developments on the U.S. OCS.

PURPOSE AND OBJECTIVES

The purpose of this study was to undertake a detailed analysis of available and proposed marine mining technologies and mitigation techniques with respect to the mining of specific mineral commodities on the U.S. Outer Continental Shelf. The objectives of the study were

- to develop realistic scenarios for marine mining activities that are likely to occur on the U.S. OCS within a ten-year time span;
- to make predictions of the environmental impacts associated with the marine mining scenarios;
- to establish guidelines for mitigation of the anticipated environmental impacts;
- to perform cost-benefit analyses of available and proposed techniques for mitigation of the environmental impacts of marine mining; and
- to formulate recommendations as to the most appropriate mitigation techniques for the scenarios and similar marine mining developments.

PROJECT TEAM

To meet the above-stated objectives, a unique multidisciplinary team was formed consisting of environmental scientists and marine mining and dredging specialists. The Project Team consisted of four principal groups, or nodes, which included a Management node, a Mining Engineering node, a Physical Environmental Effects node and a Biological/Chemical Environmental Effects node.

The Management node was based at the Centre for Cold Ocean Resources Engineering Memorial University of Newfoundland, Canada, and headed by the Principal Investigator William Scott, Ph.D., P.Geo. The Mining Engineering node was led by Richard Garnett, Ph.D. C. Eng., an international mining consultant based in Ontario, Canada. The Physical Environmental Effects node was headed by Laurie Davidson, M.Sc., Physical Oceanographer and President of Seaborne Information Technologies Ltd., located in St. John's, Newfoundland, Canada. The Biological/Chemical Effects node was directed by Derek Ellis, Ph.D., R.P.Bio., Professor of Biology at the University of Victoria, British Columbia, Canada and Principle of Derek V. Ellis Ltd. marine environmental consultants.

The report was being authored primarily by the node leaders. Supporting contributions were made by Tom Pederson, Ph.D. (environmental chemist; University of British Columbia), J. Littlepage, Ph.D. (pelagic biologist; University of Victoria), Robert Jantzen (dredging engineer, Jantzen Engineering Co., Inc.), Donald Hodgins, Ph.D. (physical oceanographer; Seaconsult Ltd.), and Laurie Davis, M.Sc. (Project Manager and marine geoscientist, C-CORE).

APPROACH AND METHODOLOGY

Marine Mining Scenarios

A variety of mineral commodities exist on the U.S. OCS and are potential targets for exploitation. These include sand resources suitable for beach nourishment, marine aggregate, heavy minerals, precious metals, phosphorites, and others. Their exploitation will inevitably result in environmental impacts that will vary in degree depending on factors such as the scale of operation, the extraction technology used, and the nature of the geological and environmental setting.

The fundamental questions dealt with in this study were what are the likely environmental impacts associated with mining of specific mineral commodities on the U.S. OCS and how might those impacts be mitigated in a cost-effective manner? These questions have been addressed through analysis of a number of marine mining scenarios detailing the scale of operation, extraction technology, and environmental setting of marine mining operations targeting a range of mineral commodities.

The mining scenarios were developed in close consultation with the MMS and were selected based on the following criteria:

1) Potential for near-term development: Only mineral commodities likely to be exploited within a ten-year time span were considered. Mineral commodities were excluded on the basis of market and technological constraints.
2) Commodity resource information: Much of the available information pertaining to the distribution of mineral commodities on the U.S. OCS is regional and lacks sufficient resolution to derive reserve or even resource estimates. However, there is sufficient detail at least to target general areas of interest in the scale of kilometers, and sometimes more precisely.
3) Proximity to markets and market demand: The proximity to the commodity market and the market demand are important considerations for all potential marine mining developments. The MMS provided valuable advice with respect to market requirements, which helped considerably in determining the most appropriate site-selections for the mining scenarios.
4) Availability of environmental data: A final but secondary consideration in selecting the marine mining scenarios was availability of local environmental data. Where environmental data were sparse or lacking, it was possible to make appropriate generalizations about distributions of biological assemblages and about likely ecological responses based on regional information and knowledge of the habitat. The need for contemporary level QA/QCC Quality Assurance/Quality Control of data banks was also considered.

A total of five marine mining scenarios were selected and developed in detail. These include

1. Precious metal mining, Alaska—bucket-ladder dredge
2. Precious metal mining, Alaska—underwater miner
3. Marine aggregate mining, Massachusetts Bay

4. Heavy mineral mining, offshore Virginia
5. Beach nourishment, Ocean City, Maryland

The first scenario is a case history of a large-scale placer gold mining operation off Nome, Alaska, carried out by Westgold during the late 1980s. While the scale of operation and use of a bucket-ladder dredge are not likely to be repeated in any future offshore mining activity in the region, the scenario is highly instructive in that it documents real experience with the practice of marine mining environmental impact mitigation. It is also the only large-scale marine mining development to occur in U.S. waters to date.

The second scenario, which involves precious metals mining using an underwater mining vehicle, is based in part on actual non-production trials carried out towards the end of the Westgold project life. The two mining methods are at opposite ends of the spectrum in terms of scale of operation and precision of extraction, and therefore provide a useful contrast of the effects of using different extraction technologies to mine the same mineral commodity.

Offshore aggregate mining, the subject of the third scenario, is thought to be a likely prospect in the near-term. The first markets to be served by such an industry will probably be the greater-metropolitan areas of Boston and New York. Recognizing that marine aggregate resources in the region are potentially widespread, the choice of a location in Massachusetts Bay for a hypothetical aggregate mining operation was based mainly on the availability of environmental information. A comprehensive baseline environmental study was done in the early 1970s in preparation for an experimental offshore aggregate mining project. The experiment did not proceed, but the baseline environmental information gathered serves as a useful resource for this study.

While the baseline study also provides what is still perhaps the most complete site-specific assessment of aggregate resources in the region, it reveals that the geology of the site under consideration is not particularly conducive to economic dredging operation. The sediments are poorly sorted and contain, on average, higher proportions of silt and clay than are normally desirable for an aggregate target. Therefore, the hypothetical marine aggregate mining operation presented in the report represents a worst-case scenario both environmentally and economically. As a marginal operation the aggregate mining scenario is a sensitive monitor of the economic costs of mitigation.

The fourth scenario, again hypothetical, involves dredging of heavy mineral sands in federal waters off Virginia Beach, Virginia. In this case the site selection for the scenario was based mainly on commodity resource information. Concentrations of industrial heavy minerals are known to exist offshore Virginia as well-sorted placer deposits. The geology and environmental setting are thought to be representative of most areas on the U.S. OCS where heavy minerals could be targeted. Any proposal for offshore mining development in the area would have to address potential conflicts with other uses, including commercial fishing, ocean dumping, and military practice.

The fifth scenario considers the use of sand resources in federal waters (seaward of the boundary) for beach nourishment. The site selected for the scenario, Ocean City, Maryland, has undergone repeated coastal restoration projects; the most recent was in the fall of 1994. Borrow sites have moved progressively offshore and the need for sand resources from federal waters appears imminent.

MITIGATION ANALYSIS

As stated above, the ultimate objective of this study was to develop recommendations about the most appropriate techniques for mitigation of the environmental impacts associated with mining of specific mineral commodities on the U.S. OCS. The recommendations are derived from cost-benefit analyses of a broad range of available and proposed mitigation measures. The selection of mitigation techniques for analysis was based upon the environmental impacts and mitigation guidelines, or targets, identified for each of the mining scenarios.

At the time of the writing of this paper, the mitigation analysis had not been completed. Therefore, that information is not presented here. The full report should be available by contacting the MMS Office of International Activities and Marine Minerals, 381 Elden Street, MS 4030, Herndon, Virginia 22070, telephone number 703-787-1300.

Dr. Derek V. Ellis is a professor of biology at the University of Victoria, Victoria, B.C., Canada. He has a B.Sc. in zoology from the University of Edinburgh, Scotland, and an M.Sc. and Ph.D. in marine ecology from McGill University. Dr. Ellis has done extensive research into the effects of marine mining operations on biological organisms.

LIVING WITH A NEW LAW

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INTRODUCTION

In October 1994 Public Law 103-426 passed following a year of debate. The new law amends the Outer Continental Shelf (OCS) Lands Act to provide the Secretary of Interior with expanded authority to negotiate agreements for use of federal offshore sand, gravel, shell for certain projects of public benefit. By delegation, the MMS is charged with the responsibility for implementing the new law. This paper explains the basic provisions of the new law, the MMS approach to implementing the law, and several case examples.

BASIC PROVISIONS OF THE NEW LAW

OCS Lands Act Section 8(k) Amendments

Eligible projects: Prior to passage of P.L. 103-426, rights to develop sand, gravel and shell resources on the OCS could only be obtained through a competitive lease sale process. The new law provides the Secretary of Interior with discretionary authority to negotiate agreements for use of federal offshore sand, gravel, shell resources under certain circumstances. The first set of circumstances include programs or projects for shore protection, beach restoration, or coastal wetlands restoration if undertaken by a federal, state, or local government agency. The other circumstances involve construction projects, other than those aforementioned, that are authorized by or funded in whole or in part by the federal government.

Fees: A fee may be assessed for the resources based on their value and public interest served. However, no fee can be assessed either directly or indirectly against another federal agency. Determination of fees is left to the Secretary of the Interior and, by delegation, to the MMS.

Memorandum of Agreement: If another federal agency is directly involved in the project, they must sign a Memorandum of Agreement (MOA) with MMS to insure proper coordination and avoid delays. For example, a cost-sharing project for beach restoration authorized by Water Resources Development Act legislation typically involves the U.S. Army Corps of Engineers (Corps). The Corps undertakes feasibility, engineering and cost/benefit studies and contracts for dredgings. In cases where federal OCS sand resources are involved, the Corps is required to enter into an MOA with MMS so that a common ground for planning, scheduling, and issue resolution can be achieved. Early collaboration by the federal agencies would enhance each agency's ability to meet its responsibilities in a timely and efficient manner.

Congressional Notification: The law includes a provision that several Congressional committees be given notification of proposed projects prior to the use of OCS resources. The committees to be notified were the House Merchant Marine and Fisheries Committee (since abolished) and the Senate Energy and Natural Resources Committee. In the case of the House, MMS now provides notification to the House Resources Committee.

OCS Lands Act Section 20 Amendments:

The law further amends the OCS Lands Act to explicitly include minerals (other than oil and gas) and mineral leasing actions as candidates for environmental impact studies. The MMS Environmental Studies Program (ESP) currently directs some $14 million in studies, among which are contracts that pertain to marine mineral development. Another paper in this ITM session will provide details on past, present and future marine minerals-related environmental studies funded by the ESP.

BEFORE AND AFTER: HOW THE NEW LAW CHANGED THE LEGAL REGIME

Prior to passage of P.L. 103-426, Section 8(k) and about 20 other sections of the OCS Lands Act and three sets of regulations provided the basis for marine minerals leasing decisions. The law and regulations still apply; nothing changed with respect to situations where hard minerals would be competitively leased. A competitive sale could be requested and held with leases awarded for the highest qualified bids.

However, Congress recognized situations in which the competitive process could prove ineffective. These situations include projects addressing national concerns such as the severe coastal erosion and wetlands loss that affect significant segments of the U.S. coast. Congress expressed concern for a process that places state and local projects in jeopardy because of an inability to win a lease competition. The negotiated process was seen as providing greater certainty in planning and implementing public projects.

IMPLEMENTING P.L. 103-426

In keeping with the goals of Executive Order 12866, the MMS is attempting to achieve full implementation of the new law without new regulations. In place of additional regulations, MMS is developing guidelines which outline a process for deciding when negotiations are appropriate and how the negotiations process will be handled. MMS has advised the governors of all coastal states of the new law and the basic procedures for requesting and conducting negotiations. The procedures are essentially these:

- Any person may ask MMS to negotiate under provisions of the new law. (The OCS Lands Act defines "person" to include "any natural person, an association, a State, a political subdivision of a State, or a private, public, or municipal corporation.")
- MMS will ask the requestor for information (project description, funding, authorizations, location, etc.) that relate to the need for OCS sand, gravel, or shell resources.
- MMS will determine if the project falls within the prescriptions of the new law.
- If there is a clear cut decision to negotiate:
  - The requestor will be informed.
  - Detailed discussions on project needs and MMS information needs will commence.
  - If another federal agency is involved in the project, a MOA with MMS is signed.
  - Environmental information relating to the project and the borrow area will be evaluated. If an environmental assessment or Environmental Impact Statement (EIS) exists that relates to the action and/or area, a decision will be made by MMS on whether it is sufficient for assessing impacts and reaching a leasing decision. If insufficient or absent, MMS will determine what further environmental information needs exist, and the agency will meet National Environmental Policy Act and decision-making requirements.
  - Negotiations on lease terms and conditions, including environmental stipulations, will proceed in tandem with other steps.
  - If the environmental information and other factors (multiple use, national defense, resource management conflicts, etc.) do not preclude a lease, a lease document will be drawn up and signed.
  - The process will continue after the negotiated lease is signed, insofar as there are requirements for verifying compliance with the terms and conditions of the lease.
- If the negotiation request is rejected, or negotiations terminate: The requestor, by regulations, has the option of asking MMS to hold a competitive lease sale. If MMS receives such a request, it will evaluate the feasibility of holding a sale. To do this it will consider available information and request further input from the public. If a lease sale process is started, MMS will identify a provisional lease area and hold public hearings to scope out environmental issues and other concerns. Public input will be integrated into the critically important environmental impact assessment phase of the preleasing process. After completing a Final Environmental Assessment or Environmental Impact Statement, the agency will decide, based on the final document and all other pertinent information, whether or not to proceed with a sale. The prelease and postlease procedures to be followed by the agency and lessees are detailed in the Code of Federal Regulations (30 CFR 280-282). These three regulations deals with prospecting, leasing, and operations for OCS minerals other than oil, gas, and sulphur.

CASE STUDIES OF NEGOTIATED AGREEMENTS

Case Study 1: Jacksonville

The first project that qualified for a negotiated lease came to the attention of MMS inadvertently through a conference meeting in January 1995. The Jacksonville beach restoration project was first authorized by Congress as a federal/state cost sharing arrangement in the 1970s, and earlier beach nourishments had been conducted using State water sand and possibly federal resources prior to 1995.

MMS's first task was to contact local project sponsors and the U.S. Army Corps of Engineers Jacksonville District Office and explain the provisions of the new law and its impact on the proposed project. The first test of the new law was anything but an ideal situation with which to begin since project sponsors knew little about the new law, many contractual arrangements were established, and timetables were in place for initiating work within several months.

Considerable confusion existed as to whether the lessee for the negotiated lease would be the state of Florida, the city of Jacksonville, or Duval County. Once it was established that the city was to step forward as the local sponsor and lessee, permission to enter into a lease had to be granted to the mayor through a City Council resolution. To meet schedules, emergency procedures had to be invoked. The process of entering into an MOA with the Corps, negotiating the lease terms, allowing time for legal reviews and resolving differences consumed months before a negotiated, noncompetitive lease was signed and the project could proceed. Nevertheless, the project was successfully initiated using 1.2 million cubic yards of federal sand from a borrow site approximately seven miles offshore. This first case provided valuable experience and insights into implementing the new law.

Case Study 2:Isles Dernieres, Louisiana

A very different situation exists for the negotiated agreement requested by the State of Louisiana. Through a MMS/Louisiana cooperative arrangement begun in 1991, MMS has been fully aware of Louisiana's wetlands problems and need for sand resources. Through this process, resource and environmental issues have been evaluated in a timely fashion. The cooperative agreement identified Ship Shoal as a 1.57 billion cubic yard federal offshore sand source of which about 25 million cubic yards (<2%) would be needed to restore the Isles Dernieres barrier islands. This kind of cooperative work is expected to be a precursor for many negotiated leases.

What may have been a straightforward negotiated lease situation has been complicated by MMS involvement with a broader wetlands restoration and management plan precipitated by another federal law. Under the Coastal Wetlands, Planning, Protection and Restoration Act (CWPPRA) a more comprehensive management plan for saving wetlands, the Isles Dernieres project would be but one facet. MMS has become involved because it is has jurisdiction over a prime sand source and because CWPPRA could provide funding needed to undertake an EIS for this major federal action. Although federal and state agencies have disagreed on the procedure for handling the EIS, a resolution is now imminent. If CWPPRA funding is authorized in early 1996, an EIS will be contracted out and overseen by the MMS.

SUMMARY

- Certain risk has been accepted in deferring regulations. MMS will reconsider the need for regulations if its alternative approaches are not adequate to meet the needs of implementing the new law.
- The law represents compromise language forged in the heat of legislative debate and which created interpretive questions MMS is attempting to settle.
- The new law is affecting longstanding practices in the shore protection business.
- The concept of charging fees to local sponsors has received a mixed reception.
- MMS still disagrees with the Corps over the question of 50-year leases. MMS believes it ties up resources unnecessarily and complicates its stewardship responsibilities. The Corps says it cannot cost a project or enter into agreements with local sponsors without a guaranteed sand source.
- The growing interest in federal sand and the implementation of the new law are seriously straining the limited resources of MMS. Although the Administration requested incremental funding for the sand and gravel program in fiscal 1996, such funding has been dropped in current Interior appropriations conference negotiations.
- On the positive side, MMS did conclude its first negotiation with Jacksonville despite difficulties and the Louisiana project stands an excellent chance of succeeding.
- Other negotiation requests have been received from South Carolina, the Navy, and a private company. A handful of additional requests are expected in the next 1-2 years.
- The ultimate success of the new system may depend on the willingness of Congress to live with its own law.

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THE PERMITTING PROCESS FOR MINERALS OTHER THAN OIL, GAS AND SULPHUR IN THE OCS

Mr. Jerry Brashier
Mr. G. Ed Richardson
Mr. Ronald J. Brinkman
Minerals Management Service
Gulf of Mexico OCS Region

INTRODUCTION

The authority for information collection on prospecting for minerals other than oil, gas, and sulphur in the Outer Continental Shelf (OCS) is provided for by 30 CFR Part 280. The information is collected to inform the Minerals Management Service (MMS) of proposed minerals activities. It is also used to ensure that such activities are conducted in a safe and environmentally responsible manner (MMS, Gulf of Mexico OCS Region, Revised 16 January 1990).

General Requirements

Geological or geophysical activities for OCS minerals prospecting under 30 CFR Part 280 shall be conducted so that the activities do not:

A. Interfere with or endanger operations under any lease or right-of-way issued or maintained pursuant to the OCS Lands Act;
B. Cause harm or damage to aquatic life;
C. Cause pollution;
D. Create hazardous or unsafe conditions;
E. Unreasonably interfere with or harm other uses of the area; or
F. Disturb cultural resources.

