OCS Study
MMS 97-0038

Proceedings:
Sixteenth Annual Gulf of Mexico Information Transfer Meeting

December 1996

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

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SUMMARY

The 1996 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.

Sessions included Offshore Structure Decommissioning/Artificial Reef Development, Gulf Environmental Issues; Ship Shoal Sand and Gravel on the OCS; the Internet and Marine Science; Deepwater Issues (Development, Industry Perspective, and Environmental); OCS Air Quality Issues; Coastal Marine Institute; Safety and Environmental Management Program (SEMP); Northeastern Gulf of Mexico Coastal and Marine Ecosystem Program; Gulf-Wide Information System (G-WIS); Northeastern Gulf of Mexico Physical Oceanography; and Socioeconomic Issues on the OCS.

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

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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 Chair of the Deepwater Issues: Industry Perspective session, which was coordinated and developed using an informal customer-partnership arrangement through the ITM Coordinator and Mr. Virgil Harris, Executive Director, Offshore Operators Committee. Mr. Harris created an informative agenda acknowledging successful deepwater platforms in the Gulf of Mexico.

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

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.

SESSION 1A

DECOMMISSIONING AND ARTIFICIAL REEF DEVELOPMENT, PART I

Co-Chairs: Mr. Villere C. Reggio, Jr.
Mr. Les Dauterive

Date: December 10, 1996

Presentation	Author/Affiliation
Decommissioning and Artificial Reef Development	Mr. Villere C. Reggio, Jr. Minerals Management Service Gulf of Mexico OCS Region
Update on Decommissioning Issues Resulting from the Marine Board Report and International Workshop	Mr. Elmer P. Danenberger Minerals Management Service Herndon, Virginia
Innovative Removal Techniques—Creative Engineering Options (Manuscript not submitted)	Mr. Vance Mackey Mr. Greg Schulte Chevron USA
Constructive Destruction—Reef Development Options	Dr. Ann S. Bull Minerals Management Service Gulf of Mexico OCS Region
Platform Reef Ecological and Biological Productivity: Fact or Fiction?	Dr. Quenton R. Dokken Center for Coastal Studies Texas A&M University
Texas Artificial Reef Development Program	Ms. Jan. C. Culbertson Mr. Hal Osborne Mr. Douglas Peter Texas Parks and Wildlife Department
Louisiana's Artificial Reef Program	Mr. John E. Roussel Mr. R.A. Kasprzak Louisiana Department of Wildlife and Fisheries

DECOMMISSIONING AND ARTIFICIAL REEF DEVELOPMENT

Mr. Villere C. Reggio, Jr.
Minerals Management Service
Gulf of Mexico OCS Region

INTRODUCTION

Almost 50 years of increasing interest and participation in offshore "rig" fishing has paralleled the extension and expansion of offshore oil and gas development into the Gulf of Mexico. Rig fishing interest along with widespread support for effective artificial reef developments by most coastal states led Congress to enact the "National Fishing Enhancement Act" in 1984 which led to a National Artificial Reef Plan in 1985, and an MMS artificial reef policy that encourages support for planned artificial reef developments using oil and gas structures. Some facts and figures bearing on oil and gas development and Rigs to Reefs in the Gulf of Mexico include the following:

- There are about 6,000 active leases and 5,000 offshore structures in the Gulf of Mexico (4,000 in Federal waters and 1,000 in State waters).

- Approximately 1,200 structures have been removed from the OCS and disposed of onshore since Federal gas and oil leasing began in the early 1950s.

- 110 obsolete petroleum structures have been permanently dedicated to fisheries enhancement on the Federal outer continental shelf over the last 10 years through placement on permitted artificial reef sites, primarily as a result of the Louisiana and Texas Artificial Reef programs. MMS continues to be a catalyst and facilitator in encouraging industry and gulf states to cooperate in developing compatible and functional Rigs to Reef projects.

- Oil and gas platform removals have outpaced installations in two of the last five years when an average of 125 structures were removed and 132 structures were installed per year on the federal OCS. The trend of increasing removals and installations is expected to continue throughout the central and western planning areas in the foreseeable future.

- Over the last 10 years and average of 10–12 structures or 10% of removals per year are being converted to permitted artificial reefs in the Louisiana and Texas Rigs to Reef programs.

- Rigs to Reef projects have been created in water depths ranging from 75'–345' with at least 13 structures permitted for reefs at sites in more than 300' of water.

- Rigs to Reef projects range from 7–112 miles form shore with at least 16 structures placed on reef sites more than 100 miles from shore.

- Besides the platform jackets, participating oil companies have donated over $10 million in disposal savings to sponsoring states for fisheries conversation, research, and management. Presumably these companies saved a comparable amount in structure disposal costs.

- 36 companies, or approximately one-third of existing oil and gas operators, have participated in development of Rigs to Reef projects since publication of the National Artificial Reef Plan and creation of state sponsored Rigs to Reef programs about 10 years ago.

- In the last two years hundreds of obsolete Army tanks and armored personnel carriers have been donated by the Department of Defense to Gulf and Atlantic state artificial reef programs and placed on offshore reef sites. Prior to the first dedicated Rigs to Reef project in 1980, several Gulf states had acquired surplus Liberty Ships from the Federal Government for sanctioned offshore artificial reef developments.

As we cross the bridge to the 21st century, should we strive harder to retain and utilize oil and gas structures for fisheries enhancement and development considering that 90% of current removals are "getting away" to become onshore disposal problems? Should we be even more selective and conservative in encouraging artificial reef development with obsolete structures? Just how important are these structures to ecological productivity and diversity, fisheries sustainability, or the development, use, and enjoyment of marine fisheries in the Gulf of Mexico? Have oil and gas structures become essential fisheries habitat? Some of us are convinced there has been a profound and very valuable change in the fisheries and fishing in the Gulf of Mexico brought on the OCS energy development directly related to the cumulative and long-term effects of the pervasive introduction of petroleum structures in the marine environment. What more can MMS do to facilitate better use of these structures as tools of fishery management, and what can we do to facilitate cooperation between fishery managers, reef sponsors, and oil companies to capture potential public benefits inherent in the artificial reef value of petroleum structures? What more can we do as well to avoid problems and conflicts with other users of the marine environment? What are the biological, legal, social, economic, technological, and regulatory limits to using oil and gas structures for artificial reef development in the Gulf of Mexico?

These and other questions were addressed by several of the most influential offshore structure donators, oil and gas and fishery policy regulators, Rigs to Reef program sponsors, major artificial reef users, and respected marine reef researchers. Summaries of the presentations received from the speakers, or developed by MMS, are included in these proceedings.

Mr. Villere C. Reggio, Jr., is an outdoor recreation planner with Minerals Management Service Gulf of Mexico OCS Region. His responsibilities include assessment, research, and reporting on the interrelationship of the OCS oil and gas program with the recreational elements of the marine and coastal environment throughout the Gulf region. For the past 20 years Mr. Reggio has had a special interest in evaluating the fisheries' value and potential of oil and gas structures.

UPDATE ON DECOMMISSIONING ISSUES RESULTING FROM THE MARINE BOARD REPORT AND INTERNATIONAL WORKSHOP

Mr. Elmer P. Danenberger
Minerals Management Service
Herndon, Virginia

In the report "An Assessment of Techniques for Removing Offshore Structures," the NRC Marine Board made recommendations to MMS regarding changes in well and platform abandonment requirements. These recommendations and other issues were discussed at an April 1996 international workshop in New Orleans. The following is an update on MMS activities related to the key issues raised by the Marine Board and the workshop participants:

DEPTH OF REMOVAL

The Marine Board report recommended that the minimum depth of removal for well casings and platform legs be changed to 3' below the mud line (from 15' BML). The intent of the commendation was to encourage the use of nonexplosive and other low-impact removal methods. At the New Orleans workshop, MMS raised concerns about this recommendation by noting the following:

- Bulk explosives have proven to be a safe and effective means of removal. Other techniques may pose greater risks to human safety, even if the depth of removal is reduced.
- Mitigations associated with explosive removals have minimized the risk to turtles and marine mammals.
- The 15' removal depth has proven to be effective in preventing seafloor obstructions.
- The Marine Board report indicates 3 – 5' scour potential in water depths less than 30'. With a 3' removal depth, the potential for obstructions in shallow water would be high.

- Shell mounds and silty bottom conditions affect the precision of removal depth determinations. With only a 3' removal depth, there would be no safety factor.

- Any exposed casing stubs or pilings could remain in place for 100 years or more. The former operators would remain liable for any damages.

- Thousands of trawling vessels work in the Gulf to depths of up to 400'. Trawling and other marine activities could be affected well into the future.

- If casing cannot be cut at the desired depth, the normal practice is try again at a lesser depth. This would not be possible if the first attempt was at 3' BML.

- Although pipelines have mostly smooth surfaces, burial to 3' has not always proven to be sufficient. During Hurricane Andrew, at least 9 pipeline segments were exposed, 10 were damaged by mud slides, and 18 were damaged by anchor dragging. Shrimpers have often raised concerns about pipeline obstructions.

Several panels at the workshops addressed the depth-of-removal issue. Their recommendations differed. The platform removal group concurred that the removal depth should be reduced, but indicated the 3' would not be deep enough in all cases. The site clearance group indicated the 3' could be a problem in high erosion areas. Fishers have consistently raised concerns about any change in removal depth. The habitat planning group favored actions that preserve the reef environment, including partial removals and reductions in the depth of removal.

Since the workshop, MMS personnel have further reviewed this issue. Because of the previously expressed concerns, MMS does not believe a change in the dept the removal requirement would be prudent. However, MMS rules authorize the District Supervisor to approve removal depths different than 15'. If an operator (1) intends to utilize nonexplosive removal techniques or other special mitigations, (2) can demonstrate that the scour potential in the area is minimal, and (3) is concerned about the safety or effectiveness of removals to 15' BLM, the operator should consult with the District Supervisor regarding a shallower removal depth.

PARTIAL REMOVALS

The Marine Board report recommended the MMS allow partial removals in water depths of 300' or more. That habitat planning group at the workshop supported this recommendations. No workgroups expressed opposition.

MMS has already approved two partial removals at designated reef sites offshore Texas. If the platform location is approved as a reef site, partial removals are the best means of preserving the reef habitat and maximizing the habitat value of the remaining structure. MMS will continue to cooperate with State reef programs to facilitate partial removals at designated reef sites.

No operators have proposed partial removals for non-reef sites. MMS approval of other (non-reef) partial removals would be dependent upon satisfactory resolution of liability issues and assessments of the potential for conflicts with other offshore activities.

MITIGATIONS ASSOCIATED WITH EXPLOSIVE REMOVALS

The Marine Board report recommended a series of changes in the mitigations associated with explosive removals including the following:

1. Develop guidelines for determining the size of explosive charges for cutting various structural elements.

2. Remove the limit on the number of detonations at any one time.

3. Shorten the observation time to 24 hours before the blast.

These recommendations were supported by the platform removal group at the international workshop. The platform removal group also recommended other measures that would simplify the monitoring and approval process and add flexibility. Another workshop group, habitat planning, endorsed the concept of reducing the preblast observation time to 24 hours.

MMS has met with the National Marine Fisheries Service and industry to discuss implementation of these recommendations, but no final action has been taken.

STUDIES

The Marine Board study and international workshop generated recommendations on additional studies that would improve the decision-making process. Many of these studies are planned or in progress. Some of the projects MMS is funding include efforts to assess turtle detection and scaring devices, compare the ecological role of natural reefs and oil and gas platforms, evaluate scour and sediment transport, advance explosive and nonexplosive removal techniques, consider deep-water pipeline abandonment procedures, evaluate the reef-effect associated with deep-water platforms, evaluate the habitat value of structures in cold water environments, determine the water depth profile for fish killed by explosives, consider the effects of platform size on fish attraction, and evaluate platform disposal options.

INTERNATIONAL CONVENTIONS

One of the workshop panels addressed international conventions affecting platform removal decisions. Much of the discussions related to the London Convention of 1972 (LC), and international convention to prevent marine pollution caused by the dumping of wastes and other matter at sea. There are currently 75 countries that are LC signatories, only 24 of which are offshore oil and gas producers. The United States ratified the LC in April 1974.

A proposed moratorium on ocean disposal of decommissioned offshore installations was considered at the nineteenth meeting of the LC Scientific Group in May 1996. The United Kingdom and the International Exploration and Production Forum presented information regarding the decommissioning of oil and agas installations and concluded that the proposed LC Waste Assessment Framework (WAF) is adequate to evaluate all types of waste for sea disposal, including oil and gas installations. On the pro-moratorium side, the Netherlands presented current capabilities of the marine construction industry, and therefore, all installations should be totally removed. Greenpeace took the position that because opportunities exist to recycle and reuse both shallow and deep-water offshore installations, all permits for offshore disposal of such installations should be refused. Both the position advanced by the Netherlands and by Greenpeace International fail to acknowledge the factors of extreme cost, unacceptable risk to human health, and unacceptable risk to the marine environment.

After considering all of the formal presentations and discussions, the Scientific Group agreed that offshore oil and gas installations should be included on the "reverse list" of substances that may be considered for dumping under the LC. The Scientific Group is developing guidelines for disposal of each of the substances on the reverse list. The delegation of Denmark, supported by Canada, Germany, and the United States, suggested that a specific WAF be developed for the offshore disposal of decommissioned oil and gas installations. The U.S. delegations volunteered to take the lead in developing the specific WAF guidelines for the disposal of platforms at sea. An interagency workgroup has been convened to draft these guidelines. A draft is scheduled for completion by the end of the year. The WAF guidelines will be compatible with existing International Maritime Organization (IMO) guidelines and will provide a decision-making framework for deciding: (1) how to best dispose of structures that must be removed under the IMO guidelines; and (2) for structures that do not have to be removed under the IMO guidelines, if leaving structures partially or wholly in-place is the preferred alternative.

FINANCIAL RESPONSIBILITY

Total abandonment and site clearance costs for existing OCS facilities are estimated at approximately $5 billion. MMS is intent on ensuring that lessees fulfill their abandonment responsibilities. In 1993, MMS established higher levels of minimum bond coverage. The Regional Director may also require supplemental bonds to cover the total estimated abandonment costs for a lessee's facilities.

MMS expects to promulgate a followup bonding rule in the near future. This followup rule will address certain administrative details associated with the minimum and supplemental bonding requirements.

Mr. Danenberger earned a B.S. degree in petroleum and natural gas engineering and a M.S. degree in environmental pollution control, both from Pennsylvania State University. He has been employed as an engineer in the Department of the Interior's offshore oil and gas program since 1971. He has served as District Supervisor for the Minerals Management Service (MMS) field offices in Santa Maria, California and Hyannis, Massachusetts; as a staff engineer in the Gulf of Mexico regional office; and a Chief of the

Technical Advisory Section at headquarters office of the U.S. Geological Survey. He is currently the Chief of MMS's Engineering and Technology Division with responsibilities for safety and pollution-prevention research, engineering support, and offshore operating regulations.

CONSTRUCTIVE DESTRUCTION—REEF DEVELOPMENT OPTIONS

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

Numerous environmental issues arise when an active lease is terminated and platforms are decommissioned. The following paper touches upon biological and technical questions concerning the underwater portions of a platform at the time of decommissioning. This includes aspects of artificial reef building, platform removal options, and newly arisen deepwater concerns.

The Minerals Management Service (MMS) bases their present platform removal policy upon regulations originating in the OCS Lands Act. The present policy requires the platform structure be completely removed to a depth of 15 feet below the seafloor and any debris cleared from the surrounding area. The structure must be taken to shore, recycled, reused, or scrapped. As an alternative, the structure may be donated to a recognized State Artificial Reef Program. The Federal Fisheries Enhancement Act of 1984 allows states to become the actual owners and managers of artificial reefs with reduced liability. Of course, MMS's policy is to support both Acts where applicable.

At the time of platform decommissioning, the operator of the platform must consider a number of removal and disposal options. If the platform is going to be scrapped or reused the options are few and the operator has a fairly straight forward set of decisions. If the platform is going into a reef program there is a host of questions. For example: What are the different Artificial Reef Programs in the northwestern Gulf? How do they differ? Are there different removal options for Artificial Reef Programs?

To scrap or reuse the platform, it must first be severed from its anchor pilings 15 feet below the seafloor. Both mechanical and explosive methods are used to accomplish this objective. Explosives are safer, reliable, and less expensive. About 70% of all removals are accomplished using explosives to severe the jacket legs. Mechanical methods tend to be unsafe, unreliable, and more expensive. Of the jackets that become artificial reefs about 85% are severed with explosives during decommissioning.

There are three main ways that a platform might physically move into a State Artificial Reef Program. The first and third, termed "topple-in-place" and "partial-removal" only apply to platforms located in already permitted artificial reef sites. The second called "tow-and-place" applies to any platform. For all three of the methods, if the state receiving the reef material is willing to maintain large, US Coast Guard-approved, lighted buoys, then the reef may reach to within 50 feet of the sea surface. If smaller, intermittent, marker buoys are used then a clearance of 85 is required.

Topple-in-place occurs when a platform is prepared and severed from its anchor pilings and pulled over onto the seafloor to lie on one of its sides (Figure 1A.1). The area directly beneath and surrounding the platform must be a permitted artificial reef site. Tow-and-place occurs when a platform is severed from its anchor pilings, pulled free of the seafloor and towed to its final destination (Figure 1A.2). The platform is allowed to sink to the seafloor in its new permitted reef site. Partial-removal is a relatively recent option for the disposal of offshore platforms. During a partial-removal a minimum of the uppermost 85 feet of the jacket is cut off and may be placed on the seafloor next to that part left standing below 85 feet of seawater (Figure 1A.3).

There have been two partial-removals since 1994 in the Gulf of Mexico, and several more are planned for the summer of 1997. Union Pacific Resources partially removed a platform at Padre Island A-58 in 255 feet of water and Oxy Petroleum partially removed a platform in 305 feet of water at High Island 355. Both removals used mechanical methods to cut off the upper 85 feet of the platform's jacket and explosives to severe the well conductors 15 feet below the seafloor. The upper

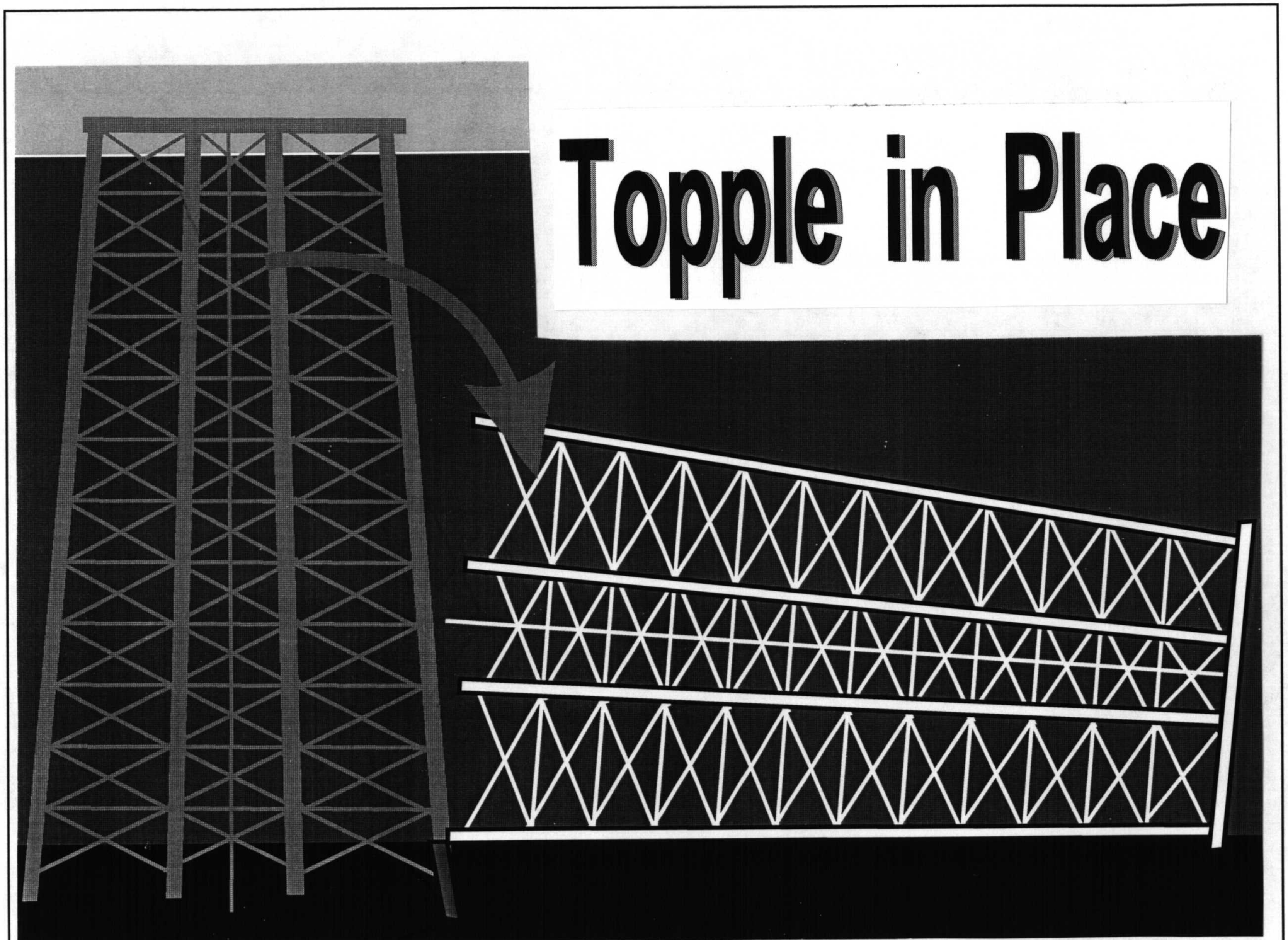

Figure 1A.1. The topple-in-place rig decommissioning method.

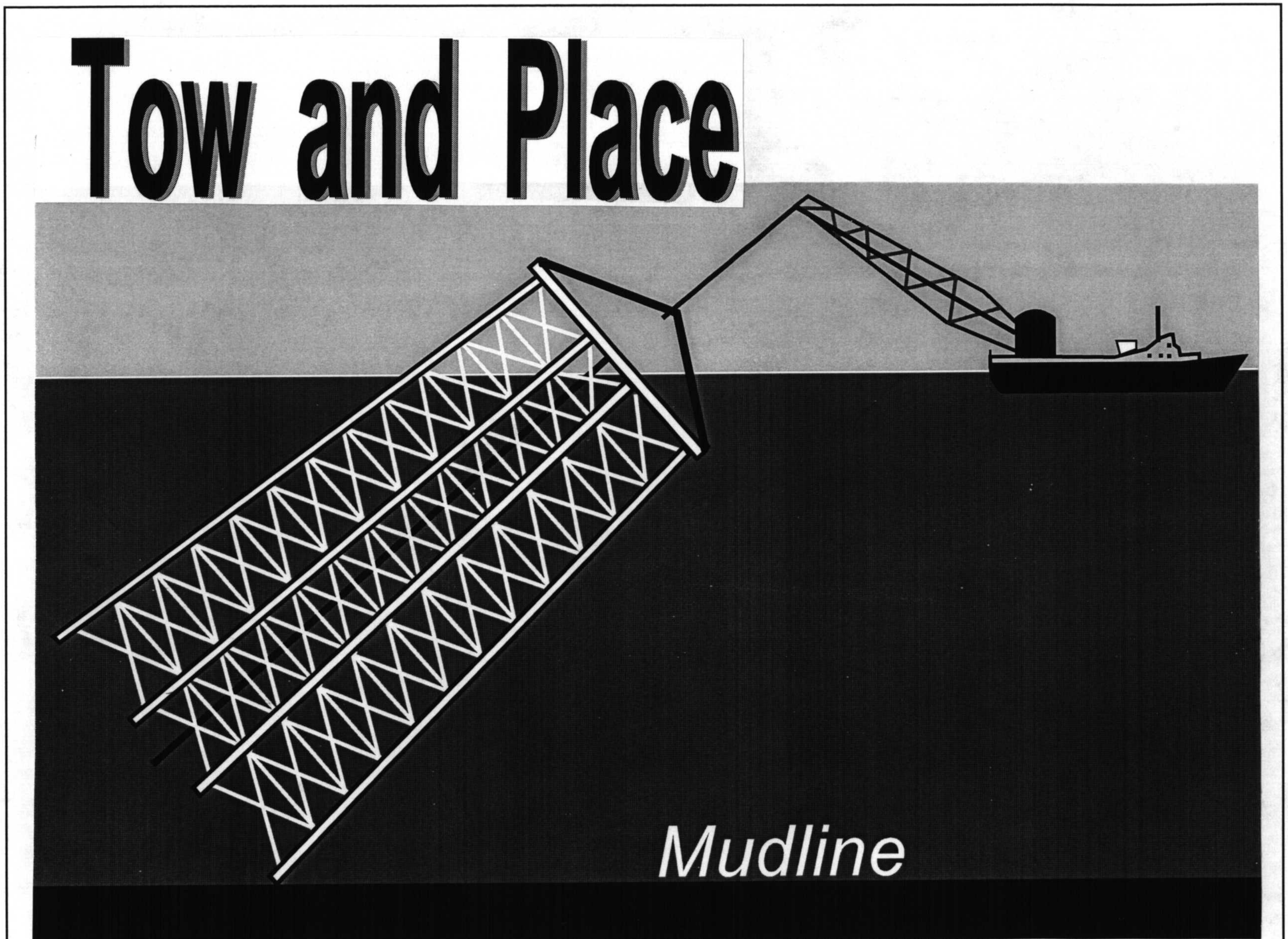

Figure 1A.2. The tow-and-place rig decommissioning method.

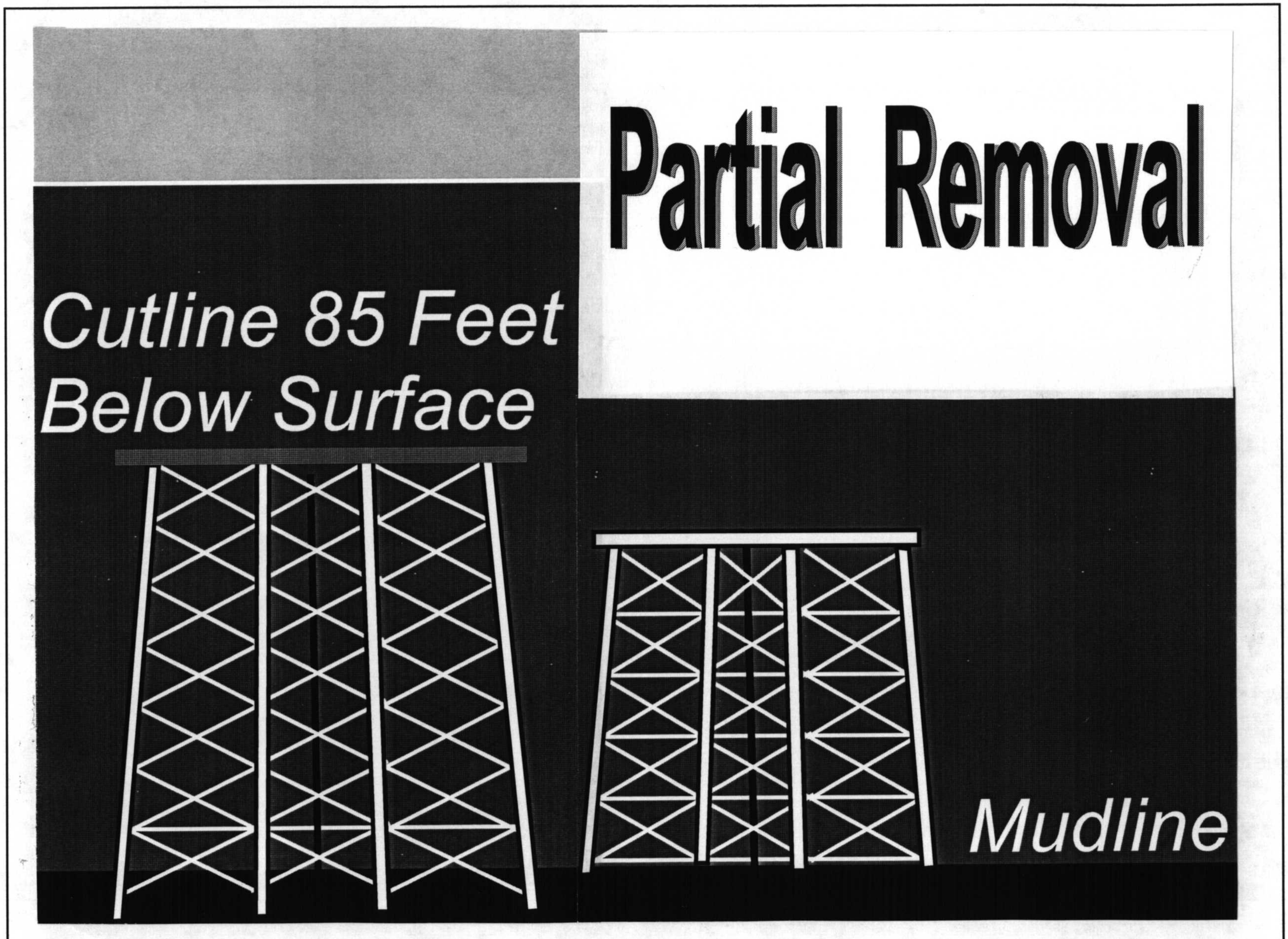

Figure 1A.3. The partial-removal rig decommissioning method.

portions were both placed on the bottom next to the standing remains. A 1996 application for a partial-removal was delayed due to concerns over leaks if conductors are cut and left standing above the seafloor.

In the Fall of 1996, the MMS Gulf of Mexico Region completed an internal engineering and structural assessment based on theoretical loading and actual down-hole well disturbances and shut-ins from Hurricane Andrew. The Field Operations Division determined that there are no potential leaks from a plugged and abandoned well that is left standing any distance above the seafloor. For this and a number of other reasons, partial-removals will likely become an attractive option for platforms permitted to become artificial reefs in water depths greater than 200 feet.

There are consequences to the actual and potential reef community with each removal option and method. Using explosives kills nearly all the fish associated with the platform and causes more than 60% of the platform fouling community to fall off. It does provide excellent reef material in good condition that, with tow-and-place, can become a very productive artificial reef in many locations within 5-10 years. Explosives are by far the most cost-effective and safest way to severe a platform below the seafloor and remains the method of choice. Using mechanical methods preserves the entire living community associated with the platform. If mechanical methods are used for a partial-removal, the jacket remaining below 85 feet provides some vertical profile no matter what the seafloor depth.

The deepest Gulf of Mexico artificial reefs composed of obsolete oil and gas platforms are in 345 feet of water with about 200 feet of clearance to the sea surface over the structures. That means that issues for artificial reefs in the Gulf deepwater begin at water depths of about 350 feet. Concerns for the appropriateness and function of artificial reefs begin there and continue into the depth range of 700-900 feet and beyond: the area of focus for recent offshore activity. The technology, engineering, and expense associated with removal of enormous deepwater structures is daunting. Partial-removals where platforms may be cut some distance below the sea surface will soon be a pressing issue for MMS.

Data from a single platform in approximately 700 feet of water indicate that there may be a critical depth below which little or no biological community develops in association with the platforms. Hydro-acoustic signals and ROV surveys indicate that at Green Canyon 18, fish in the upper water column are at the expected density but density begins to decrease at a depth of about 300 feet and is nearly zero by 400 feet. Artificial reefs in water depths greater than 350 feet may have very little influence on fisheries' production. When a North Sea platform is slated to be placed below any functioning reef depth, the action is called "Ocean Dumping" by all parties, and although it has been permitted on paper by the various governments, environmental activists have been able to prevent such actions.

Data from numerous visits to standing platforms in water depths of 150-200 feet and visits to toppled rigs-to-reefs in water depths of 100-150 feet indicate that vertical relief may be an influential component for successful reef development. However, the significance of the uppermost part of the platform (from a depth of 85 feet to the sea surface) to the establishment and continuation of increased fisheries production in the Gulf is unknown.

There have been a number of discussions within the Gulf of Mexico Region about MMS's information needs concerning the above topics. These discussions have taken place between the Offices of Field Operations and Leasing and Environment as well as within the Offices. Information must be gathered as soon as possible regarding the functioning of rigs-to-reefs in deepwater and a possible critical depth for fisheries. The concerns over a vertical profile in the uppermost water column are an important issue for partial removals, each of which at this time must be given a waiver from existing regulations and practices. These identified information needs will become part of a lengthy list of data gaps that will be prioritized and incorporated into the MMS Environmental Studies Program.

Dr. 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.

PLATFORM REEF ECOLOGICAL AND BIOLOGICAL PRODUCTIVITY: FACT OR FICTION?

Dr. Quenton R. Dokken
Center for Coastal Studies
Texas A&M University

ABSTRACT

Estimated to provide more than 25% of the submerged hard substrate in the northwestern Gulf of Mexico, oil and gas production platforms have the potential of significant impact upon the biology/ecology of the region as artificial reefs. They are primary fishing sites for both commercial and recreational fishers and diving sites for recreational scuba divers. It is clearly evident, both through casual observation and scientific investigation, that platform reefs are dynamic and do entrain significant biomass in the form of mobile and sessile species, but their overall impact upon the population dynamics of targeted harvest species and the overall ecological health and productivity of the Gulf of Mexico is not known. Nor are the dynamics of these artificial reefs understood adequately to support management efforts to maximize their contributions toward increasing and stabilizing population density, biomass, biodiversity, and/or ecological productivity and health.

DISCUSSION

Reef Dynamics

Whether it be to enhance fishing success, recreational opportunities, or biological/ ecological health and productivity of a regional ecosystem, artificial reefs exist to serve human needs. As such, it is incumbent upon resource and artificial reef program managers to employ reef structures in a strategy that creates the greatest potential for maximizing productivity. And, to do this, a clear and comprehensive understanding of the dynamics of artificial reef productivity relative to the biological, chemical, geological, meteorological, and oceanographic characteristics of the area of placement is required.

In supporting the productivity and sustainability of living resources, several factors effect the outcome (Figure 1A.4). Habitat quality and stability are factors of the reef materials. Production platforms present a hard, smooth, metal surface of simple surface complexity (=rugosity). Platform structures provide not only vertical and horizontal surface, but also an internal volume bounded by the outer structural members, which allows schooling pelagics to maintain school integrity within the reef structure. The metals used in the structural members are dense and long lived.

Recruitment is an ongoing process that begins the minute a platform is placed into the water. Ocean currents, climatic zones and seasons, biological zones, and geology affect recruitment. In the northwestern Gulf of Mexico, from biological collections at oil and gas platforms, Galloway and Lewbel (1982) described three biological zones, the coastal, offshore, and bluewater zones. Moving from the nearshore coastal zone, Galloway and Lewbel described a change from substantial seasonal water quality and climatic variation toward minimum variation in water quality and climatic conditions in the bluewater zone. The biological communities changed from temperate assemblages in the coastal zone to tropical assemblages in the bluewater zone.

Residency time is an important character in describing the productivity of artificial reefs. Do artificial reefs provide an important habitat for intermediate life stage of some species such as red snapper, *Lutjanus campechanus*, as they migrate from coastal nurseries to spawning areas offshore? If so, how long do the intermediate stages reside in the platform reef ecosystem? What species are active spawners at platform reefs? Are there differences in residency times at platform reefs in coastal, offshore, and bluewater zones? In the trophic structure framework, at what life stages do various species arrive and how long do they stay? These characters in a large part describe the import and export of energy and biomass into and out of the reef ecosystem.

Water quality is a function of meteorological, hydrological, and anthropogenic influences, and can be a limiting factor when the management of the artificial reef is directed at a specific species. Salinity, annual temperature regimes, nutrient and toxic contaminant loads, currents, river outflow, suspended sediments, and water clarity affect the biological character of the reef

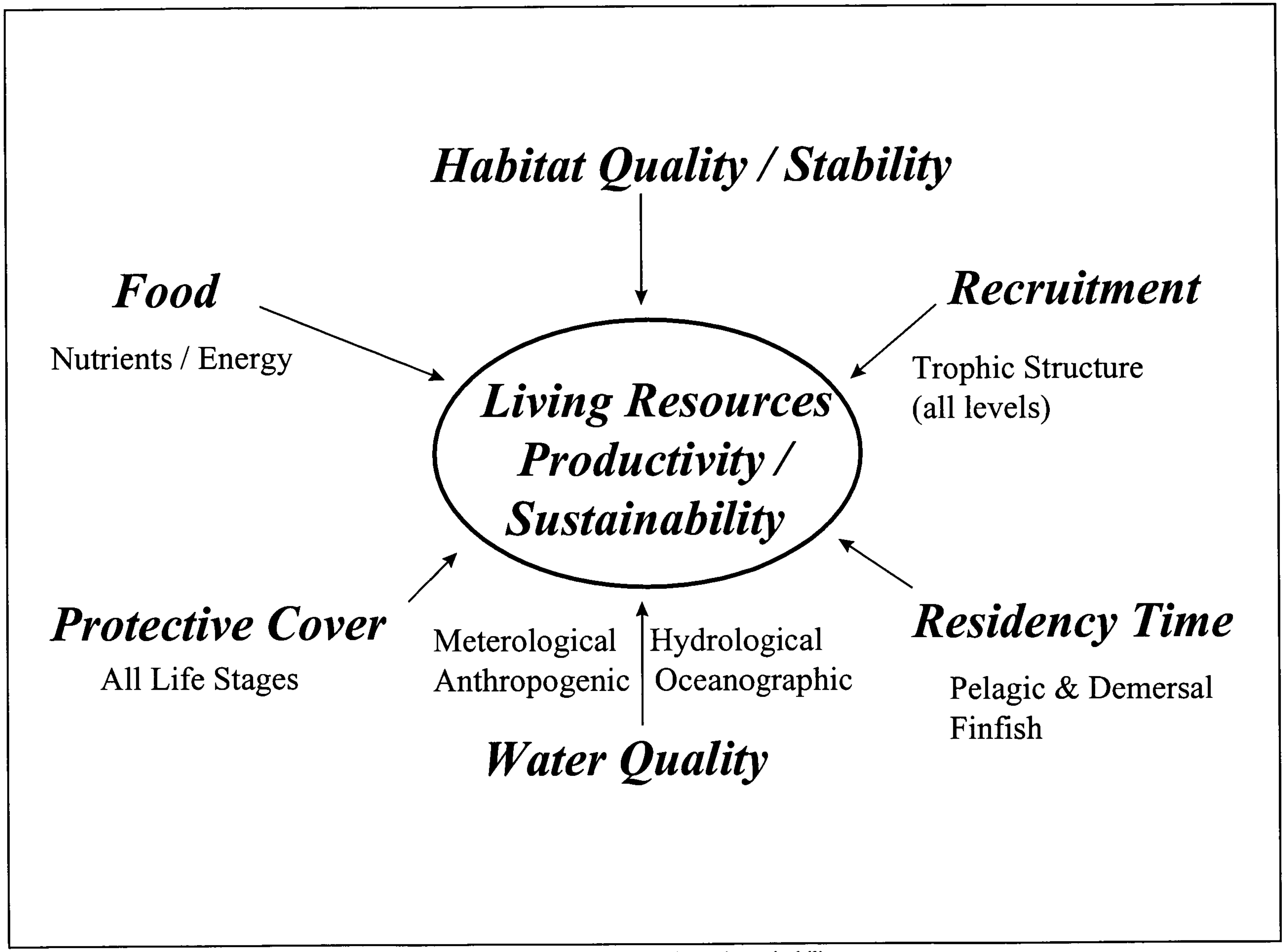

Figure 1A.4. Artificial reef habitat components affecting living resources productivity and sustainability.

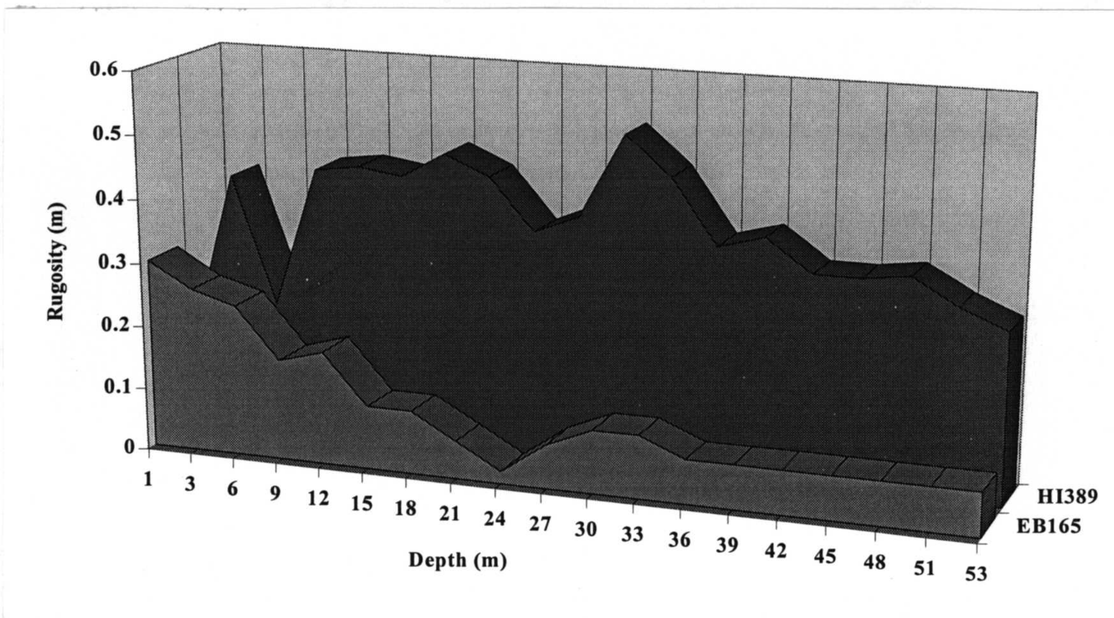

Figure 1A.5. Comparison of rugosity between platforms High Island A389A and East Breaks A165 in bluewater biozone of the northwestern Gulf of Mexico (after Dokken *et al.* 1995).

community. Artificial reef placement would have to occur in an area of suitable water quality to meet the needs of the targeted species.

The fouling community, composed of algae and sessile invertebrates, provides the greatest amount of protective cover for post settlement juvenile and subadult fishes. Surface rugosity on a platform reef is a function of the sessile fouling community and can differ markedly between platforms (Figure 1A.5). Dokken *et al.* (1995; Figures 1A.6 and 1A.7) demonstrated distinct vertical zonation in the fouling community on two platforms in the bluewater biozone of the northwestern Gulf of Mexico. In the shallow high-energy, high-intensity photic zone near the surface, algae, barnacles, and bivalve molluscs dominated. Hydroids, sponges, and bryozoans dominated at deeper depths. The more complex and rugose the fouling community surface, the greater the concealment opportunities for cryptic life stages and species. Rooker *et al.* (1994, 1996; Figure 1A.8) demonstrated strong correlation between rugosity and degree of fouling with fish concentrations.

Along with protective cover, feeding opportunities provide the greatest draw for migratory demersal and pelagic species to a platform ecosystem. And this, in turn, forms a major pathway of nutrients, energy, and biomass into and out of the ecosystem. Typically, it is the upper trophic structure carnivores that are harvest targeted and can readily be assigned a dollar value. And, as such, the status of these species is generally used as the measure of value of the artificial reef ecosystem.

Considering production platforms in the operational configuration, that is vertical and penetrating the water surface (Figure 1A.9), a dynamic flow of energy and biomass into and out of the reef system can be described. Energy and biomass enter the system through photosynthesis in the photic zone, bacterial action, active recruitment of pelagic and other migratory species, and passive recruitment of post larval and juvenile stages settling out of planktonic stages. Sessile filter feeders and planktivores capture additional energy/ biomass from the currents flowing past.

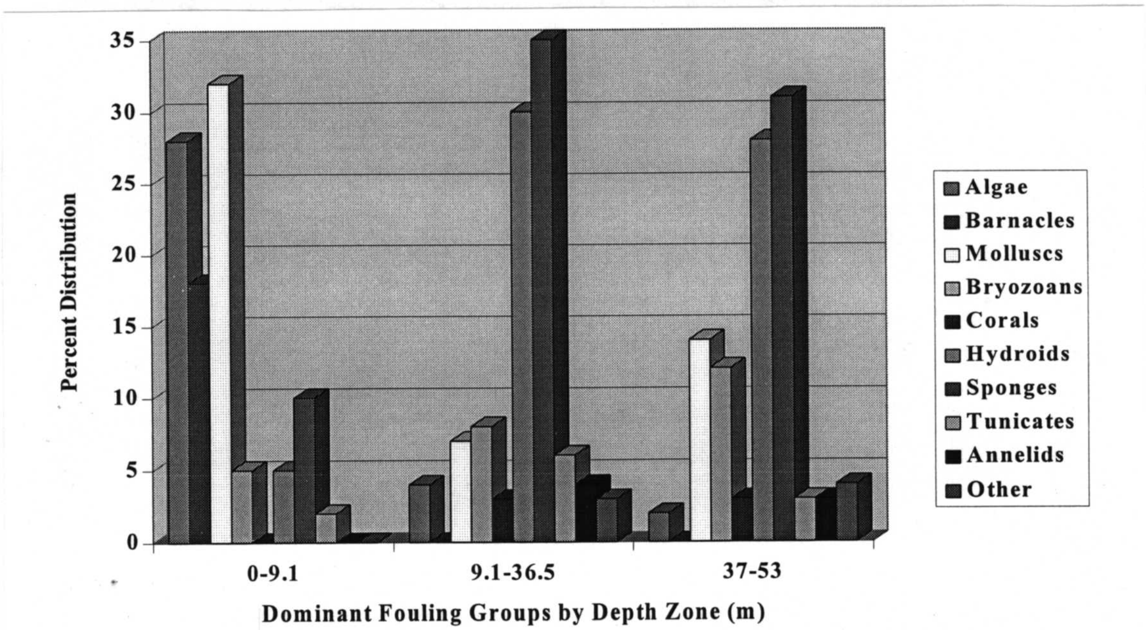

Figure 1A.6. Vertical zonation of algae and sessile invertebrates on platform High Island A389 in the bluewater biozone of the northwestern Gulf of Mexico (after Dokken *et al.* 1995).

Energy/biomass is exported from the system via harvest by commercial and recreational fishers, active emigration of pelagic and other migratory species, and planktonic spawn. Within the system, trophic webs support the movement of energy and biomass upwards to the apex carnivores. Fecal material and detritus from both mobile and sessile community members is cycled on/in the seabed by the benthos.

Research and Management Considerations

In its operational configuration, penetrating the most intense photic zone at the water's surface, platforms create a physical, biological, and nutrient/energy link between the water surface and the seabed. Upon decommissioning, when a platform structure is severed from its mooring below the seabed and toppled, the physical connection between the intense photic zone of the surface and the seabed is lost. And, depending on depth and water clarity, the connection with the effective photic zone (i.e. light penetration/intensity capable of sustaining photosynthesis) can also be lost.

Evidence is beginning to mount which indicates that the productivity of platform artificial reefs is enhanced by penetration into the photic zone of the surface waters. And, that at greater depths, below the effective photic zone, these structures begin to function more as fish attractant devices rather than biologically productive artificial reefs. This forces contemplation of the question: Could the potential for biological productivity be enhanced by severing these structures at the shallowest depth that navigation safety would permit rather than severing the structure below the seabed and toppling them once they cease to function as producers of hydrocarbons and are committed to an artificial reef program? This is a particularly important consideration as the offshore industry increases its activity in deeper offshore waters.

What is the impact of the loss of penetration of the platform reef structure into the shallow water photic zone on harvest targeted finfish? This question has not been answered yet. Preliminary results of studies of the trophic structure relationships (Beaver 1997) indicate that feeding patterns occur on both diurnal and seasonal temporal scales. And that top trophic level pelagic and demersal

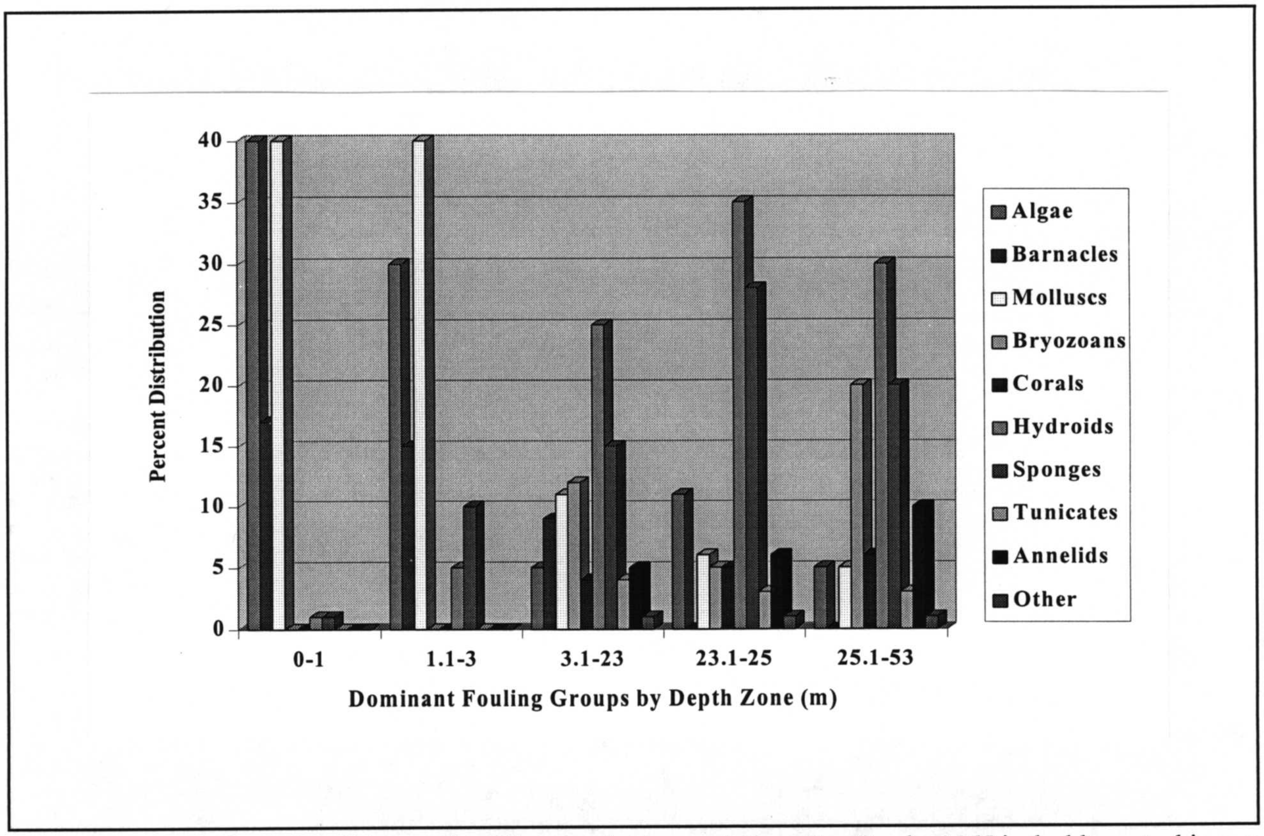

Figure 1A.7. Vertical zonation of algae and sessile invertebrates on platform East Breaks A165 in the bluewater biozone of the northwestern Gulf of Mexico (after Dokken *et al.* 1995).

carnivores are drawing energy and nutrients from the lowest level of the trophic structure. Clearly, all food sources from the surface down to the seabed and its margins around the platform structure are utilized and integrated into the food webs.

What is the impact of the loss of penetration of the platform reef structure into the shallow water photic zone on the overall biological/ecological health and productivity of the northwestern Gulf of Mexico? Again, this question has not been conclusively answered. By virtue of the sessile fouling community, without question, platform artificial reefs do increase the biomass and biological productivity of the Gulf of Mexico ecosystem. But the impact of this additional biomass upon the overall population density and stability of harvest targeted species is not known. Nor do we understand the impact of this algal and invertebrate biomass upon the overall ecological health and productivity of the Gulf of Mexico. If we accept the hypothesis that the fouling community does not have positive influence upon those species with dollar value or on overall ecological health and productivity, then we would conclude that platform reefs function as fish attractant devices and not productive reefs. In this event, the impacts and management requirements would be radically different than the impacts and management required for productive reef ecosystems (Grossman *et al.* 1997; Steimle and Meier 1997).

Based on current understanding, the author would hypothesize that platforms toppled in deep waters with the uppermost point of the structure below approximately 70 meters would function primarily as fish attractant devices and not productive artificial reefs. If scientific investigation supports this hypothesis, then the challenge becomes to devise a management strategy to ensure that structures extend upwards into the shallow water photic zone in order to function as biologically productive reefs and not primarily as fish attractant devices.

CONCLUSION

By virtue of the fouling community, platform artificial reefs do contribute to the overall biomass and ecological productivity of the northwestern Gulf of Mexico. Additional study is required to answer some of the

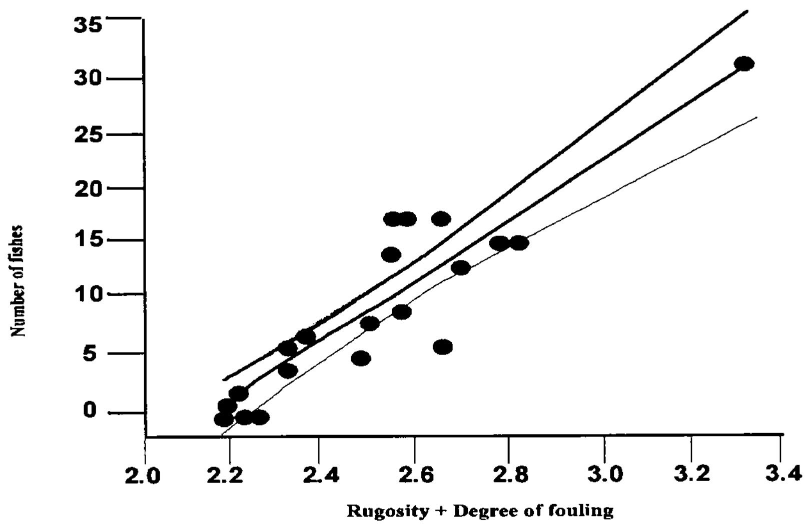

Figure 1A.8. Correlation of reef-dependent finfish to rugosity and degree of fouling on High Island A389 in the bluewater biozone of the northwestern Gulf of Mexico (after Rooker *et al.* 1996).

fundamental questions as to the dynamics and impacts of platform artificial reefs upon harvest targeted species and the overall ecosystem (Dokken *et al.* 1993; Bohnsack *et al.* 1997; Lindberg 1997). And the question should be addressed at the ecosystem level as well as at the level of population dynamics and harvest potential of targeted finfish species.

Management considerations such as at what depth to sever obsolete platforms and where to locate platform artificial reefs need to be addressed. The management goal should be to maximize biological and ecological productivity of the Gulf of Mexico including overall health and productivity and fisheries harvest potential.

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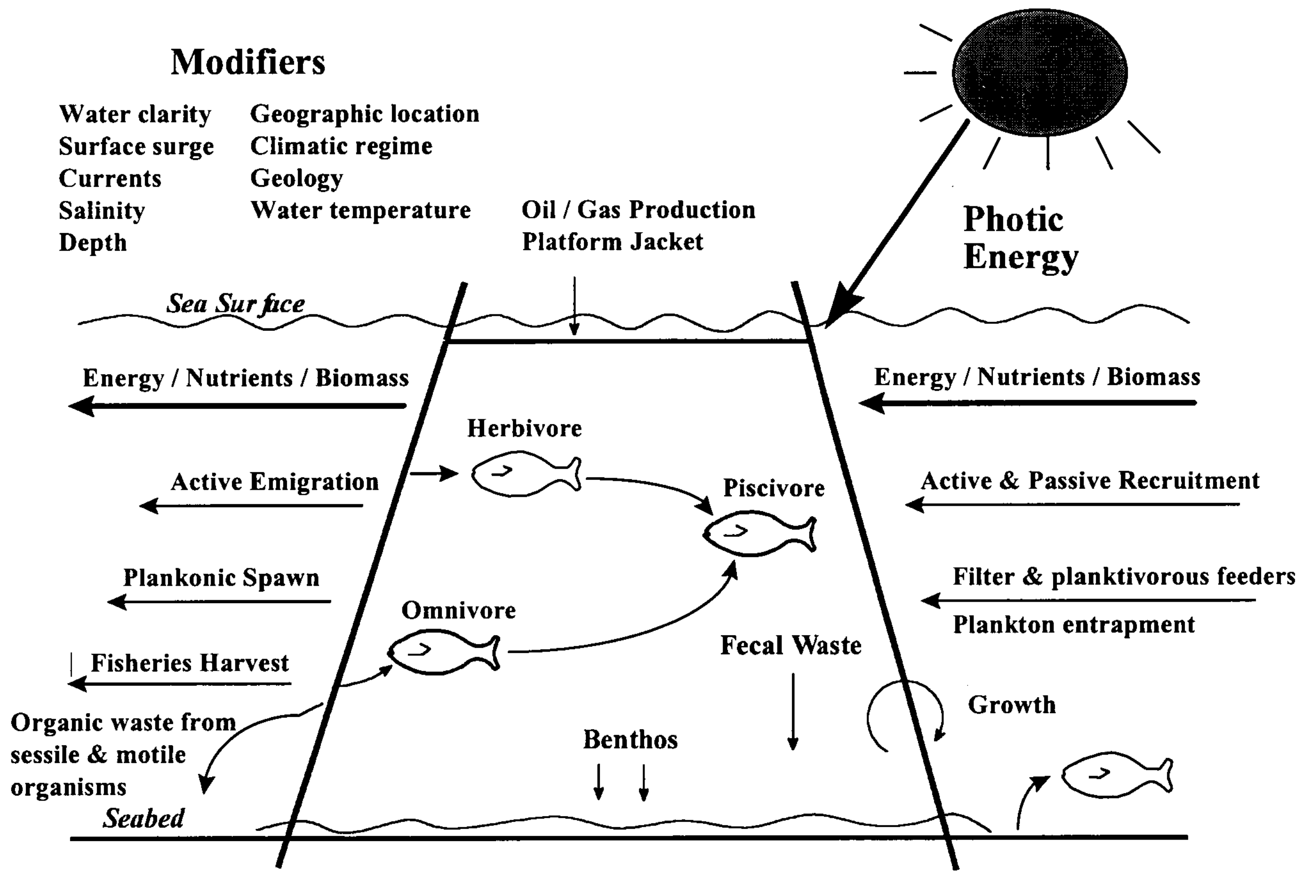

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Dr. Quenton Dokken, a graduate of Texas A&M, is currently the Associate Director of the Center for Coastal Studies at Texas A&M University, Corpus Christi and Director of the Flower Gardens Ocean Research Program. Dr. Dokken has been researching marine related topics in the Gulf of Mexico for over 20 years.

TEXAS ARTIFICIAL REEF DEVELOPMENT PROGRAM

Ms. Jan. C. Culbertson
Mr. Hal Osborne
Mr. Douglas Peter
Texas Parks and Wildlife Department

The National Fishing Enhancement Act of 1984 gave authority to the states to create artificial reefs in order to enhance the fishery resource. Although Texas Parks and Wildlife Department was creating reef sites using materials of opportunity prior to this legislation, the placement of 12 Liberty Ships at 5 strategic locations in 1976 represented the first time complex, stable, and durable material was used to create reef fish habitat.

TEXAS ARTIFICIAL REEF ACT OF 1989

In 1989, the Seventy-first Texas Legislature directed the Texas Parks and Wildlife Department to develop a State Artificial Reef Plan. Guidance as well as limitations for the program are provided by this enabling legislation and are embodied in specific recommendations in the State Plan.

TEXAS ARTIFICIAL REEF PLAN OF 1990

As directed by the legislature, an artificial reef covered under this Plan must be sited, constructed, maintained, monitored, and managed in a manner such that it:

- enhances and conserves the fishery resources to the maximum extent practicable;
- facilitates access and use by Texas recreational and commercial fishermen;
- minimizes conflicts among competing water resources uses;
- minimizes environmental risks and risks to personal and public health and property;
- is consistent with generally accepted principles of international law and national fishing law
- does not create any unreasonable obstruction to navigation; and
- uses the best scientific information available.

All these concerns must be taken into consideration when determining the location of prospective artificial reef development.

The Texas Artificial Reef Plan provides flexibility to allow for changes in policy as new information becomes available. Geographic, social, economic, and environmental concerns have been incorporated into a resource planning framework developed by the Sport Fishing Institute that can help in siting reefs designated for the enhancement of recreational fisheries. This framework can be modified to include the provisions mandated by Chapter 89 of the Texas Parks and Wildlife Code.

CHECKS AND BALANCES OF THE PROGRAM

The program does not operate without limitations and preferences. The program uses a ten-member citizen's advisory committee to monitor the creation of artificial reefs and appropriate material donations in a multiple use environment such as the Gulf of Mexico.

This Artificial Reef Advisory Committee, composed of major interest groups in the Gulf of Mexico, are represented by: Salt Water Fishing Group; Offshore Oil and Gas Industry; Texas Tourism Industry; Texas General Land Office; Shrimping Organization; Texas Diving Club; Attorney General's Office; Texas University; Environmental Group; Texas Antiquities Committee.

MATERIAL CONSIDERATIONS

The program actively pursues complex, stable and durable structures in a "form as close to their current form" as possible. These structures must meet EPA clean water standards. Guidance for accepting materials is based on scientific research and minimizing user conflicts. The program does not accept unstable materials that may move offsite and create potential conflict.

PAST DONATIONS TO THE PROGRAM

- 36 oil and gas structures
- 12 Liberty ships
- 4 barges
- 1 tugboat
- 44 concrete culverts
- 300 fly-ash blocks
- one welded pipe structure

GENERAL SITING CONSIDERATIONS

The program considers the following factors for each reef site to help assure optimum benefits while still meeting Plan goals: Biological, Hydrographic, Geographic, Geological, Ecological, Social, and Economic.

BIOLOGICAL CONSIDERATIONS: HABITAT LIMITING

The Texas Program considers the hard bottom habitat in the Gulf of Mexico to be habitat limiting. Twenty-five percent of the hard bottom habitat in the Gulf of Mexico is provided by oil and gas platforms. Loss of structures means loss of reef habitat. Currently there are no limitations on preserving reef habitat in the Gulf environment.

HYDROGRAPHIC CONSIDERATIONS: DEPTH OF WATER AND PROFILE OF STRUCTURE

Biological activity occurs at all depths. Deepwater natural reefs have been documented to enhance the fishery resource as a result of venting, hydrates, oil and gas seepage, and nutrients brought in by currents. However, the higher the profile the better the reef.

Recent research has documented that the majority of biological activity surrounding a platform structure is above 300 feet. More research is needed. The Texas Parks and Wildlife Department is interested in helping with those efforts where appropriate.

HYDROGRAPHIC CONSIDERATIONS: POLICY

The Texas Program has flexibility to assess general priorities and to focus on the profile of the structure rather than the depth of water. The current policy is to accept jacket structures in less than 300 feet of water or that have a profile that extends into the upper 300 feet of water. The program will continue to specifically look on a case-by-case basis to determine the biological benefits at each new reef site in the donation evaluation process.

PARTIAL REMOVAL: ALTERNATIVE REMOVAL OPTION

In January 1995, the National Research Council requested MMS look at alternative removal options to the standard explosive removal operation.

In April 1996, an International Abandonment Conference Habitat Work Group made a formal recommendation to MMS to:

> Allow partial removal of structures in 300 (or more) feet of water, with the cut subject to Coast Guard Regulations below the water surface when nonexplosive or advanced explosive techniques were used and determined on a case-by-case basis.

The Department with the assistance of the MMS has taken the lead to promote the Partial Removal option where the structure is being made into an artificial reef.

PARTIAL REMOVAL PARTICIPANTS IN THE TEXAS PROGRAM

Union Pacific Resources Company (UPRC) was first to complete a mechanical partial removal in the Gulf of Mexico, in North Padre Island A-58. They donated a 4-pile jacket, severed by commercial divers at 86 feet in 254 feet of water. This donation saved UPRC $650,000.

OXY U.S.A. was the second mechanical partial removal in the Gulf of Mexico in High Island A-355. They donated an 8-pile jacket, severed by abrasive cutters at 90 feet, in 305 feet of water. An additional benefit to the realized savings for using this new method for the donor was reusing a portion of the upper jacket at another location.

Such donations allow for the maximum biological profile in the water column within current Coast Guard regulations and eliminate the need for explosives in deepwater removal operations. The Partial Removal method needs to be an option in every practical case when a structure is being considered for artificial reef enhancement.

We need to challenge the Industry to allow the preferred biological option to become the preferred economic option through engineering advances.

FINANCIAL INCENTIVES IN DEEPWATER APPLICATIONS

Certainly there are financial incentives for the oil and gas industry for cutting the structure above 300 feet. A recent quote from an Industry source indicates that it would cost $40 million dollars to remove a 950-foot structure in deepwater.

Monetary donations from deepwater structures are also beneficial to the program, in that these funds can be used for enhancement of near-shore reef sites.

GEOGRAPHIC CONSIDERATIONS: DISTANCE FROM SAFETY FAIRWAYS AND DISTANCE FROM SHORE

The Artificial Reef Plan has specific geographic criteria concerning the siting of new reef sites. Current policy for artificial reef development requires reef sites to be established at least two nautical miles from any safety fairway.

Geographic criteria also take into consideration social and economic implications for distances fishermen and divers are willing to travel offshore. The Department recently contracted Texas A&M University to survey charter boat captains to document their preferences for reef siting with regard to distance from shore.

The survey showed that divers were willing to travel farther offshore to dive artificial reefs, and anglers want reef sites closer to shore. The average distances boats traveled offshore for recreational purposes were:

- Fishing Boats (Charter and Party) – 54 km / 34 mi
- Diving Boats – 99 km / 62 mi

Fishing boats frequented reefs in near-shore waters with lower reef profiles. Diving boats frequented reefs in deeper water with higher reef profiles.

GEOLOGICAL CONSIDERATIONS: BOTTOM SEDIMENTS

Current Policy requires reefs to be located on stable bottom sediments and not on natural hard bottom areas. Inside the High Island General Permit area (2,500 square miles) reef sites are planned at least one nautical mile away from any natural hard bottom community.

ECOLOGICAL CONSIDERATIONS: SPACING LIMITATIONS

Inside the High Island General Permit area there are guidelines for planning reef sites more than five nautical miles apart in order to promote the clustering of jackets in a 40-acre reef site and to minimize user conflict.

Other areas outside the General Permit Area have no specific requirements on spacing between reef sites. However, spacing limitations are primarily dictated by social issues where boating distance from shore and accessibility to the reef site are important. Previous research shows the greatest need for sites is close to major passes near major cities. To optimize benefits for these users, it may be appropriate to locate reefs close to each other.

- Boatmen's Reef and Lone Star Reef, located 6-10 nautical miles offshore of Port Aransas, are individually permitted reefs established close to shore for small boat access.

- The Basco and Sabine Reefs, located 23 nautical miles offshore of Sabine Pass, are two reef sites less than three nautical miles apart and were permitted under an individual permit through a public hearing process to establish reefs on non-trawlable bottom near a major pass.

SOCIAL/ECONOMIC CONSIDERATIONS: NUMBER OF REEF SITES AND DISTANCE FROM SHORE

The Texas Program does not specify a maximum limit on the number of reef sites. Every stakeholder's involvement is considered in the program's management decision process.

Artificial Reefs will have minimal impact on total bottom offshore. If all 800 structures in Texas territorial seas were made into 10-acre reef sites, that would take up 8,000 acres. This number represents less than .0006 % of total bottom (13,829,760 acres) offshore of Texas in the Economic Exclusive Zone in the Gulf of Mexico. Even if every structure was converted into an artificial reef site, there would not be a significant impediment to the shrimp fishery since these structures are already avoided by the shrimp fleet.

Gulf Artificial Reef Programs have the advantage of being the pace setters for using obsolete oil and gas platforms as artificial reefs. Oil and gas riches created jobs, and the platform structures provided unique fishing and diving opportunities. The results were economically beneficial to everyone. As previously discussed, reef sites need to be strategically placed at both near and farther offshore distances in order to optimize the benefits to divers and fishermen.

FUTURE CONSIDERATIONS:

The Texas Artificial Reef Program will continue to work with the Minerals Management Service and the petroleum industry on a case-by-case basis to create reef sites from obsolete platforms.

The Department will also continue to work with MMS to utilize the partial mechanical removal method in both shallow and deepwater applications to enhance the reef fishery resource and benefit 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.

LOUISIANA'S ARTIFICIAL REEF PROGRAM

Mr. John E. Roussel
Mr. R.A. Kasprzak
Louisiana Department of Wildlife and Fisheries

Offshore oil and gas platforms began functioning as artificial reefs in 1947, when Kerr McGee completed the world's first commercially successful oil well, out of sight of land in 5.6 m of water, 70 km south of Morgan City, Louisiana. With the capability of drilling offshore and the development of new technologies, Louisiana's offshore oil and gas industry quickly expanded. In 1993, Minerals Management Service estimated there are over 3,746 platforms in the northern Gulf of Mexico, in water depths up to 609 m. In addition to supplying 25% of the annual U.S. production of natural gas and approximately 13% of its oil, the platforms also form the world's largest artificial reef systems. Most of the Gulf's oil and gas platforms (3,203) lie in Federal waters off Louisiana's coast. A few lie east of the Mississippi River, in waters off Mississippi and Alabama; the rest (505) are scattered off the Texas coast. The Gulf of Mexico Fisheries Management Council estimated that the total natural reef habitat in the Gulf of

Mexico covered approximately 39,900 km. Only one-third of this natural reef habitat lies off Louisiana's and Texas' coasts where approximately 99% of the Gulf of Mexico oil & gas platforms exist. Gallaway, *et al.* (1981) estimated that offshore petroleum platforms provide an additional 5,000 hectares of artificial reef habitat, increasing the total amount of reef fish habitat by an estimated 27%. This habitat is particularly important in the northern Gulf of Mexico where bottoms are typically clay, silt, or sand, with little or no relief. The addition of these platforms, and other oil and gas related facilities, has undoubtedly positively affected fish populations, although such effects are not well understood (Stanley 1994).

These platforms have become an important component of both the recreational and commercial fishing communities and have long been recognized as defacto artificial reefs. Nearly 20-50% more fish occupy the area around an oil and gas platform than around the neighboring soft mud of the Gulf of Mexico (Driessen 1985).

Reggio (1987) estimated that 70% of all saltwater fishing trips in the Exclusive Economic Zone (generally 4.8 km from shore) off Louisiana were destined for one or more of these oil and gas structures. Avanti (1991) using data from the National Marine Recreational Fisheries Statistics Survey, estimated that 30% of the recreational fisheries' catch, of the approximately 15 million fish caught off Louisiana and Texas, were caught near platforms.

Before long, Louisiana and neighboring states began to recognize the bountiful fishery resources beneath these oil and gas platforms. Since these platforms are so commonplace in coastal Louisiana and Texas, many citizens and management groups mistakingly believed that they were permanent and would always be available for fishing. From 1973-92, over 1,115 structures (Table 1A.1) have been removed from the Gulf of Mexico, as required by Federal law. At present, there are 885 additional platforms in the Gulf of Mexico that are greater than 25 years of age, and these will probably be removed within the next 10 years. This number does not include those platforms that will need to be removed because of damage, regulatory requirement due to lease abandonment, or economic circumstances. Removal of these structures will reduce artificial reef habitat and may have negative long-term impacts on reef fish populations. At a minimum, loss of these structures will result in the dispersal of fish populations away from traditional fishing locations (GMFMC 1989).

In 1984, then Congressman John Breaux authored the National Fishing Enhancement Act (NFEA) (PL 98-623). The NFEA mandates that the Secretary of Commerce and other support groups develop a long-term plan for planning, siting, permitting, constructing, installing, monitoring, managing, and maintaining artificial reefs within and seaward of state jurisdictions.

To take advantage of the availability of obsolete oil and gas platforms that provide valuable reef fish habitat, Louisiana passed enabling legislation entitled The Louisiana Fishing Enhancement Act (Act 100) on June 25, 1986. This act sets up a mechanism to transfer ownership and liability of the platforms from oil and gas companies to the State when the platforms cease production. It has been estimated that cumulative removal costs will reach $1 billion by the year 2000 (Lee 1985). Allowing some of the obsolete structures to remain offshore could significantly reduce this estimate.

Act 100 mandates that a plan be drafted to establish the rationale and operational guidelines for the program, including the siting criteria for Louisiana's artificial reefs. The plan was accepted and endorsed by the 1987 Louisiana Legislature (Wilson *et al.* 1987).

With the plan in place for guidance, Louisiana began the lengthy process of identifying areas inappropriate for reef development. This process known as "exclusion mapping," excluded areas such as shipping lanes, traditional commercial fishing areas, pipeline corridors, restricted military zones, existing live bottoms, and other areas deemed unsuitable by other user groups (Christian 1984; D'Itri 1985; Myatt 1985).

Nine artificial reef planning areas were chosen (Figure 1A.10) in which specific artificial reef projects could be sited. These planning areas facilitate platform abandonment planning by oil and gas companies and provide flexibility in specific site selection within the planning areas, thereby encouraging industry cooperation.

Act 100 does not authorize state general funds for the artificial reef program, but does establish the Louisiana Artificial Reef Trust Fund. Oil and gas companies that donate structures to the program are asked to contribute half the disposal savings realized through program participation into the trust fund. Based on average removal cost of an oil and gas structure, Louisiana authorities estimate that the oil and gas industry may save up to $1 million per structure, depending on water depth and size of the structure, by converting it into an artificial reef, as compared to the cost of traditional onshore abandonment. The interest earned by the Artificial Reef Trust Fund is designated for program operations and development.

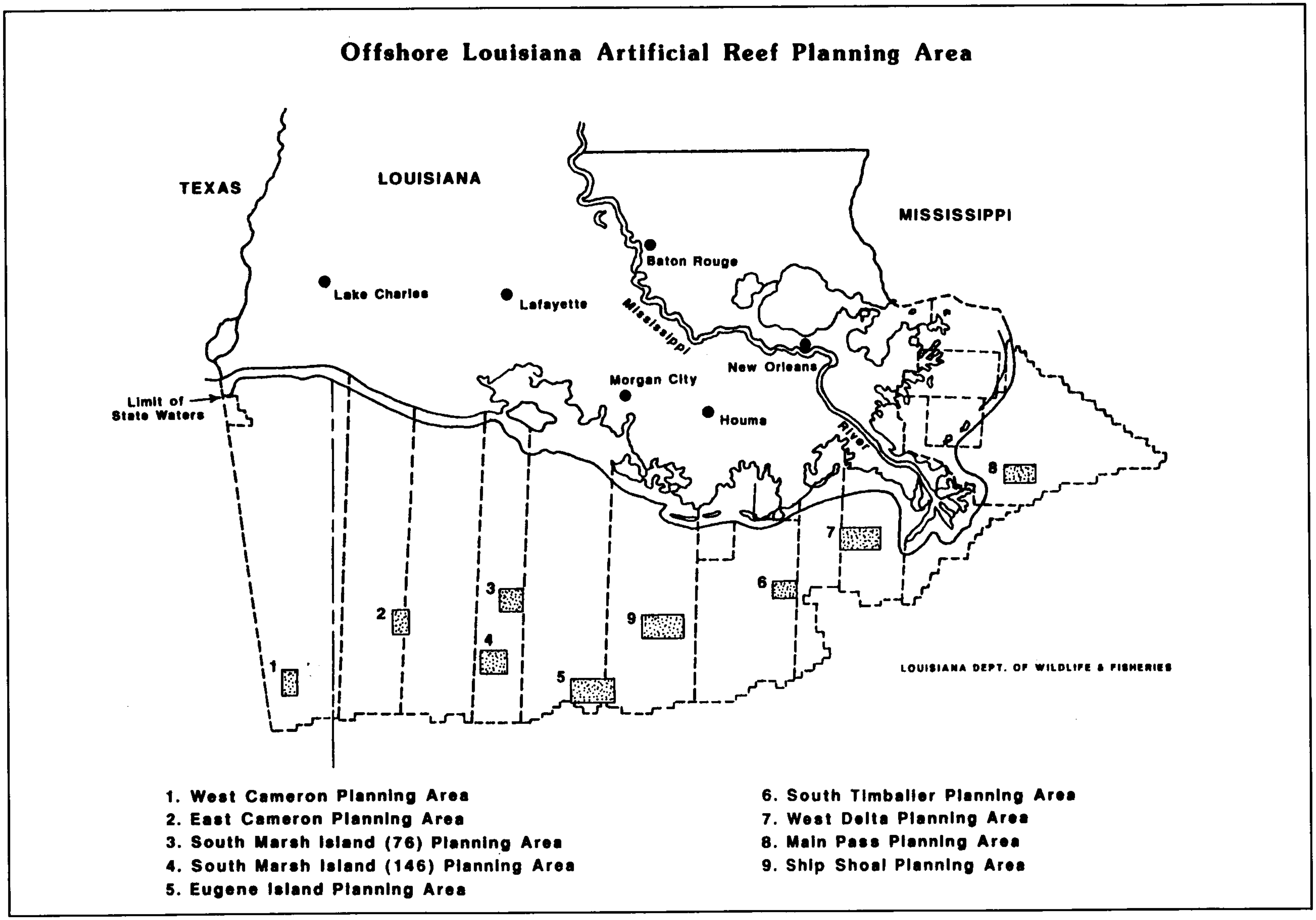

Figure 1A.10. Offshore Louisiana artificial reef planning areas: (1) West Cameron Planning Area; (2) East Cameron Planning Area; (3) South Marsh Island (76) Planning Area; (4) South Marsh Island (146) Planning Area; (5) Eugene Island Planning Area; (6) South Timbalier Planning Area; (7) West Delta Planning Area; (8) Main Pass Planning Area; (9) Ship Shoal Planning Area.

Table 1A.1. Number of permitted artificial reefs utilizing oil and gas platforms and existing oil and gas platforms and weight and anticipated removal costs by water depth in the Gulf of Mexico.

Water Depth (M)	Oil & Gas Structures[a]	Structures Removed[b]	Artificial Reefs Gulf of Mexico[c]	Average Total Weight (tons)	Structure Removal Cost (Millions $)
0-6	380	168	0.00	<100	0.05-0.5
6.1-30.5	2293	757	7	500-700	0.5-1.5
30.6-61	689	152	63	700-1500	1-2.5
61.1-122	346	38	32	1,000-5,000	5-15
122.1-610	38	0.00	0.00	5,000-50,000	15-100
TOTAL	3746	1115	102		

a Adopted from Reggio and Kasprzak, 1991
b MMS database on OCS structure removals and installations, 1993
c From Lukens, ed. 1993 and Texas Parks and Wildlife personal communication

Oil and gas platforms have proven themselves to be excellent artificial reef material. The National Artificial Reef plan cites five major characteristics or standards for artificial reef materials. Standards include function, compatibility, durability, stability and availability, (Stone 1985); oil and gas platforms appear to possess all these characteristics.

Function refers to the selection of materials that are known to be effective in stimulating desired growth of micro and macro organisms and in providing habitat for target species. It is well documented that oil and gas platforms function well as artificial reefs by providing habitat for a variety of species otherwise only associated with coral reefs, since many of these species are habitat limited (Moran 1986; Parrish 1987; Sale 1991). This is further emphasized by the fact that over 70% of all recreational angler trips in the Exclusive Economic Zone in Louisiana are destined for one or more of these structures (Reggio 1987). The steel members of the platform provide the necessary hard bottom substrate for many of the encrusting organisms critically important in developing reef habitat.

These structures also have proven themselves to be compatible with the marine environment since generally only the jacket of the structure or that portion of the platform that has never come in contact with hydrocarbons is used. When the deck portions are used in the Louisiana program, all the processing equipment is either removed or cut open and the piping and vessels flushed clean. The residue and contaminants are then packed in drums and shipped to shore for disposal. Certification that the decks are clean is then generally performed by a third party and a certification report provided.

Reefs constructed of oil and gas platforms are also very durable and stable, rarely if ever moving from where they were placed. In August 1992, Hurricane Andrew (a Class 4 storm with winds over 140 miles per hour) entered the Gulf of Mexico and affected the Federal (Minerals Management Service's) mineral leasing areas of Ship Shoal, South Timbalier, and West Delta. The storm destroyed or damaged over 151 active platforms and caissons, five of which subsequently entered the Louisiana Artificial Reef Program. Side scan surveys of two reefs in areas affected by the storm at ST-128 and ST-86 were conducted in 1993, and indicated no detectable movement. These platforms also appear to be relatively durable. Quigel and Thorton (1989) estimated a life span of approximately 300 years, based on an estimated 15-year life remaining on the existing cathodic protection and utilizing the average corrosion rate of steel immersed in saltwater.

Oil & gas platforms are also readily available, with over 3,700 in the Gulf of Mexico alone. However, it is not always economical to convert a platform into an artificial reef. The size of the structure, water depth, distance from shore, proximity to final reef site, and potential resale value will dictate whether or not an obsolete platform becomes a reef (Pope 1988). From 1987-94, of the over 1,115 platforms removed from Louisiana and Texas waters, only 90 platforms, or approximately 10%, became artificial reefs. If, however, we look at those platforms in operating depths of 30 to 122 m, 95 out of the 190 platforms removed, or approximately 50%, were converted into artificial reefs (Table 1A.1) (Kasprzak and Perret 1996).

There are several disadvantages to using oil and gas platforms as artificial reefs. Individual U. S. Coast Guard districts are responsible for developing marking guidelines for obstructions to navigation. For instance, the 8th Coast Guard District, with jurisdiction from Western Florida to the Texas-Mexican border, requires a minimum of 25.9 m clearance above the obstruction in order to be exempt from maintaining expensive lighting requirements. An exemption of the lighting requirements may be granted on a case-by-case basis if at least 15.2 m of clearance is maintained. Since many of these structures have a maximum relief of at least 15.2 m, a minimum of at least 30.5 m is required to properly site and maintain oil and gas platforms as reefs. In Louisiana, the 30.5 m exists between 48 km to 120 km offshore, making some reefs inaccessible to many fishermen. Another disadvantage is the expense in removing the structures. Derrick barge rates are currently between \$50,000-\$100,000 per day, depending on the lifting capabilities of the barge. The size of the structure to be removed determines the size of barge required. A third disadvantage is the method of removal. State-of-the-art techniques required to sever these structures from the sea floor involve the use of explosives and create concerns regarding potential impact on endangered sea turtles and marine mammals. To address this issue, MMS and NMFS require a review of the operator's abandonment plan under Section 7 of the Endangered Species Act. The Gulf of Mexico Fisheries Management Council also has become concerned about the impacts of explosives on red snapper and other commercially and recreationally important reef fish (GMFMC 1989).

The oil and gas industry has attempted to find alternatives to the use of explosives such as cryogenic cutting, hydraulic abrasive cutting, mechanical cutting, and torch cutting. Most of these techniques have either proven to be ineffective or are successful only in limited situations. At present, the industry maintains that explosives are by far the safest, most reliable, and most cost-effective method of platform removal. Regulatory changes may encourage the use of non-explosive or advanced explosive techniques. Allowing the structures to be removed at the 85-foot level or at any level above the mud line would provide additional habitat throughout the water column and may discourage the use of explosives.

Stanley (1994) estimated the sphere of influence around a platform in 22m of water to be about 16m in radius from the jacket, well within the effective range of the explosive charge. Techniques are currently being developed to drive the fish from the platform and beyond the effective kill zone of the charge. To date, those attempts have proven impractical or unsuccessful.

Currently there are 38 platforms in waters deeper than 122 meters (Table 1A.1), many of which are coming off line in the very near future. To date, these platforms have proven impractical to remove or determined to be too costly. An alternative to removal would be to allow them to be converted as artificial reefs. However, it is generally thought that enhancing habitat for reef-associated species beyond 100m would not be successful. Thus, toppling the platform in place may be attractive economically but may not provide sufficient relief to be attractive from a habitat standpoint. However, partially removing the structure to provide safe navigation and provide sufficient habitat may be a conceptual possibility.

Unfortunately, one of the program's chief criticisms is that many of our reefs are already located too far offshore, making them inaccessible to many of our fishermen. To place additional reefs farther from shore would only enhance this criticism. However, creating unexploited habitats has always been one of the program's main goals.

To date, the components of 57 obsolete platforms are located in 22 reef sites contributed by 23 operators in Louisiana.

This program has been highly successful since its inception in 1986. Federal and state governments, the oil and gas industry, as well as commercial and recreational fishermen, have been beneficiaries of Louisiana's artificial reef program. However, it will take the continued cooperation of the various state and Federal agencies involved and the support of the Gulf user groups to ensure that Louisiana's program will enjoy continued success.

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Mr. John Roussel has been employed by the Louisiana Department of Wildlife and Fisheries for the past 17 years, serving in a number of positions in both the Inland and Marine Fisheries Divisions of the Department. For five of those years he served as Marine Fisheries Division Administrator, overseeing all of the Department's marine fisheries programs. In February 1996, he was appointed by Governor Foster to the position of Assistant Secretary over the Office of Fisheries. He holds a B.S. in marine biology from Nicholls State University and a M.S. in biology from Tennessee Tech University.

Mr. Richard A. Kasprzak is the program manager of the Louisiana Artificial Reef Program for the Louisiana Department of Wildlife and Fisheries. The focus of this program is to coordinate the conversion of decommissioned oil and gas platforms into artificial reefs for the enhancement of fisheries resources. Mr. Kasprzak previously was a biologist with the Department of Wildlife and Fisheries, focusing on the population dynamics of finfish and shrimp populations of the state. He has a B.S. degree from Loyola College, Maryland (1975) and has pursued graduate studies at the University of Alabama and Louisiana State University.

SESSION 1B

GULF ENVIRONMENTAL ISSUES, PART I

Co-Chairs: Ms. Dagmar Fertl
Dr. Pat Roscigno

Date: December 10, 1996

Presentation	Author/Affiliation
Marine Biodiversity: Crisis in the World's Oceans?	Dr. Bruce A. Thompson Louisiana State University Dr. Darryl L. Felder Southeastern Louisiana University
The Hypoxia Issue Along the Louisiana Coast of the Gulf of Mexico: Progress Report	Dr. Eugene P. Meier Gulf of Mexico Program U.S. Environmental Protection Agency
Some Observations Regarding Shrimp Trawl Bycatch of Red Snapper in the Western Gulf of Mexico	Dr. Benny J. Gallaway LGL Ecological Research Associates, Inc.
Environmental Contaminants in Dolphins and Turtles and Their Effects on Body Systems (Manuscript not submitted)	Dr. Terri Rowles National Marine Fisheries Services
Kemp's Ridley Turtles from International Project Return to Texas to Nest	Ms. Donna J. Shaver U.S. Geological Survey Padre Island National Seashore

MARINE BIODIVERSITY: CRISIS IN THE WORLD'S OCEANS?

Dr. Bruce A. Thompson
Louisiana State University

Dr. Darryl L. Felder
Southeastern Louisiana University

Biodiversity is a concept that has grabbed hold of scientists, politicians, and the "man on the street." Ten years ago the term basically did not exist; now it is used in classrooms, scientific journals, and government institutions by teachers and students, conservationists and ecologists, senators and presidents. What we need to be concerned about is that this dynamic concept does not become a "buzzword" or meaningless cliché from thoughtless overuse. The international political and scientific communities have established numerous working groups directed towards preserving and enhancing biodiversity. For example, the International Union of Biological Science (IUBS) launched a major "umbrella" program with themes promoting an understanding of: (1) the ecosystem function of biodiversity; (2) origins, maintenance, and loss of biodiversity; and (3) inventory and monitoring of marine biodiversity (Lasserre 1995).

What is biological diversity? It is the natural result of evolutionary descent with modification producing lineages that are unique and irreplaceable. Much more simply described, it is the variation of the earth's organisms. Diversity occurs and needs to be studied at hierarchical levels of organization: genetic, species, and ecosystem.

How much do we know, and is there a crisis in the world's oceans? It has been noted numerous times that much attention has been focused on worldwide losses of terrestrial biodiversity, and Stiassny (1996) laments how little attention has been given to freshwater systems, but overall, perhaps surprisingly considering that our planet is mostly ocean, the marine environment has been almost completely neglected with regards to conservation of biodiversity. Norse (1993) noted that in a 1990 meeting at the Smithsonian Institution, 11 biologists concluded that "the entire marine realm, from estuaries and coastal waters to the open ocean and deep sea, is at risk." Ninety-five percent of earth's water is ocean and the general concept is that it is so vast that nothing man can do will ever effect the marine environment, but no organism prior to man has been able to make the impact on the world's ocean that our species can. Modern technology has made man a predator unlike the world has ever seen. This same technology has also given man the power to alter ecosystems, both physically and ecologically, unlike any species that has ever existed.

In 1609, Hugo Grotius published his treatise "Mare Liberum," stating that the seas should be free "for the innocent use and mutual benefit of all" and the seas could not be spoiled and therefore needed no protection. This long-standing concept is, basically, that the oceans are ours to do with what we please.

Our knowledge of the world's ocean biology lags far behind our knowledge of both terrestrial or even freshwater biota. Winston (1992) surveyed experts of various marine groups to estimate the biodiversity in the marine realm. She concluded that, at a conservative estimate, there are about 250 thousand described marine species, mostly invertebrates, with vertebrates making up only about 5% of the total. Estimates of undescribed organisms range as high as 1 million, made up mostly of microscopic organisms.

There are serious threats to our world's ocean biota, with an ever-increasing level of man's activities impinging on the biodiversity of the marine realm. Organizing these into broad categories, the most damaging are: (1) habitat loss; (2) eutrophication; (3) chemical pollution; (4) exotic species; (5) direst genetic change; (6) indirect genetic change; (7) global changes; and (8) extinction. Norse (1993) provides an excellent review and discussion of these impacts. In order to fully appreciate the severity of these impacts, we must understand the ecological interactions that many of these activities have at all levels of biodiversity. In the face of so many direct threats to the world's marine biodiversity, many scientists now discuss what choices need to be made on what to protect and what, out of necessity, to let become extinct. To those who say we cannot save everything, so we must choose, I remind them of what Aldo Leopold (1953) said, "To keep every cog and wheel is the first precaution of intelligent tinkering." Are we intelligent tinkerers? Not with our "track record" of marine extinctions throughout history, including Atlantic grey whale, Steller's sea cow, great auk, Steller's spectacled cormorant, Bonin night heron, Caribbean monk seal, sea mink, and New Zealand grayling (Day 1981).

Addressing future directions, the following five topics are important towards stabilizing and reversing the decline of marine biodiversity: (1) awareness; (2) inventory; (3) management; (4) legislation; and (5) advocacy. Gould (1992) said as well as can be said why we must preserve the earth's biodiversity: (it) "is our ballast, our anchor, our only safe mooring in the flood of time. We either preserve this nurturing variety, or ultimately, we may intone a requiem for all humanity...." Our lack of taxonomic expertise prevents other biodiversity research from going forward, thus impeding our understanding of the interactions of the hierarchical levels of biodiversity. "If taxonomists—the scientists who describe and classify species—were a species, they would be classified as endangered." (Norse 1993) Management and legislation will need to go "hand in hand" since many new ideas will need to be explored to address the problems facing today's marine biodiversity. For example, marine reserves is a concept starting to receive serious consideration in management of marine biodiversity. New Zealand has worked with "no-take" areas since the late 1970s (Ballantine 1996), although they are just now being discussed in North America (Bohnsack 1996), and still are considered controversial. Basically, the idea is management of habitat, not species or fishers. Moyle and Yoshiyama (1994) outlined an approach towards conservation of biodiversity that could easily be adapted to the marine environment, particularly for shallow coastal areas. A positive program enhancing marine biodiversity here in the Gulf of Mexico is the "rigs to reefs" program that maintains scarce hard-bottom habitats important to many marine species by using industrial rig structures as artificial reefs after they have served their purpose as work platforms. Advocacy is perhaps as important as any of the above categories, as Franklin (1993) implored: "biodiversity is not a 'set-aside' issue that can be physically isolated in a few, or even many, reserves.... We must see the larger task-stewardship of all the species on all of the landscapes (also seascapes?) with every activity we undertake as human beings—a task without spatial and temporal boundaries."

Perhaps at the international, national, or state level of government we need an Office of Biodiversity.

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Dr. Bruce A. Thompson has been at Louisiana State University for nearly 20 years working in coastal Louisiana estuaries and the northern Gulf of Mexico. Research interests include systematics, evolution, and

life history strategies of fishes and imperiled and exotic species. He obtained a B.S. in vertebrate zoology from Cornell University, and both M.S. and Ph.D. from Tulane University in ichthyology.

Dr. Darryl L. Felder has been at Southwestern Louisiana University, where he is Professor of Biology, for over 20 years. Research interests include systematics and life history dynamics of crustaceans.

THE HYPOXIA ISSUE ALONG THE LOUISIANA COAST OF THE GULF OF MEXICO: PROGRESS REPORT

Dr. Eugene P. Meier
Gulf of Mexico Program
U.S. Environmental Protection Agency

Over the last few years, there has been increasing concern about a large area of oxygen-depleted waters that develops seasonally each year in the nearshore Gulf of Mexico near the mouth of the Mississippi River. The area of oxygen depletion in the Gulf has been called the "Dead Zone" in the media but is more appropriately called "hypoxia" or "hypoxic waters," which refers to waters with dissolved oxygen concentrations of less than 2 parts per million (PPM). Two PPM dissolved oxygen is generally accepted as the limit for most aquatic life survival and reproduction.

The size of the oxygen-depleted area varies from year to year, extending from the mouth of the Mississippi River west to near the Texas border. The oxygen-depletion is typically associated with the bottom waters but can extend above the bottom. The zone of oxygen depletion in the nearshore Gulf has exceeded 6,000 square miles in size and may form as early as February and last as late as October, with the most widespread and persistent conditions occurring from mid-May to mid-September.

Although hypoxic waters occur near the mouths of other large rivers around the world, the northern Gulf of Mexico hypoxia represents one of the largest zones of oxygen-deficient bottom waters in the western Atlantic Ocean. The areal extent of the hypoxic zone, in recent years, has rivaled the hypoxic regions of the Baltic and Black Seas.

Research studies have shown a relationship between Mississippi River flow, riverborne nutrients, plankton productivity, and bottom water hypoxia. Riverborne nutrients cause phytoplankton blooms in the Gulf. Decomposition of dead phytoplankton from the blooms consumes nearly all the oxygen in the water. Combined with stratification of fresh and salt water, this results in a zone of hypoxia with very low fish and shellfish densities. The hypoxic conditions vary spatially and seasonally depending on the flow of the Mississippi River discharge and are affected by physical features such as water circulation patterns, salt and fresh water stratification, wind mixing, tropical storms, and thermal fronts.

The nature of the hypoxia problem is complicated by the fact that nutrients from the Mississippi River are vital to the productivity of Gulf fisheries. A large percentage of the U.S. fisheries landings, including a substantial part of the nation's most valuable fishery (shrimp), come from this productive area. In addition, the area also supports a large and valuable sport fishery. The concern is that the hypoxic area, which may have always existed to some extent, has been slowly enlarging since the 1960s as a result of increased nutrient loads from human activities in the watershed. The potential impacts of Gulf hypoxia zone include:

- Altered coastal phytoplankton-based food webs
- Noxious algal blooms
- Altered benthic ecosystems
- Reduced economic productivity in both commercial and recreational fisheries
- Both direct and indirect impacts on fisheries such as direct mortality and altered migration, which may lead to declines in populations and landings.

The Gulf of Mexico Program (GMP), a cooperative program of federal, state, and local agencies, as well as business and citizens, has been studying this problem in the northern Gulf of Mexico. Much of the information on hypoxia in this area has been derived from the work undertaken by the GMP. The Nutrient Enrichment Issue Committee of the GMP has conducted studies of the nutrient concentrations in the Mississippi River and preliminary conclusions indicate that a significant amount of nutrients delivered to the Gulf come from the upper Mississippi, Ohio River, and lower Mississippi watersheds. The combined areal extent of these watersheds requires a concerted national effort to reduce nutrient enrichment in the watersheds and its impact on the hypoxia problem in the Gulf.

The GMP is facilitating efforts to study all aspects of the hypoxia problem including other sources of nutrients such as atmospheric deposition and coastal upwelling that are not related to drainage from the watershed. These efforts will include studies of the linkage between nutrient loadings from the Mississippi River, the hypoxia zone, and Gulf fisheries. The studies will better define the impacts of hypoxia on the ecosystem and help determine what minimum level of nutrient loading is required to maintain productivity in the Gulf yet reduce the size and impact of the hypoxia zone on the Gulf ecosystem. This information can then be used to establish goals, if required, for reduction of nutrient levels in the watersheds.

Border states of the upper and lower Mississippi and Ohio River watersheds as well as other states within the watershed are being asked to work with the Gulf states and the GMP to address the hypoxia problem. Efforts are underway to make everyone more aware of the problem and to use existing programs in the watershed to reduce the runoff and discharge of nutrients.

Under Section 319 of the Clean Water Act, the Environmental Protection Agency (EPA) has established a nonpoint source program that is functioning in all states in the watershed. Through this national program, all states in the Gulf of Mexico watershed, and many other states have initiated cooperative projects with local, state, and federal agencies, as well as with farmers and citizens to combat runoff problems which contribute pollutants, including nutrients, to the streams of the watershed.

The Natural Resources Conservation Service, formerly the Soil Conservation Service, also maintains programs in most states to address nutrient runoff and discharge problems. The agricultural community, in general, has been very supportive of water quality improvement through the National Association of Conservation Districts, Cooperative Extension and Experiment Stations, and local Soil and Water Conservation Districts. All of these agencies are working closely with agriculture, industries, and municipalities to reduce nutrient discharges and runoff and have already succeeded in improving water quality in many local watersheds.

For further information on this issue, contact the Gulf of Mexico Program at (601) 688-3726, or access information through the Program's Gulf of Mexico Information Network (GIN). The GIN relies on the Internet as its communication vehicle with a WWW site on the Pelican Server (http://pelican.gmpo.gov).

Dr. Eugene P. Meier has 27 years of experience in basic and applied research related to health and environmental science. He joined the EPA in 1978, and is currently assigned as the EPA Office of Research and Development (ORD) Liaison to the Gulf of Mexico Program (GMP). He is responsible for linking the EPA's research programs and technical capabilities to the operational requirements of the GMP, and he assists the GMP as a member of the Hypoxia Internal Support Team. Dr. Meier received a B.S. in chemistry from Texas A&M University, 1965, and a Ph.D. in analytical chemistry from the University of Colorado, 1969. His areas of specialization include the development of methods for analysis of environmental samples and for the management and disposal of pesticide and hazardous wastes.

SOME OBSERVATIONS REGARDING SHRIMP TRAWL BYCATCH OF RED SNAPPER IN THE WESTERN GULF OF MEXICO

Dr. Benny J. Gallaway
LGL Ecological Research Associates, Inc.

INTRODUCTION

Shrimp trawl bycatch of red snapper has emerged as one of the major issues involving regulation of the Gulf of Mexico shrimp fishery. The Gulf of Mexico red snapper stock assessment shows that the red snapper population is overfished. Overfishing is reflected by Spawner per Recruit Ratios (SPR) which are presently far less than 20%, the threshold used to define an overfished status. The numerator of SPR index is the estimate of spawners per recruit at the observed levels of fishing mortality, and the denominator is the same estimate that would have occurred had there not been any fishing mortality.

Since 1985, the Gulf of Mexico Fishery Management Council (the Council) and the National Marine Fisheries Service (NMFS) have taken actions to reduce fishing mortality on the spawning segment of the population. These actions have included placing size limits and annual quotas on both the commercial and recreational fisheries. Total allowable catch (TAC) is split between the commercial (51%) and recreational (49%) sectors. Once commercial landings reach their quota, the commercial fishing season is closed. Bag limits are used as an attempt to maintain recreational fishery catch within their annual quota. The present bag limit allows for only 5 fish per day and a total possession limit of 10 fish. Despite these limits, the recreational fishery has consistently overrun their part of the annual quota, often substantially.

These management actions have resulted in a trend of increases in the Gulf of Mexico red snapper stock. Catch per unit effort in the commercial fishery between 1990 and 1995 has more than doubled, with the fishery reaching its annual quota within a shorter time period each year. Population estimates reflect a similar trend of increase for fish Age 10 and older. Despite these increase in stock and spawners, the SPR index has improved only slightly. The apparent reason for this lack of improvement in SPR is excessive mortality resulting from shrimp trawl bycatch of juvenile (Age 0 and Age 1) red snapper. If the shrimp trawl bycatch estimates are correct, even a complete closure of the directed fishery would not result in achievement of an SPR of 20% by the target date of 2019.

A requirement for Bycatch Reduction Devices (BRDs) in shrimp trawls has been adopted as the technological fix for the problem. These devices doe not effectively exclude Age 0 red snapper in their first summer-spring period of life, but do exclude red napper at a size corresponding to Age 1 red snapper in their second summer and fall of life. Additionally, most of the fishing mortality occurs between summer and fall of the second year of life for juvenile red snapper. Based on this set of conditions, BRD's have been mandated as the solution to the problem, and fishing quotas have already been increased, assuming that the use of these devices will achieve the expected results (a 50% reduction in cumulative fishing mortality on Age 0 and Age 1 red snapper).

This past year, I was asked by the Texas Shrimp Association, Inc. (TSA) to provide an independent review of the red snapper stock assessment, particularly the bycatch estimates, and report the results of this review to the Council. This paper focuses on our findings regarding the estimation of shrimp trawl bycatch of red snapper.

RESULTS

We began our review of the bycatch estimates by calculating the mean CPUE for time-space cells based on the OBSR data only for 1992 to 1995. Our assumption was that when actual data are available, these constitute the best data. Further, if the proper calibration has been achieved by the model using both data sets, the estimates based on the OBSR dat only should conform to the GLM estimates. They did not. The estimates based on eh OBSR data alone were, in fact, substantially smaller than the GLM estimates. We further learned that the GLM used by NMFS to estimate red snapper bycatch also systematically overestimates shrimp landings when shrimp are treated as bycatch and the estimated catch is compared to reported landings. This finding led to a more critical examination of the data and models used to estimate bycatch.

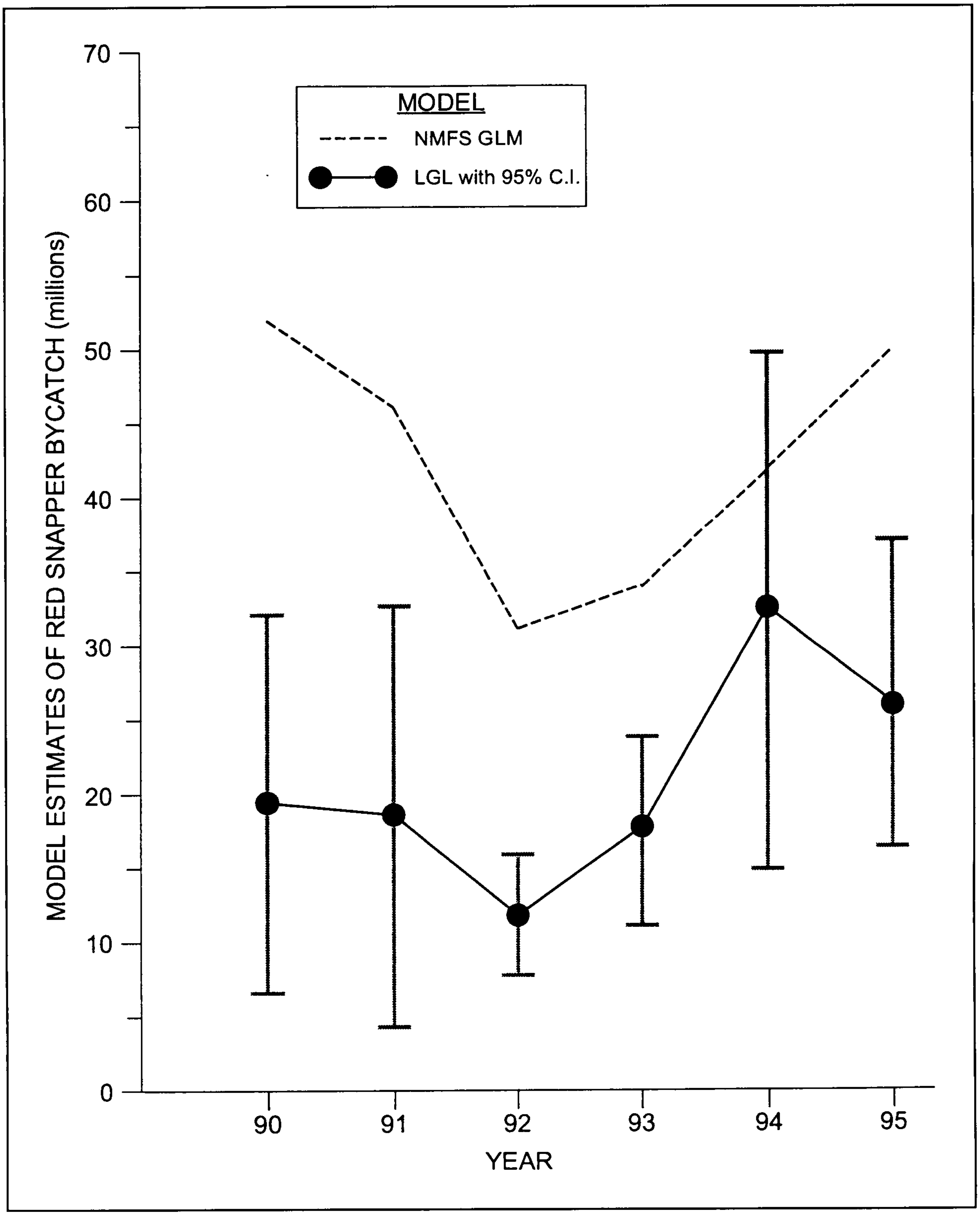

Figure 1B.1. Estimated red snapper bycatch based upon the National Marine Fisheries Service's (NMFS) GLM analysis with a log (CPUE+1) data transform; and the LGL analysis using a SEAMAP-OBSR calibration curve and the Δ-distribution following Pennington (1983).

BYCATCH ESTIMATES

Based upon the results of our review, we developed a more straightforward approach for estimating red snapper by catch for the period 1990 to 1995, also using the OBSR and SEAMAP data. We divided the western Gulf into "Texas" and "Louisiana" primary regions, each containing two subregions. The regions were further subdivided into cells ≤ 10 fathoms and >10 fathoms in depth. The annual data were grouped by trimester following the NMFS precedent using January-April (winter), May-August (summer), and September-December (fall) periods. The mean of the OBSR data was calculated for each time/space cell following Pennington (1983), and these were multiplied by the NMFS effort estimates for the corresponding time/space cells. The individual estimates were then summed to produce annual estimates of bycatch.

The mean of the SEAMAP data was also calculated for each time/space cell following Pennington (1983). If the number of OBSR tows within a cell was <5, we used the weighted regression of OBSR data on SEAMAP data to estimate bycatch for that cell. The p-value of the overall regression was 0.0009with a $r2 = 0.704$ ($r2adj = 0.589$). Region ($p = 0.0014$) and region by depth (0.0043) effects were both significant. The appropriate region by depth submodel regression was used to fill holes on a case by case basis. There were no SEAMAP data for the winter trimester. Therefore, the pooled OBSR data for all winter data 1992-1995 was used to fill "holes" in the winter data set when necessary.

We also hindcast bycatch for 1990 and 1991, years in which there were not observer data. Bycatch for the summer and fall trimesters of 1990 and 1991 was estimated by applying the OBSR-SEAMAP regressions to the SEAMAP data for 1990 and 1991. The pooled winter data for 1992-1995 was used for the winter bycatch estimates for 1990 and 1991. The resulting estimates for each time and space cell were multiplied by the corresponding NMFS shrimping effort data dn summed to produce annual estimates of bycatch.

The estimates of bycatch for 1990 to 1995 based on the LGL analysis are shown by Figure 1B.1, with comparisons to the NMFS GLM-derived estimates for the same time frame and data sets. A substantial reduction was indicated.

The questions and concerns we have raised about the bycatch estimates used in the Gulf red snapper stock assessment are soon to be reviewed by a select statistical panel which is being assembled by the Council. That group is to review the issues related to data transformations and the appropriateness of the respective models.

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Dr. Benny J. Gallaway has worked at LGL Ecological Research Associates for the past 22 years. His Gulf of Mexico experience dates from the late 1970s and includes studies of natural and artificial reefs, shrimp mark-recapture and spawning site surveys, and analysis of the shrimp catch and effort data. Recently, his research focus has been directed towards sea turtle and finfish bycatch issues. Dr. Gallaway received his Ph.D. from Texas A&M University where he presently serves as a visiting member of the graduate faculty for the Department of Wildlife and Fisheries Sciences.

