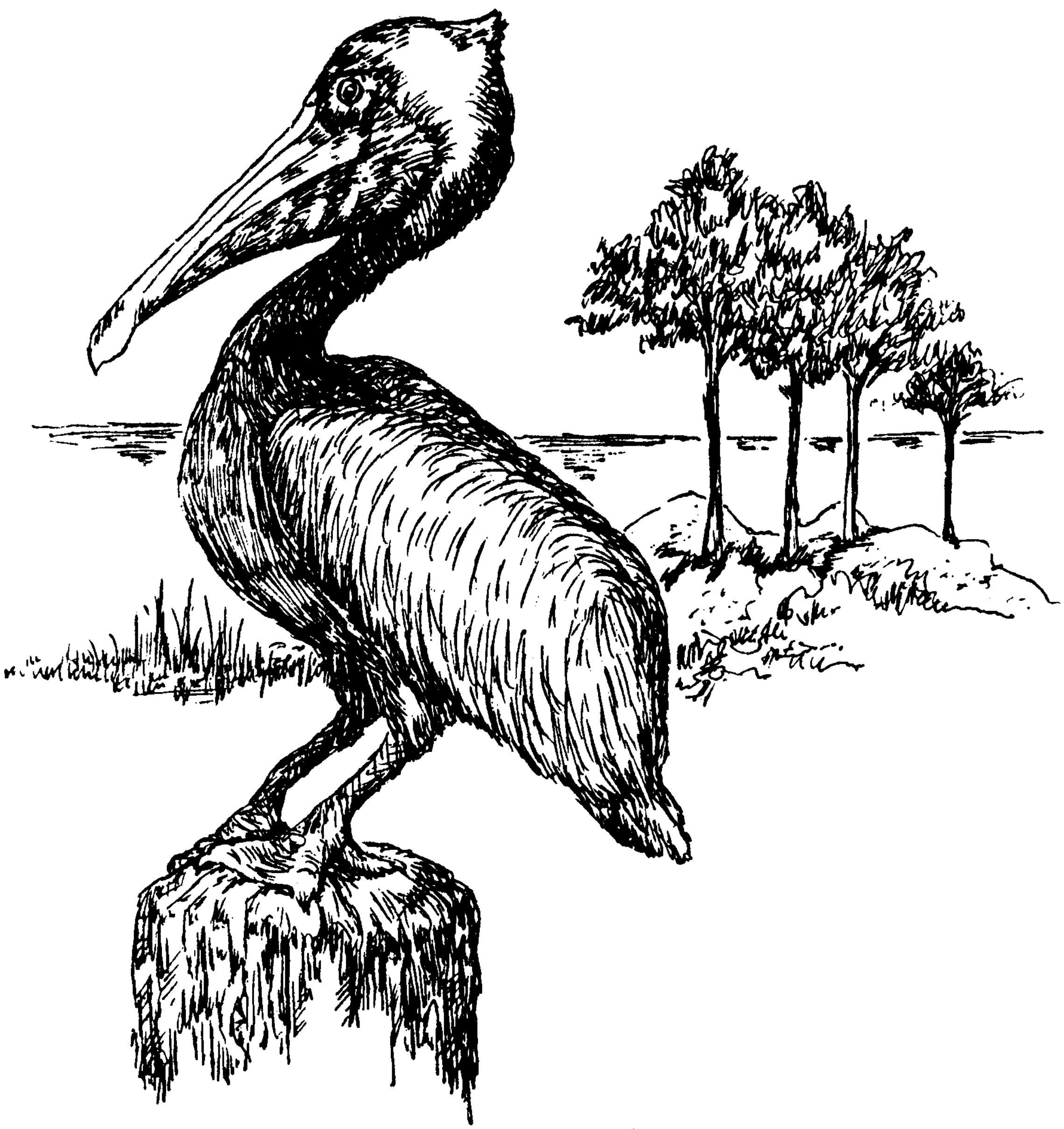
OCS Study
MMS 90-0027

Proceedings: Tenth Annual Gulf of Mexico Information Transfer Meeting

December 1989



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

OCS Study
MMS 90-0027

Proceedings: Tenth Annual Gulf of Mexico Information Transfer Meeting

December 1989

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SUMMARY

This Proceedings volume presents summaries of the presentations and discussions of the Tenth Annual Information Transfer Meeting (ITM) held on December 5-7, 1989, in New Orleans, Louisiana. These annual ITM's have been sponsored by the Minerals Management Service (MMS), Gulf of Mexico OCS Regional Office, since 1980 in support of the OCS oil and gas program to foster exchange of information among participants, including MMS staff; invited speakers from academic institutions, Federal and State agencies, industry, conservation groups, and knowledgeable individuals; contractors for MMS-funded environmental and socioeconomic studies; and the audience of general invitees. This volume includes session overviews by the respective session chairpersons, each of which is followed by short accounts of presentations by the authors.

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

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ABBREVIATIONS AND SYMBOLS

ADAPTS	-	Air-Deployable AntiPollution Transfer System
ADCP	-	Acoustic Doppler Current Profiler
AVHRR	-	Advanced Very High Resolution Radiometer
BLM	-	Bureau of Land Management
BOA	-	Basic Operating Agreement
BPJ	-	best professional judgement
BTEX	-	benzene, toluene, ethylbenzene, xylene
cm	-	centimeter
CNG	-	compressed natural gas
COE	-	Corps of Engineers
COTR	-	Contracting Officer's Technical Representative
CPUE	-	catch per unit effort
CZCS	-	Coastal Zone Color Scanner
DOCD	-	Development Operations Coordination Documents
DOE	-	Department of Energy
DOI	-	Department of the Interior
DP	-	dynamically positioned
EOF	-	empirical orthogonal function
E&P	-	exploration and production
EEZ	-	exclusive economic zone
EPA	-	Environmental Protection Agency
ESFF	-	energetic surface flows features
FGCC	-	Federal Geodetic Control Committee
FOSC	-	Federal On-Scene Coordinator
FPSO	-	floating production, storage and offloading units
ft	-	feet
FWS	-	Fish and Wildlife Service
FY	-	Fiscal Year
GC/MS	-	gas chromatography/mass spectrometry
GIS	-	Geographical Information System
GOM	-	Gulf of Mexico
GPS	-	Global Positioning System
ha	-	hectare
HLPC	-	high performance liquid chromatography
HRPT	-	High Resolution Picture Transmission
HSWA	-	Hazardous and Solid Waste
IJF	-	interjurisdictional fisheries
IMO	-	International Maritime Organization
ITM	-	Information Transfer Meeting
kg	-	kilogram
km	-	kilometer
LM	-	leasing map
LTL	-	Letter to Lessee
m	-	meter
mi	-	miles
mm	-	millimeter
MCSST	-	Multichannel Sea Surface Temperature
MDIO	-	Marine Debris Information Offices
MIRG	-	Marine Industry Group
MLLW	-	mean lower low water
MMS	-	Minerals Management Service
MOMS	-	Meteorological and Oceanographic Measurement System
MRA	-	multiple regression analyses
NAAQS	-	National Ambient Air Quality Standards

ABBREVIATIONS AND SYMBOLS
(cont'd)

NAD	-	North American Datum
NASA	-	National Aeronautics and Space Administration
NCP	-	National Contingency Plan
NES	-	National Energy Strategy
NGS	-	National Geodetic Survey
NMFS	-	National Marine Fisheries Service
NOAA	-	National Oceanic and Atmospheric Administration
NOW	-	Nonhazardous Oilfield Waste
NTL	-	Notice to Lessee
OPD	-	Official Protraction Diagram
OCSLA	-	Outer Continental Shelf Lands Act
OSRV	-	oil spill response vessel
OSC	-	On-Scene Coordinator
OSCP	-	Oil Spill Contingency Plan
OCS	-	Outer Continental Shelf
PAH	-	polynuclear aromatic compounds
PCA	-	principle component analysis
POE	-	Plans of Exploration
psi	-	per square inch
R&D	-	Research and Development
RFP	-	Request For Proposal
ROV	-	remotely operated vehicle
RVP	-	Reid Vapor Pressure
SCS	-	Soil Conservation Service
SDD	-	secchi disk depths
SLAR	-	Side Looking Airborne Radar
SOOP	-	ships of opportunity
SPCS	-	State Plane Coordinate System
STD	-	salinity, temperature, density
TLWP	-	tension leg well platform
TM	-	thematic mapper
TOVS	-	Tiros Operational Vertical Sounder
TPH	-	total petroleum hydrocarbons
USCG	-	U.S. Coast Guard
USDA	-	U.S. Department of Agriculture
USGS	-	U.S. Geological Survey
UTM	-	Universal Transverse Mercator
UVF	-	ultraviolet fluorescence spectroscopy
VEEP	-	Value Engineered Environmental Payload
VOPS	-	Viscous Oil Pumping System

ACKNOWLEDGEMENTS

The Minerals Management Service wishes to thank all ITM participants. Special recognition goes to the speakers whose timely individual and panel presentations stimulated discussions and exchange of technical information.

Grateful appreciation is extended to the staffs of: Geo-Marine, Inc., the Contractor, who handles the logistics for these meetings: the Doubletree Hotel, who always go beyond expectations to meet our needs; and Minerals Management Service's Gulf of Mexico OCS Regional Office, for their participation in planning and funding.

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

Mrs. Cynthia Raymond of MMS provided clerical support in preparation for this meeting, while Mrs. Patti Knowles of Geo-Marine, Inc., was responsible for the preparation of this document. Editing was done by Mrs. Connie Landry, the Contracting Officer's Technical Representative for this project, Mrs. Janice Blake, Mrs. Debbie Miller, and Mr. Michael Dorner.

Special recognition is given to Dr. Sneed Collard, University of West Florida, and his graduate students for their assistance with projectors, lights, and general helpfulness.

And finally, special thanks to Dr. Robert Rogers for sharing with us his creative talents by allowing us to use his artwork on our cover. All other graphics were supplied by the authors with the summaries of their presentations for inclusion in this document.

OPENING PLENARY SESSION

Session: OPENING PLENARY SESSION

Co-Chairs: Dr. Richard E. Defenbaugh
Mr. Ruben G. Garza

Date: December 5, 1989

Presentation	Author/Affiliation
Opening Plenary Session Overview	Dr. Richard E. Defenbaugh Minerals Management Service Gulf of Mexico OCS Region and Mr. Ruben G. Garza Geo-Marine, Inc.
Agency Welcome	Mr. J. Rogers Pearcy
Descriptive Studies: Merits and Utility to Decisionmakers	Dr. Rezneat M. Darnell Department of Oceanography Texas A&M University
The Merits of Process-Oriented Studies	Dr. Robert S. Carney Coastal Ecology Institute Louisiana State University

OPENING PLENARY SESSION OVERVIEW

Dr. Richard E. Defenbaugh
Minerals Management Service
Gulf of Mexico OCS Region

The primary purposes of the Opening Plenary Session are to welcome attendees to the Information Transfer Meeting (ITM) and to initiate the meeting with one or two major presentations that are of interest to a broad cross-section of meeting attendees and are pertinent to the interests of the Minerals Management Service's (MMS) Gulf of Mexico Outer Continental Shelf (OCS) Regional Office.

The ITM was called to order by Mr. Ruben Garza, who welcomed attendees, introduced the staff responsible for meeting logistical support, made appropriate housekeeping announcements, and introduced Dr. Defenbaugh who discussed the purposes and functions of the ITM and introduced subsequent speakers.

The primary purposes of the ITM are to provide a forum for "scoping" topics of current interest or concern relative to management issues, environmental assessments, or studies in support of offshore oil and gas activities in the Gulf of Mexico OCS Region; to present the accomplishments of the MMS Environmental Studies Program for the Gulf of Mexico, and of other MMS research programs or study projects; to foster an exchange of information of regional interest among scientists, staff members, and decisionmakers from MMS, other Federal or State governmental agencies, regionally important industries, and academia; and to encourage opportunities for attendees to meet and develop or nurture professional acquaintances and peer contacts.

The ITM agenda is planned and coordinated each year by the MMS Gulf of Mexico OCS Regional Office staff around the three themes mentioned above--issues of current interest to the Region or the MMS oil and gas program; accomplishments of the agency; and regional information exchange. Most presentations are invited, through personal contacts between session chairpersons and speakers known to be knowledgeable on a given topic. A few presentations are "contributed" at the initiative of the speakers. All presentation topics are screened by the MMS Regional Office management, to assure that sessions and topics are timely, pertinent, and sound. Meeting support funding is provided through the MMS Environmental Studies Program. All meeting logistical support is provided by a contractor (Geo-Marine, Inc.) and subcontractors selected through the usual federal procurement process. A proceedings volume is prepared for each ITM, based on summaries of technical presentations submitted by each speaker and on session overviews prepared by each session chairperson.

Mr. J. Rogers Pearcy, Regional Director of the MMS Gulf of Mexico OCS Region, formally welcomed the audience on behalf of the MMS. He reflected on the fact that recent ITM's have been well planned and received, but that this tenth annual ITM seemed to be an even better program. He briefly reviewed highlights of the agenda and closed with the thought that all attendees should learn something from the various sessions they attend and hopefully would enjoy themselves as well.

Our two Opening Plenary Session technical presentations addressed the relative merits and utility to decisionmakers of descriptive studies and of processes studies, respectively. These topics were suggested by Dr. Jerry Wermund, who represents Texas on the MMS OCS Advisory Board's Gulf of Mexico Regional Technical Working Group. Historically, MMS environmental studies for the Gulf of Mexico have tended to be descriptive of the nature of the environment at offshore sites where oil and gas activities were proposed, planned, or in progress. We are now turning to focus on process-oriented studies, to expand our predictive capability. These presentations were made by Dr. Rezneat Darnell of Texas A&M University and Dr. Robert Carney of Louisiana State University.

Dr. Darnell spoke on the MMS management process and the relative merits and utility of descriptive studies. Dr. Darnell's research interests are wide-ranging, but for the past two decades have focused largely on ecology of continental shelves and management of marine resources. He has been involved in several MMS-supported studies, generally to synthesize technical information and provide a readable narrative for management use. These studies, largely of a descriptive nature, have addressed Gulf-wide fisheries resources and the environments and biological communities of the Texas-Louisiana Shelf, of shelf-edge topographic banks, of the Mississippi-Alabama Shelf, and of the Southwest Florida Shelf.

Dr. Darnell described and discussed MMS pre- and post-lease procedures and responsibilities, and the extent of current offshore oil and gas development in the Gulf. He described the process of OCS pre-lease assessment and post-lease management as "well-defined sequential decisions" which provide recurring opportunities for MMS decisionmakers to consider and use appropriate information, including the results of descriptive environmental studies.

He then described the information content of various sorts of descriptive studies, of the physical and biological environment, and discussed how inventory or baseline studies provide an information base for management use. These include: fundamental description of the environment at the site of concern; application of published information (descriptive, process-oriented, life-history, etc.) once the environment of concern is known; inference of processes information, based on repetitive descriptive studies; and advice of expert specialists knowledgeable of such environments. Dr. Darnell described such studies as a cost effective means of gathering information at the regional scale, and a necessary first step to identify the need for further studies to more comprehensively describe areas of special concern, or to study the processes which influence an environment of interest.

Dr. Darnell described a few situations where descriptive information is fully adequate for management decisions. Generally, if the environment under consideration is known to be widespread, monotonous, and biologically non-sensitive; and, if the known effects of the activities being considered are of limited spatial extent, then descriptive information is adequate for decisionmaking. However, if the environment includes varied and/or sensitive biological communities, or if the potential impacts of an activity are far-reaching, then process information on community dynamics is important.

Dr. Darnell closed with the opinion that MMS has done a "remarkably good job" of decisionmaking, given the magnitude of offshore oil and gas operations in the Gulf, and the apparent lack of severe or lasting environmental degradation. He attributed this to development of a good information base for management use and tight inspection and regulation of offshore oil and gas activities.

Dr. Carney spoke on the relative merits and value of process-oriented studies. Dr. Carney's research interests have centered on fauna and ecology of the deep sea and related management issues. He has been involved in several MMS-supported studies, generally as an advisor on scientific approach and soundness of work performed. These projects have included studies of the fauna and unique communities of the Gulf continental slope; summary of information on many topics for the south Florida area; study of oil spill effects on tropical biological communities, and environmental recovery from these effects; and leadership of a workshop for planning major MMS-supported studies for the northern Gulf of Mexico.

Dr. Carney made several important points concerning the value of process-oriented studies for management decisions. Of primary importance, he noted the need for predictive information to answer the "what happens if..." questions which arise during decisionmaking concerning offshore resources or activities. He observed that inventory studies typically produce vast quantities of supportive environmental data which are not directly considered during the decisionmaking process. Since these data are often very expensive to gather, there seems to be an inefficiency in the descriptive-study approach, as reflected in the limited value of much data gathered compared to the manager's information needs. Furthermore, repetitive descriptive studies provide relatively little new information for management use; they may demonstrate a change in the environment over time or space, but an understanding of the environmental processes is needed for predictive capability. To illustrate this point, he discussed a current study to assess recovery of oiled mangrove communities in Panama, where biological processes seem to determine success and distribution of mangrove seedlings.

He cautioned against a mindset of "completion of baseline studies", which implies that the biological systems are static, and once described remain the same. He described the benthic marine environment as inherently quite variable due to natural causes which might mask or confuse assessment of offshore oil and gas impacts attributed to changes in the benthic environment. Because of the degree of environmental change which occurs routinely and naturally, the environment should not be considered static, and observation of a change should not be considered an impact. He called for a continuum of environmental studies to understand the dynamics of biological processes, leading to predictions of the environment, and refinement of predictive capability by seeking to reiteratively understand the difference between predicted and observed environmental settings.

He commented that the study of marine environmental processes, as opposed to descriptive study of the marine environment, is a relatively recent approach; there currently is no concise definition or agreement in scientific circles on the optimal nature or design of process studies, and there is no current "off the shelf" approach to understanding environmental processes. He suggested, however, that process studies should seek to understand environmental change, both in time and space; that sampling design should be optimized to quantify observed changes; and that researchers must identify processes which can cause change.

The utility of process studies lies in consideration of how oil and gas activities can impact the processes which determine environmental change. However, current process-study approaches will probably limit application of results to MMS concerns. For example, MMS often makes decisions based on species or habitats of concern (due to commercial importance, endangered status, aesthetic qualities, etc.), while process models tend to address biogeochemical flows. Also, scales of transport are not congruent; impacts of offshore oil and gas activities are typically limited to a few kilometers from a drilling site, while areas contributing larvae which determine recruitment to the benthic communities extend over many thousands of square kilometers.

The Opening Plenary Session met our objectives well. Attendees learned from Drs. Darnell and Carney that descriptive studies provide an adequate information base for many management decisions, and that process-oriented studies should provide an enhanced capability for environmental or impact prediction. Study designs and methods for descriptive studies are currently well developed, but study approaches for process studies are in their formative stages. Results of descriptive studies often have immediate application, although supportive data may be far removed from management consideration. Results of process studies should eventually provide more powerful tools for management decisions, although near-term results may be difficult to apply to management issues.

Dr. Richard E. Defenbaugh is Chief of the Environmental Studies Section of the MMS Gulf of Mexico OCS Regional Office. His graduate work on the natural history and ecology of estuarine and continental shelf invertebrates at Texas A&M University led to a M.S. in 1970 and a Ph.D. in 1976. He has been involved with the MMS/Bureau of Land Management environmental studies and assessment programs since 1975.

Mr. Ruben Garza is President of Geo-Marine, Inc. and program manager for the contract to support the MMS Information Transfer Meeting. His current responsibilities center on business development, company management, and administrative and quality control of projects and reports. He holds a B.S. in physics from the University of Texas at El Paso, and formerly supervised development of computer processing techniques for analysis of seismic data at Texas Instruments, Inc.

DESCRIPTIVE STUDIES: MERITS AND UTILITY TO DECISIONMAKERS

Dr. Rezneat M. Darnell
Department of Oceanography
Texas A&M University

INTRODUCTION

Management involves the mobilization of available resources in order to achieve particular societal goals. In effect, management must act upon a system and move that system from its present state to one or more perceived future states. In so doing, management must operate within boundaries or constraints. These are of two classes, conditional and absolute. Conditional constraints are negotiable, and they may be exceeded for short periods of time without subjecting the system to long-term consequences. Absolute constraints, on the other hand, are non-negotiable. They are categorical constraints which cannot be violated without foreclosure of major future options to society.

Management operates through a series of sequential decisions which are based upon available information and future projections. Most often the available information and the projection methods provide only incomplete guidance. However, because of the possibility of future mid-course corrections, this is generally adequate. Thus, through a series of approximately informed decisions, management may proceed into the indefinite future, and it may keep the system within the desired limits by repeated mid-course alterations.

In the discharge of its duty, management must define its goals and these must be factored into both short-term and long-term goals. Management must identify and define the operational constraints including those related to social, political, economic, and environmental considerations. It must develop the tools including personnel, protocols, and other hardware and software required to get the job done. Finally management must develop the data and knowledge resources upon which informed decisions may be made. In this context it is noted that the data required for decisionmaking do not always have to measure up to the rigor required in detailed scientific study. Approximations will often suffice.

Although decisions often have to be made within short time frames and based upon limited knowledge, the possibility of course alterations at a later date buys time and permits more informed decisions after additional knowledge has been gained.

MINERALS MANAGEMENT SERVICE GOALS, PROCESSES, AND CONSTRAINTS

The present discussion focuses upon the Gulf of Mexico Outer Continental Shelf (OCS) Regional Office of the Minerals Management Service (MMS) as the management agency. The oil and gas industry is the primary system being managed, although industries associated with the actual or potential extraction of salt, sulphur, and other minerals would also fall within its jurisdiction. Primary tasks of the agency include the following:

- evaluation of potential mineral resources,
- leasing and lease adjudication,
- inspection and regulation of field operations, and
- environmental assessment and protection.

Primary industry activities being regulated include exploration, development, production, transportation, and final site clean-up. MMS exercises a primary interest in the federal domain (i.e., the outer continental shelf), but it also has a secondary interest in the continental slope, the nearshore and coastal waters, and the coastal lands directly affected by oil and gas activities. The magnitude of these activities is indicated by the fact that to date there have been produced 9 billion barrels of oil, 90 trillion cubic feet of gas, 15 million tons of sulphur, and 4.8 million tons of salt (all figures are approximate). In achieving this task 27 thousand oil and gas wells have been drilled, 17 thousand miles of pipeline have been laid, and $70 billion have been added to the national treasury.

The MMS operates under a series of legislative acts which define the purpose and duties of the agency and establish legal constraints under which it must perform its management activities. Among the most important of these, in terms of environmental protection, are the National Environmental Policy Act (1969) and the Endangered Species Act (1973), both as amended. Management tools available include the OCS leasing process itself as well as the legal authority to regulate and to establish policies and procedures under which industry must operate. Management options which may be involved to regulate the industry and to protect the environment include the following:

- exclusion of certain areas from leasing consideration,
- attachment of stipulations to OCS leases,
- requirement that offshore operations avoid or mitigate undesirable impacts, and
- requirement of industrial compliance with various regulations and protocols during all phases of oil and gas operations.

The oil and gas industry itself operates in a very hazardous environment and is subject to a series of environmental risks. The primary hazards include meteorological factors (major storms and hurricanes), oceanic factors (strong ocean currents, eddies, and deep water), and geological factors (faults, unstable sediments, and near surface gas pockets). Significant environmental risks include the possibility of ship collision from heavy traffic of marine vessels; major oil spills, minor oil spills, and routine discharges into air and water; physical damage to bottoms from structures, pipelines, and anchors; and impacts on nearshore waters and coasts from construction, wetland channelization, and related activities. The management agency must be well aware of these hazards and risks, and it must regulate the industry in a manner calculated to minimize the potential environmental impacts which could result from industry activities. The agency must also take into account various social, political, economic, and environmental considerations. It is worth noting that during the early years there was a very limited environmental knowledge base to serve as guidance and that most of our present environmental knowledge of the continental shelves and adjacent areas of the northern Gulf have had to be developed by MMS during the period of heavy industry activity.

MANAGEMENT IN ACTION

Early in the OCS program, realizing the need for reliable environmental information, the Bureau of Land Management (BLM) instituted a major effort toward acquisition of environmental knowledge upon which informed OCS leasing decisions could be made. This effort, which was continued and expanded under MMS, has by now resulted in the establishment of one of the most thorough continental shelf and coastal area databases in the world. The main study series include the following: Environmental Mapping Series, Marine Ecosystems Series, Coastal Studies Series, Endangered Species Series, and Ecological Effects of Oil and Gas Activities Series. Some of this information deals strictly with the environment, but much of the knowledge has been focused upon specific management problems.

In order to understand how the environmental information is employed in making management decisions it is necessary to examine the sequential series of steps which MMS must take in relation to the leasing and development of an oil and gas field on the outer continental shelf. These steps (greatly simplified) are summarized in Table 1.1. During the pre-leasing period decisions must be made concerning which areas should be leased or held back from leasing. Preparation of the Draft and Final versions of the Environmental Impact Statement (EIS) requires environmental decisions at a great many points involving different developmental scenarios and future projections. During the post-leasing period there are also many decision points and possibilities for industry regulation associated with environmental protection. Such mid-course corrections may relate to generic or to site-specific considerations.

In addition to these routine management activities, MMS has worked out methods of dealing with special problems including biologically sensitive areas; rare, threatened, and endangered species; and a variety of potential crisis situations. The agency has developed the knowledge, skills, personnel, and instruments necessary to handle such situations in advance of their specific need. Internal scoping documents have been developed to provide the basis for immediate decisionmaking in a variety of crisis situations. Further, the agency has designated various staff members as the local experts on a variety of subjects and situations of management interest. Each expert is expected to be fairly knowledgeable concerning the published and unpublished information on the subjects of interest. Library and computer databases are also geared for the rapid retrieval of relevant information. By these means, the MMS office is prepared to handle emergencies and other situations which may arise. Most of the information resources are of a descriptive nature.

DESCRIPTIVE STUDIES: A BASIS FOR ENVIRONMENTAL DECISIONS

Descriptive studies are sometimes referred to as environmental baseline studies. They are essentially inventories of the geological, physical, and chemical features of the environment as well as the biological and ecological characteristics of the area. One-time inventories provide a single "snapshot" of the water column, bottom, and biota. Repeated inventories can provide information concerning seasonal and other changes in the various parameters. In either case, inventories permit the application of much

Table 1.1. A simplified overview of major MMS management activities during the pre- and post-leasing periods of oil and gas field development.

A. Pre-leasing period

1. Lease area identification.
2. Environmental data gathering and other input.
3. Preparation of Draft EIS.
   a. Analysis of potential impacts under different development scenarios.
   b. Identification of significant (vs. minor) issues.
   c. Development of environmental stipulations.
   d. Internal review of Draft EIS.
4. Release of Draft EIS and public comment.
5. Review of all information and issues.
6. Preparation and release of Final EIS.

B. Post-leasing period

Oil and Gas Industry	MMS Office
1. Submit exploration plans plus environmental report and other data.	1a. Review and prepare documents required by National Environmental Policy Act, as necessary. b. Modify/approve.
2. Carry out various steps of exploration, development, and production. At each stage submit plans and apply for necessary permits.	2a. Review plans and permit applications. b. Apply regulations, protocols, and (as necessary) require mitigating measures. c. Modify/approve. d. Carry out periodic field inspections.
3. Post-production clean-up.	3. Post-production site inspection.

derivative knowledge. Published information may be brought to bear, and this includes both descriptive and process-oriented knowledge. Technical specialists from academia and elsewhere may be brought in to discuss, interpret, summarize, and synthesize the information into its most complete and useful form for management decisions. Thus, by inference, much more information becomes available to the manager than just the raw data of the original descriptive studies.

Inventory information provides the necessary basis for most in-house scoping documents and for the development of scenarios for a variety of decisionmaking situations. It provides the background needed for planning further studies such as the examination of interesting areas in greater detail or the conduct of process-related studies. Inventory studies are generally the cheapest and most economical means of providing broad-scale views of large geographical areas. Descriptive studies clearly represent the necessary first step when approaching any new and relatively unknown area.

Do descriptive studies by themselves provide an adequate basis for decisionmaking? This depends upon the nature of the decisions to be made, the nature of the area under consideration, and the detail with which the descriptive studies have been carried out. Many decisions do not require in-depth knowledge, and approximate information will suffice, especially if mid-course corrections may be made at a later date. Descriptive studies alone may suffice if the area under consideration is widespread, monotonous, and biologically uninteresting, i.e., it is populated by few endangered species and contains little that can be considered biologically sensitive. The inventories themselves must have been carried out in sufficient detail to provide this type of information.

Under what circumstances do descriptive studies alone not provide an adequate basis for decisionmaking? Here, three situations stand out, but there are others. The first arises when dealing with biologically sensitive areas such as live bottom communities, seagrass beds, mangrove swamps, coral reefs, and algal-sponge bottoms. Wise decisions concerning potential impacts, size of buffer zones, and the like must rest upon some knowledge of growth rates, sensitivities to various perturbations, and recovery rates from various types and degrees of impact. The second situation arises when dealing with the protection of rare, threatened, and endangered species. The same general considerations apply as when dealing with biologically sensitive areas. In addition, it is essential to know the peculiarities of the life histories and behavior patterns of the species of concern. Many of these species represent highly dispersed and moving targets which may seasonally pass through or even be attracted to situations which place them in jeopardy. The third situation in which descriptive information fails is that involving the monitoring of biological impact, especially long-term or far-distance impact. Here the effects may be quite subtle and show up only through alterations of metabolism, growth, reproduction, and population parameters, or shifts in species composition.

CONCLUSIONS

Descriptive studies are a necessary first step, and under certain circumstances they provide most of the information needed for management decisions. Indeed, they have served the Agency well in the northwestern and north-central Gulf due largely to the widespread and monotonous sedimentary habitat, presence of a nepheloid layer (which reduces live bottom habitat), and the relative absence of endangered species. Descriptive studies alone will clearly not suffice in the eastern Gulf due to the presence of hard bottoms, absence of a nepheloid layer, widespread distribution of live bottom habitat, presence of many endangered species, and presence of major biologically sensitive areas (seagrass beds, mangrove swamps, and coral reefs). Descriptive studies also fail when approaching problems of impact monitoring.

Despite extensive oil and gas activities in the northern Gulf, the industry safety record has been remarkably good, and so far as can be judged, the environment remains in reasonable shape. Great credit is due to the staff of the MMS which has developed the environmental knowledge required and applied this knowledge in its management decisions. The fact that most of the knowledge upon which decisions have been based is of a descriptive nature testifies to the effectiveness of this approach. Proceeding into the future, descriptive studies should not be abandoned, but they must be supplemented with wisely selected process-related studies to provide specific information for certain management decisions which lie ahead.

Dr. Rezneat M. Darnell is Professor of Oceanography at Texas A&M University. He has investigated ecosystem composition and dynamics of streams, estuaries, and continental shelves. Most recently, he has studied the distribution of demersal fish and penaeid shrimp populations of the U.S. Gulf of Mexico continental shelf in an effort to discern the structure of shelf communities and to develop appropriate management implications. Dr. Darnell received his B.S. in biology from Southwestern College (Memphis, Tennessee), his M.S. in biology from Rice University, and his Ph.D. in zoology from the University of Minnesota.

THE MERITS OF PROCESS-ORIENTED STUDIES

Dr. Robert S. Carney
Coastal Ecology Institute
Louisiana State University

During the course of this presentation there are really only two points which I want to make sufficiently well that they may be remembered and taken into account when future Outer Continental Shelf (OCS) studies are planned. The first is an enthusiastic endorsement that a process-oriented approach to studies will increasingly become the most effective mode of operation for Minerals Management Service

(MMS), or any agency charged with regulating or avoiding impacts to the marine environment. The second is a critically important warning that the adoption of process-oriented studies must be viewed as a developmental effort in which MMS or similar agency must carefully foster innovation. It is easy to embrace "process-oriented studies" in generic planning documents, but it will be a much harder task to develop field studies which both adhere to the process philosophy yet make obvious contributions to MMS mission needs.

I would like to begin my case for the value of process studies with an example which I just learned of in conjunction with a MMS supported study of the Bahia Las Minas oil spill in the Republic of Panama. The lowland coast in the area oiled are lined with a mixed species mangrove forest showing distinct species zonation along transects perpendicular to the shore. Traditional floral surveying, conceptually similar to OCS benthic surveying, can be used to describe the pattern of species replacement with very great precision. From the detailed distribution maps such a survey could produce, it might be possible to propose (but not confirm) various processes to be in operation. Indeed, in Panama, the zonation has been explained in terms of the physical sorting of propagules by the tidal inundation.

Now, if we have carried out our descriptive study and accepted the suggestion that tidal flow controls species composition, then we would conclude that the original pattern of zonation would eventually return. Of course, we assume that there will always be a supply of propagules and that the tidal pattern could not possibly be influenced by an oil spill. However, let's look carefully at another component of the system, the forest floor. Here we find herbivorous crabs consuming both leaf fall and mangrove propagules. An important question arises. Could the pattern of tree zonation reflect the process of herbivorous cropping of mangrove propagules? If so, the species composition of the recovered forest will be controlled by the recovery of the impacted benthic fauna, and the outcome of recovery becomes less certain.

The moral of this story of the crab and the mangrove is that while MMS can articulate several different goals, there is really only one overwhelming need...PREDICTIVE CAPABILITY. There is really only a single management question, "What Will Happen If Development Takes Place?" It is impossible to develop a predictive capability and answer the what if question on the basis of descriptive studies alone. So long as management decisions are made without a predictive capability then the criteria for yes or no decisions will remain subjective, arbitrary and subject to changing fashions. This serves neither the public whose resources are to be wisely developed nor the industry which seeks to profit through the efficient development of these resources.

Before exploring the value of process studies, let me second remarks made by Dr. Darnell as to the value of descriptive studies as an appropriate starting place. Twenty years ago, when MMS OCS studies were new, we knew very little about the ecology of the continental shelves, and nothing of the processes beyond rather speculative accounts of how the systems might function. Environmental protection took an appropriately conservative approach which demanded a good descriptive baseline to recognize the existence of commercial species, endangered species, and/or special habitats. While these descriptions often amounted to very comprehensive inventories, without a process based framework, only a small fraction of the data entered into regulatory decisions.

In my mind, the greatest problem with additional descriptive studies is that they pose a seductive management trap. Scoping, bidding, carrying out, and including descriptive results in Environmental Impact Statements (EIS's) are all familiar tasks. The ease of management is so comforting, the costs are so acceptable, that the limited predictive capability bestowed by the studies seems like an acceptable annoyance. MMS' decision to progress into process studies is an appropriate and timely move. However, care must be taken to assure that the process studies supported are fostered in such a way as to address MMS needs better and better.

My sympathies go out to MMS which is faced with a difficult problem in the application of science. It is precisely known what a descriptive study should or may consist of, but I am afraid that the academic community can give only limited guidance for design of process studies. Indeed, coastal biological oceanographers only began exploring process ecosystem studies seriously about 10 years ago. Something as important as an exact measure of primary productivity on a regional basis has yet to be made. It is not even agreed upon as to what all the major components of such an ecosystem are!

At this time, the major interests of coastal process workers is not in a direction of immediate value to MMS management needs. Decisions concerning oil and gas development require information on the status of animal populations. However, the typical process study does not attempt to deal with populations. Rather, energy or chemical fluxes through integrated communities is studied from a geochemical or trophic perspective.

If MMS is to successfully employ process studies, it will be necessary to foster development of the necessary concepts and technology. It is not simply possible to issue a Request for Proposal (RFP) and then pick the best application from the proposals submitted for a packaged field study. It will be necessary for MMS to articulate carefully and exactly what processes are important and on what scales the information is needed. Then, the scientific community can be encouraged to develop methods of obtaining this information.

So, what does MMS need to know? As stated earlier, it needs to know "what will happen if...". The first step in obtaining this predictive capability is the ability to explain all the natural changes undergone by the OCS benthos. This benthos, which has been described many times by MMS studies, must be understood in terms of population dynamics and the links between population dynamics and regional environmental variation, especially primary productivity.

Dr. Robert S. Carney is Director of the Coastal Ecology Institute at Louisiana State University. His major research interests include spatial ecology of benthic systems, ecology of deep-sea megafauna, environmental planning for the deep sea, and effective management of research efforts. He has participated in numerous research projects, particularly of deep-sea fauna and communities; has served on many national-level policy boards, commissions, and scientific review boards; and has served as a National Science Foundation program director for biological oceanography. Dr. Carney received his B.S. in zoology from Duke University, his M.S. in biological oceanography from Texas A&M University, and his Ph.D. in biological oceanography from Oregon State University.

WETLANDS CONCERNS

Session: WETLANDS CONCERNS

Co-Chairs: Dr. Norman Froomer
Mr. Dennis Chew

Date: December 5, 1989

Presentation	Author/Affiliation
Wetlands Concerns: Session Overview	Dr. Norman Froomer and Mr. Dennis Chew Minerals Management Service Gulf of Mexico OCS Region
A Study of Wetlands Mitigation: Marsh Management	Dr. Donald R. Cahoon and Dr. Charles G. Groat Louisiana Geological Survey
Overview of USFWS Coastal Louisiana Wetlands Initiative	Dr. Ed Pendleton and Dr. Mary Watzin U.S. Fish and Wildlife Service
New Physical Process Research on Wetlands Loss in Louisiana	Dr. Harry H. Roberts Coastal Studies Institute Louisiana State University
Long-Term Recovery of a Brackish Marsh from an Oil Spill in Coastal Louisiana: A Research Plan	Dr. Irving A. Mendelssohn Center for Wetland Resources Louisiana State University, Dr. John M. Hill Remote Sensing and Image Processing Laboratory Louisiana State University, Dr. Marion E. Fischel Shell Oil Company, and Mr. Mark W. Hester Center for Wetland Resources Louisiana State University
Effects of Spilled Oil on Smooth Cordgrass	Dr. James W. Webb Marine Biology Department Texas A&M University at Galveston and Dr. S.K. Alexander Mary Hardin-Baylor College
Fate and Effects of Produced Water Discharges in the Northern Gulf of Mexico	Dr. Nancy N. Rabalais Louisiana Universities Marine Consortium

WETLANDS CONCERNS: SESSION OVERVIEW

Dr. Norman Froomer
and
Mr. Dennis Chew
Minerals Management Service
Gulf of Mexico OCS Region

The session on wetlands at the Information Transfer Meeting (ITM) this year focused on two topics. First, the commitment of Agencies within the Department of Interior to research on the wetlands loss problem in coastal Louisiana was described. Three Agencies, the Minerals Management Service (MMS), the Fish and Wildlife Service (FWS), and the Geological Survey, have begun major studies and programs to develop understanding of the management practices and the biological and geological processes that affect wetlands loss.

The second topic covered during the session was the effects of spilled oil and produced waters on coastal wetlands in the Gulf of Mexico. Since the occurrence of the Exxon Valdez oil spill this year, public attention has focused on the possible impacts of oil spills on coastal habitats. Three speakers presented the results of their investigations into the impacts of oil spills and produced water discharges on wetlands and coastal habitats in Louisiana and Texas.

The first speaker was Dr. Donald Cahoon of the Louisiana Geological Survey. He has been project manager for a two-year study funded by the MMS to determine the suitability of marsh management practices for mitigating wetlands loss in coastal Louisiana. The study will result in seven reports that will summarize the essential aspects of marsh management in Louisiana - the administrative framework within which it occurs, public interest goals, engineering and construction techniques, an annotated literature review, environmental conditions within which it occurs, historical and field monitoring, and ecological consequences. Dr. Cahoon's presentation emphasized work and accomplishments since last year's ITM in October 1988. Data on the monitoring program have been collected and are being compiled. These data are based on analyses of monitoring data collected by land owners who have initiated marsh management plans, on the historical analysis of habitat change using air photo data, on field monitoring at marsh management and control areas, and on a comparison of fisheries access and production figures between the managed and control areas. It is premature to draw final conclusions at this stage of the study because additional field monitoring and data acquisition will occur. During six months of data collection, however, when water control structures were being operated to draw down water levels which kept water from entering the managed marsh, more transient marine organisms were collected in the control areas, salinity was higher in the managed areas, and sediment accretion was greater in the control area.

The next speaker, Dr. Edward Pendleton of the FWS, Coastal Ecosystems Team, described the ongoing and planned efforts on the part of the FWS for wetlands research in the Gulf. The FWS has been requested by the U.S. Senate to investigate past and current research on wetlands loss and to make proposals on needed additional research. The FWS has decided to focus on two areas: identifying the critical processes that influence wetlands loss, and conducting multilevel investigations of these processes at work in coastal wetlands. A coast-wide Geographical Information System (GIS) database is being developed to support these multilevel investigations. Within the coastal region, basin level studies will be conducted in areas with contrasting characteristics, such as sediment-starved versus sediment rich areas. At a more detailed level, site specific studies will be conducted. The plan of study includes the following projects: creation of a coastwide GIS database, an update of habitat mapping to include 1988 overflight data, and studies of critical biological processes.

Dr. Harry Roberts of the Coastal Studies Institute at Louisiana State University is the program manager for a multiyear study of "Critical Physical Processes of Wetland Loss" sponsored by the Geological Survey. The goal of this effort is to quantify and to obtain a better understanding of the physical processes that are responsible for land loss in coastal Louisiana. Some of the topics that will be researched during this study include sediment fluxes in bays and marshes; sedimentation and erosion rates and processes on very short time scales; processes that convert interior marshes to ponds; and subsidence processes and variations. Data will be acquired through the deployment of current meters and suspended sediment sensing instruments, acquisition of event-related airborne multispectral scanner data on surface water turbidity, and radionuclide dating techniques that will determine erosion and accretion events of days' duration.

Coastal wetlands along the Gulf of Mexico coast are contacted frequently by spilled oil from a variety of sources including tanker and barge spills, pipeline accidents, accidents at production facilities, and routine discharges of oily wastes. The effects of this spilled oil on wetlands in coastal Louisiana are obscured by the high background rates of wetlands loss that are occurring as a result of other processes. Dr. I. A. Mendelssohn has been studying the recovery of a brackish marsh in coastal Louisiana from a 300 bbl oil spill that occurred in 1985. He has been monitoring the recovery of wetland plants from spill impacts since that time by using vegetation sampling and air photo analyses. He will be continuing this marsh recovery study at the spill site and will be determining the growth response of transplanted marsh grasses in impacted areas. Dr. Mendelssohn's work will provide a perspective on the long-term impacts of a spill on the recovery and the survival of wetlands in a coastal area that is experiencing rapid rates of wetlands loss.

Dr. James Webb has been studying the effects of oil spills on salt marshes in coastal Texas for the past 10 years. He has studied the impacts of real and simulated spills of different kinds of crude and fuel oils on smooth cordgrass in the Galveston Bay area of Texas. He has also evaluated the effects of cleanup operations on the coastal marshes.

Dr. Nancy Rabalais is currently investigating the fates and effects of produced water discharges that originate on the Outer Continental Shelf (OCS) in coastal and estuarine water bodies. She is conducting field studies at 11 sites where OCS-produced waters are discharged into coastal waters. At these sites, sediment, water column, and biological sampling is being done to determine the effects of these discharges on the coastal environment.

Dr. Norman Froomer is currently an Environmental Analyst on the Environmental Assessment staff of the Minerals Management Service Gulf of Mexico OCS Regional Office. He earned a Ph.D. degree in geography and environmental engineering from Johns Hopkins University and was previously on the faculty at the University of New Orleans.

Mr. Dennis Chew is a biologist with the Environmental Operations staff of the Minerals Management Service Gulf of Mexico OCS Regional Office. He has worked as a marine biologist since 1970 with emphasis on wetlands and coastal areas. Mr. Chew earned a B.S. degree in marine biology from Auburn University and a M.S. in biological sciences from the University of Southern Mississippi/Gulf Coast Research Laboratory.

A STUDY OF WETLANDS MITIGATION: MARSH MANAGEMENT

Dr. Donald R. Cahoon
and
Dr. Charles G. Groat
Louisiana Geological Survey

INTRODUCTION

A wetlands mitigation study is being undertaken for the Minerals Management Service (MMS) by the Louisiana Department of Natural Resources (DNR) through the offices of the Louisiana Geological Survey and the Coastal Management Division, with assistance of the Sea Grant Legal Program of Louisiana State University (LSU). The purpose of this two-year study is to determine the suitability of marsh management practices for mitigating wetland loss in the varied habitats of coastal Louisiana. The study will result in seven reports summarizing the essential aspects of marsh management in Louisiana: the administrative framework within which it occurs, public interest goals, engineering and construction techniques, an annotated literature review, environmental conditions within which it occurs, historical and field monitoring, and ecological consequences. This abstract presents a summary of our accomplishments since the last Information Transfer Meeting (ITM) in October 1988.

METHODS AND RESULTS

We presented a review of the project design and methodology and the first two reports, administrative framework and public interest goals, at the last ITM. Since that meeting, we have completed the annotated bibliography and the report on general environmental conditions of the coast. Also, continuous progress has been made on preparation of the engineering and construction techniques report and completion of the monitoring program.

Annotated Literature Review

Nearly 800 literature citations from the "grey" literature (e.g., reports with limited circulation) as well as serial publications were reviewed and 150 included in the annotated bibliography. Citations pertinent to marsh management were identified using computerized literature searches, perusing journals known to contain marsh management articles, searching the references of articles related to marsh management, contacting personnel in government agencies involved in marsh management, and interviewing researchers working on the ecology of coastal marshes. This literature review focuses mainly on structural management techniques. Approximately 45% of the annotated articles describe/evaluate impoundment techniques (the use of levees and water control structures to manipulate water levels), 25% report research on fixed-crest weirs, and the remaining 25% report on other management techniques or do not differentiate between management strategies. The effects of structural management on fisheries are reported in 30% of the selected citations, followed by management effects on vegetation (20%), water quality (15%), and waterfowl and wildlife (10% each). A review of these 150 citations revealed several topics important to an evaluation of structural marsh management that have not been adequately researched and/or reported. These data needs are summarized in Table 2.1.

General Study Area Conditions Report

A narrative description of the general study area has been prepared that summarizes hydrologic/geologic conditions, habitat characteristics, and feasibility for marsh management of the coastal environment as well as providing an informational profile of marsh management projects.

Hydrologic/Geologic Characterization

This report describes the environmental characterizations of the hydrologic basins in Louisiana's coastal marshes. Marsh management is taking place in all the coastal basins of Louisiana. The Louisiana coastal zone is both spatially and temporally heterogeneous. The chenier and delta plains differ significantly in geomorphology, soils, and geologic history. Some coastal basins are dominated by river flow; in others, tidal processes dominate. However, nearly all management areas lie within the reach of tidal influence. Water quality and human development impacts are concentrated in areas of intense human activity. Threatened or endangered plants and animals live in all coastal basins. Annual and seasonal changes in climate, particularly the occurrence of major storms, influence hydrologic and sedimentologic processes along the coast.

Habitat Characterization

This section describes the habitats and habitat change in areas where marsh management is occurring in coastal Louisiana. The habitat characterization consists of a description of vegetative habitats and associated vegetation and wildlife for 15 habitat classifications. Areal extent or land cover of each habitat was calculated for 1956, 1978, and 1984 using a computer database and portrayed on computer-generated maps. A literature search was conducted for the habitat description and species composition.

Coastal habitats are undergoing rapid changes with much of the coastal wetlands being converted to open water. In 1956 there were approximately 1.25 million hectare (ha) of coastal marsh (i.e., emergent marsh only). In 1978 total marsh habitat decreased to 1.0 million ha and was only approximately 0.82 million ha in 1984 with another 0.26 million ha of broken marsh identified. Between 1956 and 1978, 12% of all classified lands had changed category, including approximately 243,000 ha of marsh that changed to open water. Sixteen percent of all classified lands changed category between 1978 and 1984, including approximately 93,000 ha of marsh that changed to open water and nearly 200,000 ha of marsh that converted to broken marsh. From 1956 to 1978, the greatest land classification change occurred in the

Table 2.1. Marsh management topics either not adequately researched or reported.

1. The effects of various structural management techniques on land loss, sediment deposition, subsidence, plant health, and target species, as determined from a comparison of managed with nearby, unmanaged areas;
2. The cumulative impacts of structural management on hydrologic processes, land loss, and secondary productivity;
3. The development of management tools and techniques designed to maximize marine fisheries access while reducing land loss or providing beneficial wildlife habitat;
4. The environmental effects of operational failure or abandonment of the management plan;
5. The identification and evaluation of factors affecting the success and cost-effectiveness of structural marsh management.

Calcasieu (25%), Mississippi River (19%), Barataria (18%), and Sabine (18%) basins. In the years from 1978 to 1984, the greatest land classification change occurred in the Sabine (33%), Calcasieu (26%), Barataria (25%), and Terrebonne (22%) basins.

Marsh Management Plan Profile

A computerized database was created of all marsh management permit files on record at DNR as of May 15, 1989. The database was analyzed statistically to develop a profile of marsh management activities in coastal Louisiana.

Since the State of Louisiana began in 1980 to require landowners to obtain a permit to manage their marshes, 165 applications have been received to manage 203,000 ha of coastal wetlands, or 12% of all Louisiana's coastal wetland habitats (based on the 1984 inventory described above). During that period, 126 permits were issued to manage nearly 122,000 ha, or 9% of all coastal wetland habitat. Most applications are from Terrebonne, Barataria, Mermentau, and Vermilion-Teche basins; most permits are issued for wetlands in the Terrebonne, Barataria, and Vermilion-Teche basins. Terrebonne basin has the highest number of applications and implemented plans, but Barataria basin has the greatest wetland area proposed for and under management. Only 43 permittees have officially indicated to the state that they have commenced their management plan. Of these 43 implemented plans, only a portion are fully implemented. The average size of a management area is 1,344 ha in the delta plain and 952 ha in the chenier plain.

Most plans are designed to manipulate water levels for the purpose of mitigating land loss. The second- and third-ranked purposes (i.e., goals) are improving waterfowl and furbearer habitat. Approximately 80 km of new levees and 80 km of new trenasses have been requested since 1980. The number of requests for levee construction and repair is three to four times greater in the deltaic plain than in the chenier plain. Most applications are requests to manage brackish marsh; permits for fresh marsh are the second-most requested, but the greatest wetland area applied for management lies in fresh marsh, followed by brackish and intermediate marsh. Landowner response to monitoring requirements is poor. Only nine private marsh management programs have ever provided monitoring data.

Marsh Management Feasibility

The environmental and socioeconomic conditions that affect the feasibility of marsh management in coastal Louisiana have been identified by reviewing the literature and consulting with personnel working in the structural management field. This analysis of feasibility will provide a general, broad-scale description of those coastal environments which have a low feasibility for successfully supporting marsh management. It is not intended to be a definitive explanation of the feasibility of marsh management at every specific locale within coastal Louisiana. It is intended as a reference source for permit applicants and reviewers to provide a general indication of the suitability of an area for structural marsh management. The final determination of feasibility for any proposed management plan should be based on a detailed evaluation of the specific locale.

Environmental factors may substantially influence the feasibility of marsh management by increasing construction and/or maintenance costs, increasing the probability of structural failure, and hence decreasing the operational efficiency of a management plan. Eight factors were identified as influencing marsh management feasibility but three are most useful in determining it on a broad-scale: soil properties, habitat stability, and, the rate of relative sea level rise.

Management is least feasible on soils with high organic content in brackish and saline habitats because of the high potential for subsidence and the corrosive action of salt. These soils provide poor support for water control structures and artificial levees. These soil types occur in the southern portions of all basins in the delta plain. Areas of low habitat stability (i.e., high rates of wetland deterioration and loss) have a low feasibility rating because of the high water:land ratio. Levee construction is more difficult and costly in open water than it is in vegetated marsh. The potential for erosion and levee failure caused by wave action is also greater there than in vegetated areas. Areas of high land loss density occur in all the coastal basins. Relative sea level rise affects the feasibility of structural marsh management by increasing the costs of maintaining levees, decreasing the effectiveness of many types of water control structures, and increasing the duration and effects of inundation caused by storm tides and precipitation. The highest rates of relative sea level rise occur in southern Terrebonne basin.

Engineering and Construction Techniques Report

This report describes the design, uses, feasibility, engineering, construction, and maintenance of several water management structures, most of which can be found in Louisiana wetlands. A few structures that are used in other states have been described because they may be useful in Louisiana. Structures being evaluated include wakefield, slotted, rock weirs, plugs, stop-logs, embankments, flap-gated culverts, South Carolina trunks, Florida structures, double divergent pumps, and trenasses. A draft narrative of this report is 80% complete.

Monitoring Program

A monitoring program was established to evaluate the quality of current monitoring efforts and provide new monitoring data through both historical analysis of habitat change and monitoring of ecological processes. The monitoring program, therefore, consists of three parts: review of file monitoring data, historical analysis of habitat change through aerial imagery analysis, and field evaluation of management impacts.

Review of File Monitoring Data

Every operator of a permitted marsh management plan is required to submit annual monitoring data to DNR. Only nine operators have submitted monitoring data to DNR. The data are mainly descriptive with little or no analysis and interpretation, often have large gaps in time, and rarely are compared to non-managed areas. We are in the process of evaluating and summarizing this database.

Historical Analysis of Habitat Change

Changes in land:water ratios and dominant vegetation types in 16 fully implemented plans and associated controls (32 sites in total) are being determined from color infra-red photography for 1956, 1978, 1981 or 1983, 1985, and 1988. The imagery has been photointerpreted and digitized into the DNR computer. Data generated from this digitization process is being analyzed for trends in marsh:water ratios, fresh:non-fresh marsh ratios, and changes in species dominance. The 30 year time span provides for historical analysis of habitat change before and after management began and direct comparison to non-managed areas. An example of the type of results being generated is presented in Figure 2.1.

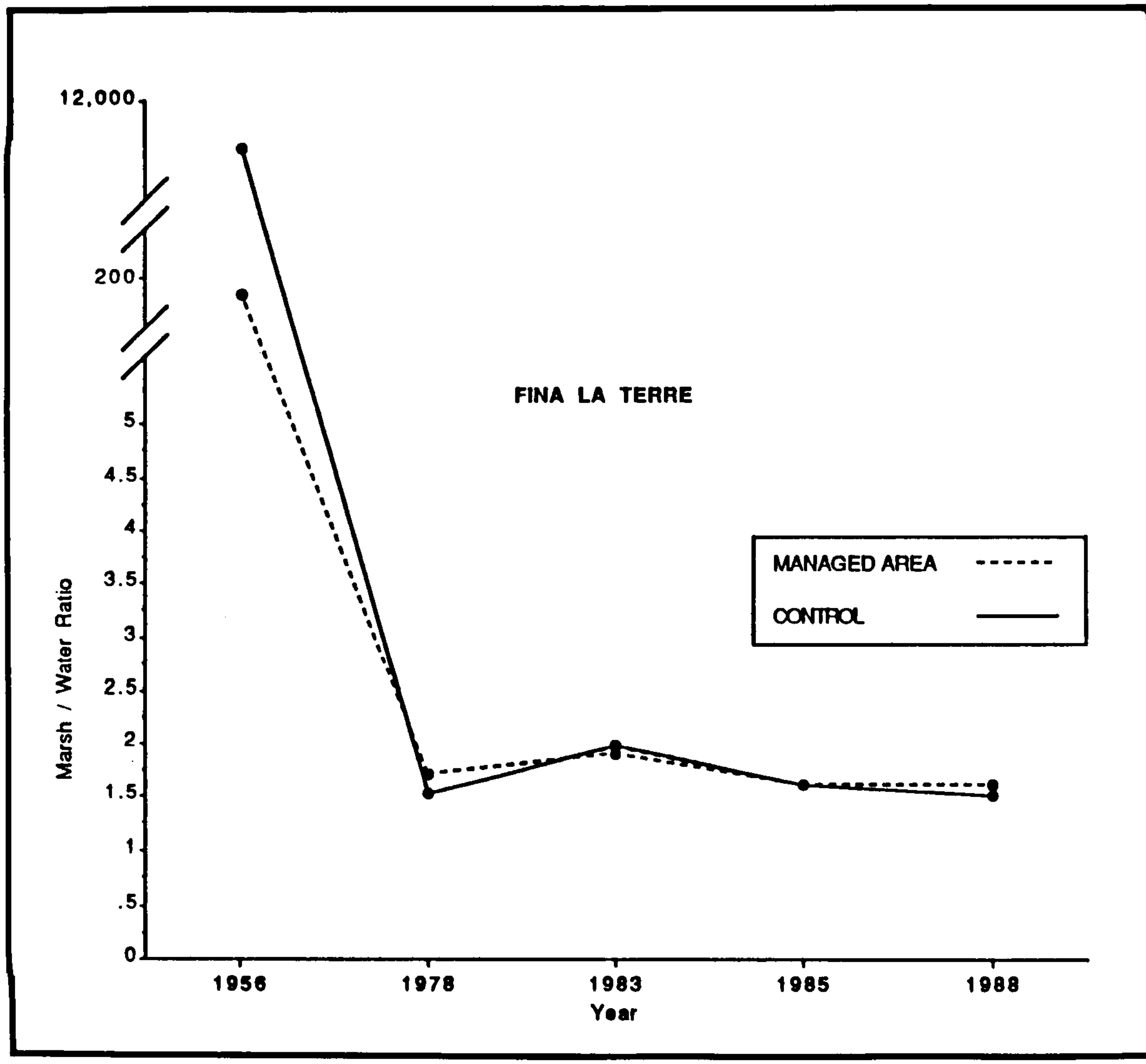

Figure 2.1. Marsh:water ratio for managed and control areas at Fina La Terre.

Field Monitoring

Intensive field sampling is being conducted at 2 of the 16 sites (with their associated control areas) evaluated above: Fina La Terre, Inc. mitigation bank site and Rockefeller Refuge. In response to information needs indicated by a technical advisory panel, we are monitoring and comparing hydrology, vegetative dynamics (e.g., plant stress, production, and composition), soil erosion-accretion, sediment-nutrient dynamics (e.g., flux), soil characteristics, and fisheries access and production between the managed and control areas at each site. Field monitoring commenced in January 1989. Field data collection was completed by December 1, 1989 for vegetation dynamics, sediment-nutrient dynamics, and soil characteristics. Field data collection will continue through January 1990 for hydrology, soil erosion-accretion, and fisheries studies. Sample and data analysis and report preparation are on-going for all phases of this program.

It would be premature to draw conclusions at this time from six to nine months of field monitoring data. However, it can be noted that during the first six months when the water control structures were being operated to drawdown the water levels and thus keep water from entering the managed marsh, more transient marine organisms were collected in the control area than the managed area, salinity was consistently higher in the managed area, and sediment accretion was greater in the control area at the Fina La Terre site. A final analysis of the influence of management on all the ecological processes described above at both locations will be made after all data collection and analysis are complete.

SUMMARY

A factual array of data and data analysis is being prepared for all aspects of marsh management in coastal Louisiana. This analysis will provide an evaluation of the effectiveness of marsh management to mitigate land loss. Four of the seven volumes of the report are completed in at least draft form with two others (Engineering and Construction Techniques and Monitoring Program) 80% complete. All of this information will be synthesized into a seventh volume presenting an ecological evaluation of the influence of marsh management on wetland processes and a suitability index describing the effectiveness of marsh management techniques.

Dr. Donald R. Cahoon is an Assistant Professor-Research at the Louisiana Geological Survey. He is project manager for the Wetlands Mitigation Study and is charged with coordinating all project efforts. He is experienced in coastal regulatory affairs and is actively involved in scientific research into the causes of wetland loss in Louisiana. Dr. Cahoon, a wetlands ecologist, received a B.A. from Drew University in botany, and a M.S. and Ph.D. in plant ecology from the University of Maryland.

Dr. Charles G. Groat is State Geologist and Director of the Louisiana Geological Survey (LGS). He is project director for the Wetlands Mitigation Study being conducted by the Louisiana DNR through LGS and the Coastal Management Division, with assistance of the LSU Sea Grant Legal Program. Dr. Groat, a geologist, holds a Bachelor's degree from the University of Rochester, a Master's degree from the University of Massachusetts, and a Ph.D from the University of Texas at Austin.

OVERVIEW OF USFWS COASTAL LOUISIANA WETLANDS INITIATIVE

Dr. Ed Pendleton
and
Dr. Mary Watzin
U.S. Fish and Wildlife Service

Presentation Summary
Text Not Submitted

Dr. Ed Pendleton
Dr. Mary Watzin

NEW PHYSICAL PROCESS RESEARCH ON WETLANDS LOSS IN LOUISIANA

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

Coastal wetland loss in Louisiana, now considered to amount to more than 100 km^2/year, is receiving ever increasing amounts of attention. This loss is the result of a variety of complex interactions among a number of physical, chemical, biological, and cultural processes. Important geologic phenomena include sea-level change, subsidence, compaction, and change in location of deltaic depocenters. Of the many catastrophic events that cause erosion, the hurricane with its high energy is the most important in Louisiana. Biological factors include rates of marsh growth (especially in relation to subsidence, compaction, and saltwater/freshwater proportion) and the degradation caused by marsh fauna.

During the last few decades, the human factor in wetland loss has increased drastically. The placement of dams and levees across and along the tributaries and distributaries of the Mississippi River have reduced both the amount and texture of sediment reaching the coast. In addition, canal and highway construction in the wetlands has altered drainage patterns and caused marsh deterioration. Fluid withdrawal is also causing local subsidence.

To date, few of the processes responsible for land loss in south Louisiana have been quantified and the data sets that do exist are often in conflict with each other and reflect multiple interactions. Hopefully, the U.S. Geological Survey sponsored study of physical processes associated with coastal land loss will provide a quantitative and new appraisal of this complex problem.

Within the framework of this wetland loss study, a team of physical, geological, and biological scientists has been assembled to study the role of critical physical processes in the overall problem of coastal marshland deterioration. Since our present database on this subject is extremely limited, products from the proposed research should reveal fundamental mechanisms of marsh accretion and deterioration related to combined effects of physical processes and sediment transport. Knowledge of these mechanisms can be applied to managing and/or mitigating wetland loss. A significant part of the final year's effort will be focused on applications of our results.

Studies will be conducted in both sediment-rich (Atchafalaya) and sediment-poor (Terrebonne) basins as well as on both regional and local scales. Because of equipment and financial constraints, detailed data collections will be concentrated on only one basin at a time for the first two full years of activity after the startup period. Instrument arrays will be placed in both basins simultaneously for high-priority events during the third year of data acquisition. Bay-scale studies of circulation and water-level fluctuations will be accomplished with an array of near-continuously recording current meters and water-level gauges. This measurement net will be augmented by acquisition of event-related airborne multispectral scanner data with simultaneous collection of basinwide surface-water turbidity data. The high-resolution scanner data will be augmented with coarser-resolution and more regional satellite data. Remote sensing data (NOAA AVHRR) can be captured and processed in real time. *In situ* measurements provide the inputs for modeling bay-scale circulation and sediment flux under a variety of conditions ranging from spring floods to winter cold-front passages.

Developing methods to improve or reverse the trend of marsh deterioration requires a better understanding of sediment flux in both the bay and marsh. Crucial to this understanding is quantification of critical erosion velocities of wetland sediments and of their transport magnitudes and directions. A project objective is to measure flood and long-term (annual) transport of suspended sediments within the wetland complex and to characterize the forcing mechanisms that induce resuspension and transport of the fine-grained components. The measurement program entails deployment of current meters and suspended-sediment sensing instruments at five stations, four within a coastal bay control area and one in a contiguous tidal channel. Pairs of these sensors at two levels in the water column will provide data necessary for estimating sediment flux through the volume encompassed by the sensors.

Coincident with the current, wave, and sediment transport studies will be sedimentological studies measuring erosion and accretion related to events of days' duration by radionuclide techni ques utilizing naturally occurring ^{7}Be and ^{234}Th. These measurements will actually allow us to assess the sedimentological responses of tides, storms, and floods in both the nearshore bay bottom environment and various sectors of the marsh. Longer-term radionuclides such as ^{137}Cs and ^{210}Pb have proved extremely useful for measuring vertical accretion of marshes, which maintains marshes against rising water levels due to a variety of processes, including sea level rise and subsidence. Although numerous studies have incorporated these methods, the role of physical processes in interpreting results has not been evaluated in the framework of maintaining marsh viability.

Previous studies have determined that one of the major mechanisms of wetland loss is the conversion of interior marsh to open water. This project will address the physical mechanisms that cause small ponds and lakes in the marsh to enlarge and coalesce. The balance of physical forces, marsh resistance, and sediment dynamics of a representative pond will be assessed in the control site of each basin. Measurements of wave and current stresses on the pond bottom and perimeter as well as sediment transport to and from the pond will be quantitatively evaluated. Rare earth tracers will be used to evaluate sediment transport routes and sinks. Measurements will be planned around key physical process events.

Underlying the overall problem of coastal land loss is subsidence, which includes a spectrum of processes from surficial sediment compaction to downwarping of the Gulf Coast geosyncline. The variability in published subsidence data is great. This project is designed to determine rates of subsidence on a variety of spatial and temporal scales as well as to quantify the geological and human-induced processes driving subsidence in Louisiana's wetlands. Site-specific research will establish age, rate, morphostratigraphic, geotechnical, and diagenetic process relationships in fresh, brackish, and saline habitats within basins of contrasting age and origin. The stratigraphic and radiocarbon analysis of representative wetland habitats will establish the subsidence framework within basins on a scale of centuries. Analysis of tide gauge and geodetic leveling data will establish the subsidence framework on a scale of decades for the basins. A detailed analysis of the geological processes controlling marsh substrate development and wetland stability of sediment-rich and sediment-poor basins will complement this effort. These research elements will be integrated and linked together in a model describing the mechanics and processes of subsidence and marsh substrate development during the transgression and rejuvenation of an abandoned delta complex system. Results of the subsidence research element will be tested by analyzing the geomorphic changes that have occurred within each wetland study area in order to determine the contribution of the controlling critical processes driving habitat change.

Dr. Harry H. Roberts is Director of Coastal Studies Institute, Louisiana State University in Baton Rouge, Louisiana. He is a marine geologist/sedimentologist who has actively worked on Mississippi River delta problems for nearly 20 years and is currently coordinating the multiyear study of "Critical Physical Processes of Wetland Loss" sponsored by the U.S. Geological Survey.

LONG-TERM RECOVERY OF A BRACKISH MARSH FROM AN OIL SPILL IN COASTAL LOUISIANA: A RESEARCH PLAN

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On April 23, 1985 a break in an oil pipeline near Nairn, Louisiana resulted in the release of approximately 300 barrels of Louisiana crude oil into a brackish to saline marsh. An assessment of the impact of the spill to the marsh vegetation and benthos was conducted approximately three months after the spill. Vegetation response to the spill was determined in 68 permanent plots randomly selected within (1) the visually oil-contaminated marsh, (2) the marshes, which may have received some oiling, located immediately north and south of the oil-contaminated marsh, and (3) reference marshes located further north and south of the oil-contaminated marsh. Assessment of the oil impact within these permanent plots in conjunction with soil petroleum hydrocarbon determinations resulted in the conclusion that impact to the vegetation was primarily confined to the marsh immediately surrounding the pipeline rupture. Our understanding of the capability of this type of marsh to recover from an oil spill is unknown.