Any person conducting geological or geophysical prospecting for OCS mineral exploration shall immediately report to the Director, MMS:

A. Detection of OCS minerals and/or hydrocarbon occurrences;
B. Encounters of environmental hazards which constitute an imminent threat to human activity; or
C. Activities which adversely affect the environment, aquatic life, cultural resources, or other issues of the area in which the exploration activity is conducted.

Any person conducting shallow test drilling activities under a permit for OCS mineral prospecting shall use the best available and safest technologies which the Director, MMS, determines to be economically feasible.

Authorization granted under 30 CFR Part 280 to conduct geological prospecting for OCS minerals shall not confer a right to any discovered OCS minerals including oil and gas, or to a lease under the OCS Lands Act, as amended {30 CFR 280.3(a)}.

Geological or geophysical prospecting for OCS minerals may not be conducted on the OCS lands without an approved permit and/or plan unless such activities are being conducted pursuant to a lease issued or maintained under the OCS Lands Act.

If the Director, MMS, disapproves an application, the statement of rejection shall state the reasons for the denial within 30 days, and shall advise the applicant of those changes needed to obtain approval.

Shallow test drilling activities under a permit for OCS mineral prospecting under 30 CFR Part 280 require certain information to be submitted to the Minerals Management Service (MMS) so that a permit for prospecting for minerals other than oil, gas, and sulfur can be issued.

For each OCS area, each plan of application for a permit shall be filed in triplicate with separate copy(s) for each adjoining state(s) and one public information copy. For the Gulf of Mexico OCS, this information is to be sent to:

Regional Supervisor for Resource Evaluation
Minerals Management Service
Gulf of Mexico Region
1201 Elmwood Park Boulevard
New Orleans, Louisiana 70123-2394

Approval of a plan or permit for the specified period, including requests for extensions, are limited to a period not to exceed one year. Any modification to the permitted operations requires prior approval from the Regional Supervisor for Resource Evaluation. The application for prospecting permit should be submitted at least 60 days prior to the expected date of start up for the activities. The application and permit are processed by MMS at the same time.

Information Requirements

Each applicant for a permit for prospecting for minerals other than oil, gas, and sulphur shall complete a MMS permit application stating the following information:

A. The name, address, and telephone number of the service company conducting the activity and the name, address, and telephone number for the purchaser(s) of the data.
B. The purpose and description of the activity.
C. A description of the environmental effects of the proposed activity including potential adverse effects on marine life, and what steps are planned to minimize these adverse effects and monitoring any effects.
D. A description of any known archaeological resources in the area.
E. A description of any potential conflicts with other uses or users in the permit area.
F. The expected commencement date.
G. The expected completion date.
H. The name of the individual in charge of the field operation, local telephone number, marine number, and radio call sign.
I. The name, registry number, and registered owner of the vessel(s) to be used in the operation.
J. The port from which the vessel(s) will operate.
K. A description of the vessel navigation system.

Each applicant shall include a page-size plat(s) showing the location of the proposed activity. The plat(s) should show geographic coordinates relative to MMS area and block numbers, an easily identified onshore point of reference, and the distance and direction from the point of reference to the area of activity. Line locations should not be included on these plat(s).

In addition, each applicant for a permit shall submit the following information in accordance with 30 CFR 280.5-1(a)(7) as appropriate.

A. Brief description of method of drilling of borehole and sampling.
B. Brief description of shallow drilling or sampling equipment to be used.
C. Number of borings or sample locations to be occupied.
D. Navigation system or method to be used to position sample locations.
E. A prospecting plan.
F. Method of sample analyses, storage, and handling.
G. A description and list of the final processed data and information which will result from operations under the proposed activity.
H. The estimated date on which samples, logs, and processed data and information will be ready for inspection and copying.
I. Map(s), plat(s), or chart(s) showing specific block numbers, specific boring, or sample locations, and total number of borings or samples proposed.
J. Items A-B above shall be attached to the Application for Permit as appropriate for the type of activity being permitted and shall be considered as "PROPRIETARY INFORMATION."

(To obtain a copy of the permit application, contact Mr. Ronald J. Brinkman at (504) 736-2720.)

Environmental Effects

In March 1995, Amboy Aggregates submitted an application for a permit to prospect using vibracores for sand and gravel in Federal lands offshore the coast of New Jersey. This was the first and, up to now, the only application for a marine mining permit other than for oil, gas, or sulphur submitted to the MMS Gulf of Mexico Regional OCS Office for processing.

The potential effects from proposed prospecting are evaluated by MMS to determine the need for mitigative measures as required by 30 CFR 280.10. Certain types of prospecting activities will not cause significant environmental impacts and are normally categorically excluded from additional environmental analysis. A Categorical Exclusion Review (CER) is conducted on such activities. This includes:

A. Gravity and magnetometric observations and measurements;
B. Bottom and subbottom acoustic profiling or imaging without the use of explosives;
C. Mineral sampling of a limited nature such as that using either test drillholes or cores to less than 300 feet below the seafloor;
D. Water and biotic sampling, if the sampling does not adversely affect shellfish beds, marine mammals, or an endangered species or if

permitted by the National Marine Fisheries Service or another Federal Agency;

E. Meteorological observations and measurements, including the setting of instruments;
F. Hydrographic and oceanographic observations and measurements, including the setting of instruments;
G. Sampling by box core or grab sampler to determine seabed geological or geotechnical properties;
H. Television and still photographic observation and measurements;
I. Shipboard mineral assaying and analysis; and
J. Placement of positioning systems, including bottom transponders and surface and subsurface buoys reported in Notices to Mariners.

If the prospecting activity is not categorically excluded, an Environmental Assessment is prepared. An Environmental Assessment will lead either to a FONSI (Finding Of No Significant Impact) if there is no significant impact, or to preparation of an Environmental Impact Statement (MMS, Headquarters, 2 June 1986).

A CER was done for the Amboy Aggregates permit application since the cores were to be taken less than 300 feet below the seafloor. The CER analyses concentrated on biological, archaeological, and geological parameters; military warning areas; and coastal zone consistency.

SUMMARY

Regulations are in place which require that prospecting for mineral resources be conducted in a safe and environmentally responsible manner. Regulations are in place to ensure that the required information is forwarded on the permit application to MMS by the appropriate party seeking the permit. Regulations also require that an environmental analysis be conducted. The permit application and permit are processed at the same time.

REFERENCES

MMS, Gulf of Mexico OCS Region, Revised January 16, 1990. Requirements for geological and geophysical exploration or scientific research on the Outer Continental Shelf; Application for permit to conduct geological or geophysical prospecting or scientific research on the Outer Continental Shelf related to minerals other than oil, gas, and sulphur; Nonexclusive use agreement for scientific research.

MMS, Headquarters, June 2, 1986. Final postlease Categorical Exclusion Review and Environmental Assessment procedures.

Mr. Jerry Brashier has a B.S. degree in biology and a M.S. degree in fisheries from Louisiana State University. He is chief of the Environmental Operations Section for the MMS Gulf Of Mexico Regional Office. He has over thirty years of environmental experience.

Mr. G. Ed Richardson is a Supervisory Environmental Protection Specialist with the Mineral Management Service's Gulf of Mexico OCS Region. His career spans over 24 years of environmental and regulatory experience in state and federal government and in the oil and gas industry. He received his M.S. degree from Clemson University in microbiology, environmental health, and biochemistry.

SESSION 6D

CONTAMINANTS RESEARCH IN THE GULF OF MEXICO

Session: 6D - CONTAMINANTS RESEARCH IN THE GULF OF MEXICO

Co-Chairs: Ms. Gail Rainey and Dr. Pasquale F. Roscigno

Date: December 14, 1995

Presentation	Author/Affiliation
The Latest Knowledge on Hypoxia in the Gulf, Including EPA's Gulf Initiative	Dr. Nancy N. Rabalais Louisiana Universities Marine Consortium Dr. R. Eugene Turner Louisiana State University
Biodegradation of Aromatic Hydrocarbons and Heterocycles from Petroleum and Pyrogenic Sources in Marine Sediments	Dr. W. James Catallo Laboratory for Ecological Chemistry and Toxicology Louisiana State University
Development and Application of Sub-Lethal Toxicity Tests to PAH Using Marine Harpacticoid Copepods	Mr. Gui Lotufo Dr. John W. Fleeger Department of Zoology Physiology Louisiana State University
Role of Bottom Sediment Redox Chemistry near Oil Production Facilities in the Sequester/Release and/or Degradation of Metals, Radionuclide and Organics	Mr. B.C. Banker Mr. T.Z. Guo Dr. R.D. DeLaune Wetland Biogeochemistry Institute Louisiana State University
Ocean Discharge Criteria Evaluations (ODCEs) for OCS Discharges	Dr. Gary Petrazzuolo *Avanti* Corporation Annandale, Virginia
Environmental Assessment of Produced Water Discharges from Gulf of Mexico Oil and Gas Operations	Ms. Anne F. Meinhold Brookhaven National Laboratory Upton, New York Dr. David Gettleson Continental Shelf Associates, Inc. Jupiter, Florida

THE LATEST KNOWLEDGE ON HYPOXIA IN THE GULF, INCLUDING EPA'S GULF INITIATIVE

Dr. Nancy N. Rabalais
Louisiana Universities Marine Consortium

Dr. R. Eugene Turner
Louisiana State University

INTRODUCTION

The existence of a large low dissolved oxygen, or hypoxic, area that develops in the northern Gulf of Mexico adjacent to the effluents of the Mississippi and Atchafalaya Rivers each summer is well documented. Research indicates that seasonal hypoxia is related to nutrient over-enrichment of the river resulting from human activities in the watershed. Further, the severity and extent of hypoxia may threaten important commercial fisheries. The Sierra Club Legal Defense Fund, representing a coalition of 18 environmental, social justice and fishermen's groups, petitioned the Administrator of the U.S. Environmental Protection Agency (EPA) to convene a management conference under section 319(g) of the Clean Water Act to develop a management strategy for nutrients in the Mississippi River watershed. EPA's response was that the Gulf of Mexico Program will "develop viable solutions through a strategic assessment process, which will assess the existing data and identify and prioritize the areas of greatest need." To begin this process, the Gulf of Mexico Program held a Hypoxia Management Conference in New Orleans, Louisiana on 5-6 December 1995. The conference provided information on the following elements:

- characterization of the hypoxic zone
- impacts on resources/fisheries
- worldwide perspective
- causes
- sources and delivery of nutrients
- current nutrient management programs

This summary will highlight some of the information presented at the meeting with an emphasis on the results of the NOAA Coastal Ocean Program, Nutrient Enhanced Coastal Ocean Productivity (NECOP) program and data generated from research programs of the authors. Where the results of other researchers' works are presented, they will be duly noted as such. This summary does not represent the views of the Gulf of Mexico Program.

DISTRIBUTION AND DYNAMICS OF HYPOXIA IN THE NORTHERN GULF OF MEXICO

The inner to middle continental shelf of the northern Gulf of Mexico, from the Mississippi River birdfoot delta westward to the upper Texas coast, is the site of the largest zone of hypoxic bottom water in the western Atlantic Ocean. The areal extent of this zone during mid-summer surveys of 1993-1995 (approx. 16,000 km^2 to 18,000 km^2; Rabalais *et al.*, *in review*; Figure 6D.1) rivals the largest hypoxic areas elsewhere in the world's coastal waters. Conditions during the Great Summer Flood of 1993 point to the importance of the river in the formation and persistence of hypoxia (see references in Dowgiallo 1994). As a result of higher streamflow and increased flux of nutrients, especially in mid-to late summer, there was a significantly lower oxygen content of the lower water column, and an approximately two-fold increase in the areal extent of hypoxia with respect to the 1985-1992 mid-summer averages (Rabalais *et al.* 1994a). Prior to 1993, the average areal extent of bottom water hypoxia in mid-summer was 8,000 to 9,000 km^2 (Rabalais *et al.* 1991) (see 1992 in Figure 6D.1).

Critically depressed dissolved oxygen concentrations occur below the pycnocline from as early as late February through early October and nearly continuously from mid-May through mid-September. Stratification is a necessary component of the physical setting for hypoxia (Rabalais *et al.* 1991, Wiseman *et al. in review*). Hypoxic waters are distributed from shallow depths near shore (4 to 5 m) to as deep as 60 m water depth, but more typically in depths between 5 and 30 m. In March, April and May, hypoxia tends to be patchy and ephemeral; it is most widespread, persistent, and severe in June, July and August. The persistence of extensive and severe hypoxia into September and October depends primarily on the breakdown of the stratification structure by winds from either tropical storm activity or passage of cold fronts. Hypoxia may occur well up into the water column, depending on the water depth, and encompass from 10% to over 80% of the total water column. Continuous time series show long periods of hypoxia and anoxia, a draw down of hypoxia in the spring in response to respiration in the lower water column and at the seabed, vertical mixing and loss of stratification, response to winds (e.g., upwelling of deeper oxygenated waters), and, in other parts of the shelf, the influence of tidal advection (Rabalais *et al.*, 1992, Rabalais *et al.* 1994b).

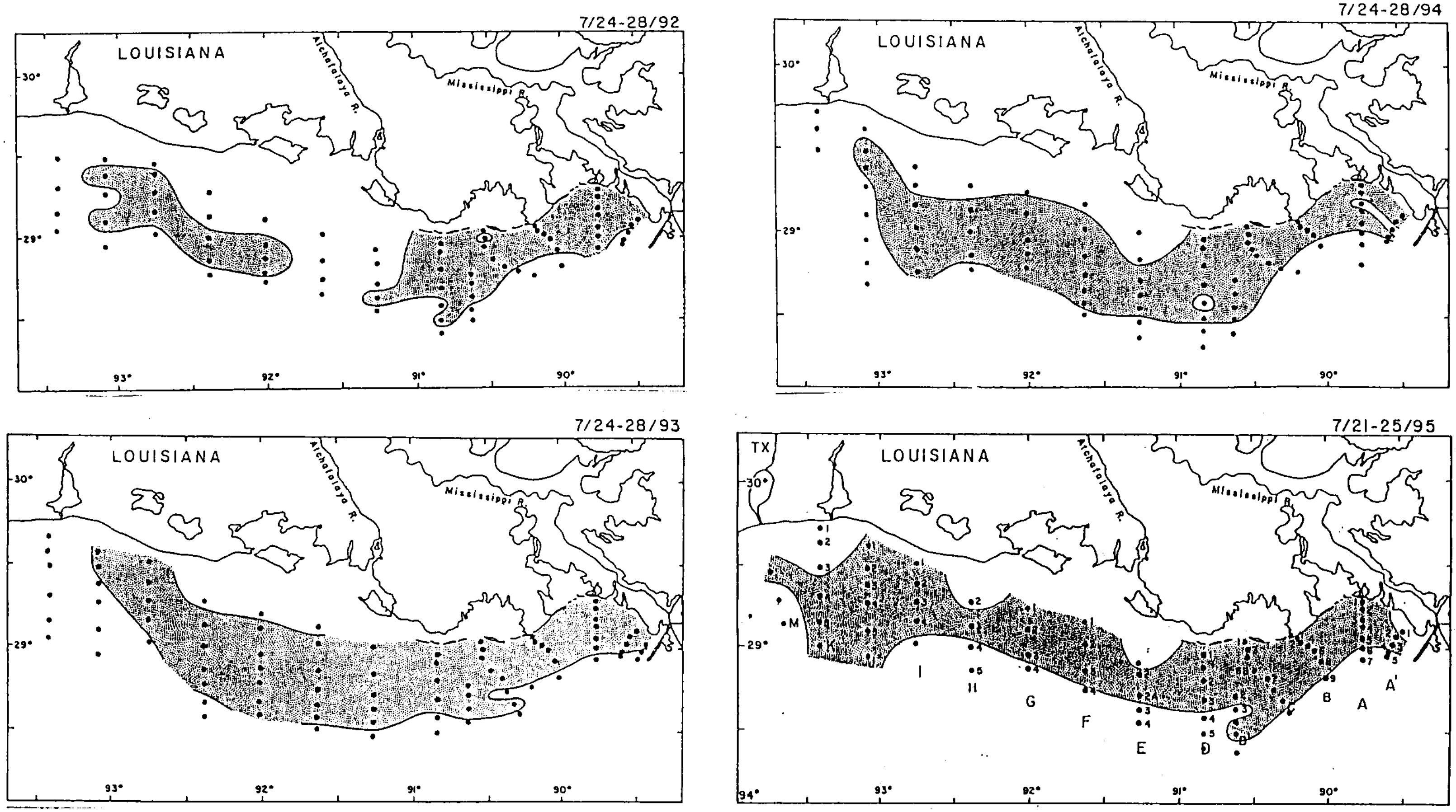

Figure 6D.1. Distribution of near-bottom water hypoxia (dissolved $O_2 \leq 2$ mg l^{-1}) in mid-summer for the dates indicated in 1992, 1993, 1994 and 1995. Data from hypoxia monitoring studies of N.N. Rabalais, R.E. Turner and W.J. Wiseman, Jr. (from Rabalais *et al. in review*).

LINKAGES WITH THE MISSISSIPPI RIVER

The relative magnitude in changes of freshwater discharge and nutrient flux from the Mississippi and Atchafalaya Rivers to the coastal ocean affects water column stability, surface water productivity, carbon flux, and oxygen cycling in the northern Gulf of Mexico. On a monthly time scale, productivity is most influenced by Mississippi River flow and nutrient flux to the system. Long-term seasonal variations in net productivity are coherent with the dynamics of freshwater discharge (Justić *et al.* 1993). The surface layer shows an oxygen surplus during February-July; the maximum occurs in April and May and coincides with the maximum flow of the Mississippi River. The bottom layer exhibits an oxygen deficit through the year, but reaches its highest value in July (coincident with maximum pycnocline strength). The correlation between the Mississippi River flow and surface oxygen surplus peaks at a time-lag of one month, and the strongest correlation for bottom water oxygen deficit is for a time-lag of two months.

HISTORICAL CHANGES IN NUTRIENTS AND ECOSYSTEM RESPONSES

Nutrient concentrations and loads have changed dramatically this century and accelerated since the 1950s. These results are outlined in papers by Turner and Rabalais (1991), Justić *et al.* (1995a,b):

- Concentrations of dissolved nitrogen and phosphorus have doubled, and silica have decreased by 50%.
- A spring nitrate peak is now present, and was not historically
- Nutrient composition in river and adjacent Gulf waters has shifted towards ratios closer to the Redfield ratio and more balanced than previously.
- Changes are closely related to N and P fertilizer applications in the watershed.
- Offshore nutrient compositions shifted along with potential and probable nutrient limitations.
- Water quality changes are specific to changes in nutrients and not changes in discharge volume.