KEMP'S RIDLEY TURTLES FROM INTERNATIONAL PROJECT RETURN TO TEXAS TO NEST

Ms. Donna J. Shaver
U.S. Geological Survey
Padre Island National Seashore

INTRODUCTION

Kemp's ridley (*Lepidochelys kempii*) is the most critically endangered sea turtle species in the world, with fewer than 3,000 adults in the entire population. Most Kemp's ridley nesting occurs in the vicinity of Rancho Nuevo, Tamaulipas, Mexico (Marquez-M. 1994). An international, multi-agency, experimental project was conducted from 1978-1988 to aid in the recovery of this species by establishing a secondary nesting colony of them at Padre Island National Seashore (PAIS), near Corpus Christi, Texas (Shaver 1989). A few Kemp's ridley nests were documented at PAIS prior to 1978 (Werler 1951). In 1979, PAIS staff began maintaining consistent records of sea turtle nesting along the entire Texas coast, and in 1986 they began a program to detect nesting on North Padre Island. The effort to establish a secondary nesting colony of Kemp's ridley turtles at PAIS, nesting detection program on North Padre Island, and nests found on the Texas coast since 1979 will be discussed.

MATERIALS AND RESULTS

Attempts were made to imprint Kemp's ridley turtles to PAIS so that they would return there to nest and establish a secondary nesting colony (Shaver 1987). Between 1978 and 1988, 22,507 eggs were collected in Rancho Nuevo, packed in Padre Island sand, and shipped to PAIS for incubation (Shaver 1989, 1990). National Park Service (NPS) staff at PAIS provided care for the incubating eggs. After the eggs hatched, the hatchlings were released on the beach at PAIS, allowed to enter the surf, and recaptured using aquarium dip nets. The hatchlings were raised in captivity (head-started) at the National Marine Fisheries Service laboratory in Galveston, Texas, where most were held for 9-11 months but some for longer time periods (Fontaine *et al.* 1990; Caillouet *et al.* 1995). The turtles were marked with up to four types of extrnal and internal tags (Fontaine *et al.* 1993) and released at a variety of locations (Fontaine *et al.* 1990; Caillouet *et al.* 1995).

Detection and protection of nesting Kemp's ridley turtles and their eggs on North Padre Island are priority items in the Kemp's Ridley Sea Turtle Recovery Plan (U.S. Fish and Wildlife Service and National Marine Fisheries Service 1992). In 1986, NPS staff began a detection and protection program. At that time the age at sexual maturity for L. kempii was unknown. However, it was thought that the oldest turtles from the project may have been sexually mature and capable of returning to nest. Critical components of the detection and protection program have been public education regarding sea turtles and patrols for nesting turtles and tracks. These patrols have been conducted along the Gulf of Mexico shoreline on North Padre Island (125 kilometers in length) from April through August during each year since 1986. The most comprehensive patrol efforts have occurred since 1990. During 1996, PAIS staff members and volunteers spent 2,387 hours patrolling a total of 46,234 kilometers.

From 1979-1996, 17 confirmed Kemp's ridley clutches were found along the Texas coast (Shaver 1995, 1996), more than found at any other single location in the United States during that time. Twelve of the 17 were located at PAIS, three at Mustang Island, one at North Padre Island just north of PAIS, and one at Boca Chica Beach. Three of the 17 were found by PAIS patrollers and the other 14 by beach visitors. Ten of the 17 nests were detected during 1995 and 1996.

The six Kemp's ridley nests found on the Texas coast during 1996 were more than found during any previous year since consistent nesting records have been maintained, beginning in 1979. Of the six nests found during 1996, five were located at PAIS and one at Boca Chica Beach. Two of the five nests found at PAIS were from the first documented nestings by two returnees from the experimental project to establish a secondary nesting colony. None of the turtles from the project had previously been confirmed to have nested at PAIS or anywhere else outside of captivity. One of the returnees had been incubated and hatched at PAIS in 1983 and released off Mustang Island, Texas on 5 June 1984 (Fontaine *et al.* 1993; Caillouet *et al.* 1995). The other had been incubated and hatched at PAIS in 1986 and probably released offshore from Mustang Island, Texas on 17 April 1987, but possibly released elsewhere after 22-39 months in captivity (Fontaine *et al.* 1990). The turtles that laid the other four clutches were observed and reported by the public and thus could not be conclusively linked to the experimental project.

The two clutches of eggs from the returnees, and 14 of the other 15 confirmed Kemp's ridley clutches detected along the Texas coast since 1979, were retrieved and transferred to the PAIS incubation facility for protected care. Hatchlings from the two clutches, and from 13 of the other 15 clutches, were released on the beach at PAIS and allowed to enter the surf without retrieval.

The sightings of the two returnees are the first documentation of any sea turtle species nesting at an experimental imprinting site and outside of captivity after being head-started. The increase in nesting detected along the Texas coast during 1996 is at least partially the result of the experimental effort to establish a secondary nesting colony. It is unknown how many turtles from the experimental project will return to PAIS to nest in the future. Long-term monitoring of beaches for nesting, observations of nesting turtles by trained biologists, and evaluation of hatching success for located clutches are necessary to accurately assess project results. Even if a secondary nesting colony becomes established at PAIS, it is still imperative that Kemp's ridley turtles continue to be protected at the nesting beaches in Mexico and in the marine environment.

SUMMARY

From 1979-1996, more Kemp's ridley nests were located at PAIS than at any other single area in the United States. Of the 17 confirmed Kemp's ridley nests found on the Texas coast during those years, 12 were found at PAIS and one at North Padre Island, just north of PAIS. The number of detected nests increased during 1995 and 1996. During 1996, the first two confirmed returnees from the experimental project to establish a secondary nesting colony of Kemp's ridley turtles were located nesting at PAIS. To meet conservation goals and evaluate results of the experimental project, efforts to detect nesting Kemp's ridleys and to protect their eggs must be continued.

ACKNOWLEDGMENTS

Agencies in Mexico, including the Instituto Nacional de la Pesca, are thanked for their assistance with this program. Canon U.S.A., Inc., Gladys Porter Zoo, H.E.A.R.T., National Marine Fisheries Service, National Park Foundation, National Park Service, Texas Parks and Wildlife Department, U.S. Coast Guard, U.S. Fish and Wildlife Service, U.S. Geological Survey, and others in the United States are gratefully acknowledged for their contributions to various aspects of the project.

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Ms. Donna Shaver has worked at Padre Island National Seashore for the last 16 years and is currently employed there by the U.S. Geological Survey, Biological Resources Division, as a Research Biologist. Ms. Shaver conducts a variety of sea turtle research and conservation projects and is the Texas Coordinator for the Sea Turtle Stranding and Salvage Network and a member of the Kemp's Ridley Sea Turtle Working Group. She received her B.S. in wildlife biology from Cornell University and her M.S. in biology from Texas A&I University and is currently enrolled in a Ph.D. program in zoology at Texas A&M University.

SESSION 1C

SHIP SHOAL AND THE RESTORATION OF THE LOUISIANA BARRIER SHORELINE IN THE BARATARIA/TERREBONNE BASIN

Co-Chairs: Mr. Barry Drucker
Mr. Alvin Jones

Date: December 10, 1996

Presentation	Author/Affiliation
Coastal Wetlands Planning, Protection and Restoration Act (CWPPRA) Process	Mr. Tom Podany U.S. Army Corps of Engineers New Orleans District
Overview of the Barrier Shoreline Feasibility Study	Mr. Steven Smith T. Baker Smith and Sons, Houma, Louisiana
The MMS's Perspective on Louisiana Barrier Island Restoration and the Use of Ship Shoal Sand as Restoration Material	Mr. Barry S. Drucker Minerals Management Service Office of International Activities and Marine Minerals
Physical Aspects of Ship Shoal: Suitability of Shoal as a Source of Barrier Island Restoration Material and Early Environmental Studies	Dr. Mark Byrnes Louisiana State University Coastal Studies Institute
Physical Environmental Studies Within the Ship Shoal Area: Wave Climate and Ongoing Physical Field Study	Dr. Gregory W. Stone Coastal Morphodynamics Laboratory Department of Geography Louisiana State University

COASTAL WETLANDS PLANNING, PROTECTION AND RESTORATION ACT (CWPPRA) PROCESS

Mr. Tom Podany
U.S. Army Corps of Engineers
New Orleans District

I. GENERAL INFORMATION.

The CWPPRA was signed into law in November 1990. The act created a task force with the following members: Secretary of the Army (who is designated chairman and represented by the New Orleans District Engineer); Governor of Louisiana (represented by Dr. Len Bahr, Executive Assistant for Coastal Activities); Administrator, Environmental Protection Agency (represented by Mr. William Hathaway, Division Director, Water Quality Protection Division, Region VI); Secretary of Agriculture (represented by the Louisiana State Conservationist, Mr. Donald Gohmert); Secretary of Commerce (represented by Mr. Tom Bigford, Acting Director, Office of Habitat Protection) and Secretary of the Interior (represented by Mr. Dave Frugé, Field Office Supervisor).

The purpose of the CWPPRA is to plan, design, construct, maintain, and monitor coastal wetlands restoration projects that provide for the long-term conservation of coastal wetlands and dependent fish and wildlife populations in coastal Louisiana.

Funding for activities under the CWPPRA, including construction of projects, is provided by the act. Approximately $35 million is made available each year for CWPPRA activities in Louisiana. Funding is provided by the Highway Trust Fund, a portion of which is dedicated to the Department of the Interior's Sport Fisheries Restoration Account. A portion of this fund (the amount depends on fuel tax revenues in any given fiscal year) is transferred to the Corps each year. The New Orleans District serves as the banker for the program, distributing planning and construction funds to the other agencies.

A maximum of $5 million may be used for project planning in any given year; the balance is reserved for project construction. The State of Louisiana provides 25 percent of the cost of projects; planning is not cost shared. The act calls for a reduction in the State's cost share to 15 percent upon approval of a Conservation Plan designed to attain no net loss of coastal wetlands as a result of development (see section IV below for more information). The Water Resources Development Act of 1996 contains a provision that cost sharing be 90 percent Federal/10 percent nonFederal for projects contained on the 5th and 6th priority project list.

The Department of the Interior has determined that funding under the CWPPRA is available through fiscal year 1998.

The CWPPRA calls for the following items:

1. development of priority project lists (section 303(a));
2. development of a comprehensive restoration plan (section 303(b));
3. a scientific evaluation of projects (section 303(b)(7));
4. development of a conservation plan (section 304)—authorized but not required;
5. formation of a mechanism to ensure that Federal navigation, flood control, irrigation, and emergency actions under other authorities are consistent with purposes of the comprehensive restoration plan; and
6. investigation of the feasibility of increasing the share of the Mississippi River flows and sediment down the Atchafalaya River for the purposes of land building and wetlands nourishment.

II. PRIORITY PROJECT LISTS

In accordance with section 303(a) of the act, the Task Force has produced five priority project lists. These five lists contain a total of more than 68 projects, with a total estimated cost of about $179,000,000. The fifth list, which the Task Force approved in February 1996, contains three projects which will be funded over several years; this represents the first time priority list projects have not been funded with a single year's allocation. Thirteen projects have been completed, and several more are currently under construction.

For both the fourth and fifth priority project lists the State was unable to provide its full complement of matching funds. These two lists are based on funds of about $20 million each instead of the usual $40 million.

The CWPPRA actually requires priority project lists only until the comprehensive restoration plan has been developed; however, the Task Force has continued to prepare these lists, as they are the best means available of selecting projects for construction. The current process for development of priority project lists is given below. The process differs from previous years in that candidate projects are selected on a coastwide basis; in the past, a predetermined number of candidate projects was selected from each hydrologic basin in the coastal zone.

Process for development of priority project lists:

1. The Planning and Evaluation Subcommittee solicits nominations for candidate projects from the agencies, local governments, and the public.

2. The subcommittee selects a number of candidate projects for consideration.

3. The lead Federal agencies develop designs and cost estimates for the candidate projects. Multi-agency site visits are done for each candidate project.

4. The Environmental Work Group evaluates the wetlands benefits associated with each candidate project (reported in terms of average annual habitat units).

5. The Engineering Work Group reviews cost estimates for consistency.

6. The Economic Work Group determines the annual and fully funded cost of each project.

7. The subcommittee ranks the candidate projects according to cost-effectiveness, longevity/sustainability, partner support (willingness of a non-State entity to pay all or a portion of the local share), support for the Restoration Plan, risk and uncertainty, and public support.

8. The Technical Committee reviews the findings of the subcommittee and prepares a recommendation for the Task Force.

9. The Task Force approves the priority project list. A report is prepared and forwarded to the Congress; Congressional approval is not required.

III. COMPREHENSIVE RESTORATION PLAN

In November 1993 the Task Force completed the Louisiana Coastal Wetlands Restoration Plan report, which details the comprehensive plan called for in section 303(b) of the act. The plan contains about $1.3 billion worth of projects, which if implemented would prevent about 65 percent of the projected loss of Louisiana's coastal wetlands. Many of the projects contained in the plan came out of a series of scoping meetings held in the fall of 1991. All proposed projects were reviewed for their compatibility with the restoration strategy developed by the Task Force for each hydrologic basin in the coastal zone. The report has been forwarded to the Office of the Assistant Secretary of the Army and thence to the Office of Management and Budget, where it awaits transmittal to the Congress.

IV. CONSERVATION PLAN

Section 304 of the act authorizes the development of a Conservation Plan, with the goal of achieving no net loss of coastal wetlands as a result of development. The act provides for a reduction in the State's share of project costs from 25 percent to 15 percent upon approval of the plan.

On June 22, 1995, Governor Edwards signed a Memorandum of Agreement with the Environmental Protection Agency, the U.S. Fish and Wildlife Service, and the U.S. Army Corps of Engineers concerning the development of the Conservation Plan. The cost of plan development is $239,000 (75 percent Federal and 25 percent non-federal). The Federal share has been granted to the State through EPA. The State expects the Conservation Plan to be completed in May 1997.

V. PROJECT MONITORING

Section 303(b)(7) requires the Task Force to prepare and forward to the Congress an evaluation of wetlands restoration projects implemented under the CWPPRA. In order to comply with the act's requirements, the Task

Force has developed a comprehensive monitoringprogram. The program, administered largely by the Louisiana Department of Natural Resources (LDNR), with assistance from the Department of the Interior's National Biological Service, lays down guidelines for the monitoring of various types of project. The monitoring program is one of the means by which the academic community is formally involved in the CWPPRA process.

The evaluation report is being prepared by the Department of Natural Resources, with oversight by an ad hoc committee of agency representatives. LDNR expects the report to be completed in November 1996.

VI. THE WETLAND VALUE ASSESSMENT

The Wetland Value Assessment (WVA) is a community-based habitat model derived from the Habitat Evaluation Procedure of the U.S. Fish and Wildlife Service. The WVA was developed by the Task Force to provide a means of comparing the wetlands benefits of various types of projects in different locations throughout the coastal zone. The WVA has gained recognition beyond this program; the Corps of Engineers has since employed this methodology in assessing the wetlands benefits attributable to projects in its traditional programs (for example, the Mississippi River-Gulf Outlet Reconnaissance Report).

VII. ACADEMIC INVOLVEMENT

The academic community has been involved in the CWPPRA process virtually since its inception, and the input of academic scientists contributed greatly to the Louisiana Coastal Wetlands Restoration Plan. The Task Force has taken steps to formalize this involvement with its Academic Assistance Group. The group is selected through a solicitation prepared by the Louisiana Universities Marine Consortium, or LUMCON, and it assists in project evaluation, review of the Wetland Value Assessment, project monitoring, and feasibility studies.

VIII. PUBLIC INVOLVEMENT

The Task Force has instituted a vigorous public involvement program which has included more than 30 public meetings in less than 5 years. The current priority list selection process provides for public input at the very beginning of each cycle and again before final selection is done by the Task Force. The Citizen Participation Group was established to present to the Task Force the views of the various user groups in the coastal zone.

IX. FEASIBILITY STUDIES

Recognizing that restoration of the state's coastal wetlands requires projects of a more complex nature and a larger scope than can be analyzed in the process of developing annual priority lists, the Task Force has authorized the initiation of two feasibility studies. The Mississippi River Sediment, Nutrient, and Freshwater Redistribution study, which is being managed by the Corps of Engineers, is intended to develop a plan for optimizing the resources of the Mississippi River, giving consideration to the river's many uses (e.g., navigation and water supply, in addition to creation and nourishment of wetlands). The Louisiana Barrier Shoreline study, which is being managed by the Louisiana Department of Natural Resources, is intended to determine the feasibility of restoring the state's barrier islands and other shorelines for the purpose of protecting coastal wetlands. The studies are expected to take about three and one-half years to complete.

Mr. Tom Podany is a coastal engineer with the Army Corps of Engineers New Orleans District Office. He is currently chair of the Technical Steering Committee for the Louisiana Barrier Shoreline Feasibility Study.

OVERVIEW OF THE BARRIER SHORELINE FEASIBILITY STUDY

Mr. Steven Smith
T. Baker Smith and Sons, Houma, Louisiana

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 currently being evaluated with respect to their role in wetlands protection and enhancement. CWPPRA is funding a feasibility study to assess and quantify wetland loss problems linked to diminishing protection from barrier islands 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, currently ongoing, encompasses the Barataria-Terrebonne island chain; Phase 2 will focus on the Chenier Plain coast; Phase 3 will focus on the Chandeleur Islands.

The Phase 1 report is currently scheduled for completion in March 1997.

Mr. Steven Smith is one of the principal directors of T. Baker Smith and Sons, an engineering and environmental consulting firm located in Houma, Louisiana. He is a lawyer by trade and is licensed to practice law in Louisiana. He is presently managing the Louisiana Barrier Shoreline Feasibility Study.

THE MMS'S PERSPECTIVE ON LOUISIANA BARRIER ISLAND RESTORATION AND THE USE OF SHIP SHOAL SAND AS RESTORATION MATERIAL

Mr. Barry S. Drucker
Minerals Management Service
Office of International Activities and Marine Minerals

Within the Phase 1 feasibility study area of the Coastal Wetlands Planning, Protection, and Restoration Act (CWPPRA), it has been suggested that Isles Dernieres and Timbalier Islands, two severely eroded barrier islands, could be renourished using Federal offshore sand deposits from Ship Shoal, a submerged sand bar located approximately 10 miles offshore. The MMS has funded several studies to evaluate the potential of Ship Shoal as a sand source for barrier island renourishment. These studies indicate that Ship Shoal certainly contains the quality and quantity of sand to undertake a large-scale renourishment project.

On 19 April 1995, the Governor of the State of Louisiana contacted the MMS to request a noncompetitive lease to use Federal sand resources from Ship Shoal for restoration of the Louisiana barrier islands. The MMS has determined that the use of Federal sand from Outer Continental Shelf (OCS) areas such as Ship Shoal for barrier island restoration and subsequent wetlands protection meets the negotiated agreement requirements under Section 8(k)(2)(A)(I) of the OCS Lands Act (43 U.S.C. 1337(k)(2)(A)(I)).

The National Environmental Policy Act (NEPA) process is initiated when Federal agencies consider major actions which may significantly affect the environment. Because the environmental consequences of barrier island restoration are not fully understood and the extraction of Federal sand for the purposes of barrier island and wetlands restoration is considered a major Federal action, an EIS will need to be prepared. Using funds allocated by CWPPRA, they entered into a cooperative arrangement with Louisiana State University to prepare the EIS.

This specific EIS will support the Phase 1 portion of the feasibility study. Impacts associated with Phases 2 and 3 will be evaluated in subsequent NEPA documents. The EIS will be used to assist the CWPPRA Task Force in making funding decisions regarding Phase 1 restoration methods as well as aid the MMS with respect to the request for a noncompetitive lease to the State of Louisiana for the use of Federal sand.

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. Mr. Drucker has a M.S. in marine geology and physical oceanography from C.W. Post College of Long Island University and a B.A in geology and oceanography from the City University of New York.

PHYSICAL ASPECTS OF SHIP SHOAL: SUITABILITY OF SHOAL AS A SOURCE OF BARRIER ISLAND RESTORATION MATERIAL AND EARLY ENVIRONMENTAL STUDIES

Dr. Mark Byrnes
Louisiana State University
Coastal Studies Institute

Numerous studies examining the use of Ship Shoal sand for barrier island restoration have been completed. This includes physical as well as preliminary environmental studies. The geological investigations reveal that the sand from the shoal is extremely compatible with the material found on the barrier islands. Wave refraction analysis indicates that even with the removal of as much as 20 million cubic yards of sand from the shoal, the local wave patterns are unlikely to be affected. These studies certainly indicate that Ship Shoal represents an ideal source of material to restore the nearby severely eroded barrier islands.

Dr. Byrnes has 13 years' experience with coastal and nearshore process studies, particularly related to coastal change analyses, wave transformation and sediment transport, and hard mineral resource investigations. He received a Ph.D. in oceanography from Old Dominion University (1988) and a B.A. in earth science from Millersville University (1978). He has been responsible for managing and conducting numerous projects focused on coastal sedimentation processes and the regional response of marine depositional systems to incident processes. In January 1997, Dr. Byrnes joined the staff at Aubrey Consulting Inc., of Catuamet, Massachusetts as a senior scientist, where he is managing several marine mineral-related environmental biological/physical impact studies.

PHYSICAL ENVIRONMENTAL STUDIES WITHIN THE SHIP SHOAL AREA: WAVE CLIMATE AND ONGOING PHYSICAL FIELD STUDY

Dr. Gregory W. Stone
Coastal Morphodynamics Laboratory
Department of Geography
Louisiana State University

PROGRAM OVERVIEW

It is now well established in the literature that the barrier islands comprising the Isles Dernieres (Figure 1C.1) have been experiencing among the highest rates of shoreline retreat in the United States (McBride *et al.* 1992; Williams *et al.* 1992; Stone and Penland, 1992). The primary factors responsible for deterioration of these islands include (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 22.0 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 degradation 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 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. The objective of this project is to numerically model the wave field and quantify the effects of shoal removal on wave conditions in the study area. Although total removal of the shoal is an unlikely scenario, this approach will permit an evaluation of the importance of Ship Shoal on the wave field during a variety of fairweather, storm, and hurricane-generated wave scenarios.

The research outlined above has been broken into two phases. The first phase deals specifically with numerical modeling of the wave field across Ship Shoal with particular emphasis on storm wave conditions. The primary objective of this phase is to numerically quantify the effects of Ship Shoal on the wave field. Phase II is designed to provide information on the wave field and sediment transport dynamics in the bottom boundary layer in the vicinity of Ship Shoal and landward, in the nearshore along the Isles Dernieres.

PHASE I

A significant amount of time and effort was spent on reviewing and adopting state-of-the-art models for this phase. STWAVE was chose and 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

$$\frac{\partial}{\partial x}(CC_gE(f,\theta)) + \frac{\partial}{\partial y}(CC_gE(f,\theta)) + \sum S_i = 0$$

where E(f,θ)=spectral energy density, f=frequency of spectral component, θ=propagation direction of spectral component, S_i=source terms (shoaling, refraction, wind forcing, wave-wave nonlinear interactions, bottom interaction, etc.).

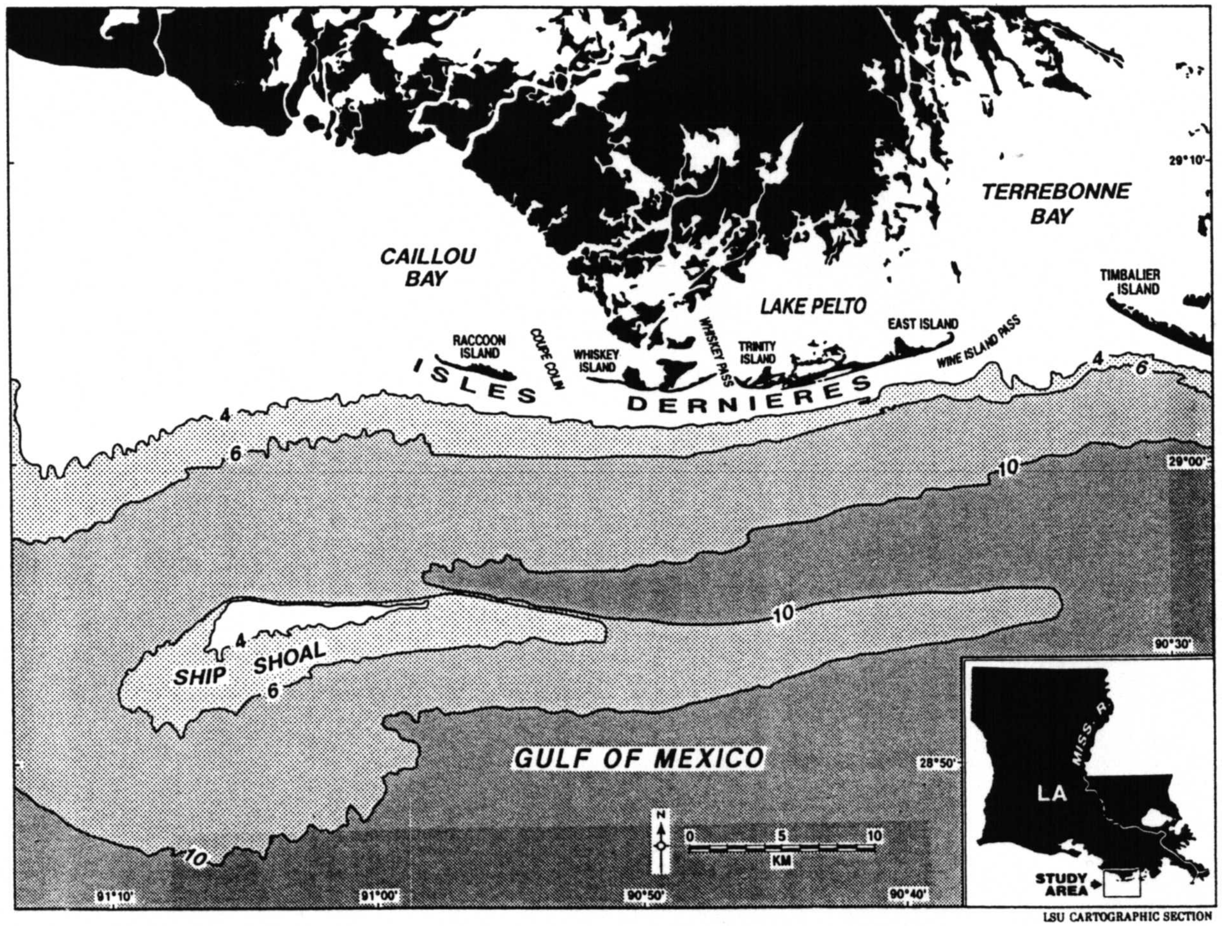

Figure 1C.1. Map of the Ship Shoal complex and Isles Dernieres, Louisiana.

STWAVE simulation requires a wave energy spectrum specified for the input boundary of the computational grid. It transforms the spectrum across the grid, including refraction and shoaling effects. The spectrum is modified to include the effects of bottom diffraction and the convergence/divergence of energy influenced by the local bathymetry. Wind-wave generation, nonlinear energy transfer, wave field and wave-bottom dissipation and wave breaking are considered. The model is computationally efficient because of its 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. Don Resio, personal communication).

Computational bathymetric grids and deep water wave conditions (directional amplitude and period weighted by frequency of occurrence) are necessary inputs for numerical modeling of surface wave behavior across the study site. Three different types of bathymetric grid were generated for application in this study. The grids differed in resolution, and underwent embedding of "local" (high resolution) in "global" (coarser resolution) grids.

The deep water wave inputs representing winter storms and fairweather conditions were obtained from three sources: (1) 20 years (1956-1975) of hindcast data obtained from the Wave Information Study (WIS) (Abel *et al.* 1989; Hubertz and Brooks 1989); (2) National Oceanic and Atmospheric Administration's (NOAA) National Data Buoy Center (NDBC) buoy 42017 (25.9°N, 89.7°W); and (3) Louisiana-Texas Shelf Physical Oceanography Program (LATEX). On synthesizing these data, four scenarios are presented which represent the respective deep water wave conditions for fairweather (wave heights of 1-2 m) through severe storms (wave height of 6 m)—excluding hurricanes. To simulate peak intensity wave conditions off the Louisiana coast, the hindcast data generated by Cardone and Cox (1992) were used as input to the WAVENRG model providing the opportunity to incorporate decreases in wave height outward from the storm center, as a function of a decaying wind field. The input data consist of seven sectors in which the significant deep water wave height ranges from 11 to 13.3 m, and the significant wave period approximates 14 secs.

The following main conclusions can be made from the research conducted in Phase I on the significance of Ship Shoal regarding wave climate off the Isles Dernieres:

(1) Removal of Ship Shoal will alter wave propagation, dissipation and wave energy distribution. The magnitude and spatial distribution of the alteration depends on the initial wave direction is not an important factor in determining the wave climate change. During severe storms (Case 1; H_s=6 m, T_p =11 sec.) And strong storms (Case 2; H_s=4 m, T_p =9 sec.), the propagating waves reach breaking conditions seaward of the west part of Ship Shoal. Therefore, removal of Ship Shoal causes a maximum increase of the significant wave height over the shoal complex and its lee flank. Wave breaking does not occur on the east part of Ship Shoal because of much deeper water, and the magnitude of the wave height increase due to shoal removal is secondary on comparison with the value on the west flank of the shoal. During weak storms (Case 3; H_s=2 m, T_p =6 sec.) And fair weather conditions (Case 4; H_s=1 m, T_p=5 sec.), waves never reach breaking conditions over any part of Ship Shoal. The magnitude of the significant wave height increase due to the removal of the shoal is considerable smaller, and the magnitudes of the wave height increase on the east part of the shoal.

(2) The nearshore wave fields are largely dependent on the offshore wave conditions. Numerical simulations indicate that under high energy conditions (Case 1 and Case 2) removal of Ship Shoal may result in larger breaking wave heights and, therefore, displacement of the breakers zone offshore by 0.5 - 1.0 km. Energy levels however do not show a marked increase in the nearshore zone due to post-breaking frictional dissipation, when the shoal is removed. This is even less apparent under the weaker energy conditions in Case 3 and Case 4.

(3) Inclusion of a wind forcing function in the numerical model significantly enhances the overall significant wave height. A 20 m/s wind (Case 1) in the wave direction causes an increase of the significant wave height by as much as 1.0 m. A 5 m/s wind in Case 4, also in the wave direction, can increase the wave height by 0.2 m. Consequently the width of the surfzone is also increase significantly during "local" winds.

PHASE II

Although the results obtained from the numerical modeling phase will provide guidance in management decision making and developing the Environmental Impact Statement pertaining to Ship Shoal, three critical questions remain unanswered: (1) To what extent does the numerical model realistically represent conditions in the field? As stated explicitly in Phase I of this study, a comprehensive field data set from which the wave climate, among other things, can be constructed from the study area off the Isles Dernieres on the inner shelf will be necessary to help check and validate model output. The data necessary to accomplish this are not available at present. Although the model (STWAVE) has gained acceptance in the scientific and engineering literature (Kraus *et al.* 1994), comparisons with measurements obtained from *in situ* measurement is necessary on applying the model locally; (2) What are the dynamic characteristics of the bottom boundary layer in the region? How do they control the suspension and transport of bed sediment? (3) If Ship Shoal is mined, what will be the transport dynamics of sediment introduced to the inner shelf from the shoal on dredging completion, and what changes will occur to the bottom boundary layer? How will this ultimately affect the distribution and fate of sediment along the nourished coast? The following describes a new project that is proposed to answer these questions. The proposed project will study, for the first time in the area, the dynamic characteristics of the bottom boundary layer, directional suspended sediment flux, and the morphodynamic behavior (erosion and accretion) of the bottom in the study area in addition to providing guidance on the disposal and fate of beach/nearshore nourishment material.

Phase II is summarized below:

(1) *Procurement and fabricating of an additional bottom boundary layer instrumentation system.* Directional wave spectra measured simultaneously at two geographical locations are required to check the numerically modeled results. Hence, in addition to the Sea-Pac 2101 directional wave gauge system that is currently owned by the Coastal Morphodynamics Laboratory at LSU, another directional wave gauge will be obtained. The new instrumentation package will have sophisticated measuring capabilities and will include a 4-sensor bottom boundary layer velocity profiling system, and essential element in studying bottom boundary layer dynamics and suspended sediment transport.

(2) *Obtaining direct field measurements of temporally- and spatially-varying directional wave spectra at two proposed locations.* These field measurements will be conducted under different wave conditions (storms, fair weather, *etc.*) To facilitate numerical model output checking and to develop a quantitative wave climate for the study area.

(3) *Obtaining direct field measurements of bottom boundary layer hydrodynamic processes and suspended sediment transport.* These measurements include total bed shear stress, bed roughness, drag coefficient and their relationship to wave directional spectral characteristics, mean current velocity profile, bedform (*e.g.*, ripples), and suspended sediment concentrations. This approach will provide essential information on sediment flux at potential sites of beach/nearshore nourishment.

To accomplish the above objectives, two types of field experiment design are planned: measurements of directional wave spectra and measurements of bottom boundary layer hydrodynamics processes. Under each category, at lease tow deployments, are conducted for the coverage of different hydrodynamic conditions, *i.e.*, storms and fair weather.

The proposed project is highly relevant to MMS' future involvement with mining Ship Shoal for beach nourishment along the Louisiana barrier islands for two reasons: Firstly, the proposed study is a continuation of an ongoing project currently funded by MMS in which the efforts have been solely focused on numerical modeling of the wave climate in the Ship Shoal-inner Louisiana shelf area. The modeled results include distribution of wave energy, characteristics of wave propagation, dissipation, and breaking as well as various responses of the wave climate to the new bathymetric configuration relevant to mining Ship Shoal. The proposed project will significantly enhance confidence in the modeled output and thus assist MMS in EIS preparation and decision making pertaining to mining Ship Shoal. Secondary, the proposed project will study, for the first time in the area, the dynamic characteristics of the bottom boundary layer, directional suspended sediment flux, and the morphodynamic behavior (erosion and accretion) of the bottom in the study area. This study will also provide much-need field measurements of dynamic characteristics associated with the bottom boundary layer in the region and their relationship to the suspension and transport of bed sediment and directional sediment flux. These data are highly relevant in predicting sediment transport pathways and the fate of material mined from Ship Shoal and deposited on the inner shelf adjacent to the Louisiana barrier islands during future barrier island restoration efforts

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Dr. Gregory Stone is an assistant professor in LSU's Department of Geography and Anthropology and a visiting research professor at the University of West Florida. He has a Ph.D. in physical geography from the University of Maryland, a M.S. in coastal studies from the University of West Florida, and a B.Sc. in environmental science from the University of Ulster, Northern Ireland. His interests and experience have centered on modeling sediment transport in the nearshore in addition to the overall sedimentary dynamics of coastal systems.

SESSION 2A

DECOMMISSIONING AND ARTIFICIAL REEF DEVELOPMENT, PART II

Co-Chairs: Mr. Villere C. Reggio, Jr.
Mr. Les Dauterive

Date: December 10, 1996

Presentation	Author/Affiliation
Discussion Points on Limitations on Rigs-to-Reefs Development in the Gulf of Mexico (Panel Discussion)	Mr. Ronald R. Lukens Gulf States Marine Fisheries Commission
Statement on Converting Obsolete Oil and Gas Structures to Artificial Reefs (Panel Discussion)	Mr. William B. Jackson National Marine Fisheries Service Southeast Regional Office Habitat Conservation Division
Red Snapper, Hypoxia and Petroleum Platforms: Some Curious Correlations (Panel Discussion)	Dr. Benny J. Gallaway LGL Ecological Research Associates, Inc.
Recreational Fishermen (Panel Discussion)	Mr. Steve Tomeny Charter Boat Operator
The Alabama Artificial Reef Program (Manuscript not submitted)	Mr. Steve Heath Alabama Department of Conservation & Natural Resources
Mississippi's Artificial Reef Program	Mr. Michael K. Brainard Mississippi Department of Marine Resources
Florida's Artificial Reef Program	Mr. Jon Dodrill Mr. William Horn Florida Department of Environmental Protection Division of Marine Resources

DISCUSSION POINTS ON LIMITATIONS ON RIGS-TO-REEFS DEVELOPMENT IN THE GULF OF MEXICO (PANEL DISCUSSION)

Mr. Ronald R. Lukens
Gulf States Marine Fisheries Commission

ARTIFICIAL REEFS CONSTITUTE HABITAT

Why are fish and invertebrates found in association with artificial reefs? Artificial reefs, like naturally occurring substrates, provide habitat that supports life history requirements of the associated species. Oil and gas structures provide some of the best habitat for reef associated species, because of their structural complexity and vertical relief. While the habitat benefits of offshore oil and gas structures are secondary to the primary function of the structures, many studies have documented their suitability as habitat for reef associated species of fish and invertebrates.

Historically, artificial reefs have been built to increase assess to fishing and to enhance fishing success. While these are important aspects of artificial reef development, the creation and enhancement of habitat for fish and invertebrate populations should be the primary driving force. Interestingly, regarding the Rigs-to-Reefs programs in Louisiana and Texas, they should be thought of as habitat maintenance and protection programs, since removal of offshore oil and structures constitutes removal of habitat.

LIMITED DISTRIBUTION OF OIL AND GAS STRUCTURES AS ARTIFICIAL REEFS

Even though oil and gas structures are known to function well as habitat for certain fish and invertebrate species, they represent only a small fraction of the materials that have been used in the United States to develop artificial reefs. In fact, Louisiana and Texas are the only Rigs-to-Reefs programs in the Nation. Why? The primary reason is because of the proliferation of oil and gas exploration and production in the offshore waters of those states.

LIMITATIONS ON THE DISTRIBUTION OF OIL AND GAS STRUCTURES FOR ARTIFICIAL REEF APPLICATION

Structures of the size and complexity of oil and gas platforms, designed and constructed specifically for artificial reef application, are economically prohibitive for most, if not all, artificial reef programs in the U.S. The main factors that make the use of oil and gas structures as artificial reefs possible are their availability and the mutual benefits derived from both the oil and gas industry and the programs that seek to enhance habitat for fisheries. Early in the development of the Rigs-to-Reefs concept, oil and gas structures were provided to programs as far away as Florida. The costs incurred in towing the structures long distances were justified by the opportunity to demonstrate the benefits of applying retired oil and gas structures to habitat creation and enhancement. Currently, the driving force behind the availability of oil and gas platforms for artificial reefs is the economic benefit realized by the oil and gas industry through a reduction in decommissioning and disposal costs. In both the Louisiana and Texas programs, half of the savings realized by a company making a structure available to the program is donated to the artificial reef programs, to ensure their long-term viability and success. The farther deployment sites are from the original location of oil or gas structures, the less the savings realized by deploying them as artificial reefs, to the point that transporting them to other states would likely incur additional costs rather than result in savings. This fact limits the distribution of the majority of oil and gas platforms in the Gulf of Mexico.

LIMITATIONS ON THE APPLICATION OF OIL AND GAS STRUCTURES AS ARTIFICIAL REEFS

While oil and gas structures deployed as artificial reefs function as habitat for fish and invertebrate species, the primary motivation for artificial reef development over the last 20 years has been to enhance access for and success of fishing. Because offshore oil and gas platforms are by nature very large, safe deployment as artificial reefs requires relatively deep water, to ensure navigable clearance above the structure.

The continental shelf off the norther Gulf of Mexico is very broad and gently sloping, requiring traveling a considerable distance from shore to locate water depths sufficient to receive an oil or gas platform and maintain safe navigable clearance. This fact limits the use of the structures by anglers to those offshore fishing vessels that have the capability to safely navigate that far offshore. When the structure no longer protrudes above the surface of the water, and may or may not be marked by a buoy, there is a further lack of security, since there is nothing for a vessel to tie to, and anchoring in very deep water can be difficult. While the establishment of an artificial reef in areas that limit exploitation by fishermen can provide benefits to the resources, the perceived lack of benefits to the fishing community make such a development difficult to justify.

LIMITATION ON EXPANDING THE USE OF OIL AND GAS STRUCTURES AS ARTIFICIAL REEFS

Many of the oil and gas structures that will be taken off-line in the future are located in deep water. While the oil and gas industry would still be able to realize a benefit by donating those structures, toppled in place, for deployment as artificial reefs, it is questionable whether or not such an action would constitute habitat for fisheries. It is generally thought that below 300 feet, well within the aphotic zone, enhancing the habitat for reef associated species would likely not be successful. Without question accessibility to the site by fishermen would be limited or non-existent. In cases such as these, it is more likely that deployment of the oil and gas platform, toppled in place, would constitute ocean disposal of the platform rather than creation or enhancement of habitat for fisheries.

The option of removing a deep water structures and moving it to a shallower site that would have the likelihood of creating or enhancing fisheries habitat would be limited by the economics. For example, the deep water structure would have to be dismantled to the point that it could be towed into shallower water. The extra time and manpower required to achieve that goal would likely remove any economic incentive for the oil and gas industry to donate such a structure for artificial reef deployment.

Partial removals are conceptually possible. A partial removal involves removing the upper portion of the platform to specifications for safe navigable clearance, leaving the remaining jacket and associated structures upright in the water column. Even in extremely deep water, such a structure would provide habitat for fish and invertebrate species in the upper water column. This, however, could create liability problems.

OTHER ISSUES

The use of oil and gas structures, as with the use of any material of opportunity, for the creation or enhancement of habitat for fisheries must be controlled by the applicability of the structure and the expressed need for the structure. The option of scrapping retired oil and gas structures landside must always be available to accommodate the disposition of those structures that will not be applicable to deployment as artificial reefs.

The reliance on explosives to move oil and gas structures to designated artificial reef development sites can be biologically problematic. Several years ago, concern were raised regarding mortality to endangered and threatened sea turtles. In response, observers were placed on site to certify that no sea turtles were present and to approve the explosive removal. More recently, concerns have been raised over mortality of red snapper due to explosive removals. Studies are currently underway, at the Galveston Laboratory of the National Marine Fisheries Service, to quantify and evaluate the impact of fish mortality due to explosive removals. Alternative removal methods are being pursued; however, to date none are as cost-effective as explosives. This issue could constitute a major limitation to continued or expanded development.

Oil and gas structures are artificial reefs representing high profile habitat. In order to maximize the habitat quality of an artificial reef site, combining high and low profile materials is beneficial. The inclusion of barges or other small vessels or concrete rubble, among other suitable materials, would provide habitat for a larger variety of organisms that would enhance the total community associated with the site. Such a combination of materials may also provide habitat for juvenile and adult fish and invertebrates, thus contributing to the success of a variety of life stages.

Another concept is to connect high profile materials with corridors of low profile materials. For example, oil and gas structures that are separated by several hundred feet could be connected by a corridor of concrete rubble. This use of high and low profile materials into a reef complex has been applied by Japanese ventures in the past for commercial production of fish.

Ron Lukens is Assistant Director and Sport Fish restoration Administrative Program Coordinator for the Gulf States Marine Fisheries Commission located in Ocean Springs, Mississippi. Ron has always had professional interest in the development of marine artificial reefs with personal experience in planning, permitting, construction, and monitoring artificial reefs

off the Mississippi coast. Mr. Lukens was the driving force behind the creation of a very functional Gulf States Artificial Reef Coordinating Committee composed of state and federal administrators most active in the development and approval of artificial reefs in the Gulf of Mexico.

STATEMENT ON CONVERTING OBSOLETE OIL AND GAS STRUCTURES TO ARTIFICIAL REEFS (PANEL DISCUSSION)

Mr. William B. Jackson
National Marine Fisheries Service
Southeast Regional Office
Habitat Conservation Division

Oil and gas structures, whether upright and under active production, obsolete upright, or laid on their side as an artificial reef, may provide new habitats that can support fishery resources associated with reefs. This can help improve commercial and recreational fishing opportunities. The NMFS endorses the use of obsolete oil and gas structures as artificial reefs in the Exclusive Economic Zone (EEC). It welcomes the opportunity within legal and fiscal constraints, to work with other Federal, State, and local governments, the oil and gas industry, private associations, Fishery Management Councils, and others to cooperate in the conversion of structures to reefs.

There is consensus that properly designed and placed artificial reefs can improve the environment in areas of depauperate bottom topography and low relief. However, debate continues concerning their proper design and placement in relation to biological impacts. Studies suggest that increasing habitat complexity, using artificial reefs, can increase the local abundance of fishes and that fish abundance and composition will differ depending on where artificial reefs are located in terms of depth, currents, surrounding substrate, and distance to natural reefs. Studies further suggest that multiple small reefs support more individuals and more species than one large reef of equal material. Smaller reefs seem to have greater fish density while larger reefs have a higher biomass from larger, but fewer, individuals.

The NMFS encourages the conversion of oil and gas structures to artificial reefs when done in a manner that promotes environmental benefits, does not impact fishing activities or other uses of the marine environment, and avoids other risks such as to navigation. The NMFS also encourages further research on the conversion of rigs to reefs to better define benefits, impacts, and risks. Additional research into refining appropriate site selection, placement, and configuration also would be useful.

William Jackson received a B.S. in wildlife and fisheries science and a M.S. in fisheries science from Texas A&M University. He joined NMFS in 1975 and has worked in the fields of fishery research, fishery management, oil spill and hazardous material response, and fishery habitat conservation. He has been the NMFS Southeast Region point of contact for review and comment on all MMS oil and gas and pipeline permit applications in the Gulf of Mexico since 1991.

RED SNAPPER, HYPOXIA AND PETROLEUM PLATFORMS: SOME CURIOUS CORRELATIONS (PANEL DISCUSSION)

Dr. Benny J. Gallaway
LGL Ecological Research Associates, Inc.

INTRODUCTION

November 1947 was a significant time in the history of the Gulf of Mexico. On that date, a major oil and gas field was discovered 19 km off the coast of western Louisiana in shallow waters of the Gulf. This discovery was followed by many others over the years, from the beach to the continental slope, from the panhandle of Florida to the southern tip of Texas. The most extensive development has occurred on the continental shelf in the central region of the northern Gulf. Now, 50 years after the discovery, the distribution of marine platforms used to produce offshore hydrocarbon reserves provides an extensive archipelago of "steel islands" extending to the south and west.

These platforms provide habitat for an array of biota, including the commercially valuable red snapper (*Lutjanus campechanus*). Red snapper begin to congregate around petroleum platforms when they are about one-year old and 14 to 20 cm long. Population levels around larger platforms have been observed to be as high as 7,000 (Gallaway and Martin 1980) to 8,000 (Stanley 1994) individuals. On the order of 80% of the recreational and commercial catch of red snapper in the Gulf is taken at petroleum platforms.

From the mid-1960s to the early 1980s, commercial catches of red snapper in the central Gulf in National Marine Fisheries Services' (NMFS) Statistical Areas 8 to 15 were variable but generally high, as compared to other regions of the Gulf. However, the early to mid-1980s catches in this region plummeted to record-lows. In recent years, catches in NMFS Statistical Areas 16 to 19 also having a high density of petroleum platforms, began a trend of increase. In this paper we present some interesting correlations between the observed changes in catch patterns and the development of wide-scale hypoxia in the affected region.

RED SNAPPER CATCH RATES AND HYPOXIA

Coincident with the decline in red snapper catches, a shift in the distribution of red snapper catches was observed. Historically, the highest catches were made in Statistical Areas 13 and 14, but by the mid-1990s, the highest catches were taken in statistical areas 16 and 17. Commercial catch rates of red snapper in statistical areas 13 and 14 have been low relative to catch rates in statistical areas 16 and 17 since 1991, and have shown no trend of increase. In contrast, catch rates in statistical areas 16 and 17, while variable, have exhibited a trend of increase. This trend of increase in red snapper catches in Statistical Areas 16 and 17 correlates directly to the size of the hypoxic zone. The observed decline in red snapper catches coincident with the initiation of large-scale hypoxia, and the observed shift in distribution of red snapper catches adjacent to the hypoxic region is consistent with a cause and effect relationship.

Compilation of data describing the extent and distribution of hypoxia in the western Gulf were observed from a number of sources, especially the work of Rabalais *et al.* (1986a, b); Rabalais (1987); Rabalais *et al.* (1991, 1992); and Rabalais (pers. comm. 1996). Bottom water oxygen data show that Statistical Areas 13 and 14 experienced hypoxia every year since 1990 and likely before. Statistical Area 15 was not affected by hypoxia in 1992, and Statistical Areas 16 and 17 are at the extreme western end of the hypoxic region.

These data, in combination with quantification of biologically bound silica (BSi) in diatom remnants in dated sediment cores from affected area (Turner and Rabalais 1994) suggest large-scale hypoxia presently occurs most every year and that this is likely a recent phenomena. The level of BSi in the sediments provides an index to productivity levels; enhanced productivity being one of the prerequisites for hypoxia.

For the moment, assume these observations do reflect a cause and effect relationship between catchability of red snapper and hypoxia. Would the change necessarily equate to a population effect? The main habitat of red snapper in the western Gulf, petroleum platforms, extend from the bottom to the surface. Red snapper can, and, based on the observations of Gallaway and Lewbel (1982), Render (1995), and Dr. David Stanley (pers. comm. 1996), do simply migrate up the platform legs to escape bottom areas having unfavorable dissolved oxygen levels. Thus, a population effect does not necessarily follow the observed changes in catchability. However, if all or a substantial fraction of the platforms in the hypoxia region were either removed or toppled to the bottom within the hypoxic zone, populations effects would almost certainly follow.

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Dr. Benny J. Gallaway has served as President of LGL Ecological Research Associates, Inc. since1974. In addition to biological research duties with LGL, he serves on the graduate faculty of the Department of Wildlife and Fisheries Sciences, Texas A&M University. His general research interests focus on shelf and slope ecosystems and behavioral responses of organisms in these habitats to environmental gradients. In recent years, he has focused on the effects of environmental gradients on migrations of Arctic anadromous fish. Dr. Gallaway received his Ph.D. from Texas A&M University in 1978.

RECREATIONAL FISHERMEN (PANEL DISCUSSION)

Mr. Steve Tomeny
Charter Boat Operator

March through November 1996 was a busy season for the charter business with bookings five to seven days a week, weather permitting. Normal trips ranged 30–35 miles into the Gulf, but occasional two-day trips extended farther. A normal day trip carried 10–20 recreational fishermen and made approximately 12 stops, mostly at active and turned over (Rigs-to-Reef) rig locations.

Operators with boats equipped with modern electronics can easily locate Rigs-to-Reef sites. These locations are exceptional fishing spots because they are more difficult to find and fish than active platforms. Mr. Tomeny has perfected his fishing techniques to enable him to hover the boat over submerged platforms while his customers fish just above the artificial structures. This type of fishing resembles chumming in that it brings the fish above the reef, saves on lost tackle, and works very well once mastered. He normally fishes Rigs-to-Reef sites with 50–200 feet of water above the top of the reef. The deeper reef sites are more difficult to fish during strong currents.

Mr. Tomeny recommended that the state focus on building more sites rather than larger sites or sites with multiple structures. He indicated that some Rigs-to-Reef sites, like some active structures, are consistently better producers of fish, irrespective of factors such as reef size, depth, or water clearance to the top of the reef material.

A self-described "end user" of the Rigs-to-Reefs Program, Steve Tomeny has been chartering fishing trips in the Gulf of Mexico for over 25 years. He currently owns and helps operate three offshore charter boats based at the Fourchon dock in coastal Louisiana.

MISSISSIPPI'S ARTIFICIAL REEF PROGRAM

Mr. Michael K. Brainard
Mississippi Department of Marine Resources

Mississippi's artificial reef efforts began in the early 1960s. Because Mississippi's offshore water bottoms are characteristically featureless and unbroken sandy mud, fishermen had to travel considerable distances to find fish habitat that attracted desirable reef species such as snapper, grouper, king mackerel, and cobia. A group consisting primarily of charter boat operators and recreational fishermen obtained funding from their local coastal counties and constructed a car body reef site in the early 1960s. In 1972, the Mississippi Marine Conservation Commission, the organizational predecessor of the current Mississippi Department of Marine Resources (MDMR) acquired five surplus liberty ships. These ships were scrapped for salvage down to the bare hulls, and the salvage funds were used to finance the acquisition and placement of these ships at two additional reef sites. This surplus liberty ship project was completed in 1978. The excess funds from the project and the reef permits were transferred to the Mississippi Gulf Fishing banks, Inc. (MGFB), a private reef building organization made-up of conservationists, charter boat operators and recreational fishermen. The MGFB used the surplus funds to construct two more reef sites, bringing the total number of reef sites to five. From 1978 to date, the MGFB in conjunction with the MDMR have developed four additional offshore sites for a total of nine sites located in the EEZ. In addition several low profile reef sites located in near shore waters have been developed, at popular fishing locations.

Presently, Mississippi has 25 nearshore low profile fishing reefs and 9 offshore reefs in the EEZ (see Figure 2A.1 for offshore sites). The majority of the offshore sites are located within 16–32 kilometers from shore. Materials used to date on these offshore reef sites include liberty ships, rig quarters, tugboats, barges, boxcars, buses, dumpsters, concrete rubble, concrete modules, tires and FADS. These materials were deployed using a combination of funds including County, Wallop-Breaux and Tidelands Funds (a fee for leasing coastal water bottoms). These sites encompass approximately 3,300 hectares with the largest site approximately 2,583 hectares. Site locations and water depths for the offshore sites located in the EEZ are as follows:

FH-1	20 meters
FH-2	18 meters
FH-3	14 meters
FH-4	9 meters
FH-5	11 meters
FH-6	18 meters
FH-7	40 meters
FH-12	14 meters
FH-13	24 meters

All of these sites have active permits and suitable material can be deployed at these sites as they become available.

FH-7, approximately 72 kilometers off of Mississippi's coastline, is located in the Southeast corner of Main Pass block 165 and was permitted as a rigs to reef site in 1986, it encompasses roughly 260 hectares. The site is relatively undeveloped with only two barges, a tug

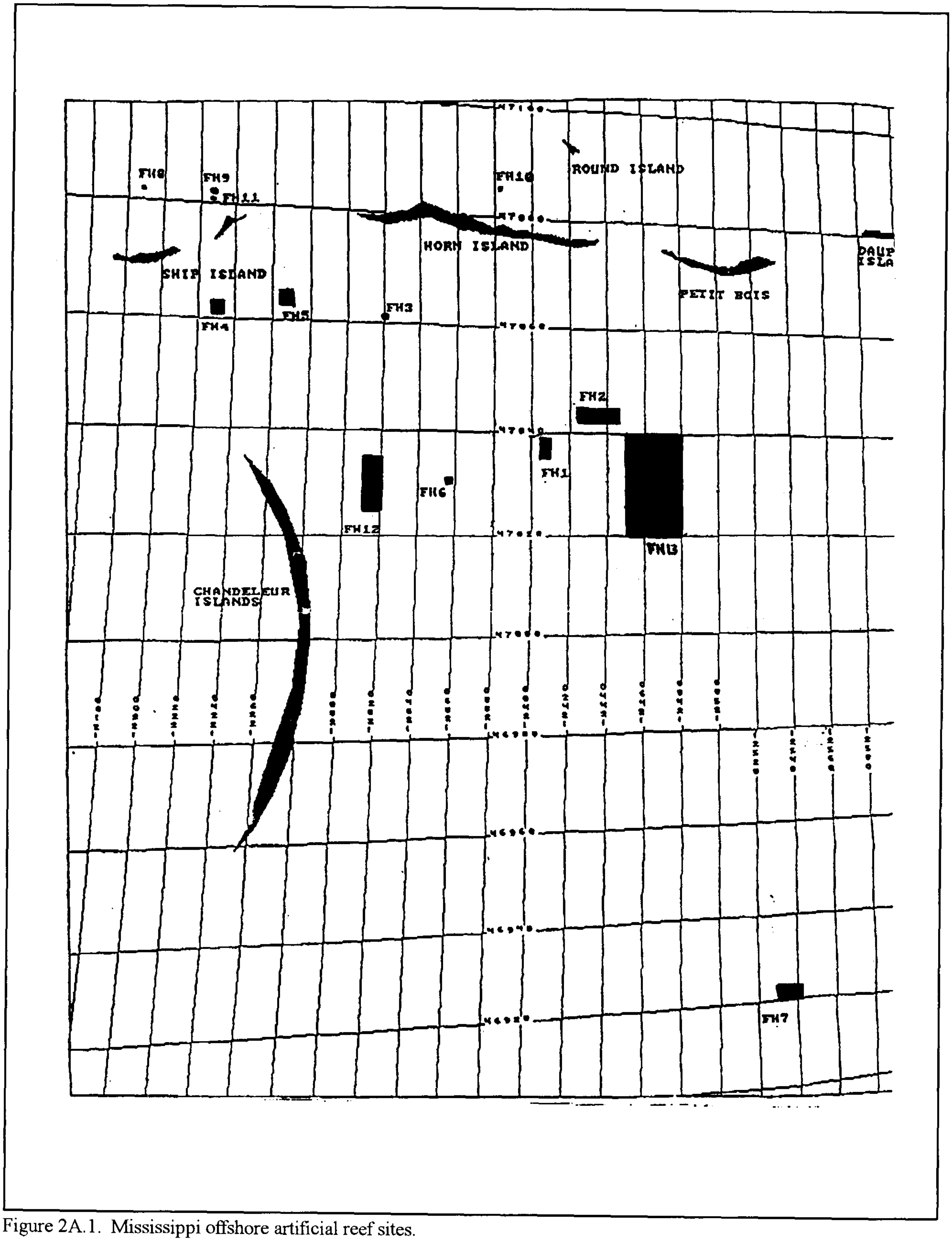

Figure 2A.1. Mississippi offshore artificial reef sites.

boat and rig living quarters, donated by private industry, placed on the site.

The Department has a designated artificial reef coordinator who works with the MGFB on the development of reef sites. The MDMR is currently developing a formal artificial reef plan, which will include decommissioned rigs as an important artificial reef material for deployment on approved sites. Oil and gas platforms have been used as artificial reefs by other Gulf States and have proven to be effective, stable and durable. The two primary constraints for Mississippi are the requirements for deep water in which to deploy the structures and the distance from shore that fishermen must travel to reach these deep water sites.

Michael Brainard is employeed as a biologist with the Mississippi Department of Marine Resources. He received his B.S. in marine biology from Troy State University in 1989, earned graduate level credits in marine science at Dauphin Island Sea Lab, and has been with the State of Mississippi assisting with fisheries research and development work since 1990.

FLORIDA'S ARTIFICIAL REEF PROGRAM

Mr. Jon Dodrill
Mr. William Horn
Florida Department of Environmental Protection
Division of Marine Resources

INTRODUCTION

Florida is the nation's leader in the number of public artificial fishing reefs developed. In the sixteen year period from 1980 to 1996, no fewer than 480 publicly funded artificial reef materials deployments were made in state and federal waters off 33 Florida coastal counties on both Gulf and Atlantic coasts. Reefs were built at depths ranging from eight feet to over 200 ft. with an average depth of 70 feet (Department of Environmental Protection artificial reef database). This was an estimated four fold increase in the number of artificial reefs previously developed in Florida since the first artificial reef permit was secured in 1918 (Pybas 1997). Over the last 40 years the state program has experienced a gradual transition in reef materials use, funding sources, and recognition of the importance of measuring the effectiveness of its program.

PROGRAM ADMINISTRATION AND FUNDING

The rapid proliferation of publicly funded artificial reefs in Florida beginning in the mid 1980s is the result of increased levels of federal, state and local government funding for artificial reef development. Consistent federal funding for Florida's reef program became available in 1986 as a result of the Wallop-Breaux amendment to the 1950 Federal Aid in Sport Fish Restoration Act (Dingle-Johnson). Under the Act, funds are derived from import duties on boats and tackle, excise taxes on all items of fishing tackle and taxes on small engine and motorboat fuel. This revenue is returned to the states by the Federal Aid Division of the U.S. Fish and Wildlife Service and with a 25% state match is used in activities which benefit the boating and angling users (Christian 1989). In 1995 3.25 million dollars went to Florida of which about 10% went to the artificial reef program. During the decade of reef building activity from 1986-1996, Sport Fish Restoration Funds provided almost three million dollars to complete 164 Florida reef projects.

In January 1990, Florida instituted a saltwater fishing license program. About 5% of the revenue from the sale of over 850,000 fishing licenses annually became available for additional artificial reef projects. Two additional personnel were hired into the state artificial reef program to assist with coordination, information sharing, grant monitoring/compliance and diving assessment of artificial reefs. Limited general revenue funding available for reef development was phased out. Saltwater license funds available for reef development were initially $700,000 in the 1991-92 fiscal year, dropped slightly to $600,000 per year from 1992-95 then declined to $300,000 per year during 1995-96 and 1996-97 with the same level proposed for the 1997-98 fiscal year. Over the last 10 years, the 16-30 annual individual state or federally funded reef construction projects have ranged from $20,000-$90,000 per project. The typical state/federal reef grant project has an expenditure ceiling of about $25,000. Grants in aid reimbursements to local governments have been used chiefly to pay marine contractors for loading and offshore transportation of donated material. During the last three years, the cost of prefabricated reef module construction and limited monitoring of artificial reefs has also been covered.

Other revenue sources used for artificial reef projects are variable, however, currently these revenues cumulatively exceed the total annual state/federally funded artificial reef development grant program project budget of $600,000. Seventeen of 33 local governments applying for artificial reef project grant assistance for the 1997-98 fiscal year had no cash matching funding sources for reef development. Total coastal local government funds allocated to artificial reef activities for the 1997-98 fiscal year by the remaining 16 local government applicants were projected to be $824,000 with an additional $635,000 in mitigation money directed at artificial reef activities in Dade County, and an unknown reef program budget to support a full time four man crew and a barge used to construct reefs in Pinellas County. Private or fishing club pledged donations for proposed 1997-98 reef projects were $45,000 in Dade County, and $25,000 in Broward and Lee County respectively (all three populous south Florida Counties).

RESEARCH

Artificial reef research projects undertaken with over a million dollars in state funding since 1990 have included studies on reef spacing and design, material stability and storm impact studies, long term studies of reef community succession, residency of gag grouper on patch reefs through tagging and radio telemetry, juvenile recruitment to reefs, and impacts of directed fishing.

STATE/LOCAL GOVERNMENT REEF PROGRAM COORDINATION

For the last 20 years, Florida's artificial reef program has been a cooperative local and state government effort, with additional input provided by non governmental fishing and diving interests. The state program's primary objective has been to provide grants in aid to local coastal governments for the purpose of developing artificial fishing reefs in state and adjacent federal waters off both coasts in order to locally increase sport fishing resources and enhance sport fishing opportunities.

Florida is the only coastal state active in artificial reef development which does not have a direct state managed artificial reef program. Eighty percent of Florida's 14.5 million persons reside in the coastal zone spread along 1,197 statute miles of Gulf and Atlantic coastline. More than 17% of the forty million tourists who visit annually saltwater fish. There are 771,459 registered boaters (Department of Motor Vehicles 1997) and an estimated 594,802 resident licensed saltwater anglers and an estimated 240,820 non resident licensed anglers (DEP saltwater license program 1997). Florida recreational saltwater fishing landings for 1995 were estimated at 130,214,634 lbs. (National Marine Fisheries Service 1997). Public reef development has occurred on over 330 permitted reef sites from bay environments to 30 miles offshore. The logistics and scale of this program have necessitated a decentralization of reef development activities to the local government level.

All but four active permitted reef sites are held by individual coastal counties or cities. Three are held by the state of Florida and one is a small experimental site held by the Boy Scouts of America in the Florida Keys. This is a significant shift from the 1960s-early 70s when half or more of the permit holders were fishing clubs and other non governmental organizations. The Florida DEP holds permits to two large areas totaling 120 sq. nautical miles in federal waters off Escambia County in the western Florida Panhandle and one 56.7 sq. nautical mile site off Okaloosa County. This large area is scheduled for transfer to Okaloosa County in late 1997. These sites were secured by DEP in October 1994 at the request of the local governments. These areas are used for both local government reef grant projects and by private citizens on a limited basis As of January 1997 only seven different individuals have gone through the material inspection and approval process to personally deploy their own reefs, consisting of a total of 56 concrete or steel pieces meeting the permit requirements of these large areas. Most private deployments have been directly undertaken by two small commercial firms deploying a total of 309 prefabricated concrete modules for their clients.

The advantages of having both county and state funding, and the involvement of nearly three dozen coastal governments has resulted in the development of more statewide annual reef projects than could be carried out from Tallahassee with a staff of three.

Disadvantages have been that the rate of production of artificial reefs has outstripped formal long range planning, research, monitoring, and socio-economic studies to determine biological impacts and function, fishing activity levels and cost benefits of these reefs. Only 8 out of 33 counties have support boats or staff capable of evaluating the material placed off shore. Reef management expertise at the local government level is variable. Reef programs are found in solid waste management, public works, natural resources, recreation and parks, administrative, and planning departments. Local government reef coordinators range from biologists and marine engineers to city clerks, grants coordinators, planners, and even unpaid volunteers. Reef management and coordination are generally collateral duties for most local government reef coordinators.

Long range systematic planning and general reef management at the local government levels have lagged behind the rate of reef construction in Florida. Site specific projects are planned but the broader areas of program evaluation, and actual management have not received much attention. This lack of planning beyond site level considerations, while problematic in Florida's decentralized reef development situation, has also been cited as a national concern (Gordon 1994). A "State Artificial Reef Development Plan" was drafted in 1992 but there are currently few formal county level or regional artificial reef management plans which tie in with this plan or the National Artificial Reef Plan.

Florida's state and local programs have been working to improve information exchange and coordination. Sea Grant extension agents in coordination with DEP have periodically arranged regional reef coordinators meetings. Semi-annual Gulf and Atlantic States Marine Fisheries Commission Artificial Reef Technical Committee meetings, and two state wide Reef Summits (1991, 1993), along with information dissemination and outreach by the state artificial reef program section within the DEP Office of Fisheries Management and Assistance Services (OFMAS) have been valuable tools in raising awareness of artificial reef related issues. DEP is embarking upon efforts to update data bases and transfer artificial reef fish survey information and other data to Geographic Information Systems (GIS).

ARTIFICIAL REEF MATERIALS USE

Vehicles, White Goods, and Tires

There has been a shift in the types of materials used for artificial reef construction in Florida waters over the last 35 years. In the early 1960s when a reef permit request was made, a biologist from the Florida Board of Conservation Marine Lab in St. Petersburg (now the Department of Environmental Protection's Florida Marine Research Institute, FMRI) would evaluate the proposed site and make a recommendation (usually positive) that the Board of Conservation issue the permit. Eighteen artificial reef development requests approved at the field level for 1960-62 which were made by seven fishing clubs, a Moose Lodge, a chamber of commerce and nine city or county governments. These included proposals to use no fewer than 6,600 auto bodies roped, cabled, or chained together in groups of 2-5; a bus and three trucks, no fewer than 1,580 washing machines, 130 refrigerators, an unknown number of stoves, three wooden vessels, an unknown number of tires weighted with concrete, and airplane parts. Only one of eighteen permits requested to use concrete or natural rock. No trace of any of these white goods or vehicles is documented today.

Beginning in 1964 through 1977 the Governor and Cabinet with input from the Department of Natural Resources (DNR), Department of Pollution Control (both now one agency, DEP) and the Florida Game and Freshwater Fish Commission personally reviewed all state artificial reef permit requests. By 1975 the DNR was recommending denial of the use of appliances due to "acknowledged short life expectancy in the marine environment" (17 June 1975 Minutes of Internal Improvement Trust Fund Vol. 40, 1974-75). During 1974-75 alone, five local governments two fishing clubs, a high school and a college were approved for permits to use ballasted or bound and perforated tires. Approved tire deployments included 40,000 tires in 21 ft. of water off Naples, 30,000 off Stuart (Southeast Atlantic coast), several barges filled with perforated tires off Miami, 150 tires in the Indian River Lagoon, tires in the Banana River, an unknown quantity of bundled tires proposed at five sites off Pinellas County (central Florida Gulf Coast), a giant tire reef of bound and perforated tires eight feet tall, by 20 ft. wide by 3000 ft long off Broward County (southeast Florida), and two concrete ballasted tire reefs in the Florida Keys. Over two decades of tire use ended in the early 1980s with the deployment of thousands of bundled tires off Bay County (Florida Panhandle) in 1981-83. Several hundred thousand tires remain in the water off both Florida coasts though hundreds have washed ashore on beaches at multiple locations. Few of these tire projects are intact components of artificial reefs today.

By 1979, DNR no longer would fund reef projects using auto bodies, white goods or individual tires (DNR Division of Marine Resources Artificial Fishing Reef Program Manual of Operations, August, 1979).

Concrete and Steel

By 1980, increasing emphasis on the use of stable reef habitat shifted material use towards concrete materials and heavy gauge steel. Over 40 different material types were used in artificial reef construction from 1980 through 1996. The DEP's artificial reef program which has performed dive assessments since 1992, has evaluated most of these material types. Their reports along with feed back from county reef coordinators and other state coordinators have resulted in the discontinuation of further public funding of 16 types of reef materials (Table 2A.1), due chiefly to lack of either durability or stability. A typical example was the use of commercial aircraft (Boeing 727s, DC-3s) all of which broke apart within a year of deployment.

The 19 January 1995 Army Corps of Engineers CESAJ-50 general artificial fishing reef permit for Florida, Puerto Rico, and the U.S. Virgin Islands restricts its eligible reef materials list to concrete and steel culverts, army combat tanks, steel hulled or ferro cement vessels without engines, construction-grade aluminum and ferrous metals such as bridges, limestone boulders, concrete blocks, slabs, and similar material. The permit further states, " materials must be selected to avoid movement of the reef due to sea conditions and are to be free of asphalt, creosote, petroleum, other hydrocarbons, toxic residues, loose free floating material, or other deleterious substances. No vehicular tires may be used unless split and substantially imbedded in concrete."

The Florida DEP general permit for construction of artificial reefs (62-341.600, Florida Administrative Code) states that allowable reef construction material shall be clean concrete or rock, clean steel boat hulls, other clean, heavy gauge steel products with a thickness of 1/4 inch or greater, and prefabricated structures that are a mixture of clean concrete and heavy gauge steel. The material must be free of soils, oils and greases, debris, litter, putrescible substances, and other pollutants. A bottom survey is required of the area where the reef is proposed to be constructed, to demonstrate avoidance of grass bed communities, shellfish, corals or other hard bottom communities.

Concrete materials, chiefly culverts and other prefabricated scrap steel reinforced concrete were the primary reef material in 51.7% of the 480 public reef deployments made the past 16 years. (Figure 2A.2). Pinellas County (Tampa Bay area) whose full time year round reef building operations were not included in the above figure, leads all other counties in concrete deployments with an average of 2,500-3000 tons per year placed offshore as reefs as part of their solid waste recycling/reduction program. This still represents only a fraction of the 189,000 tons of concrete waste generated annually in that county alone. Most of this concrete is ground up for recycling purposes (Rebecca Stone, Pinellas County Waste Management, personal communication).

Steel Vessels

Eighty deployments of steel vessels in Florida over the past 16 years have catered to fishermen fishing for pelagic species, and a rapidly expanding resident and tourist diving population. The majority of vessels sunk as artificial reefs are concentrated off Dade, Palm Beach, and Broward Counties with a secondary concentration of smaller vessels (tugs, work boats) in the western Florida Panhandle. Requirements for at least fifty feet of clearance have limited large vessel deployments on the Florida Gulf Coast outside the western panhandle. All but two of the largest size class vessels (over 300 ft.) sunk as artificial reefs were government vessels: two Coast Guard cutters, two troop ships, and 5 liberty ships. Concerns about PCB contamination in large decommissioned military vessels have curtailed the availability of these ships since 1990. The typical south Florida sunken ship is a 100-250 ft. coastal ocean freighter.

Steel ships, particularly those over 100 ft. long are expensive to secure, clean, properly transport, and sink (with costs often exceeding $100,000). High vessel profile and extensive hull and superstructure surface area can make vessels vulnerable to damage in storm/hurricane events. In south Florida, a major impetus to use ships has been as a pyrotechnic media event at the time of sinking to promote the local government's artificial reef program. The majority of funding for these larger vessels is provided by local governments using other state or county revenue sources as well as private donations.

Table 2A.1. List of funded reef materials placed at public artificial reef sites, 1980 through 1996.

MATERIAL	MATERIAL TYPE	CURRENT USE
1. Concrete	bridge spans	in use
	culverts/pipes	in use
	pilings/ poles	in use
	junction boxes/manholes	in use
	construction blocks	being evaluated
	miscellaneous rubble	in use
2. Steel	cement mixers barrels	being evaluated
	auto/truck/bus/ bodies	no longer funded
	military armored vehicles	in use
	liquid storage tanks	no longer funded
	dumpsters	no longer funded
	radio towers sections	being evaluated
	boat trailers	no longer funded
	turbine stacks	no longer funded
	boxcars	no longer funded
	platforms	being evaluated
	steel boxes	no longer funded
	metal pipe	no longer funded
	metal boiler parts	being evaluated
3. Steel vessels	ferries	in use
	coastal freighters	in use
	tugboats	in use
	military auxiliary craft	in use
	barges	in use
	motor yachts, sailboats, etc.	no longer funded
	houseboats	no longer funded
4. Obsolete oil rigs	4 sites	in use
5. Natural limestone rock	boulders	in use
6. Fiberglass/Plastic (scrap)	boat molds	no longer funded
	storage tanks	no longer funded
7. Aircraft bodies	commercial airplanes	no longer funded
	military jet fighter/bombers	no longer funded
8. Prefabricated modules	solid concrete tetrahedrons	in use
	tetrahedrons with imbedded tire chips [1]	in use
	hollow dome shaped balls with holes [2]	in use
	hollow pyramid with holes [3]	in use
	cylindrical fiberglass (Japanese)	in use
	sheet PVC glued in blocks [4]	being evaluated
	Dade county concrete & rock	in use
	hollow cubes (Lindberg)	in use
	midwater fish attracting devices (FAD)	no longer funded
9. Vehicle tires	tied together in bundles	no longer funded
	loose	no longer funded

[1] Stability Reefs™
[2] Reef Balls™
[3] Grouper Ghettos™
[4] ARCOA Reefs™

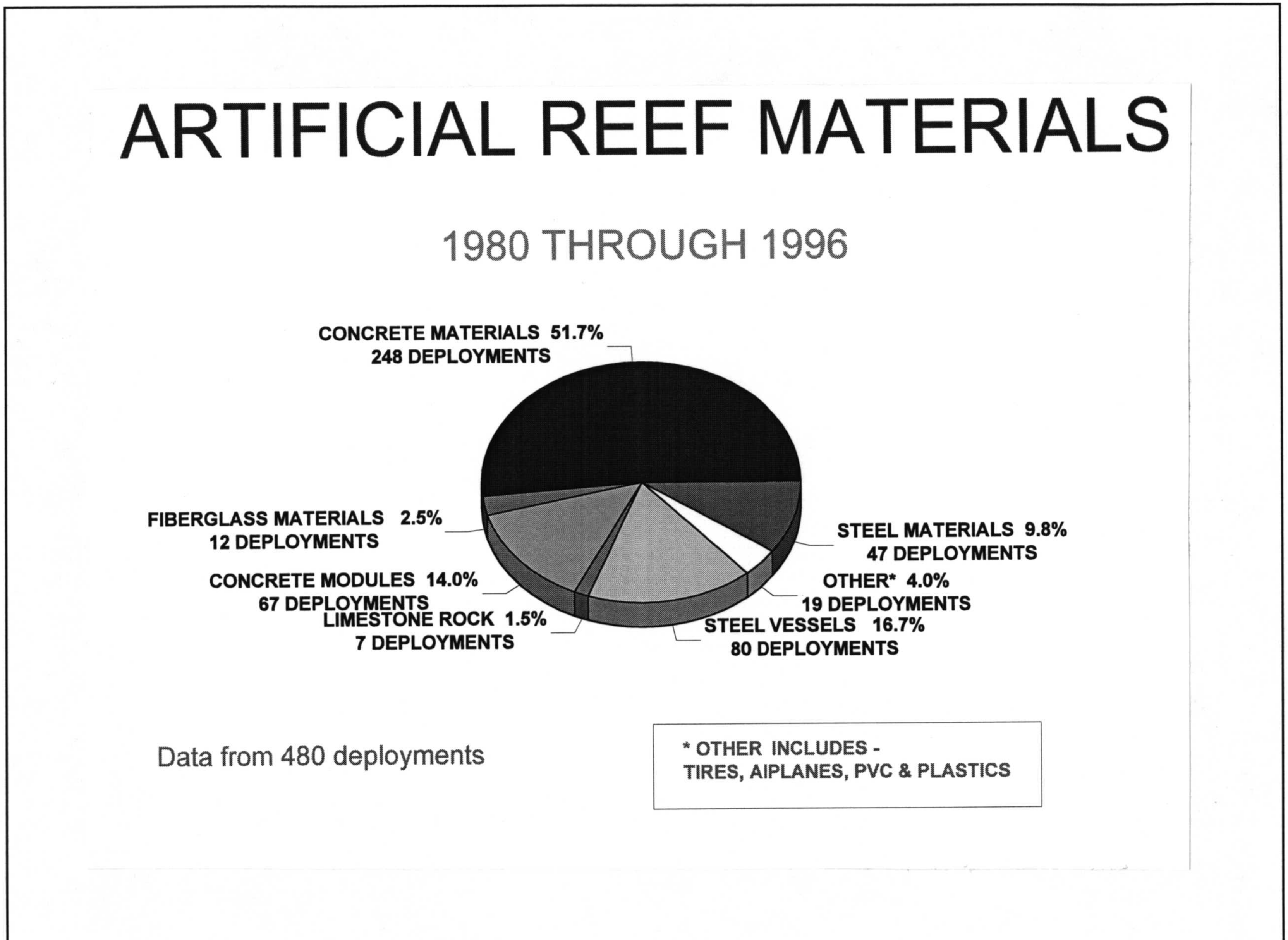

Figure 2A.2. Artificial reef materials, 1980 through 1996.

Oil Rigs

Obsolete oil rig structures have been placed as reefs at four locations in Florida or adjacent federal waters (Table 2A.2). These include two Tenneco structures off Escambia County (Florida Panhandle)(1982), and two off Broward County (southeast Florida)(1985). An Exxon jacket off Franklin County (Florida Panhandle) (1980) is the oldest deployment. The most recent deployment was a Chevron structure in 1993 off Escambia County. Materials and transportation for all of the above projects were donated by the respective oil companies.

The most extensive evaluation of these Florida rigs as marine habitat, has been limited to a four day multi-institutional examination of the Broward County Tenneco II site (Seaman *et al.* 1987) There, 47 fish species from 20 families were noted with increased fish diversity observed on the grated deck portion of the platform as opposed to the solid deck. Recommendations were made for investigating methods for increasing complexity of the open interior spaces of these structures for biological purposes. Shinn and Wicklund (1987) reported on results of submersible video sweep observations of the above mentioned Broward County Tenneco structures (three parts in 100 feet and two in 200 feet). Shinn and Wicklund noted that "although the rigs were shrouded with fish, the fish were for the most part quite small. We suspect that hook and line and spear fishing tend to keep the populations of large edible fish to a minimum." They also observed noticeably fewer tropical fish on the solid deck platform plating than the platforms composed of steel grating.

The DEP artificial reef Dive Assessment Team made single brief field assessments of the three other Florida rig structures which are summarized in Table 2A.3. No formal evaluations of recreational or commercial fishing use have been conducted for these structures. Tenison (1985) reported on a fishing trip taken to the Escambia County Tenneco structure eight months after deployment. He stated more than 2,000 lbs of amberjack were caught in 1.5 hours of fishing.

The three large DEP areas off the western Florida Panhandle are permitted to accept obsolete oil/gas rig structures as artificial reefs, as is a fourth small site off Okaloosa County. Four panhandle counties have expressed an interest in these structures as artificial reefs. The present expense of barge transportation for available decommissioned shallow water Louisiana structures to western Florida presently makes procurement of these structures economically not feasible even in a joint state/multi-county project. This is based on current state and panhandle county funding levels for reef development.

Prefabricated Structures

Prefabricated units designed specifically to serve as artificial reefs in Florida first appeared as Japanese fiberglass reinforced tube reefs in 1981. After two years of monitoring, these reefs were reported to attract and support a more abundant and diverse fish population than the culverts of equal void volume. They were reported more attractive for pelagic and forage fish as well as reef target species (Sheehy and Mathews 1985).

Engineered artificial reef units are a small but growing component of Florida's artificial reef program. During the last five years no fewer than five other prefabricated concrete artificial reef designs have been utilized in 67 publicly funded reef deployments. Five additional designs have been used in research and mitigation projects. Most but not all units designed specifically for use as artificial reefs have proven to be stable in major storm events. Future requirements for engineering evaluation of modules prior to deployment due to the initial cost of modules will be required. Prefabricated units designed specifically for use as artificial reefs have focused on improving upon habitat complexity, stability, and durability, as well as provide a standard design for research and monitoring.

SUMMARY

Florida has had a long and diverse history of artificial reef development. Over the last 40 years there has been a shift in emphasis on use of any available material of opportunity which would serve as a three dimensional fish attractor without regard to the longevity or ultimate fate of the material to emphasis on non polluting, durable, and storm resistant items with a life expectancy of at least twenty years. A shift has also taken place during the last two decades from non governmental control of reef development to cooperative state/county/private partnerships where the local governments assume responsibility and management of the permitted reef sites.

Table 2A.2. Oil rig structures as artificial reefs off Florida.

NAME & DESCRIPTION	DEPLOY & DIVE DATES	DEPTH	RELIEF	DISTANCE OFFSHORE	LORAN TD's	LATITUDE LONGITUDE
Chevron (off Escambia County) Two separate platforms placed about 60 feet apart.	10/28/93 08/07/96	137 ft.	62 ft.	21 mi.	13361.9 47037.2	30 °04.244' N 87 °02.118' W (GPS)
Tenneco (off Escambia County) Two separate structures.	09/29/82	175 ft.		23 mi.		
North - Platform	n/a		25 ft.		13324.1 47014.1	30 °00.07 N 87 °05.28' W
South - Jacket	08/07/96		90 ft.		13324.5 47012.7	29 °59.731' N 87 °05.141' W (GPS)
Exxon (off Franklin County) One large 65 x 95 feet square jacket portion.	1980 06/06/96	106 ft.	65 ft.	26 mi.	14226.9 46246.7	29°17.720 'N 84°36.824 ' W (GPS)
Tenneco (off Broward County) Two separate platform structures;	10/ 3/85					
Shallow (3 oil rig decks)	n/a	105 ft.	55 ft.	1.6 mi.	14246.9 62122.7	25°58.04 'N 80°04.50' W
Deep (2 oil rig legs)	n/a	190 ft.	80 ft.	2.1 mi.	14247.3 62121.0	25 °58.03' N 80 °04.16' W

Table 2A.3. DEP dive assessments of three obselete oil rigs as artificial reefs.

On June 6, 1996, an assessment dive was conducted on the "Exxon Template," a submerged oil rig structure. This structure was deployed as an artificial reef in 1980, in 106 feet of water and is located about 26 miles Southeast of St. George Island (Franklin County, near Apalachicola). No signs of structural damage were observed. No debris field was evident on the bottom where portions of the structure may have fallen. This structure held many hundreds of fish and 9 species were identified in the very short dive time, although a fish census was not the objective of this dive. The fish observed appeared to be healthy and no dead fish were observed on the bottom adjacent to or inside the structure. The most abundant species were gray snapper *(Lutjanus griseus)* of all sizes and large schools of greater amber jack *(Seriola dumerili)*. Relative fish abundance data for this dive is listed in Table 2A.3a below.

Table 2A.3a. Relative fish abundance for the "Exxon Template."

ABUNDANCE	COMMON NAME	SCIENTIFIC NAME
Abundant (> 100)	gray snapper	*Lutjanus griseus*
Common (11 - 100)	amber jack great barracuda bar Jack tomtate grunt blue angelfish gag	*Seriola dumerili* *Sphyraena barracuda* *Caranx ruber* *Haemulon aurolineatum* *Holocanthus bermudensis* *Mycteroperca microlepis*
Occasional (2 - 10)	cocoa damselfish white grunt spot fin butterfly spadefish	*Pomacentrus variabilis* *Haemulon plumieri* *Chaetodon ocellatus* *Chaetodipterus faber*
Single individual	scamp	*Mycteroperca phenax*

On August 6, 1996, DEP performed assessment dives on the " Tenneco platform." This reef consists of two structures that lie in an north-south direction in 175 feet of water. This reef is located 22.8 nautical miles at a bearing of 150° from the Pensacola pass (Escambia County). The uppermost portion of the jacket (NW corner) lies in 85 feet of water, giving a maximum relief of 90 feet. The jacket was well-fouled with encrusting sponges, soft corals, and hydroids. All of the divers were surprised at the lack of fish biomass on the reef (see Table 2A.3b below), given its large dimensions (jacket: 130 feet long by 80 feet wide by 90 feet tall, deck: 50 feet wide by 72 feet long by 26 feet high). Twelve species were identified on this rig. A relatively rare species (banks butterflyfish, *Chaetodon aya*) was observed on this structure, which is not known to inhabit reefs shallower than 60 feet. Relative fish abundance data for this dive is listed in Table 2A.3b below.

The deployment of the "Tenneco platform" was the first use of a complete platform (deck and jacket) as an artificial reef in coastal U.S. waters. No damage to either the structure or the biofouling community was observed, most likely due to the depth of the structure, mass (deck-200 tons, jacket-300 tons), and lack of large, flat surfaces subjected to the hydrodynamic forces experienced during Hurricanes Erin and Opal. Even after 20 years of exposure to the marine environment producing oil and natural gas and an additional 17 years as an artificial reef, no significant structural degradation was apparent. Relative fish abundance data for this dive is listed in Table 2A.3b below.

Table 2A.3b. Relative fish abundance for the "Tenneco platform."

ABUNDANCE	COMMON NAME	SCIENTIFIC NAME
Abundant (> 100)	none	
Common (11 - 100)	greater barracuda blenny species	*Sphyraena barracuda* *Blenniidae family*
Occasional (2 - 10)	banks butterflyfish bicolor damselfish blue angelfish creole fish greater amber jack purple reef fish redspotted hawkfish reef butterflyfish yellowtail damselfish	*Chaetodon aya* *Stegastes partitus* *Holacanthus bermudensis* *Paranthias furcifer* *Seriola dumerili* *Chromis scotti* *Amblycirrhitus pinos* *Chaetodon sedentarius* *Microspathodon chrysurus*
Single individual	coney	*Epinephelus fulvus*

Also dove on August 6, 1996, was the "Chevron Rig." This structure is located about 20.7 nautical miles from the Pensacola Pass (Escambia County) in 137 feet o f water. It has only been in place as an artificial reef for three years, but has withstood two major storm events (hurricanes Opal and Erin, 1995) without evidence of structural or biological damage. Additionally, as this structure was acquired without any state or county funding, it is a welcome addition to the artificial reefs offshore of the western panhandle.

A greater abundance and diversity of both benthic and pelagic fishes were observed on the Chevron structure as compared to the Tenneco jacket. One possible explanation is that the Tenneco platform had recently been subjected to intense fishing pressure, whereas the Chevron platform had not been fished for a period of time. Most of the benthic species were below legal size, but several individuals of greater amber jack (*Seriola dumerili*) were some of the largest that Tom Maher had observed, with estimated weights of 90 pounds or greater. Large specimens of great barracuda (*Sphyraena barracuda*) up to 30 pounds in size were also observed.

There was a larger number of benthic fishes seen on the deck structure as compared to the jacket structure, as the former was much more complex in terms of cryptic cavities, which offer greater protection from predation. However, all of the species of benthic fishes observed were of sub-legal size. Another interesting observation was the large size (up to 5 inches) of the arrow crabs (*Stenorhynchus seticornis*) which were abundant throughout the structures. The fish census combined data from both portions of the structure due to their close proximity to each other (see Table 2A.3c below).

Table 2A.3c. Relative fish abundance for the "Chevron jacket rig."

ABUNDANCE	COMMON NAME	SCIENTIFIC NAME
Abundant (> 100)	none	
Common (11 - 100)	greater amber jack greater barracuda	*Seriola dumerili* *Sphyraena barracuda*
Occasional (2 - 10)	banks butterflyfish blue angelfish gag grey snapper purple reeffish red snapper scamp whitespotted soapfish	*Chaetodon aya* *Holocanthus bermudensis* *Mycteroperca microlepis* *Lutjanus griseus* *Chromis scotti* *Lutjanus campechanus* *Mycteroperca phenax* *Rypticus maculatus*
Single individual	creole-fish yellowtail damselfish	*Paranthias furcifer* *Microspathodon chrysurus*

Florida has an aggressive program of artificial reef construction where over three fourths of all the reef program funds have been used to meet that objective. The Florida state artificial reef program and many of the cooperating coastal local governments have begun to recognize that it is not enough to continue to put material in the water and say, "We've given something back to the fishermen. It has been good public relations. Let's go on to the next reef deployment." Comprehensive long range planning, measuring the consequences of reef development activity in the context of regional fisheries and ecosystem management issues, and determining the long term cost-benefits of this activity must be undertaken if Florida is also to be a leader in understanding what artificial reefs are accomplishing on a broad scale.

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SESSION 2B

GULF ENVIRONMENTAL ISSUES, PART II

Co-Chairs: Ms. Dagmar Fertl
Dr. Pat Roscigno

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Presentation	Author/Affiliation
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DISTRIBUTION AND ABUNDANCE OF MARINE MAMMALS IN THE NORTHERN GULF OF MEXICO: GOALS FOR THE GULFCET II PROGRAM

Dr. Randall W. Davis
Dr. Jeffrey C. Norris
Texas Institute of Oceanography
Texas A&M University at Galveston

The GulfCet II Program commenced in March 1997 as a continuation of the GulfCet I Program that was conducted from October 1991 to July 1995. The Texas Institute of Oceanography (TIO) will manage this 38-month research program and has incorporated the extensive expertise in marine mammal biology, bioacoustics, and oceanography from Texas A&M University at Galveston and the Department of Oceanography. Externally, we have teamed with partners from the National Marine Fisheries Service (NMFS) at the Southeast Fisheries Science Center for their expertise and experience in aerial and shipboard surveys of marine mammals. Our team also includes a statistician from the U.S. Geological Survey's Wisconsin Cooperative Wildlife Research Unit at the University of Wisconsin at Madison, and a scientist from the Colorado Center for Astrodynamic Research at the University of Colorado who has been modeling the Loop Current and eddies of the Gulf of Mexico using satellite altimetry.

The purpose of the GulfCet II program is to conduct studies on cetaceans in the northern Gulf of Mexico to determine their seasonal and geographic abundance and distribution, and to characterize their habitat in areas potentially affected by oil and gas activities now or in the future. This program will include systematic aerial overflights and shipboard surveys to document cetacean and sea turtle populations. This work will be accompanied by physical and biological oceanographic data acquisition designed to further characterize habitats and reveal cetacean-habitat associations.

The specific objectives of the study are the following:

1. Obtain data on patterns of distribution and minimum abundance of cetaceans using line-transect and acoustic survey techniques directly comparable to those used in previous surveys. This represents a continuation of surveys in the north-central and western Gulf that began during the GulfCet I program, and extends them into the Eastern Planning Area.

   To accomplish this objective, we will conduct aerial surveys and simultaneous shipboard visual and acoustic surveys using line-transect methods. We hypothesize that cetaceans are non-uniformly distributed (which we confirmed during GulfCet I) and that their distributions are related to variability in prey availability and physical oceanographic features in the marine environment.

2. Identify possible associations between cetacean high-use habitats and the ocean environment, and attempt to explain any relationships which appear to be important to cetacean distributions. To characterize habitat, we will use a multidisciplinary approach and include physical features (i.e., sea surface temperature, ocean depth, oceanographic features such as warm-core and cold-core eddies, and bottom topography) as well as biological features such as prey availability. We hypothesize that the distribution and abundance of marine mammals in the northern Gulf of Mexico are positively correlated with spatial and temporal variations in regional food stocks of zooplankton and micronekton. These food stocks are concentrated in nutrient-rich areas offshore from the Mississippi River, within cold-core eddies, or along the edges of warm-core eddies.

A goal of this program is to determine which cetacean species may potentially be affected by present and future oil and gas activities based on analyses of seasonal and geographic distributions of each species, habitat associations, and an interpretation of behavioral information collected during this study and from previous surveys. Evaluation will result in the determination of which species could potentially be affected, estimation of the proportion of the population this would represent, geographic and temporal degree of effect, and effect on critical activities (i.e., breeding, feeding, and mating areas).

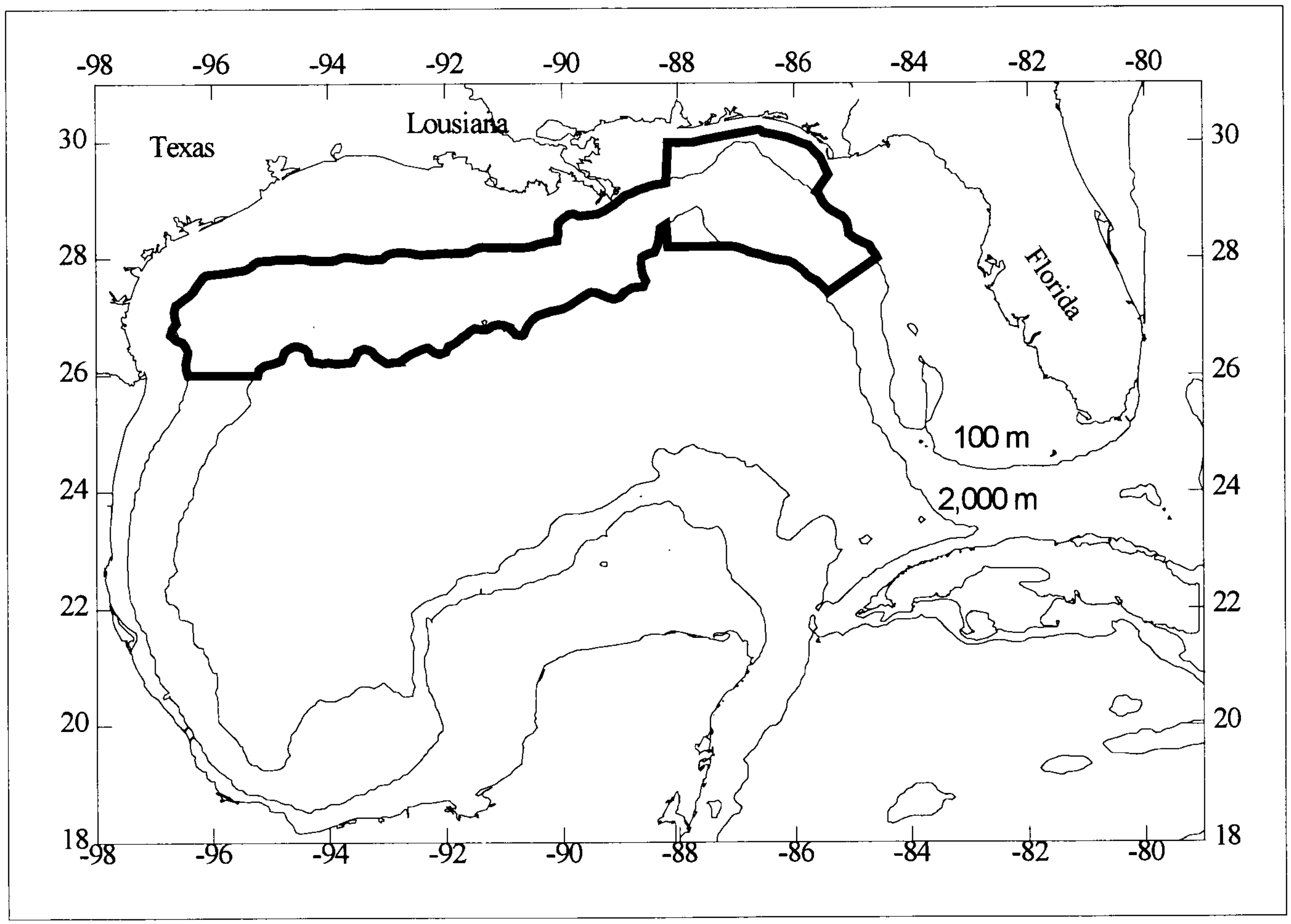

Figure 2B.1. Outline of the GulfCet II study area: the continental slope north of 26 degrees N between 100-2,000 and to 10 NM offshore near the Florida panhandle.

The study area will include the entire continental slope of the northern Gulf of Mexico (i.e., the continental slope north of 26í N latitude) between the 100- and 2,000-m isobaths (Figure 2B.1). We will conduct synoptic shipboard surveys of the entire study area using line-transects methods. We will focus additional shipboard and aerial survey effort on the Eastern Planning Area, which was not included in the GulfCet I program, and for which there is little information on cetacean abundance and distribution. Finally, we will conduct focal shipboard studies (e.g., south of the Mississippi River delta and along the edges of eddies) in order to better understand the effect of oceanographic features and prey availability on cetacean distribution.

Dr. Randall W. Davis, Program Manager, is head of the Marine Biology Department at Texas A&M University, Galveston. His field experience is 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. He received his Ph.D. in physiology from the University of California, San Diego in 1980.

Dr. Jeffrey C. Norris, P.I. - Acoustic Surveys, Texas A&M University, Galveston, has been active in the study of mammal bioacoustics since 1977. He has studied marine mammals in terms of vocal production and reception. His research interests include animal communication, acoustics, marine mammals, primates, and conservation biology. Dr. Norris received his Ph.D. in wildlife and range sciences from the University of Florida in 1990.

MARINE MAMMAL STRANDING IN FLORIDA: THE RESPONSE BY THE DEPARTMENT OF ENVIRONMENTAL PROTECTION

Dr. Scott D. Wright
Marine Mammal Pathobiology Laboratory
Florida Marine Research Institute
Department of Environmental Protection

The Florida Department of Environmental Protection maintains a response to recover marine mammal carcasses, especially manatees, statewide. To accomplish this task the program includes 14 staff members located within 5 field locations around the state. Whenever practical, carcasses are transported to a central necropsy facility (Marine Mammal Pathobiology Laboratory) located in St. Petersburg. Data collected from this program is especially useful for management of manatees.

The State began its commitment to carcass recovery of marine mammals in 1985 when it accepted the responsibility for manatee carcass recovery from the United States Fish and Wildlife Service. Over the ensuing 11 years, the State has expanded the program to include 5 field stations and sufficient staff as well as a necropsy facility dedicated to manatees and other marine mammals. The MMPL is staffed with a pathologist and anatomist/functional morphologist along with support staff. Extensive data is collected and maintained in a number of computer-based systems, which coupled with the data collected by the USFWS represents over 22 years of manatee mortality information. Data collected on other marine mammal mortalities are archived and sent to the Southeastern Marine Mammal Stranding Network headquartered at Sea World in Orlando.

At the MMPL there are several long-term collections of various marine mammal tissues. While the majority of the material is from manatees, there are samples collected from other species as well. As a matter of routine, we collect and freeze liver, kidney, and blubber from every mortality of appropriate body condition. These tissues are frozen in vacuum- sealed, heavy-duty plastic bags and inventoried on computer. We also have a wet fixed tissues collection, trimmed tissues in cassettes (blocks), and slides (stained H&E). We maintain an osteological collection for voucher and research. During the last 8 years, we have established a microbiological database of clinical isolates from manatees, and we have established a serum bank of sera collected from wild manatees from around the state. Over the last two years, we have established an epithelial and fibroblast cell lines from manatees, and we are developing virus isolation and characterization capabilities.

Because we have developed the necropsy program over the last 11 years, we were in a better position to respond to a recent manatee epizootic this past winter. Indeed, this single event represented a challenge to the program, which was already enduring the greatest level of manatee mortality experienced during any year.

From early March to mid-May 1996 at least 158 manatees died along approximately 80 miles of the southwest coast of Florida. At approximately the same time, there was a significant algal bloom largely composed of *Gymnodinium brevis* dinoflagellates in the same geographic area as the manatee epizootic. These algae produce a biotoxin, known as brevetoxin which is neurotoxic and can be fatal to fish, mammals, and birds.

The appearance of the carcasses at necropsy suggested the animals were suffering a rapid death, and there was a substantial consistency in the appearance of lung and upper respiratory lesions. A microscopic examination of tissues supported rapid death, but overall there was a limited inflammatory response. Moderate brain lesions were found along with significant inflammation in the nasal mucosa. These findings were not compatible with the typical findings described with brevetoxin intoxication. Furthermore, during a previous manatee epizootic in the same area in 1982, many of the animals had ingested sea squirts which were believed to be the source of concentrated brevetoxin. However, during the current epizootic, very few manatees had ingested sea squirts. As a result, and to ensure that all possibilities were examined, appropriate tissues were sent to many collaborators to determine if there was evidence of an infectious agent involved in these mortalities.

We immediately launched into a simultaneous investigation for various possible causes of the mortalities. Well before the event was over, we had begun analyses for infectious agents, biotoxins, and toxicants. Within a relatively short time period and with extensive collaboration, we had determined that an infectious agent was not a likely cause of this event. This conclusion was supported by the progression of mortalities throughout the event. That is, carcasses appeared throughout the entire geographic range of the involved area throughout the entire time of the event. This strongly suggested that the mortalities did not spread as they might if an infectious agent was involved. Moreover, the mortalities declined at the same approximate time as the red tide in the area subsided.

Dr. Dan Baden and his staff at the University of Miami, examined stomach contents and various tissues for the presence of biotoxins. Because there are many potential biotoxins in Florida waters (approximately 30), analyses were conducted to assure that all potential biotoxins were tested. Dr. Baden isolated brevetoxin in stomach contents that was at a concentration 10-fold higher than controls. He also found brevetoxin in various tissues (liver, kidney, lung) and performed mouse bioassays utilizing extracts from affected manatees, further confirming brevetoxin toxicity. Drs. Baden and Greg Bossart developed an immunoperoxidase assay that visualizes brevetoxin in fixed tissues. With this assay, brevetoxin was revealed in brain tissue as well as all the other tissues. During the last month of the event (April), four live manatees were recovered that had clinical signs compatible with those described from brevetoxin intoxication. All four animals survived and have been released back into the wild.

Through extensive analyses and collaboration along with a process of elimination, it appears that brevetoxin is a primary component of the manatee mortality event. Many questions remain. We know that manatees are exposed to brevetoxin repeatedly throughout their lives in southwest Florida. The significance of brevetoxin in tissues needs to be evaluated against tissues from previous mortalities in the same area at an earlier time. Investigation of the possible inhalation route of exposure to brevetoxin is necessary, as this may represent a whole new avenue of exposure. There remains the possibility of a second as yet determined agent/s in this event, as carcasses were recovered from areas well away from the concentrations of red tide and weeks after the red tide had subsided.

Press coverage of this event has brought an immense public attention to manatees. At the same time, we have gained a great deal of information about manatees in a shorter period of time largely as a result of the tremendous response of the scientific community. The level of cooperation and eagerness to assist in the investigation on the part of government and private agencies as well as the concern expressed by the public, was responsible for the high level of response to this event.

Dr. Scott Wright has worked at the Florida Marine Research Institute for the past 8 years and serves as a Research Scientist and the Director of the Marine Mammal Pathobiology Laboratory. His areas of research interest are comparative pathology and diseases of wild animals. Dr. Wright received his B.A. in biology from the University of South Florida and his Ph.D. in pathology from the University of Connecticut. He completed postdoctoral studies in wildlife diseases at the University of Florida before taking his present job.

EFFECTS OF NOISE ON MARINE MAMMALS AND SEA TURTLES

Dr. Bernd Würsig
Texas A&M University

Contrary to the 1950's book *The Silent World* by Jacques Yves Cousteau, the oceans are not silent at all. There are low frequency infrasonic (below human hearing) rumblings from earthquakes and giant breakers on islands and distant shores; sounds of wind, waves, and rain of somewhat higher but still low frequencies; crackling of ice in arctic and antarctic latitudes, and a cacophony of biological signals wherever you go (Wenz 1962) . Water transmits sounds very efficiently, and without forests and mountains to absorb them, sounds in mid-depth waters travel unimpeded before they decay after many miles. This low attenuation is especially pronounced for infrasonic and other low frequency sounds because the long wavelengths of these sounds lose energy only gradually. Indeed, waves of sound from even a minor earthquake off Japan, for example, can be heard underwater off California about 1.5 hours later. The underwater world only seemed silent to Cousteau because our ears are adapted to hear sounds in air, not water, and we need specialized equipment to detect this underwater wealth of noises.

Because sound transmits so well underwater, animals have made it a major channel of passive listening and active communication. Shrimp on the bottom create clicking sounds for territorial spacing and advertising themselves to potential mates, fishes grunt and moan to the same ends, as do whales and dolphins *par excellence*. The baleen whales, especially fin and blue whales, are now known to communicate with infra sound over distances of at least several hundred kilometers. Possibly, they also use their low frequency moans to detect echoes bouncing off the bottom, and reverberating back from islands and continental slopes in order to navigate (Clark 1996). Toothed whales (the sperm whale, beaked whales, and dolphins and porpoises) use human-audible whistles and click sequences to communicate, and ultrasonic (above human hearing) clicks to echolocate. They thereby receive fine-scale information about their environment: they detect prey and predators in front and below them, and they can "see" by returning echoes even in the darkness of night and depth.

The same excellent sound transmission capabilities of the sea that favor non-biological and biological sound transmission also pollute the oceans in our modern world. There is now a low frequency hum of noise wherever we go on earth made by huge ships that ply their lanes as they move from port to distant port and accentuated by loud sporadic bursts of sounds from explosions, seismic surveys to map bottom stratigraphy, and oil and gas exploration and development activities. Even researchers get into the act as they use loud, low frequency sounds to measure pressure profiles in the oceans and determine temperature profiles and gradients by measuring speeds of sounds over thousands of kilometers (Munk 1990). This giant and ever-increasing background noise is now believed to seriously affect large whale communication and navigation capabilities, and may be affecting the higher-frequency-hearing toothed whales as well. Low frequency noises may also be affecting the hearing of sea turtles, which are attuned to hearing at about 100 to 1,000 Hz (Ridgway et al. 1969). However, we know virtually nothing of how sea turtles may be processing sounds that they apparently can detect.

Although we know some beginning details about short-term and regional effects of noise on marine mammals, we know little about long-term effects, including possible displacement of animals from intensively loud areas of sea. This gap in knowledge is especially evident for the Gulf of Mexico, where about thirty species of marine mammals and sea turtles reside. At present, we need to look towards experiments with other than Gulf of Mexico residents in order to extrapolate to potential reactions by whales, dolphins, and sea turtles to human activities. While experimental work on disturbance reactions has now been conducted on a suite of marine mammals outside of the Gulf of Mexico, some of the best examples come from gray and bowhead whales.

Gray whales that were subjected to loud airguns used for seismic surveys reacted clearly when these sounds were at or above 160 dB (re 1 uPa), a very loud intensity. The whales, which were on northward migration off California in spring, would generally slow their travel, turn away from the source of sound, increase respiration rates, and even seek an area of sound shadow created by underwater topography. Whales reacted at distances that would correspond to a full seismic surveying array about 5 km away (Malme et al. 1984). Mothers and calves showed especially strong and clear reactions. It is not understood how these short-term reactions translate to long-term effects, but one may surmise that if there is much noisy industrial activity over a large area, the whales could change some aspects of their migratory routes. If, for example, mothers and calves move offshore more than usual, the recently-born calves would likely become more prone to killer whale attacks than in the normally very shallow and nearshore migratory corridor.

Bowhead whales during summer in the Beaufort Sea also reacted to seismic pulses made by an airgun array with changes in respiration and surfacing/dive patterns evident when the array was between 5 and 10 km distant, and stronger when less than 5 km. Number of respirations per surfacing decreased during disturbance, and durations of surfacing and dives also decreased. In other words, disturbed whales cycled through their surfacing/dive pattern faster than when not disturbed (Richardson et al. 1986). As was found in the gray whale studies, bowhead whales also changed orientations away from the source of sound when a single airgun fired at ranges up to about 4 km distant; a full seismic array would have affected the animals at even greater distance (Richardson et al. 1986). Sounds from moving vessels and airplanes also resulted in startle responses and in some respiration shifts. For example, during a study of potential airplane disturbance, bowhead whales strongly decreased their respiration intervals when the observation plane descended from 610 m (2000 ft) altitude down to 457 m (1500 ft), and then to 305 m (1000 ft; summaries by Richardson et al. 1995).

No such data exist for toothed whales. Sperm whales, who use clicks for communicating, identifying each other, and probably echolocation, are sensitive to roughly the same frequency sounds as humans. The smaller toothed whales, the dolphins and porpoises, rely on mainly mid-range sounds from the lower kHz, up to 100 kHz and higher in the ultrasonic range (Thompson and Herman 1975). Since they tend to be less sensitive to the very low frequencies where so much of industrial noise pollution resides, we guess, but with scant data, that dolphins are generally less affected than the baleen whales by most human-made noises.

When we consider the potential significance of noise impacts, we need to consider area affected versus area available to the animals. For example, if we ensonify a bay that is critical to calf rearing, and the animals either change their behavior or leave the area, we have had a huge impact. If we ensonify the same or an even greater area, but where animals pass unconstrained from area to area to feed, breed, or migrate, then our impact is likely to be minimal. But even in the expanse of ocean, we must learn enough about marine mammal lives in order to gauge potential disturbance effects. In the Gulf of Mexico, for example, certain areas near shelf waters appear to be important sperm whale habitat. If a giant oil rig, with its associated support vessels and construction and operating noises, is placed in such an area, it may have an important negative effect by chasing away whales. On the other hand, the effect may be minimal. In any case, at this time we are in the unfortunate position of not knowing.