Thus, the primary goals of the present study were to determine the degree of marsh recovery since the spill and evaluate marsh degradation at this site relative to natural and man-induced causes. The specific objectives are as follows: (1) document pre-spill land loss rates using historical aerial photography, (2) document post-spill rates of marsh recovery using recent aerial photography and vegetation monitoring, (3) determine the effect of the oil spill, if any, on the study area's rate of deterioration, and (4) determine the growth response of transplanted marsh grasses in impacted areas for remediation strategy considerations.

Historical photography is being acquired and photomosaics constructed to visually assess regional land loss rates. The historical imagery will also be used to generate detailed maps of the original study site (impacted and control marshes). Approximately 8-10 year intervals will be mapped. Comparison of these maps will establish pre-spill marsh deterioration rates. Color infra-red imagery will also be acquired of the study site every other year and used to determine post-spill recovery rates. The mosaics will be photointerpreted and land cover categories assigned and digitized. Acreage estimates will be acquired for both pre- and post-spill conditions. By comparing these data, an estimate of the impact of the spill on background rates of marsh deterioration can be established.

The ground-truth research will consist of reanalyzing the vegetative status in the 68 permanent plots established after the spill in 1985. In addition, sites that were delineated as oil-stressed in 1985 will be randomly chosen and plant carbon assimilation determined and compared to immediately adjacent non-stressed sites to determine if any residual oil impact is apparent.

We shall also assess the potential of mitigating oil impacts by determining if vegetative transplants can be used to re-establish vegetation at sites that have deteriorated due to the oil impact. The purpose of this transplantation study is to test a number of hypotheses concerning why vegetation is not recolonizing the previously oil-affected sites. Elevation will be manipulated to test whether this factor is primarily responsible for the negligible plant recolonization at certain sites. Transplant success will be correlated with initial oil impact at each of the sites to indicate whether initial intensity of stress determines recovery potential.

Dr. Irving A. Mendelssohn is Professor in the Department of Marine Sciences and in the Laboratory of Wetland Soils and Sediments at Louisiana State University. He is a coastal plant ecologist who has specialized in studying the response of coastal marsh vegetation to various stressing factors, and in the use of vegetation to restore and preserve eroded and eroding coastal areas.

Dr. John M. Hill received his Ph.D. in biology from Texas A&M University. Dr. Hill is presently Associate Director of the Remote Sensing and Image Processing Laboratory and Associate Professor of Civil Engineering at Louisiana State University. Dr. Hill has specialized in the acquisition, processing, and interpretation of photographic and digital remotely sensed data for the monitoring and analysis of environmental and ecological conditions. Dr. Hill is an active member of numerous professional societies and has authored over 50 technical publications.

Dr. Marion E. Fischel is a Staff Specialist-Biological Sciences, Environmental Affairs Department with Shell Oil Company and serves as internal consultant to the company on a broad range of biological issues including wetlands, natural resource damage assessment, biological monitoring, marine flora and fauna, endangered species, artificial reefs, and oil spill cleanup. Dr. Fischel holds a B.A. degree in zoology from the University of California, Berkeley, an M.A. degree in biology from the University of California, Santa Barbara, and a Ph.D. degree in biology from the University of Southern California.

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EFFECTS OF SPILLED OIL ON SMOOTH CORDGRASS

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INTRODUCTION

Salt marshes are important environmental resources. They provide food and protection for estuarine organisms, waterfowl, wading birds, terns, mammals, alligators and other species (Davidson and Chabreck 1983; Beccasio et al. 1982). Approximately 66% of the commercially important fish and shellfish of the Atlantic and Gulf waters of the U.S. utilize estuarine wetlands during young and juvenile stages of their life cycle (McHugh 1968; Lindall and Saloman 1977; Peters et al. 1978; Herke 1971). The smooth cordgrass (*Spartina alterniflora*) zone, which occurs at elevations of daily tidal fluctuations, is an extremely important part of a salt marsh. Some estuarine species invade marshes, particularly the smooth cordgrass zone, at flood tide zone in significant numbers to derive nutrition and protection from predators (Zimmerman and Minello 1984a). Brown shrimp (*Penaeus aztecus*) strongly select for vegetated habitat dominated by smooth cordgrass (Zimmerman and Minello 1984b). The large amount of biomass produced in salt marshes, particularly by smooth cordgrass, may be an important source of energy in the form of detritus to estuarine ecosystems (Odum et al. 1972). Smooth cordgrass marshes are instrumental in prevention of shoreline erosion (Knutson et al. 1981).

Since smooth cordgrass is the dominant lower intertidal salt marsh plant on the Gulf and Atlantic coasts of the U.S., this species is often impacted by oil spills. The Gulf of Mexico is one of the most intensive oil-producing areas in the world and is heavily traveled by tankers (Geyer 1980). The largest percentage (37%) of oil spills in U.S. coastal waters have occurred in Gulf waters (Fletcher 1977). With 2.43 million hectares of salt marsh on the Gulf coast (Lindall and Saloman 1977), spilled oils often enter salt marshes (Crow 1974; Holt et al. 1978; Webb et al. 1981).

Because of the importance of salt marsh habitat and the likelihood of oil spills, the effects of oil on smooth cordgrass were examined in a series of studies in Galveston Bay from 1981 to 1986. Our preliminary studies from 1977 (Webb et al. 1981) plus various studies have shown that the response of salt marsh plants to oil varies with oil type, amount of plant coverage, components of the oil and alteration by weathering prior to plant contact, soil penetration, seasonal effects related to plant phenology, and tidal inundation associated with differences in elevation. We designed a controlled study of impact to determine with more certainty the effects of future oil spills in Gulf Coast marshes. These studies were conducted to clarify the effects of oil due to those factors.

METHODS

Preliminary observations - 1977 study: Observations were made on a salt marsh dominated by smooth cordgrass after an oil spill October 31, 1977. Effects of the spill at three sites were recorded. Notes also were made on a spill in 1978 (Webb et al. 1981).

First series of experiments: Four types of oil were applied on November 11, 1981 and to a second area on May 23, 1983 to smooth cordgrass in a randomized complete block design. The two dates correspond to periods of declining and increasing growth for smooth cordgrass. The four oils were a light crude (Arabian), a heavy crude (Libyan), a heavy fuel oil (No. 6), and a light fuel oil (No. 2). A set of 64 plots (1 m^2) was established at each of two elevations that were 20 m and 60 m from and parallel to the shoreline. Commercial sprayers were used to apply oil. The four oils were applied at four levels (no oil, 1 l on the sediment surface, 1.5 l on the sediment surface and lower portions of plants, and 2 l on the sediment and entire plant surfaces). No barriers were established around plots to contain the oil (Webb and Alexander 1985; Alexander and Webb 1985). Measurements of smooth cordgrass were made in 0.25 m^2 sub-plots to determine the effects of the oils at the different levels and seasons. Measurements included live and dead biomass, live and dead stem density, and stem height. Plots were monitored for one year.

Second series of experiments: No. 2 fuel oil effects were examined in larger plots to determine if regrowth in plots was actually from surviving roots and rhizomes or from encroaching tillers outside plots and from seeds. Oil was applied at levels described above. Plots were 4 m^2 and live stem densities were compared in 0.25 m^2 inner and outside sub-plots at monthly intervals for one year. Oil was measured in sediment to a depth of 5 cm. Oil also was measured in plants in a nearby marsh sprayed with No. 2 fuel oil (Webb and Alexander 1989).

Third series of experiments: Cleanup techniques were evaluated on three types of oil spills that simulated long-term damaging types of spills (based on our previous findings). The first type represented a No. 2 oil spill in the fall in which oil only reached lower portions of plant and sediment surfaces. The second series simulated a winter spill with only partial coverage of plants but large quantities penetrating the marsh sediment. The third series simulated a crude oil spill that completely covered plant surfaces during an active growth period. Six treatments were applied to each series of randomized complete blocks with four replications. Treatments were (1) no oil/no clean, (2) oil/no clean, (3) oil/flushing with sea water, (4) oil/flushing with sea water plus dispersant, (5) oil/clipping and sorbent pads, and (6) oil/burning. Oil was applied with sprayers and retained in plywood retaining structures. Cleanup was delayed 18 to 24 hours and then plywood structures were removed and cleaning initiated. For the flushing treatment, plots were flushed for 60 seconds. Corexit 7664 (manufactured by Exxon Chemical Americas) was added to plots receiving dispersants. Designated plots were clipped at ground level and sorbent pads (Type 157, 3M Company) were stepped on to remove remaining oil. A propane torch was used to burn plots (Kiesling et al. 1988).

The amount of oil removed from the sediment and damage to smooth cordgrass were assessed. Sediment to a depth of 5 cm was taken from each plot immediately after cleanup and total hydrocarbons were later determined from frozen samples. Plant samples were collected 1, 5, and 12 months after each spill from 0.25 m^2 sub-plots. Live and dead plant biomass were measured and analyzed.

RESULTS

Results of 1977 No. 6 fuel oil spill: Above ground biomass was removed with shovels by cleanup crews at one site but plants regrew the following spring without apparent ill effects. In a second and third area where cleanup did not occur, above ground plant parts were killed when complete or near complete coverage of plants by oil occurred. Partial coverage by No. 6 fuel oil caused no apparent damage to above ground plant parts. Clipping of oiled vegetation did not negatively affect growth the following spring. Plants that were partially oiled by a crude oil spill in spring 1978 were not negatively affected by crude oil. These data indicated that smooth cordgrass response varied with the amount of coverage and that above ground growth could be removed during cleanup without long-term adverse effects.

Effects of oil types, seasons, and plant coverage: Partial coverage of plants did not significantly damage plants. Complete coverage of plants by crude and No. 6 fuel oils caused death of above ground plant parts but below ground plant parts (roots and rhizomes) regenerated new growth. Complete recovery of plots occurred but recovery of plots oiled in the spring was significantly slower. The plots oiled in late fall apparently were near dormancy and were less affected than the spring oiled plots, which were actively growing and in which root reserves may have been low after initiation of spring growth. No. 2 fuel oil caused complete death of plants (above ground and below ground) when oil completely covered plants. Slow recovery occurred in plots with initial mortality of above ground and below ground plant parts. Seedling growth and little oil residue in sediments indicated that plants could recolonize or be transplanted into some areas that had complete death of plants.

No. 2 fuel oil also caused decreases in biomass and stem density when oil partially covered plants but plants were able to initiate new stems from below ground material. Recovery was much quicker in those plots. Plants responded similarly at low and higher elevations of the salt marsh.

No. 2 fuel oil studies: The severe effects of No. 2 fuel oil warranted further examination of the effects of this oil. When plants were completely covered with No. 2 fuel oil, no regrowth from rootstock occurred. When oil was applied to the sediment alone, a slight reduction in stem density occurred. Presumably, oil penetrated the soil and contacted the root system and caused damage. Since hydrocarbons were in the root system after application to the foliage, the oil apparently was translocated from the foliage to the root system. Regeneration is prevented by damage to the root system.

Cleanup studies: Cleanup techniques, which were applied 18 to 24 hours after the oil spill, did not remove oil that had penetrated into the sediment. However, flushing techniques reduced oil levels present on sediment surfaces by 73 to 83%. Addition of a dispersant to the flushing waters only slightly enhanced oil removal. Clipping of vegetation followed by sorbent pad utilization was moderately effective, reducing the oil from sediments by 36% to 44%. Burning actually increased oil in the sediment by 27% to 72%.

None of the cleanup techniques reduced initial plant damage and none of the cleanup techniques enhanced long-term recovery. Flushing did not cause further damage but clipped and burned plots sustained additional initial damage. "No cleanup" appears to be the least disturbing alternative where adequate tidal flushing occurs. Flushing is warranted where large accumulations of oil occur and tidal flushing is not adequate to remove the oil. Flushing may require that oil be located on the edges of streams where oil can be easily skimmed. Clipping can serve as an alternative technique in marshes that can not be adequately flushed by pumps or natural means. Burning is not recommended because of enhanced oil penetration into sediments and substantial plant damage. Ignition of the oil in this study also was very difficult.

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Dr. S.K. Alexander is presently an associate professor at Mary Hardin-Baylor College. He was an assistant professor in the Marine Biology Department at Texas A&M University at Galveston and acted as co-principal investigator on the effects of oil spills on smooth cordgrass.

FATE AND EFFECTS OF PRODUCED WATER DISCHARGES IN THE NORTHERN GULF OF MEXICO

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Louisiana Universities
Marine Consortium

Daily, there are an estimated 3.4 million barrels of produced waters discharged into the estuarine and marine waters of the Gulf of Mexico (Boesch and Rabalais 1989). Over 1 million barrels per day are generated in the federally-controlled outer continental shelf (OCS). Of this total, over two-thirds are discharged into the federal OCS, but the remainder (434,772 barrels per day) are discharged into the state waters of Louisiana. These produced waters generated in the federal OCS but disposed of in Louisiana state waters are the focus of our current research program funded by the Minerals Management Service.

There are 16 discharges at 11 sites where OCS-generated produced waters are discharged into Louisiana state waters (Figure 2.2). Eleven of the discharges are being investigated in our current research program. The studies of the fates and effects of these produced water discharges are multidisciplinary (Table 2.2) and are in-progress. Some of the study sites are being investigated in more detail, temporally and/or spatially. Others are being characterized during a single sample period.

At any one study site, a grid of stations is arranged around the discharge and in a gradient of increasing distance away from the discharge. An example of the station grid at the Pass Fourchon study area is given in Figure 2.3. Within each station grid, some stations are "vertical" stations where deeper sediment cores are taken for a vertical characterization of chemical constituents and sediment characteristics. At the "vertical" stations, near-bottom water samples are also taken. "Surface" stations are those at which only surface sediments are analyzed for chemical constituents and sediment characteristics and no water samples are taken.

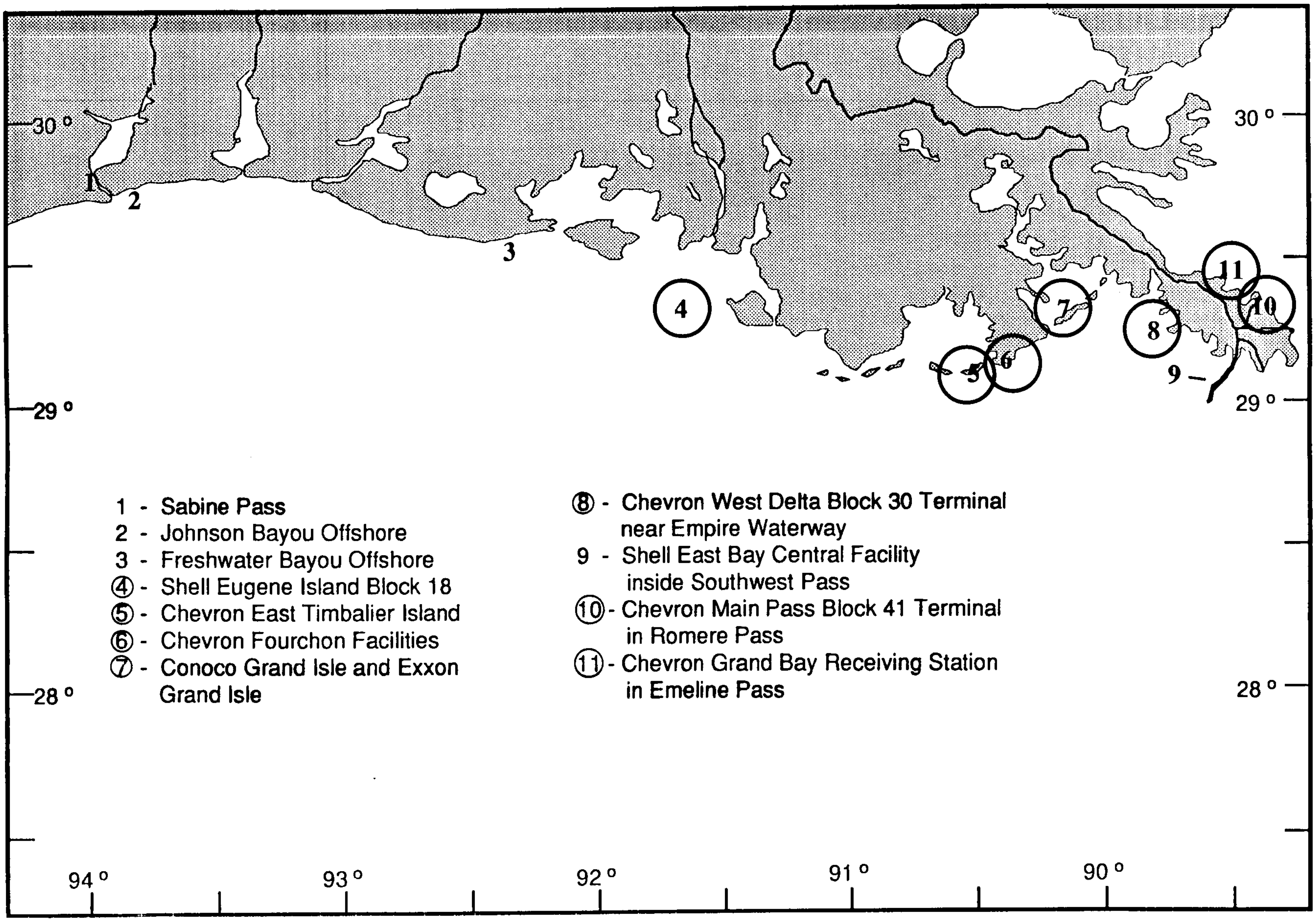

Figure 2.2. Locations of OCS-generated produced water discharges in Louisiana state waters with circled numbers indicating sites being studied in the described research program.

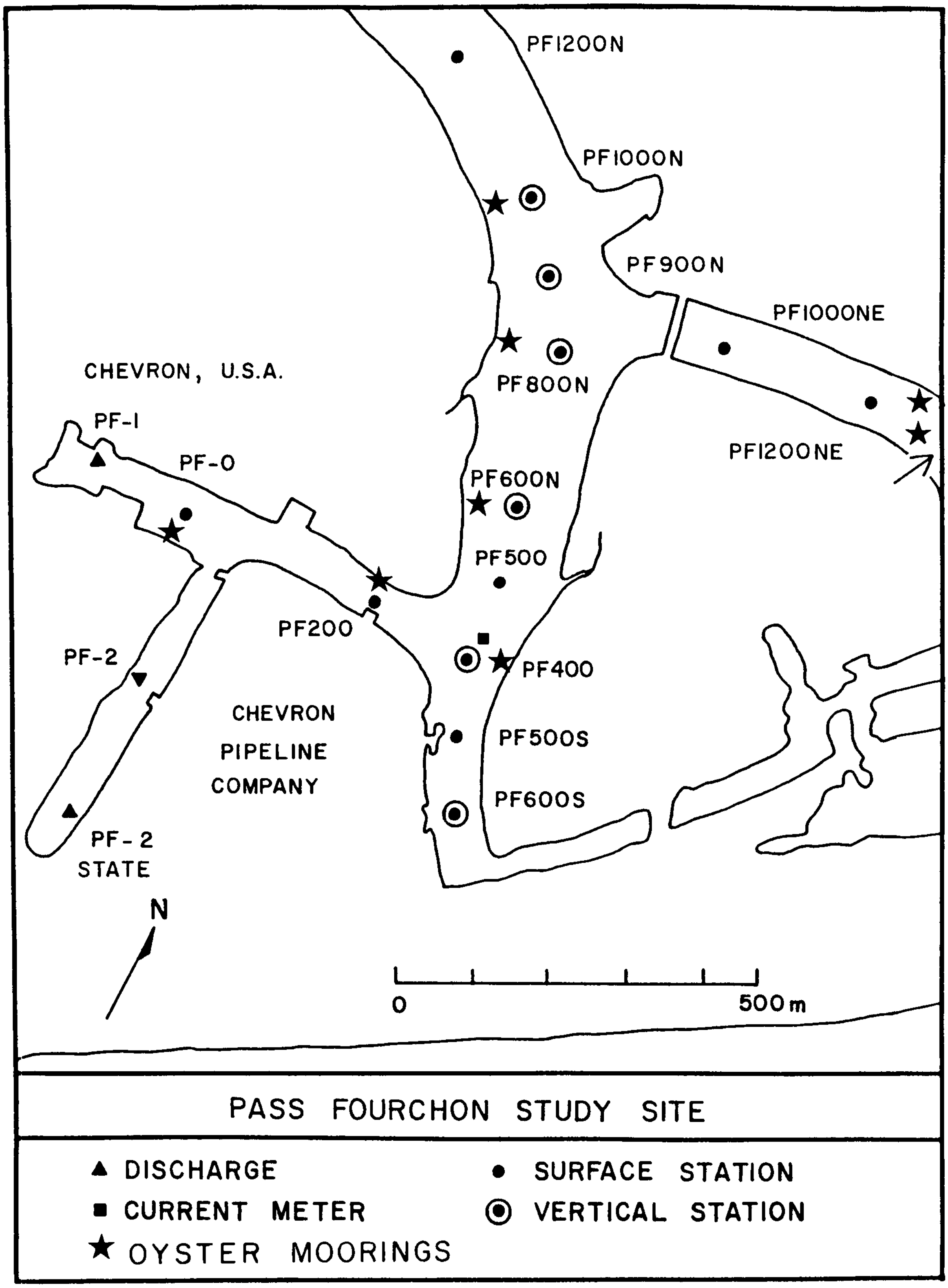

Figure 2.3. Locations of stations and types of collections at the Pass Fourchon study area.

Table 2.2. Fate and effects of nearshore discharges of OCS produced waters.

LOUISIANA UNIVERSITIES MARINE CONSORTIUM AND LOUISIANA STATE UNIVERSITY, INSTITUTE FOR ENVIRONMENTAL STUDIES	
Nancy N. Rabalais (LUMCON)	Program Manager Hydrography Sulfides Benthos Interstitial Salinity
Denise J. Reed (LUMCON)	Currents Sediment Total Organic Carbon Sediment Grain Size
Brent A. McKee (LUMCON)	Radionuclides Sedimentation Rates
Jay C. Means (LSU)	Hydrocarbons Trace Metals Bioavailability

The produced waters from the discharge points are being characterized for salinity, hydrocarbons, trace metals, and radionuclides. The sediments and water column from the surrounding environments are being characterized for similar constituents. Sediments are also being analyzed for grain size composition, total organic carbon, and interstitial water salinity. Water column measurements include hydrographic structure, near-bottom water sulfide concentrations, and current speed and direction. Biological studies include the community structure of the macroinfaunal organisms at all stations at all sites and bioavailability studies of moored filter feeding molluscs at selected stations at selected sites in gradients away from the discharge point.

Sample analyses, data analyses, and interpretation of results are in progress for this study. Additional samples are due for collection in February of 1990. The completion of the project is targeted for January of 1991.

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Dr. Nancy N. Rabalais is a member of the scientific staff of the Louisiana Universities Marine Consortium where she has been employed since 1983. She received her Ph.D. in zoology from The University of Texas at Austin in 1983. She is the Program Manager for the above described research program funded by the Minerals Management Service.

OIL SPILL RESPONSE

Session: OIL SPILL RESPONSE

Co-Chairs: Ms. Darice K. Breeding
Mr. Michael D. Joseph

Date: December 5, 1989

Presentation	Author/Affiliation
Oil Spill Response: Session Overview, Part I	Ms. Darice K. Breeding Minerals Management Service Gulf of Mexico OCS Region
Oil Spill Response: Session Overview, Part II	Mr. Michael D. Joseph Minerals Management Service Gulf of Mexico OCS Region
Exercising the Oil Spill Contingency Plan: Computer Enhanced Crisis Management Simulation Exercises	Mr. Robert J. Meyers Robert J. Meyers and Associates
Clean Seas' Response to the Sinking of the PacBaroness	Mr. Skip Onstad Clean Seas and Mr. Thomas McCloskey The McCloskey Group, Inc.
Emerging Sorbent Technologies	Mr. Don Smith Environmental Protection Agency Region VI, Ms. Julie Jordan Scientex Corp., and Mr. Thomas Spargo Ecology and Environment, Inc.
Field Tests of Satellite-Tracked Surface Drifting Buoys for Simulation Oil Spill Trajectories	Dr. Mark Reed Applied Science Associates, Inc.
Real-Time Trajectory Modeling of a Spill Event	Dr. Jerry Galt National Oceanographic Atmospheric Administration
The Petroleum Industry Response Organization (PIRO)	Vice Admiral John D. Costello PIRO Implementation, Inc.
State of Florida - Disposal Options for Recovered Oil and Oiled Debris	Mr. John K. Gentry and Mr. Greg Lee Florida Department of Environmental Regulation
Recovered Oil Disposal Options, Regulations and Considerations	Mr. Mike Ryan Environmental Protection Agency

Session: OIL SPILL RESPONSE (cont'd)

Presentation	Author/Affiliation
Louisiana State Regulations Governing Disposal of Recovered Oil and Oiled Debris	Mr. R. Bruce Hammatt Louisiana Department of Environmental Quality
Alabama's Regulations Governing the Disposal of Recovered Oil and Oiled Debris	Mr. John C. Carlton Alabama Department of Environmental Management
Mississippi's Regulations Governing the Disposal of Recovered Oil and Oiled Debris	Mr. Richard Ball Mississippi Department of Environmental Quality
Texas State Regulations Governing the Disposal of Recovered Oil and Oiled Debris	Mr. David Barker Texas Water Commission
Contingency Planning for Exploration Activity	Mr. Jim O'Brien O'Brien's Oil Pollution Service and Dr. Bela M. James Continental Shelf Associates, Inc.
"State-of-the-Art Oil Spill Response Equipment"	Mr. Parag Gandhi and Mr. Mark Ploen Ajat Shaw, Inc.
An Evaluation of Oil Spill Response Methodology/Equipment Used During the Cleanup of the Exxon Valdez Spill and U.S. Coast Guard Atlantic Area Strike Team Response Capabilities in the Gulf of Mexico	LCDR Glenn A. Wiltshire U.S. Coast Guard As Presented By CWO Fred Gonzales U.S. Coast Guard

OIL SPILL RESPONSE: SESSION OVERVIEW, PART I

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The prevention, containment, and cleanup of oil spills has become an even greater area of concern and focus for Minerals Management Service (MMS), the oil industry, and the general public after the March 24, 1989, Exxon Valdez grounding on Bligh Reef in Prince William Sound, Alaska, where 260,000 bbls of oil was spilled. As a result of the Exxon Valdez incident, greater emphasis has been placed on potential spill response research, planning, and equipment needs. This session was initiated to gain information on some of the recent spill response developments that could be used to enhance the MMS oil spill contingency planning program.

The first presentation was given by Mr. Robert Meyers, president of Robert J. Meyers and Associates, an environmental consulting and emergency response firm which specializes in contingency planning and training for responding to oil spills. Mr. Meyers discussed the effectiveness of exercising an oil spill contingency plan through a computer enhanced crisis management simulation exercise, and stressed the advantages of conducting such a drill before a spill occurs to assure that the contingency plan will work when the real event happens. Simulated exercises teach the participants how to solve problems associated with emergency response situations and help identify appropriate individuals on the response teams to address particular problems associated with the response operation. Computer enhancement provides interactive graphic representation of spill movement and of the response team's interventions. By adjusting graphic displays in response to actions taken by team members during the simulation, the participants actually see the effects of their actions and decisions, e.g., boom placements. Mr. Meyers reported that computer enhancements greatly enhance the effectiveness of simulation exercises.

Mr. Skip Onstad, manager of Clean Seas, an industry owned oil spill cooperative located in Santa Barbara, California, discussed Clean Seas' response to the sinking of the PacBaroness, and the lessons learned as a result of the incident. On September 21, 1987, the bulk carrier PacBaroness collided with another vessel approximately 14 miles west of Point Conception and resulted in an initial slick 1.5 miles long and 0.5 miles wide in the vicinity of the wreck site. A large quantity of bunker oil (IFO 180) continued to bubble to the surface for several days. The exact quantity is unknown, but was believed to be several thousand barrels. As the oil spill resulting from the sinking of the PacBaroness was the first major incident in Clean Seas' area of responsibility since the cooperative's formation in 1970, the event posed the first opportunity for Clean Seas to test its manpower and equipment under "real world" conditions.

The incident revealed several areas where Clean Seas felt its response capabilities should be enhanced to improve the cooperative's ability to respond to future incidents. These areas included: administration of a nonmember spill; establishment of a prespill contractual relationship with the U.S. Coast Guard; an improvement in the cooperative's slick surveillance capabilities; the development of multiple vessel response techniques; and the establishment of procedures for the coordination of dispersant application operations. Mr. Onstad further defined the positive steps taken to preclude future occurrences and to make improvements in the aforementioned areas.

Mr. Don Smith, the U.S. Environmental Protection Agency's Region VI On-Scene Coordinator, discussed emerging sorbent technologies. Of the wide array of sorbent products available, the most widely used sorbent for oil spill cleanup is melt-blown polypropylene which comes in a wide variety of forms. Criteria that should be considered when selecting a sorbent would include an assessment of its ability to take up and retain oil; its cost, including the cost of the labor required to deploy and retrieve a particular type of sorbent; and its disposal requirements. Advantages of sorbents are found in the variety of configurations available, selectivity for sorbing oil even in low concentrations, and the ease of application in hard to reach places. Disadvantages include the relatively high costs per unit of oil removed, high labor requirements, the relative difficulty in retrieval, and disposal problems.

During the shoreline cleanup in Prince William Sound, Alaska, a sorbent boom was used to capture oil outflow following high pressure water spraying of beaches and in conjunction with deflection booms to protect high-priority areas such as fish hatcheries. Additionally, the organic sorbent, peat moss, was used effectively early on in the spill for soaking up oil on rocky beaches. Peat moss was less effective on weathered oil, however, as it was reported to have hardened and sunk. The use of geotextile bags filled with absorbents was also proposed for use in Alaska. It was proposed that these bags be tied to the beach where wave action would cause the oiled sediments to contact the sorbents in the bags. The bags would later be recovered and discarded.

One emerging sorbent technology mentioned by Mr. Smith was the use of a polymer absorbent which allows oil to be initially absorbed into the product and then plasticized into hard chunks of rubber. Once the oil is absorbed it will reportedly not leach back into the water column and can be landfilled as the oil will not be released at pressures exceeding 50 pounds per square inch.

Dr. Mark Reed, operations manager and senior scientist with Applied Science Associates, Inc., discussed the field test of satellite-tracked surface drifting buoys for simulation oil spill trajectories that were conducted in late June/early July 1989 at Haltenbanken about 150 km from the Norwegian Coast. The primary objectives of the experiment were to identify which surface drifting buoy configuration(s) best simulated the drift of crude oil on the sea surface under a variety of real environmental conditions, and to develop reliable mathematical transfer functions from buoy to oil to assist in the future interpretation of buoy trajectories. The field test, which involved an oil spill of 30 tonnes of crude oil, represented the second phase of a three-phase program during which the two top rated buoys (a disk and a sphere), recommended as a result of the first phase of the study, were field tested. The final goal of this program will involve the acquisition and deployment of large numbers of drifting buoys in the various Outer Continental Shelf Planning areas. The trajectories of these buoys can then be used as measures of potential oil spill trajectories, and as test data for trajectory models. The data analysis for the field test is currently ongoing.

Dr. Jerry Galt of the National Oceanic and Atmospheric Administration (NOAA) Hazardous Materials Response Division provided a presentation on real-time trajectory modeling of a spill event. Dr. Galt's discussion covered the general uses for trajectory analyses or modeling, particularly during a spill response. Some of the questions/problems that can be addressed during a spill event through the use of a trajectory analysis include: (1) Will there be landfall? (2) Would it be preferable to disperse the oil or leave it alone? (3) Will it hit high value targets? (4) What is the length of time projected before landfall? and (5) Where are the most advantageous areas to place booms? Trajectory results can also be used in deciding where to move a stricken vessel and whether offloading or refloating such a vessel should be attempted.

The NOAA model was designed to be communicated quickly and has the ability to run in a short period of time. This model works on a relatively coarse resolution (80 x 48 standard line printer graphics picture) and is designed to be transmitted by a variety of modes. In the NOAA model areas reporting floating oil are assigned numerical values ranging from 0-9 which reflect the concentration of spilled oil. Once floating oil approaches shoreline or beach in the NOAA trajectory, the numerical value is then assigned a "letter" designation. Trajectory requests to NOAA are made for approximately 200 spills per year. Half of these requests involve oil spills. The model is run for approximately 80% of the requests received to aid in the prediction of spilled oil movement. If NOAA has run trajectories in a subject area previously, it takes approximately 1 to 1.5 hours to run the analysis. If NOAA has no previous experience or information on an area, the trajectory will take approximately 2 to 3.5 hours.

The final presentation was provided by Vice Admiral John Costello, who is currently serving as president of PIRO Implementation Inc. Vice Admiral Costello stated that in its report of June 14, 1989, the American Petroleum Institute's (API) oil spill task force recognized the nation's oil spill problem and recommended several initiatives to prevent and remove catastrophic oil spills and to conduct spill related research. Among the initiatives were the establishment of an industry response organization to be known as the Petroleum Industry Response Organization and the development of an aggressive oil spill research and development program. Vice Admiral Costello emphasized, however, that these initiatives cannot be fully implemented at this time, because of pending legislature presently before Congress, which is likely to determine their final scope.

The estimated cost for PIRO over the first five years was originally estimated to be 250 million dollars. (However, the cost for the first five years has recently been projected to require between 450-500 million dollars.) This would create a system with 5 regional response centers, 18-22 sites for prepositioned materials, and a small headquarters in Washington, D.C. The API's report also identified a comprehensive 30-35 million dollar 5-year research and development program for PIRO that would cover such issues as prevention of oil loss from/away from ships, on-water oil recovery and treatment, prevention and mitigation of shoreline impact, oil-in-water fate and effects research, wildlife research, and worker health and safety. Vice Admiral Costello further reported that it was presently hoped to have PIRO in initial operational capacity 12 months after the pending oil spill legislature becomes law and to have the full system operational 12 months thereafter.

Ms. Darice K. Breeding is a physical scientist in Leasing and Environment, Environmental Operations Section of the Minerals Management Service Gulf of Mexico OCS Regional Office. Her responsibilities include the research, assessment, and reporting on the interrelationship of the OCS oil and gas program in the Gulf of Mexico OCS Region with oil spill response and contingency planning issues.

OIL SPILL RESPONSE: SESSION OVERVIEW, PART II

Mr. Michael D. Joseph
Minerals Management Service
Gulf of Mexico OCS Region

The National Oil and Hazardous Substances Pollution Contingency Plan (40 CFR Part 300), effective February 18, 1986, requires that the predesignated U.S. Coast Guard (USCG) On-Scene Coordinator make every reasonable effort to have the responsible party voluntarily and promptly perform removal actions when an oil spill occurs. So that Outer Continental Shelf operators can effectively accomplish these removal actions, the Minerals Management Service (MMS) requires in 30 CFR 250.33 and 30 CFR 250.34 that all Exploration Plans and Development Operations Coordination Documents include oil spill containment and cleanup plans.

This portion of the session was designed to address issues pertaining to oil spill response planning. Included were discussions on contingency planning, state regulations governing disposal of recovered oil and oiled debris, and effectiveness of response equipment and methodologies.

For the first presentation, a panel was convened to discuss recovered oil disposal options, regulations, and considerations of the States of Florida, Louisiana, Alabama, Mississippi, and Texas.

Mr. Greg Lee of the Florida Department of Environmental Regulation was the first panel member to speak. Mr. Lee discussed disposal options in the State of Florida. He stated that land disposal of any pollutants should be dealt with as near the source as possible. Thermal destruction was recommended as the most cost effective method of disposal. The discussion covered three types of thermal destruction methods including: municipal solid waste combustion, stationary thermal treatment facilities, and mobile incinerators.

Mr. R. Bruce Hammatt of the Louisiana Department of Environmental Quality provided an overview of his state's procedures for disposal of recovered oil and debris. The presentation included discussions of the state offices responsible for regulating disposal and disposal sites. Additionally, the state's air quality regulations were discussed in relation to burning recovered wastes as a method of disposal. The State of Louisiana classifies recovered oil and oily debris as a Nonhazardous Oilfield Waste.

Mr. John C. Carlton of the Alabama Department of Environmental Management provided an overview of disposal options in the State of Alabama. The discussion included topics from regulatory authority to methods of disposal. The practice of burning as a method of disposal is expected to increase in the future as the capacity of available facilities capable of land farming dwindles.

The panel member representing the State of Mississippi was Mr. Richard Ball of the Mississippi Department of Environmental Quality. Mr. Ball's presentation addressed the limited capacity of disposal facilities capable of handling oiled debris. The state classifies recovered oil and oiled debris as nonhazardous waste. Open burning of solid waste is prohibited in the State of Mississippi.

Mr. David Barker of the Texas Water Commission was the final panel member to speak on the topic of Regulations Governing Disposal of Recovered Oil and Oiled Debris. Mr. Barker discussed the procedures involved in the classification of solid wastes for the State of Texas. Disposal options were also addressed and state offices with regulatory authority were identified. The State of Texas generally classifies oiled debris as nonhazardous waste with some exceptions. All disposal requests are handled on a case-by-case basis after proper waste classification is accomplished.

Mr. Jim O'Brien of O'Brien's Oil Pollution Service presented a paper prepared by himself and Dr. Bela M. James of Continental Shelf Associates, Inc. The presentation addressed contingency planning for exploration activity. Mr. O'Brien discussed oil spill contingency plan requirements of the MMS. An outline was presented of the information necessary to develop adequate response plans for implementation in the case a spill occurs. Responses to oil in open water as well in the coastal zone were discussed.

Mr. Parag Gandhi and Mr. Mark Ploen of Ajat Shaw, Inc. provided an overview of state-of-the-art oil spill response equipment. The presentation included discussions on aerial surveillance, containment, recovery, separation, storage and transportation, and shoreline remediation. Airborne surveillance systems were discussed as a source to provide real time information necessary for the spill response decisionmaking process. The advantages and disadvantages of the different types of booms available and their intended uses were addressed. Skimmer systems were identified by type and working conditions best suited for their use. Alternative methods of storage were discussed, including portable storage devices that were easily transportable when conventional methods were not available or logistically possible. Shoreline remediation techniques were addressed, including several useful mechanized techniques. However, the most commonly used shoreline techniques include manual labor working with pressure washers and oleophilic hand tools.

The final presentation of the session was a paper prepared by Lieutenant Commander Glenn A. Wiltshire as presented by Chief Warrant Officer (CWO) Fred Gonzales, both of the USCG. CWO Fred Gonzales presented an overview of the oil spill response methodology and equipment used during the cleanup of the Exxon Valdez spill. Weir type skimmers were effective while the oil was still fresh, however, as the oil weathered they became ineffective and belt type skimmers worked better. Problems were encountered in off-loading recovered oil from onboard tanks. The massive size of the spill overwhelmed response capabilities. One of the most significant problems encountered was the availability of temporary storage devices to hold recovered oil. Additionally, the USCG's Atlantic Strike Team capabilities for response in the Gulf of Mexico were addressed. The discussion included a summary of equipment most likely to be used in the Gulf and an overview of the mission of the strike team.

Mr. Michael D. Joseph is a petroleum engineer in the Exploration/ Development Plans Unit of the Office of Field Operations of the Minerals Management Service Gulf of Mexico OCS Region. He has 10 years of government experience relating to the oil and gas industry. Currently, he is involved in the review and approval of Oil Spill Contingency Plans required of the companies operating in the Gulf. Mr. Joseph received his B.S. in civil engineering from Tulane University.

EXERCISING THE OIL SPILL CONTINGENCY PLAN: COMPUTER ENHANCED CRISIS MANAGEMENT SIMULATION EXERCISES

Mr. Robert J. Meyers
Robert J. Meyers and Associates

INTRODUCTION

To ascertain the effectiveness of an oil spill contingency plan, it must be exercised, either during an actual oil spill or through some type of training activity. The key, however, is to exercise the plan before a spill occurs to assure that it will work when the real event happens.

One way to exercise the plan is through Computer Enhanced Crisis Management Simulation Exercises. These simulations are not necessarily limited to environmental type incidents, but could include all types of emergencies.

Simulations address all types of problems that can arise during response to an oil spill, hazardous material spill, vapor cloud, fire/explosion, or any other type emergency. In addition to teaching the participants how to solve problems associated with emergency response teams, simulations also help identify appropriate individuals on the response team to address particular problems associated with the response operation. Computer enhancement provides interactive graphic representation of spill and release movements and of the effect of the response team's interventions. Among other functions, the computer is also used to provide important information comparing "idealized" contingency plans with actual performance of response teams during the simulation.

This paper describes these type simulations. The utilization of "event cards" and role playing techniques to prompt the response team is discussed. The use of the computer for helicopter surveillance and tracking of the spilled oil and the effects of response team actions and decisions, i.e., boom placements, etc., are also described.

The use of computer enhanced crisis management simulations to exercise oil spill response teams has proven very effective. This paper describes how these simulations are conducted.

PLANNING

Preparations for conducting a simulation begin with the design of a scenario. A practical oil spill scenario that will provide the response team with a "test" simulation that relates directly to the operations and risks for the personnel participating in the drill will exercise the plan most effectively. This will insure the maximum benefits gained for the response team.

The next step is designing problems that present realistic situations that can arise during an actual oil spill response. These problems will not only serve to train the participants on how to solve specific problems, but will also identify the appropriate individuals on the response team to address the particular problem at hand. The problems can be "served up" to the response team through the use of event cards and/or role playing.

Several problems that are likely to arise during an oil spill can be role played. On-scene inquiries from irate citizens, concerned public officials, regulators (if not participating in the exercise) and interested environmentalists and others can be role played. Role playing adds to the realism of drills and trains response team members in the proper handling of the public.

SIMULATION METHODOLOGY

The next step is conducting the simulation itself. First you need a proper location. Ideally, four separate rooms within an office or hotel will be required with telephone and/or portable radio communication between rooms; and a small fifth room as a control center where a computer can be operated and a resource desk manned.

Figure 3.1 outlines a typical agenda for the drill. The exercise begins with the presentation of the ground rules and the scenario. After an initial gathering of the response team led by the On-Scene Commander, the team groups then go to their respective rooms, and the drill commences. The team is then prompted with event cards and role plays while the computer is utilized to provide helicopter overflight searches and spill tracking. The simulation can either be real time or accelerated time based on the experience of the response team and the objectives of the exercise. A "resource desk" manned by an individual experienced in the support and logistical demands of an oil spill response operation is set up. This "resource desk" simulates all "outside" requirements such as manpower, equipment, food, lodging, medical services, etc. and regulatory agencies (if not participating in the exercise), in a realistic manner. (The participation of regulatory agencies, however, is strongly recommended.)

	First Day
0800-0815	Welcome - Introductions - Purpose
0815-0845	Ground Rules for the Simulation
0845-0915	Team Organizes for Simulation
0930	Simulation Begins
1400-1500	Simulation Ends
1500-1600	Wrap-Up
	Second Day
0800-0815	Review of Scenario
0815-0915	Team Groups Critique Actions
0915-1015	Team Group Presentations
1015-1030	Critique of Simulation
1100	Wrap-Up - Farewell

Figure 3.1. Typical agenda.

With graphics, the movement of the spill is displayed in relation to natural and man-made features in response to a simulated helicopter overflight. By adjusting graphic displays in response to actions taken by team members during the simulation, the participants actually see the effects of their actions and decisions, i.e., boom placements, etc.

With polaroid film, pictures can be taken during the surveillance flight in response to "flight plan" requests and then distributed to team members. These pictures provide a realistic dimension to the simulation by helping the response team locate the spill or discharge and allowing participants to describe spill movements, develop search patterns, develop and adjust response and surveillance operations, and make appropriate responses to what they find in the overflights.

At the completion of the simulation, all resolutions to event cards, self-initiated actions, and logs are collected. A brief wrap-up session is conducted to summarize and advise team members of the next day's activities. After the drill, all materials collected are reviewed during the evening. The data collected is then returned to the response team groups at a critique session the next morning. Each group is asked to self-critique their actions at that time and then report back to the entire response team on how well they believe they did, what actions they took they felt were good, those which were not so good, and lessons learned. (A self analysis and self critique can contribute greatly to the success of the simulation exercise in training response team members for an actual incident.)

A comprehensive report is then prepared on the simulation exercise to include the scenario, event cards, routing and actions taken, the critique, and recommendations for improvements. This documented complete record can then be used by management to evaluate response capability and plan contingency planning improvements and pursuant training needs.

Computer enhancements serve not only to increase the effectiveness of the simulations, but also to increase management's ability to assess the performance of team members during the simulation. In addition, a better perspective can be obtained regarding the comprehensiveness and effectiveness of emergency response plans.

CONCLUSIONS

Simulation exercises are an ideal way to exercise a contingency plan and a response team to prepare for the real thing. Computer enhancements greatly augment the effectiveness of simulation exercises.

Mr. Robert J. Meyers is president of Robert J. Meyers & Associates, an environmental consulting and engineering firm he founded in 1986 which specializes in contingency planning and training for responding to oil spills. Prior to that, Mr. Meyers spent over 20 years with

Exxon where he occupied numerous management positions: the last seven years as Environmental Conservation Coordinator for Exxon Shipping Company responsible for oil spill response planning and oil spill management. Mr. Meyers has chaired and served on many committees which have addressed oil spill response capabilities and techniques. Most recently, he was a member of the National Academy of Sciences Committee that studied the effectiveness of oil spill dispersants.

CLEAN SEAS' RESPONSE TO THE SINKING OF THE PACBARONESS

Mr. Skip Onstad
Clean Seas
and
Mr. Thomas McCloskey
The McCloskey Group, Inc.

INTRODUCTION

Clean Seas is a nonprofit oil spill cooperative headquartered near Santa Barbara, California. The organization, which was formed by the oil and gas industry in 1970, is structured to provide a prompt and effective response capability for marine oil spills. The Clean Seas designated area of responsibility comprises the open ocean and coastline of California between Cape San Martin on the north and Point Dume on the south, including the Channel Islands.

Within its area of responsibility, Clean Seas maintains a multimillion dollar inventory of state-of-the-art response equipment, including: 3 fully equipped oil spill response vessels, 12 response vans positioned at strategic locations along the coastline, and a large inventory of containment, recovery, and other equipment. This equipment is available 24 hours per day to member and nonmember companies, and government agencies.

The purpose of this paper is to report on Clean Seas' response to the "PacBaroness" oil spill which occurred in fall 1987. The events surrounding this oil spill are important because they constitute Clean Seas' first significant test of its oil spill response capability.

DESCRIPTION OF THE INCIDENT

At 0530 Monday, September 21, 1987, the PacBaroness, a 562-foot, Liberian dry bulk carrier collided with the Atlantic Wing, a 494-foot, Panamanian car carrier. The PacBaroness was damaged below the water line and began to take on water in two holds on the starboard side, forward of the bridge. The crew of the PacBaroness abandoned ship to the Atlantic Wing which, though damaged, was able to maneuver on its own. By 0730, the PacBaroness was reported to have a 10-degree list to starboard, and its stern was under water.

The PacBaroness foundered throughout the day and, at one point, was drifting toward an oil and gas production platform. The PacBaroness agreed to take on a tow line at 1300 and was under tow, out to sea, when it sank at 1618.

Prior to sinking, the PacBaroness released a small quantity of oil (i.e., < 25 barrels). At 1700, a large discharge of oil began rising to the surface from the sunken vessel, and by 1800 a slick had formed in the vicinity of the wreck site which was 1.5 miles long and 0.5 miles wide.

A large quantity of bunker oil (IFO 180) continued to bubble to the surface from the sunken ship for several days. The exact quantity will never be known, but estimates put this spill at several thousand barrels. Initially, wind and current conditions combined to confine the slick to an offshore area well away from the Channel Islands and mainland. By Thursday, however, a shift in wind direction and intensity caused the slick to move to the south toward San Miguel Island which is part of the Channel Islands National Marine Sanctuary.

By Friday, a reduced quantity of oil bubbling to the surface, favorable weather conditions which enhanced natural dispersion and degradation processes, and response efforts which included both mechanical recovery and dispersant application operations succeeded in eliminating the threat to San Miguel Island. Although the PacBaroness was still leaking a small quantity of oil by October 12, 10 days of observation overflights indicated that the slick was confined to the wreck site and did not pose a threat to the Channel Islands or the mainland.

SUMMARY OF RESPONSE OPERATIONS

The Clean Seas response organization was activated minutes after the collision. Mr. Clean III, an oil spill response vessel (OSRV) owned by Clean Seas and stationed in the Point Arguello oil field, was notified of the collision and dispatched to the scene. Mr. Clean III arrived on-scene at 0745, accompanied by a smaller fast response vessel. At 0730, the Manager of Clean Seas dispatched Mr. Clean II from Avila Beach to the western portion of the Santa Barbara Channel to stand by, and Mr. Clean departed its mooring in Santa Barbara Harbor at 1045 for a sheltered anchorage just east of Point Conception.

All three of Clean Seas' OSRVs were on-scene from Tuesday, September 22 to Friday, September 25, when the U.S. Coast Guard (USCG) released Mr. Clean and Mr. Clean II from service. Mr. Clean III remained on-scene until September 29. During the incident, Clean Seas engaged in the following activities:

- search and rescue operations, including the transfer of the crew of the PacBaroness from the Atlantic Wing to another vessel for transport to shore;
- monitoring and reporting of weather conditions;
- surveillance of the slick by vessel, helicopter, and tracking buoys;
- at sea containment and recovery of 350 barrels of oil during day 2 and 3 of the spill;
- the test application of 100 gallons of dispersant, and the monitoring of results on day 2;
- the operational application of 250 gallons of dispersant, and the monitoring of results on day 4;
- participation in the test application of dispersants for a government sponsored research program; and
- oiled seabird cleaning, rehabilitation and release operations.

The management of Clean Seas' response operations was hampered by the fact the oil spill incident involved a nonmember company which resulted in difficulties in signing a contract with Clean Seas.

In addition, conditions at the wreck site were not, for the most part, conducive to the conduct of operations. Because of the water depth at the wreck site (i.e., approximately 1,500 feet), Clean Seas was unable to station containment booms and surround the oil as it bubbled to the surface. As a result, the oil (IFO 180) spread out on the ocean surface, primarily in the form of sheens and discontinuous windrows of heavier concentrations. In addition, low visibility throughout the entire period, caused by dense fog, restricted vessel and aerial observation of the slick. This affected Clean Seas' ability to direct its OSRVs and aircraft to areas where slick concentrations were conducive to mechanical recovery and/or chemical treatment operations. Finally, strong winds and high seas on day 1 of the spill and days 4 and 5 either prevented the deployment or reduced the effectiveness of equipment and spread the relatively light oil over a wide area. Despite these problems, Clean Seas OSRVs were able to recover 350 barrels of oil, and treat approximately 100 barrels of oil with dispersants.

LESSONS LEARNED

Strengths

The oil spill resulting from the sinking of the PacBaroness was the first major incident in Clean Seas area of responsibility since the cooperative's formation in 1970. As such, the event posed the first opportunity for Clean Seas to test its manpower and equipment under "real world" conditions.

Manpower

There was a good response from the Clean Seas Executive Committee and personnel. The Chairman of the Executive Committee was able to poll Executive Committee members and authorize the Clean Seas Manager to respond by 1030 on September 21.

Equipment

The responsible party and the USCG relied exclusively on Clean Seas equipment throughout the incident. Although slick characteristics and severe weather conditions reduced the effectiveness of the equipment, the major systems utilized by Clean Seas operated without mechanical breakdowns throughout the incident.

Weaknesses

The incident also revealed several areas where Clean Seas believes its response capabilities should be enhanced to improve the cooperative's ability to respond to future incidents. These include: administration of a nonmember spill; establishment of a prespill contractual relationship with the USCG; an improvement in the cooperative's slick surveillance capabilities; the development of multiple vessel response techniques; and the establishment of procedures for the coordination of dispersant application operations.

Administration of a Nonmember Company

During the PacBaroness incident, Clean Seas reached a "verbal" agreement with the ship owner on September 21, but was unable to get him to sign Clean Seas Standard Nonmember Contract throughout the incident. On September 24, the impasse with the owner forced a breakdown in negotiations and the USCG stepped in and assumed financial responsibility for the response effort until September 28 when the owner acted to meet its financial obligations to Clean Seas.

The Clean Seas Standard Nonmember Contract was developed in 1975 and never used until the PacBaroness incident (it is similar to those of other oil industry cooperatives in terms of indemnification requirements and other conditions.). In light of the problems it engendered in this case, it has been reviewed to: (1) make sure that its terms are still acceptable to the Clean Seas member companies; (2) protects the interests of the Clean Seas member companies; (3) guarantees full reimbursement of all costs incurred by Clean Seas; and (4) specifies responsibility for liabilities incurred by Clean Seas during the response operations.

The difficulties in this case also pointed out the need for a rapid and efficient way to provide a nonmember company with the following information:

- the purpose of Clean Seas, and how the cooperative is organized;
- the capabilities of Clean Seas;
- the role of nonmember company (i.e., where they fit in and what they are expected to do); and
- the terms and conditions of Clean Seas involvement (i.e., both contractual and financial);

Since the incident, this information has been compiled in a concise document that can be telefaxed, express mailed, or hand delivered to a nonmember company as quickly as possible after the initial contact.

Basic Operating Agreement With the U.S. Coast Guard

When the USCG assumed financial responsibility for the response effort on September 24, an inordinate amount of time and resources were devoted to negotiations over a Basic Operating Agreement (BOA) which would specify the terms and conditions of Clean Seas involvement in a USCG-funded response operation. Following the incident, negotiations began anew on the development of a BOA between Clean Seas and the USCG to cover any future USCG-funded response operation.

Slick Surveillance

One of the biggest operational problems Clean Seas encountered during the PacBaroness incident was its inability to observe the slick from the air due to thick fog. During the incident, the only instrument able to penetrate the fog and obtain a picture of the slick was the side looking airborne radar (SLAR) on the USCG AirEye system. Since the incident, the AirEye system has been moved to the East Coast and there are no plans, at the present, to replace the system.

Aerial surveillance is absolutely essential to determine the position of the slick, the threat the slick poses to coastline areas, and the optimum locations for mechanical containment, recovery, and dispersant application operations. Because of this, Clean Seas and other west coast oil spill cooperatives are examining the availability of aerial surveillance systems which can provide at least a SLAR capability for use during future oil spill incidents.

Multiple Vessel Response Techniques

Problems were encountered by the OSRVs working together in a closely coordinated fashion during the incident. This highlighted the need to develop multiple vessel response techniques (e.g., using containment boom on one vessel to direct oil to the advancing skimmer system on another vessel). Since the incident, exercises have been held to test techniques.

Dispersant Application Procedures

Clean Seas experienced difficulties in the coordination of dispersant spraying operations. There were more aircraft on-scene than necessary, some carrying too many people. Communications between the helicopters and OSRVs were poor. Terminology was used by people in the helicopters which was 'foreign' or confusing to those in the spray aircraft who were experienced with the vernacular used in the spraying business. Clean Seas is in the process of improving procedures to be followed to coordinate spraying operations. At a minimum, the procedures will include information on: (1) how the target slick will be identified, and by whom; (2) how the spray aircraft will be directed to the target slick, and by whom; (3) how communications will be handled between the spotter aircraft and the spray aircraft; and (4) the terminology to be used during the course of operations.

Future operations will also keep to an absolute minimum the number of "observers" who are carried in the spotter aircraft. While it may be necessary for agency decision-makers to be on scene during all or a portion of the spray operations, they should not be in the spotter aircraft, but in a separate observation aircraft. Their instructions or information should be passed by radio to the spotter or control aircraft.

CONCLUSION

This was an excellent spill as a test of Clean Seas' capabilities. The lessons learned were many but dealt mostly with dispersant use and spill administration. Considering the conditions, a reasonable amount of oil was recovered. When the spill was perceived to threaten sensitive areas, agency response personnel acted quickly to counter the threat. There were no shoreline impacts throughout the incident and only minor oiling of seabirds. Finally, the weaknesses identified have allowed Clean Seas to take positive steps to preclude future occurrences and make improvements.

Mr. Skip Onstad is Manager of Clean Seas, an industry-owned oil spill cooperative located in Santa Barbara, California. Prior to becoming Clean Seas Manager, he served for over twenty years in the USCG dealing with maritime operations, safety and pollution preparedness, and response matters. He is a USCG Academy graduate and holds an MBA from the George Washington University.

Mr. Thomas McCloskey is President of The McCloskey Group, Inc. (formerly Hooks, McCloskey and Associates, Inc.), a full service consulting firm which specializes in regulatory and environmental matters relating to the permitting of offshore and onshore energy facilities, particularly in California and Alaska. Prior to cofounding the firm, he served as Special Assistant to the Assistant Secretary for Energy and Minerals in the U.S. Department of the Interior and was the Executive Director of the Citizens Advisory Council to the Pennsylvania Department of Environmental Resources. Mr. McCloskey holds a Master's Degree from the Monterey Institute of Foreign Studies.

EMERGING SORBENT TECHNOLOGIES

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Environmental Protection Agency
Region VI,
Ms. Julie Jordan
Scientex Corp.,
and
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INTRODUCTION

A paper entitled, "Sorbent Performance Study for Crude and Refined Petroleum Products," (Flaherty and Jordan 1989) presented at the February Oil Spill Conference in San Antonio, Texas, addressed various types of sorbents, performance criteria, tests performed in previous studies, and guidance on sorbent application.

Based on a review of available literature on sorbents, the paper discussed desirable sorbent performance traits and offered a range of characteristics to consider when selecting a sorbent. The paper also raised a number of issues with regard to sorbent performance and noted that several characteristics were often incompatible. Brief mention of an emerging technology was made in the paper as well. The purpose of this paper is to revisit some of the characteristics discussed in the earlier paper from the perspective of an On-Scene Coordinator (OSC) and to provide an elaboration of the emerging technology presented in the first paper.

PRODUCT AVAILABILITY

There is a wide array of sorbent products/available. The World Catalog of Oil Spill Response Products (Schulze 1987) cites over 30 manufacturers offering sorbent products in a variety of configurations including booms, pillows, rolls, sweeps, and pads. These products are manufactured from natural organic and inorganic materials such as treated peat moss and perlite and man-made products including polyurethane and polypropylene. Combinations of natural and synthetic products are available as well. According to the publisher of the World Catalog, the most widely used sorbent for oil spill cleanup is melt-blown polypropylene which comes in a variety of forms including rolls, pads, booms, sweeps, sheets, and particulate.

SORBENT SELECTION CONSIDERATIONS

Response to a major discharge of oil which invariably requires large expenditures of manpower, time, and money, could quickly exhaust stockpiles of equipment and materials, including sorbents. The OSC or incident commander must expediently consider the range of options available and choose response methods for each operable unit that are effective for the situation, cost efficient, and will not cause more harm than the oil they are intended to remove.

From the perspective of the responder, the most important feature of a sorbent is its ability to take up and retain oil. How this is accomplished, whether by absorption or adsorption, is not particularly relevant during the cleanup action. Current American Society for Testing and Materials (ASTM) testing standards specify different measures of effectiveness for absorbents and adsorbents which prevent meaningful cross comparison of the two classes of sorbents (ASTM 1987).

Another concern of the OSC is cost. Given the current state of the 311(k) Fund, finite resources are a reality in a Federally financed cleanup effort. Guidance on cost versus the capacity of a particular type of sorbent to recover oil is not available. Synthetic sorbents, while more effective than natural products, are more expensive. The cost of the labor required to deploy and retrieve a particular type of sorbent must also be factored into the cost equation. The ability to evaluate cost and effectiveness would be of great assistance to the OSC.

As a rule, sorbents are used for final cleanup of trace amounts of oil or to remove oil from areas inaccessible to skimmers and other large equipment. Sorbents are the preferred method for removing oil from confined areas or sensitive habitats such as wetlands, where mechanical equipment would be disruptive.

The limited scope of sorbent use has evolved through time and experience which balances the advantages of sorbents against their limitations. Advantages of sorbents are found in the variety of configurations available, selectivity for sorbing oil even in low concentrations, and ease of application in hard to reach places. Disadvantages are relatively high costs per unit of oil removed, high labor requirements, relative difficulty in retrieval, and disposal problems.

During the shoreline cleanup following the spill in Prince William Sound, Alaska, sorbent booms were used to capture oil outflow following high-pressure water spraying of beaches. They were also used in conjunction with deflection booms to protect high-priority areas such as fish hatcheries.

Historically, disposal of oil-contaminated debris including sorbents, has been accomplished by open burning, incineration, landfarming (aerobic biodegradation), or burial or landfilling (anaerobic biodegradation). Oiled sorbents must be disposed of in a safe manner and in compliance with State and U.S. Environmental Protection Agency (EPA) regulations. However, up-to-date published information regarding recommended disposal practices is not readily available.

Regarding the disposal of oil-contaminated sorbents, there are several regulatory initiatives that will likely complicate the selection process even further. The characteristics of a sorbent have a bearing on the disposal options available to the OSC, and the OSC's initial choice may limit subsequent disposal options. Once the oil or hazardous material has been removed, the OSC may end up with a solid or hazardous waste problem.

Sanitary landfilling at established sites may be the most commonly selected method of disposal. However, recent regulatory actions regarding solid waste disposal are likely to impact landfill disposal decisions which require that this issue be more closely examined.

A solid waste not otherwise listed as a hazardous waste may still be defined as such if it exhibits any of the following characteristics: ignitability, corrosivity, reactivity, or toxicity. Since several refined petroleum products such as gasoline would meet the ignitability criterion, sorbents contaminated with these products would be subject to Section 3004(c)(2)(B) of the Hazardous and Solid Waste Amendments of 1984.

This section also requires EPA to develop regulations to prohibit land disposal of liquids absorbed in materials which biodegrade or release liquids when compressed, as might occur during routine landfill operations. To ascertain structural stability of sorbents, proposed EPA regulations may require that a 50 pounds per square inch pressure test be used to determine if a product can be landfilled or not.

Furthermore, both solid and hazardous waste landfill space is becoming scarce throughout the United States and finding a landfill willing and able to accept large quantities of oil-contaminated sorbents may become increasingly difficult. Wastes generated by another community or state are meeting increasing resistance and public outcry from the communities and states in which disposal facilities are located.

Because it eliminates the need for costly transportation and minimizes disposal fees for oiled sorbents and debris, on-site incineration might be a practical and efficient method of disposal, especially in remote locations. For successful incineration, the sorbent should not contain too much water. The amount of ash that will be generated by the oil and sorbent package is also a concern and may preclude the burning of some organic sorbents. The fumes from some synthetic sorbents may be toxic, so additional information should be obtained on these products before incineration. Pursuant to air quality regulations, state and Federal approval would have to be obtained before incineration operations can be initiated.

ENVIRONMENT CANADA TESTS

The reports on the four series of tests performed on 45 sorbents by Environment Canada between 1974 and 1985 provide the most complete and comprehensive evaluation of commercially available sorbents and lay the groundwork for a quantitative basis of comparison (Environment Canada 1976, 1978, 1983, 1985).

One important outcome of the Canadian tests was the development of an alternative measure of sorbent effectiveness, referred to as "sorption capacity" which is composed of three quantitative parameters. Initial Capacity (g of test liquid/g of sorbent) is the amount of test liquid picked up by a sorbent on initial exposure to a particular test liquid. Maximum Capacity (g of test liquid/g of sorbent) refers to the maximum amount of test liquid picked up by a sorbent either on initial exposure to a particular test liquid or in subsequent reuse trials. Water Pickup (g of water/g of sorbent), is the weight of water picked up by a sorbent during a given test. A 48 hour immersion test to measure a sorbent's ability to stay afloat was also performed.

To simulate realistic conditions, diesel, crude and Bunker "C" oils were weathered for periods of one day and seven days. However, in presenting the results of the studies, Environment Canada made the caveat that laboratory and simulated field tests cannot cover the range of environmental circumstances during an actual oil spill. It should be cautioned that the data from the four test series are not always comparable since protocols varied. As evidence of the trend emphasizing sorbent effectiveness with regard to hazardous substance spills, tests using toluene and cyclohexane were performed in the 1985 tests (Environment Canada 1985). A fifth study in the series is planned by Environment Canada.

RECENT EXPERIENCE WITH SORBENTS

A recent article in "Hazmat World" (Fahys 1989) highlighted several sorbent products that were used in cleaning up the shoreline around Prince William Sound. The organic sorbent, peat moss, was found to be effective in the early days of the cleanup for soaking up oil on rocky beach areas used by seals for pupping. While the material prevented oil from leaching beneath the beach surface and protected wildlife, it was less helpful on weathered oil in later applications. According to the article, one such problem arose when the oil-soaked peat hardened and sank.

The article also noted that oleophilic, synthetic pompons were used successfully for picking up stray oil in the waters off the coast of the Olympic Peninsula in Washington State last year. Made out of the same plastic used to coat telephone wires, the pompons consisted of thin stands bound together with a wire puff and strung into a chain.

The "Hazmat World" (Fahys 1989) article also reported that the use of geotextile bags filled with absorbents was being proposed by the state of Alaska for treatment of Valdez oiled beach sediments. The bags would be tied to the beach, where wave action would drive contact with the sediments. The sediments would become trapped in the sorbents and the bags would then be recovered and discarded.

EMERGING TECHNOLOGIES

One emerging sorbent technology is a polymer absorbent sold under the name of OIL SOLIDIFIER. Manufactured by Liquid Waste Technologies, the active ingredient of the product is polynorbornene developed by a French company, Cdf Chimie, and sold under the name of NORSOREX AP. Consistent with the requirements of Subpart H of the National Contingency Plan (NCP), Liquid Waste Technologies submitted data to the EPA Emergency Response Division (ERD) and the product called OIL BOND-100 was listed on the NCP Product Schedule in the miscellaneous category in 1986. Recently, the particulate form of OIL SOLIDIFIER was added to the Schedule as an "also known as" for OIL BOND-100. The EPA ERD is reluctant to set the precedent of listing products such as sorbent booms and pads. A major consideration in this decision would be the requirement that products on the Schedule are governed by the authorization of use procedures in Subpart H. There are a great many sorbents, booms, and other products that are used literally every day that are not listed on the NCP Product schedule.

An alternative to dispersants, OIL SOLIDIFIER is an absorbent and plasticizer. The oil is initially absorbed into the product and then plasticized into hard chunks of rubber. Once the oil is absorbed it will not leach back into the water column. Solidifiers immobilize the oil and keep it out of the water column.

The manufacturer asserts that the particulate form of OIL SOLIDIFIER will work effectively on calm water spills. Effectiveness is enhanced in rough waters. The products can be applied around the outer edges of the spill initially to start solidifying the oil and impeding its spread by manual, blowers, or high pressure water methods. If rough waters prevent the pick up of the solidified oil, it will not leach oil to the water column and will remain floating until such time as weather conditions permit its retrieval. Solidifier products are nontoxic, nonbiodegradable and hydrophobic. They do not mix into the water column.