Analyses of long-term data sets and biogenic markers in sediments supports the inference of increased eutrophication and hypoxia in the Mississippi River delta bight primarily because of changes in nitrogen loadings. These results are outlined in Eadie *et al.* (1994), Turner and Rabalais (1994a,b), Rabalais *et al.* (in press) and Sen Gupta *et al.* (in press):

- increased productivity
- increased marine-origin carbon accumulation
- increased silicate-based phytoplankton productivity
- phytoplankton composition shifts
- increase in oxygen stress
- changes consistent with nitrate flux and nitrogen fertilizer use.

EFFECTS ON LIVING RESOURCES

Hypoxia may affect fisheries resources by direct mortality, altered migration, reduction in suitable habitat, increased susceptibility to predation (including by humans), changes in food resources and susceptibility of early life stages. Fisheries-dependent data from the National Marine Fisheries Service (presented by R. Zimmerman) indicated that over a 10-year period in the fishery zones coincident with the delineation of hypoxia there were no changes in catch per unit effort. There was, however, a decided reduction in effort where hypoxia exists because the trawlers avoid the areas. There were some indications of a reduced yield related to the presence of hypoxia. Fisheries-independent data analyses were limited (J. Hanifen, Louisiana Department of Wildlife and Fisheries), but indicated a reduced catch in areas of hypoxia. No population-level data were provided during the meeting. Examples of reduced fisheries yield under increasing nutrient loads were provided from work in Osaka Bay, Japan (by D. Boesch, University of Maryland, Center for Environmental and Estuarine Studies), areas of the Baltic (R. Diaz, Virginia Institute of Marine Science), and from the literature (e.g., Caddy 1992).

Studies of benthic communities and demersal communities show distinct responses of various members of the communities to decreases in dissolved oxygen concentration (Rabalais and Harper *in prep.*). Oxygen deficiency stressed benthic communities are characterized by limited taxa (none with direct development, e.g., amphipods), characteristic resistant infauna (e.g., a few polychaetes and sipunculans), reduced species richness, severely reduced abundances (but never azoic), low biomass, and limited recovery following abatement of oxygen stress (Rabalais *et al.* 1993, 1995).

CAUSES

A series of hypotheses were presented to explain the observed increases in eutrophication and oxygen stress. All but the last one was rejected. A more detailed treatment of this issue is in Turner *et al.* (*submitted*):

Ho1: Severe restriction of overland flow through coastal wetlands this century. Rejected because restricted flow overbank (2.6%) is insignificant in proportion to the total flow, the amount of freshwater swamps is insufficient to absorb nutrients at the rates measured, and there is a mismatch of overland flow potential and river stage.

Ho2: Nutrient and organic loadings from the estuaries. Rejected because the deposition/accumulation of biogenic silica (a surrogate for diatom production) is strikingly different in both end members, and the carbon isotope ratio of offshore sediments indicates an *in situ* source not an estuarine source.

Ho3: Intrusions of offshore oxygen minimum layer. Rejected because there is no documented physical connection, and oxygen consumption rates in the oxygen minimum layer are insufficient to account for the decline in oxygen on the shelf.

Ho4: Short- or long-term climate changes (riverine flux fluctuations). Rejected because there is no statistical long-term change in riverine discharge.

Ho5: Organic loading from the Mississippi River. Rejected because the amount of organic loading is insufficient for the observed decline in oxygen, and the isotopic ratios of the sediments indicate a marine origin rather than a terrestrial one.

Ho6: Increase in nutrient loading from the Mississippi River. Accepted because the long-term changes in eutrophication indices and oxygen stress are coincidental with the changes in nutrients in the Mississippi River.

FUTURE SCENARIOS

To reach the 1950s levels of dissolved nitrogen would require a 40-50% in the current loadings that exit the Mississippi River delta. Identification of sources of nutrients within the Mississippi River watershed that eventually reach the Gulf of Mexico should lead to avenues of management. While the results of changes in nutrient delivery to the northern Gulf of Mexico are clear, the delineation of the sources and their fate and transformation as they are delivered to the Gulf is not yet complete. Three presentations (R. Alexander, R. Antweiler, and D. Goolsby, all of the U.S. Geological Survey), however, clearly demonstrated that the majority of the nitrogen flux from the Mississippi River originated in the upper watershed, above the confluence with the Ohio, and that the flux resulted from nonpoint source runoff, primarily from agricultural practices, especially the application of fertilizers.

There is a direct connection between river nutrient loading and the hypoxic zones on the Louisiana shelf, and these river diversions aimed at wetland restoration might be considered as a possible management tool to decrease oxygen problems offshore. However, the amounts of river water to be diverted (based on U.S. Army Corps of Engineers maximal estimates for Davis Pond, Caernarvon and Bonnet Carré) are so small relative to the size of the discharge (1% of annual discharge volume) that it will have an insignificant effect on the size, frequency and duration of oxygen depletion within bottom waters offshore. Further diversions of river waters to the east of the Mississippi River delta may aggravate the limited and ephemeral conditions of hypoxia there or further flow through the Atchafalaya delta might increase the duration, severity or extent of hypoxia on the southwestern Louisiana shelf or the upper Texas coast.

Any discussion of nutrient management scenarios must be undertaken within another overall context--that of global climate change. Justić *et al.* (*in press*) applied a predicted 20% increase in freshwater flux with a doubled CO_2 climate, primarily during the May-August period, to calculate an estimated average monthly runoff of the Mississippi River at Tarbert Landing compared to 1985-1992. Surface salinity in the Gulf is likely to decrease substantially, and water column stability will increase. Manipulations of a physical-biological two-box model (Justić *et al. in press*) revealed that there will be a 30-60% decrease in summertime subpycnoclinal oxygen content, relative to the 1985-1992 average. Under those conditions, the hypoxic zone in the northern Gulf of Mexico will expand and encompass an area greater than that of the summer of 1993.

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BIODEGRADATION OF AROMATIC HYDROCARBONS AND HETEROCYCLES FROM PETROLEUM AND PYROGENIC SOURCES IN MARINE SEDIMENTS

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PROJECT STATUS SUMMARY

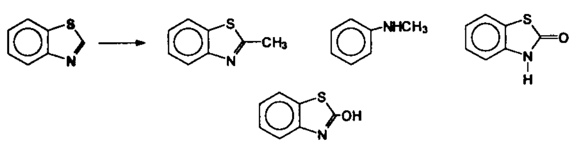
The focus of this work is to understand the biological and chemical transformation sequences that occur when hydrocarbons and heterocycles are discharged to marine sediment-water systems. The goals are to 1) more fully understand the fates of these chemicals in sediments, 2) evaluate the effects of central physicochemical variables (e.g. redox potential) on these fates, 3) determine chemical versus biochemical transformation endpoints, 4) characterize the microbial communities involved and, 5) examine the use of biological and physicochemical modifications of the system to promote desired outcomes (e.g., more complete degradation of the compounds and/or less generation of toxic and mobile partial transformation products and/or increase rates of degradation of selected analytes).

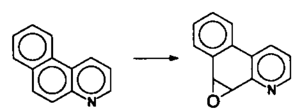
The following target compounds have been synthesized in deuterated form using a) high temperature-dilute acid (HTDA) syntheses in glass sealing tubes over Pd catalysts and b) post synthetic deuterium-hydrogen exchange in supercritical deuteroxide: benzothiazole, quinoxaline, 2-methylquinoxaline, 2,3-dimethylquinoxaline, benzo(f)quinoline, phenothiazine, dibenzofuran, and phenazine. The supercritical deuteroxide methods developed for these compounds in this work has resulted in an application for a U.S. patent by the authors.

The protiated homologs of the target compounds above have been added to a) oxidized and reduced brackish marsh sediment slurries in sealed glass microcosms, b) batch chamber microcosms maintained under permanently flooded (reduced), drained (oxidized), and alternately flooded and drained (pulsed) conditions and, c) batch liquid cultures. (Deuterated tracer studies are being conducted in liquid cultures and sediment-water slurries.) Several degradation studies have been performed using complex mixtures in addition to the protiated and deuterated compounds. These mixtures included a) south Louisiana crude oil (SLC) and, b) anthracene oil. The liquid systems and sediments are extracted with organic solvents, concentrated, chemically dried, and subjected to gas chromatography (GC) and GC-mass spectrometry (GC-MS) under semi-quantitative conditions.

To date, the following data and conclusions have been developed:

a) Most of the target compounds are highly resistant to degradation under conditions typically found in Louisiana brackish and salt marshes. Microbial activity was high in the liquid and sediment systems containing the target analytes and the analytes in the presence of SLC. Nevertheless, in incubations lasting over 90 days, only minor amounts of chemical and biological degradation products have been observed for benzothiazole and benzo(f)quinoline, e.g.:

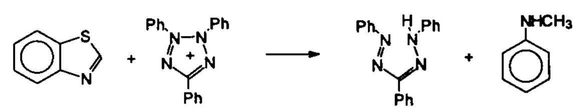




b) The addition of nitrogen and phosphorus containing inorganic nutrients and the trace elements including Fe, Cu, Zn, Co, Mo, and B, to the system promoted microbial activity (as estimated by tetrazolium salt reduction rates, redox potential changes, and evolution of gaseous sulfides) but also appeared to *decrease* the already slow rates of target analyte transformation. Liquid cultures and sediments became anaerobic and then highly reducing following nutrient enrichments, with sulfide generation evident even in liquid cultures. In batch liquid cultures containing the compounds in SLC, redox potentials decreased from + 190 mV versus saturated calomel electrode (SCE) (oxidized) to - 270 mV versus SCE (reduced) within three days of nutrient enrichment. Differential target compound degradation was not observed.

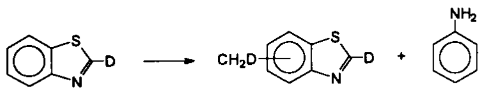
c) Immediately after the introduction of the target compounds to sediment and water, a primary route of removal of benzothiazole was volatilization. This process, however, decreased after 24 - 48 hours, and there was indirect evidence of metabolism of the remaining compounds after about 10 days of incubation. The major products observed after 10 days included water soluble ketones and phenols, the latter of which were detected spectrophotometrically using tetrazotized-o-dianisidine complexing agents.

d) There was a considerable amount of chemical (i.e., non-biological) transformation of benzothiaziole. Numerous experiments using protiated (I.) and site-specifically deuterated benzothiazole confirmed that the compound is a reducing agent that acts either by transferring H· radicals or hydride ions to oxidized acceptors. This was shown using iodonitrotetrazolium violet (INT, II.), which is reduced to an insoluble formazan (III.) after a 2 electron/H^+transfer:



I. II. III. IV.

Oxidized products from this chemical reduction included N-methylaniline (IV.), aniline, and a series of conjugated benzothiazoles, dimers, and their alkyl homologs. The presence of dimers suggested that the stoichiometry of this reduction was 2 moles of benzothiazole per one mole of reduced INT. This reaction was further confirmed using a deuterium oxide medium and observing the reduced INT using NMR, and analysis of the reduced products using FAB-mass spectrometry. Subsequent experiments also suggested that benzothiazole can transfer methyl groups abiotically. Starting with vacuum distilled benzothiazole-2-D synthesized in this laboratory (i.e., a single deuterium placed on the labile 2 carbon, I.), rapid generation of mono-methylated benzothiazoles was observed:



I. II. III.

This unexpected and fascinating reaction is being investigated further.

Preliminary microbial characterizations have shown that some target compounds may be partially metabolized by a limited number of species including *Enterobacter sp.*, *Bacillus sp.*, and *Psuedomonas sp.* The presence of a benzo(f)quinoline epoxide intermediate (confirmed by tandem runs using protiated and deuterated substrate) indicated that micro-eukaryotes, probably fungi, are involved in degradation processes along with the prokaryotes mentioned previously. In all cases, C and N limitation was a pre-requisite for the onset of detectable degradation. The addition of nutrients prolonged the time needed to generate C and N limitation.

Preliminary conclusions may be summarized as follows: The target compounds, and many other constituents of SLC (e.g., branched hydrocarbons, cycloalkanes), are resistant to biological degradation under conditions found in brackish marsh and marine sediment-water in Louisiana. Addition of nutrients to water and sediment does not increase degradation rates in these systems, and in many cases may cause them to decrease relative to systems deficient in N, P, and especially C. This applies particularly to systems that are mildly reduced or oxidized: addition of nutrients can cause stimulated respiration of naturally occurring organic substrates thereby generating highly reduced electrochemical conditions. As SLC and other diagenetic materials originate in highly reduced sediments, it is unsurprising that constituents of the mixture would be resistant to degradation under these conditions. It is common to measure microbial respiration after spills and during biotreatment for use as an indicator of biodegradation of the spilled hydrocarbons. Current data indicate that this can be misleading, as very high respiration was observed for long periods, with no detected change in hydrocarbon levels or ratios versus controls. The primary removal processes of hydrocarbons immediately after introduction to quiescent sediment-water were volatilization, chemical degradation (e.g., benzothiazole, above) and emulsification/tar ball formation. Biological degradation became significant only after extended periods of incubation, and was frequently incomplete (i.e., stable products were observed).

DEVELOPMENT AND APPLICATION OF SUB-LETHAL TOXICITY TESTS TO PAH USING MARINE HARPACTICOID COPEPODS

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INTRODUCTION

Petroleum drilling and production operations in the Gulf of Mexico have made a substantial impact on the local marine and estuarine environment. A broad range of chemicals are used and largely discharged as produced water or in spills. As a result, the biota can be exposed to petroleum compounds for many years. Among all petroleum hydrocarbons, polycyclic aromatic hydrocarbons (PAHs) occur in high concentrations and are among the most carcinogenic, mutagenic, and toxic compounds of the pollutants discharged to the marine environment. An estimated 2.3×10^5 metric tons of PAH enter the aquatic environment annually. PAH are highly hydrophobic compounds and strongly bind to the organic fraction of sediment particles. Therefore, the PAH concentrations in sediments are typically much higher than those in the overlying water.

We are developing sub-lethal toxicity tests for sediment-associated PAH using harpacticoid copepods. Harpacticoids are wide-spread epibenthic and infaunal members of the meiofauna (invertebrates passing a 1 mm sieve but retained on a 0.063 mm sieve). They are very abundant in most marine sediments, second, among metazoans, only to nematodes. Harpacticoids play a significant role in food webs of juvenile fish and shellfish. Upon hatching, copepods mature through six naupliar stages, then metamorphose to six distinct copepodite stages, the last of which is the mature adult. Many benthic harpacticoids spend their entire life cycle in the sediment. Their short generation time (few weeks) and easily distinguishable life stages facilitate rapid assessment of population growth, and sublethal effects on reproduction. Harpacticoids have been used in toxicological studies of sediment-bound metals, PCBs and pesticides; however, few data are available on PAH effects.

SELECTION OF PAHS

From the long list of PAH single compounds, two, phenanthrene and fluoranthene were selected. Both are medium molecular-weight PAH and usually constitute a high percentage of total PAH in sediments. USEPA has issued sediment quality criteria (SQC) guidelines for phenanthrene and fluoranthene derived using the equilibrium partitioning theory and marine invertebrates. For a more realistic approach concerning natural PAH contamination in sediments, diesel fuel, a complex mixture of hydrocarbons, was also used.

CONTAMINATION PROCEDURES

Mud-flat sediment was homogenized with 25ppt artificial sea water (ASW), sieved through a 45 µm mesh and allowed to settle for 24 hours. The supernatant was removed via aspiration leaving reconstituted test sediment (solids content =14 %, total organic carbon = 1.5%). PAH (phenanthrene or fluoranthene) carried in 200 µl of acetone was spiked dropwise on a vigorously stirring slurry of 150 g wet-weight sediment. Mixing was maintained for 4 hours and the PAH-amended sediment was stored at 4°C in the dark. The amount of PAH spiked was calculated on a dry weight basis. The concentrations for single compounds ranged from 10 to 2,000 mg/kg (ppm).

Diesel fuel was mixed with autoclaved mud-flat sediment and after tumbling for seven days was thoroughly washed with water to remove non-adsorbed hydrocarbons. The final total PAH concentration measured was 660 mg/kg (stock sediment). This full-concentration sediment was diluted with clean sediment from the same site on a dry weight basis and vigorously stirred for 12 hours. The resulting total PAH concentrations in 300 g of wet sediment (mg/kg) ranged from 10 to 400 mg/kg.

ANALYTICAL CHEMISTRY

Single compound (phenanthrene and fluoranthene) sediment-concentrations were analyzed using HPLC. PAH total concentration in diesel fuel concentrations was determined using Iatroscan.

TEST ANIMALS

Developing a toxicity test is labor intensive. A series of experiments to evaluate and select several factors involved in detecting hazardous effects in living organisms must be performed. The main goals are to achieve maximal discriminatory power and repeatability. It is desirable to have high performance in the controls (i.e., good survivorship) and low variability within treatments. An "unlimited" supply of test organisms was made available by culturing one species of sediment- dwelling harpacticoid representative of the local estuarine copepod assemblage from the Louisiana coast. *Schizopera knabeni* is a member of the Diosaccidae, the most speciose and diverse family in Harpacticoida. It is currently cultured, sediment-free at room temperature in static conditions in 2 L Erlenmeyer flasks. The water is partially renewed fortnightly and the culture fed with diatom paste and yeast. Although cultured in the absence of sediment, these copepods always burrowed instantly when transferred to dishes containing sediment. It was desirable to compare the responses of *Schizopera knabeni* to PAH exposure with the responses of other harpacticoid species. However, attempts to culture other species of salt-marsh copepods were unsuccessful. Three of the most abundant mud-flat copepod species from Louisiana salt marshes (*Cletocamptus deitersi*, *Pseudostenhelia wellsi* and *Coullana sp.*) were field collected and kept in the laboratory for a few days before used in experiments.

SEDIMENT TOXICITY TESTS WITH *SCHIZOPERA KNABENI*

The effects of sediment-associated PAHs on the survivorship, reproduction, development and grazing activity of harpacticoid copepods were initially investigated in a series of experiments using laboratory cultured *Schizopera knabeni*. Glass vials (15 ml) were filled with 10 ml of 25 ASW and 1.5 ml test sediment was added with minimal disturbance creating a 2- to 3-mm sediment layer. A known number of copepods were added to all vials, which were placed in moisture chambers and kept in the dark at 25°C. At the end of each experiment, the contents of each chamber were sieved through a 45 µm mesh and retained copepods were examined. Tests protocol and results are presented below.

96-h survivorship: 15 or 20 individuals of various life history stages per replicate (x4) were exposed to sediment treatments for 96 hours, and surviving organisms were enumerated. Survivorship data was used to calculate LC50 values and respective 95% confidence limits.