Whales and dolphins are bright social mammals, and they—as we humans too—can habituate to sounds and other forms of potential disturbance as long as the stimulus is not followed by danger (in other words, whales that are hunted tend to become sensitized to boats rather than habituated). We expect that predictably occurring noises, even when rather intense, can become an ignored stimulus as whales or dolphins habituate to the noises. They simply may not react after a while but go about their normal business of making a living. There are two major pitfalls here, though. First, loud noises may mask communication and prey-acquisition sounds (such as passive listening for fish); and even though the animals habituate to them behaviorally, food or mate finding and calf rearing may be compromised. Second, we do not know when animals habituate versus when they simply behaviorally tolerate the noise pollution. Toleration implies the possibility of long-term physiologic damage due to increased adrenalin action, lowered immune responses due to stress, and other factors of physiological impairment (Berglund and Lindvall 1995).

Humans can attempt to minimize noise impacts by mitigation techniques. Equipment can be designed to run as silently as possible, hourly and seasonal timing can be adjusted relative to whale and dolphin presence and behavior patterns, and routes to be taken for supply and other vessels can avoid heavily used mammal areas. Recently, loud percussive pile driving noise during construction an oil docking facility was shrouded by a bubble screen of compressed air forced out of a set of tubes surrounding the activity (Jefferson *et al.* in prep). The bubble netting decreased noises from pile driving by two to three times the unscreened noise.

To ascertain noise-related problems, dedicated research has to be conducted on mammals that are in the vicinity of loud noises. Such work can be done by ship, from offshore platforms, from airplanes, by hydrophone recordings underwater, and by conventional and satellite tracking of marine mammals during experimental or ongoing work (summary by Richardson and Würsig 1995). We may well find that in many cases, both the activity and the mammals can co-exist with no or only slight operational modifications. In those instances where more difficult measures need to be taken, we must prepare ourselves through research designed to describe short and long-term reactions to the human activities.

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Dr. Bernd Würsig has taught at Texas A&M University, Galveston, for the past 7 years. He is a professor in the departments of Marine Biology and Wildlife and Fisheries Sciences and director of the Texas A&M Marine Mammal Research Program. His main areas of interest are in whale and dolphin behavioral ecology and human effects on wild marine mammal populations. Dr. Würsig received his B.S. in zoology from Ohio State University and his Ph.D. from the State University of New York at Stony Brook.

GULF OF MEXICO OYSTER-BORNE DISEASES

Mr. Thomas L. Herrington
Associate Director
Gulf of Mexico Program
U.S. Food and Drug Administration

In late fall of 1993, and again in 1994, there were multistate outbreaks of viral gastro-enteritis associated with the consumption of oysters. Over 200 persons who consumed oysters fell victim to acute gastroenteritis. Raw, steamed, or roasted oysters had been consumed in a variety of settings, ranging from individual consumers to a large three-day festival. Oysters were the only food associated with illness. Illness attack rates ranged from 43% to 100%. Oysters from the outbreaks were traced to the implicated harvest areas. The state health departments of Louisiana, Maryland, Mississippi, North Carolina, Florida, and Texas had notified CDC of several outbreaks occurring in their states. The Louisiana Department of Health and Hospitals identified the Grand Pass and Cabbage Reef harvesting areas off the Louisiana coast as the source of oysters in one of the scenarios, and Apalachicola Bay was identified as the harvest area in another.

On February 23, 1996, Black Bay, Lake Fortuna, and Lake Machias in Louisiana were closed by the Louisiana Office of Public Health due to an oyster-borne illness outbreak involving some 233 persons. The epidemiological evidence indicated that oyster harvesters had harvested oysters from Black Bay (some around Stone Island). The harvesters had been working in the south Black Bay area during January and February when the implicated oysters were harvested. The only possible sources of human fecal material cited in the investigation were fishermen and oil rigs. Fecal samples from individuals involved in the outbreak showed the causative agent to be a Norwalk-like virus. An illness outbreak among oil rig workers in Black Bay occurred at the time that the oysters that caused the illnesses were harvested. Serum samples from the oil rig workers also found elevated titers for Norwalk-like viruses. Further investigation found that the source of oyster contamination may have been sewage effluent from an oil rig on which there were ill employees.

The National Shellfish Sanitation Program (NSSP) sets forth the guidelines to which all states and countries must adhere in order to ship within the United States. To meet the bacteriological guidelines for approved areas, the median of samples collected from each station cannot exceed 14 fecal coliform most probable number/100ml (f.c.) nor can 10% of the samples exceed 43 f.c. To understand how strict this bacteriological criteria is, compare this guideline to that for swimming waters. The criteria for swimming waters is 200 f.c. To look at it another way, it takes approximately 8 million cubic feet of coliform free dilution water to dilute one person's fecal waste in one day to meet these guidelines. In other words, it would take an area the size of 13 football fields 13 feet deep or approximately 60 million gallons of coliform free dilution water to dilute one person's waste dumped overboard in one day. That's a lot of water, and the water that is generally available for dilution is not coliform free.

There are other classifications that are required by the NSSP. An area may also be classified Conditionally Approved, Restricted, Conditionally Restricted, or Prohibited. Each classification has specific guidelines that it must meet. The NSSP guidelines state that monitoring harvest waters for fecal coliform is required from each station once a month in Conditionally Approved areas and as little as five times a year in an Approved area. However, a detailed sanitary survey of each growing area is mandatory for any classification except Prohibited, and the surveys are required to be kept current. Fecal coliform results from both areas during the illness-causing oyster harvest period indicated that the water quality met the guidelines.

The NSSP also requires that each sack of oysters be tagged indicating, among other requirements, from where the oysters were harvested. Trace-back procedures conducted by those state health departments and FDA confirmed those areas in Louisiana and Florida. No insanitary handling practices were observed in any of the establishments nor in areas where the oysters were handled or held.

So, if these all met the fecal coliform guidelines, how did the oyster become contaminated? The Louisiana and Florida outbreaks were the first where overboard discharges were implicated. In the Louisiana outbreak, indicator data was obtained by the Northeast Seafood Laboratory. The key indication was that this was not a case of sewage contamination as would occur with sewage from a wastewater treatment facility failure or illegal harvest. The reason? There were no male-specific bacteriophage found in the oysters . Male specific bacteriophage are infrequently found in fresh human feces (<10). Nor were fecal coliform or other indicators found in any significant numbers in the shellfish. One oyster sample contained 1700 fc/100 grams. Interestingly, experience in other outbreaks dictates that the male-specific bacteriophages should be higher, but they were only found at the level of assay detection, which is 4/100 grams. Aerobic plate counts were found to be relatively low at 5.5 x 10^9 /gram. Due to the fecal coliform densities determined, it can be suggested that no appreciable depuration had taken place from the oysters since routinely fecal coliform densities can be reduced >99% within 48 hours. Microbial analyses in conjunction with personal interviews of harvesters strongly suggest that the contamination was direct fresh fecal discharge into the growing area. Epidemiological investigation supported by molecular similarity of the viral nucleic acids (genome) extracted from the stool specimens of infected patients established a significant relationship between those cases and the oysters from the harvest sites.

Requirements for the collection of samples are based on the shoreline pollution sources survey, both actual and potential, and the hydrography of the area samples. In other words, specific actual identified pollution sources on land, correlated with meteorological events and

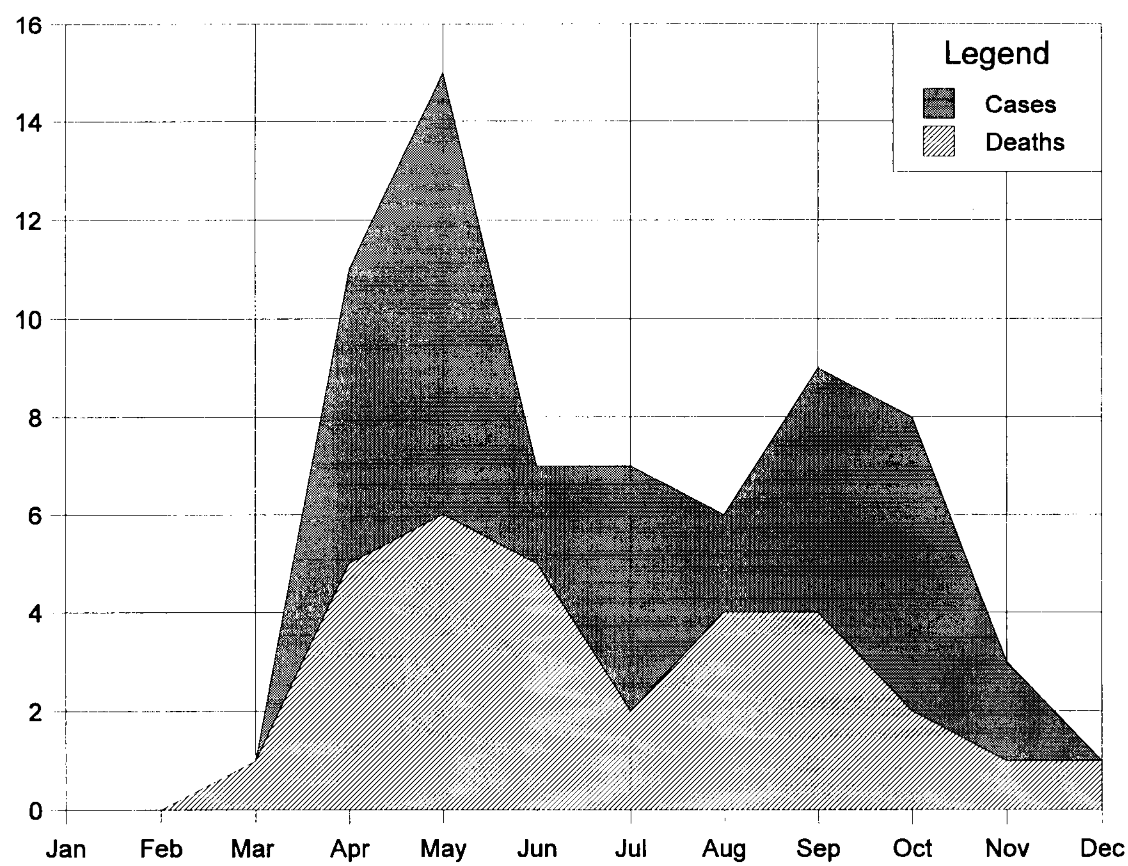

Figure 2B.2 *Vibrio vulnificus* cases/deaths by month for years 1992-1995.

subsequent transportation of the fecal material by water currents and movement, indicate when and where to collect samples.

Epidemiological investigations by CDC and FDA and thorough interviews of the harvest vessel crews in the Louisiana waters found that direct fecal contamination and vomiting occurred overboard in the harvest area by at least one member of the crew. The one individual admitted to having diarrhea and direct overboard discharge. Further, the harvest area, as in nearly all Gulf states' shellfish harvest areas, was a relatively shallow body of water and at the time of harvest had little tidal movement. Likewise, findings suggest that the Florida oysters may have become contaminated by sewage dumped overboard by recreational and commercial boaters in the area.

The NSSP manual of operations states that harvesters are not to dump waste overboard. It also states that the state, upon need, shall conduct an educational program to teach boaters that fecal waste dumped overboard can and has caused disease, and that each vessel should contain any such waste. Additionally, in 1996, FDA, an issue was passed at the Interstate Shellfish Sanitation Conference (that governing body of the NSSP), to require vessels to have an approved waste receptacle on board to contain fecal waste. It then becomes necessary that pump-out facilities be provided to download fecal material contained on board these harvest vessels.

The U.S. Fish and Wildlife Service has the responsibility under the Clean Vessel Act to provide monies to each state for the construction, renovation, operation, and maintenance of pump-out stations for holding tanks and dump stations for portable toilets. The Environmental Protection Agency has the authority to designate certain estuarine areas as no- discharge zones provided those areas meet certain criteria. If approved or conditionally approved shellfish harvest areas had a sufficient number of pump-out facilities, those areas would probably meet the guidelines to be established as no-discharge areas. This designation would be an important step in halting sewage entering shellfish waters from boats and causing subsequent illness. What can you do to help carry out this designation and prevent illnesses?

In summary, direct discharge of fecal materials overboard has been shown to cause large disease outbreaks and makes ineffectual the national guidelines designed to protect consumers from shellfish associated diseases. Additionally, it negates the millions of dollars spent annually to conduct such strict sanitary programs and costs the taxpayers thousands of dollars in medical bills. I believe that these outbreaks will continue until positive steps are taken to contain all vessel wastes and shellfish harvest areas are designated as no-discharge zones.

But, all Gulf of Mexico shellfish-borne illnesses are not linked to pollution. In 1976, *Vibrio vulnificus*, a ubiquitous gram-negative marine bacterium, was first identified and described at the Centers for Disease Control (CDC). It was initially referred to as the halophilic *Vibrio X*, and later as the lactose-positive vibrio. In 1979, a CDC epidemiologist described the clinical syndromes and epidemiology of a *Vibrio vulnificus* infection and gave the bacteria its current name. There are two clinical syndromes of oyster-borne infection:

1. Primary septicemia: Occurs when bacteria invade the bloodstream and are disseminated throughout body. Characterized by fever and chills, usually accompanied by nausea, vomiting, and diarrhea. A sharp drop in blood pressure commonly occurs. >50% of patients die. More than 95% of patients with primary septicemia have a pre-existing chronic illness, usually involving the liver.

2. Gastroenteritis: Syndrome consists of vomiting, diarrhea and abdominal cramps. Patients with gastroenteritis may require hospitalization but very rarely die.

Since 1979, there have been reported an average of 16.5 illnesses and 9.3 deaths per year and from 1989 to date there have been approximately 139 raw oyster-borne illnesses reported to the FDA Southeast Regional Office. Of these reported illnesses, 72 resulted in death attributed to *Vibrio vulnificus*. The average morbidity and mortality during this period was 17.6 illnesses and 9 deaths per year. The victim is typically male, white, and over forty, and has a pre-existing chronic illness, which is usually a liver disease or alcoholism (82.9% known immunocompromised). This susceptibility may be a function of the victim's blood sera having transferrin >65% saturated with iron. The average meal size is approximately one dozen raw oysters on the half-shell. The average meal size ranges from one oyster to four dozen oysters.

Illnesses have been reported from 18 states (TX, MS, AL, LA, FL, NY, TN, OK, CA, GA, SC, MD, NC, WI, IL, MI, OH, KY). The meals resulting in the above illnesses were consumed in 13 states. However, with the exception of two reported clam-related cases, only oysters harvested from the Gulf of Mexico have been epidemiologically implicated. Of the total number of reports, 66% have been traced back to point of harvest. The estimated percentage of illnesses by originating harvest state:

Florida-47%
Texas-11%
Louisiana-36%
Alabama-6%
Mississippi-0% (no summer harvest)

While the majority of the illnesses and deaths occur between 1 April and 31 October (Figure 2B.2), one study found that 91.9% of the deaths occurred during this time period. It is not certain if the cause of the vibriosis is a function of the virulence of the organism, different strains (capsulated) being more virulent, or the fact that there are higher numbers occurring in the warmer months. Reports indicate that *Vibrio vulnificus* was found in samples collected from waters with salinities between 9 and 32 ppt, and salinities of 16 ppt being most favorable during the warmer months.

Heat has a detrimental effect on *Vibrio vulnificus* . The bacteria is generally found in highest densities in waters when the temperature exceeds 20° C (68° F). Additionally, multiplication of the organism may occur in shellstock oysters when stored above 13° C (55° F). While temperatures above 45° C (113° F) kills the organism, simply heating oysters for 10 minutes in water at 50° C (122° F) reduces *Vibrio vulnificus* to a non-detectable level. Freezing at -20° C (-4° F) does not eliminate the organism but does reduce the number of culturable cells.

The average number of days between harvest and consumption is 5.7 days and ranges between 1 and 20 days. One study of commercial shellstock Gulf of Mexico oysters shipped in interstate commerce found that during the period of December through mid-March, the median was <3 MPN/g. During the period of mid-March through November, the median value was 45,000 MPN/g. The authors suggested temperature abuse after harvest as a contributing factor. Attempts to cleanse shellfish through a depuration process have been ineffective in eliminating *Vibrio vulnificus*.

In summary, Gulf of Mexico oyster-borne illnesses have occurred and continue to occur as a result of oysters containing pathogenic viruses and bacteria being consumed. While the virus pollution is definitely caused by man, it is uncertain what role pollution or nutrient enrichment has in the occurrence of virulence of *Vibrio vulnificus*.

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Tom Herrington is the Associate Director of the Gulf of Mexico Program for the U.S. Food and Drug Administration (USFDA), where he serves as liaison and public health advisor. Previously, he was the Senior Regional Shellfish Specialist for USFDA, where he assists and evaluates states and foreign countries (Australia and New Zealand) in molluscan shellfish and marine biotoxins programs.

AN ASSESSMENT OF THE INTERACTIONS OF MIGRATING BIRDS AND OFFSHORE PLATFORMS—A CALL FOR INDUSTRY COOPERATION

Mr. Donald Norman
Norman Wildlife Consulting

Anyone who has been offshore during the spring and fall in bad weather may have noticed hundreds of small birds flying around and often landing on offshore platforms and boats. At the 1995 Minerals Management Service Information Transfer Meeting, a symposium was held on the status of neotropical migrants, those landbird species that migrate between North America and Central and South America every spring and fall. Bird migration over the Gulf of Mexico has been a major area of research, and the outcome of the symposium was that studies on offshore platforms might improve the understanding of migration and could be linked with monitoring techniques, such as the use of doppler radar, to help provide an annual evaluation of migration "health" (Gauthreaux 1996).

The following issues were discussed:

- Do the platforms play a positive or negative role for the species migrating across the Gulf?
- Can the dynamics of arrival-departure, mortality and occurence be related to other migration studies?
- How does adverse weather impact migrants? Do lights on the platforms attract birds?
- Can these structures provide a collection point for the study of the physiological stress of migration and monitoring for pesticide exposure or other environmental contaminants?

Through a program funded by MMS at the Coastal Marine Institute at LSU, the Museum of Natural Science has been funded to initiate such a research program (Remsen *et al.* 1996). This presentation at the MMS ITM outlined some of the goals of the project and placed its importance in the conservation effort to protect migratory landbirds.

THE DECLINE OF NEOTROPICAL MIGRANT PASSERINES

For several decades scientists have been concerned about the decline of many of the migrating species, but only recent quantitative studies have documented the decline of many species (Robbins *et al.* 1989, Gauthreaux 1992). This decline prompted the formation of a large interagency initiative called Partners in Flight (PIF). PIF has resulted in the design of standardized research techniques, and has sponsored research to assess the long-term survival of migratory bird populations. These projects are working towards an improvement in the management of public and private lands (Hagan and Johnson 1992, Finch and Stengel 1993). The major focus of research on the cause of the decline has been habitat destruction, nest predation, and cowbird nest parasitism (Askins 1995, Robinson *et al.* 1995). To date, little research has evaluated migration itself as a cause of decline of neotropical migrants (Rappole and MacDonald 1994).

TRANS-GULF MIGRATION

In the 1940s, there were doubts about trans-Gulf migration, but studies by George Lowery at LSU provided conclusive evidence (Lowery 1946, Williams 1947). Studies have since documented large numbers of birds on boats in the Gulf in spring, as well as in the fall (Paynter 1953). Students of Lowery continued to study migration, resulting in an understanding of the evolution of migration patterns (Able 1972, Gauthreaux and Able 1970). Despite the growing presence of offshore platforms in the early 1970s, research offshore never occurred. Now with new platforms planned even farther offshore, the presence of birds on these platforms can provide an opportunity to study the migration phenomena.

HISTORICAL INFORMATION ON PLATFORM INTERACTIONS: THE NORTH SEA GAS FLARES

The interaction of migrants with offshore platforms was first studied in the North Sea. Concern about the attraction of birds to gas flares on drilling platforms was first reported in the late 1970s (Bourne and Merrie 1978, Bourne 1979, Sage 1979, Hope Jones 1980). The situation occurs in fall during foggy weather, when large number of Redwing thrushes (*Turdus iliacus*) and starlings (*Sturnus vulgaris*) are migrating from the

Scandinavian peninsula to the British Isles. Few detailed studies were made, but it was documented that some birds did perish by being attracted by the light. This has long been a problem at lighthouses. Current studies conducted on the platforms have found that mortalities occurring on the platforms appear to be mostly birds that are landing upon the platforms in poor condition, as opposed to landing in the ocean, where they would instantly perish (Personal communication, Peter Cosgrove, corresponding secretary of the North Sea Bird Club). This is what we anticipate in our studies in the Gulf. Because of the large number of platforms in the Gulf, over 3700, we would like to determine what percentage of the migrants are grounded in adverse weather and estimate the effectiveness of the platforms in reducing major mortalities.

PROPOSED RESEARCH OBJECTIVES AND PROJECT DESIGN

Anecdotal evidence of massive mortality of landbirds on platforms is typically associated with adverse weather conditions. It is presumed that birds on the platforms died after they landed upon the platforms to rest, and the presence of the platforms may have actually assisted the survival of some migrants, especially during spring cold fronts. Observers will be stationed on platforms before, during, and immediately after adverse weather. How many birds actually arrive and depart platforms remains unknown and is also a major objective of this study. The scattered location of platforms south of Louisiana offers an opportunity to observe migration dynamics and to collect a subsample of the birds that die upon migration, which has never been sampled in such a statistically and well designed manner. By quantifying the birds collected, information on the "health" of the migration can be collected. This data will be compared to dozens of ongoing breeding and wintering studies to determine if the species of concern are having disproportionately higher mortality than species without declining populations.

To study the interaction of birds on the platforms, professional ornithologists with behavioral observation skills are required. With over 75 species in a multitude of plumages, observers need to be well trained, especially to correctly identify birds just briefly using platforms. Fortunately, the LSU Museum has such observers, and a stint on a platform will be a relaxing adventure compared to living in a tent in Peru for two months without a shower. The proposed design will place one observer continuously on 6 platforms for the entire spring and fall migration, a total of 8 weeks in the spring and 10 weeks in the fall. The location of the platforms will be determined by their availability by cooperating oil companies. As of the meeting, Phillips, BPX, Mobil, and Exxon have provided a list of available platforms.

Once the program is in place and operating, the data will be coordinated with doppler radar observations along the coast. It is also anticipated that many employees working offshore may be interested in assisting in the monitoring of their platform. Training programs will be instituted and individuals trained to be sub-permittees will be allowed to salvage any dead birds found on platforms. Other observers can use photographs or notify the observers on platforms to retrieve species by visiting other platforms.

CAN PLATFORMS PROVIDE AN IMPORTANT FIELD SAMPLING DESIGN?

The presence of these platforms as discrete sampling points in time provides an incredible opportunity for sampling migration. Recent studies on energetics in many waterfowl have shown that body condition prior to breeding is related to breeding success, and if birds are initiating migration in poor condition, it would be expected that those birds would have trouble making the migration across the Gulf. It would be relatively easy to set up regular collections of birds on platforms to document these patterns. Systematic studies at other remote "islands," such as the Farallon Islands off San Francisco, or in coastal woodlands (Rappole and Warner 1976) have resulted in important studies. Only by documenting which birds are actually present on the platforms can these questions be answered. The relationship between these data collected and ongoing radar, coastal, and inland studies may provide important species-wide data on a scale not possible once birds disperse to their breeding grounds. This information will be related to other continental studies, such as the Breeding Bird Survey, that indicates which species are declining.

WHAT FACTORS ON PLATFORMS CAUSE PROBLEMS TO MIGRATING BIRDS?

What are the impacts of lights on large platforms? Are birds attracted to the lighted platforms? In typical weather, spring migration initiates at nightfall from Central America, reaching the Gulf Coast during the late morning, passing over platforms over 2000 feet in the air. In adverse weather, lights may be helpful. In the fall, the impact of offshore platforms to provide a landing location during the overshoot of the coast, as well as during storms, will also be evaluated. Timing of arrival and departure of birds on platforms, behavior of birds on platforms with different types of lighting, and condition of birds will help address these questions. Studies of the numbers of birds on the coast, linked with the doppler radar data, will help address some of the dynamics of migration during adverse weather.

Other issues observed during the studies may result in easy improvements for survival of migrants landing upon platforms. Recent studies have shown that dehydration may be an important issue (Moore and Simons 1992). Providing water on the platforms may be of additional benefit to the migrating birds. Where on platforms can birds assess the best location for water as well as escape the multitude of predators on the platforms will also be studied. The location on platforms where birds prefer to land can also be determined, and this information can be used to avoid these locations in future platform designs .

CAN SAMPLING BIRDS ON PLATFORMS PROVIDE CLUES TO PESTICIDE EXPOSURE?

Little is known about the impact of pesticide exposure upon birds in the tropics, breeding ground and during migration (Gard *et al.* 1993). A transition in pesticide use has recently occurred in most of the tropical countries, from the traditional persistent organochlorine insecticides to organophosphate (OP) and carbamate insecticides. While the newer pesticides are much less persistent, they are far more acutely toxic to passerine birds than the organochlorines. These pesticides are neurotoxins, and because of their widespread use, there are concerns over the impact of sub-lethal exposure, particularly during migration. Recently, it has been demonstrated that sub-lethal exposure to acephate, an organophosphorus insecticide, caused disorientation in white-crowned sparrows (Vyas *et al.* 1995). Migration is a stressful time for many birds; a slight orientation problem from pesticide exposure may result in increased mortality. If some migrating birds are suffering from effects of exposure to pesticides, the mortality of these species on the platforms may provide a natural collection point, as these birds will be the least likely to effectively make the migration, and could thus provide some measure of exposure. If a major mortality occurs on platforms in poor migration weather, there is an opportunity to salvage dead birds almost immediately after dying because birds dying in the wild are rarely ever found due to scavenging of carcasses (Balcomb 1986). Blood samples from live birds arriving on the platforms offer a non-lethal means of measuring cholinesterase activity to assess exposure to OP or carbamate insecticides. Several ongoing studies are using prothonotary warblers to assess exposure and link the exposure to reproductive success (Collins *et al.* 1996).

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Donald Norman is a wildlife toxicologist who has studied migratory birds for over 10 years. He received a B.S. from Tulane University and the University of Washington, and a master's degree from Western Washington University. He is co-PI on the migratory bird project with J.V. Remsen, a zoology professor at LSU and the curator of birds at the LSU Museum of Natural Science.

SESSION 2C

THE INTERNET AND MARINE SCIENCES

Co-Chairs: Mr. Keith Good
Mr. Gary Goeke

Date: December 10, 1996

Presentation	Author/Affiliation
The U.S. National Oceanographic Data Center A Source for Global Ocean Data	Mr. Ronald L. Fauquet NOAA National Oceanographic Data Center
The Gulf of Mexico Information Network	Mr. J.E. Matthews Gulf of Mexico Program Office Stennis Space Center, Mississippi
The Internet and Marine Science—MMS Gulf of Mexico Internet Experience	Mr. Robert G. Zainey Minerals Management Service Gulf of Mexico OCS Region

THE U.S. NATIONAL OCEANOGRAPHIC DATA CENTER A SOURCE FOR GLOBAL OCEAN DATA

Mr. Ronald L. Fauquet
NOAA
National Oceanographic Data Center

ABSTRACT

The U.S. National Oceanographic Data Center (NODC), together with the co-located and operated World Data Center A Oceanography, is the largest publicly available global archive of oceanographic data in the world. Over 4 million stations comprising more than 450 million observations are held in relational data bases accessible over the Internet. Observations include temperature, salinity, nutrients, and many additional chemical components, and various biological observations including chlorophyll and primary productivity. In addition, NODC maintains the oceanographic portion (300,000 entries) of the Interagency Taxonomic Information System. This data base contains peer-reviewed scientific names and a cross reference capability for common synonyms. The NODC oceanographic data bases are interactively accessible at URL http:// www.nodc.noaa.gov.

INTRODUCTION

The U.S. NODC was formally chartered in 1961 as a multi-agency center housed and operated by the U.S. Navy Hydrographic (now Oceanographic) Office. The Center was chartered to acquire, process, preserve, archive, and distribute all oceanographic data. The NODC was included in the creation of NOAA in 1970. It is one of three environmental data centers operated by the National Environmental Satellite, Data, and Information Service (NESDIS) of NOAA. Together these Centers represent a comprehensive archive of earth system data and information. The data holdings go back to the 1700s and include weather observations, oceanographic observations and bathymetric observations, as well as many more earth science parameters. The data is held in data base form and have been built with data from U.S. agencies, state and local government agencies, research institutions, and foreign agencies and institutions. The NODC has more than 160,000 oceanographic cruises with nearly 4.5 million stations comprising 450 million individual observations.

Over the years, the NODC has worked with program planners, managers, and principal investigators to coordinate data management support for major ocean science research efforts such as FOCI, OCSEAP and GEOSECS. Currently the NODC provides data management support for major ocean science projects including WOCE (World Ocean Circulation Experiment), the Florida Bay Restoration Project and JGOFS (Joint Global Ocean Flux Study). To promote improved working relations with the academic ocean research community, the NODC has established three joint centers with university research groups. The three centers are:

- Joint Environmental Data Analysis Center (JEDA) with Scripps Institution of Oceanography of the University of California at San Diego,
- Joint Archive for Sea Level (JASL) with the University of Hawaii, and
- Joint Center for Research in the Management of Ocean Data (JCRMOD) with the University of Delaware.

BACKGROUND

In 1990, the NODC received, inventoried, processed, archived, and retrieved data in essentially the same way it had in 1975. The archive consisted of several standard formats for common physical oceanographic observations and thousands of "originator format" ocean observations that did not "fit" into standard formatted files. Originator-formatted data sets were accessioned, inventoried, archived, and retrieved exactly as received from the submitter. For data types that fit in standard formatted files, accessioned data were inventoried, quality controlled, archived, and retrieved in many ways. Legacy data processing systems stored standard format data as flat files by parameter and/or instrument type on nine-track magnetic tape. Separate inventories delineating what parameters had been received and what data sets existed on which tape were maintained. Retrieving this type of data in many different ways was possible, e.g., selecting on fields such as an investigator, latitude/longitude, date range, a ship, country, etc. Since everything was in sequential files on magnetic tape, the retrieval was labor intensive and quite complex, at times requiring hundreds of tapes to be mounted. As a result, separate inventories were created with parameter data sorted by region, a time frame, etc. These individualized inventories proliferated until each oceanographer answering data retrieval requests had his or her own set of special ways to find data in the archive.

The archive itself was normally at least six months out of date simply due to data processing equipment limitations. Considering only classical physical oceanography, nearly three million records comprised more than 15 gigabytes of data on 350 magnetic tapes. The logistics of recompiling all of the data tapes, inventories, and tape contents lists to add newly acquired data into the proper location for the geo-sort and time-sort data tapes ensured that updates were held to a minimum. In addition, the data processing power at NODC was limited. On-site computing "power" consisted of a Vax 11/780/785 cluster with 2.5 MIPS and remote batch-job access to a UNISYS mainframe and program library in Asheville, NC.

When a client contacted NODC to get archived data or even to decide whether data existed, an oceanographic information specialist had to work closely with the client to decide exactly what was needed. The old technology systems required a very specific definition of how to search the data bases, and the results were not always as intended. It was not unusual for a data retrieval from the nine-track tape archives to require 50 to 100 separate tape mounts. These methods were not user friendly.

NODC MODERNIZATION

NODC began to modernize in 1992. The objectives were to bring modern technology to data processing and distribution and to improve user friendliness. An Ethernet LAN was installed with a FDDI backbone. A UNIX-based client-server architecture was adopted with PCs and UNIX workstations integrated into the network. On-site computing power was increased to approximately 150 MIPS for each file server, and to nearly 10 MIPS on each desktop. Massive on-line WORM and spinning disk storage totaling 401 gigabytes was procured, installed, and operating on the network by early 1994. Storage has continued to grow, totaling 920 gigabytes in 1996.

It was decided that all existing data bases would be published on CD-ROM, with periodic reissues of newly acquired data. Data received in each individual data base since the last CD-ROM was published would be made available on-line across the Internet. In this way, the amount of data that needed to be transmitted across the Internet would be reduced. In addition, potentially hundreds of sub-archives would be established around the world, and NODC would be fulfilling its primary mission to preserve and distribute oceanographic data. To date the NODC has produced 72 CD-ROMs holding many of its most-used data sets. The CD-ROM publishing capability also has resulted in preparation of "one-off" CDs as a medium to meet user requests for large data sets. An average of 1.4 "one-off" CD-ROMs are prepared monthly.

To improve data distribution within the ideas mentioned above, servers were installed on NODC's UNIX workstations and registered with the WWW. These servers became operational in February 1994, and allow use of common graphical user interfaces to browse information about NODC and available products and order designated oceanographic data via the Internet. At this time, the NODC Catalog of Data, upper ocean thermal data base, moored coastal buoy data base, acoustic doppler current profiler data base, and U.S. coastal AVHRR meteorological satellite data base are available for interactive browse, order and download. Tools to allow interactive custom sorting and sub-setting of most of NODC's data bases have been developed and will become available on the Internet during the summer of 1997. Selections can be downloaded during the same session or (if the file is too big) copied to an anonymous FTP space for pickup by the client at a later time.

The modernization program has essentially created a new NODC. These processing and data distribution improvements have reduced the average data ordering turnaround time to 2.4 days for orders requiring intervention by NODC customer service personnel, and immediately for online data downloading. In 1992, the NODC provided data and information services on paper and 9-track magnetic tape to 11,035 clients. In 1996, the NODC served 149,215 clients, of which 123,307 were Internet users who accessed NODC data and information resources using the Web, Gopher, and FTP. In 1992, the NODC distributed 200 gigabytes of data. In 1996, the NODC distributed 2,185 gigabytes of data. Nearly 95 percent of this total was provided on CD-ROM and most of the remainder was provided online via FTP. Today very few data orders are fulfilled using magnetic media (tape or diskette). From 1992 to 1996, the number of NODC clients and the volume of data distributed increased about 1,000 percent. By taking advantage of new technology, these improvements were accomplished as staff decreased by 35 percent.

OCEANOGRAPHIC DATA AVAILABILITY

Since 1993, the NODC data base of parameters that are measured at more than one depth has increased in size by over 30% to nearly 4.5 million profiles. This Oceanographic Profile Data Base uses RDBMS technology with a Web-forms GUI to build interactive queries to the Catalog. Thus the most comprehensive relational data base of global oceanographic data that NODC has ever made available is now interactively accessible. Through the Catalog and On-Line Data Products page, a user may build a Catalog query to determine if the desired data are at NODC. At present, the user must contact the NODC User Services staff to actually retrieve data that can be mailed or put into an FTP space for pickup. Software is being tested which will allow interactive sub-setting of the actual data in the OPDB and online download by the customer. This actual data delivery via the Internet will be available to the public in the summer of 1997, and will be limited to temperature, salinity, oxygen, and nutrients profiles.

There are data sets listed in the Catalog that are not yet interactively accessible; these include ship drift, drifting buoys, current meters, sea level data, wave spectra (from buoys), sea level winds from buoys, water chemistries, toxic substances, plankton (phyto- and zoo-), primary productivity, intertidal/benthic organisms, and pollution measurements.

The recent additions of profiles and new data parameters to the Profile data base were derived from the Intergovernmental Oceanographic Commission approved Global Oceanographic Data Archaeology and Rescue (GODAR) project. Some individual data bases, such as chlorophyll and primary productivity, have increased by orders of magnitude. The Global Ocean Data Base will be published on CD-ROM in late 1997, and will be available on the Internet soon thereafter. It is an improvement in spatial, temporal, and parameter coverage over the World Ocean Atlas series published in 1994-1995.

WHERE NODC IS GOING

It is also clear that more emphasis must be placed on accessioning and archiving many types of oceanographic data heretofore not considered by NODC. Chemical, biological, and coastal oceanography are being emphasized at NODC; new high-resolution sensor development must be followed and evaluated for archive requirements; inclusion of remote sensing instruments such as altimeters, scatterometers, and/or active radars need to be investigated. A dialogue should be opened with the marine science community to determine what role NODC should play.

SUMMARY

The National Oceanographic Data Center has moved into modern data and information processing techniques. It has improved the availability of data through use of modern random access media, relational data base technology, and on-line data. Internally, it is an order of magnitude more efficient in data processing and quality control than just four years ago; this is primarily due to use of modern networking, client server architecture, and automated procedures. NODC is an Internet domain and is on the World Wide Web with interactive Catalog and data browse, with some data retrievals available and more scheduled to become interactively accessible. It has published 72 CD-ROMs of popular data bases and data products.

THE GULF OF MEXICO INFORMATION NETWORK

Mr. J.E. Matthews
Gulf of Mexico Program Office
Stennis Space Center, Mississippi

The Gulf of Mexico Program is a non-regulatory consortium of the five Gulf Coast States, numerous public and private organizations, and eighteen Federal agencies, including the Minerals Management Service. It was formed to facilitate the development and implementation of a management strategy to protect, restore, and maintain the health and productivity of the Gulf of Mexico ecosystem. One of the primary functions of the Program is to coordinate efforts in the Gulf among these various organizations to eliminate duplication and to achieve economies of scale. Critical to such an effort is the sharing of information. The Gulf of Mexico Information Network (GIN) is a World Wide Web based information system (http://pelican.gmpo.gov) being developed by the Gulf of Mexico Program Office to serve this purpose.

There are several general style considerations being observed in the development of GIN pages, the most basic being, keep it simple. A relatively primitive html is being used that provides an "acceptable" appearance on all platforms and a variety of browsers (Version 2.0 without extensions). The file size of all interlaced graphics are held to a minimum (generally under 10 kbyte per page; 31 kbyte is the current maximum). Large graphic files are individually accessed by hyperlink, and their file size is stated in the hypertext. A generic page template of a title, graphic, short text, and list of hyperlinks is used to provide continuity throughout the site. Long hyperlink lists are subdivided using small icons accompanied by a title. Page size is kept small (generally under the equivalent of two typed pages), except for ASCII text files.

The basic architecture of the Web site has been developed, but it is still sparsely filled with material. The philosophy of its design varies, depending upon the intended user. The GIN has three basic functions: communication, data and information sharing, and education and outreach. Participants in the Program comprise the primary audience for its communication section. The data and information section is targeted for the technically oriented environmental community. The education and outreach section is targeted for the general public.

The communication section includes links to Program participants, its committees, and other information of a programmatic nature. The Program Office is in the process of building a new LAN that will be interfaced to the Web server and automatically update selected files (calendars, press releases, and notices). One segment of the communication section is password protected and used for testing pages, software, etc. This protection is designed only to minimize access, and the user name and password are freely given verbally to interested parties. Several list servers are also maintained as part of the communication component.

The data and information sharing section is designed primarily for the Program's scientific participants. It includes Web search starting points and information on data and metadata standards, but its two main components are the Near-Real-Time Data and Predictions and the Historical Data and Information segments. There are only a small number of Web sites providing near-real-time data or predictions of environmentally significant parameters, so this category has been separated from what is termed historical data. It is anticipated that most of the historical information will eventually be catalogued under and accessible through the National Spatial Data Infrastructure (NSDI). Many States are following the Federal lead and requiring, or at least urging, the use of the Federal Geographic Data Committee's (FGDC) metadata standards by all of their agencies. It is my belief that the FGDC metadata standards are rapidly becoming the *de facto* U.S. standard. The Gulf Program itself does not own large amounts of data and information, but its participating organizations do, and most of them will become part of the NSDI. The GIN will probably become certified as a NSDI node (level C2), and serve data only for selected Program organizations that would not otherwise be able to do so.

The Gulf Program, through its Data and Information Transfer Committee, is investigating methods to facilitate data searches. These include approaches such as pre-determined geographic polygons and lists of suggested key words for selected metadata fields to make Gulf-region NSDI data searches more user friendly. We are also building hierarchal hyperlink lists to environmental data servers around the Gulf region. For example, not just a link to NOAA (Washington, D.C.), but to NOAA's National Marine Fisheries Service at Stennis Space Center, Pascagoula, St. Petersburg, etc. The data and information section will be devoid of frills and will not have graphics below the highest level unless they have technical significance.

The education and outreach section is intended to be the major portion of the GIN designed for the public. It is subdivided for three distinct audiences: educators (primarily teachers), students (K through 16), and the public at large. A brainstorming session was conducted last summer with local primary and secondary science teachers to determine what teachers wanted from the Web. The result was predictable—lesson plans, classroom materials, grant and fellowship information, and summer opportunities (courses, workshops, and employment). A decision was made to focus first on teacher needs, and then to solicit their support to ascertain student needs and desires. The teachers were matter of fact and wanted "no frills" content, but for students it was suggested that we "lighten up," providing solid content along with fun, though marketing will have to be conducted. I have no specific market research on how to best reach the public at large. It is my belief that we are dealing with an educated segment of the population that currently gets much of their information from newspapers and magazines rather than just television. Given this assumption, I believe the material should be presented at a level comparable to an editorial but go a step farther by providing suggested solutions. Many environmental issues can only be solved by an educated and caring public. This does not mean that the material should be devoid of humor, and we also plan to include topics of general Gulf-Region interest, such as food, history, places to visit, outdoor recreation, etc.

Jim Matthews has worked in the Gulf of Mexico Program Office on an Environmental Protection Agency grant for the past two years. His primary function there is designing the Gulf of Mexico Information Network. Jim is retired from Federal Civil Service, having spent 33 years performing oceanographic and geophysical research for the U.S. Navy. He received B.S. degrees in both mathematics and geology from the University of Oklahoma, and a M.S. degree in geophysics from the University of Utah.

THE INTERNET AND MARINE SCIENCE—MMS GULF OF MEXICO INTERNET EXPERIENCE

Mr. Robert G. Zainey
Minerals Management Service
Gulf of Mexico OCS Region

INTRODUCTION

"Internet" has become a familiar household word in what seems an incredibly brief period of time. In the blink of an eye, those companies considering placement of a Homepage on the Internet found themselves in a position of catching up to those thousands who already had one. And those thousands range from multimillion dollar corporations to single individuals. Purposes range from direct sales of products, such as ordering a book from the Homepage of an electronic bookstore, to non-profit, for-information proposes only, such as those Homepages of the United States Government and the Homepages of over 150 foreign countries.

From the Homepage of the United States Government, information on every level of service, can be found as well as links to all government websites. Among these are the Gulf of Mexico OCS Region. The following has been this Region's experience in creating, implementing, and maintaining this site.

GETTING STARTED

On 30 March 1996, the Regional Director, Gulf of Mexico OCS Region, called a meeting of all senior-level managers, major program administrators, and information supervisors and staff. The objective was to brainstorm ideas for topics to be included on the Region's initial Internet Homepage. This resulted in identification of 50 subjects. It was an important first step both in determining the scope of the project and in identifying subjects of interest to potential website visitors. These subjects are listed in Table 2C.1.

At this same meeting, a Committee was formed to create a website starting with the 50 topics as the foundation. Committee selection was based on job function and on knowledge of overall information activities in the Regions as follows:

- Chairman: Chief, Information Services, for information and information services provided to customers.
- Technical Expert: Chief, ADP Applications and Data, for automated data systems.
- Public Affairs: Public Affairs Officer, for news media and outreach activities.

Table 2C.1. Subjects of interest identified through brainstorming.

Who is MMS	District Information
Organizational Chart	Leasing
GOMR Vision Statement	Bid Recaps
Message from Regional Director	Lease Sale Information
Current Events	Unleased Blocks
Press Releases	EIS Information/Availability
Fact Sheets	Archaeology Report
Regional Statistics; Fast Facts	Artificial Reef Map
ITM Proceedings	Leasing Schedule
Calendar of Events	Swiler Report
Feature Articles	Pipeline
Summary of Deep Water Projects	Production
What's New	Production by Lease Well
Frequently Asked Questions	Gulf Wide Production Data
Fact Sheets	Indicated Hydrocarbon List
Feedback	Well
Comment Page	Platform/Rig
External Presentations and Reports	Reserves
Technical Papers	Field Level Reserve Estimates
Regulations	Maps
Description of Regulatory Process	Index of Available Maps
NTLs	Index of Available Visuals
Notice of Lease Sale	How to Order Maps
Approved Forms	Publications
Field Operations Policy	Index of Available Publications

Table 2C.2. Selected subjects for initial website structure.

Who is MMS	Leasing
Current Events	Pipeline
What's New	Production
Frequently Asked Questions	Well
Feedback	Platform/Rig
Teachers Resource Section	Reserves
External Presentations and Reports	Maps
Regulations	Publications
Inspections	

- Public Information: Supervisor, Public Information Office, for information accessible by the public.
- Communication- Education: Staff Assistant to the Regional Director, for public awareness programs, special interest topics.
- Leasing and Environment: Supervisor, Information Management Team, for lease sales,status and statistics, and environmental programs and publications.

On 21 March 1996, the Committee began its task by reviewing the subjects previously determined through brainstorming, categorizing them by like topics, and selecting those categories that would comprise an initial structure of the website which could later be built upon. By combining in this manner, the list (Table 2C.1) was reduced from 50 subjects to 17. These are identified in Table 2C.2.

Now that the structure was identified, the information within the outline had to be formatted into Hypertext Markup Language (HTML) or converted to a portable data file (PDF) for use on the Internet. The preparation of the information into HTML or PDF took the majority of the time from the initial meeting on 20 March 1996, until the Region's Homepage was made available on the Internet on 20 May 1996. On that date the Region's Homepage was released to very favorable reviews.

MOVING ALONG

The Committee soon found there was more work to be done. Three items needed immediate attention. First, an index to detailed information within the Homepage was needed. With a first phase issue of over 300 pages (hardcopy) of information, the task seemed insurmountable. It was resolved by incorporating a website search engine within the Homepage to give the visitor the ability to search by words describing a concept, or by keywords related to the information. This satisfied the need for a detailed Table of Contents. Second, another need was recognized, ironically, from the favorable reviews received on publishing the Region's Homepage. The compliments and comments came by telephone, fax, and in person. There had been no communication tool setup to receive comments over the Internet. It became evident a "Guestbook" was needed to provide this mode of communication. Development of a Guestbook was initiated and has proven to be a valuable communication tool (Figure 2C.1).

Third, it became clear that a structured internal approval process was necessary due to the volume of information considered for the Region's Homepage. An "Application to Develop Internet Homepage Materials" was created that described the step-by-step process required to move information to the Internet. The "Application" set forth three levels of approval: "Approval of Concept" defined the idea; "Approval of Written Material" consisted of the actual documents to

Fill in the blanks below to add to our guestbook. This information will be used to provide better services and will not be released to anyone for other purposes. Thanks!

Name:	
Title:	
Company:	
Address:	
City:	
State:	
Country:	USA
Zip:	
Phone:	
Fax:	
E-Mail:	
Company URL	http://

Figure 2C.1. Guestbook illustration.

be converted to HTML or PDF for the Internet; "Approval of the Internet Pages" created from the written documentation was the last step before moving the information to the Internet.

DEMONSTRATION OF GULF OF MEXICO OCS REGION'S INTERNET HOMEPAGE

(A live demonstration of the Region's Homepage was presented by Mr. Eldin Graffeo of the Region's Public Information Office. The website was projected on a widescreen for audience viewing.)

RESULTS

The power of the Internet cannot be underestimated as an effective communication tool. A six month comparison of information processing by the Gulf of Mexico Region's Public Information Office offers dramatic indication of this (Table 2C.3).

There are various factors such as lease sales, policy changes, conferences, etc., that account for the month-to-month variations that focus particular interest in the Region's information. The fluctuations appearing in Table 2C.3 are normal and the Table is meant to describe the results of new accessibility of information due to the Internet Homepage. Table 2C.4 gives a good example of information processed on a weekly basis for a clearer depiction of information processing in a typical work week.

The MMS Gulf of Mexico Internet Experience has been exciting in the design, challenging in the implementation, and rewarding in feedback in its usefulness to those who access it. Further, the MMS Gulf of Mexico Homepage has supported new dialog and a higher level of interaction both within and outside of the Region. And more, the experience continues.

MMS GULF OF MEXICO REGION INTERNET ADDRESS

http://www/mms/gov/omm/gomr/

Table 2C.3. Public information requests processed.

1996	July	August	September	October	November	December
Documents	713	711	388	472	511	516
Maps/Map Sets	1,475	488	1,222	222	1,551	98
Automated Reports	51	86	50	123	142	55
Well Logs	411	969	1,045	414	891	640
Telephone Calls (Regular)	876	915	636	924	778	887
Telephone Calls (Toll Free)	303	272	230	298	382	275
Visitors	283	292	319	287	224	185
Internet Hits	8,000	10,000	18,000	16,000	12,000	10,000

Table 2C.4. Public information requests processed weekly.

Documents	130
Maps/Map Sets	220
Automated Reports	25
Well Logs	170
Telephone Calls (Regular)	210
Telephone Calls (Toll Free)	70
Visitors	70
Special Requests	15
Freedom of Information Act Requests	5
Internet Visits	2,900

Robert Zainey is Chief of the Information Services Section, Gulf of Mexico Regional Office, Minerals Management Service. His areas of responsibility include evaluation and development of information dissemination services and programs, records management, optical imaging, and public information. He is Chairman of the Gulf of Mexico Region's Internet Committee, Team Leader of the Customer Service Team, and a member of the Customer Service Pilot Leader Team. Mr. Zainey held previous positions on the staff of KPMG Peat Marwick LLP, Certified Public Accountants; as Chief Accountant of East Jefferson General Hospital, a 1,200-bed major medical center in the New Orleans area; and as an Information Management Analyst with MMS prior to his current position as Information Services Chief. He received his B.S. in accounting from Louisiana State University, and his M.B.A. from Loyola University.

SESSION 1D

DEEPWATER DEVELOPMENT ISSUES

Co-Chairs: Mr. Gary Rutherford
Mr. Sam Holder

Date: December 11, 1996

Presentation	Author/Affiliation
Deepwater Operations Plans	Mr. James B. Regg Minerals Management Service Gulf of Mexico OCS Region
A Socioeconomic Analysis of Port Expansion at Port Fourchon (Manuscript not submitted)	Dr. David Hughes Coastal Environmental & Energy Resources Louisiana State University
Current & Projected Industry Plans (Manuscript not submitted)	Mr. M.F. Lang Chevron USA, Inc.
Deepwater Pipeline Transportation Limitations	Mr. Daniel M. Houser J. Ray McDermott, Inc.
The Usefulness of Enhanced Surface Renderings from 3-D Seismic Data for High Resolution Geohazard Studies	Mr. E.H. Doyle Mr. J.S. Smith Dr. P.R. Tauvers Mr. J.R. Booth Mr. M.C. Jacobi Ms. A.C. Nunez Dr. F.A. Diegel Shell Deepwater Development Mr. M.J. Kaluza Fugro McClelland Marine Geosciences, Inc.

DEEPWATER OPERATIONS PLANS

Mr. James B. Regg
Minerals Management Service
Gulf of Mexico OCS Region

ABSTRACT

Deepwater oil and gas activities in the U.S. Gulf of Mexico Outer Continental Shelf (OCS) are regulated by the Minerals Management Service (MMS). The level of OCS deepwater activities in both the drilling and production arena has shown a steady increase over the past 3 years. The number of nonproducing discoveries in the deepwater Gulf of Mexico is also increasing. Very high rates of production by prolific deepwater wells have convinced operators that the deepwater Gulf of Mexico is a sound economical investment, and the trend in this area is expected to increase. Regulatory concerns have been viewed by some as a potential barrier to deepwater development successes. Existing OCS operating regulations have largely been developed on the basis of the expansion of successful bay and inland estuary production activities. These regulations reflect mostly surface (platform) based operations where daily access to the wellhead(s) is usually possible. One specific concern is that the existing regulations do not adequately address the technology associated with new deepwater hardware and operating procedures.

Discussions with the industry consortium DeepStar and MMS's active involvement with the Regulatory Issues Committee have successfully provided an open forum between the regulators and operators to identify those regulatory and operational issues that impact the industry. This paper will briefly address the interaction with industry and the process developed to minimize the potential barriers. Specifically, the paper will identify the parts of a deepwater operations plan and its use in evaluating the total deepwater production system. The contents of a typical deepwater operations plan and how it fits into the operator's project timing and the MMS's current permitting process will also be summarized.

Note to readers: This paper was previously presented at the Offshore Technology Conference in May 1996, titled "The Future of Deepwater Regulations for the Gulf of Mexico OCS," OTC 8243. Where necessary, it has been updated to reflect the current regulatory status.

INTRODUCTION

Deepwater drilling activity is at an all-time high, and production from deepwater reservoirs is also increasing. MMS statistics indicate that the number of rigs concurrently operating in water depths greater than 1,000 feet has increased from an average of 16 during late 1995 and early 1996 to 24 by December 1996. Roughly one-half of the drilling rigs capable of operating in deepwater are now committed to operations in the Gulf of Mexico. The continued growth of the deepwater Gulf of Mexico, especially the ultra-deep blocks, might be constrained by the availability of drilling vessels capable of operating in those water depths. The successes of GOM deepwater projects have been well documented in various forms of media. The important point is that the GOM offshore has seen a much-needed revitalization with the excitement of deepwater drilling and production. It is in everyone's best interest that the successes continue.

DEEPWATER REGULATION

There are probably as many answers to the question "How deep is deepwater?" as there are responses. From an operations perspective, MMS considers deepwater with respect to regulating production activities as beginning where industry uses different technology to develop and produce oil and gas from the OCS. In the Gulf of Mexico, this shift occurs where industry stops using fixed platforms and begins using other types of facilities to produce oil and gas from deeper waters, i.e., subsea facilities, floating production facilities, tension leg platforms, etc. The exact water depth of deepwater is not important; however, the change in production technology generally begins in water about 1,000 to 1,300 feet. The MMS adopted 1,000 feet as the marker for deepwater.

MMS Regulations

Existing MMS offshore operating regulations were promulgated based on an expansion of successful bay and inland estuary production activities. These regulations reflect mostly surface operations where daily access to the wellhead(s) is possible. In 1988, MMS had consolidated a multiple layer of regulations, orders, and policies into the single document containing all then-existing regulations. This effort resulted in updating regulatory requirements with industry operating practices and standards and incorporating performance-oriented requirements into the regulatory structure. Those regulations continued the focus on surface-based operations; the 1988 revision did not address in specific terms the requirement for subsea production systems and several other particulars associated with deepwater operations. Because of this lack of specific regulations and different functional requirements for deepwater and subsea activities, the MMS has been required to review development proposals on a case-by-case basis. Approvals have relied on alternative compliance measures as well as departures from the existing regulations to allow deepwater development to proceed where an appropriate level of safety is demonstrated. Both MMS and industry have concerns about the use of departures for regulating offshore operations. A proactive approach to addressing the MMS and industry concerns was needed.

MMS Deepwater Work Group

In response to this need, MMS formed a work group to examine regulatory issues associated with deepwater operations and development. The primary functions of the work group were to (1) review the current offshore operating regulations for applicability to deepwater and subsea operations and (2) recommend measures to improve the deepwater regulatory program. This internal MMS Deepwater Production Work Group began its regulatory analysis in early 1992 by investigating options regarding regulations for floating and subsea production systems. One goal of the work group was to develop a report that would address the needs of the current regulatory program with respect to deepwater. Case studies of several deepwater projects were key to obtaining an accurate picture of how MMS regulates deepwater activities.

Concurrent with the MMS effort was industry's DeepStar. The DeepStar effort is a consortium of offshore operating companies and vendors that supply services and equipment. MMS joined with DeepStar in November 1992 to further delineate and address the regulatory issues affecting deepwater development projects. DeepStar and MMS have since that time interacted through the Regulatory Issues Committee, establishing a forum for discussing industry and regulatory concerns relative to deepwater development issues. Periodic meetings between MMS and DeepStar personnel has provided an open dialogue to solicit information about deepwater technology, development concerns, regulatory revisions and updates.

Focused discussions concerning the MMS and DeepStar interests resulted in the issuance of the MMS Deepwater Work Group's Final Report in April 1995, titled "Deepwater Regulatory Issues." One recommendation from the MMS work group addressed the revision of regulatory requirements for deepwater production wells and facilities. The work group identified specific regulations that were ambiguous toward deepwater activities. But instead of simply revising the specific equipment requirements to address the rapidly evolving technology, the work group took a new approach and recommended that MMS begin to regulate deepwater production activities through a total systems approach. The new approach reaffirms MMS's interest and mandate regarding OCS safety by specifying an approach to evaluate the entire production system as a whole rather than the individual parts.

Deepwater Operations Plan

The new approach for reviewing deepwater development activities is referred to as the Deepwater Operations Plan (DWOP). The MMS/DeepStar effort developed a set of guidelines to be used for developing deepwater operations plans. Those guidelines were based on the types of information required for a subsea development project. The cooperation and open dialogue from both the industry and MMS were key to the formulation of this first set of guidelines. The MMS has adopted the guidelines and announced the implementation of the Deepwater Operations Plan requirement by a Notice to Lessees and Operators, NTL 96-4N, dated August 19, 1996. Before finalizing the guidelines, the trade organizations that typically represent the Gulf of Mexico offshore operators were consulted.

The DWOP does not create new requirements for the offshore operator; it just repackages existing requirements in a total system approach that documents to overall project. The DWOP also provides early opportunity for MMS and industry to dialogue about emerging technological issues that would necessitate long review time by MMS.

In general terms, the Deepwater Operations Plan addresses the following information needs:

- Application of new technology;
- Emergency shutdown system (includes safety valve closure times and sequence);
- Inspection, testing, and maintenance practices;
- Predictive process hazards analysis; and
- Alternative compliance to current regulatory requirements with appropriate justifications.

The guidelines for implementing the Deepwater Operations Plan identify specific needs concerning the areas noted above. An important point to recognize is that the Plan is not intended to duplicate other submittals required by the MMS; anything that has received prior approval or that is pending can simply be cross-referenced in the Plan. MMS and industry

benefit from the Deepwater Operations Plan through the early interaction and dialogue regarding the proposed development strategy.

The Deepwater Operations Plan is submitted to MMS in three parts: Conceptual, Preliminary, and Final. Each part reflects the operator's state of knowledge regarding the project and will provide an early opportunity for the operator and MMS to agree on the proposed development strategy (design basis and philosophy) prior to major expenditures. This three-part submittal approach for a Deepwater Operation Plan is intended to help reduce the overall risk of the project.

CONCEPTUAL PART

The Conceptual Part addresses the general design basis and philosophy used to develop the field. It also addresses innovative and unusual technologies that are essential for the viability of the project. This part provides an early opportunity for MMS and the lessee to agree on a plan of development prior to major expenditures for engineering design. The Conceptual part should be submitted for approval after the lessee has identified the concept(s) for development and prior to commencing with engineering design. At the lessees discretion, the Conceptual Part may be submitted in conjunction with the Preliminary Part.

PRELIMINARY PART

The Preliminary Part provides an opportunity for approval of the system and associated operations plan prior to major commitments and expenditures for hardware. This part identifies the alternative compliance measures to be used along with the description of the overall production and system configuration. It should be submitted for approval after the lessee has substantially completed system design and prior to commencing procurement and fabrication. Recognizing that various facets of the development require different lead times for procurement and fabrication, the Preliminary Part may be submitted in several different parts to suit the project schedule. In any case, the Preliminary Part must be approved by MMS prior to initiating production.

FINAL PART

The Final Part updates information previously submitted in the Preliminary Part. This Part is designed to bring the DWOP process to a close. It is submitted for MMS action within 90 days following initial production from the project.

The Deepwater Operations Plan benefits both industry and MMS by:

- Minimizing the need for numerous departures by having a comprehensive plan developed for regulatory review prior to full-scale design and fabrication;

- Providing justification for equipment and procedures that differ from MMS's requirements;

- Addressing deepwater technical considerations not currently regulated;

- Providing a predictive process hazards analysis for the operation;

- Reducing the need for MMS to constantly revise regulations to keep up with changing technology;

- Ensuring the operator adequately plans for safe operations;

- Providing a proprietary mechanism for the operator to submit production system details;

- Helping the operator organize the planning process for a deepwater development project; and

- Providing an early dialogue mechanism that industry and MMS can use to address issues in the critical path of the project.

CONCLUSIONS

The MMS and DeepStar have cooperated since 1992 to facilitate the development of deepwater discoveries in an environmentally and safety-conscious manner. The purpose of this cooperative effort has been to move both industry and regulators toward a common goal of mitigating all barriers to deepwater development. The approach has been positive, identifying issues and concerns to be fully discussed before actions are formulated. Through the interaction and substantial contributions from industry through DeepStar, MMS has been able to adopt a total-systems approach to reviewing deepwater development activities. This new approach, referred to as the Deepwater Operations Plan, provides for the use of alternative compliance measures where justified, rather than obtaining departures from regulations and policies based on fixed-leg platform type operations. The approach also avoids, at least in the near term, the development of safety regulations that would require frequent revisions because of evolutionary deepwater technology. The Deepwater Operations Plan approach provides an early regulatory review prior to full scale development, a measure that should reduce some of the risk associated with deepwater development planning.

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Jim Regg is a staff petroleum engineer with the MMS Gulf of Mexico OCS Region. He currently works in the Field Operations office where he is responsible for deepwater technical, safety, and regulatory issues relating to drilling and production activities. He represents MMS on the Regulatory Issues Committee of DeepStar. Mr. Regg has offshore experience in drilling and production operations in Alaska and the Gulf of Mexico and with the MMS offshore inspection program. He received a degree in petroleum engineering from Pennsylvania State University.

DEEPWATER PIPELINE TRANSPORTATION LIMITATIONS

Mr. Daniel M. Houser
J. Ray McDermott, Inc.

The Gulf of Mexico offshore construction industry is currently experiencing a period of careful expansion into ever greater waterdepths. Ideas developed in the 1980s are safely being put into practice at a pace not thought possible only a few years ago. This presentation, accompanied by Figures 1D.1–1D.13 , addresses limitations that we foresee based on feedback from our clients, engineers, and project managers involved with the move into deepwater.

The three primary means of offshore pipeline installation used today consist of S-Lay, Reel-Lay or J-Lay techniques. Equipment and procedures using these techniques have been developed which increased the waterdepth laying capabilities from approximately 350 meters in 1988 to 1650 meters in 1996. For smaller diameter pipe, this equipment can potentially be used in 5000 meter waterdepths or more. Larger diameter pipe is currently limited to around the 2000 or 3000 meter range, depending on numerous factors. Technically, equipment and procedures are potentially available, as was demonstrated on the proposals developed for the Oman to India pipeline, which crossed depths of 3350 meters with 27-inch pipe.

Design of the pipeline route, considering the rugged seabottom bathymetry, span criteria, pipeline crossings and remediation, route restrictions, pipe insulation/heating systems, and long distance multi-phase flow problems all enter into the design. As waterdepths rise, pipe diameters and/or pipe weight (i.e. pipe-in-pipe designs) increases, tensioning requirements, abandonment and recovery systems, and tooling sizes increase, which, in turn, puts greater demands on equipment. At depths beyond approximately 500 meters, lay vessels, which operate using dynamic positioning in lieu of anchor-based moorings, should potentially be considered. Constructability issues arise with the greater depths and with advanced system designs such as pipe-in-pipe based designs. Terminating and connecting the pipelines to risers or trunkline subsea taps also require advanced planning. The means of repair and tooling preparation also requires preplanning to facilitate future requirements.

The design of the pipelines to operate efficiently impacts installation. Pigging systems, flow remediation (wax/hydrate formation), flow separation, internal/ external corrosion, and multiphase flow considerations all effect the pipeline design, routing, etc., which, in turn, must be installed and impact equipment requirements and associated development costs.

There are a number of strategic factors facing contractors today both domestically and globally. Prevailing demand for equipment and services may not be reflected for a sustained period of time, hence dampening a contractor's enthusiasm for expensive capital expansion. This is a global economy, and marine equipment is sufficiently mobile to follow the work globally; hence, both supply and demand can vary with time. This, in turn, effects pricing of equipment and services. When the work falls off, it is difficult, if not impossible, for a contractor to stack newly capitalized equipment in a given area.

The system design is strategically effected by upstream supply conditions, host/processing facilities, and the downstream distribution infrastructure that are currently available. Future infrastructure requirements and availability also are a major consideration.

Government issues that impact the pipeline systems include outdated codes (need fit for purpose), domestic supply enhancement, royalty relief, permitting requirement, and associated time required, and most importantly, environmental issues.

There are a number of commercial influences. Motivators include:

- Profitability – Contractors & Owners
- Enabling Technology Development
- Expansion of Business Opportunities
- Sustained Market
- Supply/Demand for Services

Demotivators include:

- Supply/Demand for Services
- Risk of Loss During Construction
- Risk Insurability
- Capital Investment Requirements
- Competitive Environment

The future holds many interesting challenges from the technical, strategic, governmental, and commercial standpoints. Technically, the impact of hydrates formation, wax deposition, and various flow problems result in pipeline designs with challenging installation, connection, and repair problems. Strategic considerations face both the operators and contractors with regard to the pipeline systems and the equipment required to install and maintain them. Governmental issues to improve the efficiency and safety of the systems and infrastructure in light of the above needs are necessary. All of the needs are based on the commercial/market requirements, which match the demand and supply for the benefit of all parties involved.

Daniel Houser has 19 years of experience in marine construction in engineering and management associated with design, fabrication, and installation of offshore platforms and pipelines. His background includes operation of major work barges, support vessels, and specialized offshore construction equipment. He has worked in the Gulf of Mexico, the Middle East, and Southeast Asia.

J. Ray McDermott, Inc.
Deepwater Pipeline Transportation Limitations

Deepwater Pipelay Achievements

Year	Project	Method	Diameter	Water Depth (M)
1989	Bullwinkle	S-Lay	12”	412
1993	Marlim	Reel	12”	1001
1994	Rocky	Reel	3”/6” PIP	451
1994	Auger	J-Lay	12”	872
1994	Cooper	S-Lay	12”	713
1995/96	Foinaven	Reel	8”/10”	500
1996	Mars	J-Lay	18”	893
1996	Mensa	S-Lay	12”	1646

Figure 1D.1. Deepwater pipelay achievements.

J. Ray McDermott, Inc.
Deepwater Pipeline Transportation Limitations

Maximum Void J-lay Water Depths for Gulf of Mexico J-lay Equipment and Derrick Barge 50

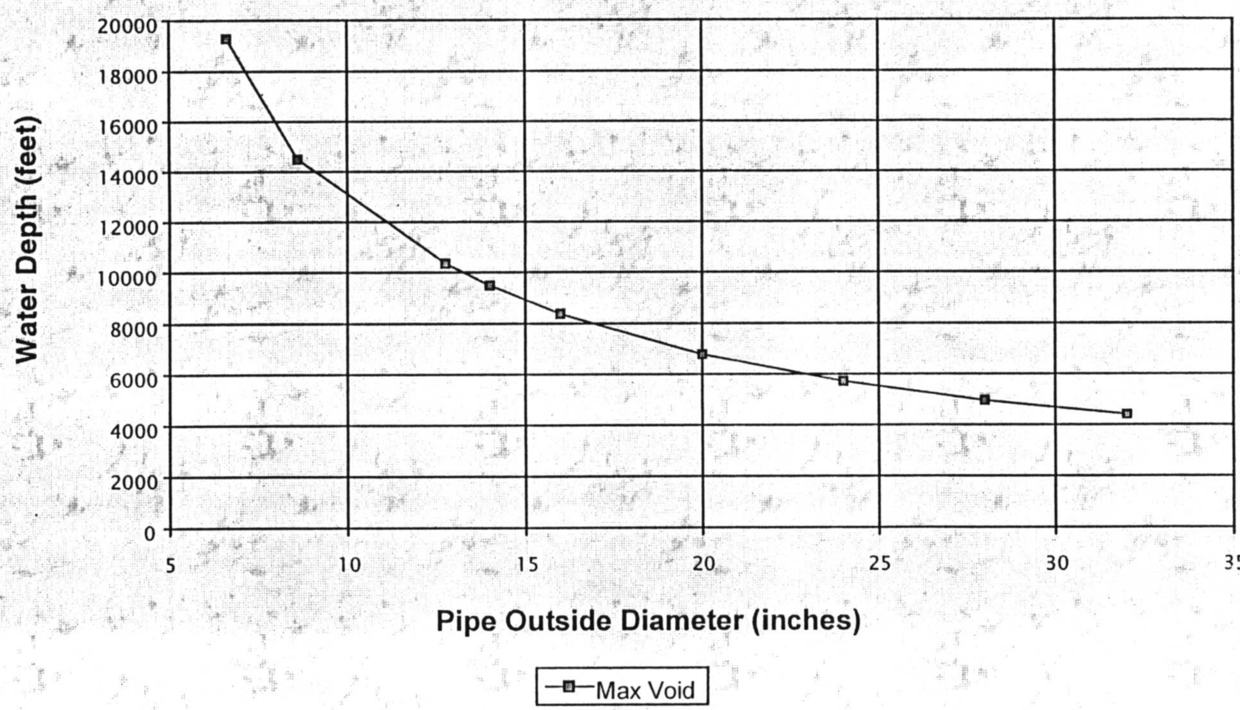

Figure 1D.2. Maximum void J-lay water depths for Gulf of Mexico J-lay equipment and Derrick Barge 50.

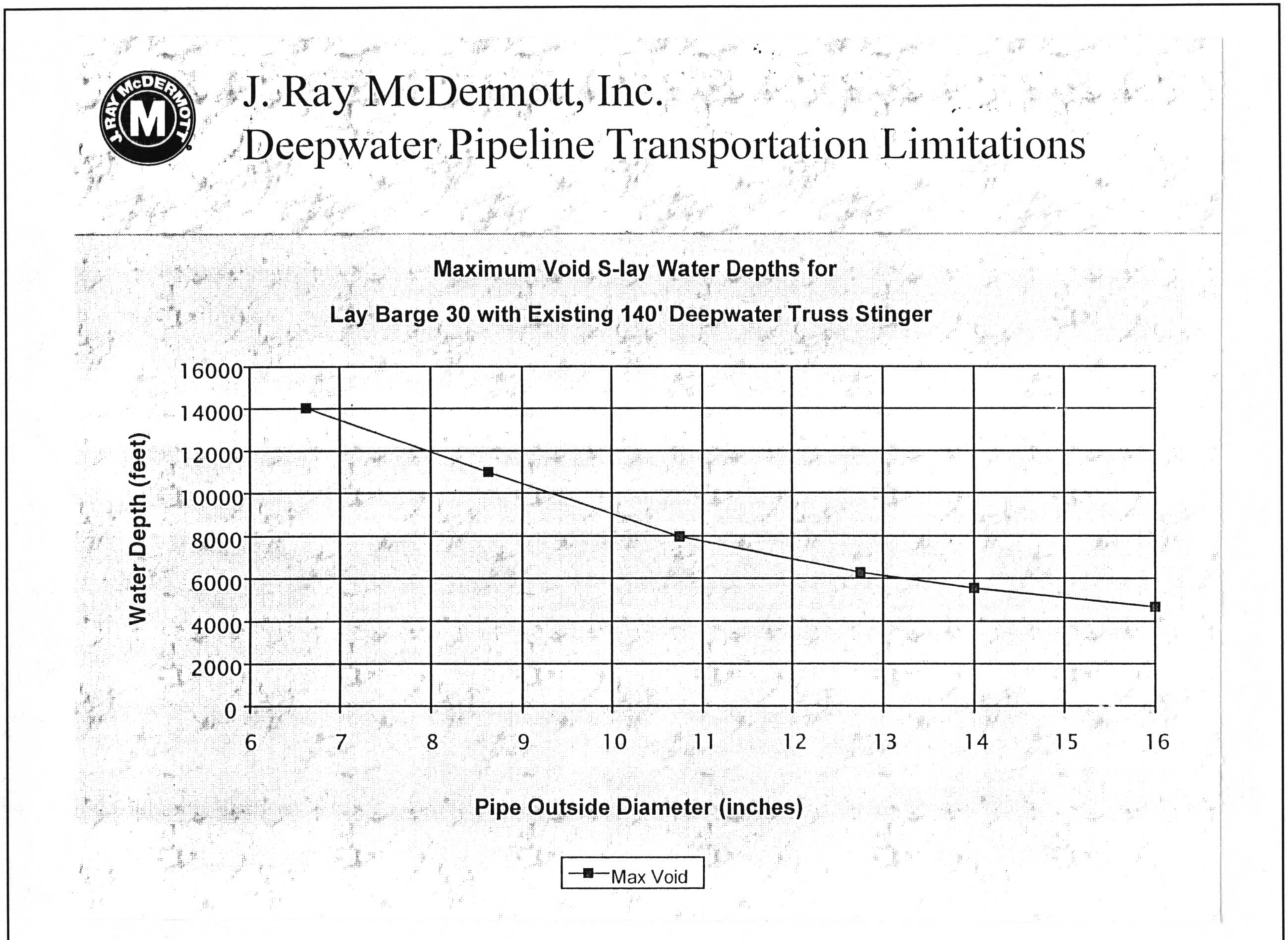

Figure 1D.3. Maximum void S-lay water depths for Lay Barge 30 with existing 140' deepwater truss stinger.

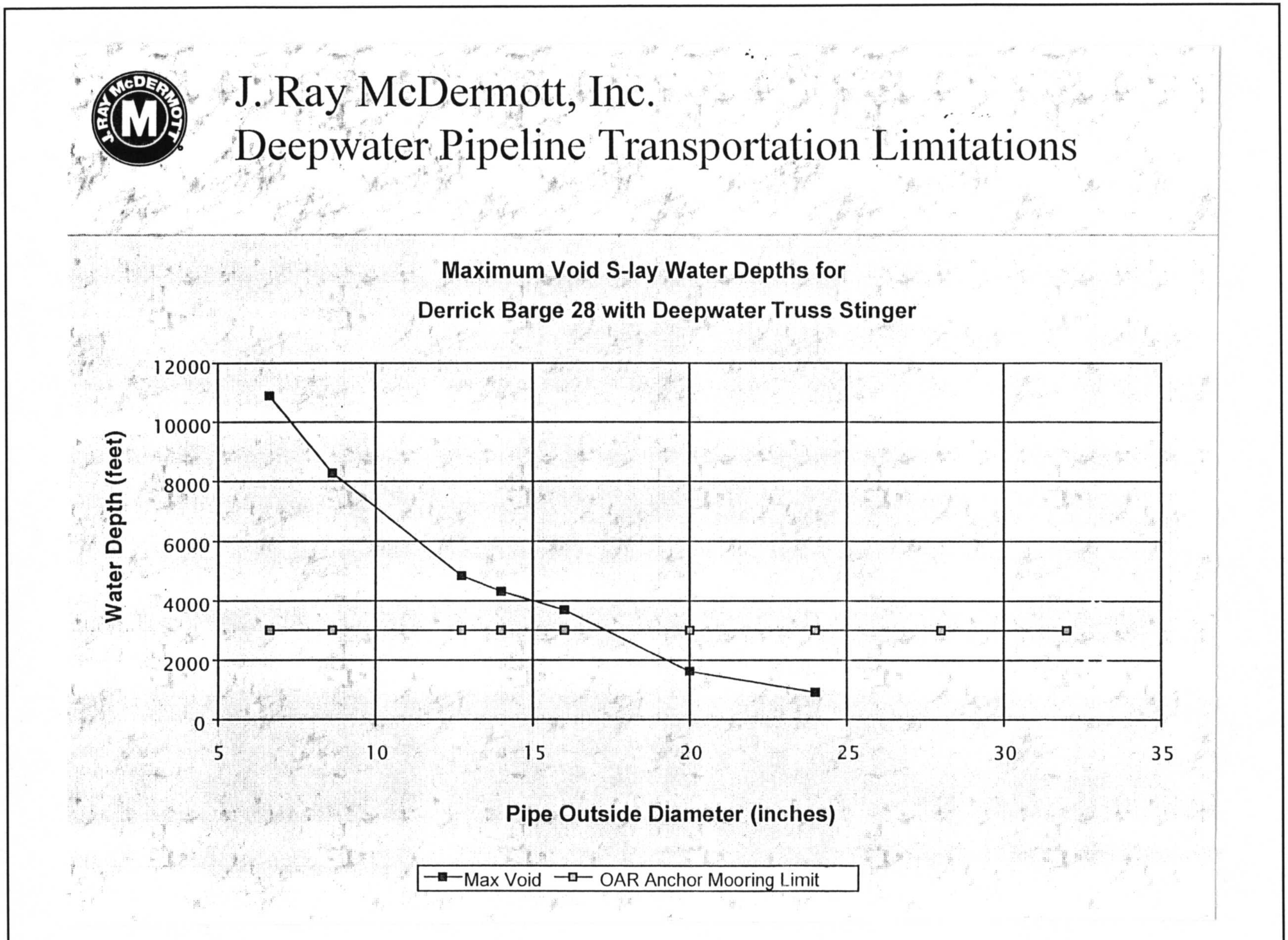

Figure 1D.4. Maximum void S-lay water depths for Derrick Barge 28 with deepwater truss stinger.

J. Ray McDermott, Inc.
Deepwater Pipeline Transportation Limitations

Technical Limitations

Design

- Seabed / Bathymetric Irregularity (Hills & Valleys)
- Routing - Slope / Inclination
- Span Criteria / Remediation
- Pipeline Crossing Systems
- Tow Route Restrictions
- Insulation / Heating Systems
- Long Distance Multiphase Flow

Figure 1D.5. Technical limitations, part 1.

J. Ray McDermott, Inc.
Deepwater Pipeline Transportation Limitations

Technical Limitations (Cont'd)

Construction / Installation Methods

- Diameter (Dimensional Limits)
- Tension Requirements (Export Lines & PIP Flowlines)
- Abandonment & Recovery
- End Connection Systems
- Station Keeping (Moored vs. D.P.)
- Constructability (Pipe-in-Pipe, Etc.)

Figure 1D.6. Technical limitations, part 2.

J. Ray McDermott, Inc.
Deepwater Pipeline Transportation Limitations

Technical Limitations (Cont'd)

Operations

- Pigging Schemes
- Flow Remediation (Wax / Hydrates)
- Separation (Slugs, Etc.)
- Corrosion (Internal & External)
- Repair Systems / Methods
- Multiphase Flow (Slugs, Etc.)

Figure 1D.7. Technical limitations, part 3.

J. Ray McDermott, Inc.
Deepwater Pipeline Transportation Limitations

Strategic Factors

Global / Domestic O&G Market Conditions

- Prevailing vs. Sustained Demand;
- Prevailing vs. Sustained Supply;
- Prevailing vs. Sustained Pricing
- Storage

Upstream Supply Conditions

- Pressure (P)
- Temperature (T)
- Flow Rate (Q)
- Well Fluid Quality

Figure 1D.8. Strategic factors, part 1.

J. Ray McDermott, Inc.
Deepwater Pipeline Transportation Limitations

Strategic Factors (Cont'd)

Host / Processing Facilities

- P / T / Q
- Pigging Facilities
- Processing Capability
- Future Expansion

Downstream Distribution Infrastructure

- P / T / Q
- Pigging Facilities
- Market Destination Variability
- Future Expansion (Sidetaps, Y's, Etc.)

Figure 1D.9. Strategic factors, part 2.

J. Ray McDermott, Inc.
Deepwater Pipeline Transportation Limitations

Governmental Issues

- Outdated Codes (Need Fit-for-Purpose)
- Domestic Supply Enhancement
- Royalty Relief
- Permitting Requirements / Time
  - MMS
  - U.S. Army Corps of Engineers
  - DOT / USCG
  - FERC
  - State
- Environmental Requirements
  - OPA 90
  - Marine EcoSystem Protection
  - Pollution Response Procedures
  - Abandonment Obligations

Figure 1D.10. Governmental issues.

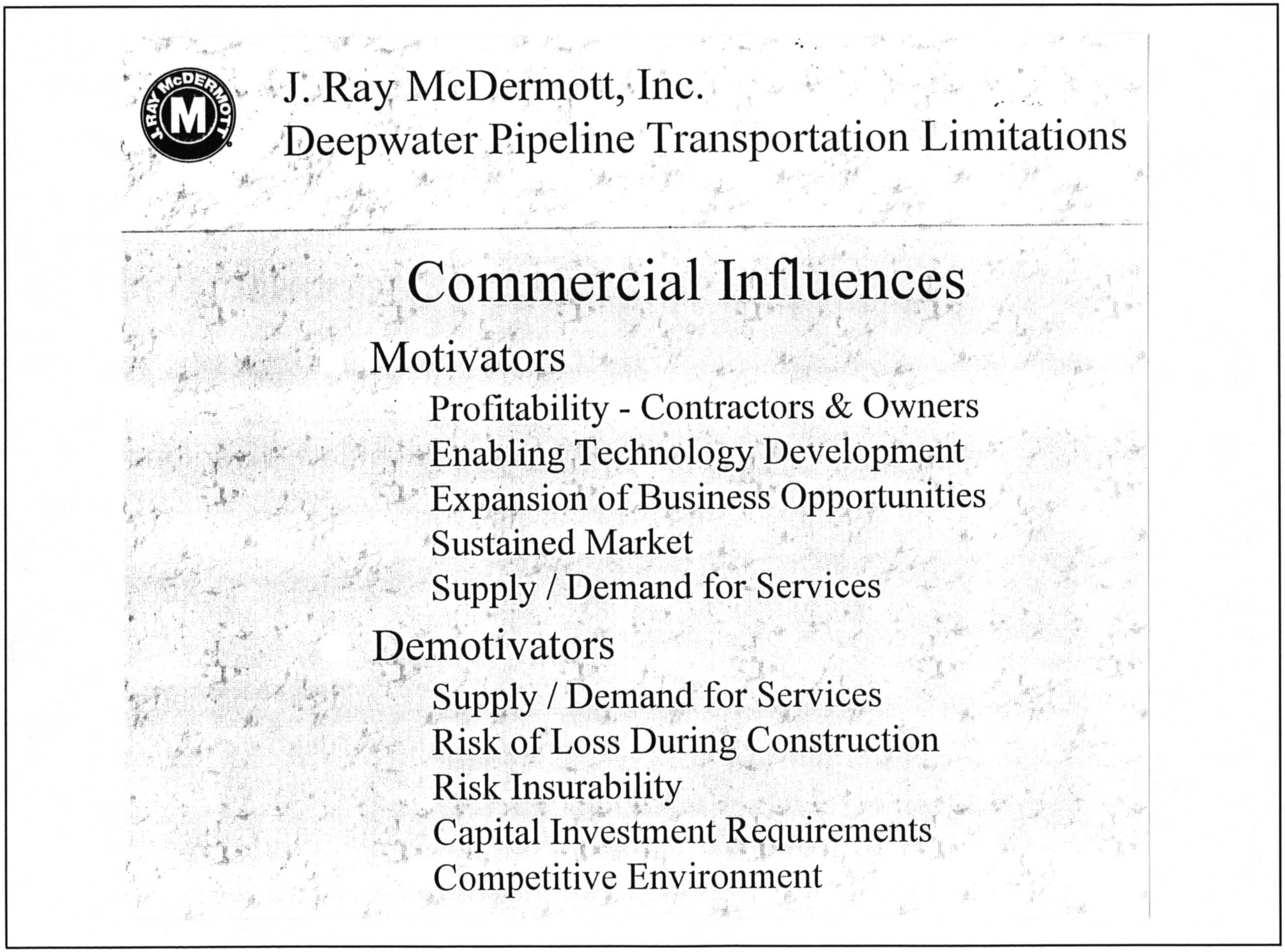

Figure 1D.11. Commercial influences.

J. Ray McDermott, Inc.
Deepwater Pipeline Transportation Limitations

Future Challenges

Technical

- Insulation / Heating Systems
- Definition or “Thresholds”
- Economical / Practical Pipe-in-Pipe Systems
- Develop Repair / Intervention Methods & Equipment
- Multiphase Pumping / Metering

Strategic

- Prediction of Sustained Supply Requirements
- Dimension Growth of Market Services
- Evaluate “Line Life” Operational Needs
- Design in Expandability (Side Taps, Y’s, Etc.)

Figure 1D.12. Future challenges, part 1.

J. Ray McDermott, Inc.
Deepwater Pipeline Transportation Limitations

Future Challenges (Cont'd)

Governmental

- Development of Codes (Fit-for-Purpose)
- Improve Efficiency of Permitting
- Incentivize Domestic Production / Construction
- Protect Lines of Supply
- Preach What is Practical

Commercial

- Define Sustained Market Needs (Demand)
- Balance Supply to Match Demand
- Evaluate Long-Term Profit Potential
- Expand Technical Capability to Meet Sustained Market Demand

Figure 1D.13. Future challenges, part 2.

THE USEFULNESS OF ENHANCED SURFACE RENDERINGS FROM 3-D SEISMIC DATA FOR HIGH RESOLUTION GEOHAZARD STUDIES

Mr. E.H. Doyle
Mr. J.S. Smith
Dr. P.R. Tauvers
Mr. J.R. Booth
Mr. M.C. Jacobi
Ms. A.C. Nunez
Dr. F.A. Diegel
Shell Deepwater Development

Mr. M.J. Kaluza
Fugro McClelland Marine Geosciences, Inc.

ABSTRACT

This paper describes a technique to produce artificially-illuminated rendered surfaces based on 3-D seismic data. The renderings are used to make high-resolution assessments of near-surface geological features for geohazard studies. The technique has been used in several offshore prospects to evaluate near-surface geologic features as to their potential constraint on deepwater activities. The method has substituted the need for other types of high-resolution geophysical systems at some locations. The usefulness and limitations of the method is governed by data quality and a complete understanding of the geological processes in the context of the features observed.

INTRODUCTION

Geohazard evaluations consist of a field acquisition phase, a data processing phase and a phase to evaluate the data and interpret the results. Typical field acquisition systems consist of devices to measure water depth, view the planar surface of the sea floor (e.g., side scan sonar), and profiler systems, which penetrate to various depths below the sea floor. Typically, high frequency sources, such as 3.5 kHz subbottom profilers, are used to penetrate the upper sediments to provide high resolution images while lower frequency sources (up to 500 Hz) are used to image deeper horizons. Today, much of the data is recorded digitally, which allows for a variety of post-acquisition methods to enhance the data quality and presentation.

Another method to assess geohazards is to render closely gridded geophysical data in such a way as to produce a three-dimensional image of a particular geophysical horizon. Two-dimensional horizons are then presented with depth relationships. Renderings provide a perspective view which begs interpretation of geology in contrast to two-dimensional presentations (e.g., maps) which require the brain to transform contours into a three-dimensional shape before the geology can be evaluated. Thus, if high quality data can be rendered to show geology, then data interpretation is aided.

One source of closely gridded data for high resolution geohazard evaluations can be the 3-D data set normally used to find hydrocarbons. These data have usually been thought to be of little use to sea floor and near-surface geological studies because of their lack of high frequency content. As discussed in this paper, 3-D data sets can be used to understand and evaluate the surface and near-surface geological processes normally evaluated in a geohazard study.

ENHANCED SURFACE RENDERING METHODOLOGY

The technique described in this paper is called Enhanced Surface Rendering (ESR). In simple terms, it is a method to display gridded horizon data as an artificially-illuminated surface. The steps used to create these images involve: 1) deriving fully populated data grids from partially interpreted seismic horizons using commonly available autopicking methods, and 2) rendering such a surface as a solid by calculating and assigning a value to each grid node representing the brightness of the sloping surface at that point relative to a given light source. In addition, any one of several derived attributes of that horizon, such as event thickness or amplitude, can be used to "paint" the surface using color. Many commercial software packages do this type of grid calculation and image processing.

The uniqueness of this method is that the ESRs provides a means of identifying near-surface geohazards using 3-D seismic data without the need for more conventional side scan sonar and subbottom profiling systems. The method is particularly suitable for prospective drilling in water depths greater than about 800 feet because water at about this depth is required for obtaining a robust water-bottom event. In shallower water, it is difficult to obtain shallow 3-D seismic data acceptable for high frequency enhancement. It is also best practiced where the sea floor slope is less than about 5° and not a geologically "complex" surface. When the sea floor is steeper than about 5° or geologically complex, the method may be utilized along with other information to obtain a more complete understanding of potential near-surface geologic hazards. However, the significant advantage of avoiding the requirement for deep tow and other seismic acquisition systems is not likely to be achievable.

ESR images are strongly dependent on data quality and density. They provide the viewer with a three-dimensional rendering, that represents every data point. A conventional contour map or grid-mesh is by nature depopulated and not as visually rich nor as informative. Ideally, rendered surfaces are best made using dense data sets, on the order of a 50-meter grid spacing for regional work, or standard 3-D track-bin spacing (15-25 meters for shallow hazard work). The 3-D data set should be first subset to represent the first two to three seconds of data to reduce the volume of data to be processed. The subsetted seismic data are enhanced using high frequency enhanced and whitening methods that are well known in the industry. The grid is prepared by seeding the water-bottom and selected subbottom horizons and then applying an autopicker to volume pick the water-bottom or subbottom horizons to create a dense grid of surface points. For horizon grid sets, the zero phase of the seismic pulse is chosen. Water-bottom data are particularly easy to autopick as the seismic signal is easily identified and has sufficient contrast between the negative and positive peaks of the seismic wavelet. Elevation data are then extracted from the dense grid.

Amplitude-based ESRs can also be developed. The zero phase of a wavelet is first identified (e.g., the water-bottom wavelet) and the corresponding positive peak of the wavelet is noted for each trace. A color scale (or gray scale) is assigned to these amplitude values and applied as an overlay to the ESR developed for a particular horizon. Amplitude ESRs have been correlated to hard grounds and chemosynthetic communities where 3-D coverage overlaps with conventional side scan sonar data.

Vertical resolution is on the order of two to three meters for features which are larger than one gridnode. Features on the digi level (i.e., the smallest vertical resolution from seismic-one vertical seismic sample) are not readily visible on seismic cross sections but are clearly imaged in mapview using ESR technology. Normally, 3-D seismic data are processed in order to best image events at the objective level, commonly sacrificing data quality near the water-bottom. For shallow hazard work, we use high-resolution 3-D seismic data (frequency enhanced and whitened) to generate water-bottom and subbottom horizon grids. These surfaces are then rendered as solids in a top-down, orthogonal sense, at the appropriate scale. Views are colored by either elevation or amplitude and several illumination directions are rendered to highlight variously trending sea floor morphologic features such as faults, slumps, salt structures, carbonate buildups on the sea floor and fluid expulsion features. When used in conjunction with high-resolution seismic data, surface features can be traced into the subsurface with sufficient confidence to avoid near-surface geological features which may constrain field operations.

The methodology described in this paper has received a patent (Booth, *et al.* 1996). The summary of the invention as described in the patent is

> accomplished by a method to identify the existence of near-surface drilling hazards in the vicinity of a sea floor location, the method comprising the steps of:
>
> - obtaining 3D seismic data for the sea floor in the vicinity of the sea floor location;
> - preparing a high resolution 3D vertical profile from the 3D seismic data;
> - preparing an artificially-illuminated rendered surface based on the 3D seismic data; and
> - identifying the existence of near-surface hazards in the vicinity of the sea floor location by visual analysis of the rendered surface with reference to the high resolution 3D vertical profiles.

In this method, 3D seismic data is used to perform a drilling hazards study without the need for obtaining deep tow or geohazard data. 3D seismic data is typically available for prospective drilling sites, and considerable time and money is saved with the practice of the present invention.

ESR EXAMPLES

Several example renderings are presented to demonstrate the usefulness and applicability of ESR s to geohazard evaluations.

REGIONAL EVALUATIONS

Large area renderings can be easily created to develop a regional understanding of the geological features that affect the local area being evaluated. Regional ESRs are also useful in planning the size and orientation of field acquisition programs. Shown in Figure 1D.14 is an ESR of a two-block area in Garden Banks, which was developed from NOAA data gridded to a 50-meter grid spacing. (The original NOAA data is available as raw altimetry data. That data were re-aligned and gridded to 50 meters.) The three-mile square lease block on the left had been surveyed in 1994. The data for the lease block on the right was obtained from another operator and was collected in 1983. The 1994 survey data showed numerous outcrops on the sea floor, which were interpreted to be shelf edge bioherms and carbonate reefal mounds. The older survey showed a paucity of mounds which might have been due to poor data. Since the proposed platform was to be installed in the block at the right, it was important to know if the mounds extended further into the lease block. The ESR produced from the NOAA data clearly showed that the 1983 maps were correct and led to us *not* obtaining additional high resolution data in that block. The ESR was also used for pipeline planning purposes. Possible computer generated pipeline routes are also shown in Figure 1D.14.

Another regional ESR of a large area is shown in Figure 1D.15 for the area around the Auger TLP. This particular ESR was used in the planning of anchor lines and pipelines, which are shown as straight lines emanating from the TLP center on the ESR. This image is based on 3-D seismic data and is of sufficient high quality to evaluate large scale geological sea floor processes. The most obvious feature is a sea floor mound over a salt dome immediately east of the TLP site. Slump features originating on the north side of the image can also be seen. The geologic features have been previously reported by Kaluza and Doyle (1994) and Prior and Doyle (1993). The data used in the evaluations were acquired with the EDO deep tow system reported by Prior *et al.* 1988.

AMPLITUDE ESRs

Another use of ESRs is to present the amplitude of a seismic wavelet in a rendering. One such rendering over the top of the salt dome in the Auger prospect is shown in Figure 1A.16. Overlain on top of this ESR is an area mapped with the EDO deep tow system as an area of authigenic rock outcrop and active fluid expulsion. These features are often associated with chemosynthetic communities and are a constraint to drilling and production operations. The ESR shows that high amplitudes can be correlated to outcrop/fluid expulsion areas. Thus, amplitude-based ESRs offer the potential for evaluating areas where operational constraints are imposed by federal regulation.

Another amplitude ESR is shown in Figure 1D.17 over one of the near-surface slumps in the Auger area. The slump was mapped using EDO deep tow side scan sonar and 3.5 kHz subbottom profiler data. The amplitude ESR clearly displays the slump as a higher amplitude region on the ESR. The slump is recent in age but is covered by 1-3 meters of hemipelagic material and is probably several thousand years old. Since low frequency systems penetrate the sea floor, the slump was picked up within the sea floor seismic trace and can be imaged due to the variation in signal amplitude over the slump feature.

ESR LIMITATIONS

The methodology discussed in this paper has limitations. The greatest limitation is that high quality data must be used. As previously mentioned, the data must be closely gridded. A 50-meter grid is a minimum for regional geohazard evaluations. At this scale, large areas can be evaluated. A 15-25 meter grid is required for shallow hazard evaluations at the lease block scale. The ESR does not "see" everything. For example, ship wrecks, well heads, and other point source objects (i.e., objects as small or smaller than the grid spacing) can be difficult to identify. Thus, side scan sonar may still have to be acquired in areas with potential cultural constraints.

Data quality is particularly important for an amplitude ESR. Shown in Figure 1D.18 is an amplitude ESR over

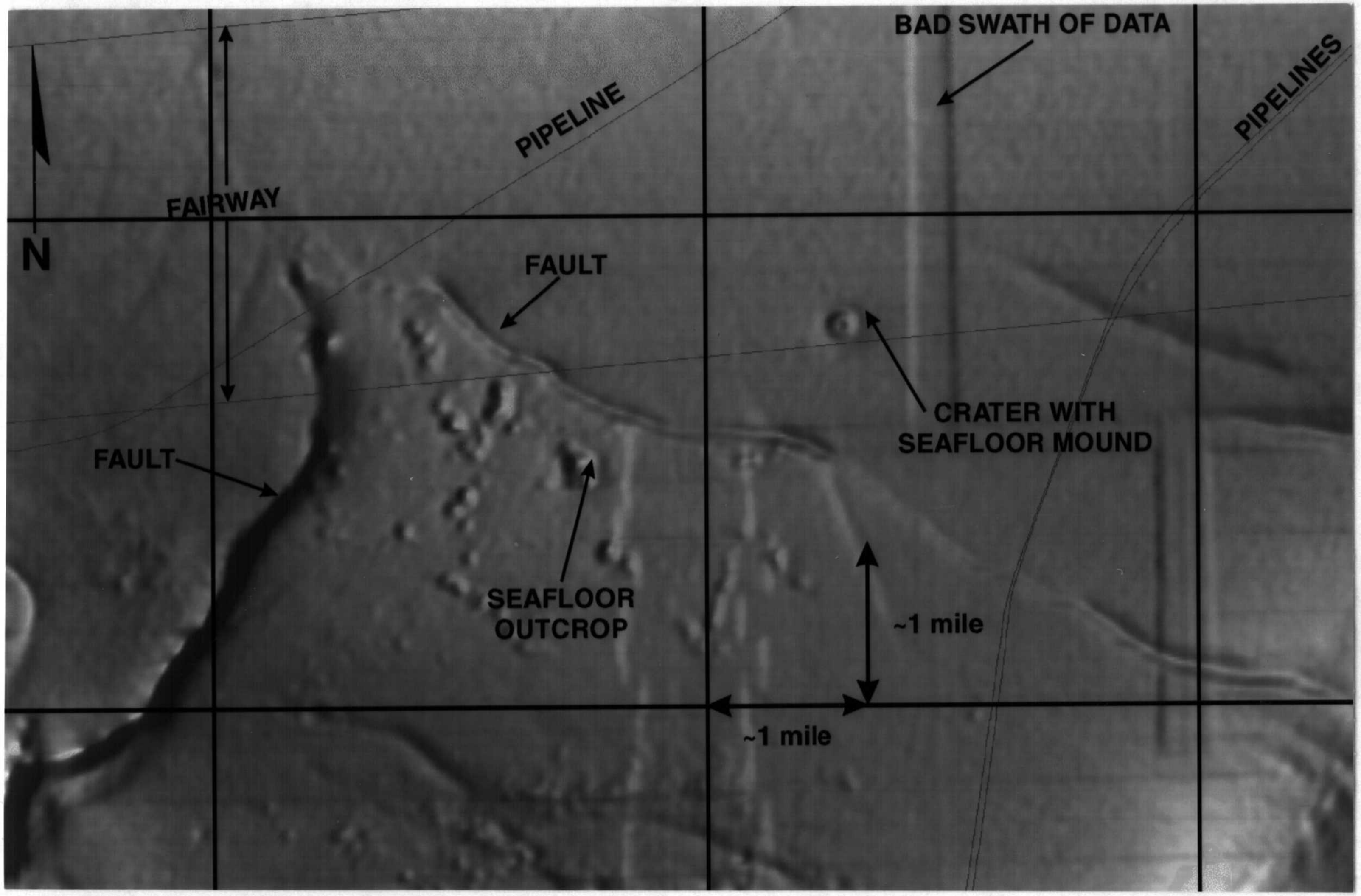

Figure 1D.14. Enhanced Surface Rendering showing fault scarps and outcrops on the seafloor, northern Gulf of Mexico.

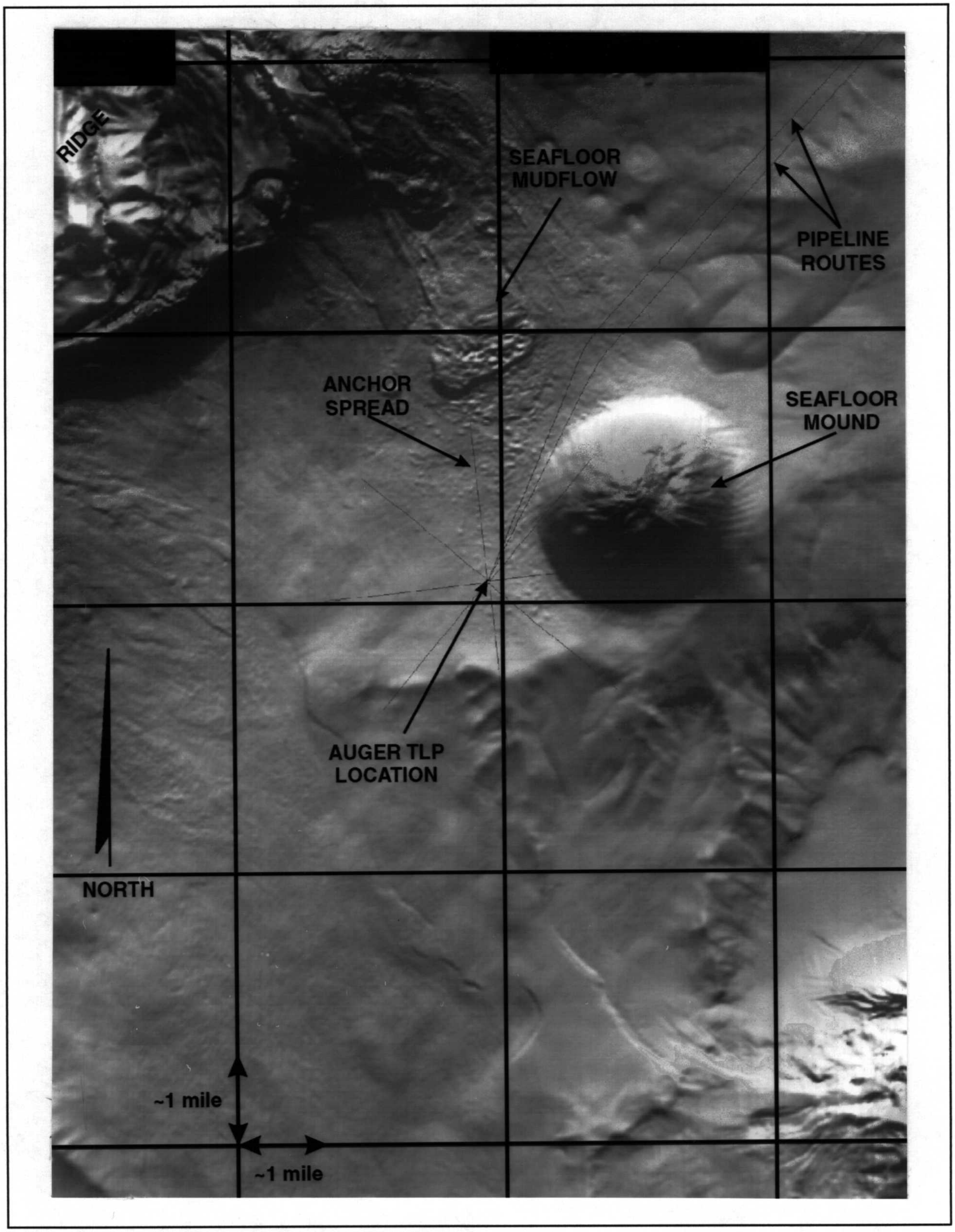

Figure 1D.15. Enhanced Surface Rendering of Auger Prospect.

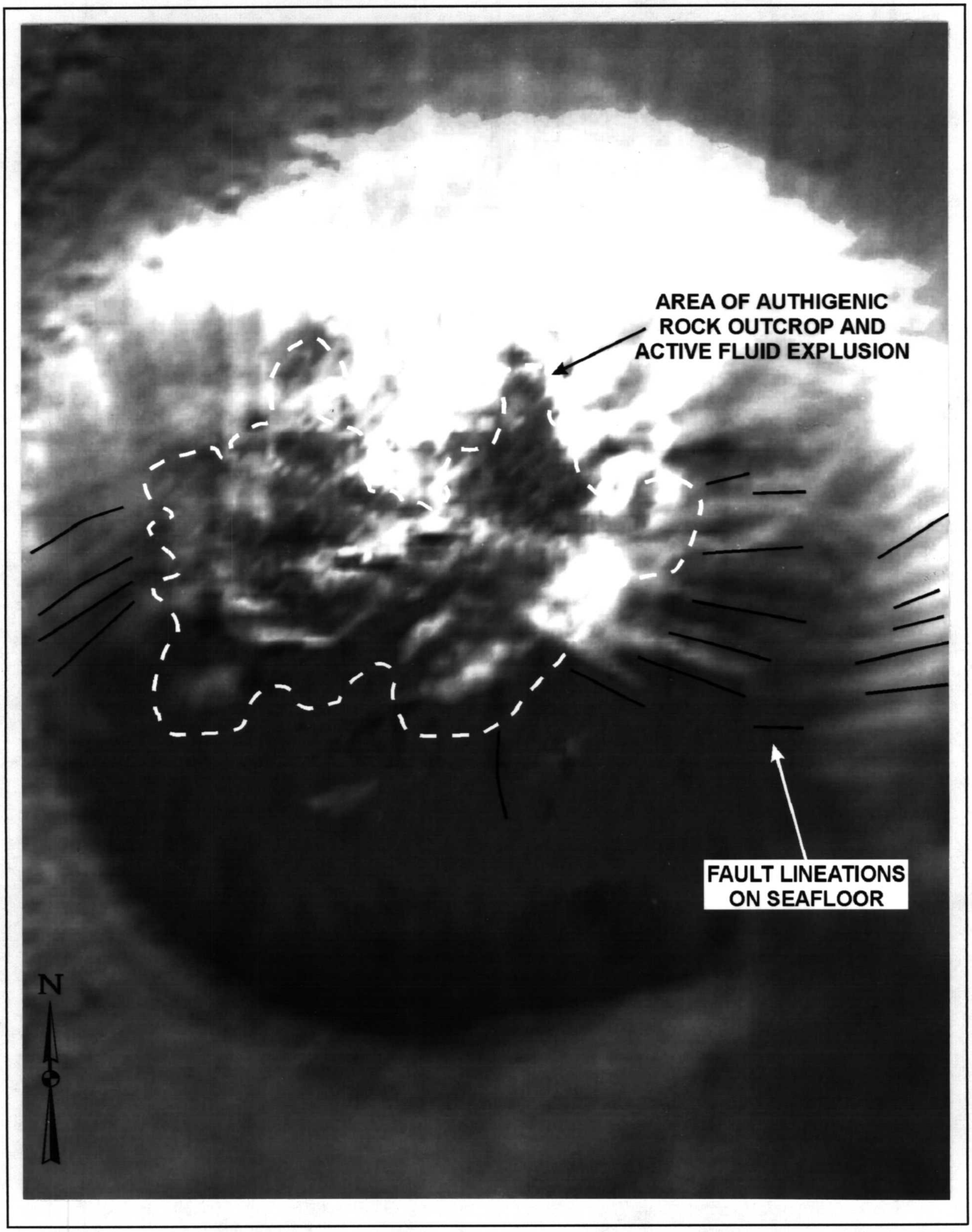

Figure 1D.16. Amplitude-based Enhanced Surface Rendering over diapiric hill in Auger Prospect, Garden Banks 427.

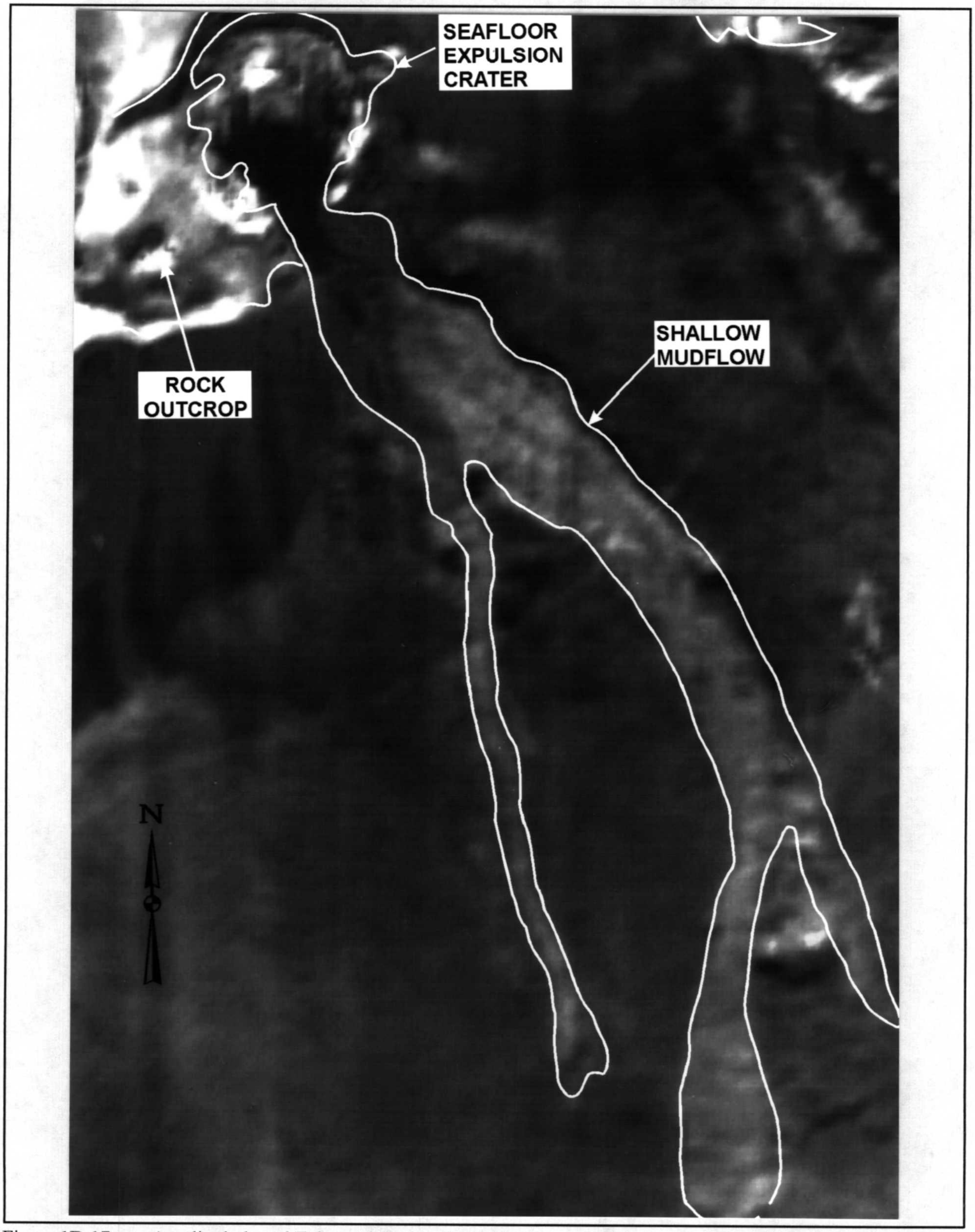

Figure 1D.17. Amplitude-based Enhanced Surface Rendering over expulsion crater and mudflow in Auger Prospect, Garden Banks 427.