According to Liquid Waste Technologies (pers. comm. 1989), OIL SOLIDIFIER booms are available in 5 inch and 2.25 inch diameters which can be used to line both sides of a containment boom to absorb oil and prevent entrainment. The booms are also recommended for use as containment booms for small spills in calm or very slow moving water.

In the information provided to EPA's ERD, oil viscosity affects the amount of oil that an OIL SOLIDIFIER boom or pillow can absorb, and temperature also has a bearing on the rate of absorption. Liquid Waste Technologies asserts that 4 feet of a 2.25 inch diameter boom can pick up 1 gallon of diesel fuel, and a 10 foot length of the 5-inch boom can sorb 8 gallons of diesel fuel. A one-foot square pillow can take up one gallon of diesel fuel.

Solidified oil after it is collected can be landfilled. It will not release the oil at pressures exceeding 50 psi. Solidified oil can also be incinerated or ground up and used as fuel for boilers in the wood pulp or other industries.

According to EPA's researchers in Cincinnati, the product OIL BOND-LOQ is under active consideration for use in an in-situ removal process for PCBs and hydrocarbon based pollutants found in sediments in rivers, harbors, and industrial lagoons. OIL BOND-100 performed well in laboratory scale tests, sorbing up to 10 times its weight in these pollutants.

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Mr. Don Smith currently serves as the EPA Region VI On-Scene Coordinator, a position he has held for five years and specializes in oil spill response and contingency planning. Mr. Smith is a graduate of the University of Texas.

Ms. Julie Jordan is currently employed as a specialist for intergovernmental relations relative to environmental policy for Scientex Corporation, Rockville, Maryland. Scientex is under contract to the EPA ERD to provide technology and policy support regarding oil and hazardous material spills. Ms. Jordan has a Masters degree in Public Administration from the University of Colorado.

Mr. Thomas Spargo is a member of the EPA Region VI Technical Assistance Team for oil and hazardous material emergency response. Mr. Spargo is based in Houston, Texas and is employed by Ecology and Environment, Inc. of Buffalo, New York. Mr. Spargo has a Masters degree in chemical engineering from Washington University (St. Louis) and a Bachelors degree in chemical engineering from Purdue University.

FIELD TESTS OF SATELLITE-TRACKED SURFACE DRIFTING BUOYS FOR SIMULATION OIL SPILL TRAJECTORIES

Dr. Mark Reed
Applied Science Associates, Inc.

The experimental oil spill and associated analyses described here represent the second phase (field portion) of a three phase program. Phase I was a theoretical review of surface drifting buoys (Reed et al. 1988), and resulted in a ranking of candidate drifters for their ability to track oil slicks. Phase II involved field testing the two toprated buoys recommended as a result of Phase I, a disk and a sphere. The final goal of this program will involve the acquisition and deployment of large numbers of drifting buoys in the various Outer Continental Shelf Planning Areas. The trajectories of these buoys can then be used as measures of potential oil spill trajectories, and as test data for trajectory models.

Phase II focused on three objectives:

1. field test the selected buoys during a planned oil spill, and evaluate their performance relative to slick movement;

2. during the field test, measure physical forces moving the oil and the drifters;

3. based on detailed analysis of drifter and oil motions and forcing functions, make appropriate recommendations to Minerals Management Service, potentially including design modifications to improve drifter performance.

The experiment took place in late June/early July 1989 on Haltenbanken, about 150 km from the Norwegian coast (Figure 3.2). The primary objectives of the experiment were to identify which surface drifting buoy configuration(s) best simulate the drift of crude oil on the sea surface under a variety of real environmental conditions, and to develop reliable mathematical transfer functions from buoy to oil to assist in the future interpretation of buoy trajectories.

Specific components of the experiment included:

- a spill of 30 tonnes of crude oil;
- deployment of 11 copies of two satellite-tracked surface drifting buoys;
- a meteorological buoy recording residual current at 3 m depth, wave period and height, wind velocity, air and sea surface temperatures, and air pressure;
- a wave-riding buoy recording wave height, direction, and period;
- an acoustic surface velocity profiler;
- airplane overflights with vertical photographic, ultraviolet, infrared, and side-looking airborne radar sensing;
- a moored current string with acoustic meters at 3, 10, and 20 m below the surface;
- time series of oil properties (density, viscosity, evaporation/ composition, water content);
- a horizontal array of satellite-tracked flooded volume Stokes drifters to produce a record of the mean surface current field;
- three hydrographic surveys (before, during, and at the end of the test) recording salinity, temperature, density and acoustic doppler current profiler measurements.

The results of these various components will be used to achieve project objectives as outlined in Figure 3.3. Here the statistical and engineering modeling components represent the key analytical steps in the process. The data analysis is currently in progress.

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Dr. Mark Reed is the operations manager and senior scientist with Applied Science Associates, Inc. in Narragansett, Rhode Island. His research interests are in the area of fates and effects of pollutants in marine and freshwater systems.

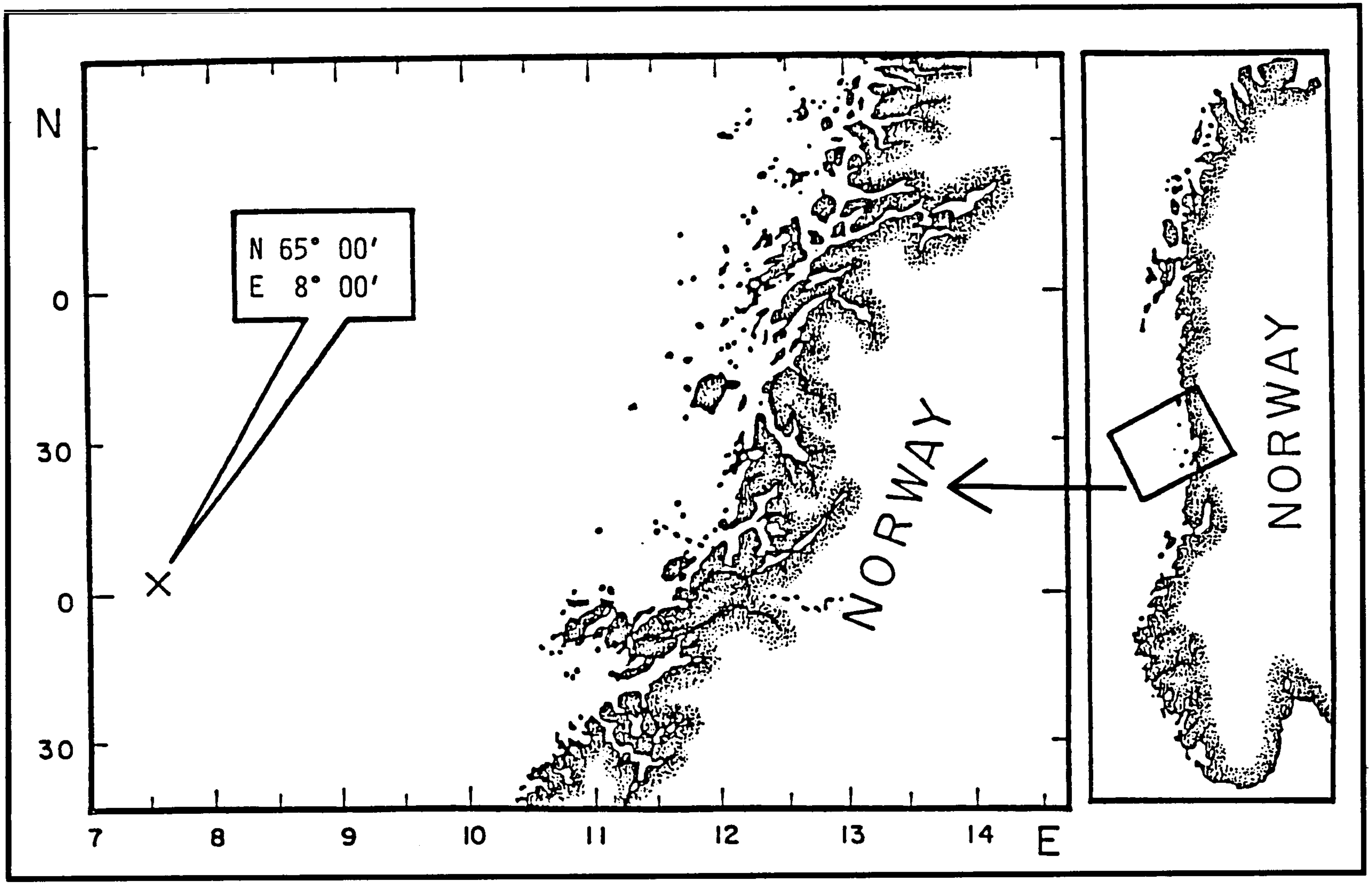

Figure 3.2. Map showing the geographical location of the experimental oil spill on Haltenbanken.

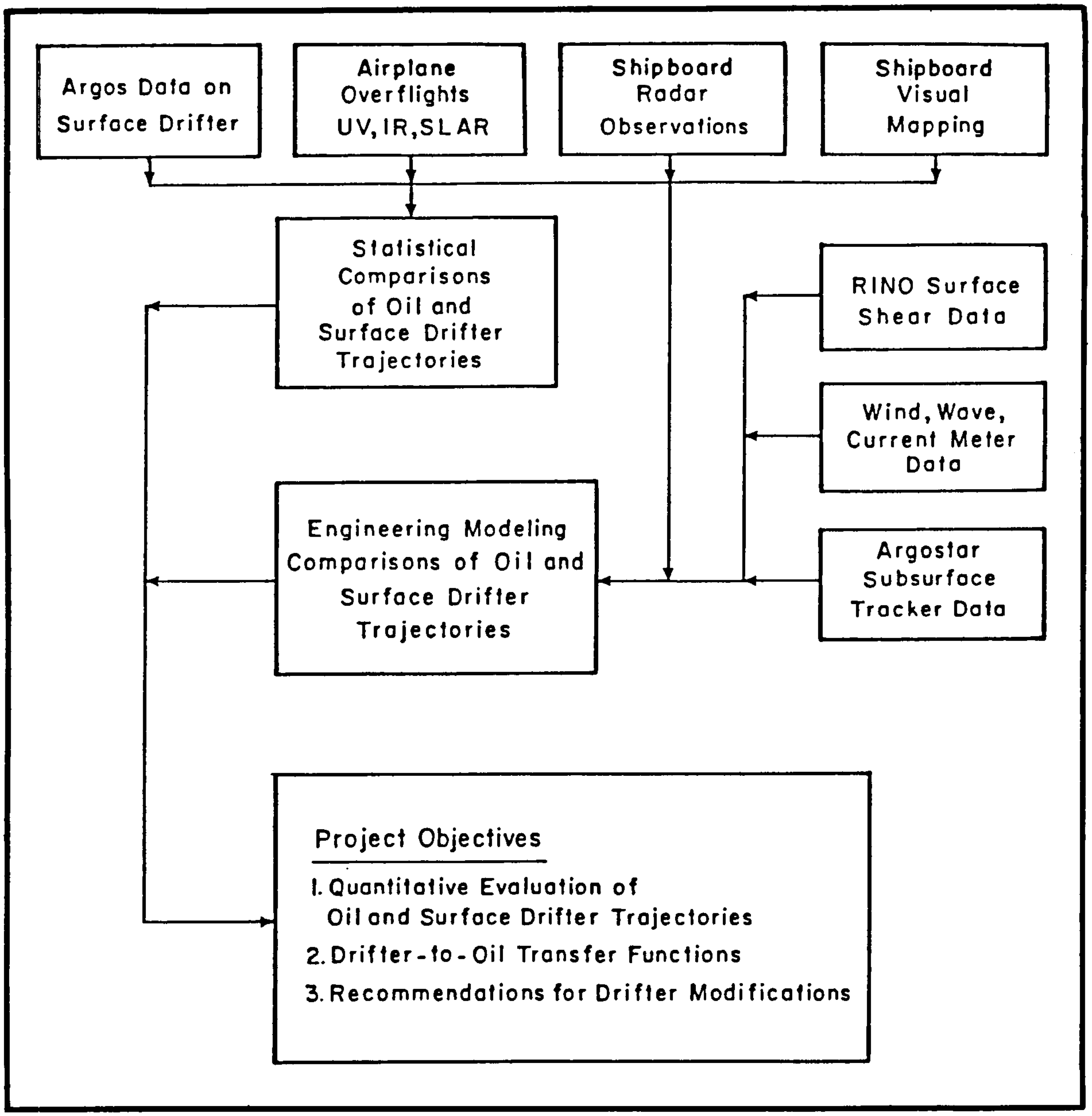

Figure 3.3. How data results will be used to achieve project objectives.

REAL-TIME TRAJECTORY MODELING OF A SPILL EVENT

Dr. Jerry Galt
National Oceanographic
Atmospheric Administration

Presentation Summary
Text Not Available

Dr. Jerry Galt

THE PETROLEUM INDUSTRY RESPONSE ORGANIZATION (PIRO)

Vice Admiral John D. Costello
PIRO Implementation, Inc.

BACKGROUND

In its report of June 14, 1989, the American Petroleum Institutes's Oil Spill Task Force recognized the nation's oil spill problem and recommended initiatives - both legislative and from private industry - to prevent and remove catastrophic oil spills and to conduct spill-related research. The focus of the report was the 30,000 ton, open ocean spill. Major report recommendation areas included:

- improvement to the tanker movement system external to the ship;
- changes relating to tanker personnel;
- changes relating to tanker design and construction;
- establishment of an industry response organization - PIRO; and
- development of an aggressive oil spill research and development program.

The Petroleum Industry Response Organization (PIRO) will be concerned with only the last two of the Task Force's recommendations.

In a real sense the "R" in PIRO captures our missions; Readiness, Response, and Research and Development (R&D) are at the heart of what PIRO will eventually become. At this time these missions cannot be finally described because oil spill legislation presently before Congress is likely to affect their final scope. Until that legislation is law, the definitive nature of PIRO's activities in each of these missions must remain incompletely resolved. However, irrespective of the outcome of those deliberations, we believe it is safe to assume that these three "Rs" will be part of the final program.

The 5-year implementation cost for PIRO was originally estimated to be 250 million dollars, however, this cost has recently been expanded to 450-500 million dollars. This would create a system with 5 Regional Response Centers and 18-22 sites for prepositioned materials. A small headquarters in Washington, D.C. is included in the organization.

PIRO MISSIONS

Readiness

Readiness is the most fundamental of the three "Rs" and must be first addressed in planning. Pending Federal oil spill legislation mandates preapproved contingency plans before vessels and facilities can handle oil. The requirement for oil spill prevention and control contingency plans will enhance the nation's ability to effectively deal with oil spills. Unlike today these plans will not be "paper tigers." Likely legislation will mandate that those transporting or handling oil over water must have a pre-approved plan that deals with a worst case spill scenario and must show satisfactory evidence that a ready capability exists to carry out that plan should the need arise. All plans will be approved by the Federal Government. The process of plan development will insure that all aspects of spill prevention, containment, mitigation, recovery, and disposal are covered. Before the fact, tough questions like whether or not to use dispersants; how/where recovered oil will be disposed of, etc. should be resolved. The critical time right after a spill occurs will not be lost in getting decisions. Approved plans will have been coordinated with environmental groups, local, state and Federal agencies.

Readiness means more than better planning however. Of equal importance, people will be available and trained to combat a spill. It is expected that pending legislation will require this. It is in this response readiness arena that PIRO sees one of its important roles: the maintenance of a continuing relationship with oil spill cooperatives and contractors as a leader, trainer, and auditor of operational performance.

Response

In spite of even the best of efforts, spills will occur. Therefore, response is the heart of PIRO. A tiered concept of operational forces is central to the PIRO approach. The first line of defense listed in contingency plans will be company resources or local cooperatives and/or contractors. Should these prove inadequate, PIRO regional assets listed in the contingency plan would respond. If more resources are needed, other PIRO regions would be tasked from our headquarters. Importantly, PIRO looks for the Federal Government to play the critical leadership role in directing, overseeing, and managing response and cleanup efforts. An important point to underscore is that PIRO will not compete with contractors and cooperatives. Its role will be to assist them when the task at hand exceeds their capabilities and responding to federal directions during a spill.

Research and Development

It is no secret that today, even with the best equipment and trained personnel our present knowledge and technology is not sufficient to insure oil will not reach our shorelines.

Technological innovation and equipment improvements need to be made. A commitment to increased R&D is important but it is not the entire answer. The full answer lies not only in more - but in a coordinated R&D program. Industry, federal agencies, and academia must join together and channel scarce R&D dollars and talent into the most promising projects. One of PIRO's important responsibilities lies in being part of such a program. The American Petroleum Institute's (API's) report identified a comprehensive 30-35 million dollars five year R. & D program for PIRO. Some categories making up such a program are:

- prevention of oil loss from/away from ships;
- on-water oil recovery and treatment;
- prevention and mitigation of shoreline impact;
- oil-in-water fate and effects research;
- wildlife research; and
- worker health and safety.

CURRENT STATUS

Establishing PIRO in a timely fashion will be a challenge. Since the publishing of the API Report in June, 1989, approximately 75 oil industry experts (divided into 8 subcommittees) have been working on a comprehensive requirements analysis for PIRO. For example, we are looking at state-of-the-art spill response, containment, and removal equipment designed and constructed to meet offshore conditions. This includes lightering pumps, fenders, and dracones; offshore and medium booms; skimmers, powerpacks, and skimming barriers; dispersant equipment and miscellaneous support, command, control, and communications gear. All of this will be air transportable, yet rugged. Much of what is needed for a national system is not immediately available. Some will have to be custom manufactured. The original capital cost estimate for outfitting a regional center was 14.7 million dollars.

In September, 1989, PIRO Implementation, Inc. was formed as a transitional entity, to develop specific implementation plans for a permanent, not for profit corporation, called the PIRO. We at PIRO are presently engaged in melding the work of these subcommittees into a cohesive action plan needed to create PIRO. We hope to have an initial operational capability 12 months after oil spill legislation becomes law and the full system operational 12 months thereafter.

Vice Admiral John D. Costello is currently serving as the President of PIRO Implementation, Inc. He is a 36-year veteran of the U.S. Coast Guard. His last assignment was Commander of the U.S. Coast Guard's Pacific Area. Vice Admiral Costello has also served as the Secretary of Transportation's Emergency Transportation Coordinator for Federal Region IX with responsibilities for the coordination of Federal transportation activities in peace and wartime emergencies, and as the Commander, U.S. Maritime Defense Zone Pacific also known as Task Force 16, under the Commander In Chief, U.S. Pacific Fleet. Major awards include a Coast Guard Meritorious Service Medal, four

Legion of Merit medals, and the Distinguished Service Medal. Vice Admiral Costello is a graduate of the U.S. Coast Guard Academy, the Naval Post Graduate School, where he was a distinguished graduate in management, and George Washington University, where he earned a Masters degree in government.

STATE OF FLORIDA - DISPOSAL OPTIONS FOR RECOVERED OIL AND OILED DEBRIS

Mr. John K. Gentry
and
Mr. Greg Lee
Florida Department of
Environmental Regulation

The purpose of this discussion is to review the disposal options that the Florida Department of Environmental Regulation (DER) has identified for the recovered oil and oil contaminated debris that would be generated by the cleanup of a petroleum spill in Florida's coastal waters.

It is the intent of the DER, to identify the range of disposal options that are available, list the facilities that can provide these services, and to provide case-by-case technical assistance in selecting the options most suitable for the nature and volume of the recovered material.

Before detailing preferred disposal options it is necessary to discuss the issue of land disposal of pollutants. Florida has no permitted land disposal facilities designed to accommodate hazardous waste or significant petroleum contaminated residues. The hydrogeology over most of the state is such that valuable ground-water resources would be at risk from land disposal of pollutants.

It has been suggested that the DER should predesignate locations in the state where these contaminated materials could be taken to be landfilled or landfarmed. We do not believe that this is the correct approach for several reasons. First, pollutants should be dealt with as near the source as possible. This minimizes the chance of additional accidental spills and it reduces transportation costs. Unless a large number of disposal sites were identified throughout the state, transportation costs could be enormous. Second, and more importantly, in the hierarchy of waste management options that the DER has established, land disposal of any pollutant is the least attractive option. Even in a secure location, the contaminants in landfills will have to be managed and monitored for a long period.

The DER proposes that residue from coastal cleanups be staged in the contaminated area on synthetic flexible membrane liner material until disposal occurs. In most cases, thermal destruction of the residue will be the most cost effective option. Options for thermal treatment fall into three categories:

- municipal solid waste combustors;
- stationary thermal treatment facilities; and
- mobile incinerators.

Which of these facilities or combination of these facilities to use will depend on the following factors:

- where the release occurred;
- what was spilled;
- how much came ashore;
- what type of coastal environment was affected; and
- what type of residue must be disposed of and how contaminated the material is.

The following guidelines are recommended:

- Heavily contaminated residue such as sorbent pads, seaweed, and debris should go to solid waste combustors. With operating temperatures approaching 1800 °F, these facilities can blend the residue in with the solid waste and effectively destroy it. As a side benefit, most of these facilities recover energy in the form of steam or electricity so that some resource recovery is accomplished in the process. These facilities cannot, however, handle residue containing a great deal of sand or soil. Fine grained materials would fall through the grates in the burner and generally be hard on machinery at the plant.

- Contaminated soils should be disposed of at one of the thermal treatment facilities located in the state. These facilities are either rotary kilns or asphalt dryers and are designed to process fine grained materials. Depending on their intended primary use such as cement production, clay processing, or asphalt drying, they operate at varying temperatures and have different throughput capacities. The choice of which to use will depend on location, how contaminated the soils are, and the capacity of the facility. Soils heavily contaminated with heavy petroleum such as bunker C should go to treatment facilities with higher operating temperatures. Once the soil is treated to the standards established by DER it can be sold as clean fill.

If a spill were to occur in a remote area, bringing in a mobile incinerator might be the most cost effective option. DER has permitted three such units on a statewide basis. The choice would once again depend on location, what type of cleanup residue was present, and how much of it there was. An advantage with this method is that treated soils could be replaced in the once contaminated area.

A final option to be considered would be to use lightly contaminated sand as daily cover material for one of the lined landfills in the area. This option would be at the discretion of the operator and would require some review by the DER staff before it could be implemented.

In summary, the most cost effective and environmentally sound disposal option for the residue from a spill is highly dependent on a number of factors. Rather than pursuing the designation of landfill disposal areas for the material, the DER has identified thermal treatment as the most likely means of disposal. Lists of these facilities are available from the DER. When the need arises, DER staff can provide case-by-case assistance to determine what option or combination of options should be employed.

The DER maintains the following specific information to assist in determining the available options of disposal:

- "Guidelines for the Assessment and Remediation of Petroleum Contaminated Soil";

- a list of permitted heat treatment facilities in Florida including mobile incinerators;

- A complete directory of solid waste facilities in the state by county (includes mass burn and refuse energy facilities);

- a list of permitted hazardous waste storage/treatment facilities in Florida;

- a list of hazardous waste transporters; in Florida demonstrating the required financial responsibility; and

- a list of commercial facilities nationally by treatment method.

Mr. John K. Gentry is a P.E. with 18 years experience in water supply, groundwater resource evaluation, and environmental protection. Mr. Gentry has a degree in water resources engineering from the University of South Florida and his work experience includes consulting, municipal engineering, and environmental regulation. Mr. Gentry is presently the Deputy Director of the Division of Waste Management at the Florida DER.

Mr. Greg Lee is the Environmental Administrator of the Emergency Response Section of the Florida DER. Mr. Lee has been in this position since 1984 and has been a state representative on the Regional Response Team since 1982. Mr. Lee has a degree in biology from Florida State University.

LOUISIANA STATE REGULATIONS GOVERNING DISPOSAL OF RECOVERED OIL AND OILED DEBRIS

Mr. R. Bruce Hammatt
Louisiana Department of
Environmental Quality

Louisiana' s economy is based to a large degree upon the production and transportation of crude oil and petroleum products. Since Louisiana is one of the nation's leading producers of petroleum, with extensive maritime and pipeline transportation of both crude and refined products, the State is vulnerable to significant and numerous oil spills.

The Louisiana Department of Environmental Quality (DEQ) is the lead agency in the state responsible for environmental protection, regulation, and planning and will, therefore, assume the lead role for the proper cleanup and mitigation from crude oil spills within the state.

Louisiana's primary concern is to minimize the potential for these spill events; however, it is recognized that with the best of planning and prevention, spills are going to continue to occur. A coordinated effort will be needed to properly handle the recovered oils and waste debris resulting from these spill events. The DEQ encourages that as much of the spilled material as possible be recovered for processing or recycling to a useable product.

The materials collected in a crude oil cleanup operation such as the oil itself, any oiled vegetation, absorbent pads, etc., are considered as Nonhazardous Oilfield Waste (NOW) under Statewide Order No. 29-B. Nonhazardous oilfield waste is not currently regulated by the provisions of the Louisiana Hazardous Waste Regulations, but falls under the jurisdiction of the Department of Natural Resources (DNR). The generator of the NOW is responsible for the proper handling and transportation of the wastes to an approved commercial facility.

Several commercial facilities within the state can accept NOW collected in crude oil spill cleanup operations. These sites operate under permits issued by the Office of Conservation which is within the DNR. Questions regarding Statewide Order No. 29-B and the proper disposal of NOW materials should be addressed to the Office of Conservation at (504) 342-5440.

There are instances where it would not be possible nor prudent to collect and transport wastes gathered during major oil spill cleanup efforts. Examples include spills occurring far from highway or navigable waterway systems, and cleanup operations along many of our coastal marsh regions.

In some cases, the cleanup operations may be more damaging to our natural resources than the wastes themselves. Waste hydrocarbons spilled from pipeline breaks or other transport failures which cannot practicably be recovered or disposed of, may be burned at the site where the spill occurred due to safety considerations, or a different location may be chosen.

Regulations pertaining to outdoor burning may be found in the state's Air Quality Regulations (LAC 33:III 1109). In general, burning must not be within or adjacent to a city or town or in such proximity as to affect the ambient air in the city or town. Burning must be conducted between the hours of 8:00 a.m. and 5:00 p.m., and prior approval to conduct these open burns must be obtained from the DEQ.

Cleanup activities will be closely monitored to avoid excessive disturbances of the environment including any affected vegetation. Burning of the oiled debris will probably be considered as an effective mitigating measure in our relatively inaccessible and highly sensitive coastal marshes.

The DEQ should be contacted by the persons responsible for the spill by using the Department's 24-hour notification number (504) 342-1234. All spills and the resultant cleanup activities appropriate for each incident will be handled on a case-by-case basis.

Mr. R. Bruce Hammatt is the Louisiana Member of the Federal Region VI Regional Response Team. He is currently the department-wide Emergency Response Coordinator in the Office of the Secretary. He worked for the Water Pollution Control Division for 10 years as the Emergency Response Coordinator for that Division dealing with all aspects of oil and hazardous materials releases prior to his current assignment. Mr. Hammatt received his B.S. and M.S. degrees from Louisiana State University with primary courses in wildlife management and chemistry.

ALABAMA'S REGULATIONS GOVERNING THE DISPOSAL OF RECOVERED OIL AND OILED DEBRIS

Mr. John C. Carlton
Alabama Department of
Environmental Management

The Alabama Department of Environmental Management (the Department) is the state agency within Alabama responsible for implementing the various environmental regulatory programs and, as such, has the responsibility of responding to environmental incidents. The Department's role in oil spill response varies somewhat depending on the location of the event, but generally entails coordination of the state's resources to insure environmental impacts are minimized and mitigated. This may be as involved as: first response to scene; deployment of containment booms; identification of a responsible party; coordination and monitoring of cleanup; enforcement action; or, as uninvolved as remaining on stand-by.

Recovered oil disposal is generally left up to the responsible party or cleanup contractor, subject to the Department's approval. Recycling or use as a fuel is strongly encouraged.

The Department closely monitors the disposal of oiled debris. Although there are no specific regulations for oiled debris, it is considered a solid waste and subject to the Department's Division 13 regulations. Fortunately most spills which occur in Alabama have been small and have resulted in small quantities (<10 yds.) of contaminated debris, soil, and sorbents. These small quantities are routed to the closest permitted facility which has a groundwater monitoring system and must be, bladeable with no free oil. There are six sites within the two coastal counties (Mobile and Baldwin) which meet the Department's requirements to receive oiled debris. The operators of these facilities do retain the right to refuse the material, but to date this has not presented a problem. Disposal charges (tipping fees) average approximately \$10/ton. Transportation cost is unavailable.

In a catastrophic event which would result in large quantities of debris, the Department, under Rule 13.4.21(b), would permit burning of debris at permitted facilities and/or special areas. These activities are coordinated with the Department's Air Division and other appropriate state and local agencies. This practice will undoubtedly increase in light of the fact that many of the permitted facilities are reaching capacity and the new siting and construction requirements are expected to result in a substantial increase in disposal charges.

Both disposal and burning are handled on a case-by-case basis and require reasonable assurance that the material is nonhazardous as defined by the Department's Division 14 regulations. At this time, there are no pre-approved disposal/burn sites.

Mr. John C. Carlton is Chief of the Alabama Department of Environmental Management's Mobile Field Office where he has served in that capacity for 10 years. He has a B.S. degree in marine biology from the University of South Alabama, Mobile. Mr. Carlton's experience spans a period of 12 years and includes water quality studies and spill response.

MISSISSIPPI'S REGULATIONS GOVERNING THE DISPOSAL OF RECOVERED OIL AND OILED DEBRIS

Mr. Richard Ball
Mississippi Department of
Environmental Quality

Recovered oil and oiled debris is classified as nonhazardous waste. Mississippi requests that all oil recovered, that can be processed, be processed.

Oiled debris associated with the clean-up of a crude oil spill may be disposed according to Mississippi Solid Waste Regulations with stipulations. These stipulations will be developed on a case-by-case basis.

At present, no facility in Mississippi is designed for the disposal of a large volume of oiled debris. Mississippi's permitted solid waste disposal facilities are designed for the disposal of household waste.

With approval by the Bureau, oiled debris may be taken to these facilities. When a disaster occurs, and results in the urgent need for a solid waste disposal facility, the Bureau may approve a site for immediate operation, subject to stipulated conditions, and for a limited period of time.

Open burning of solid waste shall be prohibited.

Further questions should be directed to Mr. Richard Ball, Emergency Response and

Transportation Division, of the Department of Environmental Quality at (601) 961-5171.

Mr. Richard Ball has served as an on-scene coordinator in the State of Mississippi's Emergency Services and Transportation Division of the Department of Environmental Quality since 1984. Mr. Ball has responded to over 400 oil and chemical spills from the Gulf of Mexico to the Tennessee State line. Mr. Ball received a B.S. degree in marine biology from the University of South Alabama in 1983.

TEXAS STATE REGULATIONS GOVERNING THE DISPOSAL OF RECOVERED OIL AND OILED DEBRIS

Mr. David Barker
Texas Water Commission

During an emergency situation involving a discharge or spill, the Texas Water Commission (TWC) responsibilities, as outlined in the *State of Texas Oil and Hazardous Substances Spill Contingency Plan* (GP 88-01) and the *Texas Hazardous Substances Spill Prevention and Control Act* (Chapter 26, Subchapter G, *Texas Water Code*), include the approval of the spill cleanup, restoration of the spill site, and disposal of spill waste. Any temporary storage area for recovered materials shall also be approved prior to use. On a limited basis, these responsibilities are shared with or delegated to the Texas Department of Health - Bureau of Radiation Control (TDH) as they relate to spills of radioactive materials. These responsibilities may also be shared with or delegated to the Railroad Commission of Texas (RRC) as they relate to spills of crude oil: (a) from a pipeline in the state; (b) a truck on an oil or gas lease; (c) into coastal waters from a transportation-related storage facility in the state; or, (d) a well, rig, platform, storage tank, or other nontransportation-related facility in the state associated with the exploration, development, or production of oil and gas.

The TWC does not consider spill materials that are recovered in a form suitable for reprocessing, recycling, or other beneficial uses to be waste. Viable options for dealing with oil and/or certain liquid recoverables may include separation, refining, and marketing as fuels. Additionally, depending on the specific spill site or circumstances, some solids may have a beneficial use. The State of Texas has made allowances for the placement of lightly oiled sand from spill cleanups at the foot of dunes for dune stabilization in certain dune-blowout areas as well as placement in temporary disposal sites on the barrier islands in an effort to minimize sand loss from the Texas Coastline.

Spill waste is generally not managed in the same way as other solid wastes covered under the *Texas Solid Waste Disposal Act* (Article 4477-7, *Vernon's Texas Civil Statutes*). Under Texas law, the TDH regulates nonhazardous municipal solid waste and the TWC regulates hazardous and industrial solid waste. It is neither necessary nor appropriate to attempt to categorize spill waste as municipal or industrial for purposes of determining jurisdiction. However, all spill cleanup waste is subject to the requirements of a hazardous waste determination. This determination should be made by the person responsible for causing or allowing the spill since the spill event and the subsequent TWC-directed cleanup will, in effect, cause that person to assume waste generator status. In most instances, oiled debris will be classified as nonhazardous.

Four possible options exist regarding the use of state-permitted or regulated disposal sites. These are:

1. TDH-permitted sanitary landfills;
2. TWC-permitted commercial disposal sites;
3. TWC-registered noncommercial disposal sites; and,
4. RRC-permitted disposal wells or pits.

If the waste is determined to be hazardous, a TWC- or RCR-permitted site is the only option. Waste generator identification numbers and waste codes are then issued by the TWC for waste tracking and data management purposes.

If the waste is determined to be nonhazardous, all of the aforementioned disposal options may be available.

Figure 3.4 depicts the waste classification systems used by the TWC and the TDH. Class

I wastes require the manifesting of any waste shipments. Wastes classified as special wastes are not manifested to TDH disposal sites. In considering the use of a TDH-permitted sanitary landfill for disposal of spill waste, the waste should not have the potential to adversely affect the liner material, commingling with putrescible wastes should be safe, and the waste should be essentially insoluble. For oil-contaminated soils, disposal in a TDH-permitted site as a special waste is possible if the soil: (a) is not saturated; (b) has low levels of BTEX (benzene, toluene, ethylbenzene, and xylene) and TPH (total petroleum hydrocarbons); and (c) does not contain hazardous levels of metals. Soils contaminated with used motor oil should also be tested for organic chlorine since it will be considered a hazardous waste if the chlorine concentration exceeds 1000 parts per million (ppm). Soils should not exceed the following test values for disposal at TDH-regulated sites:

Parameter	Value
TPH	< 1000 ppm
BTEX	< 500 ppm
Total organic halogens (TOX)	< 100 ppm
Total metals	< 500 ppm
EPToxic (EPTOX) - Lead	< 2.5 ppm
Toxicity Characteristic Leaching Procedure (TCLP) - Lead	< 5.0 ppm

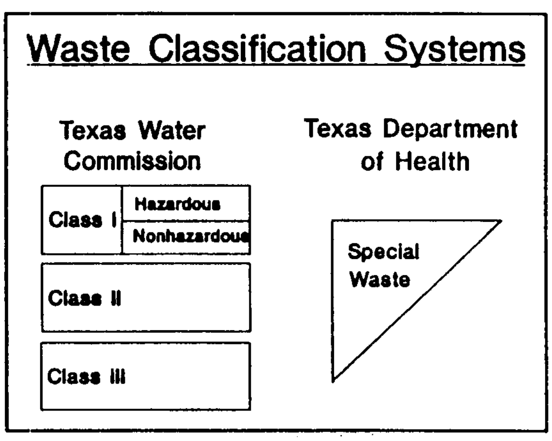

Figure 3.4. Waste classification.

Approval of arrangements for spill waste disposal at TDH-regulated sites is documented in writing by a letter from the TWC to the TDH.

Disposal arrangements utilizing any of the options listed in this abstract are approved on a spill-by-spill basis. Information on permitted disposal sites is available through the TWC. For assistance in the disposal of spill waste, the person responsible for the spill should contact the appropriate TWC Field Office or the TWC Emergency Response Unit at (512)463-7727.

Mr. David Barker is the Texas member of the Federal Region VI Regional Response Team. He is the supervisor of the Emergency Response Unit of the TWC and has been involved with Texas' spill response program for over 18 years. Mr. Barker was instrumental in developing the *State of Texas Oil and Hazardous Substances Spill Contingency Plan* as well as *Coastal and Inland Spill Response Map Series*, both of which have proven invaluable for deployment of spill response resources and the development of cleanup strategies. Mr. Barker received his B.S. and M.S. from Southwest Texas State University with major and minor courses in biology and chemistry, respectively.

CONTINGENCY PLANNING FOR EXPLORATION ACTIVITY

Mr. Jim O'Brien
O'Brien's Oil Pollution Service
and
Dr. Bela M. James
Continental Shelf Associates, Inc.

Prior to early 1988, Federal rules governing oil and gas operations on the Outer Continental Shelf (OCS) were contained in OCS Orders, Notice to Lessees, and related documents. On April 1, 1989, rules of the Offshore Program of the Minerals Management Service (MMS) that govern oil, gas, and sulphur exploration, development, and production operations in the OCS were presented in the Federal Register (Vol. 53, No. 63, pp. 10596-10776) and codified in 30 CFR Parts 250 and 256. Regulations governing the Oil Spill Contingency Plan

(OSCP) are found in 30 CFR 250.41-43. The MMS Gulf of Mexico OCS Region, in a Letter to Lessees (LTL) dated February 1, 1989, presented guidelines for the content and format of regional and site specific OSCP's. Following the March 24, 1989, oil spill of the Exxon Valdez, both industry and regulatory agencies have increased their scrutiny and requirements for OSCP's. The present-day trend of the regulatory agencies, with respect to Site Specific OSCP's, is to have the operator prepare an almost stand-alone document.

Table 3.1 summarizes the general content of a Site Specific OSCP. The topics are presented in the order that they occur in 30 CFR 250.42, and they follow the sequence suggested in the February 1, 1989, LTL. The Introduction should describe the function of the document, present the location of the drilling activity, and discuss the type of prospect (oil and/or gas) and the probabilities of encountering various API gravities of liquid hydrocarbons. Following the outline, the next section should discuss in detail the risk of spilling liquid hydrocarbons from refueling operations as well as from a blowout. In addition the section must summarize the results of trajectory analyses and address the general response strategies necessary to mitigate oil reaching the identified environmentally sensitive areas. The results of trajectory analyses may be taken from Environmental Impact Statements or other public documents; however, affected states may require additional trajectory information. The general response strategy should address the following topics: (1) spill discovery; (2) spill evaluation; (3) containment and countermeasures; (4) recovery, mitigation, and disposal; (5) cleaning and repositioning of equipment; (6) documentation. Section 3.0 of the outline requires the operator to present in detail the initial response equipment that can be utilized in the event of a spill, and the operator is also required to present operational response scenarios for single incident spills (fuel) and a continuous (blowout) spill. Response times for equipment and personnel are to be calculated according to the guidelines of the September 5, 1989, LTL. Information on the remaining sections of the outline are detailed in the February 1, 1989, LTL. In these latter sections, the operator should list the primary and secondary source of personnel and equipment (with phone numbers) for each activity. In all sections, it must be perfectly clear as to who has the responsibility to make the decision and to initiate the notifications and requests.

Mr. Jim O'Brien is currently president of O'Brien's Oil Pollution Service (OOPS, Inc.). Mr. O'Brien is a retired commander of the U.S. Coast Guard, Pacific Strike Team. Mr. O'Brien has been a technical response supervisor for over 100 major oil spills including the Exxon Valdez. Mr. O'Brien is principal author of the "MIRG Response and Logistics Directory" and has been technical consultant and author for over 30 Oil Spill Contingency Plans.

Dr. Bela M. James is currently a senior scientist with Continental Shelf Associates, Inc. Dr. James has 18 years experience with programs involving oil and hazardous wastes. He has authored over 25 oil spill contingency plans for locations within the Gulf of Mexico, the Santa Barbara Channel, and off the East Coast for 11 oil and gas companies.

"STATE-OF-THE-ART OIL SPILL RESPONSE EQUIPMENT"

Mr. Parag Gandhi
and
Mr. Mark Ploen
Ajat Shaw, Inc.

The purpose of this presentation is to illustrate progressive technologies regarding oil spill response equipment in the areas of aerial surveillance, containment, recovery, separation, storage/transportation, and shore-line remediation.

AERIAL SURVEILLANCE

Flexible documentation of all relevant information regarding oil spill tracking, qualifying, and quantifying is important in any oil spill recovery operation. Airborne surveillance systems utilizing side-looking radar, infrared and ultraviolet scanning systems, microwave radiometer, camera, data link, and flight logging information can provide much of the necessary information.

Table 3.1. Contents of a typical site specific oil spill contingency plan.

1.0	Introduction		
2.0	Risk of Oil Spills, Oil Spill Trajectory Analyses, and Response Strategies [30 CFR 250.42(a)]		
	2.1	Risk of Oil Spills	
	2.2	Summary of Oil Spill Trajectory Analyses	
	2.3	General Response Strategies	
3.0	Response Equipment and Response Strategies [30 CFR 250.42(b)]		
	3.1	Response to Oil on Open Water	
		3.1.2	Response Equipment at the Drillsite
		3.1.3	Response Equipment at the Shorebase
		3.1.4	Response Scenarios to Single Incident Spills
		3.1.7	Response Scenario to a Continuous (Blowout) Spill
	3.2	Response to Oil in the Coastal Zone	
4.0	Dispersant Use Plan [30 CFR 250.42(c)]		
5.0	Inspection and Maintenance of Equipment [30 CFR 250.42(d)]		
6.0	Detection and Notification of a Spill [30 CFR 250.42(e)]		
7.0	Local and Regional Inventory of Equipment and Services [30 CFR 250.42(f)]		
8.0	Logistical Response Actions [30 CFR 250.42(g)]		
	8.1	On-Site Personnel	
	8.2	Local Contractors	
	8.3	Company's Response Team Organization	
	8.4	Drills	
9.0	Provisions for Disposal of Oily Wastes [30 CFR 250.42(h)]		
10.0	Provisions for Monitoring and Predicting Spill Movement [30 CFR 250.42(i)}		
Appendices			

combating a spill. A typical system is capable of covering up to a 50 mile wide path regardless of most weather or light conditions.

CONTAINMENT

There are many different types of containment booms presently being manufactured. Generally they all fit into three basic categories: self inflating or rapid deployment booms, fixed flotation booms, and long term deployment booms. For rapid deployment, self inflating light weight booms provide the best means for quick, effective containment. These booms are constructed of light weight material with an inner spring device built into the buoyancy chambers of the boom. Upon deployment, the spring expands allowing the buoyancy chamber to fill with air, thus providing flotation. The advantages of this boom over others are quick deployment and recovery, light weight for ease of transport and excellent stowability.

These systems can also supply real time information vital to the decision process required in Fixed flotation booms are the most popular and widely used booms in the United States. In part, this is due to their moderate price and wide availability. There are numerous types of fixed flotation booms manufactured for a multitude of applications. Shoreline barrier booms are designed specifically for protecting the shoreline, fast water booms are designed to work in greater currents, and external tension booms are designed to maintain good performance while withstanding the pressure encountered in towing operations and river operations. For best results, the boom must be matched to the specific task and conditions.

For long term deployment, the larger inflatable booms constructed of heavy synthetic rubber and hypalon provide superior resistance to the elements. Typically, these booms range from four feet to seven feet in height. Due to their size and durability they can be deployed and are effective in rough seas.

RECOVERY

Over the years there have been many different types of skimmers available for recovering oil. The many different operating principles make it difficult to identify a skimmer ideally suited for a particular operation. However, extensive testing has shown that weir principle skimmers operating with a rotor to create a surface current and vortex to draw the oil into the pump drastically increase the efficiency of the skimmer. Although ideally suited for fresh or less viscous oil, these skimmers decrease in efficiency rapidly as the oil weathers and picks up debris. This creates an altogether different scenario in which a skimmer utilizing a screw pump equipped with cutters for handling debris would be more advantageous. Such skimmers incorporating a modified archimedean screw pump will devour sea weed, tin cans, drift wood, plastic bottles and a host of other items invariably encountered during recovery operations.

Another principle which has proven itself over the years is the belt skimmer. This method incorporates a belt much like a conveyor belt designed to carry the oil up out of the water where it can then be deposited into an onboard holding tank. A popular version of this skimmer came out of France in the wake of the Amoco Cadez spill of 1978. This was the first to combine the capabilities of a large holding capacity with built-in separation and a double screw pump for off loading oil incorporated with a paddle belt which could be operated in a stationery or advancing mode.

For larger response capabilities, a dedicated vessel should be utilized. The built-in rotary brush principle skimmer for weathered and debris laden oil and the weir principle skimmer for fresh, less viscous oils have proven to be the two most efficient systems available for a dedicated skimming vessel, particularly if side arm sweeps mounted alongside such vessels have been incorporated enabling them to cover swath paths with widths in excess of 150 feet through a slick. This type of system offers several advantages; on-board skimmers, built-in separators, and holding tanks all can be integrated into a vessel large enough to handle sea states where smaller skimmers would fail. This method not only solves the problem of transportation, but the crew can be trained to operate the response equipment eliminating the problem of skilled response equipment operators.

SEPARATION

For an efficient skimming operation, the use of an oil/water separator on location reduces the problem of handling and disposing of water. In most cases, a typical baffled gravity separation tank would be sufficient for decanting the recovered oil. For larger tasks, systems are available as a permanent installation or as a transportable unit which can handle as much as 8,600 barrels of oil polluted water per hour.

STORAGE AND TRANSPORTATION

Storage and transportation of recovered product presents numerous problems when responding to a spill. This has created a demand for products that go beyond the capabilities available from conventional tanks and barges. Portable tanks, storage bladders, towable bladders, and inflatable barges are examples of light weight, easily transportable effective alternatives to storage and transportation problems.

SHORELINE REMEDIATION

Steam cleaning, hot pressure washing, cold pressure washing, high volume water flushing, oleophilic hand tools, absorption, collection trenching, and bio-remediation are examples of techniques available to aid in the monumental task of removing oil from the shoreline or tidal interfacial zone. Due to the many varying characteristics in the immediate environment that make up a particular section of shoreline, a flexible combination of the aforementioned techniques may be utilized. Although the advent of several mechanized techniques for shoreline cleanup has been useful, manual labor armed with pressure washers and oleophilic hand tools is still the most popular and commonly used technique throughout the world.

SUMMARY

The state-of-the-art equipment for one application may be totally ineffective for another by changing a few variables on any recovery operation. Therefore, all aspects of a proposed spill scenario should be explored in an effort to provide the most effective equipment available for the identified task and each set of circumstances that may be encountered. In order for any equipment to be effective, it must be properly maintained; and trained, competent operators must be available.

Mr. Parag Gandhi is the Marketing Executive for Ajat Shaw, Inc. with whom he has been employed for the last three years. Mr. Gandhi has worked on several spills, exercises, and demonstrations in California and Alaska, including the Valdez spill in Prince William Sound. Mr. Gandhi has a B.S. in business administration.

Mr. Mark Ploen has been employed by Ajat Shaw, Inc. (ASI) since 1985. Mr. Ploen has served both as ASI's North Slope Operations Manager and ASI's General Manager in Alaska. Mr. Ploen has been employed in the oil spill industry for over seven years where he has played a major role in the remediation of several major oil spills including the Glacier Bay spill in Cook Inlet in 1987 and was contracted to the Exxon Command Team during the recent Exxon Valdez oil spill.

AN EVALUATION OF OIL SPILL RESPONSE METHODOLOGY/EQUIPMENT USED DURING THE CLEANUP OF THE EXXON VALDEZ SPILL AND U.S. COAST GUARD ATLANTIC AREA STRIKE TEAM RESPONSE CAPABILITIES IN THE GULF OF MEXICO

LCDR Glenn A. Wiltshire*
U.S. Coast Guard

INTRODUCTION

By now everyone is aware or the grounding of the Exxon Valdez in Prince William Sound, Alaska, the resulting catastrophic oil spill, and the monumental cleanup effort that continues today. While many people assume that the cleanup was a failure based on the news coverage of the activities carried out by the Federal, state, and local governments, Exxon, and their contractors, this was not the case. During the response to the spill, almost every cleanup technology and method ever tried was used, and new methods were developed and implemented with varying degrees of success. The purpose of this presentation is to summarize some of the methods that were used and to provide an assessment of the effectiveness of these methods for recovering or mitigating the effects of the Alaska North slope crude oil on the environment. The names of particular brands of equipment have been left out, since the intent is to discuss the effectiveness of the type of equipment, not a specific brand or manufacturer.

Since the question has risen on many occasions since March, "What if the Exxon Valdez occurred in the Gulf of Mexico? Would we be ready," I will also briefly describe the capabilities of the U.S. Coast Guard's (USCG) Atlantic Area Strike Team to respond to oil spills in the Gulf of Mexico.

EXXON VALDEZ RESPONSE

As almost everyone is aware, the grounding of the Exxon Valdez resulted in the rapid discharge of approximately 11,000,000 gallons of Alaska North Slope crude oil into Prince William Sound. Over the next few months, this oil spread over 500 miles and impacted hundreds of miles of shoreline. With this amount of oil entering the water in such a short period of time, the available response equipment was overwhelmed, requiring an air and sealift of thousands of tons of cleanup equipment from around the world. Below is a summary of the operations and problems encountered when using each type of equipment.

Skimmers

Almost every type of skimming technique that exists was used during this response. Initially, weir type skimmers were used for oil recovery. These were effective for the first week or two while the oil was still light and had not weathered extensively. As time went on, however, weir skimmers became ineffective both due to the viscosity of the oil and the amount of debris and kelp mixed with the floating oil; that clogged the weirs. A large number of belt and paddle-belt type skimmers were used as the oil weathered. These were very effective recovering the oil from the water but were hampered by problems emptying recovered product from the onboard tanks. Archimedean screw or auger pumps were added to move the oil/debris mixture from the onboard tanks to the storage devices. The thick consistency of the weathered oil also required the use of suction devices such as "supersuckers" and "vac-alls." These devices were placed on barges or vessels with large tank capacity for mobility. While these were all generally effective picking up the oil from the water or from tankage of smaller skimming devices, those with gravity type discharge were inefficient due to their slow emptying times. This required the use of devices that had a pressurized discharge capability to facilitate emptying into the vessel's storage tanks. Rope-mop and disk type skimming devices were also used to a limited extent but were not as efficient due to the consistency of the oil. Two U.S. Army Corps of Engineers hopper dredges were also brought in along with a Soviet oil recovery/dredge ship and acted as "skimmers." To do this, the dragheads were inverted and the dragarms lowered into a pool of oil collected by boom-towing vessels. The large centrifugal pumps would suck anything within the boom into the dredge's hopper where gravity separation would occur. While this operation was effective in recovering oil, it turned out to be very difficult to remove the recovered product from the enclosed hoppers since the oil debris mixture congealed and had to be broken up with high pressure hoses to allow the pumps to get suction.

While the skimming systems were effective for what they were designed to do, there were a number of problems that reduced their efficiency. These included the lack of onboard tankage or rapid offloading systems, the sensitivity to sea conditions, the lack of sufficient trained and experienced operators to sustain operations over the months of the cleanup, and the inadequacy of berthing for the skimming crews in the early stages of the response.

Booms

Hundreds of thousands of feet of boom were used throughout the cleanup operation, ranging in size from small 8-12 inch calm water booms to massive 84 inch offshore booms. The wide range of sizes was necessary due to the varying environmental conditions encountered during the cleanup. The larger offshore booms were used primarily in the Gulf of Alaska and other unprotected areas to attempt to corral and collect free-floating patches of oil or to protect fish hatcheries threatened by the oil. Hundreds of small fishing boats were used to tow booms in a "U" configuration to concentrate and collect the floating patches. Once these booms were full, they would be emptied by a recovery device, towed to a bay, and emptied into a larger "storage boom," or sometimes formed into a "donut" and anchored or cast adrift until a recovery device became available. In many areas along the southern Alaska coast, villages constructed log booms to protect their harbors and coastlines from the approaching oil. Smaller booms were used in conjunction with the shoreline cleanup operations to contain oil flushed from the shore during cleaning and to protect treated shorelines from recontamination. The large tidal range adversely affected the ability to deploy and maintain these booms. Sorbent booms were used with some success during the shoreline cleanup operation to contain and recover the sheens resulting from the shoreline flushing operations and miles of "snare boom" were fabricated by the workers for shoreline oil collection and recovery.

Recovery and Storage Devices

What may have been the most significant problem faced by the responders was the availability of temporary storage devices to hold the recovered product. In the early stages of the response when the skimming resources were most effective, there was a shortage of barges to transfer the recovered product to. Thus, skimmers had to sometimes wait for hours to empty their onboard tanks or had to transit long distances to empty their tanks at the closest storage device. For remote operations or where barges were not available large rubber storage bladders were used for temporary holding. This created additional problems when the bladders were filled and became difficult to empty due to the consistency of the oil. Holds of fishing vessels were also used for temporary storage. As noted above, as the oil weathered and mixed with debris and kelp, recovery and storage became even more difficult. Auger pumps had to be used to transfer the product between devices, a slow and frustrating process. Attempts to use steam coils and emulsion breakers to ease the transfer process were partially effective. As the cleanup progressed, sufficient storage capacity became available to hold the recovered product while disposal options were identified and approved by the appropriate regulatory officials.

Shoreline Cleanup Methods

Initial shoreline cleanup operations were carried out using a deluge flushing system and both low and high pressure hot and cold water pumps to break the oil free from the shoreline and refloat it where skimmers could be used for recovery from the water. In more environmentally sensitive or inaccessible areas along the Alaska coastline, shoreline cleanup consisted of large groups of workers using rakes and shovels to collect and bag mousse paddies and oily debris or wiping oiled rocks with sorbents or snare. While this was very inefficient, in many areas it was the only method acceptable to the various Federal and state environmental agencies overseeing the cleanup. As shoreline operations progressed, more efficient methods using barges equipped with remote controlled articulating arms, high volume water heaters capable of using sea water, and high capacity pumps were developed. These were used primarily on rocky shorelines and cliffs that were inaccessible to cleanup crews. Shoreline treatment using chemicals and bioremediation techniques (fertilizers) were tried during the latter stages of the cleanup and have not yet been fully evaluated for their effectiveness.

Cleanup Logistics Support

This cleanup, more than any other ever done, required a monumental logistics network to support the thousands of workers deployed in the field. Hundreds of boats were chartered to transport personnel, equipment, and supplies to the remote areas. This included a number of offshore supply vessels brought around from the Gulf of Mexico. Self-supporting task forces were developed to allow for independent operations during the cleanup. Because of the remote areas affected, cleanup crews operated independently in the field for weeks with daily logistics support by boat and helicopter from shore bases in Valdez, Seward, Homer, Kodiak, and other communities. Vessels ranging from small pleasure craft to large Navy troop ships and deck barges with house trailers were brought in to house the cleanup workers along with various support personnel. A constant flow of food, fuel, water, and cleanup supplies as well as field equipment repair facilities were needed to support the massive cleanup force. Obviously, an operation such as this could not be set up overnight, and there was a "learning curve" as personnel gained experience.

Disposal

A major problem encountered was what to do with the thousands of barrels of oily material recovered from the water and the tons of oily debris and sorbent material, contaminated protective clothing, garbage, sewage, and other wastes generated during the cleanup. Much of this material had to be placed in temporary storage locations while the necessary permits were obtained to properly dispose of it. Portable incinerators were brought in to burn some of the oily material; open burning was authorized in very limited circumstances; oil liquid was transported by barge to refineries for reprocessing; sewage was transported by vessel to shore-based reception facilities; and garbage was transported to shore for disposal at permitted landfills. Some of the disposal issues remain unresolved.

STRIKE TEAM CAPABILITIES

The USCG's Atlantic Area Strike Team, based in Mobile, Alabama, is one of two Strike Teams maintained by the USCG to assist in responding to oil or hazardous materials spills throughout the country. The Team's operating area covers 36 states in the East, South, and midwestern U.S., the Caribbean, Puerto Rico, and the U.S. Virgin Islands. Within this area, we may be called on to respond to both incidents involving water as well as incidents on land. The Pacific Area Strike Team provides the same support in 12 states in the western portion of the continental U.S., Alaska, Hawaii, and the Trust Territories of the Pacific.

The primary mission of the Strike Teams is to provide support to the predesignated Federal On-Scene Coordinator (FOSC) responsible for Federal response actions within a given geographic area. The FOSC is provided by the USCG in the coastal areas of the U.S. and by the U.S. Environmental Protection Agency for inland areas. The Strike Team offers a wide range of support to these FOSC's. Capabilities include providing trained personnel for on-scene technical assistance, safety monitoring, monitoring of responsible party cleanup actions, supervision of Federally-funded commercial cleanup contractors, and cost documentation. The Strike Teams also maintain an extensive inventory of response equipment that is available to conduct or support cleanup activities. As a government agency, a Strike Team is not authorized to compete with commercial contractors. Thus, Strike Team cleanup equipment is used only when it can be deployed and used faster than commercial equipment, when a similar piece of equipment cannot be obtained from commercial sources, or when the equipment will significantly enhance response efforts and supplement responsible party actions. When Strike Team equipment is used, the responsible party is financially liable for the costs incurred.

Although there are many types of equipment in our inventory, this discussion will focus on that most likely to be used responding to a major oil spill in the Gulf. This includes our skimming barrier, pumping systems, dracone barges, and various support gear.

The primary oil containment and recovery device in the Atlantic Strike Team inventory is the Open Water Oil Containment and Recovery System, commonly referred to as the Skimming Barrier. This system has three components: the containment barrier, a pump subsystem, and a prime mover for the pumps. The containment barrier is 612 feet in length with a draft of 27 inches and a freeboard of 21 inches. It consists of 102 struts each with flotation bags, with 6 weir-type skimming struts in the middle of the barrier. It is outfitted with towing lines to allow its use in the normal "U" configuration. The pumping subsystem consists of three hydraulically-driven single diaphragm, double action pumps to transfer liquid collected in the weirs. These pumps have a combined capacity of 825 gallons per minute. The prime mover used to run the hydraulic pumps is our Air-Deployable Anti-Pollution Transfer System (ADAPTS) III prime mover. There is no oil storage capability with the system. A ship, barge, or other portable container such as a Dracone barge is needed to operate the system in the recovery mode. The system is designed to operate in up to 6 foot seas and can survive 10-12 foot seas. The entire system can be delivered by truck over the road or transported by air to an airport close to the staging area. Once at the dock, the system can be deployed and towed to the scene or placed aboard a vessel or barge for transportation to the spill area. Three of these systems are located in Mobile.

The pumping systems, the ADAPTS, and the Viscous Oil Pumping System (VOPS) are used for lightering damaged vessels or transferring oil or other products at high flow rates. Both use diesel-powered hydraulic prime movers to drive hydraulic submersible pumps. There are six different submersible pumps in the Atlantic Strike Team's inventory which could be used depending on the products involved and the pumping capacity required. Pumping rates vary from 200-1,800 gpm. These pumping systems can be deployed to the scene by vessel or airlifted by helicopter. Seven ADAPTS and two VOPS systems are located in Mobile.

If a ship or barge cannot be obtained to store the recovered product, one of the Dracone barges in the inventory can be used. These are large buoyant rubber bladders. There are 3 sizes in the Strike Team's inventory; 10,000 gallons, 42,000 gallons, and 240,000 gallons. The largest one weighs 14,300 lbs empty and is 300 feet long and 14 feet in diameter when deployed.

This equipment is used to provide temporary storage until a suitable barge or other vessel becomes available.

In addition to these three major systems, the Strike Team inventory also includes a wide range of support equipment including small boats, command posts, generators and portable lighting systems, communications systems, chemical protective clothing and all monitoring instruments, and portable computers. All of this equipment is made available to provide support to the FOSC.

This paper only covers the Strike Team's equipment and does not address the large quantities of equipment and response resources available or inventoried throughout the Gulf of Mexico from Clean Gulf Associates, the Marine Industry Group, and numerous other commercial cleanup contractors and spill cooperatives. These would be the primary resources brought to bear during a major spill in the Gulf.

SUMMARY

In summary, it is wrong to say that the Exxon Valdez response was a failure. Each piece of equipment worked as it was designed to. As the physical properties or the oil changed with the weathering, so did the effectiveness of various equipment types. The responders took this into account and developed new equipment or new configurations of existing equipment to make the cleanup as efficient as possible. While hindsight is always 20/20, it is safe to say the cleanup forces did the best they could given the situation at hand: the largest oil spill ever in the United States in one of its most remote areas.

LCDR Glenn A. Wiltshire is presently the Commanding Officer of the USCG's Atlantic Area Strike Team. He has over 11 years of experience in the USCG's Marine Environmental Response program both in the field and at Headquarters. He has a B.S. degree in marine sciences from the USCG Academy and a Master of Public Administration degree from the John F. Kennedy School of Government, Harvard University.

CWO Fred Gonzales has over 19 years of experience in the USCG and is currently assigned to the National Strike Force, Atlantic Area Strike Team in Mobile, Alabama. He has had extensive sea duty and has worked in the areas of law enforcement and marine sciences.

*As presented by CWO Fred Gonzales, U.S. Coast Guard

GULF OF MEXICO ISSUES AND INITIATIVES
(CONTRIBUTED PAPERS)

Session: GULF OF MEXICO ISSUES AND INITIATIVES (CONTRIBUTED PAPERS)

Co-Chairs: Dr. Richard E. Defenbaugh
Mr. Ted Stechmann

Date: December 5, 1989

Presentation	Author/Affiliation
Gulf of Mexico Issues and Initiatives (Contributed Papers): Session Overview	Dr. Richard E. Defenbaugh and Mr. Ted Stechmann Minerals Management Service Gulf of Mexico OCS Region
OCS Hydrocarbon Production in the 1990's: the Role of the Gulf of Mexico	Dr. Pulak Ray Minerals Management Service Headquarters Office
An Economic Model for Artificial Reefs with Special Reference to the Use of Obsolete Oil and Gas Platforms	Dr. Semoon Chang Center for Business and Economic Research University of South Alabama
Sources of Long-Term Variability in the Northern Gulf of Mexico Continental Shelf Ecosystem	Dr. R. Eugene Turner Department of Marine Sciences Louisiana State University and Dr. Nancy N. Rabalais Louisiana Universities Marine Consortium
Distribution, Relative Abundance, and Seasonality of Outer Continental Shelf Cetaceans in the North-Central Gulf of Mexico: A Pilot Study	Dr. Ren Lohoefener, Dr. Keith Mullin, Mr. Wayne Hoggard, Ms. Carol Roden, Ms. Carolyn Rogers National Marine Fisheries Service and Lieutenant Brian Taggart Office of NOAA Aircraft Operations Center
The Gulf of Mexico Program Mobile Bay Demonstration Project	Dr. Frederick C. Kopfler U.S. Environmental Protection Agency
Education and Awareness: Keys to Solving the Marine Debris Problem	Ms. Kathy O'Hara and Ms. Patty Debenham Center for Marine Conservation

GULF OF MEXICO ISSUES AND INITIATIVES (CONTRIBUTED PAPERS): SESSION OVERVIEW

Dr. Richard E. Defenbaugh
and
Mr. Ted Stechmann
Minerals Management Service
Gulf of Mexico OCS Region

The objective of the Contributed Papers Session is to provide a forum for presentation and discussion of recent research or other efforts which pertain to the overall purposes of the Information Transfer Meeting (ITM), but which are not among the various subjects developed into technical sessions by Minerals Management Service (MMS) staff.

As part of the springtime ITM announcement, MMS solicited "contributed presentations" on current or recently completed research or other efforts which pertain to the ecology of Gulf coastal or marine communities or species, or to the effects of oil and gas activities in coastal or marine environments, or to similar topics of interest to the ITM audience. Presentations offered by respondents were screened by MMS management; some were selected for this session, some were incorporated into other technical sessions, the remaining offers were declined.

Dr. Pulak Ray, of the MMS Headquarters Office Division of Resource Evaluation, spoke on Outer Continental Shelf (OCS) hydrocarbon production in the coming decade, and the relative role of the Gulf of Mexico. Dr. Ray's predictions are based on statistical analyses of current and historic trends in exploration, discovery, development, and production. Current production from the Gulf OCS is substantial: about 10% of all oil produced in the U.S., and about 95% of all oil produced from the U.S. OCS; as much as 25% of all gas produced in the U.S., and about 99% of all gas produced from the U.S. OCS. Dr. Ray suggests that the larger oil/gas fields on the Gulf continental shelf are now known, and that exploration and production of smaller fields is not economically feasible, so that new resources developed on the Gulf shelf will be intermediate-size fields. The major opportunity in the Gulf is in "deep-water", where little exploration has occurred to date. However, economic constraints on deepwater exploration and development will require higher oil prices or federal encouragement of some sort. In any event, the Gulf of Mexico is expected to be a major producer of oil and gas throughout the 1990's.

Dr. Semoon Chang, of the University of South Alabama's College of Business and Management Studies, described and discussed an economic model he has developed to assist coastal planners who may be considering development of offshore artificial reefs. The model can be used to assess the economic benefits of fishing prior to development of an artificial reef, and can project the probable benefits of the artificial reef. The model is of particular interest to the offshore oil and gas industry, since all offshore platforms must be removed from their locations following cessation of oil or gas production, and are scrapped, refurbished for further use, or may be converted into an artificial reef.

Dr. Gene Turner, of Louisiana State University's Center for Wetland Resources, presented data on long-term changes in the Mississippi River, with interpretations of the impact of these changes on the ecology of the River and of the continental shelf. The Mississippi River drains about 40% of the continental U.S. and is affected by various land-use practices and river-control activities. Analysis of available historical records demonstrates an enormous range of variability in river flow, both month-by-month and annually. Flow during peak flooding has decreased since the turn of the century, apparently due to storage capacity of upstream reservoirs. River flow onto the continental shelf has a major impact on shelf ecology, due to salinity depression, limitation of light penetration into offshore waters, and enhancement of nutrient or trace chemicals. Dr. Turner presented statistics on historical trends in riverine suspended sediments, nutrients (phosphorus, phosphate, silicate, nitrogen, nitrate), and other metals (lead), and postulated that the changes in Mississippi River flow, suspended sediments, and water chemistry have had profound influences on phytoplankton communities within the river and on the continental shelf. The consequences of these changes in phytoplankton communities to other components of the offshore ecosystem are currently unknown.

Dr. Ren Lohoefener, of the National Marine Fisheries Service's (NMFS) Pascagoula Laboratory described and discussed aerial surveys he is currently conducting to assess the occurrence and distribution of deepwater cetaceans in the northern Gulf, primarily offshore Louisiana and the Mississippi Delta. This study is cooperatively supported by the MMS and the NMFS to support assessments of the potential effects to large cetaceans from deepwater oil and gas exploration and development. Data now available from historic whaling records, from stranding network records, and from aerial surveys shows that 26 species of dolphins and whales have been reported in the Gulf of Mexico. Dr. Lohoefener presented slides of the species his team has observed, and commented on the natural history of each species.