Phenanthrene:
- nauplii, LC50 = 322 (265-391) mg/kg
- copepodites, LC50 = 317 (260-384) mg/kg
- adult females, LC50 = 543 (446-659) mg/kg
- adult males, LC50 = 1,081 (985-1187) mg/kg

Fluoranthene:
adult females, LC50 = >2,000 mg/kg

Diesel fuel:
adult females, LC50 = 187 (114-287) mg/kg

10-d reproductive output: 10 mating pairs per replicate (x 4) were exposed to sediment treatments for 10 days. During this period one female would typically extrude several broods of eggs, the earlier ones developing into nauplii and copepodites. Two endpoints were used: total number of offspring (eggs, nauplii and copepodites) or number of realized offspring (nauplii and copepodites only) from each vial divided by the number of surviving females. Results are expressed as the concentration of contaminant estimated to cause a 25% reduction in offspring production, as compared with control numbers (IC25).The survivorship of males and females was also determined, and allowed the calculation of 10-d LC50 values in the phenanthrene experiment only.

Phenanthrene:
total offspring, IC25 = 48 (6.47 - 74) mg/kg
realized offspring, IC25 = 26 (0 - 57) mg/kg
Female 10-d LC50 = 345 (291-407) mg/kg
Male 10-d LC50 = 348 (291 - 417) mg/kg

Fluoranthene:
total offspring, IC25 = 22 (17.38 - 32.9) mg/kg
realized offspring, IC25 = 18 (16 - 22) mg/kg)

Diesel fuel:
total offspring, IC25 = 47 (12- 71) mg/kg
realized offspring, IC25 = 18 (10 - 59) mg/kg

Grazing activity: 5 adult females per replicate (x 4) were exposed to sediment treatments for 24 hours and fed with approximately 2 x 105 [^{14}C] radiolabeled *Thalassiosira wesflogii*. Following a grazing period of 6 hours, the copepods were formalin killed and assayed for radioactivity.

Incorporated radioactivity was converted to number of ingested algae. Results are expressed as the concentration of contaminant estimated to cause a 25% reduction in grazing activity, as compared with control numbers (IC25).

Phenanthrene:
IC25 = 26 (19 - 36) mg/kg

Fluoranthene:
IC25 = 65 (17 - 94) mg/kg

Diesel fuel:
IC25 = 19 (10 - 39) mg/kg

10-d nauplius survivorship and development: 15 one-day old nauplii per replicate (x 4) were exposed to sediment treatments for 10 days. At test termination, surviving organisms were enumerated and examined for development stage (nauplius or copepodite). This experiment was conducted using phenanthrene only and yielded a 10-d LC50 of 84 (74-95) mg/kg. In the control treatment, all surviving copepods metamorphosed and developed to copepodite stages. However, as the concentration of phenanthrene in the sediment increased, a higher fraction of copepods remained in the nauplii stages, failing to metamorphose into copepodites.

10-d copepodite survivorship and development: 20 eight-day old copepodites per replicate (x 4) were exposed to sediment treatments for 10 days. At test termination, surviving organisms were enumerated and examined for sex and development stage (copepodite or adult). This experiment was conducted using phenanthrene only and yielded a 10-d LC50 of 150 (136-165) mg/kg. In high phenanthrene concentrations, a smaller fraction of females were carrying their first brood of eggs and a larger fraction of copepods still remained in copepodite stages, as compared to the control.

DISCUSSION OF PAH ACUTE TOXICITY TO *SCHIZOPERA KNABENI*

The toxicity of sediment-associated PAHs to harpacticoids was demonstrated using single compounds (phenanthrene and fluoranthene) and a complex mixture (diesel fuel). In short term exposures (96 hours), diesel fuel was toxic at lower concentrations compared to the single compounds, as revealed by the LC50 values. Fluoranthene was the least acutely toxic compound in short exposures, even at very high concentrations. The acute toxicity of phenanthrene to different life cycle stages was also investigated. In 96-h exposures, immature copepods (nauplii and copepodites) were most sensitive and adult males least. In 10-d exposures, nauplii were much more sensitive than copepodites or adults, suggesting that reproduction/ development is impaired at fairly low levels of contamination. Adult copepods were most tolerant, males and females being equally sensitive.

DISCUSSION OF PAH SUBLETHAL TOXICITY TO *SCHIZOPERA KNABENI*

The three contaminants used in this investigation decreased offspring production at sediment-concentrations much lower than those causing significant mortality. Copepods also developed at a slower rate when exposed to PAHs: nauplii took longer to metamorphose into copepodites and copepodites took longer to attain sexual maturity. Similar effects occurring to copepods in their natural environment are expected to cause a negative impact on their population dynamics. PAHs mode of action is by general narcosis. As organisms become intoxicated, their overall activity lowers down and eventually leads to death. The grazing experiment successfully detected decreased ingestion of microalgae on copepods exposed to sublethal concentrations of PAH for a short time period (24 hours)

SEDIMENT TOXICITY TESTS WITH FIELD COLLECTED HARPACTICOIDS

96-h survivorship: 15 or 20 individuals per replicate (x4) were exposed to sediment treatments (phenanthrene only) for 96 hours and surviving organisms were enumerated. Survivorship data was used to calculated LC50 values and respective 95% confidence limits.

Cletocamptus deitersi, LC50 = 540 (481-605) mg/kg
Pseudostenhelia wellsi, LC50 = 504 (451-563) mg/kg
Coullana sp., LC50 = 54 (39-75) mg/kg

LC50 values indicated that *Cletocampus deitersi* was the most tolerant species, followed closely by *Pseudostenhelia wellsi* (both approximately as sensitive as *S. knabeni*). *Coullana sp* was much more sensitive than the other copepod species investigated.

SEDIMENT PREFERENCE/AVOIDANCE EXPERIMENT

In order to determine whether *S. knabeni* detects and actively avoids exposure to PAH- contaminated sediment, preference experiments were conducted. Seven preference arenas were set up in 175x90 mm crystallizing dishes containing a solidified agar substrate with five wells (di = 3cm) equidistant from the center. The dish was filled with ASW and each well filled with one sediment treatment. A group of 150 adult *Schizopera knabeni* was loaded to the center of the dish and allowed 12 hours to search and burrow into the sediment within each well. After this time period, the sediment from each well was aspirated, sieved and examined for copepods. This experiment was run using seven preference arenas per contaminant (phenanthrene, fluoranthene and diesel). Results show that copepods did not burrow randomly in the wells within each arena. Rather, they clearly preferred uncontaminated sediment over any other treatment as indicated by the higher proportion of copepods found in this treatment (>50% of the total burrowed).

To generate LC50 values for sediment-associated phenanthrene, fluoranthene and diesel fuel, copepods were exposed for 96 hours to test-sediments and assessed for mortality. Thirty adult copepods in each test chamber in four replicates were used for each treatment.

Two chronic or sub-lethal tests, in which mortality is not the endpoint, were developed and applied to *Schizopera knabeni.* The first assessed the effects of PAH on the reproductive capacity by determining the average number of offspring produced by one fertile female. A second test explored PAH effects on grazing activity by quantifying the amount of algae grazed on by copepods in a given period of time.

The reproductive-output test was performed by exposing one mating pair (sub-adult female and adult male) to PAH-contaminated sediment for the period of 14 days. This period of time was enough for the offspring produced from the first brood to develop into late copepodite stages and for the females to produce a second brood. Each sediment concentration was replicated with ten test chambers containing one mating pair in each. Each unit received a dose of food consisting of 0.2 mg of Microfeast Plus larval diet (yeast) after 24 hours. At the end of the experiment, all life stages were recovered from the sediment, adult mortality was assessed and egg clutch size, nauplii and copepodites produced were enumerated.

In the grazing activity experiment, a group of five adult females were placed and kept unfed for 24 h in the test chambers. Radiolabeled algae (the *dinoflagellate Isocrysis galbana* cultured in 14C bicarbonate) was offered in a known amount and copepods were allowed to graze for a period of three hours. Grazing was terminated by washing the copepods from the sediment and transferring to 4% formalin. Copepods from each experimental unit were solubilized in scintillation vials and radioactivity incorporated through ingestion of algae was measured in a scintillation counter.

Table 6D.1. Mean percentage survivorship and corresponding standard deviation in the fluoranthene, phenanthrene and diesel 96-h survivorship experiments.

Treatment (mg/kg)	Mean survivorship (%)	Standard deviation
Fluoranthene		
0	100	0
60	100	0
125	96	0
250	87.5	6.16
500	67.5	9.88
1000	24	11.25
Phenanthrene		
0	99.25	1.5
60	97.75	1.5
125	96.75	2.87
250	77.5	33.93
500	34.25	23.21
1000	8.25	16.5
Diesel		
0	99.25	1.5
25	99.25	1.5
50	91.5	8.35
100	58.5	7.05
200	4	4.25

RESULTS

In all phenanthrene and fluoranthene experiments, the carrier (acetone) treatment was never significantly different from the acetone-free control.

96-h Survivorship

Excellent performance in the controls was achieved, with survivorship close to 100% in both control treatments. There was a direct positive relationship between mortality and sediment PAH concentrations in the sediment with phenanthrene, fluoranthene, and diesel fuel (Table 6D.1). Significant mortality was observed at sediment PAH concentrations as low as 250 mg/kg of phenanthrene and fluoranthene, and as low as 100 mg/kg of diesel fuel.

14-Day Reproductive Output

The total offspring produced in 14 days by one fertile female was determined by enumerating eggs in the egg sac, and larval (nauplius) and juvenile (copepodite) stages. Nauplii and copepodites together comprised the so-called realized offspring, individuals that hatched from egg and survived until experiment termination. In the fluoranthene experiment (Figure 6D.2), a significant reduction in the total offspring produced was detected at 250 mg/kg. However, a significant reduction in the realized offspring was detected at a lower concentration, 125 mg/kg. In the phenanthrene experiment (Figure 6D.3), no statistically significant difference was observed in the total offspring between the control and all PAH treatments. But again, a significant reduction in the number of nauplii and

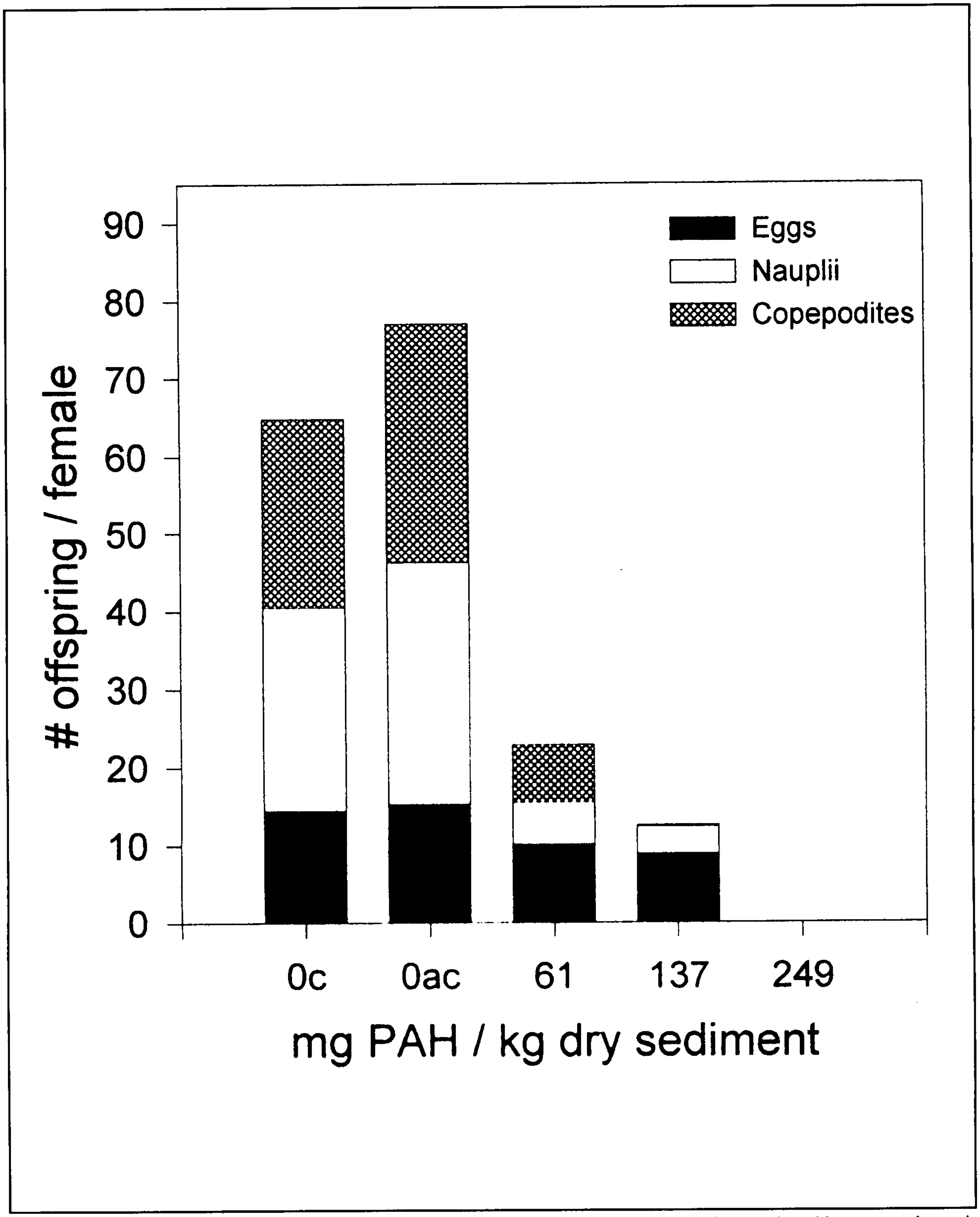

Figure 6D.2. Histogram of total reproductive output in terms of mean number of offspring produced by one mating pair in the fluoranthene 14-day reproductive output experiment with *Schizopera knabeni*. Total is fractionated into number of eggs, nauplii and copepodites. 0ac = acetone control.

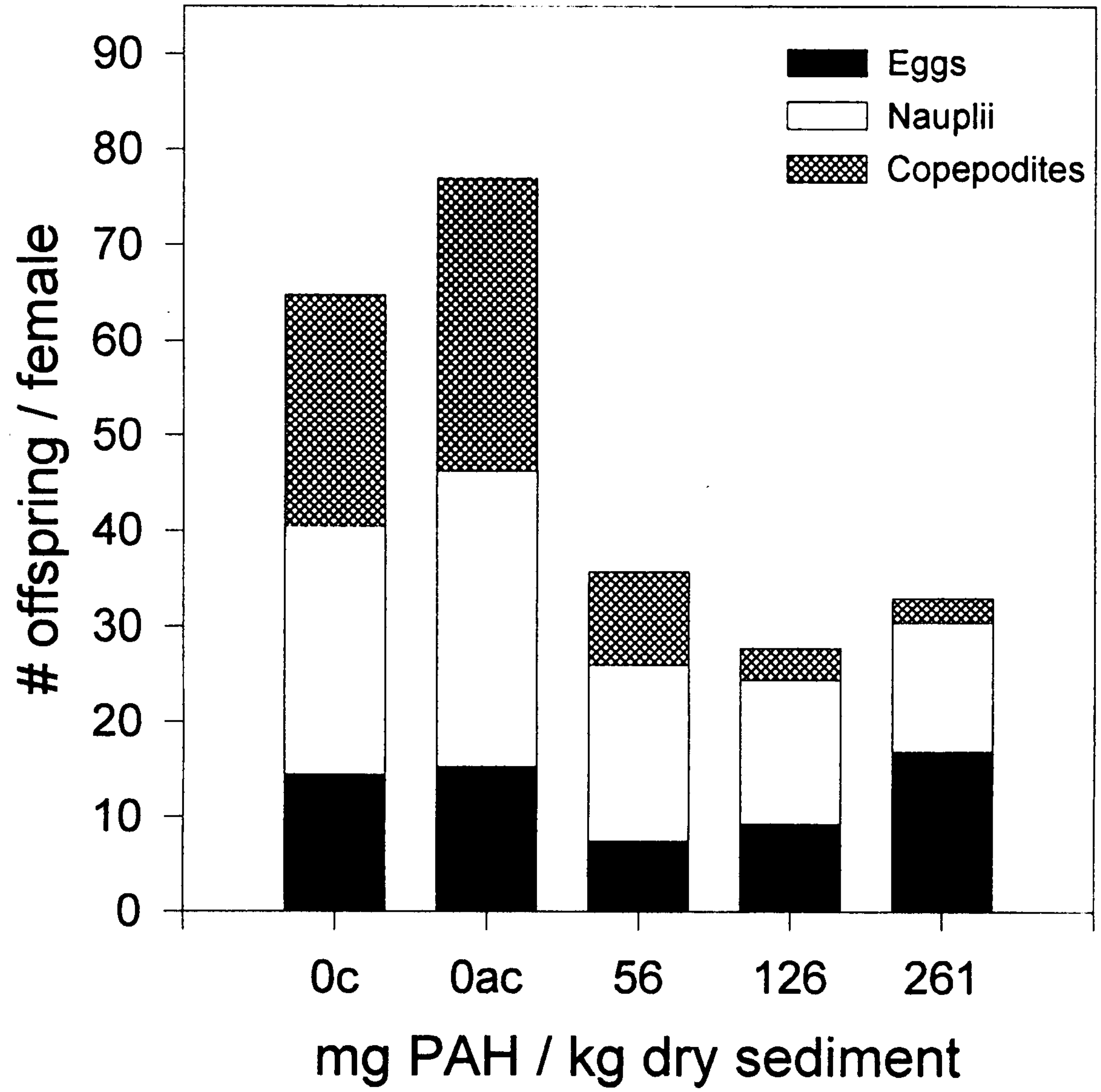

Figure 6D.3. Histogram of total reproductive output in terms of mean number of offspring produced by one mating pair in the phenanthrene 14-day reproductive output experiment with *Schizopera knabeni*. Total is fractioned into number of eggs, nauplii and copepodites. 0ac = acetone control.

copepodites occurred at 125 mg/kg. In the diesel experiment (Figure 6D.4), total reproduction and realized offspring were significantly reduced at 50 mg/kg, whereas total number of copepodites was reduced at 10 mg/kg. It was evidenced by the three experiments that besides an overall adverse effect on offspring production, PAH had a stronger impact on the normal development of eggs into nauplii and copepodites.

Grazing Activity

As determined by the total radiolabel incorporation in copepods via ingestion of radioactive algae, grazing activity was adversely impaired by phenanthrene in the sediment (Figure 6D.5). A mean decrease in grazing was observed in the 60 mg/kg treatment, but a significant decrease was detected at 125 mg/kg and higher. Incorporation of label into dead control copepods was minimal, indicating that the radioactivity in copepods is due to active ingestion of radiolabeled cells. Sub-lethal toxicity tests usually require long-term exposures to contaminants, as for the reproductive output experiment described above. An adverse effect on feeding, an important physiological activity, was detected after a short-term exposure of only 24 hours applying the test protocol developed in this project. Tests using fluoranthene and diesel fuel will be performed shortly.