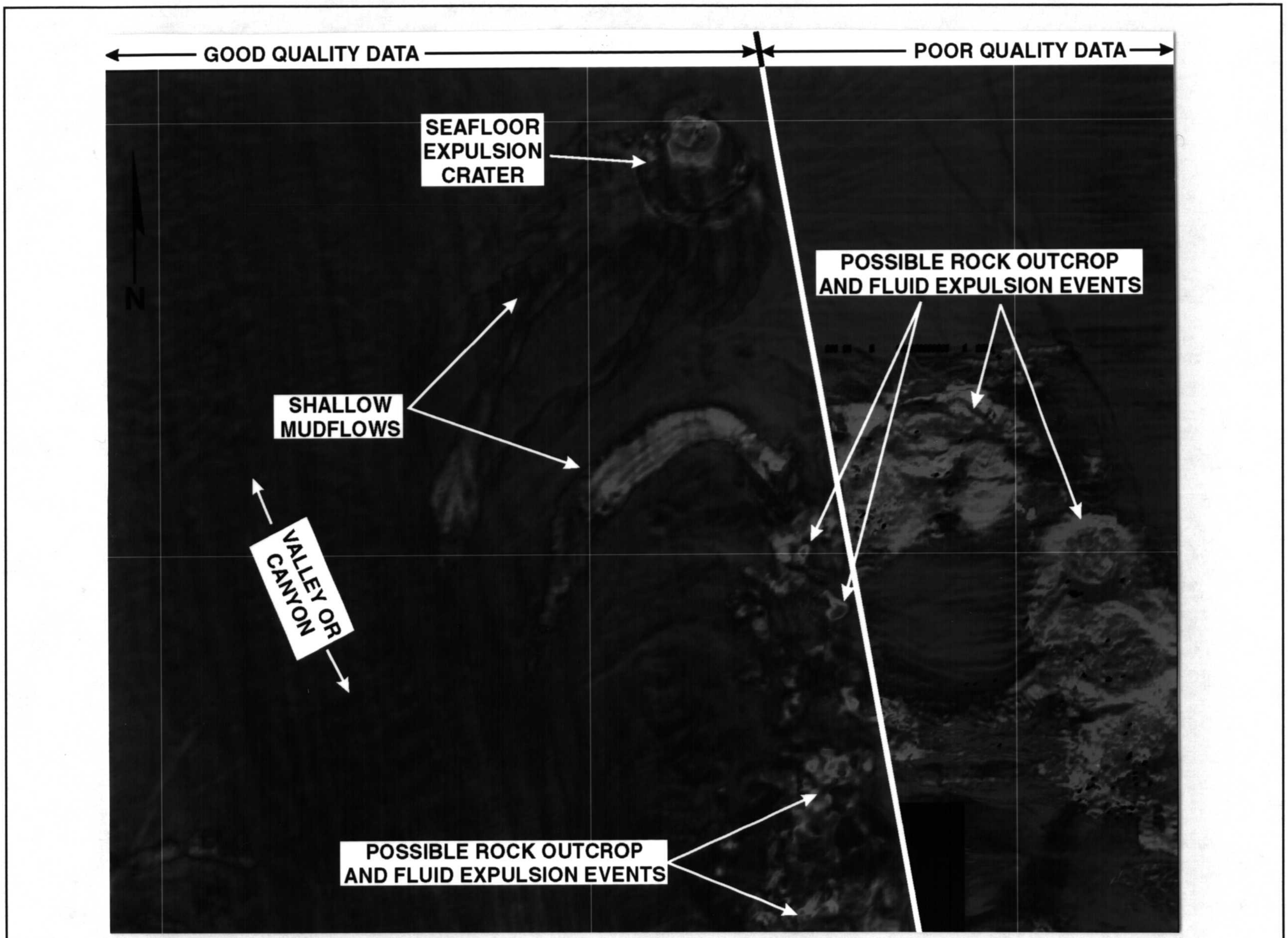

Figure 1D.18. Amplitude-based Enhanced Surface Rendering showing “good” and “poor” quality data.

a four-block area. The left side of the figure shows the result of high quality data while the right side shows the effect of poor quality data. On the left, two sea floor flows and numerous outcrop areas were imaged. The outcrop areas on the right are smeared and not independently shown. Placing anchors and anchor lines using the poorer quality data would be a challenge. Using the high quality data, anchor placement is considerably less problematic.

CONCLUSIONS

Enhanced Surface Renderings (ESRs), based on closely gridded data, can be used to evaluate shallow hazards. Its usefulness is based on high quality data. It was also shown that ESRs can be developed from 3-D seismic data. The method has been correlated with other high resolution systems such as deep tow side scan sonar and 3.5 kHz subbottom profilers.

In addition to data quality, ESRs should be used as an aid in understanding geological processes and as a means to equate the features seen in an ESR with the interpreter's knowledge of near-surface processes. It is not intended to completely replace other high resolution field acquisition systems. It serves as just one of the tools an interpreter uses in evaluating geohazards. Judgement and experience, as usual, are the primary keys as to the applicability of using only an ESR to conduct geohazard evaluations.

ACKNOWLEDGMENTS

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Earl H. Doyle is a senior staff civil engineer with Shell Deepwater Development, Inc. (SDDI) in Houston. For 17 years, he was involved in geotechnical engineering research with Shell Development Company. For the past 12 years, Mr. Doyle has designed the foundations for several important structures, including the Auger and Mars tension leg platforms. He is also active in integrating deepwater, high resolution geophysical data with near surface geology and geotechnical properties. Mr. Doyle holds a M.S. degree in ocean engineering from the University of Rhode Island.

Jonathan S. Smith is a senior survey specialist with SDDI in New Orleans. He has planned, coordinated, and actively supervised numerous geohazard surveys using shallow and deep towed acquisition systems. He is a focal point for the preparation of the shallow hazard analysis reports for exploration and development projects as well as acoustic positioning projects in the deepwater Gulf of Mexico. After receiving his degree in design technology, he studied math and computer science at Tulane University.

Peter R. Tauvers is a senior geologist with SDDI in New Orleans. He has conducted research on salt tectonics at Shell Development Company and for the past four years has been involved with SDDI's deepwater exploration efforts. Tauvers holds a B.S. in geology from City College of New York, a M.S. in geology from the University of Vermont, and a Ph.D. in geology from the University of Texas.

James R. Booth is a senior geologist with SDDI in New Orleans. He is presently a project geologist for several deepwater prospects. His career has included evaluating and maturing deepwater prospects and shallow hazards analyses. Mr. Booth holds a B.S. degree in geology from Northeast Louisiana University and a M.S. degree in geology from Louisiana State University.

Michael C. Jacobi is a staff geophysicist with SDDI in New Orleans. His assignments have included seismic data acquisition and seismic interpretation of both wild-cat and appraisal wells. He is a graduate of Whitman College with a B.A. in history and Western Washington University with a B.S. in geophysics.

Arlette C. Nunez is a shallow hazards interpreter with SDDI in New Orleans and is responsible for deepwater geohazard interpretations and acts as SDDI's primary interface with the MMS.

Fredric A. Diegel is a staff geologist with SDDI in New Orleans. He previously conducted geologic research at Shell Development Company prior to his present assignment. He is a graduate of Franklin & Marshall College with a B.A. in geology and holds a Ph.D. in structural geology from the Johns Hopkins University.

Michael J. Kaluza is a senior supervising geologist with Fugro McClelland Marine Geosciences, Inc. in Houston. For the past 20 years, he has been involved with the acquisition and interpretation of high resolution geophysical data for the purpose of geohazard evaluations. He has led the contractor interpretive effort for all of SDDI's deepwater shallow hazard evaluations. Kaluza is a graduate of Texas A&M University.

SESSION 1E

OCS AIR QUALITY ISSUES

Co-Chairs: Ms. Terry Scholten
Dr. William Hutzell

Date: December 11, 1996

Presentation	Author/Affiliation
An Analysis of Ambient Pollutant Concentrations and Meteorological Conditions Affecting EPA Class I and Class II Areas in Southeastern Louisiana	Dr. S.A Hsu Coastal Studies Institute Louisiana State University
Case Study in Emissions Reductions from Long-Term Drilling Operations	Ms. Terry Rooney British Petroleum Exploration & Oil, Inc. Mr. Don McIntyre Santa Fe International Corporation Mr. Christopher Arms Hunt Engine, Inc.
Development of the Graphical User Interface (GUI) and Other Enhancements for the Offshore Coastal Dispersion (OCD) Model	Mr. Joseph C. Chang Ms. Kathy J. Hahn EARTH TECH, Inc.
Alternative Models for Air Quality Assessments: CALPUFF (Manuscript not submitted)	Mr. John Vimont National Park Service
Hybrid Grid Models for Regional Air Quality Assessment	Dr. Mark A. Yocke ENVIRON International Inc.

AN ANALYSIS OF AMBIENT POLLUTANT CONCENTRATIONS AND METEOROLOGICAL CONDITIONS AFFECTING EPA CLASS I AND CLASS II AREAS IN SOUTHEASTERN LOUISIANA

Dr. S. A. Hsu
Coastal Studies Institute
Louisiana State University

INTRODUCTION

The purpose of this ITM presentation summary is to provide our preliminary analyses and results related to the air quality measurements and dispersion meteorology for the Breton Island area in the northeastern Gulf of Mexico.

METHODS AND RESULTS

Air Quality

The data record from November 1994 through March 1996 at Breton Island (Figure 1E.1) was searched for the highest 5-minute average concentrations of NO_2 and SO_2. For each month with valid data, the highest and second highest 5-minute cases were determined. Days in which the 5-minute maximums occurred were then analyzed for hourly air quality concentrations as well as hourly wind speed and direction and 24-hour (daily) averages. The data are summarized in +++Tables 1E.1 and 1E.2 for SO_2 and NO_2, respectively. From these highest days, the maximums during the data record were determined. These are plotted in Figures 1E.2 and 1E.3 for SO_2 and NO_2, respectively. The NO_2 maximums are often associated with light East-Southeast winds while the SO_2 are related most to moderate north-northeast flow.

Meteorology

To better understand the overwater transport physics in the northeast Gulf of Mexico, improved knowledge of shear velocity and mixing height are needed. On the basis of wind-wave interaction, the parametric wave model is verified by four NDBC stations in our study area. From the parametric (Spectral) wave model

$$\frac{gH_s}{U_{10}^2} = 1.6 * 10^{-3}\left(\frac{gF}{U_{10}^2}\right)^{\frac{1}{2}} \qquad (1)$$

$$\frac{gT_p}{U_{10}} = 2.857 * 10^{-1}\left(\frac{gF}{U_{10}^2}\right)^{\frac{1}{3}} \qquad (2)$$

Eliminating F, we get

$$\frac{\left(\dfrac{gH_s}{U_{10}^2}\right)}{\left(\dfrac{gT_p}{U_{10}}\right)^{\frac{3}{2}}} = A = 0.01048 \qquad (3)$$

where A ≡ Wind-Wave Interaction Coefficient.

During 15-16 November 1996, when easterly winds prevailed and the wind and wave directions were within 20°, we have the following Buoy Station readings:

#42036	A = 0.01223 ± 0.00100
#42039	A = 0.01193 ± 0.00106
#42040	A = 0.01129 ± 0.00109
#42007	A = 0.00832 ± 0.00186
Mean	A = 0.01094 ± 0.00179

Therefore, the parametric wave model is applicable in the northeast Gulf of Mexico and from this result the shear velocity can be obtained.

Since convective boundary layer prevails over the DeSoto Canyon region of the Gulf in summer and winter (see Figure 1E.1), parameterization of free convection is also discussed.

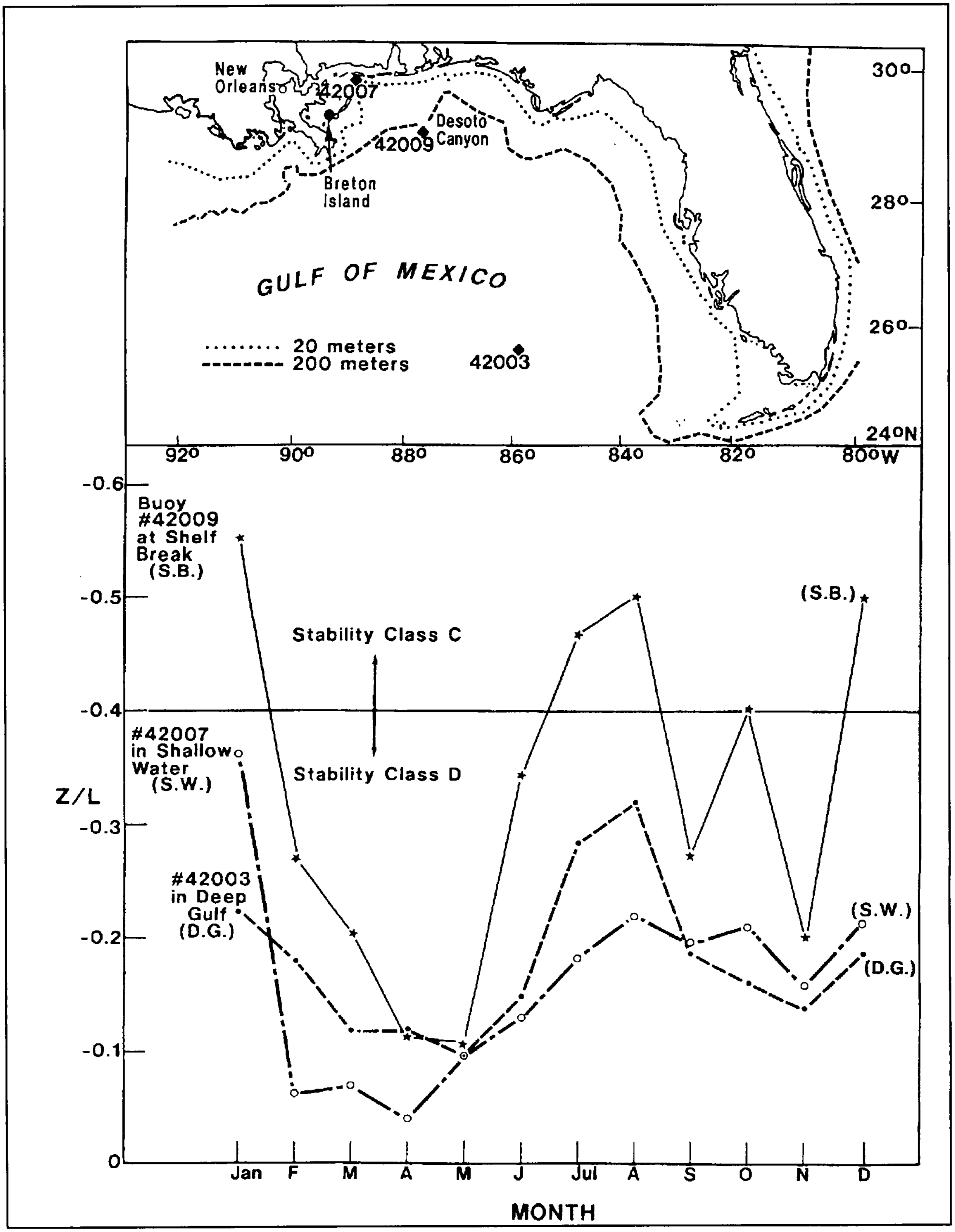

Figure 1E.1. The study area and its monthly variation of stability characteristics.

Table 1E.1. Breton Island SO_2 Maximums (ppb). (Note: preliminary data analysis)

Year	MM/DD	5 minute Maximum (ppb)	Hourly Maximum (ppb)	Hourly WS/WD m s^{-1} / deg	24 Hour Maximum (ppb)
1994	11/25	25.6	6.9	6 / 43	3.8
	11/6	23.8	5.8	8 / 353	2.8
	12/20	37.5	5.4	4 / 68	Missing
	12/17	18.4	11.8	5 / 37	4.0
1995	1/3	27.6	15.4	8 / 19	6.1
	1/24	23.6	8.5	4 / 20	Missing
	2/19	57.6	33.2	6 / 11	5.6
	2/6	51	8.7	11 / 12	3.2
	3/12	18.7	5.0	10 / 86	2.5
	3/3	17.4	11.3	6 / 50	6.1
	5/21	16.5	12.9	6 / 45	3.9
	5/22	12.2	5.2	6 / 68	2.9
	6/20	22.4	6.9	4 / 8	2.5
	6/24	9.2	3.7	3 / 134	1.0
	7/8	12.1	5.6	2 / 169	1.0
	7/9	10.4	9.2	7 / 270	2.5
	9/28	16.3	6.3	Missing	2.4
	9/9	13.3	11.5	Missing	2.5
	10/29	27.4	11.3	10 / 13	1.0
	10/8	15.7	12.6	Missing	5.8
	12/28	19.1	9.9	10 / 19	4.9
	12/29	11.4	8.7	10 / 29	3.8
1996	1/31	28.3	15.1	7 / 6	2.5
	1/29	21.2	6.1	4 / 114	0.7
	2/5	15.9	8.6	9 / 11	2.7
	2/13	13.3	5.6	8 / 15	1.6
	3/2	33.3	16.9	5 / 342	2.3
	3/11	19.4	10.6	6 / 355	3.8
Maximums		57.6	33.2		6.1

Table 1E.2. Breton Island NO_2 Maximums (ppb). (Note: preliminary data analysis)

Year	MM/DD	5 minute Maximum (ppb)	Hourly Maximum (ppb)	Hourly WS/WD m s^{-1} / deg	24 Hour Maximum (ppb)
1994	11/25	95.8	26.6	2 / 93	4.9
	11/21	71.9	20.2	4 / 189	7.5
	12/7	68.3	16.0	3 / 129	6.1
	12/31	48.2	25.1	2 / 144	7.2
1995	1/25	74.6	22.8	1 / 290	12.7
	1/26	62.2	21.1	Calm	8.1
	2/23	122.3	29.2	3 / 127	9.4
	2/27	63.4	20.1	3 / 145	7.3
	3/15	78.1	21.0	2 / 141	9.2
	3/19	42.9	13.6	Calm	5.4
	4/15	82.6	28.3	1 / 145	11.6
	4/30	66.2	22.0	2 / 142	6.9
	5/26	57.6	27.9	2 / 128	6.9
	5/24	50.2	17.6	4 / 129	4.6
	6/15	61.1	31.3	2 / 136	Missing
	6/21	59.9	31.8	3 / 128	7.9
	7/1	41.6	18.3	2 / 144	6.3
	7/7	38.3	17.5	2 / 137	6.3
	9/9	54.4	18.0	Missing	5.2
	9/12	33.0	23.9	Missing	5.9
1996	1/31	29.0	25.7	5 / 203	13.9
	1/30	28.6	20.5	5 / 139	8.2
	2/9	48.4	31.0	3 / 238	13.5
	2/25	41.3	27.1	2 / 140	10.7
	3/23	54.1	24.5	1 / 150	13.0
	3/17	39.2	30.4	4 / 232	18.4
Maximums		122.3	31.8		18.4

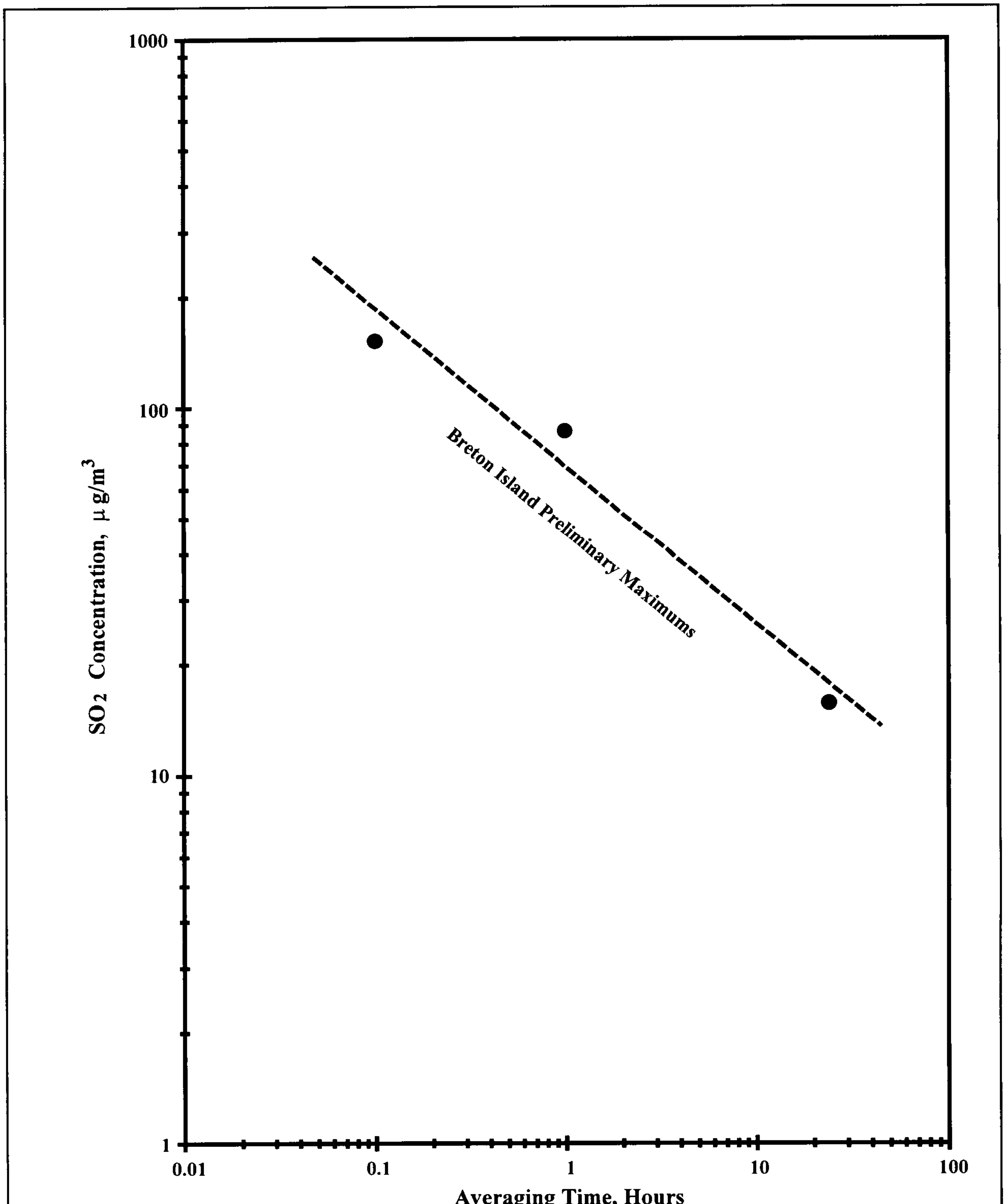

Figure 1E.2. Variations of SO_2concentration with the averaging times on Breton Island.

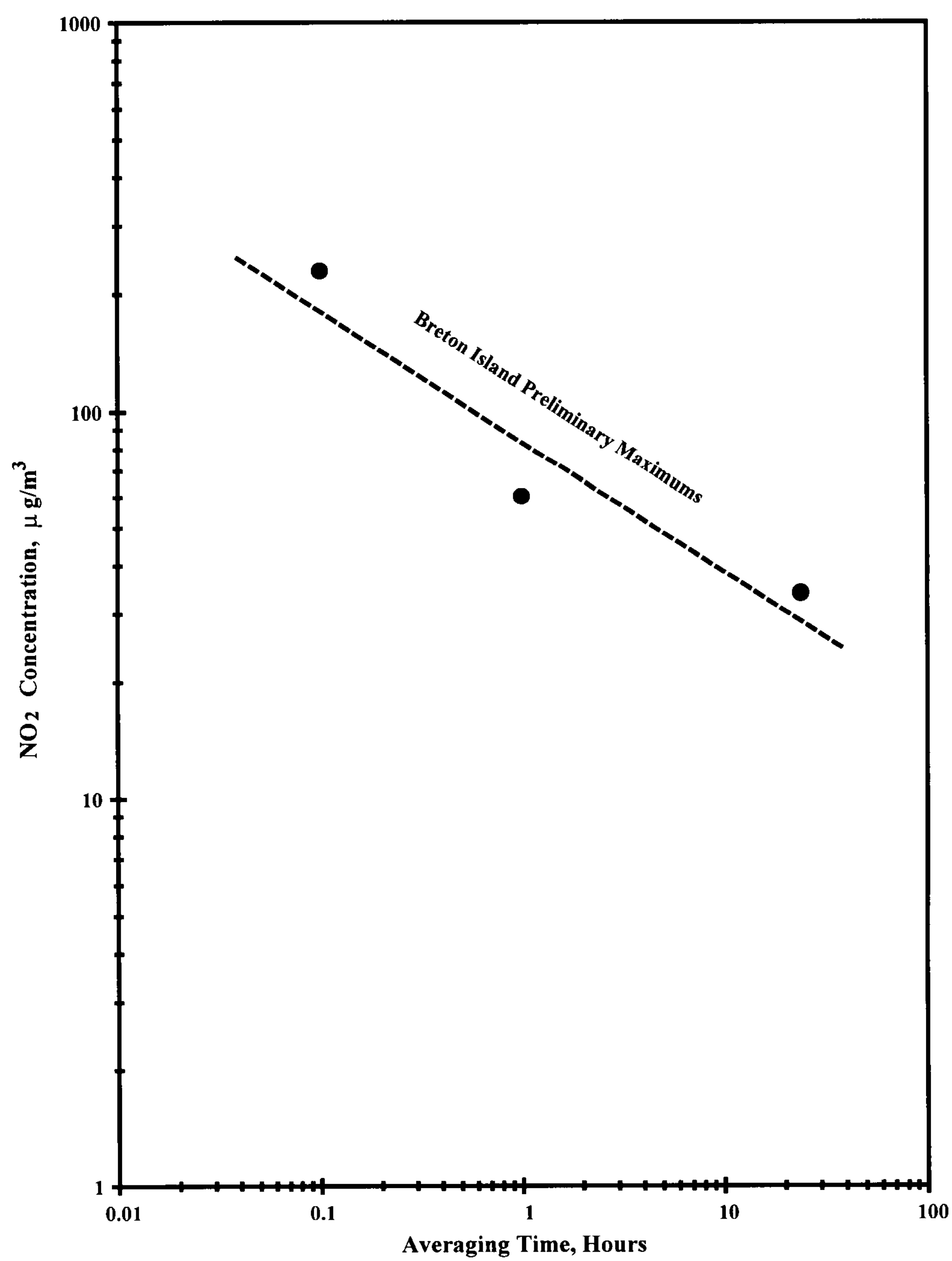

Figure 1E.3. Variations of NO_2 concentrations with the averaging time on Breton Island.

CONCLUSIONS

1. Between November 1994 and March 1996, maximum one-hour and 24-hour concentrations of SO_2 were 33.2 and 6.1 ppb, respectively. For NO_2, they were 31.8 and 18.4 ppb. Generally, SO_2 maximums are associated with moderate north-northeast winds whereas NO_2 with lighter east-southeast flows.

2. Since convective boundary layer was found to prevail in summer and winter over the DeSoto Canyon region, better shear velocity and mixing height parameterizations are provided based upon improved understanding of wind-wave interaction in the northeast Gulf of Mexico.

Dr. S. A. Hsu received his Ph.D. in meteorology from the University of Texas at Austin. He has been a professor at Louisiana State University since 1969. His research interests are coastal and marine meteorology, air-sea interaction, and pollution transport physics. Dr. Hsu has published extensively, including a book entitled *Coastal Meteorology*.

CASE STUDY IN EMISSIONS REDUCTIONS FROM LONG-TERM DRILLING OPERATIONS

Ms. Terry Rooney
British Petroleum Exploration & Oil, Inc.

Mr. Don McIntyre
Santa Fe International Corporation

Mr. Christopher Arms
Hunt Engine, Inc.

INTRODUCTION

This case study reviews the process and results from a joint effort between BP Exploration, Santa Fe, and Hunt Engine to reduce NOx and SOx emissions as part of a long-term drilling project. The process involved evaluating engine conditions that affect emissions and fuel consumption, implementing the recommended changes, and subsequently analyzing performance. The true significance of this project lies with the overall trends observed in the area of NOx reductions and decreased fuel consumption, not the exact NOx measurements and fuel use. The objective of presenting this study is to heighten an awareness of these trends and point out factors to be considered before initiating a similar program. More data is needed to establish reasonable industry-wide expectations.

The project described in this summary lies within the 100 kilometer arc surrounding Breton National Wildlife. The rig is operating over a subsea template in 1800 feet of water. Produced fluids flow four and one-half miles to BP's Pompano platform (1300 feet of water) located 25 miles southeast of the Mississippi Delta. Santa Fe Rig 140 was contracted to drill 14 wells over a two and one-half year period. This type of operation—a large new development within the 100 km arc of the Breton Class I airshed, with the potential for short-term emissions peaks from drilling operations—may require a special effort to reduce drilling emissions.

Rig 140 is a semi-submersible floating rig, built in 1982, capable of drilling in up to 2200 feet of water. It has been in continuous service in the North Sea since that time, with the exception of a 9-month period in 1986. It began drilling in the Gulf of Mexico when it started work for BPX in October 1995. Power generation on Rig 140 is supplied by four 2200 horsepower EMD engines.

In the initial planning stages, BPX evaluated a wide range of possible NOx reduction options for diesel engines. The range included major engine combustion modifications, ignition timing retardation, new technology, and power management. A comparison of the advantages of each option and associated limiting factors, combined with a thorough inspection of the actual condition of the engines, focused our selection to the combination described in this summary. See the proceedings from the June 1995 Air and Waste Management Association Conference held in San Antonio, Texas, for the technical paper discussing this evaluation process, "Strategies for Evaluating NOx Control Options for Future Outer Continental Shelf Projects."

METHODS

An onsite rig investigation was the first step towards identifying the range of emissions reductions feasible for this rig and the associated costs. While operating in the North Sea, a two-person Hunt Engine team traveled offshore and performed the preliminary engine inspection on the rig during normal drilling operations. They documented engine conditions, fuel consumption rates, emissions levels and standard operating practices. Other parameters which can greatly affect performance, such as valve timing position, injector calibration and air flow conditions were also checked. NOx emissions were measured while the engines were operating at manufacturer-specified settings and following a 6° timing retard. A portable NOx analyzer, Enerac 2000E, was used. The unit was calibrated with certified test gas prior to going offshore. This model provides measurements within at least 10% of the newer EPA accepted model. They obtained fuel-use measurements, used to evaluate engine efficiency, based on a known weight of fuel consumed over a specified time period while the engine was operating at a given load. Most rigs are not equipped with flow meters accurate enough to represent a repeatable measure of efficiency.

This initial rig inspection will take two to three days, depending on drilling operations underway. Delay time should be figured in for planning purposes. A similar inspection and report with recommendations should cost approximately $5,000.

Their initial rig engine inspection revealed NOx emissions and fuel consumption rates in excess of the manufacturer's specifications. They also noted a restriction in inlet air flow. Based on these findings, Hunt Engines recommended a combination of modifications to be made which optimized NOx reduction and fuel consumption. Exhaust valve timing adjustments, fuel injection retardation, fuel injector calibration, and power management were expected to significantly lower emissions and fuel use.

MODIFICATIONS

Hunt Engines returned to the rig in July 1995 to adjust the valve timing, install calibrated fuel injectors, and retime the injectors. Correct exhaust valve timing should range between 104° after top dead center (ATDC) to 110° ATDC. NOx emissions are highest at the lower end of this 6° range. Rig 140's timings were predominantly at the lower, high NOx range(103°). Retiming the exhaust valves closer to 110° ATDC was recommended to bring the NOx levels down to published rates of 15.2 g/BHP*hr. This was determined to be the optimal setting to achieve the emissions reductions without black smoke or excessive fuel consumption. This work takes about 20 days at a cost of $20,000 and can be scheduled during ongoing drilling operations.

Engine fuel injectors were retarded from 4° BTDC to 2° ATDC based on the results of the preliminary inspection testing performed on engine #4. This reduces peak combustion temperature and associated thermal NOx formation. The range of reduction is very engine-specific. February 1995 measurements resulted in a 44% decrease in NOx. Experience predicted an associated 2 - 3% increase in fuel consumption. Retarding fuel injectors takes one to two days and can be done during normal operations at a cost of about $2,000.

Testing of a sampling of engine fuel injectors and "off the shelf" unused injectors resulted in 12 of 14 injectors over fueling. On average the engines were burning fuel 5.5% over their theoretical fuel consumption rate measured in lb/BHP*HR. Purchase and installation of matched calibration fuel injectors costs $12,000 and when done with the injector retard, adds 2 days to the project. Hunt estimated that this calibration could reduce fuel consumption by up to seven percent.

To evaluate Power Management options, an analysis of engine load over a two week drilling period was conducted. It showed average load of 40%. For optimal performance each engine should run at no less than 60% load whenever possible. Two engines, each carrying 40% load, waste 17% more fuel and emit 35% more NOx than a single engine carrying 80% load. When engines are operated in their optimum range, both NOx emissions and fuel consumption are reduced. A concerted effort to maintain a 60% or greater load was recommended to lower daily fuel use by five to ten percent.

Table 1E.3. Engine conditions: four 2200 HP EMD diesel engines (model 16-845E8 - roots blown engine).

	NOx (g/BHP*HR) average	Fuel Consumption (gallons/ day)	Conditions
February 1995 Initial Inspection	18	3818	Recent Overhaul Testload 1380 - 1935 HP Standard Timing
July 1996 Following modifications	6	3263	Match Calibrated Injectors Testload 1480 - 1645 HP Injector Retard 6° Altered Valve Timing Corrected air flow restriction Introduced Power Management
December 1996 (preliminary)	8 - 9	3454	Same

Santa Fe engine room personnel subsequently established Power Management guidelines to safely satisfy load demands using the minimum number of engines and generators necessary. Each generator is rated at 1400 KW and the operators allow a 200 KW for miscellaneous startups such as air compressors, air conditioning, etc. When total load requirement is 1200 KW, only one generator would be operating. Once the demand reaches 1300 KW, the second generator would be started. Conversely, if the load drops to 1100 and two generators are on-line, the maintenance staff works with the Driller and Toolpusher to forecast load demands. If the load is expected to remain at 1100 or lower for more than an hour the second generator is shut down. Since engine wear and oil consumption are at their highest during warm up, it's important to minimize the number of engine starts and stops.

ANALYSIS OF RESULTS

Based on these engine and behavioral modifications, Hunt originally predicted NOx emissions reductions from 18 to 8 grams and under similar drilling conditions, that at least 10% less diesel would be consumed. Table 1E.3 summarizes actual NOx emissions, fuel consumption and engine conditions. The February 1995 information is based on data collected and measured during the initial investigation. The July 1996 data is based on actual emissions measurements and average fuel consumption rates resulting from the engine modifications, power management, and 9 months of continuous operations. The December data is based on the most recent NOx measurements and is very preliminary at the time of this report. The December fuel consumption data is an average of January through September as measured at the rig.

As a result of these altered conditions, NOx emissions at Rig 140 have been reduced 50 - 66% from those occurring during the initial inspection prior to beginning rig operations in the Gulf of Mexico.

Fuel consumption during the first six months of 1996 was reduced 20% historic consumption rates. This translated into 100,000 fewer gallons burned during this time period. Average fuel use during the third quarter of 1996 increased, bringing the 1996 average up to 3454, a 10% reduction. Historic fuel consumption for this rig was estimated by comparing usage rates from wells with similar drilling programs (hole size, depths, drilling days).

Presently we're attempting to allocate the percent of this reduction attributed to recent intervention and the portion attributed to an imprecise historic baseline. For points of reference, the historic data compares well with industry average daily usage rates for semisubmersible rigs. Also, Hunt's original prediction based on experience, predicted a 10% reduction. Therefore, the preliminary conclusion is that both factors, imprecise representation of historic rates and better performance during the last 9 months, are in play, but the majority of the reduction from the baseline is due to the recent interventions. Future investigations must address a more precise and standard method of determining baseline conditions. That will allow proper allocation to the real reductions made individually from the engine overhaul, matched injectors and power management. More accurate measurements of the overall efficiency on the engines may also aid in this pursuit.

Hunt Engine recommends a maintenance program to insure continued low NOx emissions and fuel use. Injectors should be replaced annually with new matched calibrated sets. The cost of around $12,000 should more than offset the benefits of continued fuel savings.

Low sulfur fuel is being burned at this facility to reduce SOx emissions. The sulfur content is .05% by weight according to manufacturer's specifications. BPX paid on average $.085 per gallon more during the first six months of 1996. Calculated SOx emissions were reduced from 20 tons to 3 tons over this same time period. This level will remain consistent while LSF is in use.

SUMMARY

Substantial emissions and fuel consumption reductions were achieved as a result of this project. Timing retard alone is predicted to lower NOx by about 30%, but with the unwanted side effect of two to three percent increase in fuel consumption. The alterations in equipment and behavior in this instance resulted in 50 - 65% NOx reductions along with lower fuel use which more than offset the costs. This is only one set of data for one operation. The trend is very encouraging. More work needs to be done on evaluating rig conditions to get a more representative idea of overall conditions, which can then be used to predict candidates that could see significant NOx and fuel use reductions.

BPX, Santa Fe, and Hunt Engine are continuing to monitor performance and define costs and maintenance requirements to continue to achieve these results at Rig 140. BPX is working to develop a standard approach to be used during the initial investigation and the follow-up measurement survey, particularly in the area of fuel consumption. BPX intends to continue to work with its drilling contractors and Hunt Engine to measure engine conditions and performance associated with other long-term drilling partnerships.

Terry Rooney, Environmental and Regulatory Supervisor with BP Exploration & Oil, Inc., is a graduate of the University of Wyoming with a B.S. degree in biology. She has worked in a variety of onshore and offshore environmental and regulatory capacities with BPX for the past 14 years. This current assignment has oversight responsibility for regulatory compliance and technical support for environmental issues affecting offshore exploration and development.

Don McIntyre, Manager of Safety, Training and Environmental Affairs for Santa Fe International Corporation, is a graduate of the University of North Texas with a degree in business administration (management). He has been with Santa Fe for over 16 years and was reassigned from a 19-rig operation in Kuwait when Rig 140 moved into the Gulf of Mexico in September 1995.

Christopher Arms, Vice President of Hunt Engine, Inc. is a graduate of General Motors Institute in Flint Michigan, with a bachelor's degree in mechanical engineering. He has worked with EMD engines for almost 20 years and co-founded Hunt Engine in 1979. His personal efforts towards reducing fuel consumption dates back to the early 1980s and has naturally evolved into parallel studies directed towards reducing emissions.

DEVELOPMENT OF THE GRAPHICAL USER INTERFACE (GUI) AND OTHER ENHANCEMENTS FOR THE OFFSHORE COASTAL DISPERSION (OCD) MODEL

Mr. Joseph C. Chang
Ms. Kathy J. Hahn
EARTH TECH, Inc.

ABSTRACT

Current progress on the development of the Graphical User Interface (GUI) and the implementation of other enhancements for the Offshore Coastal Dispersion (OCD) model is summarized. The GUI seeks to increase the user-friendliness of the model and reduce the potential for user errors. Other code enhancements have added more features to the model and made the model more robust.

INTRODUCTION

The Offshore Coastal Dispersion (OCD) model (Hanna *et al.* 1985; DiCristofaro and Hanna, 1989) was first developed in the 1980s to simulate the effects of offshore emissions from point, area, or line sources on the air quality of coastal regions. The model includes special algorithms that account for overwater plume transport and dispersion, as well as changes that take place as the plume crosses the shoreline.

The original OCD model uses the traditional "input stream" approach for the specification of the input data. This approach is not user-friendly because of its rigid file structure. The original OCD model is also sensitive to user errors, due to the lack of adequate error-checking performed by the model on the input data. Furthermore, after being applied by many modelers in the past few years, it has become apparent that some additional technical features, such as the automatic creation of a Cartesian receptors network and more input data formats supported, should be added to the model. As a result, the Minerals Management Service (MMS) is funding a project with the objectives that a GUI program for OCD would be developed, and that the FORTRAN source code for OCD would be enhanced. (The current phase of the project does not include revisions to the basic dispersion algorithms used in OCD.) The GUI program for OCD makes the model more user-friendly and reduces potential user difficulties in applying the model. With the GUI, the user can prepare, execute, and analyze an OCD application in a graphical or menu-driven environment. Extensive error-checking on the input data is performed by the GUI program. On-line help is also provided through the GUI, so that the user rarely would have to consult the user's guide for further instructions.

The progress made so far on the design of the GUI and the implementation of additional code enhancements is summarized below. Note that since the project is still ongoing, it is expected that the final software product will be further improved.

DEVELOPMENT OF GUI

The GUI allows the user, through a series of menu-driven "screens," to easily set up the control file, execute the OCD model, and post-process the results. A sample "screen" is shown in Figure 1E.4. In addition to leading the user through a series of screens to set up a new control file, the GUI also allows the user to open an existing control file and make necessary changes. The user can refer to the on-line help system of the GUI when questions arise. Default values, if applicable, for some input parameters are provided by the GUI. Map displays of the GUI allow the user to quickly visualize the input data (such as the distribution of the sources, receptors, and shoreline) and the model results (such as the locations where the maximum impacts were predicted). The GUI also performs error-checking on the input data specified by the user. Any invalid input will be flagged by the GUI. A hierarchical approach is used to design the GUI in order to further minimize user errors. For example, in OCD, the need to specify certain parameters depends on the values of other parameters previously defined. Therefore, a "screen" that is not relevant to the current case will be deactivated.

The current version of the GUI program has a total of six "menus," including *File, Input, Run, Utilities, Setup,* and *Help* (see Figure 1E.4). The *File* menu defines the paths and names of the model input, output, and log files, and allows the user to save files under different names. The *Input* menu is responsible for the specifications of the model input. The OCD model is executed via the *Run* menu. Various pre- and post-processors for OCD can be accessed via the *Utilities*

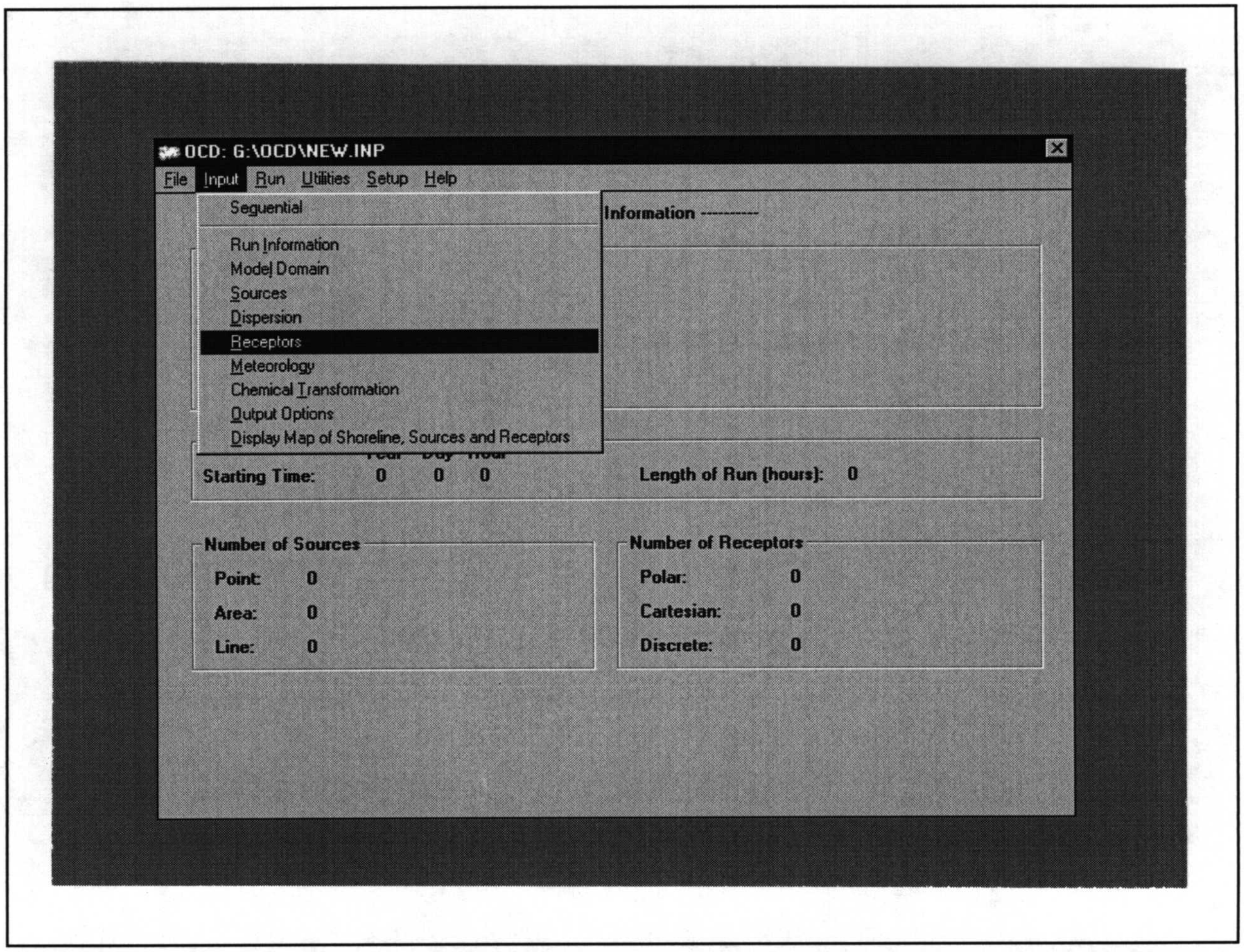

Figure 1E.4. A sample "screen" for the GUI program of the OCD model that shows the general layout of the main program menus and a list of sub-menus for the *Input* menu.

menu. The *Setup* menu allows the user to change the settings of the Windows environment. The *Help* menu includes on-line help, which is also available through the *Help* button in various screens.

The data needs of the OCD model are more complex than those of most steady-state Gaussian-type air quality models. For example, in order to properly simulate the transition between marine and land-based environments, the model requires the specification of the shoreline geometry. The traditional approach required the user to overlap a grid on the area of interest, then manually create a map that contains digitized information of the distribution of land and water. This is clearly a very tedious process. Therefore, the MMS developed a preprocessor called TOPOMAP that automates the generation of such a map based on the U.S. Geological Survey (USGS) data. The input data for TOPOMAP include the two latitudes and the two longitudes that define the area of interest (or the modeling domain). As described below, the GUI is designed to work closely with the TOPOMAP preprocessor.

Once the *Input* menu of the GUI is selected and the user has specified information such as the title and length of the run, the GUI then asks the user to specify the two latitudes and the two longitudes that define the modeling domain. The information is then used by the GUI to run the TOPOMAP pre-processor to generate the required shoreline geometry data (see Figure 1E.5). Since a Cartesian coordinate system should be used in OCD, the GUI further converts the latitudes and longitudes into the Universal Transverse Mercator

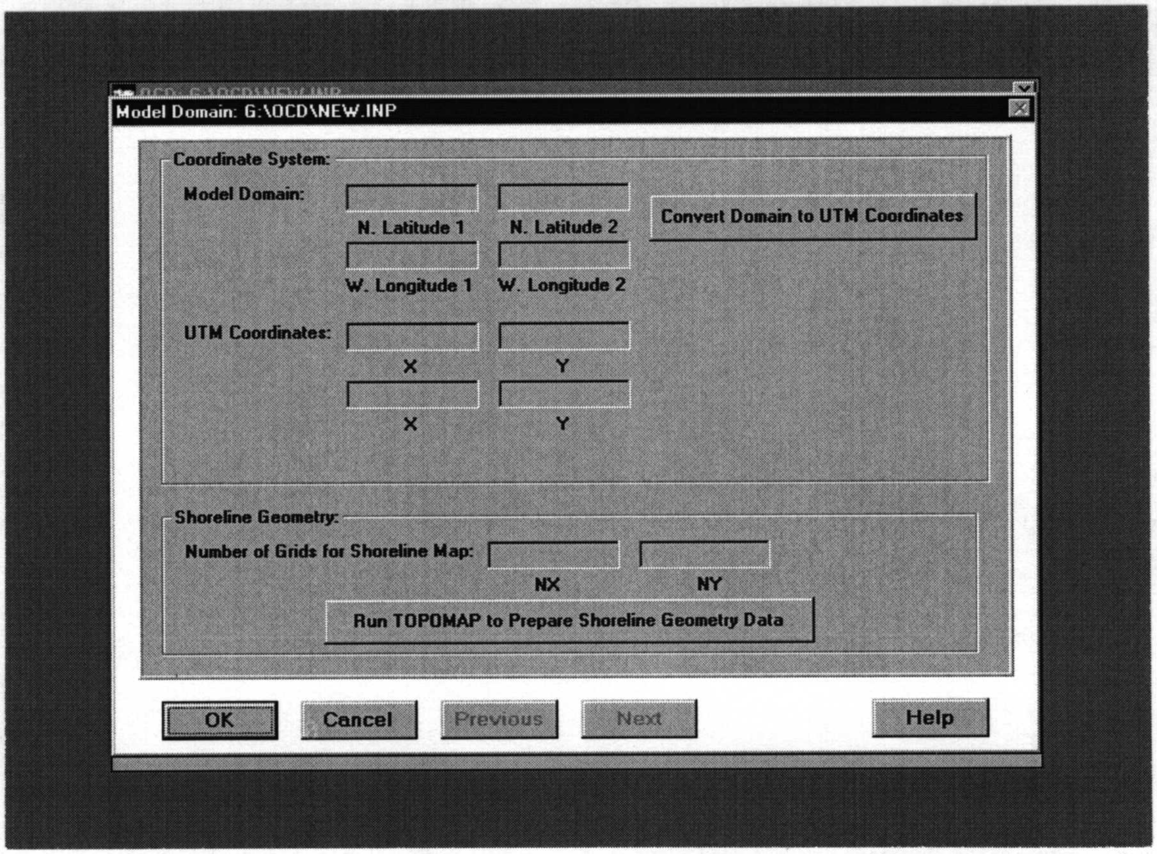

Figure 1E.5. The GUI "screen" whereby the modeling domain (in latitudes and longitudes) is defined, and the TOPOMAP pre-processor is executed to prepare the shoreline geometry data. Note that the latitudes and longitudes used to define the modeling domain will be converted internally by the GUI to the UTM coordinates once the "Convert Domain to UTM Coordinates" button is pressed.

(UTM) coordinates, and the southwest corner of the modeling domain will be assigned as the origin. For example, if the UTM coordinates for the southwest corner of the modeling domain and a source are (400, 3800 km) and (402, 3806 km) respectively, then the coordinates internally assumed by OCD for the southwest corner and the source will be (0, 0 km) and (2, 6 km) respectively. Later on, when specifying the locations for the sources and receptors, the user has the option of using either the internal OCD coordinate system just described, or latitudes and longitudes, which will be converted to the proper internal coordinates by the GUI. The second option allows the user to easily designate the locations of the sources and receptors regardless of the definition of the modeling domain. Note that if the modeling domain happens to span across the boundary of two UTM zones (each UTM zone covers a six-degree strip of longitude), then the GUI program will always use the UTM zone that corresponds to the southwest corner of the modeling domain to convert all latitude/longitude coordinates.

The control file for the OCD model consists of 16 data groups, where some input parameters from different data groups can be considered the same category. In order to follow a more logical approach that is appropriate to a menu-driven environment, the GUI program places all related input parameters under one "sub-menu." For example, the sixth (the pollutant indicator) and seventh (the number of significant point sources) parameters in data group 4, and the sixth (read hourly emissions), seventh (specify significant point sources), and 20th (source type) parameters in data group 5 are all related to sources. Therefore, these parameters together with other source data (e.g., location, emission rate, stack height, stack temperature, stack exit velocity, etc.) are all placed under the *Sources* sub-menu by the GUI program.

After all input parameters have been entered by the user, the GUI program can display a map that shows the locations of the sources, receptors, and shoreline. The map facilitates immediate visualization of the model input, so that errors, if any, can be identified before running the model.

The *Run* menu of the GUI program allows the user to start a normal OCD model run, or a "test run," where the code will go through all quality assurance checks, but perform no dispersion calculations, in order to validate the model input.

The *Utilities* menu provides access to various pre- and post-processors for OCD, including (1) OCD4TO5, a program that converts the OCD control file from the old to the new format (see below); (2) OCDPRO a program that prepares the overwater meteorological data; and (3) ANALYSIS, a program that post-processes the OCD modeling results.

On-line help is available through the *Help* menu, where information such as the definition of and the allowed range for the input parameters is included. The goal is that the user rarely has to consult the user's manual of the model in order to set up a model run. Note that on-line help is also available through the *Help* button in each screen.

The GUI is being developed using Visual Basic and runs under the Windows 3.1 and 95 environments.

OTHER CODE ENHANCEMENTS

In addition to the development of the GUI program, the current project also includes the following enhancements to the FORTRAN source code for OCD.

As mentioned above, the control file for the original OCD model has a very rigid file structure. That is, the locations of various input parameters in the control file must be precise. The GUI essentially makes this rigid file structure transparent to the user. However, OCD is occasionally to be run on other computer platforms, such as UNIX, where the GUI program described above does not function. In order to further increase the user-friendliness of OCD, it was decided that the original control file format should be made similar to the one used in the CALPUFF model (Scire *et al.* 1995). The format for the new control file is flexible in that there are not requirements on the exact placement of input parameters in the control file. Only the information enclosed by special delimiters, such as "!", will be retrieved by the reader program for the new control file. Therefore, the new control file can include comments that describe the input parameters. Figure 1E.6 shows an example of the new control file. Again, the objective is to allow the user to prepare an OCD model run without consulting the user's manual.

The new version of the OCD model now also supports a Cartesian network of receptors. The default is to generate $20 \times 20 = 400$ receptors that cover the modeling domain defined previously. Moreover, the new PCRAMMET (USEPA 1995) meteorological data file, either ASCII or binary, is acceptable to the new OCD model.

In the original OCD model, the limits on the numbers of sources, receptors, and grid cells used to represent the shoreline geometry were all "hardwired" in the code. In the new OCD model, all these limits have been replaced with PARAMETER statements in an INCLUDE file. Therefore, if the user decides to increase the number of receptors allowed by the model, all that is required is to change one line of code and recompile the program.

Better error-checking has also being implemented in the new OCD model. The error messages are now written to a separate file instead of the regular model output listing file. This facilitates the passing of the error messages between the OCD model and the GUI program.

SUMMARY

The current progress on the development of a prototype Graphical User Interface (GUI) program for the Offshore Coastal Dispersion (OCD) model is summarized. The GUI together with a suite of pre- and post-processor programs constitute a user-friendly modeling environment for the OCD model, where the user can easily and efficiently set up a model run, execute the program, and analyze the results. Various enhancements to the FORTRAN source code for OCD have also been made, which make the model more robust.

```
OCD Test Case
Carpinteria Complex Terrain
SF6 Release
---------------- Run title (3 lines, INPUT GROUPS 1, 2, and 3) ---------------

                    OCD MODEL CONTROL FILE
                    ----------------------

------------------------------------------------------------------------------
INPUT GROUP 4 -- Control parameters and constants (mandatory)
--------------
! IDATE(1) =          85 !  Starting year for this run
! IDATE(2) =         265 !  Starting Julian day for this run
! IHSTRT   =           1 !  Starting hour for this run
! NPER     =          36 !  Length of runs (no. of averaging periods)
! NAVG     =           1 !  No. of hours in an averaging period
! IPOL     =           7 !  Pollutant indicator, 3 = SO2, 4 = TSP, 5 = NOX,
                            6 = CO, 7 = Other
! NSIGP    =           1 !  No. of significant point sources (0-25)
! NAV5     =           0 !  A fifth averaging time to be included in the
                            high-five tables (0 means a fifth averaging
                            time will not be added)
! CONTWO   =         1.0 !  Conversion factor that converts user horizontal
                            length units (by multiplication) to km
! CELM     =         1.0 !  Conversion factor that converts user height
                            length units (by multiplication) to m
!END!
INPUT GROUP 5 -- Main model options (mandatory)
--------------
! IOPT(1)  =           1 !  1 = Terrain adjustment,
                            0 = No terrain adjustment
! IOPT(2)  =           1 !  1 = No stack-tip downwash
                            0 = Stack-tip downwash
! IOPT(3)  =           1 !  1 = No gradual plume rise
                            0 = Gradual plume rise
! IOPT(4)  =           0 !  1 = Buoyancy-induced dispersion
                            0 = No buoyancy-induced dispersion
! IOPT(5)  =           1 !  0 = Read overland met data from separate binary PCRAMMET file
                            1 = Read overland met data from control file
                            2 = Read overland met data from separate ASCII PCRAMMET file
! IOPT(6)  =           0 !  1 = Read hourly emissions from EMIS.DAT
                            0 = No hourly emissions
! IOPT(7)  =           0 !  1 = Specify significant sources
                            0 = Do not specify significant sources
! IOPT(8)  =           0 !  0 = Discrete receptors only
                            1 = Discrete and polar receptors
                            2 = Discrete and Cartesian receptors
                            3 = Discrete, polar, and Cartesian receptors
                            4 = Polar receptors only
                            5 = Cartesian receptors only
                            6 = Polar and Cartesian receptors
! IOPT(9)  =           1 !  0 = Include emissions with height table
                            1 = Delete emissions with height table
! IOPT(10) =           1 !  0 = Include meteorological data summary
                            1 = Delete meteorological data summary
! IOPT(11) =           1 !  0 = Include hourly contribution of significant sources
                            1 = Delete hourly contribution of significant sources
```

Figure 1E.6. Partial listing of a sample control file for the new OCD model. Note that only the data values within the "!" delimiters are used by the model, and all other information is used for documenting purpose.

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Mr. Joseph Chang is manager of the Model Development and Analysis Section of EARTH TECH. Mr. Chang's main areas of interest include passive plume dispersion, heavy-gas dispersion, and model uncertainty. Mr. Chang, a certified consulting meteorologist, is co-developer for the Hybrid Plume Dispersion Model (HPDM), the Offshore Coastal Dispersion (OCD) model, and the UF_6 version of the HGSYSTEM dense gas dispersion model. Mr. Chang is one of the authors for a 1996 AIChE workbook, entitled *Guidelines for Use of Vapor Cloud Dispersion Models*. Mr. Chang received his B.S. in atmospheric sciences from National Taiwan University and his M.S. in meteorology from Massachusetts Institute of Technology.

Ms. Kathy Hahn, a senior scientist at EARTH TECH, has more than 11 years of experience in the design and development of application software for microcomputers. Ms. Hahn is involved with radiological dose assessment computer models, air quality models, scenario development software for the nuclear industry, and various Windows-based data management software. Mr. Hahn received her B.S. in mathematics from Pennsylvania State University.

HYBRID GRID MODELS FOR REGIONAL AIR QUALITY ASSESSMENT

Dr. Mark A. Yocke
ENVIRON International Inc.

INTRODUCTION

Sophisticated air quality models are the preferred means of addressing the complex and nonlinear factors and processes that affect the regional-scale transport, dispersion, and chemical and physical transformations of air pollutants in the troposphere. There are two principal types of air quality models: (1) Eulerian type wherein the coodinate systems are fixed in space, and (2) the Lagrangian type with coordinate systems that move with the winds. The Eulerian approach has produced box- and grid-type models, whereas puff- and plume-type models are examples of Langrangian models. All air quality models interrelate air pollutant emissions and prevailing meteorological conditions to ambient air pollution concentrations and/or deposition. A number of recent regional-scale models merge the Eulerian and Lagrangian modeling concepts into what are called "Hybrid Grid Models." A few of these have been employed for urban- and regional-scale air quality planning.

Eulerian and Lagrangian modeling formulations each has theoretical and practical advantages and disadvantages. For example, Lagrangian plume and puff models may be the most cost-effective solution at relatively close ranges for a relatively small number of sources. However, they have rather severe technical limitations especially for large numbers of sources, for regional-scale transport applications, or for photochemically reactive pollutants. In particular, most Lagrangian models invoke the assumption of plume, puff, or particle coherency, which breaks down quickly not far from an emissions source, especially in complex wind flow situations. Furthermore, chemical interactions between puffs, segments, or particles cannot be properly treated.

Grid models have been considered too expensive to apply for long periods and have subgrid-scale resolution limitations. Their strengths are in their inherent technical superiority for large transport times and large numbers of sources, and their more comprehensive, explicit treatment of physical and chemical processes, especially chemical interactions between emissions from many sources. Grid models have also been expensive to use because many runs were required to establish source-receptor relationships needed for emission control strategy evaluation.

Recent hybrid grid models overcome many of these grid model limitations and obviated many of the prior practical advantages of Lagrangian models. Most particularly, for regional-scale applications, nested-grid, plume-in-grid, and source apportionment treatment and fast numerical features make the latest hybrid grid models not only technically superior but also practically superior to Lagrangian and the prior generation of air quality grid models.

In this paper, we discuss examples of hybrid grid models. We also present the results of one particular example, UAMX, since it is currently the only hybrid grid model with a source apportionment capability.

HYBRID GRID MODEL FEATURES

The latest hybrid grid models incorporate combinations of the following advanced features.

Nested Grid Structure

This feature allows a grid model to be run with coarse grid spacing over a wide regional domain in which high spatial resolution is not particularly needed, while within the same run, applying fine grid spacing in areas where it is needed. Any number of fine grid nests can be used, and several grid spacings can be employed within a single run. Vertical layer structures can vary from one nest to another. The entire grid structure is usually two-way nested, meaning the information propagates into and out of all fine grid nests. A nested grid capability allows a grid model to be cost-effectively applied to large regions in which regional transport occurs, yet at the same time providing resolution sufficiently fine to address small-scale impacts.

Fast Plume-in-Grid Module

Even with nested-grids there is a lower limit on the grid size. Practical and theoretical considerations suggest the 500-1000 meters as a lower limit. However, in the case of point source plumes, finer resolution may sometimes be needed. To deal with subgrid scale impacts, hybrid grid models may also incorporate a plume-in-grid (PiG) feature. This allows tracking of individual plume segments, accounting for plume dispersion and chemical evolution, until such time as they can be adequately represented within the grid model framework. The latest PiG methods are many times faster than earlier PiG versions (fast enough to treat all point sources) and allow calculation of ground-level impacts of plume segments prior to their release into the grid.

Grid Model Source Apportionment

A novel technique was recently developed that allows grid models to track source region or source category contributions to predicted grid cell concentrations. The method is applicable to both primary and secondary pollutants, either gaseous or aerosol. It will separately track the source contributions to ozone, SO_2, NO, NO_2, CO, particulates (primary sulfate, other primary, secondary sulfate, secondary organic and ammonium nitrate) concentrations. Thus, for any selected each receptor point and time, a grid model with source apportionment capabilities can give a clear picture of what concentrations of various pollutant are likely present and what emission sources contributed to each. For ammonium nitrate, the source apportionment will also show whether ammonium nitrate formation is more limited by availability of nitric acid or ammonia. For ozone, an indication of whether the ozone at the selected time and location would more likely respond to upwind NO_x or VOC controls. Examples of the displays of the types of information that can be generated by a grid model with source apportionment are given in Figures 1E.7 through 1E.10.

With source apportionment, a single grid model run can yield complete source apportionment information that would literally require hundreds of runs without source apportionment. Furthermore, source apportionment information derived from a single grid model run is much more internally consistent than source apportionments derived from multiple model runs. Thus, source apportionment allows grid models to be used much more cost-effectively.

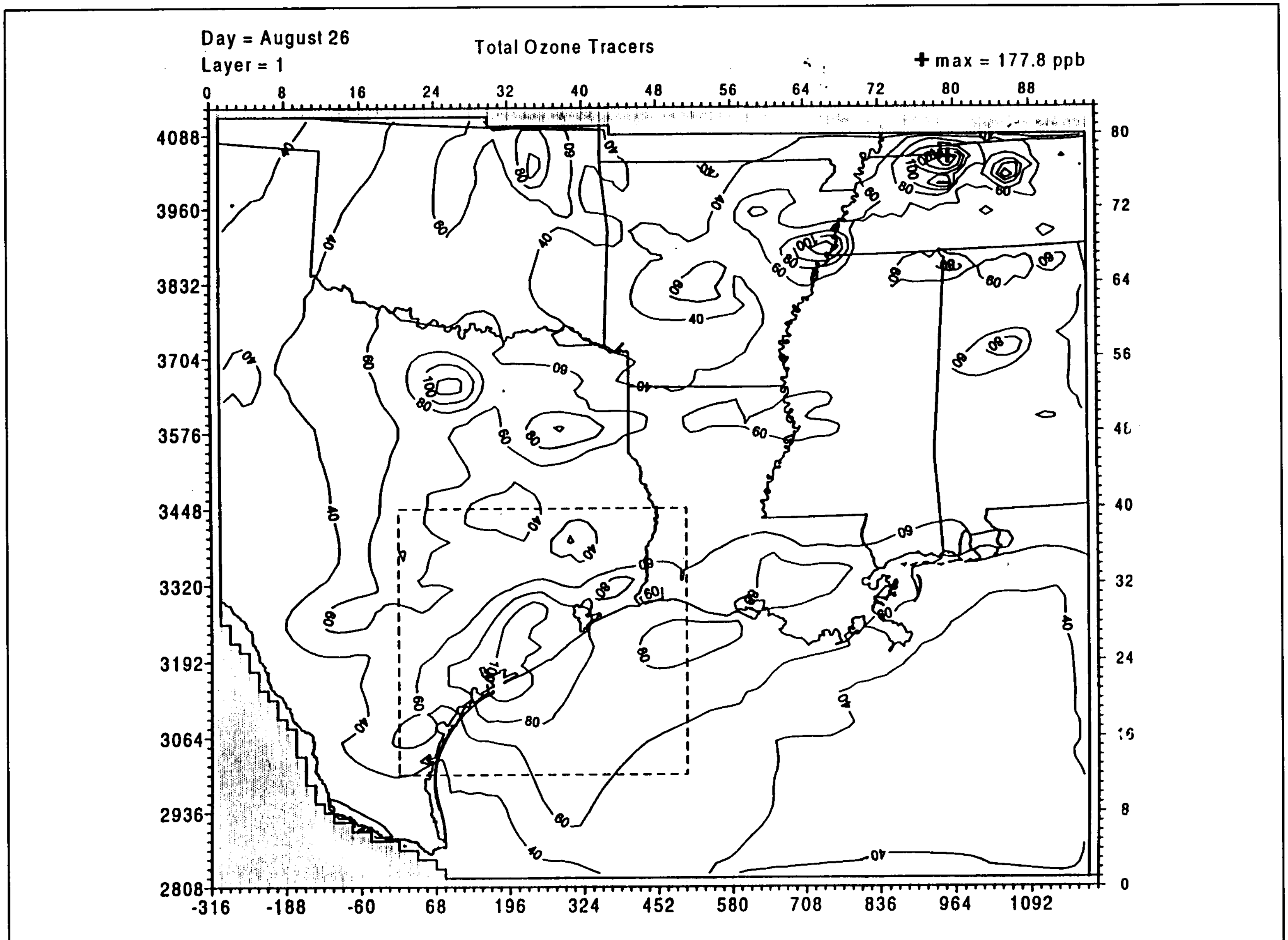
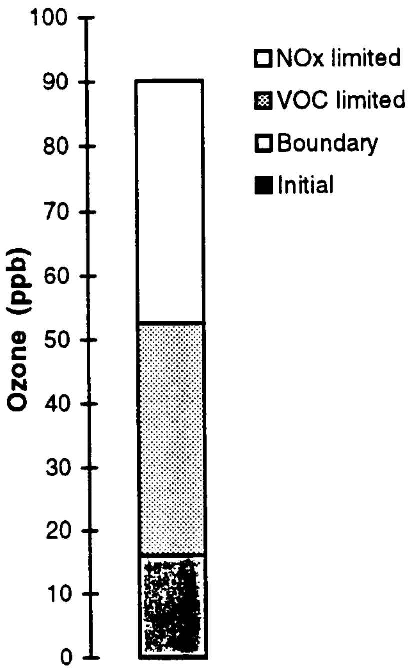
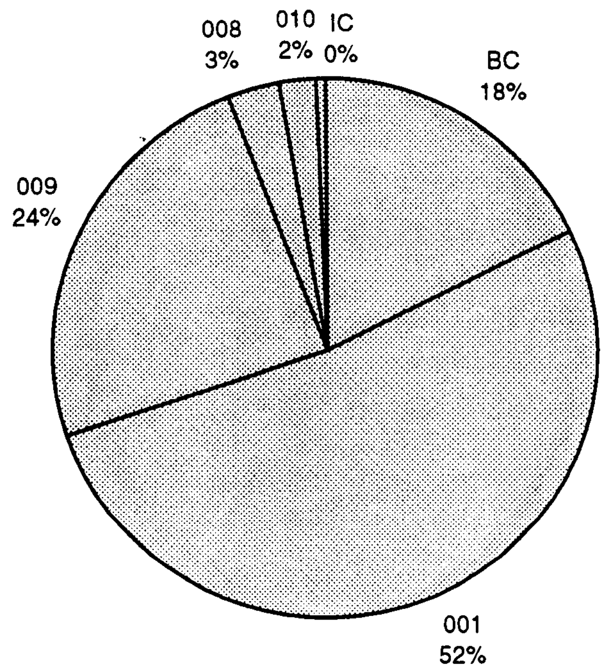


Figure 1E.7. Example of an hourly ozone concentration map generated by the UAMX Hybrid Grid Model.

Contributions By Type



Contributions By Source Area



Receptor	=	**Victoria**		
Time	=	**15**	**To**	**16**
Date	=	**8/26/93**		
Scenario	=	**REGIONAL Base Case: 1 16 km Grid**		
Total Ozone	=	**90**		

Detailed UAM Ozone Apportionment

Source Area	*Source Group*	*Percent Ozone from NOx*	*VOC*	*Total*	*Time Emitted*	*Recirculation Likely*
IC				0%		
BC				18%		
001	000	26%	27%	52%		
009	000	13%	11%	24%		
008	000	2%	2%	3%		
010	000	1%	1%	2%		
002	000	0%	0%	1%		
All Others				0%		

Figure 1E.8. Example of UAMX ozone source apportionment results for one receptor point.

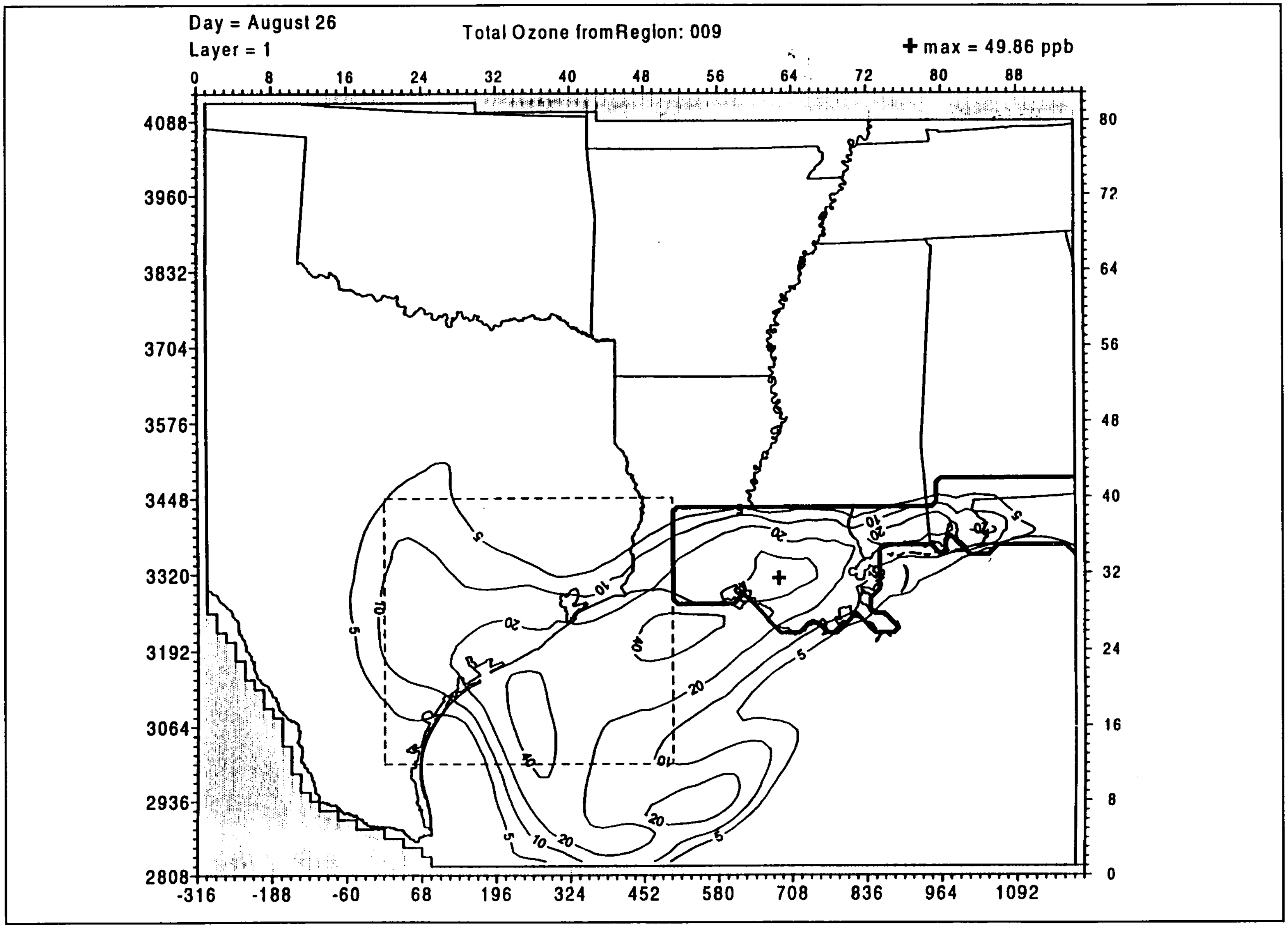


Figure 1E.9. Example of ozone contributions of a single source region produced by UAMX with source apportionment. Bold region indicates boundaries of source region in question.

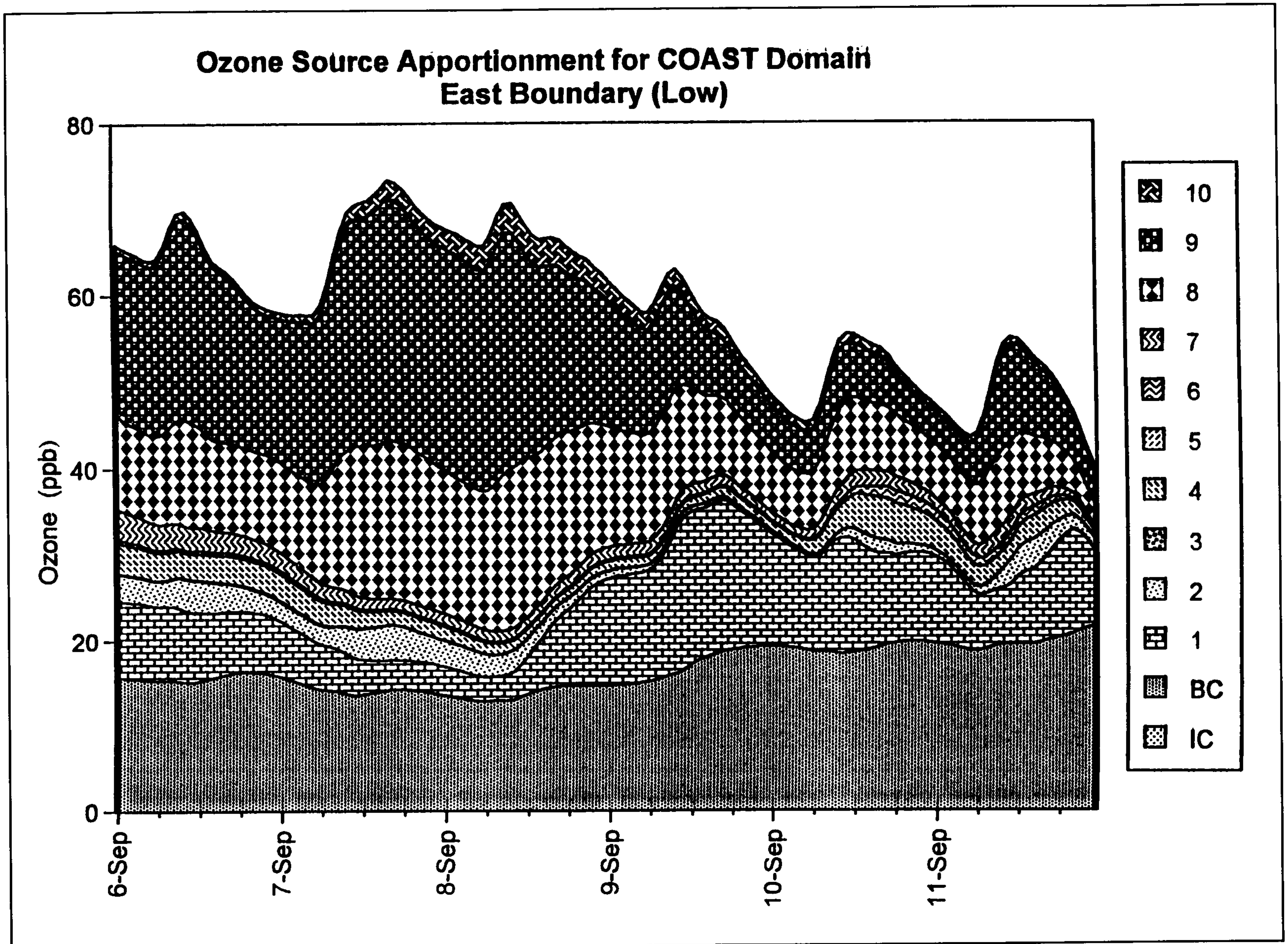


Figure 1E.10. Example of UAMX ozone source apportionment results along an internal boundary.

Chemical Kinetics Solution Methods

In cases where involving photochemically reactive pollutants, typically 80 percent of a photochemical grid models CPU time is spent numerically integrating (solving) the time evolution of the chemistry. The desire to increase the complexity of photochemical mechanisms will tend to push this figure higher. Recently, highly efficient chemistry solvers have been developed that are based on an "adaptive-hybrid" approach. Relative to the standard chemistry solvers, these new solvers produce about a ten-fold speedup in chemistry solution and a speedup in overall grid model run times of 3 to 4 times. Model performance with these fast solvers is nearly identical to standard chemical solvers.

Advection/Dispersion Solution Methods

A variety of numerical methods are used in Hybrid Grid models to solve the atmospheric diffusion equation. They include both finite difference (e.g., Smolarkowicz, Bott) and finite element (e.g., Taylor-Galerkin, SUPG) methods for numerical solution of advection/dispersion equations. While finite element methods are more accurate, mainly because they produce less numerical diffusion, finite difference methods are significantly less expensive to apply. In practice, given other modeling uncertainties, finite difference methods are adequate for most purposes. However, in special cases finite element methods may be preferred.

Meteorological Modeling

Recent prognostic meteorological models incorporate state-of-the-art grid nesting and four-dimensional data assimilation needed to drive advanced Hybrid Grid models. These models have been used to generate highly resolved three-dimensional meteorological input fields for hybrid grid models over large regions for periods of days and weeks to months and years.

Particle Dynamics Module

Aerosol dynamics modules have been installed within some hybrid grid models to treat secondary particle formation, evolution, and dispersion. These simulate the formation and evolution of the particulate chemical and size distribution properties and produce estimates of particle concentration and chemical composition within a number of particle size bins. They account for both gaseous and heterogenous phase chemistry.

Atmospheric Optics/Visibility Module

Atmospheric optics packages have also been used in grid models to address regional visibility impairment. They take into account the absorption and scattering of sunlight due the presence of particles and gases along specified sight paths. They produce estimates of visual range, contrast, coloration, and delta E (a standard measure of human perceptibility of visibility impairment).

Graphical User Interface (GUI)

GUI software systems (user-friendly, point and click, graphical operating systems) are being written as the driver/controller for hybrid grid models. These will include 3-D graphical visualization/animation packages for model output presentation and emission forecasting tools for simple future scenario construction and evaluation.

When installed on a modern, fast workstation, the features described above allow hybrid grid models the capability to address nearly all regional/urban air quality modeling and planning issues. Furthermore, when coupled with a modern GUI front-end and graphical animation/visualization, hybrid grid modeling system will be both technically powerful, simple and efficient to use, and produce results that are concisely presented, easy to interpret, and directly answer the types of questions that air planners frequently ask.

EXAMPLES OF HYBRID GRID MODELS

A summary of the features of some recent hybrid grid models is provided in Table 1E.3. Six models are summarized: CALGRID, URM, UAM-V, SAQM, MODELS-3, and UAMX. Each of these has some combination of the features described earlier, but all contain (or will soon contain) a plume-in-grid capability which qualifies them as hybrid grid models. As mentioned earlier, UAMX is the only hybrid grid model that currently offers a source apportionment capability.

UAMX RESULTS

Results of recent applications UAMX are presented in Figures 1E.7 through 1E.10. In this particular application, UAMX was applied for a large region in the southeastern U.S. encompassing: all of Louisiana, Mississippi, Alabama, Arkansas; most of Texas, Oklahoma, Tennessee, and Georgia; a portion of Florida; and a large section of the northern Gulf of

Table 1E.4. Summary of the features of some recent regional-scale hybrid grid models.

Model `	CALGRID[1]	URM[2]	UAM-V[3]	SAQM[4]	MODELS-3[5]	UAMX[6]
Full Model Name	CALGRID	Urban and Regional Multiscale Model	Nested-Grid UAM	SARMAP Air Quality Model with Aerosol Module	under development, beta release expected 1997, targetted features decscribed below	Extended Urban/Regional Airshed Model
Model DevelopersSAI	Earthtech	CMU	SAI CMU	SUNY and CARB	USEPA and others	ENVIRON
Model Formulation						
Advection/Dispersion Solver	Finite Difference Yanartino	Finite Element SUPG	Finite Difference Smolarkiewicz	Finite Difference Bott	Finite Difference Bott	Finite Difference Bott or Smolarkiewicz
Cloud TransportNo	No	No	No	Yes	Yes	No
Dispersion	Spatially Varying	Spatially Varying	Spatially Varying	Spatially Varying	Spatially Varying	Spatially Varying
Dry DepositionNo	Yes	Yes	Yes	Yes	Yes	Yes
Wet DepositionNo	Yes	Yes	Yes	Yes	Yes	Yes
Gas-Phase Chemistry	LCC	LCC	CBM-IV	CBM-IV, SAPRC	CBM-IV,SAPRC	CBM-IV
Two-Way Grid Nesting	Under Development	Yes	Yes	Yes	Yes	Yes
Subgrid-Scale Processes	No	Yes	Yes	Under Development	Yes	Yes
Aqueous-Phase Chemistry	No	Yes	No	Partial	Partial	No
Integrated Source Apportionment	No	No	No	No	No	Yes
Vertical Treatment	Limited Flexibility	Tied To Mixing Depths	Flexible	Flexible	Flexible	Flexible
GUI Interface	No	No	No	No	Yes	under development
Data Requirements						
Meteorology	3-D WS, WD, T, RH 2-D Mixht	3-D WS, WD, T, RH; 2-D Mixht	3-D WS, WD, T, RH, K_H, K_V	3-D WS, WD, T, RH, K_H, K_V	3-D WS, WD, T, RH, K_H, K_V	3-D WS, WD, T, RH, K_H, K_V
Fully Couple to	No	No	SAIMM, RAMS	MM5	MM5	MM5, RAMS
Emissions	Gridded Hourly Speciated VOC, NO_x, CO	Gridded Hourly Speciated VOC, NO_x, CO	Gridded Hourly Speciated VOC, NO_x, CO	Gridded Hourly Speciated VOC, NO_x, CO	Gridded Hourly Speciated VOC, NO_x, CO	Gridded Hourly Speciated VOC, NO_x, CO
Air Quality	Initial and Boundary Conditions	Initial and Boundary Conditions	Initial and Boundary Conditions	Initial and Boundary Conditions	Initial and Boundary Conditions	Initial and Boundary Conditions
Output						
Min. Time Resolution	minutes-hourly	minutes-hourly	minutes-hourly	minutes-hourly	minutes-hourly	minutes-hourly
3-D concentrations	Yes	Yes	Yes	Yes	Yes	Yes
Source Apportionmnt	No	No	No	No	No	Yes
PM versionYes	No	No	Yes	Yes	Yes	Yes
Practicality/Regulatory Acceptability						
Computational Requirements	Medium-High	High	Medium	Very High	Projected to beVery High	Medium
Documentation	Fair	Fair	Fair	Good	Poor	Poor-Fair
TransportabilityGood	Unknown	Unkonwn	Good	Poor	Unknown	Good
Ease of UseGood	Fair	Poor	Fair	Poor	Unknown	Fair
Availability	Latest Version Restricted Restricted	Restricted	Restricted (code proprietary)	Public Domain	Still Under Development	Publicly Available
Regulatory Acceptability	Low	Low	Medium	Medium	Medium-High	Low-Medium

Mexico. The model was applied to a 28-day period from the summer of 1993. UAMX meteorological inputs were derived from a 28-day run of the RAMS prognostic meteorological model. Emission inventory inputs were developed from the OTAG emission information. This application was performed for the Texas Natural Resource Conservation Commission (TNRCC) to provide boundary conditions for its smaller-scale urban ozone modeling.

Figure 1E.7 depicts an example of hourly surface level ozone concentrations generated by UAMX. The dashed box indicates a fine grid region within the UAMX regional domain. An example of UAMX source apportionment results from the same run for one receptor point is provided in Figure 1E.8. This shows the contributions of various source grouping to total predicted ozone concentrations at one receptor. It also reveals the extent to which ozone was formed under NO_x- or VOC-limited conditions. Figure 1E.9 shows an example of UAMX predicted ozone contributions of a single source region (in this case southern Louisiana, Mississippi, Alabama, and Florida; outlined in bold) The simulation hour of the results shown in Figure 1E.9 corresponds to that in Figure 1E.7. The results shown in both Figures 1E.7 and 1E.9 were produced by the same single UAMX run, along with the source apportionment results for 11 other source regions. Figure 1E.10 shows a time-series of source contributions to ozone fluxes across an internal plane (the eastern boundary of the dashed region in Figure 1E.7); this also was produced using the source apportionment information generated by the same UAMX run.

Figures 1E.9 and 1E.10 illustrate a tremendous advantage of grid model source apportionment; that is, the ability to produce a wealth of information from a single run, which otherwise would have required many expensive, time-consuming runs. The source apportionment capability, coupled with the other advanced features (e.g., plume-in-grid, fast solvers, etc), creates the potential of hybrid grid models to cost-effectively address a wider range of air quality modeling issues in a more rigorous fashion than other candidate air modeling approaches.

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Dr. Mark A. Yocke is a principal at Environ Corporation. He has over 22 years of experience in developing and applying emissions, meteorological, and advanced air quality models throughout the world. He was a principal contributor to the development of several notable photochemical gas and particle phase air quality models including the Reactive Plume Model (RPM), the Particle Plume Model (PPM) the Regional Transport Model (RTM), and the Urban Airshed photochemical grid models (UAM-IV and UAM-V). Most recently, he has been leading development of UAMX, a new regional-scale photochemical hybrid grid model. Dr. Yocke also managed the recent MMS Gulf of Mexico Air Quality Study.

SESSION 1F

COASTAL MARINE INSTITUTE, PART I

Co-Chairs: Dr. Robert S. Carney
Dr. James J. Kendall

Date: December 11, 1996

Presentation	Author/Affiliation
Coastal Marine Institute Progress Reports—Introduction	Dr. Robert S. Carney Coastal Marine Institute Louisiana State University Dr. James J. Kendall Minerals Management Service Gulf of Mexico OCS Region
Assessing Environmental and Safety Risks of the Expanding Role of Independents in E&P Operations on the Gulf of Mexico OCS	Dr. Allan Pulsipher Dr. Omowumi Iledare Mr. Robert Baumann Dr. David Dismukes Mr. Dmitry Mesyanzhinov Center for Energy Studies Louisiana State University
3d-seismic Surface Amplitude Mapping: A New Source of Information for Improved Benthic Habitat/Geohazards Evaluations	Dr. Harry H. Roberts Coastal Studies Institute Louisiana State University
Coastal Currents in the Northern Gulf of Mexico	Dr. Scott P. Dinnel Stennis Space Center Dr. William J. Wiseman, Jr. Dr. Lawrence J. Rouse, Jr. Coastal Studies Institute Louisiana State University
Spatial Variation in Fish Density and Target Strength at Three Petroleum Platforms as Measured with Dual-Beam Hydroacoustics	Dr. David R. Stanley Dr. Charles A. Wilson Coastal Fisheries Institute Louisiana State University
The Effects of Simultaneous Exposure to Petroleum Hydrocarbons, Hypoxia, and Prior Exposure on the Tolerance and Sublethal Responses of Marine Animals	Dr. William B. Stickle, Jr. Department of Zoology and Physiology Louisiana State University
Use of Toxicological Tests in Understanding the Effects of PAH on Benthic Communities	Dr. John W. Fleeger Department of Zoology and Physiology Louisiana State University
Management Concern for Continental Slope Deepwater Resource Development	Dr. Robert S. Carney Coastal Marine Institute Louisiana State University

COASTAL MARINE INSTITUTE PROGRESS REPORTS—INTRODUCTION

Dr. Robert S. Carney, Director
Coastal Marine Institute
Louisiana State University

Dr. James J. Kendall
Minerals Management Service
Gulf of Mexico OCS Region

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
- 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 are completed or were well underway at this time and continues the information transfer process between the CMI scientific and management personnel and decisionmakers of both the state and the MMS.

Dr. Robert Carney, a benthic ecologist, began deep-sea studies as a master's student at Texas A&M University (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. His published works are in the area of deep-sea ecology and environmental studies in the marine environment.

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.

ASSESSING ENVIRONMENTAL AND SAFETY RISKS OF THE EXPANDING ROLE OF INDEPENDENTS IN E&P OPERATIONS ON THE GULF OF MEXICO OCS

Dr. Allan Pulsipher
Dr. Omowumi Iledare
Mr. Robert Baumann
Dr. David Dismukes
Mr. Dmitry Mesyanzhinov
Center for Energy Studies
Louisiana State University

OBJECTIVES

Independent gas and oil producers are doing more of the exploration and production (E&P) of offshore petroleum reserves in the Gulf of Mexico. Both industry and regulatory analysts have expressed concern that this trend will increase the risk of more accidents and oil spills in the Gulf (Gachet 1993; Trent 1994).

Our initial objective was to ascertain if there was an empirical justification for such apprehension in the historical data. As the study progressed it also seemed appropriate and efficient to use our data to examine statistically the Minerals Management Service (MMS) platform inspection program and to see if it has reduced the frequency or severity of accidents or spills in the Gulf.

METHODS

We used descriptive statistics and econometric techniques to study data on accidents and oil spills recorded in the MMS event file. These data were organized on an operator-by-operator basis. Descriptive statistics and regression models were then used to determine the relationship between the frequency and severity of accidents or spills and several hypothesized explanatory factors.

The study was limited to the 1987-1993 period because of extreme variation and possible discontinuities in the accident and oil spill data in the MMS event file prior to 1987 (see Figure 1F.1). To us, these anomalies suggested classification or reporting changes that we were unable to account for or verify. Moreover, there are no data on MMS inspections and instances of non compliance (INCs) prior to 1986. Although this limitation in the study period was necessary because of time and budget constraints, accident rates in the Gulf were not only more stable in the post-1987 period but were an order of magnitude below their pre-1987 levels. Ascertaining the reasons for this dramatic, post-1987 decline might be a more important study.

RESULTS

Descriptive statistics show that the nominal or unweighted accident rate, measured as the number of accidents per million platform-hours, was:

- 3.34 for majors,
- 3.01 for large independents, and
- 2.08 for small independents.

Similarly, a weighted accident rate, which attempts to distinguish among accidents according to their severity (by weighting accidents without injuries as one, accidents with injuries as five, and accidents with fatalities as twenty-five) was:

- 8.00 for majors
- 5.35 for large independents, and
- 3.85 for small independents.

Each operator-category's weighted accident rate as a share of the industry total was calculated and divided by the corresponding share of total platform years.

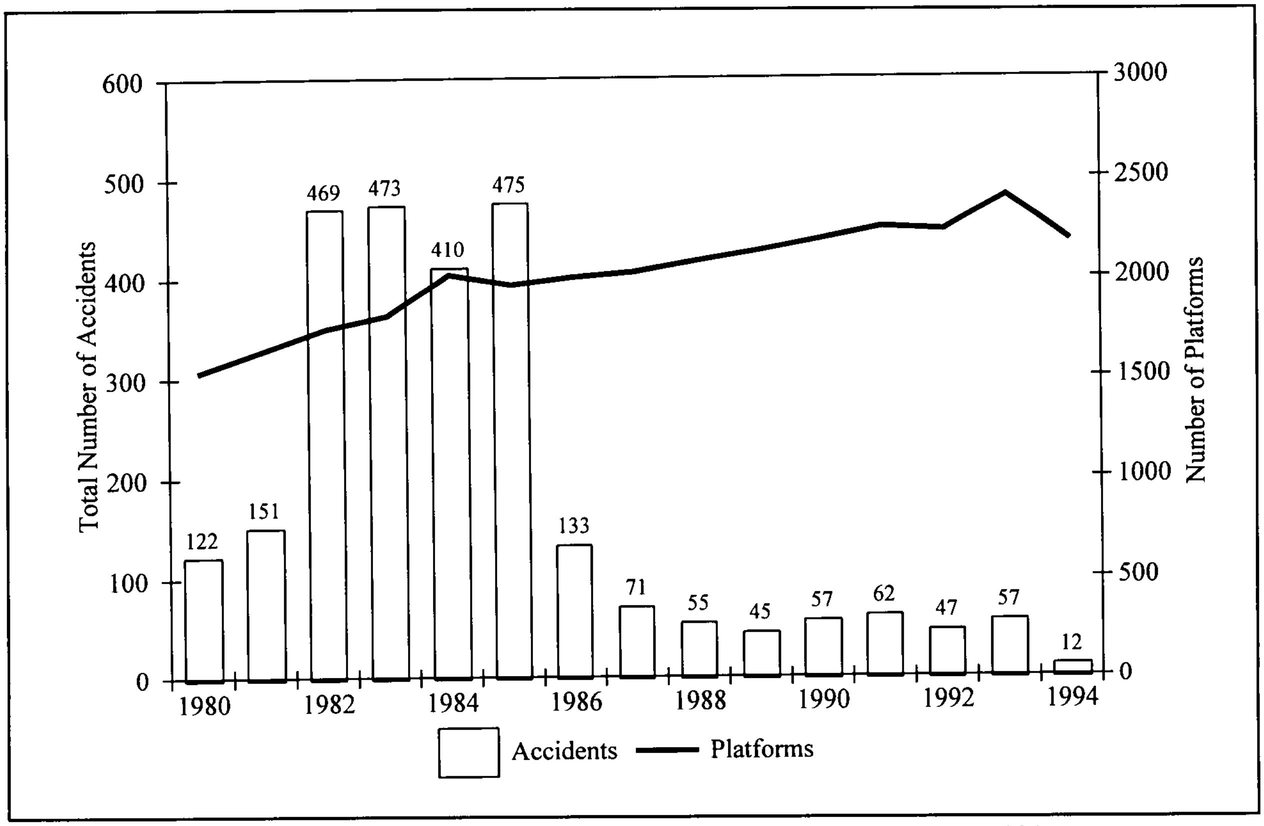


Figure 1F.1. Total number of accidents compared with number of operating platforms, 1980-1994.

Hence, values smaller than one mean that the operator-category had a smaller share of weighted accidents than of platform years and visa versa. According to this measure the ratio for majors was 1.22 compared with a ratio for independents of approximately 0.6.

The differences among majors and independents, measured with spills rather than accidents, were similar but more extreme. For example, relating reported spills to platform hours, we found:

- Majors reported 255 barrels spilled per million platform hours, and
- Independents reported 24 barrels spilled per million platform hours.

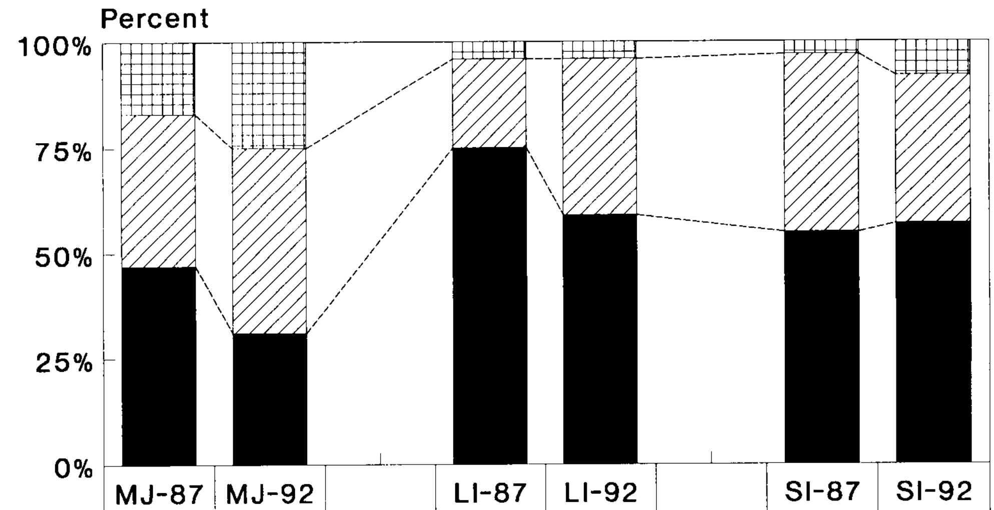
Using production as the basis for comparison, we found:

- Majors reported 15 barrels spilled for each million barrels produced, while
- Independents reported four barrels spilled per million barrels produced.

Accidents may be a better indicator of environmental performance (or risk) than barrels spilled. Many spills are small with negligible effects in the marine environment. In fact, MMS recently increased the threshold size at which operators are required to report spills. Thus, risks to the marine environment the public seems to be most concerned about may be better measured by the accident rate, since major catastrophic spills are more likely to be the consequence of major accidents.

There are factors other than firm size and the degree of economic integration—the attributes that are usually used to classify majors and independents—that are likely to explain accident and spill rates. Without taking such intervening factors into account, the descriptive comparisons summarized above may be misleading.

For instance, some of the concern about more independents working offshore appears to rest, at least partially, on the belief that independents are entering the Gulf by buying older, more accident-prone



	MJ-87	MJ-92		LI-87	LI-92		SI-87	SI-92
› 26 years	17	25		4	4		3	8
› ll ‹ 26	36	44		21	37		42	35
‹ 11 years	47	31		75	59		55	57

‹ 11 years   › ll ‹ 26   › 26 years

Source: Calculated from MMS data.

Figure 1F.2. Age distribution of offshore platforms, majors and independents: 1987 compared with 1992.

platforms from the majors. The data indicate, however, that older platforms comprise a much larger share of the majors' platforms than is true for independents (see Figure 1F.2). Thus, if age of platforms is an important intervening factor, the apparent superior performance of independents may simply be a consequence of the younger, safer, platforms they operate. Accordingly, if we were to account for the effects of the age of platforms statistically, it may be that independents should be expected to have fewer accidents than they do in actuality, given the age of the platforms they operate.

Regression analysis is one way to estimate how much of the variation in the outcome or dependent variable can be explained by such intervening factors. Because of the nature of the distribution of data on accidents and spills among operators, we have relied on specialized tobit and logit regression techniques to measure and account for ("hold constant" is the term often used) intervening variables. The results, using either the tobit model, or the logistic model confirm our earlier analysis—even with intervening influences "held constant"—that independents have a better record than the majors over the study period.

The regression equations indicated that the age distribution of platforms is an important intervening variable—as are our measures of the MMS platform inspection program. Other influences that we hypothesized as important, such as the proportion of drilling compared to production taking place on the platform, did not turn out to be statistically significant in some of the models we used.

A final objective of the study was to test the "bad actor" hypothesis. This hypothesis postulates that a few "bad actors" with very poor safety and environmental records may dominate and distort the safety and environmental statistics. Measured in terms of operators, we found a relatively small number of firms that were significantly different than the average, according to traditional statistical criteria. Some of the firms we identified, however, operated a large number of platforms; thus, the influence of "bad actors" may exceed their numbers. But when the "bad actors" were excluded from the data set and the regression equations were reestimated, we found the same patterns in our results, indicating our statistical estimates were not dominated by undue influence from a few firms with poor records.

SUMMARY AND RELEVANCE

Statistical and descriptive analyses of accidents and oil spills recorded in the MMS event file provide little statistical evidence to support the apprehension that an expanded role by independents in E&P activity constitutes a new or heightened threat to worker safety and the marine environment. In fact, our analyses uniformly suggest that on average independents had a marginally better safety record than the majors. In this respect, these findings mirror previous studies by the authors showing that the economic record of independents, as measured by finding rates, was also marginally but significantly better than that of the majors (Iledare *et al.* 1995, Pulsipher *et al.* 1995).

Using two different regression models to investigate the relationship between accidents or spills and various explanatory variables, we found that the age of an operator's platform and the number of instances of noncompliance (INCs) issued per MMS inspection of an operator's platforms were related to accidents or spills in a statistically significant way. This relationship held even when using a tobit regression technique, which enabled us to test for "unobserved" or unmeasured effects specific to firms or time periods.

We have not attempted to formulate economic or behavioral models that would provide a theoretical foundation for hypotheses as to why independents appear to have fewer accidents and spills than the majors. Nor have we attempted to determine if the overall frequency of accidents and spills is optimal or "correct" from either an economic, philosophical, or technical standpoint.

Our analysis is relevant to MMS policy or program planning only insofar as proposals for new policies or changes in policies are driven by the premise that a larger role for smaller, independent firms pose new or heightened risks to worker safety or the environment. But some specific findings seem relevant to other objectives or issues that are important for MMS. For example, it is evident from our econometric results that, along with other variables, the aging of operating platforms and safety and inspection programs of the Minerals Management Services (MMS) significantly affect the risk of an accident or an oil spill during E&P operation in a statistical sense. These findings may be relevant for MMS's ongoing efforts to monitor the effectiveness of its inspection program or to develop standards for "requalifying" older platforms. Further, the significance of the platform age variable also contradicts findings based on descriptive or bivariate analyses that are accepted by many analysts (Arnold 1995).

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Allan Pulsipher is the Director of Policy Analysis and Acting Executive Director of the Center for Energy Studies at Louisiana State University. Prior to coming to LSU in 1990, he held a number of academic and governmental positions, including Chief Economist at the Tennessee Valley Authority, Senior Staff Economist at the President's Council of Economic Advisers, and a program officer with the Ford Foundation. He organized and chaired the workshop on

Offshore Platform Abandonment and Disposal for MMS in April 1996. He has a B.A. from the University of Colorado and a Ph.D. from Tulane University, both in economics.

Omowumi Iledare is an assistant professor, research, with the Center for Energy Studies. Prior to coming to LSU, he was a faculty member at Fayetteville State University and worked for the California Energy Commission as well as Shell and Mobil in Nigeria. He has a B.S. in petroleum engineering from the University of Ibadan, a M.S. in energy resources from the University of Pittsburgh, and a Ph.D. from West Virginia University in mineral economics.

Robert Baumann is a special assistant to the Provost at LSU and the Managing Director of the Central Gulf Region Petroleum Technology Transfer Council. Formerly, he served as the Executive Director of the Center for Energy Studies. He has been actively involved in energy and coastal studies and policy in Louisiana for 20 years and participates on several state and industry commissions and committees. His B.S. degree is from the University of Rhode Island and his M.S. from LSU in eonomics.

David Dismukes is an assistant professor, research, with the Center for Energy Studies. He has worked for the Florida Public Service Commission as well as for private consulting firms. He received his B.A. in history from the University of West Florida, a M.S. in international studies as well as a M.A. and a PhD in economics from the Florida State University.

Dmitry Mesyanzhinov is a research associate at the Center for Energy Studies where he previously worked as a graduate student assistant. He is an economic geographer and data analyst. His M.A. in geography is from Moscow Lomonosov State University. He is a Ph.D. candidate in the Geography and Anthropology Department at LSU.

3D-SEISMIC SURFACE AMPLITUDE MAPPING: A NEW SOURCE OF INFORMATION FOR IMPROVED BENTHIC HABITAT/GEOHAZARDS EVALUATIONS

Dr. Harry H. Roberts
Coastal Studies Institute
Louisiana State University

INTRODUCTION

The best possible evaluation of sea floor geology is necessary as input for successful solutions for deepwater engineering problems on the continental slope of the northern Gulf of Mexico. Constraints on drilling-production platform sites and pipeline routes, for example, depend largely on an assessment of sea floor geology, using the output from a variety of high resolution acoustic survey instruments as a primary data base. These same data sets are utilized to meet federal requirements relating to assessment of types and spatial distributions of shallow geohazards and the locations of specialized habitats supporting protected chemosynthetic communities. The purpose of this part of the MMS-CMI sponsored project, entitled "Digital High Resolution Acoustic Data for Improved Benthic Habitat/Geohazards Evaluations," is to emphasize the important role that 3D-seismic surface amplitude data can play in enhancing interpretations of sea floor geology, using both standard high resolution acoustic data and 3D-seismic surface amplitude extraction maps. Although this technology is routinely applied to the subsurface for exploration and production purposes, it has not gained full acceptance in the engineering, geology, or regulatory sectors for use in evaluating the modern seafloor. Considering the complexity of the northern and northwestern Gulf of Mexico continental slope, every possible avenue for creating a better understanding of this geologic province should be thoroughly explored.

The specific intent of this part of the aforementioned MMS-CMI study was to choose a spectrum of sea floor types and associated features in order to test the usefulness of 3D-seismic surface amplitude extraction data for upgrading interpretations of sea floor geology. In order to provide a reasonable test for the amplitude extraction method, extremes of the sea floor feature spectrum are selected. Hard bottom areas with little or no evidence of gas expulsion are compared to soft bottom areas with abundant gas in the shallow subsurface and escaping the surface to the water column. Hard bottom areas are represented by Green Canyon block 140 and Garden Banks block 189. Gas-prone areas are represented by Green Canyon blocks 185 and 272 (Figure 1F.3).

CONTINENTAL SLOPE GEOLOGY

The dynamic nature of the northern Gulf of Mexico's continental slope is inherited from the interplay of rapid input of large volumes of sediment mainly during periods of falling-to-low sea level and the compensatory movement of underlying allochthonous Jurassic salt. As Budhijanto and Weimer (1995) point out, these conditions were typical of the Plio-Pleistocene when high frequency sea level change was common. The slope is an extremely valuable resource since it has produced more oil and gas than any shelf-slope complex in the world. However, exploration and production of hydrocarbons from the Louisiana-Texas slope has not been easy or inexpensive because of the region's extreme sea floor and subsurface complexity. Although the Gulf of Mexico is categorized as having a passive continental margin, because of salt-sediment interplay it is perhaps the most dynamic passive margin in today's oceans (Roberts and Aharon 1994) and as Bryant *et al.* (1995) point out, it is anything but passive. Superimposed on this regional framework dominated by canyons, domes, and interdome basins are smaller-scale features associated with faults, slope failures, and the flux of fluids and gases to the modern sea floor.