Dr. Fred Kopfler, of the Environmental Protection Agency's Gulf of Mexico Program Office presented an overview of the goals, organization, and activities of the "Gulf Program", and described a pilot project for development of a sophisticated database management system for the Mobile Bay area. The "Gulf Program" is being developed as a forum for coordination and communication of agencies involved in management of resources or activities which affect the Gulf of Mexico, with particular focus on environmental problems which are cross-jurisdictional or pervasive (rather than localized). The Program is being developed and implemented through the actions of three committees: a Policy Review Board (agency heads with authority to commit action or support of their agencies); a Technical Steering Committee (scientists, technical staff, or resource managers who have identified the issues of concern and are undertaking studies to prepare action plans); and a Citizens Advisory Committee (imminent citizens appointed by Governors of each state). The Mobile Bay Demonstration Project is being developed as a pilot effort for exploration of resource management options and strategies. The project involves cooperative efforts of several Federal (Environmental Protection Agency, Corps of Engineers, Fish and Wildlife Service, Soil Conservation Service, NMFS) agencies and State of Alabama agencies to develop a geographic information system (GIS) based management tool to assess the effects of natural processes and man's activities in the coastal zone; to understand the consequences of activities permitted by these agencies in the past; and to support the review of future permit applications. The system is scheduled to be operational by December 1990.

Ms. Patty Debenham, of the Center for Marine Conservation's Marine Debris Information Office, described the efforts of the Center to develop and conduct a national education program pertinent to marine and beach debris. Ms. Debenham reviewed the magnitude of the marine debris problem at various locales, from various sources, and the impacts of marine debris on marine life and aesthetic values. Steps to control marine debris include the recent MARPOL treaty, which includes an Annex to control dumping of trash and debris at sea. With support from Environmental Protection Agency (EPA) and National Oceanic and Atmospheric Administration (NOAA), the Center for Marine Conservation (CMC) has developed educational materials and has coordinated with certain groups which produce marine debris (including the commercial fishing industry, the marine transportation industry, the plastics industry, and the recreational fishing and boating sector) to enhance their awareness of the issue and to gain their support and involvement in controlling marine debris. CMC has organized beach cleanups to promote public awareness and to implement actions to assess and alleviate the problem. Ms. Debenham showed a nicely produced public service video which stars the cartoon character "Popeye" which will be released to television stations to promote further public awareness and participation in beach cleanups.

The Contributed Papers Session met our objectives well. The presentations were well-given and well-received, and were clearly of interest to the ITM audience, as evidenced by attendance and by questions or discussion following each presentation. Although the theme of this session, "Gulf of Mexico issues and initiatives," was more diffuse than themes of other technical sessions, the session provided a useful forum for presentation and discussion of information on recent research, current thinking, and on-going programs of interest and concern to the Gulf community.

Dr. Richard E. Defenbaugh is Chief of the Environmental Studies Section of the MMS Gulf

of Mexico OCS Regional Office. His graduate work on the natural history and ecology of estuarine and continental shelf invertebrates at Texas A&M University lead to a M.S. in 1970 and a Ph.D. in 1976. He has been involved with the MMS/Bureau of Land Management environmental studies and assessment programs since 1975.

Mr. Ted Stechmann is a biologist on the Environmental Operations Section staff, also of the MMS Gulf of Mexico OCS Regional Office. He holds a B.S. in biology from the University of Southern Mississippi at Hattiesburg, and taught biology, chemistry, and marine biology in Mississippi and Louisiana high schools for 12 years prior to his Government career. He has worked for the U.S. Geological Survey and the MMS for 11 years, primarily involved in review of offshore oil and gas operational plans to assure their compliance with environmental protection requirements. Special interests include protection of biological resources, particularly Eastern Gulf live-bottom areas; structure removal operations; and deep-Gulf chemosynthetic communities.

OCS HYDROCARBON PRODUCTION IN THE 1990'S: THE ROLE OF THE GULF OF MEXICO

Dr. Pulak Ray
Minerals Management Service
Headquarters Office

Presentation Summary
Text Not Submitted

Dr. Pulak Ray

AN ECONOMIC MODEL FOR ARTIFICIAL REEFS WITH SPECIAL REFERENCE TO THE USE OF OBSOLETE OIL AND GAS PLATFORMS

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This study is intended to suggest guidelines in converting obsolete oil and gas platforms into artificial reefs. Illustrative figures are presented for population centers in Alabama, Florida, and Mississippi.

SUMMARY OF FINDINGS

Artificial reefs are established if their benefits are greater than their costs of installation. Oil and gas platforms are a special case of artificial reefs.

The decision by oil companies on whether to sell platforms for scrap or to donate them for use as artificial reefs is a matter of economics. Public policy may influence decisionmaking by oil companies by allowing oil companies to claim tax deductions for donating platforms for use as artificial reefs, and by allowing fishermen or local agencies to assume part of the transportation costs of platforms.

PROCEDURES OF APPLYING THE MODEL

Summarized below is a cookbook procedure of making decisions as to whether a population center should have an artificial reef established in its waters.

Step 1: Identify the population center.

A given community that considers establishing an artificial reef is the population center.

Step 2: Develop an exclusion map.

An exclusion map should identify areas where artificial reefs may not be placed. These areas include shipping lanes, offshore ports, biologically sensitive areas, marine sanctuaries, military areas, and areas of particular shipping interests.

Step 3: Clarify the requirements and procedures of obtaining a permit to establish an artificial reef.

Early in the process, the population center should make sure that no problems arise from the permit procedure.

Step 4: Obtain the numbers of commercial and recreational fishermen for the population center.

These numbers are necessary in estimating potential benefits from use of the artificial reef under consideration. The local fishermen's association, the U.S. Coast Guard, or a state office issuing fishing licenses may be the source for this information. Estimates by fishermen in the Biloxi area, for instance, indicate that there are approximately 800 commercial fishermen and 4,000 recreational fishermen in the area.

Step 5: Estimate the dollar value of additional fish catch.

The dollar value is the sum of retail prices of fish that both commercial and recreational fishermen are expected to catch off the artificial reef under consideration. Opinions of local fishermen and marine biologists would be the source of estimates.

Step 6: Obtain the numbers of resident and tourist recreational fishermen in the population center.

These numbers are necessary to estimate total fishing days of recreational fishermen in the population center. Fishing communities may use the findings of the National Survey of Fishing, Hunting, and Wildlife Associated Recreation published in November 1988 by the U.S. Department of the Interior and the U.S. Department of Commerce. The survey indicates the ratios of resident recreational fishermen and tourist recreational fishermen relative to an area's residence recreational fishermen (Fr). Residence fishermen refer to fishermen who live in the population center. Resident fishermen refer to residence fishermen who fish in waters of the population center. If a residence fisherman fishes in areas other than the population center, the residence fisherman is not a resident fisherman. Our assignment is to obtain the number of resident recreational fishermen and the number of tourist recreational fishermen on the basis of the number of residence recreational fishermen (Table 4.1.).

Step 7: Estimate the total annual fishing days of the population center's recreational fishermen.

Total annual fishing days of the population center are obtained by adding total annual fishing days of the resident recreational fishermen and total annual fishing days of the tourist fishermen. According to Bell, Sorenson, and Leeworthy (1982), the annual fishing days for the northwest Florida area are 17.5 days per resident recreational fisherman and 8.1 days per tourist recreational fisherman. Since no comparable data are available in the national survey, the same numbers may be applied for other areas.

Estimates by fishermen who attended town meetings for this study indicate that the fishing days of a typical recreational fisherman in Biloxi are 25 days (based on 20 responses) and the fishing days of a typical out-of-town fisherman in Mobile is 8.4 days (based on 17 responses).

Step 8: Estimate the total dollar value of recreational fishing.

To estimate the dollar value of recreational fishing, the total number of fishing days for recreational fishermen should be multiplied by how much each day is worth to each fisherman (Table 4.2). Unless reliable studies are available for particular population centers, population centers may use the guidelines for assigning points for special recreation, developed by the Corps of Engineers (1983). The unit-day value for saltwater recreational fishing in 1990 price is $17.28. Based on estimates of fishermen who attended town meetings, however, even this figure may be an overestimation. Recreational fishermen in the Biloxi area were willing to pay only $72.76 in 1990 price (based on 21 responses) for use of artificial reefs for the entire year.

Step 9: Estimate the value of recreational fishing for the artificial reef under consideration.

The value of recreational fishing derived in step 8 is based on the assumption that all fishing days of all recreational fishermen are spent around the artificial reef. The value, therefore, should

Table 4.1. The number of resident recreational fishermen (Fr) and the number of tourist recreational fishermen on the basis of the number of residence recreational fishermen.

	Population Centers In		
	Alabama	Florida	Mississippi
Area's residence recreational fishermen (from step 4)	Fr	Fr	Fr
Multiplied by	x 0.94	x 0.97	x 0.96
Resident fishermen	0.94 Fr	0.97Fr	0.96Fr
Multiplied by	x 0.31	x 0.61	x 0.49
Tourist fishermen	0.29 Fr	0.59Fr	0.47Fr

Table 4.2. Estimate of the dollar value of recreational fishing, the total number of fishing days for recreational fishermen (Fr) multiplied by how much each day is worth to each fisherman.

Alabama:						
Resident annual fishing days	=	0.94Fr	x	17.5	=	16.45Fr
Tourist annual fishing days	=	0.29Fr	x	8.1	=	2.35Fr
Total annual fishing days					+	18.80Fr
Multiplied by					x	$17.28
Value of recreation					=	$324.86Fr
Florida:						
Resident annual fishing days	=	0.97Fr	x	17.5	=	16.98Fr
Tourist annual fishing days	=	0.59Fr	x	8.1	=	4.78Fr
Total annual fishing days					+	21.76Fr
Multiplied by					x	$17.28
Value of recreation					=	$376.01Fr
Mississippi:						
Resident annual fishing days	=	0.96Fr	x	17.5	=	16.80Fr
Tourist annual fishing days	=	0.47Fr	x	8.1	=	3.81Fr
Total annual fishing days					+	17.28Fr
Multiplied by					x	$17.28
Value of recreation					=	$356.14Fr

be multiplied by the percentage of fishing days spent on fishing around the artificial reef relative to total fishing days. The population center must make the best judgment for the percentage. For the purpose of illustration, the percent is assumed to be 25. The percent of fishing around artificial reef is approximately 35% (based on 21 responses) in the Biloxi area, according to the questionnaire survey at town meetings. The option and existence values may also be included if they can be estimated objectively.

Step 10: Estimate the expenditure impact owing to the artificial reef.

The net economic development impact from expenditures by out-of-town fishermen and additional local fishermen, if there are any, should be included in estimating the expenditure impact. The annual expenditure per fisherman by state for each recreational activity is available in the national survey. The annual expenditure for one saltwater fisherman in 1990 price is $190.66. The expenditure impact by out-of-town and local (commercial and recreational) fishermen who are newly attracted to the area due to the artificial reef under consideration is obtained by multiplying additional fishermen by $190.66. A more accurate study will differentiate expenditures by out-of-town fishermen from those of local fishermen.

Step 11: Estimate the total annual benefit from the artificial reef.

The total annual benefit from the artificial reef under consideration is obtained by adding the following benefit categories.

(A) the dollar value of additional fish catch from the artificial reef [step 5]
(B) the dollar value of recreational fishing for the artificial reef [step 9]
(C) the expenditure impact of the artificial reef [step 10].

Step 12: Convert the total annual benefit from the artificial reef to its present value.

Since total benefit figures are recurring each year, these figures should be converted to their present values so that benefits can be compared with costs for the same price level. To simplify the computational procedure, it may be assumed that the discount rate is 10% and the life of an artificial reef is 25 years. The present value of the total annual benefit then is obtained by multiplying total annual benefit by 9.077040.

Step 13: Estimate the total cost of establishing the artificial reef.

The total cost of establishing an artificial reef consists of (a) manufacturing or dismantling cost, (b) transportation cost that may include a liability insurance on shipment of an artificial reef, and (c) the maintenance cost including an annual liability insurance premium. The maintenance cost should be discounted to the present value since it is recurring annually.

Step 14: Identify the sources of external funding and apply for funds.

The amount that can be acquired from external sources should be subtracted from total cost obtained in Step 13 to obtain the net cost of establishing an artificial reef to the population center.

Step 15: Make the decision

NTB = Present Value of TB
TB = Bc + Br + Be

Bc = additional catch
Br = user value + option value + existence value
Be = additional income (+ employment + tax revenue)

NTC = Present Value of TC
TC = Cd + Ct + Cm - Fe

Cd = dismantling cost
Ct = transportation cost
Cm = maintenance cost
Fe = external funds

If NTB - NTC > 0, establish the artificial reef.
If NTB - NTC < 0, do not establish the artificial reef.

This study is a summary of an earlier project that was supported in part by National Oceanic and Atmospheric Administration, National Marine Fisheries Service, U.S. Department of Commerce under Grant Number NA84-WC-H-06150, the Mississippi-Alabama Sea Grant Consortium, and the University of

South Alabama. The earlier study was published by the Mississippi-Alabama Sea Grant Consortium.

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Dr. Semoon Chang is a Professor of economics and Director of the Center for Business and Economic Research at the University of South Alabama. Dr. Chang has research interests in a wide range of topics, which include coastal issues. Dr. Chang has over 20 refereed journal articles and 3 books with the latest one being Modern Economics, published by Allyn and Bacon in 1990. Dr. Chang's articles on coastal issues have been published in such journals as Maritime Policy and Management, Urban Affairs Quarterly, Growth and Change, Transportation Journal, and Oil & Gas Tax Quarterly.

SOURCES OF LONG-TERM VARIABILITY IN THE NORTHERN GULF OF MEXICO CONTINENTAL SHELF ECOSYSTEM

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Variability in the ecosystem of the northern Gulf of Mexico continental shelf occurs, in part, because of changes in the water quality of the Mississippi River which are generally concentrated relative to its oceanic mixing end member. River water quality has changed considerably this century and these changes are reviewed. The concentration of suspended sediments has declined this century due to flood protection and navigation improvement efforts. Further, channel shallowing below New Orleans and channel deepening in the Atchafalaya Basin have contributed to varying amounts of suspended sediments being delivered to offshore. These changes affect the light regime, thus influencing phytoplankton production rates.

The various estimates of light transparency using secchi disk measurements are summarized for the northern Gulf of Mexico continental shelf, especially for the near Mississippi River delta. These data include results from *in situ* studies, monthly across shelf transects, plume surveys at the river deltas, and continental shelf surveys from Mobile Bay to Texas.

Concurrent measurements of light transparency (submarine photometer) and extinction coefficients estimated from secchi disk depths (SDD) are very similar, especially in well-mixed water columns. In addition, the extinction coefficients estimated from secchi disk data and estimated from *in situ* phytoplankton production are also strongly correlated.

SDD varied between 0.2 cm and >30 m and were, of course, lowest in salinity waters located near sediment sources. SDD changed slightly in the Mississippi River turbidity maximum and substantially increased around 20 $^{\circ}/_{\circ\circ}$ and <20 mg/l suspended sediment concentration. It appears as if SDD increased from the 1950's to the 1980's.

Nitrate, silicate, and phosphate concentrations in river water have also changed, probably reflecting the general increased eutrophication of freshwaters through increased fertilizer usages. These changes undoubtedly have resulted in increased phytoplankton production on the continental shelf, perhaps influencing hypoxic conditions, presently widespread and severe.

Additional sources of variation are eustatic sea level rise, climatic cycles (many of which operate over periods longer than decades), river discharge, and solar radiation. All of these sources of variation, and others, will cause measurable variability in the aquatic communities offshore, and complicate discernment of impacts due to Outer Continental Shelf activities.

Dr. R. Eugene Turner is a Professor of marine sciences in the Center for Wetland Resources, Louisiana State University. His interests include wetland management, mitigation and restoration, biological oceanography, and fisheries ecology. Dr. Turner received his Ph.D. from the University of Georgia.

Dr. Nancy N. Rabalais holds concomitant positions as Assistant Professor at the Louisiana Universities Marine Consortium, Cocodrie, Louisiana; Department of Marine Sciences, Louisiana State University, Baton Rouge; and the University of Southwestern Louisiana, Lafayette. Her research interests focus on processes in biological and physical oceanography. Dr. Rabalais received her B.S. and M.S. in biology from Texas A&M University and her Ph.D. in zoology from the University of Texas at Austin.

DISTRIBUTION, RELATIVE ABUNDANCE, AND SEASONALITY OF OUTER CONTINENTAL SHELF CETACEANS IN THE NORTH-CENTRAL GULF OF MEXICO: A PILOT STUDY

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INTRODUCTION

Except for data from strandings (Schmidly 1981; Odell 1989) and from Fritts et al. (1983) surveys, virtually nothing is known about cetaceans in Gulf of Mexico waters deeper than 180 m (100 fm). Historically, about 26 species or types of cetaceans occurred in the Gulf of Mexico (Schmidly 1981). Recently, only 24 species have been documented (Odell 1989).

Fritts et al. (1983) used aerial surveys to study areas offshore of southern Texas and western Louisiana. About 69% of the Texas and 27% of the Louisiana study areas had water depths exceeding 180 m. Their study was well planned and very productive. However, their primary objective was not surveys of deep water and only one-fourth of the survey effort in each study area was over deep water. They surveyed these areas in June, August, and October 1980 and February and April 1981. They identified eight species or types of deep-water cetaceans.

In 1989, the National Marine Fisheries Service (Mississippi Laboratories), Minerals Management Service, and Aircraft Operations Center (National Oceanic and Atmospheric Administration) cooperated in planning and conducting a pilot study in the north-central Gulf of Mexico. The objective of our research was to determine whether aerial surveys would be an efficient method of studying deep water cetaceans along the continental shelf.

METHODS

It has been speculated that areas of high sea floor relief may concentrate cetaceans (Collum and Fritts 1985; Payne et al. 1986; Kenney and Winn 1986; Selzer and Payne 1988). From July through November 1989, we selected and studied four study areas that had high degrees of sea floor relief (Figure 4.1).

"Sea Mountains"

This area covered about 2,930 km^2 and was centered at 27 °55' and 91 °19.5'. The "mountains" were northwest and south of the center. Water depths ranged from about 90 to over 1,080 m. The southern "mountains" were about 200 m high.

Mississippi Canyon

The canyon area covered about 2,370 km^2 and was centered at 28 °25' and 89 °42.5'. Water depths ranged from less than 180 to greater than 900 m.

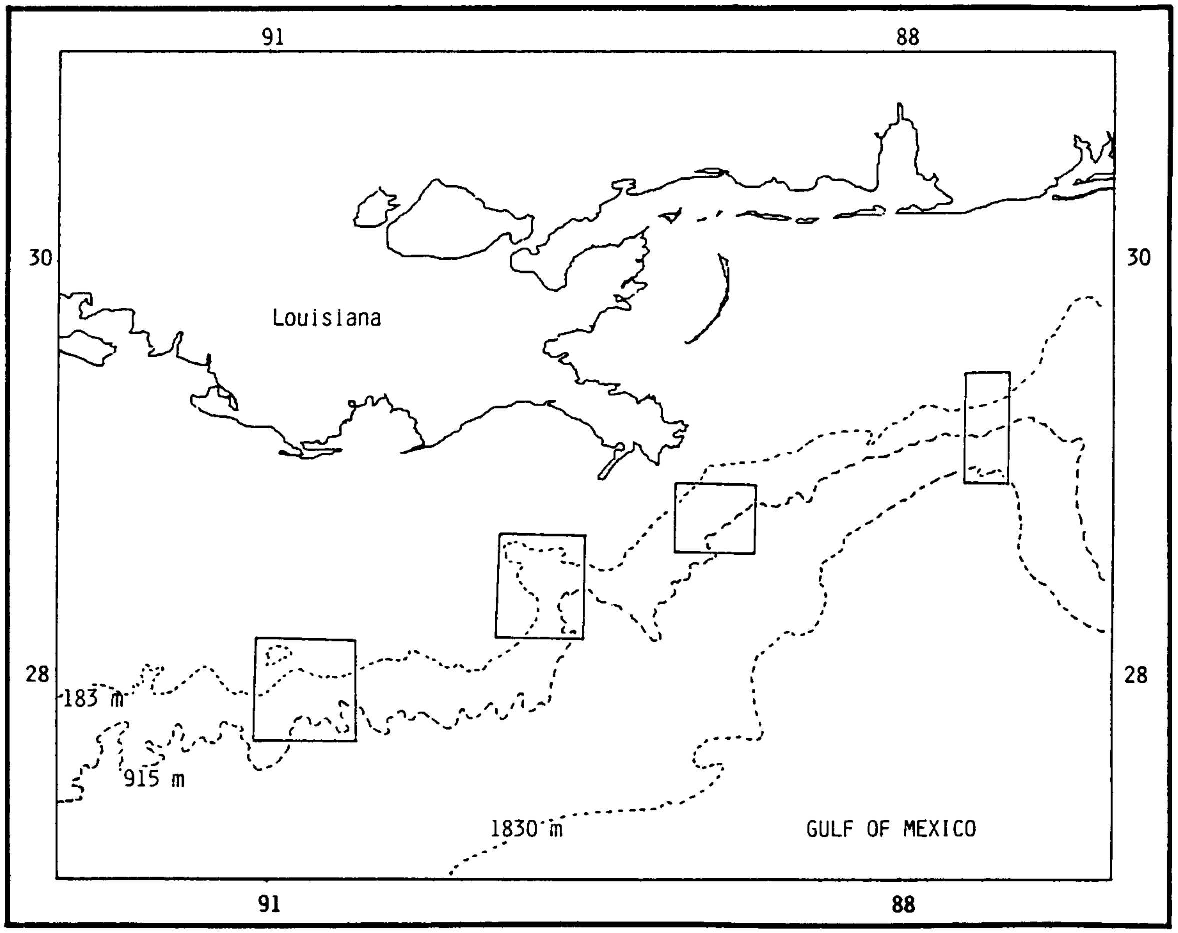

Figure 4.1. Locations of study areas.

Mississippi River Cliff

The area offshore of the mouth of the Mississippi River covered about 1,450 km² and was centered at 28°45' and 88°53.5'. Water depths ranged from less than 180 to greater than 1,260 m.

DeSoto Canyon

This area was selected to survey the abrupt change in water depths (less than 180 to greater than 1,800 m) associated with the DeSoto Canyon. The area covered about 1,210 km² and was centered at about 28°11' and 87°36'.

We used the same aerial survey methods used to study sea turtle and petroleum platform associations (Lohoefener et al. 1989). To summarize, we used National Oceanic and Atmospheric Administration's (NOAA) Twin-Otter aircraft to survey each study area three to five times a month (except DeSoto Canyon, which was only studied from September through November, and, in October, poor weather prevented surveying the Sea Mountain area). During each survey, a series of systematically located transects, from a single randomly chosen starting point, were surveyed. The surveys were conducted at 229 m altitude and about 204 km/h ground speed. Two observers, one on each side of the aircraft, observed the trackline and adjacent water areas through large plexiglass bubbles. The observers relayed observations to the computer operator. The computer was interfaced with a Loran-C receiver and automatically recorded the study area, date, time, and location for each data record. Many observer-supplied variables described the survey environment and animal behavior. A high resolution video camera, mounted in a belly porthole, was used to record sightings on and near the trackline. Cetacean sightings were circled, sometimes for periods exceeding 30 minutes, and 35 mm cameras and SVHS video cameras with telephoto lenses were used to document the sightings.

RESULTS AND DISCUSSION

Sightings were made most frequently in the DeSoto and Mississippi Canyon study areas and least frequently in the Sea Mountain study area (Table 4.3). During the course of the pilot study we identified 11 species or types of deep water cetaceans in the 4 study areas.

"Spotted" Dolphin types (*Stenella frontalis* and/or *S. attenuata*)

We observed about 1,260 dolphins in 27 herds. Twenty-two of the herds were sighted in water less than 540 m deep. Spotted dolphins were sighted every survey month but were least common in November. Spotted dolphins were sighted in all study areas. Fritts et al. (1983) thought spotted dolphins were the most common deep water cetacean in the Gulf. At least in water from 180 to 720 m deep, our data suggests this statement may be correct.

"Spinner" Dolphin types (*S. longirostris*, *S. coeruleoalba*, and/or *S. clymene*)

We observed about 600 spinner dolphin types in 6 herds. Four of the herds were sighted in November. No herds were sighted in the Sea Mountain study area. Herds occurred in water from less than 360 to grater than 1,080 m deep. Fritts et al. (1983) identified one herd of spinner dolphins in their south Texas study area.

Common dolphins (*Delphinus delphis*)

We observed about 680 dolphins in 9 herds. Common dolphins were only sighted in the Mississippi River Cliff and DeSoto Canyon study areas and were not sighted during the July surveys. Herds were sighted in water from 180 to greater than 1,620 m deep. Fritts et al. (1983) did not identify any common dolphins during their surveys.

Risso's Dolphins (*Grampus griseus*)

We sighted 154 Risso's dolphins in 14 herds; 11 of the herds were sighted in July and August. Herds were sighted in all study areas but were most common in the Mississippi River Cliff study area (seven herds). Herds were sighted in water from 180 to 720 m deep. Jennings (1982) reported 5 Risso's dolphin herds were sighted in Gulf waters from 200 to 1,800 m deep.

Short-finned Pilot Whales (*Globicephala macrorhynchus*)

We sighted 5 herds of pilot whales that totaled about 91 animals. One herd was sighted in August in the Sea Mountain area in water about 450 m deep. These whales were associated with Risso's dolphins. The other 4 herds were sighted in November in the Mississippi River Cliff study area in water ranging from 540 to 900 m deep. Fritts et al. (1983) identified pilot whales in their Texas and Louisiana study areas.

Table 4.3. **Deep-water cetacean sighting rates per 100 km of transect in four study areas from July through November 1989. (A dash [---] indicates that the area was not studied. Numbers in parenthesis are monthly study effort [100 transect km]).**

Study Area	1989 Study Month				
	July	August	September	October	November
River Cliff	1.0 (8.4)	2.4 (6.8)	2.3 (9.6)	2.3 (5.7)	1.1 (9.2)
Miss. Canyon	1.8 (4.4)	1.6 (4.5)	1.5 (4.0)	1.8 (5.0)	5.4 (1.7)
Sea Mountains	1.3 (4.0)	1.2 (4.9)	1.0 (4.1)	---	1.2 (1.6)
DeSoto Canyon	---	---	4.0 (1.8)	2.0 (3.6)	1.7 (5.4)

False Killer Whales (*Pseudorca crassidens*)

During the August surveys we sighted one herd of three whales. The herd was in the Mississippi River Cliff area in water about 1,000 m deep. Fritts et al. (1983) did not recognize any false killer whales in the Gulf.

Pygmy Killer Whales (*Feresa attenuata*)

During the August surveys we sighted one herd of 25 whales in the Mississippi Canyon study area. The herd was in water about 300 m deep over the west wall of the canyon and was associated with a herd of Risso's dolphins. Fritts et al. (1983) sighted one herd of pygmy killer whales during their southern Texas surveys.

Pygmy and Dwarf Sperm Whales (*Kogia simus* and *K. breviceps*)

We sighted 16 groups of *Kogia* that totaled 32 whales. Nine groups were sighted in the Mississippi Canyon study area and all but one were in water about 360 to 540 m deep over the west wall of the canyon. No *Kogia* were sighted in the Sea Mountain area. Three *Kogia* sighted in the DeSoto Canyon appeared to be smaller and more sleek than other *Kogia* sighted; they may have been *K. simus*. Fritts et al. (1983) did not report any *Kogia* sightings from their Gulf surveys.

Sperm Whales (*Physeter macrocephalus*)

Sperm whales were sighted 27 times and totaled 63 whales. Twenty-three of the sightings and 59 of the whales were sighted in the Mississippi River Cliff study area. Herd sizes ranged from one to eight whales and included three cow and calf pairs. Almost all of these sightings were in water ranging from about 700 to 920 m deep. Three sperm whales were sighted in the DeSoto Canyon and one whale was sighted in the Mississippi Canyon. Most sightings were in September and October. Collum and Fritts (1985) reviewed 17 sightings of 59 whales. Their herd sizes ranged from one to 14 whales. Most of the whales they sighted were in water greater than 200 m deep. Gulland (1974) thought sperm whales were most common near areas of upwelling and high productivity. Perhaps the Mississippi River Cliff area, where water depths ranged from about 720 to 920 m, was an area of high productivity during the September and October surveys.

Beaked Whales (*Mesoplodon* spp. and *Ziphius cavirostris*)

Three species of *Mesoplodon* (*M. densirostris*, *M. europaeus*, and *M. bidens*) have been documented in the Gulf. We sighted eight unidentified beaked whales in six herds. Beaked whales were observed in all of the study areas but were not sighted in October. One beaked whale in the DeSoto Canyon was photographed and identified as *Z. cavirostris*. This whale was in water about 1,800 m deep. Fritts et al. (1983) sighted unidentified beaked whales three times during their southern Texas surveys.

Fin Whale (*Balaenoptera physalus*)

Only one baleen whale was sighted during the pilot study. During the November surveys, a large baleen whale was photographed and identified as a fin whale in the DeSoto Canyon study area. The whale was observed in water about 180 m deep. Fritts et al. (1983) did not sight any baleen whales in the Gulf of Mexico.

SUMMARY

We used aerial surveys to study four areas of the north-central Gulf of Mexico from July through November 1989. Each area had high relief in sea floor topography. Water depths ranged from less than 90 to over 1,800 m. Not counting unidentified cetacean sightings, we made 113 sightings that totaled about 2,900 dolphins and whales. Average sighting rates ranged from about 1.2 to 2.5 sightings per 100 transect km. Ten species or types were sighted in August, nine in November, six in September, and five in July and October. Among study areas, nine species or types were sighted in the Mississippi River Cliff, eight in the DeSoto Canyon, seven in the Mississippi Canyon, and four in the Sea Mountain study areas. We concluded that aerial surveys are an efficient method of studying the distribution, seasonality, and relative abundance of deep water cetaceans in the Gulf of Mexico. Continued cooperative research in 1990 will study a larger portion of the north-central Gulf of Mexico.

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THE GULF OF MEXICO PROGRAM MOBILE BAY DEMONSTRATION PROJECT

Dr. Frederick C. Kopfler
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INTRODUCTION

The environmental problems of the Gulf of Mexico are the result of broad regional activities and consequently require broad-based regionally coordinated efforts to mitigate or resolve them. While the effects of environmental degradation in the Gulf are manifested locally, they result from sources and activities that are regional, national, and international in nature. Currently, there are no effective regionally focused institutional procedures to address them; instead there are a number of state, local, and Federal agencies working under the auspices of individual environmental statutes.

The Gulf of Mexico Program was established by the U.S. Environmental Protection Agency (EPA) in August, 1988 to develop and implement a comprehensive strategy for managing and protecting the resources of the Gulf. It is an effort to achieve a balance between the needs and demands of modern society and the preservation and enhancement of the Gulf's living marine resources. The Gulf Program provides a mechanism for addressing complex problems that cross state and federal jurisdictional lines and a focal point for better coordination among federal, state, and local programs affecting the Gulf. Through these efforts the effectiveness and efficiency of pollution control measures and resource management will be enhanced. The agencies involved, recognizing the need for coordination of these activities, have supported the establishment of the Gulf of Mexico Program as a vehicle for this purpose.

Therefore, a principal element of the Gulf of Mexico Program is the development of an institutional structure that will:

- provide a mechanism for addressing complex problems in the Gulf of Mexico that cross federal, state, or international jurisdiction;
- provide systematic coordination among federal, state, and local programs affecting the Gulf which will increase the effectiveness and efficiency of long-term efforts to manage and protect Gulf resources;
- provide a regional perspective to identifying information needs and subsequent direction to research efforts with ultimate utility for managing and protecting Gulf resources; and
- provide a forum for affected user groups, public and private educational institutions, and the general public to participate in the resolution of problems.

A second principal element of the Gulf of Mexico Program is the development of a regional framework for action through the newly comprised institutional structure. It is envisioned that this framework for action will consist of management options for resolving selected environmental problems through implementation of federal and state regulatory controls, enlistment of public and private participation, and provision for direction of research and information gathering efforts.

Therefore, the Framework-for-Action Plan will address the following general areas with greater specificity in programmatic direction being identified as the communication process matures:

- assessment and characterization of environmental problems in the Gulf of Mexico;
- selection of key Gulf of Mexico environmental issues having a reasonable prospect of solution;
- establishment of an interactive database system for use in scientific and regulatory determination; and
- development of management control options for resolution of environmental problems.

PROGRAMMATIC OBJECTIVES AND GOALS

The principal goals of the Gulf of Mexico Program are as follows.

Goal I--Establish an effective infrastructure for resolving complex environmental problems associated with man's use of the Gulf of Mexico.

Objective 1: Establish and provide support to a Gulf of Mexico Program Office.

Objective 2: Establish and implement a Gulf of Mexico Program committee structure.

Objective 3: Establish a public education network that includes information transfer, educational outreach, and participation activities.

Goal II--Establish a Framework-for-Action for implementation of management options for pollution controls, remedial and restoration measures for environmental losses, and for research direction and environmental direction and environmental monitoring protocol.

Objective 1: Prepare environmental characterizations.

Objective 2: Prepare environmental assessments.

Objective 3: Develop an interactive data management system.

Objective 4: Develop predictive assessments.

Objective 5: Develop and implement a Gulf of Mexico Environmental Management Plan.

Objective 6: Develop and implement a Gulf of Mexico Monitoring Plan.

PROGRAM STATUS

During the first year of the Gulf Program a significant effort was focused on forming an effective infrastructure and informing participants about potential roles and responsibilities. A Gulf of Mexico Program Office was established in August, 1988 at the John C. Stennis Space Center, Mississippi and Dr. Douglas Lipka was selected as Director. The three committees making up the principal infrastructure were formed and convened by December. These committees and their responsibilities are:

- Policy Review Board--The Policy Review Board consists of senior level representatives from state and Federal agencies across the Gulf and representatives from the Technical and Citizens Committees. This board, chaired by the EPA Regional Administrators, guides and reviews the overall activities of the Program. The board approves program goals and objectives and establishes priorities and direction for the program. The Policy Review Board provides broad-based support for the program in all policy and political matters while leaving operational duties to the other working committees.

- Citizens Advisory Committee--The Citizens Advisory Committee is comprised of representatives of five areas in the public sector (environment, agriculture, business/industry, tourism/development, and fisheries) from each of the five Gulf coastal states. Each citizen representative was selected by the governor of his respective state. This committee provides a mechanism for structured citizen input into the program from their respective states and areas of interest. They assist in dissemination of information relevant to the goals and results of the program. The committee is also active in public outreach and consensus building and implementation of program strategies.

- Technical Steering Committee--The Technical Steering Committee is comprised of representatives of state and federal agencies, academia, and private and public sectors. The Technical Steering Committee's principal responsibility is to provide technical support to the Policy Review Board in the form of development and evaluation of environmental issues and development of program options. This committee provides advice and guidance related to research, data management, modeling, and sampling and monitoring efforts that affect the scientific adequacy of the program. The committee conducts peer review of studies, reports on the status and trends in the Gulf, and alerts the Policy

Review Board to emerging environmental issues. The Technical Steering Committee has established a standing subcommittee to address each of the following issues: habitat degradation, nutrient enrichment, toxic substances and pesticides, marine debris, freshwater inflow, public health, coastal erosion, public education and outreach, and data and information transfer.

MOBILE BAY DEMONSTRATION PROJECT

At a meeting of the Technical Steering Committee (TSC) in March, 1989, acting on a proposal of the Data and Information Subcommittee, recommended that a prototype project be initiated to focus existing but disparate data and information on a single decisionmaking problem in a specified area of the Gulf. This project would serve as a model for developing such a system on a small scale which could later be used as the basis for the establishment of an interactive database system for use in scientific and regulatory determination. This project supports one of the objectives of the Gulf of Mexico Program.

After discussions among members of the TSC, a decision was made to develop a user-friendly geographical information system (GIS) that could be used to address the cumulative effects of natural processes, Section 404 permitted activities and other human activity on wetlands in the vicinity of Mobile Bay, Alabama. The principal agencies participating are the EPA, U.S. Fish and Wildlife Service (FWS), U.S. Army Corps of Engineers (COE), the National Marine Fisheries Service (NMFS), the Soil Conservation Service (SCS), National Aeronautics and Space Administration (NASA),Alabama Department of Economic and Community Affairs (ADECA) Alabama Department of Environmental Management (ADEM), and numerous other state and local agencies.

After identification of the problem area, numerous meetings were held in April and May to finalize the proposed project. Guidelines were: (1) the project should demonstrate that information brought together in a single information system can be applied in a more systematic, consistent, and useful way; (2) the project should demonstrate how various agencies can pool both monetary and human resources to better address wetland issues in the Bay; and (3) the preliminary results should be completed for presentation at the proposed International Symposium on the Status of the Gulf of Mexico in December 1990.

The objective of this effort is to develop and demonstrate a wetland regulatory and resource management system for the Mobile Bay area which (1) utilizes automated wetland and permit inventories; (2) enhances determination of cumulative losses; and (3) aids in identifying appropriate needs for mitigation, restoration, and enhancement. The project has three major tasks: (1) establishment of a Mobile Bay wetland digital database; (2) development of a regulatory (Section 404 permits) database for the Bay; and (3) development of a user-friendly GIS system that will allow these two databases to be overlaid along with others. Features of the project include the development of a comprehensive digital database on wetlands for 1956, 1979, and 1988-89 and Section 404 permits for use by numerous federal and state agencies. The primary GIS to be utilized will be the ARC/INFO system.

Using this system, agencies will be able to determine wetland losses between the mid 1950's and late 1980's, locations and types of losses, and better determine if the causes and changes of loss are a result of various man-induced activities and natural loss. Lastly, since the cost to produce digitized maps from aerial photographs for a GIS is costly and time-consuming, one of the tasks will explore the validity and cost-effectiveness of wetland geo-referenced data from LANDSAT thematic mapper (TM) imagery. Recently acquired TM data will be classified and compared to 1989 wetland maps to determine their validity in use for regulatory decisions.

During the first year of the project, the following agencies will be responsible for completing the following and contributing funds, as well as personnel, for the tasks.

- EPA will be responsible for coordinating the overall effort and will take the lead in development of the user interface for the GIS and in the feasibility study to determine the validity of using TM data for wetlands mapping. EPA will provide funds to update the existing wetlands digital database for the western and eastern portions of Mobile

Bay and to remake selected portions of the 1956 wetland digital database which was deemed unusable due to drought conditions that prevailed when the photographs were taken.

- FWS will arrange to have the maps made by their contractor and will provide funds and personnel for quality control of maps and digital databases being prepared. FWS will be responsible for transferring the digital databases to other agencies. FWS will also provide other digital databases on selected biological information and other available features for use in the project. FWS will assist EPA in development of the GIS and the TM effort.

- COE will provide funds and personnel to complete the computerized database on Section 404 permits in selected U.S. Geological Survey (USGS) quadrants for use in the GIS. In order for the demonstration project to be successful, historical permit information must be entered for at least the past five years. However, 10 years is preferred to assess wetland changes between 1979 and 1989.

- SCS will digitize the medium intensity standard soil survey maps of the study area and provide this data to the other agencies.

- ADECA will provide funds to update existing wetland digital database for the northern portion of the Bay. They will have lead responsibility for coordination of databases and information to other state and local agencies.

- ADEM and NMFS are providing advice from the user perspective and NMFS is also providing advice and expertise on GIS development.

- NASA is providing satellite imagery and software and assistance in processing of the raw data.

For the first year of the project, emphasis is on developing an operational GIS covering eight 7.5 minute USGS quadrangles in the upper bay. This geographic area was selected because it includes a wide variety of wetland types and a high number of permit actions. This can be used to demonstrate the usefulness of the system in managing the wetland resources of the bay, such as reviewing Section 404 permits at the Status of the Gulf Symposium in December, 1990.

In subsequent years, the effort will focus on completing the wetland and regulatory digital databases for the Bay, analyzing effectiveness of TM data for wetland mapping and establishing GIS user system for federal, state, and local agencies.

Dr. Frederick Kopfler serves as Chief Scientist for the EPA's Gulf of Mexico Program Office, at Stennis Space Center, Mississippi. He earned his B.S. in chemistry at Southeastern Louisiana University, and his M.S. in biochemistry and Ph.D. in food sciences from Louisiana State University, Baton Rogue. He performed post-doctoral research on the chemistry of milk proteins at the U.S. Department of Agriculture's Philadelphia Agricultural Research Service laboratory; worked on oyster and shellfish issues for the Public Health Service at Dauphin Island; and worked at several laboratories of the EPA's Office of Research and Development on public health aspects of wastewater and drinking water. He joined the EPA Gulf of Mexico Program Office in 1988.

EDUCATION AND AWARENESS: KEYS TO SOLVING THE MARINE DEBRIS PROBLEM

Ms. Kathy O'Hara
and
Ms. Patty Debenham
Center for Marine Conservation

The Center for Marine Conservation (formerly known as the Center for Environmental Education) is a non-profit conservation organization. The Center for Marine Conservation (CMC) currently conducts a national education campaign on the problems caused by plastic debris in the marine environment. The campaign includes the development and distribution of educational materials to the commercial fishing, merchant shipping, and plastics industries as well as to recreational fishermen, pleasure boaters, and the general public. This program is sponsored in part by the National Oceanic and Atmospheric Administration's (NOAA) Marine Entanglement Research Program and the Society of the Plastics Industry. Under contract to NOAA, CMC operates NOAA's Marine Debris Information Office to distribute information about marine debris. CMC also administers the National Marine Debris Data Base. With support from NOAA, the U.S. Coast Guard (USCG), and the Environmental Protection Agency (EPA), in 1989 CMC distributed 70,000 data cards to volunteers in all 25 coastal states. Information obtained from volunteer data collection efforts will become part of CMC's national analysis of marine debris data.

DISCUSSION

There is virtually unanimous agreement that education is necessary to motivate groups and individuals to properly dispose of plastics and marine debris. Several international conferences have stressed the need for marine debris education programs, including the 1984 International Conference on the Fate and Impacts of Marine Debris, the North Pacific Rim Fishermen's Conference on Marine Debris, and the Oceans of Plastic Fishermen's Workshop. Federal legislation entitled the Marine Plastic Pollution Research and Control Act of 1987 mandates that the NOAA and the EPA conduct a three-year public education program. The 1989 Interagency Task Force on Marine Debris encourages marine debris education, "Concerned federal agencies should work with each other, state and local governments, private industry, and environmental groups to develop comprehensive educational materials on problems caused by marine debris and on ways to solve those problems (Interagency Task Force on Persistent Marine Debris 1988)."

Marine debris is an international problem that impacts marine wildlife, coastal economics, and boater safety. In 1974, the National Academy of Sciences estimated that 14 billion pounds of litter are dumped into the oceans every year. That's almost three times the weight of all fish and shellfish caught in the U.S. in one year. A more recent study estimates that the world merchant shipping fleet alone dumps more than 5.5 million metal, glass, and plastic containers into the ocean every day. Recreational vessels also contribute to the problem. The USCG estimates that 1.5 pounds of trash is dumped every time a boat goes out for a cruise. Other contributors to the marine debris problem are the U.S., international navies, commercial fishermen, and various Gulf industries.

The problem of plastics in the ocean is more than a litter problem. Plastic trash kills wildlife.

Northern fur seals were once so abundant they were commercially harvested. In recent years, scientists have documented that 30,000 northern fur seals die each year as a result of entanglement. For marine animals, entanglement is just part of the problem. Many animals also die from eating plastic. Sea turtles have been shown to mistake plastic bags for one of their favorite food items, jellyfish. Eighty of the worlds 280 seabird species have been shown to eat plastic, mistaking it for real food and vessel disablements have burdened Gulf fishermen with costly delays and repair bills. In some instances entanglement can endanger human safety. Many coastal communities are suffering economic burden as a result of dirty beaches.

CMC knows that education will be the most effective method to alter 4,000 years of ocean disposal behavior. When mariners realize and understand the effects that their age-old habits have on wildlife, human, and vessel safety, they are willing to make a change.

Since 1985, CMC has developed a unique education campaign that encourages all members of industry, the general public, and the maritime community to get involved. CMC publishes documents, organizes beach cleanups, and responds to requests for information that encourages groups and individuals to take part in the solution to ocean pollution.

Prior to 1984 there were only a handful of programs working to teach people about the problem of marine debris. Judie Neilson's "Get the Drift and Bag It" campaign was not only the first marine debris education program, but also a highly successful coastal cleanup in Oregon (Neilson 1985).

In 1986, the EPA commissioned CMC to prepare a report on the plastic debris problem in the marine and Great Lakes waters of the U.S. As the first comprehensive review of available information on marine debris, this document showed that plastic debris is a nationwide problem for marine wildlife. The report identified the major ocean and land-based sources of plastic debris, and indicated that the total amount of debris generated by these sources is unknown. The report noted the absence of appropriate laws to address the plastic debris problem (CMC 1987a). Finally, the study helped to redirect attention from general marine debris to those problems caused specifically by plastic items.

Upon completion of the document, CMC presented the report to members of the Society of the Plastics Industry (SPI). CMC explained that plastic debris was threatening wildlife and vessel safety in addition to being unsightly. The Plastics Industry accepted CMC's invitation to become part of the solution. The result has been the development of numerous brochures, books, and posters geared at promoting proper disposal of plastics at sea.

CMC's most successful efforts have been our citizen beach cleanups in Texas, Florida, and California. Volunteers work in pairs to share the tasks of debris collection and data recording. From volunteer data, CMC published two reports on the Texas debris problem (CMC 1987b, CMC 1988a). Our work that started in 1986 in Texas has now spread to all Gulf states. Texas now has a thriving Adopt-a-Beach program and all 5 states participate in the Gulf's "Take Pride-Gulf-Wide" effort during the fall beach cleanups.

From 1986 to 1988 CMC organized the largest beach cleanups in American history accounting for one-third of the nation's total participation. These cleanups are also the perfect example of CMC's efforts to involve diverse groups working toward a common goal. Industry provides financial and in-kind support; for example, Mobil Chemical provided free garbage bags to all beach cleanups in the Gulf states. Government and environmental organizations act as regional coordinators; all these groups, and the general public remove trash from the beaches.

Since 1984, there has been a steady growth in beach cleanup participation (Figure 4.2). In 1984 Judie Neilson encouraged 2,100 Oregonians to clean the beaches. Nationwide during COASTWEEKS '89, more than 65,000 people participated in coastal cleanups. In 1990 we hope to encourage 100,000 citizens to clean the beach.

A beach cleanup is not just a one-day event, but rather an ongoing education campaign. CMC's volunteer data collection system is one mechanism that ensures continuing education. Beach cleanup data helps identify possible sources and quantifies the amounts of debris found by volunteers. Each cleanup volunteer receives a data card and a Guide to Good Data Collection. The data card lists 65 items volunteers will likely collect during a beach cleanup. The Guide explains the importance of data collection and describes items that are found on most beaches yet are difficult to identify. For example, not many volunteers can recognize write-enable protection rings used by vessels conducting seismic exploration activities in the Gulf.

In 1988, CMC expanded its Texas data collection efforts to establish a National Marine Debris Data Base. With support from the EPA, NOAA, and the USCG, CMC distributed 70,000 data cards to cleanup volunteers in all 25 coastal states. In addition, Spanish data cards were sent to cleanups in Puerto Rico, Mexico, and the Virgin Islands. The resulting data base is providing essential information for understanding specific debris problems in each part of the country. Information about the types and amounts of trash found during the 1988 National Beach Cleanup is available from CMC (1989) in a report entitled *Cleaning America's Beaches: 1988 National Beach Cleanup Results*.

CMC's data base relies on volunteer cooperation and we realize it is not the same as a rigorous scientific survey. Nonetheless, CMC's data gives consistent perspectives of the problem and indicates some common trends. For example, in all states plastics account for 62% of all debris types collected. Other items such as metal and glass are less abundant. In some cases it is possible to attribute certain types of beach debris to a specific source. CMC labels these materials as "indicator items." For example, volunteers found 4,170 plastic light sticks on Texas beaches in 1987. Fishermen commonly use light sticks to attract fish to their hooks. Nationwide last year, these groups contributed at least six percent of all trash items collected. Recently CMC has begun working with the passenger cruise line industry to insure that beach cleanup volunteers don't find trash

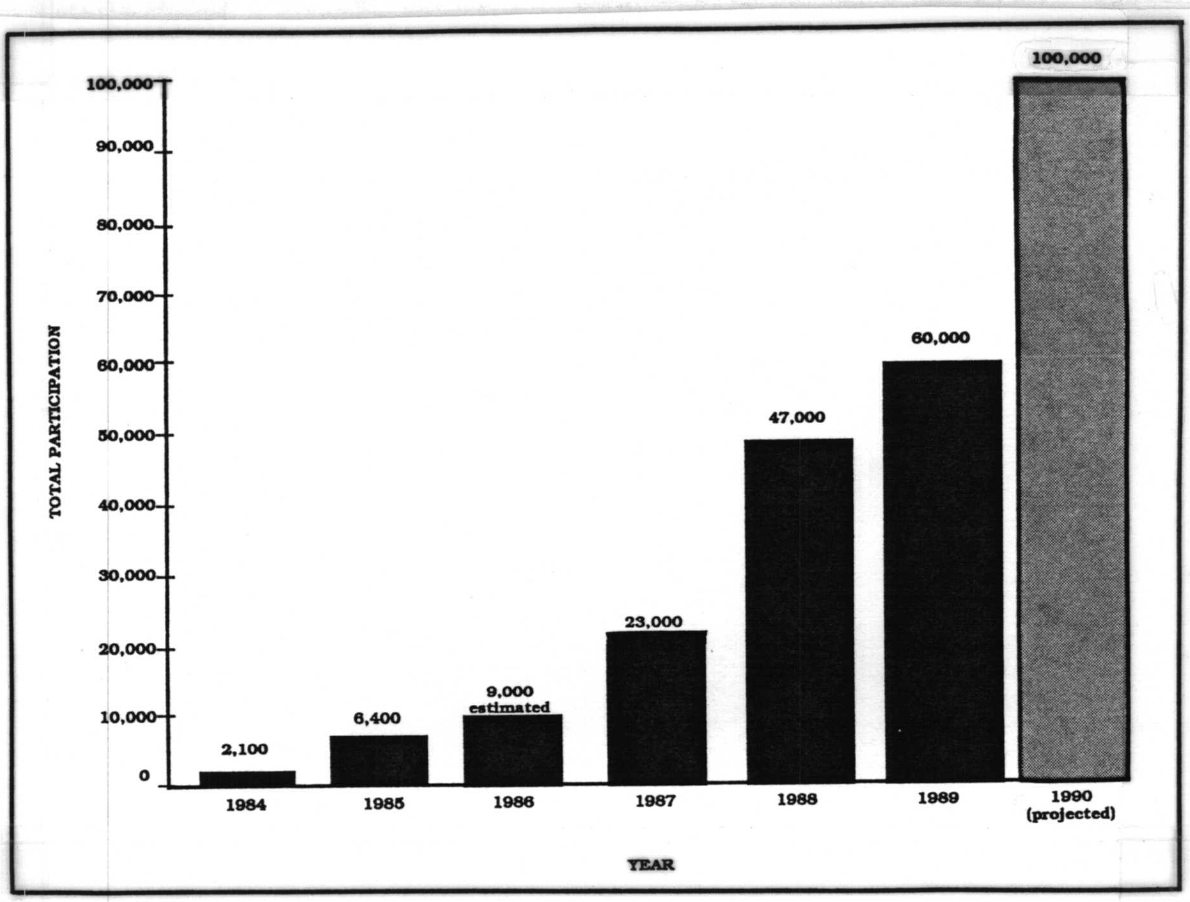

Figure 4.2. Participation in National Beach Cleanups - 1984-1990.

items such as those listed in Table 4.4 that were collected during the 1989 Florida Coastal Cleanup. Although it is counter productive to point accusatory fingers, CMC uses indicative data to encourage possible debris contributors to become active contributors to the solution.

In 1988, Florida volunteers collected 304 miles of monofilament fishing line. This information showed us that we need to encourage recreational fishermen to keep their trash on board. Subsequently, CMC conducts "Stow It, Don't Throw It" activities to encourage fishermen to bring back their trash and monofilament fishing line.

Press generated from a cleanup also helps maintain the long term education effects. Media generated from a cleanup reaches people who may not donate their Saturday morning to clean the beach, but may unconsciously discard their boat or beach trash. CMC uses the media to remind the public that their plastic trash can have disastrous effects on marine wildlife.

Coastal Cleanup reports and current data are available through NOAA's Marine Debris Information Office. Under contract to NOAA, CMC operates two Marine Debris Information Offices (MDIO). The first is in Washington, D.C. to serve the Atlantic Coast and Gulf of Mexico. The second in San Francisco, California responds to Pacific Coast inquiries. NOAA created these offices in response to a growing number of requests for information on the marine debris problem. NOAA's MDIO functions to disseminate educational materials and other information on marine debris to government agencies, industry groups, educators, the press, and the general public. In most cases requests for information fall into specific categories. To efficiently respond to these requests we developed 15 standardized educational packets:

Table 4.4. Debris from cruise lines reported during 1989 Florida cleanup.

CRUISE SHIP INDICATED	TYPE OF DEBRIS[1]
Chandris Fantasy Cruise Lines	whole bag of debris; plastic cups; cans; other garbage (near Marathon Key); name on cups (near Marathon Key)
Crown	shampoo bottle and cups
Holland America	shampoo bottles and cups
SS Norway	toiletries; caps and lighters
Norwegian	cups
Premier	shampoo bottles
Princess	item not identified
Royal Caribbean	shampoo bottles; cups; bottle; pencil
Starlite Princess	napkins

[1] Information reported by regional beach cleanup coordinators ("Zone Captains").

- General Public
- Teachers and Educators
- Elementary (K to 5th grade) Middle School, High School (6th to 12th grade) and College Students
- Beach Cleanup Information
- Recreational Fishermen and Boaters
- Press and Media Personnel
- Plastics Recycling and Degradable Plastics Information
- Cruise Ship Passengers
- Fishermen and Fish Processors
- Cargo Vessel Operators and Crews
- Offshore Oil and Gas (companies)
- Offshore Oil and Gas (workers)
- Plastics Manufacturers and Resin Pellet Producers
- Port and Terminal Operators
- Charter Vessel Operators

All packets contain general information about the marine debris problem with additional information specific to the requestor's interest. From the establishment of the MDIO in October 1988 until October 1, 1989, CMC responded to over 6,000 requests for information including 2,000 requests for large amounts of materials that they in turn distributed to members of their group.

Also available from NOAA's MDIO are numerous education materials developed by NOAA, SPI, and CMC as part of a national campaign to promote the proper disposal of plastics.

Chronologically, the first element of the joint educational campaign consisted of print public service advertisements developed for commercial fisheries, merchant shippers, the plastics industry, recreational boaters, and recreational fishermen. To date these ads have appeared in 30 magazines and major trade journals in addition to several regional and local publications including National Fisherman, Marine Log, Modern Plastics, Outdoor Life, and Saltwater Sportsman. Each advertisement directs interested persons to contact the MDIO for more information about marine debris. The MDIO in turn responds to each request by sending the appropriate information packet and relevant materials.

Each public service advertisement has a corresponding eight-panel brochure with more information on how marine debris affects their group. For example, commercial fishermen may be more interested in the fact that discarded gill nets will foul their propeller rather than the effects it may have on a seal, that in some cases are viewed as competitors. Groups often request large quantities of brochures for their own distribution. To date, the MDIO distributed over 200,000 brochures to educators, individuals, and the government including 15,000 National Safe Boating Week press packets, 8,000 for National Fishing Week, and the 3,000 to USCG Port Captains.

The Citizens Guide to Plastics in the Ocean: More Than a Litter Problem is another product of the cooperative NOAA/SPI/CMC campaign that is now available through the MDIO (CMC 1988b). The book informs citizens of the growing problem of plastics in the ocean and gives suggestions on how individuals can become involved in solving this problem. We have distributed 30,000 copies of this guide since September 1988 including 5,000 copies to the U.S. Navy as part of their educational package on marine debris. This education program will be especially useful on the U.S.S. Lexington based out of Pensacola, Florida. Beginning in the spring of 1990 the U.S.S. Lexington will begin a zero-discharge demonstration program. This demonstration program is concurrent with discussions by the USCG and the International Maritime Organization to designate the Gulf of Mexico as a "Special Area." "Special Area" designation would prohibit dumping of any trash in Gulf waters.

Recently, CMC obtained permission to use the cartoon character of Popeye the Sailor in our marine debris materials. As a result, CMC has distributed 39,000 copies of a poster that has Popeye saying "I Hopes Ya Swabs Won't Be Throwin' No Plastics Overboard." In addition, CMC produced a 30-second television public service announcement that will be released to air during the summer of 1990.

The MDIO also distributes materials produced by other groups. Fran Recht's *Reference Guide for Ports* is a valuable source of information on how ports can comply with the requirements of MARPOL Annex V and the U.S. Marine Plastics Pollution Research and Control Act.

CMC staff believe each person requesting information is a potential grassroots organizer able to educate others about the problems of plastic debris. We cultivate each request and act to network people and information. CMC will be happy to work with any group that wants to produce their own educational materials, background statistics, information, or graphic materials on marine debris.

CMC makes one primary assumption in its approach to solving the marine debris problem. CMC believes that education will motivate people to alter any harmful disposal behavior. Enforcement of international and national legislation will be very difficult. Marine debris research is both expensive and difficult to conduct in the ocean environment. CMC feels that education in the form of publicity, books, and if possible hand-on education events such as beach cleanups will encourage people to keep harmful trash out of the water.

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Ms. Patty Debenham is the Director of MDIO at the CMC. Previously, she was a research associate at Science Applications International Corporation where she supported projects for the EPA Office of Marine and Estuarine Protection. After graduating with a degree in marine biology from Stanford University in 1985, Ms. Debenham received two scholarships that sent her to teach SCUBA diving in the Cayman Islands, and work with a documentary film crew in Patagonia, Chile.

Ms. Kathy O'Hara is a marine biologist with CMC. She was co-author of a study on plastic debris for the EPA and scientific coordinator for CMC's 1986 and 1987 Texas Coastal Cleanup Program. Ms. O'Hara received her bachelor's degree in zoology in 1982 from Duke University and her master's degree in marine biology in 1985 from the College of Charleston, South Carolina.

MISSISSIPPI/ALABAMA SHELF
MARINE ECOSYSTEMS STUDY

Session: MISSISSIPPI/ALABAMA SHELF MARINE ECOSYSTEMS STUDY

Co-Chairs: Dr. Robert M. Rogers
Dr. Robert M. Avent

Date: December 6, 1989

Presentation	Author/Affiliation
Mississippi/Alabama Shelf Marine Ecosystems Study: Session Overview	Dr. Robert M. Rogers and Dr. Robert M. Avent Minerals Management Service Gulf of Mexico OCS Region
Mississippi/Alabama Marine Ecosystem Study	Dr. James M. Brooks Geochemical and Environmental Research Group Department of Oceanography Texas A&M University
The Mississippi/Alabama Marine Ecosystem Study Sediment Characterization	Dr. Mahlon C. Kennicutt II Geochemical and Environmental Research Group Texas A&M University
Mississippi/Alabama Shelf Marine Ecosystem Study: Physical Oceanography Characterization	Mr. Frank J. Kelly Civil Engineering Department Texas A&M University and Dr. A.C. Vastano Department of Oceanography Texas A&M University
Geological Characterization of the Mississippi/Alabama Marine Ecosystem Study Area	Dr. William W. Schroeder Marine Science Program The University of Alabama, Dr. W.W. Sager and Dr. Richard Rezak Department of Oceanography Texas A&M University
Biotic Assemblages on Topographic Features of the Louisiana/Mississippi/Alabama Continental Shelf	Dr. Stephen R. Gittings, Dr. Thomas J. Bright, Mr. Ian R. MacDonald Department of Oceanography Texas A&M University and Dr. William W. Schroeder Marine Science Program The University of Alabama

Session: MISSISSIPPI/ALABAMA SHELF MARINE ECOSYSTEMS STUDY (cont'd)

Presentation	Author/Affiliation
Macroinfauna and Macroepifauna of the Mississippi/Alabama Continental Shelf	Dr. Donald E. Harper, Jr. Marine Laboratory Texas A&M University at Galveston
Mississippi/Alabama Marine Ecosystems Study Summary/Synthesis	Dr. Rezneat Darnell Department of Oceanography Texas A&M University

MISSISSIPPI/ALABAMA SHELF MARINE ECOSYSTEMS STUDY: SESSION OVERVIEW

Dr. Robert M. Rogers
and
Dr. Robert M. Avent
Minerals Management Service
Gulf of Mexico OCS Region

Early in the planning process for this studies series, the Minerals Management Service (MMS) recognized that the Mississippi/Alabama region was an area of unique resources requiring special environmental protective considerations. Concentrated in this relatively small area are productive commercial and recreational fisheries, significant tourism and recreational interests, and waterborne transportation systems including well-developed ports and harbors. In light of increasing outer continental shelf oil and gas development interest in this area, the MMS initiated a data search and synthesis study to provide an information base for the planning of needed data gathering efforts. In 1985 this culminated in a report and atlas entitled the "Tuscaloosa Trend Regional Data Search and Synthesis Study."

From this information base, study needs were identified and in 1986 a multi-year, multi-disciplinary project was begun to address these information gaps. A contract was awarded to Texas A&M University to carry out the field effort and subsequent sample analysis and information synthesis. This study is now entering the final year of a three year study effort. All field efforts have been completed and current meter arrays were removed in February 1990. The program is now entering a synthesis phase where results from the different project aspects (hydrocarbons, trace metals, sedimentology, satellite imaging, current movements, infaunal numbers and variability, macroepifauna, and demersal fishes) are being correlated to observe relationships in environmental processes.

In the early planning stages of this study it was thought that the Mississippi/Alabama continental shelf was a relatively homogeneous study area consisting mainly of a mud bottom environment occasionally punctuated by a number of sharply rising topographic features previously termed pinnacles. This has proven to be far too simplistic. There is a vast array of topographic features ranging from small rock outcrops to high relief pinnacles harboring extensive live bottom communities and diverse fish populations. Processes on the mud bottoms are complex with extensive seasonal changes in sediment composition, benthic chemistry, and biological diversity probably explained by active currents and storm events. Interpretations of the data are presently at a draft stage of development and are subject to a great deal of further synthesis.

Dr. Robert M. Rogers has served as Contracting Officer's Technical Representative (COTR) on numerous marine ecosystem studies, including the Mississippi/Alabama Marine Ecosystem project. His graduate work in trophic interrelationships among Gulf marine fishes led to a Ph.D. from Texas A&M University. He has been with the MMS/Bureau of Land Management (BLM) environmental studies program since 1977.

Dr. Robert M. Avent received the M.S. and Ph.D. degrees in biological oceanography from Florida State University in 1970 and 1973. His main fields of interest include marine physiological ecology and deep-sea biology. He has pursued investigations on the biological effects of hydrostatic pressure, animal zonation, and reef morphology. He has worked in the consulting industry and for state government. He came to the MMS/BLM in 1981 from the National Marine Fisheries Service.

MISSISSIPPI/ALABAMA MARINE ECOSYSTEM STUDY

Dr. James M. Brooks
Geochemical and Environmental
Research Group
Department of Oceanography
Texas A&M University

An organizational plan for the Mississippi/Alabama Marine Ecosystem Study (MAMES) was presented and discussed. The MAMES study is being managed by Dr. Jim Brooks in the Geochemical and Environmental Research Group (GERG) at Texas A&M

University. Principal investigators for the biological, geological, chemical, and physical oceanography components are drawn from GERG, the Department of Oceanography, Civil Engineering Department, and Texas A&M University at Galveston. The study is currently entering the last year of a three year study. A summary synthesis effect will be developed during this third year.

The four major headings of the Summary/Synthesis effect will include: The Natural System, Human Effects, Sensitive Biological Areas, and Knowledge Gaps. Heavy emphasis will be placed upon understanding the composition and process of the natural system in relation to external driving mechanisms. Historical data suggest that there are two basic scenarios for control of the shelf ecological systems: those which operate in regular cyclic fashion versus those which involve massive episodic intrusive events. Efforts will be made to examine the ecological systems from both perspectives.

Biological, physical, chemical, and geological characteristics were studied in a series of five cruises between March 1987 and February 1989 along three north-south transects across the continental shelf of Mississippi and Alabama. Four stations in depths of approximately 20, 40, 100, and 200 m were sampled along each of these transects. Side-scan sonar, Remotely Operated Vehicle, underwater color photographs, and video data were collected around topographic features in the study area. Subbottom profiler records indicate that the shelf edge is built upon delta-front forest beds that were truncated by erosion during the last low stand of sea level in the Pleistocene. Holocene sediments thickness (15 m) in the central part of the survey area cap the erosional surface, and the topographic features were constructed on top of these sediments. Topographic features were, generally, of three classes: (1) pinnacles, with heights of about 2-15 m and widths of 2-200 m, probably formed by coral-algal assemblages; (2) linear ridges, perhaps lithified coastal dunes; (3) enigmatic features. Sediments contained a mixture of biological and petroleum hydrocarbons. Biological hydrocarbons were predominantly plant biowaxes (n-C_{23}-n-C_{33}) with a possible minor planktonic input (n-C_{15}-n-C_{19}). Petroleum hydrocarbons were present as polynuclear aromatic hydrocarbons (PAHs), a complete suite of n-alkanes, and an unresolved complex mixture. Sediment PAHs on the shelf are on average six times lower than PAHs analyzed in sediments in adjacent bays. High hydrocarbon concentrations were generally at the seaward end of the transects between the 100 and 200 m isobaths with the stations closest to the delta containing the highest concentrations of hydrocarbons. Observed variations in sediment chemistry between samplings is possibly explained by a large episodic influx of riverine material followed by slow biological mixing by bioturbation or active currents on the shelf scouring the organic matter out of the sediments and depositing the organic rich material in a band along the shelf break. Sediments varied greatly in iron and trace metal content, but the variations seem to be largely the result of natural variability in grain size and mineralogy. Deep water sediments were enriched in iron and trace metals compared to shallow water ones, but all were typical of unpolluted Gulf of Mexico shelf sediment. Manganese concentration was only about half of that expected based on iron concentration for many of the samples. This shows the sediments of the area to be biochemically active and capable of solubilizing manganese and perhaps other metals. Fish food analyses have been completed for 2,500 specimens representing 42 fish species. Adequate depth, transect, and size representations are being attempted. Types of results being obtained are illustrated for the longspine porgy, *Stenotomus caprinus*. The food of this species is primarily polychaetes and small crustaceans, with significant amounts of organic detritus (mainly polychaete mucous mixed with sedimentary materials). The percentage of polychaetes is highest in young fish, nearshore areas, and on muddy/sandy bottoms off Mobile Bay and near the Mississippi River Delta. The percentage of crustaceans increases with age, distance from shore, and proximity to DeSoto Canyon.

Dr. James M. Brooks is a Senior Research Scientist and Director of the GERG in the Department of Oceanography at Texas A&M University. He is Project Manager for the Mississippi/Alabama Marine Ecosystem Study. His expertise is in trace contaminant analysis and marine chemistry. He has authored over 100 papers.