CONCLUSIONS

The first part of this project was successfully accomplished by providing test protocols that proved to be useful in detecting adverse effects of PAH on copepods, a ecologically important group of estuarine metazoans.

Four basic conclusions were drawn from the experiments performed with the harpacticoid *Schizopera knabeni*:

- PAH in the sediment phase had an adverse impact on survival, reproduction, development and feeding of a harpacticoid copepod.
- Sub-lethal tests were more sensitive than acute exposures, detecting the toxicity of sediment-associated PAH at lower concentrations.
- Diesel fuel, a complex mixture of PAH, had a significant impact at lower concentrations than the single compounds phenanthrene and fluoranthene.
- The grazing activity test, performed for the first time with meiobenthos, proved to be more sensitive and more time-effective when compared to the reproductive-output test.

FUTURE RESEARCH AND TEST APPLICATIONS

Our future research will focus on performing the developed test protocols to detect and compare PAH adverse effects on three of the most abundant species of harpacticoids in the estuaries of the Gulf of Mexico. We also propose to test the hypothesis that pre-exposure to PAH increases tolerance to this compounds. This will be accomplished by comparing the sensitivity of two populations of the same species: one from Louisiana, subjected to historical chronic exposure to hydrocarbons; the other from a more pristine estuary, potentially in Florida. We will also test the hypothesis that PAH in the sediment may exert a selective pressure towards development of resistance. Laboratory experiments will be performed to compare the tolerance across generations of a population of harpacticoid chronically exposed to PAH in laboratory-controlled conditions.

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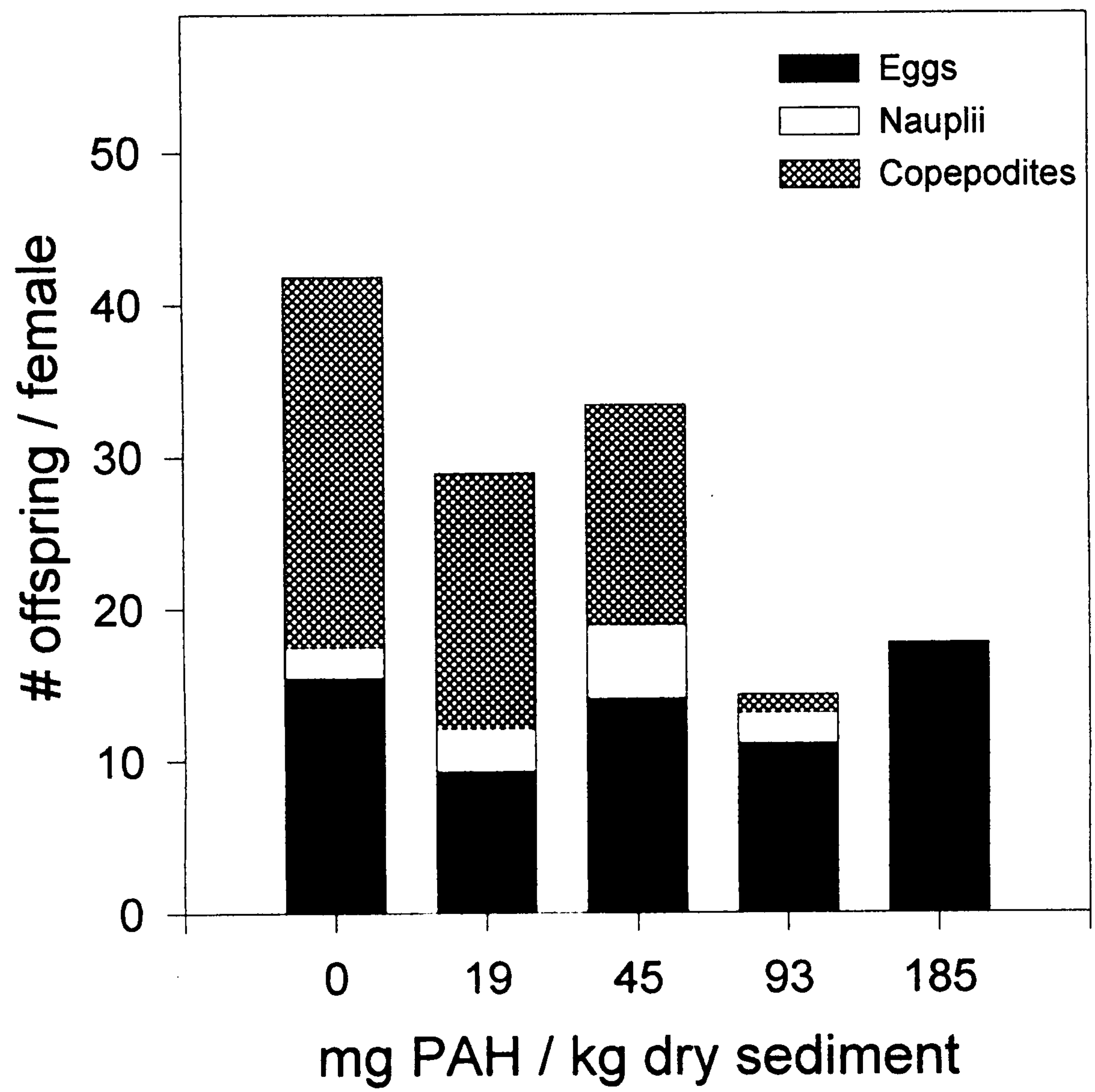

Figure 6D.4. Histogram of total reproductive output in terms of mean number of offspring produced by one mating pair in the diesel fuel 14-day reproductive output experiment with *Schizopera knabeni*. Total is fractioned into number of eggs, nauplii and copepodites. 0ac = acetone control.

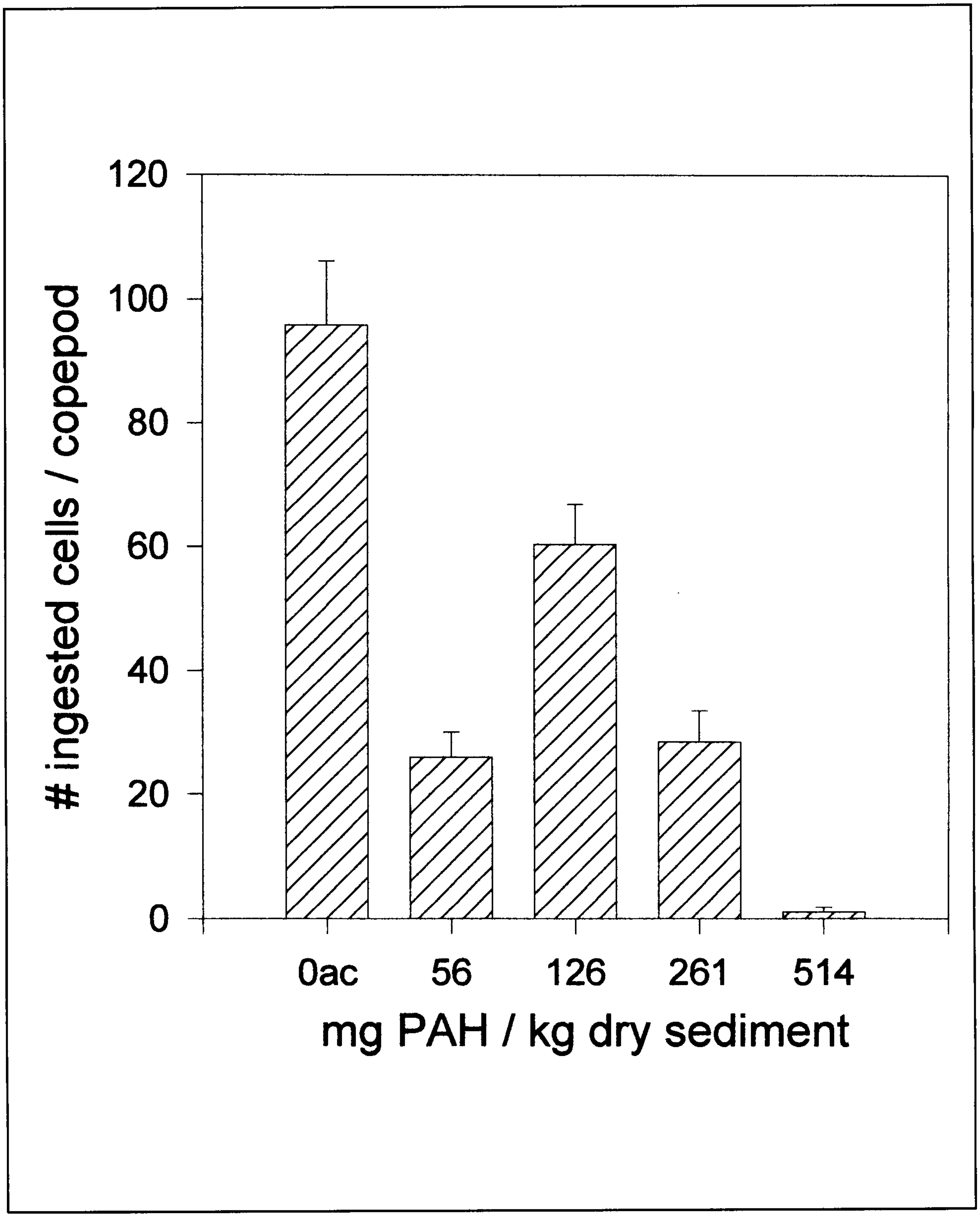

Figure 6D.5. Histogram of the radioactivity incorporated in *Schizopera knabeni* after grazing for 3 hrs on 14° C radiolabeled *Schizopera galbana*. c = control; ac = acetone control; dc = dead control; dpm = disintegration per minute.

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ROLE OF BOTTOM SEDIMENT REDOX CHEMISTRY NEAR OIL PRODUCTION FACILITIES IN THE SEQUESTER/RELEASE AND/OR DEGRADATION OF METALS, RADIONUCLIDE AND ORGANICS

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SUMMARY

Sediment was collected from a produced water discharge site in a brackish marsh environment. Elevated levels of radium, selected metals, and petroleum hydrocarbons were detected. The mobility and/or sequester of these contaminants was investigated. Laboratory studies have shown metal speciation and petroleum degradation in sediment receiving discharge is predominately a function of redox conditions of the receiving sediment. The influence of sediment redox chemistry on the degradation of petroleum hydrocarbons, metal and radium speciation and fractionation are reported. It was found that there was a significant effect of redox sediment conditions on the degradation of petroleum hydrocarbons and in the solubility of various metals. The redox effect upon the mobility of radium was minimal, being more tied to the co-precipitation within sulfide-containing minerals.

INTRODUCTION

The environmental impact of oil exploration and refining is an inevitable consequence of a modern society's energy needs. This consequence is especially important in South Louisiana, where production and refining are prevalent. Oil exploration practices lead to the contamination of soils and streams. One such common practice associated with oil production is the use of drilling mud pits which are required at every site. Drilling muds utilized in the drilling process are discharged into the pit. These fluids serve to clean rock fragments from beneath the bit and carry them to the surface, exert sufficient hydrostatic pressure against subsurface formations to prevent formation fluids from flowing into the well, keep the newly drilled borehole open until steel casing can be cemented in the hole, and cool and lubricate the rotating drillstring and bit (Bourgoyne *et al.* 1986) For each onshore drilling operation about 100-150 m^3 of drilling mud is produced (Chaineau *et al*, 1995). Petroleum hydrocarbon components, specifically polyaromatic hydrocarbons, contain numerous carcinogenic and mutagenic compounds. The persistence and mobility of these compounds in the environment is important to reduce risk to human exposure. Remediation of these mud pits will become necessary as the public perception of risk increases and government action is deemed necessary.

Environmental factors greatly affect the rate of biodegradation. Important parameters include oxygen availability, pH, temperature, salinity, and nutrient status. Temperature is important in that microbial activity increases exponentially over the range of 0-20°C. Furthermore, both salinity and NO_3^- availability have been shown to be limiting factors in estuarine environments (Bartholomew and Pfaender 1983; Bakker 1977). However, oxygen availability, or redox condition, may be the most significant environmental factor related to biodegradation. It is generally concluded that hydrocarbon biodegradation occurs faster under aerobic than anaerobic conditions (DeLaune 1980, DeLaune 1990).

Metals in the water phase of an ecosystem have a tendency to accumulate on sediments and suspended solids; thereby pollutants are pulled into the sediment. Parameters which affect the mobility/sequester of toxic metals in the sediment are: the amount of organic matter, amount and type of clay minerals, and sediment pH and Eh or redox potential (Gambrell *et al.*1980, 1991). Metals may exist in several different valence states and compounds which differ in their mobility, ranging from readily available forms to unavailable forms bound within the crystal lattice of clays. The available forms range from metals in pore water space to metals available due to equilibrium between exchangeable sites that are readily mobilized. Metals that readily diffuse into the water column are of interest due to the chronic influx of produced waters and subsequent metal movement into surrounding waters. As redox conditions change, the oxides of iron and manganese effectively adsorb many toxic metals. During times of tidal movement, and consequent changing redox, metal retention may be regulated.

MATERIAL AND METHODS

The site is located along Humble Canal in Montegut, Louisiana about 20 miles southwest of Houma, Louisiana, where there is a tidal influence (see Figure 6D.6). Reportedly, five wells directed 13,850 barrels per month of produced water to a pit between January 1988 to January 1990 which discharged into a canal (see Figure 6D.7). The petroleum recovery operation is still in effect and directing produced waters to the pit. Sediment for experimentation was obtained at the outfall of the pit.

The sediment was incubated in microcosms (Patrick *et al.* 1973) under various redox conditions ranging from oxidized (+450 mV) to reduced (-200 mV). Rates of petroleum hydrocarbon degradation were established in the microcosms. This was compared to rates over various redox levels, and selected microcosms were amended with two separate fertilizers. ^{226}Ra was sequentially extracted in an adaptation of methods outlined by Shannon *et al.* (1991). For the metals, including barium that are closely related to ^{226}Ra, psuedo zero order models were determined at various redox levels.

RESULTS

Previously published radium results shall be reviewed in the following discussion. Sediment gathered from the site had significantly high levels of ^{226}Ra activity. Results indicated that the solubility was closely related to the co-precipitation within sulfate minerals, barite ($BaSO_4$) and gypsum ($CaSO \cdot 2H\,O$). $_2$ Sequential extraction indicates that very little ^{226}Ra was in available or potentially available forms; nearly all radium could only be extracted through the use of strong acids. A modified MINTEQ model indicated the sediment porespace was unsaturated with respect to pure radium, but supersaturated with respect to other sulfate minerals. Calculations indicated that radium activity in the sediment can be accounted for by co-precipitation in a small amount of these sulfate minerals. Bottom sediments, in anaerobic conditions, convert sulfate to sulfide and result in a redistribution of small amounts of radium to potentially mobile forms. This release of ^{226}Ra to the surroundings was less than 5% of the total available. Effects of Eh-pH on radium solubility were minimal, even with very low pH and waste pit sediments oxidized. Also despite the high activity in the contaminated sediment, fluxes of ^{226}Ra were of the same magnitude as in uncontaminated systems. Figure 6D.8 shows a comparison between waste pit sediment and surrounding sediment.

Sediment redox conditions have a pronounced effect on the solubility behavior of Ni, Cd, Ba, Pb, and other significant metals. Koons *et al.* reported finding higher

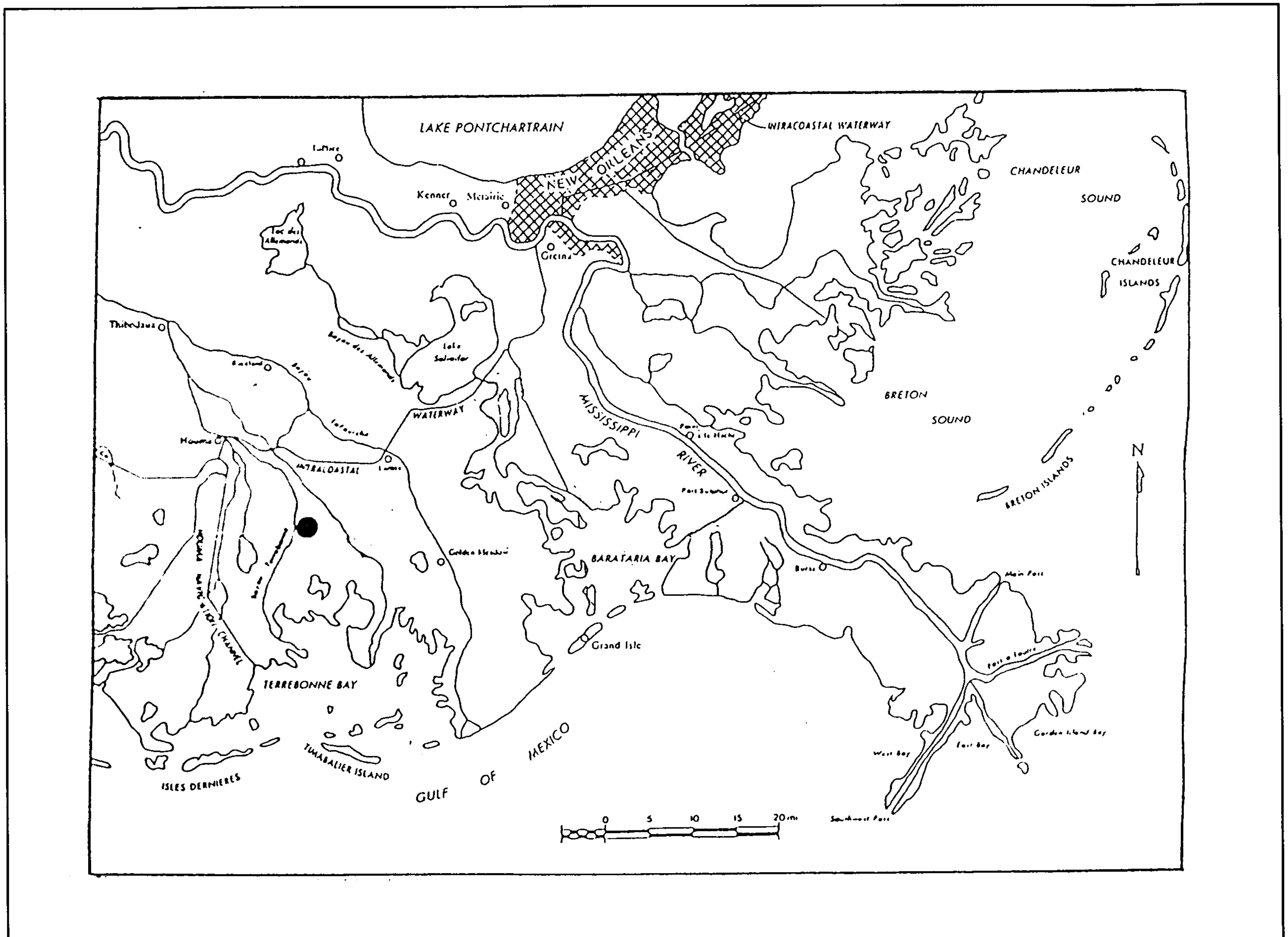

Figure 6D.6. Locations of the study site from which sediment was collected.