In this study, data have been collected primarily from fault-related features that in a direct or indirect way

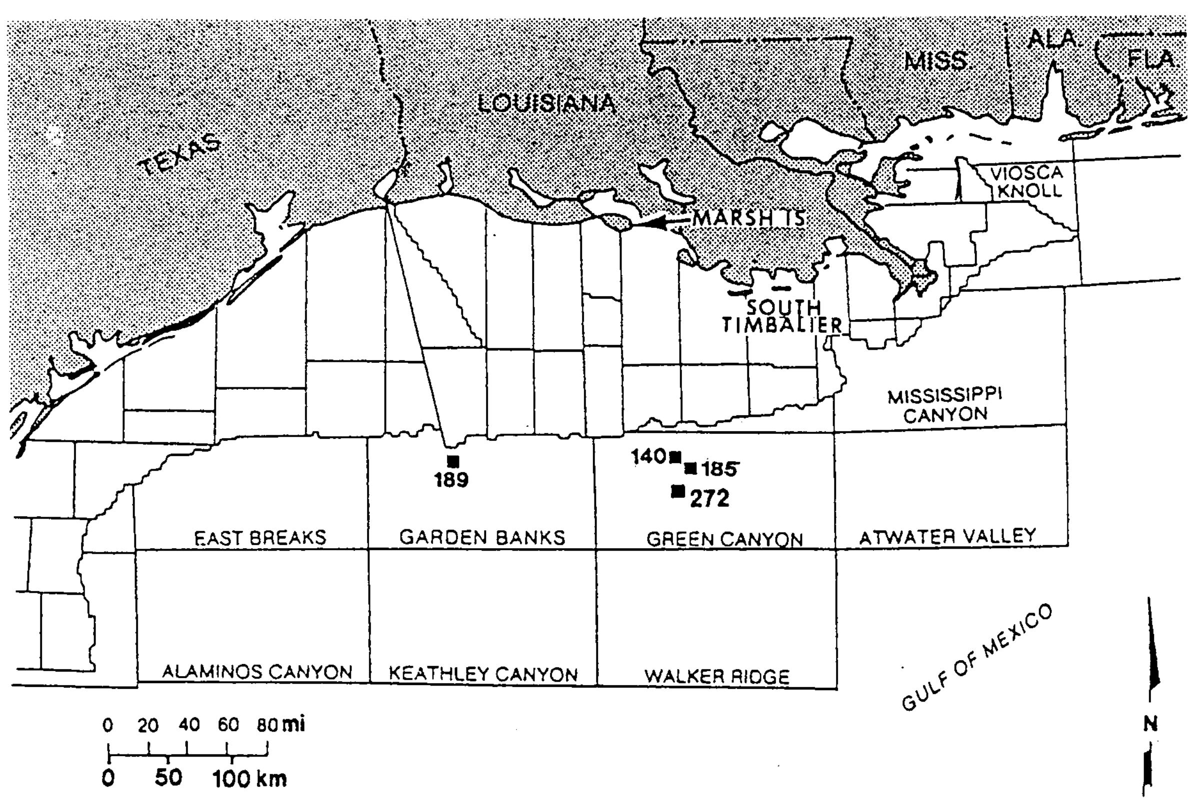

Figure F1.3 Location map of lease blocks discussed in this paper.

develop from the flux of sediment, water, crude oil, or gas (or some combination of these products) to the present sea floor. These selected features occur in the Green Canyon and Garden Banks lease areas of the continental slope and represent sites containing substantial geohazards, and/or protected benthic communities.

DATA SETS

Three different data sets are used to evaluate each site discussed in this study: (a) standard geohazards data consisting of high resolution seismic and side-scan sonar data; (b) surface amplitude extraction data derived from 3D-seismic data acquired primarily for exploration and reservoir identification/characterization; and (c) feature verification using a research submersible to collect visual data and site-specific samples from particular areas of sea floor identified on the other data sets. This multifaceted approach to feature detection and interpretation sets this study apart from others in that exploration-scale acoustic data as well as direct observation and sampling is used to arrive at the best interpretation of modern sea floor geology.

Standard Geohazards Data

Since the mid-1970s when the petroleum industry started actively exploring the northern Gulf of Mexico's continental slope, many high resolution acoustic tools have been used to evaluate the sea floor and shallow subsurface. These sources include sparkers, minisparkers, sleeve guns, small chamber water guns and air guns, boomers, and transducer-type subbottom profilers, which are the highest resolution but typically have low penetration power. Each tool has its own characteristic outgoing acoustic signature, bed resolution, reliability, and deployment considerations. A variety of side-scan sonar systems became available during this same period starting with high frequency units (100-500 kHz), which have ranges from 50-500 m and data swaths of 100-1000 m. Lower frequency units, intermediate scale side-scan systems, have frequencies in the 23-37 kHz with ranges from 500-2500 m and data swaths up to 5 km wide. Even lower frequency and longer range (15-20 km) systems like Gloria have proved extremely valuable for imaging features like canyons and fans (Somers *et al.* 1978). However, the intermediate and long range side-scan systems are normally used in regional sea floor evaluations (Kenyon *et al.* 1978) while detailed site-specific surveys are conducted with high frequency units.

A problem in slope-depth environments has been the effective application of short-range high-resolution (high frequency) instrumentation to detailed evaluations of sea floor and shallow subsurface geology. Surface-tow seismic sources lose energy to the water column, and returned energy is often badly scattered over the long ray path, especially when trying to image areas of topographic variability. These conditions result in poor definition of sea floor features. For effective side-scan sonar imaging of the bottom, the towfish height above the sea floor should be 10-30% of the range (10-30 m on the 100 m range). To meet these requirements, long lengths of cable must be used, depressors must be installed on the towfish, and a navigation system must be used that tracks the position of the towfish. Maintaining an appropriate towfish height above the bottom and maneuvering over variable bottom topography with adequate navigational tracking are all problems in deepwater. In order to solve these problems and acquire high resolution data sets comparable to those collected in shelf-depth waters, deep-tow techniques were developed. These systems typically incorporate a 100 kHz side-scan for determining sea floor configuration and a transducer-type 3.5 – 7.0 kHz subbottom profiler for extremely high resolution (bed resolution <1 m) imaging of the shallow subsurface. The deep-tow towfish is positively buoyant and maintains a constant height above the bottom (typically ~ 30 m). A constant height is achieved by attaching the buoyant towfish to the tow cable and a length of deadweight anchor chain that is pulled across the bottom. True topography is later reconstructed on records from water depth data. These deep-tow systems produce the best high resolution acoustic data available for deepwater settings. However, even with the best data available, many features and sea floor areas defy definitive interpretation. Use of 3D-seismic surface amplitude data can help solve some of these interpretation problems.

3D-Seismic Surface Amplitude Maps

In both the Green Canyon and Garden Banks study areas, 3D-seismic data were available at all sites described in this paper. Similar techniques were used on all data sets to produce surface amplitude extraction maps for areas containing sea floor features of interest. Sea floor time maps were generated using the horizon-oriented approach. Interpretation was conducted using relative amplitude data. The sea floor "horizon" was mapped for each survey by generating a control grid of in-lines and cross-lines. Typical control grids were interpreted using every tenth in-line, every 250 m.

Cross-lines were picked at a wide range of spacings to check in-line picks and improve the consistency of the interpretation. The large acoustic impedance contrast at the sea floor creates a regionally coherent reflector. This condition allowed interpretation of the control grid to be performed semi-automatically. Control grid lines were quickly auto-picked on the sea floor reflection event. These picks were then checked and edited interactively.

The control grid of interpreted in-lines and cross-lines was then "infilled" using a batch automatic tracking program. The sea floor horizon infill extended the interpreted two-way time values over the entire data set. The sea floor infill time map was then used as reference input for batch extraction of reflection amplitudes. The extracted map provided a picture of sea floor amplitude distribution over the entire area of interest. This procedure was used to quickly generate amplitude maps covering features of interest. Because strong amplitude anomalies at or near the sea floor are believed to be related to low-velocity gas-charged zones, amplitude maps in conjunction with geohazard data sets were used to select and prioritize submersible dive sites to provide ground truth for correlating high-resolution acoustic data to 3D-seismic amplitude response.

Manned Submersible Observations

A unique aspect of this study and those that this study follows (Roberts *et al.* 1992, 1996) is the use of a manned research submersible to directly observe and sample features identified and evaluated using the acoustic methods discussed above. This sea floor verification step is necessary to establish confident links between sea floor geology and acoustic response. Most studies incorporating the use of submersibles in the northern Gulf have concentrated on site-specific biology, geochemistry, and sedimentology of hydrocarbon seeps. Notable exceptions have used submersibles to support sea floor engineering studies (Doyle *et al.* 1992) and surficial geology (Roberts 1995).

The highly maneuverable Johnson Sea-Link was used for photographically documenting and sampling the sea floor. This particular submersible allows the investigator a panoramic view of the sea floor from an acrylic dome. The vehicle is capable of dives to 1000 m where bottom time can be in excess of two hours, depending on the amount of maneuvering which affects battery life. In addition to 35 mm and video photography, the submersible can sample rocks, sediments, biota, water, and gas using the robotic arm and associated specialized collecting systems. The submersible data function as "ground truth" in support of and for refined interpretations of remotely sensed acoustic data.

SUMMARY

Proliferation of 3D-seismic in support of hydrocarbon exploration/production has created new data for improved interpretation of sea floor and shallow subsurface geology. Processing of digital seismic data to enhance surface amplitude anomalies produces information for improved assessment of geohazards and identification of sensitive benthic communities protected by environmental regulations. Coupled with high resolution acoustic data and direct observation/sampling using a manned research submersible, surface amplitude maps add critical interpretive information for identification of sea floor types and associated features. Non-reflective zones (acoustic wipeouts) represent the acoustic response of many slope features. Mud diapirs, mud mounds, mud volcanoes, gas-changed sediments, gas hydrates, slump deposits, carbonate hardgrounds, and various types of carbonate mounds are all features that exhibit this common response on high resolution seismic profiles. Surface amplitude data help make specific identifications. Since 1988, submersible data from mid-to-upper slope features (Garden Banks, Green Canyon, and Mississippi Canyon lease block areas) have been analyzed with conventional high resolution acoustic data and 3D-amplitude extraction maps. Areas of rapid venting of sediment and hydrocarbon-charged formation fluids are clearly distinguishable from areas of hard bottom (slow-to-no seepage). Gas hydrates occur as mounds and mounded zones along faults. They are the products of moderate flux rates below ~ 500 m water depths. Gas hydrates function as stored trophic resources that support sensitive chemosynthetic communities. Amplitude extraction maps clearly help identify these and other gas-charged mud-rich areas by a strong low impedance amplitude anomaly. Refinement and "field calibration" of the surface amplitude extraction method may eventually lead to a new standard for evaluating geohazards and the probable locations of sensitive benthic communities on the continental slope.

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Dr. Harry H. 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. He is a marine geologist/sedimentologist who 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 M.S. and Ph.D. from Louisiana State University.

COASTAL CURRENTS IN THE NORTHERN GULF OF MEXICO

Dr. Scott P. Dinnel
Stennis Space Center

Dr. William J. Wiseman, Jr.
Dr. Lawrence J. Rouse, Jr.
Coastal Studies Institute
Louisiana State University

In an effort to synthesize knowledge of the low order statistics of near-shore currents in the northern Gulf of Mexico, existing current meter records of more than 27 days duration from near-surface meters within 36.5 km (~20 n. mi.) of the coast from Baldwin County, Alabama to south Texas were acquired and analyzed. Data were rotated into an orthogonal coordinate system parallel and perpendicular to shore before analysis. Means, standard errors, maxima, minima, variances, and orientations of the variance ellipses were estimates for each seasonal record. Similar statistics were estimated for the 40-hour low-pass filtered data records.

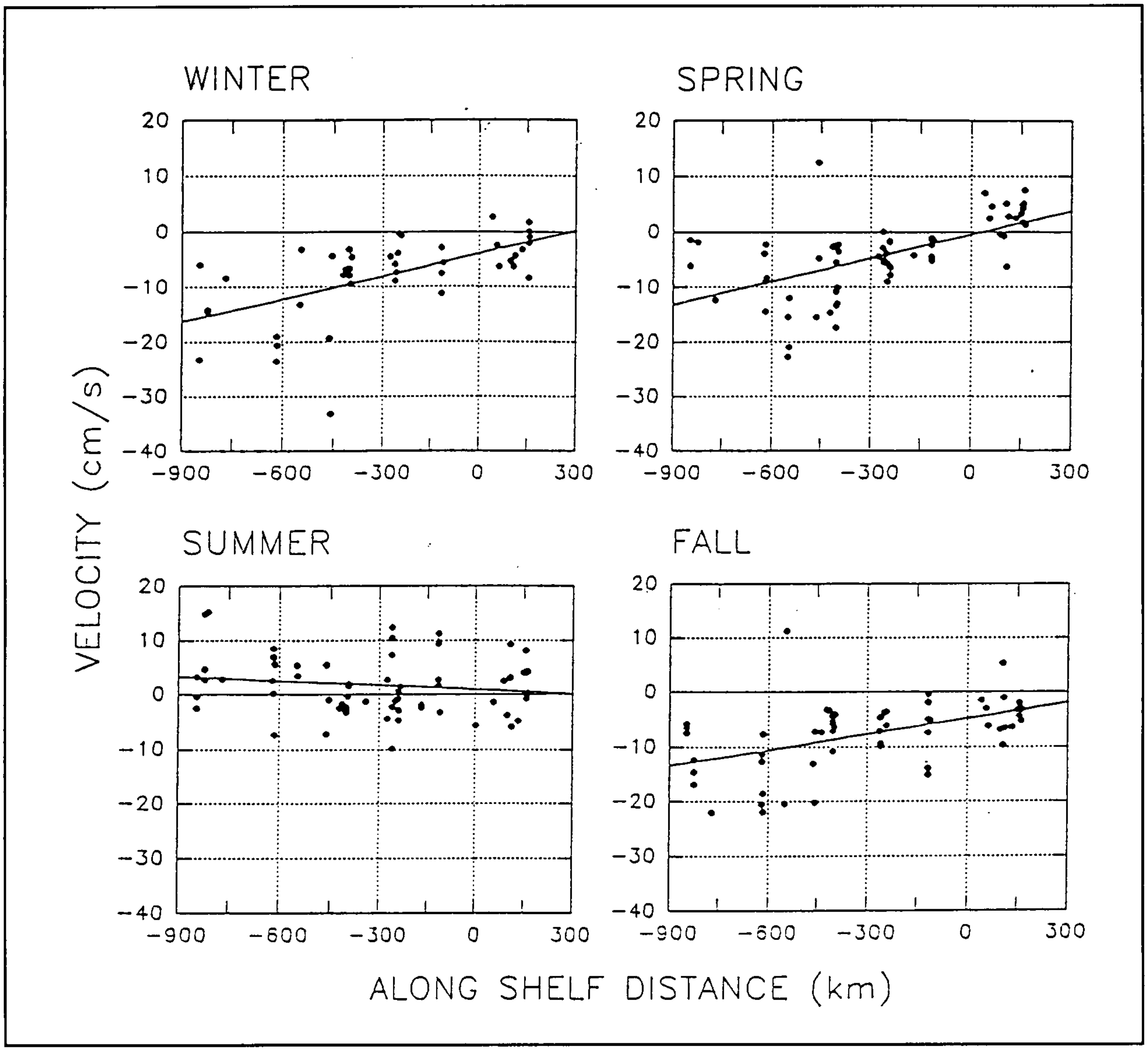

Figure 1F.4. Seasonal alongshore mean velocity versus alongshelf distance. Positive alongshore velocity is eastward. Zero distance is the Mississippi Delta, distance west is negative. Linear regression slopes were tested as different from zero with a student t test. The slopes for winter, spring, and fall were significantly different from zero at the 99% level (t=4.615, n=44; t=6.048, n=66; t=4.110, n=59, respectvely), and the slope for summer was not significant at the 80% level (t=-1.259, n=66).

Finally, a number of measures of alongshore flow persistence were estimated.

Mean flows tend to be shore-parallel and variance ellipses are also, generally, elongated in the shore-parallel direction, although some regions of significant variation to this trend exist and are associated with local coastal morphology. Spatial trends in the low order statistics of the data records are obvious. Temporally, summer stands out as different from the other seasons.

During most of the year, alongshore velocities are westward, and they increase in magnitude with location downcoast (towards Mexico) from the Mississippi Delta (Figure 1F.4). Summer has different characteristics; over most of the region, no clear directionality is assignable to the mean flows. Along the Texas coast,

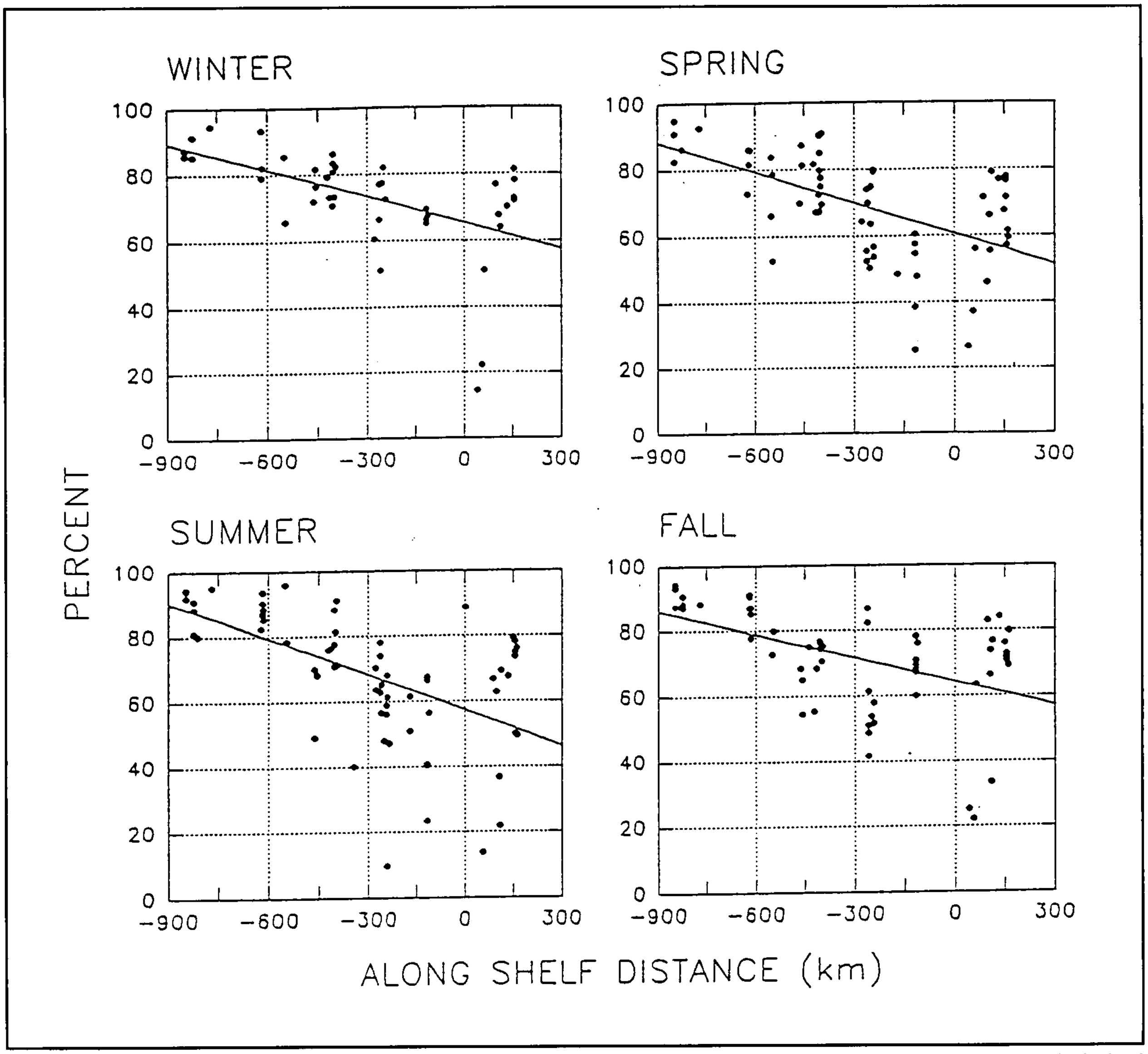

Figure 1F.5. Percent low-pass alongshore seasonal variance versus alongshore distance. Zero distance is the Mississippi Delta, distance west is negative. Linear regression slopes were tested as different from zero with a student t test. The slopes for all seasons were significantly different from zero at the 99% level (t=-4.114, n=44; t=-5.638, n=66; t=-5.365, n=66; t=-4.032, n=59 for winter, spring summer, fall, respectively).

the mean currents are towards the Mississippi Delta, and they decrease with location in the same direction. Cross-shore mean flows exhibit no discernible trends.

A general tendency exists for the percent of the variance of the alongshore flow within the low-passed band to increase downcoast. The energy in the tidal-inertial band seems to be maximum near the Mississippi Delta (Figure 1F.5).

The percent of time the flow is downcoast generally exceeds 50% and increases in the downcoast direction. In spring, the percentage drops below 50% for stations east of the delta. During summer, the percentage is highly variable, with a mean near 50% and slight evidence for a trend increasing in the upcoast direction.

Dr. Scott P. Dinnel received his Ph.D. from Louisiana State University. He is presently employed as an Oceanographer at the Naval Oceanographic Office at Stennis Space Center, Mississippi. Dr. Dinnel's research interests include shelf transport processes.

Dr. Wm. J. Wiseman, Jr. received his Ph.D. from Johns Hopkins University. He is Professor of Oceanography and Coastal Sciences and Director of the Coastal Studies Institute at Louisiana State University. Dr. Wiseman's research interests include shelf and estuarine dynamics.

Dr. Lawrence J. Rouse, Jr. received his Ph.D. from Louisiana State University. He is an Associate Professor in the Department of Oceanography and Coastal Sciences and the Coastal Studies Institute at Louisiana State University. Dr. Rouse's research interests include shelf and estuarine transport processes and coastal remote sensing.

SPATIAL VARIATION IN FISH DENSITY AND TARGET STRENGTH AT THREE-PETROLEUM PLATFORMS AS MEASURED WITH DUAL-BEAM HYDROACOUSTICS

Dr. David R. Stanley
Dr. Charles A. Wilson
Coastal Fisheries Institute
Center for Coastal, Energy and Environmental Resources
Louisiana State University

INTRODUCTION

In the waters of the northern Gulf of Mexico are approximately 4,000 petroleum platforms functioning as defacto artificial reefs. As reflected by the number and size of these structures, they constitute the largest artificial reef complex, albeit unplanned, in the world. Because of the long history and ubiquitous presence of platforms in the region, they are an important resource to recreational and commercial user groups and are thought by regional fisheries managers and the user groups to enhance fisheries and organisms dependent on hard substrate.

Petroleum platforms differ from traditional artificial reefs in their vertical profile, extending throughout the water column, providing habitat in the photic zone, and potentially increasing the productivity of these systems. A major similarity between platforms and other reefs is the difficulty in assessing the abundance and species composition of associated fishes. To address this sampling problem, we have successfully used two complimentary techniques—dual-beam hydroacoustics and point-count visual surveys—to accurately estimate the abundance and species composition of fishes at these structures. Hydroacoustics provides precise estimates of density, size distribution, and the near field area of influence of the platform, thereby enabling accurate estimates of the total fish abundance at the platform. Visual point-count surveys have a long history of use in both natural and artificial reef research and when used in conjunction with hydroacoustics, such surveys yield accurate estimates of abundance of each species.

Numerous attempts have been made to document the abundance and composition of fishes associated with petroleum platforms using a variety of methods (Sonnier *et al.* 1976; Gallaway *et al.* 1981; Continental Shelf Associates 1982; Gallaway and Lewbel 1982; Putt 1982; Scarborough-Bull and Kendall 1994; Stanley and Wilson 1990, 1991, 1995, 1996, *in press,* Wilson and Stanley 1991; Stanley 1994), and despite the varied methods, sites, timing, etc., one commonality between the studies is the high variability in the number and species composition of fishes associated with these sites. Previous research has found that platform size, depth, distance from the platform, location, and time of year dramatically affected fish abundance and species composition (Continental Shelf Associates 1982; Putt 1982; Scarborough-Bull and Kendall 1994; Gerlotto *et al.* 1989; Stanley 1994; Stanley and Wilson 1996, *in press*). Past research efforts have also documented a zonation of the assemblage of fishes associated with platforms and have divided the shelf waters of the northern Gulf of Mexico into three zones: coastal (water depth < 27 m); offshore (27 to 64 m); and bluewater (> 64 m) (Gallaway 1980; Gallaway and

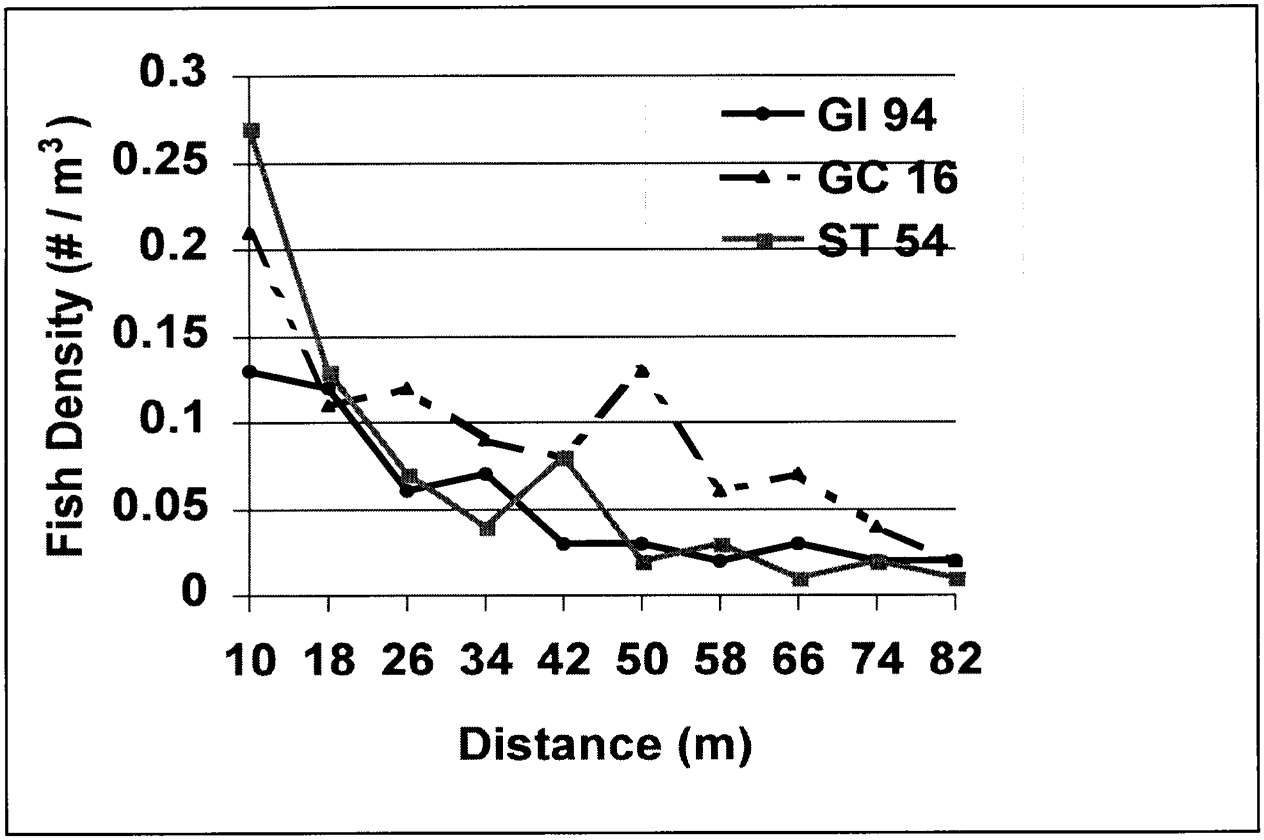

Figure 1F.6. Plot of relative fish density with distance from the platform at Green Canyon 18, Grand Isle 94, and South Timbalier 54.

Lewbel 1982; Gallaway *et al.* 1981). The objectives of this project were to measure the fish density associated with three petroleum platforms (water depth 20, 60, and 219m), determine the near field area of influence, estimate the total number of fishes, and measure the effect of water depth on fish abundance at the sites.

METHODS

Quarterly research trips were conducted (August 1994 to August 1996) at petroleum platforms Grand Isle 94 (GI94, water depth 60m, operated by Mobil Exploration and Producing USA, Inc.), Green Canyon 18 (GC18, water depth 219m, operated by Mobil Exploration and Producing USA, Inc.), and South Timbalier 54 (ST54, water depth 20m, operated by EXXON USA, Inc., from August 1995 to June 1996). Dual-beam hydroacoustics was used to measure vertical density of fishes from 1m above the sea floor to 1m from the surface at ST 54 and GI 94, and from 5m above the sea floor to 1m from the surface at GC 18. Horizontal density of fishes was measured on each side of the platform from the edge to 82m away from the platform. Data for vertical and horizontal densities were collected at noon, dusk, midnight, and dawn during each effort.

RESULTS AND DISCUSSION

Dual-beam hydroacoustics revealed several differences between the sites. A significant near field area of influence ($P < 0.01$) of 18 m was detected at GI94 and ST54, while at GC18, a 10m area of influence ($P < 0.05$) was documented (Figure 1F.6). Horizontal fish density varied between platforms but was consistently higher adjacent to the platform (Figure 1F.7) then dropped to densities typical of the open waters of the northern Gulf of Mexico (Morgan 1996). The relationship between horizontal fish density and distance from the platform at GC18 was not as clearly defined as the shallow sites, as density did decline with distance, but the decline was not as rapid (Figure 1F.6). This is likely due to the change in species composition and water clarity between sites on the continental shelf and on the slope.Differences in vertical fish densities

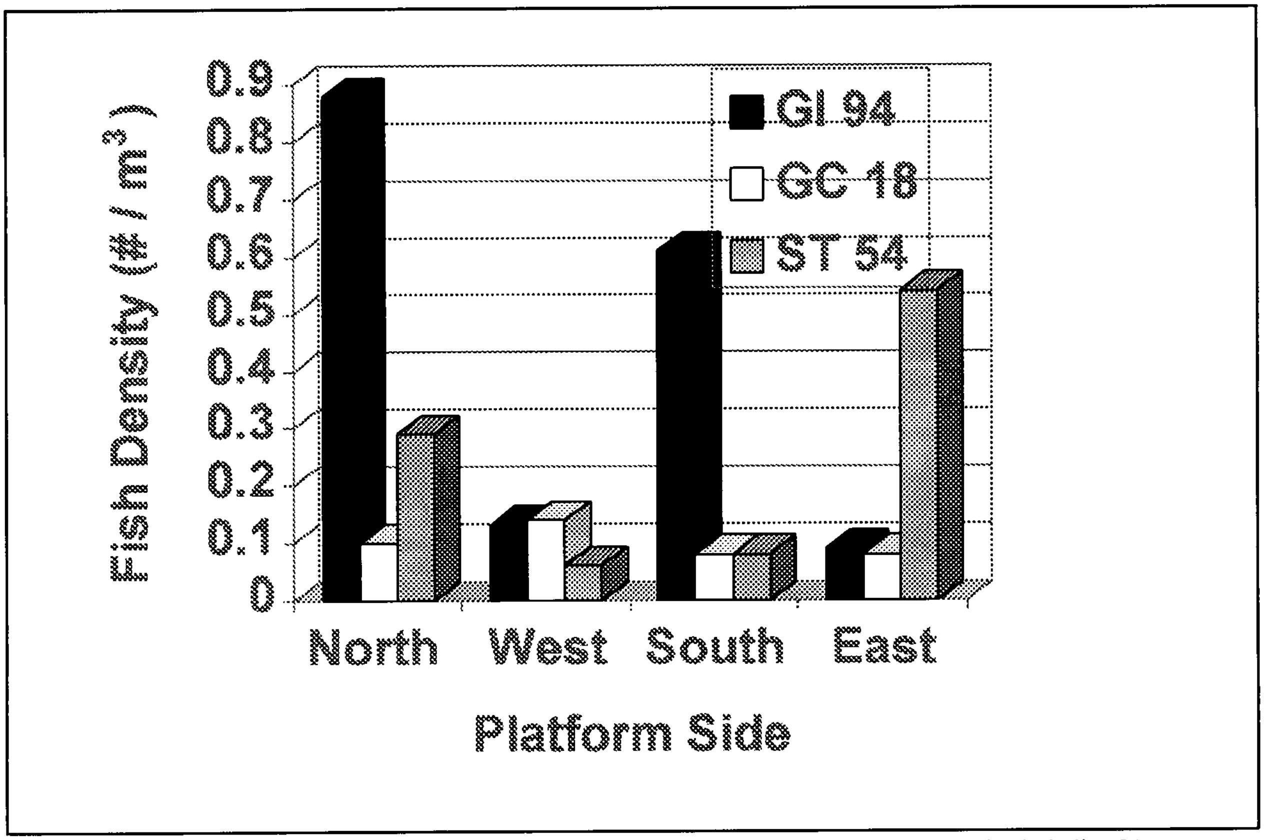

Figure 1F.7. Plot of fish density by platform side at Green Canyon 18, Grand Isle 94, and south Timbalier 54.

were also observed between sites as significant differences were found in vertical fish densities between sides of the platform and depth at all of the sites ($P<0.01$, Figures 1F.7, 1F.8, and 1F.9). Fish density varied at each site from side to side although a consistent pattern was not observed at any of the sites (Figure 1F.7). The greatest differences between sides were observed at GI94 and ST54, as fish density varied by up to a factor of 8.5, with side reinforcing the importance of sampling on all sides of the platform to obtain accurate estimates of fish abundance at a site (Figure 1F.7).

The most dramatic results of the study were the differences in fish density with depth between the three sites. At GI94 and ST54, fish density was fairly uniform throughout the water column, although significantly ($P < 0.05$) higher densities were found immediately adjacent to the surface and the bottom (Figure 1F.8). At GC18 there was a drop in fish density with depth, and below 100m fish density was essentially zero (Figure 1F.9). Fish density was significantly ($P < 0.01$) higher at water depths shallower than 60m but was still 4 to 8 times less than the densities observed at ST54 or GI94.

Since the near field area of influence was defined, we estimated the total fish abundance at each site. Average estimated abundance over the study's periods were 26,347 at GI94 (with an 18 m area of influence); 13,444 at ST54 (with an 18 m area of influence); and 11,224 at GC18 (with a 10 m area of influence). At the sites on the continental shelf, fishes were uniformly distributed through the water column, while at GC18, over 88% of the fishes were found in the upper 60m.

The effect of depth on fish density demonstrated by this study has implications on retired platforms sited as deepwater artificial reefs. Platforms utilized as artificial reefs on the continental shelf should prove effective; however, in deepwater environments it is apparent that maintaining vertical relief into the upper water column is crucial in providing effective artificial reef habitat. The NRC (1996) has recommended that the siting of deepwater platforms (water depth > 90m) as artificial reefs be changed to allow for the removal of the upper

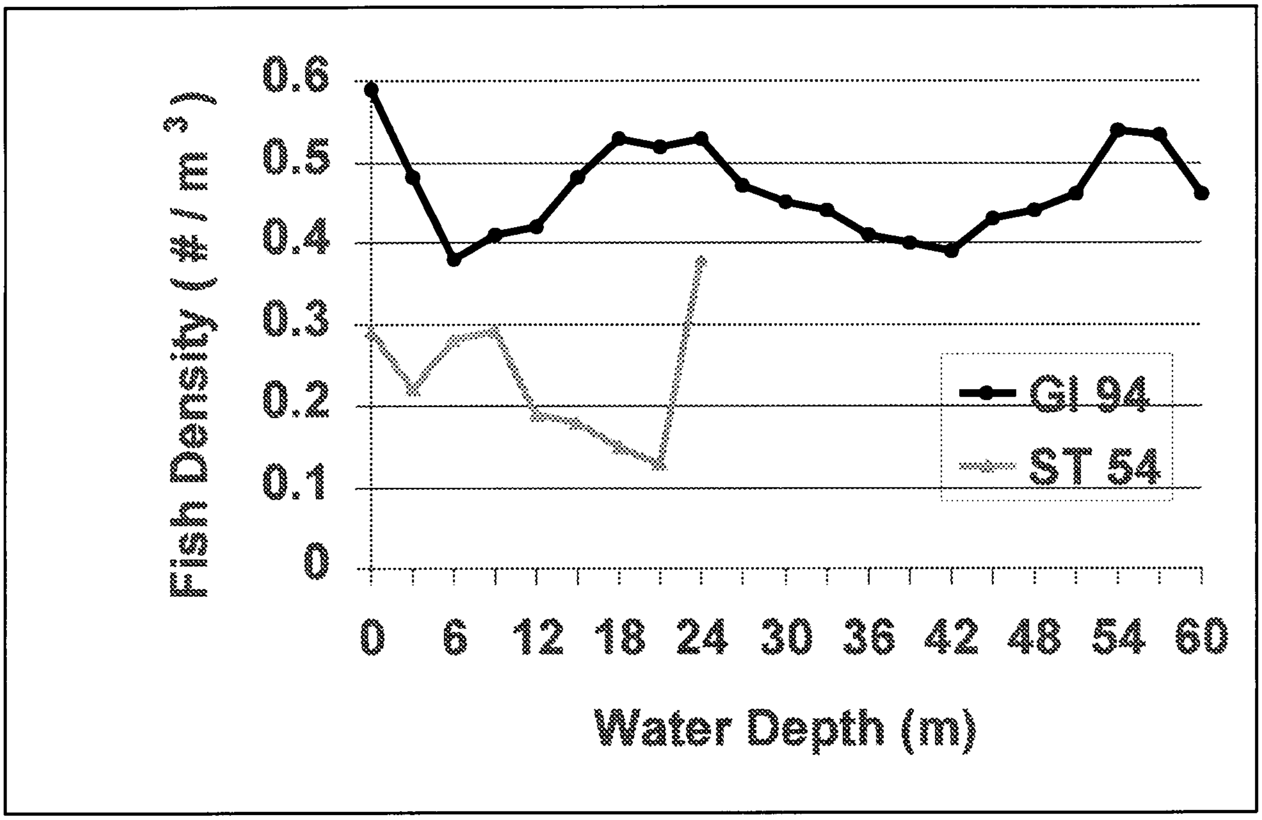

Figure 1F.8. Plot of fish density with depth at Grand Isle 94 and South Timbalier 54 from quarterly research trips, August 1994 – August 1996 at GI94, and August 1995 – June 1996 at ST54.

reefs be changed to allow for the removal of the upper 27m of the structure with the remainder left standing. Our results support this recommendation. If GC18 was conventionally sited as an artificial reef (i.e., toppled in place after explosive cutting of legs), its effectiveness as a reef would be greatly diminished as it would project only 70m off the bottom and based on our results few fishes would be associated with this structure.

Our results also reinforce the variability observed in the abundance of fishes associated with petroleum platforms. Previous researchers have demonstrated that variability is related to time (Continental Shelf Associates 1982; Gallaway and Lewbel 1982; Putt 1982; Scarborough-Bull and Kendall 1994 Stanley and Wilson 1990, 1991, 1996, *in press*), structure size (Gallaway *et al.* 1981; Continental Shelf Associates 1982; Gallaway and Lewbel 1982; Scarborough-Bull and Kendall 1994; Stanley and Wilson 1990, 1991, 1996, *in press*), geography (Sonnier *et al.* 1976; Continental Shelf Associates 1982; Gallaway and Lewbel 1982; Stanley and Wilson 1990, 1991), distance from the platform (Gerlotto *et al.* 1989; Stanley and Wilson 1996, *in press*), and the particular platform side examined (Stanley and Wilson 1996, *in press*; Wilson and Stanley 1991). Our research supports and expands earlier findings. Because the abundance of platform-associated nekton is highly variable, our study has demonstrated that it is essential to sample on each side of the platform and throughout the water column to obtain an accurate estimate of fish abundance. Although generalities can be drawn from the platform research to date, it is difficult to extrapolate the results from one site to another due to the associated variability.

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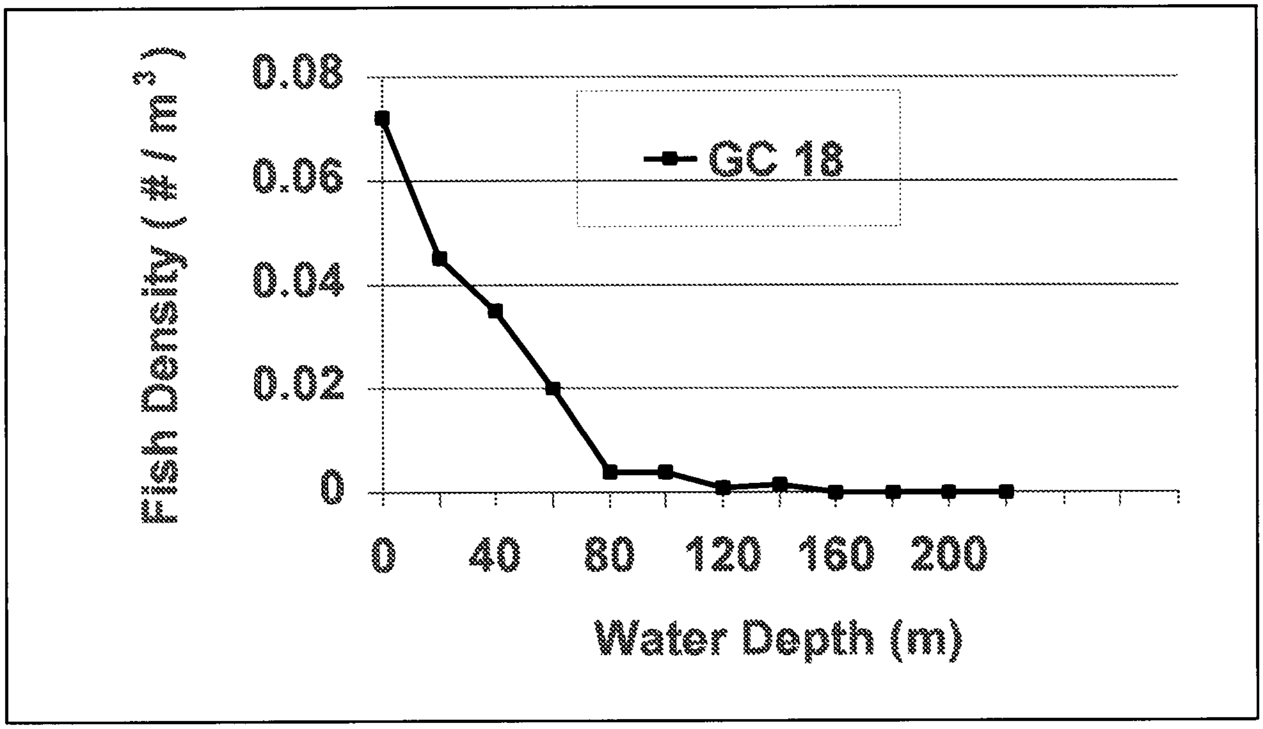

Figure 1F.9. Plot of fish density with depth at Green Canyon 18 from quarterly research trips, August 1994 – August 1996.

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Dr. David Stanley received his B.S. degree from the University of Guelph, Ontario, Canada, and his M.S. and Ph.D. from Louisiana State University. He developed a new methodology to quantify accurately the number and species of fishes associated with petroleum platforms and artificial reefs. With two complementary techniques, dual-beam hydroacoustics and pint-count visual surveys, precise estimates of the species abundance of these sites are now possible. Dr. Stanley is currently 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 he is interested in the function of artificial reefs.

Dr. Charles Wilson is a professor in the Coastal Fisheries Institute at Louisiana State University. He was a co-author of the Louisiana "Rigs-to-Reefs" Program. His research interests include the use of artificial reefs by fishes, age, and growth techniques for fishes as well as the reproductive biology of fishes.

THE EFFECTS OF SIMULTANEOUS EXPOSURE TO PETROLEUM HYDROCARBONS, HYPOXIA, AND PRIOR EXPOSURE ON THE TOLERANCE AND SUBLETHAL RESPONSES OF MARINE ANIMALS

Dr. William B. Stickle, Jr.
Department of Zoology and Physiology
Louisiana State University

INTRODUCTION

Coastal Louisiana has been impacted by oil field activities for the last half century, and the waters over the continental shelf west of the Mississippi River delta are also subject to extensive periods of hypoxia during the summer months. These hypoxic events are known locally as dead water zones because of a paucity of fauna in the water mass during their development.

Marine and estuarine fish are sensitive to exposure to the water soluble fraction (WSF) of crude oil, but their tolerance doesn't change much after 12-24h exposure because of the presence of an inducible cytochrome P-450 enzyme system for metabolizing aromatic hydrocarbons as illustrated by the response of coho salmon, *Oncorhynchus kisutch*(Stickle *et al.* 1982). All mortalities occurred during the first two days of exposure to toluene and naphthalene even though the experiment ran for 42 days. In contrast, invertebrates tolerate high concentrations of the WSF for short periods of time, but their tolerance declines during 28 days of exposure (Stickle *et al.* 1987; Wang and Stickle 1989).

The determination of long-term tolerance and two sublethal biomarkers will have been used to assess the effects of gradients of oxygen tension and the WSF of crude oil on marine and estuarine fauna (Das and Stickle 1987; Kapper and Stickle 1993; Stickle *et. al.* 1989; Wang and Stickle 1988).

This project was designed to test the following null hypotheses: Null hypothesis 1: The WSF of crude oil and hypoxia gradients acting alone and in concert do not alter the 28-day LC_{50} of the Gulf killifish, *Fundulus grandis*, or the two conspecific species of portunid crabs, *Callinectes sapidus* and *C. similis*; and, Null hypothesis 2: Prior exposure to sublethal concentrations of the WSF of crude oil and hypoxia acting alone and in concert do not alter the tolerance, RNA:DNA ratio in all three species and EROD activity in the Gulf killifish.

METHODS AND RESULTS

Juvenile *Callinectes sapidus, Callinectes similis*, and *Fundulus grandis* were collected from two sites by dip nets and fish traps and returned to LSU for experimental use. The site at Port Fourchon, Louisiana, is impacted by produced water discharge (Rabalais *et al.* 1991) and the non-polluted site was the beach, sea grass, and local streams in the vicinity of the Florida State Marine Laboratory at Turkey Point, Florida. *Callinectes similis* was not found at the Turkey Point site. GCMS aromatic hydrocarbon analysis of *Callinectes sapidus* documented that the body burden was higher at the Port Fourchon produced water site (30.6 ng.g wet weight^{-1}) than in those collected at Turkey Point, Florida, (11.9 ng.g wet weight $^{-1}$). Likewise the aromatic hydrocarbon body burden of *Callinectes similis* from the Port Fourchon produced water site was (57.1 ng.g wet weight^{-1}) higher than that of *C.* sapidus from Turkey Point, Florida.

The constant hypoxia exposure system was described in detail in Kapper and Stickle (1987). Oxygen tensions were determined daily by injecting water samples taken anaerobically into a syringe and injected into a water jacketed Strathkelvin flow through oxygen electrode-chamber system that was connected to a Strathkelvin oxygen meter.

The flow through WSF of South Louisiana crude oil was designed and is in use in the Laboratory of Dr. Stanley Rice at the NMFS laboratory in Auke Bay, Alaska. Different amounts of South Louisiana crude oil and pentane were poured into a commercial cement mixer that contained a known amount of three-eighths inch pea gravel and mixed for five minutes. After five minutes of mixing, the oil coated pea gravel was poured onto plywood, raked regularly, and allowed to dry. Known weights of different doses of oiled gravel were put into WSF generators that were constructed of 12" PVC pipe that was 1 meter high. A perforated plate was placed in the bottom of each generator so sea water flowed into the bottom. Seawater (30 $^{o}/_{oo}$S) flowed through each generator by gravitational flow by

Table 1F.1. LC_{50} values after 28 days' exposure of *Callinectes sapidus*, *C. similis*, and *Fundulus grandis* to hypoxia, and the water soluble fraction (WSF) of South Louisiana crude oil under normoxia (156 mm Hg O_2) and hypoxia (75 mm Hg O_2 for *F. grandis* and 113 mm Hg O_2 for *C. sapidus and C. similes*). W.F. data are given in n.l.$^{-1}$ of total aromatic hydrocarbons.

Stressor	Species	Louisiana	Florida
Hypoxia	*Callinectes sapidus*	111	113
	Callinectes similes	45	xxx
	Fundulus grandis	28	33
W.F. + Normoxia	*Callinectes sapidus*	27	26
	Callinectes similes	26	xxx
	Fundulus grandis	22	17
W.F. + Hypoxia	*Callinectes sapidus*	28	29
	Callinectes similes	26	xxx
	Fundulus grandis	17	13

entering via an inlet at the bottom and exit at the top at a rate controlled to ~50 ml.min^{-1}. Oil doses were monitored weekly by extraction into methylene chloride using standard methods established at the Auke Bay, Laboratory NMFS Laboratory(Larsen *et al.* 1992) and analyzed by HPLC.

The duration of all bioassays and experimental exposures was 28 days. Animals were collected at 0, 1, 7, 14, and 28 days in dosing experiments. Crabs were frozen whole in liquid nitrogen and killifish were dissected into white muscle and liver then stored in an ultracold freezer until analyzed for RNA or EROD analysis.

RNA:DNA analysis followed procedures outlined in Das and Stickle (1993). EROD activity was determined in the liver of *Fundulus grandis* as the microsomal O-dealkylation of ethyoxyresorufin according to modification of the method of Burke *et al.* (1985). Protein concentration was determined by the method of Lowry *et al.* (1951). Activity was calculated as picomols resorufin/mg protein/min.

Statistical analyses were performed with the Statistical Analysis System (SAS Institute 1996). Data on the LC_{50} of all species (Table 1F.1) were analyzed using probit analysis (Hamilton *et al.* 1977). Non-overlap of 95% fiducial limits were used as a criterion to determine significant differences between individual LC_{50} values.

No significant difference existed in the 28-day LC_{50} values of either species of crab from the less contaminated site from Turkey Point, Florida, and the produced water site at Port Fourchon, Louisiana, when exposed to the WSF of South Louisiana crude oil under either normoxia or hypoxia. In contrast, *Fundulus grandis* from the produced water site in Louisiana tolerated the WSF of South Louisiana crude oil better than those from Turkey Point, Florida, under both normoxia and hypoxia, but the difference in tolerance was of small magnitude.

There was no significant difference in the RNA:DNA ratio of either *Callinectes sapidus* or *C. similis* exposed to 0, 9, and 35ng oil.l^{-1} over 28 days. In contrast, RNA:DNA ratios of *C. sapidus* exposed to the WSF of South Louisiana crude oil declined with WSF concentration and duration of exposure(Wang and Stickle 1988).

Table 1F.2. RNA:DNA ratios from the white muscle of *Fundulus grandis* exposed to the WSF of South Louisiana crude oil for 28 days. WSF concentrations are given as $ng.l^{-1}$ total aromatics and aliphatics. For clarity, only mean values and sample sizes (n) are presented in the table.

Population	**Day**	**Control**	**9 $ng.l^{-1}$**	**35 $ng.l^{-1}$**
Port Fourchon, LA	1	1.335(8)	1.335(8)	xxx
	7	0.831(13)	5.168(14)	1.223(7)
	14	1.687(16)	4.357(13)	1.226(16)
	28	2.584(15)	xxx	2.826(16)
Turkey Point, FL	1	1.458(14)	1.487(15)	0.836(16)
	7	xxx	1.468(16)	1.031(15)
	14	1.031(15)	1.157(12)	xxx
	28	1.117(13)	1.375(8)	1.040(5)

In contrast, the white muscle RNA:DNA ratio of *Fundulus grandis* from both sites varied significantly as a function of the population, day, oil concentration, and day by treatment interaction(ANOVA). Treatment means are given in Table 1F.2.

No significant difference existed in liver EROD activity between the Port Fourchon and Turkey Point populations of *Fundulus grandis*, but duration of exposure, population by duration of exposure, oil concentration, population and day interactions with oil concentration, and all three interactions varied significantly(ANOVA; Table 1F.3). EROD activities peaked on day 7 of the experiment then declined. Treatment means were generally higher for the Port Fourchon population. Winston *et al.*(1989) have documented induction of EROD activity in the liver of the channel catfish, *Ictalurus punctatus*, exposed to PCBs.

SUMMARY

The hypoxia tolerance of the Gulf killifish, *Fundulus grandis* (28 day LC_{50} = 28 Torr O_2), was significantly greater than that of the lesser blue crab, *Callinectes similis* (45 Torr) and the blue crab, *Callinectes sapidus* (111 Torr). Minimal site differences (Florida and Louisiana)existed in hypoxia tolerance. There was no differance in the 28 day tolerance of blue crabs to the WSF of South Louisiana crude oil under either normoxia or hypoxia.In contrast, *Fundulus grandis* from the produced water site in Louisiana were slightly more tolerant of the WSF of South Louisiana crude oil than those from Florida, and fish exposed to the WSF of South Louisiana crude oil under normoxia were more tolerant than those exposed under hypoxia. Although RNA:DNA ratios are a good biomarker of bionutritional stress(starvation), this ratio is not as effective as a biomarker upon exposure of Gulf killifish or blue crabs to the WSF of South Louisiana crude oil. Induction of EROD activity occurred in a dose-related manner in *Fundulus grandis* from both locations exposed to the WSF of South Louisiana crude oil under hypoxia (75 Torr O_2), peaked on the seventh day of exposure, and was significantly higher in fish exposed to 35µg oil/liter from the produced water site in Louisiana than in those exposed to 35µg/liter from Florida.

Statistically significant but minor differances exist in the tolerance of the Gulf killifish from a less contaminated site and a more contaminated produced water site. RNA:DNA ratios are not a particularly sensitive indicator of sublethal WSF stress in either Gulf killifish or the blue crab. EROD activity, as an indicator of cytochrome p-450 induction increases in a dose-related manner in the liver of *Fundulus grandis* from both locations,peaks on the 7th day of exposure,

Table 1F.3. EROD analysis measures the conversion of ethoxyresorufin to resorufin by microsomal ethoxyresorufin-O-deethylase (EROD) isolated from the liver of *Fundulus grandis*. EROD activity is given as picomols resorufin/mg protein/min (sample size=n).

Population	Day	Control	9 $ng.l^{-1}$	35 $ng.l^{-1}$
Port Fourchon, LA	1	10(8)	61(8)	xxx
	7	27(15)	68(16)	301(15)
	14	32(16)	36(16)	136(16)
	28	8(12)	85(11)	51(10)
Turkey Point, FL	1	47(15)	29(16)	11(16)
	7	44(16)	60(13)	136(16)
	14	41(14)	25(16)	71(16)
	28	35(10)	89(8)	128(5)

and is higher in the Gulf killifish from the produced water site. Therefore, *Fundulus grandis,* from the chronically polluted site are slightly more tolerant of exposure to the WSF of South Louisiana crude oil and exhibit an increased rate of EROD activity compared with the Florida population. However, these biological differances in response patterns appear to be minor.

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Dr. William B. Stickle has been employed at Louisiana State University since 1972. He is a professor in the Department of Zoology and Physiology. His expertise is in environmental toxicology and physiology of marine animals. He has published over 70 journal articles. Dr. Stickle received his B.S. in biology from Slippery Rock State College , M.S. in zoology from the University of South Dakota, and Ph.D.in biology from the University of Saskatchewan in Regina.

USE OF TOXICOLOGICAL TESTS IN UNDERSTANDING THE EFFECTS OF PAH ON BENTHIC COMMUNITIES

Dr. John W. Fleeger
Department of Zoology and Physiology
Louisiana State University

Recent microcosm studies have identified consistent and predictable effects of polynuclear aromatic hydrocarbons (PAH) on the microalgae and meiofauna of Louisiana mudflats (Carman *et al.* 1995, 1996, 1997; Carman and Todaro 1996), and on the effects of PAH on fish feeding on meiofauna (Gregg *et al.* 1997; Hinkle-Conn *et al. submitted*). Effects near the base of the food chain may be summarized in the following way: Microalgal productivity and standing crop increases with the addition of PAH (above a threshold), while the meiobenthic harpacticoid copepod fraction of the fauna decreases (nematodes and total meiofauna are unaffected). With the exception of *Cletocamptus deitersi*, all meiobenthic copepod species (particularly *Pseudostenhelia wellsi* and *Coullana* sp.) decrease in density within seven days of the application of diesel fuel (total PAH ~50 ppm). *C. deitersi* increases in abundance 14-28 days post exposure. The mechanisms behind these changes are of interest and are potentially varied. For example, microalgae might increase due to direct contaminant effects or due to the indirect effect of a reduction in grazing pressure as meiobenthic copepod mortality occurs. Additionally, meiobenthic copepods may decrease in abundance due to direct toxic effects of contaminants, indirect contaminant-induced alterations in the microalgal community or reductions in sediment oxygen concentration in the presence of contamination. Here, we discuss the results of bioassays developed for use with meiobenthic copepods (designed to determine the effects of PAH on survivorship, reproduction, grazing, and avoidance) to specifically test among these various hypotheses. Bioassays were developed by Dr. Guilherme Lotufo as part of his Ph.D. dissertation (Lotufo 1996) with support from the CMI.

Bioassays were developed by testing the toxicities of sediment-associated phenanthrene, fluoranthene, and diesel fuel to the estuarine copepod *Schizopera knabeni* (Lotufo 1997). A four-day survivorship bioassay was conducted as follows: Test units (28 x 45 mm carrier glass vials) were filled with 10 ml of sea water using a volumetric flask. One ml of sediment treatment was dispensed with minimal disturbance to the bottom of each vial creating a 2-3 mm sediment layer. Four replicates were used per sediment treatment (phenanthrene: 0, 0 S, 126, 261, 514, 1030 µg/dry g; fluoranthene: 0, 0 S, 137, 249, 451, 990, 2170 µg/dry g; diesel: 45, 93, 185, 370 µg/dry g). Vials were placed in moisture chambers (loosely covered plastic containers underlined with soaked paper towels which created a humid environment to retard evaporation from experimental dishes). They were kept overnight in the dark at 25 °C in an incubator with no illumination. Fifteen adult female *S. knabeni* were introduced to each experimental unit and vials were returned to the incubator. The animal dry weight : SOC ratio was approximately 1:200. After four days, the contents of all vials were sieved through a 45-µm mesh and retained copepods were enumerated as live or dead. Copepods immobilized by PAHs were considered live if they displayed body contraction upon contact with a probe. Results (Lotufo 1997) show that the 4-d LC_{50} was lowest for diesel fuel (194 µg/dry g), followed by phenanthrene (473 µg/dry g), and fluoranthene (> 2,100 µg/dry g). As a follow up, the lethal and sublethal toxicity of phenanthrene to two species of harpacticoid copepods (*Schizopera knabeni* and *Nitocra lacustris*) was investigated (Lotufo and Fleeger 1997). Individuals of different life stages (nauplius, copepodite, adult male and female) were exposed to sediment-associated phenanthrene in separate 10-d bioassays (also developed by Lotufo). Overall, *N. lacustris* (10-d LC_{50}s ranging from 43 to 105 µg/dry g) was more sensitive than *S. knabeni* (10-d LC_{50}s ranging from 84 to 349 µg/dry g). Significant differences in life-stage-specific sensitivity were observed for *S. knabeni*, with nauplii most sensitive, followed by copepodites and adults; adult males and females were equally sensitive. For *N. lacustris*, females were significantly more sensitive than all other stages; no significant differences were evident among the other stages. Phenanthrene effects on offspring production were investigated in the adult 10-d bioassay. Significant decreases in offspring production occurred at sublethal concentrations for *S. knabeni* (as low as 22 µg/dry g), but at concentrations in the same range as the 10-d LC_{50}s for *N. lacustris*. In addition, phenanthrene significantly prolonged embryonic and larval development and decreased egg hatching success for both species. Results suggest that PAHs have a negative effect on the reproduction of meiobenthic copepods at sublethal concentrations mostly due to a decrease in brood production rate and impairment of hatching. Overall, deleterious effects were manifested in the same range of concentrations for both species, but species-specific differences in the pattern of responses were evident.

These bioassay techniques were used to test for differences in survivorship among the copepod species abundant in the microcosm experiments. Tests were performed to examine the synergistic effects of reduced oxygen and PAH to test the null hypotheses that survivorship in the presence of hypoxia and PAH is not different among species. Four-day bioassays were conducted using the techniques discussed above on *Cletocamptus deitersi*, *Pseudostenhelia wellsi* and *Coullana* sp. in sediment amended with a single PAH congener (fluoranthene) under normoxic (~50% saturation of oxygen) and anoxic conditions (measured with an oxygen microprobe). The 96 LC_{50}s (in ppm) are shown below:

	Normoxic	Anoxic
C. deitersi	138	41
P. wellsi	79	<<32
Coullana sp.	128	63

These results suggest that *P. wellsi* is less tolerant of PAH than the other species and much less tolerant when hypoxia and PAH exposure co-occur. *P. wellsi* mortality in microcosms occurs within hours to days of exposure and appears to be a direct consequence of contaminant effects. However, *C. deitersi* (no mortality in microcosms) and *Coullana* sp. (almost complete mortality within one week in microcosms) have similar tolerances to both PAH and anoxia. Behavioral differences between these species may be the cause of this observation. Pace and Carman (1997) show that *Coullana* sp. is a surface feeder that ingests settled phytoplankton. *C. deitersi* is also a surface feeder but on benthic diatoms. These life-style differences likely put *Coullana* sp. at greater risk through increased exposure because of the method of addition of contaminants. Diesel-contaminated sediment was added daily by injecting into overlying water with a syringe, exposing *Coullana* sp. as contaminated sediment settled to the bottom. The toxicity test was a valuable tool to allow tests to be conducted to discriminate among the various hypotheses that explain the causes of changes in abundance in microcosm studies.

In summary, Lotufo (1996) developed methodologies to examine contaminant effects on survivorship, feeding, reproduction, and avoidance using harpacticoid copepods as an experimental subject. The work has increased our understanding of the toxic effects of PAH on meiobenthic animals and allows hypothesis testing to reveal the mechanism underlying contaminant effects in microcosm studies. Future studies using bioassay techniques will likely be varied but used to test specific theories. For example, future studies may address the critical body residue theory (which suggests that toxic effects occur for compounds with similar modes of action at predictable tissue concentrations), multiple factor effects (such as metals or PAH in complex mixtures), or genetic adaptation to contamination.

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Dr. John Fleeger is a professor and the Chairman of the Department of Zoology and Physiology, Louisiana State University, Baton Rouge. He received his B.S. from Slippery Rock University (1971), his M.S. from Ohio University (1974), and his Ph.D. from the University of South Carolina (1977). Dr. Fleeger has served as the President of the Gulf Coast Research Society (1980-82); a member of the Governing Board, Estuarine Research Federation (1980-81); and the Chairperson of the International Association of Meiobenthologists and Editor of Psammonalia, the Newsletter of the International Association of Meiobenthologists (1987-89). Dr. Fleeger's primary research interest is marine ecology with emphasis on benthic ecology, including meiofaunal ecology, toxicology, and fish predatory-prey interactions.

MANAGEMENT CONCERN FOR CONTINENTAL SLOPE DEEPWATER RESOURCE DEVELOPMENT

Dr. Robert S. Carney
Coastal Marine Institute
Louisiana State University

During the last five years we have experienced a peculiarly disjunct shift in plans to study the deep ocean versus plans to exploit it. Heavily funded futuristic schemes for nodule mining and waste disposal have faded away, bringing uncompleted research to a premature close, and federal ocean agencies are rushing to focus upon the coastal zone. So, deepwater natural gas and oil development is a reality at the same time that deepwater environmental research is at a low. This presents MMS, and the industry it regulates, with a serious problem. Environmental information pertaining to deepwater is needed, but it is very expensive to obtain, and there are few opportunities to acquire it in partnership with other user groups. Therefore, MMS must assure that its deepwater needs are succinctly defined and met very efficiently.

There are at least two ways that succinct definitions and efficient answers may be sought. They are based upon the way that MMS makes decisions. In the northwest Gulf of Mexico where OCS development is well established, if not welcomed, MMS tends to make use of general understanding of the impacted ecosystems rather than focus upon a list of issues. Building upon this, limited contrasting of ecosystems is a viable approach. Alternately, in regions where OCS development is new or seen as a poor choice among competing resources, decisions are issue or conflict driven. Thus, MMS could develop a priority list of traditional shelf-depth issues then investigate the most critical in deepwater.

CONTRASTED ECOSYSTEMS

MMS typically expends considerable cost and effort establishing a general understanding of a particular marine environment. These comprehensive studies combine physical, biological, chemical, and some elements of geological investigation. Rather than repeat such a comprehensive effort in deepwater, MMS could make extensive use of models. Critical parameters in the models could be selected that allow for a parsimonious comparison of deep versus shallow systems. Then field efforts would be limited strictly to estimation of those critical parameters only. Once estimated, the deep models could be used to make predictions and the models tested. The key aspect of the Contrasted Ecosystems approach is that general understanding is emphasized over specific detailed knowledge.

CONTRASTED CRITICAL ISSUES

There are many "critical issues" that come up when oil and gas development is discussed. For our purposes we can classify them as resource conflicts and general habitat degradation. Far from land, using seabed rather than sea-surface structures, and outside traditional fisheries grounds, it can be expected that relatively few resource conflicts will arise in deepwater. Therefore, most concerns will focus on general habitat degradation. MMS can identify the concerns about degradation that have been addressed at shelf depths and limit deep studies to the highest priority concerns.

Deep habitat degradation may narrow down to two issues. First, how are reef-like chemosynthetic systems to be protected? Second, are deep soft bottoms more ecologically sensitive than shelf-depth areas? To a certain degree, the chemosynthetic issue can be treated as any reef system and may be adequately addressed by current MMS research. However, the possibility that seeps and oil wells compete for the same hydrocarbon is an intriguing possibility, which cannot be addressed until development takes place. The question of soft bottom sensitivity may center upon an understanding of diversity maintenance, a very elusive topic.

In the end, MMS 's future approach must be dictated by one central question about the past. Has extensive oil and gas development on the continental shelf caused unacceptable damage? If not, then MMS is either lucky or doing something right and can enter deepwater using its shallow experiences and ecosystems and issues. If there is unacceptable damage, MMS has been doing something wrong and must seek new approaches for the deep.

Dr. Robert Carney is a benthic ecologist who began deep-sea studies as a master's student at Texas A&M University (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.

SESSION 2D

DEEPWATER ISSUES: INDUSTRY PERSPECTIVE

Co-Chairs: Mr. Virgil Harris
Ms. Debbie Vigil

Date: December 11, 1996

Presentation	Author/Affiliation
Introduction	Mr. Virgil Harris Executive Director Offshore Operators Committee
Mars	Mr. Bob Markway Shell Offshore
Gorillas	Mr. Paul Kelly Rowan Companies, Inc.
Gulf of Mexico Subsalt: The Mahogany Field Development	Mr. Dan Rycroft Phillips Petroleum Co.

INTRODUCTION

Mr. Virgil Harris
Executive Director
Offshore Operator Committee

Many changes have occurred in the offshore industry during the past 8-10 years. I remember the days when I first went to work in the industry and I reflect on a conversation I had with one of my contemporaries a few years ago. My friend was a man of few words and I asked if he ever imagined that we would be drilling in 7,500 feet of water. In a typical manner he moved the cigar from one side of his mouth to the other and responded, "Nope"! A very succinct response but I think that covers it. I also remember the days in the Denver-Julesburg Basin when we drilled and completed wells for about $25,000. That hardly covers the monthly coffee bill on some of the offshore installations today.

The papers from this session are a record of success and achievement brought about by technology that has been developed in the industry at great expense during the past few years. Hopefully, the rewards will justify the expenditure of those research and development dollars. It is an exciting time in the industry and the developments in deepwater and subsalt make a considerable contribution to the excitement.

Virgil Harris joined Shell Oil Company in 1958 and worked in the Rocky Mountains and the offshore Gulf of Mexico for a total of 35 years before retiring. During that time, he worked as a field engineer, designed production facilities, and was involved in project management. He was a production superintendent, manager of safety and environmental Conservation, Procurement Manager, and Purchasing Operations Manager. After his retirement, he worked on a gas gathering project in Azerbaijan. Upon his return to the U.S., he became the Executive Director of Offshore Operators Committee (OOC).

MARS

Mr. Bob Markway
Shell Offshore

THE MARS TENSION LEG PLATFORM DEVELOPMENT PROGRAM

The Mars discovery well was drilled on Mississippi Canyon Block 763 in 1989, ultimately using a total of five delineation wells, 15 penetrations (including S/T & B/P holes), and two 3D seismic surveys were used to evaluate the prospect. The field lies under six deepwater blocks, originally leased by Shell Offshore Inc. (SOI) and British Petroleum (BP). Officially the field is known as MC Block 807, with SOI holding a 71.5% interest and BP holding the remaining 28.5%.

Shell is the operator of the project; however, BP has contributed about 25% of the project engineering staff and significant technical expertise. The project team, which was formed on 1 July 1992, considered 26 different scenarios to develop the Mars reserves, including multiple Compliant Towers and Tension Leg *Platforms* (TLPs) and variations thereof. During 1992, Shell selected a single TLP with two subsea wells as Phase I in a staged development strategy, though due to scheduling conflicts with other SOI subsea projects, only one subsea well was completed (Figure 2D.1). The TLP was installed in 2,940 feet of water at a location 130 miles southeast of New Orleans, Louisiana.

Staff responsible for operating the platform had to be assembled and trained years before first production. They had a significant impact from the outset on TLP design. In addition to addressing Preliminary Hazard Analysis, P&ID Reviews, Operability Reviews, Produce While Drilling Guidelines (and other Simultaneous Operations) they also established state of the art Preventive Maintenance Programs, borrowing from

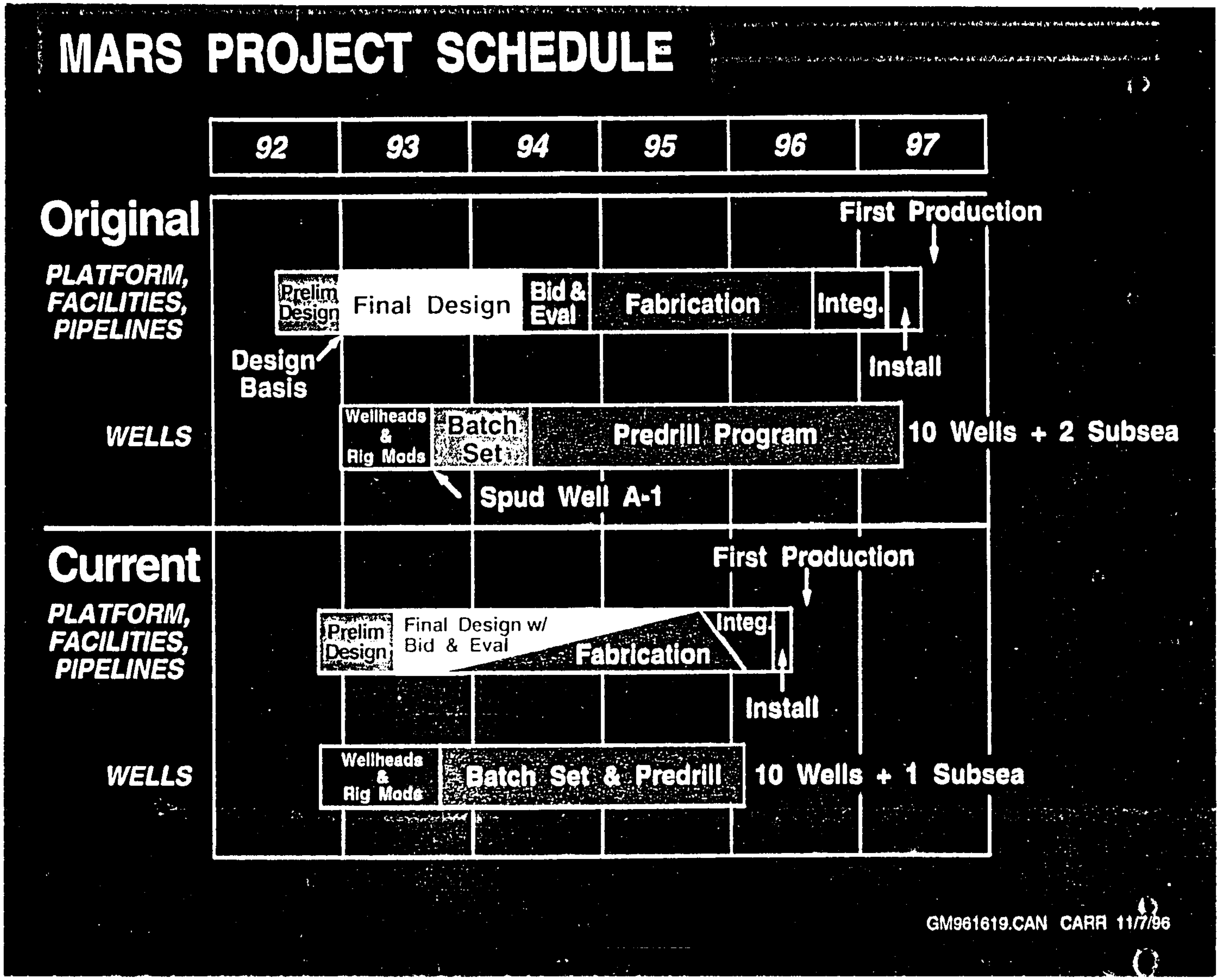

Figure 2D.1. Mars project schedule.

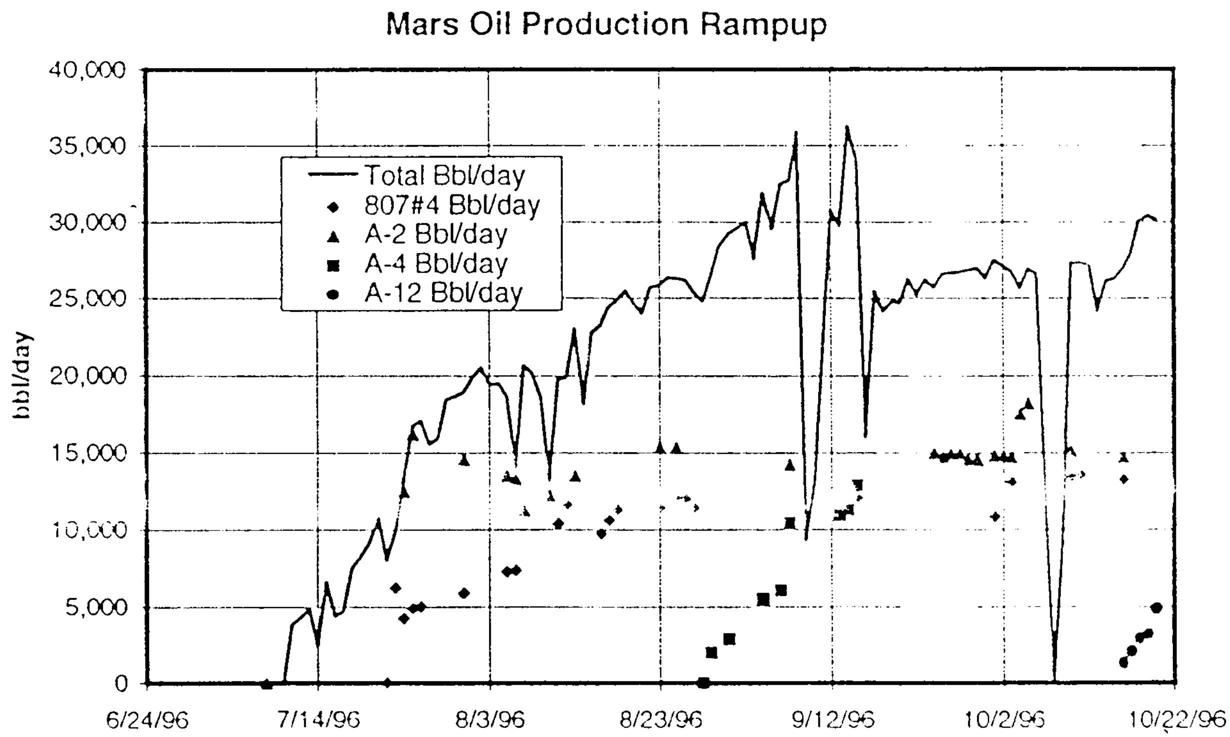

Figure 2D.2. Mars oil production rampup

techniques and tools originally developed by the Airline and Nuclear Power Industries.

Mars Phase I will cost approximately one billion dollars. Reserves are estimated at better than 500 million barrels equivalent of oil and gas for Phase I. Ultimately, we expect to recover approximately 700 million barrels equivalent, making this the largest Gulf of Mexico oil and gas discovery in the past 20 years.

During the fabrication of the TLP, the George Richardson concurrently drilled all TLP wells down to the surface casing point through a shallow geopressured zone prone to uncontrolled water flows. By drilling all the TLP wells through this zone, any potential problems from shallow water flows were eliminated prior to the setting of the TLP. Ten of the TLP wells were drilled to TD resulting in 11 wells available for production in the initial completion cycle. This is allowing a rapid TLP production rampup (Figure 2D.2)

The TLPs hull structure was constructed by Belleli in Italy and dry towed across the Atlantic to Ingleside, Texas, in August, 1995. Concurrent with the hull construction, the deck modules were fabricated in Amelia, Louisiana, prior to being towed to Ingleside and mated with the hull. In April 1996 the TLP was towed from Ingleside to its permanent location at MC 807. The oil and gas export lines were tied back to the TLP. Subsea flowlines were installed. The oil and gas export lines were laid and tied into the TLP and WD 143.

The plan called for a shallow water platform at WD 143. This platform was to be equipped with pig receivers and slug catchers to accommodate phase changes in the Mars production stream as it travels through the cold, deepwater section of the pipelines. The Mars export oil line from the TLP to WD 143 is 18 inches in diameter with a capacity of 150,000 barrels per day. The line then transitions to 24 inches in diameter capable of carrying 250,000 barrels per day and runs to the LOOP storage facility at Clovelly, Louisiana. The oil will go into a dedicated three million barrel salt dome cavern, which can feed any of 5 major inter-connecting pipelines serving the national refining market. By December 1996, the process of tieing back and completing the 10 wells predrilled by the George Richardson. Two TLP wells and a subsea well were producing 37,000 barrels per day, and the third TLP well was being brought on production. We expected to see 60,000 barrels per day by the end of 1996.

Mars was also producing 40 million cubic feet of gas per day by December 1996. Its gas line is 14 inches in diameter with a 150 million cubic feet per day capacity between the TLP and platform at WD 143. Leaving WD 143, the line expands to 30 inches with a capacity of 600 million cubic feet per day as it continues to the Warren gas plant in Venice, Louisiana. SOI's gas is marketed by Coral Energy.

During the first half of 1997, the Mensa subsea gas well development in 5400 feet of water will be tied into and operated from the WD 143 platform. Estimated production from the 3 Mensa subsea wells will be 300 million cubic feet of gas per day. In 1999 the Ursa tension leg platform will be installed and also routed to West Delta 143.

The Mars TLP briefly held the Gulf of Mexico record for oil well production rates (over 15,000 barrels per day). This rate was recently eclipsed by an Auger well (21,700 barrels of oil per day). Auger was Shell's first TLP. The Mars design differs significantly from Auger in that Auger contains a dedicated drilling rig using a subsea BOP stack, a marine drilling riser, and a lateral mooring system to position the rig over a well's location at the mudline. In contrast, the Mars TLP utilizes a high pressure drilling riser, guideline system, surface BOP stack, and a conventional API skiddable rig. Another significant difference is the use of five modules for the deck structure at Mars vs Auger's one piece topsides structure. The Mars TLP contains 24 well slots with Xmas trees at the surface, one subsea well, capacity to fully process 100,000 barrels of oil per day and 110 million cubic feet of gas per day. Auger was originally designed with 14 well slots and a capacity of 45,000 barrels of oil per day and 125 million cubic feet of gas per day. Mars uses Catenary risers for the oil and gas export lines. Additionally, the Mars permanent living quarters accommodate one hundred and six people.

In 1992 first production was forecasted for mid-1997. This actually occurred on 8 July 1996, a year ahead of schedule. We will begin drilling from the TLP during 1997. This activity will fill our 24 well slots and will include a mixture of horizonal frac-n-pac and high rate water pack well completions. Of the 10 predrill wells, three have open hole horizonal completions. Mars hopes to achieve its facility name plate capacity of 100,000 barrels per day, 110 million cubic feet per day, by mid-1997. Our engineers are now planning to expand the Mars facility beyond name plate capacity.

Bob Markway received a B.S. in petroleum engineering from LSU and joined Shell in 1973. He has worked largely in the offshore area in Production Engineering, Drilling Engineering, Engineering Management, and Staff Planning. He has been both a production superintendent and a drilling superintendent, and he was the manager of Drilling Research. Since 1992, Mr. Markway has led an operations group involved with the planning of Shell's Deepwater Gulf of Mexico developments. He is currently the asset leader for SOI's Mars TLP.

GORILLAS

Mr. Paul Kelly
Rowan Companies, Inc.

OFFSHORE DRILLING INDUSTRY OVERVIEW—STRENGTH IN THE MARKET

During the second half of 1996, we have seen continual increases in utilization and dayrates of offshore drilling rigs, along with several key indicators that the oilfield service sector will experience additional growth in the coming year.

Worldwide rig utilization is at 93% and has been above 90% for months. Competitive utilization rates, which exclude unavailable rigs, are even more impressive. Worldwide competitive utilization is at 98% for all rigs and 99% for jackups. Throughout most of the third quarter, there were less than 10 total rigs ready, stacked, and available. Furthermore, the utilization figures are high in all of the major drilling regions: the Gulf of Mexico, the North Sea, West Africa, and Southeast Asia. With no weak areas, rigs will continue to be near full utilization and contractors should see daystar increases in all regions.

The strength in the worldwide market is illustrated by the mobilization activity among the regions. As we speak, the *Rowan Gorilla IV* (Figures 2D.3 and 2D.4) is preparing to leave for the UK North Sea under a term contract with Phillips Petroleum. Semisubmersible rigs have moved from the North Sea to the Gulf; jackups from the Gulf to West Africa. Also, Pemex is planning to step up its activity in the Bay of Campeche and will probably draw another four to six rigs out of the Gulf over the next several months. With a comparable number of rigs planning to return to the Gulf over the same time frame, the net effect will likely be little change in the rig count here. The point is that the high level of movement does demonstrate that demand is high—everywhere; and all indications are that the record rates of drilling activity will continue.

In the Gulf of Mexico by October there had already been as many total drilling permits awarded as there were during all of 1995, and deepwater drilling permits were at record levels. In addition, the length of drilling contracts is increasing. In the deepwater market, term contracts have been common for some time. Now, however, lower-tier semisubmersible rigs and jackup rigs are being awarded contracts for terms of six months, one year, or more. Operators are moving to ensure that they will have rigs when they need them. Turnkey operators have been especially aggressive on this front. In addition, operators are becoming both more creative and more cooperative in an effort to assure themselves of rig availability. Sublets and farmouts among operators have become increasingly common in the jackup markets.

GULF OF MEXICO LEASE SALES

The most significant positive indicator for the offshore industry during fall 1996 was the Western Gulf of Mexico Lease Sale No. 161 held on September 25. The sale generated record activity of 929 bids on 617 tracts. A total of 73 companies participated in the sale, and 57 submitted bids. There was an average of one and a half bids per tract. Total high bids of $356.1 million were submitted, more than three times the $114.3 million bids in last year's sale No. 155. The previous record activity at a Western Gulf lease sale was in 1983 when there were 773 bids on 436 tracts. The success of Sale No. 161 comes on the heels of the Central Gulf sale in April that generated a record 1,381 bids on 924 blocks by 78 companies. Total high bids in that sale, Lease Sale No. 157, were $521 million. In this sale alone, the

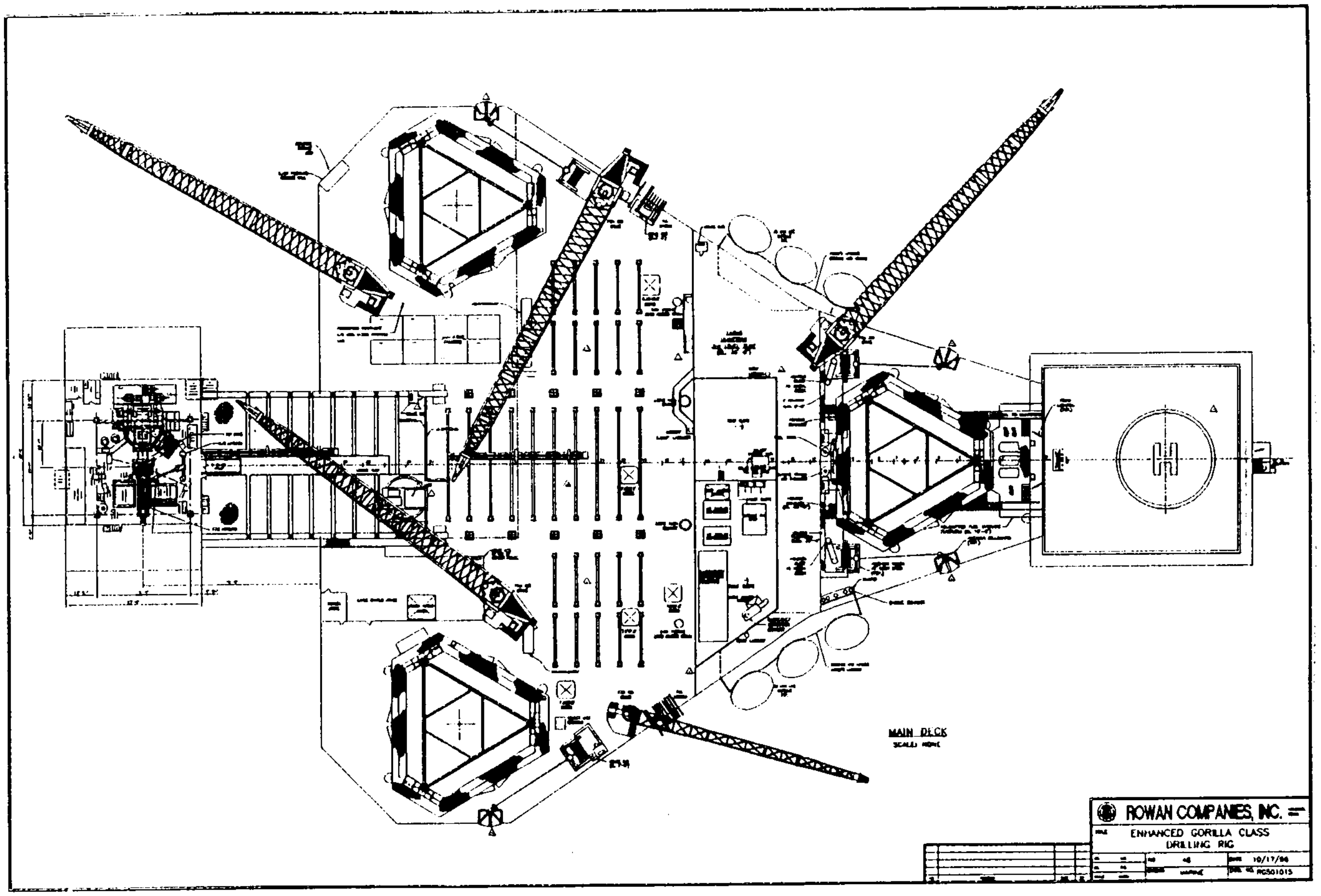

Figure 2D.3. Rowan Companies, Inc., enhanced Gorilla class drilling rig.

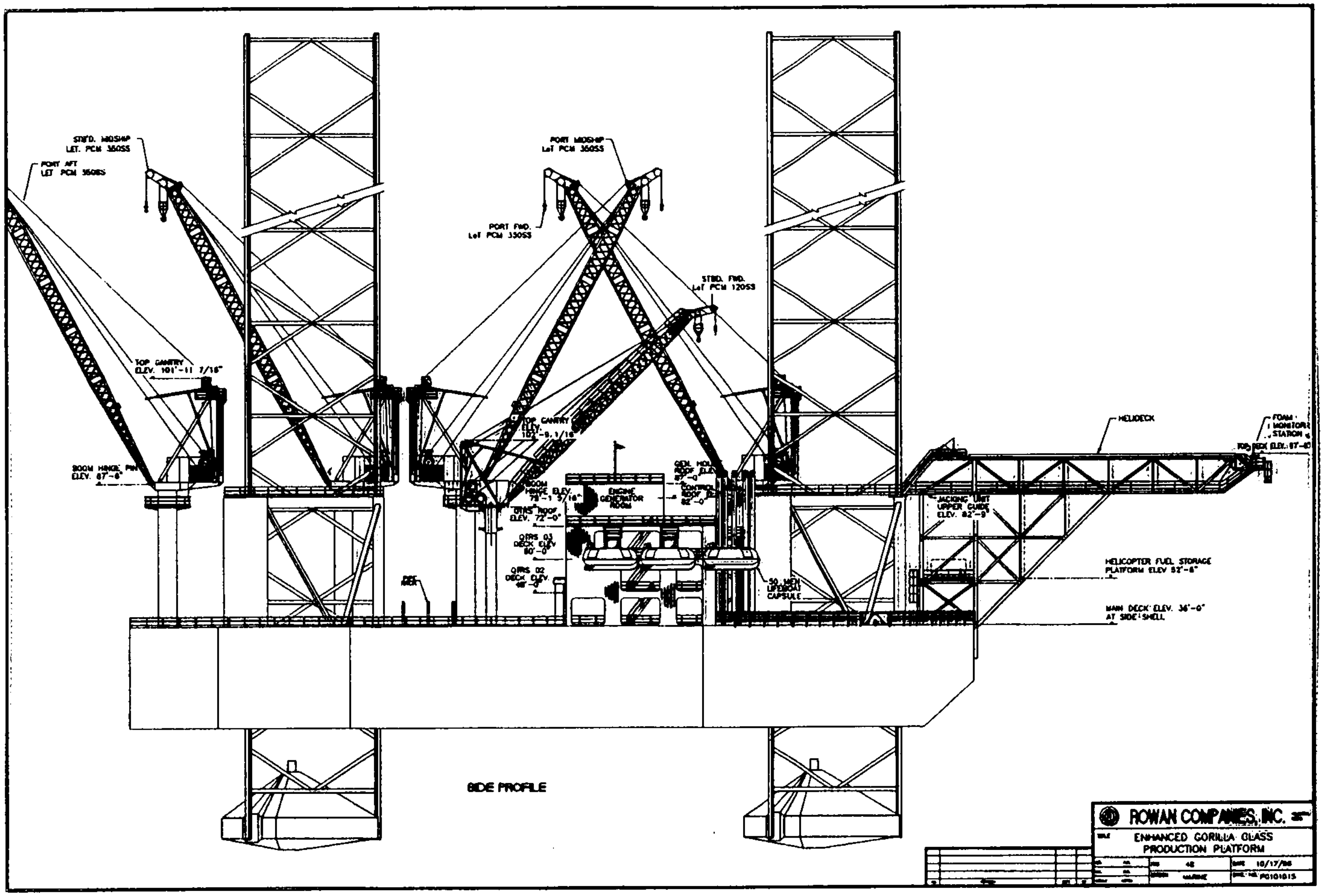

Figure 2D.4. Rowan Companies Inc., enhanced Gorilla class production platform.

leases bid equaled 45% of the acreage currently under lease in the Western Gulf.

INCREASED EXPLORATION AND PRODUCTION

Here in the fourth quarter of 1996, we are gaining visibility of 1997 capital expenditures by oil and gas companies. The consensus seems to be that operators across the board will be increasing their capital budgets over 1996 levels. On the whole, those increases are expected to be in the high single-digit percentage growth range. Not only is it noteworthy that operators will be investing more money in exploration and development, but it is also significant that the companies are using conservative assumptions in determining their expenditure levels. By and large, oil and gas companies are using $18 crude oil and $1.90 natural gas in their economic analyses. This is a critical difference between the boom of 15 years ago and the recovery today. In the early 1980s industry professionals and analysts were predicting commodity prices at unheard-of levels, with crude oil forecasts at well over $50 per barrel. Today the market is being driven more by the demand for rigs than it is by speculation about future crude oil prices.

The ability of oil and gas companies to be profitable in a flat commodity price environment is a result of improved technologies in the exploration and production industries, as well as considerable downswing by the companies themselves. Certainly 3D seismic surveying has led to much higher success rates for exploration companies. In addition, less glamorous technologies extended reach drilling, improved mud chemistries and the metallurgy of drillbits have improved efficiencies and reduced costs in the exploration and production processes. Profits in the 1990s are not as dependent upon higher commodity prices as they were in the 1980s. Indications of increased levels of reinvestable cash flow by oil and gas companies provide confidence of even higher levels of activity next year, both in the Gulf of Mexico and worldwide.

ENHANCED ROWAN GORILLA RIGS—NICHE MARKET

Despite the fact that dayrates have been climbing for months, according to some analysts they are not yet near the level that justifies the speculative construction of new rigs. For example, according to Global Marine's Summary of Current Offshore Rig Economics (SCORE), jackup rig dayrates are only at 57% of replacement level and semisubmersibles are at 58%. This approach to replacement investment is reflected in the fact that the handful of new rigs being constructed are almost all backed by firm contracts that ensure sufficient financing of these rigs. Rowan Companies is the only company that is building jackup rigs without contracts, and in our case, the rigs are not true competitors with the vast majority of existing jackups. The Rowan rigs are large, harsh environment jackups capable of drilling in 400 feet of water in the North Sea or 550 feet of water in the Gulf of Mexico and are really aimed at a smaller niche market.

Rising demand for drilling rigs, coupled with a dwindling fleet, is generating supply shortages around the world, particularly at the high specification end of the market. Even allowing for an increase in the historical retirement age from 20 to 25 years, rig attrition continues at a level of about 18 per year. To give you some idea of the universe in which we are operating, there are this week 163 mobile drilling units working in the Gulf of Mexico, and worldwide the working fleet of MODUs numbers about 550. Clearly, rig attrition will be outpacing rig construction by a significant number through the turn of the century. Matt Simmons, President of Simmons & Company International, believes that the petroleum industry "is out of touch with reality" in being so complacent in the face of numbers which show a coming shortage in mobile offshore rigs. He estimates that, if we started tomorrow, only 20 new offshore rigs at most could be delivered within the next five years. More than the lack of shipyard capacity, it is the fact that manufacturers of rig and drilling equipment are not geared up to meet a big step-up in demand. The *Rowan Gorilla V*, the first of three new enhanced *Gorilla* class rigs planned by Rowan, is the only new offshore rig under construction in the United States today.

The international fleet of large hostile environment rigs in which Rowan's present three *Gorilla* rigs compete includes about 16 units, depending on the specifications one applies. Our present three *Gorillas* came into service in 1984 and 1986. With the exception of one *Rowan Gorilla* contracted in the Gulf of Mexico and another offshore eastern Canada, the rest of this high specification fleet is working in the North Sea, often drilling high pressure/high temperature wells, under contracts, that commit most of them until the 1998-2001 time period. Thus, demand for these heavy duty jackups is very high, and they are not readily available in the near term.

ROWAN'S STRATEGY

Apart from the jackup market per se, however, Rowan's strategy in designing and building enhanced *Gorillas* is to improve and expand upon existing jackup drilling technology and offer its customers a greatly enhanced product which gives the operator the versatility to operate as a drilling unit, a mobile production unit, or both simultaneously in either open water locations or alongside existing platforms. The enhanced *Gorilla* is constructed under dual classification by the American Bureau of Shipping and Det Norske Veritas, which will enable it to meet relevant government regulatory requirements in the harsh offshore environments of the North Sea, Eastern Canada, Australia and Argentina, as well as the United States.

COMBINATION DRILLING AND PRODUCTION RIG CONCEPT PROVEN IN CANADA

The concept of using a large jackup rig as a combination drilling and production facility has been proven in Nova Scotia, where since 1992, the *Rowan Gorilla III* has been serving as a drilling and production unit in the Cohasset Project, Canada's first producing offshore oilfield situated approximately 138 miles southeast of Halifax. Total production from Cohasset to 30 September 1996 was 31 million barrels. PanCanadian has been the operator of the Cohasset Project since January 1996, with a 50 percent working interest; Nova Scotia Resources holds the remaining 50 percent. Under current forecasts, production is expected to continue until late 1998. The Cohasset Project actually includes three fields that have been produced using the *Rowan Gorilla III*. Production began from the Panuke Field in 1992. Cohasset Field production was added in 1993, and, thirdly, Balmoral Field production began in February 1996. Balmoral is produced from an extended reach well directionally drilled by the *Rowan Gorilla III*, 3.5 kilometers from the Cohasset jacket. Crude oil is transported from the *Gorilla III* into a supertanker moored nearby. The oil is then lightered by smaller tankers to ports in Canada and the United States. The rig also does workovers. The Cohasset Project successfully demonstrates the feasibility and economic appeal of using a jackup as a combined drilling and production facility, and when the fields are depleted in 1998 or later, the operator and government regulatory authorities will have no platform decommissioning problem to worry about. When it completes its work, *Gorilla III* will simply jack down and move off to be used on another project.

ROWAN'S DECISION TO BUILD

In May 1995, Rowan announced the commitment to design and construct an enhanced version of its *Gorilla* class of rigs, the *Rowan Gorilla V* at LeTourneau Inc.'s Vicksburg, Mississippi, shipyard. LeTourneau is a wholly owned subsidiary of Rowan. Over the last 41 years, LeTourneau has designed and manufactured in excess of 33 percent of the mobile jackup fleet operating in the world today, including the already proven *Gorilla* class design. The rig is expected to cost some $170 million and is scheduled for delivery in mid-1998. Financing has been arranged and construction is now underway. The workforce at the shipyard now exceeds 400. As the project progresses and the training of many additional welders is completed, total employment at Vicksburg will top 550.

Meeting in October of this year, Rowan's board of directors approved the construction of *Gorillas VI* and *VII* for delivery in 1999 and 2000. The estimated aggregate cost of these two units is $380 million.

CHANGES AND IMPROVEMENT IN ENHANCED GORILLAS

Rowan has used the knowledge and experience gained in Canada, the North Sea, the Gulf of Mexico and elsewhere in designing the enhanced *Gorilla* series. The enhanced *Gorilla*—designed operating criteria were established based on year round operations in 400 feet of water, satisfying the North Sea 50-year storm environmental criteria south of the 61st parallel. Anyone in the offshore exploration business knows that this is about the toughest environment drillers face anywhere in the world. Maximum operating depth in the more benign Gulf of Mexico will be 550 feet.

Ten years after the delivery of *Gorilla IV*, what are we doing with the enhanced *Gorilla* series that's new and different? Many things.

DESIGN AND OPERATING FEATURES

- The enhanced *Gorilla* design will greatly increase the variable deck load available. The designed variable deck load is 12,500 kips (12,500,000 lbs) compared to 4,188 kips (5,188,000 lbs) on *Gorilla IV*, and combined hook/setback tensioning load is 3,750 kips (3,750,000 lbs) compared to 2,500 kips (2,500,000 lbs) on *Gorilla IV*. This increased load capacity will reduce the oil company operator's supply costs, reduce weather related flat time associated with supply and re-supply risks and have the capability to perform drilling and production. This can reduce the operator's production capital expenditures, increase cash flow, and provide a more rapid return on investment.

- The rig will have triangular shaped legs instead of the previous square truss type. The new triangular type opposed pinion design will increase the allowable environmental loads by reducing the surface area affected by winds, seas and currents. Also, it will further increase the efficiency of the jacking system and the maximum elevated storm criteria. The increased jacking and holding capacities of the rig will allow substantial expansion of operating criteria over historically proven *Gorilla* designs, allowing the unit to serve a dual role as both a mobile production platform and a self-elevating jackup drilling rig.

- The expanded capacity of the jacking system will provide beneficial hull design changes resulting in additional storage area. The hull depth will increase from 30 feet to 36 feet and the hull length will increase from 297 feet to 300 feet.

- The cantilever deck longitudinal skidding capabilities provide a drilling operations envelope of 100 feet by 40 feet. Extension of the cantilever beams will allow drilling operation 75 feet aft of the transom compared to 52 feet on *Gorilla IV.* This additional reach will eliminate capital expenditures required on large platforms or expanded wellhead platforms to support skid-off operations.

- Pipe racks are arranged to facilitate drilling and/or production tubular segregation. The total combined pipe rack area is 7,472 sq. feet.

- The enhanced *Gorilla* design eliminates many main deck obstructions. Available deck space is large enough to allow placement and operation of simultaneous drilling and production equipment.

- Accommodation spaces and life saving equipment are increased substantially. The unit will be capable of housing 120 men and women.

DRILLING CAPABILITY AND EQUIPMENT

Likewise the enhanced *Gorilla* design includes many improvements in drilling and production capability and equipment. For starters, the unit is equipped with five turbocharged, after-cooled diesel engines rated for a total of 16,975 continuous horsepower and 18,672 intermittent horsepower. This is 70 percent more than the horsepower on *Gorilla IV*. The power generated by the unit will provide operators with versatility to supply small amounts of power for extended well tests while drilling *or* supply large amounts of electric power for production equipment while supporting hotel loads.

Other features include:

- Fully automated rig floor
- 750 ton top drive
- 4,000 HP draw works rated for 2,000 kips
- 15K bop
- Four 2,200 horsepower mud pumps rated for 7,500 psi
- 5,700 barrels of liquid mud capacity
- Zero discharge capability

The list of advances and improvements is too long to cover here, but suffice it to say that the enhanced *Gorilla* contains enough state-of-the-art technology to warm every drilling engineer's heart.

GEOGRAPHICAL AREAS FOR ENHANCED GORILLA APPLICATION

In terms of geographical application, the enhanced *Gorilla* class of rigs was designed to conduct exploration, development and production operations throughout the world in harsh, ice-free environments in water depths as great as 400 feet in the North Sea or 550 feet in the Gulf of Mexico. Three leading markets stand out at this time.

- Gulf of Mexico: In the Gulf of Mexico a band of leases in 250 feet - 550 feet of water offer a particularly good potential market for the enhanced *Gorilla.* This band runs right through the heart of the sub-salt trend where existing *Gorilla* rigs have proven themselves to be a highly effective answer to the special technical and geological challenges of sub-salt drilling.

- Eastern Canada: Another good potential market is the Sable Island area offshore Nova Scotia where *Gorilla III* has worked since 1992, and a number of new projects are slated for development in the next five years. Additional prospective areas are offshore Newfoundland and Labrador.

- North Sea and Other Markets: Finally, the combined drilling and production concept should have application in the North Sea where the enhanced *Gorilla* will take bottom-supported drilling north to the 61st degree parallel for the first time, as far as the Shetland Islands. Moreover, the enhanced *Gorilla* greatly extends the application of jackups in the Norwegian sector. Measuring markets by numbers of planned developments, for which the enhanced *Gorilla* concept would have application, the North Sea represents the largest potential market for the enhanced *Gorilla* over the next decade. We also see potential in Australia and Argentina.

CONCLUSION

As you can see from this presentation, Rowan Companies remains committed to constructing and equipping its new generation jackup platforms with the latest technological innovations. Then enhanced *Gorilla* class jackup represents the most technologically advanced jackup unit constructed to date. We have designed the unit structurally to meet year-round weather challenges in all these harsh geographical environments. At the same time, in terms of drilling equipment, we have furnished the latest technology, which will enable operators to address difficult drilling challenges such as those encountered in high pressure/high temperature formations and sub-salt plays. Moreover, this mobile platform will have the capability of drilling and producing simultaneously and even serving as production platform for the life of a field, thereby eliminating the environmental and financial costs of platform decommissioning. The rig will also reflect current concerns about water and air quality, have zero discharge capability, and generally be well equipped in terms of both human and environmental safety.

We firmly believe that the oil company operator who contracts this new rig will receive considerable economic benefits in the form of earlier cash flow returns from a more efficient drilling machine that can provide early production and long term production from a mobile platform, which eliminates the need for costly investment in a permanent platform that later has to be decommissioned at considerable expense. This type of unit may well make the difference in a decision to proceed with a marginal field development.

In conclusion, what we are talking about here is a seriously new and improved product—not just another jackup rig to replace on retiring from the fleet.

Paul Kelly is a senior vice president of Rowan Companies, Inc., with responsibility for special projects and government and industry affairs. He also serves on the U.S. Secretary of Interior's Outer Continental Shelf Policy Committee and on the U.S. Coast Guard Safety Advisory Committee (NOSAC). He is a director of both the Alaska Oil and Gas Association and the International Association of Drilling Contractors as well as an advisory member of the Executive Subcommittee of the Offshore Operators Committee. Mr. Kelly has written widely on the subject of energy policy and is a member of the Editorial Board of *World Oil*. From 1985 to 1987, he served as the managing director of British American Offshore Ltd., London, which is 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 its president in 1989. He currently serves on the Global Advisory Council of the Thunderbird Graduate School of International Management. Mr. Kelly holds a B.A. in political science and law degrees from Yale University.

GULF OF MEXICO SUBSALT: THE MAHOGANY FIELD DEVELOPMENT

Mr. Dan Rycroft
Phillips Petroleum Co.

INTRODUCTION

Mahogany is the first commercial subsalt development in the Gulf of Mexico. Discovered in 1993, the field is located in 370 feet of water 80 miles offshore Louisiana on Ship Shoal South Addition Blocks 349/359. Mahogany is owned by Phillips Petroleum Company (Operator), 37.5%; Anadarko Petroleum Corporation, 37.5%; and Amoco Corporation, 25%. Its discovery and subsequent announcement as commercial caused quite a stir in the news media and financial communities and injected a large dose of optimism in the prospects for the Gulf of Mexico.

BACKGROUND

The idea of good quality reservoir sands around salt structures has been around a long, long time. Industry has successfully explored around salt domes and structures for years along the Gulf of Mexico and on the Outer Continental Shelf. Hydrocarbons were first found trapped against salt structures. But identifying large structures in the sediments beneath large salt sheets was not possible with any degree of certainty. Occasionally, hints of what lay beneath the salt could be seen on 2D seismic.

Subsalt drilling began in the 1980s. Gulf Oil drilled through about 1,600 feet of salt on Eugene Island Block 324 in 1984. In 1990, Exxon recorded the first subsalt discovery on Mississippi Canyon Block 211 in over 4,300 feet of water.

PHILLIPS SUBSALT ENTRY

Phillips began looking at subsalt in 1987. An Exploration Team was formed to assimilate a regional basin-wide subsalt geological framework and conduct external research on salt tectonics.

The Team's conclusions were:

- a subsalt play on the Shelf existed
- good potential accumulations below salt
- new seismic technology was necessary
- entry could be high cost
  - need basin-wide 2D & 3D seismic
  - need dedicated R&D team
  - need to develop 3D depth migration
- early entry for best chance of success
- subsalt play could be economically viable

The location of the subsalt play in the Gulf of Mexico had obvious advantages: A politically stable environment and infrastructure. On the other hand, the Team noted there had been 12 subsalt wells drilled prior to 1989 with zero discoveries. The problem was the inability to image below salt. For the play to make business sense, geological and geophysical risk needed improvement. The Team believed that could be accomplished, given time and money. Critical was development of seismic processing technology necessary to image the subsalt in time to appraise the acreage before expiration of the five-year lease term. Development of workable seismic images requires 3D depth migration. At the time, geophysicists knew how to do 3D depth migration but application did not occur until later, with the advent of new computer technology, specifically known as massive parallel processing computers.

The Exploration Team completed their geologic and economic models incorporating identified risks. A strategy and plan were formed and recommended. In late 1989, Phillips Management made the long-term commitment to acquire acreage, develop the technology, acquire and process the data, and drill wells.

Phillips acquired Mahogany and 14 other subsalt trend leases in OCS Lease Sale #123 in 1990. Acquisition of 2D and 3D seismic data began. An existing Phillips R&D supercomputer was dedicated to the project and the Team went to work building velocity models and post-stack depth migration algorithms to image the subsalt. The first images of the Mahogany subsalt were produced in 1992.

Partners were solicited to reduce risk. In late 1992, two companies with similar subsalt objectives, Anadarko and Amoco, joined as co-venturers. The first well was spudded on the Mahogany Prospect in May 1993.

DISCOVERY & APPRAISAL

The Mahogany discovery well, SS 349 #1, was drilled to a measured depth of 16,500 feet in 1993. The main pay sand (named the "P" sand) tested at a rate of 7,256 bopd and 7.3 mmcfd at a flowing tubing pressure of 7,063 psi. The first appraisal well, SS 349 #2, was drilled to 19,101 feet in the first half of 1994. The "P" sand was wet, but we found another sand uphole which we named "O." It tested at 4,366 bopd and 5.3 mmcfd at a flowing tubing pressure of 6,287 psi. The "O" sand was also present in SS 349 #1. The deeper "S" and "T" sands had hydrocarbon shows but were wet.

The announcement of the discovery and appraisal of Mahogany caused quite a stir in the press and financial communities. Among the reasons: About 60% of the Shelf is covered with salt sheets. That meant many leases being held by production above salt had new potential. The play held promise of many discoveries and potentially large accumulations of oil and gas. The discovery was on the relatively shallow and mature Shelf. Infrastructure was already in place. New production technology was not required. Seismic and data processing technology would likely continue to develop and improve. Risk would be further reduced; finding and development costs would come down.

MAHOGANY APPRAISAL & DEVELOPMENT

After the discovery, a drilling template with six slots was placed on the sea floor at the site of the first well and drilling continued on the second and third appraisal wells from a semisubmersible rig.

All the while, technology continued its advance. We had used 3D post-stack depth migration to make the discovery. In 1994, we made another leap forward when we purchased a new Cray T3D supercomputer and produced our first in-house 3D pre-stack depth migration images.

Mahogany was declared commercial after the third well in April 1995, and drilling of a fourth appraisal well commenced. In May 1995, construction began on a 20-slot, eight-leg drilling and production platform at Aker Gulf Marine in Corpus Christi, Texas.

The platform is designed for 45,000 bopd and 100 mmcfd. The platform supports a platform drilling rig capable of drilling to 20,000 feet. Construction of the deck and jacket was completed in July 1996; installation occurred in August. The deck weighed 5,000 tons and was lifted onto the jacket in a single lift. Oil and gas pipelines were layed in June and July; undersea pipeline connections were finished in September. A platform rig was installed in September. Five wells have been tied back to the platform and we have begun well completion operations. The rig will be used for future drilling.