THE MISSISSIPPI/ALABAMA MARINE ECOSYSTEM STUDY SEDIMENT CHARACTERIZATION

Dr. Mahlon C. Kennicutt II
Geochemical and Environmental Research Group
Texas A&M University

Sediments in the study area contain a mixture of biological and petroleum hydrocarbons. Biological hydrocarbons are predominantly plant biowaxes (n-C_{23}-n-C_{33}) with a minor planktonic input (n-C_{15}-n-C_{19}) possible. Petroleum hydrocarbons are present as polynuclear aromatic compounds (PAHs), a complete suite of n-alkanes, and an unresolved complex mixture. Sediment PAHs on the shelf average six times lower than PAHs analyzed in sediments in adjacent bays. High hydrocarbon concentrations are generally at the seaward ends of the transects between the 100 and 200 m isobaths with the stations closest to the delta containing the highest concentration of hydrocarbons. Large variations in sediment chemistry were observed between samplings, apparently related to the influx of riverine material. One possible scenario is a large episodic influx of riverine material followed by slow biological mixing (bioturbation) diluting the input. It is also possible that active currents on the shelf scour the organic matter out of the sediments, transport it offshore, and deposit the organic rich material in a band along the shelf break. Shelf sediment PAHs are typical of unprocessed petroleum as contrasted to adjacent bay sediment PAHs which are predominantly of a pyrogenic origin. Pyrogenic sources include fossil fuel combustion, carbonization of coal, and forest fires. The bay sediments were intentionally sampled away from point sources of pollution such as large urban areas and industrial complexes. In general, higher hydrocarbon concentrations are associated with finer grained, organic rich sediments, but the association was weak. Normalization of hydrocarbon data to grain size or organic matter content did not significantly reduce data variability.

The temporal variations in sediment properties in the study area can be explained by various scenarios. Individual sediment components vary independently and are subject to a variety of different processes. These scenarios are as follows:

- cyclic - on time frames of six months, one year, two years and possibly longer. This can be explained by regular inputs (such as seasonal variations) being balanced by either removal processes or dilution events (i.e., aromatic and aliphatic hydrocarbons).

- steadily increasing - in this scenario input continues overtime with no efficient (or active) removal process. The episodic occurrence of mass movement of sediments only redistributes components within the system. Another possible explanation is input exceeds removal processes thus leading to a build-up (i.e., the unresolved complex mixture - residual petroleum).

- random variation - episodic perturbation due to one-time or infrequent events such as major storm events (i.e., extractable organic matter).

- no change - could reflect input equal to removal rate with a relatively constant rate of input or the timeframe of change is greatly in excess of the two years monitored in this study (i.e., carbonate content at some locations).

Sediments on the Mississippi/Alabama shelf are very dynamic and change on time scales varying from less than six months to more than two years. Inputs are complex and often independently driven. Removal processes are complex, constituent dependent, and vary independently. Sediment properties vary by an order of magnitude or more over the two years of the study. Many of these variations can be directly related to variations in land derived inputs that are mediated by river outflow from the Mississippi River/Delta system as well as other rivers in the area. Hydrocarbon pollutant loading to sediments is primarily derived from fresh, unrefined petroleum closely associated with fine particulates derived from riverine transport. Aeolian transport and outflow from coastal bays appear to be minor influences.

In contrast to the view of sediments as relatively stable repositories of particulate matter, very dynamic interactions are apparent. Clearly, if sediments are to be characterized temporal as well as spatial, variations need to be considered. As an intimate part of the benthos as well as an interface with the overlying water column, these dramatic variations in sediment composition and character need to be assessed in light of ecological assessments of man's potential impact on these areas.

Dr. Mahlon C. Kennicutt II, Associate Researcher/Scientist, is a senior member of the Geochemical and Environmental Research Group within the Oceanography Department at Texas A&M University. Dr. Kennicutt has expertise and research interests in marine chemistry, environmental chemistry, and organic geochemistry. He received a B.S. in chemistry in 1974 from the Union College and a Ph.D. in Oceanography from Texas A&M University in 1980.

MISSISSIPPI/ALABAMA SHELF MARINE ECOSYSTEM STUDY: PHYSICAL OCEANOGRAPHY CHARACTERIZATION

Mr. Frank J. Kelly
Civil Engineering Department
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and
Dr. A.C. Vastano
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Texas A&M University

INTRODUCTION

The physical oceanography component of the project has as its primary objective the characterization of the circulation on the outer shelf, with emphasis on exchange processes between the outer shelf and the deep ocean. We are synthesizing the results of previous studies (e.g., Dinnel 1988) and the new data obtained during this study from CTD surveys, moored instruments, satellite imagery, meteorology, river discharge, and tide gauges. A total of 5 inter-disciplinary cruises collected CTD/Transmissivity, dissolved oxygen, and nutrient data at the 12 primary stations shown in Figure 5.1, and at additional stations-of-opportunity, between March 1987 and February 1989. The time-series data from the moored instruments constitute the bulk of the new data set. A cross-shelf array of three current meter moorings, designated A, B, and C (Figure 5.1), was deployed in December 1987. In February 1989, Moorings D and E (Figure 5.1) were added. All five are scheduled to be removed in February 1990. Moorings A, B, and D, which are on the continental shelf in 30 and 60 m water depth, have instruments 10 m below the surface and 3.5 m above the bottom. Moorings C and E, located on the continental slope in 430 m water depth, have instruments at 25 m below the surface, 150 m, and 4 m above the bottom.

RESULTS

Although conclusions cannot be made until the full data set is available, the results thus far suggest that the circulation on the outer shelf is dominated by large-scale, long-period mesoscale flow events. Shorter, synoptic period fluctuations modulate and intersperse the mesoscale events. Figure 5.2 shows the currents observed at Moorings B and C from September through December 1988 in the form of 40-hour, low-pass-filtered stick vectors. The vertical axis in Figure 5.2 is oriented along the direction of the trend of the isobaths, so that vertically up is towards 55 degrees and horizontally to the right is towards 145 degrees. (This orientation emphasizes the along-isobath flow.)

Some flow events, for example the ones that occurred during the periods of 1-20 September and 10-31 November, are coherent between Moorings B and C and are probably caused by mesoscale eddy flow in DeSoto Canyon. Also note that the currents at 10 m at Mooring B are more similar to those at 150 m at Mooring C than they are to the shallower currents at 25 m at Mooring C. The temperature and salinity data recorded by the current meters are being studied as part of an analysis of the vertical structure of the currents.

Cross-isobath flow is strong at times in these records, particularly during the longer-period events, as, for example, during the period 10-31 October. Analysis by current roses shows that the dominant flow direction is southeastward, i.e., off-slope, at 25 m at Mooring C during the period of September-December 1988, which is consistent with Dinnel's (1988) analysis of historical hydrographic data for this region. Westward and southwestward directions dominate the flow records from the deeper two meters at Mooring C and both meters at Mooring B.

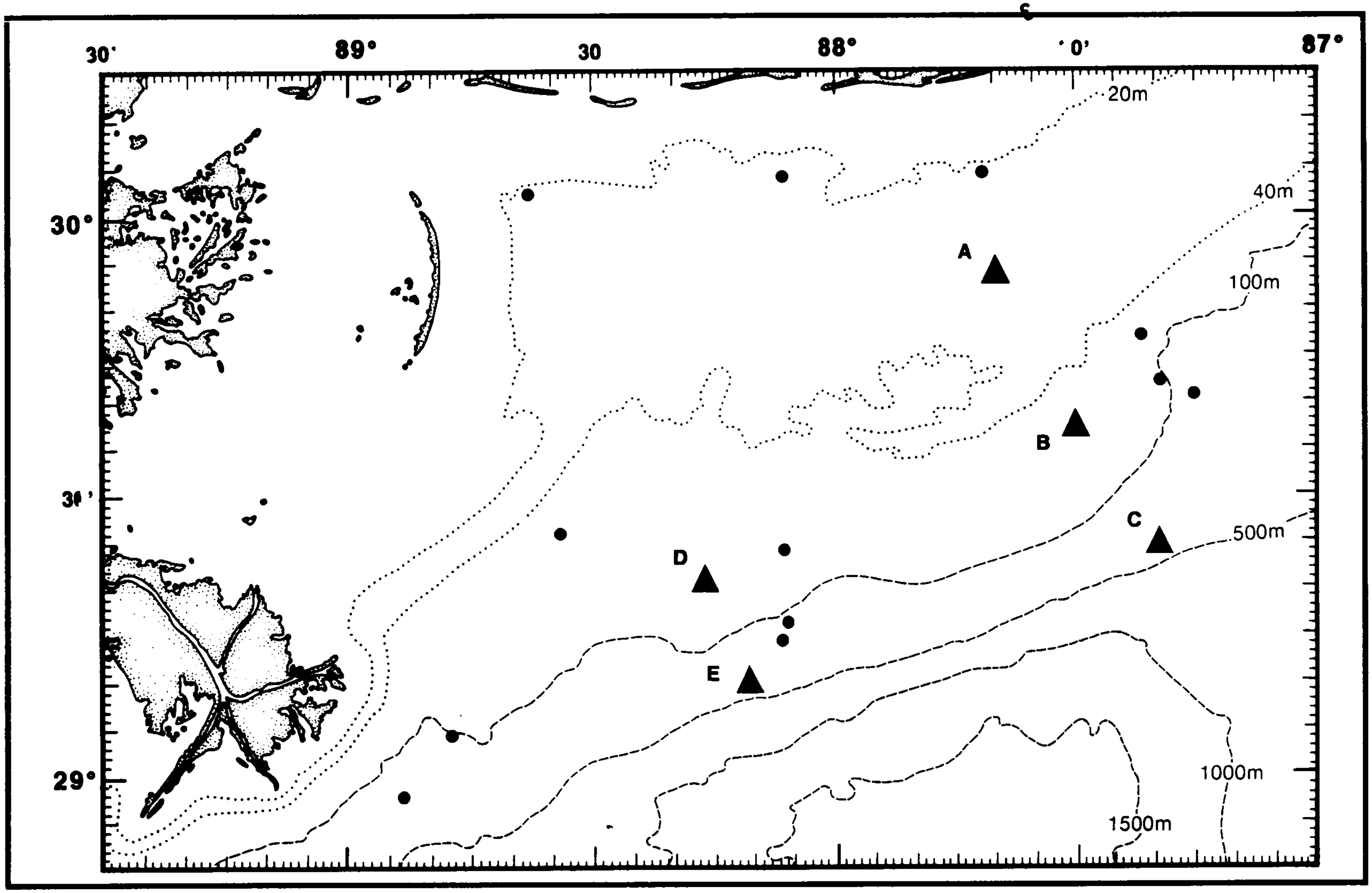
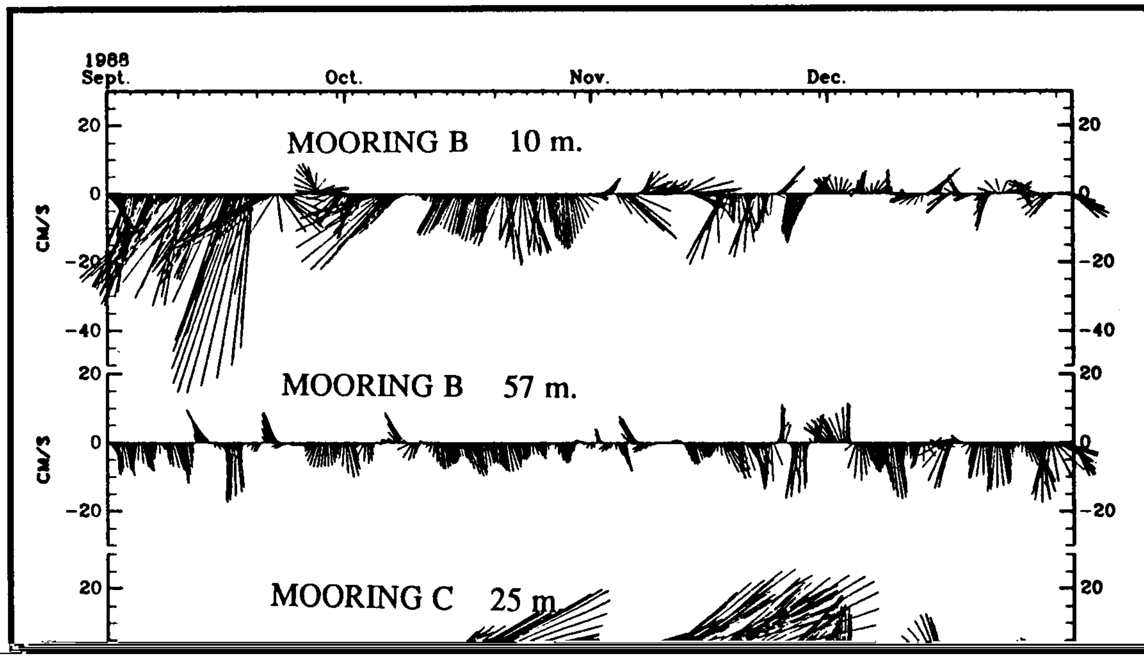


Figure 5.1. Locations of the 12 primary sampling stations for the study and the five current meter moorings.


1988
Sept.
Oct.
Nov.
Dec.
MOORING B 10 m.
MOORING B 57 m.
MOORING C 25 m.
CM/S
CM/S
20
0
-20
-40
20
0
-20
20

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Mr. Frank J. Kelly is an Assistant Research Scientist and Lecturer in the Civil Engineering Department, Environmental and Water Resources Area, at Texas A&M University. He received a Bachelor's Degree in physics from the University of California, Berkeley and a Master's Degree in oceanography from Texas A&M University. He has been conducting research in the Gulf of Mexico for the past 15 years.

GEOLOGICAL CHARACTERIZATION OF THE MISSISSIPPI/ALABAMA MARINE ECOSYSTEM STUDY AREA

Dr. William W. Schroeder
Marine Science Program
The University of Alabama,
Dr. W. W. Sager
and
Dr. Richard Rezak
Department of Oceanography
Texas A&M University

INTRODUCTION

The middle and outer continental shelf off Mississippi and Alabama, between the Mississippi River mouth and DeSoto Canyon, has previously received scant attention from marine geologists. There has been only one previous attempt at a comprehensive synthesis of the geology of the outer-shelf region (Ludwick and Walton 1957). Other studies have either focused on the inner-shelf, omitted discussions of topographic features and hardbottoms, or examined only small, selective areas of the outer shelf (Moore and Bullis 1960; Ludwick 1964; Upshaw et al. 1966; Shipp and Hopkins 1978, Doyle and Sparks 1980, Kindinger 1988; Schroeder et al. 1988a; 1988b). Additionally, a few commercial reports of geologic studies of small areas (usually one lease block) exist.

Ludwick and Walton (1957) found that topographic features, which they called "pinnacles", were found in clusters along the outer Mississippi/Alabama shelf. They noted that these were not like those commonly found farther west in the Gulf of Mexico. In the northwest Gulf, topographic highs generally tend to be the result of uplift caused by salt, or occasionally shale diapirs (Rezak et al. 1985). However, on the Mississippi/Alabama outer shelf, topographic features are apparently calcareous reef structures built during the late Pleistocene and early Holocene. They also surmised that these reefs were not actively growing, but were instead in an intermediate stage between active growth and fossilization.

Our study has verified many of these conclusions, but more importantly, it has shown that there exists a far greater diversity and distribution of topographic features than envisioned by Ludwick and Walton (Schroeder et al. 1989). The topographic features range from <2 m to greater than 20 m in height. Most are drowned patch reefs which are more-or-less equidimensional in plan view and occur singly or in clusters often along preferred isobaths. However, there are also numerous linear ridges and scarps, up to 8 m in height, which are probably constructed of indurated sand, shell, and gravel.

During the first year of geophysical surveying, approximately 2,160 km of side-scan sonar and subbottom profile data were collected. All of these were data collected in a reconnaissance mode with the side-scan sonar imaging a wide swath of seafloor (half-width either 300 or 400 m). The second year surveys were of two types, reconnaissance surveys similar to those of the Year 1 effort and detailed surveys of features observed during the Year 1 cruises. The latter used the side-scan sonar in a narrow swath mode (half-width 100 or 200 m) with closely spaced ship tracks.

The reconnaissance surveys extended east and west from the area surveyed during Year 1 (Figure 5.3) and were positioned to follow the 40 fm (73.2 m) isobath which was found to be the locus of numerous topographic features in the previous survey. Approximately 620 km of geophysical data were collected in the

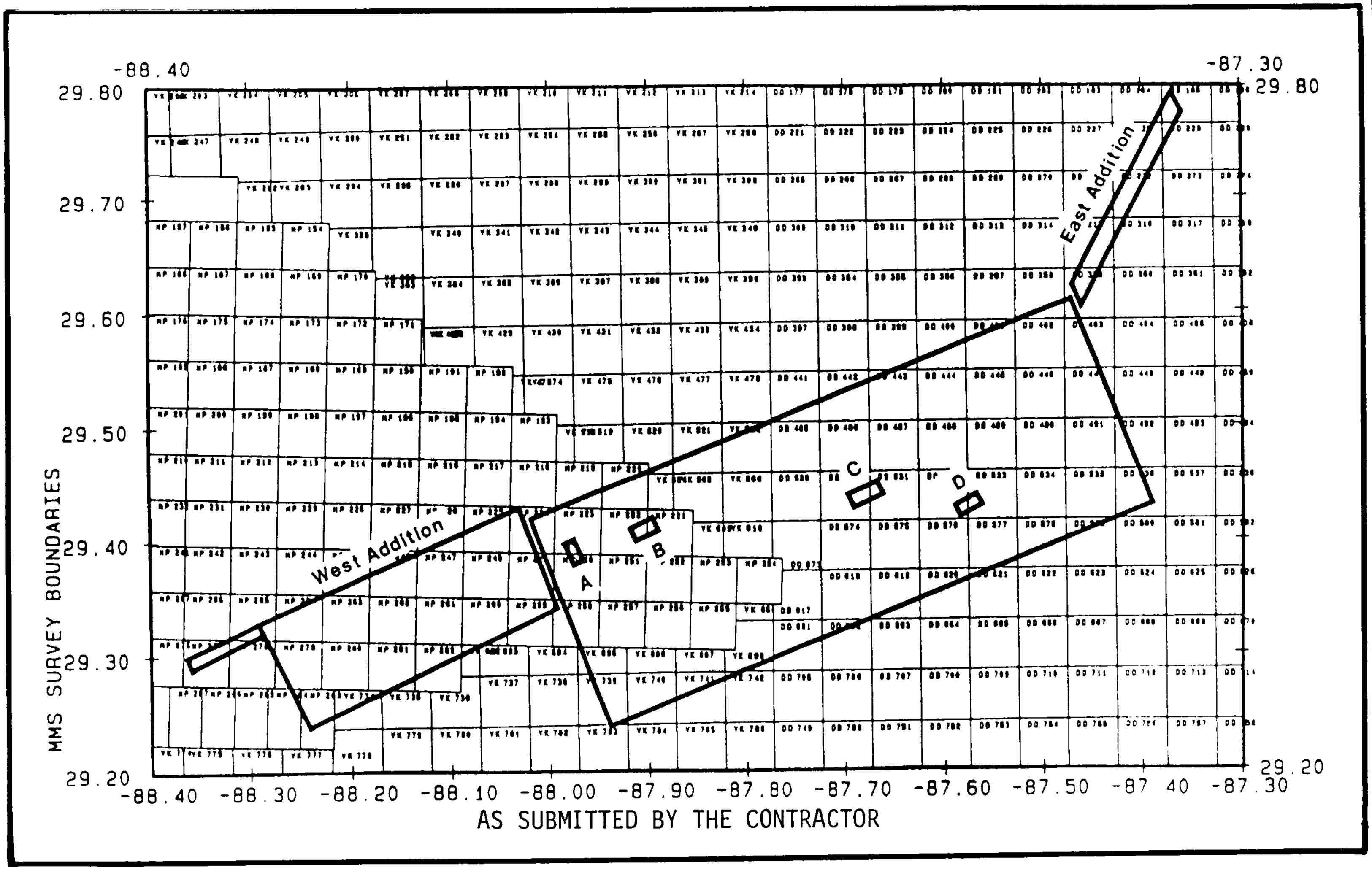

Figure 5.3. Locations of geological characterization surveys. (Heavy lines denote the boundaries of the MMS Mississippi/Alabama Ecosystems Study project surveys. East Addition, West Addition, and small rectangles labelled A, B, C, D are the Year 2 survey areas; large rectangle in center outlines borders of Year 1 survey for comparison. Detailed surveys labelled as follows: (A) flat-topped reef survey; (B) linear ridge survey; (C) patch reefs "boulder field" survey; and (D) 40 fathom reefs survey. Light lines show lease block boundaries.)

reconnaissance mode along 20 lines to the west of the Year 1 survey area and 3 lines to the east. About 35 km of detailed side-scan sonograms were obtained from the four smaller areas (Figure 5.3).

In the northwest portion of the Year 1 survey area, detailed studies were done on a cluster of large flat-topped reefs and on a section of the linear ridges following the 60 m isobath. Detailed images were also obtained of the drowned patch reef field (previously called "boulder field") in the center of the Year 1 and of some large reefs along the 40 fathom trend in the southeast portion of the Year 1 area (Figure 5.3).

RESULTS

Bathymetry plots have been made for the Year 1 survey area and contoured at 10 m intervals. Generally, the shelf and slope are smooth, except where they are punctuated by topographic features which are usually limited in areal extent. An accurate evaluation of the area covered by the topographic features has not yet been made, however, it appears to be small, about 5 to 10%. The depth ranges from about 48 m along the north side of the survey to over 260 m in the southwest corner and 340 m in the southeast corner. The shelf generally has a low slope to a depth of about 100 m past which it deepens rapidly to the south and southeast.

In the first year annual report, topographic features were highlighted. Three different classes of feature were recognized: (1) coral-algal reefs, (2) linear ridges, and (3) depressions. The reef category contains most of the topographic features mapped in the surveys. These range in size from about 20 m tall and hundreds of meters across (pinnacles and banks) to smaller than 1 to 2 m in height and less than 10 m across (drowned patch reefs). They often occur in clusters but are also found as isolated features. The second class, linear ridges, occur in various localities, but mainly along the 70 m isobath. These are thought to be shoreline sand ridges that have become indurated. The last class contains enigmatic features that were nicknamed "footprints" because they are small, often elongated, shallow depressions. These depressions are usually found in clusters and are on the order of 10 m in length. One remotely operated vehicle (ROV) station was devoted to these features, but nothing other than apparently flat seafloor was observed. It is not clear whether these features are so subdued as to be hard to see with the ROV cameras or that they are simply so small and widely spaced as to be hard to find with the ROV.

The completion of the side-scan sonar mosaics for the Year 1 survey area has shown that although the topographic features are interesting, they are only one facet of the overall geologic story. The most impressive aspect of the side-scan mosaics is the complex variation of seafloor reflections. These reflections were divided into twelve classes as follows.

R1 - Low reflectivity--homogeneous light area on side-scan record showing usually featureless bottom; weak seafloor echo.

R2 - Moderate reflectivity--homogeneous, often featureless bottom producing moderate acoustic backscatter.

R3 - Moderate to high reflectivity--homogeneous, often featureless bottom producing moderately high acoustic backscatter; greater reflectivity than R2, but less than R4.

R4 - High reflectivity--homogeneous, often featureless bottom producing high acoustic backscatter; bottom appears black on side-scan records.

R5 - Patchy reflectivity--discontinuous, but predominantly strong acoustic back-scatter; areas of strong reflections are usually equidimensional, hundreds of meters across, and show no preferred trend.

R6 - Moderate reflectivity with linear, high-reflectivity patches--seafloor dominantly low to moderate reflectivity; high-reflectivity patches usually lineated, can occasionally be traced between tracklines, and often show preferred trends within small areas.

R7 - Mottle reflectivity--discontinuous moderate to high acoustic backscatter; areas of high reflectivity are usually equidimensional and show no preferred trend, but are smaller in size than in R5; called "pox" in previous reports.

R8 - Linear reflectivity, large features--predominantly strong acoustic backscatter with lanes of lower reflectivity; lineations are subparallel, trending generally northeast; lineations are wide and long, measuring on average about 150-200 m across and 500 to 1,500 m or greater in length.

R9 - Linear reflectivity, small features--similar to R8 except that areas of strong reflectivity are smaller and shorter, averaging about 50 to 75 m across and less than 500 m in length; there is also a greater area of low to moderate reflectivity between the linear features than in R8.

R10- Confused reflectors--strong acoustic backscatter with properties of R7, R8, and R9; areas of high reflectivity separated by areas of low to moderate reflectivity, but with no preferred orientation.

R11- Drowned patch reefs--areas containing many small patch reefs, 5 to 10 m across and 2 to 5 m high; previously called "boulder fields".

R12- Other topographic features--areas of strong reflectivity and shadow caused by topographic relief.

Figure 5.4 shows the areal distribution of the different types of seafloor reflections. The areas of high reflectivity are mainly organized into two patches and one long band. One patch is in the northeast part of the survey and has no dominant trend and the other patch is a small linear band in the northwest part. The long band trends across the southern part of the survey. Most of the large reefs are associated with these areas of highly reflective seafloor. Furthermore, most of the linear ridges are associated with the northwestern band of moderate and high reflectivity sediments.

The high reflectivity sediments are found mainly at 3 different depths, 70, 80, and 115 m. The southern band of high reflectivity is misleading in Figure 5.4 because it includes seafloor at two of these levels. In mosaics 7 and 8 the high reflectivity seafloor runs along a trend of large reefs (the "pinnacles" of Ludwick and Walton 1957) located at a depth of about 115 m at the edge of the shelf. To the northeast, in mosaics 10 and 11, at the other end of this band of reflective sediments the high reflectivity is again associated with reefs, these at depths of 70-80 m (the "40 fathom fishing ground" of Schroeder et al. 1988a). The high reflectivity sediments in the northwest section are associated with the linear sand ridges. In mosaic 1 there is a patch of high reflectivity, located seaward of the ridges, which contains a luster of flat-topped reefs at a depth of about 75-80 m, a depth that suggests a relation to the reefs at a similar depth in mosaics 10 and 11. The linear ridges follow the 60 m isobath from mosaic 1 through 2 and 3 and back and forth across the northern borders of mosaics 9 and 10 and the southern edge of 4. Although the linear ridges peter out in the northwest corner of mosaic 10, areas of high reflectivity and linear reflectors are associated with the 70 m isobath as it trends across the bottom of mosaic 5 and diagonally northeast across mosaic 6.

The different levels of high reflectivity and associated reefs suggest that there were several episodes of reef formation at different stages of the Holocene transgression. Ludwick and Walton (1957) suggested that the reef trends formed when sea level was lower and Poag (1973) cites evidence for several sea level still stands in the Gulf Mexico during the last transgression. Our results are consistent with these interpretations and suggest at least three levels. The deepest level was near the shelf edge and there the pinnacles in the southwest part of the survey were formed. A shallower level was around 70 m. At this isobath the sand ridges formed just offshore in shallow water, now at a depth of 75-85 m. A third, even shallower level is implied by the reefs found landward of the 70 m isobath. These clearly had to have formed south of the coast which may have been located somewhere along the north side of the survey area or further landward.

Another effect of sea level is evident in the lineated reflectors found in the northern part of the survey area (Figure 5.4). Reflector types R6, and R8-R10 are characterized by linear "wavelike" features. These features have little or no topographic relief, appearing instead to be caused mainly by variations in the composition of the sediments. All of these

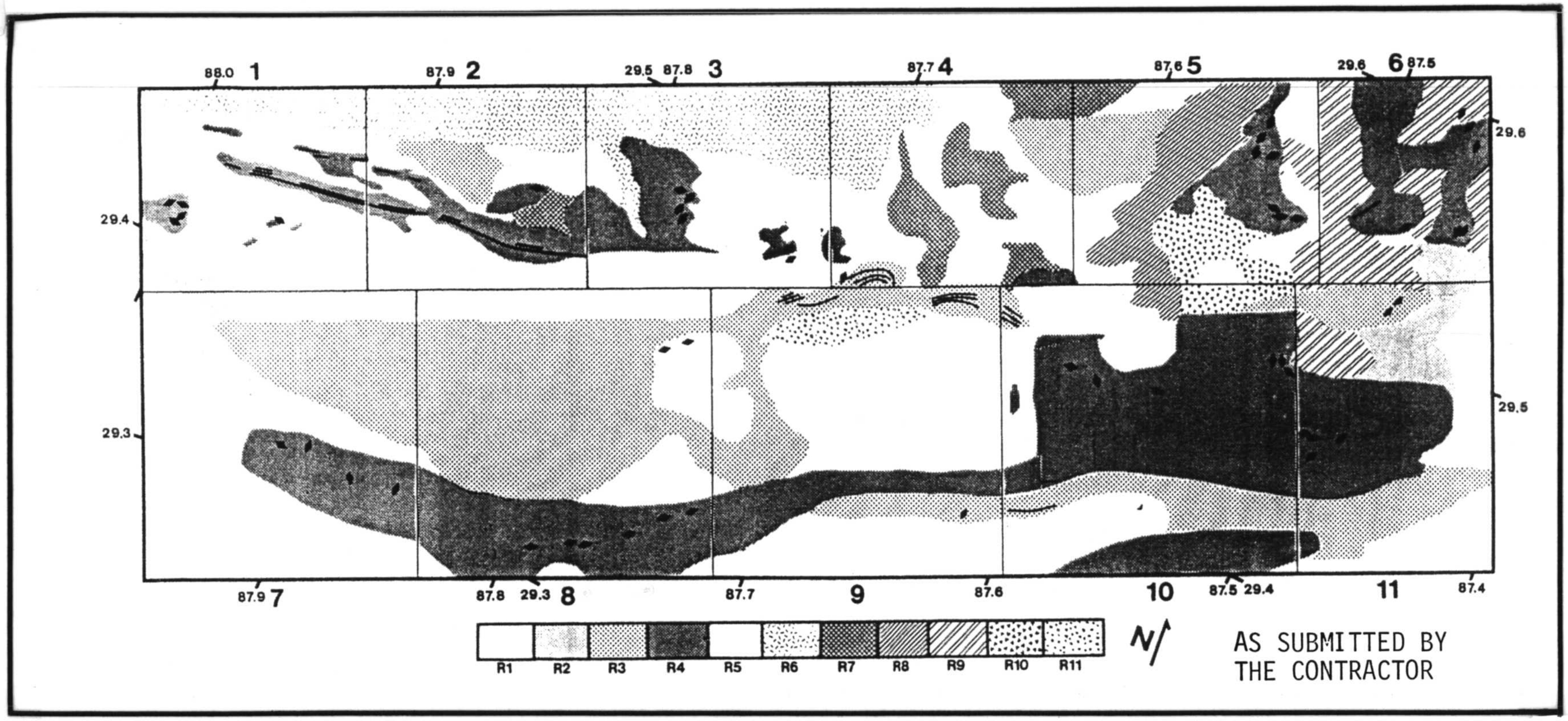

Figure 5.4. Generalized sketch map of bottom reflectivity character in the Year 1 survey area interpreted from side-scan sonar mosaics. (Thin lines denote mosaic boundaries; mosaics identified by bold numbers. Patterns represent different reflection characteristics, labelled R1-R11 and discussed in text. Diamonds show locations of large [diameters greater than about 150 meters] reef features or reef clusters. Long axis of diamonds show orientation of long axis of elongated reefs. Lines show linear ridge features.)

reflector types are located on the north side of the survey, in the shallowest water. This association suggests a link with present sea level. A reasonable possibility is that the linear features are caused by sediment sorting associated with large storm waves. The depth of some of these features, down 70-80 m, implies that these waves must be very large, perhaps so much so that they could only be from a major hurricane. If this is the case, then the pattern found during 1987 and 1988 may be ephemeral, created by the last large hurricane and bound to be reworked by the next one.

Bathymetric data for the Year 2 surveys has been digitized, but not contoured. Both the East and West Addition surveys were designed to follow the 40 fathom isobath; consequently, the long axis of each survey parallels the shelf edge. There were no surprises in the bathymetry. Generally, the areas are smooth and the east addition is punctuated by topographic features like those found in the Year 1 survey.

Production of mosaics from the Year 2 surveys is awaiting the finishing of the Year 1 mosaics and interpretation figures. Consequently, our observations from the Year 2 sonograms are only preliminary. The four detailed surveys provide the basis for a closer look at several interesting features. In particular, the flat-topped reefs survey shows that the tops of these features are very smooth. These flat surfaces may represent sea level surfaces, formed either by erosion or by limiting the upward growth of the reef. Additionally, the "boulder field" survey helped to confirm our suspicions that the "boulders" are small drowned patch reefs.

Sonograms from the East Addition survey were surprising in that the three lines show little but nearly featureless bottom. This is in distinct contrast to the Year 1 survey in which there are no featureless areas this large. Similarly, the northern part of the West Addition survey is also nearly featureless. It is not until about line 10 that significant reflectivity variations and topographic features are found. The topographic features imaged within the West Addition are similar to those mapped in the Year 1 surveys. There is one exception. This is a tall, steep-sided reef imaged near the west end of line 14. It is about 65 m in diameter and its shadow on the sonogram indicates a height of 18 m.

CONCLUSIONS

Side-scan sonar mosaics show 12 different types of seafloor reflections character demonstrating the complexity and variety of the geologic environment in the study area. There are basically three different types of reflections character: (1) topographic features, which are primarily reefs and ridges, (2) homogeneous seafloor with low to high acoustic backscatter, and (3) seafloor with patchy reflections, either with linear trends or with no particular trend. The reefs occur mainly in conjunction with the areas of high reflectivity. Furthermore, the distribution and depths of the reefs and high reflectivity seafloor suggest that they were formed at successively higher sea level stands during the Holocene transgression. At least three sea level stands are implied by the data from the Year 1 study area. Additionally, the distribution of linear patches of high reflectivity are found in the shallowest water in the survey area implying depth control over their formation. These features may be created by large waves during major hurricanes.

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BIOTIC ASSEMBLAGES ON TOPOGRAPHIC FEATURES OF THE LOUISIANA/MISSISSIPPI/ ALABAMA CONTINENTAL SHELF

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INTRODUCTION

Various types of hardgrounds occur in waters off Mississippi, Alabama, and eastern Louisiana. These range from low relief "broken bottoms" or "ragged bottoms" on the inner shelf (Schroeder et al. 1989), to large shelf edge and continental slope features in depths of 73 to 366 m (Ludwick and Walton 1957; Moore and Bullis 1960; Ballard and Uchupi 1970; Shipp and Hopkins 1978). Some hardgrounds in this region may represent "drowned reefs" or "paleo-reefs" (Ludwick and Walton 1957; Ballard and Uchupi 1970).

Ludwick and Walton (1957) noted a zone of prominences over 1.5 km wide and discontinuous with 16-40 km gaps in depths from 73-100 m between the Mississippi River and Cape San Blas, Florida. Average relief of these "pinnacles" was 10 m, but some were over 15 m tall. They are thought to be calcareous biogenic structures that formed during lower sea level stands. Biological sampling of the pinnacles, some of which were surveyed in this study, has been carried out using rock dredges (Ludwick and Walton 1957) and combinations of dredges and television and still cameras (Woodward-Clyde Consultants 1979; Continental Shelf Associates 1985; Schroeder, unpublished data). Biotic assemblages were considered to be of tropical Atlantic origin and dominated by ahermatypic hard corals, octocorals, crinoids, and hydroids.

Other organisms included antipatharians, various crabs, asteroids, ophiuroids, and a number of fish commonly associated with hard-bottom habitats in the Gulf of Mexico. The biotic assemblage was considered by Continental Shelf Associates (CSA 1985) to be comparable to that of the "transitional antipatharian zone" described by Rezak et al. (1985) at depths below 82 m at the Flower Garden Banks off Texas.

Within the boundaries of the Mississippi/Alabama Marine Ecosystems Study, Minerals Management Service (MMS) requested complete side-scan coverage and selective video reconnaissance of topographic features in the area shown in Figure 5.5. Such features often harbor organisms intolerant of unnatural perturbations, which may occur with anthropogenic insult. Such areas, termed "live-bottom areas" by MMS are defined as "...those areas which contain biological assemblages consisting of such sessile invertebrates as sea fans, sea whips, hydroids, anemones, ascidians, sponges, bryozoans, or corals living upon and attached to naturally occurring hard or rocky formations with rough, broken, or smooth topography; or areas whose lithotope favors the accumulation of turtles, fishes, and other fauna." The reconnaissance carried out by Texas A&M was designed to evaluate the nature and extent of live-bottom assemblages in the area outlined above.

The principal objectives of the study were as follows:

- determine biological community composition on the various types of topographic features in the study area;
- determine the relationship between pertinent environmental controls and biotic composition and zonation patterns;
- compare biota to that in other hard-bottom areas (e.g., northwest Gulf diapiric features and coralgal reefs, shallower, and deeper areas of the Mississippi Bight, Florida Middlegound, east coast reefal features);
- ascertain community condition (evidence of natural perturbations and human insult);
- categorize features on the basis of geological structure and biological community characteristics and development.

METHODS

Two reconnaissance cruises were made during the first two years of this three-year study. The surveys were performed using a Benthos RPV-2000, medium-sized, remotely operated underwater vehicle (ROV). The unit contained a Subsea Model CM-8 low light sensitive S.I.T. black-and-white video camera, one strobe, six Birns flood lights, a 3-CCD Photosea 3000 series color video camera, and a Photosea 2000 Series 35 mm stereo camera. Two underwater optical lasers were installed adjacent to the color video/stereo package in a parallel configuration at a prescribed spread, allowing for size and scale determinations on video images. The ROV is acoustically tracked with ultra-short baseline navigation using a Ferranti/ORE Trackpoint II system.

RESULTS AND DISCUSSION

Sites visited and/or sampled on the first two cruises included:

- two areas of acoustically transparent sediment; generally indicates fine textured, soft-bottom (Stations 19 and 20 on Figure 5.5),
- one wave field (closely spaced, low relief sand waves; Station 3),
- two areas of patchy (polka-dot) side-scan sonar returns (Stations 1 and 22),
- one area that may be part of a "sediment apron"; relatively coarse sand surrounding a topographic feature (Station 21),
- one field containing what appear to be small depressions (Station 11),
- four sites on a semi-continuous paleo-shoreline (?) (Stations 4, 5, 7, and 10),
- one site along a deeper ridge or paleo-shoreline (Station 12),

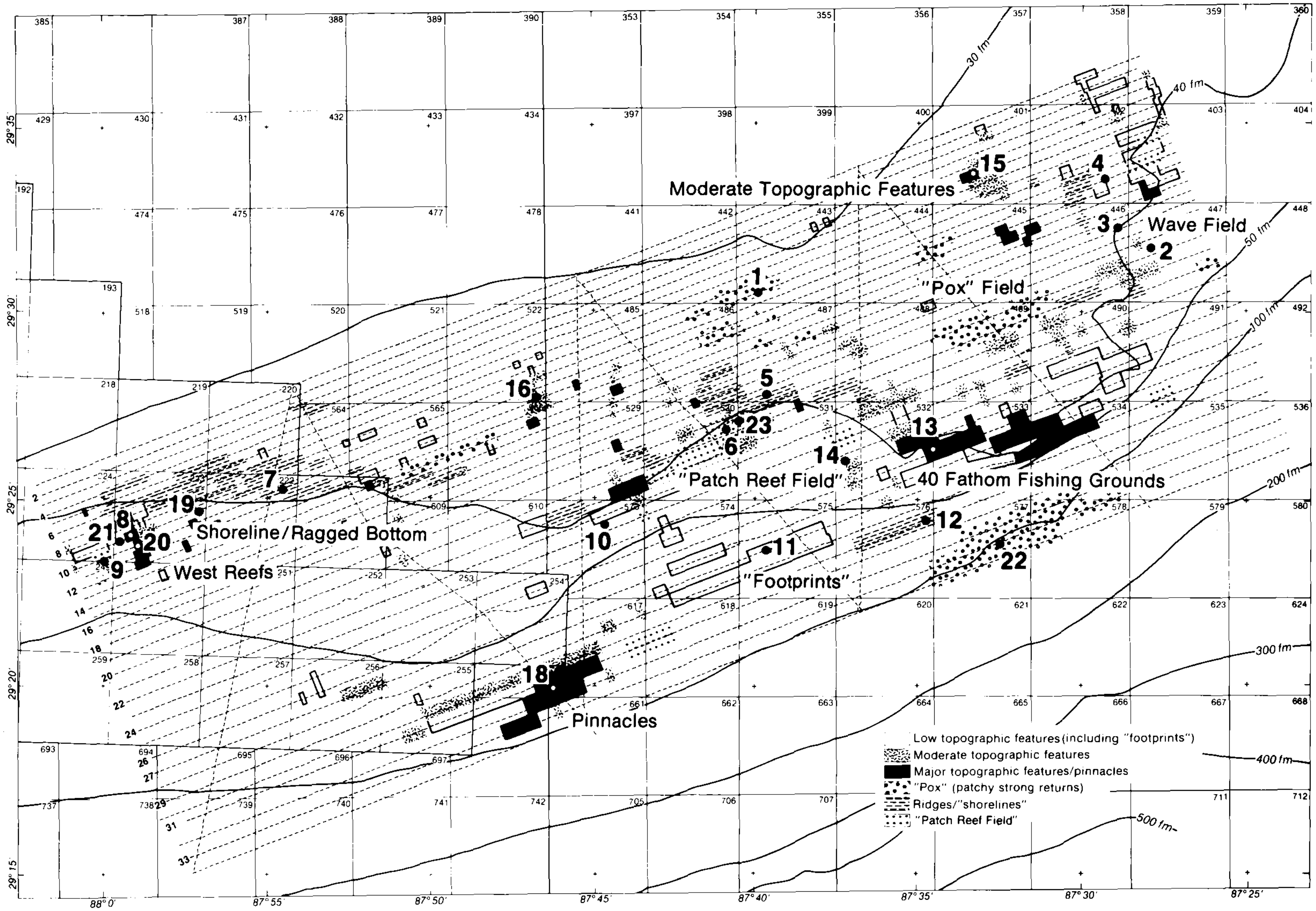

Figure 5.5. Map of study area, showing preliminary feature interpretation and sample site locations.

- two fields of reefs comparable to present-day lagoonal patch reefs (Stations 6 and 9, dredge sample at 23),
- one area with features of low topographic relief (Station 2),
- two features of moderate topographic relief (Stations 15 and 16),
- four features of major topographic relief (three smooth-topped, and one spire-like; Stations 8, 13, 14, and 18).

Geological characteristics of these features and hypotheses regarding their origin are covered elsewhere in this volume. The following discussion is mostly restricted to biological aspects of features in the study area.

Present-day biological assemblages on features in the northeastern Gulf are dominated by suspension feeding invertebrates. Abundance and diversity on features appear to increase with amount of exposed hard bottom, relief, roughness, and habitat complexity (i.e., the number of habitat types available to hard-bottom organisms). Populations are depauperate on features of low topography, those in habitats laden with fine sediments, and at the base of larger features (where resuspension of sediments limits community development). On larger features, the diversity and development of communities appear to depend mostly on habitat complexity. On reefs containing extensive reef flats on their summits, there are rich assemblages distinguished by a high relative abundance of sponges, gorgonian corals, crinoids, and bryozoans. Small coralline algae crusts were observed on some of these reefs. Other organisms on reef flats include holothuroids, basket stars, and myriads of fishes (particularly roughtongue bass, *Holanthias martinicensis*). On reefs lacking a reef flat habitat, as well as on reef faces of flat-topped features, the benthic community is characterized by a high relative abundance of ahermatypic corals (both solitary and colonial scleractinians). Other frequently observed organisms on these rugged, often vertical reef faces include crinoids, gorgonians, sea urchins, and basket stars.

Though depth limits, and probably eliminated, significant reef development in this area, it appears to play a minor role in present-day community control on these reefs. Depth does, however, appear to affect the distribution of coralline algae within the study area. These algae were not observed below approximately 70 m. In fact, production of calcium carbonate in the area is probably limited to the impoverished calcareous algae population on features above this depth.

Zoogeographic affinities are tropical for most species on these features. The fauna on reefs in this study area is most similar to that on deep portions of topographic features in the northwest Gulf and on hard substrates on the rim of the DeSoto Canyon. Comparable communities in the northwest Gulf are found in the Antipatharian and Nepheloid Zones on outer shelf, mid-shelf, and south Texas banks (see Rezak et al. 1985). Community descriptions in this study are particularly similar to descriptions of fauna inhabiting drowned reefs between 82 and 88 m on northwestern Gulf shelf-edge features.

Coralline algae development is poor on features in the NE Gulf compared to outer shelf banks in the NW Gulf, but development of octocoral, sponge, and crinoid assemblages on some reefs in the study area is higher. The distribution of coralline algae suggests water quality in the study area, particularly with respect to light penetration, is intermediate between shelf-edge and mid-shelf features off Texas and Louisiana.

Human impact in these environments appears to be minimal at present. Discarded debris, though present at many sites, was not abundant, and therefore poses little threat to the environment. Cables and ropes can affect shallower reef communities, but probably have little impact at these depths once they become tangled on or lodged against reefs. Fishing pressure on these relatively small features may reduce the population of the larger, commercially important species, and may explain the abundance of smaller individuals of unprofitable species on heavily fished reefs.

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MACROINFAUNA AND MACROEPIFAUNA OF THE MISSISSIPPI/ALABAMA CONTINENTAL SHELF

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Five semi-annual collections of benthic organisms, including macroinfauna and macroepifauna, have been made during the course of the Mississippi/Alabama Marine Ecosystem Study (MAMES). The study area consisted of four stations (20 m, 60 m, 100 m, and 200 m depths) on each of three transects (C-transect adjacent to the Chandeleur Islands, M-transect off Mobile Bay, and D-transect that terminated at the DeSoto Canyon). Macroinfaunal organisms were collected by box core and Smith-MacIntyre grab. A 20-foot trawl was used to collect samples of fish and macroepifaunal invertebrates.

The bottom was of two basic types. Soft mud to muddy sand occurred on C-transect, along the Mississippi Delta, and at all the 200 m deep stations. Sandy to shelly sand to coral rubble occurred at most of the M- and D-transect stations. The box core was used on softer sediments, but would not penetrate hard bottoms; the Smith-MacIntyre grab had to be used on the latter.

Data analyzed to date indicate several trends. First, there does not appear to be any one infaunal species that is an outstanding numerical dominant. In contrast, in the western Gulf, one species, very often *Paraprionospio pinnata*, may have such large populations that its abundance controls the overall abundance trends of the benthic community. Second, the temporal abundance patterns of both infauna and epifauna indicate fall maxima and spring minima. This is the opposite the pattern usually observed in the western Gulf of Mexico. Third, the greatest fluctuations in abundance occur at the 20 m depth stations and the least at the 200 m depth stations. This agrees with data from the western Gulf and suggests environmental stability and lower recruitment rates at the deeper stations and high recruitment rates at the shallower stations. Fourth, the very soft mud sediments off the mouth of the Mississippi River harbor enormous quantities of heart urchins and associated organisms that form a unique assemblage. Fifth, some event, as yet unexplained, caused an extreme reduction of numbers of fish, macroepifauna, and heart urchins between cruises 3 and 4 (October 1988 and February 1989). In prior collections, as much as 500 kg of adult urchins were collected per trawl, but in February 1989, very small numbers of smaller urchins were collected.

Dr. Donald E. Harper, Jr. is presently an Associate Professor, Department of Marine Biology, Texas A&M University at Galveston. He received his Ph.D. and M.S. in marine biology from Texas A&M University and B.S. in zoology from the University of Miami. Dr. Harper's research interests include the ecology of macrobenthic communities and taxonomy of polychaetous annelids.

MISSISSIPPI/ALABAMA MARINE ECOSYSTEMS STUDY SUMMARY/SYNTHESIS

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The summary/synthesis program involves two phases. During the first phase efforts were devoted to reviewing the historic literature, examining the findings of the various investigators, and planning for the actual data analysis. The second phase involves data standardization, manipulation, analysis, and interpretation. Phase two could not begin until some of the component studies had been completed, but at the present writing this phase is already well underway.

Preliminary stereogrammatic views of the continental shelf have been prepared for the areas included in the three study transects (Figures 5.6, 5.7, and 5.8). These diagrams will be revised and produced in greater detail as more information becomes available. They are quite helpful in the interpretation of multi-component data, and they are also useful in the final presentation of complex information.

Analytical procedures must be carried out on a database which has been previously standardized, and much recent attention has been given to calculation of the actual area covered by each trawl. This has been completed, and the resulting data will reflect the density of macro-epifaunal invertebrates and demersal fishes per hectare of ocean bottom. All the fishes have been identified, and the catch of each species in each trawl has been weighed and the body lengths determined. Thus, fish biomass data are available for individual species as well as for the total catch at each station. Around 330 species of fishes have been identified representing about 100 families. It is projected that the fish food studies will provide information on food changes associated with (a) growth of the fish, (b) depth along a transect, and (c) different transects at a given depth.

Once the individual databases have been entered into the computer and standardized, they will be subjected to a sequential series of analytical procedures. The first step involves the graphing of relationships (scatter diagrams and

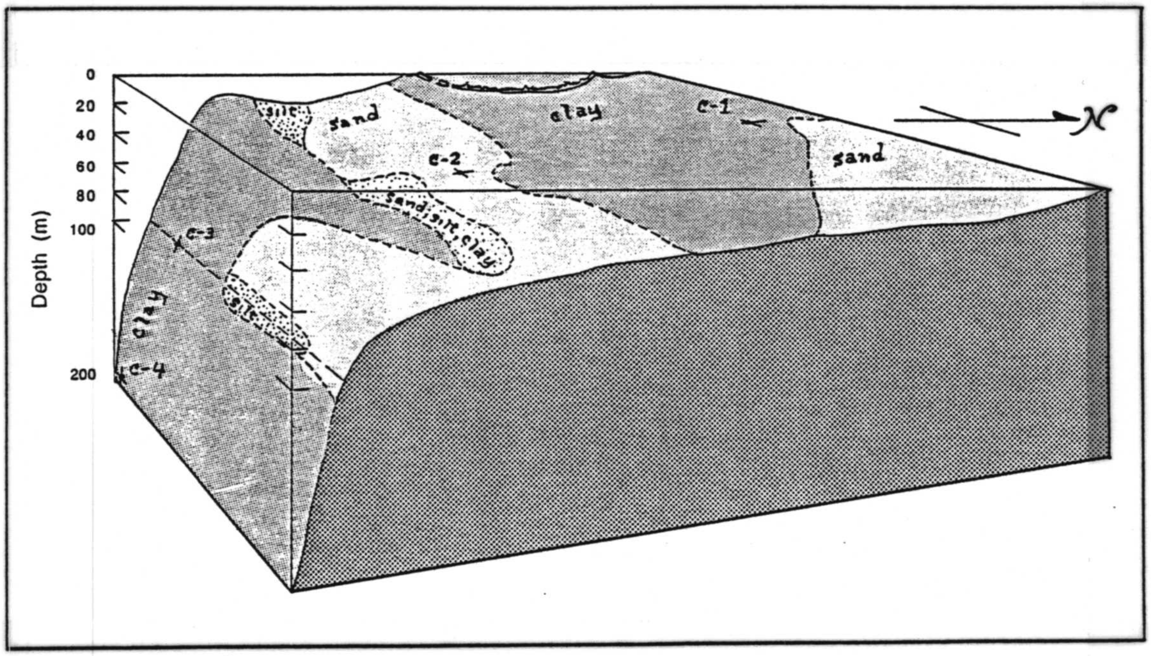

Figure 5.6. Transect off the Chandeleur Islands (stereogrammatic view).

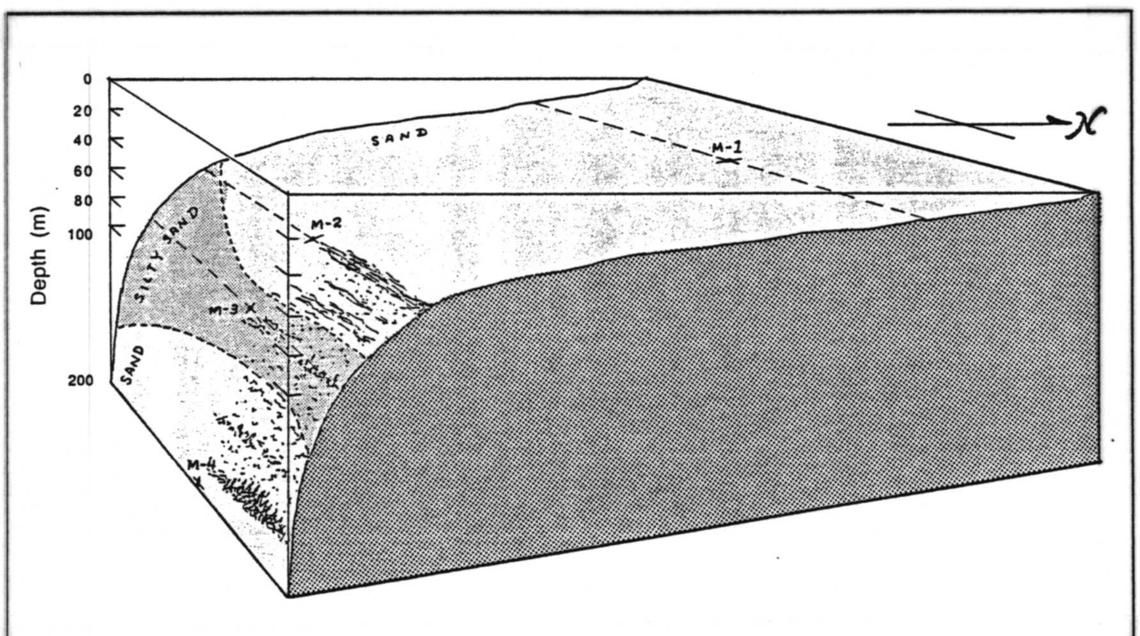

Figure 5.7. Transect off Mobile Bay (stereogrammatic view).

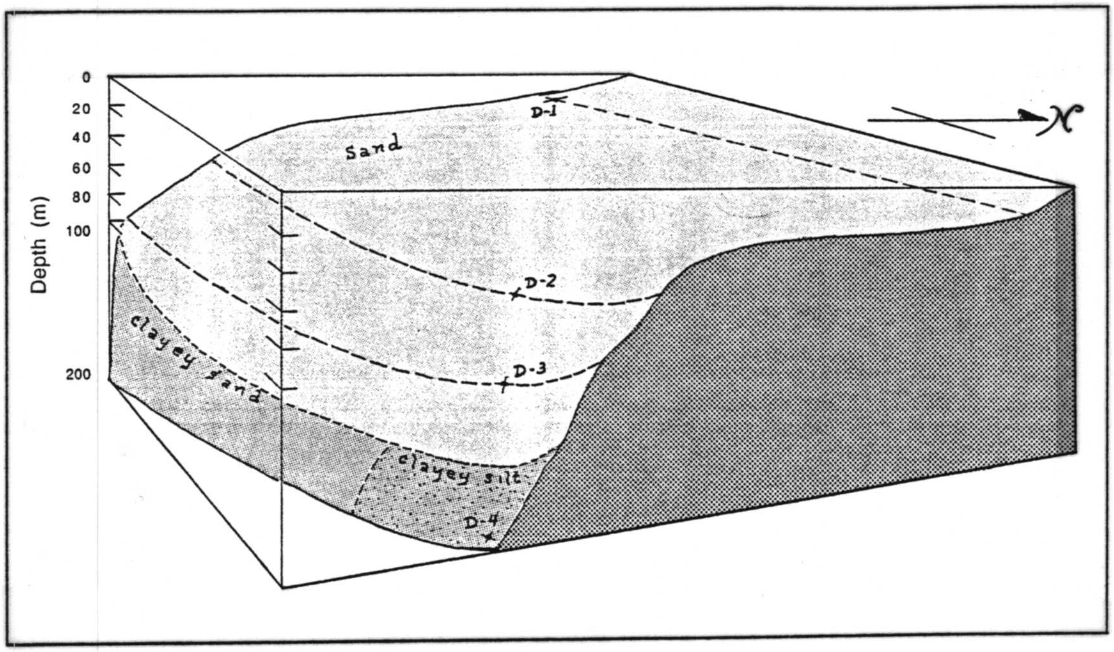

Figure 5.8. Transect off DeSoto Canyon (stereogrammatic view).

regressions) along with analysis of variance. This will be followed by multivariate analysis of variance, correlation analysis (as product moments), and rank order correlation analysis. Finally, the data will be examined by cluster analysis (using Canberra-metric and recurrent group analysis procedures) as well as principal component analysis (summarizing the multivariate data).

These various procedures should provide information on the subgroupings within the databases and the relationships of the subgroups to each other and to the larger systems. Coupled with the historical information they should permit interpretation of the ecological systems and subsystems of the Mississippi/Alabama shelf as well as their relationships with the forcing and controlling physical factors.

Dr. Rezneat M. Darnell is Professor of oceanography at Texas A&M University. He has investigated ecosystem composition and dynamics of streams, estuaries, and continental shelves. Most recently, he has studied the distribution of demersal fish and penaeid shrimp populations of the U.S. Gulf of Mexico continental shelf in an effort to discern the structure of shelf communities and to develop appropriate management implications.

Dr. Darnell received his B.S. in biology from Southwestern College, his M.A. in biology from Rice University, and his Ph.D. in zoology from the University of Minnesota.

ALTERNATIVE ENERGY: NOW AND THE FUTURE

Session: ALTERNATIVE ENERGY: NOW AND THE FUTURE

Co-Chairs: Mr. William T. Johnstone
Ms. Linda Castaño

Date: December 6, 1989

Presentation	Author/Affiliation
Alternative Energy: Now and the Future: Session Overview	Mr. William T. Johnstone and Ms. Linda Castaño Minerals Management Service Gulf of Mexico OCS Region
Progress Toward A National Energy Strategy	Ms. Cherri J. Langenfeld U.S. Department of Energy Office of Technology Policy
An Assessment of the President's Proposal on Alternative Fuels	Dr. Michael Shelby U.S. Environmental Protection Agency
Future of Oil and Gas As It Relates to Alternate Fuels	Dr. Michael E. Canes American Petroleum Institute
How Can You Have An Energy Policy in a Market Economy?	Dr. Richard D. Tabors Massachusetts Institute of Technology
The Status of Alternative Fuels - A Congressional Perspective	Mr. James Bruce Committee on Energy and Natural Resources, U.S. Senate
Potential From A National Energy Efficiency Policy	Mr. Nicholas A. Fedoruk Energy Conservation Coalition
The Future of Nuclear Energy in the United States	Mr. Bill Harris U.S. Council for Energy Awareness

ALTERNATIVE ENERGY: NOW AND THE FUTURE: SESSION OVERVIEW

Mr. William T. Johnstone
and
Ms. Linda Castaño
Minerals Management Service
Gulf of Mexico OCS Region

The Outer Continental Shelf Leasing Program is concerned with oil and gas extraction of federal minerals developed offshore. The program is conducted as part of a national interest in achieving energy independence for the nation. Other forms of energy currently share the overall energy demand. New sources and forms of energy are being explored. These alternative energies have environmental consequences. The objective of the sessions on alternative energy was to learn the status of current and future energy use and the environmental effects of these alternatives.

The sessions were held consecutively and were planned as a single unit. The agenda was arranged so as to start with a general approach and proceed to more specific subjects.

Ms. Cherri Langenfeld, Acting Director for Technology Policy with the U.S. Department of the Energy, described current progress toward establishing a national energy strategy. The process of developing national policy for the use of energy is most complex and involves all economic, environmental, and social interests in the country. Ms. Langenfeld briefly reviewed the process and the central issues faced by the Department of Energy.

Mr. Michael Shelby presented the views of the U.S. Environmental Protection Agency supporting the President's proposal for revising the Clean Air Act. The proposal includes recommendations for the use of alternative fuels in motor vehicles in nine areas around the country where ozone pollution is a problem. Clean fueled vehicles would be achieved by using methanol or gasoline blends of methanol. Other fuels to be considered include compressed natural gas and reformulated gasoline.

Dr. Michael E. Canes, Vice President of Finance, Analysis, and Statistics for the American Petroleum Institute located in Washington, D.C., discussed the future of oil and gas as it relates to alternative energy. He stated the use of oil and gas in this country is likely to remain the same for the next 10 years, but may change in the future due to environmental concerns. Reformulated gasoline has been marketed in the form of lead free fuel and work continues in this area. Electric vehicles could play a greater role in transportation, but the success of this fuel would require a plan to supply electricity utilizing a very different fuel mix from what is now economic.

Dr. Richard Tabors, author and consultant, is associated with the Massachusetts Institute of Technology. His remarks challenged some of the ideas that have been proposed to formulate and implement national energy policy. He states any formulated policy must fit within the context of our market economy and any implemented policy must rely on influencing the marketplace, not controlling it. Many examples of past mistakes and successes were presented to support the general thesis that national policies, particularly in energy, must work within the marketplace, not try to supplant the market.

Mr. James Bruce, Senior Council for the Senate Committee on Energy and Natural Resources, offered to the audience a Congressional perspective on alternative transportation fuels. He pointed out the lack of national policy on alternative fuels and other forms of energy complicates the formulation of legislation by the Congress. He reviewed the many trade offs confronting the Congress as they consider alternative fuels, increasing oil imports, and economic constraints.

Mr. Nicholas Fedoruk, Director of the Energy Conservation Coalition, talked about the value of improving energy efficiency in the United States economy. Conservation of energy would contribute to improving problems concerned with oil imports, international competition, and the quality of life for low income and disadvantaged people. Mr. Fedoruk reviewed ten areas of energy use that could offer opportunity for greater energy efficiency. He explained the amount of energy, dollars, and carbon emissions that could be saved by the nation in the next 10 years.

Mr. Bill Harris, Vice President of the U.S. Council for Energy Awareness, dealt with the role of nuclear energy in the future. Growing demand of electric power, energy conservation, foreign oil dependency, environmental concerns, and renewable energy (wind, solar, hydroelectric, etc.) sources were briefly discussed in terms of the many problems faced by the country. The present state of nuclear power was explained. Both positive and negative benefits were described.

The sessions on alternative energy explored many aspects of the energy field in the United States today. Questions concerned with policy were discussed in greater detail than questions of technology. This was due to the limitation of time and the magnitude or scope of the subject. The speakers were well prepared and highly informed about their areas of expertise. Many of the question and answer periods that followed each talk allowed the audience to participate extensively in the discussion of various issues. The questions were very good and the answers were informed and to the point. The environmental consequences, economic realities, and political dilemmas surrounding energy questions were well presented and sharply focused so that the audience could better understand the problems and prospects of alternative energies now and in the future.

Mr. William T. Johnstone is a Community Planner with the Office of Leasing and Environment in the Gulf of Mexico OCS Region of Minerals Management Service. He earned a B.S. degree from Ohio State University and a Master of Regional and City Planning from Oklahoma University. Mr. Johnstone's current work involves environmental impact assessment. As a planning coordinator with the Bureau of Land Management, he was involved with resource management in New Mexico. Prior to his work in New Mexico, Mr. Johnstone served as a Project Manager for flood control studies with the U.S. Army Corps of Engineers.

Ms. Linda Castaño is an economist with the Environmental Assessment Section of the Minerals Management Service (MMS) Gulf of Mexico OCS Region. She earned a B.S. degree in engineering from Tulane University in 1984. Prior to her association with MMS, Ms. Castaño worked as a planning engineer and as a forecast analyst for Entergy Corporation in New Orleans.

PROGRESS TOWARD A NATIONAL ENERGY STRATEGY

Ms. Cherri J. Langenfeld
U.S. Department of Energy
Office of Technology Policy

INTRODUCTION AND OBJECTIVES

Upon assuming office, one of the Secretary of Energy's chief objectives was to conduct a comprehensive assessment of the nation's energy future. This assessment will enable the Department of Energy (DOE) to

- design a long-term national energy strategy that will meet our strategic and environmental needs in the energy field while allowing all Americans to achieve the standard of living made possible by a healthy and growing economy;
- tell the energy story to the American people, and try to provide a better understanding of choices that must be made--to educate--if we are to meet the requirements of the 21st century.

President Bush directed the Secretary to develop a blueprint for America's energy policy decisions, not only for the short-term, but looking ahead to the 21st century. This plan will be the National Energy Strategy (NES). It will chart our course, set our pace, and measure our progress--and, we hope, begin to establish a national consensus on the energy challenges facing the U.S.

DEVELOPMENT OF THE NATIONAL ENERGY STRATEGY

The DOE has solicited views from all interested parties with information to contribute, and is especially sensitive to public opinion.

Earlier this fall, five public hearings were held all across the country to address local, regional, and national issues, in order to make the nation aware of the central role that energy plays in our economic life. They were broad in topic and touched on many concerns and issues.

A second, more focused, set of public hearings are currently being conducted, and will focus on more specific concerns and issues.

Concurrent with the public hearing process, DOE has mobilized the considerable expertise of its national laboratories to help assess four key issues. The labs have already submitted draft "white papers" to the department, specifically addressing

- energy efficiency and conservation;
- global climate change;
- renewable energy technologies; and
- technology transfer.

An "interim" report on the NES will be issued for comment on April 1, 1990, which will include a description of NES goals, problems and assessment of the issues, and the possible solutions.

The release of the Interim Report will be followed by

- a 5-month comment period;

- a third round of public hearings in summer and early fall of 1990, which will be designated to help the Secretary make the hard choices that must be made;

- the release, by December 21, 1990, of the final NES report with specific short-term, mid-term, and long-term recommendations extending out to the year 2030; and

- the release, in early 1991, of a clear statement of the Administration's NES, energy program and budget priorities, and an implementation plan for the NES, including legislative and regulatory energy proposals.

To ensure that the NES is thoroughly grounded in fact and sound analysis, DOE is drawing on every available source of expertise and advice, including

- the Secretary's Advisory Boards and Councils;
- DOE National Laboratories;
- the National Academy of Sciences; and
- an Economic Policy Council Working Group.

NES recommendations will be a balanced package of proposals that seek to reconcile and integrate our energy, economic, environmental, and strategic interests on a consistent and long-term basis.

DOE is also looking to International Energy Agency member countries especially to provide valuable assistance in our data building and analytical work.

CENTRAL ISSUES

The potential for global climate change is central to development of the NES. DOE will look at

- high and low economic growth futures;
- levels of greenhouse gas emissions associated with those growth scenarios;
- ways the U.S. could reduce the levels of greenhouse emissions; and
- effects such U.S. actions would have on U.S. and projected global greenhouse gas emissions.

DOE will:

- evaluate a broad array of strategies that respond to energy needs and to environmental goals;
- examine adaptation strategies to address possible climate changes; and
- examine strategies to reduce greenhouse gas emissions caused by industrial, urban, and agricultural activities of man.

On December 14 a hearing will be held in Atlanta to focus on global climate change.

The following was heard during the course of the public hearings on petroleum

- independent producers are fighting for their very lives;
- price stability is critical;
- tax incentives are necessary; and
- access to OCS, ANWR, and federal lands for exploration and development of all energy resources is necessary if we are to avert intolerable dependence on oil imports.