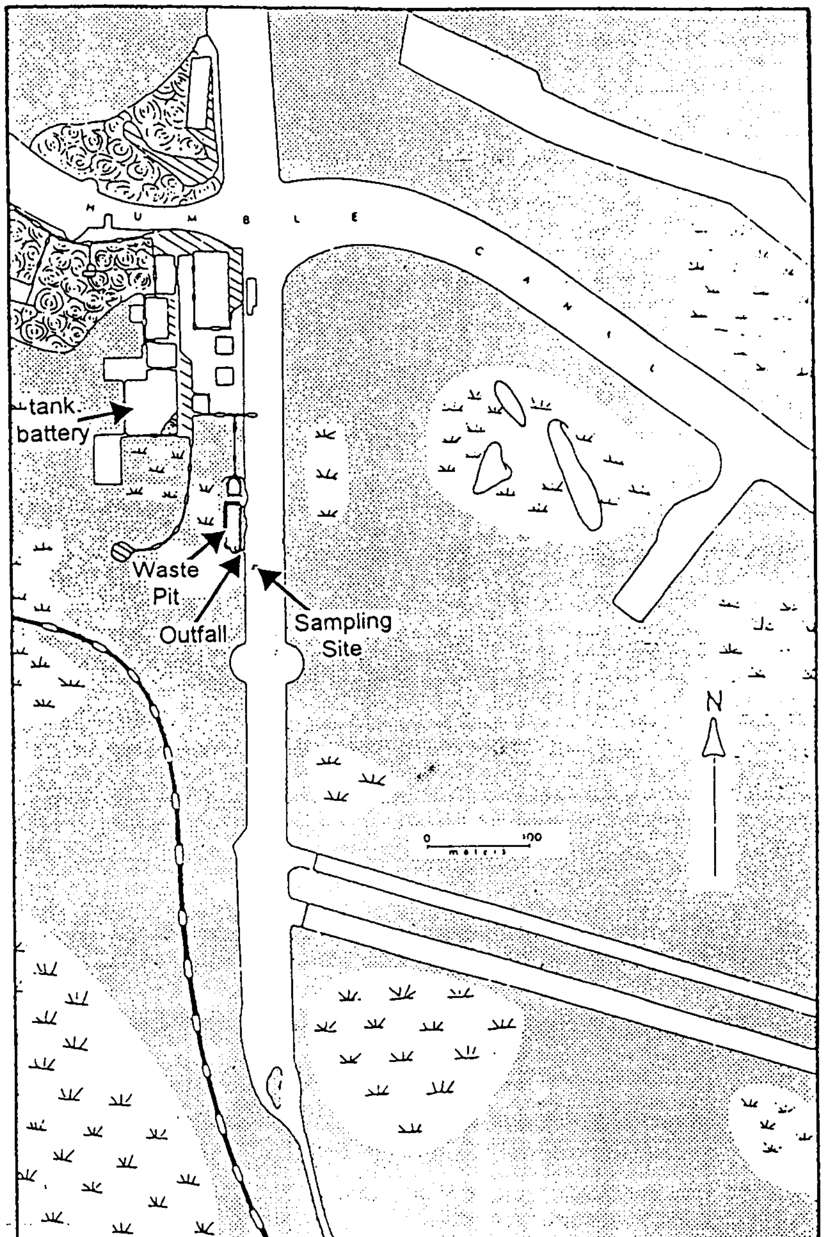

Figure 6D.7. View of sampling site and petroleum operations.

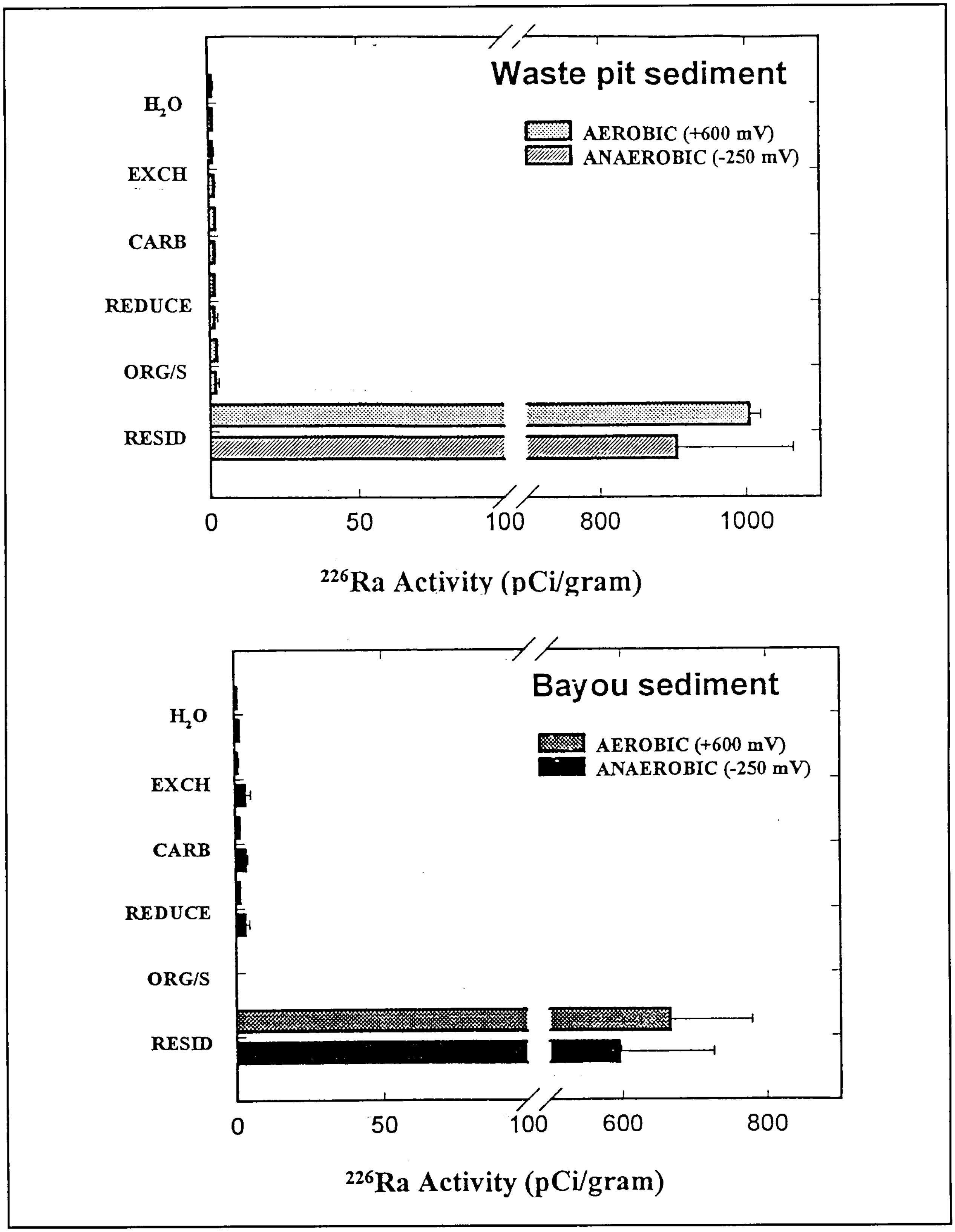

Figure 6D.8. Radium activity in sediments.

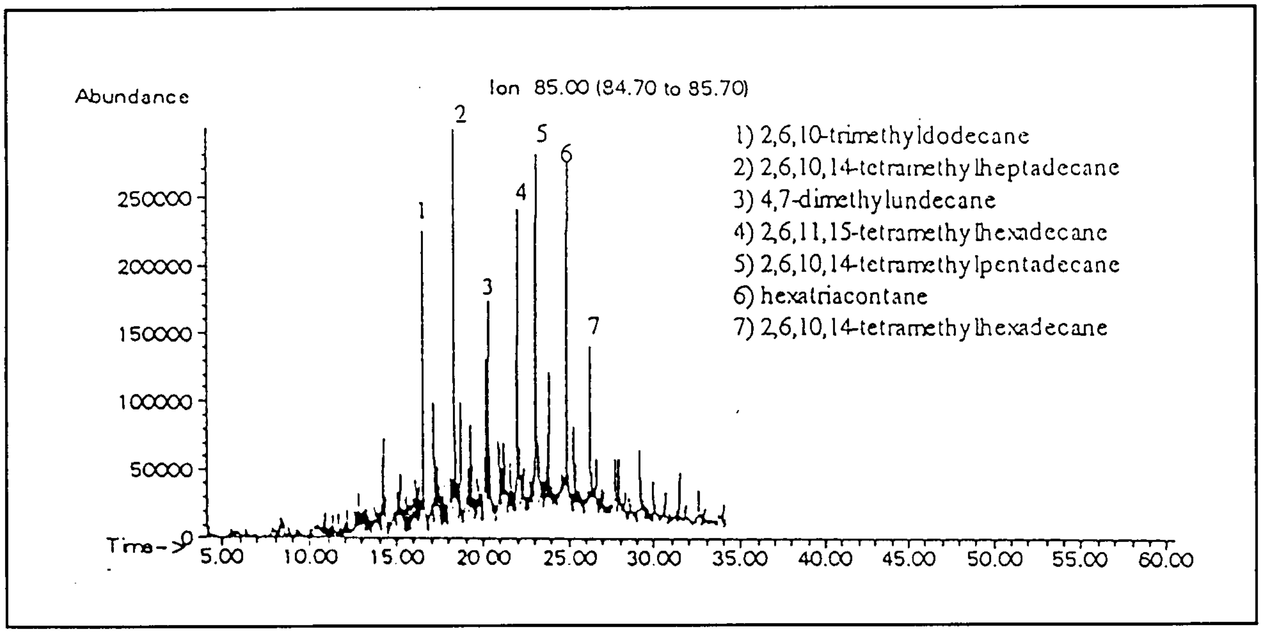

Figure 6D.9. Spectral analysis identifying primary petroleum hydrocarbons in the sediment at outfall.

concentrations of As, Cd, Cr, Cu, Hg, Pb, and Zn in produced waters. A major component of drilling fluids is barium sulfate, or barite, and is a major source of many of these metals (Bourgoyne, Jr., *et al.*1986). Laboratory studies indicate that barium may be bioaccumulated by a factor of 30, chromium by 15, and lead by a factor of 2-3 (Dames, *et al.* 1985). Sediment was introduced into a microcosm and maintained at a pH of 7.0 by additions of HCl or NaOH. A sequential fractionation technique was developed for the determination of metal speciation and/or release. The five metal fractions were exchangeable, carbonate, bound to iron and manganese oxide, bound to organic matter and sulfide, and mineral matrix or residue. Metals from the water soluble portion and from sediment extracts were analyzed by ICP methods.

Metal kinetics may be influenced by many factors, including temperature, organic content, salinity, surface activity associated with Fe and Mn compounds, and other sediment characteristics. There are too many variables to consider within a practical model, therefore all factors are combined into a single parameter. This is referred to as the pseudo zero order reaction model. For this rate reaction model, a positive rate constant indicates there is a release of metals into solution. Conversely, when the rate constant is negative there is a metal movement into the sediment. The rate constant is identified by a "K."

As Eh (redox potential) decreased Fe^{+3} and Mn^{+4} oxides were released into solution. Adsorbed lead decreased (K= -1.1 ppm/day) with a significant amount being released to solution (K= 17 ppb/day). Decreasing Eh, the dissolved lead concentrations also decreased as a result of the formation of insoluble lead associated with sulfides (K= 1.72 ppm/day), humic portions (K= 0.17 ppm/day) and carbonates. As a result, most of the released lead by Fe^{+3} and Mn^{+4} reduction was apparently converted to lead sulfide.

Nickel adsorbed onto the Fe^{+3} and Mn^{+4} decreased (K= -3.2 ppm/day) when sediment Eh decreased, thereby releasing some nickel into solution (K= 1.5 ppm/day). When sediment Eh decreased further, dissolved nickel concentration decreased (K= -1.6 ppm/day). This change was attributed to nickel bound to carbonates, sulfides and the humic portion. Most of the nickel released is that which is bound to carbonates, with a small portion bound to sulfides and humic portions. Overall, nickel under oxidizing conditions was bound to Fe^{+3} and Mn^{+4} oxides; and under reducing conditions nickel was mainly bound to carbonates. nickel was not strongly influenced by sulfides.

Sediment Eh had little effect on dissolved barium levels due to the fact that barium has only one valence state, Ba^{+2}. There were small movements of constant formation of barium to carbonates (K= 0.91 ppm/day). Under oxidizing condition the barium was bound to insoluble, large molecular humic portions, while under reducing conditions the barium behavior was controlled mostly by the carbonate fraction.

Cadmium was found to have a high affinity with the humic portions. This meant that the adsorption capacity for cadmium was higher in a reducing condition than in the oxidizing condition. Sulfides were also found to contribute to the adsorption capacity under reducing conditions. Maximum adsorption was found at an Eh of -130 mV. This is similar to lead and barium adsorption, in the formation of tiny sulfide particles which had highly disordered crystal lattice, high surface area and therefore a high adsorption capacity. For all metals, redox conditions were shown to be important in predicting the mobility and transport of the metal in sediment receiving produced water or other sources.

Petroleum contamination is to be expected at the site of an oil production facility. The residence time of the petroleum through the mud pit has been seen to greatly influence the specific hydrocarbons found in surrounding sediment at the pit outfall. The degradation of these petroleum hydrocarbons will influence the persistence of hydrocarbon contaminants. Degradation most commonly occurs through mineralization by indigenous microbial population. Petroleum hydrocarbons generally degrade following the order of, n-alkane > branched alkanes > low-molecular weight aromatics > cyclic alkanes. Figure 6D.9 showing a spectral analysis of the sediment at the outfall of the production pit identifies the primary petroleum hydrocarbons. In order to develop an analysis of the degradation potential of the sediment receiving the produced water discharge, a south Louisiana crude (SLC) oil was added to the sediment slurry maintained in the microcosms. Conditions in the microcosms were kept under controlled redox conditions, within a range of -100mV (reducing) to 400mV (oxidizing). These separate experiments investigated the effect of two fertilizers, ammonium nitrate and potassium phosphate.

Oxidizing conditions were maintained in the microcosms to estimate the degradation rate of selected hydrocarbons. The sediments slurry contained a 20:1 water to sediment ratio to facilitate mixing. Once oxidizing conditions were established and equilibrated, 25 ml of SLC were added. Samples were removed every three days for a one month period. Samples were then analyzed for n-alkanes and various polynuclear aromatic hydrocarbons. A regression analysis was performed with the listed compounds as the dependent variable and time as the independent variable (SAS Inst, Cary, N.C.). All compounds were found to be significant (α=.05). Sample dates of 1, 4, 7, 16, and 28 days were used in the model. Rates of degradation (μg compound/g sediment dry weight * day) indicate that there is a higher rate of degradation with the shorter alkanes to an insignificant rate with the polycyclic aromatic hydrocarbons. F-values were also calculated and indicate the power of the number in relation to the model. It was found that the highest values were in a class of n-alkanes ranging from n-dodecane through n-hexadecane. This trend was observed in all studies. This is most likely due to the fact that the samples were withdrawn through a pipette in the slurry, thereby allowing those compounds with the higher solubility to be preferentially removed. The lighter fractions may be stripped by the bubbling and stirring of the microcosms, while the heavier fractions form waxes and "tar balls" on the bottom of the flasks.

In further investigations, the comparison between oxidized and reduced conditions were examined. Microcosms were set up similar to the previous experiment, the difference being that the Eh was set at levels of -100, 0, 50, and 350 mV. The degradation rate showed a greater loss in the oxidized environment. Degradation within reduced environments was minimal over the course of the 28-day study. With the longer n-alkanes, the degradation rate became positive, which would indicate an increase in the compound. This was most likely due to the stripping of a methyl group from an isoprenoid, prevalent in the sediment, making the unbranched form thus resulting a n-alkane. Further degradation of these long chained n-alkanes is a slow process and may not be seen in the time span of a 28-day study. These are presently being investigated with an experimental run of 120 days, and results will be reported in a final summary.

Effect of fertilization on the degradation of selected petroleum hydrocarbons components was examined. Microcosms were set as previously described and fertilization amendments were begun one day after addition of SLC. Amendments were divided into a high and low treatment plus a control. The high treatment consisted of 4 grams of ammonium nitrate and 2 grams of potassium phosphate, while the low treatment contained half as much of the compounds. Solubility problems were encountered with certain compounds, however results do appear to be indicative of processes occurring. The losses within the oxidized environments were consistently greater than reduced conditions for both treatments. All compounds with similar redox conditions demonstrated degradation rates which increased with amount of fertilizer amended. Fertilization can be seen to be an important factor in biodegradation rates and an important factor to consider in remediation.

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OCEAN DISCHARGE CRITERIA EVALUATIONS (ODCEs) FOR OCS DISCHARGES

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NPDES PERMITS AND THE CLEAN WATER ACT

Authority to issue National Pollutant Discharge Elimination System (NPDES) permits is provided to the U.S. Environmental Protection Agency (EPA) under Section 402 of the Clean Water Act (CWA), which charges EPA with regulating point source discharges to surface waters of the United States. Three regulatory strategies are used by EPA in developing these NPDES permits—water quality-based, technology-based, and for marine discharges (i.e., seaward of the baseline) CWA Section 403 Ocean Discharge Criteria-based limitations.

Water quality-based permit conditions are based on water body usages as designated by states. This approach uses pollutant-by-pollutant limitations (the notable exception; whole effluent toxicity) to prevent impairment of designated uses. The endpoints of this approach are end-of-pipe, numeric permit limitations on individual pollutants (or whole effluent toxicity). Waste load allocation analyses can be used to control multiple pollutant sources to a single water body or segment. This strategy, however, while capable of maintaining water body usage designations, offers little on its own to improve overall water quality.