First production is scheduled for December 1996. Production is expected to average approximately 22,000 bopd and 30 mmcfd in its first year of production.

THE FUTURE OF THE SUBSALT PLAY

Through 1992, fifteen subsalt wells had been drilled with only one discovery, Exxon's Mickey in deepwater. Since Mahogany's discovery in 1993, 18 subsalt wells have been drilled with eight discoveries for a 44% discovery rate. Two of these discoveries, Shell's Enchilada and Texaco's Gemini, are in deepwater. Overall, the discovery rate is 27%. Since no subsalt reservoir has been produced at this time, it is unknown whether all these discoveries will be profitable.

At Phillips, we will continue to assess and likely drill our subsalt inventory on the Shelf. As noted above, two recent subsalt discoveries, Enchilada and Gemini, are in deepwater. Phillps is also moving out in deepwater. We recently announced a deepwater Alliance with Mobil and participated in OCS Lease Sale 161. As a result, we now have interest in 107 blocks in the Gulf of Mexico deepwater. Many of these leases we have an interest in have subsalt potential. Many of the deepwater leases that other Operators acquired in OCS Sale 161 have subsalt potential. With this inventory of leases to drill and continuing technological advances to reduce risk, you can bet the subsalt play will be with us for a long time.

Mr. Rycroft is an engineer for Phillips Petroleum Company and is currently located in Houston, Texas, where he is managing Phillips' Mahogany Field Development as well as looking outward to Phillips' entry into the Gulf of Mexico deepwater. He has been with Phillips for 20 years and worked in various assignments; onshore engineering and operations, industry/governmental affairs, and Gulf of Mexico subsalt development.

SESSION 2E

SAFETY AND ENVIRONMENTAL MANAGEMENT PROGRAM (SEMP)

Chair: Mr. G. Ed Richardson

Date: December 11, 1996

Presentation	Author/Affiliation
Introduction	Mr. G. Ed Richardson Minerals Management Service Gulf of Mexico OCS Region
SEMP Survey, Performance Measures, and RP 75 Revision	Mr. Peter K. Velez Shell Offshore Inc.
Measuring Semp Effectiveness	Mr. Henry G. Bartholomew Offshore Operations & Safety Management Minerals Management Service
Safety and Environmental Management A to Z	Mr. Jay T. Hoyle Paragon Engineering Services, Inc. Mr. J. David Dykes Taylor Energy Company

INTRODUCTION

Mr. G. Ed Richardson
Minerals Management Service
Gulf of Mexico OCS Region

The roots of the Safety and Environmental Management Program (SEMP) go back to 1990 with studies by the Minerals Management Service (MMS) and the National Research Council's Marine Board. In 1991, the MMS announced the SEMP concept and two years later, May 15, 1993, the American Petroleum Institute (API) published its Recommended Practices for Development of a Safety and Environmental Management Program for Outer Continental Shelf (OCS) Operations and Facilities, i.e., API Recommended Practice 75 (RP 75). The MMS endorsed API's Recommended Practice 75 in 1994. The oil and gas industry started the voluntary program that same year. Recommended Practice 75 Training Workshops were held in 1994 to assist industry representative to understand the Program and to help them begin to implement the Program's purposes and objectives. Three industry surveys have been conducted to ascertain the progress made by companies to implement SEMP.

The purpose of SEMP is clearly explained in API's RP 75. It part, the RP states,

> ...to assist in development of a management program designed to promote safety and environmental protection during the performance of oil and gas and sulphur operations on the Outer Continental Shelf (OCS). This recommended practice addresses the identification and management of safety and environmental hazards in design, construction, startup, operation, inspection, and maintenance, of new, existing, or modified drilling and production facilities.

Recommended Practice 75 sets forth eleven Management Program Elements. These elements address the following areas:

- 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-Startup Review
- Emergency Response and Control
- Investigation of Incidents
- Audit of Safety and Environmental Management Program Elements

Programs for all of these elements must be included in a company's SEMP for it to be effective.

The first presentation in this session will address the upcoming Third Annual SEMP survey and the results of the 1995 RP 75 survey, the MMS's and the offshore industry's performance measures, and possible revisions to RP 75. The second presentations is the MMS's perspective on measuring the effectiveness of SEMP. The last presentation is a report by an operator who has a contract with the MMS and the Department of Energy to demonstrate how small- and medium-sized OCS operators might develop and implement a SEMP.

SEMP SURVEY, PERFORMANCE MEASURES, AND RP 75 REVISION

Mr. Peter K. Velez
Shell Offshore Inc.

OVERVIEW

This presentation addressed the following:

1. the upcoming Third Annual SEMP Survey and the results of the 1995 RP 75 survey,
2. MMS's and offshore industry's performance measures, and
3. possible revisions to RP 75.

SEMP SURVEY

The third annual SEMP survey will be conducted for 1996 data. The prior two surveys have been successful. Survey completion and data collection by the participating companies have been good. However, new, merging, and changing companies and survey return timeliness have necessitated extra work in order to process the data from the survey.

The third survey will use the same format. The survey is expected to be mailed out to the participating companies by mid-January 1997. The projected return date is scheduled for mid-February 1997. Industry representatives will meet with MMS in the June to July 1997 time frame to evaluate the results of the survey. The compiled results will be forwarded to all participating companies.

RP 75 ASSESSMENT OVERVIEW

The three-page assessment survey contains 12 sections and has 31 elements. Each survey element is assessed using a six-point implementation status. The status includes the following notations:

CODE	DEFINITION
NO	No action taken to date
EV	Evaluating existing company practices against RP 75
DP	Developing program to implement RP 75
IM	Implementing RP 75
GIP	RP 75 generally in place
RE	Reassessing RP 75 implementation for continuous improvement

Results from the survey are summarized in two ways. They are based on production and on population. The 1994 survey had 94% of the production reporting and 80% of the total population reporting results. Conditions improved in the 1995 survey with 99.8% of the production (3,498,400 BOED) responding and 95% of the population base (105 operating companies). Total U.S. OCS population includes 111 operating companies that produce 3,505,500 BOED. Figure 2E.1 shows the 1995 RP 75 overall survey results. Points are assigned to each level of response for implementing the SEMP, with lower points (1) for no action taken to date to higher points (6) for reassessing RP 75 implementation for continuous improvement. Based on the production criteria, the overall score for 1995 was 4.3. A score of 3.6 was determined for responses based on population. Figure 2E.2 depicts the 1995 RP 75 survey results by individual survey section. The three highest rated sections were Management Principles, Safe Work Practices, and Emergency Response.

MMS PERFORMANCE MEASURES

The objective of the performance measures is to develop a plan for scoping, implementing, gathering, reporting, and benchmarking a defined set of offshore safety and environmental (SEMP) performance measures. The performance measures were developed for three principal reasons:

1. To determine if OCS safety and environmental performance is improving after implementation of RP 75,
2. To provide the average and range of various measures against which companies can compare, and
3. To give MMS assurance that safety and environmental performance is improving and provide partial justification to relax prescriptive regulations and detailed site inspections for companies with good performance and implementation of RP 75.

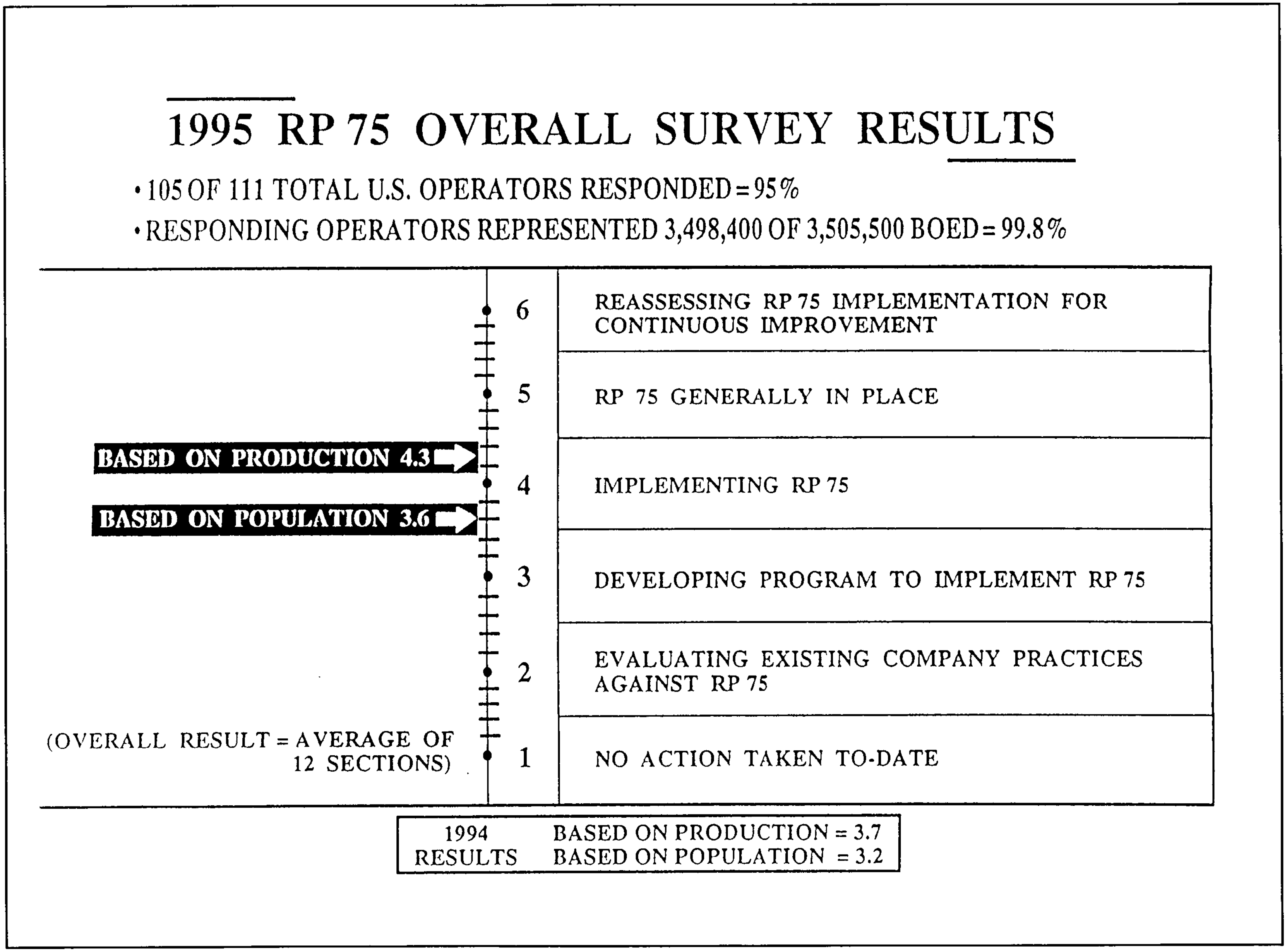

Figure 2E.1. 1995 RP 75 overall survey results.

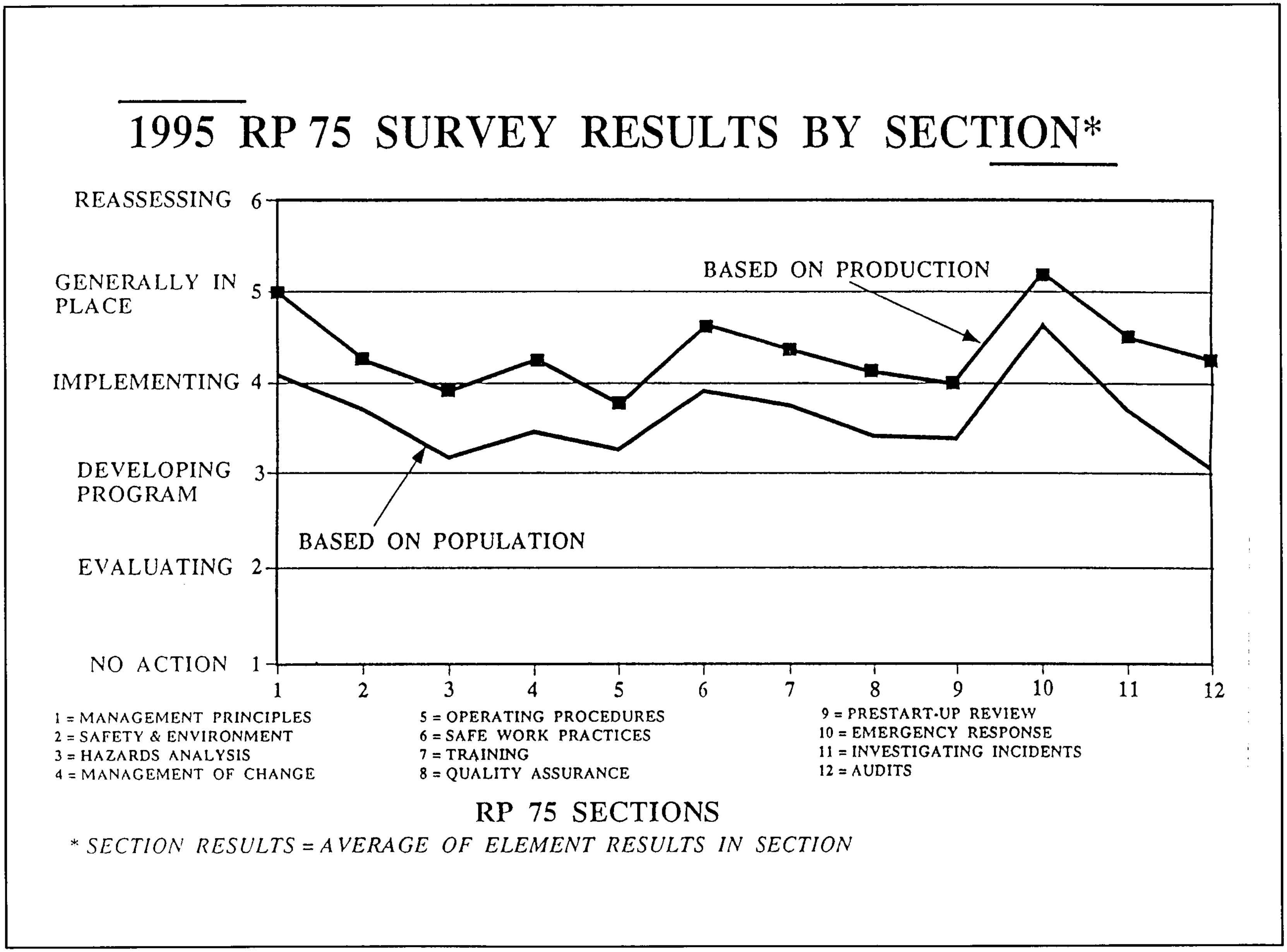

Figure 2E.2. 1995 RP 75 survey results by section.

MMS's performance measures are *not* to be used for enforcement actions, for setting industry-wide performance targets or goals that must be achieved to avoid penalties, or to disclose individual company performance—except "pacesetter company(ies)," which may volunteer to share information in each measure.

The format for working performance measures involves a small group to work on specific issues. Their work will be consensus validated with a larger industry group.

MMS AND INDUSTRY OFFSHORE PERFORMANCE MEASURES

The following are performance measures to be used to evaluate the effectiveness of the program:

- Safety—"Recordable" and "Days Away" incident rates for both company employees and contractors
- Fire/Explosion incident rate
- Blowout incident rate
- Oil spill count incident rate (number/liquid production) for (1) all spills, (2) spills greater than one barrel, and (3) spills greater than ten barrels
- Oil spill volume incident rate
- Production discharge permit exceedance incident rate
- Drilling discharge permit exceedance incident rate
- MMS production "Incident of Non-compliance" (INC) incident rate
- MMS drilling and workover "INC" incident rate

RP 75 REVISION

The first edition of RP 75 was issued on May 15, 1993. Eighteen months transpired for development and API approval. It is generally the practice of API to revise documents on a 5-year cycle. Changes may also be required to RP 14 J, "Design and Hazards Analysis for Offshore Production Facilities."

Since SEMP covered a new concept, it is appropriate to begin a revision to the recommended practice to improve and upgrade the document. The revision should include:

- Clarifications
- Additional material/topics
- New information on subjects
- Information and best practices from other/similar efforts
- Knowledge and information from SEMP coordinators and implementers

Other areas requiring work include:

- The contractor's role in SEMP, including the impact on safety and environmental issues, operations, information exchange, etc.
- SEMP's applicability and interface with drilling rigs
- Sharing of best practices
- Training needs
- Other areas

The committee to suggest revision to RP 75 had its first meeting on 23 January 1997, in New Orleans, Louisiana. Additional volunteers are welcome, e.g., API, IPAA, MMS, NOIA, OOC, USCG, etc. The contact person is API's Tim Sampson at (202) 682-8153.

Mr. P.K. (Peter) Velez is the Manager of Regulatory Affairs for Shell Offshore Inc., a subsidiary of Shell Oil Company. Mr. Velez received B.S. and M.S. degrees 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, Production Superintendent, Manager of Production Engineering, and Manager of Health, Safety, and Environment. He is active in trade association groups including: Chairman of the Louisiana Mid-Continent Oil and Gas Environmental Conservation Council; API ECEC–Water Issue Manager; Chair of the USCG National Offshore Safety Advisory Committee; and Chair of the RP 75 Development Task Force. He was a member of the National Research Council's Marine Board Committee that studied platform abandonment issues.

MEASURING SEMP EFFECTIVENESS

Mr. Henry G. Bartholomew
Offshore Operations & Safety Management
Minerals Management Service

SEMP HISTORY

The history of SEMP began in 1990, with studies by the MMS and the Marine Board. The following is a chronology of SEMP.

Event	Date
MMS and Marine Board studies	1990
MMS announces SEMP concept	1991
API publishes RP 75	1993
MMS endorses RP 75	1994
Industry starts voluntary program	1994
Start RP 75 training workshops	1994
Industry survey No. 1	1995
Industry survey No. 2	1996
MMS extends voluntary program 1 year	1996

FACILITY COMPLIANCE WITH APPLICABLE REGULATIONS

Inspections determine compliance with applicable laws and regulations. Non-compliance sanctions include:

- Incident of Non-Compliance (INC)
- Component or Facility Shut-ins
- Civil and Criminal Penalties

Regulatory compliance is probably *not* the best measure of performance.

GOAL OF SEMP

SEMP's goal is clean, safe operations, not merely regulatory compliance. Regulations focus on engineering, planning, and safety systems, yet 80% of all accidents result from human failures. Even the best regulations cannot foresee all problems or prevent all mishaps. Compliance alone does not assure clean, safe operations.

SAFE AND ENVIRONMENTALLY WELL-MANAGED FACILITIES

Performance counts, not just compliance with the "rules." An effective SEMP plan leads to a safe and clean facility.

MEASURING AND EVALUATING SEMP PERFORMANCE

Measuring and evaluating SEMP performance is not easy. One must measure outcomes. These measures may include:

- Fatalities
- Injuries
- Fires
- Explosions
- Oil Spills
- Other measures

A need for internal process measures includes:

- Process reviews
- Safety meetings
- Safety audits
- Training
- Management-of-change
- Transactions
- Incident investigations
- Other SEMP elements

WHAT TO DO

Operators should identify and gain consensus for SEMP performance measures. They have to identify, compile, and analyze data. An assessment of the industry-wide performance needs to be made. "Top Performing Operators" should be identified and recognized. It is essential that operators share information. Operators should start to "benchmark" others that are performing at the highest rates. Operators need to develop SEMP process measures. There is a need to develop a basis for alternative performance-based regulations. MMS must formulate risk-based inspections and audits. Both the oil and gas industry and the MMS must identify information and research needs.

POSSIBLE SEMP RISK-BASED INSPECTION AND AUDIT STRATEGIES

The MMS should inspect higher-risk facilities more often. This must occur at least annually. The MMS

Table 2E.1. United States' SEMP versus United Kingdom's Safety Case.

	SEMP	Safety Case
Facilities	Few high-risk platforms Many small, unmanned platforms	Few, but huge, high production
Weather	Benign, except hurricanes	Severe storms, heavy seas
Analysis	Qualitative or quantitative, as suitable	Emphasis on quantitative risk analysis
Focus	Safety and environment	Catastrophic failures
Trigger	Exxon Valdez	Piper Alpha

should inspect the hundreds of lower-risk facilities less frequently. Examples of the lower-risk facilities could include low-production, artificial lift wells, and unmanned platforms with no production or processing facilities.

POSSIBLE CANDIDATE RISK CRITERIA

The following are some risk criteria that may be used to develop the inspection and audit strategies:

- Manned or Unmanned
- Size and Complexity
- Pressures and Volumes
- Simultaneous Operations
- H_2S or Other Hazards
- Environmentally Sensitive Areas
- Operator's Safety and Environmental Performance

FUTURE REGULATORY FOCUS

The focus for future regulatory actions should concentrate more on systems, processes and performance. Less emphasis should be placed on components. A switch to more effort on preventing unsafe acts is needed. This proactive role will lead the MMS away from just detecting infractions. More emphasis is needed on high-risk facilities, activities, and unsafe operations. This is a better use of the MMS's limited resources. Likewise, less effort should be committed to low-risk facilities and safe operators.

UNITED STATES' SEMP VERSUS UNITED KINGDOM'S SAFETY CASE

The United States' SEMP differs from the United Kingdom's Safety Case in the various aspects highlighted in Table 2E.1.

Mr. Henry G. Bartholomew directs the development of regulatory policies governing offshore safety and pollution prevention, including inspection, compliance and enforcement programs, accident investigations, training requirements for offshore industry workers, and the innovative Safety and Environmental Management Program (SEMP). He also oversees the MMS's technology assessment and research program which is intended to promote the use of the best available and safest technologies in offshore oil and gas operations. Mr. Bartholomew received a B.S. degree in engineering from U.C.L.A. in 1960 and is a member of the Senior Executive Service.

SAFETY AND ENVIRONMENTAL MANAGEMENT A TO Z

Mr. Jay T. Hoyle
Paragon Engineering Services, Inc.

Mr. J. David Dykes
Taylor Energy Company

OVERVIEW

On June 30, 1994, the Minerals Management Service (MMS) published a *Federal Register* notice requesting that the industry voluntarily adopt API RP 75 (SEMP). Under SEMP, offshore producers would be responsible for identifying potential hazards in the design, construction, and operation of oil and gas-producing facilities and developing specific approaches to reduce the occurrence of accidents.

On May 1, 1995, the MMS and Department of Energy entered into a contract with Taylor Energy Company (TEC) and Paragon Engineering Services, Inc., to demonstrate how small- and medium-sized OCS operators might develop and implement a Safety and Environmental Management Program. The project, termed a "case study," was to develop, implement, and monitor a SEMP on at least five Taylor OCS facilities. As part of the contract, Taylor has been charged to conduct an aggressive Technology Transfer program that will share the results of the work as it is completed to help all interested operators develop their own SEMPs.

Taylor Energy, now 19 months into the 30-month contract, is approximately 75% complete in developing and implementing the SEMP. Four of the seven subject facilities are at 100% development and currently implementing the program elements. The remaining three are 30-60% complete. Impromptu audits have been ongoing since the start of the project and adjustments made accordingly. Official auditing of the program is estimated to begin in late second quarter of 1997.

There have been some problems in both developing and implementing the program. Some have been major, but most have been minor and are discussed below.

SAFETY AND ENVIRONMENTAL INFORMATION

One problem that developed within Taylor was determining essential and nonessential information to be included on the facility "P&IDs." This issue was resolved as outlined in the presentation by Rick Bresler and Gerald Von Antz at the Energy Week/Petro Safe 1996. This list outlined what Taylor and Paragon thought to be essential and optional information; however, other companies may have a different approach.

A major problem was discovered when running PSV calculations. It was found that some PSVs were not properly sized for original vessel design capacities. The PSV capacities did exceed current and expected future production rates.

Original vessel specifications and operating procedures should be compiled during the safety and environmental data-gathering process. This information does not have to be included in this section but will help with some decision-making later on.

HAZARDS ANALYSIS

The checklist method developed by Paragon was used to conduct the analyses. The first problem encountered was time allotment. It was initially proposed that it would take one to four man-weeks to conduct a hazards analysis depending on the complexity of the facility. Satellite platforms were accomplished in 1-2 weeks, while the central oil processing platforms took as much as 10 man-weeks. This process does include relief valve calculations and analyses.

Most problems identified in the hazards analysis dealt with piping specification breaks and verification against API 14C. Electrical classification integrity presented another problem. While verifying if electrical junction boxes and other fixtures were properly sealed, some boxes were destroyed in the process. Another administrative problem was the lack of Lockout/Tagout procedures regarding locked isolation valves.

MANAGEMENT-OF-CHANGE

A sound management-of-change procedure is imperative to safe operations. Implementing a management-of-change procedure has been a challenge due to limited review staff and work load. Management-of-change request forms are being generated and work is being done but with very little review. Due to these circumstances, the process cannot be truly "function tested" at this point in time.

OPERATING PROCEDURES

Operating procedures are one of the most effective tools available to improve safety. If properly written and used, they should help reduce the large number of accidents attributed to human error.

Operating procedures should be available before conducting the hazards analysis. Whether or not they should be written is questionable, but the various facility and equipment operations should be reviewed. One minor problem TEC incurred was that as procedures were being prepared for one of the facilities, modifications to the facility were being made at the same time. Ensuring that the modifications were included in the procedures was quite time consuming. Taylor elected to have the procedures revised in house to free up Paragon to continue on other locations.

For operating procedures to be useful they must incorporate two things. They must have operator input, and they must be written in laymen's terms for the operator. Operator input and review of drafted and revised procedures is and will be very time consuming. TEC, however, feels that this is time and money well spent due to the quality of the end product. An operator will have a "tool" with which he can train new and "green" operators and help trouble-shoot process malfunctions.

SAFE WORK PRACTICES

Three manuals were produced early on for operations. They were the Safety Manual, Safety Handbook, and Safe Drilling and Workover Practices Manual. The original intent of the Safety Handbook (given to each employee as pocket reference to the Safety Manual) was good. However, most employees feel they are having to refer to the Safety Manual much too often. They would prefer a condensed combined version of both manuals in a pocket/briefcase size. This would eliminate having to refer to the Safety Manual all of the time.

In the review process it was discovered that Taylor's Lockout/Tagout Program did not have procedures that addressed locked valves, i.e., the locking or unlocking of PSV isolation valves. It was also discovered that the HAZCOM program did not have clearly defined procedures for labeling chemicals in the workplace. Another minor oversight with the Safety Manual involved the Hot Work Program and Operations Procedures—Welding and Cutting. Elements within the two plans contradicted each other and neither directly addressed the requirements of 30 CFR 250.52—Welding and Burning Practices and Procedures. Taylor's approved Welding and Burning Plan was then incorporated into the manual.

TRAINING

Training has been ongoing since the start of the project. One hurdle was defining minimum training requirements for the operators and determining refresher requirements for nonregulated training. Another hurdle along this same line is contractor training requirements and verification. Taylor has budgeted approximately $50,000 for training in 1997 alone, covering everything from T-2 to HAZWOPER.

MECHANICAL INTEGRITY

Erosion/Corrosion inspections have been ongoing since the start of this year. Taylor has hired the services of an inspection company to conduct API 510 and 570 guided inspections of the critical vessels and piping. There have been some problems with the older facilities where vessel nameplates are either missing or illegible. This has made identification of steel grades next to impossible. Taylor has drafted a plan of action to address this problem.

The initial data gathering for mechanical integrity inspections should be done as part of the safety and environmental information data gathering. Manufacturer U1A data sheets or National Board certification sheets should be obtained prior to conducting the inspections. From the availability of this data, a clearly defined scope of work can be determined. The main objective is to determine if the vessel is fit for service and not "does the vessel meet original design specifications."

PRE-STARTUP REVIEW

Taylor has developed and is in the process of implementing pre-startup reviews. At present, reviews have been conducted on equipment startups, i.e., compressor installations, overhauls, etc.

EMERGENCY RESPONSE AND CONTROL

This section has been very easy to implement. Taylor had these plans in place prior to RP75; they follow an annual review schedule and are updated when necessary.

INCIDENT INVESTIGATION

Taylor along with Paragon has developed and implemented incident investigation procedures. The main objective of incident investigation, once again, is to determine root cause to prevent future incidents. Another objective of incident investigation is to protect and reduce the company liability. Each company should involve their legal group in some fashion when putting their incident investigation guidelines together.

AUDITING

Impromptu audits have been ongoing. Taylor is ready to begin auditing procedures early 1997.

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Jay Hoyle is Paragon's Project Manager for the Taylor/ DOE SEMP Demonstration Case Study. Mr. Hoyle has been with Paragon Engineering for three years, during which time he has led a number of SEMP and PSM projects. He has over 20 years of experience in process safety, engineering, and project management and is currently manager of Paragon's Process Safety Management group. He earned a B.S. in chemical engineering from Oklahoma State University and is a registered professional engineer in the state of Texas.

David Dykes has over 12 years of hands-on experience in offshore oil and gas production operations and is currently Safety and Purchasing Manager for Taylor Energy Company. Prior to Taylor Energy, he worked for Meridian Oil in various positions from Lease Operator to SEMP Coordinator/Safety Representative. His responsibilities have included site hazards assessment, environmental/safety program development, and SEMP implementation. Mr. Dykes received an A.S. in industrial safety and B.S. in petroleum technology from Nicholls State University

SESSION 2F

COASTAL MARINE INSTITUTE, PART II

Co-Chairs: Dr. Robert S. Carney
Dr. James J. Kendall

Date: December 11, 1996

Presentation	Author/Affiliation
Introduction	Dr. Robert S. Carney Coastal Marine Institute Louisiana State University Dr. James J. Kendall Minerals Management Service Gulf of Mexico OCS Region
Importance of Zooplankton Secondary Production to Fishes at Offshore Petroleum Platforms	Dr. Mark C. Benfield Dr. Richard F. Shaw Coastal Fisheries Institute Louisiana State University Mr. Sean F. Keenan Department of Zoology & Physiology Louisiana State University
Feasibility of Selecting Superior Oil-Tolerant Populations of *Spartina patens*	Dr. Mark W. Hester Department of Biological Sciences Southeastern Louisiana University Dr. Qianxin Lin Dr. Irving A. Mendelssohn Wetland Biogeochemistry Institute Louisiana State University
Historical Reconstruction of the Contaminant Loading and Responses in the Central Gulf of Mexico Shelf Sediments	Dr. R.E. Turner[1] Mr. C. Henry[2] Dr. E.B. Overton[2] Mr. E. Platon[3] Ms. P. Roberts[2] Dr. B.K. Sen Gupta[3] Dr. N.N. Rabalais[4] [1]Coastal Ecology Institute Louisiana State University [2]Environmental Studies Institute Louisiana State University [3]Department of Geology and Geophysics Louisiana State University [4]Louisiana Universities Marine Consortium
The Future of the Louisiana Coastal Marine Institute	Dr. Robert S. Carney Coastal Ecology Institute Louisiana State University

INTRODUCTION

Dr. Robert S. Carney
Director
Coastal Marine Institute
Louisiana State University

Dr. James J. Kendall
Minerals Management Service
Gulf of Mexico OCS Region

This is a continuation of Session 1F, CMI Progress Reports, Part I. As noted previously, the CMI, a cooperative agreement between the MMS and the State of Louisiana, was established to address 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 (LSU), 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, which provides broad boundaries for guidance in the development of specific research projects, was designed to include the following: 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 projects that improve the application and distribution of multisource information.

Projects proposed for support under the CMI are reviewed by the CMI Technical Steering Committee, on which MMS and LSU are equally represented. Daily activities of the program are administered from LSU's Baton Rouge campus by the CMI Director, Dr. Robert Carney. The CMI 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 session includes topics ranging from the development of bioremediation techniques for oil spill cleanup to physical oceanography.

Dr. Robert Carney is a benthic ecologist who began deep-sea studies as a master's student at Texas A&M University (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.

Dr. James J. Kendall is the Chief of the Environmental Studies Section, of the 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. He received his B.S. in biology from Old Dominion University and his Ph.D. in oceanography from Texas A&M University.

IMPORTANCE OF ZOOPLANKTON SECONDARY PRODUCTION TO FISHES AT OFFSHORE PETROLEUM PLATFORMS

Dr. Mark C. Benfield
Dr. Richard F. Shaw
Coastal Fisheries Institute
Louisiana State University

Mr. Sean F. Keenan
Department of Zoology & Physiology
Louisiana State University

ABSTRACT

Offshore oil and natural gas platforms comprise a large amount of the available hard substrate in the northwestern Gulf of Mexico. Large populations of economically important fishes congregate around these platforms. Current investigations also indicated large swarms of macrozooplankton around and beneath the superstructure. It is not known if this secondary production is sufficient to sustain these large aggregations of fish. Between June and August 1996, we conducted research on the food habits of *Caranx crysos* (Carangidae), a medium sized, schooling, pelagic fish, at a platform located 66 km from the Louisiana coast in 63m depth. Our findings demonstrate that macrozooplankton are an important dietary component of a relatively large predator. Direct consumption of zooplankton apparently bypasses the usual intermediate (i.e., forage fish) trophic levels. Such energy transfer, from macrozooplankton to higher trophic levels, would be more efficient and may explain, in part, how platforms help sustain the high fish biomass observed around these offshore structures.

INTRODUCTION

Offshore petroleum structures account for a large proportion of the available hard substrate in the northwestern Gulf of Mexico. There are over 4000 manned and unmanned platforms in the northwestern Gulf, which provide approximately 28% of the hard-bottom habitat off Louisiana (Scarborough-Bull 1989). The casings of these platforms are rapidly colonized by a benthic fouling community, which leads to the unusual situation of a benthic community, which projects into, and interacts closely with pelagic communities within the euphotic zone. We have termed this phenomenon *vertical benthos.*

High concentrations of fish are associated with platforms, and the question—how is this high fish biomass sustained? — remains unanswered. This question has important implications for platform decommissioning strategies designed to convert platform structures into productive reefs. The State of Louisiana, along with most other Gulf States, is currently committed to aggressive rigs-to-reefs programs, the success of which are contingent on decommissioned platforms functioning as viable, productive artificial reef communities.

Our group is currently conducting research on the recruitment periodicity, growth and mortality of ichthyoplankton and pre- and post-settlement juvenile fishes at offshore petroleum platforms. This research (The Postlarval and Juvenile Fish Nursery Ground/ Refugia Function of Offshore Oil and Gas Platforms) is funded by the Minerals Management Service through Louisiana State University's (LSU) Coastal Marine Institute (CMI) and involves regular (fortnightly) collections of surface and subsurface (20 m) plankton, net and light-trap samples beneath production platforms. During May 1996, at a mid-shelf platform, we observed blue runner *Caranx crysos* (Carangidae) (Figure 2F.1) feeding in the surface waters beneath the platform and concurrently collected high concentrations of hyperiid amphipods in our plankton samples. The stomach contents of a single *C. crysos*, collected by hook and line, were full of hyperiid amphipods (Figure 2F.2). This observation of direct consumption by a fairly large (25 cm standard length (SL)) fish feeding directly on small (2-5 mm) zooplankton suggested a trophic linkage between the platform and surrounding fish community and formed the basis of a grant from the LSU Sea Grant College Program to investigate this relationship.

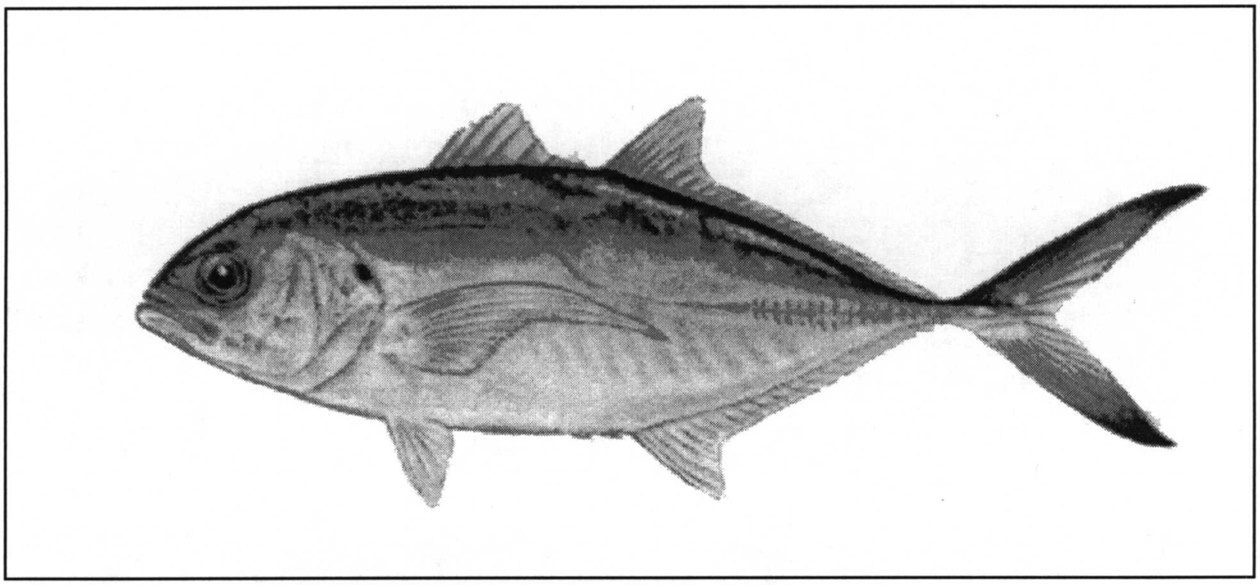

Figure 2F.1. Blue runner *Caranx crysos*. Illustration from McClane (1978).

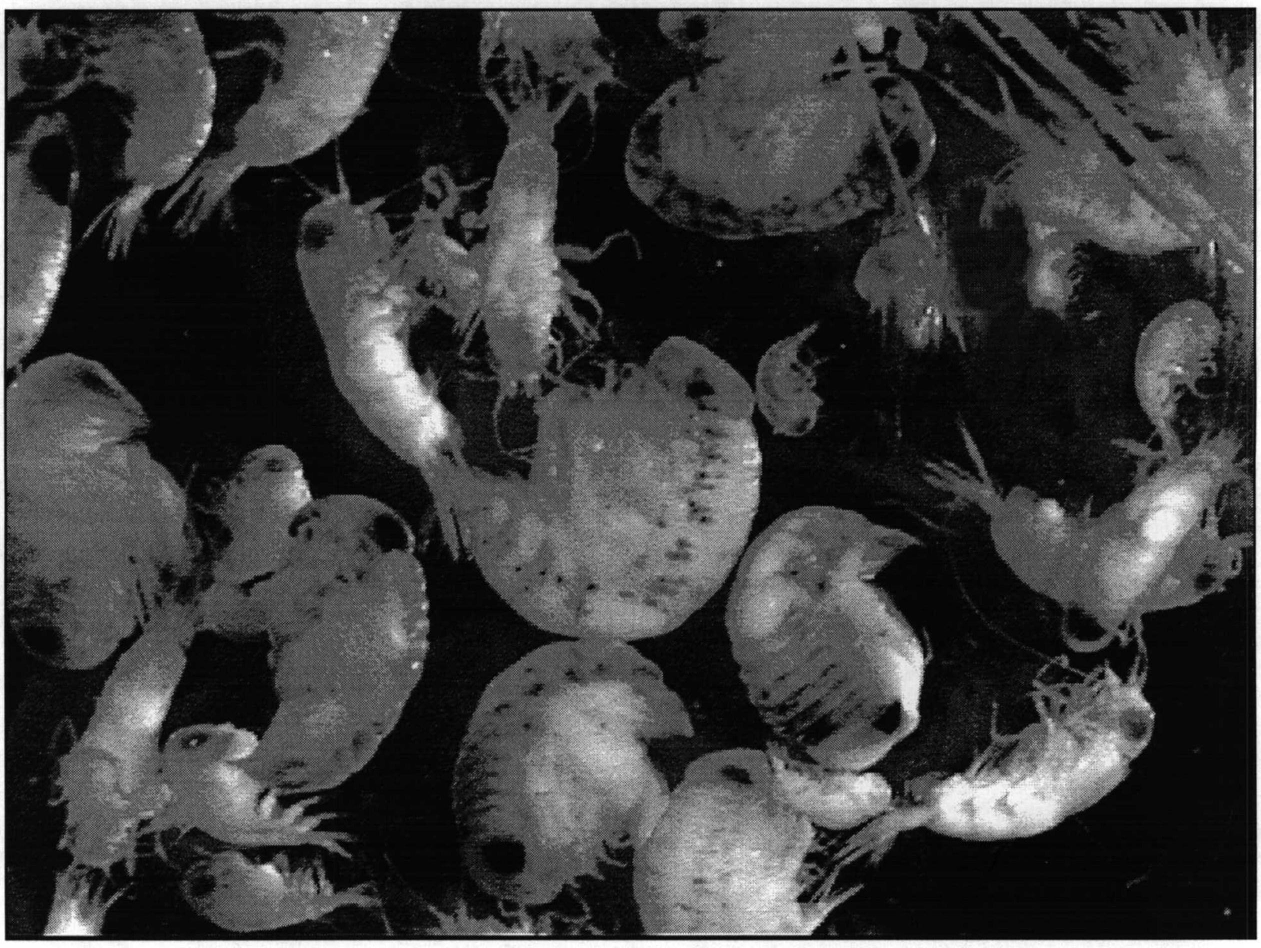

Figure 2F.2. Hyperiid amphipods from a plankton sample collected at Mobil's GI94B platform during May 1996.

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The objectives of our investigation were: (1) to determine whether hyperiid amphipods were major components of the diets of *C. crysos* feeding beneath the platform; and (2) to compare the species composition of prey items within the stomachs with the species composition of the plankton.

METHODS

Our investigation was conducted at Mobil platform Grand Isle 94B (GI94B) located at 28.5267°N - 90.0983°W in 63m depth. Blue runner feeding data were collected during three sampling trips on June 28-30, July 28–August 1, and August 12–15, 1996. On each occasion we collected blue runner opportunistically by hook and line methods employing artificial lures. The mass, length, sex, and time of capture (to the nearest prior hour) were recorded and the stomachs were removed and preserved in ethanol for subsequent examination and identification of contents. Nocturnal surface plankton collections, which were part of our regular MMS ichthyoplankton research, were taken using a 60 cm diameter plankton net equipped with 335 µm mesh and a flow meter, which was passively fished in the tidal stream.

In our laboratory the stomach contents were enumerated and assigned to the following taxonomic categories: hyperiid amphipods, decapods, copepods, ostracods, fish, chaetognaths, fish eggs, other invertebrates, and unidentified material. Displacement volumes were measured for each taxonomic group. The electivity (or preference) of the blue runner for specific prey items was estimated using an Index of Relative Importance (IRI): IRI=(numeric % + volumetric %) x frequency of occurrence (Pinkas 1971).

RESULTS

A total of 40 blue runner (including the first fish captured on May 19) were collected from near surface waters. All fish were at or approaching sexual maturity and ranged in length from 24.5–42.5 cm SL. Most fish were collected on the June 28-30 and August 12–15 trips (Figure 2F.3). Peak catches occurred at 1200h, 2000-2100h, and 0100h (Figure 2F.3).

The stomach contents of 28 fish had been examined at the time of this meeting. The mean gut fullness of these stomachs suggest that blue runner feed during the night and around mid-day (Figure 2F.4).

Zooplankton comprised a large numerical fraction (80-100%) of the stomach contents of blue runner in May (single fish), June, and July with a dramatic shift in the diet to fish during August (Figure 2F.5). Planktonic decapod crustaceans constituted approximately 50% of the total prey numbers during June and July, followed by hyperiid amphipods (approximately 15%). Chaetognaths were present in moderate proportions (33%) in June. On a volumetric basis, zooplanktonic groups accounted for at least 50% of the prey volume during May, June, and July (Figure 2F.5) with the balance made up of unidentified amorphous material, which could not be assigned to a taxonomic category and which was therefore excluded from the numerical proportion calculations (Figure 2F.5).

IRI estimations for June and July based on 28 fishes indicated that decapods were the most important prey items (IRI= 8300.4) followed by hyperiid amphipods (2884.1), chaetognaths (1959.8), other invertebrates (1739.8), and fishes (141.9).

DISCUSSION

The importance of zooplankton to blue runner was confirmed in this investigation. Blue runner appear to rely heavily on zooplankton throughout June and July (and probably during May) then switch over to fish during August. Hyperiid amphipods were not as abundant in the diet either numerically or volumetrically as the stomach contents of the first fish captured in May suggested. This may have been due to the general decline in the concentration of hyperiids within the water column as measured with our plankton samples. Hyperiid amphipod abundance peaked during mid-May and appeared to be much lower for the remainder of the investigation. The early-midsummer dependence on zooplankton may also reflect the lack of availability of appropriately sized fish prey until the end of the summer recruitment period.

The switch over to fish in August was interesting because blue runner appeared to be foraging primarily on a codlet (Bregmacerotidae), which was probably the antenna codlet *Bregmaceros atlanticus*. Codlets are small benthic fishes that do not normally occur within our light trap or plankton samples. Their presence in the diet of blue runner may indicate another linkage between pelagic and demersal communities.

The unidentified material in stomach, which could not be assigned to any taxonomic category, may have represented fish tissue. Given the warm water temperatures during our study and the rapid digestion

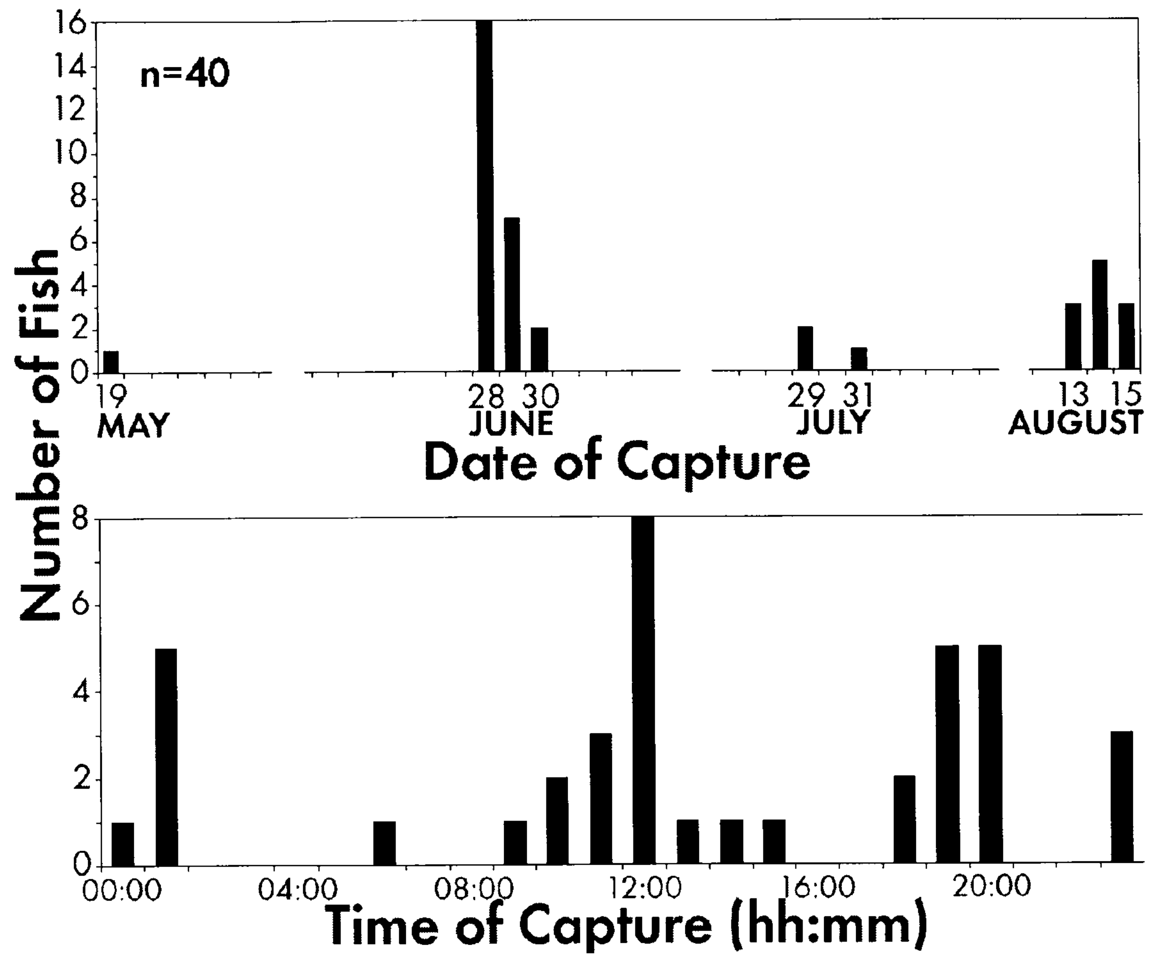

Figure 2F.3. (Upper panel) Dates of capture of blue runner at GI94B. (Lower Panel) Times of capture for blue runner.

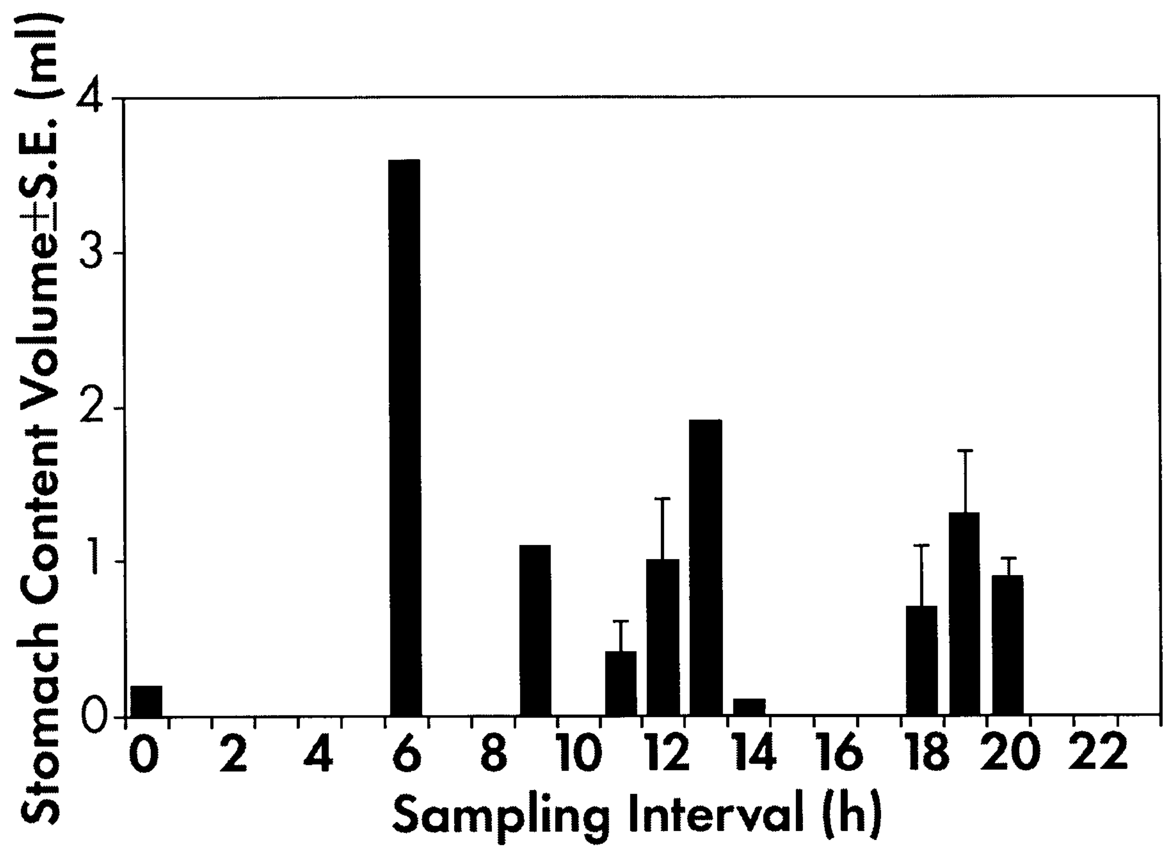

Figure 2F.4. Mean gut fullness±standard error of blue runner collected during the first two trips to GI94B (June and July, 1996).

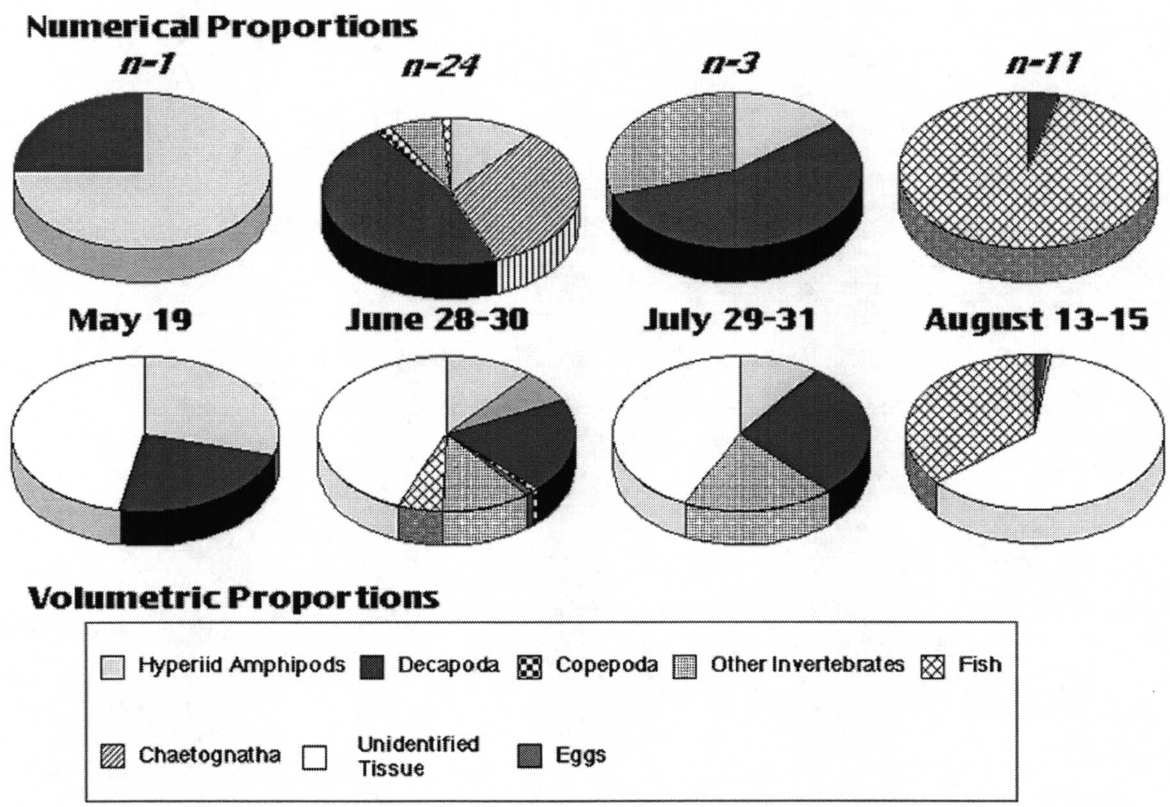

Figure 2F.5. Numerical (upper row) and volumetric contribution (lower row) of prey to the diet of blue runner at four sampling times in 1996.

times for fish tissue, this material could have been quickly digested. However, the absence of skeletal parts or scales from these same stomachs makes it difficult to evaluate this hypothesis. If the unidentified material does represent fish tissue, then zooplankton and fish make comparable volumetric contributions to the diet of blue runner in June and July.

The presence of zooplankton in the blue runner diet does not in itself indicate a trophic linkage between the platform and the pelagic community. Almost all the zooplanktors found in the stomachs belonged to holoplanktonic or meroplanktonic groups. Our plankton samples suggest high concentrations of dominant zooplankton beneath GI94B. It is unknown whether these high concentrations are the result of an active affinity for the platform structure or some other mechanism. For example, hyperiid amphipods are generally considered to be planktonic or associated with structures of gelatinous organisms such as jellyfish and salps. Such amphipods do not normally encounter fixed structures in their planktonic realm. How the presence of such a structure might modify their behavior is unknown.

Another hypothesis, which is perhaps more plausible and testable, may explain the high aggregations of zooplankton around platforms. At night there is a very bright light field around most manned platforms. The attraction of zooplankton and fish to bright lights is well documented and is the reason behind our use of light traps. Zooplankton entrained in the light field of a platform may actively swim to maintain their position in the field. As currents bring more zooplankton into the light field of the platform, zooplankton concentrations will increase. Comparisons of the within (beneath) platform and upstream zooplankton concentrations during the day and night should allow us to confirm or reject this concentration mechanism. This high concentration of prey coupled with increased prey consciousness in the artificial light may provide blue runner with enhanced foraging beneath the platform.

The bimodal feeding periodicity with increased prey volumes around mid-day and after dark suggests that blue runner are also exploiting zooplankton during the day. We are confident that the stomach contents of fish reflect their recent feeding history as zooplanktonic prey items of the size and type we observed would be rapidly digested by blue runner at the prevailing June-August temperatures. Haywood (1995) found that juvenile fishes were capable of digesting postlarval penaeid shrimp almost completely within 3 h. Most of the organisms in our fish stomachs were in recognizable and largely whole condition, indicating that they had been consumed shortly before capture. Stomach contents from daylight hours reflected daytime predation. Thus, even without the influence of platform lights, zooplankton appear sufficiently abundant during daytime to warrant inclusion in the diet of their much larger predators.

To the best of our knowledge, this study represents the first examination of the food habits of any fishes associated with Gulf of Mexico petroleum platforms. Blue runner are an obvious candidate for study because of their broad geographical distribution and high abundance. Ecologically they are important because of their positions as both low-order predators of small fishes and invertebrates and as important prey items for higher-order, larger pelagic (e.g., cobia, tunas) and reef-associated (e.g., barracuda, amberjack) predators. Thus, direct zooplanktivory by blue runner bypasses the usual small forage-fishes normally considered to be zooplanktivores and allows more efficient energy transfer to blue runner biomass and on to higher-order predators. This may, in part, explain how platforms can support such high associated fish biomass.

ACKNOWLEDGMENTS

This research was funded by a Louisiana State University Sea Grant Undergraduate Research Opportunity Program (UROP) grant to Sean F. Keenan and Mark C. Benfield. All data were collected within a research project: The Postlarval and Juvenile Fish Nursery Ground/Refugia Function of Offshore Oil and Gas Platforms which was funded through the Coastal Marine Institute by the Minerals Management Service with industrial match from Mobil. We are grateful to the crew of Grand Isle 94B, particularly Mr. Darryl Plaisance and Mr. Al Melvin, for their hospitality and assistance in collecting blue runner. Ms. Talat Farooqui, Mr. Jim Ditty, and the LSU Coastal Fisheries Institute's Ichthyoplankton Laboratory assisted in the analysis of our data.

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Dr. Mark C. Benfield is a Research Associate V in the LSU Coastal Fisheries Institute. He has a Ph.D. in wildlife and fisheries from Texas A&M University and was a postdoctoral investigator in the Biology Department at the Woods Hole Oceanographic Institution from 1993-96. He has worked with estuarine and open ocean zooplankton in the Gulf of Mexico, North Atlantic and Southeastern coast of South Africa.

Dr. Richard F. Shaw is the Director of the LSU Coastal Fisheries Institute and is a professor in the Department of Oceanography and Coastal Sciences. He has a Ph.D. in oceanography from the University of Maine. He has worked extensively with ichthyoplankton in the Gulf of Maine and Gulf of Mexico. He currently is the principal investigator in an MMS-Funded examination of the habitat function and value of offshore petroleum platforms to larval fish.

Sean F. Keenan received a B.S. degree in zoology from LSU. His research interests include crustacean ecology, predator-prey interactions, habitat selection and the ecology of artificial reefs. He currently resides in Florida and is planning to continue his research via a graduate study program.

FEASIBILITY OF SELECTING SUPERIOR OIL-TOLERANT POPULATIONS OF *SPARTINA PATENS*

Dr. Mark W. Hester
Department of Biological Sciences
Southeastern Louisiana University

Dr. Qianxin Lin
Dr. Irving A. Mendelssohn
Wetland Biogeochemistry Institute
Louisiana State University

Project: The Potential for Accelerated Bioremediation and Restoration of Oil-Impacted Marshes Through the Selection of Superior Oil-Tolerant Vegetation

Principal Investigators: Dr. Mark W. Hester and Dr. Irving A. Mendelssohn

INTRODUCTION

The cleanup of oil spills in coastal marshes remains a problematic issue because wetlands can be extremely sensitive to the disturbances associated with oil spill cleanup. Therefore, there has been interest in developing alternative, less intrusive, oil spill cleanup/bioremediation techniques. Ideally, these alternative techniques should be compatible with the delicate wetland environment and may be utilized singularly (without other cleanup methods) in marshes oiled by minor spills, or utilized in conjunction with existing cleanup methodologies in heavily oiled marshes to accelerate the bioremediation and restoration of the impacted marsh. The primary objective of this research project is to test the feasibility of selecting superior oil-tolerant populations of *Spartina patens* and *Spartina alterniflora* (dominant Gulf coast brackish and salt marsh grasses, respectively) that may be utilized in the restoration and bioremediation of oil-impacted marshes. The research reported herein resulted from the first year of the two-year project and focuses on *Spartina patens*.

Spartina patens (Aiton) Muhl. is the most frequently encountered coastal grass species in Louisiana coastal marshes, encompassing fresh, brackish, and saline marsh habitats (Chabreck 1972). *Spartina patens* has been reported to be nearly twice as common as the second most important coastal marsh species, *Spartina alterniflora* Loisel (Chabreck 1972). *Spartina patens* is especially dominant in the expansive brackish marshes of Louisiana, whereas *Spartina alterniflora* dominates the higher salinity coastal salt marshes (Chabreck 1972). Both of these species are widespread marsh dominants throughout the Gulf and Atlantic coasts (Godfrey and Wooten 1979).

Although a number of studies have shown that different wetland plant species may respond quite differently to oiling (i.e., interspecific variation; see Lin and Mendelssohn 1996 and references therein), we are aware of no studies to date that have investigated differences within single species (intraspecific variation) for differential tolerance to oiling. Furthermore, although there has been considerable effort and a fair amount of success in breeding agricultural crops for stressful environments (Blum and references therein 1988), there has been little emphasis to date on selecting superior stress-tolerant wetland vegetation. The research that has been conducted on population differentiation in wetland vegetation has focused on the natural environmental stresses of salinity and flooding (Nestler 1977; Silander and Antonovics 1979; Cain and Harvey 1983; Eleuterius 1989; Blits and Gallagher 1991; Pezeshki and DeLaune 1991; Pezeshki and DeLaune 1995; Hester 1995; Hester *et al. in press*; Lessmann *et al. in press*). Therefore, results from this study will contribute greatly to our understanding of the amount of intraspecific variation to oiling that exists across populations of two dominant Gulf coast wetland plant species.

The objectives of the first year of this research project specifically addressed whether superior oil-tolerant populations of *Spartina patens* could be identified that displayed (1) superior growth response and plant production under oil stress; (2) superior vegetative regrowth through oiled sediment; and (3) superior oil degradation potential.

MATERIALS AND METHODS

To accomplish these objectives, plant material from populations of *Spartina patens* were collected from coastal marshes of Louisiana, Texas, and Florida and propagated under uniform conditions in the greenhouse for several vegetative generations. Plants from each population were then established in a uniform potting mix (approx. 10% organic matter by weight) in 12-liter plastic pots equipped with side drains near the bottom of the pot and a water-level sight gauge. Once the plants became established, water levels were raised slightly above the soil surface and South Louisiana crude oil was applied at a rate of 5 liter m^{-2} directly to surface flood water of one-half of the pots (treatment pots). The drain valve was then opened and the applied oil allowed to slowly drain through the soil column over a period of about two hours. The water-level gauges of each pot were monitored during this process and drainage was stopped just prior to outflow of the oil, thereby ensuring even oiling of the substrate without loss of oil. For each pot, the drain water was collected in a reservoir and subsequently slowly returned to the top of the treatment pot soil. The control pots received no oil, but were similarly drained and had the solution returned to the surface of the pots. Throughout the study, water levels were maintained at the level of the soil surface.

Monthly measurements of plant photosynthesis (net CO_2 assimilation rates) were conducted during the course of the experiment using an ADC portable infrared gas analyzer under light-saturated conditions. An initial harvest of plant aboveground biomass was conducted three months after oil application, and biomass was partitioned into live and dead components, dried and weighed. To assess regrowth potential, the clipped pots were monitored for emergence of new shoots through the oiled sediment for three additional months. Final harvest was then conducted six months after oil application. Residual crude oil remaining in the soil was analyzed using a modification of the gravimetric method (Alexander and Webb 1985) using DCM (dichloromethane) as the extractant.

RESULTS AND DISCUSSION

Significant population and treatment (oil vs. no oil) differences were detected in plant photosynthetic response (net CO_2 assimilation) within the first month after oiling. These differences became even more pronounced by the third month, in which there was also a significant population x treatment interaction, indicating that population responses to oiling relative to their controls were different (Figure 2F.6). Three months after oiling, most populations had photosynthetic rates in the range of 30% to 60% of their respective controls, whereas populations C, G, and J showed no significant reduction in photosynthesis relative to their controls (i.e., essentially 100% of

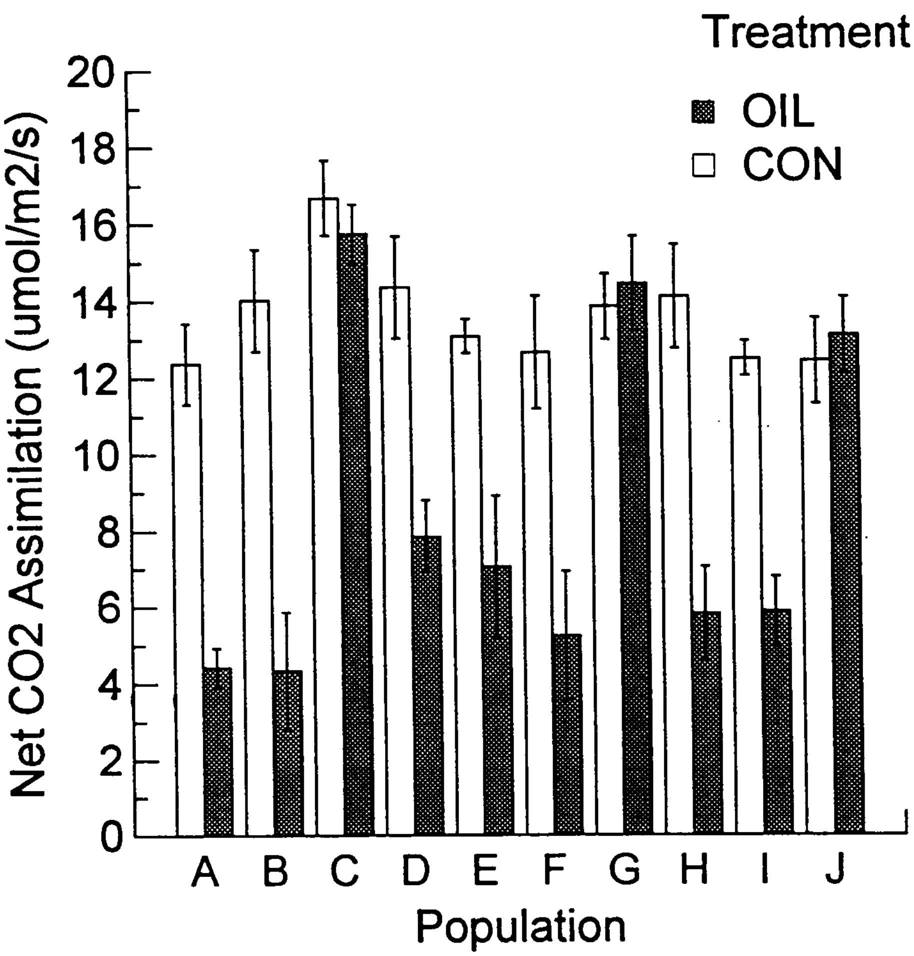

Figure 2F.6 Mean (±SE) net CO_2 assimilation in control and oiled populations of *Spartina patens* three months after oiling (n=5).

controls). Furthermore, populations C, G, and J also had the highest treatment photosynthetic responses.

Significant population and treatment differences were also detected in the proportion of dead aboveground biomass (dead/total aboveground) three months after oiling. Similarly, there were significant population and treatment differences, as well as a significant population x treatment interaction, in the amount of biomass regrowth six months after oiling. Patterns of biomass regrowth generally paralleled patterns of treatment photosynthetic response and may reflect the fact that greater photosynthetic rates resulted in greater belowground reserves for subsequent regrowth and/or may simply reflect a greater tolerance to oiling as new stems emerged and contacted the oiled sediment. However, the tendency for different amounts of residual oil remaining in the soil (as discussed below) in the different populations precludes a conclusive interpretation of the underlying reason for differences between populations in regrowth.

Results from the analysis of residual oil (TPH) in the sediment six months after oiling were variable within populations and overall displayed a lack of significant population differences in oil degradation (P=0.15). However, the amount of residual oil in populations C, G, and J were generally low compared to the other populations and ranged from about 12 to <15 mg oil per g dry weight of soil.

CONCLUSIONS

Results from this study have provided first-time data on significant intraspecific (within species) variation in oil tolerance in the widespread coastal grass species, *Spartina patens*. Populations displayed significant variation in photosynthetic and growth responses and a tendency (though not significant) for differences in the rate of oil degradation. Therefore, the potential exists for identifying superior oil-tolerant populations that may be utilized in marsh restoration projects in oil-impacted marshes or in marsh creation projects in areas prone to a higher frequency of oil impacts. The identification of differentially oil-tolerant populations may also prove valuable in future research on the underlying physiology of oil tolerance in wetland plants.

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Dr. Mark W. Hester is an assistant professor in the Department of Biological Sciences at Southeastern Louisiana University. Prior to to SLU, Dr. Hester was employed as a research associate at the Wetland Biogeochemistry Institute of Louisiana State University. His areas of research interest are wetland ecology, plant stress ecophysiology, and restoration ecology.

Dr. Hester received his B.A. in biology from Indiana University and both his M.S. in marine sciences and his Ph.D. in oceanography and coastal sciences from Louisiana State University.

Dr. Qianxin Lin is a research associate at the Wetland Biogeochemistry Institute of Louisiana State University. His areas of research interest are plant responses to oiling and bioremediation of oil-impacted wetlands. Dr. Lin received both his B.S. in biology and his M.S. in plant ecology from Nanjing University and his Ph.D. in oceanography and coastal sciences from Louisiana State University.

Dr. Irving A. Mendelssohn has worked at the Wetland Biogeochemistry Institute of Louisiana State University for over 18 years and is a professor in the Department of Oceanography and Coastal Sciences. His main areas of research interest are wetland ecology, plant stress physiology, and the development of sublethal indicators of plant stress, in which he has contributed much to the literature on waterlogging stress. Dr. Mendelssohn received his B.A. in biology and chemistry from Wilkes College, his M.S. in marine science from College of William and Mary, and his Ph.D. in Botany and ecology from North Carolina State University.

HISTORICAL RECONSTRUCTION OF THE CONTAMINANT LOADING AND RESPONSES IN THE CENTRAL GULF OF MEXICO SHELF SEDIMENTS

Dr. R.E. Turner[1]
Mr. C. Henry[2]
Dr. E.B. Overton[2]
Mr. E. Platon[3]
Ms. P. Roberts[2]
Dr. B.K. Sen Gupta[3]
Dr. N.N. Rabalais[4]

[1]Coastal Ecology Institute, Louisiana State University
[2]Environmental Studies Institute, Louisiana State University
[3]Department of Geology and Geophysics, Louisiana State University
[4]Louisiana Universities Marine Consortium

INTRODUCTION

A pervasive, continuing, and confounding feature of the OCS Program and continental shelf investigations involves the influences of regional forcing functions, such as riverine discharge and constituent concentrations, climate and exchanges with estuaries that vary "naturally" and have also changed over decades from landscape-scale influences. These influences complicate estimations of the more localized releases from oil and gas drilling and production operations. Frequent small contaminant releases and large infrequent contaminant releases are difficult to detect in a dynamic ecosystem under the influence of a large river. Whether these releases are significant in terms of background or "natural" amounts is an issue complicated by transport and degradation processes. A National Academy of Sciences report on MMS offshore studies, the Rowe and Turner (1989) recommendations, and Bender *et al.* (1979) contain similar conclusions: (1) basic information on the ecosystem is missing; (2) a broad analysis is informative, and more interdisciplinary studies, especially of a long-term nature, are required; (3) the benthos is a repository of long-term trends; and (4) the role of the Mississippi River must be teased out of the more localized impacts of oil and gas recovery efforts.

In this context, we are documenting the changes in chemical contaminants of the central Gulf of Mexico signature of ecosystem changes found within them, and the biological response in the foraminiferal community. We are placing these changes within the framework of the regional influence of the Mississippi River, oil and gas recovery efforts, and the natural variability of the ecosystem. The approach is to use dated sediment cores continental shelf sediments, the biogeochemical as part of an ongoing and integrated project. The work requires: (1) careful collection of sediment cores from the continental shelf; (2) dating these cores in approximately five-year increments; (3) determination

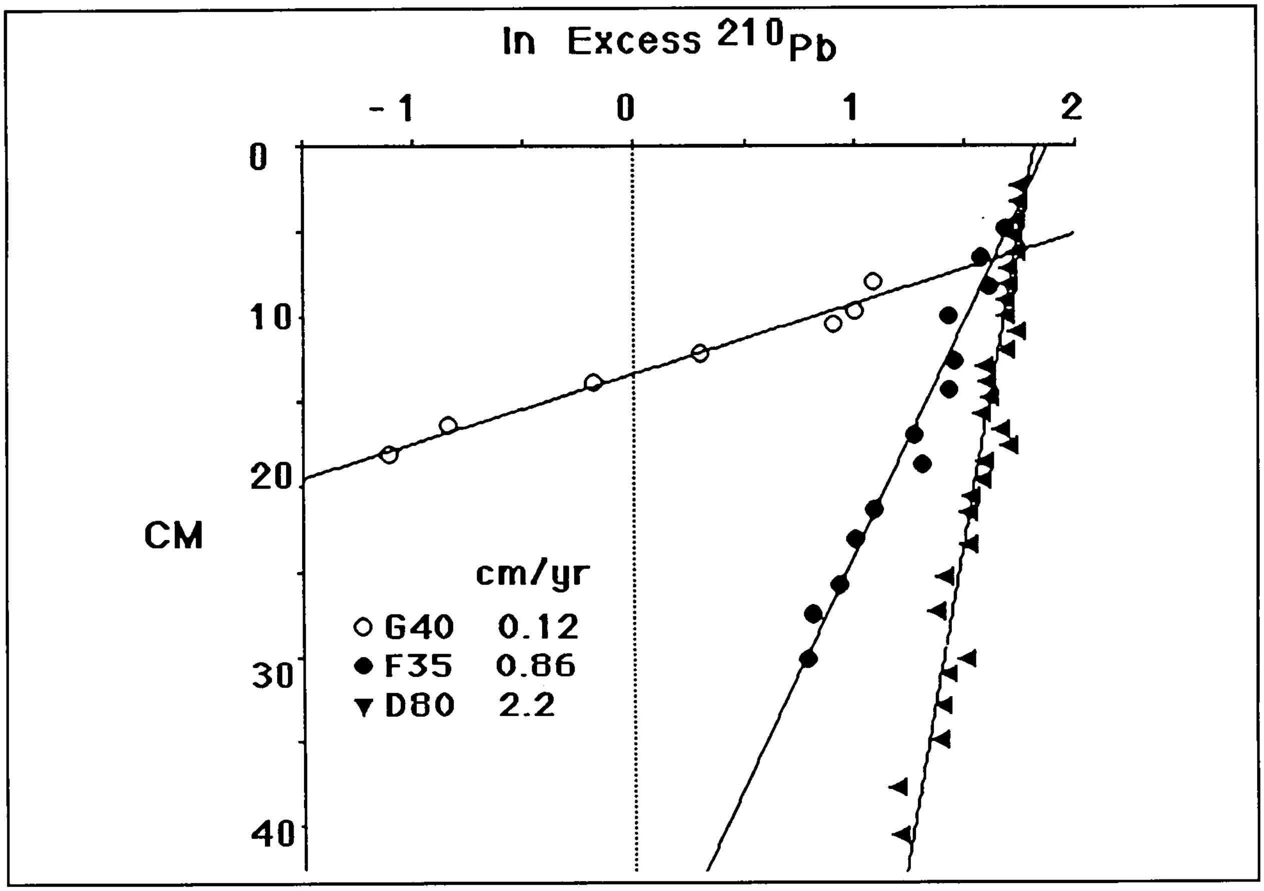

Figure 2F.7. Example of the ^{210}Pb dating of three cores used for the analytical analyses.

of sediment N, P and organic C, and trace metals and organic compounds, including petroleum biomarkers (e.g., Zn, Pb, Cd, Ba, alkylated PAH, triterpenes, sterenes), within core segments; and (4) quantitative estimation of benthic foraminiferal species abundances (a) in surface sediments to assess the effects of hydrocarbon contamination on these shelled protozoans (because of toxicity or oxygen depletion), and (b) in downcore sediments to interpret environmental changes in historical time (some possibly related to hydrocarbon contamination) in addition to regional changes and natural variability.

The questions being addressed include:

- What are the historical changes in contaminant storage of the Outer Continental Shelf (OCS) ecosystem?
- Are the anticipated biomarkers of petroleum sources localized or regional; are they temporally isolated in the sediment core?
- To what depth contour and distance downstream of the Mississippi River plume does the oilfield or regional (Mississippi River) framework extend?
- How does the contaminant storage near or around oilfields contribute to the regional framework influenced by the Mississippi River discharge plume?
- Are these changes reflected in the assemblages of benthic foraminifera and other ecosystem indicators?

Examples from the field research of the first year are shown below.

DATING

Dating sediments with ^{210}Pb has been successful. Three examples are shown in Figure 2F.7, for cores of different sedimentation rates. The statistical fit is

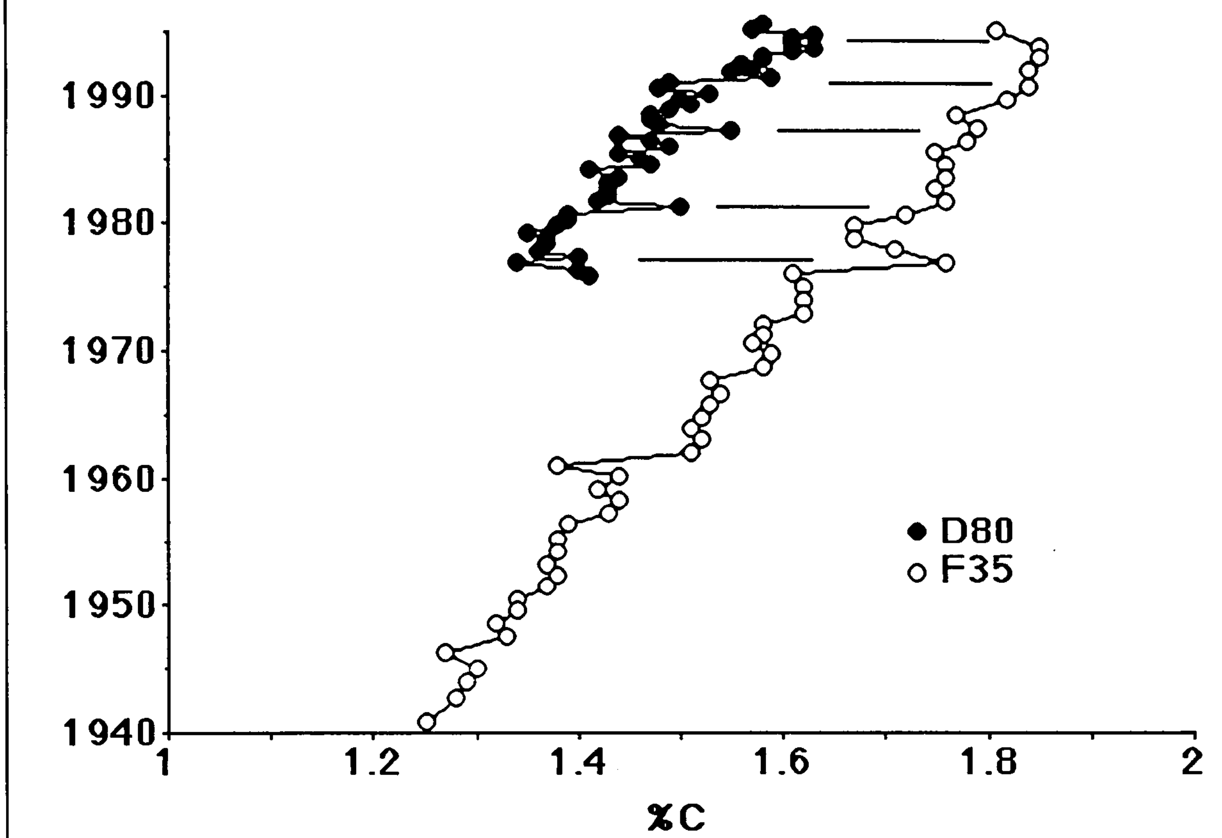

Figure 2F.8. The percent carbon downcore. Note the coherence in variation among cores.

excellent, and we can therefore proceed to analyze the constituents, per the original plans.

CARBON

The percent carbon deposited varies downcore, but in concert between cores. The highest amounts are in the surface, which reflects both diagenesis and increased eutrophication offshore (Figure 2F.8).

FORAMINIFERS

The foraminiferal census is complete only for D80, the core with the highest rate of sedimentation (2.2 cm/yr). Because of its outer-shelf water depth, the effect of seasonal hypoxia would be least pronounced on the benthic foraminiferal community at this site. There are 25 species of benthic foraminifera in the 30 subsamples. Figure 2F.9 shows some results from this core. There was a decrease in density from 1981 to 1990, followed by minor, apparently random, variations. If the increase in the number of living foraminifers in the uppermost part of the core (especially in the upper 5 cm where most foraminifers live) is taken into account, then the density reduction in this part becomes even more severe. The fluctuations in species richness (S), i.e., the number of species in a sample, are much larger between 1981 and 1988 than between 1989 and 1995; the smallest variations are between 1989 and 1992 (Figure 2F.10). Such variations, however, may be an artifact of the counting procedure (different numbers of individuals counted in different samples).

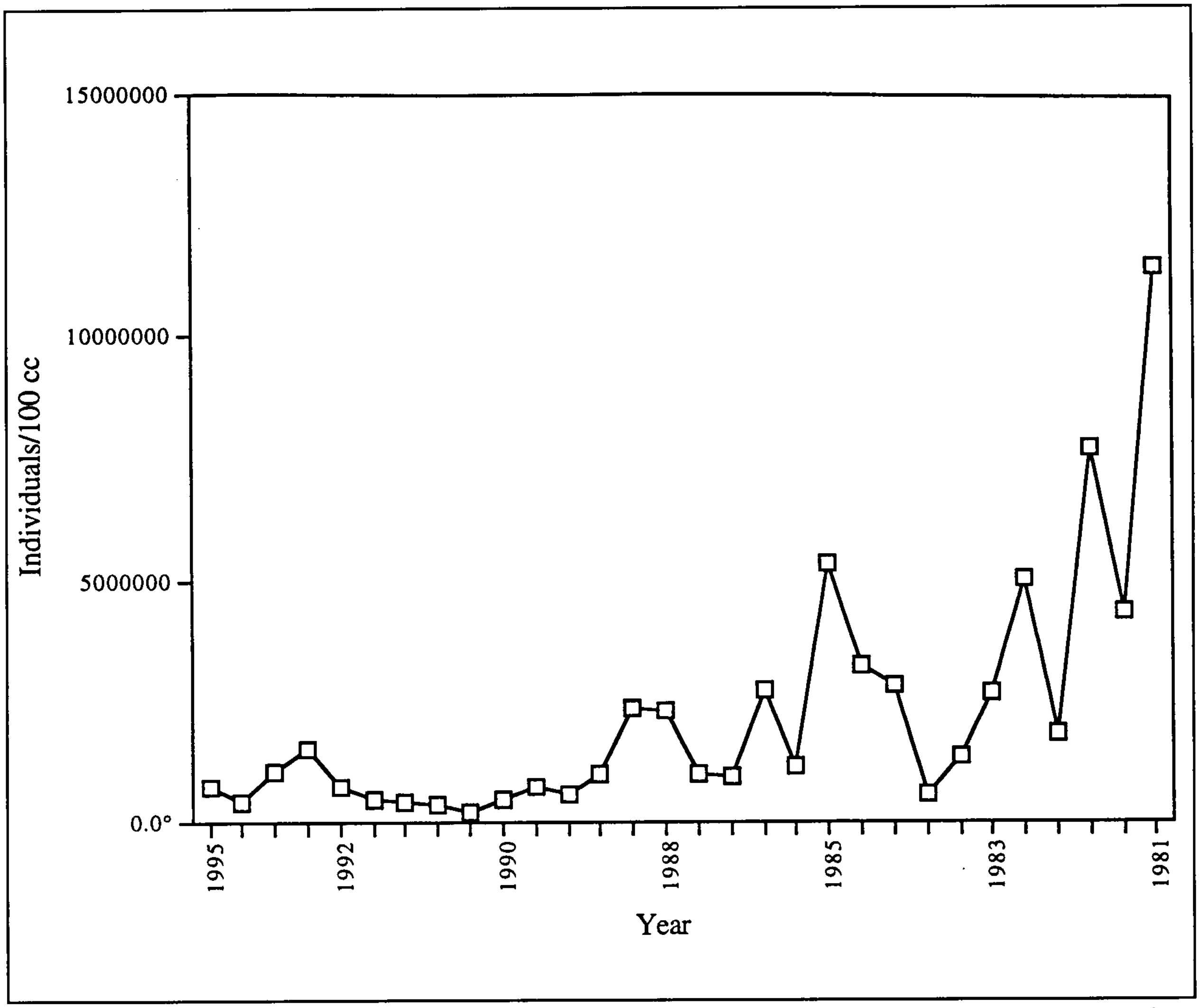

Figure 2F.9. Foraminifera density in core D80. There was a decrease in density from 1981 to 1990, followed by minor, apparently random, variations.

Epistominella vitrea is the dominant species in the total assemblage throughout the core, its relative abundance staying close to 50% and showing no significant trend. In the living assemblage, its abundance is significantly less. Pending the completion of foram counting for the other cores, and because of the high abundance of *E. vitrea* in the Mississippi plume (Blackwelder *et al.* 1996), we conjecture that NE-SW transport processes may have enhanced the concentration of shells of this species in our D80 samples.

The relative abundance of *Buliminella morgani*, the second dominant species of the total assemblage (and the dominant species in the present-day living fauna), also does not show any significant trend for the time interval of the core.

Opposing stratigraphic trends are discernible in the relative abundances of *Bolivina lanceolata* and *Bolivina albatrossi* in D80. Overall, the values for *Bolivina albatrossi* increase tenfold from 1981 to 1995, with a much higher peak in 1990-91. In contrast, the distribution of *Bolivina lanceolata* shows a nearly continuous decrease between 1985 and 1988, after which, with one exception, its relative abundance stabilizes at low values. Stronger fluctuations in the relative abundance of *Nonionella basiloba* are seen after 1990. There are several species, e.g., *Bolivina barbata, Cassidulina subglobosa, Textularia porrecta,*

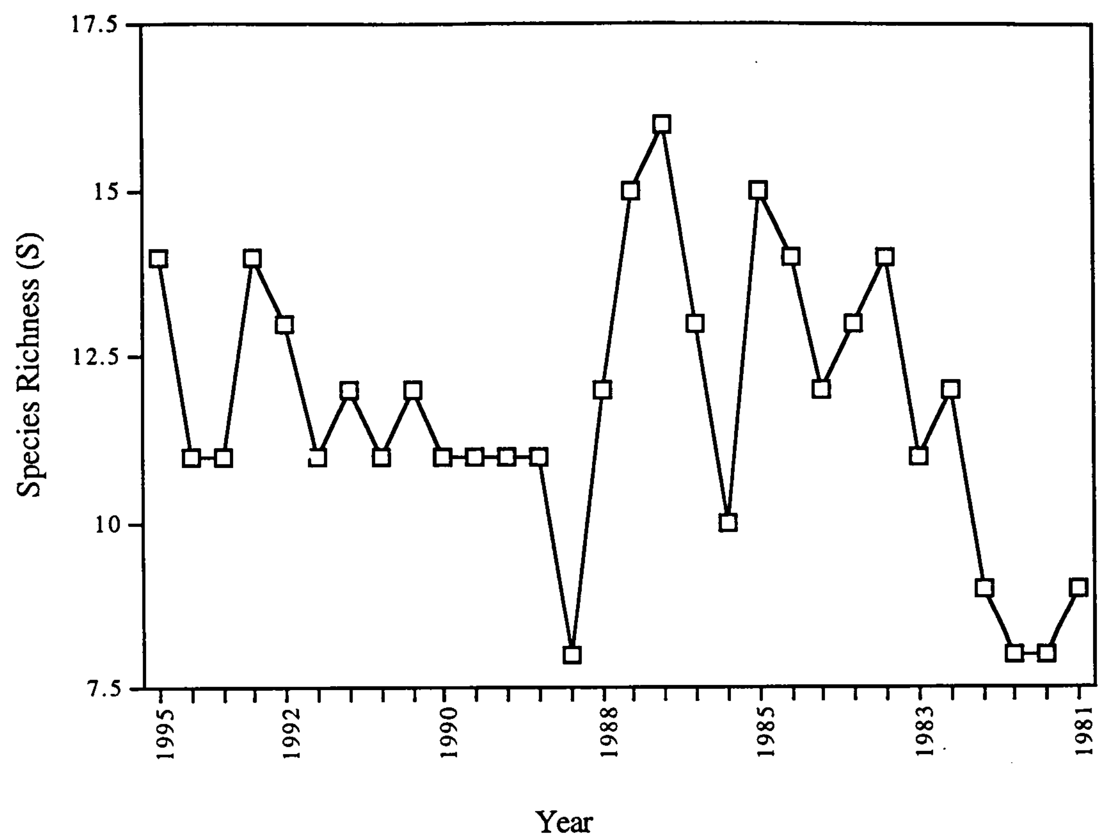

Figure 2F.10. The species richness (S), i.e., the number of species in a sample, in core D80.

and *Miliolinella warreni*, whose relative abundances show occasional high values in downcore samples.

The statistical significance of such short-lived increases is yet to be investigated.

CHEMISTRY

The concentration of polycyclic aromatic hydrocarbons (PAH) in each of the three cores was relatively homogeneous throughout the core. No evidence of episodic events attributed to oil spills was found. The lacking evidence of historical petroleum spills could indicate ecosystem adaptation and utilization of the additional carbon sources, enhanced mixing in the region, or simply the contribution from spills was less than other sources. The PAH components were assessed for influence of combustion as well as petroleum. The influence of combustion was similar to the petroleum abundance, relatively low concentrations and homogeneous. The summation of the PAH concentrations, referred to as total target PAH (TTPAH) were 100 to 500 ppb in G40, 300 to 1,000 ppb in F35, and 500 to 1,000 ppb for G40. The pesticide results from D80 indicated low levels of various chlorinated pesticides; again the concentrations were homogeneous.

Perylene, a PAH derived from incomplete combustion, petroleum or biologically produced (Wakeham 1980 and 1979; Hites 1980), exhibited a marked change between and within each core. The analyzed cores indicated biological production caused either by Mississippi River input differences or significant environmental alterations. The perylene increase and decrease in cores was not consistent; the analytical results were:

- D8090 ppb on surface20 ppb on bottom
- F3541 ppb on surface30 ppb on bottom
- G4050 ppb on surface300 ppb on bottom.

The perylene D80 core contained a subtle increase in in towards the surface, reaching 10% of the TTPAH, or more recent sediments, compared to 2.5% TTPAH at the core bottom. The F35 core contained 5 to 10% total perylene with only a slight increasing in percent towards the deeper sediments and significant variability on the surface. G40 contained a higher surface concentration of perylene beginning at 25% of the TTPAH and significant increase in perylene towards the deeper sediments, reaching 75% of the TTPAH. The reasons for these trends are unclear. Perylene has been documented as a compound biogenically produced in reducing marine environments, generally found at background levels of 10 ppb (Venkatesan 1988; Didyk 1978). The observed trend in relative perylene concentrations in the central Gulf of Mexico Shelf cores may indicate environmental changes over time.

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Dr. R. E.Turner has worked at LSU for the past 23 years and serves as Director of the Coastal Ecology Institute and a professor in the Department of Oceanography and Coastal Sciences. His areas of interest are coastal ecology and management, paleo-oceanography and wetland ecology. Dr. Turner received his Ph.D. from the University of Georgia and his M.S. from Drake University.

Charles B. Henry, Jr. received his M.S. in oceanography and coastal sciences from LSU in 1995 and a B.S. in Environmental Science in 1985. He is currently a Research Associate V at the Institute for Environmental Studies, managing research projects and functioning as a co-principal investigator. Mr. Henry has developed an in-depth understanding and working knowledge of environmental issues from a multidisciplinary prospective.

Dr. Edward B. Overton has been a professor at LSU since 1984 and Director of the Institute for Environmental Studies for the past 12 years. Dr. Overton received his Ph.D. from the University of Alabama in 1970. He specializes in environmental-analytical chemistry, with professional interests in chemical hazard assessment, state-of-the-art analytical methods, and techniques in environmental problem resolution.

Emil Platon is currently a dual degree student (Ph.D. in geology and M.S. in computer science) at Louisiana State University. His previous positions were as a scientific researcher at the Geological Institute of Romania and an academic visitor at University College of London. His major areas of interest include stratigraphy, taxonomy of agglutinated foraminifera, and ecology and paleoecology of benthic foraminifera. Mr. Platon received his M.S. in geology from the University of Bucharest.

Paulene O. Roberts is currently a Research Associate IV at the Institute for Environmental Studies. She received her B.S. in chemistry from the University of Alaska, Anchorage, in 1990 and is currently working on a M.S. at LSU. Ms. Roberts' interests include assessment of environmental alterations caused by anthropogenic influences.

Dr. B. K. Sen Gupta has been a professor at the LSU Department of Geology and Geophysics since 1979. His previous service includes teaching and research positions at Indian Institute of Technology (Kharagpur, India), Bedford Institute of Oceanography (Dartmouth, Canada), and University of Georgia (Athens). He has also been a Fulbright Senior Fellow at University of Utrecht, Netherlands, and a Visiting Professor at University of Rio Grande do Sul, Brazil, and University of Bordeaux, France. He has an M.S. from Cornell University and a Ph.D. from Indian Institute of Technology. The major areas of his research are stratigraphy, biogeography, ecology, and paleoecology of benthic foraminifera, paleoceanography of deep basins, and geological history of Neogene continental margins.

Dr. Nancy N. Rabalais is an associate professor at the Louisiana Universities Marine Consortium where she has been employed for the last 13 years. She graduated with a Ph.D. in zoology from the University of Texas in 1983. Her research interests include aspects of river/ocean interactions and dynamics and distribution of hypoxia.

THE FUTURE OF THE LOUISIANA COASTAL MARINE INSTITUTE

Dr. Robert S. Carney
Director
Coastal Ecology Institute
Louisiana State University

This final session was open discussion to provide input as to how a second five years of the CMI program might be structured. The original CMI program at LSU was established as an extension of the MMS University Research Initiative (URI). In many respects the URI program was very successful. It increased the expert pool addressing OCS issues, made small awards a more viable means of meeting MMS information needs, and directed MMS funds toward the educational institutions of major OCS states. However, the full utility of the URI was limited by narrow ties to MMS staff and the lack of a significant state investment. The subsequent CMI structure increased MMS participation and required a 1:1 match from the state partner.

As the CMI program enters its second five-year period, two opposing forces must be met. First, OCS issues are becoming so extremely complex that no single institution's expertise base can be an adequate source of innovation for all topics. Second, the current fiscal climate in the federal government precludes creating a CMI for each OCS state. Therefore, initial discussions between LSU and MMS have explored the feasibility of expanding the LSU CMI to be open to all Gulf of Mexico region universities. There are two possible models that might be adopted.

- Partner Institutions: Since the CMI is intended as a federal-state partnership, there needs to be a well-structured mechanism for state input of needs and of funds. These are most easily accomplished if a single research institution in each state enters into some formal agreement with MMS and LSU. This model provides an adequate expert base and stresses state input.

- Centrally Administered Open Program: Since the CMI needs to mobilize a very broad spectrum of experts, open solicitation to all institutions in the Gulf region will bring the greatest response. MMS would contract with LSU to run such a program. This model stresses expertise pool at the cost of centralized input by the Gulf states.

SUMMARY OF DISCUSSION

A CMI based around an alliance of major research institutions, one per state, was viewed as most desirable from the MMS perspective but caused mixed response from the academic researchers worrying about how universities would be selected. Researchers from likely candidate institutions liked partnerships; researchers from smaller institutions preferred an open program. A suggestion that the partnerships be instituted over four years, beginning with Louisiana-Texas, brought a similar mixed response.

When MMS's needs are weighed against researchers' desires for access to funding, MMS must be given top priority. Therefore, a partnership model is preferred. It will meet MMS's needs and provide an orderly state input. The extent to which it "locks out" interested investigators at non-partner institutions can be minimized by in-state cooperative research much like the LSU-LUMCON cooperation under the LSU CMI.

Dr. Robert Carney is a benthic ecologist who began deep-sea studies as a master's student at Texas A&M University (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.

SESSION 1G

DEEPWATER ENVIRONMENTAL ISSUES: GULF OF MEXICO, PART I

Co-Chairs: Dr. Robert Avent
Dr. Ann S. Bull

Date: December 12, 1996

Presentation	Author/Affiliation
Introduction	Dr. Robert M. Avent Dr. Ann S. Bull Minerals Management Service Gulf of Mexico OCS Region
Circulation in Deep Waters of the Gulf of Mexico: A Review	Dr. Peter Hamilton Science Applications International Corporation
Geologic Framework for the Northern Gulf of Mexico Continental Slope: New Concepts and New Challenges	Dr. Harry H. Roberts Coastal Studies Institute Louisiana State University
Addressing the Ecological Unknowns of Deepwater Oil and Gas Development	Dr. Robert S. Carney Coastal Studies Institute Louisiana State University
Stability and Change in Gulf of Mexico Chemosynthetic Communities	Dr. Ian R. MacDonald Geochemical and Environmental Research Group Texas A&M University

INTRODUCTION

Dr. Robert M. Avent
Dr. Ann S. Bull
Minerals Management Service
Gulf of Mexico OCS Region

The legal definition of "Outer Continental Shelf" (OCS) for purposes of offshore leasing, exploration, and development is the submerged land seaward of acreage under the respective states' jurisdiction. The Gulf of Mexico OCS extends from the Federal-State boundaries (three miles from land off Louisiana, Mississippi, and Alabama, and three marine leagues, about ten miles, off Texas and the west coast of Florida). The "OCS" extends into abyssal depths greater than 3,000m so much of it is not the shelf *per se*, but the physiographic slope.

Industry's progress in the exploration and development of deep petroleum reserves is limited less by engineering and operational constraints than by economic ones: for example, costs of distant deep-water facilities and operations, introduction of new technologies (e.g., directional drilling, sub-salt prospecting, and 3-D geophysical methods), projections of product value, and estimated reservoir size. In recent years, the oil and gas industry has leased tracts in depths greater than 3,000 m drilled wells in depths greater than 2,000 m, and has recently developed to a depth over 1,600m. This has placed archibenthal and deep pelagic communities well within the range of any potentially adverse environmental effects of this industry. These effects may include physical disturbance from facility emplacement and toxic effects from the disposal of various materials and suffocation by drilling muds and formation cuttings.

With these recent developments in mind, the MMS is reviewing available deep-water environmental information to meet its obligations under the National Environmental Policy Act and the OCS Lands Act. This ITM session provided an opportunity to reflect on the state of knowledge in deep-sea physical oceanography, geology, and biology (with some emphasis on chemosynthetic communities). During an afternoon session, interested participants discussed the organization, purpose, and content of an upcoming Deepwater Workshop held in New Orleans in April 1997.

Dr. Robert M. Avent is a biological oceanographer with the Environmental Studies Section of the Minerals Management Service . He has been the Gulf of Mexico program officer for deep-sea field studies since 1982, including the Gulf-wide Northern Gulf of Mexico Continental Slope Study, and two multiyear studies on chemosynthetic communities. His professional interests include marine benthic ecology, physiological ecology, and zoogeography.

Dr. 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, Massachusetts, and her post doctoral work at Johns Hopkins Unverisity in Maryland. Her research interests focus on the role of offshore platforms in the fisheries of the Gulf of Mexico and the ecology of deep pelagic communities.

CIRCULATION IN DEEPWATERS OF THE GULF OF MEXICO: A REVIEW

Dr. Peter Hamilton
Science Applications International Corporation

INTRODUCTION

Since the last review of deepwater circulations in the Gulf of Mexico in 1991, there has been considerable progress in defining the characteristic scales and interactions of the eddy field. Major field studies in this period include the Louisiana-Texas (LATEX) Eddy Circulation Study and GulfCet hydrographic surveys, which concentrated on the northern slope region between the Mississippi Delta and the Mexican-U.S.

border. This review concerns mainly the eddy field in the western Gulf but includes a brief survey of two other important topics: Loop Current (LC) variability and the deep circulation (below 1000 m) which is dominated by topographic Rossby waves (TRWs).

LOOP CURRENT VARIABILITY

The LC is the major source of energy for both anticyclonic eddies, which propagate into the western basin, and deep Topographic Rossby Waves (TRWs) which also propagate westward. Sturges (1992, 1994), using long time series of the northward LC extension derived from imagery and regular Ship-of-Opportunity XBT sections, showed that the best estimate of the fundamental eddy shedding period was 8-1/2 to 9 months. He speculated that interactions of this fundamental period, with the annual cycle of LC transport through the Yucatan Straits, could generate the other peaks in the spectrum that create the variability of approximately 5 to 16 months in the periods between eddy sheddings.

Recent measurements of the transport in the Florida Current between Key West and Havana (SAIC, 1992) showed that the annual transport of 25-26 Sv is less than the 30-31 Sv usually assumed. The latter figure is based on extensive transport measurements at 27°N between Jupiter, FL and Settlement Point in the Bahamas. The one-year transport study of the Florida current showed that 27°N monthly transports were not closely related to transports of the LC leaving the Gulf through the Florida Straits because of contribution from side channels. The 25-26 Sv measurement produces eddy shedding cycles in numerical model simulations that are closer to the observed nine months.

DEEP BASIN TOPOGRAPHIC ROSSBY WAVES

The study of deep current meter records from under the LC, in the center (91°W) and in the Northwest corner of the basin by Hamilton (1990), showed that energetic, highly vertically coherent current fluctuations were correlated with extensions of the LC. Periods were longer than 10 days with 25-day fluctuations prominent. These TRWs were shown to propagate westward across the basin with a minimum group velocity of 9 km/day. This is faster than the LC eddy westward translation speed of 3-6 km/day; thus, the TRW motions below ~1000 m are essentially independent of the major LC anticyclones. These characteristics of the deep currents have been reproduced by numerical models (Oey—personal communication).

LOOP CURRENT EDDIES IN THE WESTERN BASIN

The LATEX-C program tracked 4 major LC anticyclones (U, V, W, and Y) with drifters, supplemented by periodic AXBT surveys, between 1992 and 1995. These data showed that these LC eddies interacted frequently with small and large cyclones. Altimetric maps of the sea-surface height show that cyclones are quite frequently observed in the western Gulf and they seem to play a role in the merging of a young anticyclone with an older anticyclone against the western slope. Cyclones are often formed when a LC eddy encounters the topography of the western slope, similar to that described by Lewis *et al.* (1989), for eddy B.

Eddies U and W were large and both spawned secondary eddies, V and W_N, in a similar manner, apparently, to the eddy shedding process from the LC. Eddy V was quite vigorous and propagated along the 2000 m isobath at the base of the slope until moving up onto the slope in the northwest corner region where it remained for several months, eventually dissipating in June 1993. The northern part of W (W_N) interacted with a cyclone on the slope in August 1993, moved south-southwest off the slope, and was reabsorbed into W (Berger *et al.*, 1996). Eddy Y behaved more like a typical anticyclone with a steady WSW path across the basin. However, it also interacted with a relatively large cyclone in the middle of the northern slope in early 1995.

Using the drifter data from a number of programs, statistics on eddy paths in the central and western Gulf were assembled from 10 eddies (1985-1995). The individual paths are shown in Figure 1G.1. The most northerly path along the base of the slope is for eddy V and is quite clearly anomalous to the general west-southwestward trend of the other paths. Many of these eddy center tracks show anticyclonic tendencies with periods of 20-30 days. It is not known whether these fluctuations in the paths are related to the deep energetic TRWs at these frequencies. One important result from the statistics of the paths west of 94°W is that the net northward translation velocity is not significantly different from zero. Therefore, the eddies have equal tendencies to move both north and south along the Mexican slope in this data set. Vukovich and Crissman (1986), using image analyses, consider that northward movement is the norm for eddies encountering the slope between 23 and 24°N.

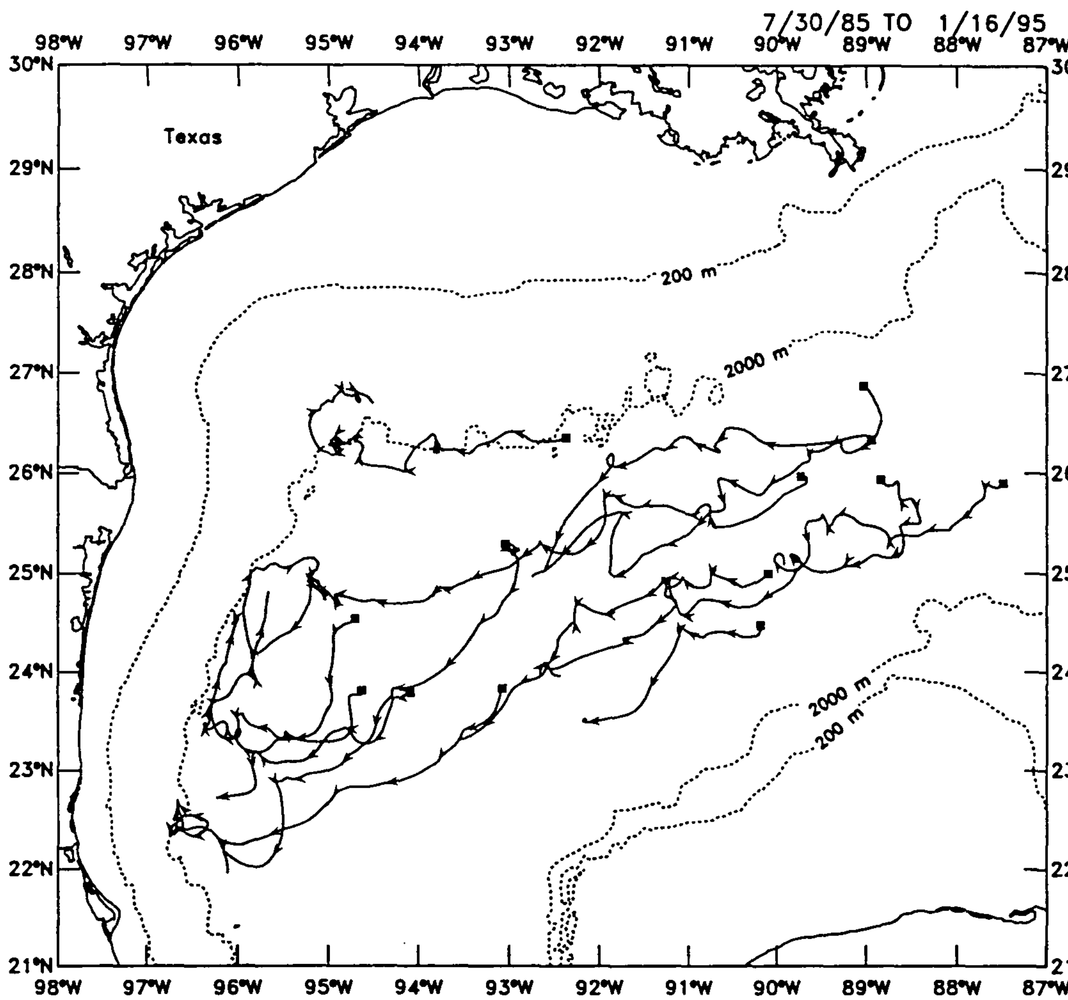

Figure 1G.1 Paths of eddy centers derived from satellite tracked drifter orbits. Arrow heads are at 10 day intervals.