Oil will be fundamental to our economy for foreseeable future.

The following was heard during the course of the public hearings on natural gas.

- more research is needed on innovative use of gas;
- in the area of technology transfer, we should support the development and use of natural gas in other countries;
- consider modifying vehicles so that they can be fueled by natural gas;
- encourage greater storage capability; and
- deregulate the "merchant function" of pipelines and create a secondary market in transport services.

The vast majority of our transportation fuel still will come from oil well into the next century.

U.S. oil use will remain at about the same level for the next 10 to 12 years.

Since domestic oil production will decline, even extraordinary conservation efforts will not prevent increased dependence on imported oil.

Alternative fuels have the potential to enhance both our technical options and our market options in the frequently volatile world energy markets.

DOE has undertaken a comprehensive assessment of the costs and benefits of flexible and alternative fuel use in the U.S. transportation sector. This assessment has focused on

- what changes must be made to permit use of alternative fuels;
- cost and likely sources of supply; and
- potential safety and environmental problems.

DOE is leading a comprehensive interagency assessment of the energy security and other implications of all alternative fuels.

We must devote ourselves to finding energy technologies that do not generate waste and treat properly those wastes whose generation cannot be avoided.

A healthy, safe, and clean environment is an essential component in all of our planning and policy-making.

Intelligent discussion and disciplined compromise will be required to develop sound, balanced national energy policies.

We have a massive public education effort ahead, as we seek to develop the National Energy Strategy.

CONCLUSIONS

The future of U.S. energy is intertwined with the future of U.S. technology.

The Secretary of Energy considers America's scientific and technical illiteracy to be one of our most serious challenges.

If the nation continues to stumble in its standards in math and science, it won't be long before we suffer serious economic consequences.

DOE hopes that efforts in developing the NES will gain momentum and help prod the nation to address the key role science and technology play in America's future.

Ms. Cherri J. Langenfeld is Acting Director for Technology Policy, DOE. In this capacity, she serves as an advisor to the Deputy Under Secretary for Policy, Planning and Analysis in the formulation and review of policies related to technology research, development, transfer, and utilization. She is also a member of DOE's Development Committee for the National Energy Strategy.

Before joining the DOE on August 14, 1989, Ms. Langenfeld was the Director of Consulting Services for Scientific Systems Services, Inc., a Computer Task Group Company. As a consultant, Ms. Langenfeld specialized in the planning, justification, and implementation of integrated manufacturing strategies in a variety of industries, including automotive, aerospace, metals, petroleum, chemicals, and consumer products.

From 1984 to 1987, Ms. Langenfeld was employed by General Motors (GM) Corporation in Detroit, Michigan. She served two years in GM's Marketing and Product Planning staff, coordinating a corporate-wide capacity planning task force. She then served one year as a general foreman in an automotive assembly plant.

From 1976 to 1982, Ms. Langenfeld worked for Exxon Company U.S.A. in New Orleans, Louisiana, in a variety of engineering and supervisory positions. She is knowledgeable of a wide range of policy, regulatory, technology, and market issues pertaining to the exploration and production of oil and gas, including offshore development.

A native of Merrillville, Indiana, Ms. Langenfeld received a Bachelor's of Civil Engineering from the Georgia Institute of Technology in 1976, and an M.B.A. from the Harvard Graduate School of business administration in 1984. Ms. Langenfeld resides in Arlington, Virginia, with her husband, James, and their three cats.

AN ASSESSMENT OF THE PRESIDENT'S PROPOSAL ON ALTERNATIVE FUELS

Dr. Michael Shelby
U.S. Environmental
Protection Agency

The President recently announced his proposal for revising the Clean Air Act. A central feature of his proposal is the alternative fuels program designed to limit air pollution from motor vehicles. This program is both innovative and controversial. An assessment of the President's proposal follows.

REVIEW OF AIR POLLUTION PROBLEMS

The alternative fuels program is designed to reduce three significant air pollution problems: ambient ozone, carbon monoxide (CO), and inhalable particulates. Ambient ozone is formed in the atmosphere in the presence of sunlight by the interaction of two pollutants, hydrocarbons, and nitrogen oxides. It is a respiratory irritant and can cause immune system impairment. Exposure to ozone aggravates asthma, emphysema, and bronchitis. In addition, ambient ozone causes crop, forestry, and material damages.

CO reduces the capacity of the blood to carry oxygen and can impair cardiovascular, nervous and pulmonary systems. Inhalable particulates reduce lung function, cause lung tissue damage, and can aggravate pre-existing respiratory diseases.

The U.S. Environmental Protection Agency (EPA) establishes national ambient air quality standards (NAAQS) for criteria air pollutants that it regulates and records the numbers of air quality areas in the country that do not attain these standards. Currently, 101 areas are in nonattainment of EPA's ozone standard. Roughly, 60 areas of the U.S. are not attaining the CO NAAQS.

Motor vehicles are a significant emitter of all three of these pollutants. Roughly, 50% of the hydrocarbons emitted in the urban areas are from mobile sources. For CO, the number is higher--motor vehicles emit roughly 60% of the CO in urban areas. Buses and trucks emit large amount of inhalable particulates.

ELEMENTS OF THE PRESIDENT'S PLAN

There are four central components to the President's alternative fuels proposal. The first would significantly increase the number of clean fueled vehicles in severe ozone nonattainment areas. In 1995, 500,000 clean fueled vehicles would be required to be sold, 750,000 in 1996 and 1,000,000 thereafter through the year 2004. These vehicles would be sold in the following areas: Los Angeles, Houston, New York City, Milwaukee, Baltimore, Philadelphia, Hartford-New Haven, San Diego, and Chicago. In these nine areas, high volume gas stations would be mandated to offer clean fuels.

The program would also require gasoline to be blended with fuels containing levels of oxygen necessary to attain NAAQS. Oxygenated fuels would be sold during the portion of the year in which there are high ambient concentrations of CO. The program leaves open for rulemaking what portion of the year would require oxygenated fuels and the mandated level of the oxygen content. Finally, the program would phase-in alternative-fueled buses in large urban areas starting in 1991.

The program has a number of economic incentives so that all fuels can compete to achieve the overall reduction in pollution designed by the program. A clean vehicle credit system will be established patterned after the heavy-duty truck nitrogen oxide and particulate matter averaging/trading and banking program to be promulgated in 1990. Also, a clean fuel credit system will be developed broadly modeled on the lead phase-down.

IMPACTS OF THE PROGRAM

Depending upon the fuels that are used to satisfy the program requirements, a variety of environmental and economic outcomes could be envisioned. For illustration, the impacts of the program with methanol will be examined. Methanol is one likely candidate for use in the program because of its low reactivity. It is predicted by EPA's Air Office that flexible fueled vehicle (designed to run on gasoline or methanol) could achieve up to a 30% reduction in ambient ozone. If vehicles were designed to run exclusively on methanol, up to an 80% reduction is achievable. Another advantage of methanol is that it is a liquid fuel that is easily accommodated with the existing infrastructure.

It is anticipated that most of the methanol that would be used in the program would come from remote natural gas deposits from a variety of sources throughout the world. Likely candidates for the location of methanol production plants include diverse areas such as Trinidad and various countries in South America and in the Middle East.

If methanol is used to meet the program requirements, EPA's Air Office predicts that hydrocarbons (that cause ambient ozone) will be reduced by 4.1% in the nine urban areas and 10 cancer cases due to air toxics will be eliminated. The first year cost of program, largely service station modifications, are estimated at $280 million. The 10-year cost effectiveness of the program is estimated to be $390/ton of hydrocarbon reduced, assuming no difference in fuel cost between methanol and gasoline.

How do other fuels fit into the program? The use of compressed natural gas (CNG) will result in ozone and CO reductions of between 50 and 90%. There is no particulate matter from this fuel. CNG is recognized as having a clear role in specialized markets such as fuel for urban buses but is also perceived as having disadvantages as a general substitute for gasoline. Its major problems revolve around the fact that it is a gaseous fuel that is not compatible with the existing distribution infrastructure and would require some type of compression system for refueling.

It may be possible to reformulate gasoline to achieve the environmental goals outlined by the President. The advantage of reformulated gasoline is that it can achieve reductions over the whole fuel pool. This means that emission reductions can be achieved immediately instead of in the future as new vehicles capable of using alternative fuels are introduced to the fleet. At this point in time, it remains to be seen to what role reformulated gasoline can play in achieving environmental goals.

Dr. Michael Shelby earned his doctorate in economics from Boston University in 1983. He has been with the EPA since that time.

FUTURE OF OIL AND GAS AS IT RELATES TO ALTERNATE FUELS

Dr. Michael E. Canes
American Petroleum Institute

This presentation will address some recent developments in alternate fuels and their relationship to future oil and gas consumption. First, however, some background information on oil and gas markets and on the aggregate U.S. energy market may prove useful.

U.S. oil and natural gas consumption is likely to rise over the next decade. Domestic oil production is likely to fall, so that a large increase in oil imports is virtually inevitable. There is scope for increased domestic gas production, but demand probably will increase more than production so that imports of gas, principally from Canada, are likely to rise.

Overall, the proportions of total energy use comprised by oil and by gas are unlikely to change much between now and the year 2000. Over a longer time horizon, however, environmental concerns make this less predictable.

Energy conservation is an important component of the future U.S. energy demand/supply picture. However, it would be a mistake to believe that energy conservation can completely remove the demand for greater energy use in a steadily growing economy, and truly radical energy conservation can be voluntarily induced only at a very high cost.

Recent interest in alternate fuels has been stimulated by a desire to deal with air quality problems, principally in urban areas. The administration has proposed an alternative fuels/vehicles program to cover nine U.S. cities, and California and others are pursuing similar ends. In theory, these programs are "fuel neutral" in the sense that they will allow markets to develop the most cost effective fuels and vehicles capable of achieving air quality goals.

The petroleum and auto industries have proposed examining the air emissions characteristics of reformulated gasoline and altered auto emissions systems. In fact, refiners have been reformulating gasoline for environmental purposes for many years, first to reduce lead content and more recently to reduce volatility as measured by Reid Vapor Pressure.

ARCO already is marketing a reformulated gasoline, called "EC-1." Although it is a substitute only for leaded gasoline, it shows a potential for reformulated gasoline to be an important means to reduce air quality problems.

The automobile and oil industries have embarked upon a very ambitious research program to test the emissions characteristics of alternative forms of gasoline as well as other fuels (e.g., methanol). New auto emissions equipment also will be tested. The first part of this program is to be completed by next summer and the second part is to begin early next year. The results will be publicly available as the industries have invited EPA and other governmental entities to participate as observers.

Other alternate fuels have greater or lesser promise. Compressed natural gas (CNG) could play a role in reducing emissions, but its economic application probably is limited to centrally fueled fleets. Methanol and ethanol can help reduce ozone or carbon monoxide problems under certain conditions, but neither is likely to be economic means of doing so generally. Their best use for the purpose may well be as a component of others such as MTBE or ETBE.

The use of alternate fuels for air quality purposes is unlikely to much change the U.S. energy mix over the next decade, for at least two reasons. First, their absolute quantities likely will be small over this time period. And second, the principal contenders, reformulated gasoline, CNG, and methanol, utilize oil or natural gas as their principal input. Over a much longer time horizon this could change, with electric vehicles playing a greater role, but that would require a plan to supply electricity that would utilize a very different fuel mix from what is now economic.

Dr. Michael Canes has been associated with the American Petroleum Institute (API) for 15 years. Dr. Canes joined the staff of API in 1974 as senior economist. He was promoted to Deputy Director, and then Director of his organization's policy analysis department. In 1982, Dr. Canes became API's Vice President of Finance, Analysis, and Statistics.

Dr. Canes has earned four degrees: a B.S. and M.B.A. from the University of Chicago; a M.S. from the London School of Economics; and a Ph.D. in economics from the University of California at Los Angeles.

HOW CAN YOU HAVE AN ENERGY POLICY IN A MARKET ECONOMY?

Dr. Richard D. Tabors
Massachusetts Institute of Technology

The objective of this paper is, from a critical standpoint, to review the role that the U.S. government can play in developing and implementing an energy policy. It offers a set of lessons learned from the period of the 1970's and 1980's concerning our policy efforts to direct the energy economy of the country. Based on this it provides a structure for evaluating energy policy in the context of a market economy. Two major conclusions are reached. The first is that our policies must fit within the context of our market economy, not attempt to replace that market, if they are to be successful. The second is that issues such as energy use and now global environmental policy (which are quite similar in scope and approach) can not be approached through naive assumptions. These are issues with complex economic interactions requiring a breadth of analysis within the context of the U.S. market economy.

In the U.S. developing an energy policy is very different from developing a defense policy because, unlike defense where the government controls the supply and demand, in the energy area the government per se neither owns, nor produces, nor consumes energy, i.e., all energy systems are in the non-government or private sector--regulated yes--but private.

Probably the most important lesson that we learned in the 1970's and early 1980's was that our national policy, but particularly our national energy policy, needs to be built around those factors over which we have some level of control. This is particularly true when the control points are as intertwined with the basic market economy of the U.S. as is the case with the energy sector.

This implies that the policy tools available to the government are those associated with influencing the marketplace--not with controlling or directing the marketplace. This requires that the policy tools both be carefully analyzed and fully defined before they are implemented. What we learned in the 1970's was that it is possible to proceed hastily with programs that may have little actual impact on the desired final outcome but can cost a significant amount of money. As an example we, as a nation, spent a significant amount of money and effort in forcing into the market a set of renewable technologies. The stated goal of each of the renewable programs was to provide a competitive alternative by 1990--basically today. There were elaborate government funded research and development programs, major expenditures in technology demonstration, and major expenditures in commercialization programs. What were the effects of these programs? In terms of their stated goals, there probably were nearly no positive effects. Money was cycled through the economy, technical break throughs that some day may have a benefit were made; but these technical improvements were made, however, in research, not in demonstration or commercialization.

Two examples that we use in our recent book Energy Aftermath (Lee et al. 1989) may be instructive in seeing the manner in which our past energy policy was poorly conceived and, in all likelihood, why at a number if not most points, it failed. These examples concern our policy on renewables and on natural gas.

In the case of renewable technologies our policy was to attempt artificially to induce a market for a set of technologies that had never gone through the stages of economic development. In simplest terms we tried to force feed technologies into a well established market. The results should be well known by all. They were unsuccessful in the extreme.

In the case of natural gas, our policy was to control both the prices and the possible end uses because we believed that natural gas was of such a high value that it should not be burned as a boiler fuel. The fallacy was that we could regulate the market economics so as to keep the fuel sufficiently inexpensive for small consumers while forbidding its use to big consumers. The results, in retrospect, were predictable: the natural gas shortage of the late 1970's. This was initially interpreted as a physical storage. In fact it was a regulated shortage. Natural gas was simply held out of the market.

What do these two examples say about our energy policy? Above and beyond all else, they say that the U.S. has a market economy and that it works fairly efficiently. Technologies that are heavily subsidized will be purchased so long as the subsidy is in place and not thereafter--unless they are cost effective or have some other attributes deemed by the purchaser to be worth the premium. Fuels are fuels are fuels. They have no intrinsic value except in terms of their btu or chemical use. Regulating price will always have the same effect, increasing demand and decreasing supply. The result--an apparent shortage. Furthermore, market forces will generally find ways around absolute prohibitions in use as was certainly the case with natural gas in electric power generation.

What are the lessons learned? The role of the government is to provide policies which guide the economy. The policies, particularly in energy, must work within the marketplace, not try to supplant the market.

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Dr. Richard D. Tabors is Principal Research Associate in Technology and Policy and Assistant Director of the Laboratory for Electromagnetic and Electronic Systems at Massachusetts Institute of Technology. He is an engineering economist with 20 years of experience in energy and environmental policy and planning and has written widely in energy pricing. Recent works include Electricity Spot Pricing with Schweppe, Caramanis and Bohn (Kluwer 1988) and Energy Aftermath with Lee and Ball (Harvard Business School Press 1989). Dr. Tabors holds a B.A. (1965) from Dartmouth College in biology and a Ph.D. (1971) in geography and economics from the Maxwell School of Syracuse University.

THE STATUS OF ALTERNATIVE FUELS - A CONGRESSIONAL PERSPECTIVE

Mr. James Bruce
Committee on Energy and
Natural Resources
U.S. Senate

To say that the subject of alternative fuels is on the front burner in Congress is no exaggeration. When Congress returns into session in January of 1990, the first order of business in the Senate, according to the Majority Leader, will be consideration of legislation on Clean Air Act Amendments. That legislation will likely include a major floor amendment on alternative fuels.

In fact the Senate Environment and Public Works Committee in an unusual step, will hold a hearing in January on alternative fuels--several days before the Senate even reconvenes. On the House side one Subcommittee has taken action on this subject and another Subcommittee and its parent full Committee likely will consider it next year.

Trying to predict the outcome in Congress for alternative fuels is not easy. On the one hand, a good case can be made for caution in this area. Why is that?

First, there are some who think we are getting the cart before the horse. A national policy on alternative fuels should fit within the larger context of a national energy policy. Unfortunately, we don't yet have a national energy policy.

The Bush Administration is in the process of formulating a national energy strategy, but it apparently will not be ready for months. Decisionmaking on alternative fuels will be hampered by the absence of that overall context. It is increasingly clear that our future energy security will require consideration of alternative fuels.

Environmental policy, not energy policy is what is driving the alternative fuels debate right now. The alternative fuels legislation is contained in a package of Clean Air Act Amendments that are extraordinarily complex, and extraordinarily contentious. Alternative fuels are not even the prime focal point in the debate.

Therefore some caution is justified because the guideposts of a national energy strategy are missing. Second, there is a history of false starts in this area--synfuels, shale oil, and yes, some might add cold fusion, are a few examples.

A third reason for caution is that our current system of oil production and distribution has worked fairly well. We might question it occasionally--such as why are Americans led to pay an extra 20 cents per gallon for premium gasoline for new cars designed to run perfectly well on regular unleaded gasoline? But generally, the system works fine, so why tamper with it in any fundamental way?

Fourth, there are some good political reasons for caution. No elected official is anxious to come between an American and the love affair he has with his automobile. If government-mandated requirements for alternative fuels result in cars that won't start in cold weather or worse, 5 miles of fuel left in a car 20 miles from the next suitable fuel station, there will be hell to pay.

And other than environmental pressure, there really isn't any grass roots political pressure to change the status quo, and frankly, there isn't likely to be. OPEC seems to have changed its tune. It was hurt by roller coaster oil pricing. They want to assure us of a stable oil supply at gradually increasing oil prices. They do not want to provoke a big shift toward alternative fuels. Therefore, big jumps in gasoline prices, gasoline lines--the things that might create a demand for alternative fuels will not likely be seen.

Finally, there is the California factor. California is often ahead of the rest of the country. They happen to be way ahead of the rest of the country in air pollution. State and local government in California are blazing a path looking for ways to reduce that pollution. They seem intent on taking dramatic, even draconian steps to reduce that pollution. They will expand the use of methanol-powered cars whatever the Federal government does. Electric cars will come next. Washington is looking at California with something of wide-eyed amazement. It is terribly tempting to let California make a guinea pig out of itself in alternative fuels.

So those factors counsel caution in mandating a switch to alternative fuels.

However, there are some countervailing factors that may well carry the day, not the least of which is our growing oil import problem. The key item is that President Bush has made legislation on alternative fuels a priority item of his environmental policy.

Earlier this year the Administration sent to Capitol Hill Clean Air Act legislation, introduced as S. 1490, that included provisions on alternative fuels. The fact that the President supported any clean air act proposal at all signified that clean air legislation would likely move.

The alternative fuels section mandates the sale of 500,000 clean fuel vehicles in 1995, rising to one million vehicles per year for the years 1997-2004. These vehicles would be sold in the nation's worst nine cities for ozone (smog) nonattainment. Large service stations would all be required to offer clean fuels.

A clean fuel vehicle is one that runs on "clean fuels" defined to mean methanol, ethanol, natural gas, propane, electricity or any other fuel, such as reformulated gasoline that EPA determines has "comparably low emissions."

Initially, U.S. Environmental Protection Agency (EPA) was perceived as making methanol as the fuel of choice. EPA believes that a car powered by neat methanol could produce 80% less volatile organic compounds than future gasoline vehicles.

This perceived push for methanol faltered in the Congress and it did so for several reasons. First, the advocates of other fuels, such as ethanol, compressed natural gas, and reformulated gasoline, felt that the playing field wasn't level. They wanted the chance to prove that their fuel was the clean fuel of choice.

Second, some members felt that making the auto companies legally obligated to sell a certain number of cars in certain markets was unfair and unrealistic. As a result, in a very close vote, the amendment offered by Mr. Hall and Mr. Fields won.

Under the Hall-Fields amendment, the performance standard for clean fuels would be tied not to 100% methanol, but rather to a blend of 85% methanol and 15% gasoline, which other fuels, especially reformulated gasoline would have a better chance of meeting. And the auto companies need only certify that they have the capacity to produce these clean fuel vehicles, subject to fuel availability. The administration opposes these changes, but insists that they are not biased in favor of methanol. They say that any fuel that meets their standards will qualify as a clean fuel.

The $64 question is what will the Chairman of the full Committee on Energy and Commerce, John Dingell, do with the alternative fuels provision when his committee considers the legislation? He has already compromised on the tailpipe emissions standards for automobiles and is unlikely to want to burden the auto industry any further with mandated sales requirements for clean fuel vehicles.

On the Senate side, the situation is even more unclear. The Senate Committee on Environment and Public Works reported out Clean Air Amendments without including anything on alternative fuels. We understand that the committee may offer an amendment on the floor to address this issue.

One telling event on the Senate side concerns the committee's requirement in nonattainment areas with high levels of carbon monoxide; gasoline must contain a specified level of oxygen. This can be achieved with oxygenating additives such as ethanol, ETBE, or MBTE. However, this specific provision is generally regarded as requiring the addition in gasoline of some ethanol, not just MBTE or ETBE. Ethanol is made from agricultural products. An amendment was offered in committee to loosen this requirement and it failed. There is clearly a strong sentiment in the Congress to help the farmers while cleaning up the environment.

In the Committee to which I am a counsel, the Committee on Energy and Natural Resources, Chairman Bennett Johnston, has chaired two hearings on alternative fuels. It will be late December before the legislative report of the Environment and Public Works Committee will be available. Once we see that and what that committee intends to offer on the floor, our committee may have its own alternative fuels amendments.

The general consensus I've found in Washington is that we indeed will enact provisions on alternative fuels next year. A coalition could rally together. Strong environmentalists could join conservatives who defer to the President. Also joining may be members who see a greater demand for ethanol and ETBE (which is produced from ethanol) as a way to help farmers. Other members from natural gas producing states will likely favor a program to encourage fleets of automobiles and buses to operate on natural gas. The question is how stringent will the measures be? That is simply unclear for now. The only thing that is clear is that alternative fuels will be a matter of intense Congressional interest next year.

Mr. James Bruce is the Senior Counsel for the Committee on Energy and Natural Resources of the U.S. Senate. Mr. Bruce has been associated with the U.S. Senate since 1975. Following his completion of engineering degrees (B.S. and M.S.) from Princeton University in 1971, and a law degree from George Washington University in 1974, Mr. Bruce started as a staff member and subcommittee counsel for the Committee on Aeronautical and Space Sciences of the U.S. Senate. From 1977 to 1980 Mr. Bruce was the Counsel for the Subcommittee on Energy Regulation, a subcommittee of the Committee on Energy and Natural Resources. Between 1980 and 1986, Mr. Bruce was the Counsel for the full Committee on Energy and Natural Resources. In 1987, Mr. Bruce was named Special Counsel for the Subcommittee on Energy Regulation and Conservation, and in November 1987, Mr. Bruce was promoted to Senior Counsel of the full Committee on Energy and Natural Resources in the Senate.

POTENTIAL FROM A NATIONAL ENERGY EFFICIENCY POLICY

Mr. Nicholas A. Fedoruk
Energy Conservation Coalition

Improving the energy efficiency of the U.S. economy promises to play a critical role in meeting several critical national needs: environmental quality, cost-effective economic development, energy security, international competitiveness, and protection of family incomes.

- Improving Environmental Quality - Energy efficiency reduces energy use and thus environmental harm resulting from exploration, production transportation, and consumption of energy. Such problems include acid rain, air pollution, land use, oil spills and nuclear waste.

  However, the most challenging energy related environmental problem is the threat of global warming. In June 1988, a conference of international scientists met in Toronto and agreed that the world needs to reduce carbon dioxide emissions by 20% by 2005 to slow the progress of global warming to an acceptable rate. As the largest single contributor to global warming, the U.S. must play a major role in meeting this goal. Several members of Congress have called for an accelerated U.S. target of reducing carbon dioxide emissions by 20% by 2000. The National Academy of Science and other organizations in the scientific community believe our understanding of global warming is sufficient to justify remedial action now. Analyses by Oak Ridge National Laboratory and the Environmental Protection Agency show that energy efficiency is crucial for an effective global warming strategy.

The most promising method for reaching this goal is to increase the efficiency of combustion and thereby get more usable energy per unit of fuel. It has been estimated that increasing the efficiency of energy use by 2.5% per year is technically and economically feasible and would have a substantial impact in slowing global warming.

- Meeting Energy Needs Cost-Effectively - Energy conservation has already significantly reduced our national energy bill and the potential for additional economic conservation investments is enormous. The Department of Energy's FY 1989 Energy Conservation Multi-Year Plan reports that over the last seven years the U.S. has saved the equivalent of 20 billion barrels of oil, equal in energy value to two-thirds of U.S. oil reserves, and valued at more than $400 billion. Numerous studies suggest that the U.S. could further reduce its present annual energy bill from $400 billion to $300 billion or less by employing energy conservation technologies and measures that are less costly than acquiring energy from conventional supplies.

- Reducing Oil Imports - Energy conservation can reduce oil imports and stretch the U.S.' diminishing domestic oil supplies. U.S. dependence on foreign oil has surged from 27% of oil consumption in 1985 to 46% by the third quarter of 1989. Our rate of energy consumption would be even worse without the significant strides in energy conservation that have been made over the last decade. If the U.S. economy still consumed oil and gas at the 1973 rate, we would be consuming an additional 13 million barrels of oil equivalent per day, almost half of OPEC's production capacity.

- Improving America's International Competitiveness - Continued advances in energy-saving technology can play a key role in assuring the competitiveness of U.S. industry in the world market. Over the past decade, American automakers lost one-fourth of the global market to fuel-efficient Japanese cars. A similar challenge to our domestic and international market is emerging from foreign competitors in lighting, heating and air conditioning, motors, appliances, manufacturing equipment, and industrial processes. Unfortunately, as the President's Commission on Industrial Competitiveness Report noted, America has recently lost global market shares in 7 out of 10 high technology market areas, despite leadership in developing high technology products. R&D in energy efficiency can reverse this trend and insure against further erosion of competitiveness.

- Improving Quality of Life for Low-Income and Disadvantaged Households - While energy prices are important for everyone, they have special importance for the disadvantaged. Increases in energy prices have a greater effect on low-income and fixed-income citizens. Low-income families generally have the least energy efficient homes. In 1986, low-income families used 14-15% of their income for energy bills, three times the national average. Retrofit programs can assist the neediest families and also extend the benefits of assistance programs.

The good news about improving energy efficiency is that rather than asking the nation to sacrifice to meet these many challenges, placing energy efficiency at the center of our national energy strategy promises to provide large economic benefits. The Energy Conservation Coalition, the Alliance to Save Energy, the American Council for an Energy Efficient Economy, and the Natural Resources Defense Council have developed a 10 part national energy efficiency platform that promises to save 15.9 quads per year, $75 billion per year and 356 million tons of carbon per year by the year 2000 when compared to the Energy Information Administration's base case. The policies and their associated savings are found on the Table 6.1.

The policies represented in our platform are designed to overcome market imperfections that prevent the economy from realizing the full potential benefit of cost-effective energy

Table 6.1. Potential benefits from the energy efficiency platform.

Policy Proposal	Savings in 2000 Energy (Quads)	Money (Billion $)	Carbon Emissions (Megatons)
Vehicle efficiency standards	2.0	12	41
Gasoline tax	0.9	10	19
Conservation in acid rain legislation	1.9	9	48
Reform utility regulation	3.8	14	94
Increase the efficiency of electricity supply	0.9	--	20
Appliance efficiency standards			
existing standards	1.2	6	25
new standards	1.1	5	25
Buildings standards and retrofit programs	1.2	5	22
Reduce federal energy use	0.2	1	4
Reduce industrial energy use	2.7	13	58
Increase conservation R&D	-	-	-
Totals	15.9	75	356

efficiency investments and purchases. You will notice that they are designed to address barriers in every sector of the economy, transportation, utility, residential/commercial and industrial. In addition there are recommendations for improving the governments own energy efficiency and for increasing energy efficiency research and development.

Taken together, these policies can provide substantial insurance against the worst dangers of global warming and assure the many benefits described above. Given the fact that after over a decade of improving energy productivity, the overall energy efficiency of our nation has stalled, it is imperative that we implement these policies now.

Mr. Nicholas A. Fedoruk is Director of the Energy Conservation Coalition, an alliance of 20 national public interest organizations committed to promoting efficient use of energy and expanded use of renewable energy resources. Mr. Fedoruk has been active in energy policy over the last 15 years at the Hudson Institute, the Department of Energy and the Energy Conservation Coalition. He has authored numerous articles and studies on energy conservation and, more recently, global warming.

THE FUTURE OF NUCLEAR ENERGY IN THE UNITED STATES

Mr. Bill Harris
U.S. Council for
Energy Awareness

Thank you for the invitation to be here today. Better than most audiences, you understand that the nation's energy policy today stands at a crossroads. Our nation needs--our nation demands--increasing supplies of energy to fuel our industrial and economic growth, to light our schools, to warm our homes.

We must produce and use that energy with the smallest feasible impact on our health and on our environment. And we must do so without increasing our dangerous reliance on foreign oil. That is a tough assignment, which calls for some important balancing-for unless these competing demands are reconciled, the picture will be bleak for our nation's energy future.

I am going to talk to you today about how the energy situation looks to those of us concerned with electricity supply, and particularly, those of us who produce nuclear energy. Three important trends are already posing significant problems for our nation's energy security.

First, as I am sure you are all aware, U.S. dependence on foreign oil is once again rising to dangerous levels. We are already importing almost half the oil we use. That is more than we were importing just before the Arab oil embargo of 1973. And increasingly, this oil is coming from the unstable Middle East region. That should make all of us who remember the mid-1970's more than a little uneasy.

Beyond the rise in oil imports, there is a second problem. Electricity demand is growing much faster than predicted, much faster than new generating plants are being built. The day of reckoning is approaching fast. In some parts of the country, brownouts are already routine on days when electricity demand is high.

Third, energy producers, as never before, are being held strictly to account for how energy production affects the environment. Americans are not willing to accept polluted water and air as the price they pay for energy. Our nation wants it all--plentiful, affordable energy, and a clean environment.

In short, those of us in the energy industry face a major challenge in the coming decades. We are charged with finding an answer to a difficult question: how can our nation develop ample supplies of energy--from domestically abundant fuel--and still protect our environment.

ELECTRICITY HAS FUELED A GROWING ECONOMY

It is impossible to understand the overall U.S. energy picture without looking at electricity's role in fueling America's economic growth. There is no doubt America is using energy more efficiently than we did before the 1973 oil embargo. The U.S. gross national product has risen 47% since 1973, but total energy consumption rose only 8%. So we have been squeezing more work out of every BTU of energy we use. Our per capita energy use is also down.

But these numbers conceal an important trend. Our economy has become increasingly electrified. In other words, we are substituting electricity for the direct burning of fuels. In the 15 years since the embargo, U.S. electricity consumption increased by a whopping 50%, hand-in-hand with the 47% GNP grown, while non-electric energy consumption actually dropped about 6%. Clearly, electricity has fueled much of the growth in the U.S. economy over the past 15 years. It is electricity which has helped our nation use energy more efficiently. And if our economy is to continue to grow at a healthy rate, our electricity supplies must grow, as well.

ELECTRICITY DEMAND IS OUTPACING SUPPLY

But supplies of electricity in the U.S. are running dangerously low. Year after year, the demand for electricity grown faster than new generating capacity is being added.

Since 1982, peak demand for electricity has grown 27%, new supplies by only 11%. This trend is especially true in the New England and mid-Atlantic regions.

During the summer of 1988, there were 14 brownouts on the East Coast, more than half of these in New England. Businesses and industries suffered power outages. Some hospitals were forced to use emergency generators. Utilities appealed to the public to cut power use. Many utilities recorded electric demand not expected until the next decade or beyond.

Unfortunately, while demand is rising, construction of new electric power plants is at a 15-year low. Additions planned over the next 10 years will support a growth rate of only one percent a year with any degree of reliability. That is about one-fourth the growth rate we have recently been experiencing.

If our economy continues to grow at its present rate, the U.S. could need as much as 200,000 megawatts of new generating capacity by the year 2000. That is about as much electric generation capacity as there is today in all of California, Arizona, New Mexico, Utah, Idaho, Nevada, Colorado, Oregon, Washington State, New York, Maine, Vermont, New Hampshire, Rhode Island, Massachusetts, Connecticut, Pennsylvania, and New Jersey. That is a lot of additional electricity.

Unfortunately, most Americans do not realize there is a problem. In fact, only 24% of the public think their area will need any new power plants in the next 10 years. While energy is fast becoming one of our most serious economic and national security problems--while it is costing the American economy productivity and growth, imposing higher energy prices on the American people, and making us less energy-secure--the public does not even know we have a problem.

CONSERVATION AND ENERGY EFFICIENCY ARE IMPORTANT

I do not mean to suggest that we can--or should--do nothing but produce our way out of our supply problems. We must continue to conserve and we must continue to use energy and electricity more efficiently. A lot of people do not realize this, but the electric utility industry and its customers have already accomplished a great deal in this area.

Utilities now have in place about 1,300 programs, on which they spend one billion dollars each year, to maximize their customers' energy efficiency, either by using less or by shifting their usage to off-peak hours. These programs have added up to peak load savings totaling more than 21,000 megawatts. That is equivalent to the output of 21 large power plants. Certainly even greater savings can be realized in the future.

Unfortunately, conservation, higher efficiency, and renewable energy--by themselves--will not solve the problem. U.S. Council for Energy Awareness (USCEA) recently asked an energy economics consulting firm to give us an estimate of what we could expect from an aggressive push in these areas. We assumed that electric demand over the next 10 years would grow about 3% percent a year, the average over the last 15 years.

Then we assumed that half of all households installed a high-efficiency refrigerator (and tossed their old one out), and that half of all households replaced 60-watt incandescent light bulbs with 20-watt fluorescent bulbs.

We also assumed that we could double the amount of wood burned to make electricity, and increase by 10 times the amount of electricity we get from trash, wind power, and solar.

Do you know what we found? Even a high-powered effort like this would replace or produce only 14% of the new electric supply we will need over the next 10 years. That is good....but not good enough. The simple fact is, the U.S. will need to produce more electricity than we are capable of producing now.

OUR NATION IS DANGEROUSLY DEPENDENT ON FOREIGN OIL

But adding new electrical generating capacity is only part of the solution. We also must ask ourselves, what <u>kind</u> of generating capacity. This leads me to the second disturbing trend I want to talk about. With domestic oil production falling, our nation is increasingly, and dangerously, dependent on imports of foreign oil. Foreign oil now accounts for nearly 40% of U.S. oil consumption.

We also should not forget that this dependence on imported oil means a constant flow of dollars out of this country and into the coffers of foreign oil producers. The U.S. today pays foreign countries $840 million each week for oil--and that now accounts for a whopping one-third of the U.S. trade deficit.

And it is going to get worse. By the year 2000, we may be importing as much as 10 million barrels a day, or 55% of our total oil needs, and paying other countries over $100 billion a year for that dangerous dependence.

We believe that encouraging domestic oil production is in the best interest of this country. But with domestic production declining and imports from Persian Gulf nations increasing, we must face the facts. The wise course is for the utility industry to do all it possibly can to avoid increasing its use of foreign oil.

Today, however, over 25% of U.S. electric capacity is still fueled by oil and natural gas. Because of rising oil costs, the utilities try to reserve much of that capacity for peaks in demand. But some regions of the country are depending more and more on oil to meet day-to-day demand. New England gets some 35 to 40% of its electricity from oil-fired plants. On Long Island, it is close to 100%.

If we fail to meet rising electric demand by using sources other than oil, the utilities' only option will be to crank up oil-fired units. This will leave us increasingly at the mercy of imported oil suppliers--their unstable political agendas and whatever prices they choose to charge. The result will be higher electricity costs--and threats to reliable supply.

This is not just a hypothetical danger. We are already moving in that direction. In 1973, utilities used 1.5 million barrels of oil a day to generate electricity. By 1987, thanks largely to coal and nuclear energy, that had been reduced to 546,000 barrels. But ominously, in 1988, we had climbed back up to 679,000 barrels a day, an increase of 24%. This year, it is 785,000. By the mid-1990's, utilities will again be burning 1.8 million barrels of oil a day--almost all of it imported. That is right back to where we were in 1973. This trend must be stopped. Our nation is so dependent on foreign oil for other uses, like transportation, that we simply cannot afford to make it worse by using more oil to generate electricity.

ENVIRONMENTAL CONCERNS ARE REAL AND GROWING

Protecting our environment must be the third important priority in our national energy policy. The list of environmental concerns is a long one, and increasingly, each is a part of the public's daily media fare: oil spills, acid rain, carbon dioxide, chlorofluorocarbons, nitrogen oxides, sulphur dioxide. Along with concern about air quality, Americans are becoming more and more concerned about global warming, the so-called greenhouse effect. In a recent survey by Cambridge Reports, 68% of Americans said they had heard about the greenhouse effect. That is an eight-point jump since February.

Public attitudes toward the environment are clear. In April of this year, 15% of Americans interviewed mentioned the environment as one of the two most important problems facing the nation--the highest percentage ever. Fifty-two percent said they were willing to sacrifice economic growth for the sake of the environment, but only 19% would sacrifice the environment for economic growth. However, as I said before, Americans think we can have both--that neither really has to be sacrificed.

RENEWABLES: DOWN THE ROAD

Renewable energy sources--wind, hydro, solar, geothermal, biomass--have always spurred a great deal of interest. No question, they are very appealing. They are clean and inexhaustible. They hold promise for the future. But today, they are just not ready to make a substantial contribution to our nation's energy supply. Renewable energy supplied less than nine percent of U.S. electricity in 1988. The lion's share, over eight percent, came from hydroelectric power. Solar, wind and geothermal power <u>combined</u> supplied only four-tenths of one percent of America's electricity needs.

This is partly because most renewables are geographically limited. Solar energy has greater potential in Southern California than in Maine. Most large hydroelectric sites have already been developed. Also, most renewable technologies are still in their infancy and not yet economical for widespread use.

The nation's utilities are funding many innovative projects to help renewable technologies play a larger role in our future energy picture. But for the coming decades, we must depend primarily on other, more available sources of electricity. Among them: nuclear energy.

THE IMPORTANT ROLE OF NUCLEAR ENERGY

Nuclear energy has been used broadly, reliably, and safely worldwide for 30 years. Today, it is America's second-largest source of power. The nation's 100-plus nuclear power plants supply nearly 20% of U.S. electricity. By substituting for coal, oil, and natural gas, nuclear energy has saved consumers $50 billion in electricity costs since the 1973 oil embargo.

Nuclear energy has reduced U.S. dependence on foreign oil. Since 1973, nuclear plants have cut our use of foreign oil by nearly four billion barrels and reduced our foreign oil payments by $115 billion. That is a big step toward U.S. energy independence.

Nuclear energy is one of the most environmentally benign sources of energy available today. It emits no pollutants, no greenhouse gases. In fact, except for renewables, nuclear energy is America's only completely clean source of electricity. Unlike renewables, however, nuclear energy is available and economical today.

The nuclear industry was severely jolted by Three Mile Island in 1979. Although no one was injured, the industry undertook a painstaking reevaluation of every phase of nuclear plant operations and a concerted drive for excellence. The Nuclear Regulatory Commission (NRC), which keeps close watch on the industry, reports dramatic improvement in all areas of performance. The industry is committed to maintaining and even improving those high marks.

There is no higher priority than the safe, permanent disposal of the waste from nuclear electricity plants. Every bit of this waste has been stored safely from the start. But Congress recognized the need for permanent disposal and passed the Nuclear Waste Policy Act of 1982. This landmark legislation created a complete program and timetable for the creation of the nation's first underground waste repository by the end of the century. In 1987, lawmakers chose Yucca Mountain, Nevada, about 100 miles northwest of Las Vegas, for scientific evaluation as a possible location.

Independent scientific groups, including the National Academy of Sciences, have concluded repeatedly that by using the earth's own natural barriers, along with modern technology, we can create stable repositories deep underground that will isolate the waste from our environment. Today, the major obstacle to managing nuclear waste is not scientific or technical--it is political.

We often hear in the media about opposition to nuclear energy. But scientific survey data indicates that a broad cross-section of the American people support the use of nuclear energy. There is a growing national consensus that we should move forward with our nuclear energy program.

Fortunately, there are some indications that people are growing more concerned about energy supply. When they were asked how serious our energy problem is, we have seen a large 12-point jump between February and May of this year in the percentage of Americans saying our energy supply problem is <u>very</u> serious, from 36 to 48%. America seems to be waking up from the complacency about energy that has kept energy issues on the back burner since 1982. And we at USCEA are pushing to get greater awareness of that point.

The public is increasingly aware of the benefits of nuclear energy. Recent opinion polls by both Gallup and Cambridge Reports show that about 76% of the American public believe nuclear energy will be important in meeting our electricity needs in the years ahead. More than three-fourths of the people believe the need for nuclear energy will increase in the years ahead, and three-fourths believe we are likely to need more nuclear plants. Nuclear energy is named far more often than any other source as the primary source of electricity 10 years from now. And in an indication of desire, 70% believe nuclear energy <u>should</u> play an important role in our energy supply.

Americans are counting on the availability of nuclear energy when it is needed, and this public acceptance is reflected in political support. During the 100th Congress, there were 21 recorded floor votes on nuclear energy legislation. Each time, the House and Senate supported positions favoring continued nuclear energy development. President Bush is an outspoken supporter of--in his words--"clean, safe nuclear energy." The National Conference of State Legislatures and the National Governors Association have also taken the position that nuclear energy must play a growing role in solving our nation's energy problems.

I am not saying that people love nuclear energy. But as they weigh the risks of not using nuclear energy--like the greenhouse effect or foreign oil imports--they consider nuclear energy a good and realistic alternative.

I do not mean to give the impression that all is rosy for our industry. Utilities investing in nuclear plants have been subjected to punitive rate regulation by state utility commissions, as well as continually changing requirements imposed by the NRC which have unnecessarily slowed down and driven up the cost of construction. As a result, utilities today are leery of ordering additional nuclear electric plants.

Our industry is working to reduce or eliminate these obstacles. We are working to modernize the present system of plant licensing, for example, to create greater consistency and predictability. Members of our industry are presently seeking NRC approval of new, advanced designs for nuclear electric plants. These plants are simpler and make greater use of natural safety systems. They will be quicker and less costly to build than the generation of plants that were completed in recent years, which will make them more attractive to both utilities and state regulators. We are convinced that such changes can and will be accomplished. Once they are, nuclear energy will be able to make an even greater contribution to our nation's energy security.

Our industry is working hard toward that day, just as the oil and gas producers are working to develop the energy America will need, despite the many obstacles you face. You know, as we do, that Americans do not want an energy supply problem any more than they want a polluted environment. Solutions will not be simple--but they must be forthcoming. We believe there has never been a better time to expand our use of nuclear energy.....for never has America more urgently needed this clean, safe source of electricity.

Mr. Bill Harris is Senior Vice President of the USCEA, headquartered in Washington, D.C. Prior to his affiliation with the Council for Energy Awareness, Mr. Harris was legal counsel to Congressman Mike McCormack.

Mr. Harris has been in the forefront of energy matters in recent times. He is a member of the American Nuclear Society and is on the Board of Directors of the Electric Information Council. Mr. Harris has earned degrees from Iowa State University and the Georgetown University Law Center. He is a member of the bar in both Virginia and the District of Columbia.

PHYSICAL OCEANOGRAPHY

Session: PHYSICAL OCEANOGRAPHY

Co-Chairs: Dr. Murray Brown
Dr. Alexis Lugo-Fernandez

Date: December 6, 1989

Presentation	Author/Affiliation
Physical Oceanography: Session Overview	Dr. Murray Brown and Dr. Alexis Lugo-Fernandez Minerals Management Service Gulf of Mexico OCS Region
Program Overview Gulf of Mexico Physical Oceanography Program - Year 5 -	Dr. Evans Waddell Science Applications International Corporation
Analysis of Louisiana Shelf Currents	Dr. William J. Wiseman, Jr. Coastal Studies Institute Louisiana State University
Cold and Warm Eddies on the Louisiana Slope	Dr. Peter Hamilton Science Applications International Corporation
New Atlas of Front Locations in the Gulf of Mexico	Dr. Fred M. Vukovich Research Triangle Institute and Dr. Peter Hamilton Science Applications International Corporation
Analysis of Drifting Buoy Trajectories from Year 5	Dr. James K. Lewis Science Applications International Corporation
Gulf of Mexico Circulation Modeling Study	Dr. Alan J. Wallcraft JAYCOR, Inc.
The Texas Institutions Gulf Ecosystem Research Initiative: Multi-Year, Repeated Hydrographic Surveys in the NW Gulf of Mexico Continental Shelf and Slope	Dr. Doug C. Biggs Department of Oceanography Texas A&M University
Nelson Eddy, 1989	Mr. Kent J. Schaudt, Marathon Oil Company Dr. George Z. Forristall Shell Development Company, Dr. Doug C. Biggs, Department of Oceanography Texas A&M University and Dr. James B. Bole Amoco Production Company

Session: PHYSICAL OCEANOGRAPHY (cont'd)

Presentation	Author/Affiliation
Meteorological and Oceanographic Measurement System (MOMS) in the Gulf of Mexico	Mr. Raymond H. Canada National Data Buoy Center John C. Stennis Space Center
Navy-Sponsored Deep Ocean Research Island	Dr. David Moran U.S. Navy David Taylor Laboratory
NASA-Sponsored Coastal Zone Color Scanner Data Archive	Dr. Frank E. Müller-Karger Department of Marine Science University of South Florida
Remote Sensing of Energetic Ocean Features/Large Waves near Energetic Ocean Features	Dr. David Sheres Center for Marine Science University of S. Mississippi
Acquisition and Analysis of Polar Orbiting Environmental Satellite Data at Louisiana State University	Dr. Lawrence J. Rouse, Jr. Coastal Studies Institute Louisiana State University

PHYSICAL OCEANOGRAPHY: SESSION OVERVIEW

Dr. Murray Brown
and
Dr. Alexis Lugo-Fernandez
Minerals Management Service
Gulf of Mexico OCS Region

The 1989 Information Transfer Meeting (ITM) provided an opportunity for researchers in the five year Gulf of Mexico Physical Oceanography Program (FY 1982-FY 1986) to present publicly the first results from the final segment of the program, the field effort offshore central Louisiana. Previous work in Years 1, 2, and 4 was directed at the southwest Florida shelf; work in Year 3 occurred offshore the Texas/Mexico border in the Western Gulf. Year 5 included all of the methodologies employed in previous years, and in some respects represents a maturation of synthesis techniques, particularly regarding newer methods such as synoptic aerial probe surveys and altimetry.

The program manager for the contract study, Dr. Evans Waddell, of Science Applications International Corporation, presented an overview of Year 5. The primary measurements taken during the work included: subsurface currents, ship- and aircraft-base hydrography, drifting buoys, ships-of-opportunity (SOOP), satellite remote sensing, satellite altimetry, marine optics, inverted echo-sounder, and collateral wind and water level data. The results characterized the north central zone in the Gulf as rich in anticyclonic and cyclonic eddies. Evidence was presented that inverted-sounders may detect about twice as many eddies as previous satellite and SOOP data were able to identify. Topographic Rossby waves appear to be evident in westward-propagating motions. Shelf processes and circulation were found to be driven by three factors: local and remote winds, the coastal boundary layer (Mississippi River plume), and eddy interaction along the outer shelf edge. A wide range of optical conditions was measured, with major implications for any future biological oceanographic assessments.

Dr. Bill Wiseman, of Louisiana State University (LSU), discussed the results of current measurements on the continental shelf from five moorings located meridionally along 92 °W. Most of the current activity appears in the along-shelf (east-west) component, associated largely with winds. Cross-shelf activity was associated largely with tidal and inertial motions. The flow field in the upper layer over the shelf was demonstrably different from that of the lower shelf layer and upper slope waters. Mean flow in the former regime was consistent with the model of Cochrane and Kelly, i.e., a broad gyre in the cyclonic sense over the Louisiana shelf. Both local and distant winds play important roles in forcing shelf circulation, possibly along with wind-stress curl. During the measurement period (April 1987 - October 1988) there was no clear evidence that any Loop Current eddy strongly affected shelf circulation.

Dr. Peter Hamilton, of Science Applications International Corporation, discussed cold and warm eddies on the slope, using data from the three current meter moorings. The lower slope tends to be dominated by "small eddies" (that is, smaller than typical Loop Current eddies), which can remain in place for periods on the order of one month. These features may not always be seen in remote sensing data, or even near-surface thermal data, but their influence on upper circulation was evident in the track of one drifting buoy. The buoy described through an eddy field evident in hydrographic data only below a few hundred meters. One scenario for the behavior of the eddies observed in the measurement period call for both westward and eastward movements in an as-yet unexplained regime.

Dr. Fred Vukovich, of Research Triangle Institute, described the derivation of an "atlas" frontal locations in the Gulf of Mexico. The work was based on a 10-year set of satellite sea surface thermal observations, in which various fronts and water masses were identified. The resulting figures, to be presented in the Year 5 report, include frequency distributions for the following: Loop Current fronts, Loop Current water, Loop Current eddy fronts, Loop Current eddy water, shelf/slope front.

Dr. Jim Lewis, of Science Applications International Corporation, discussed the results of analyses of drifting buoy trajectories. During the 28-month period from August 1986 to December 1988, 11 drifters were deployed in the Gulf, aimed at studying 3 Loop Current eddies which appeared then. His work indicates that anticyclonic eddies can coalesce in the western Gulf, the process causing some mixing of eddy water with resident Gulf Common Water. Additionally, the interaction between anticyclones and cyclones appears to be vigorous, although the origin of the latter is poorly understood. Lewis' observations appear to be consistent with previous theoretical models of cyclone origin and cyclone-anticyclone interaction.

Dr. Allan Wallcraft, of Jaycor Inc., discussed the final products of a long-term circulation modeling study of the Gulf, closely coordinated with the field measurements activities described above. The original intention was to model the entire Gulf using the so-called "NORDA Model" developed by Hurlburt and Thompson. Difficulties in simulating the shelf with this code, led to the assimilation of a separate model, originally written by O'Brien, for the shelf, the two being linearly blended along the edge of the shelf. The final blend, which simulates the circulation as upper and lower vertically integrated "slabs", has been subjected to a post-processing step, based on Thompson's work, that supplies a realistic vertical velocity profile. The results are being supplied as 10-year simulation of the entire Gulf surface and several selected depths, at 3-day intervals, as well as complete vertical current profiles for several sites identical to current meter moorings during the 5-year program.

Dr. Doug Biggs, of Texas A&M University, described a program of hydrographic surveys in the northwestern Gulf, jointly sponsored by the University and the Minerals Management Service (MMS). The work is aimed at verification and characterization of the presence of major eddy circulation structures in the area, due in part to the western migration of Loop Current anticyclones. The work, just begun, will continue into 1993 in conjunction with the planned Louisiana/Texas Physical Oceanography Program of MMS.

Mr. Kent Schaudt, of Marathon Oil Company, discussed observations from Nelson Eddy, a Loop Current ring. It was first seen in satellite imagery and confirmed by drifting buoys. The eddy was stationary throughout the spring and early summer, by July a surge of the Loop Current into the continental shelf south of the Mississippi Delta induced currents in excess of 100 cms^{-1} in water depth of 100 m. Vertical profiles of currents and temperatures were made along a southeast to northwest line across the eddy. Also, transects of surface salinity, temperature, and water chemistry were made along the same line. Current measurements in water depth of less than 500 m showed speeds in excess of 100 cms^{-1} in the northeast quadrant, and measurements with acoustic current profilers showed speeds in excess of 141 cms^{-1} at the surface.

Mr. Raymond H. Canada, of the National Data Buoy Center, discussed the Meteorological and Oceanographic Measurement System (MOMS), a 3-year joint program between the National Weather Service and five oil companies. The program collects information on wind speed and direction, barometric pressure, air temperature, and wave data which are transmitted using the GOES satellite. In addition, oil companies collect current and wave directional data on a proprietary basis. Recently, the observational system has been upgraded with the Value Engineered Environmental Payload. This system records wind speed and direction, wind gust, barometric pressure, air, and sea surface temperature. Also, wave height, period, and wave spectra are collected by this system. The data collected are archived and available from National Oceanic and Atmospheric Administration's (NOAA) National Climatic Data Center and National Oceanographic Data Center.

Although not included in the Presentation Summaries, due to security restrictions, a presentation was given by Dr. David Moran, of the U.S. Navy David Taylor Research Center, on the planned Deep Ocean Research Island (DORI). The DORI is a rebuilt semisubmersible platform that will be installed by the Department of Defense in the central Gulf of Mexico as a base for anti-drug surveillance. In addition, it will be a national laboratory for deep ocean naval research, designed to serve the entire ocean research community in the Gulf of Mexico. At present, deployment is scheduled for mid-1990 for the first 5-year cycle of operations.

Dr. Frank Müller-Karger, of the University of South Florida, discussed the 4 km resolution data from the Coastal Zone Color Scanner (CZCS) archived at the University of South Florida. Only data from 1978-1980 is availabl e for distribution because of sensor calibration problems. The CZCS data allowed study of the Loop Current and associated eddies between late May and October, the season characterized by a uniform sea surface temperature; which impedes the used of infrared imagery for their studies.

Dr. David Sheres, of the University of Southe rn Mississippi, discussed detection of energeti c features of the ocean (fronts and eddies) and regions of high sea states near ocean features such as meandering fronts using remote sensing techniques. Incoming swells are refracted by these energetic surface flows features (ESFF). The refraction pattern being dependent on wavelength and direction of the swell and the flow distribution of the ESFF is used to infer the ESFF flow. The refraction patterns can be detected using several remote sensing techniques. The ESFF can also focus wave energy by refraction, creating zones of focused energy called caustics. These caustics can be hazardous to equipment, people, and marine operations. Once these caustics are located and studied, the data can be used with wave-current interaction models that determine wave energy distribution.

Dr. Lawrence J. Rouse, Jr., of Louisiana State University, discussed LSU's facility to acquire and analyze direct broadcast High Resolution Picture Transmission data from NOAA's Polar Orbiting Environmental Satellites. Data received comes from three instruments: (1) the advanced very high resolution radiometer, (2) the three dimensional temperature and humidity fields from TIROS, and (3) data from mobile platforms such as drifting buoys by ARGOS. Data coverage includes the entire Gulf of Mexico at a rate of seven to nine pass es per day. Such data helps study large features of the oceans, atmosphere, and land masses.

In summary, the above presentations indicate that a rich program of physical studies is taking place in the Gulf, and that important connections between research efforts are being made. The continuing exchange of information through the ITM process and other inter-program activities points toward increased visibility of Gulf research and toward an evolution in planning and management modes. This successful session provided a necessary forum for the emerging community of cooperating physical oceanography researchers in the Gulf of Mexico.

Dr. Murray Brown received his B.S. degree in chemistry at Duke University in 1969, his Licentiate (Ph.D.) in marine chemistry from the University of Copenhagen in 1975. He has worked for the U.S. Army Corps of Engineers in a variety of assignments, and, since 1978, within the Offshore Studies Program, of Bure au of Land Management and MMS. At prese nt, he is project officer for the MMS physical oceanography study series and has special interest in information management.

Dr. Alexis Lugo-Fernandez is an oceanographer with the Minerals Management Service, Gulf of Mexico OCS Region. His primary interests are physical processes on corals reefs and circulation in the shelf. Dr. Lugo 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.

PROGRAM OVERVIEW GULF OF MEXICO PHYSICAL OCEANOGRAPHY PROGRAM - YEAR 5 -

Dr. Evans Waddell
Science Applications
International Corporation

OVERVIEW

In 1982, the Minerals Management Service (MMS) initiated a study of physical oceanographic conditions in the Gulf of Mexico. The fifth and final program year, which has recently been completed, had a primary objective of documenting and characterizing shelf, slope, and deep water conditions and circulation patterns in the north central Gulf. Specifically, the majority of measurements were made along 92° W in water depths ranging from 15 to 3,500 m (Figure 7.1).

Primary measurements which were taken during the nominal study period of April 1987 through October 1988 included:

- subsurface currents/temperature/ transmissometry;

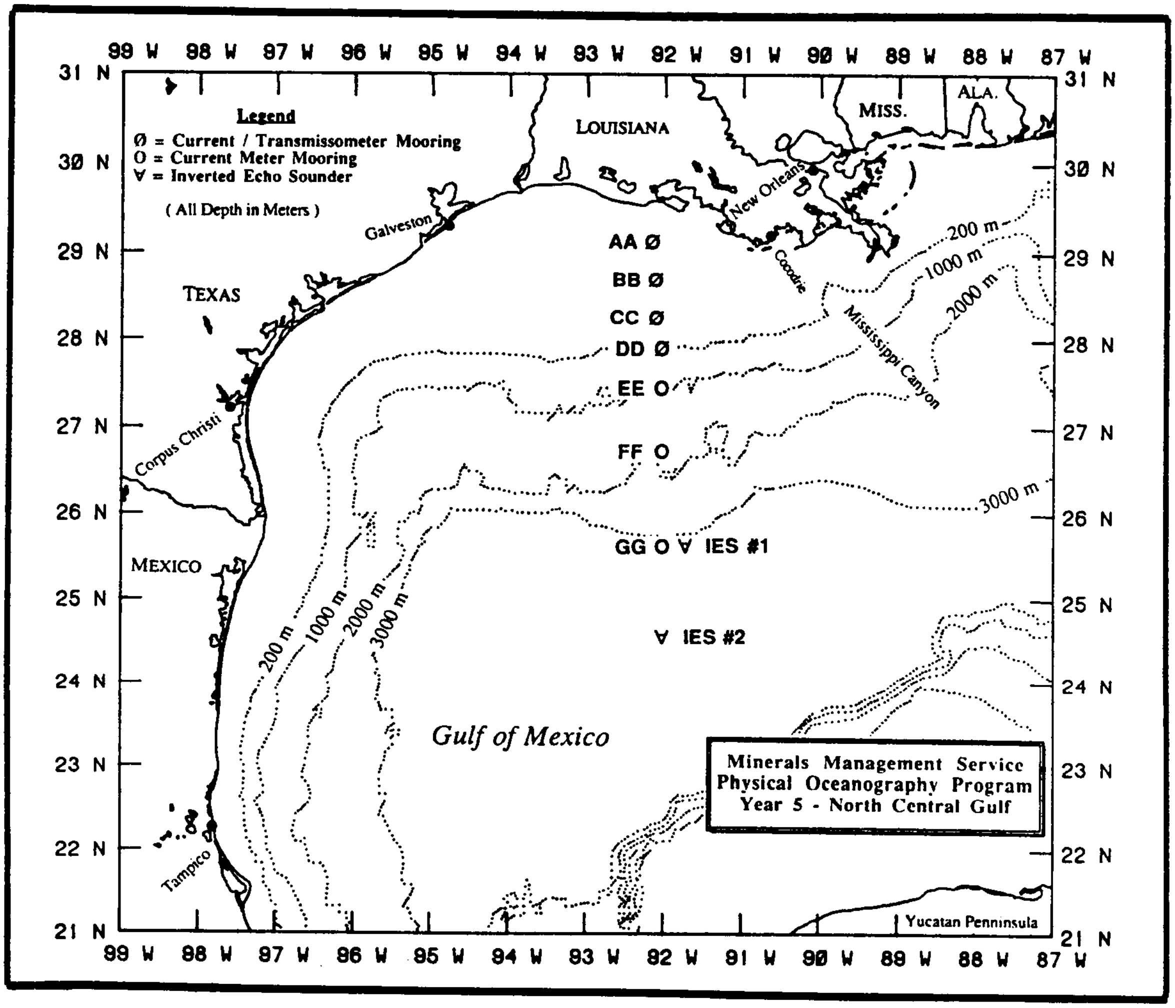

Figure 7.1. Mooring locations during Year 5 of the MMS-sponsored Gulf of Mexico Physical Oceanography Program.

- ship and plane-based hydrographic surveys;
- satellite-tracked drifters (ARGOS);
- ship-of-opportunity XBT transects;
- satellite thermal imagery;
- geosat altimetry;
- marine optical measurements;
- inverted echo sounders; and
- winds and waterlevels.

These observations were used by a group of scientific and technical participants to develop the primary insights resulting from this study. These are presented in the Year 5 Final Report (Science Applications International Corporation 1989).

DISCUSSION

Eddies

A key result of this study was the documentation and partial description of anticyclonic and cyclonic eddies with a broad range of sizes. Measurements showed that a "rich" and diverse eddy field existed in the deep Gulf and over the slope (Figure 7.2). A major factor governing the number and type of eddies seen in the Gulf at any given time was the period of Loop Current (warm core/anticyclonic) eddy separation which was estimated to average approximately nine months.

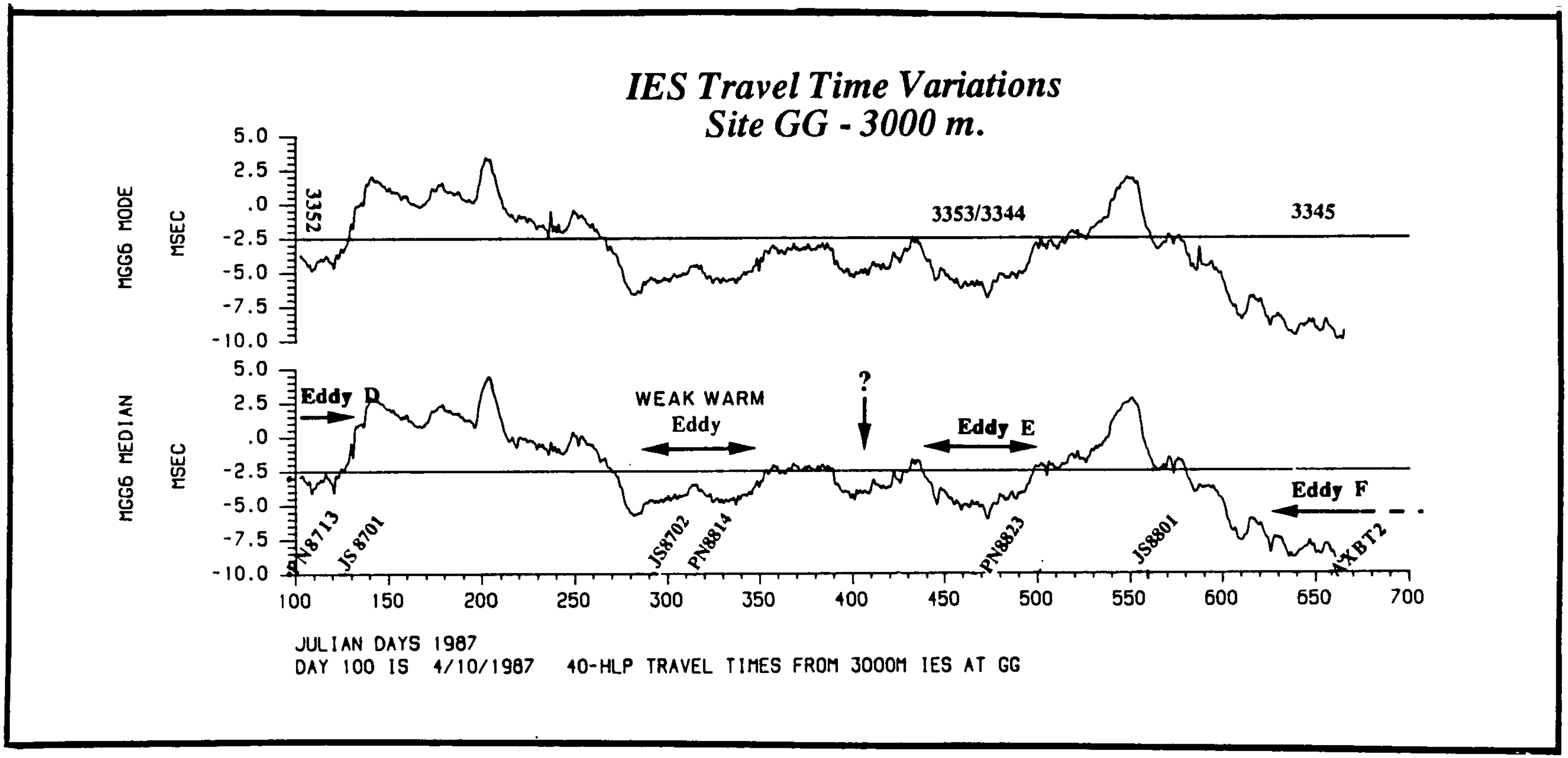

Figure 7.2. Forty-HLP travel times from an IES in the central Gulf. (Anticyclonic eddies moving over the site are identified [reduction in travel time] along with the approximate dates of hydrographic cruises and ARGOS drifters in these features. Some cyclonic features are shown by the peaks in the travel times.)

During westward translation of Loop Current (LC) eddies in a bounded basin such as the Gulf, it is almost inevitable that evolving primary and secondary eddies will interact among themselves and with the adjacent margin. This eddy/eddy and eddy/topography interaction was not well resolved and a topic requiring additional work. As an example: Can eddies coalesce and if so how; Can and how does interaction with the slope produce eddy division or pairing; Are subsurface cyclones related to larger proximate anticyclones and how; What is involved in eddy dissipation? It is clear that a comprehensive understanding of these eddy and eddy-related features requires diverse, coordinated data sets such as rapid yet geographically extensive surveys, subsurface observations (current/temperature sensors and inverted echo sounders), drifting buoys, and satellite imagery and altimetry.

Slope

Evidence showed that some of the observed deep circulation patterns were associated with topographic Rossby waves moving from east to west. Statistical and analytical relations suggested their origin in the eastern Gulf under the Loop Current. The slope circulation was strongly event (eddy) dependent. As a consequence, observed patterns were influenced by the relation of the measurement site to the eddy. Because the eddies move, this relationship is changing and hence the measurements were generally nonstationary, i.e., the representative statistics changed with time.

Analysis of currents in LC eddies suggested that on the lower slope the barotropic and first baroclinic modes accounted for significant portions of the observed current variability. Hydrographic data clearly showed the major baroclinic components of LC eddies is in the upper approximately 1,000 m. Those well-resolved cyclonic features tended to have little baroclinic expression in the upper portion of the water column; rather they had maximum vertical isobath deflection in the middle portion of the water column.