Technology-based permit conditions are based on technical (engineering) feasibility and economic achievability. This strategy uses an industry-by-industry approach to control three categories of pollutants. These three categories are the five conventional pollutants, toxic pollutants, and nonconventional pollutants. (Conventional pollutants are: biochemical oxygen demand, total suspended solids, pH, oil and grease, and fecal coliform. Toxic pollutants are periodically specified and listed by EPA. Nonconventional pollutants are those pollutants that are neither conventional nor listed toxic pollutants.) For these technology-based regulations, industrial sources are classified as existing sources or new sources; new sources are subject to less stringent tests of economic achievability. To be promulgated, these regulations must meet either absolute cost criteria for conventional pollutants or subjective (i.e., "reasonable") criteria for toxic and nonconventional pollutants. Endpoints of technology-based permit strategy are numeric, end-of-pipe limitations. Technology-based limitations are not to be developed on the basis of any environmental factor. However, environmental assessments are routinely prepared to evaluate the expected improvements that may result from technology-based standards.

CWA Section 403, or Ocean Discharge Criteria-based permit conditions are based on ten broad factors. This approach uses whole effluent or pollutant-specific analyses, process or end-of-pipe analyses, local or regional-scale fate and effects assessments, and single or multiple source fate and effects assessments. Possible endpoints are determinations of "no unreasonable degradation" or "no irreparable harm." This strategy results in end-of-pipe limitations or a variety of permit conditions that can be imposed anywhere in the operational train (e.g., monitoring, shunting, feedstock limitations). Section 403 evaluations may include environmental, technology, economic, or aesthetic considerations.

In the current "common sense" regulatory environment, Section 403 of the CWA stands out from technology-based or water quality-based NPDES permit strategies. CWA Section 403 retains an ultimate command-and-control characteristic, in as much as its endpoints include legally enforceable limits or conditions in NPDES permits. However, Section 403 also allows for procedural inclusion of a broad spectrum of concerns (and concerned parties) into a framework that accommodates a diverse set of considerations that can range from economics to aesthetics. This accommodation under CWA Section 403 has resulted in a history of open technical discussions that have produced negotiated agreements instead of litigation. It is not surprising, that litigation occurred for OCS oil and gas operations only after EPA's promulgation of technology-based regulations, despite OCS permits being issued under CWA Section 403 for many environmentally contentious areas, including Georges Bank, the Flower Gardens, Southern California, and the Bering and Beaufort Seas. CWA Section 403 has served an important role in the history of offshore oil and gas NPDES permitting, continuing through to current permits, and serves as a useful model for environmental regulation.

CWA SECTION 403–OCEAN DISCHARGE CRITERIA

NPDES permits must prevent unreasonable degradation of the marine environment. Under the CWA, marine waters are defined as waters seaward of the baseline. This definition includes waters both of the Federal Outer Continental Shelf (OCS) and of the territorial seas of coastal states. Unreasonable degradation (40 CFR Part 125) is defined as

- significant adverse changes in ecosystem diversity, productivity, and stability of biological community within the area of discharge and surrounding communities;
- a threat to human health through direct exposure to pollutants or through consumption of aquatic animals; or
- the loss of aesthetic, recreational, scientific, or economic values that is unreasonable in relation to the benefit derived from the discharge.

Ocean Discharge Criteria Evaluations (ODCEs) are prepared for each permit issued to a discharger to marine waters. The ten factors that constitute the Ocean Discharge Criteria, listed in 40 CFR Part 125, and considered in NPDES permit issuance are

1. Quantities/composition/bioaccumulation potential or persistence
2. Biological/physical/chemical transport
3. Composition/vulnerability of biological communities, including unique, endangered, or critical species
4. Receiving water importance to surrounding biological community
5. Existence of special aquatic sites
6. Human health impacts
7. Recreational/commercial fishing
8. Approved CZM plans
9. Such other factors as may be appropriate
10. Marine water quality criteria.

If a finding is that unreasonable degradation will occur, no discharge permit may be issued. If a finding of "no unreasonable degradation" (with any permit conditions in place) is possible, a permit may be issued. If a "no unreasonable degradation" determination is not possible due to insufficient information, the permit may still be issued if three conditions are met. The first condition is that EPA can make affirmative determination there will be "no irreparable harm" (no significant impacts occurring after the date of the permit that will not be reversed after a cessation or modification of the discharge). The second condition is that there are no reasonable alternatives to onsite disposal. The third condition is that the permittee complies with all conditions imposed as a result of the ODCE (including toxicity limitations, monitoring, or other provision) and that the permit include a reopener clause.

The contents of a typical ODCE for OCS dischargers includes discussions organized generally along the following lines:

Section 1	Introduction
Section 2	Physical and chemical oceanography
Section 3	Characterization of the effluent
Section 4	Transport and persistence
Section 5	Toxicity and bioaccumulation
Section 6	Biological overview
Section 7	Commercial and recreational fisheries
Section 8	CZM/special aquatic sites
Section 9	Federal water quality criteria
Section 10	Potential impacts
Section 11	Evaluation of ocean discharge criteria

The characterization of proposed effluents (ODCE Section 4) addresses ODC Factor 1, and for OCS permits generally would include the following effluents:

Drilling fluids	Deck drainage
Drill cuttings	Domestic wastes
Produced water	Sanitary wastes
Produced sand	Treatment/Completion/ Workover fluids
Bilge water	Blowout preventor fluid
Boiler blowdown	Source water and sand
Ballast water	Desalination unit flows
Cement	Uncontaminated seawater

The characterization of the physical and chemical oceanography of the permit coverage area (ODCE Section 2) addresses concerns of OCD Factor 2. Elements reviewed include offshore and inshore circulation, temperature, salinity, dissolved oxygen, and micronutrients. The section on transport and persistence of effluents (ODCE Section 3) also addresses concerns considered under ODC Factor 2. This analysis is generally conducted for drilling fluids and produced water, the two discharges of greatest volume and concern, for OCS NPDES permits. The analyses include descriptions of physical transport processes, chemical transport processes, bioaccumulation, discharge plume modeling, sea floor sedimentation, and sediment reworking.

Toxicity and bioaccumulation potential (ODCE Section 4) are also typically assessed for drilling fluids and produced water, as required by ODC Factors 1 and 6. Analyses include review of whole effluent acute toxicity, chronic toxicity, sublethal toxicity, and the effects of metal and organic components. The biological overview (ODCE Section 5) required for ODC Factors 3 and 4 provides a review of the primary productivity (phytoplankton, macrophytes, algae, and zooplankton); benthic fauna (marsh, estuarine, and continental shelf communities); fish ; marine mammals; and endangered species as identified through consultation with the National Marine Fisheries Service and the Fish and Wildlife Service. Commercial and recreational fisheries (ODCE Section 6) are identified and potential impacts assessed to address ODC Factor 7. For example, for the Western Gulf of Mexico permit, the shell fisheries for shrimp, oyster, and crab and the fin fisheries for menhaden, snapper, croaker, drum, sea trout, mackerel, and flounder were reviewed.

To address ODC Factors 5 and 8, existing Coastal Zone Management Plans and special aquatic sites are identified and reviewed (ODCE Section 7). A consistency assessment is prepared for affected states to determine compliance with their CZMP. Special aquatic sites are also identified and potential impacts assessed in ODCE Section 7. Federal water quality criteria compliance analyses for drilling fluids and produced water (ODCE Section 8) are conducted by modeling specific pollutants and whole effluent toxicity at the edge of the 100-m mixing zone specified in the ocean discharge regulations at 40 CFR Part 225. These water quality analyses address concerns specified in ODC Factors 3, 4, 6, and 10. Section 9 of the ODCE summarizes the analyses of potential impacts, generally including considerations of toxicity, benthic impacts, bioaccumulation, and fisheries (direct and socioeconomic). Lastly, the ODCE includes an evaluation of the ocean discharge criteria (ODCE Section 11) and presents the correspondence between the findings of the ODCE and the justification under CWA Section 403 for the imposition of any permit limitations, conditions, or requirements.

ACTIONS OR CONDITIONS PERFORMED UNDER SECTION 403

The application of Section 403 in the development of NPDES permits issued to the offshore oil and gas industry has resulted in three broad types of actions or conditions that have been either part of the permit itself or part of the permit process. These three types of actions are: the specification of permit conditions or limitations; the requirement for process, effluent, or ambient monitoring to address areas of technical uncertainty; and the use of Section 403 to serve as a focal point and framework for consensus-building efforts during permit development.

Permit conditions imposed as a result of Section 403 analyses have been numerous and varied. Examples include: the generic mud concept; operational and water depth-related discharge rate limitations; pre-dilution requirements; seasonal discharge restrictions; shunting; buffer zones (rate limitations) near areas of biological concern; process modifications; and monitoring (effluent, ambient, or process).

Monitoring requirements have ranged from site-specific effluent dispersion studies to multi-disciplinary, regional-scale monitoring plans. A few examples that demonstrate the range of monitoring programs resulting from Section 403 analyses include: individual and area-wide studies required under a settlement agreement with environmental groups for individual permits issued near the Flower Garden Banks (an joint industry-sponsored effort); broad regional studies for individual permits issued for Georges Bank and a general permit for Southern California (sponsored by MMS); site specific studies under a general permit for the Eastern Gulf of Mexico and an area-wide study of Mobile Bay/ Mississippi Sound (sponsored by individual oil companies).

CWA Section 403 also has provided an important role in serving as a focal point and framework in the NPDES permit development process for consensus-building among concerned parties. An important factor in the consensus-building utility of Section 403 is the breadth of its scope. For example, a Section 403 ODCE includes considerations as diverse as technological, environmental, economic, scientific, and aesthetic. Additionally, a broad scope of action is authorized by the Ocean Discharge Criteria regulations, which range from process modifications at individual facilities to joint industry research and monitoring efforts at a regional scale. Furthermore, although the breadth of Section 403 ODCE considerations is wide-ranging its endpoints are relatively concrete, resulting in conditions and limitations in an NPDES discharge permit. Thus, Section 403 has served as an effective framework to efficiently focus diverse constituencies on specific issues and problem-solving approaches.

Examples of such consensus-building efforts that have utilized Section 403 as a framework for discussions include the effluent limitations and monitoring program for Flower Garden Banks individual permits (resulting in a negotiated settlement between a group of major oil companies and environmental groups); site-specific and regional monitoring plans developed as a result of the Mobile Bay/Mississippi Sound Drilling Fluids Transport Workshop (developed by representatives of Federal and state regulatory agencies, industry, and academia); and permit conditions based on whole effluent particulate/toxicity characteristics, effluent dispersion/sediment transport modeling, and individual/population effects modeling (two adaptive environmental workshops).

CASE STUDY OF CWA SECTION 403: ODCE, CURRENT WESTERN GULF OF MEXICO GENERAL PERMIT

In the development of the current ODCE for the Western Gulf of Mexico NPDES General Permit, two key issues that were CWA Section 403-related were identified: produced water biomonitoring and produced water whole effluent toxicity. Central to both of these issues was the surface water quality model used to develop the water quality and whole effluent toxicity compliance analyses.

The current, reissued Region 6 permit responded to several previous and ongoing actions. In 1986 Regions 4 and 6 jointly issued a Best Professional Judgement (BPJ) NPDES general permit, for which Regional permit writers were required to establish technology-based limitations in the absence of final, national Best Available Technology (BAT) effluent guidelines under development at EPA/Headquarters. Although BAT guideline promulgation was imminent, this permit expired prior to promulgation and Region 6 reissued the BPJ permit, modified to comply with remanded provisions of the 1986 permit and with EPA's third round NPDES permitting strategy. EPA's third round strategy required compliance with whole effluent toxicity limitations, and for the first time produced water was subject to a toxicity limitation. (Drilling fluids had been subject to a technology-based whole effluent toxicity limitation, based on product substitution and the generic mud concept, since 1986).

For the 1991 proposed reissuance permit, a model developed for simulating dispersion of discharge plumes for ocean outfalls, UDKHDEN, was used as the surface water quality model for produced water to assess water quality and whole effluent toxicity compliance under Section 403. Problems with this model developed for low flow rates and/or large outfall diameters: if the Froude number fell below a threshold value, the model ceased to run. Likewise, if the plume descended to within one half-width of the sea floor, the model would cease to run. The result was that the proposed permit contained tables (for a span of discharge rates, water depths, and outfall diameters) of whole effluent toxicity limitations that were based on a high number of default values, set at the next most stringent case for those cases in which the model would not run. Industry commented on this portion of the permit and supporting ODCE. A second result of third round permitting was the inclusion of a requirement for permittees to conduct biomonitoring for produced water toxic pollutants. Consistent with other NPDES industrial permits, this requirement was imposed on an individual facility basis. Industry also commented that a joint study would provide a better approach and data for assessing toxic impacts from produced water discharges.

The Region agreed that its water quality compliance approach resulted in overly conservative permit conditions and between proposal and promulgation a new surface water quality model, CORMIX1, was identified. CORMIX1 was developed for EPA's Office of Research and Development as an expert system for single outfalls at Cornell University. It was a widely accepted surface water quality model and had undergone considerable peer review during its development. CORMIX1 was used to develop the water quality and whole effluent toxicity compliance assessments for the 1992 final, reissued permit. Industry discussed with Region 6 their concerns that CORMIX1 also had characteristics that, under certain circumstances, lead to substantial underestimation of dilution and overly restrictive toxicity limitations. Region 6 initiated a review of the technical merits of industry's comments and CORMIX1. This review confirmed that under certain conditions (primarily, those in which the discharge plume never descended to a point of contact with the sea floor) CORMIX1 did produce substantial underestimates of dilution. Region 6 then initiated a modification to CORMIX1 that corrected its tendency to underestimate dilution in applicable cases.

Essentially contemporaneous with this review and revision of CORMIX1, EPA promulgated national BAT guidelines, and the reissued BPJ permit was subject to reopening and modification to a BAT level of technology-based pollution control. Thus, at this time Region 6 also considered industry's modification request to review and revise the water quality and whole effluent toxicity-based limitations and to accept a joint industry study for assessing potential produced water toxic impacts. Therefore, in the 1993 proposed modification of the BPJ permit, the revised CORMIX1 model was used to develop the tables of produced water whole effluent toxicity limitations. For the final modified, BAT permit this approach was expanded to allow the use of CORMIX2, an expert system developed for multi-port outfall diffusers. This provision allowed for the possibility of using diffusers for those operators that could not meet their toxicity limitations using CORMIX1 and a single port outfall. In addition, Region 6 accepted the industry's submission of a joint biomonitoring study to satisfy the requirements of EPA's third round permitting strategy.

In the case of the current NPDES general permit, CWA Section 403 provided the framework for the water quality, whole effluent toxicity, and biomonitoring analyses required for this permit. But perhaps more importantly, Section 403 also provided the regulatory flexibility required to respond to new information, revise EPA's assessments and requirements, and modify the general permit consistent with an improved state-of-the-art and state-of-knowledge.

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ENVIRONMENTAL ASSESSMENT OF PRODUCED WATER DISCHARGES FROM GULF OF MEXICO OIL AND GAS OPERATIONS

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INTRODUCTION

The United States Department of Energy (DOE) is funding two parallel projects to assess environmental and human health risks associated with produced water discharges from offshore and coastal oil and gas operations in the Gulf of Mexico region (Smith 1995).

The study titled "Environmental and Economic Assessment of Discharges from Gulf of Mexico Region Oil and Gas Operations" is being performed by Continental Shelf Associates, Inc. (CSA) and its team of subcontractors. The study involves 1) environmental field sampling, testing and analysis of Naturally Occurring Radioactive Material (NORM), metals and organics in produced water, ambient water, sediment, and biota at offshore Gulf of Mexico discharge sites; 2) monitoring of the recovery of terminated produced water discharge sites in coastal Louisiana; 3) gathering and synthesizing data regarding seafood catch, use, and consumption patterns for the Gulf of Mexico region; and 4) preparation of an economic assessment of the impacts from offshore and coastal discharge requirements on present and future oil and gas operations in the Gulf of Mexico region. The specific tasks that comprise this study are described in more detail in Gettleson *et al.* (1993).

This summary focuses on results of radionuclide measurements in produced water, ambient water, sediment, and biota for the offshore platforms sampled in the field study. Data describing metals and organics in water, sediment, and biota associated with offshore and coastal discharges will be reported elsewhere.

The second project consists of a series of human health and ecological risk assessments that use data collected in the field studies being completed by CSA and its subcontractors. This work is being performed by

Brookhaven National Laboratory. The objective of these risk assessments is to assist regulatory agencies in developing technically sound and justifiable regulations for the oil and gas industry.

Work performed during fiscal year 1995 emphasized risks from the continuing discharge of produced water to open bays in Louisiana. Results of these assessments are summarized here. Work planned for fiscal year 1996 includes human health and ecological risk assessments for offshore discharges of radium, metals and organic compounds, and an assessment of the risk reduction achieved through termination of coastal discharges.

NORM ASSOCIATED WITH OFFSHORE PRODUCED WATER DISCHARGES

Sampling Locations

Sampling was conducted at 15 sites in the northwestern Gulf of Mexico (Figure 6D.10). These sites were classified in four categories: primary discharging sites, secondary discharging sites, non-discharging sites, and ambient reference sites. There was an additional site where reference bivalve collections were made. Discharging sites were designated as primary when preliminary information indicated that high loadings of NORM occurred at these sites.

Produced water samples were collected directly from a spigot located immediately prior to the waste stream being discharged overboard from the platforms. Plume samples were taken along the centerline of the plume at 5, 10, 30, 50 and 100 m. Sediments were collected at distances of 0, 20, 50, 100, 150, 300 and 2,000 m from the discharges, by divers (shallow water) or grabs (deep water). Bivalve specimens were collected from the platform support structure within a 100 m horizontal radius of the discharge. Crustaceans were collected in crab traps and by trawling. Fishes were collected using hook and line, traps, and trawls. All trawling was conducted within 1,000 m of the discharge points.

Results and Discussion

Table 6D.2 shows mean ^{226}Ra, ^{228}Ra, and ^{210}Pb concentrations in the sampled produced water discharges. The activities of the three radionuclides measured in the produced water samples were variable, but it was clear that produced water discharges are sources of ^{226}Ra, ^{228}Ra, and ^{210}Pb.

Additional sampling was performed at the four primary discharging sites to investigate the variability of NORM activities over time. Table 6D.3 shows concentrations of ^{226}Ra, ^{228}Ra and ^{210}Pb at one of these sites (South Marsh Island 236A) over time. The results indicate that a single sampling of produced water at a platform may not be entirely representative of NORM levels over long periods of time.

NORM was determined in water samples collected in the plume at four platforms at 5, 10, 30, 50, and 100 m from the discharges and at reference stations greater than 2,000 m from the discharge points. Table 6D.4 shows concentrations of ^{226}Ra, ^{228}Ra and ^{210}Pb in the plume and at the reference station at the South Marsh Island 236A site. Clearly, the activities of the radionuclides are quickly reduced after discharge of the produced water, approaching levels comparable to ambient conditions within short distances of the discharge point.