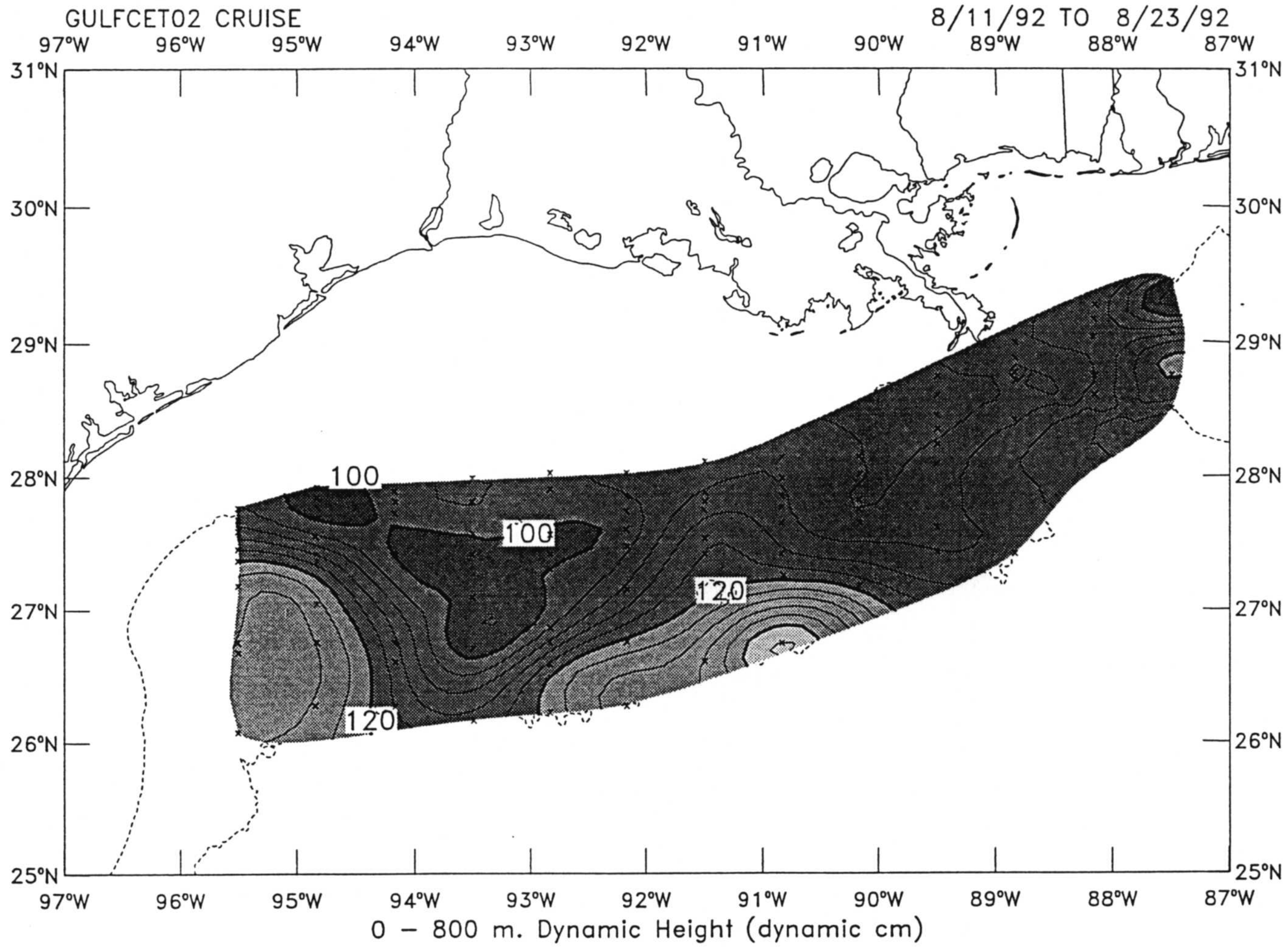

Figure 1G.2. Dynamic height relative to 800 decibars from the GulfCet02 Slope hydrographic survey.

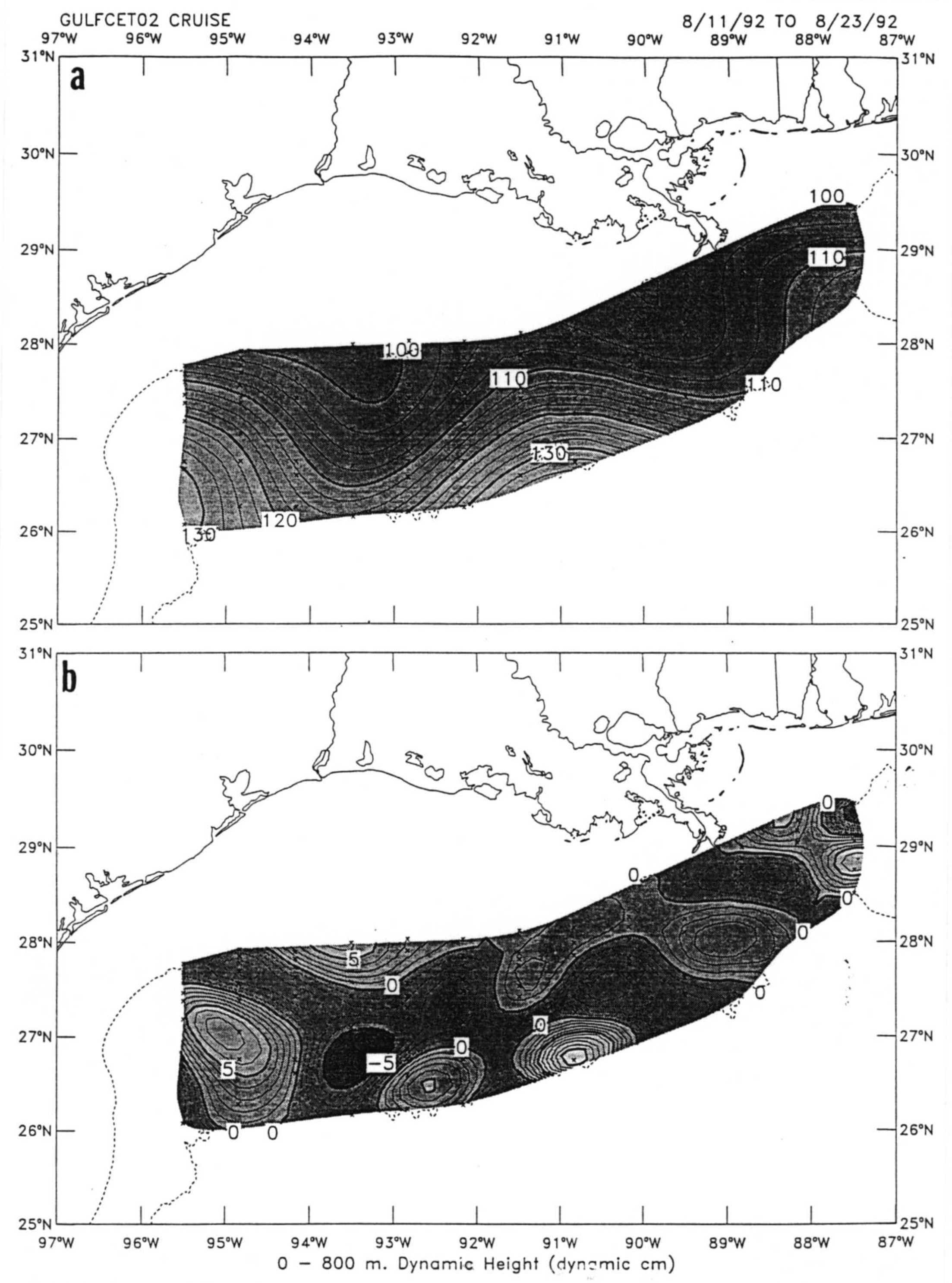

Figure 1G.3. The dynamic height field of Figure 1G.2, (a) low pass filtered (Gaussian influence scale = 150 km), and (b) band pass filtered (scales 50 to 150 km).

EDDIES ON THE NORTHERN SLOPE

Twenty-one AXBT/AXCP surveys by LATEX-C along with seven GulfCet hydrographic cruises have shown that both anticyclones and cyclones with diameters ranging from about 40 to 150 km are ubiquitous on the slope. An example is the dynamic height plot for GulfCet02 in August 1992 (Figure 1G.2). This becomes clearer when this field is low and band passed filtered for length scales greater than 150 km and 50 to 150 km, respectively (Figure 1G.3). These kinds of patterns are found in nearly all the surveys that encompass a reasonably large section of the slope. Examination of drifter records (Surface Current and Lagrangian-drift Program (SCULP) and LATEX-C programs) shows that the cyclone-anticyclone pairs have a tendency to rotate around each other and can move both east and west. The large scale wave-like patterns are associated with LC eddies in deeper water and propagate to the west. The small scales can be found at any position on the slope, including the shelf break, whereas the larger scales (Figure 3) are most energetic in the deepest water depths.

The occurrence of small scale eddies along the shelf break is a dominant influence on the shelf break currents, and where cyclones and anticyclones are adjacent, water can be moved across the isobaths on or off the shelf. These small eddies can mask the influence of large eddies, farther south, on the shelf break currents. Consequently, there is little continuity of flows along the shelf break and, thus, usually poor coherence between current meters with 50 km, or less, separation. Therefore, speculation on eastward jet-like flows along the shelf break are not borne out by direct measurement or the analysis of the hydrographic fields.

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Dr. Peter Hamilton is a senior oceanographer with Science Applications International Corporation. He has served as a principal investigator on many MMS programs. He received his Ph.D. from the University of Liverpool (U.K.) in 1973.

GEOLOGIC FRAMEWORK FOR THE NORTHERN GULF OF MEXICO CONTINENTAL SLOPE: NEW CONCEPTS AND NEW CHALLENGES

Dr. Harry H. Roberts
Coastal Studies Institute
Louisiana State University

INTRODUCTION

Renewed interest in deepwater exploration in the Gulf of Mexico has stimulated economic growth in oil-related industries and presented industry with a new set of challenges uniquely associated with little known areas of the deep slope environment. The latest Outer Continental Shelf (OCS) lease sale 161 resulted in over

3 million acres leased at a cumulative cost of over $500 million. A total of 62 companies participated in the high bid with Shell winning the most lease blocks with 115. Many of these blocks are at the base of the continental slope where water depths are well over 6000 feet (~ 1800 m). This push to explore the northern Gulf of Mexico's deepwater frontier areas clearly emphasizes industry's confidence in deepwater reserves and the associated technology it takes to find and produce them. At present Shell's Auger platform (Garden Banks 425), in a water depth of 2,861 ft. (872 m), is the deepest permanent producing structure. However, their Mars platform is currently being completed in 2,940 ft. (896 m) and in conjunction with Texaco, another platform (Fuji) will be completed in 4,243 foot waters (1293 m) some 50 miles southwest of New Orleans.

The increase in oil and gas related activity in the deepwater province of the northern Gulf is accompanied by a new need to understand slope geology to meet both engineering and regulatory requirements. New technology, primarily improvements in acoustic imaging of both the sea floor and subsurface (particularly 3D-seismic), has provided new insight to the slope's structural and stratigraphic architecture. Improvements in seismic processing have also provided new imaging of salt and subsalt relationships plus reduced drilling risks by using "bright spot" or amplitude anomaly analysis. These and other technologies, such as new deep-tow systems for high resolution imaging of the seafloor and shallow subsurface, and are necessary to develop the best working models of the slope's complex geology. This dynamic geologic framework for the northern Gulf's continental slope is inherited from the interplay of large volumes of sediment input to the slope primarily during periods of lowered sea level and the compensating movement of allochthonous Jurassic salt.

GEOLOGIC FRAMEWORK

In order to understand the geologic framework and stratigraphic architecture of the northern Gulf continental slope, a proper understanding of the evolution of allochthonous salt, associated faults, and intraslope sedimentary basins is essential. Seismic profiles and well data (various types of well logs and associated micropaleontological data) provide the main elements for evaluating the evolving depositional environments, sedimentary facies, and salt characteristics. Some authors have produced sequential structural restorations from these types of data sets (Worrall and Snelson 1989; Diegel *et al.* 1995; Peel *et al.* 1995; Rowan 1995; and McBride 1995). Such reconstructions help explain the evolution of salt structures coincident with sedimentation. This new understanding of the dynamic changes that have taken place through time to give us the present slope configuration is possible because of improved seismic imaging technology (Ratcliff 1993), better physical modeling of salt-sediment systems (Vandeville and Jackson 1992), and the application of sequential restorations (McBride 1996). This new generation of work on the slope has shown us that tabular allochthonous salt sheets and nappes are not new to the slope, but have occurred previously and have undergone various stages of deformation and evacuation (Diegel and Cook 1990). The emplacement and eventual evacuation of allochthonous salt appears to vary spatially and temporally throughout the northern Gulf of Mexico basin. No single model for salt movement can explain the array of salt geometries presently imaged in the subsurface. However, it is clear that original salt geometries and the manner in which they interact dictate the positions of later minibasins, remnant salt diapirs, extensional growth faults, contractional structures, and strike-slip deformation (McBride 1996). In addition, it is clear that this framework provided by salt deformation and sediment loading is the template for understanding the complexities of the modern seafloor.

Salt deformation and ultimately slope configuration is largely linked to the way sediments are input to deepwater. As is now widely recognized by the geologic community, sediment input to the outer shelf and continental slope is strongly modulated by sea level changes (Suter and Berryhill 1985). During periods of sea level lows, fluvial systems entrenched themselves as they prograded across the shelf to eventually deposit their sediments in thick and discrete shelf-edge deltas (Suter and Berryhill 1985; Roberts *et al.* 1991; Sydow and Roberts 1994). In addition, these rapidly deposited deltas loaded the shelf margin, an inherently unstable area, frequently causing shelf-edge failures that contributed large volumes of sediment to downslope depositional sites (Coleman *et al.* 1983). The interplay between intense periods of sedimentation, largely at low sea levels, and compensating salt tectonics has resulted in a present-day slope configuration that is characterized regionally by numerous domes and basins (Martin 1980). As a product of the processes outlined above, the interdome basins are filled with thick sedimentary sequences composed of sand-rich slope fans and turbidities as well as thick clay-rich units. Because of sea level forcing of fluvial-deltaic sediment input to the continental slope, during periods of high sea level, fine-grained hemipelagic sediments with a high pelagic foraminiferal content drape the slope topography, except on topographic highs in outer shelf and upper slope settings, where physical processes may remove much or all of this deposit. These sediments vary in thickness but are typically 3-5 m thick on the mid- to upper-slope.

SEAFLOOR GEOLOGY

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 with oversteepened slopes, faults are responsible for numerous constructional sea floor features related to the vertical flux of fluids and gases and expulsion of these products at the ocean bottom. At one end of the feature spectrum are large mud volcanoes (Neurauter and Bryant 1990; Neurauter 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). The following discussion highlights important small-to-mesoscale features on Louisiana's continental slope that make the surficial geology of this province very complex.

Dome-Top Mounds

Common features on the sea floor over shallow subsurface salt diapirs are carbonate mounds having various dimensions and frequencies of occurrence. 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 widespread mound complex occurs in the Green Canyon Area, Block 140. Each one of these mounds is the site of slow seepage of both hydrocarbon gases and crude oil. The mounds have developed from deposition 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). This process produces carbonate that is C-13 depleted and at this site $\delta^{13}C$ values of -48 to -55 are common. Most samples analyzed thus far have been composed of Mg-calcite, although dolomite comprises up to 40% of some samples (Roberts *et al.* 1992b). The average relief of these mounds is about 10 m with some greater than 20 m. 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 display coarse sediment lags which seem to be evidence of considerable dome-top erosion (Figure 1G.4). 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.

Dome-Top Erosional Features

Studies of currents active on the upper continental slope (e.g., Hamilton 1990) indicate that intrusions of the Loop Current and its westward-moving eddies have associated currents at upper slope depths sufficient to transport sand-sized sediments. Regional relief features, specifically dome tops, represent zones where much of this energy is naturally focused. Certainly, the coarse sediment lags, as described above in associations with carbonate mounds, and the commonly occurring truncated beds associated with the dome-top settings reflect the existence of persistent and on-going erosive forces. In isolated cases, coarse sediments, largely composed of biogenic grains (shell hash) and nodules/clasts of diagenetic origin, are organized into migratory bed forms. This association is direct evidence of strong bottom currents on the upper slope and helps explain truncation of bedding and missing sedimentary section associated with the sea floor over salt structures.

Gas Hydrate Mounds

Because of the strong fault-related vertical flux of both gas and water to the sea floor, as described above, gas

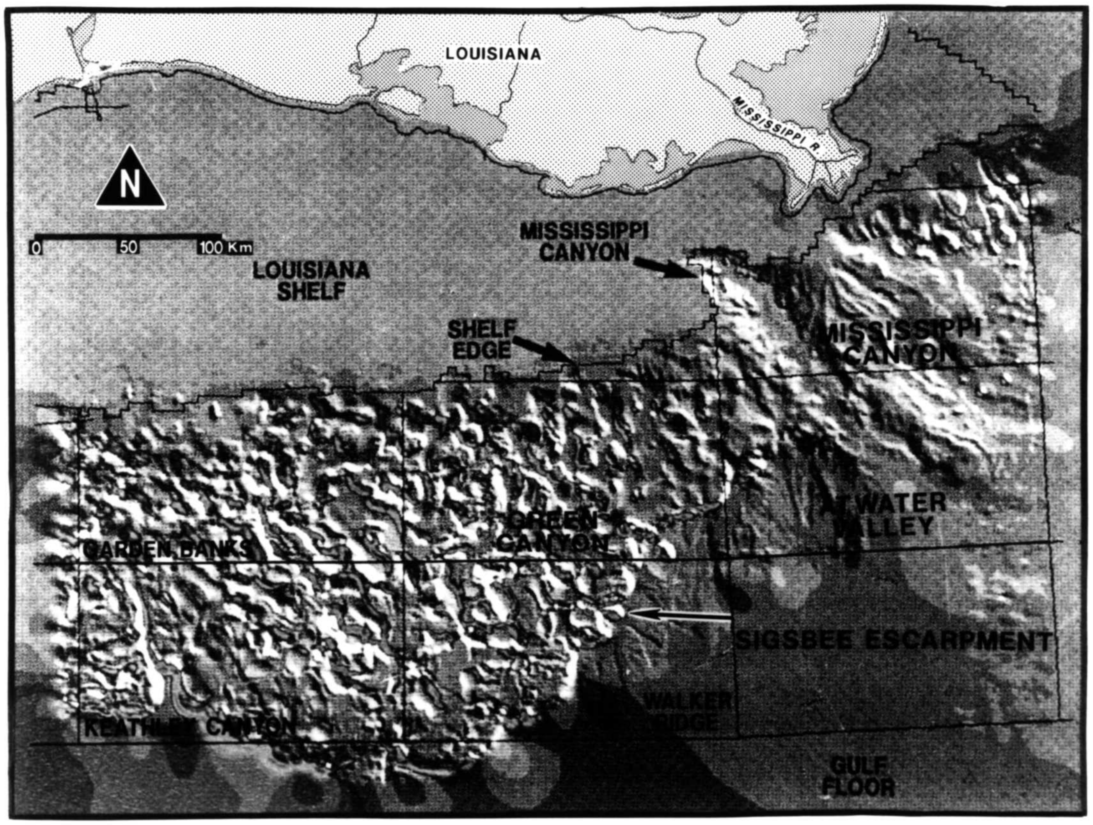

Figure 1G.4. Highlighted GLORIA side-scan sonar composite image of the Louisiana and Texax continental slope. The complex mound and basin configuration reflects the interplay between sedimentation and salf deformation.

hydrates are able to exist at or near the sea floor in water depths greater than about 500 m and below. Gas hydrates are ice-like substances composed of rigid cages of water molecules that enclose molecules of hydrocarbon gases, primarily methane. 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. Recently, they have been observed as "outcrops" on the sea floor by the author and others (McDonald *et al.* 1994). In most cases, however, hydrates occur below the surface with an overlying and insulating layer of fine-grained sediment. Collectively, the process of vertical flux of water and gas up faults results in mound-like accumulations. These features characteristically display acoustic "wipe out" zones beneath them on high resolution seismic profiles. In addition to affecting local topography/geology, gas hydrate mounds function as a rather constant trophic resource for chemosynthetic communities. Also, as interpreted from piston cores and direct submersible sampling, they are intermeshed with anthigenic carbonates. These carbonates frequently take the form of small nodular masses to ledge-like outcrops. Both types are usually very C-13 depleted but may have varied carbonate mineralogies.

Mud Vents and Mud Volcanoes

When the transport of fluids, gases, and fine-grained sediment up fault planes is rapid, 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 not only common in this setting, but they have been described from many submarine environments throughout the world oceans. From submersible observations, 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, add a new accretion unit to the cone's flank, and extend the diameter of the mud volcanoe's base. Features of this description occur on a variety of scales from small cones less than 1 m diameter to large features with over 30 m relief and bases of over 1 km in width. Kohl and Roberts (1994) demonstrate that the process of fluid mud extrusion results in displaced micro faunas and inversion of biostratigraphic marker horizons in slope sediments. For example, they show that surface sediments at four vent sites contained micro fossils yielding age dates of Pleistocene to early Miocene. 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 area (determined by personal observation using the JSL and inspection of geohazards data provided by Shell Oil Company). Stacked sequences of thick mudflow deposits carrying "old" microfaunas result in these circumstances.

Slope Instability Features

Rapid deposition of sediment at the shelf edge faulting, and vertical migration of shallow salt create instabilities primarily by over steepening of slopes. A wide range of failure features results, from massive shelf edge evacuation features (Winker and Edwards 1983) to small-scale slumps along fault faces and on the sides of diapirs. Depending on scale, massive volumes of sediment can be transported down slope in association with subaqueous mass movement processes (Coleman *et al.* 1986). These processes currently pose a considerable risk to man's activities on the northern Gulf's continental slope. Even thin deposits of hemipelagic highstand sediments that drape topography of the slope display a tendency to fail (Doyle *et al.* 1992). Sediments displaced by slumps, submarine landslides, and other mass movement processes tend to have chaotic-to-acoustically opaque internal reflectors on high resolution seismic data and commonly produce small-scale irregular surface topography. Some intraslope basins contain fill-sequences of repeated and stacked chaotic units that are interpreted as the products of massive failures. These deposits likely originated at or near the shelf edge during periods of lowered sea level and failed during the loading process. The rugged surfaces of these deposits and chaotic internal reflectors mimic similar slumped units currently found at the sea floor in many places on the present continental slope.

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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.

ADDRESSING THE ECOLOGICAL UNKNOWNS OF DEEPWATER OIL AND GAS DEVELOPMENT

Dr. Robert S. Carney
Coastal Studies Institute
Louisiana State University

INTRODUCTION

As the offshore oil and gas industry progressively moves down the continental slope, industry and the Minerals Management Service (MMS) face a variety of new information needs. This presentation is intended to take a quick but critical look at the ecological information needs, not so much in terms of exactly what must be studied, but in terms of the problems of determining the broader scope of needs. The method of identifying these problems will be to contrast our experence at shelf depths with the unknowns of deeper water.

In shallow water, regulatory agencies have generally paid for the application of existing ecological ideas to particular questions rather than fostering new concepts, and this is true for MMS and its regulation of offshore development. Although there can be various criticisms leveled at this strategy, the fact is that in that environment MMS could successfully limit itself to application of existing ideas, since a host of new ideas were always being generated independently of MMS by a large, diverse, and adequately funded body of oceanographers and marine ecologists. Ten years ago, this would have been somewhat true of the deep ocean as well.

LEARNING FROM PAST EFFORTS

Compared to shallow water, the deep ocean has a small pool of experts, many questions remain intractable, and high logistics costs slow the rate of progress even when funding is available. When attempts to focus this expertise on applied problems over the past decade are reviewed, it becomes quickly obvious that MMS and the offshore industry have little to apply. This can be quickly seen with two case histories.

1. High-Level Radioactive Waste Disposal—For approximately a decade the Department of Energy explored the "ocean option" for disposal (Hollister *et al.* 1981.) through its Sandia National Laboratory with participation of the major academic oceanography centers. Funding was in the tens of millions of dollars. This massive project was terminated as a matter of policy without any scientifically well-established understanding of either the environmental impact of disposal or the possible biological pathways back to the upper ocean.

2. Manganese Nodule Mining—The Seafloor Hard Minerals Act was a U.S. law passed to protect mining interests in international water at a time when the U.S. objected to the provisions of the Law of the Sea Treaty. From a regulatory perspective the act is important in that it extended U.S. environmental regulation to the deepest parts of the ocean well beyond the U.S. Exclusive Economic Zone. The primary environmental protection strategy was to set aside areas of the central north Pacific nodule fields as stable reference areas in which and near which mining would be internationally banned. Again, over about a decade but at a more modest funding level of a few million dollars, the National Oceanic and Atmospheric Administration (NOAA) studied mining and simulated mining effects (NOAA 1994). With no definitive results in hand, the project was terminated as a matter of policy.

Over the same decade in which deep ocean oil and gas development went from possibility to actuality, there has been a wholesale retreat by the major ocean agencies from deepwater. Making it worse, this cessation of effort has not come at the end of successful research, but in the most critical midpoint of projects. There are few proven ideas out there for MMS to apply.

A final and more recent example drawn from Britain illustrates the seriousness of our paucity of a solid understanding of deep-sea ecology. The Brent-Spar fiasco in 1995 is a lesson in how industry and government can go about doing something poorly together. The details are available in a report on the matter (NERC 1996). The main damaging points are simple. Shell and the British government elected to let a proposal for deep ocean scuttling go forward with only cursory field investigation. It may be safe to assume that neither industry or government thought there was any public interest in the deep environment. When such interest and a public outcry generated by Greenpeace did arise, both parties were further embarrassed by the realization that the information gathering exercise had completely ignored one of the most respected cadre of deep-sea ecologists right in Britain. Treating deep disposal casually proved very costly.

SETTING LIMITS ON WHAT MUST BE LEARNED

The Brent Spar established the fact that there can be just as much public concern over the deep-sea floor as the shallow ocean. This and the cessation of applied deep investigations by the U.S. government establishes the fact that MMS and industry must assume leadership roles in ocean research. It is necessary to decide how much of a task awaits. It is unreasonable to propose that management of oil and gas development requires the pursuit of all knowledge. Rather, I propose that MMS first pose the question, "How much of continental shelf management strategy can be effectively applied to the deeper ocean?" This shallow-water strategy centers around avoiding conflicts of resource use.

Beyond the shelf break, the oil and gas industry should experience less conflict of resource utilization. Being far from shore there should be little or no conflicting aesthetic or recreational value to seafloor or surface. Mineral conflicts are unlikely since nodule fields are located away from continental margins, and various placer deposits are more likely to be exploited more nearshore. Deep-sea bottom fisheries may seem to be a conflict, but these are usually destined to failure as old and slowly recruiting stocks are rapidly depleted. Conflicts in the upper ocean are far more likely to occur than at depths, but if industry shifts to seafloor facilities as projected, even surface impacts may be less than in shallow water.

Although current management strategy focuses first on conflicting resources, it also assigns a value to the general protection of habitat, which lacks a specific economic value. There are restrictions upon siting and operations, but the primary protection of the environment lies in its vastness relative to the small zone of possible impact around a production platform. As far as we now know, much of the shelf environment is faunistically monotonous, and the very large areas receiving no impact provide adequate assurance that overall biodiversity and ecological function will not be detrimentally impacted. Is this true for the deepsea as well?

It is here proposed that the main ecological question facing MMS and industry is whether vastness affords as much protection in the deepsea as it is assumed to afford in shallow water. It should be stressed that in shallow water this really is only an assumption, although one that seems to work. There are two lines of reasoning that reinforce the need to ask this question, faunal zonation (Carney *et al.* 1983) and species diversity (Grassle and Maciolek 1992). The first shows that the deepsea is not monotonous with respect to species distributions. Indeed, the slope may contain numerous distinct depth zoned habitats with special environmental sensitivities. The second basically says that we do not understand what controls diversity in the deep ocean, and that environment is much more species rich than its apparent physical monotony would lead us to predict. If this reflects a fine and delicate balance among species, then impacts may be of much greater consequence. In both the case of zonation and diversity, current concepts are not well enough advanced to be of immediate application for either industry or regulator.

This talk has intentionally omitted discussion of hydrocarbon seep communities since they will be treated in detail by Dr. Ian MacDonald of the Geochemical and Environmental Research Groups at Texas A&M. Only a caution will be posed. Seeps are fascinating reef-like communities, and conflicts seem inevitable between their preservation and industry dislikes for any setting aside of public lands from development. They are, however, a minuscule part of the deep Gulf of Mexico environment, and there may be more questions to be answered about avoiding development-related impacts in the normal deep environment than to the special case of seeps.

CONCLUSION

The ecology of the deep sea has been poorly studied. There are far too few experts on that environment, and much applied work has been terminated prior to completion. As a result, industry and MMS face questions for which there are few data available and few concepts with which to assuredly provide answers. Thus, a new mode of information gathering must be adopted, one that builds ideas as well as databases. It is both impossible and unnecessary for either MMS or industry to embrace all the unknowns about deepsea ecology. Rather, they can undertake studies that very specifically challenge management strategies developed in shallow water.

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Dr. Robert Carney began his oceanographic study of the deep Gulf of Mexico as a student of Willis Pequegnat at Texas A&M University in 1967 and has returned to that original interest during 11 years at Louisiana State University. At LSU he serves as director of the Coastal Marine Institute, a researcher in the Center for Coastal Ecology, and an associate professor in the Department of Oceanography and Coastal Sciences. Dr. Carney received is B.S. in zoology from Duke University, a master's degree in oceanography from Texas A&M University, and a Ph.D. in the same field from Oregon State.

STABILITY AND CHANGE IN GULF OF MEXICO CHEMOSYNTHETIC COMMUNITIES

Dr. Ian R. MacDonald
Geochemical and Environmental Research Group
Texas A&M University

OVERVIEW

On the northern continental slope of the Gulf of Mexico, chemosynthetic communities are known to occur between 94° W and 88° W, at depths between 400 and 2200 m (MacDonald *et al.* 1996). These communities comprise dense and productive aggregations dominated by chemosynthetic tube worms and mussels and including many species of heterotrophic fauna (MacDonald *et al.* 1989). These fauna are dependent upon pore-fluids and very-near-bottom sea water enriched in dissolved gases. Two gases are involved: methane (CH_4), which supports mussels, and hydrogen sulfide (H_2S), which supports tube worms (Fisher 1990). The presence of these gases in the Gulf of Mexico slope sediments is directly linked to migration of hydrocarbons from deep sub-surface reservoirs to the seafloor and the water column (Kennicutt *et al.* 1988). The greatest management concern is directed at significant cold seep communities (SCSC) with aggregations that extend over a large area and where the local high productivity supports a diverse assemblage of heterotrophic fauna (DOI MMS 1996).

Program Goals

Considerable progress has been made in understanding chemosynthetic communities in the Gulf of Mexico over the past five years, particularly as a result of the Minerals Management Service (MMS) Program entitled "The Chemosynthetic Ecosystem Study" (Chemo I) (MacDonald *et al.* 1995); however, there remain many unanswered questions and areas where qualified scientists disagree. The continuation of Chemo I is a new, 42-month program entitled "Stability and Change in Gulf of Mexico Chemosynthetic Communities" (Chemo II), which is intended to aid MMS in the scientifically sound management of seep communities.

This program will encompass studies at a community ecology scale and at a regional geologic and oceanographic scale. At the community level, effort will focus on determining the abiotic factors that control the distribution and abundance of major chemosynthetic and associated fauna and impact the life-history of these organisms. At the regional level, effort will focus on geological and geochemical processes that support communities and on circulation processes that maintain the stability of communities on the slope.

Work begun during Chemo I led to development of a variety of conceptual models that describe and explain the formation, persistence, and distribution of chemosynthetic communities on the Gulf of Mexico continental slope. Chemo II is designed to test, refine, and expand those models. The overall goal is to provide MMS with a predictive capability for management of chemosynthetic communities by seeking the best answers to basic questions: How many communities are there on the slope? Where can we expect to find them? How do they respond to the "normal" range of environmental variation? How will they respond to anthropogenic perturbation?

The team assembled for this program combines practical experience in the Gulf of Mexico region with scientific excellence in related problems throughout the world. All of the team members bring to the program active research programs on related topics. The result is great depth in scientific knowledge and direct cost-savings. The resulting program is necessarily complex and ambitious. Effectiveness is maximized by mutually reinforcing work plans for each component and by annual meetings to review and assess the status of the program.

Chemo II will require extensive sampling from submersibles. The present program will make extensive use of in-situ instrumentation, including a current meter mooring, to monitor important environmental variables during the intervening year. The sampling will continue at sites studied during the Chemo I and other related non-MMS programs. This ensures continuity of time-series observations at well-characterized stations. Additional field studies will utilize cost-effective seismic methods to gather information regarding the geophysical signature of potential seep communities in upper continental slope depths (400-900 m) and mid- to lower-slope water depths (1200-2000 m).

This presentation provides a description for what the program team considers to be important processes in controlling stability and change at the community and regional levels, details the current conceptual model and research questions at each level, and, finally, outlines the approach proposed to address these questions.

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Dr. Ian R. MacDonald is a biological oceanographer with the Geochemical and Environmental Research Group (GERG) of Texas A&M University. He is the program director for the Stability and Change in Gulf of Mexico Chemosynthetic Communities Program. He has published widely on the ecology of the Gulf of Mexico and previously served as the program manager for the Chemosynthetic Ecosystem Study.

SESSION 1H

NORTHEASTERN GULF OF MEXICO COASTAL AND MARINE ECOSYSTEM PROGRAM

Co-Chairs: Dr. Robert Rogers
Mr. Robert Meyer

Date: December 12, 1996

Presentation	Author/Affiliation
Northeastern Gulf of Mexico Coastal and Marine Ecosystem Program: Coastal Characterization	Mr. Lawrence R. Handley Dr. James B. Johnston Mr. William R. Jones Mr. Arturo Calix Mr. Pete Bourgeois U.S. Geological Survey National Wetlands Research Center
Ecology of Live Bottom Habitats of the Northeastern Gulf of Mexico: A Community Profile	Mr. M. John Thompson Continental Shelf Associates, Inc.
Northeast Gulf of Mexico Coastal and Marine Ecosystems Program: Ecosystem Monitoring, Mississippi/Alabama Shelf	Dr. David A. Gettleson Continental Shelf Associates, Inc.
Cumulative Ecological Significance of Oil and Gas Structures in the Gulf of Mexico	Dr. Benny J. Gallaway LGL Ecological Research Associates, Inc.

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

Mr. Lawrence R. Handley
Dr. James B. Johnston
Mr. William R. Jones
Mr. Arturo Calix
Mr. Pete Bourgeois
U.S. Geological Survey
National Wetlands Research Center

As oil and gas leasing proceeds in the northeastern Gulf of Mexico, environmental studies information is needed for future preleasing decisions, for necessary protective lease stipulations, and for oil spill contingency planning. The coastal areas adjacent to the proposed offshore leasing and development contain natural resources and socioeconomic infrastructures that may be affected.

During the early 1980s, available environmental and socioeconomic information of the Gulf of Mexico coastal habitats were synthesized by the National Wetlands Research Center (NWRC) for the Minerals Management Service (MMS) in a series of "Coastal Ecosystem Characterizations." This study will update these 10- to 15-year-old databases to provide federal, state, and local agencies current information, maps, and data to make their decisions in a timely manner for the proposed oil and gas development. This northeastern Gulf of Mexico coastal characterization update includes the coastal areas of the Chandeleur Islands of Louisiana, coastal Mississippi and Alabama, and the Florida Panhandle to Cape San Blas. The characterization focuses on updating the information related to the previous ecological characterization of the area through five tasks and by developing the databases of habitats, biological resources, and selected socioeconomic features in accessible electronic formats.

The study's tasks include:

1. 1992 seagrass mapping for entire study area and 1996 wetland habitat maps for coastal Mississippi and Florida (Alabama/Louisiana was completed in 1989/1990);

2. natural resources and socioeconomic features database development in the form of maps and digital coverages;

3. database management transfer to include the development of a data directory, metadata, and an automated information clearinghouse;

4. the preparation of a *Live Bottom Community Profile* for the offshore area; and

5. the completion of a synthesis report for the study area.

In February and March of 1996, approximately 800 frames of color infrared aerial photography at a scale of 1:62,500 was acquired by NASA Ames Research Center form the Pearl River Louisiana-Mississippi to Cape San Blas, Florida, with additional funding from the Mississippi Bureau of Marine Resources and the Alabama Department of Economic and Community Affairs. One hundred and eighty frames of the coastal Mississippi photography have been scanned and placed on CD-ROM for the Mississippi Bureau of Marine Resources. Photointerpretation of wetland habitats has begun form the 15 1:24,000 scale USGS quadrangles covering coastal Mississippi.

In association with the U.S. Fish and Wildlife Service's Ecological Services Office in Daphne, Alabama, 29 digital databases have been acquired and transferred to the National Wetlands Research Center for coastal Mississippi and Alabama. A draft copy of *The Live Bottom Community Profile* has been distributed for review comments.

ECOLOGY OF LIVE BOTTOM HABITATS OF THE NORTHEASTERN GULF OF MEXICO: A COMMUNITY PROFILE

Mr. M. John Thompson
Continental Shelf Associates, Inc.

INTRODUCTION

M. John Thompson of Continental Shelf Associates, Inc. (CSA) and Dr. William Schroeder of the Dauphin Island Sea Lab Marine Environmental Sciences Consortium were awarded a contract by the National Biological Service (now U.S. Geological Survey) to develop a community profile for live bottom habitats in the Northeastern Gulf of Mexico. The objective of the study is to summarize the available data on the ecology of offshore (>12 nmi from shore) live bottom habitats located between Cape San Blas in the Florida Panhandle and the Mississippi River Delta of Louisiana (Figure 1H.1). In this area, live bottom communities are seen only in association with rock or hard bottom outcrops on the continental shelf. The completed community profile will serve as a reference for both researchers and resource management interest in the northeastern Gulf of Mexico.

PREVIOUS RESEARCH

Hard bottom features have been reported along the outer shelf and upper slope of the Gulf of Mexico since the 1930s (Trowbridge 1930). Ludwick and Walton (1957) conducted the first systematic study of these features. They documented the presence of a belt of discontinuous, reef-like features ("pinnacles") near the shelf edge between the Mississippi River Delta and De Soto Canyon. Since that time, a number of marine geological, biological, and reconnaissance studies have focused on small areas or portions of these hard bottom trends (Shipp and Hopkins 1978; Woodward-Clyde Consultants, Inc. 1979; Continental Shelf Associates, Inc. 1985). Two large-scale studies, the Mississippi-Alabama Continental Shelf Ecosystem Study (Brooks, 1991) and the Mississippi-Alabama Shelf Pinnacle Trend Habitat Mapping Study (Continental Shelf Associates, Inc. 1992), mapped these features over wide areas of the outer shelf. On the inner shelf, Schroeder *et al.* (1989a,b) studied hard bottom areas in water depths of 18 to 40 m off Alabama and northwest Florida (Figure 1H.1).

Hard bottom features in the northeastern Gulf of Mexico range from very low relief, periodically exposed hard bottom that is normally covered with a thin layer of sediment, to high-relief reef structures, or pinnacles. Epibenthic community development (live bottom) increases with increasing amounts of exposed hard bottom. Live bottom development is also related to the texture (rugosity) and topographic complexity of a hard bottom area (Continental Shelf Associates, Inc. 1992; Gittings *et al.* 1992).

The ichthyofauna inhabiting northeastern Gulf live bottom consists of a mixture of tropical and subtropical reef fishes derived from Gulf of Mexico and Caribbean faunal regions. A total of 70 reef fish species were reported during remote video reconnaissance of the pinnacles area (Darnell 1991). Thirty-nine of these species were primary reef fishes (primary reef fishes are those species obligatively associated with hard bottom or reef habitats (Starck, 1968)—while the remaining 31 were secondary reef species (i.e., not intimately associated with the hard bottom habitat). The species composition of the pinnacle fish assemblage resembles that of deep-reef fish assemblages (e.g., 55 to 100 m water depths) reported off the southeastern U.S. (Parker and Ross 1986; Gilmore *et al.* 1987) Similar fish assemblages have been reported from the lower portion of the Algal-Sponge zone of the West Flower Garden Banks in the northwestern Gulf of Mexico (Bright and Pequegnat 1974; Boland *et al.* 1983; Dennis and Bright 1988), and near the head of De Soto Canyon (Shipp and Hopkins 1978; Continental Shelf Associates, Inc. 1987).

ECOLOGICAL RELATIONSHIPS

Colonial invertebrates, such as the scleractinians and gorgonians, that create live bottom habitats grow slowly and require relatively stable environmental conditions. They are very sensitive to temperature, water quality, and sedimentation. Live bottom community richness was poorest in those areas closest to the mouth of the Mississippi River and progressively increased to the east (Gittings *et al.* 1992). Gittings *et al.* (1992) speculate that the Mississippi River plume influences the long-term water quality over a longitudinal range of approximately 70 km east of the delta and retards community development of the features there.

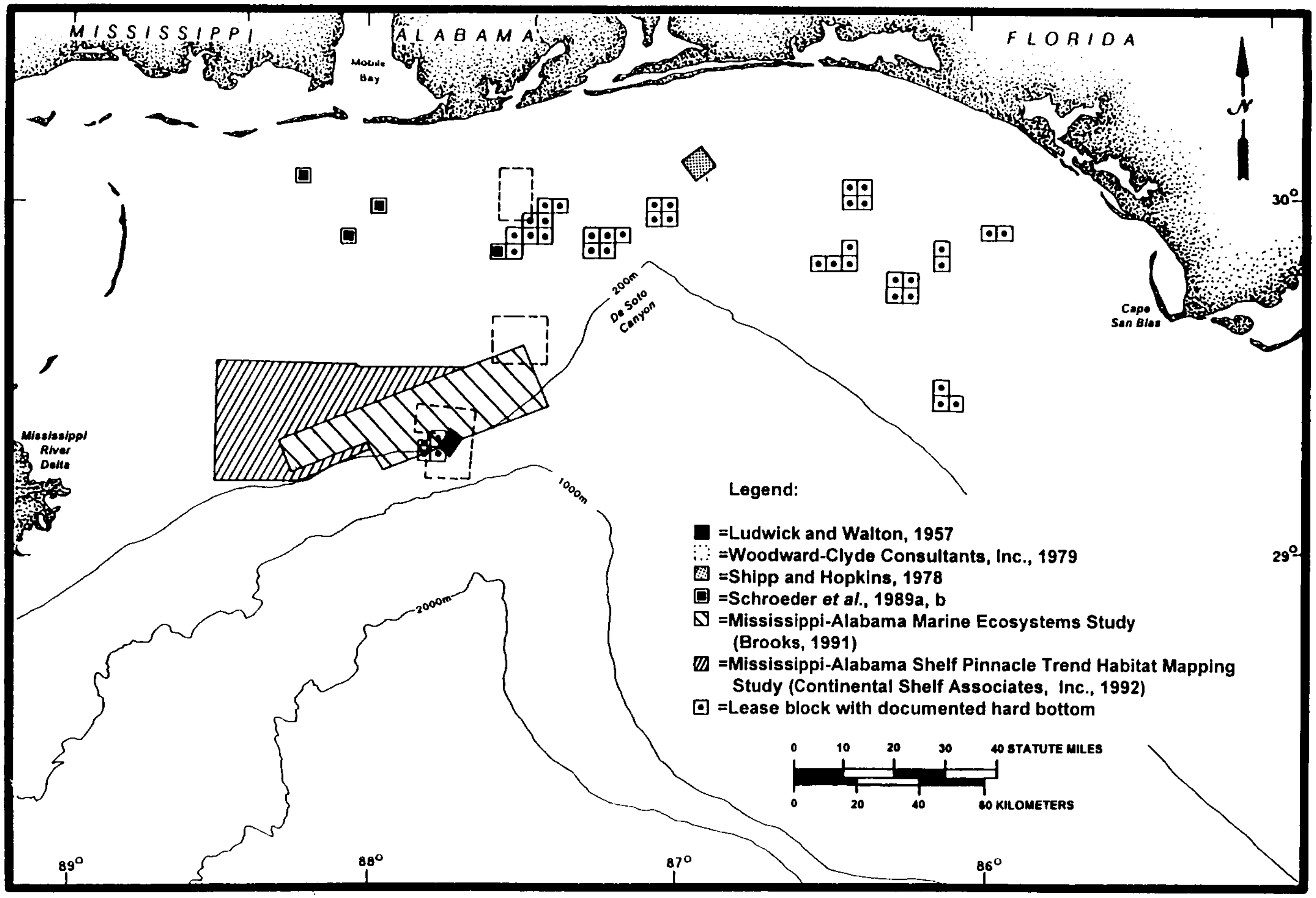

Figure 1H.1. Locations where hard bottom has been documented and/or studied in the northeastern Gulf of Mexico.

Vertical relief of individual hard bottom features is the single most significant factor influencing live bottom community development. All of the major live bottom studies conducted in the northeastern Gulf have demonstrated higher frequencies of occurrence and higher numbers of species with increasing vertical relief (Shipp and Hopkins 1978; Schroeder *et al.* 1989a, b; Brooks 1991; Continental Shelf Associates, Inc. 1992).

The reduced biotic coverage reported by Continental Shelf Associates, Inc. (1992) around the base of pinnacle structures, along with the increased coverage seen on elevated horizontal surfaces, indicates the role sediment re-suspension and habitat orientation play in the development of these communities in the northeastern Gulf. The sides and tops of high-relief features were dominated by low growing, ahermatypic stony corals, while flat topped ridges and reef-like features showed communities dominated by taller gorgonians, erect sponges, and comatulid crinoids.

De Soto Canyon is the definitive zoogeographical feature on the Mississippi, Alabama, and northwest Florida continental shelf. The live bottom communities described by both Shipp and Hopkins (1978) and Continental Shelf Associates, Inc. (1985) at the mouth of the Canyon are more complex than those described by Brooks (1991) or Continental Shelf Associates, Inc. (1992) from farther to the west, but they represent essentially the same faunal assemblage. To the east of De Soto Canyon both the sediments present and the type of hard bottom exposed are different. Live bottom faunal assemblages seen here are more closely related to those seen on the southwest Florida shelf.

Nearshore live bottom communities in the northern Gulf are subjected to relatively high seasonal temperature variations. These communities tend to resemble the warm temperate, "Carolina Province" communities described from the eastern seaboard (Schroeder *et al.* 1988). Offshore live bottom communities in the northern Gulf of Mexico have a clear tropical affinity but are much less diverse than their counterparts living in the southern Gulf of Mexico and Caribbean.

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M. John Thompson is a senior staff scientist with Continental Shelf Associates, Inc. (CSA) located in Jupiter, Florida. He has over 25 years' experience conducting marine ecological studies, much of it from the northeastern Gulf of Mexico. Mr. Thompson received his B.S. degree in Biology from the University of Tampa in 1969, and his M.S. degree in Marine Biology from Florida Atlantic University in 1974. Prior to joining CSA in 1980, he was employed by Harbor Branch Oceanographic Institution, where he worked in the areas of coral reef and seagrass community mapping and remote sensing.

NORTHEAST GULF OF MEXICO COASTAL AND MARINE ECOSYSTEMS PROGRAM: ECOSYSTEM MONITORING, MISSISSIPPI/ALABAMA SHELF

Dr. David A. Gettleson
Continental Shelf Associates, Inc.

INTRODUCTION

Continental Shelf Associates, Inc. (CSA) was awarded a contract by the National Biological Survey to conduct an ecological study of an area offshore Mississippi/ Alabama. The project team consists of CSA, the Geochemical and Research Group of Texas A&M University, University of Texas, Applied Marine Sciences, Inc., and independent consultants.

GEOGRAPHIC AREA OF STUDY

The geographic area of study is the Mississippi-Alabama pinnacle trend area in approximately 50 to 150 m water depths (Figure 1H.2). There are several previously conducted studies in the area, which was first described by Ludwick and Walton (1957). There have been four Minerals Management Service-funded studies (Woodward-Clyde Consultants 1979; Texas

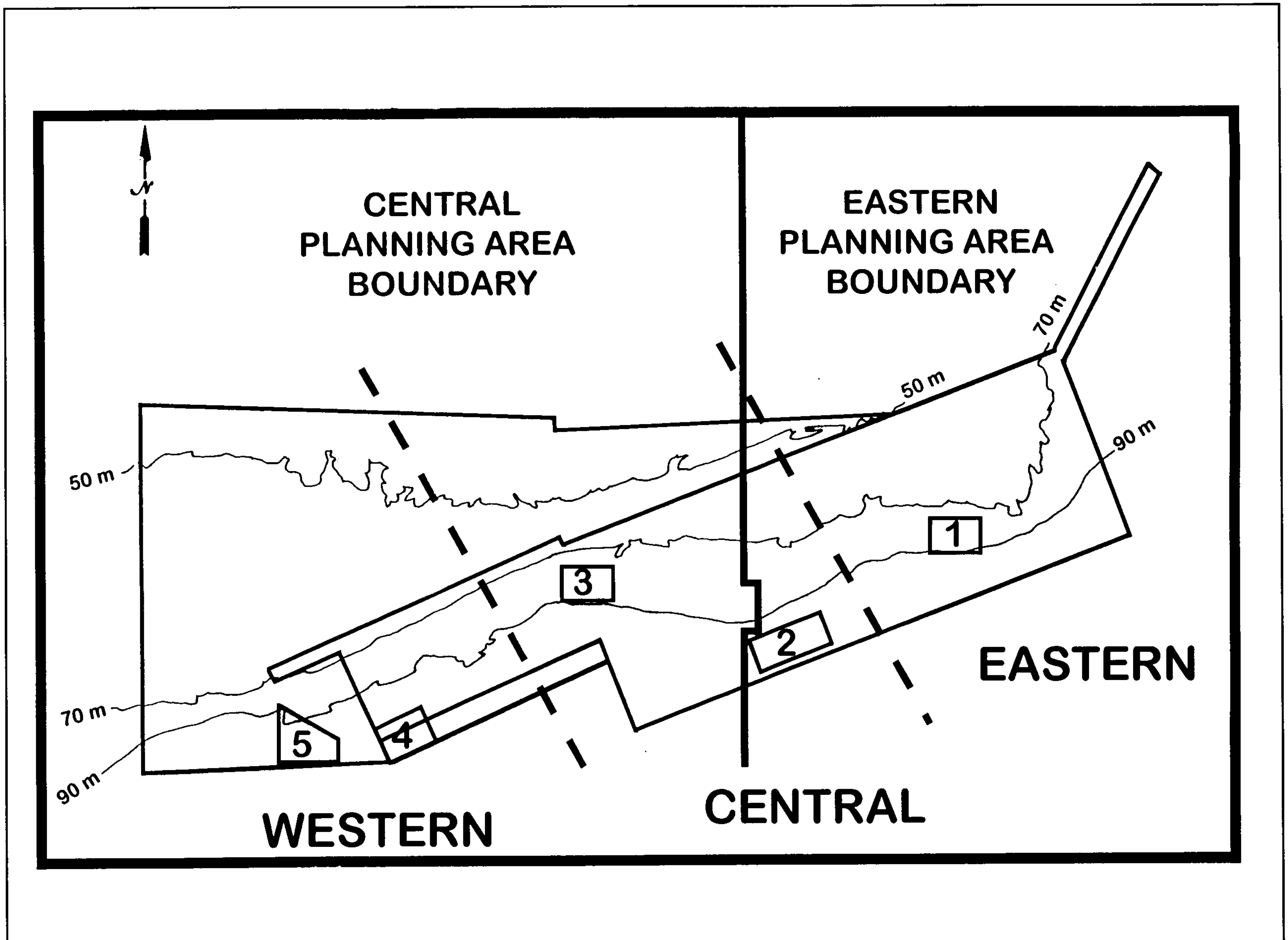

Figure 1H.2. Geographic area of study showing five areas of detailed study.

A&M University 1990; Continental Shelf Associates, Inc. 1992; Shinn *et al.* 1993) and an oil and gas lease block clearance survey (Continental Shelf Associates, Inc. 1985) conducted in the area.

STUDY OBJECTIVE

The objective of this study is to describe and monitor biological communities and environmental conditions at hard bottom features located within the geographic area of study. A number of oil and gas lease blocks are encompassed by the study area, with at least one oil and gas production platform present. Information gained from this study will be used to review existing lease stipulations to determine their adequacy in protecting the biological communities present on the hard bottom features. This study also meets several objectives of the National Research Council (1992) regarding the assessment of environmental impacts of oil and gas operations. These objectives include:

1. identifying representative species;
2. describing seasonal patterns;
3. acquiring basic ecological information for key or representative species; and
4. obtaining information on factors that determine sensitivity of biota to OCS activities and their recovery potential.

STUDY COMPONENTS

The four-year study is divided into four phases of one year duration each, with annual reports planned at the end of each phase. The phases are as follows:

Phase 1:	Reconnaissance, Baseline, and Monitoring;
Phase 2:	Monitoring;
Phase 3:	Monitoring; and
Phase 4:	Data Interpretation and Information Synthesis.

A total of 11 cruises are planned during the study. During the reconnaissance portion of Phase 1, five "megasites" (Figure 1H.2) of approximately 25 to 35 km^2 areas were selected for detailed study. These sites were selected as being representative of the hard bottom features previously identified in the area (Texas A&M University 1990; Continental Shelf Associates, Inc., 1992). The megasites were surveyed in November 1996, using swath bathymetry, high resolution side-scan sonar (11 and 72 kHz), and a subbottom profiler (2 to 8 kHz). Nine areas of approximately 0.2 to 1.5 km^2 size were selected during the cruise and surveyed in more detail. Previously collected video and still photographic data from these nine sites will be reviewed and additional visual data collected using a remotely operated vehicle to aid in the selection of nine study sites. The study sites will be selected to provide representative hard bottom features of high, medium, and low relief in the eastern, central, and western portions of the study area.

The focus of the baseline and monitoring portions of the study is to understand the geological and oceanographic processes as factors in controlling/influencing the hard bottom communities at the nine study sites. Data were gathered during the reconnaissance survey on substrate characteristics, hard bottom orientation, size and morphology, and depth of surrounding soft sediments. Four cruises will be conducted over a two-year period to collect baseline and monitoring data. Data on microtopography will be obtained from the collection and analysis of rock samples and video and photographic data during these cruises. Grab samples will be analyzed for grain size (four cruises) and concentrations of hydrocarbons and metals (first cruise only). Six instrument arrays comprised of current meters, sediment traps, and temperature, salinity, dissolved oxygen, and turbidity (optical backscattering) sensors will be deployed during the first cruise in the vicinity of the hard bottom features. The arrays will be recovered and redeployed at three-month intervals and recovered on the fourth cruise. The sediment trap contents will be analyzed for grain size, total inorganic and organic carbon, and metals. During each of the four cruises water column profiles will be made for conductivity, temperature, dissolved oxygen, transmissivity, optical backscatter, and sample collection for analysis of particle sizes, dissolved oxygen, and salinity.

Biological data will include the collection of quantitative still photographs from fixed quadrats and random stations and quantitative video from random transects during the four cruises. Voucher specimens will also be collected to aid in taxonomic identifications of biota observed in the visual data. Fish community data will be recorded from the available visual data. There will be two additional biological "companion" studies. The first will involve more in-depth analysis of the biological, geological, and physical data on a micro-habitat basis. The second will involve the deployment of settling plates on fixed arrays to study epibiota recruitment, growth, and community development. Settling plates will include enclosed and non-enclosed plates plus controls to study predation/disturbance effects. Plates will be placed near bottom and above any identified nepheloid layer. Eight arrays will be placed at one site and one array recovered each quarter. One array will also be placed at each of three additional sites for one year and recovered. An additional array will be deployed at each of the three sites after one year and recovered after a one year deployment.

The data interpretation and synthesis efforts will involve understanding the relationship of the measured geological and physical factors to the hard bottom communities through statistical analyses. A series of questions determined by the study objective with clearly stated null hypotheses will also be identified and statistically tested.

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Dr. David A. Gettleson is President and Scientific Director of Continental Shelf Associates, Inc. (CSA), located in Jupiter, Florida. He has 19 years of scientific management experience, with major research programs for federal, state, and industrial clients. He has been involved in the preparation of numerous environmental assessment documents covering a wide range of human activities in the marine environment, including oil and gas operations, dredging and dredged material disposal, beach restoration, artificial reef siting, power plant effluents, sewage outfalls, and waste incineration. Dr. Gettleson received a B.A. degree in Biology from Rollins College in 1971 and earned his Ph.D. degree in Biological Oceanography from Texas A&M University in 1976.

CUMULATIVE ECOLOGICAL SIGNIFICANCE OF OIL AND GAS STRUCTURES IN THE GULF OF MEXICO

Dr. Benny J. Gallaway
LGL Ecological Research Associates, Inc.

LGL Ecological Research Associates, Inc. (LGL), along with Science Applications international Corporation, Inc. (SAIC) and consultants (Drs. Wilson, Stanley, and Carney of Louisiana State University, LSU), were awarded this contract on 27 February 1996. The purpose of the contracted study is to determine the cumulative ecological significance of oil and gas structures in the Gulf of Mexico, with emphasis placed upon the effects of structure removals and/or relocation. The study involves the collection, organization, and analysis of available information which will be used to provide insight into the potential contribution of oil and gas structures on the biological productivity of the Gulf of Mexico study region. The approach being used is based on application of Habitat Evaluation Procedures (HEP) in conjunction with a Geographic Information System (GIS). The Habitat approach being taken results in a focus on individual species or "guilds," making the study somewhat more tractable.

The study has six primary objectives ranging from a calculation of the total hard bottom habitat provided by oil and gas platforms in the Gulf of Mexico to the development of a geo-referenced ecosystem model that characterized the biological productivity associated with petroleum platforms as compared to the surrounding soft bottoms and other natural and artificial reefs. The model is to be structured so that estimates of change in biological productivity can be associated with activities such as platform removals and relocations, and new construction.

The environmental information needed to complete this study includes the following: data describing the number, size, distribution, and history of petroleum platforms in the Gulf; data describing the number, size, and distribution of natural and other types of artificial reefs in the Gulf; and data describing long-term trends and seasonal changes in environmental factors of consequence to key biota (e.g., circulation patterns, temperature, dissolved oxygen, etc.).

We presently have submerged surface-area measurements for 310 offshore oil and gas structures, about 9% of the total structures within the Gulf. These platforms have a total area of 10,762,508 ft^2, or about 247 acres. Assuming this set of measurements is representative of all platforms, expanding these measurements by the total number of platforms (say 3,500 suggests on the order of 2,789 acres of oil and gas structure habitat in the Gulf *not* including the basal area beneath the platform. This compares to 3,957 acres as described by Gallaway and Lewbel (1982) including the basal areas beneath the platforms. We plan to 1) obtain a larger sample size of measured platforms, including calculation of the basal area; and 2) expand the sample measurements to a total estimate in a more rigorous manner. In the final estimate, we will use the frequency of platforms of different sizes and types (i.e., number of legs) as calculated by the recent National Research Council Report concerning rig removals as the basis for expanding the sample measurements to total area.

The MMS-funded LATEX-A temperature data have been used to contour the spatial distribution of monthly average temperature for "near-surface" (10 m) and "near-bottom" (about 5 m above local bottom) habitats in the western Gulf. The contours we use are fairly heavily smoothed using something that can be thought of as a geometrically-weighted distance function. Application of the function gets rid of the smaller bumps and bulls eyes (small spatial scale features) that can occur with relatively widely spaced data. Use of smoothed contours seems appropriate since we are dealing with data from different intervals, etc. We are after general patterns rather than the microstructure. The small "x"s on the map indicate the locations of data used for that contouring.

The distribution and extent of bottom water hypoxia has been mapped from 1985 to 1996. The hypoxic zone offshore western Louisiana declined each year from 1985 to 1988, especially in 1988 as compared to 1985. During 1990 to 1992, the hypoxic zone is consistently as high or higher than the 1985 level of nearly 4,000 mi^2. A step increase to an area about 7,000 mi^2 occurred in summer 1993, and the size of the area has been maintained at about this level each year through 1996. Thus, it is clear that an increase in the size of the so-called "dead zone" has occurred over the last decade (1980s and 1990s), but what was the typical size of this area in the 1960s and 1970s?

The biological information needed includes, first, a determination of what species or guilds would constitute good evaluation species for the questions being posed. A list of such species has been selected by the project team, including the USGS sponsor (Bob Meyer) and the MMS liaison, Pat Roscigno. The list includes red snapper, which I use as the primary example in this paper.

Literature searches have been conducted that describe the general life history and habitat requirements by life stage for each of the key species. The targeted information also includes environmental tolerances and preferences for factors such as temperatures, salinity, and dissolved oxygen. Information is also being obtained that describes food and feeding, age and reproduction attributes. Age-at-size determinations are particularly important since size information (but not age information) is routinely collected by most major biological studies which have been conducted in the

Gulf. The greatest disappointment from the literature searches is that very little is really known about many aspects of the basic biology for some of even the common species that occupy offshore habitats in the Gulf.

Historical data on the distribution and abundance of Gulf biota being addressed in this study is available from the late 1950s to the present. Much of the pre-1970s data was compiled in the MMS bio-atlas series by Dr. Darnell of Texas A&M University. In this study we have compiled the National Marine Fisheries Services's (NMFS) Groundfish and SEAMAP databases from the 1970s to the present, and the data collected by NMFS observers on shrimp boats during the period 1972 to 1982, and 1992 to the present. The information includes catch rates, species composition of the catch, and size information.

The data described above (and other data) are being compiled as GIS coverages compatible with MMS GIS coverages. In this fashion one can view synoptic seasonal and spatial coverages of biological distribution and environmental conditions overlaid on habitat base maps. The observed distributions allow for tests of hypotheses regarding, for example, levels of standing stocks associated with reef and non-reef areas, standing stocks at artificial reefs versus natural reefs, etc.

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Dr. Benny J. Gallaway has worked at LGL Ecological Research Associates for the past 22 years. His Gulf of Mexico experience dates from the late 1970s and includes studies of natural and artificial reefs, soft bottom communities of the continental shelf, and studies of continental slope ecosystems. Recently, his research focus has been directed towards sea turtle and finfish bycatch issues. Dr. Gallaway received his Ph.D. from Texas A&M University where he presently serves as a visiting member for the graduate faculty for the Department of Wildlife and Fisheries Sciences.

SESSION 1J

GULF-WIDE INFORMATION SYSTEM (G-WIS)

Co-Chairs: Dr. Norman Froomer
Ms. Michele Morin

Date: December 12, 1996

Presentation	Author/Affiliation
The Gulf-Wide Information System: Background, Current Status and Future Work	Dr. Norman Froomer Minerals Management Service Gulf of Mexico OCS Region
Development and Application of the Florida Marine Spill Analysis System	Mr. Christopher A. Friel Mr. Henry Norris Mr. Peter J. Rubec Florida Marine Research Institute Florida Department of Environmental Protection
NOAAÕ's Component of the G-WIS Project	Dr. M.E. Monaco Ms. T.A. Gill Mr. J.C. Christensen Mr. Tim Battista NOAAÕ's Office of Ocean Resources Conservation and Assessment Strategic Environmental Assessments Division
Environmental Database Conceptualization for the Venezuelan Oil and Gas Industry (Manuscript not submitted)	Mr. Jose Ruiz-Garagorri GIS Leader, BADEP Project Filial de Petroleos de Venezuela, S.A.

THE GULF-WIDE INFORMATION SYSTEM: BACKGROUND, CURRENT STATUS AND FUTURE WORK

Dr. Norman Froomer
Minerals Management Service
Gulf of Mexico OCS Region

The Gulf-Wide Information System is a cooperative project between the Minerals Management Service, state and federal agencies, and the oil and gas industry to develop a geographic data base for oil-spill contingency planning in the Gulf of Mexico. The G-WIS database is also being designed to serve as a data base for a broad range of environmental analyses and assessments conducted by MMS. MMS is working with each of the five Gulf of Mexico states and NOAA through cooperative agreements to develop much of the data that will be included in G-WIS. When completed, G-WIS promises a consistent and complete data base covering the entire Gulf of Mexico.

The current phase of the G-WIS project emphasizes data development and compilation. The next two presentations describe the work being done by the State of Florida at the Florida Marine Research Institute and by NOAA's Strategic Environmental Assessment (SEA) group to develop various data sets for G-WIS. States are providing a large amount of data for G-WIS. Several of the Gulf of Mexico states have mature GIS data bases. Through the G-WIS partnerships, MMS is supporting efforts to enhance, update, and format these data bases so that the most current information from the Gulf states can be used together for regional analyses and maps within G-WIS. G-WIS also includes cooperative work with federal agencies. NOAA's SEA group will be developing the G-WIS fisheries data base, based on the application of the Estuarine Marine Living resources data base to a five-fold salinity-based spatial resolution of Gulf of Mexico estuaries.

While the geographic extent of the G-WIS project stops at the Texas-Mexico border, the G-WIS data and environmental assessment and oil spill issues extend across borders, throughout the nations of the Americas that border the ocean basin that includes the Gulf of Mexico. The third speaker, Mr. Jose Ruiz-Garagorri, will describe an effort underway in Venezuela to build an environmental data base that will be used for oil and gas environmental assessments.

DEVELOPMENT AND APPLICATION OF THE FLORIDA MARINE SPILL ANALYSIS SYSTEM

Mr. Christopher A. Friel
Mr. Henry Norris
Dr. Peter J. Rubec
Florida Marine Research Institute
Florida Department of Environmental Protection

INTRODUCTION

The Florida Department of Environmental Protection (FDEP) through its Bureau of Emergency Response (BER) coordinates its activities with the United States Coast Guard (USCG) and other agencies to respond to oil spills in Florida. Successful emergency management is highly dependent upon the availability of succinct information that accurately describes the crisis conditions at hand.

In 1992, FDEP's Florida Marine Research Instititute (FMRI) received a legislative appropriation to develop an "automated marine spill sensitivity atlas" to generate targeted information for oil spill emergency response decisions. After soliciting proposals, the Coastal and Marine Resources Assessment (CAMRA) group at FMRI contracted with Environmental Systems Research Institute (ESRI) to initiate development of the Florida Marine Spill Analysis System (FMSAS).

The principal goal of the FMSAS project was to design and develop a prototype GIS application that integrated a variety of information (digital maps, imagery, and tabular data) with targeted analytical routines needed to implement an oil-spill contingency planning, response, and damage assessment strategy focused on protection of natural resources. An additional requirement was to implement a pilot study area in the Florida Keys. The project included needs assessment, conceptual and physical application design, database integration, interface development, and the formulation of a user's guide, program maintenance manual, and statewide implementation plan.

METHODS AND RESULTS

Environmental Sensitivity Index Mapping

A specific requirement of the FMSAS was the ability to portray real-time spill conditions relative to marine resources at risk, such as bird rookeries, turtle nesting sites, or fisheries habitat. From an information content perspective, environmental sensitivity index (ESI) maps provide the fundamental base map series.

Prior to FMSAS, Florida had developed two hard copy paper atlases targeted for oil spills, the "South Florida Oil Spill Sensitivity Atlas" published in 1981, and the "Sensitivity of Coastal Environments and Wildlife to Spilled Oil in Florida" seven volume series created in 1983-84 by Research Planning Institute (RPI). These atlases consist of 7.5-minute United States Geological Survey (USGS) topographic maps annotated with ESI shoreline types, wildlife-resource areas, and spill-response staging areas and strategies. The ESI ranking of shorelines is critical because it cartographically indicates the vulnerability of specific shorelines to oil spills. Expanding urbanization and coastal alteration over the last decade in Florida have rendered these ESI rankings obsolete in many areas.

In July 1993, FMRI took final delivery from ESRI of the prototype FMSAS that included over 30 natural resource and spill response-related databases for the Florida Keys, including threatened and endangered species, ESI shorelines, benthic habitats, bathymetry, managed area and National Wetland Inventory (NWI) boundaries, satellite imagery, aerial photography, and on-line tabular reference material with response strategies for specific shoreline types. It acts as a Spatial Decision Support System (SDSS) and can be used to make maps, reports, and information summaries. The system was expanded under emergency conditions to include Tampa Bay and used to respond to the Tampa Bay oil spill (Friel *et al.* 1993; FDEP 1996).

Refinement of FMSAS

Lessons learned from the Tampa Bay spill were used to further refine the conceptual design and physical characteristics of the FMSAS. FMRI held debriefings of involved parties to identify functions of the FMSAS that performed well and those that needed enhancements. The FMSAS full-scale implementation report prepared by ESRI described a long-term plan for the incremental development of a statewide GIS-based oil spill response system for Florida. The plan prioritized key datasets with the challenge being to assemble and automate the data for each region of the state. Several paths for extending the functionality of the FMSAS were identified in the plan, and FMRI has taken deliberate steps since 1993 to implement these enhancements.

Coastal ESI Mapping Statewide

From 1992 through 1996, FMRI worked with RPI to create a GIS showing the statewide distribution and location of important biological and cultural coastal marine resources as ESI maps. In addition to the five-volume hard-copy atlases (FDEP-RPI 1996), the deliverable included ARC/INFO GIS coverages. Extensive consultations with FMRI staff and partner agencies were made in order to incorporate the most recent habitat and resources at risk data. To date, 265 USGS 7.5 minute quadrangle maps have been completed in digital ESI format. Hence, most of the coast of Florida has been digitally mapped using GIS.

A new contract is currently in place with RPI to create ESI maps of the lower St. Johns River in northeast Florida. It is anticipated that ESI mapping for the lower Apalachicola River will start in September 1997. FMRI will soon be working on converting existing ESI layers into the new ESI standards (CCEER-LSU 1996) that Minerals Management Service (MMS) established for the Gulf-Wide Information System (G-WIS). The G-WIS ESI maps for west Florida will be delivered to MMS as part of a new cooperative agreement.

Habitat Suitability Index Modeling

RPI's Florida ESI maps presently lack fish and invertebrate species distributions. Normally, one would contour these distributions from fisheries monitoring data. But FMRI only conducts Fisheries Independent Monitoring (FIM) in 5 out of 18 main estuaries. Hence, an approach is being developed that allows the creation of predicted fish and invertebrate species distribution maps for estuaries that are not surveyed by FIM.

FMRI is collaborating with NOAA's Strategic Environmental Assessments (SEA) Division to model and map the geographic distributions of fishery species at different life stages. FIM data are being subjected to multivariate analyses to classify fish communities associated with environmental gradients. Biologically relevant ranges of environmental parameters are being contoured and stored in the GIS database. Suitability indices (SIs) are being determined, to explain which zones are most important in explaining species abundance. The environmental maps being created spatially summarize seasonal changes in environmental factors such as salinity and water temperature (Rubec *et al. In press*).

The Habitat Suitability Index (HSI) concept centers around the assumption that the "importance" of a geographic area can be defined by estimating the habitat requirements of a species and quantifying habitat availability as raster maps. The HSI model utilizes the ARC/INFO Grid module to access environmental data layers overlaid in the GIS database. The HSI formula calculates a composite HSI coefficient by taking the geometric mean of the SIs associated with the environmental coverages. After all the cells across the estuary are evaluated, a map is produced that depicts the geographic distribution and abundances of the species by life stage. The goal of the HSI modeling is to produce predicted maps of approximately 50 species of juvenile and adult marine fish and invertebrates in west Florida estuaries over the next few years. The fisheries distribution maps provide an important ESI component needed to support spill-response mapping and modeling as well as other ecosystem management initiatives.

The Move to ArcView

The original FMSAS was an Arc Macro Language-based application designed to run ARC/INFO on UNIX workstations. While it was quite powerful, the ESRI prototype application had some drawbacks. First, it was not very user-friendly. An ARC/INFO analyst was required to operate it. Second, it was expensive to maintain, requiring hundeds of hours simply to keep all the coding congruent with any changes or additions to the data, software upgrades, and new hardware. Third, the analytical "resources at risk" tool needed modification to be capable of handling the complex ESI data layers currently under development by RPI. These reasons prompted FMRI staff to look at developing a more easily maintained, portable application that would keep all of the functionality of the original FMSAS but run on relatively inexpensive desktop computers.

FMSAS Migration to ArcView 2.1

FMRI determined that the new application should run in ArcView because of its ability to meet all of the system requirements and maintain flexibility for future developments. Furthermore, an ArcView user license is considerably less expensive than a comparable configuration of ARC/INFO.

In early 1995, ESRI was contracted to develop a statewide ArcView version of the FMSAS that would run on both UNIX workstations and Windows PC-based platforms (FDEP 1996). ESRI developed special functions in ArcView version 2.1 and extensive AVENUE language scripting. The ArcView 2.1 FMSAS can incorporate ARC/INFO coverages. Habitat coverages and text from the original FMSAS, and the statewide ESI coverages created by RPI, were added to create a statewide oil spill response system.

By 1996, the FMSAS application and attendant GIS data were successfully installed as part of FMRI's main database, and regional portions of the database were running at BER offices. BER personnel were trained by FMRI in the use of ArcView and supplied with laptop computers. Spill response data for each BER region of Florida can now be accessed, overlaid, and displayed on laptop or desktop computers. BER spill responsers now possess a powerful SDSS capable of assessing oil spills as well as providing accurate natural resources information.

Enhancing the FMSAS

The BER staff were given several months to work with the application and get a feel for how it worked. They were then interviewed by FMRI staff to see where the application failed to meet user needs. BER staff wanted the "resources at risk" tool to differentiate between oiled resources that fell outside managed areas, such as preserves and parks, and resources that fell inside them. This would allow them to determine jurisdiction and also to calculate fines according to Florida's Natural Resources Damage Assessment (NRDA) regulations, which call for larger fines should resources in managed areas be impacted by a spill. They also wanted a tool that managed boom deployment, both graphically and in a database; the ability to display and analyze trajectory model output; a gazeteer that would allow them to move to a location by entering either a place name or a distance and a bearing from a place name; and, finally, a user guide written in plain English!

Migration to ArcView 3.0

These BER comments layed the foundation for the next wave of development. A contract with ESRI is presently in place that addresses the BER issues, as well as several additional technical issues such as a reduction in the need for RAM, increased speed, and integration of customized ArcView version 3.0 extensions. The latest version of the FMSAS is being developed to accomodate the MMS G-WIS data structure (CCEER-LSU 1996). Delivery of the ArcView 3.0 FMSAS is expected in April, 1997.

Integrating Area Contingency Plans with FMSAS

FMRI recently completed a contract for the Tampa Bay National Estuary Program, which linked the Tampa Bay Oil Spill Area Contingency Plan (ACP) to the spatial information in the FMSAS using ArcView 2.1. More than 1000 pages of hard copy textual information and maps were scanned and digitized, and then added to the FMSAS database. The Tampa Bay FMSAS application can access ESI coverages, as well as maps showing boom placements, priority areas for protection, etc., plus textual regulations, addresses, and response strategies from the ACP. The ACP maps are tiled so that they can be overlaid and compared with the ESI maps. FMRI is working with BER to link ACPs for other areas of Florida to the FMSAS.

Applications of the FMSAS

Use By Spill Command Center

The FMSAS is now being re-examined in relation to how it should be used for spill response and cleanup. In the event of a large spill, FMRI staff will respond by bringing a UNIX workstation with both ArcView and ARC/INFO loaded, a high speed laptop, a 36" inkjet plotter, and other necessary peripheral hardware to the spill response command center. This will provide a higher level of support through the production of large, high quality maps, increased flexibility to changing situations, and quicker response to complex analytical questions. Workstations will be used for applications requiring higher level cartographic analyses and output. PCs and laptops will be used for other applications, such as the generation of resources at risk reports, assessing shoreline oiling and cleanup, preliminary injury assessment, and decision-support.

Data Collection In The Field

During an oil spill, field data needs to be collected and rapidly communicated. This usually involves recording spill conditions on paper Shoreline Cleanup Assessment Team (SCAT) forms, before the data is transported or faxed to a command center. The data then needs to be brought together on a computer. Delays associated with the transcription, computer-entry, and analysis of data often prevent information from being used in a timely manner.

To overcome these problems, a pen-based computer was recently tested in wireless communication with a command center (Rubec *et al.* 1996). The Hammerhead pen-based computer containing a global positioning system (GPS) receiver was tested with SHORECLEAN and a portion of the FMSAS installed in ArcView. SHORECLEAN developed by Group LGG/ES2 facilitates entry of information concerning shoreline oiling conditions and mimics the SCAT form methodology.

The research tested the feasibility of using ArcView, GPS, and SHORECLEAN on the pen-based computer to facilitate real-time two-way communication of the information needed for spill response and shoreline cleanup (Rubec *et al.* 1996). The evaluation consisted of: 1) testing the entry of data onto the SCAT forms within SHORECLEAN; 2) querying the FMSAS installed at FMRI by means of a wireless telephone for information concerning ESI coverages in the area of a hypothetical spill; 3) making Shoreline Oiling Summary (SOS) maps of an impacted shoreline to delineate the extent of oiling in relation to resources at risk; and 4) transmitting the data to the command center situated at FMRI.

Shape files of the impacted area with shoreline segments created in ArcView, and the SCAT data collected with SHORECLEAN were transmitted to FMRI, using a U.S. Robotics Megahertz digital modem linked to a Nokia 232 cellular telephone, using PC Anywhere communications software. The data were analyzed at FMRI to create composite SOS maps of adjoining shoreline segments in ArcView.

The evaluation helped to define the specifications needed for collecting and communicating data associated with shoreline cleanup-response operations. The areal extent of oil on impacted shorelines can be monitored, and cleanup teams coordinated using the information. FMRI is examining the feasibility of linking SHORECLEAN with the FMSAS to facilitate rapid decision-making from maps in the command center during spill response operations. The shoreline assessment system being developed has the potential to support both shoreline cleanup and response, and NRDA.

Spill Trajectory Models

One of the things that was learned from the Tampa Bay spill was that NOAA's spill trajectory results could not be loaded into the FMSAS. Both the USCG and BER staff expressed an interest in being able to see large maps depicting the distribution of biological resources with spill trajectories superimposed as polygons. They also wanted to see the trajectory polygons analyzed by the "resources at risk" decision-support software in the FMSAS to help them determine protection strategies. In 1995, FMRI collaborated with NOAA HAZMAT scientists to develop a digital distribution standard that would allow the FMSAS to import spill trajectory output from HAZMAT's OSSM model (Galt *et al.* 1996). The latest version of the FMSAS will be able to load and display NOAA's spill trajectory output.

Another collaborative project underway with scientists at the University of South Florida's Department of Marine Science will integrate the FMSAS with oil spill models in Tampa Bay (Luther 1996). The project will link the FMSAS to data acquisition from the Physical Oceanographic Real-Time System, hydrodynamic circulation modeling in 3-D, and spill trajectory models to create an end-to-end contaminant management system.

SUMMARY

Several governmental agencies, utility companies, and private firms have obtained GIS coverages and interface coding from the FMSAS. The FDEP is fostering cooperative agreements and Memorandums of Understanding (MOU) with other agencies, such as MMS, to foster a collective investment so that the FMSAS design and prototype application can be shared and improved without redundant expenditures. It has become apparent that the basic design, natural resource sensitivity databases, and "resources at risk" analyses that form the basis of the FMSAS have widespread utility for analyzing a variety of marine and coastal impacts. Significant database development efforts are underway statewide, and resources are being dedicated to enhance the modeling functionality of the FMSAS. The long-term goal is to continue development of the FMSAS to provide maximum protection of Florida's natural resources from oil spills.

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Christopher A. Friel is Research Administrator and Director of the Information Science and Management (IS&M) Section at the Florida Marine Research Institute. His main interest is coastal resources management. He received his M.S. in geography from Western

Illinois University and a B.S. in geography from Northern Michigan University.

Henry Norris is an Associate Research Scientist within the IS&M Section and heads the Geographic Information Systems Program. He is an expert GIS analyst. He is presently completing an M.A. in geography at the University of South Florida and has a B.A. in geography from the same university.

Peter J. Rubec is a Research Scientist (Oil Spill Assessment) with the Ecological Modeling Program within the IS&M Section. His main interests are modeling linked to GIS that relates fisheries to habitat and developing databases to support Natural Resources Damage Assessment. He received a Ph.D. in Zoology from Texas A& M University, and M.S. and Hons. B.S. degrees in biology from the University of Ottawa.

NOAAÕ'S COMPONENT OF THE G-WIS PROJECT

Dr. M.E. Monaco
Ms. T.A. Gill
Mr. J.C. Christensen
Mr. Tim Battista
NOAAÕ's Office of Ocean Resources Conservation and Assessment
Strategic Environmental Assessments Division

PRESENTATION SUMMARY

This summary of our presentation describes an evolving federal, state, and private sector partnership towards the development of the Gulf-Wide Information System (G-WIS) database and its integration into an ArcView-based information system. This work will be integrated into NOAAÕ's NOS-GIS family of desktop systems to support coastal and marine resource assessments. Current partners in this effort are NOAAÕ's Office of Ocean Resources Conservation and Assessment (ORCA) and the Coastal Services Center, DOIÕ's Minerals Management Service (MMS), various state environmental agencies of the five Gulf of Mexico states, Environmental Systems Research Institute, Inc., and the Research Planning, Inc. Collectively, we are compiling the G-WIS data and developing computer-based products to support G-WIS oil-spill related activities, such as querying and mapping species distributions.

This effort directly supports G-WIS by providing estuarine, coastal, and marine species distributions and by the development of a prototype desktop information system to query and analyze the biological. Although our current work is primarily focused on G-WIS related activities, we envision the prototype desktop analysis system as 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 G-WIS information, estuarine and marine living resource distribution data, and estuarine physical and hydrological characteristic data. A unique aspect of this work is that our efforts build on existing ESRI Arc-View development work, including the Florida Marine Research InstituteÕ's (FMRI) AV Marine Spill Analysis System (AVMSAS). New features include: a more user-friendly front-end to ArcView for querying the data, access to offshore, G-WIS, and Estuarine Living Marine Resource (ELMR) data; and a complementary analytical GIS tool for G-WIS data. Our plans are to populate and complete the prototype ArcView-based coastal desktop system in early 1998.

Our projectÕ'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 G-WIS and will be broader in scope and capability as new partnerships are forged via the NOS-GIS.

Dr. Mark Monaco has worked for NOAA for 13 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 2H

NORTHEASTERN GULF OF MEXICO PHYSICAL OCEANOGRAPHY

Co-Chairs: Dr. Alexis Lugo-Fernández
Dr. Walter R. Johnson

Date: December 12, 1996

Presentation	Author/Affiliation
The Florida Shelf Lagrangian Experiment (FSLE): An Overview	Mr. Rik Wanninkhof National Oceanic and Atmospheric Administration Dr. Wm. J. Wiseman, Jr. Louisiana State University Dr. Gary Hitchcock University of Miami Dr. Gabe Vargo Mr. Rob Masserini Mr. Howard Rutherford University of South Florida Dr. Mary-Lynn Dixon University of Rhode Island Mr. David Ho Columbia University Dr. Bill Asher Mr. Roy Shiff Mr. Chris Zappa University of Washington
Near-shore Circulation in the Northeast Gulf of Mexico: Observations and Modeling	Dr. Walter R. Johnson Minerals Management Service Herndon, Virginia
Panel Discussion Introduction	Dr. Alexis Lugo-Fernández Minerals Management Service Gulf of Mexico OCS Region
DeSoto Canyon Eddy Intrusion Study (Panel Discussion)	Dr. Thomas J. Berger Science Applications International Corporation
Northeastern Gulf of Mexico Physical Oceanography Program: Eddy Monitoring and Remote Sensing (Panel Discussion)	Dr. Richard P. Stumpf U.S. Geological Survey Center for Coastal Geology
Northeastern Gulf of Mexico Coastal and Marine Ecosystems Program: Ecosystem Monitoring Mississippi/Alabama Shelf—An Overview of the Oceanographic Processes Study Task (Panel Discussion)	Mr. F.J. Kelly Geochemical and Environmental Research Group College of Geosciences and Maritime Studies Texas A&M University

THE FLORIDA SHELF LAGRANGIAN EXPERIMENT (FSLE): AN OVERVIEW

Mr. Rik Wanninkhof
National Oceanic and Atmospheric Administration

Dr. Wm. J. Wiseman, Jr.
Louisiana State University

Dr. Gary Hitchcock
University of Miami

Dr. Gabe Vargo
Mr. Rob Masserini
Mr. Howard Rutherford
University of South Florida

Dr. Mary-Lynn Dixon
University of Rhode Island

Mr. David Ho
Columbia University

Dr. Bill Asher
Mr. Roy Shiff
Mr. Chris Zappa
University of Washington

FSLE had three important goals:

1. to demonstrate the utility of the gas sulfur hexafluoride, SF_6, as a Lagrangian tracer in shelf environments, and to use it to characterize the dispersive regime over the west Florida shelf in spring;
2. to tag a shelf water mass in spring and follow the evolution of the phytoplankton community and associated water mass properties; and
3. to document air-sea gas exchange rates and their relationship with external processes.

All were achieved at some level of success. Sulfur hexafluoride was injected throughout the water column by bubbling it into the bottom water along a four kilometer-long line orthogonal to the isobaths and traced during the next 17 days. Water mass properties were monitored by a near-surface thermo-salinograph and nearly 100 CTD casts with associated whole water samples. Currents were monitored using CODE-type drifters and a hull-mounted 150 Khz ADCP.

Phytoplankton health was monitored with in situ and deck respiration measurements, using oxygen isotopes and growth chambers with and without nutrient additions. Air-sea exchange rates were measured by the dual deliberate tracer technique using SF_6 and He^3 (Wanninkhof *et al.* 1993). The partial pressure of carbon dioxide was measured continuously such that air-sea fluxes of CO_2 could be determined. Whitecaps and skin temperature were observed by a variety of means. Clear skies allowed acquisition of a number of good AVHRR images of the sea surface, and winds obtained from a nearby buoy corroborated those measured aboard the NOAA ship, the R/V Malcolm Baldrige.

The near surface expression of the SF_6 patch grew rapidly from its initial deployment dimensions to a patch 12 by 25 kilometers in size, with the long axis orthogonal to the isobaths, within four days (Figure 2H.1a). After 13 days, the patch was 25 by 45 kilometers in size (Figure 2H.1b). Vertical profiles of the SF_6 distribution suggest that the deeper layers sheared away from the near-surface waters, but the two patches appear to have coalesced by day 13 and the deeper waters may have been supplying gas to the near surface waters. Estimates of the patch dimensions 7 and 12 days after injection suggest an effective diffusion

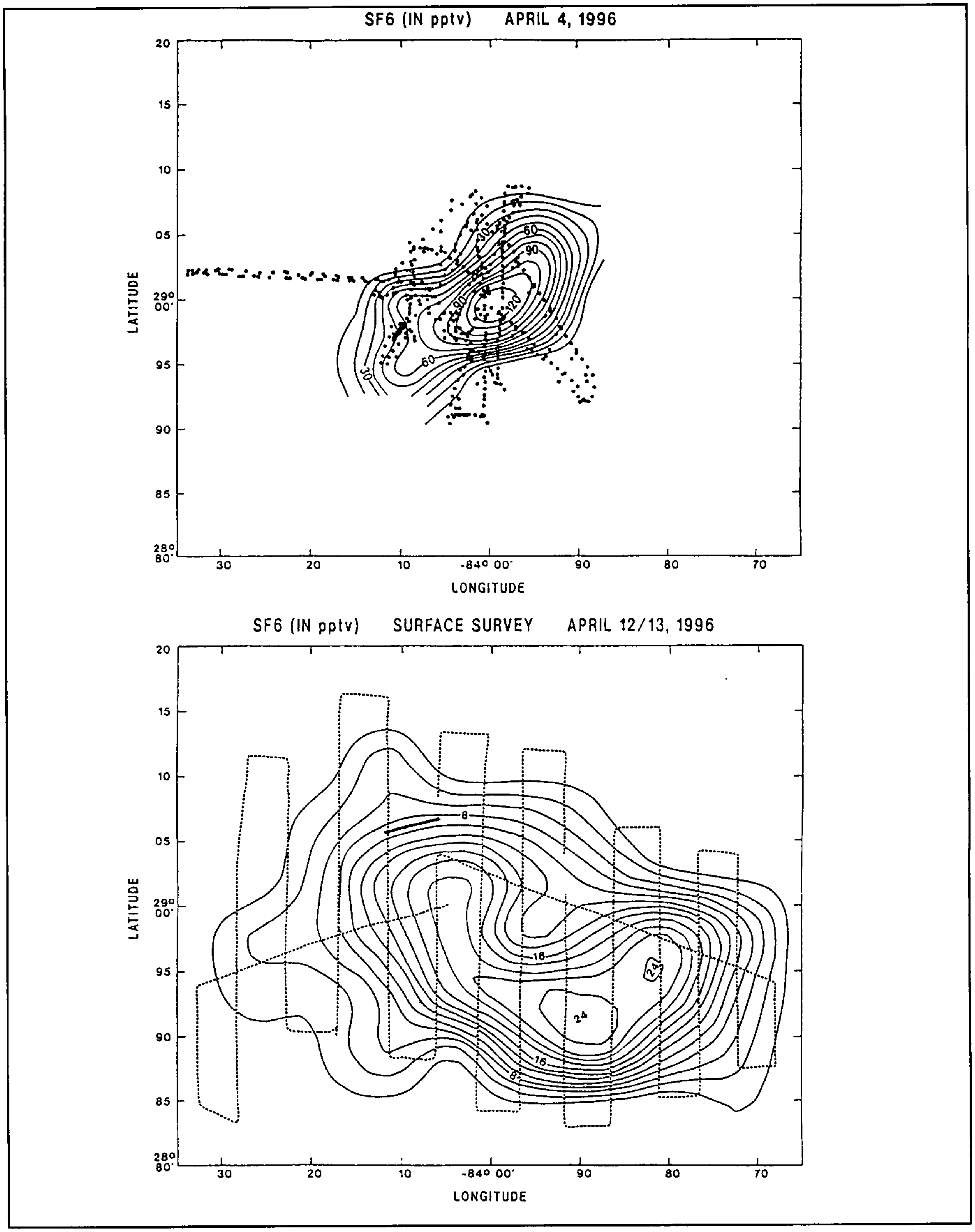

Figure 2H.1. The distribution of upper layer SF_6 at two different times after release. The thick line in the lower figure indicates the locus of the initial release.

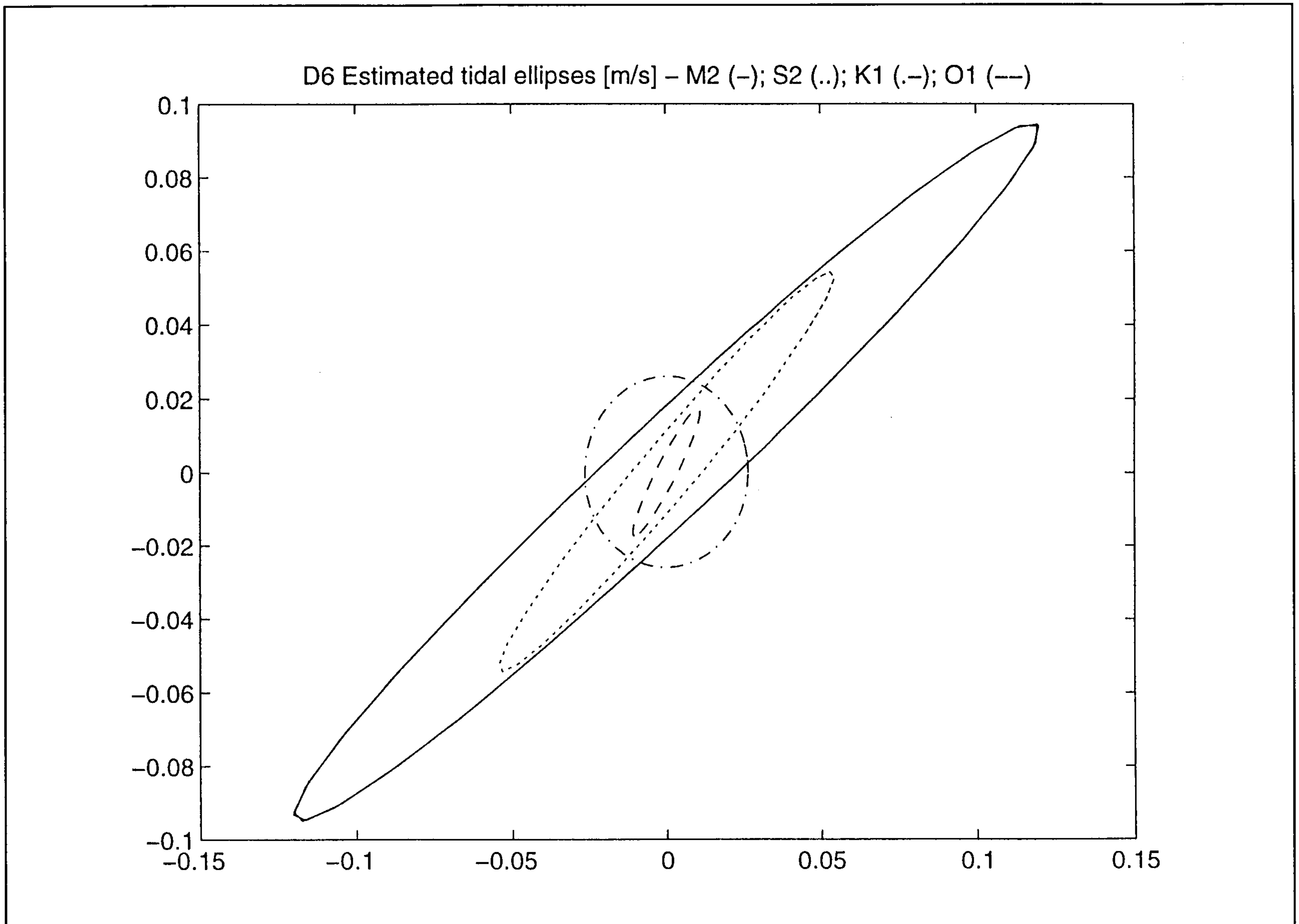

Figure 2H.2. Estimated tidal ellipses for all data collected from drifter 6, assuming the surface waters moved as a slab. The circular nature of the K1 ellipse is probably due to the confounding of inertial and K1 motions.

coefficient of 10^2 m^2 s^{-1}. This is in the upper range of Okubo's estimates based primarily on diffusion estimates for smaller patches and shorter duration (Okubo 1971).

The energetic nature of the coastal water movement and associated vertical shearing of the patch contribute to the high apparent diffusivity. The near-surface drifters indicate that the shelf waters oscillated, largely parallel to the isobaths, in response to the local wind forcing. This result is corroborated by the tracks of drifters deployed by Walter Johnson (MMS) and Peter Niiler (SIO) as part of a larger study of the northeast Gulf of Mexico. Superimposed on this low-frequency flow field was an energetic tidal-inertial regime dominated by the semi-diurnal tides. Assuming the shelf waters moved as a slab, the drifter currents were analyzed for the tides. The results (Figure 2H.2) are quite similar to those found by Marmorino (1983) and Weisburg *et al.* (1996) from longer-term moored current meter data. It is not clear that the shelf waters move as a slab. Significant divergence in the low-frequency flow field is apparent in the drifter paths from Johnson and Niiler's study. The ADCP data set has not yet been reduced.

Total dissolved nitrate and nitrite was low in the water column during the experiment. Ammonium was also, generally, low. There were, though, exceptions. Particulate carbon, nitrogen, and phosphorus were measured at one depth at 30 stations. Generally, C/N was low and N/P was high, suggesting high particulate nitrogen values due to a heterotrophic environment. Phaeophytin to chlorophyll ratios were high, variable and decreased with time. The carbon to chlorophyll ratios were also high, all of which suggests a senescent phytoplankton population. This is supported by the trend of inorganic carbon in the water column. (Historically, this has been a region where diatom blooms have been observed in February and March.) Incubation experiments with nutrient additions result in slow growth rates, while incubations without nutrient additions imply no net growth, suggesting the phytoplankton population was nutrient limited. This is supported by the oxygen bottle experiments. Three of four experiments show net respiration over a 24-hour period. The fourth experiment, which indicated net production, occurred at a time when the upper layer waters overlay a mass of high nutrient water, which might have been fertilizing the upper layers. The O^{18} experiments have not yet been fully analyzed.

The Langrangian nature of the study facilitates estimates of productivity based on changes of carbon in the water column. The region was undersaturated with respect to pCO_2 but trended towards equilibrium during the experiment. Gas exchange, heating of the water, and net respiration/remineralization all contribute to increasing pCO_2 in the water column. Initial calculations based on observations with time near the center of the patch suggest that 55 % of the increase was caused by heating of the water during the experiment, 15 % by invasion of CO_2 from the atmosphere, and 30 % due to net respiration/remineralization . Remineralization rates based on water column inorganic carbon trends are estimated to be 0.35 μmol kg^{-1} day^{-1} (9 mmol m^{-2} day^{-1}).

The weather was exceptionally fine during the experiment. Minor storms occurred on the first and last days of the experiment and for a brief period midway through FSLE. Whitecapping was minimal. An average air-sea gas exchange velocity of 7 cm/hr has been estimated from the SF_6 and He^3 data over the course of the experiment with an average wind speed of 5 m/s. The fine scale wave breaking data focusing on the laminar sub layer has yet to be fully reduced.

During FSLE, we tagged a patch of the inner shelf using SF_6 and mapped the patch for 17 days. The evolution of the patch is a non-trivial process, which is not yet fully explained. Vertical shearing in this shallow water makes a fully three-dimensional explanation of the process imperative. The water mass that was tagged appears to have been the site of a recent phytoplankton bloom, as indicated by low pCO_2 levels in the water column, which was dying at the time of FLSE. The biological data represent a uniquely comprehensive description of the evolution of a senescent phytoplankton community. The air-sea exchange studies were as comprehensive as the ambient environment permitted. The low wave conditions encountered in the field prevented any serious measurements of the role of large-scale whitecapping on the gas exchange rates across the sea surface.

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Rik Wanninkhof received his degree from Columbia University and presently is employed by NOAA. His research interests include global oceanic carbon cycling, air-sea gas exchange, and applications of deliberate tracers to bio-geochemical studies.

William Wiseman received his Ph. D. degree from The Johns Hopkins University and presently serves as Director of the Coastal Studies Institute and Professor of Oceanography and Coastal Sciences at Louisiana State University. Dr. Wiseman's interests encompass shelf and estuarine transport processes.

Gary Hitchcock received his Ph. D. degree from the University of Rhode Island and presently serves as an associate professor at the University of Miami's Rosenstiel School of Marine and Atmospheric Sciences. His research interests include physical-biological interactions, Lagrangian measurement techniques, and phytoplankton ecology.

Gabe Vargo received his Ph. D. degree from the University of Rhode Island and presently serves as Professor of Marine Science at the University of South Florida. His research interests include phytoplankton ecology.

Rob Massarini and Howard Rutherford are graduate students in the laboratory of Kent Fanning at the University of South Florida. Their interests are nutrient dynamics and development of new techniques for high precision ultra-low level nutrient analyses of sea water.

Mary Lynn Dixon received her Ph. D. degree at Oregon State University and presently serves as a Research Associate at the University of Rhode Island. Her interests include phytoplankton ecology and water column net and productivity measurements using oxygen and oxygen isotopes.

David Ho is a Graduate Student at the Lamont-Doherty Earth Observatory of Columbia University in the laboratory of Peter Schlosser. His interests lie in tracer studies of water and air masses.

Bill Asher received his Ph. D. degree from the Oregon Graduate Center. He is presently employed as a visiting faculty member at the University of Washington. His research interests focus on air-sea gas exchange as moderated by water composition and ambient wave conditions.

Chris Zappa and Roy Shiff are graduate students at the Applied Physics Laboratory of the University of Washington, working in the laboratory of Andy Jessup. Their interests lie in remote thermal sensing of the sea surface.

NEAR-SHORE CIRCULATION IN THE NORTHEAST GULF OF MEXICO—OBSERVATIONS AND MODELING

Dr. Walter R. Johnson
Minerals Management Service
Herndon, Virginia

OBSERVATIONAL RESULTS: LAGRANGIAN DRIFTERS AND CURRENT METERS

Principal Investigators:
Dr. Wilton Sturges, Florida State University
Dr. Pearn P. Niiler, Scripps Institute of Oceanography
Dr. Robert H. Weisberg, University of South Florida

Lagrangian Drifters

ARGOS-tracked drifters have been deployed by aircraft over a grid of 20 stations across the northeastern Florida shelf. The stations are located inside the 60m isobath in the innershelf region bounded by 28°N latitude and 88°W longitude (Figure 2H.3). The objectives for these deployments are: (1) to describe and quantify the seasonal velocity field; (2) to estimate Lagrangian time scales and single-particle diffusivity; and (3) to test the skill of modeled surface velocity fields from a hydrodynamic model funded by MMS. Deployments have been made approximately twice a month beginning in February 1996, for a period of one year. This will require a total of 370 drifters drogued at a 1m depth. The drifters' positions will be determined by Service ARGOS five to eight times a day for the first 30 days. Afterwards, drifters will be on for eight hours and off the following sixteen hours, over a total of 90 days. The positional data are being delivered by Service ARGOS and plots are being posted on the Internet at <http://gulf.ocean.fsu.edu> for distribution. The final data set will be prepared by the Scripps team to produce the statistical summaries, which will then be incorporated into future risk assessments.

Monthly plots of the composite tracks of all the drifters reporting (spaghetti diagrams) have been prepared, and examples are shown in Figures 2H.3 - 7.

In March, the buoys primarily indicated low-frequency alongshore movements, with reversals on the 7- to10-day time scales (Figure 2H.4). After several reversals, the drifters that were deployed in the Big Bend area moved westward, past Cape San Blas, and then into somewhat deeper water. The DeSoto Canyon area indicated significant offshore motion during southward (eastward) periods of the reversals. Two drifters that reached the shelfbreak moved along the Loop Current and made cyclonic patterns around an eddy in the area just offshore of the Dry Tortugas.

In May, the buoys moved to the west and northwest, over much of the region of interest (Figure 2H.5). The drifters seemed to recirculate in Alabama waters and offshore of the Florida Panhandle. Evidence of the cyclonic eddy off the Dry Tortugas continued.

In July, the buoys in the Big Bend waters moved slowly (Figure 2H.6). The drifters off the Panhandle moved eastward. Several buoys interacted with large eddy structures, both cyclonic and anticyclonic. One drifter was captured by a nascent Loop Current Eddy and remained in the eddy for the next several months. To the north of the Loop Current Eddy, several buoys moved around a large cyclonic feature, which may have been two cyclonic eddies adjacent to each other.

In October, a major westward event occurred, and domain of the plot was changed to include the entire northern Gulf of Mexico to show the tracks of the buoys (Figure 2H.7). Almost all of the buoys north of 28°N moved alongshore rapidly to the west, past the Mississippi River Delta. This may have been caused by the re-establishment of the Louisiana/Texas Coastal Current after the summer "reversed circulation" period. A few drifters off Tampa Bay moved southward into the Florida Straits.

In November, the westward motion of the drifters declined, although several from Alabama waters moved west of the Mississippi River Delta, and then farther offshore (Figure 2H.8). The buoys deployed in the Big Bend and the Panhandle moved southward and south-eastward alongshore. Two drifters were still moving with the Loop Current, centered about 25°N, 87°W. The buoys that had entered the western half of the Gulf continued westward in the coastal current, or moved offshore, possibly interacting with a large eddy.

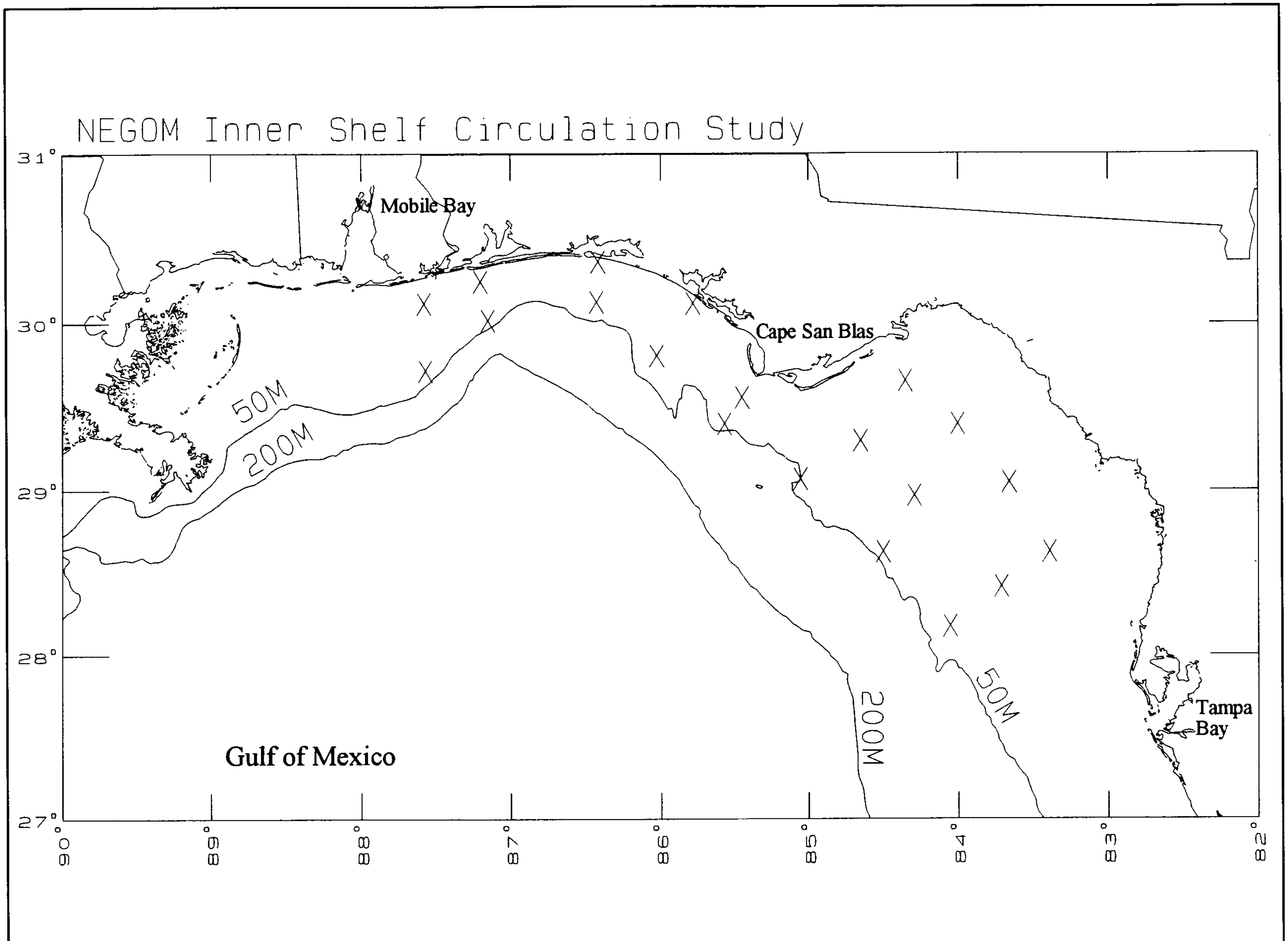

Figure 2H.3. Drifting buoy deployment locations. The 50m and 200m isobaths are indicated.

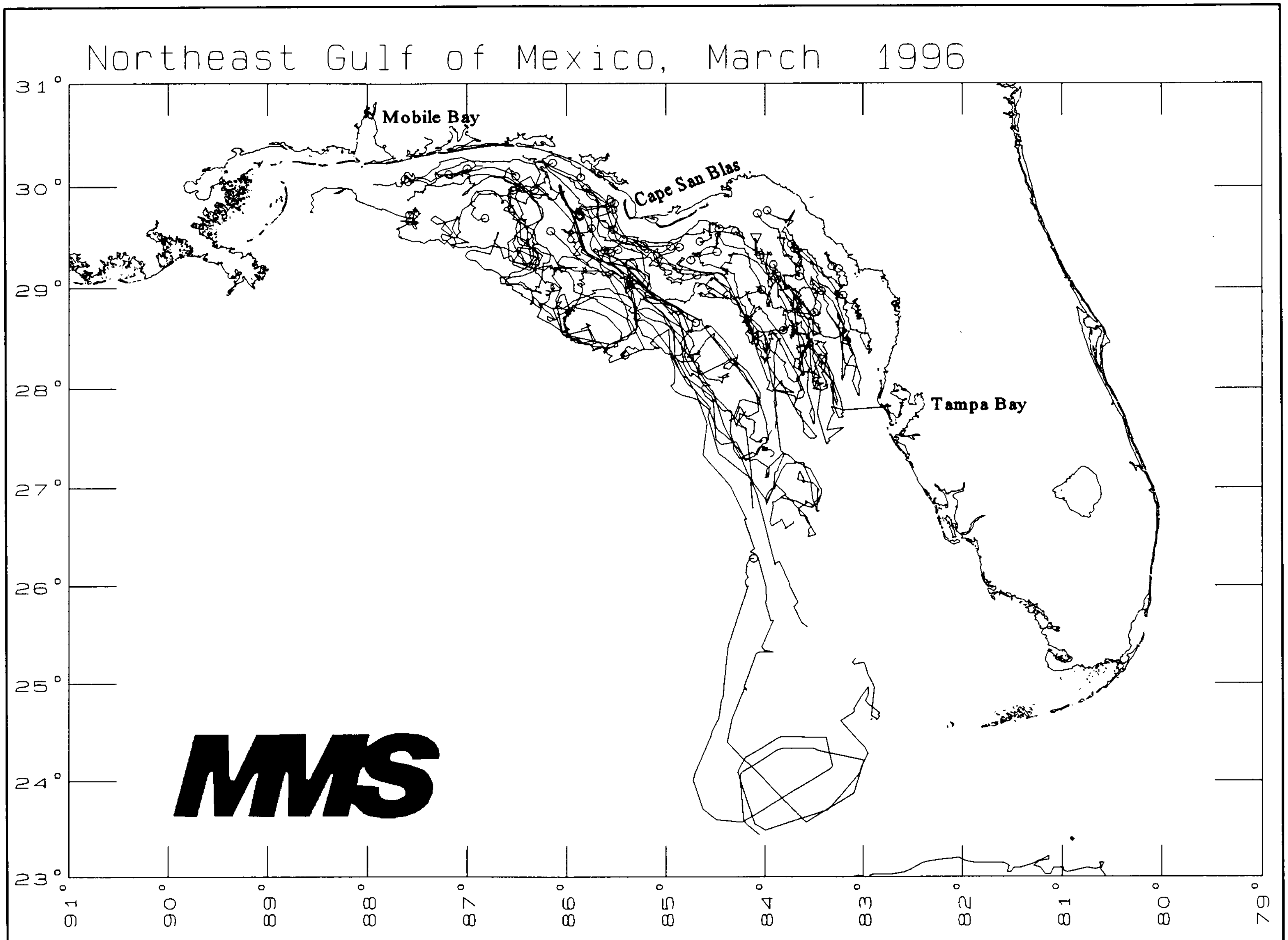

Figure 2H.4. Tracks for the drifting buoys for March 1996. Circles denote the beginnings of the tracks.