Shelf

Louisiana shelf processes and circulation seemed related to three key processes: local and remote meteorological forcing; the strong, seasonally modulated coastal boundary layer and associated density-driven patterns; and on the outer portion of the shelf, interaction with slope processes such as eddies. In addition, the curvature (not straight) of the coastline and alongshore isobaths influenced these forcing mechanisms to produce a complex and time-dependent current field in various across shelf zones.

Local shelf currents were not consistently related to local wind fields, i.e., specific wind events could be related to some corresponding current events, however, in other cases the current response to wind forcing was not apparent. Prior examination of alongshore flows showed that in the mean, alongshore currents were related to alongshore winds and in the study region partitioned across the shelf (Figure 7.3); however, the variability of currents within the monthly or seasonal averaging periods was much greater than the mean. To resolve better processes leading to specific observed circulation patterns, it will be necessary to make oceanographic and meteorological observations while documenting the time-dependent zones of influence of the coastal boundary layer and forcing from the slope.

Measurements showed that the coastal boundary layer substantially affected the optical properties of the water column on the inner half of the shelf. On the outer shelf, both "blue" water from the deeper Gulf and shelfwater were found. This is as expected from evaluation of satellite imagery which showed exchange across the shelf break.

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Dr. Evans Waddell manages the Marine Science and Engineering Division at Science Applications International Corporation, Raleigh, North Carolina. For the past 12 years Dr. Waddell has been a Principal Investigator and Program Manager on physical oceanographic investigations off of the Atlantic

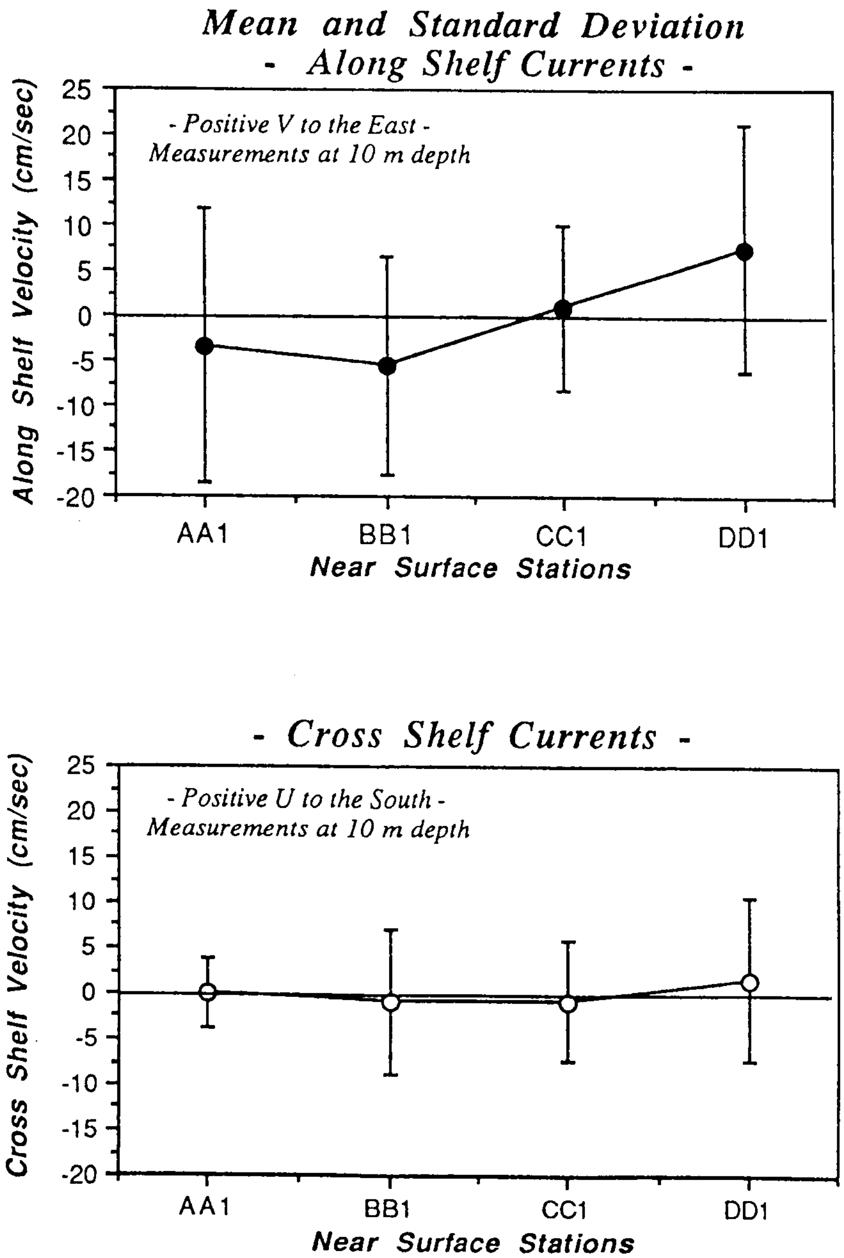

Figure 7.3. Overall mean alongshore and cross shelf currents at the near surface. (The inner shelf is directed westward while the outer shelf goes eastward. Little net cross shelf flow occurs.)

and Gulf coasts. Dr. Waddell received his Ph.D in marine sciences (physical oceanography) from Louisiana State University.

ANALYSIS OF LOUISIANA SHELF CURRENTS

Dr. William J. Wiseman, Jr.
Coastal Studies Institute
Louisiana State University

Five current meter moorings were maintained across the Louisiana shelf and upper slope from April 1987 through October 1989, approximately along 92 °W, in an effort to understand the mean and time-varying components of flow in this region of the Gulf of Mexico. Of particular interest was the interaction of the shelf with the upper slope and the possibility of shelf currents being forced by a Loop Current ring.

Data coverage was not complete during the deployment period, but long, continuous periods of record were recovered from each meter. The raw data from each meter were filtered into a high-passed data set (periods shorter than 10 hours), a tidal-inertial band (periods between 10 and 40 hours), and a low-passed band (periods longer than 40 hours). The coordinate system used for the analyses was a standard east-west/north-south system as the isobaths trend nearly east-west in this region. The low-passed data were analyzed using basic statistical techniques including spectrum estimation, cross-spectrum estimation, and empirical orthogonal function (EOF) analysis.

Most of the current variance appears in the along-shelf (east-west) component of flow and in the low-passed band. At many meters, the weaker cross-shelf (north-south) flow variance is predominantly in the tidal-inertial band. There also appears to be a tendency for a minimum in low-passed current variance to occur around mid-shelf. The correlation time scale for along-shelf low-passed currents in the upper 100 m of the water column was about 2 weeks and half this for the cross-shelf flow. Below 100 m depth and over the upper slope, the correlation time scale for the cross-shelf low-passed currents was approximately two weeks and half this for the along-shelf flow. This difference in the character of the flow field between the upper layers of the shelf waters and the lower shelf layers and upper slope waters will be a consistent feature of the analyses. The mean flows, in the upper layers of the shelf waters, estimated from all available data were consistent with published hypotheses concerning near-surface flow in this region (Cochrane and Kelly 1986). The flows are westward over the inner shelf and eastward over the outer shelf. The deeper meters over the outer shelf and upper slope exhibited a westward mean flow (Figure 7.4). The means were, generally, statistically significant. When seasonal subsets of the data were analyzed, the low-passed current variances were so large that the mean flows, while consistent with published hypotheses, were generally statistically insignificant.

Cross-spectrum estimation between long low-passed current records from meters on the same mooring usually exhibited statistically significant coherence within the synoptic weather band. Coherence between the wind at Sabine Pass or Southwest Pass and the currents were marginally significant with higher significance levels when Southwest Pass winds, i.e., upstream winds were used. The significant coherences, though, were not in consistent frequency bands at all meters. Furthermore, the portion of the total low-passed variance explained by the wind was not large. Finally, coherence between records from different moorings were generally not significant if the moorings were not neighboring. Cross-shelf coherence length scales for both the along-shelf and cross-shelf flows were short. Both stratification and forcing of the shelf are seasonally dependent. Cross-spectrum analysis of shorter, seasonal records did not improve the coherence estimates. It appears that the shelf and upper slope are not driven solely by the local wind.

Assuming that more than one important process was driving the currents, an empirical orthogonal function analysis of the low-passed currents, winds, and sea level at Galveston was performed. The data used in the analysis were from three seasonal subsets of the larger data set. These seasons exhibited distinctly different wind and runoff characteristics. Along-shelf and across-shelf currents were analyzed separately. It was quickly determined that the three meters on the mooring over the upper slope did not contribute to the dominant EOF modes. Therefore, they were omitted from the final analyses. Only the first EOF mode for the

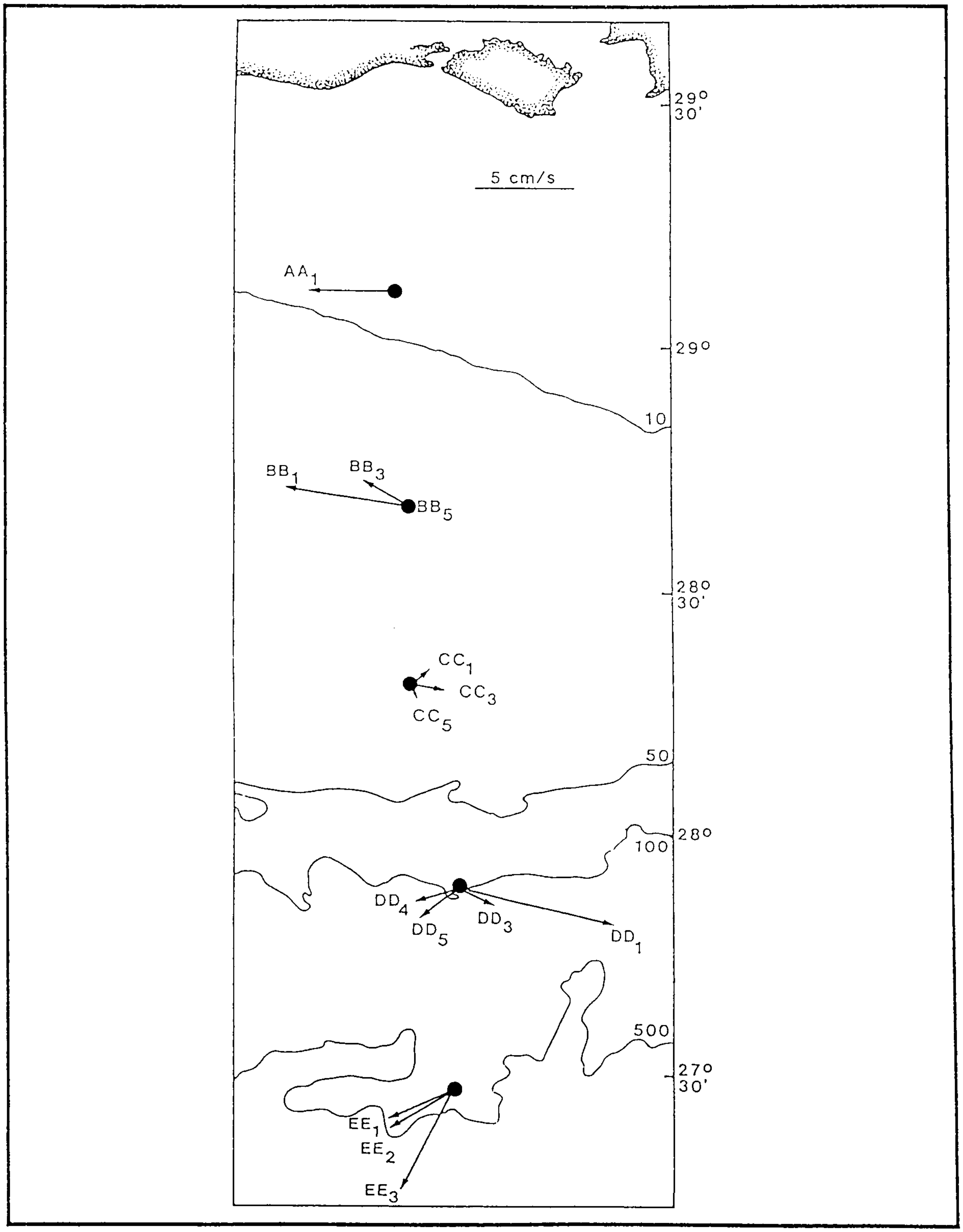

Figure 7.4. Mean current vectors from all available data for the shelf and upper slope moorings.

along-shelf and cross-shelf analyses were readily interpretable in terms of a physical model. The modal patterns were consistent between seasons. In the along-shelf direction, the shelf waters moved in a slab-like fashion in direct response to the wind and the coastal sea level responded in a manner consistent with Ekman dynamics. When the winds blew toward the west, the currents flowed to the west and water level at the coast rose. In the cross-shelf direction, when winds blew to the south, inner shelf and near-surface outer shelf water moved southward and lower layer, outer shelf waters moved northward in a compensatory flow. Coastal sea level dropped. The first EOF mode accounted for roughly 40-50% of the along shelf variance and 20-25% of the cross shelf variance. The other modes were either not statistically significant, or not readily interpretable in terms of a physical model.

The analyses carried out to date suggest that the upper slope acts independently of the shelf waters. There was no clear evidence in the analyses performed to indicate that a Loop Current eddy was driving shelf circulation during the observation period. Simple, linear wind-driven models of the shelf flow leave much of the current variance unexplained. Analyses are continuing to determine the possible roles of far-field forcing and wind-stress curl in driving this shelf region.

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Dr. William J. Wiseman, Jr., received his Ph.D. from the Johns Hopkins University. He has worked at Louisiana State University for the past 18 years and presently serves as Professor and Chairman of the Department of Geology and Geophysics and as Professor in the Coastal Studies Institute. His areas of research interest are shelf and estuarine transport processes.

COLD AND WARM EDDIES ON THE LOUISIANA SLOPE

Dr. Peter Hamilton
Science Applications
International Corporation

INTRODUCTION

The Gulf of Mexico Physical Oceanography Program deployed a line of shelf and slope moorings across the Louisiana shelf and slope along 92 °W. The details of the mooring positions, instrument depths, and time lines of the data records are given in the paper by Waddell. This paper is concerned with the interpretation of current records from Moorings EE, FF, and GG (Figure 7.5) using hydrographic surveys, thermal imagery, and ARGOS drifting buoy tracks to place the flow fields in context of the eddy fields found over the slope and in the deep basin of the central Gulf of Mexico.

ANALYSIS RESULTS

Current records from the Louisiana slope often show sustained long-period events of over a month. An example is given in Figure 7.6 where currents at FF are westward for much of June, July, and August 1988. There is little visual relationship between flows at FF with currents at EE and GG implying the length scale of the feature influencing the current field at the base slope is quite small (-100 km) compared to major warm rings in the deep basin to the south (-300 to 400 km). Another feature of the F9 and E2 records are the occurrence of strong north-south across isobath flows often accompanied by increases or decreases in temperature.

This implies that the lower slope tends to be dominated by small warm and cold eddies which can remain in approximately the same region of the slope for several months at a time.

A chronology, relating current events in Figure 7.6 to the movement of a cold cyclone, first observed in thermal imagery on day 128 (May 7, 1988) east of mooring GG, can be constructed from the time series and hydrography data. The cold events around days 160 and 218 at FF9 and day 180 at GG9 appear to be related to the cyclone moving northwestward then eastward and northward again. In the middle of July, the

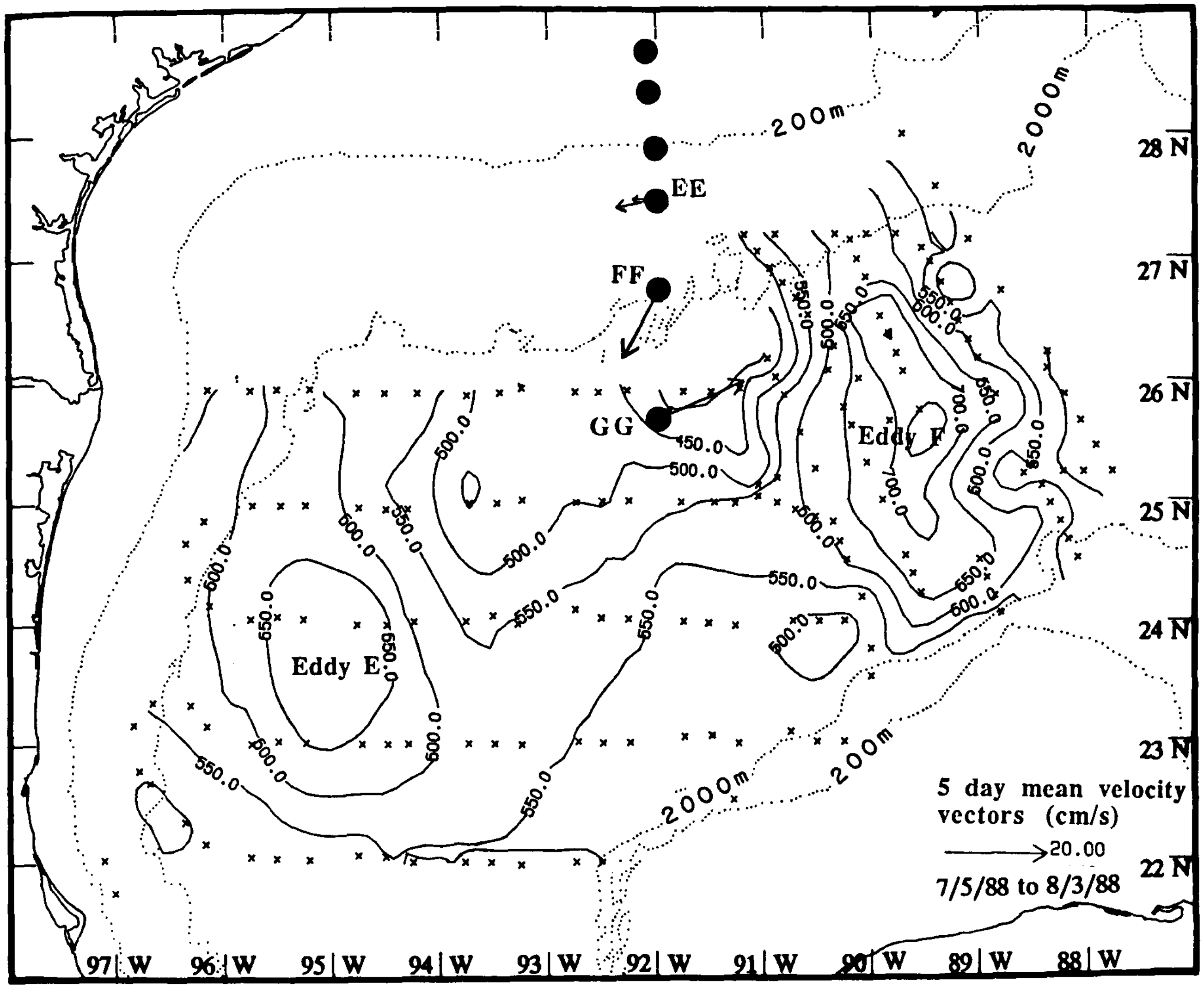

Figure 7.5. The depth of the 8 °C isotherm from multiple ship and air XBT surveys. (The 5-day average velocity vectors from the upper two levels at the moorings are shown.)

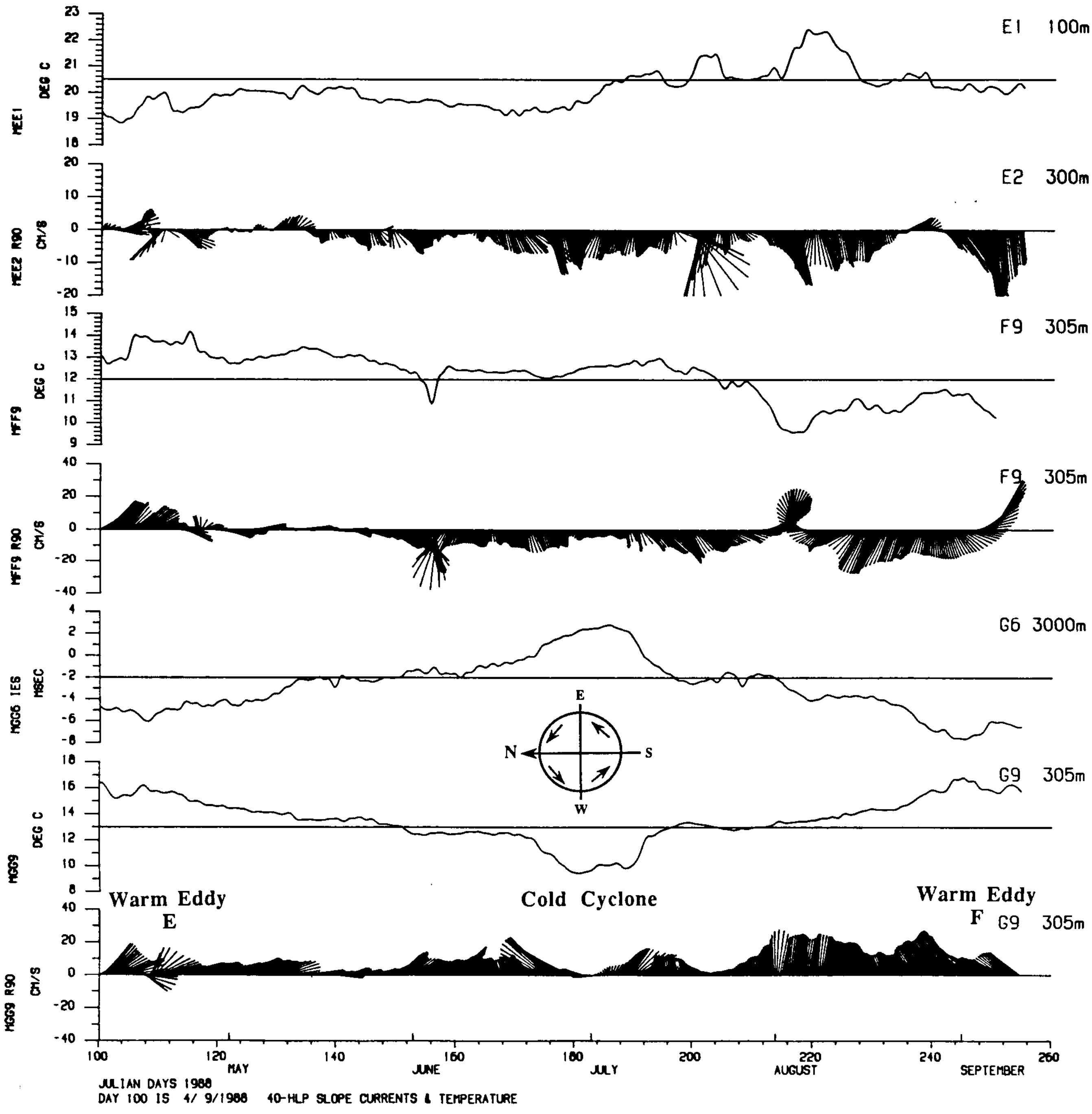

Figure 7.6. Forty-HLP velocity vectors, temperatures, and the travel times from the indicated current meters and inverse echo sounder (G6). (A representation of a cyclone with respect to the coordinate axis is shown on the compass rose.)

cyclone is suggested by the depth of the 8 °C isotherm, composited from a number of different hydrographic surveys, to be at the base of the slope just east of the mooring line (Figure 7.5). The 5-day averaged current vectors from the slope moorings closest to the times of the nearby XBT casts (7/21-7/26) show a cyclonic circulation consistent with a cyclone in this position. The approach of a Loop Current eddy (F) probably pushes the cyclone further up into the slope and creates the cyclonic rotations of the current vectors at FF and increased westward flows at EE around days 218 and 255 in Figure 7.5. The cyclone was observed in hydrographic surveys in October on the lower slope between moorings EE and FF.

A similar type of sequence can be deduced for the current records and thermal imagery in January through March 1988, but this time involving a small warm eddy on the lower slope to the west of the mooring line. This again appeared to be a long-lived eddy which only underwent relatively small displacements during the period of the observations. More detailed discussion of these two small slope eddies and other eddy events can be found in Science Applications International Corporation (1989). An illustration of both warm and cold eddies over the slope is given by the ARGOS drifter track in Figure 7.7. The drifter moves around a warm eddy, over the northwestern slope (possibly the remnants of Loop Eddy), and then is handed over to the cyclone, which is still over the slope at 92 °W in November and then is picked up by an anticyclone further to the east. The relationship of these smaller cyclones and anticyclones to major Loop eddies is unclear at this time as is their formation and eventual fate.

SUMMARY

The circulation of the Louisiana Slope appears to be dominated by small (-100 km) cyclones and anticyclones which are relatively stationary features unless affected by more vigorous Loop Current warm eddy circulations in the deep basin further south.

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Dr. Peter Hamilton is a Senior Oceanographer at Science Applications International Corporation, Raleigh, North Carolina. Over the last 10 years, Dr. Hamilton has been studying circulation processes over the continental slopes and rises of the Gulf of Mexico and the Middle and South Atlantic Bights. Dr. Hamilton has a B.Sc. in physics from the University of Sussex and a Ph.D in physical oceanography from the University of Liverpool.

NEW ATLAS OF FRONT LOCATIONS IN THE GULF OF MEXICO

Dr. Fred M. Vukovich
Research Triangle Institute
and
Dr. Peter Hamilton
Science Applications
International Corporation

INTRODUCTION

Various statistics on surface fronts in the Gulf of Mexico were derived from satellite infrared data obtained during the period 1976 through 1984. The satellite data sets that were used for the analysis were mean monthly frontal analyses that were derived for GOES and National Oceanic and Atmospheric Administration (NOAA) infrared images that were available in the satellite archive at the Research Triangle Institute. Frontal analyses were developed for the period November through May, a period characterized by significant sea-surface temperature gradients in the Gulf of Mexico and a period when absorption by water vapor is minimized. For each month, frontal analyses were developed for each day when relatively clear sky infrared data were available in the Gulf of Mexico. A day having relatively clear skies is defined as a day when the sky cover was sufficiently clear so that the analysts can detect major features in the Gulf of Mexico. On the average and for the period, five relatively clear sky days could be found for each month. The

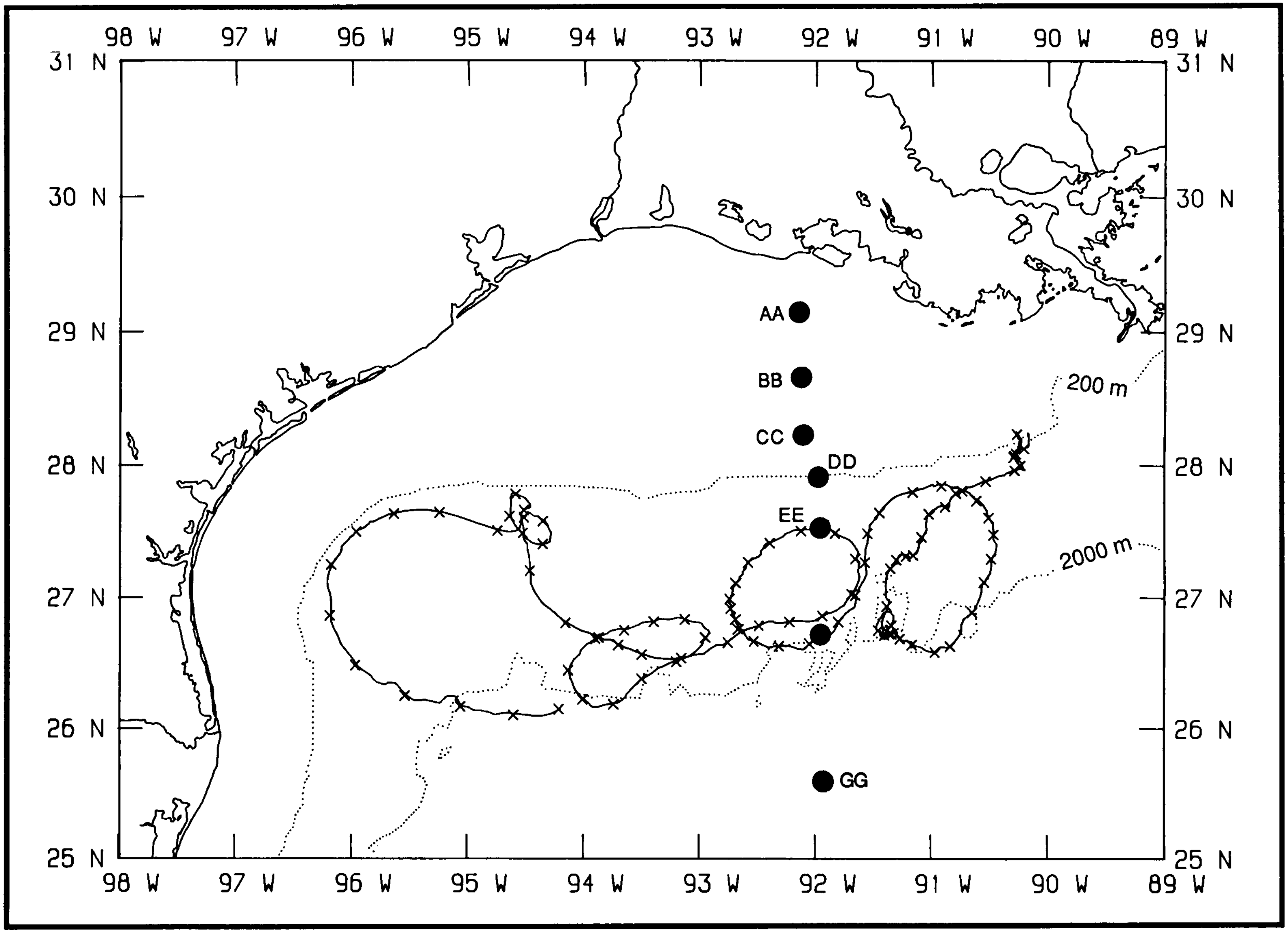

Figure 7.7. The smoothed and interpolated drifter track from Argos 3353, from 1 October to 31 December 1988. (The crosses mark 00 hours GMT for each day.)

range was 2-12 relatively clear sky days per month.

After the frontal analyses were established for each relatively clear sky day in a given month, all frontal analyses for that month were plotted on a single chart for the Gulf of Mexico. The frontal analysis that characterized that month was a graphical interpretation derived from the composite of all daily frontal analyses that were available for that month. In a given region of the Gulf of Mexico, if only one frontal position was available (e.g., shelf fronts in the southwestern portions of the Gulf of Mexico), that single position was accepted as part of a frontal analysis that characterized that month. After the frontal analyses for each month were established, these analyses were digitized, and the digitized results were used to create spatially dependent frequency distributions for the Loop Current Format, warm ring fronts, and shelf fronts.

ANALYSIS RESULTS

Figure 7.8 provides the frequency distribution for the Loop Current fronts, and Figure 7.9 provides the frequency distribution for Loop Current water. In Figure 7.8, a belt of high frequency (i.e., frequencies greater than 25%) follow the general path of the Loop Current and penetrate as far north as 27.5°N. The average northward extent of the Loop Current is found at 26.5 °N based on 13 years of data (1976-1988). Differences are due to the fact that when ring separation occurs, the Loop Current generally is found around or south of 25°N, so that on the average, the northern boundary Loop Current would be displaced south of its most frequent position. These data indicate that the Loop Current seldom penetrates west of 90°W and that its maximum westward extension was 91.25 °W. Loop Current water penetrated northward as far as 29.75 °, immediately south of Mobile Bay and west of DeSoto Canyon. The data suggest that Loop Current interaction with the shelf/slope most probably occurs on the west Florida Shelf south of 28°N.

Figure 7.10 provides the frequency distribution for warm ring fronts, and Figure 7.11, for warm ring water. The magnitude of the frequencies are lower than that of the Loop Current because of the intermittent and nonstationary nature of the warm rings. The highest probability for warm rings occurred at 25 °N and 92 °W. There was a secondary maximum immediately south of the Mississippi Delta at 27 °N and 89°W. The frequency contours intrude on the shelf in the northwest corner of the Gulf of Mexico due to the presence of warm rings in that region. The data suggests that the low probability of warm rings in the southwestern portion of the Gulf of Mexico (i.e., the Bay of Campeche). This effect is the artifact of a short monitoring period due to the rapid warming in that region in the springtime and to the effect of clouds which also limits monitoring using satellite systems.

Figure 7.12 provides the frequency of occurrence for shelf/slope fronts in the Gulf of Mexico. The highest frequency was noted off the Mississippi Delta. The data used to develop the frequency distributions were collected in late fall, winter, and spring. During late spring, the run off from the Mississippi River is a maximum. However, surges of cold water can be observed any time during the observation period mentioned above if significant rainfall occurs in the Mississippi River Basin, which would contribute to the production of a shelf/slope front in that region. It is noted that the region of high frequency extends westward in keeping with the general drift of the river water that surges onto the shelf. Another zone of high frequency is noted in the northwest corner and is potentially associated with some upwelling that occurs in that region and with warm ring interaction. The zone of high frequency on the Campeche bank is associated with persistent upwelling that occurs in that region. The 10% frequency contour is off the shelf immediately south of the Mississippi/Alabama coast indicating the presence of an exchange between the shelf and the slope in that region. Note also that the 10% frequency contour is off the shelf in the form of tongues in the northwest corner. One of the tongues is located around 25°N and the other around 27°N. The shelf/slope exchange that produced these tongues may be similar to the kinds of exchange observed by Brooks and Legeckis (1982) (i.e., large masses of cold water were transported eastward off the south Texas shelf in the form of tongues).

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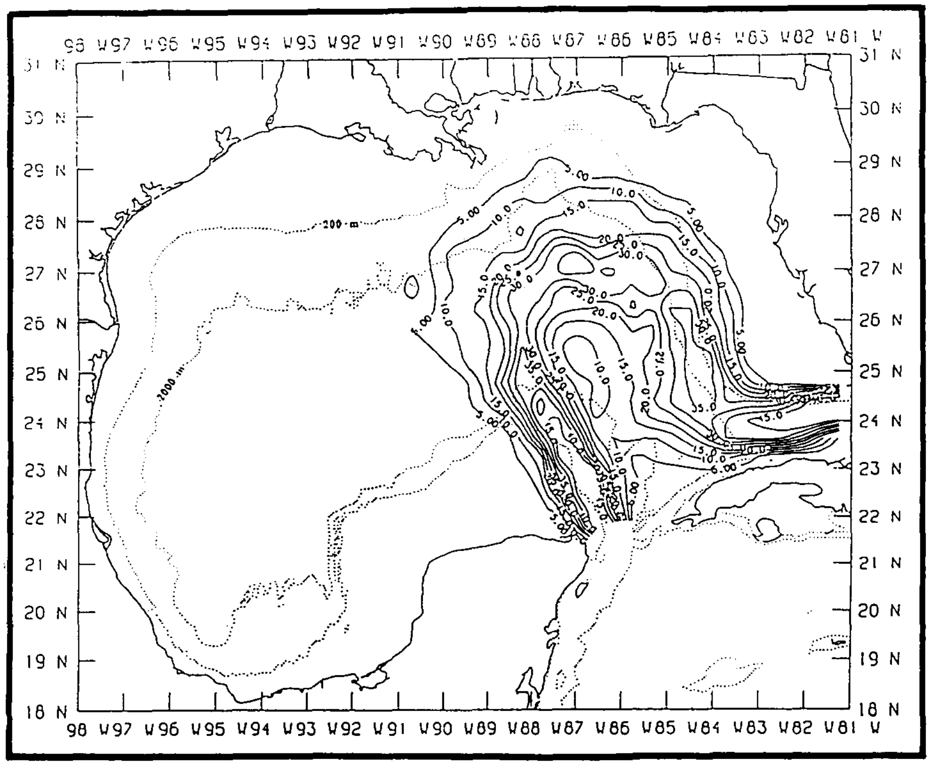

Figure 7.8. Frequency distribution (%) of Loop Current fronts.

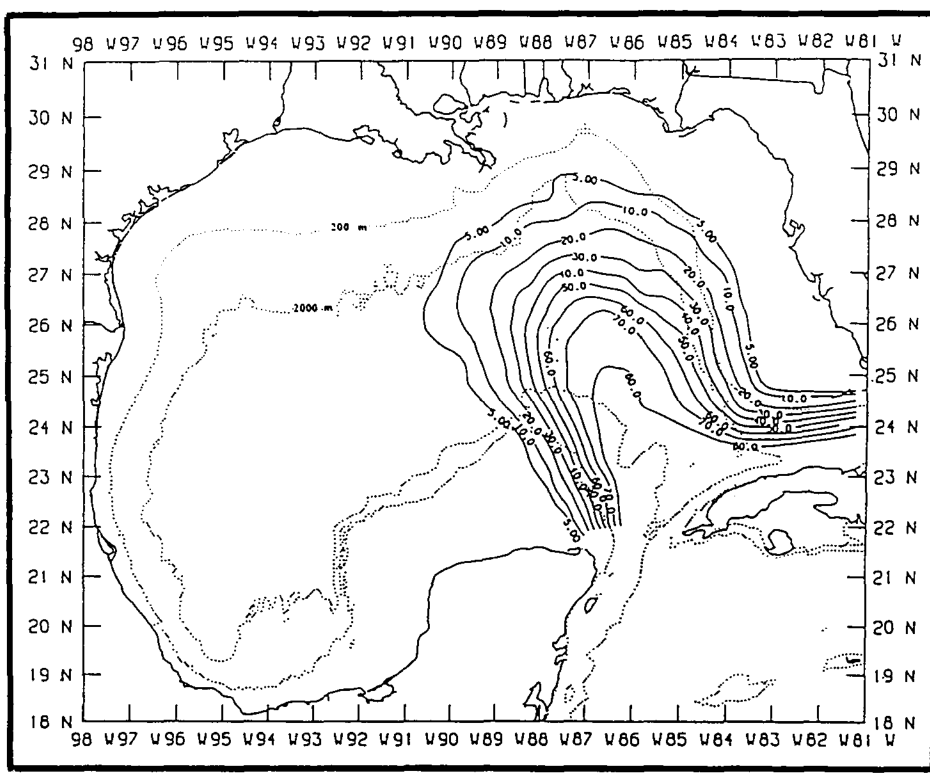

Figure 7.9. Frequency distribution (%) of Loop Current water.

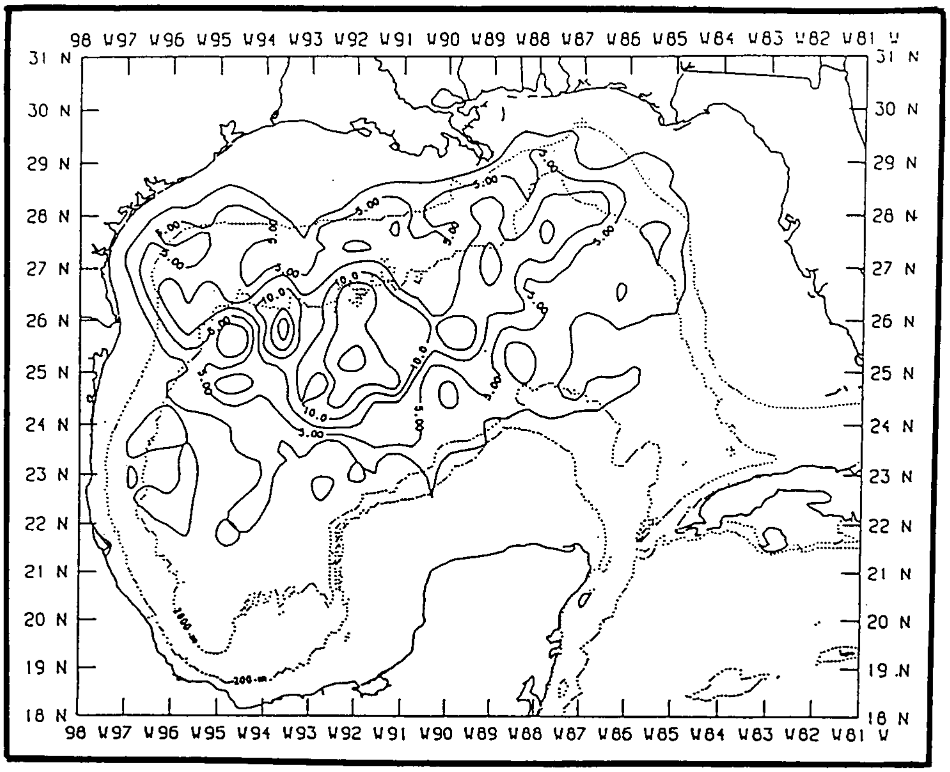

Figure 7.10. Frequency distribution (%) of warm ring fronts.

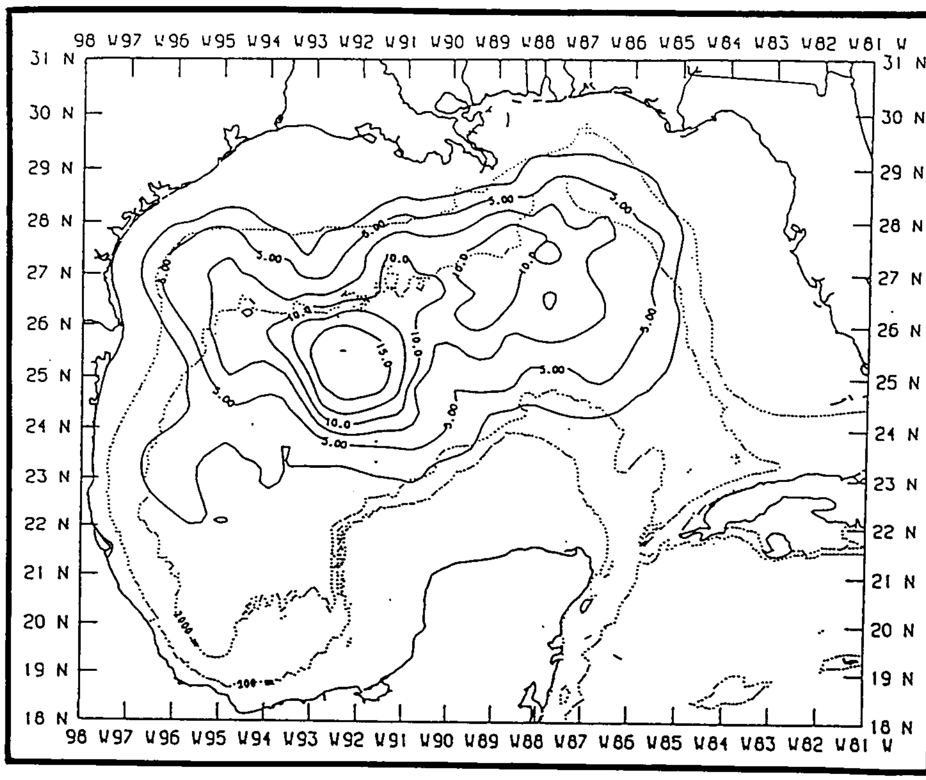

Figure 7.11. Frequency distribution (%) of warm ring water.

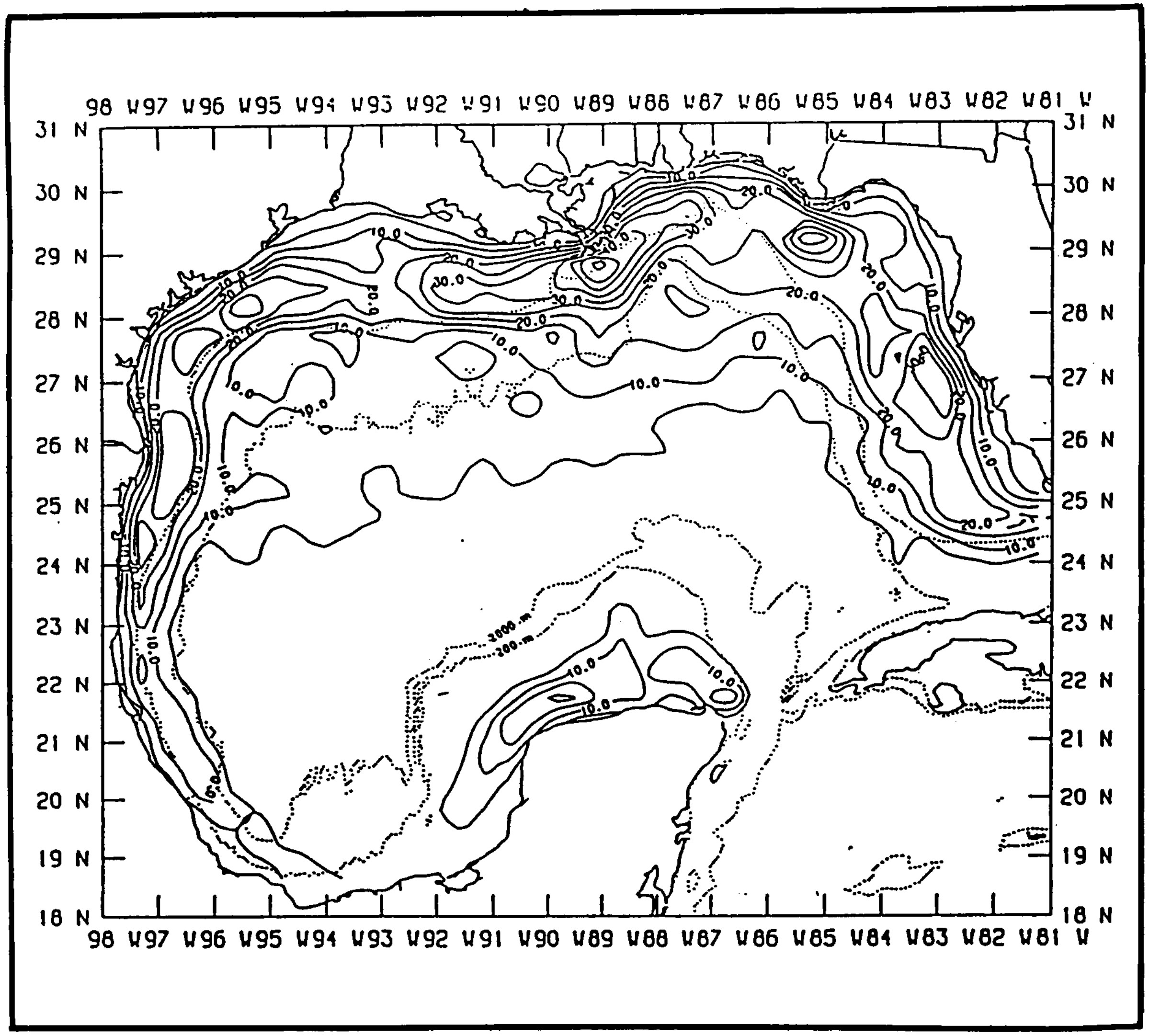

Figure 7.12. Frequency distribution (%) of shelf fronts.

in the western Gulf of Mexico. J. Geophys. Res. 87(C6):4195-4206.

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ANALYSIS OF DRIFTING BUOY TRAJECTORIES FROM YEAR 5

Dr. James K. Lewis
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INTRODUCTION

In a recent paper, Lewis et al. (1989) documented a number of physical processes related to Loop Current rings using Lagrangian and other data. That study covered August 1985 - August 1986. Eleven Lagrangian drifters were placed in and around warm-core rings in the Gulf of Mexico (GOM) from August 1986 through December 1988. In that 28 month time period, 3 additional warm-core rings were shed by the Loop Current. The data pertaining to these rings provides a continuation of the time line of ring shedding and movement as begun by Lewis and Kirwan (1987). In addition, the data provide for the first time a picture of a number of processes related to cyclones in the GOM.

The Lagrangian data indicate that the mixing of water from warm-core rings with ambient Gulf of Mexico water is influenced by coalescing processes, by transient cyclones along the northern continental slope of the Gulf, and, to some degree, by a quasi-permanent cyclone in the Bay of Campeche. Moreover, data show that there is a transformation of some of the anticyclonic vorticity of Loop Current rings to cyclonic vorticity. This mixing of water masses and transformation of negative vorticity to positive vorticity are little understood processes by which Loop Current rings are assimilated into the Gulf of Mexico.

OBSERVATIONS

Drifters were originally seeded in four sequential Loop Current rings. Drifter 3379 was originally in an anticyclonic ring called Hot Eddy (Lewis et al. 1989). It was subsequently ejected from Hot Eddy and entrained in a cyclonic flow field in the Bay of Campeche (Figure 7.13). It was then captured by Hot Eddy once again and entrained by the Bay of Campeche cyclone for a second time.

Drifter 3352 was placed in a subsequent anticyclonic ring, Crazy Eddy. Crazy Eddy was also tracked by drifter 7234, while drifters 5837 and 5839 were caught in the peripheral flow field of Crazy Eddy. The interesting aspect of the trajectories of 5837 and 5839 is that they both performed cyclonic rotations in the region between Crazy Eddy and the Texas continental shelf (Figure 7.14). Hydrographic data have allowed us to characterize these shelf slope cyclones.

The next anticyclonic ring, Lazy Eddy, was tracked by drifters 3348, 3344, and 3353. Drifter 3353 eventually moved along the Texas shelf slope, interacting with two cyclones in that region (Figure 7.15).

The last Loop Current ring studied here was called Eddy Murphy and was tracked by drifters 3345 and 3347. As Eddy Murphy approached Lazy Eddy in the western Gulf, the two flow fields coalesced. The coalescing process resulted in the ejection of drifter 3345 from the anticyclonic flow regime (Figure 7.15).

The features seen by each drifter are summarized in Table 7.1. The names for the Loop Current rings are those adopted by the offshore industry. For an on-going eddy watch program, the offshore industry assigns a name

Table 7.1. Drifters and their associated oceanographic features.

Argos Drifter ID	Feature(s)
3379	Hot Eddy, Bay of Campeche cyclone
3352	Crazy Eddy
7234	Crazy Eddy, mid-Gulf cyclone
5837	cyclones associated with Crazy Eddy
5839	cyclones associated with Crazy Eddy
3348	Lazy Eddy
3344	Lazy Eddy
3353	Lazy Eddy, shelf break cyclones and anticyclones
3345	Eddy Murphy
3347	Eddy Murphy

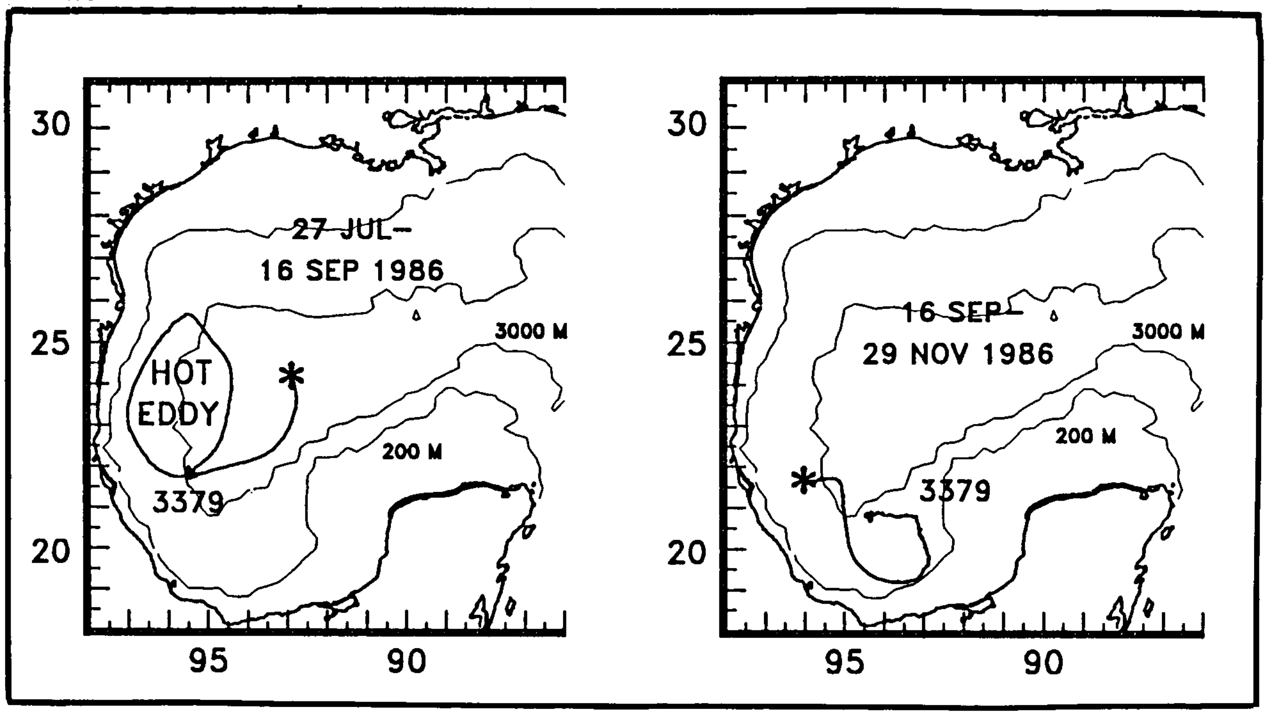

Figure 7.13. Drifter trajectory for 27 July-16 September 1986 and 16 September-29 November 1986. (The asterisks represent the initial positions of the drifter. Depth contours are in meters.)

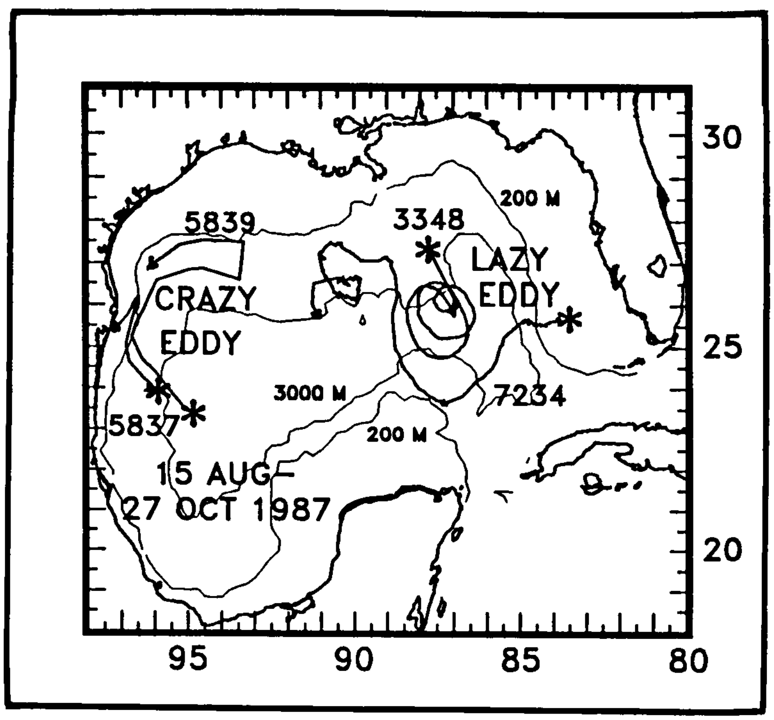

Figure 7.14. Drifter trajectories for 15 August-27 October 1987. (The asterisks represent the initial positions of the drifters. Depth contours are in meters.)

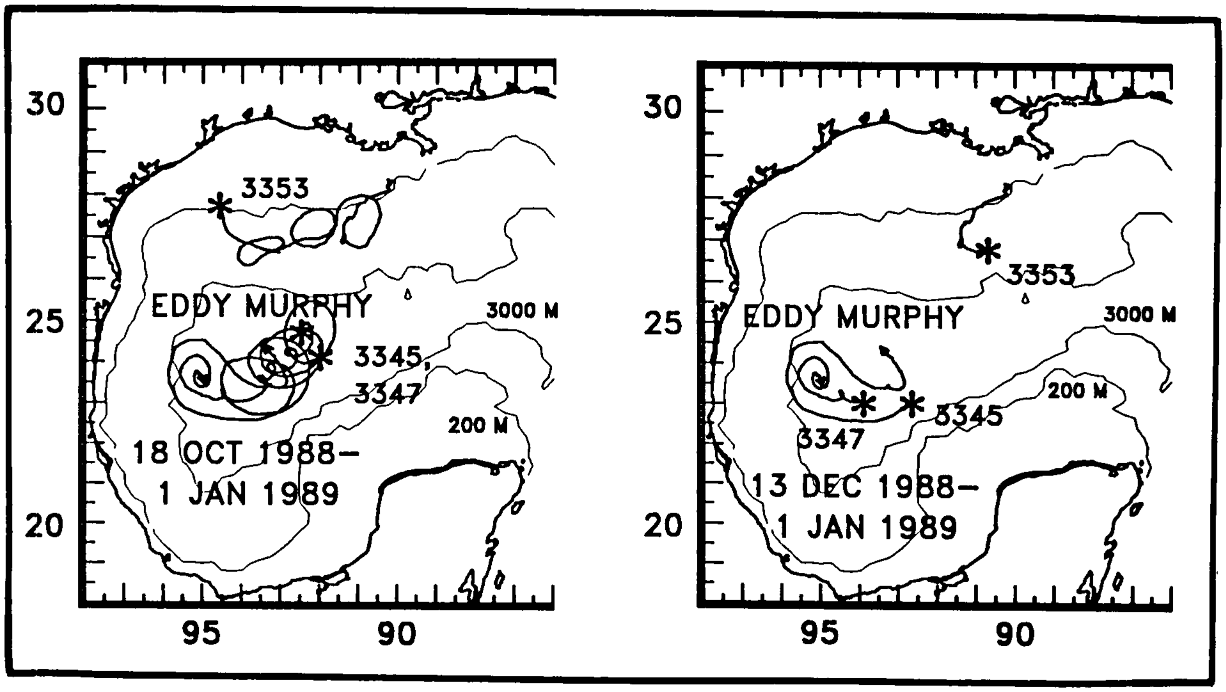

Figure 7.15. Drifter trajectories from 18 October 1988 - 1 January 1989, and 13 December 1988 - 1 January 1989. (The asterisks represent the initial positions of the drifters. Depth contours are in meters.)

storms in the world's oceans. We follow the offshore industry's naming convention for the sake of continuity pertaining to previously generated papers and reports.

PHYSICAL PROCESSES OF INTEREST

Mixing of Loop Current Water

The data indicate a number of processes by which water within Loop Current rings mix with ambient GOM water. Two mixing mechanisms can be identified. One is the exchange between the rings and cyclones in the Gulf of Mexico. The other is associated with the coalescing of Loop Current rings. We discuss this latter topic first.

Coalescing of Anticyclones in the GOM

As a young ring approaches the western Gulf region, its flow field can interact with existing, older anticyclones along the Mexican coast (Lewis and Kirwan 1985, 1987; Lewis et al., 1989). This interaction normally consists of the coalescing of the two flow fields to form one anticyclone. Nof (1988) has recently shown experimentally how such a coalescence occurs. The process has a "padlock" flow signature, with motion that often has the outline of a peanut (see Figure 7.15). Even more recent work has shown that a coalescing process will likely result in the ejection of some of the water of the two rings (Cushman-Roisin 1989). This ejection of water results from the need to conserve the volume, total energy, and angular momentum of the original geostrophically-balanced rings. In past studies, we have often reported drifters which left the anticyclonic field of motion after performing the peanut or padlock maneuver. Thus, it seems likely that the ejection of drifter 3345 from Eddy Murphy (and the corresponding retention of drifter 3347) was a reflection of the need to eject some mass during coalescence with Lazy Eddy in the western Gulf.

This issue is significant because of the amount of mass that could be ejected. Cushman-Roisin (1989) shows that, if the rings are of approximately the same size, more than 20% of the water of the rings must be ejected. Considering the size of Loop Current rings, this is a considerable amount of water. Thus, the various coalescing processes between warm-core rings in the GOM may be the principle mechanism by which water from a Loop Current ring is mixed with ambient GOM water.

The Effects of the Various Cyclones

The Lagrangian data imply an exchange of mass (and thus mixing, to some degree) between Loop Current rings and GOM cyclones. The first cyclonic feature of interest is the Campeche Bay gyre. We believe that this cyclone is primarily wind driven and is not necessarily associated with the Loop Current anticyclones (Vazquez 1975). The interesting point is that some exchange of waters between anticyclones along the Mexican coast and the Campeche Bay cyclone may occur on a regular basis.

The more curious of the cyclones are found along the northern shelf slope of the GOM. These eddies are depicted in both drifter trajectories and hydrographic data. The origins of such eddies appear to be a result of processes occurring in the western GOM. Cyclones generated in the western Gulf could move eastward as a result of the topographic beta effect. It is also possible that the cyclonic eddies are a result of the shedding of vortices as a Loop Current ring moves westward (Smith and O'Brien 1983). Yet, all the cyclones presented here are along the northern shelf slope rather than being in deeper water just east of a westwardly moving anticyclone. Regardless of their origin, these and other Lagrangian data (Lewis et al. 1989) imply an exchange of mass between Loop Current rings and these GOM cyclones along the northwestern GOM continental slope. With the limited data we now have, it is impossible to quantify the degree of mixing.

Vorticity Conversion and the Northwestern Slope Cyclones

The existence of cyclonic eddies along the Texas-Louisiana shelf slope was documented and briefly discussed by Lewis et al. (1989). New hydrographic data (Figure 7.16) have provided better documentation of these features and their characteristics. We now know that these cyclones have a diameter of ~100 km, exist in depths between the 2,000 m and 200 m isobaths, and occur from 89-95 °W. At issue here is how these cyclones are formed. A review of the observations and the available literature has led us to conclude that these cyclones are likely formed as a result of an unstable flow feature around the edge of Loop Current rings as they hit the east-west section of the Texas continental slope. This process was described analytically and numerically by Stern (1987) in his study of entrainment and detrainment in mesoscale ocean eddies.

Stern showed that an unstable, Kelvin-Helmholtz wave can be generated around an ocean ring which has its center slightly offset with respect to its outside edge. Stern also showed that the wave form would travel cyclonically around the edge of a warm-core ring. Thus, as the wave form would break (crest traveling faster than the rest of the wave), the particle trajectories would show distinct cyclonic rotation, not just shear. Moreover, the breaking of the wave will encompass (entrain) water outside of the ring. The key ingredients found in Stern's work are seen in this and other studies. Cyclonic rotation at the edge of a Loop Current ring is shown in Figure 7.14. Both drifters 5837 and 5839 make abrupt cyclonic turns along the western and northern edges of Crazy Eddy. The same process (different year) along with entrainment is seen in the SST and trajectory data presented in Figure 7.17. The data show a cyclone formed in the northwestern GOM with the entrainment of shelf slope water of ~20 °C. The outside edge of the cyclone is formed by a tongue of water extending northward from a Loop Current anticyclone.

To trigger the unstable Kelvin-Helmholtz wave form, Stern indicates that there must be an offset of the center and edge of the Loop Current ring. The northwestern region of the GOM provides a distinct mechanism for such an offset. When water on the westward side of an anticyclone moves northward beyond 26 °N, it moves into a region in which the bottom topography begins an abrupt change from a north-south oriented steep shelf slope to an east-west oriented gentle shelf slope. As the northward movement carries the water into shallower regions, the flow field must adjust. It has yet to be shown that this adjustment is an offsetting of the center and edge of the ring, but this is not an unlikely possibility. Clearly, additional research should prove to be quite interesting concerning this factor.

Thus, these data give a clear indication that Loop Current rings can interact with the

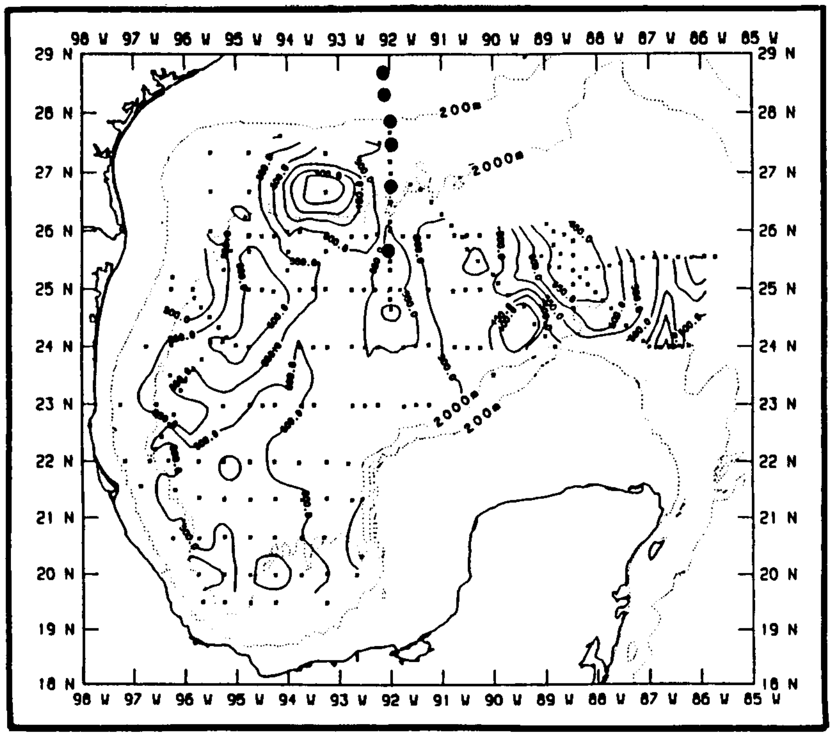

Figure 7.16. The depth of the 8 ° C isothermal surface as constructed from XBT data collected during the period of 14 October-24 November 1987.

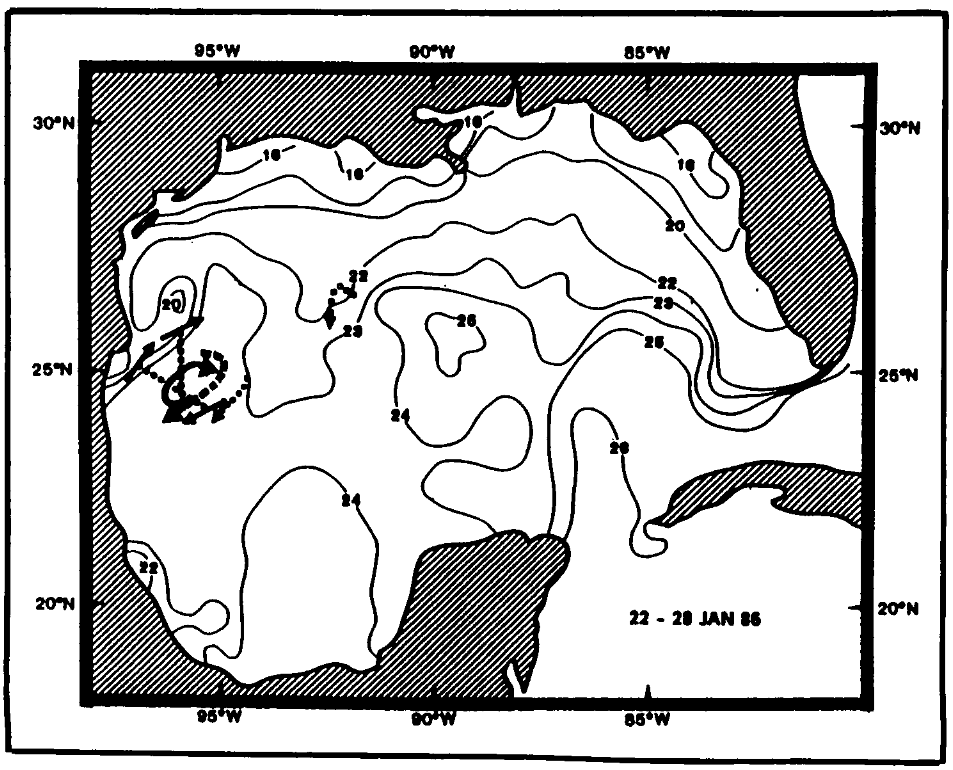

Figure 7.17. Sea surface temperature (° C) for the week of 22-28 January 1986. (Corresponding trajectories of drifters are shown by arrows while dotted lines indicate the locations of ring water as determined by XBT data. See Lewis et al. [1989] for details.)

northwestern GOM shelf region to spin off water from their outer regions, engulf slope water, and form cyclones. But such a process not only has the effect of mixing Loop Current water with ambient GOM water, it also provides a mechanism by which the negative vorticity of Loop Current rings is converted and assimilated into the Gulf of Mexico.