Sediment samples generally show low levels of activities as shown in Tables 6D.5, 6D.6, and 6D.7. The data indicate that some of the discharged radium may be accumulating in the sediments in the vicinity of discharging platforms but this requires further study as the evidence is not yet convincing.

Bivalves (American oyster, jewelbox) were sampled from the legs of seven discharging platforms; one non-discharging platform; and one discharging platform where bivalves are not thought to be exposed to the discharge because of shunting to within 10 m of the seafloor in 120 m of water. Mean activities in bivalve tissues exposed to near sea surface produced water discharges did not appear to be different from those at reference sites.

Pernaeus (shrimp) were collected in trawls around the study sites. Callinectes (blue crab) were collected in traps and trawls around the shallow water study sites, and Sicyonia (rock shrimp) were collected by trawling at the deeper study sites. Radioisotope activities were low; activities at the discharging platforms were comparable to those observed at the reference sites.

NORM activities were also determined in the flesh of fish species living around the platform (red snapper, gray triggerfish, and pinfish). The activities were consistently low at all sampling sites. Table 6D.8 shows ^{226}Ra, ^{228}Ra and ^{210}Pb concentrations measured in red snapper (*Lutjanus campechanus*) at 5 discharging platforms and the reference site.

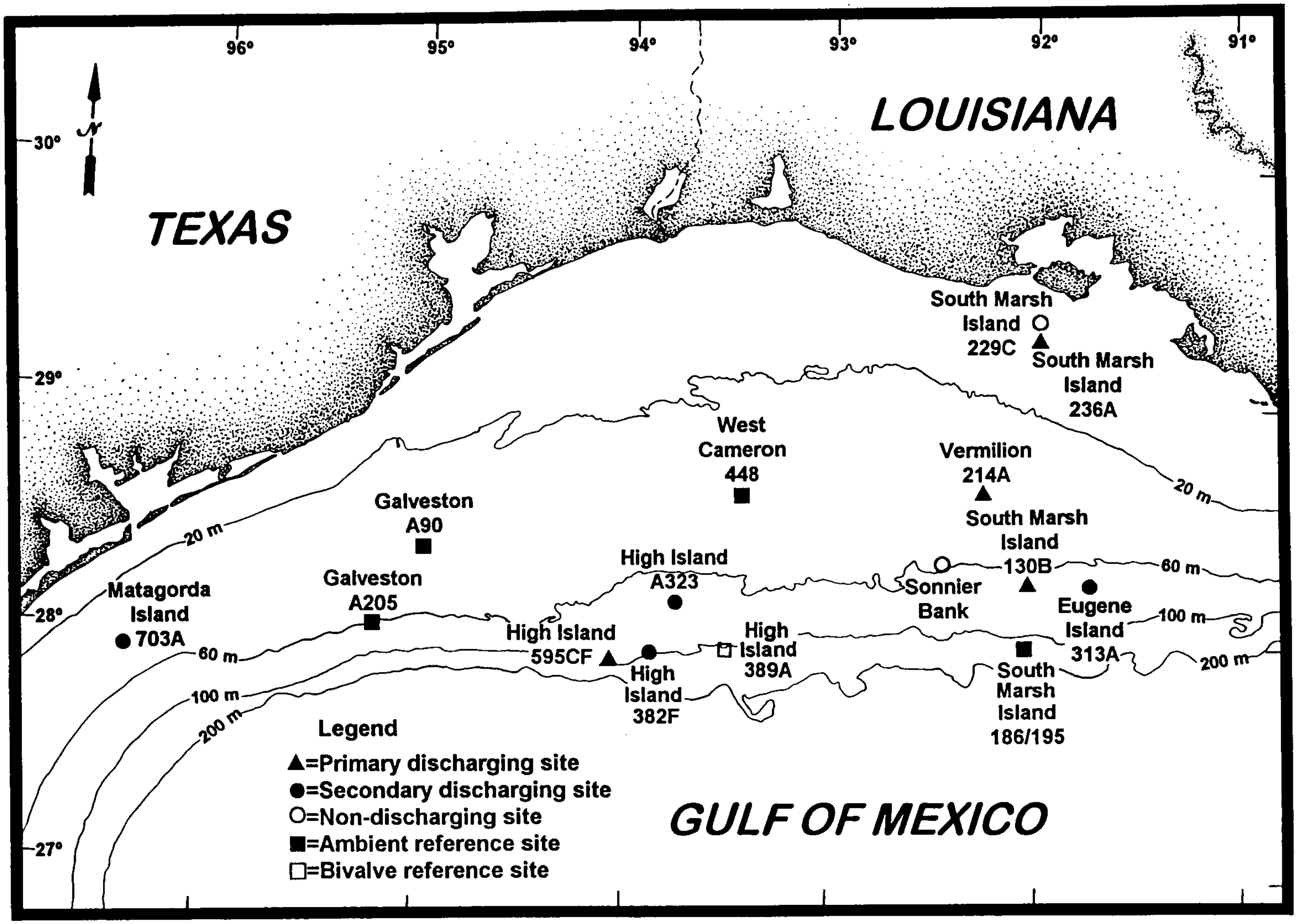

Figure 6D.10. Geographic locations of study sites.

Table 6D.2 Mean (pCi/l, ± standard deviation) concentrations of ^{226}Ra, ^{228}Ra, and ^{210}Pb concentrations in produced water samples.

Platform Location	^{226}Ra	^{228}Ra	^{210}Pb
South Marsh Island 236A	91 ± 13	239 ± 67	12.3 ± 4.3
Vermilion 214A	300 ± 157	228 ± 29	7.7 ± 4.7
South Marsh Island 130B	362± 43	164 ± 146	5.6 ± 5.5
High Island 595CF	1,494 ± 1,989	356 ± 19	12.5 ± 2.6
Matagorda Island 703A	56 ± 3	69 ± 7	2.6 ± 0.5
High Island 323A	112 ± 6	162 ± 12	5.2 ± 2.5
Eugene Island 313A	270 ± 16	388 ± 15	13.8 ± 1.9
High Island 382F	255 ± 43	600 ± 107	16.7 ± 4.1

Table 6D.3. Summary of activities of ^{226}Ra, ^{228}Ra, and ^{210}Pb in produced water samples from South Marsh Island 236A over time (pCi/l).

Time After Initial Sampling	^{226}Ra	^{228}Ra	^{210}Pb
Initial sampling	91 ± 13	239 ± 67	12 ± 4
12 h	70	138	13
24 h	66	307	16
36 h	47	126	12
48 h	175	187	16
60 h	68	166	15
1 mo	39 ± 1	119 ± 14	4 ± 1
2 mo	65 ± 2	277 ± 52	8 ± 2
3 mo	38 ± 6	126 ± 3	4 ± 1
4 mo	292 ± 11	274 ± 17	2 ± 3
5 mo	321 ± 33	306 ± 16	11 ± 9

In summary, these data indicate that produced water discharges are a potential source of NORM in offshore regions of the Gulf of Mexico. Although NORM activities in produced water are variable among platforms and over time, these activities are rapidly diluted after entering the receiving waters. The data also indicate that NORM is not accumulating in the edible tissues of organisms living in the vicinity of offshore discharges.

HUMAN HEALTH AND ECOLOGICAL RISK ASSESSMENTS FOR LOUISIANA OPEN BAYS

Open Bay Discharges

Preliminary human health and ecological risk assessments were done to support the state of Louisiana and the United States Environmental Protection Agency (USEPA) in developing regulations for coastal produced water discharges. Based on data provided by the Louisiana Department of Environmental Quality and an independent survey of operators, discharges that may be expected to continue through 1 January 1997 were identified.

The initial human health and ecological risk assessments for these discharges consisted of conservative screening analyses that identified potentially important contaminants and excluded others from further consideration. A more quantitative probabilistic risk assessment was completed for the human health effects of the two contaminants identified in this screen: radium and lead. The receptors of interest in the human health risk assessment were recreational fishermen and their families.

Table 6D.4. Summary of radionuclide activities in the plume at South Marsh Island 236A.

Sample Type	^{226}Ra	^{228}Ra	^{210}Pb
Produced Water	91.17 ± 12.61	238.67 ± 67.47	12.27 ± 4.31
Plume			
5 m	0.40 ± 0.17	0.83 ± 0.49	0.17 ± 0.15
10 m	0.30 ± 0.10	0.60 ± 0.56	0.17 ± 0.15
30 m	0.53 ± 0.12	1.07 ± 1.22	0.03 ± 0.06
50 m	0.50 ± 0.20	3.60 ± 4.94	0.13 ± 0.12
100 m	0.57 ± 0.15	3.87 ± 2.25	<0.10
> 2,000 m	0.20 ± 0.00	3.20 ± 2.31	0.33 ± 0.29
	0.23 ± 0.12	0.10 ± 0.17	0.13 ± 0.15
	0.07 ± 0.16	1.60 ± 0.70	0.30 ± 0.10
Ambient Reference	0.30 ± 0.17	<0.30	0.37 ± 0.15

Table 6D.5. Mean ^{226}Ra activities (± standard deviation) in sediment samples collected along a transect from four platforms.

Distance (m)	Platform			
	South Marsh Island 236	**Vermilion 214**	**South Marsh Island 130**	**High Island 595**
0	3.10 ± 2.79	NS*	NS	NS
20	<1.50	<1.70	0.90 ± 1.56	0.44 ± 0.76
50	<1.60	<1.30	1.03 ± 1.79	0.31 ± 0.54
100	<1.50	1.90 ± 3.29	0.16 ± 0.28	<2.50
150	<1.80	<1.80	0.93 ± 1.62	2.97 ± 2.71
300	0.50 ± 0.87	1.86 ± 3.23	<1.60	<2.00
2,000	<2.00	<2.60	1.32 ± 2.29	<1.70
Reference	<1.70	<1.60	<1.40	<1.20

*NS = Not sampled

Screening Assessment for Human Health Risk

A conservative screening human health risk assessment was done for metals, organic compounds, and radionuclides in continuing open bay discharges. Worst-case modeled concentrations were combined with generic bioaccumulation factors to estimate concentrations of contaminants in fish. This screening analysis followed the USEPA approach to estimating risks from toxic materials and carcinogens at Superfund sites (USEPA 1989).

This conservative screening analysis served to eliminate contaminants that do not warrant further time and attention. Contaminants eliminated from further consideration were arsenic, chromium, copper, silver, naphthalene, phenol, toluene, and xylenes.

Contaminants exceeding hazard quotients of one included antimony, cadmium, lead, mercury, nickel, zinc, benzene, and radium. Because of the conservative nature of this screening analysis, no important effect on human health can be assumed. Screening hazard quotients for antimony, cadmium, nickel, and zinc exceeded one by less than an order of magnitude. The cancer risk estimate for benzene exceeded 1×10^{-4} by less than an order of magnitude (6.4×10^{-4}). A more realistic and quantitative assessment is being done

Table 6D.6. Mean ^{228}Ra activities (± standard deviation) in sediment samples collected along a transect from four platforms.

Distance (m)	Platform			
	South Marsh Island 236	**Vermilion 214**	**South Marsh Island 130**	**High Island 595**
0	2.30 ± 2.01	NS*	NS	NS
20	1.17 ± 1.01	2.10 ± 0.44	0.83 ± 0.76	0.14 ± 0.25
50	0.63 ± 1.10	0.43 ± 0.75	0.67 ± 0.58	0.10 ± 0.18
100	0.43 ± 0.75	0.60 ± 1.04	<0.11	<0.30
150	<0.60	0.83 ± 1.44	0.37 ± 0.64	1.03 ± 0.91
300	<0.60	0.30 ± 0.53	1.37± 0.25	<0.60
2,000	<0.70	0.37 ± 0.98	1.40 ± 1.21	1.43 ± 0.55
Reference	0.77 ± 0.68	1.00 ± 1.41	0.93 ± 0.81	<0.60

*NS = Not sampled

Table 6D.7. Mean ^{210}Pb activities (± standard deviation) in sediment samples collected along a transect from four platforms.

Distance (m)	Platform			
	South Marsh Island 236	**Vermilion 214**	**South Marsh Island 130**	**High Island 595**
0	1.77 ± 0.81	NS*	NS	NS
20	1.30 ± 0.87	2.27 ± 0.65	1.23 ± 0.85	1.49 ± 0.18
50	0.73 ± 0.42	1.57 ± 0.06	1.40 ± 0.10	1.81 ± 0.43
100	0.50 ± 0.10	2.17 ± 0.47	1.61 ± 0.29	1.87 ± 0.29
150	0.70 ± 0.10	2.57 ± 0.72	1.37 ± 0.12	2.17 ± 0.32
300	0.93 ± 0.25	2.70 ± 0.26	3.67 ± 0.06	3.27 ± 0.59
2,000	1.53 ± 0.21	3.23 ± 0.21	3.78 ± 0.20	3.97 ± 0.80
Reference	2.27 ± 0.55	3.15 ± 0.21	2.40 ± 0.26	4.53 ± 0.55

*NS = Not sampled

Table 6D.8. Summary of radionuclide activities (pCi/g wet weight basis) in edible tissue of red snapper (*Lutjanus campechanus*).

Platform	^{226}Ra	^{228}Ra	^{210}Pb
Reference Site			
Sonnier Bank	<0.004-0.005	<0.013-0.028	<0.006-0.025
Discharging Sites			
Vermilion 214A	<0.005-0.008	<0.017	<0.010-0.026
South Marsh Island 130B	<0.005-0.008	<0.017-0.14	<0.010
Matagorda Island 703A	<0.003	<0.018	<0.010
High Island 323A	<0.005	<0.017-0.146	<0.010
Eugene Island 313A	<0.003	<0.013-0.032	0.011-0.028

using effluent concentration distributions and predicted dilutions for the entire range of discharges is expected to predict few hazard quotients greater than one, and a median risk for benzene of less than 1 x 10^{-4}.

Risk from ingestion of radium in fish exceeded 1 x 10^{-4} by more than an order of magnitude (7.8 x 10^{-3}). Contaminants that exceeded hazard quotients by more than an order of magnitude were lead and mercury. Comparison of the few mercury concentrations in effluent reported above the detection limit suggest that mercury in the continuing discharges was similar to that expected in the Gulf of Mexico. Mercury was not analyzed further. Radium and lead were analyzed quantitatively in a probabilistic risk assessment.

Screening Assessment for Ecological Risk

Worst-case water column concentrations of organics and metals in continuing open bay effluents were compared to USEPA and Louisiana water quality criteria, and to reference doses (radium).

Contaminants eliminated from further consideration included arsenic, chromium, benzene, naphthalene, toluene and radium. Water quality standards were exceeded by less than an order of magnitude for cadmium, silver, zinc, and phenol. A more realistic and quantitative assessment using predicted dilutions for the entire range of discharges and effluent concentration distributions is expected to predict few exceedances for these contaminants and will be performed.

Water quality standards for copper, lead, mercury, and nickel were exceeded by more than an order of magnitude. These contaminants are being assessed in more quantitative risk assessment. No important effect on aquatic biota can be assumed because of the conservative nature of the screening analysis.

Probabilistic Risk Assessment for Radium

A distribution of water concentrations at 200 ft was derived using data describing radium discharges in open bays and the USEPA CORMIX surface water transport model (Doneker and Jirka 1990). Concentrations in edible fish were estimated using a bioaccumulation factor distribution derived from data collected in the Gulf of Mexico (Meinhold and Hamilton 1992).

The intake rate distribution was based on data collected by Steimle & Associates, Inc., in the CSA study (average intake for recreational fishermen: 38.4 g/day). The exposure period for recreational fishermen was assumed to be a triangular distribution with a range of 5 to 65 years and a most frequent value of 20 years. Risk factor distributions for ^{226}Ra and ^{228}Ra were derived from USEPA single estimates (Meinhold *et al.* 1995).

Results are presented in Table 6D.9. Median individual lifetime fatal cancer risks for fish caught near platforms were 2.0 x 10^{-6}, and 95th percentile risks were 2.0 x 10^{-5}. Median risks from ingestion of fish caught away from open bay discharges were 5.0 x 10^{-7} , and 95th percentile risks were 1.3 x 10^{-6}. These results suggest that ingestion of radium in fish caught near open bay produced water platforms does not present an important risk to human health.

Probabilistic Risk Assessment for Lead

Lead is ubiquitous in the environment, and children, in particular are exposed to lead through a number of pathways. USEPA has developed a biokinetic/uptake model for lead (UBK Model; USEPA 1994) that relates intake in food, air, water, and soil to the probability of exceeding a blood lead level of 10 µg/dl (BL>10). This analysis used this probability as the metric for risk from ingestion of lead in fish.

Risks for most intake rates in the distribution for fish caught near platforms only slightly exceeded the background risks of 1.6% and 4.4 % for 0-7 years and 1-2 years, respectively. Fifty-two percent of the predicted intake rates at platform sites had risks of BL>10 less than 2.7% and 6.4% for age 0-7 and 1-2 years, respectively. Seventy-four percent of the predicted intake rates at platform sites had risks of BL>10 less than 5% and 10.6% for age 0-7 and 1-2 years, respectively.

Table 6D.10 shows the total probability of BL>10 for fish caught near platforms, fish caught away from platforms and background intakes from sources other than fish. Risk from ingestion of fish caught away from platforms only slightly exceeded risks from background intake of lead. The total probability of BL>10 from intake of lead in fish caught near platforms was approximately 3-5 times higher than risks from background intakes of lead.

A number of conservative assumptions remain in the analysis. The CORMIX model tends to underestimate dilution, and fish are not likely to be constantly exposed to water in the plume. A sensitivity analysis run

Table 6D.9. Risk for ingestion of radium in fishes.

	Individual Lifetime Fatal Cancer Risk	
	Fish Near Platforms	Fish Away From Platforms
mean	5.4×10^{-6}	5.0×10^{-7}
median	2.0×10^{-6}	3.8×10^{-7}
standard deviation	1.2×10^{-5}	4.4×10^{-7}
5th percentile	1.9×10^{-7}	8.1×10^{-8}
95th percentile	2.0×10^{-5}	1.3×10^{-6}

Table 6D.10. Total probability (%) of exceeding a blood lead level of 10 μg/dl.

	0-7 years	1-2 years
Fish Near Platforms	8.3	13.5
Fish Away From Platforms	2.0	5.2
Background	1.6	4.4

assuming that lead water concentrations were overestimated by a factor of 10 found that risk from ingestion of fish caught near platforms would be similar to risks from ingestion of fish caught elsewhere in the Gulf of Mexico.

Because of the conservatisms embedded in the analysis (assumptions concerning "less than" values; underestimate of dilution at low discharges rates) the risk from ingestion of lead discharged from open bay discharges in Louisiana appears to be small, although exposures to children eating a large amount of fish caught near the few platforms discharging measurable amounts of lead may be of concern.

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The Department of the Interior Mission

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

The Minerals Management Service Mission

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

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

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