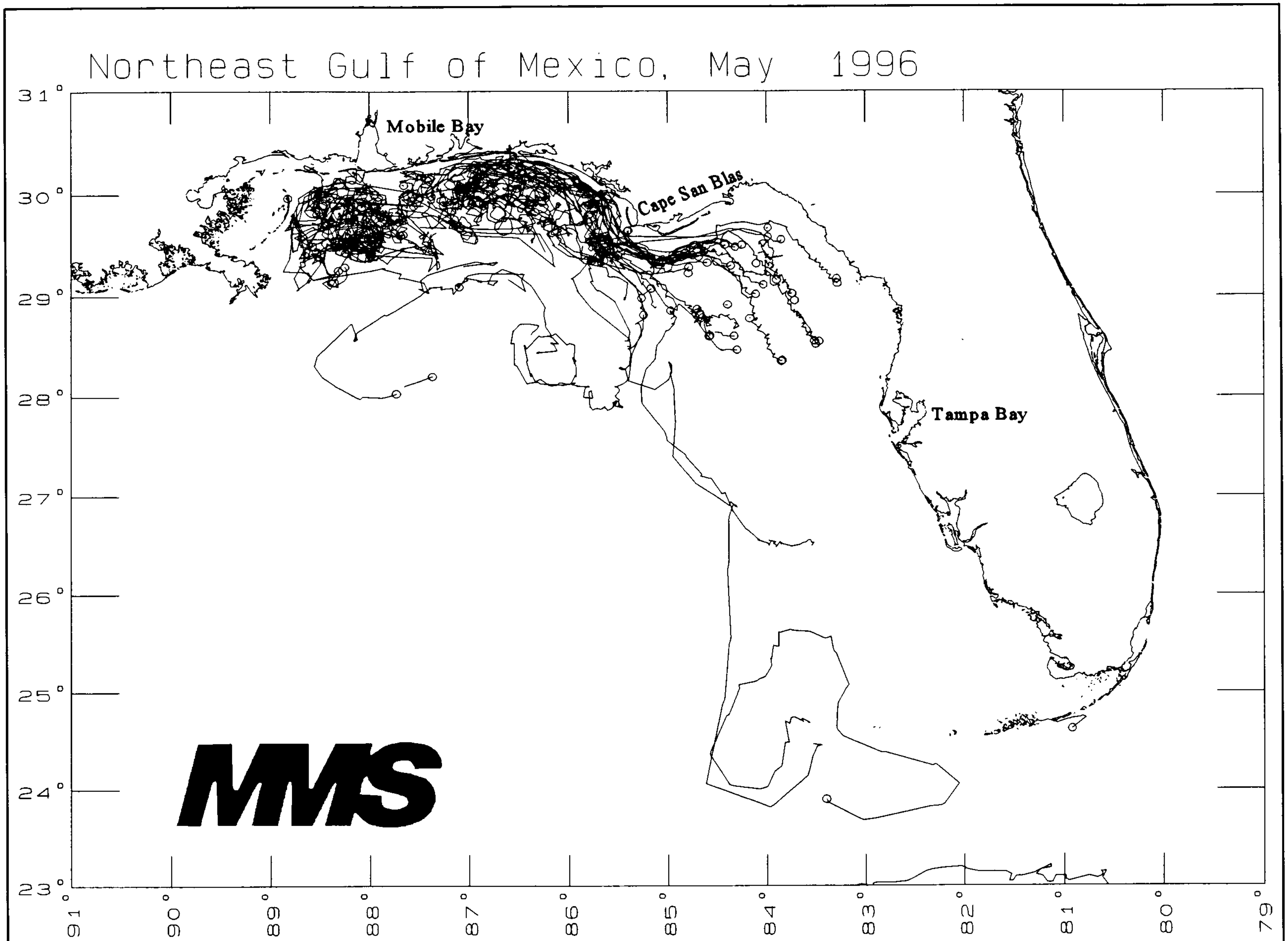

Figure 2H.5. Tracks for the drifting buoys for May 1996. Circles denote the beginnings of the tracks.

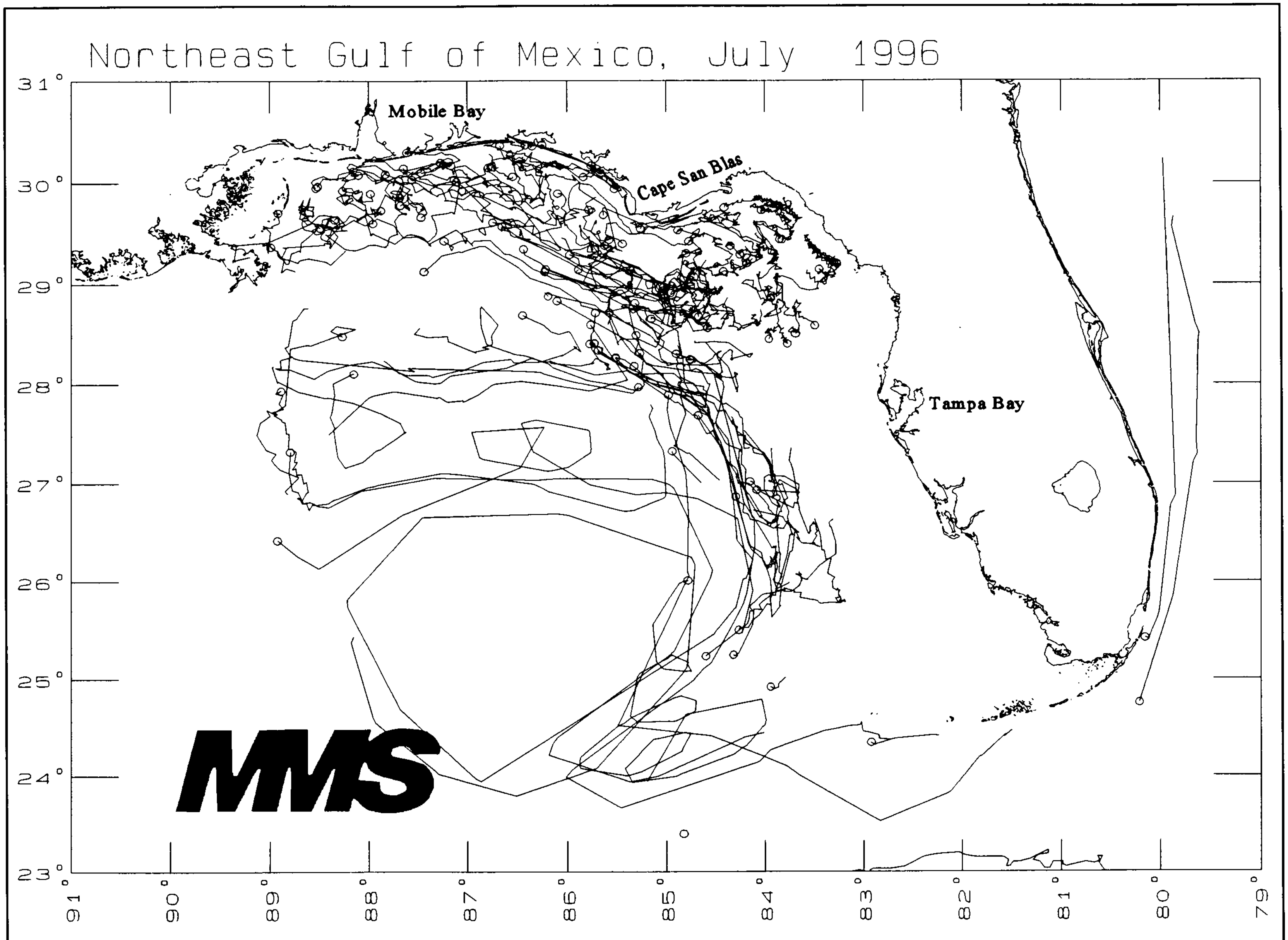

Figure 2H.6. Tracks for the drifting buoys for July 1996. Circles denote the beginnings of the tracks.

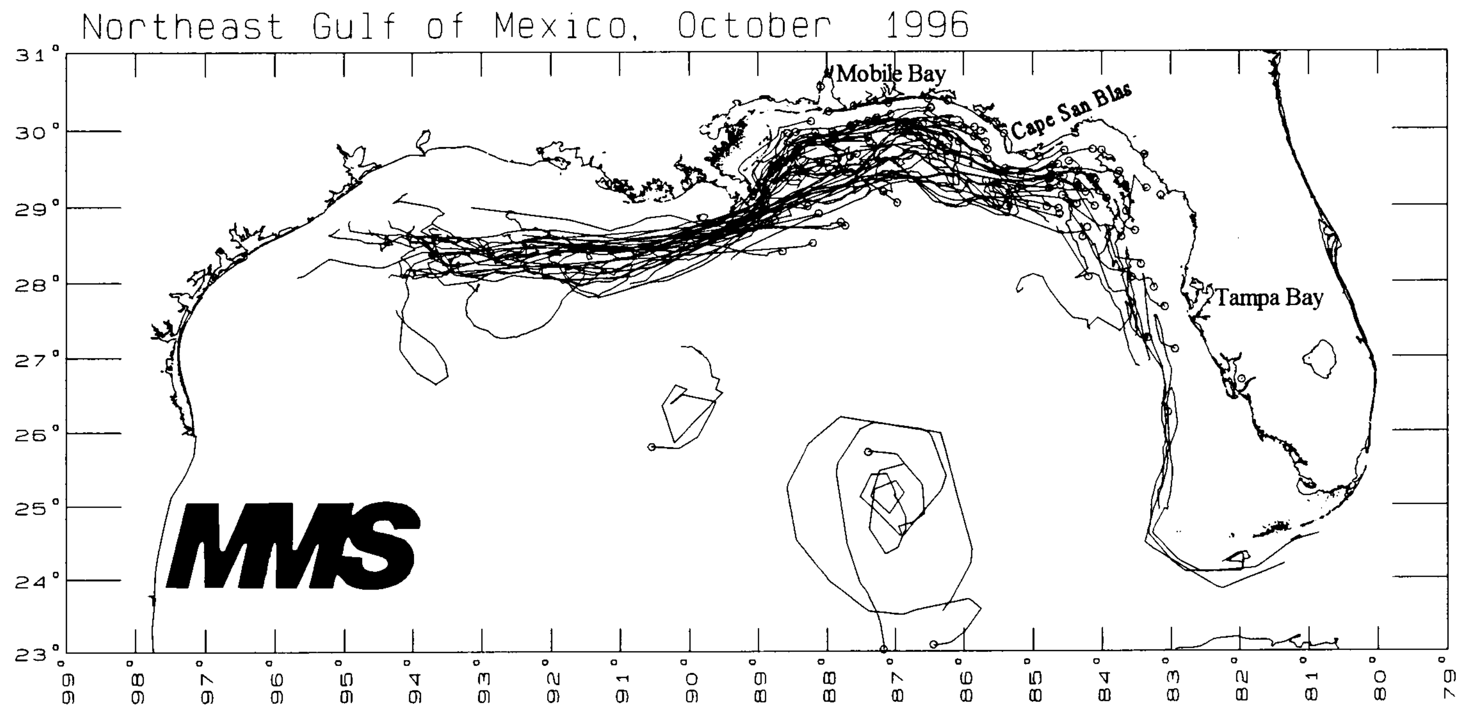

Figure 2H.7. Tracks for the drifting buoys for October 1996. Circles denote the beginnings of the tracks.

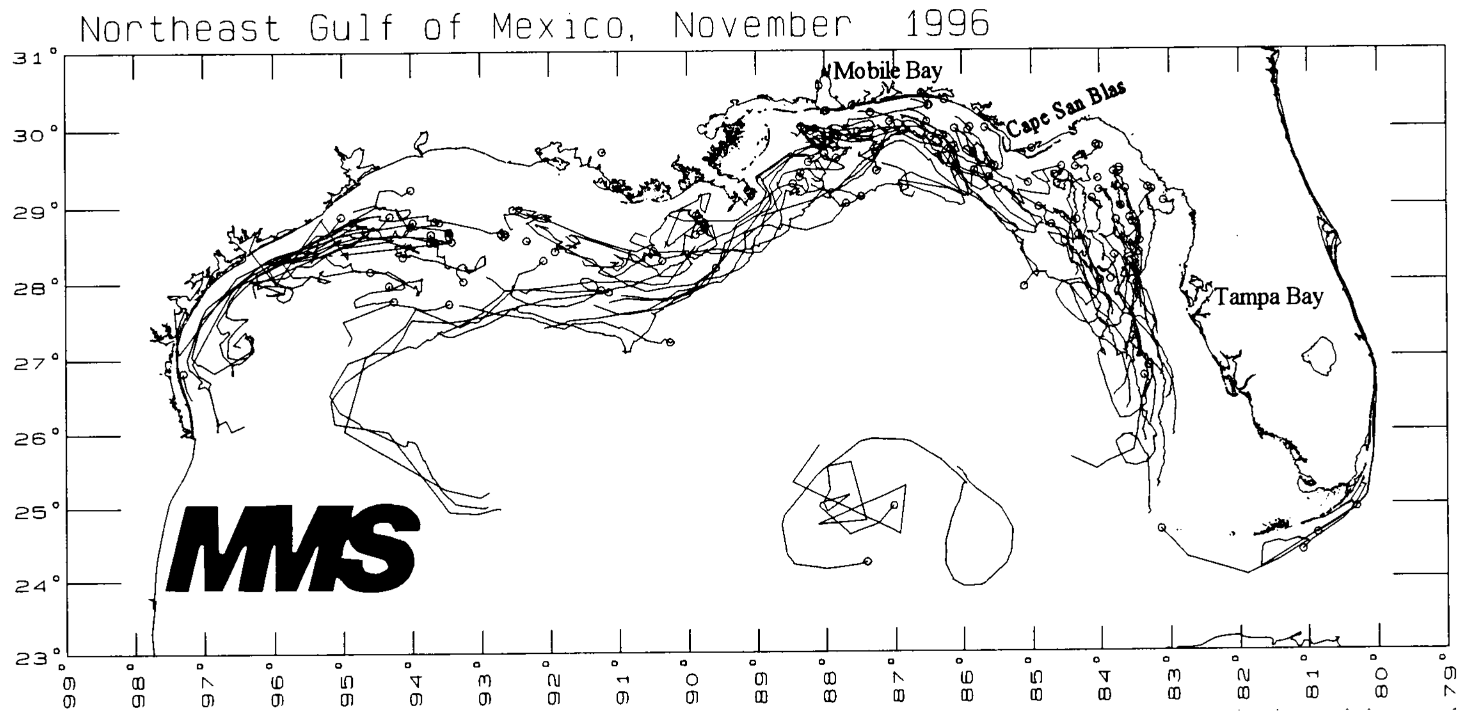

Figure 2H.8. Tracks for the drifting buoys for November 1996. Circles denote the beginnings of the tracks.

This project is still ongoing, and the statistical results of the Lagrangian drifters have not yet been calculated.

Current Meter Array

The current meter array consists of eight moorings located in the shelf region where the drifter deployment stations are located. The intent of these moorings is to provide fixed time series for higher resolution analysis in the time domain and, in some cases, to improve the interpretation of the Lagrangian observations. These data are still being processed and analyzed.

MODELING PROGRAM

Principal Investigators:
- Dr. Y. Hsueh, Florida State University
- Dr. Robert H. Weisberg, University of South Florida

Model Implementation and Initial Experiments

This effort has only recently been initiated, and the work is in the formative phase.

The Florida State University team is developing and applying the Brian-Cox model to the northeastern Gulf of Mexico. The domain for the model will be the region between latitudes 18° to 31° N and longitudes 100° and 80° W. The initial horizontal resolution will be 1/6 of a degree and 30 vertical levels. This domain imposes two open boundaries, from the Yucatan Channel to the Florida Straits. Initial experiments have examined the regional circulation driven by climatological temperature and salinity distribution, and the shedding of Loop Current Eddies has been documented. A second benchmark set of experiments has added the seasonal wind stress as forcing for the circulation. These initial model results have been analyzed using the Lyapunov Exponent method to estimate the time scales of the chaotic behavior of the circulation. Future work will include synoptic scale wind stress forcing and special analyses of the modeled circulation in the DeSoto Canyon area on a high resolution or nested grid.

The University of South Florida team will employ the Princeton Ocean Model (Blumberg-Mellor) to study physical processes in the region. This group has been working previously with this model in a limited domain (24° to 31.3° N latitude and 81° to 87° W longitude) with an evenly spaced horizontal grid of 4.6 km and 21 terrain-following levels. Completed experiments include a study of the effects on the circulation of seasonal winds and water column stratification. Future experiments will examine the effects of storms and frontal systems on the circulation.

Experiments and Model Intercomparisons

The Florida State University team is running experiments of wind forcing, Loop Current forcing, Loop and wind forcing, and, finally, the freshwater inputs. In the other simulations, the diurnal tides will be incorporated. For each driving force, experiments will be conducted to test the model's sensitivity to the forcing functions and friction coefficients. Hindcast simulations will be run to compare the results with actual observations obtained by the field program. At this stage, skill assessments of the models will be conducted. Other experiments may be conducted to attempt to develop the adjoint model so back calculations of flows can be performed.

The University of South Florida team will consider the oceanographic link between the Louisiana and the Florida coasts. The effects on the nearshore circulation of realistic stratification (horizontal and vertical) and buoyancy forcing will be studied to assess baroclinic aspects of seasonal and synoptic circulation. Introduction of density structures consistent with Loop Current Dynamics will be constructed to determine how the Loop Current interacts with the shelf. Additional experiments will be run to simulate the effects of synoptic wind forcing on the circulation.

Since the two models (Bryan-Cox and Blumberg-Mellor) employed in this study differ in the way they handle the vertical grid, a comparison between them should show the advantages and disadvantages of each. The hindcast of a common set of observations that can be compared with field observations will be performed.

Dr. Walter Johnson joined the Minerals Management Service in July 1989. Dr. Johnson received his B.S. in physics and M.S. in physical oceanography from the University of Miami and his Ph.D. in marine studies from the University of Delaware. He was a faculty member of the Institute of Marine Sciences at the University of Alaska, Fairbanks. His expertise is in coastal oceanography including wind-driven and buoyancy-driven flows and numerical modeling.

PANEL DISCUSSION INTRODUCTION

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

Renewed interests of the oil and gas industry in the Northeastern Gulf of Mexico created a need for updated environmental information. This environmental information will be employed for evaluation of exploration and development plans and preparation of documents under the National Environmental Policy Act. A series of ongoing biological and physical oceanographic studies will provide the updated data and knowledge needed. Procurement strategies for completing these studies include competitive awards, interagency agreements with sister agencies, and cooperative agreements with higher learning institutions in Florida.

Dual objectives directed the design of this half-day physical oceanography session:(1) present and inform the general audience about the ongoing projects and their preliminary results; and (2) coordinate filed work and data exchange among these studies.

To achieve the first goal the three initial talks presented results of a state-of-the-art tracer study and Lagrangian and numerical efforts in the region. A panel of Minerals Management Service and Biological Research Division personnel and Program managers of the studies was assembled to fulfill the second goal. Three talks on plans served as background material for the subsequent discussions. A product of this panel was the establishment of points of contacts among the different efforts and for sharing data and results. Another issue discussed centered around the procedures, policies, and mediums for data sharing. Based on the discussions of the panel, the second objective was moderately achieved.

Dr. Alexis Lugo-Fernández has been an oceanographer with the Minerals Management Service 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 of 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.

DESOTO CANYON EDDY INTRUSION STUDY (PANEL DISCUSSION)

Dr. Thomas J. Berger
Science Applications International Corporation

BACKGROUND AND OBJECTIVES

Science Applications International Corporation (SAIC) recently began work on the DeSoto Canyon Eddy Intrusion Study for Minerals Management Service (MMS) under MMS Contract 1435-01-96-CT-30825. This study will involve a team of Principal Investigators from Florida State University, University of Colorado, University of Miami, Woods Hole Oceanographic Institution, and SAIC in a two-year field program to study interactions between shelf and slope waters and the Loop Current in the region of the DeSoto Canyon.

The DeSoto Canyon Eddy Intrusion Study objectives are the following:

1. to document and analyze Loop Current intrusions and interactions with the NEGM slope. This study will examine at a minimum the frequency and horizontal and vertical extent of the interactions and intrusions; a conceptual model shall be developed to explain the evolution of interactions observed;

2. to document and examine the dynamical processes of momentum, mass, and vertical

Table 2H.1. DeSoto Canyon Eddy Intrusion Study cruise schedule.

Cruise	Dates	Activity
1	18-28 March 1997	Mooring deployment/hydrography
2	8-18 July 1997	Mooring rotation/hydrography
3	11-22 November 1997	Mooring rotation/hydrography
4	31 March - 11 April 1998	Mooring rotation/hydrography
5	18-28 August 1998	Mooring rotation/hydrography
6	1-12 December 1998	Mooring rotation/hydrography
7	30 March - 7 April 1999	Mooring recovery/hydrography

vorticity exchanges that occur during Loop Current-slope interactions and other driving forces;

3. to estimate the frequency of Loop Current and secondary eddy interactions with the NEGM slope and assess the vertical and horizontal current shears, exchanges of vorticity, momentum, and mass fields associated with these eddy-slope interactions; and

4. elucidate the role of the De Soto Canyon in Loop Current and eddy interactions and as a route of mass and momentum exchange between the shelf and deep water of the NEGM.

THE FIELD PROGRAM

The requisite field work will be accomplished during seven cruises at approximately four-month intervals beginning in mid-March 1997, and concluding in early April 1999. Table 2H.1 provides the cruise dates aboard R/V PELICAN. Each cruise will originate and terminate at the PELICAN home port, the LUMCON facility in Cocodrie, Louisiana, and will involve mooring deployment/recovery and servicing and standard hydrographic surveys. Figure 2H.9 shows the locations of the 13 current meter moorings to be used. Each of the moorings will have an upward looking acoustic Doppler current profiler (ADCP) about 80-100m below the surface along with conventional current meters with conductivity and temperature sensors at selected levels below the ADCP. Three of the moorings along the 100m isobath will be equipped with conductivity/temperature (C/T) sensors.

Hydrographic surveys will be conducted along six transects and the 100m isobath as shown in Figure 2H.10. Sixty-nine stations are planned. Station spacing will be denser near the shelf break and less dense further offshore. Stations will be made using the CTD system installed on PELICAN. Bottle samples will be acquired at selected depths to verify calibration of the CTD measurements.

Beginning about September 1997, after Cruise 2, and about two months after each subsequent cruise (Cruises 3-7), SAIC will provide the Principal Investigators with standard data products consisting of hydrographic sections (temperature, salinity, and density) and maps of these properties at selected depths; current component time series and stick plots for selected ADCP levels and for conventional current meters plus time series plots of salinity and/or temperature for each ADCP, conventional current meter or thermister as appropriate; spectra for each time series; and clear-sky imagery products primarily during the months of November through May. Imagery products will be based on navigated AVHRR imagery provided by the U.S. Geological Survey Center for Coastal Geology.

Satellite altimetry data will be used to provide both an historical perspective on Loop Current interactions with the slope and near-real-time monitoring of the Loop

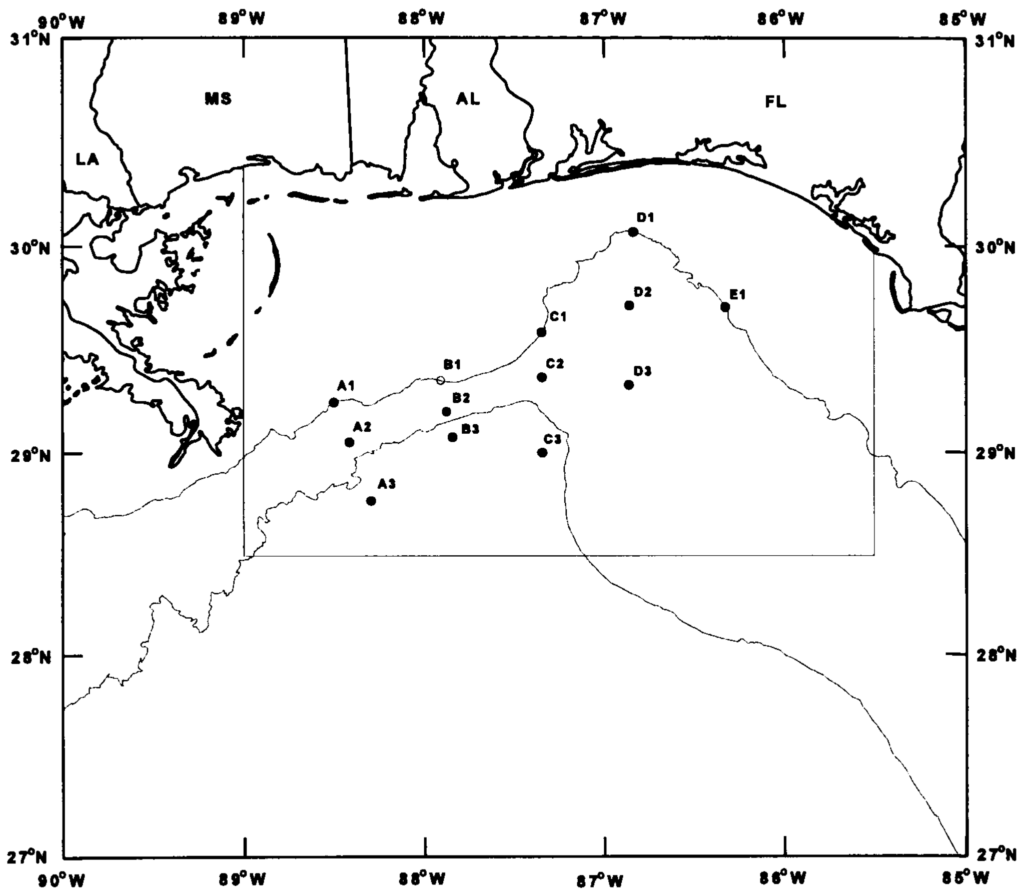

Figure 2H.9. Mooring locations. Study area is shown by solid line.

Current and associated meso-scale features during the field effort. This activity will allow better cruise planning and aid in data interpretation for the final report.

DATA ANALYSIS AND SYNTHESIS

In order to accomplish the study objectives, the data analysis and synthesis effort will be accomplished within a process-oriented framework. The regional circulation topics to be addressed include the Loop Current and Loop Current intrusions, the slope eddy field, and shelf-slope exchange processes. The Loop Current processes will be addressed from a historical perspective to determine the frequency of these events and through a detailed study of events during the study period. During subsequent ITMs the Principal Investigators will present the results of their analyses as they evolve during the study period. The process analysis topics will lead to development of a conceptual

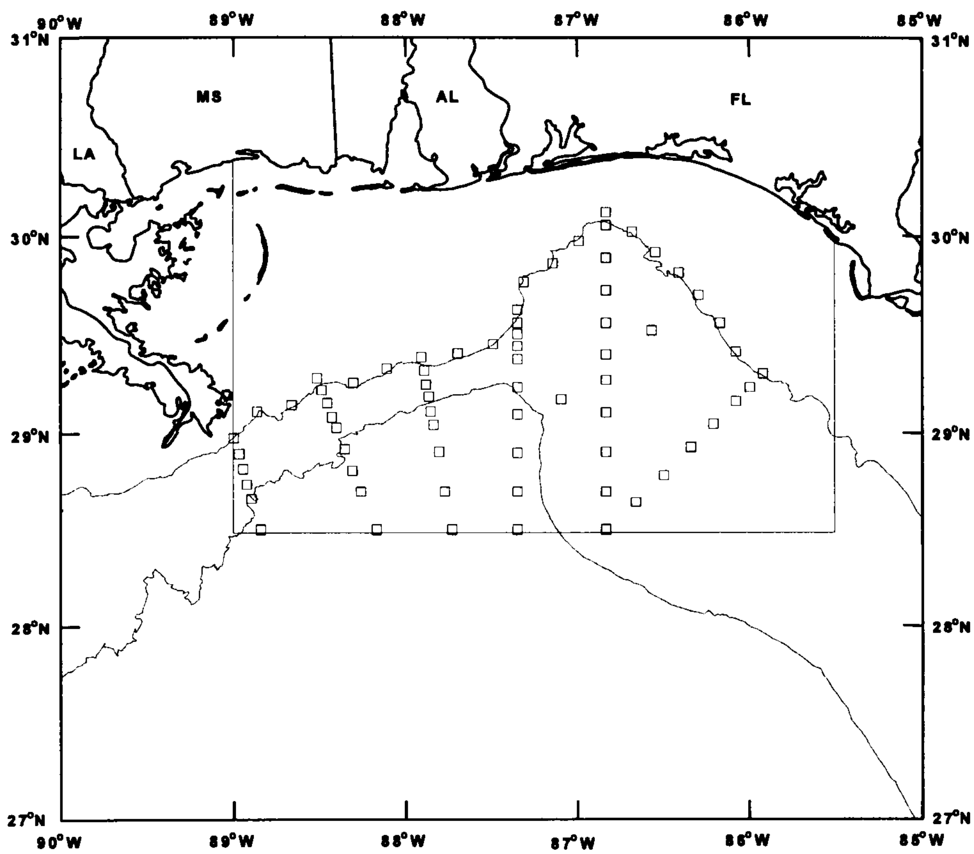

Figure 2H.10. Hydrographic station locations. Study area is shown by solid line.

model of regional circulation. The analysis effort will conclude with the draft Final Synthesis Report to be delivered to MMS in early April 2000, approximately one year following completion of the field work.

Dr. Thomas Berger has been with SAIC in Raleigh, NC, since 1987. He is currently Program Manager of two MMS-funded field programs. His research interests are in remote sensing of mesoscale processes. Dr Berger received his B.A. in zoology from Catholic University in 1959, M.S. in physical oceanography from Naval Postgraduate School in 1970, and Ph.D. in physical oceanography from Old Dominion University in 1987.

NORTHEASTERN GULF OF MEXICO PHYSICAL OCEANOGRAPHY PROGRAM—EDDY MONITORING AND REMOTE SENSING (PANEL DISCUSSION)

Dr. Richard P. Stumpf
U.S. Geological Survey
Center for Coastal Geology

INTRODUCTION

This study will collect and process satellite data (AVHRR, TOPEX/ERS-1, OCTS, and other as appropriate) to produce fully rectified images and data on the position of the Loop Current, eddies, and other major circulation features in the northeastern Gulf of Mexico (NEGOM). These images and data will be made available through the Internet in near-real time for primary use by other MMS-funded ongoing studies in the Gulf of Mexico. The information will be intended to provide guidance for research cruises, drifter and mooring deployments, and for general insight into physical oceanographic behavior of the northeastern Gulf of Mexico. Current information may be obtained from our website: <http://stimpy.er.usgs.gov/>

The objectives are as follows:

1. to assemble and process satellite imagery and data, such as AVHRR, ocean color, TOPEX, ERS-1, etc., to provide fully rectified imagery in standard map projections for use in MMS-funded studies in the NEGOM;

2. to identify and report major circulation features, such as Loop Current frontal positions, intrusions, eddies, meanders, river plumes, and other features;

3. to set up and maintain Internet sites, accessible from both ftp or World Wide Web, for use in current MMS studies in the NEGOM region;

4. to maintain an archive of imagery and observed events during the course of the NEGOM project.

The primary study area for imagery will be the NEGOM region, extending east from the Mississippi River delta (90W) to Florida (80W) and extending north from the Straits of Florida at Cuba (22N) to 32N. Information outside this area will be included as needed to assure researchers of sufficient data for cruise planning and drifter and mooring deployments.

The project will continue during the four-year MMS NEGOM study, with collection and distribution of satellite imagery for the field programs that should run for about the first 38months, and preparation of synthesis report on the imagery and results in the last 10 months.

DATA TYPES

Table 2H.2 summarizes the following data types:

1. The Advanced Very High Resolution Radiometer (AVHRR) provides the best available information on circulation through imagery of sea surface temperature. This imagery will be the primary data source for describing the NEGOM region. The USGS receives AVHRR data from the Joint Use Remote Sensing facility at the University of South Florida (USF) and Florida Department of Environmental Protection (FDEP). Backup sources include NOAA Coastal Services Center and the Louisiana State University Earth Scan Lab, as well as access to NOAA CoastWatch.

2. TOPEX and ERS-1 altimetry data sets will be acquired in a processed form through MMS-funded projects associated with NEGOM.

3. Ocean color imagery offers an important capability in resolving circulation patterns in the summer, when the Gulf is thermally homogeneous. The OCTS (Ocean Color Temperature Sensor) was launched in August 1996, and imagery is expected to become available during the first year of the project. OCTS should provide near-real time imagery and will be incorporated into the study. Data sets will be acquired through NOAA sources, including CoastWatch and the NOAA Coastal Services Center.

Table 2H.2. Eddy monitoring and remote sensing program data types.

1. SST and Reflectance AVHRR: 1.1 km Mercator projection, registered, TIFF + low-res. GIF/JPEG, land mask, cloud mask, shoreline, ticks, GIS-compatible **Currently (Dec 96): 2.2 km SST GIF/JPEG**
2. Sea surface elevation altimetry from available MMS-funded sources (TOPEX) **Currently: under development**
3. Ocean color OCTS (launched August 1996) **Currently: data not yet available from NOAA**
4. Frontal and event analysis, Daily Image Composites, etc. **Currently: under development**

4. The SeaWiFS (Sea Wide Field Sensor) ocean color instrument is expected to be launched in early 1997. The PI is a NASA-authorized research user of SeaWiFS data. When the SeaWiFS sensor is launched, data will be obtained from the USF-FDEP Facility and from NASA. However, SeaWiFS data sets cannot be routinely used in near-real time without arranging for a license from the data owner, Orbital Sciences. For specific requirements, such as selected cruises, NASA may approve real time usage. Under most conditions, SeaWiFS imagery might not be available for several weeks after the overpass and will have a limited and experimental role in this project.

Certain projects in the study may require information prior to the start of the MMS NEGOM project. Other sources of processed data, such as previous MMS-funded work in the LATEX project will be explored.

DATA PROCESSING AND ANALYSIS

The AVHRR imagery will be processed and rectified at full resolution (1.1 km) for the NEGOM study area (22N to 32 N and 80W to 90W). Other views and scales will be prepared from the full resolution as appropriate to the researchers in the study. For example, quick retrieval over the Internet will warrant publishing a thumbnail view of the NEGOM area, and an overview of the Gulf of Mexico may also be of value.

The AVHRR data will be processed using standard NOAA algorithms for sea surface temperature. Imagery will also be processed for water reflectance using current techniques. Water reflectance imagery from AVHRR may provide information on river plumes as well as vertical mixing events on the west Florida shelf. All data will be processed to a Mercator map projection to permit comparison with standard oceanographic charts of the region. UTM or other projections will also be considered if required for location in leasing areas.

Images will be made available through the Internet both from the World Wide Web (WWW) and through ftp within 1 day of overpass (webpage: *http://stimpy.er.usgs.gov/*). AVHRR imagery is subject to slight errors in positioning. Rectified imagery will be made available within 1-3 days of overpass. We will incorporate processing routines to complete the imagery rectification in order to automate the entire processing, thereby achieving 1-day processing within the first year. The next AVHRR will be on a new generation of NOAA polar-orbiting satellite. This sensor is intended to have better positioning control and also to have more sensitivity in the visible.

All imagery will include shorelines and cloud masking and tick marks for latitude and longitude. We anticipate different formats of imagery to address user requirements. A minimum of one week of imagery will remain online. While JPEG and GIF are the most common formats for WWW viewing, TIFF offers the greatest flexibility for analysis by users for both viewing and for analysis. We expect that archived imagery will use TIFF format, and the most current imagery may use the other formats.

The imagery will be analyzed for Loop Current frontal positions, eddy formation and position, and other noteworthy features (river plumes, resuspension events, etc.). Positions will be posted on the Internet in a means to allow easy access from ship. For fronts, we will explore production of images of frontal boundaries in black and white. The nature and type of products will be modified as needed in order to address the requirements of the various MMS-funded projects. During the project, we will continue to develop methods to improve the ease of interpretation of the imagery, such as compositing and improvements in frontal detection and integration of color and temperature imagery.

Temperature imagery has limited utility in finding the Loop Current during the summer when the Gulf has extremely uniform temperatures. Ocean color imagery offers the potential to locate circulation features in the summer. As the OCTS sensor was launched on August 17, the nature of the product cannot be determined at present. However, we expect that the OCTS should allow us to locate the Loop Current and eddies during the summer. OCTS data will be used to generate color boundaries.

The images will include a description of processing algorithms, map projection documentation, and data extraction information. The information will permit analysis in geographic analysis packages such as Arc/Info.

Temperature imagery will be analyzed as practical using existing algorithms for dynamic topography in comparison with altimetry data. Altimetry information on sea surface elevation will be made available through the Internet, using data prepared by USF. The project will explore refinement of products through the project to incorporate results of other components of the MMS NEGOM studies.

Dr. Stumpf joined the USGS in 1989 as an oceanographer. His research responsibilities include developing applications for satellite data—including AVHRR, ocean color, and Landsat—in coastal regions for investigations of coastal circulation, measurement and transport of sediment, phytoplankton, and pollutants, and determination of causes of coastal wetlands loss. His research has extended along the U.S. east and Gulf coasts from Maine to Louisiana, including the transport of red tide in the southeast, circulation in Mobile Bay, water clarity in Florida Bay, the impact of floods on estuaries, and marsh evolution in Florida and Delaware. Previously he was with NOAA (National Oceanic and Atmospheric Administration) in Washington, D.C. He has M.S. and Ph.D. degrees from the University of Delaware and a B.A. from the University of Virginia.

NORTHEASTERN GULF OF MEXICO COASTAL AND MARINE ECOSYSTEMS PROGRAM: ECOSYSTEM MONITORING MISSISSIPPI/ALABAMA SHELF— AN OVERVIEW OF THE OCEANOGRAPHIC PROCESSES STUDY TASK (PANEL DISCUSSION)

Mr. F.J. Kelly
Geochemical and Environmental Research Group
College of Geosciences and Maritime Studies
Texas A&M University

OVERVIEW

The pinnacle trend region along the Mississippi-Alabama outer continental shelf is the focus of a new three-year project titled "Northeastern Gulf of Mexico Coastal and Marine Ecosystems Program: Ecosystem Monitoring Mississippi/Alabama Shelf" (Gettleson 1997: this volume). The project's purpose is to describe and monitor biological communities and environmental conditions at three distinct types of pinnacles, the relatively narrow low-relief topographic features that extend up to 15 meters above the bottom. Water depth in the region ranges from 60 to 100m. An important part of this project is the Oceanographic Processes Task, described here. Its objectives are:

1. to characterize the regional and local current dynamics in the study area, which lies on the outer portion (60 to 100m water depth) of the Mississippi-Alabama continental shelf;

2. to determine the dynamics of important environmental parameters, including temperature, salinity, dissolved oxygen, and turbidity; and

3. to define the relationship of the current dynamics and environmental parameters to the geological and biological processes of the pinnacle features.

The design of the Oceanographic Processes Task relied heavily on the results and experience from the 1988-1989 Mississippi-Alabama Continental Shelf Ecosystem Study (Brooks 1991. It is commonly referred to as MAMES) and from the LATEX A project (Jochens and Nowlin 1995). This task will include the following elements for the necessary data:

1. bottom-mounted, instrument moorings at selected pinnacle sites to continuously measure current velocity, temperature conductivity, dissolved oxygen, and turbidity, plus sediment traps to accumulate suspended sediment samples;

2. vertical profiles by the same CTD instrument package used during LATEX to obtain more detailed information about the processes in progress during each monitoring cruise;

3. collateral data, such as satellite AVHRR images, satellite altimetry, river discharge, coastal wind and sea level data, and buoy observations of wind, waves, barometric pressure, air and sea temperature, to define the primary forcing mechanisms.

INSTRUMENT MOORINGS

Currents, suspended sediments, water temperature, dissolved oxygen, and salinity all affect the biological organisms that populate the pinnacles. Time scales associated with the interactions among these variables and the biological communities of the pinnacles cannot be adequately measured by just survey/monitoring cruises. The MAMES results suggest that important changes may be caused by events, such as a passage of a hurricane or an intrusion associated with the Loop Current, a ring or a filament. To capture these events and to form a long-term picture of the physically important factors, continuous insitu time series are required of the environmental variables at the pinnacle sites and of the forcing functions. The latter will be obtained as collateral data from other sources.

In April 1997, we will deploy six moorings in the study area to measure currents, conductivity, temperature, dissolved oxygen, and turbidity. Also, sediment traps will be attached to the moorings. A mooring will be placed at each of four selected pinnacle sites. Three of the four pinnacle sites are medium to high relief features located near the 100-m isobath. The fourth is a low relief site in shallower water near the 60-m isobath. These four moorings will be maintained throughout the two-year field program to provide continuous long-term time-series at each of the four sites. The three deeper sites will give us significant along-isobath coverage of the outer shelf. The shallower site, when paired with a deeper site, will yield some information about cross-isobath correlation. The sites will be selected.

The fifth and sixth moorings will be placed initially at the easternmost high-relief site to form, in conjunction with the permanent mooring, a triangular pattern. The objective is to observe any differences in the current flow and water properties around the feature. Beginning with the second monitoring cruise, the two "non-permanent" moorings will be moved to a different site each deployment period. This approach will provide a triad of moorings at several sites, again to look at small scale variability at the pinnacle sites.

Figure 2H.11 depicts the mooring design. The bottom current meter will be an Oregon Environmental Instruments 9407 current meter. The top current meter will be an Aanderaa Model RCM7 with conductivity and temperature sensors. Both types vector average currents, record into battery-backed solid-state memory, and download directly to PC-type computers. Immediately below the bottom current meter, there will be an ENDECO/YSI Model 6000 recording system with oxygen, turbidity, temperature, and conductivity sensors. The oxygen system uses rapid pulse technology, which measures oxygen current in small pulses only when the measurement is actually being made. This technique not only limits power drain but also reduces the effect of fouling on the measurement. The turbidity sensor is of the backscatter type, and it includes a small wiper that cleans the optical window. The rapid-pulse technology and the wiper have proven to significantly extend the period of good data collected by these types of sensors before biofouling takes hold. Poison collars, manufactured by Oceanographic Industries, will further ward off biofouling on the oxygen and turbidity sensors.

The moorings will be serviced at three-month intervals. Recovery will use the acoustic release/rope canister method to also recover the anchor. Should the acoustic release fail, the mooring can be released by cutting the short rope link between the acoustic release and the anchor, using a cutting tool on the ROV that will be used on each of the Monitoring cruises.

HYDROGRAPHY

Physical factors that affect the biota in region include currents, temperature, salinity, dissolved oxygen, and light levels. Moored instruments will produce time series of all these variables except light levels, but only at two depths and only at a few discrete locations. Vertical profiles of these variables taken during the monitoring and service cruises will give valuable information on the vertical distribution of these properties.

The CTD system for vertical profiles includes a Sea-Bird Electronics, Inc., SBE-9 CTD, SBE-11 deck unit and a General Oceanics rosette sampler. Additional sensors measure photosynthetically active light (PAR), transmissivity, backscattered light, and oxygen concentrations. We will collect vertical profiles at three locations around each site to determine if changes in the flow field are induced by the topographic features. We will collect water samples for total suspended matter, oxygen for calibration of the oxygen sensor, and salinity as a check on the depth at which the bottle actually closed. Sampling depths will focus on the depth from feature height to the regional bottom depth, with fewer samples in the overlying water. From these measurements we hope to infer the depth of the nepheloid layer and characterize the water masses enveloping the pinnacle features. The basic measurements of temperature, salinity, light levels, oxygen, and suspended sediment loads will be available for use as environmental variables in statistical models applied to the biological assemblages. These data will also be useful for calibration and quality control of the time-series measurements made at the moorings.

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Jochens, A.E. and W.D. Nowlin, Jr., eds. 1995. Texas-Louisiana Shelf Circulation and Transport Processes Study: Year 2 - Annual Report. OCS Study MMS 95-0028, U.S. Dept. of the Interior, Minerals Management Service, Gulf of Mexico OCS Region, New Orleans, LA. 172 pp.

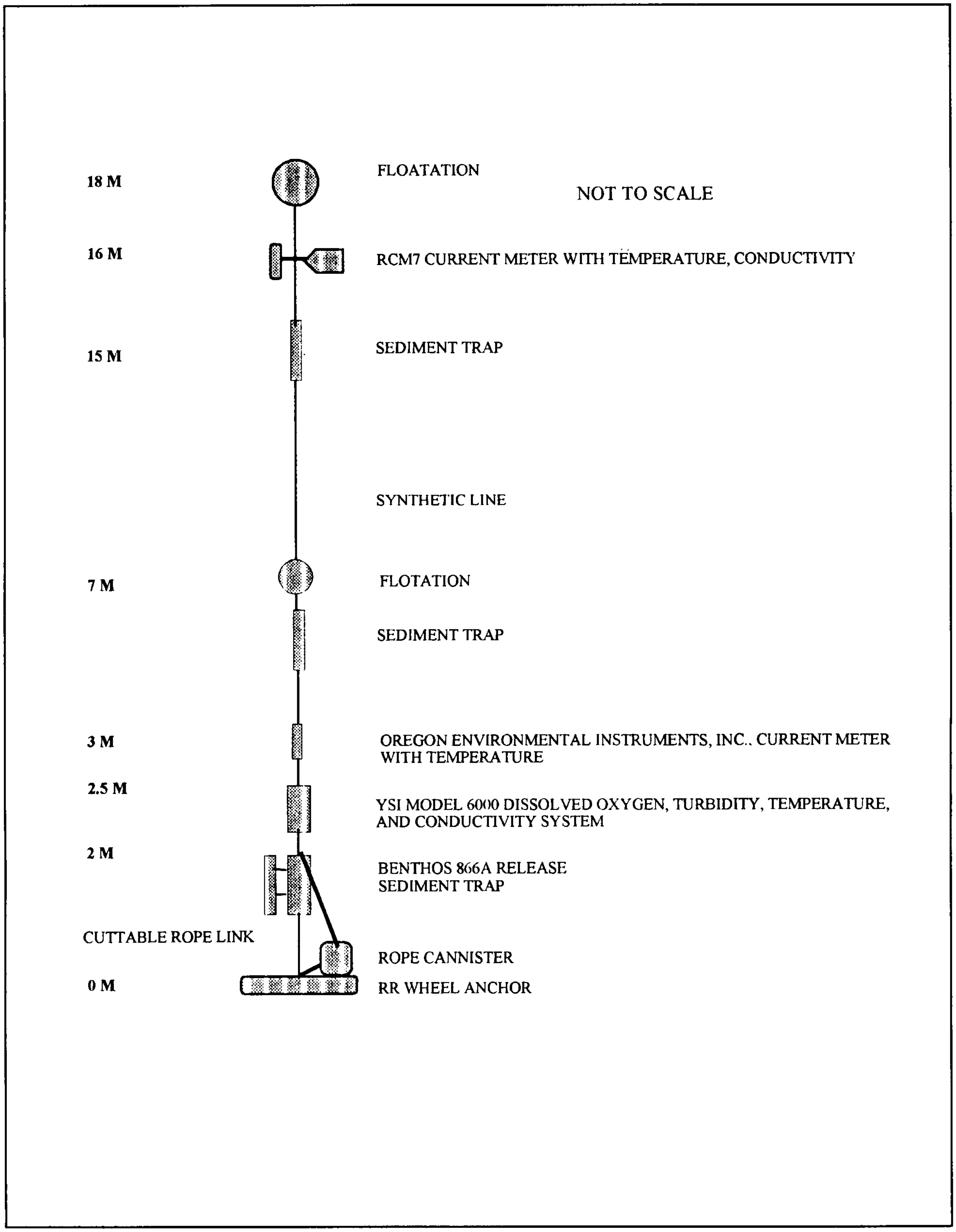

Figure 2H.11. Schematic drawing of the six instrument moorings that will be deployed near selected pinnacle sites.

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Mr. F.J. Kelly is an Assistant Research Scientist with the Geochemical and Environmental Research Group at Texas A&M University. He received his A.B. Degree in physics from the University of California, Berkeley, and his M.S. Degree in oceanography from Texas A&M University. He has been studying the physical oceanography of the Gulf of Mexico for more than 20 years, with emphasis on continental shelf circulation. He was the Principal Investigator for the physical oceanography components of the Brine Disposal Monitoring Studies for the Department of Energy's Strategic Petroleum Reserve Program and the first Mississippi/Alabama Marine Ecosystem Study. Mr. Kelly co-authored, with John D. Cochrane, a seminal paper describing the low frequency circulation on the Texas-Louisiana continental shelf. Mr. Kelly is currently the P.I. for the Oceanographic Processes Task described above and for the Texas Automated Buoy System (TABS) Project, which is providing real-time observations of surface currents off the Texas coast through a publicly accessible World Wide Web page.

SESSION 2J

SOCIOECONOMIC ISSUES ON THE OCS OF THE GULF OF MEXICO

Co-Chairs: Dr. Harry Luton
Mr. John Greene

Date: December 12, 1996

Presentation	Author/Affiliation
Introduction	Dr. Harry Luton Minerals Management Service Gulf of Mexico OCS Region
A Progress Report on the Study "Issues Analysis" for the Eastern Gulf of Mexico" Conducted by the University of West Florida	Dr. Dallas Blanchard University of West Florida
Regional Economic Impacts of Mobile Bay Baseline Natural Gas Development and Production	Dr. William W. Wade Foster Associates, Inc.
A Socioeconomic Baseline Study for the Gulf of Mexico: Phase I	Dr. Joachim Singleman Louisiana State University
Oil and Gas Development and Coastal Income Inequality: A Comparative Analysis at the Place Level	Dr. Charles M. Tolbert Dr. Edward S. Shihadeh Louisiana Population Data Center Louisiana State University

INTRODUCTION

Dr. Harry Luton
Minerals Management Service
Gulf of Mexico OCS Region

In 1992, the Gulf of Mexico Region (GOMR) hosted the "Socioeconomic Research Agenda Workshop" in response to a number of developments including a series of National Research Council (NRC) reviews of the agency's study program, a suit filed by the State of Louisiana citing socioeconomic issues in its brief, criticisms by the MMS Scientific Committee, and concerns within the GOMR itself. This 1992 workshop marked a turning point in the GOMR studies program. Since then, MMS has conducted more and varied socioeconomic research in the face of substantial budget declines. The four papers presented are the varied fruit of some of this change.

The 1992 workshop listed, as its first agenda item, the collection and analysis of stakeholder issues. Research, environmental assessments and regulatory decisions are no good if they do not address the real concerns of stakeholders. MMS has funded three studies to address these concerns, one each for the Eastern, Central and Western Gulf planning areas. The Central planning area study is complete, the other two are underway. Dr. Dallas Blanchard presented *A Progress Report on the Study "Issues Analysis for the Eastern Gulf of Mexico" Conducted by the University of West Florida*. His study was selected for a presentation because of its use of focus group meetings to elicit interests and concerns in an area where the OCS debate is very heated.

The second paper, *Regional Economic Impacts of Mobile Bay Baseline Natural Gas Development and Production*, was presented by Dr. Bill Wade. Like Dr. Blanchard's, this is a report on a work in progress. Dr. Wade's study, and similar MMS-funded efforts for the Florida Panhandle and for Port Fourchon, Louisiana, illustrate another change in study direction that grew out of the 1992 workshop, a move to assess socioeconomic effects of the OCS program on a local, rather than regional level.

Dr. Joachim Singleman delivered a paper entitled, *A Socioeconomic Baseline Study for the Gulf of Mexico: Phase I*. This study has developed, and will make public, a large database of time-series-type data for Southern tier states from the 1930s until 1990. The study is nearly complete and is a first step in a longer-term effort suggested at the 1992 workshop by the National Research Council review of the studies program. Both groups noted that, since the Gulf has been involved with offshore oil development since the 1930s, it is a perfect laboratory to study the social and economic effects of this industry. MMS's *Phase I* study will assemble a database to support this goal.

Finally, Dr. Charles Tolbert presented the findings of his research in *Oil and Gas Development and Coastal Income Inequality: A Comparative Analysis at the Place Level*. This is the second of two studies on the relationship of income inequality to location and to the upturns and downturns in the region's oil industry. It also represents a second approach MMS is taking to our "laboratory" for understanding the oil industry's influence on society and economy—the use of small, highly focused studies of past and current effects.

A PROGRESS REPORT ON THE STUDY "ISSUES ANALYSIS FOR THE EASTERN GULF OF MEXICO" CONDUCTED BY THE UNIVERSITY OF WEST FLORIDA

Dr. Dallas Blanchard
University of West Florida

Offshore oil is a sensitive topic in Florida, and the research team's approach is one used for examining public attitudes towards other contentious issues, such as abortion. The University of West Florida team has concentrated the initial stages of this project on a review of the literature and on the planning for Focus Groups and Key Informant interviews.

REVIEW OF LITERATURE

The team has used many "standard" materials in its literature review, such as MMS Reports and works cited therein. Additional sources sought have included a Library of Congress subject search and a NEXIS newspaper search. The NEXIS search is renewed periodically to determine more recent articles. Of particular note are the many local newspaper articles and reader opinions on this subject.

The status of the literature review is as follows:

1. An annotated bibliography that stresses socioeconomic/cultural factors is almost completed;

2. An exhaustive list of potential concerns and interests is essentially completed; and

3. Hypotheses of interests and concerns based on socioeconomic/cultural profiles and historical factors is also essentially completed. Some of these will be tested by analyzing the results of the Focus Groups.

SOCIOECONOMIC PROFILE OF EASTERN GULF COAST REGION COUNTIES

The study team will develop socioeconomic profiles of Eastern Region counties. Although these profiles are key parts of the final report, they have not been the focus of early work on this study. These profiles have two goals:

1. To establish "natural" socioeconomic/cultural common areas. This approach has been pioneered in the writings of Howard Odum. The group will refine its delineation of "natural" areas as the research proceeds. For example, we now perceive there to be three major ecological/cultural regions. One area runs from Gulf Shores, Alabama to Mexico Beach, Florida. White sands and interest in tourism attracted to white sands dominate this area. A second area runs from Mexico Beach to just north of Tampa. This area is dominated by commercial and recreational fishing. Finally, a third area runs from the Tampa area to the Keys. This area, too, is dominated by tourism interests. However, we will likely develop further distinctions within these three areas as the research progresses.

2. To develop hypotheses specific to the Eastern Gulf Coast Region, which delineate real interests and concerns and types of areal organizations that have concerns with, or interests in, OCS-related activities.

CULTURAL RESEARCH PROCEDURES

The group has begun developing the procedures for determining environmental concerns and how these concerns relate to basic cultural worldviews. The stress in this phase will be on cultural meanings and the sources from which they arise. Literature review, our work in other highly charged areas of interest, materials from focus group meetings, and discussions with key informants will all play a roll in this process.

FOCUS GROUP MEETINGS

Focus Group meetings are a centerpiece of our research design. They will be held in all key communities. They are organized to gather an accurate and representative sample of interests and concerns held by various individuals and groups. The following procedures will be employed:

1. Interview Key Informants by phone;

2. Interview additional informants (from Key Informant calls);

3. Develop list of interest groups and organizations; and

4. Determine representative sample of perspectives for Focus Group inclusion.

The chronology initially employed by the project will begin at Western bounds then move East and South. This process, we hope, will maintain areal commonalities among areas and groups while highlighting the real distinctions between them.

We have tentatively identified the following focus group sites, listed in the order in which we plan to conduct them. This progression and specific sites are subject to revision as we gather additional information.

Alabama
- Gulf Shores

Florida
- Pensacola-Santa Rosa County
- Ft. Walton Beach-Destin
- Panama City
- Appalachicola
- St. Marks
- Cedar Key
- St. Petersburg
- Tampa
- Sarasota
- Fort Myers
- Naples
- Key West

The study is still in its early stages but we are convinced we have developed a good methodology for identifying and characterizing the spectrum of thought on a highly charged issue.

REGIONAL ECONOMIC IMPACTS OF MOBILE BAY BASELINE NATURAL GAS DEVELOPMENT AND PRODUCTION

Dr. William W. Wade
Foster Associates, Inc.

In 1979, Mobil Oil Exploration and Production Southeast, Inc. discovered natural gas in Mobile Bay a mile northeast of Dauphin Island at a depth of 21,100 feet in the Norphlet formation. This event changed the history of the Gulf Coast as much as d'Iberville's original colonization of Dauphin Island in 1699, and Farragut's good fortune with those "damn... torpedoes" in 1864.

The gas industry has completed over 50 producing wells in state and federal Alabama waters and produces over 1 BCFD today:

- within Mobile Bay;
- just south of Mobile Bay in federal water; and
- in the Mississippi Sound to the northwest of Dauphin Island.

The State of Alabama and coastal counties will realize nearly $126 million for 1996 in spendable income from gas tax receipts and interest earnings on the invested bonus payments and annual royalty receipts. State, county, and local governments earned over $1.35 billion by the end of 1996, since the initial 1981 state lease sale. This income will continue to rise from royalty payments added to the Alabama Trust Fund.

The Coastal Alabama gas industry has been a source of economic growth, and Chevron's Destin Dome project will continue to add to the health of the Gulf Coast economy. Development of the 1979 and subsequent discoveries of natural gas in Mobile Bay state and federal waters introduced a specialized, capital-intensive industry into the Mobile Metropolitan Statistical Area. Little or no infrastructure existed to support the development activities.

Chevron's Destin Dome project will add 300 MMCFD to production in 2003—after the baseline Coastal Alabama production is in decline, sustaining local area production above 1 BCFD. This will have the effect of sustaining employment related to the gas industry. Activity to support Destin Dome will be staged from developed Mobile Bay infrastructure and from Louisiana and Texas.

Natural gas leasing, exploration and development creates economic stimuli from direct industry expenditures and from government spending of mineral bonus, tax, and royalty payments. Regional economic modeling must account for the effects of government spending in the State of Alabama and coastal counties as well as direct industry spending in plant, equipment, and services in Mobile County, Alabama, Texas, and Louisiana.

Estimating the regional economic stimulus of the natural gas baseline development during the 1980s and early 1990s, and the impacts of Destin Dome Norphlet extension in the late 1990s, requires modeling capability:

1. To deal with infrastructure changes in the Mobile MSA;

2. To estimate the impacts in Louisiana and Texas of importing services and equipment from offshore support industries not present in Alabama;

3. To estimate the effects of state and county government spending of gas industry revenues.

Results from Foster's research on Coastal Alabama—*Economic, Fiscal and Infrastructure Impacts of Coastal Alabama Baseline and Destin Dome Natural Gas Exploration and Development*—submitted 28 November 1996 by Chevron as part of the their DPP for Destin Dome was reported to the 12 December 1996, ITM meeting.

Economic impacts were estimated in three regions:

- Mobile County
- State of Alabama
- Louisiana/Texas (LA/TX)

Mobile County added 23,000 new jobs to the labor force between 1982 and 1992. Approximately 3,000 of these were related to the stimulus of the new offshore gas industry. Long-term levels of development and production will sustain more than 2,000 Mobile County jobs through the turn of the century—linked to ongoing O&M. Since 1994, the largest impetus for new jobs in Mobile County has been ongoing operations expenditures.

The State of Alabama's direct expenditures of the natural gas tax and trust fund revenues have been and will continue to be the largest impetus for new job creation statewide. Tax and trust fund expenditures have sustained about 4,000 statewide jobs annually since the mid-1980s. By the end of the century, tax and trust fund expenditures will sustain nearly 5,000 jobs statewide, including those created in Coastal Alabama in conjunction with the counties' expenditure of their share of the severance tax.

The coastal areas of LA/TX house specialized industries that support offshore oil and gas drilling, platform and platform facilities construction, and pipe-laying. Contractors from these areas provide the majority of workers needed to drill and develop Mobile Bay gas. LA/TX receives the bulk of industry expenditures.

Employment created in LA/TX in association with Mobile Bay exploration and development rose sharply in the mid 1980s to peak near 5,000 in 1985, mostly related to drilling, and 8,000 in 1988 related to MOEPSI's completion and start-up of the Mary Ann Field. Employment fluctuates with contracts related to the phases of various Mobile Bay projects. Employment in LA/TX dropped off in 1989 and 1990, but resurged between 1991–1993 as Shell and Exxon completed and started up their projects.

A SOCIOECONOMIC BASELINE STUDY FOR THE GULF OF MEXICO: PHASE I

Dr. Joachim Singleman
Louisiana State University

THE PURPOSE OF THE DATABASE

Despite the long history of offshore oil and gas activities in the Gulf of Mexico (GOM) region, little information exists on the socioeconomic impact of offshore drilling in the GOM region in general, and its coastal areas in particular. The purpose of this database, therefore, is to provide a consolidated source of information for the five states in the GOM region (Alabama, Florida, Louisiana, Mississippi, and Texas), which will enable the researchers to:

1. identify counties/parishes whose employment structures were strongly affected by oil/natural gas extraction activities;
2. examine how this impact has changed over the period 1930-90;
3. analyze the socio-economic impact of oil/ natural gas extraction for the period 1930-90.

It contains over 3,000 variables that include information about population, employment, income, establishments, and government finance for counties (or parishes) in Alabama, Florida, Louisiana, Mississippi, and Texas for the period 1930-90. The data assembled include extracts from machine readable datasets as well as data entered manually. Information on oil/gas dependency is also added based on an industry-occupation matrix specially obtained from the U.S. Bureau of the Census.

SUBJECT MATTER

The data in this dataset are classified and organized in terms of the following modules: demography (except vital statistics), vital statistics, civilian employment, establishments, income and poverty status, and government finance and employment.

The demographic data include information on age, sex, marital status, race, educational attainment, place of birth, and migration experience. Many of these data are cross-tabulated by race and sex. The data on vital statistics (live birth, deaths, marriage, and divorce) are collected separately to supplement the demographic data. The data on civilian employment include information on labor force status, class of worker, industry and occupation. These data are also cross-tabulated by race and sex whenever data are available. The employment information on mining for 1940-70, oil/natural gas for 1980-90, and the location quotient for employment in the mining industry for 1940-90 are also added to facilitate the analysis on oil dependency.

The data on government revenue include the sources of revenue (inter-governmental and own sources). Expenditure data are collected in terms of major functions such as education, highways, and public welfare that comprise the direct general expenditure. The data on debt and assets are added whenever available. The government employment data include "full-time employment equivalent" workers by major function. The data on establishment include the number, size, and employment for manufacturing, retail, wholesale, service establishments, and farms. Lastly, the income data include personal and family (household) income as well as poverty status.

REFERENCE PERIODS

The exact reference periods covered vary from subject to subject. While every effort was made to collect data for the period between 1930 and 1990, the data for earlier periods are either not available or only partially available. For example, while demographic and employment data are generally available from decennial censuses conducted every 10 years, government finance and employment data include only those from the 1957, 1962, 1972, 1977, 1982, and 1987 Census of Government. Data on vital statistics, establishments, and personal income are available for some other years.

DATA FILES

This dataset as well as codebook are available from the Louisiana Population Data Center, Louisiana State University, in the following formats, which are all included in one CD-ROM:

ASCII raw data file	1 file
SAS/Windows system file	1 file
SAS transport file	2 files

SAS program to read ASCII data	1 file
SAS program to read SAS transport file	1 file
SPSS/Windows system file	1 file
SPSS export file	1 file
SPSS program to read ASCII data	1 file
SPSS program to read SAS transport file	1 file
Lotus 123 (.wk1) files	27 files

REFERENCE MATERIALS

The major data sources utilized for building this dataset include the following:

1. Data on population, civilian employment, and income:

   1930-1960
   - Historical demographic, economic and social data. The United States, 1790-1970 (ICPSR 0003)
   - Census of Population 1960: General Social and Economic Characteristics (Bureau of the Census)

   1970 Census of Population and Housing 1970: Summary Statistics File 4C (ICPSR 8107)

   1980 Census of Population and Housing 1980: Summary Tape File 3C (ICPSR 80380)

   1990 Census of Population and Housing 1990: Summary Tape File 3 (ICPSR 6054)

   In addition, the following datasets were consulted:

   - County and City Data Book Consolidated File (ICPSR 7736)
   - County Statistics File (Co-Stat 4) (ICPSR 9806)
   - USA Counties 1994 (Bureau of the Census, CD94-CTY02)

2. Data on government employment: Census of Government 1962, 1972, 1977, 1982, 1988 (ICPSR 0017, 0069, 8117, 8395, 6069)

3. Data on government finance: Census of Government 1962, 1972, 1977, 1982, 1988 (ICPSR 0017, 0069, 8118, 8394, 9484)

4. Data on establishment:
   - County and City Data Book Consolidated File (ICPSR 7736)
   - County Statistics File (Co-Stat 4) (ICPSR 9806)
   - USA Counties 1994 (Bureau of the Census, CD94-CTY02)
   - County Business Patterns 1980 and 1990 (ICPSR 8142, 6030)

PRELIMINARY FINDINGS

We examined trends in selected key demographic and socioeconomic variables for the Gulf of Mexico (GOM) region: population, migration, income, education, revenue, and expenditure.

Population

The population in the GOM states increased at an annual rate of 1.5% during the period 1957-87, from 18 million people in 1957 to 29 million people in 1987. While the rate of growth was fairly steady during the 30-year period, the period 1982-87 witnessed the slowest rate of growth, reflecting the slowdown in oil/gas production during that time. The 1.8 percent average annual poplation growth during the 30-year period in coastal counties was slightly above the GOM regional average. Again, population growth in the coastal counties was slowest during the period 1982-87.

Migration

The average in-migration rate in oil/gas dependent counties remained substantially above the GOM average for the period 1950-80. By 1990, however, in-migration in these counties dropped to the regional average. Coastal areas displayed a different pattern: throughout the 1950-90 period, in-migration to oil/gas dependent counties remained below the coastal average, with the largest difference occuring in 1990. In that year, coastal counties with the highest oil/gas dependency attracted only about half as many migrants (in relative terms) than all coastal counties combined.

Per Capital Income

Per capita income in oil/gas dependent counties more or less equalled the average per capita in GOM states during the period 1950-70. The income in oil/gas dependent counties substantially exceeded the GOM average in 1980, refelcting the oil/gas boom at that time, and dropped below the GOM average by 1990, as a result of the ensuing oil/gas bust. In coastal areas, oil/gas dependent counties had lower per capita income than other counties throughout the period 1950-90.

Revenues

The distribution of revenue is partly a function of population distribtion among the oil/gas dependent categories. Because there were far fewer oil/gas dependent counties in 1987 than 30 years earlier, these counties in 1987 accounted for far less revenue in the GOM region than they did in 1957.

Selected Expenditures

Total per capita expenditures in oil/gas dependent counties remained below those in the GOM region and coastal areas throughout the 1957-87 period, with the exception of 1982 when they exceeded the averages in both the GOM region and coastal areas. Expenditures on *education* in oil/gas dependent counties remained above the GOM region and coastal areas averages throughout the period 1957-82, but they dropped below both averages by 1987. Spending on *public welfare* in oil/gas dependent counties remained below those expenditures in the GOM region and coastal areas throughout the entire period 1957-87. When compared with the GOM region and coastal areas in general, oil/gas dependent counties spent an above average amount on *hospital and health services* throughout the period 1957-87.

OIL AND GAS DEVELOPMENT AND COASTAL INCOME INEQUALITY: A COMPARATIVE ANALYSIS AT THE PLACE LEVEL

Dr. Charles M. Tolbert
Dr.Edward S. Shihadeh
Louisiana Population Data Center
Louisiana State University

INTRODUCTION

This study builds on earlier research conducted at the parish level. The parish-level research generated useful results and considerable interest among representatives of various agencies. Yet the research is obviously limited by the size and diversity of parishes which can mask important variations within parishes. The current study employs data on coastal Census places (urbanized areas of 2,500 or more persons). It constitutes a more closely ordered study of communities and provides more homogeneous study populations. Due to superb archival work by project graduate research assistants, we also add 1950 and 1960 Census income data. Perhaps the most telling result of our use of these earlier decennial points is the revelation that episodes of volatility are common in coastal Louisiana and are not confined to periods of expansive oil and gas development. In these several respects, the place-level study represents a substantial improvement over the earlier parish-level analysis.

METHODS AND RESULTS

We begin this analysis with an examination of family income distributions from 1950 to 1990, using histograms that show the shape of the distribution while minimizing distortion due to inflation and changing income intervals used by the Bureau of the Census. The parish-level data in the uppermost panel of Figure 2J.1 show a gradual reduction in family income inequality from 1950 to 1970 (these data are taken from our previous study). This is followed by a dramatic reduction in inequality that roughly coincides with the peak of oil and gas activities (especially offshore on the OCS). By 1990, however, the parish-level income distribution has lost its middle with shifts to both the low and high ends of the income distribution. This is graphic evidence of increased income inequality after 1980.

The next three panels of Figure 2J.1 depict family income distributions for three of the larger Census places along the Louisiana coast: New Iberia,

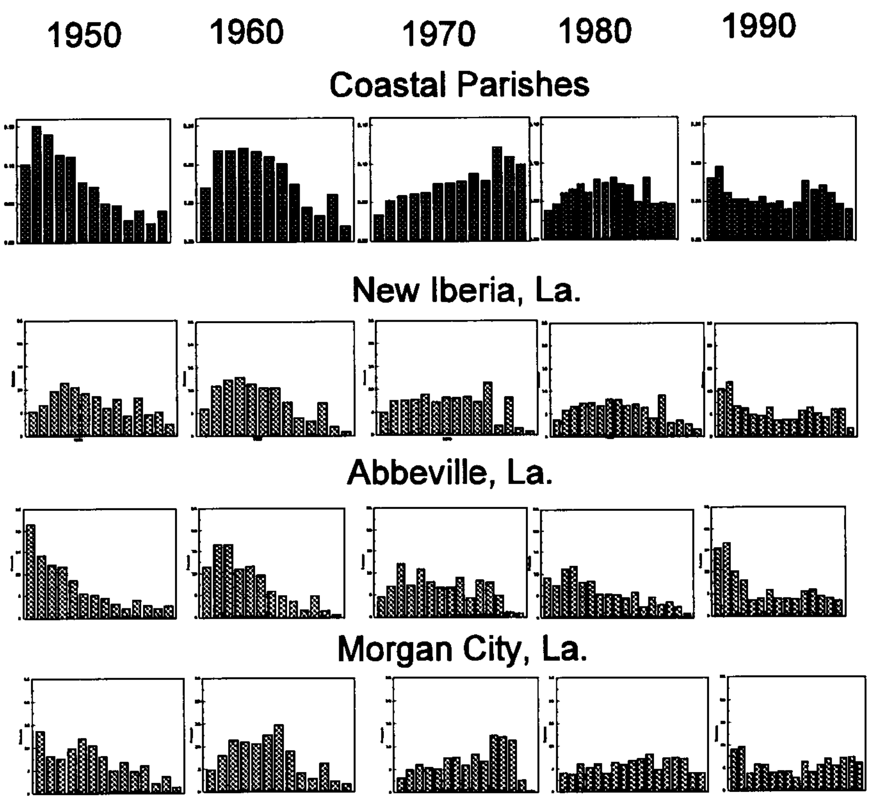

Figure 2J.1. Family income distributions: 1950-1990.

Abbeville, and Morgan City. New Iberia closely parallels the trend apparent at the coastal parish level. A substantial reduction in family income is followed by sharp increase in 1990. Abbeville exhibits a progressive reduction in inequality until 1990, when there is some evidence of an increase, especially in the lower end of the income distribution. Compared to New Iberia, however, the middle of the Abbeville income distribution holds it own. Morgan City exhibits the least 1980 to 1990 change in its income distribution.

We calculate income inequality here with the Atkinson measure calibrated in Figure 2J.2 to focus on the middle of the income distribution. The arithmetic outcome is the same as the widely used Gini coefficient. The patterns suggest that—at least for the middle of the income distribution—the most volatile response from 1980 to 1990 is exhibited by New Iberia. Over the longer run, Morgan City shows the least volatility, bordering on being counter cyclical. In more recent decades, Abbeville appears to become increasingly less volatile. It is important to note that volatility characterizes these income distributions well before the episode of increased offshore oil and gas development of the late 1970s and early 1980s. More importantly, these three communities scarcely 60 miles apart each show very different family income inequality patterns.

We explore the volatility issue further by computing a measure of relative volatility in income inequality outcomes. Our measure is equivalent to the commonly used coefficient of relative variation. We define relative volatility as the ratio of the standard deviation of absolute value of percent change to the mean absolute percentage decade-over-decade change in inequality. These measures are presented in Figure 2J.3. The Atkinson inequality measure can be calibrated to emphasize portions of the income distribution. At a

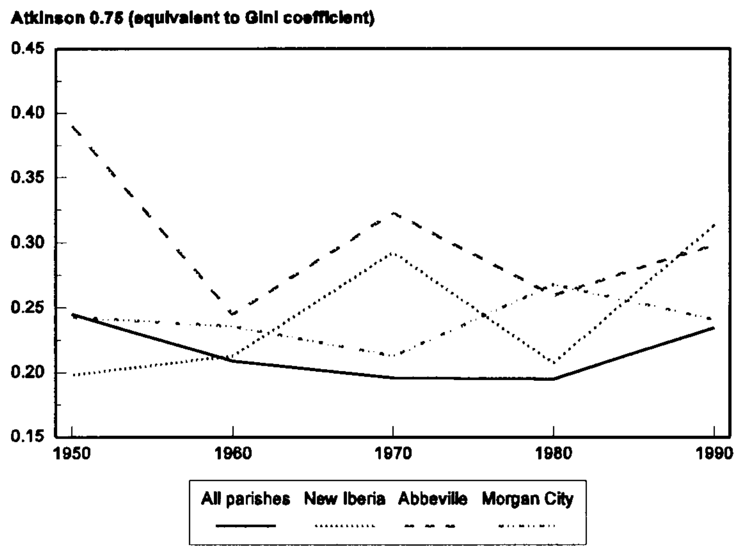

Figure 2J.2. Family income inequality.

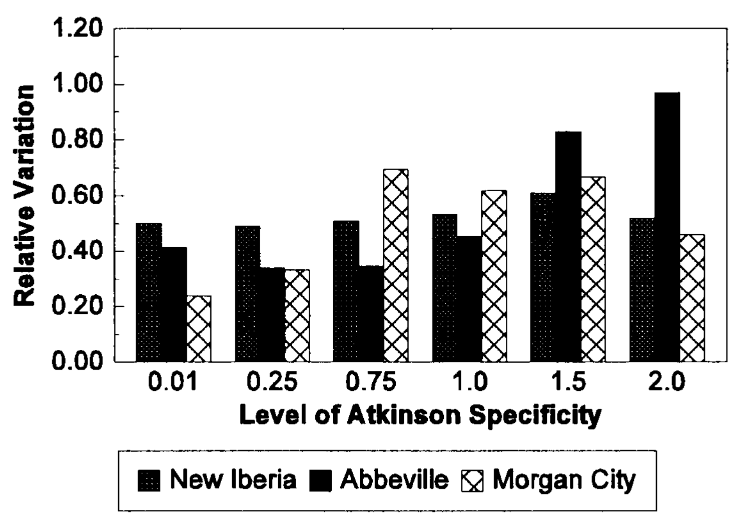

Figure 2J.3. Relative volatility in income inequality.

specificity level of 0.01, the emphasis is on the high end of the income distribution. At a level of 2.0, the emphasis is on the lower end of the distribution. As noted above, a specificity level of 0.75 is equivalent to the common Gini coefficient of income inequality. Figure 2J.3 displays the relative volatility of income inequality across the three communities at various levels of specificity. New Iberia exhibits the most volatility at the high end of the income distribution. Abbeville exhibits the most volatility at the low end, but also the least volatility in the middle ranges of income.

Our results suggest that communities experience oil and gas development in very different ways. Abbeville, for example, weathers the boom and bust episode of the 1980s rather well, especially in the middle ranges of the income distribution. This suggests a sustainable pattern of socioeconomic development that warrants further investigation. Our initial presumption about Abbeville's experience was that it did relatively well because of the opening of a large textile assembly plant. However, upon discussing our hypothesis with locals, we have since found out that the plant opened *after* the 1990 Census was taken. Thus, we suspect that we have reached the limits of the Census data in informing us about the absence of volatility in Abbeville (and perhaps elsewhere). We are now beginning a community study in Abbeville and will hold guided conversations with key stakeholders and randomly selected persons. Our main objective in the new study is to gain an understanding of the bases of the community's sustainability and resilience in the recent episode of oil and gas industry expansion and contraction.

INDEX TO AUTHORS

ATTENDEES

ACREE, SMITH
PO BOX 1507
OPELOUSAS, LA 70570

AHLFELD, TOM
OCEANOGRAPHER
381 ELDEN ST
HERNDON, VA 20170-4817

ALLEN, DAN
SR ECOLOGIST
935 GRAVIER ST
NEW ORLEANS, LA 70112

ALTOBELLI, MICHAEL
6688 NORTH CENTRAL EXPRESSWAY
SUITE 1000
DALLAS, TX 75206-3922

ANUSKIEWICZ, RIK
MMS
1201 ELMWOOD PARK BLVD
NEW ORLEANS, LA 70123

APPLEGATE, MICHAEL C
COMMAND ENVIRONMENTAL MANAGER
100 BARTLEY ST
SUITE 125E
HURLBURT FIELD, FL 32544-5273

AURAND, DON
PRINCIPAL SCIENTIST
PO BOX 1199
PURCELLVILLE, VA 20134

AVENT, BOB
MMS
1201 ELMWOOD PARK BLVD
NEW ORLEANS, LA 70123

BAERENWALD, PAUL
SR GEOLOGIST
6100 HILLCROFT
HOUSTON, TX 77081

BALLARD, ALAN
BLDG 1103, ROOM 202
STENNIS SPACE CENTER, MS 39529

BALTZ, DONALD M
COASTAL FISHERIES INST
BATON ROUGE, LA 70803

BARTON, WARREN
MMS
1201 ELMWOOD PARK BLVD
NEW ORLEANS, LA 70123

BATCHELDER, ERIC
GEOLIGIST
1201 ELMWOOD PARK BLVD
NEW ORLEANS, LA 70123

BAUD, RICHIE
GEOPHYSICIST
1201 ELMWOODPARK BLVD
JEFFERSON, LA 70123

BEAL, DAN
SR PROJECT ENGINEER
15375 MEMORIAL DR
HOUSTON, TX 77079

BEAVER, CARL
RESEARCH ASSIST
6300 OCEAN DR
CORPUS CHRISTI, TX 78412

BENNER, COLLEEN
OCEANOGRAPHER
381 ELDEN ST
HERNDON, VA 20170

BENNETT, JAMES F
MMS
MS4320
381 ELDEN STREET
HERNDON, VA 20170

BERKSHIRE, EMILY
SLIDELL, LA 70458

BERNEY, LOUISE A
LIEUTENANT
800 DAVID DRIVE
MORGAN CITY, LA 70380

BEST, G RONNIE
700 CAJUNDOME BLVD
LAFAYETTE, LA 70506

BOHRER, JOHN
PROJECT MKT MANAGER
950 THREADNEEDLE #150
HOUSTON, TX 77079

BOLDEN, JIM
1330 JIM TAYLOR, APT 54
BATON ROUGE, LA

BORNHOLDT, DAVE
RM 7A202A
12201 SUNRISE VALLEY DR
RESTON, VA 20192

BOUDREAUX, MARK A
PO BOX 61707
NEW ORLEANS, LA 70161

BOWEN, JULIE
SR REGULARORY ASSISTANT
PO BOX 60004
NEW ORLEANS, LA 70112

BOWMAN, JANET
IS APP PROGRAMER
PO BOX 98000
BATON ROUGE, LA 70808

BOYKIN, ESTHER
ASSOCIATE ATTORNEY
400 MAGAZINE ST, SUITE 401
NEW ORLEANS, LA 70130

BRADFORD, CARY

BRAINARD, MIKE
FISHERIES BIOLOGIST
152 GATEWAY DRIVE
BILOXI, MS 39531

BRASHIER, JERRY
MMS
1201 ELMWOOD PARK BLVD
NEW ORLEANS, LA 70123

BROOKS, JAMES
PRESIDENT
3953 CEDAR RIDGE
COLLEGE STATION, TX 77845

STEVE BROOKS
EXXON COMPANY USA
OFFSHORE REG & ENVIR AFFAIRS
1555 POYDRAS STREET
NEW ORLEANS, LA

BROWN, MURRAY
NEW ORLEANS, LA

BRYANT, WILLIAM
DEPT OF OCEANOGRAPHY
TEXAS A&M
COLLEGE STATION, TX 77843

BULL, ANN
MMS
1201 ELMWOOD PARK BLVD
NEW ORLEANS, LA 70123

CALDARERA, VINCENT
15375 MEMORIAL DRIVE
HOUSTON, TX 77079

CAMPBELL, DENISE
PO BOX 51007
LAFAYETTE, LA 70505

CARUSO, JOHN
LUMCON
8124 HWY 56
CHAUVIN, LA

CHEW, DENNIS
MMS
1201 ELMWOOD PARK BLVD
NEW ORLEANS, LA 70123

CHRISTOPHER, JOE
MMS
1201 ELMWOOD PARK BLVD
NEW ORLEANS, LA 70123

CHURCHILL, JAMES
17 BROWN CT
FALMOUTH, MA 02540

CIMATO, JAMES M
MMS
ENVIRONMENTAL STUDIES BRANCH
HERNDON, VA 20170

CLOPTON, PAUL
PO BOX 39500
LAFAYETTE, LA 70503

CLOUD, JENNIFER
SLIDELL, LA 70458

COLE, JOHN G
1410 CAVITT ST
BRYAN, TX 77801

COLLINS, KAREN
ENVIRONMENTAL MANAGEMENT
202 6TH AVENUE EAST
BRADENTON, FL

COMBS, SUE
1992 LEWIS TURNER BLVD
FT WALTON BEACH, FL 32547

CONGDON, BARNEY
1201 ELMWOOD PARK BLVD
NEW ORLEANS, LA 70123

COOK, J E
1200 SOUTH ST, SUITE 500
HOUSTON, TX

COTTONE, VINCENT F
EHS PROFESSIONAL
PO BOX 60252
NEW ORLEANS, LA 70160-0252

CURLEE, C K
PO BOX 53266
LAFAYETTE, LA 70505

DAUTERIVE, LES
MMS
1201 ELMWOOD PARK BLVD
NEW ORLEANS, LA 70123

DAVIS, BEN
6688 NORTH CENTRAL EXPRESSWAY
SUITE 1000
DALLAS, TX 75206-3922

DECKER, NELDA
COORDINATOR REGULATORY RPTS
CNG TOWER
1450 POYDRAS ST
NEW ORLEANS, LA 70112-6000

DESAI, YESHAVANT
1201 ELMWOOD PARK BLVD
NEW ORLEANS, LA 70123

DESLARZES, KEN
MMS
1201 ELMWOOD PARK BLVD
NEW ORLEANS, LA 70123

DEWAILLY, ED
CONSULTANT
409 TIFFANY DR
RIVER RIDGE, LA 70123

DEWITT, CYNTHIA
REGULATORY ANALYST
PO BOX 4587
HOUSTON, TX 77210

DINGER, BLAINE
DIRECTOR EH&S
PO BOX 25861
OKLAHOMA CITY, OK 73125

DONSBACH, MIKE
701 POYDRAS
NEW ORLEANS, LA 70065

DORNER, MIKE
1201 ELMWOOD PARK BLVD
NEW ORLEANS, LA 70123

DOUGALL, DAVE
MGR ENVIRONMENT/SAFETY
2950 N LOOP WEST #300
HOUSTON, TX 77092

DUHON, CHARLIE
3867 AMBASSADOR CAFFERY
LAFAYETTE, LA 70503

DUNLAP, WAYNE
ASSOC DIRECTOR
1200 MARINER DR
COLLEGE STATION, TX 77845

DUPLANTIER, DAVID
#20 CARDINAL RD
COVINGTON, LA 70433

DUPONT, ALLEN
MANAGER MARKETING
PO BOX 20116
NEW ORLEANS, LA 70141

ECKENRODE, MARK
PHYSICAL SCIENTIST
770 PAESO CAMARILO
CAMARILLO, CA 93060

ELLER, MIKE
ARTIFICIAL REEF COORD
PO BOX 1425
DESTIN, FL 32540

EVE, HAMMOND
MMS
1201 ELMWOOD PARK BLVD
NEW ORLEANS, LA 70123

FAGOT, CARYL
1201 ELMWOOD PARK BLVD
NEW ORLEANS, LA 70123

FARWELL, DENNETTE
GRAD STUDENT
ENVIRONMENTAL HEALTH STUDIES
#85 AVANT GARDE CIRCLE
KENNER, LA 70065

FERTL, DAGMAR
MMS
1201 ELMWOOD PARK BLVD
NEW ORLEANS, LA 70123

FINLEY, HEATHER
BIOLOGIST
PO BOX 98000
BATON ROUGE, LA 70898

FLEEGER, JOHN
PROFESSOR
DEPT OF ZOOLOGY
BATON ROUGE, LA 70803

FOMICH, KATRINA
SLIDELL, LA 70458

FONTENOT, LARRY
ENVIRONMENTAL SAFETY SPEC
900 S COLELGE RD #300
LAFAYETTE, LA 70503

FRANKLIN, KEVIN
MARKETING ASSISTANT
PO BOX 20116
NEW ORLEANS, LA 70141

FRIEDLANDER, NATHAN
MOBILE, AL

FROOMER, NORMAN
MMS
1201 ELMWOOD PARK BLVD
NEW ORLEANS, LA 70123

GALLAGHER, FRANK
600 CARONDELET
NEW ORLEANS, LA 70130

GAUDET, HOLLY
NEW ORLEANS, LA 70148

GHALAMBOR, A
U OF SOUTHWESTERN LOUISIANA
PO BOX 44408
LAFAYETTE, LA

GILLARD, BOB
MMS
1201 ELMWOOD PARK BLVD
NEW ORLEANS, LA 70123

GITSCHLAG, GREGG
FISHERY BIOLOGIST
4700 AVE U
GALVESTON, TX 77551

GITTINGS, STEVE
SANCTUARY MANAGER
216 W 26TH ST, SUITE 104
BRYAN, TX 77803

GOBERT, ANGIE D
1201 ELMWOOD PARK BLVD
NEW ORLEANS, LA 70123

GOEKE, GARY
MMS
1201 ELMWOOD PARK BLVD
NEW ORLEANS, LA 70123

GOOD, KEITH
PHYSICAL SCIENTIST
381 ELDEN ST
HERNDON, VA 20170-4817

GORES, CONNIE J
J CONNOR CONSULTING
16225 PARK TEN PLACE #500
HOUSTON, TX 77084

GRAFFEO, ELDIN
PUBLIC INFO ASSISTANT
1201 ELMWOOD PARK BLVD
NEW ORLEANS, LA 70123

GREENE, JOHN
MMS
1201 ELMWOOD PARK BLVD
NEW ORLEANS, LA 70123

GRIFFIN, DON
SR MARKETING REP
19170 PERKINS RD
BATON ROUGE, LA 70810

GRIFFIN, LYNN
ENVIRONMENTAL ADMINISTRATOR
3900 COMMONWEALTH BLVD MS 47
TALLAHASSEE, FL 32399

GRIMSLEY, RUSTY
ENVIRONMENTAL ENGINEER
935 GRAVIER STREET
NEW ORLEANS, LA 70112

HAMILTON, THOMAS K
SR VICE PRESIDENT
6100 HILLCROFT
HOUSTON, TX 77081

HANCOCOK, MAX
DIRECTOR
3134 BAYBROOK
CORPUS CHRISTI, TX 78418

HANIFEN, JIM
PROGRAM MGR
PO BOX 98000
BATON ROUGE, LA 70898

HARRIS, JEFF
PO BOX 44487
BATON ROUGE, LA 70804

HARRIS, VIRGIL
EXECUTIVE DIRECTOR
PO BOX 50751
NEW ORLEANS, LA 70150

HEATH, STEVE
ASST CHIEF MARINE BIOLOGIST
PO BOX 189
DAUPHIN ISLAND, AL 36528

HELM, MICHELE
MMS
1201 ELMWOOD PARK BLVD
NEW ORLEANS, LA 70123

HENRY, CHARLIE
RESEARCH ASSOCIATES
42 ATKINSON HALL
BATON ROUGE, LA 70803

HERKHOF, DIRK
METEOROLOGIST
331 ELDEN STREET
HERNDON, VA 20170

HERRIN, EVAN F
701 POYDRAS ST
NEW ORLEANS, LA

HERRINGTON, TOM
ASSOC DIR
BLDG 1103, RM 203
STENNIS SPACE CENTER, MS 39529

HILL, DON
DPD MARINE MINERALS
381 ELDEN ST
HERNDON, VA 20170

HILL, PETER
DEEPTWATER CERTIFICATION
3330 W ESPLANADE
METAIRIE, LA 70002

HOENSTEINE, RON
903 WEST TENNESSEE ST
TALLAHASSEE, FL 32304-7700

HOGGARD, WAYNE
FISHERY BIOLOGIST
PO DRAWER 1207
PASCAGOULA, MS 395687

HOLDER, SAMUEL
MMS
1201 ELMWOOD PARK BLVD
NEW ORLEANS, LA 70123

HOLLEK, DARRELL
3867 AMBASSADOR CAFFERY
LAFAYETTE, LA 70503

HOLMAN, TERRY
PROGRAM MGR
381 ELDEN ST
HERNDON, VA 20170

HOROWITZ, WARREN
13050 RIDGE VIEW DR
ANCHORAGE, AK 99516

HOWARD, DON
REGIONAL SUPERVISOR
1201 ELMWOOD PARK BLVD
NEW ORLEANS, LA

HOYLE, JAY
13939 NW FREEWAY
HOUSTON, TX 77040

HUMMEL, RICHARD
420 HACKBERRY LN
PO BOX 0
TUSCALOOSA, AL 35486

HUTZELL, BILL
MMS
1201 ELMWOOD PARK BLVD
NEW ORLEANS, LA 70123

IRVIN, ALGY
2200 TUPELO
NEW ORLEANS, LA 70117

IZON, DAVID
1201 ELMWOOD PARK BLVD
NEW ORLEANS, LA 70123

JOHNSON, BONNIE
MMS
1201 ELMWOOD PARK BLVD
NEW ORLEANS, LA 70123

JOHNSON, CARLIANE
GOVERNMENTAL ANALYST
THE CAPITOL - ROOM 1501
TALLAHASSEE, FL 32399-0001

JOHNSON, HESTER
PO BOX 44487
BATON ROUGE, LA 70804

JOHNSON, SANDRA
SLIDELL, LA

JONES, A J
MMS
1201 ELMWOOD PARK BLVD
NEW ORLEANS, LA 70123

JONES, CASEY
1000 LOUISIANA, #3800
HOUSTON, TX

JONES, LINZA
HALLIBURTON ENTERGY SERVICES
8432 SOUTH I-35
WEST ALVARDO, TX

JORDAN, TERRI
FISHERY BIOLOGIST
LSU
BATON ROUGE, LA 70803

KALUZA, MICHAEL J
6100 HILLCROFT
HOUSTON, TX 77081

KASPARZAK, RICK
PROJECT COORDINATOR
PO BOX 98000
BATON ROUGE, LA 70898

KASPRAZAK, MICHELLE
PROJECT LEADER
PO BOX 98000
BATON ROUGE, LA 70898

KEATING, TOM
PO BOX 51007
LAFAYETTE, LA 70505

KENDALL, JAMES
MMS
1201 ELMWOOD PARK BLVD
NEW ORLEANS, LA 70123

KENNICUTT, MAHLON C
DEPUTY DIRECTOR
833 GRAHAM ROAD
COLLEGE STATION, TX 77845

KENNY, JAN
EMVIRONMENTAL POLICY COORD
401 WHITNEY AVE #412
GRETNA, LA 70056

KOPFLER, FRED
ENVIRONMENTAL SCIENTIST
BLDG 1103 ROOM 202
STENNIS SPACE CENTER, MS 39529

KROLOW, MARK
PRJCT LR FOR DP WR EXPLORATION
935 GRAVIER STREET
NEW ORLEANS, LA 70112

KRUEBBE III, EDWARD A
SR ENGINEERING TECH
PO BOX 61933
NEW ORLEANS, LA 70161

KUDLA, MARC
ENVIRONMENTAL SUPERVISOR
15278 MEMORIAL DR
HOUSTON, TX 77079

KUEBEL, KAREN
MARINE BIOLOGIST
5828 SYLVIA DR
NEW ORLEANS, LA 70124

KUMPF, HERB
ECOLOGIST
3500 DELWOOD BEACH ROAD
PANAMA CITY, FL 32408

LADMER, JIM
903 WEST TENNESSEE ST
TALLAHASSEE, FL 32304-7700

LAI, RONALD
381 ELDEN ST
HERNDON, VA 20170

LAMKIN, JOHN
75 VIRGINIA BEACH DRIVE
MIAMI, FL 33149

LANDRY, CONNIE
MMS
1201 ELMWOOD PARK BLVD
NEW ORLEANS, LA 70123

LANG, BILL
MMS
1201 ELMWOOD PARK BLVD
NEW ORLEANS, LA 70123

LAROCK, PAUL
PROFESSOR
OCEANOGRAPHY
BATON ROUGE, LA 70803

LASSEIGNE, LORI
200 DULLES DR
LAFAYETTE, LA 70506

LATIMER, LONNY
REGULATORY COORDINATOR
14701 ST MARY'S LANE #200
HOUSTON, TX

LAURENDINE, TOMMY
1201 ELMWOOD
NEW ORLEANS, LA 70123

LEBEN, ROBERT
CAMPUS BOX 431
BOULDER, CO 80303

LEBLANC, DAVID L
SR ENVIRONMENTAL COORDINATOR
PO BOX 60252
NEW ORLEANS, LA 70160

LEE, ED
600 CARONDELET
NEW ORLEANS, LA 70130

LEE, GRIFF C
CONSULTANT
PO BOX 60035
NEW ORLEANS, LA 70160

LIN, QIANXIN
BATON ROUGE, LA 70803

LINDSTEDR, DIANNE
RESEARCH ASSOC
314 E HOWE-RUSSELL
LSU
BATON ROUGE, LA 70803

LITTLE, STEVE
USA
PO BOX 61707
NEW ORLEANS, LA

LIU, XIAOYU
8701 TEICHMAN RD
GALVESTON, TX 77554

LOYACANO, HAROLD
PRESIDENT
58485 PEARL ACRES RD SUITE D
SLIDELL, LA 70461

LUGO-FERNADEZ, ALEXIS
MMS
1201 ELMWOOD PARK BLVD
NEW ORLEANS, LA 70123

LUKENS, RON
ASST DIRECTOR
PO BOX 726
OCEAN SPRINGS, MS 39566

LUPPEUS, J C
101 FEU FOLLET
LAFAYETTE, LA 70508

LUTON, HARRY
MMS
1201 ELMWOOD PARK BLVD
NEW ORLEANS, LA 70123

LYONS, R MICHAEL
MANAGER ENVIRONMENTAL AFFAIRS
801 N BLVD #201
BATON ROUGE, LA 70802

MALTER, PAUL L
ENVIRONMENTAL/SAFETY MANAGER
400 N SAM HOUSTON PARKWAY EAST
SUITE 1200
HOUSTON, TX 77060-3593

MANAGO, FRANK
ENVIRONMENTAL SCIENTIST
CAMARILLO, CA 93010

MARCKS, BRIAN
PO BOX 44487
BATON ROUGE, LA 70804

MARKS, STEVEN
6241 NW 23RD ST
SUITE 500
GAINESVILLE, FL

MATHIES, STEVE
DEPUTY SECRETARY
PO BOX 94396
BATON ROUGE, LA 70804-9396

MCDADE, ELIZABETH
GEOSCIENTIST
400 POYDRAS
NEW ORLEANS, LA 70130

MCINTYRE, DON
PO BOX 4587
HOUSTON, TX 77494

MEYER, RICHARD
PO BOX 61933
NEW ORLEANS, LA

MEYER, ROBERT

MINK, ROBERT M
420 HACKBERRY LN
PO BOX 0
TUSCALOOSA, AL 35486

MIRE, MIKE
SENIOR ENGINEERING TECH
PO BOX 61933
NEW ORLEANS, LA 70161

MONAHAN, LESLIE
PETROLEUM ENGINEER
1201 ELMWOD PARK BLVD
NEW ORLEANS, LA 70123

MORAN, DAVE
MMS
1201 ELMWOOD PARK BLVD
NEW ORLEANS, LA 70123

MORAN, ROBERT J
DIRECTOR
NATIONAL OCEAN INDUSTRIES ASSOC
1120 G STREET NW
SUITE 900
WASHINGTON, DC

MORIN, MICHELLE
MMS
1201 ELMWOOD PARK BLVD
NEW ORLEANS, LA 70123

NEWTON, BOB
1201 ELMWOOD PARK BLVD
NEW ORLEANS, LA 70123

NOVAKOVIC, PAUL
3750 HACIENDA BLVD
FT LAUDERDALE, FL 33314

NUNEZ, ARLETTE C
SHALLOW HAZARDS INTERPRETER
PO BOX 61933 ROOM 3137
NEW ORLEANS, LA 70161

O'REILLY, JIM
PO BOX 2189
HOUSTON, TX 77379

ODDIE, THOMAS

OLSEN, PETER
MANAGER
8701 TEICHMAN RD
GALVESTON, TX 77554

OYNES, CHRIS
1201 ELMWOOD PARK BLVD
NEW ORLEANS, LA 70123

PARKER, MICHAEL E
SR STAFF ENGINEER
PO BOX 2180
HOUSTON, TX 77252-2180

PARKER, WANDA
PO BOX 2880
DALLAS, TX 75221

PARR, PHILLIP
600 CARONDELET
NEW ORLEANS, LA 70130

PASSMORE, JEFF
PO BOX 650232
DALLAS, TX 75265-0232

PATTON, FRANK
1201 ELMWOOD PARK BLVD
NEW ORLEANS, LA 70123

PETER, DOUGLAS
ARTIFICIAL REEF BIOLOGIST
1018 TUDVILLE RD
SEABROOK, TX 77586

PETERS, DENNIS
SENIOR ENVIRONMENTAL SCIENTIST
1247 B EGLIN PARKWAY
SHALIMAR, FL 32579

PICKETT, AL
SR REGULATORY CONSULTANT
PO BOX 61933
NEW ORLEANS, LA 70161

PRENTICE, LINDA
554 SIZELER AVE
JEFFERSON, LA 70121

RAINEY, GAIL
MMS
1201 ELMWOOD PARK BLVD
NEW ORLEANS, LA 70123

RANDLE, CLAIRE
CONSISTENCY COORDINATOR
1700 N CONGRESS
AUSTIN, TX 78701-1495

RANDOLPH, TOM
PO BOX 82860
BATON ROUGE, LA 70884

RAY, JIM
MGR-ENVIRON SCI
910 LOUISIANA STREET
HOUSTON, TX 77002

RAYLE, MIKE
BIOLOGIST
PO BOX 865
METAIRIE, LA 70004-0865

REDDING, TIMOTHY
PROGRAM ANALYST
381 ELDON ST
HERNDON, VA 20170

REGGIO, VILLERE
MMS
1201 ELMWOOD PARK BLVD
NEW ORLEANS, LA 70123

REYNOLDS, DOUG
101 HOLT ROAD
VICTORIA, TX 77905

RIALS, JOE R
200 DULLES DRIVE
LAFATETTE, LA 70506

RICHARDSON, ED
MMS
1201 ELMWOOD PARK BLVD
NEW ORLEANS, LA 70123

ROBERTS, PAULENE
RESEARCH ASSOCIATE
42 ATKINSON HALL
BATON ROUGE, LA 70803

RODEN, CAROL L
BIOLOGIST
3209 FREDERIC ST
PASCAGOULA, MS 39563

ROGERS, BOB
MMS
1201 ELMWOOD PARK BLVD
NEW ORLEANS, LA 70123

ROGERS, CAROLYN
FISHERIES BIOLOGIST
P O DRAWER 1207
PASCAGOULA, MS 39563

ROMAIRE, TERRY L
MARINE FISHERIES BIOLOGIST
PO BOX 2000
BATON ROUGE, LA 70810

ROSCIGNO, PAT
MMS
1201 ELMWOOD PARK BLVD
NEW ORLEANS, LA 70123

ROWALAND, JOHN
GEOLOGIST
381 ELDEN ST
HERNDON, VA 20170

RULLMAN, JOHN
GOV/REGULATORY LIAISON
PO BOX 61707
NEW ORLEANS, LA 70161

RUPERT, JERRY A
STAFF SAFETY ENGINEER
1340 POYDRAS ST
PO BOX 50879
NEW ORLEANS, LA 70150

RUTHERFORD, GARY
MMS
1201 ELMWOOD PARK BLVD
NEW ORLEANS, LA 70123

SARTHOU, CYNTHIA
CAMPAIGN DIRECTOR
PO BOX 2245
NEW ORLEANS, LA 70176-2245

SATTERLEE, KENT
STAFF ENVIRONMENTAL ENGINEER
PO BOX 61933
NEW ORLEANS, LA 70161

SAVOY, R J
SR EHS PROFESSIONAL
PO BOX 60252
NEW ORLEANS, LA 70160-0252

SCAIFE, BILL
1340 POYDRAS
NEW ORLEANS, LA 70150

SCALFANO, DAVID
935 GRAVIER
NEW ORLEANS, LA 70112

SCALLY, DOUGLAS
PROGRAM MANAGER
STENNIS SPACE CENTER, MS 39529

SCHANKE, GERALD A
DIRECTOR
AMERICAN PETROLEUM INSTITUTE
1220 L ST NW
WASHINGTON, DC

SCHOLTEN, TERRY
MMS
1201 ELMWOOD PARK BLVD
NEW ORLEANS, LA 70123

SCHROEDER, WILLIAM W
PROFESSOR
PO BOX 369
DAUPHIN ISLAND, AL 36528

SEENAPPA, SRI
ENVIRONMENTAL ENGINEER
HAYDEL & ASSOC
600 CARONDELET
NEW ORLEANS, LA

SEIP, JOHN
ENV SCIENCES & ENG DEPT
1200 ST CHARLES AVE
NEW ORLEANS, LA 70130-4334

SHORE, DANIEL
SLIDELL, LA

SILVA, ARMAND
DEPT OF OCEANOGRAPHY
NARRAGANSETT, RI 02882

SIMMONS, ROBERT A
COORDINATOR
PO BOX 61707
NEW ORLEANS, LA 70161-1707

SINGER, JIM
OCEANOGRAPHER
615 OBERLIN RD, #300
RALEIGH, NC 27605

SMITH, JOHNATHAN S
SENIOR SURVEY SPECIALIST
701 POYDRAS ST RM 1806
NEW ORLEANS, LA 70139

SMITH, KAREN
ENVIRONMENTAL TECH
1555 POYDRAS
NEW ORLEANS, LA 70161

SMITH, STEPHEN C
PO BOX 2266
HOUMA, LA 70364

SPACKMAN, ALAN
IADC
PO BOX 4287
HOUSTON, TX 77210

STANLEY, DAVID
COASTAL FISHERIES INST
LSU
BATON ROUGE, LA 70803

STEARNS, KENT
LAKEFRONT
NEW ORLEANS, LA 70122

STEWART, BOB
PRESIDENT
1120 G STREET NW, SUITE 900
WASHINGTON, DC 20005

STITES, RICHARD
OFFSHORE COORDINATOR
801 CHERRY ST
FORT WORTH, TX 760212

STRECKER, DAN
LAB DIRECTOR
17170 PERKINS RD
BATON ROUGE, LA 70810

STRIKMILLER, MICHAEL
MARKETING MANAGER
58485 PEARL ACRES RD, SUITE D
SLIDELL, LA 70461

STRINGFELLOW, ROBERT
1201 ELMWOOD
NEW ORLEANS, LA

SUBIK, DAN
PO BOX 60252
NEW ORLEANS, LA 70160

SUSTALA, DENNIS
SENIOR REGULATORY COORDINATOR
15375 MEMORIAL
HOUSTON, X 77079

SWITZER, TED
DEPT OF OCEANOGRAPHY
BATON ROUGE, LA 70803

SZABO, DAVID
REGIIONAL DIRECTOR
6100 HILCROFT #700
HOUSTON, TX 77081

THOMPSON, KEITH F
PO BOX 671264
DALLAS, TX

THORSTEINSON, LYMAN
OCEANOGRAPHER
909 FIRST AVENUE #800
SEATTLE, WA 98104

THOULION, RENE
600 CARONDELET
NEW ORLEANS, LA 70130

TILTON, LEE
1201 ELMWOOD PARK BLVD
NEW ORLEANS, LA 70123

TILYOU, GARY
INLAND FISHERIES BIOLOGIST
PO BOX 98000
BATON ROUGE, LA 70898

TIMES, WILFRED W
GIS/VISUAL INFO SPECIALIST
1201 ELMWOOD PARK BLVD
NEW ORLEANS, LA 70123

TODESCO, JANICE
SECRETARY
1201 ELMWOOD PARK BLVD
NEW ORLEANS, LA 70003

TOLAN, JAMES M
GRAD ASSISTANT
BATON ROUGE, LA 70803

TOLBERT, MICHAEL
1420 S CLEARVIEW PKWY
NEW ORLEANS, LA 70123

TOWER, JOHN P
LAND MANAGER
PO BOX 62102
HOUSTON, TX 77205-2102

TUCKER, DEBBY
OFFICE OF THE GOVERNOR

USHER, NATHANIEL
DIR ENGINERRING/GEOPHYSICS
15375 MEMORIAL DR
HOUSTON, TX 77079

VAUGHN, CATHY
1450 POYDRAS ST, SUITE 1550
NEW ORLEANS, LA 70112

VETTER, JERRY
ENV SCIENCES & ENGINEERING
1200 ST CHARLES AVE
NEW ORLEANS, LA 70130

VIADA, STEPHEN
328 ARIS AVENUE
METAIRIE, LA 70005

VIGIL, DEBBIE
MMS
1201 ELMWOOD PARK BLVD
NEW ORLEANS, LA 70123

VINESKI, DIANE
1 HOPE BLVD
GALVESTON, TX 77551

VOORHIES, COERTE A
MANAGER
PO BOX 57089
NEW ORLEANS, LA 57089

VORHEES, JAN
4856 F SNOOK DR SE
ST PETERSBURG, FL 33705

WADDELL, VAN
615 OBERLIN RD #300
RALEIGH, NC 27605

WAGUESPACK, MICHAEL
600 CARONDELET
NEW ORLEANS, LA 70130

WALLACE, DAVE
MGR OPERATIONS SUPPORT
PO BOX 4587
HOUSTON, TX 77210

WALLACE, MIKE
ENVIRONMENTAL PROTECTION ASSISTANT
NEW ORLEANS, LA

WETZEL, NICK
MMS
1201 ELMWOOD PARK BLVD
NEW ORLEANS, LA 70123

WILLIAMS, CLIFF
600 CARONDELT
NEW ORLEANS, LA 70130

WILSON, CHUCK
CCEER - DEPT OF OCEANOGRAPHY
BATON ROUGE, LA 70803

WILSON, JUDY
ENVIRONMENTAL SPECIALIST
381 ELDEN ST (MS 4320)
HERNDON, VA 20170-4817

WILTZ, CHRISTINE
7911 JEANNETTE ST
NEW ORLEANS, LA 70118

WITROCK, ROBERT
GEOLOGIST
1201 ELMWOOD PARK BLVD
NEW ORLEANS, LA 70123

WITTEN, MARK
ADVISOR - ENVIRONMENTAL SAFETY
935 GRAVIER ST
NEW ORLEANS, LA 70112

WOOD, ALVIN
VICE PRESIDENT
11200 WESTHEIMER, SUITE 850
HOUSTON, TX 77042

WORECESTER, COLETTE
MMS
1201 ELMWOOD PARK BLVD
NEW ORLEANS, LA 70123

ZERINGUE, KATHY
135 DEFIANCE DR
SLIDELL, LA 70458

ZERINQUE, DANA
SLIDELL, LA

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.