SUMMARY AND CONCLUSIONS

The drifter trajectories and corresponding data sets have provided us with two new insights into GOM circulation processes related to Loop Current rings. The first of these is related to the mixing of waters from anticyclonic rings in the western GOM. The data have identified two separate phenomena that aid in the mixing of Loop current water with ambient GOM water. These are (1) the ejection of some of the water of two anticyclones as they coalesce and (2) the exchange of waters between anticyclones along the Mexican coast and the Campeche Bay cyclone and the incorporation of some Loop Current water into cyclones in the northwestern GOM.

The second insight deals with the more curious of the cyclones, those which are found along the northern shelf slope of the GOM. Although we have a better understanding of the characteristics of these features and how they might be formed, we are unsure if they move east or west and why, and we have yet to relate their formation to the energetics and mass of the anticyclones. These cyclones may or may not provide the mechanism for the transfer of energy and mass back into the eastern GOM, but they surely must play a principle role in energy and mass exchange between the shelf waters to their north and the deep Gulf waters to their south.

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GULF OF MEXICO CIRCULATION MODELING STUDY

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JAYCOR, Inc.

INTRODUCTION

The Gulf of Mexico Circulation Modeling Study was started by Minerals Management Service (MMS) in October 1983 as an "extremely modest effort building on existing/ongoing modeling efforts in the Gulf of Mexico." The initial requirement was for an existing circulation model with capabilities approaching those required and the ability to deliver an "early simulation run." At the end of the four year program the requirement was for a circulation model of the entire Gulf with horizontal resolution approaching 10 km, and vertical resolution (initially less important) approaching:

mixed layer: 1-10 m
thermocline: 10 m
deep layer: 100 m

with realistic bottom topography, coastline, and wind forcing, which must exhibit loop-current eddy shedding, and other known regional circulation features.

PROGRESS

The program has now been completed. The final simulation consists of merged fields from one- and two-layer circulation models, plus an analytic perturbation analysis to obtain surface currents. The one-layer fields are used on the shelf, the two-layer fields are used in deep water, and the two are linearly combined where the Gulf is between 100 and 200 m deep. Surface current fields every 3 days for a 10 year period will be available from the blended simulation. Current fields at 100, 300, 750, and 1,600 m will be available every 6 days for the same period. Detailed vertical profiles every three days will also be available at all the locations of moored current meters from the recently completed, five year, Physical Oceanography Program.

Figure 7.18 shows a snapshot of the blended geostropic surface currents for the Texas shelf region, and Figure 7.19 shows the corresponding surface currents after the perturbation analysis. Figure 7.20 shows surface currents for 2 days, 90 days apart, as an eddy breaks off the Loop Current.

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THE TEXAS INSTITUTIONS GULF ECOSYSTEM RESEARCH INITIATIVE: MULTI-YEAR, REPEATED HYDROGRAPHIC SURVEYS IN THE NW GULF OF MEXICO CONTINENTAL SHELF AND SLOPE

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INTRODUCTION

During October-November of 1987, 1988, and 1989, oceanographers at Texas A&M University in collaboration with scientists at the University of Texas Center for Space Research and with visiting colleagues from the Republic of Mexico Direccion General de Oceanografia Naval fielded multidisciplinary cruises of R/V GYRE to study warm- and cold-core rings over the continental margin of the NW corner of the Gulf of Mexico. Here are reviewed the hydrographic data that were collected on each of these "rings" cruises, as (a) summary maps of the topography of the 15C isotherm; (b) calculated dynamic topography of the rings relative to an 800 db reference level; and (c) vertical sections of temperature in the upper 800 m at 94 °W longitude. The remote sensing characterization of these rings, as well as their biological, chemical, and geochemical characterization, will be reported elsewhere.

HYDROGRAPHIC SURVEY OF NOVEMBER 1987

Cruise 87G-11 departed Galveston at 8 pm on 17 November and returned there at 11 am on 24 November, after 8 days and 960 nautical miles at sea in the NW Gulf of Mexico. CTD/rosette multisampler stations were made at 27 °40'N, 27 °00'N, and 26 °20'N along 93°15'W, 94°00'W, 94°45'W, and 95°30'W to generate a 3 x 4 grid pattern with 40 nautical mile resolution N-S as well as E-W; resolution within the upper 800 m was enhanced by dropping T7 XBTs midway between each of the CTD stations on the N-S lines and by extending them to the south with additional XBT drops at 26°00'N and at 25°40'N.

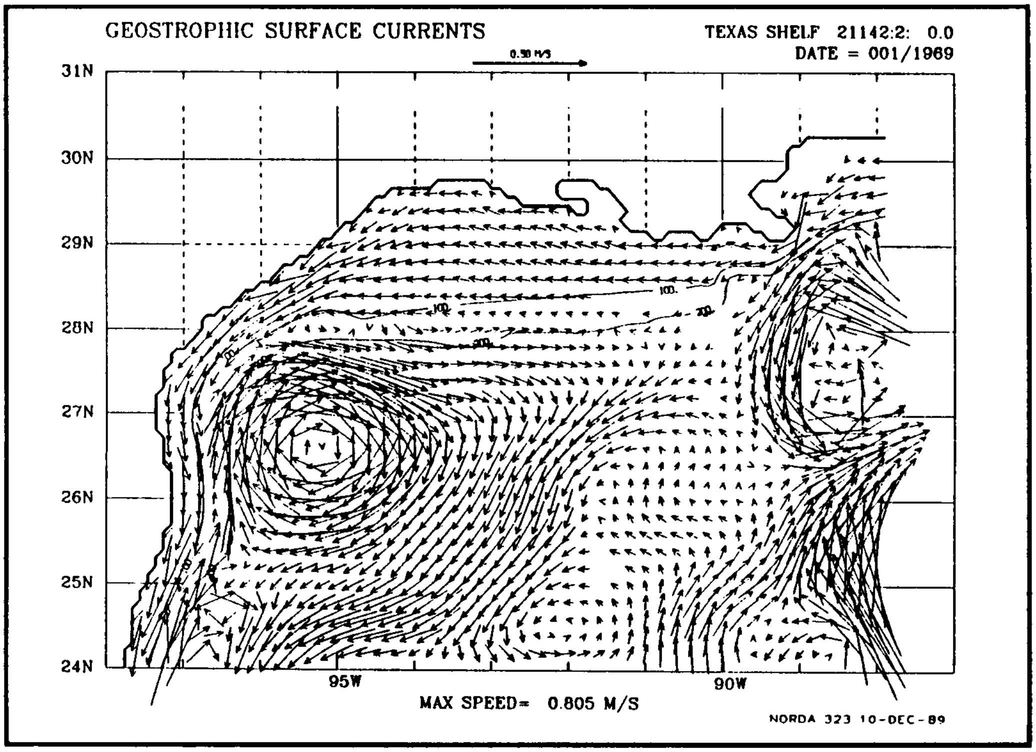

Figure 7.18. Simulated geostrophic surface currents near the coast of Texas for a day in January.

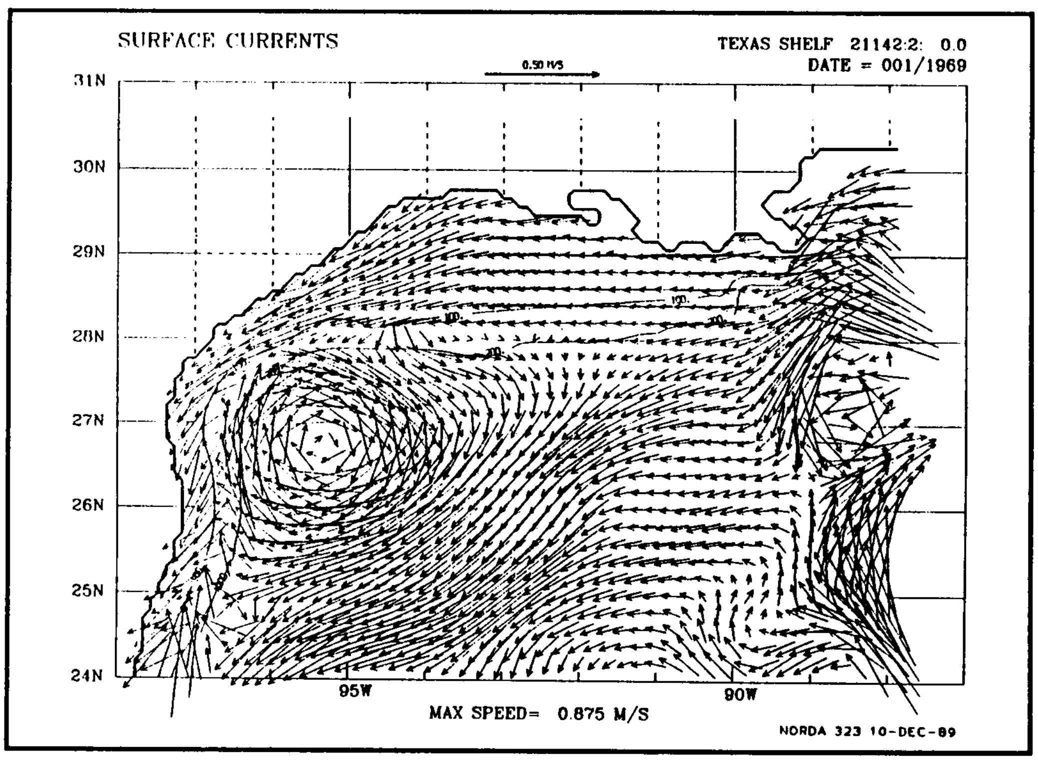

Figure 7.19. Simulated surface currents near the coast of Texas for the same day in January.

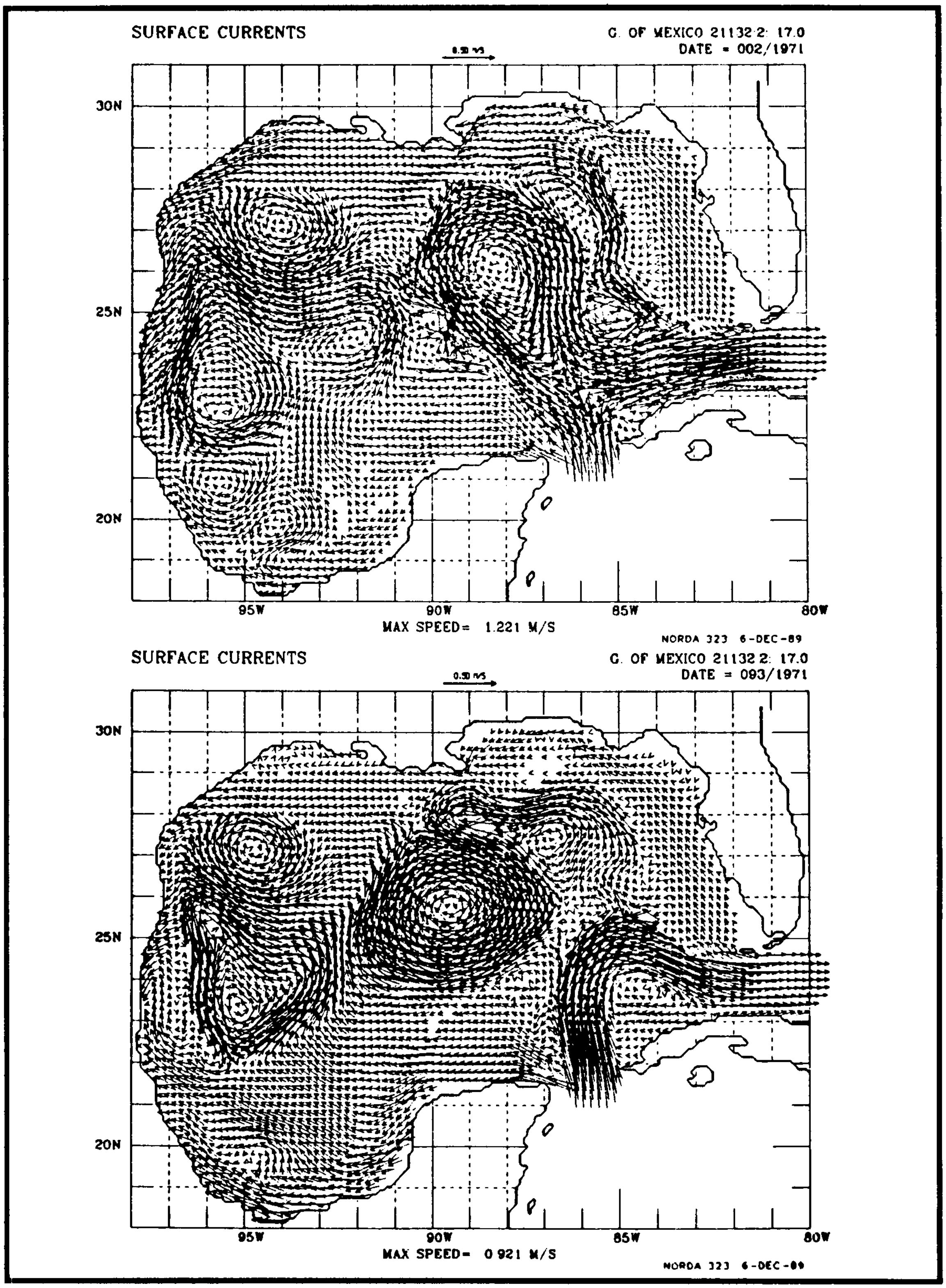

Figure 7.20. Simulated surface currents for the entire Gulf of Mexico, on 2 January 1971 and 3 April 1971 (90 days apart).

The two eastern lines of stations transected a cold-core circulation centered about 26 ° 20'N and 93 ° 15'W; the two western lines of stations resolved the northern part of a relict warm-core ring centered to the south of 25 ° 40'N. The 15C depth ranged from 275 m in the warm ring to shallower than 150 m in the cold-core circulation (Figure 7.21A); the depth of the 8C isotherm showed a similar pattern, shoaling from 574 m to 283 m, respectively. Computation of dynamic topography relative to the 800 db surface indicates that the coldest part of the cyclone surveyed was 20 cm lower than the surrounding slope water, and that the warmest part of the anticyclone surveyed was higher than the surrounding slope by a similar amount (Figure 7.21B). Such differences can be discerned by radar altimeter surveys from satellites in low earth orbit; in fact, the relative topography determined along GEOSAT tracks in this region agrees well with the dynamic topography variation calculated from the CTD + XBT data. Both warm- and cold-core rings show up in GEOSAT data from the NW Gulf, as mesoscale sea surface height variations of plus and minus 10-20 cm relative to the mean slope, respectively (Nerem et al. 1988).

Advanced Very High Resolution Radiometer sea surface temperature images for October-November 1987 show that a broad "plume" of cool temperature surface water was flowing southeastward off the Texas shelf and out across the upper slope where the cyclone-anticyclone were closest together. Geostrophic calculations of transport relative to the 800 db surface (detailed in Biggs et al. 1989), show that in this region of the NW slope there was a transport of 21 Sverdrups normal to the distance of 270 km separating the point of highest dynamic height (25 ° 40'N and 95 ° 45'W) from that of lowest dynamic height (26 ° 40'N and 93 ° 15'W).

HYDROGRAPHIC SURVEY OF OCTOBER 1988

Cruise 88G-05 departed Galveston at 8 am on 15 October and returned to Galveston at 1 pm on 24 October, after 10 days and 1,000 nautical miles at sea. Guided by trajectory information from Argos drifters 3353 and 3345 provided by Minerals Management Service (MMS) it was decided to use R/V GYRE to survey an "old" warm-core eddy west of 94 ° W, before it merged with a "new", incoming warm-core eddy ("Murphy") that MMS planned to study concurrently with R/V PELICAN. From 17-22 October, GYRE completed four longitudinal lines of CTD stations along 94 ° 00'W, 94 ° 45'W, 95 ° 30'W, and 96 ° 15'W. As for cruise 87G-11, the resultant grid had 40 nautical mile spacing between CTD stations N-S as well as E-W, and T7 XBTs were dropped midway between CTD stations to give 20 nautical mile detail for temperature structure in the upper 800 m.

The anticyclonic circulation that this survey resolved was elliptical in shape, with the region wherein the 15C isotherm depth was deeper than 250 m about 200 km in N-S dimension and 100 km in E-W dimension (Figure 7.22A). The NW "edge" of incoming Eddy Murphy can be seen at the SE corner of the station grid as a site at 25 ° 40'N and 94 ° 00'W where the 15C had plunged to greater than 250 m; however, the map of 15C depth provided no evidence of a comparison cyclonic circulation in the immediate vicinity of the two warm rings. Spatial variability of the 8C isotherm depth was similar, plunging from 455 m at 27 ° 20'N and 94 ° 00'N to 645 m in the interior of the warm ring at 26 ° 20'N and 95 ° 30'W.

Computation of dynamic topography relative to the 800 db surface indicates that, as in November 1988, the warmest part of the anticyclone was about 20 cm higher than the surrounding slope water (Figure 7.22B). Geostrophic calculations of transport relative to 800 db predict that anticyclonic surface currents of velocity 25-35 cm sec-1 circled anticyclonically around the periphery of both the "old" warm eddy and the "new" incoming warm eddy.

HYDROGRAPHIC SURVEY OF NOVEMBER 1989

Cruise 89G-15 departed Galveston at 8 am November 11 and returned to Galveston at 3 pm November 19, after 9 days at sea. Because Beaufort force 8 sea conditions prevailed for most of this cruise after passage of a "blue norther" atmospheric cold front on the evening of 15 November, only an abbreviated series of CTD/XBT stations were completed on this cruise, rather than the evenly-spaced station grid which was occupied on the previous two autumn cruises. Nevertheless, the stations able to be completed did delineate the eastern, southern, and northwest boundaries of a mesoscale cyclonic circulation. The region within which

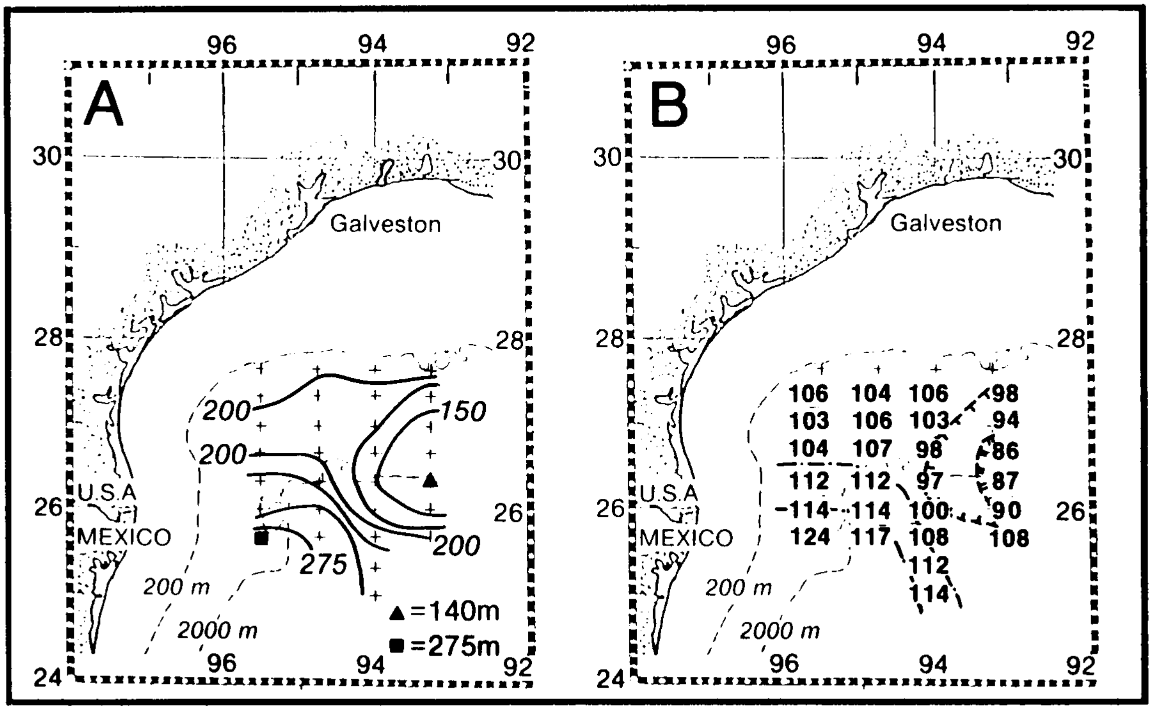

Figure 7.21. Depth of the 15C isotherm (A) and dynamic topography in dynamic centimeters relative to 800 db (B) in the NW corner of the Gulf of Mexico during November 1987 (Cruise 87G-11).

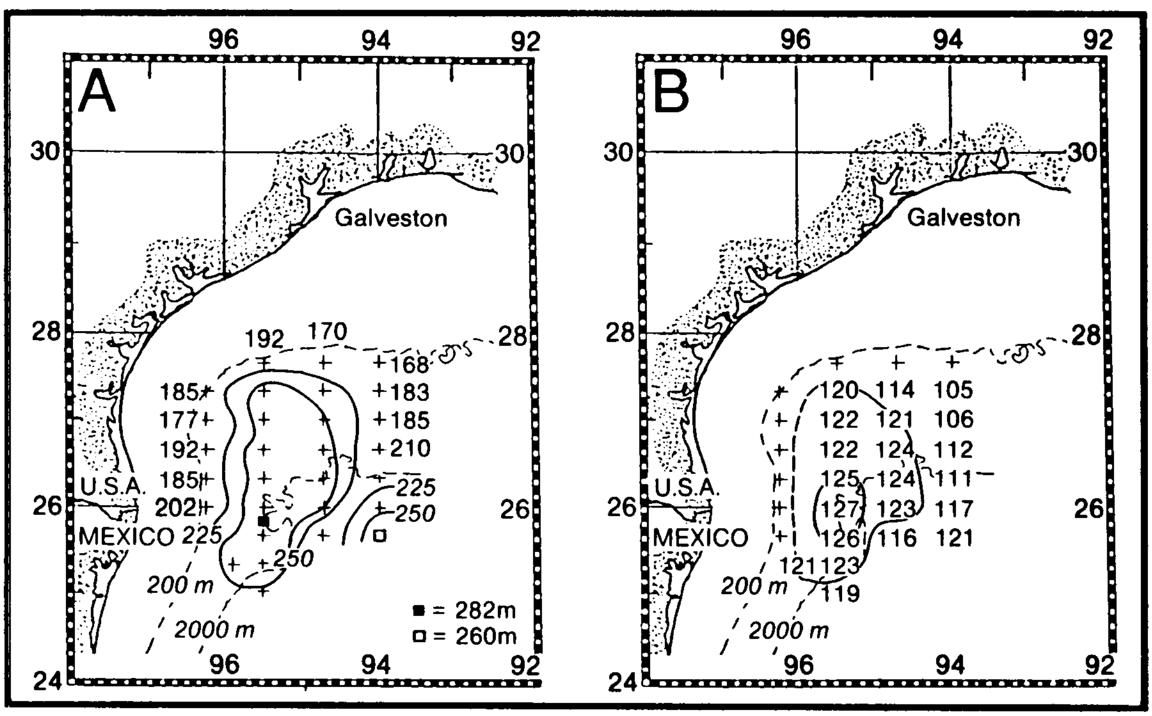

Figure 7.22. Depth of the 15C isotherm (A) and dynamic topography in dynamic centimeters relative to 800 db (B) in the NW corner of the Gulf of Mexico during October 1988 (Cruise 88G-05).

the 15C isotherm shoaled above 200 m depth was elliptical in shape, roughly 140 km by 80 km, with the 15C depth reaching 118 m at 26 ° 10'N and 95 ° 00'W (Figure 7.23A). The 8C isotherm depth exhibited a similar pattern, shoaling from 500 m at the periphery to 336 m near the center of the cold-core circulation. Computation of dynamic topography relative to 800 db indicated the surface of the cyclone was 20-25 cm lower near its center than at its periphery (Figure 7.23B).

Because the western periphery of this cold-core eddy was at or near the shelf-slope break, the cyclone apparently entrained surface water from the south Texas shelf and carried it out far into the Gulf. CTD stations along the southern periphery of the cyclone demonstrated that very low salinity water was present near surface: along latitude 25 ° 40'N, 90 km seaward of the shelf-slope break (at 95 ° 30'W) the salinity of the upper 16 m was only 34.11 PSU, and 72 km further east (at 94 ° 45'W) the salinity of the upper 10 m was only slightly higher (34.56 PSU). Such salinities are quite anomalous since mixed layer salinity over the continental slope in this part of the NW Gulf normally exceeds 36 PSU.

STANDARD STATIONS ACROSS THE CONTINENTAL SHELF

To supplement these annual "rings" surveys, beginning in academic year 1988-1989 the TIGER initiative was expanded so that three times per year two sections of standard hydrographic stations across the Texas continental shelf would be repeated (a) from Galveston Bay to the East Flower Garden Bank and (b) from Corpus Christi Bay to the shelf-slope break. The set of four standard stations along each section were selected to be representative of inner shelf (water depth 20 m), middle shelf (water depth 50 m), and outer shelf (water depth 100 m and 200 m); these are located on the Galveston-East Flower Garden Bank line at: (a) 28° 54'N; 94 ° 21'W; (b) 28 ° 23'N; 93° 56'W; (c) 27 ° 58'N; 93° 37'W; (d) 27° 46'N; 93 ° 28'W; and on the Corpus Christi line at: (a) 27 ° 39'N; 92 ° 02'W; (b) 27° 30'N; 96° 43'W; (c) 27 ° 22'N; 96 ° 27'W; (d) 27 ° 16'N; 96 ° 15'W.

At each shelf station, sampling includes: (1) a vertical profile of the water column with CTD/rosette multisampler, taking bottle samples every 5 m (20 m station), 10 m (50 m

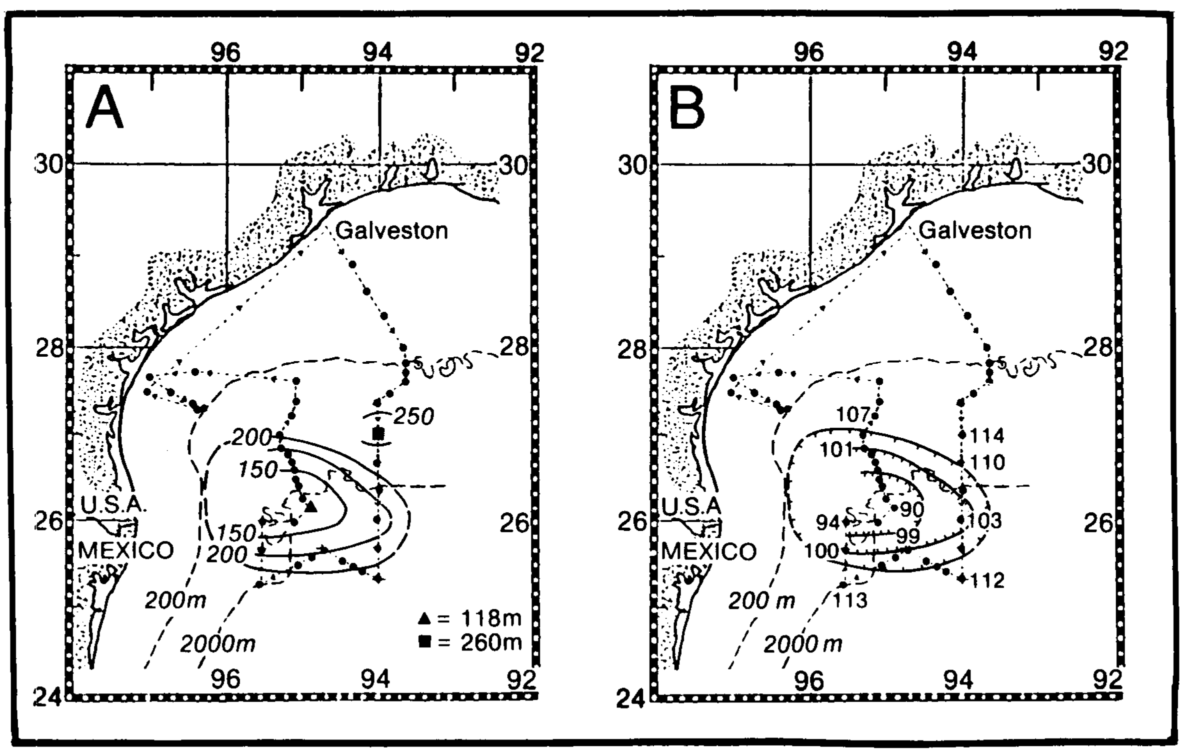

Figure 7.23. Depth of the 15C isotherm (A) and dynamic topography in dynamic centimeters relative to 800 db (B) in the NW corner of the Gulf of Mexico during November 1989 (Cruise 89G-15).

and 100 m stations), or 20 m (200 m station) for analysis of nutrients + oxygen + chlorophyll; (2) tows with zooplankton net (1 m diameter; 333-um mesh) and with a phytoplankton net (25 cm diameter; 32-um mesh); (3) six 25 cm x 25 cm samples with Small Box Core to describe trace metal contents, hydrocarbon composition, infauna biomass, and (on selected cruises) bacteria/meiofauna biomass; (4) a 15-20 min epifauna/fish collection with 30-foot otter trawl.

To date, these standard shelf stations have been occupied in October 1988 (cruise 88G-05), March 1989 (cruise 89G-02), May 1989 (cruise 89G-06), and November 1989 (cruise 89G-15). To investigate the influence of freshwater forcing on shelf circulation, additional CTD stations off Atchafalaya Bay were added on the March cruise (the time of peak riverine outflow from the Mississippi River/Atchafalaya Bay system) and on the May cruise (the onset of summertime temperature stratification).

TIGER initiative cruises of R/V GYRE are presently scheduled to continue three times a year through Fall 1992.

ACKNOWLEDGEMENTS

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Our colleagues from the Mexican Navy hydrographic section who participated in cruise 87G-11 were A. Gil-Zurita and A. Perez-Franco. Perez-Franco, along with E. Herrera-Castillo, returned for cruise 88G-05, and O. Salas-Flores and S. Escoto-Hidalgo participated in 89G-15. Dr. D. Salas de Leon, a physical oceanographer from the Universidad Nacional Autonoma de Mexico, also participated in cruise 89G-15.

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Dr. Doug Biggs is an Associate Professor in the Department of Oceanography at Texas A&M University and oversees field and laboratory support that is provided by a 10-person Technical Support Services Group of Marine Technicians, Electronics Technicians, and a scientific machinist. In addition to his studies of "rings" in the Gulf of Mexico, Dr. Biggs has supervised recent research programs in the Southern Ocean (floating sediment trap collections during ODP Legs 113 and 119) and has made several summers of zooplankton collections at Hydrostation-S off Bermuda. He received his AB magna cum laude with Honors in biology from Franklin & Marshall College and his Ph.D. from the MIT-WHOI Joint Program in oceanography.

NELSON EDDY, 1989

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Department of Oceanography
Texas A&M University,
and
Dr. James B. Bole
Amoco Production Company

Nelson Eddy was first noted on satellite imagery in February 1989. By March, the presence of closed circulation was confirmed by drifting buoys. Throughout spring and early summer, Nelson remained stalled in the eastern gulf, where it was attached to the Loop Current for part of the time. In late July, the Loop Current surged northeastward onto the continental shelf south of the Mississippi Delta. During this surge, currents in excess of 2 knots were reported by drilling operations in water depths as shallow as 100 m.

During mid-August, Texas A&M, 11 oil companies and the Minerals Management Service (MMS) cooperated to support a survey of Nelson Eddy using the R/V GYRE. Current profiles, temperatures profiles, surface temperatures and salinities, and surface water chemistry were measured along a southeast to northwest section of the entire eddy and along seven crosssections of the northwest quadrant. The measurements in the southeast quadrant showed that Nelson Eddy had almost certainly detached from the Loop Current again by August 24. The measurements in the northwest quadrant, collected while the eddy intruded into water depths under 500 m, are among the first-known measurements of the interaction between an energetic Loop Current Eddy and the northern Gulf of Mexico shelf.

Surface currents in excess of 100 cm/s were found throughout the northwestern quadrant of Nelson. Based on initial results from the acoustic doppler measurements, surface current speeds exceeded 141 cm/sec in water depths less than 500 m. Surface water temperatures were approximately 0.4° C cooler in the region of the maximum current speeds. No anomalous signature was noted in the surface salinities.

Mr. Kent J. Schaudt is an oceanographer and meteorologist with Marathon Oil Company and Chairman of the Eddy Joint Industry Projects. His primary activities are support of Marathon's worldwide exploration and production operations. Mr. Schaudt holds a B.S. and M.S. in atmospheric and oceanic science from the University of Michigan.

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Dr. Doug C. Biggs is an Associate Professor in the Department of Oceanography at Texas A&M University and oversees field and laboratory support that is provided by a 10-person Technical Support Services Group of Marine Technicians, Electronics Technicians, and a scientific machinist. In addition to his studies of "rings" in the Gulf of Mexico, Dr. Biggs has supervised recent research programs in the Southern Ocean (floating sediment trap collections during ODP Legs 113 and 119) and has made several summers of zooplankton collections at Hydrostation-S off Bermuda. He received his AB magna cum laude with Honors in biology from Franklin & Marshall College and his Ph.D. from the MIT-WHOI Joint Program in oceanography.

Dr. James B. Bole received his Ph.D. in civil engineering (fluid mechanics) from Stanford University in 1967. He has worked for the past 16 years in Offshore and Technology Research at Amoco Production. His areas of research interest are ocean climatology, hydrodynamics, and fluid loading on offshore structures.

METEOROLOGICAL AND OCEANOGRAPHIC MEASUREMENT SYSTEM (MOMS) IN THE GULF OF MEXICO

Mr. Raymond H. Canada
National Data Buoy Center
John C. Stennis Space Center

The Meteorological and Oceanographic Measurement System (MOMS) project was proposed by Chevron, USA, on March 2, 1989, in a general meeting of oil-related companies with offshore operations in the Gulf of Mexico. A number of follow-on meetings and correspondence related to agreement wording resulted in a minimum-level project funded by five companies: Arco Oil and Gas Company; Chevron, USA; Exxon Production Research Company; Halliburton Services; and Shell Development Company. Chevron, USA - Eastern Region is the Project Administrator. On May 12, 1989, a Memorandum of Agreement was signed between the National Weather Service (NWS) and Chevron, USA, for National Data Buoy Center (NDBC) support of the joint industry project.

The MOMS project is a three year Gulf of Mexico measurement program that will provide improved environmental information for forecasting, warnings, hurricane evacuation, daily industry operations planning, design criteria for future evacuation, daily industry operations planning, and design criteria for future deep-water oil platforms. While the project has broad benefits for the offshore industry and general public, it is the improved design data set along the 100-fathom line that has been funded by the project participants. Figure 7.24 shows the MOMS stations along with the Coastal-Marine Automated Network (C-MAN) and buoy stations maintained and operated by NDBC. Buoy stations 42019 and 42020 are funded by the Minerals Management Service (MMS) to support their environmental monitoring program off the Louisiana and Texas coasts. These buoys will be deployed in the spring of 1990. Buoy stations 42015 and 42016 are funded by the U.S. Army Corps of Engineers Waterways Experiment Station in support of their dredging and erosion activities. The addition of the MOMS and MMS stations greatly enhances the observation network in the Gulf of Mexico.

Presently, the MOMS consists of an NDBC C-MAN station on Chevron's Garden Banks 236 (GBCL1) production platform, and industry-installed and -maintained stations on Exxon's Lena (LNEL1) platform and Shell's Bullwinkle (BUSL1) platform. In addition, Chevron had previously funded a demonstration C-MAN station on their Main Pass 133C (MPCL1) production platform. MPCL1 was installed on February 11, 1988, and GBCL1 on August 31, 1989. The industry stations on BUSL1 and LNEL1 were installed in November 1989; however, the GOES data are being held pending final data quality verification and some shoreside software adjustments.

The MOMS data requirements (Table 7.2) call for the basic wind, barometric pressure, air temperature, and wave data to be sent hourly via the GOES satellite. Chevron, Exxon, and Shell are measuring and recording ocean currents and directional waves with independent systems. The industry-controlled data are proprietary to the project's industry participants. The GOES data will be routinely quality controlled by NDBC and National Oceanic and Atmospheric Administration's (NOAA) Ocean Product Center prior to release on the NWS's normal data distribution networks. All data transmitted via GOES are in the public domain and will be routinely archived (normally within 60 days of the end of the month of collection) in the national archive centers. Figure 7.25 shows the typical data flow for all NDBC-controlled and -monitored stations.

The NDBC has installed the Value Engineered Environmental Payload (VEEP) on both the Main Pass and Garden Banks platforms. The system reports wind speed and direction, wind gust, barometric pressure, air and surface water

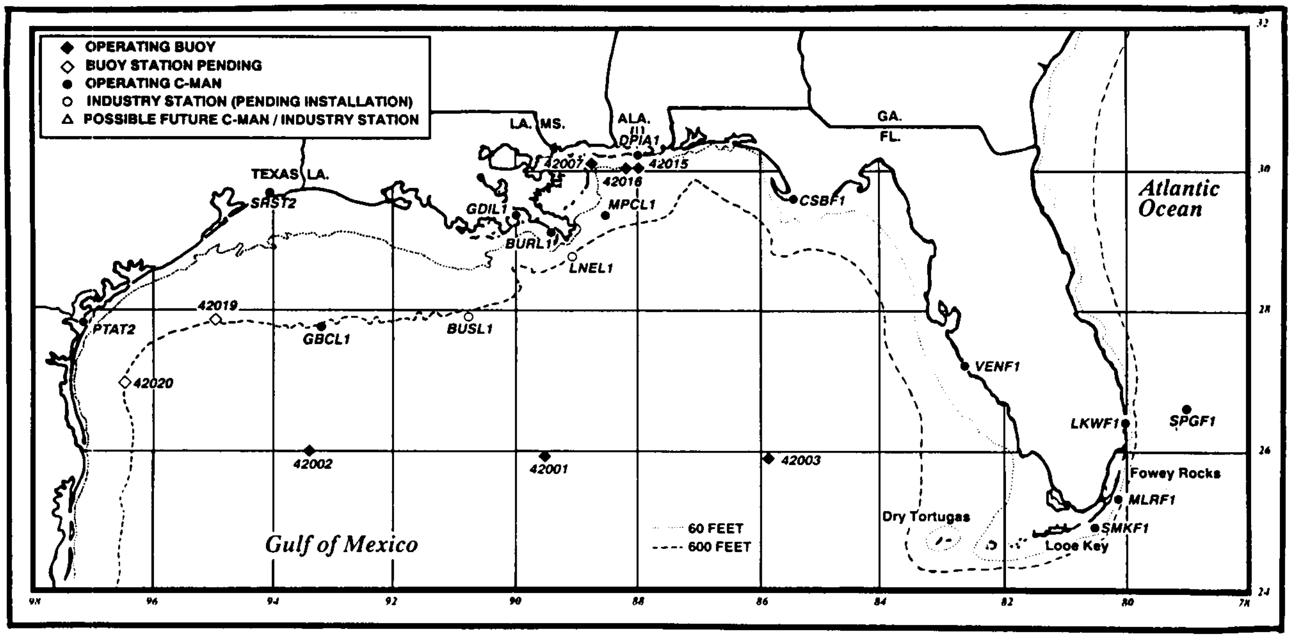

Figure 7.24. NDBC/Industry observation network.

Table 7.2. MOMS data products definition.

REQUIRED HOURLY —

- **COMPUTATION OF:**
  - -- MEAN WIND SPEED
  - -- VECTOR MEAN WIND DIRECTION
  - -- PEAK 5-SECOND WIND GUST
  - -- MEAN BAROMETRIC PRESSURE
  - -- MEAN AIR TEMPERATURE
  - -- SIGNIFICANT WAVE HEIGHT
  - -- ZERO-CROSSING WAVE PERIOD
  - -- MEAN OCEAN CURRENT SPEED*
  - -- VECTOR MEAN OCEAN CURRENT DIRECTION*

REQUIRED DURING ENVIRONMENTAL EVENT (HURRICANE OR LOOP CURRENT) —

- **CONTINUOUS TIME HISTORIES OF:**
  - -- INSTANTANEOUS WATER SURFACE ELEVATION*
  - -- INSTANTANEOUS WATER PARTICLE VELOCITIES OR VERTICAL CURRENT PROFILE*

*PROPRIETARY TO PROJECT PARTICIPANTS AND NOT TRANSMITTED TO GOES SATELLITE

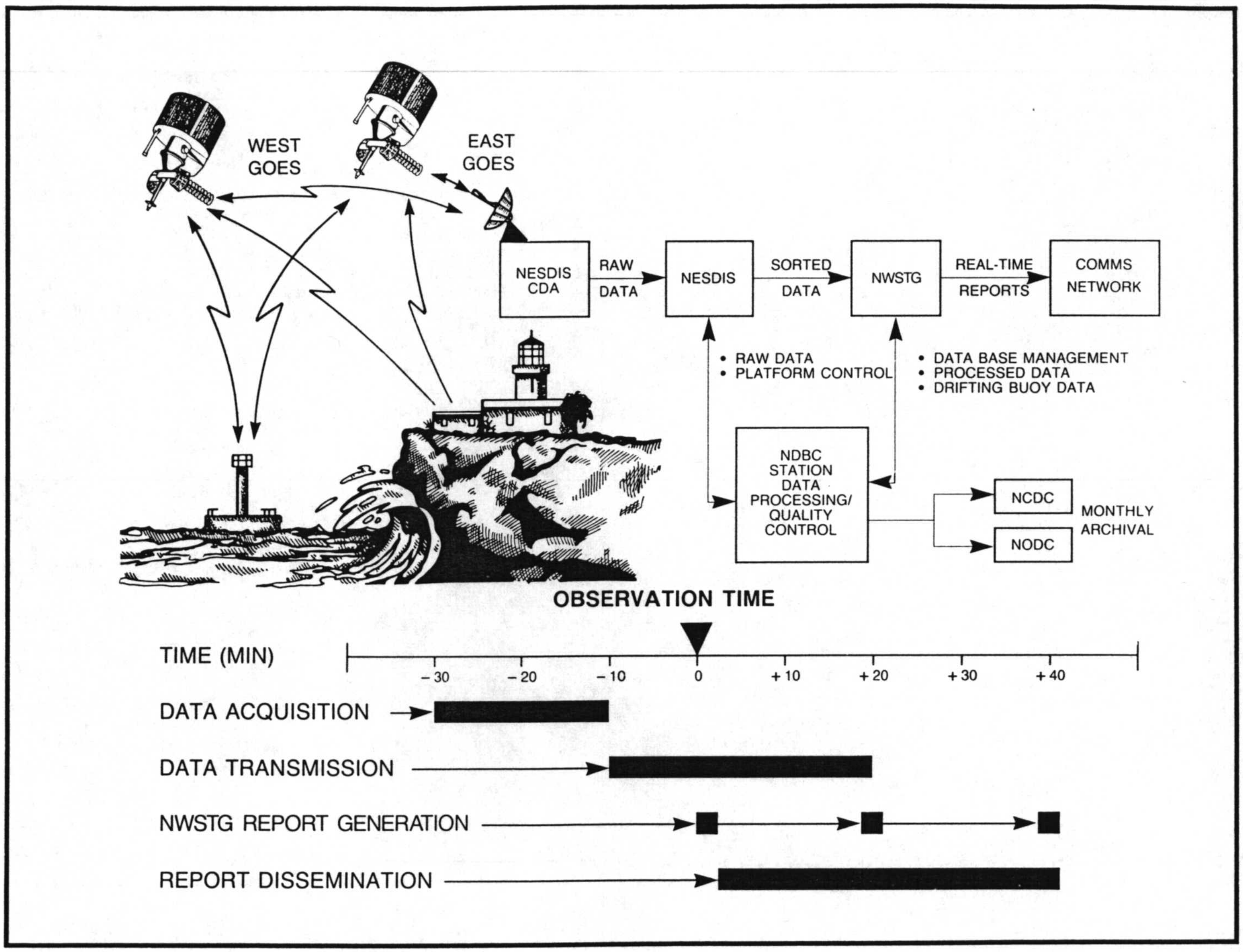

Figure 7.25. **Data flow.**

temperatures, and wave height and period, and wave spectra. It also can measure continuous winds, providing six 10-minute averages of wind speed and direction each hour. Table 7.3 gives all measurement and data requirements for the VEEP. Dew point, visibility, precipitation, and tide measurements are not measured. The VEEP electronics is housed in 76 cm x 91 cm x 41 cm (30 in. x 36 in. x 16 in.) enclosure in the platform's communications equipment compartment. The anemometers, barometer, and air temperature sensor are installed on a modified C-MAN trolley mast that is located on the platform's vent boom for clear exposure to winds. The water temperature sensor is mounted on the boat landing dock. Chevron's Baylor wavestaff is mounted on the underside of the platform.

The industry stations have the wind sensors mounted on the top of the platform's derrick. The air temperature sensor and barometer are located near the instrumentation house on the main deck. The water temperature sensor and current meters are mounted on a rack suspended from the platform by cables. A wavestaff is suspended from the underside of the platforms.

Stations 42019 and 42020 are NDBC's standard 3 m buoys, which use the Data Acquisition Control and Telemetry (DACT) payload. These buoys routinely measure wind speed and direction, barometric pressure, air and surface water temperatures, and one dimensional wave spectra. Table 7.4 lists data requirements for the DACT payload.

There are a number of other platforms in the northern Gulf of Mexico providing NOAA with cooperative measurements; however, most of these measurements are either from moving vessels or from platforms located in a small area off Louisiana between 91 ° and 93.5 °W and 28 ° and 29.8 °N. At least for the duration of the project, the MOMS will extend the available observations to the 100-fathom line. It will be a valuable addition to the core monitoring network of stations delivering high-quality, hourly observations for use by NOAA, the offshore industry, and the public. All the data from stations shown in Figure 7.24 are available to the public in near-real time through the NWS Family of Services network or a number of private meteorological service firms. The archived data are available from NOAA's National Climatic Data Center and National Oceanographic Data Center. Additional information about any of these stations in the Gulf of Mexico can be obtained by contacting the National Data Buoy Center.

Mr. Raymond H. Canada is the Assistant Chief of the Program Management Division and the C-MAN Program Manager at the NDBC located at the John C. Stennis Space Center, Mississippi. During the past 19 years, he has served in various engineering and management capacities including Developmental Projects Program Manager (1979-1981), NDBC West Coast Representative (1977-1979), Deep Ocean Moored Buoy Program Manager (1974-1977), and engineering design and development of NDBC's hull, mooring, and power systems (1970-1974). He has a B.S. degree from the U.S. Coast Guard Academy and has an MSME from the University of Connecticut.

NASA-SPONSORED COASTAL ZONE COLOR SCANNER DATA ARCHIVE

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The Department of Marine Science, University of South Florida is a National Aeronautics and Space Administration designated archive for the global Coastal Zone Color Scanner (CZCS) data set. The archive consists of 4 km resolution data, which were derived by subsampling the full-resolution (1 km) CZCS data archived at NASA's Goddard Space FLight Center (GSFC; see The Oceanography Report, EOS, June 6, 1989). Dr. Gene Feldman at NASA/GSFC is largely responsible for the generation of the archived data set.

The data are available as:

- raw CZCS radiance images (4 km Level-1);
- atmospherically-corrected radiance or pigment concentration images (4 km Level-2);

Table 7.3. VEEP measurement and data requirements.

MEASURANDS	OUTPUT PARAMETER	RANGE	REPORTING RESOLUTION	MINIMUM AVERAGING PERIOD	TOTAL SYSTEM ACCURACY
BASELINE MEASURMENTS					
WIND SPEED	AVG. WIND SPEED	0-120 KN	0.1 KN	2 MIN (NOTE 9)	± 2 KN OR 5% (NOTE 1, 2)
WIND GUST	PEAK WIND	0-160 KN	0.1 KN	NOTE 3	± 2 KN OR 5% (NOTE 1)
WIND DIRECTION	TRUE WIND DIRECTION	0°-360°	1°	2 MIN (NOTE 9)	± 5° (FIXED STATION)
BAROMETRIC PRESSURE	STATION PRESSURE SEA LEVEL PRESSURE	900-1100 hPa 900-1100 hPa	0.1 hPa 0.1 hPa	2 MIN (NOTE 9)	± 1 hPa ± 1 hPa
AIR TEMPERATURE	AIR TEMPERATURE	− 40 TO + 50°C	0.1°C	1 MIN	± 1.0°C
SEA SURFACE TEMPERATURE	SEA SURFACE TEMPERATURE	− 5 TO + 40°C	0.1°C	1 MIN	± 1.0°C
WAVES	WAVE PERIOD SIGNIFICANT WAVE HEIGHT PEAK WAVE HEIGHT WAVE SPECTRA	0-99 SEC 0-49.5 M 0-49.5 M 0.01 TO 0.40 HZ	1 SEC 0.1 M 0.1 M 0.01 HZ	NOTE 7 NOTE 7 NOTE 7 NOTE 7	0.5 SEC ± 0.2 M OR 5% ± 0.2 M OR 5% NOTE 5
DEW POINT*	DEW POINT TEMPERATURE	− 35 TO + 30°C	0.1°C	1 MIN	± 1°C
VISIBILITY*	POINT VISIBILITY	0 TO 8 STATUTE MI	NOTE 6	2 MIN	0 TO 3 MI: ± 10% 3 TO 8 MI: ± 1 MI
PRECIPITATION	CUMULATIVE PRECIPITATION	0-999 MM	1.0 MM	NOTE 4	0.25 MM
TIDE	TIDE LEVEL	0-99.99 FT	0.01 FT	NOTE 8	TBD
HOUSEKEEPING MEASUREMENTS					
BATTERY STATUS	BATTERY VOLTAGE	10 TO 15 VDC	0.1 VDC		5% READING
POWER SUPPLY STATUS	CHARGE CURRENT	0-3 AMPS	0.01 ADC		5% READING
BUOY POSITION	LORAN TIME DIFFERENCE				
DISCRETE STATUS	STATUS (GO/NO GO)				

*GROWTH CAPABILITY

NOTES

1 WHICHEVER IS GREATER APPLIES ABOVE THRESHOLD
2 REPORTED WIND SPEED CAN BE SCALAR OR VECTOR AVERAGES
3 REPORTED PEAK WIND GUST IS THE HIGHEST 5-SECOND SLIDING AVERAGE TAKEN DURING THE WIND SPEED AVERAGING PERIOD
4 RESET TO ZERO AT 0000,0600 1200, AND 1800 UTC
5 24 DEGREES OF FREEDOM BASED ON 20-MINUTE ACQUISITION DURATION AT A 2 56-HZ SAMPLING RATE
6 REPORTABLE VALUES 0 1/16 1/8 3/16 1/4 3/8 1/2 5/8 3/4 7/8 1 1-1/8 1-1/4 1-1/2 1-5/8 1-3/4 1-7/8 2 2-1/4 2-1/2 2-3/4 3 4 5 6 7 AND 8+ STATUTE MILES
7 SELECTABLE IN 5-MINUTE INCREMENTS FROM 15 TO 30 MINUTES
8 POINT SAMPLE FOR LEUPOLD STEVENS GAUGE 3-MINUTE AVERAGE FOR AQUATRAK GAUGE
9 8-MINUTE AVERAGING FOR BUOY INSTALLATIONS

Table 7.4. Moored buoy payload data.

PARAMETER	REPORTING RANGE	REPORTING RESOLUTION	SAMPLE INTERVAL	SAMPLE PERIOD	TOTAL SYSTEM ACCURACY
WIND SPEED	0 TO 62 M/S	0.1 M/S	1 SEC	8.5 MIN	$\pm$1 M/S OR 10%
WIND DIRECTION	0 TO 360°	1°	1 SEC	8.5 MIN	$\pm$10°
WIND GUST	0 TO 82 M/S	1 M/S	1 SEC	8.5 MIN	$\pm$1 M/S OR 10%
AIR TEMPERATURE	−50° TO 50° C	0.1° C	90 SEC	90 SEC	$\pm$1° C
BAROMETRIC PRESSURE	900 TO 1100 hPa	0.1 hPa	4 SEC	8.5 MIN	$\pm$1 hPa
SURFACE WATER TEMPERATURE	−7° TO 41° C	0.1°C	1 SEC	8.5 MIN	$\pm$1° C
SOLAR RADIATION*	0 TO 2150 WATTS/M^2	0.5 WATTS/M^2	1 SEC	8.5 MIN	$\pm$5%
RELATIVE HUMIDITY*	0 TO 100%	0.1%	1 SEC	8.5 MIN	$\pm$6%
SIGNIFICANT WAVE HEIGHT	0 TO 35 M	0.1 M	0.39 SEC	20 MIN	$\pm$0.2 M OR 5%
WAVE PERIOD	3 TO 30 SEC	0.1 SEC	0.39 SEC	20 MIN	$\pm$1 SEC
NONDIRECTIONAL WAVE SPECTRA	0.03 TO 0.40 Hz	0.01 Hz	0.39 SEC	20 MIN	—
DIRECTIONAL WAVES*	0.03 TO 0.35 Hz	0.01 Hz	1.0 SEC	20 MIN	$\pm$5° OF AZIMUTH

*PARAMETER REPORTED ON SELECTED BUOYS

- regional images mapped to a cylindrical equidistant projection (e.g., North Atlantic), individually or as monthly composites (Level-3); and
- global images, derived by binning the 4 km Level-2 data into 20 km squares, showing daily coverage or monthly composites of the world.

Products are generated on a VAX computer, and may be stored and distributed on either TK-50/70 VAX tape, 9-track computer tape (1600, 6250 bpi), Exabyte 8 mm video tape, 5 1/4 inch magneto-optical disk, or SONY 12 inch WORM format. The file format follows the specifications of the 'dsp' software developed at the Rosenstiel School of Marine and Atmospheric Science (RSMAS, University of Miami) for VAX VMS systems.

The CZCS was operational between November 1978 and July 1986. However, pending corrections to the calibration of the CZCS sensors, only the 1978-1980 data are available for distribution. Preliminary sets of the global monthly composites are available at 20 km resolution, but their quality is questionable due to unresolved calibration problems.

Example application: Study of the Gulf of Mexico

We examined multi-year series of 20 km resolution sea surface temperature and phytoplankton concentration fields, derived from the Advanced Very High Resolution Radiometer (AVHRR) and CZCS satellite sensors, to validate a coupled physical-biological numerical model of the Gulf of Mexico. The AVHRR series spanned January 1983 to December 1987. The CZCS series covered the period November 1978 through December 1985.

Sea surface temperature (SST) fields were derived from the National Oceanic and Atmospheric Administration operational Multichannel Sea Surface Temperature (MCSST) product (Global Retrieval Tapes) at RSMAS (University of Miami) by Drs. Otis Brown and Robert Evans. This product consists in lists of latitude, longitude, time, and MCSST (MCSST techniques are described in Walton 1988; Strong and McClain 1984; McClain et al. 1983). The data were sorted by time and grouped into 2-week bins for 1982-1986, and into 1-week bins starting in 1987. Subsequently, data points were geographically binned into pixels of a 2048x1024 matrix covering the globe (cylindrical equidistant projection). A Laplacian interpolation was used to fill gaps, with the condition that 1 valid retrieval exist within 9 pixels of the pixel being evaluated. This work focussed on the region encompassed by the northwestern Caribbean and the Gulf of Mexico.

Synoptic estimates of the concentration of pigments in surface waters of the Gulf of Mexico were derived using the CZCS launched by NASA on the Nimbus-7 satellite in October 1978. Pigment concentrations were obtained from ratios of the blue (443 nm) or blue-green (520 nm) water-leaving radiances to the green radiance (550 nm), according to Gordon et al. (1983a, 1983b). The CZCS data were processed at 1/16 of the original resolution. Pigment concentration was binned spatially into 20 km X 20 km squares, and then 30-day composites were computed based on congruent images mapped to a cylindrical equidistant projection. It was necessary to derive 30-day composites to obtain basin-wide representations of the CZCS-derived pigment concentrations in the Gulf due to either extensive cloud cover or lack of coverage (Trees 1985). Concentrations [mg m^{-3}] derived from the satellite images or model results were color-coded, with purple and blue representing low pigment concentrations and yellow and red indicating higher concentrations. Land was masked grey and clouds and missing data, black.

The combined use of infrared and ocean-color satellite images permitted year-round observation of the spatial structure associated with the near-surface circulation. Infrared images were most useful between November and mid-May, when horizontal gradients in chlorophyll concentration are small. Conversely, between late May and October, when sea surface temperature is uniform throughout the Gulf of Mexico, the Loop Current and associated eddies were studied using ocean-color data from the CZCS.

The satellite data were used to validate the surface layer of a 21-layered biochemical model nestled in a two-layered baroclinic circulation model (see Walsh et al., in press). In both the model and the satellite data the quasi-annual penetration and ring-shedding cycle of the Loop Current could be traced as warm, low-pigment water derived from the Sargasso and Caribbean Seas entering the Gulf via the Yucatan Current.

The model shed an anticyclonic ring approximately every 309 days, which is the natural frequency of the Loop Current at the specified boundary conditions. We observed the shedding of rings in the CZCS and AVHRR data collected between 1979 and 1987. However, we still could not determine the frequency of such events with certainty from the satellite data. All rings observed seemed to hover north of Campeche Bank for 2-4 months, after which they became undetectable. Ship data and model results indicate that rings drift westward at approximately 5 km d^{-1} and decay near the continental margin, generating cyclonic eddies in the process.

The temporal and spatial distribution of phytoplankton biomass produced by the numerical model compared well with that estimated with the CZCS, and reflected typical Gulf of Mexico circulation patterns. The loop current and anticyclonic rings generally showed low pigment concentration during summer, but no difference in surface concentrations with adjacent waters during the winter. While the model and CZCS-derived concentrations were in phase, there were some differences in magnitude between the derived values depending on season and location. Over the deep portions of the Gulf, summer model and CZCS products were similar, but the winter model results overestimated CZCS concentrations. The model tended to underestimate CZCS-derived concentrations in basin-wide averages, especially during summer. We believe that this reflects an omission of nutrient sources from coastal upwelling and lagoons from the model.

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REMOTE SENSING OF ENERGETIC OCEAN FEATURES/LARGE WAVES NEAR ENERGETIC OCEAN FEATURES

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University of S. Mississippi

INTRODUCTION

This talk is addressing two related issues:

1. Detection and measurement of energetic ocean features such as fronts and eddies, even under cloudy skies.

2. High sea state regions in and near energetic ocean features such as meandering fronts and eddies. Both issues are related to interaction of these energetic surface flow features (ESFF) with incoming swell.

DETECTION AND MEASUREMENT OF ESFFS

ESFFs refract incoming surface waves producing typical refraction signatures that are a known function of the wavelength and direction of the waves and the flow distribution in the ESFFs. Such a refraction pattern was used to detect and measure a ESFF in coastal water north of San Francisco, California (Sheres et. al. 1985). Figure 7.26 is an aerial photo taken from a U-2 airplane at 60,000 ft. altitude that was used to detect and measure the ESFF.

High resolution microwave imaging instruments have the capability to penetrate clouds and fog. SAR is such an instrument that could deliver real time imagery of the ocean surface containing information about ESFFs there. A number of SARs are scheduled to fly on different satellites in the near future. For example: ERS1 (European) is scheduled for late 1991. JERS (Japanese) is scheduled for 1992 and Radarsat (Canadian) is also scheduled for about 1992. Aircraft borne SAR as well as aerial photography can be made locally available.

The above capability is well suited for Loop Current and associated eddy observations during the summer months. Due to the clouds and low level haze that cover the Gulf of Mexico, it is very difficult to obtain data about the energetic features in the Gulf during the summer; satellite-borne imaging instruments such as Advanced Very High Resolution Radiometer, Coastal Zone Color Scanner, and SPOT can not penetrate the cloud cover and therefore can "look" at the water surface only irregularly. Microwave imaging instruments penetrate the cloud cover and therefore may offer the best solution for regular loop current observations during the summer. The approach outlined above could be used for obtaining velocity estimates for the energetic fronts year round.

WAVE ENERGY FOCUSING BY ESFFs

Wave energy focusing by ESFFs has been calculated by a number of investigators (Sheres et al. 1987, Sheres and Kenyon in press). There are very few observations of such phenomena (Liu et al. 1989). The mathematical model used to calculate these focusing and wave energy shadow regions (see Figure 7.27) is "robust" and therefore its predictions are likely to be realistic.

The energy focus regions (caustics) present hazardous conditions to equipment and people. Their location and degree of hazard can be predicted with data about the refracting ESFF and the incoming waves. These data can be used as an input to a wave-current interaction model that will determine the wave energy distribution.

In addition to being hazardous, the focusing areas have: large wind stress and significant variability of momentum fluxes; wave breaking and turbulence; bubbles as well as acoustic signatures. They are of interest to people working in or nearby the ESFFs.

SUMMARY

1. It is within the state of the art (theory and sensors) to detect and measure energetic surface flow features under cloudy skies. One application is the observation of the Loop Current and its eddies during the summer months.

2. We can predict the location and significance of hazardous areas due to wave energy focusing. This is done by using a wave current interaction model that has as its

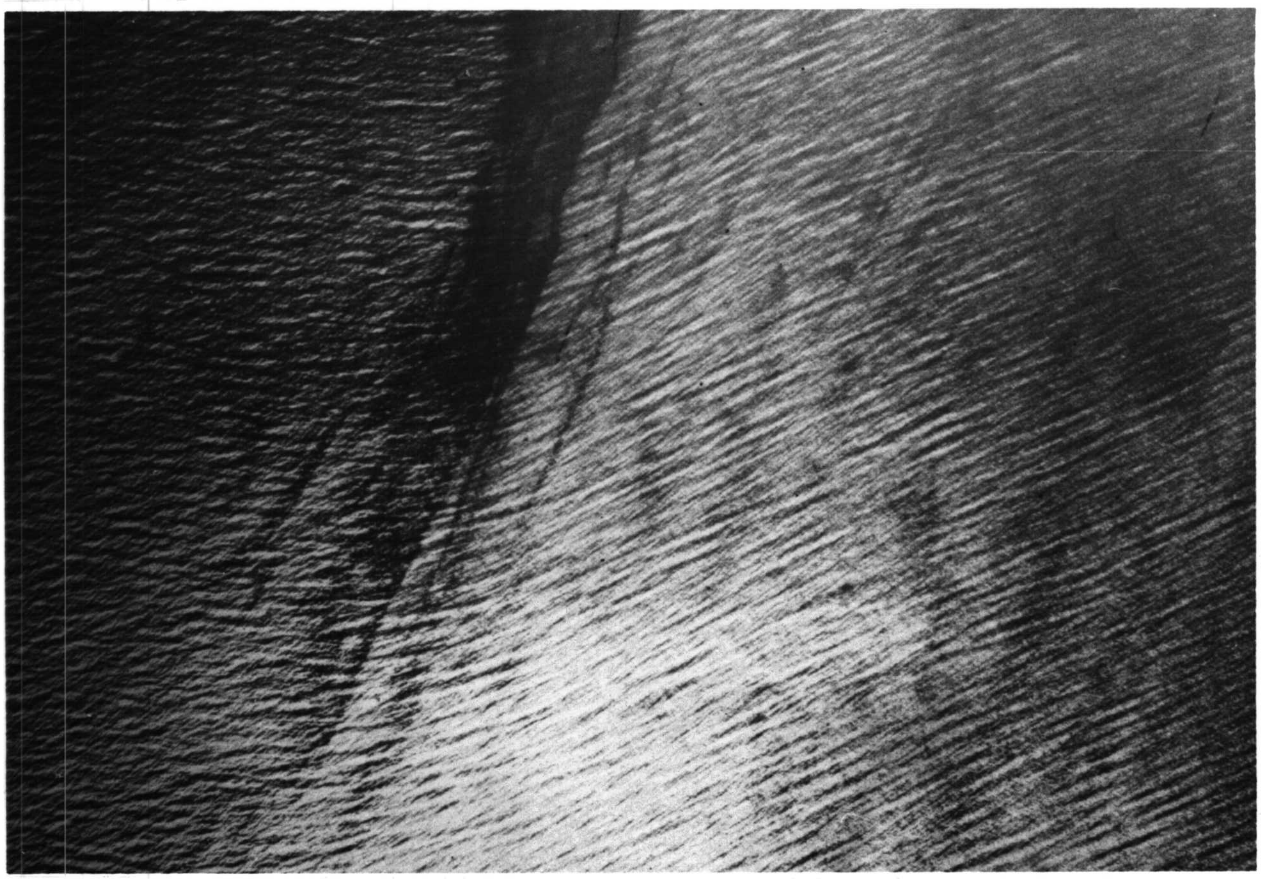

Figure 7.26A. Wave refraction data in a U-2 aerial photo taken near the CA coast. (Water depth is 90 m and dominant wavelength is about 100 m. The front was about 1 km wide.)

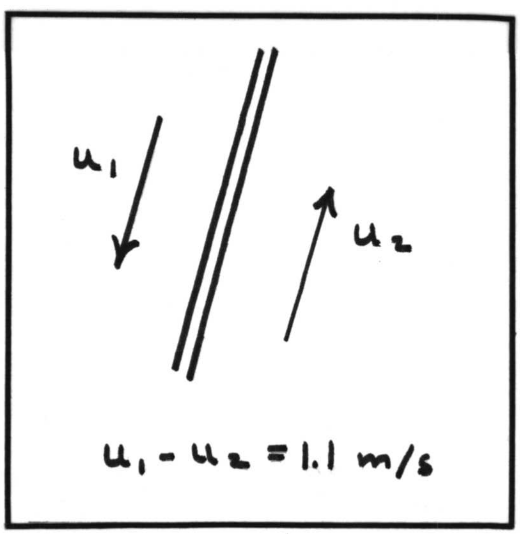

Figure 7.26B. Shear flow calculated from the above picture and validated by *in situ* measurements.

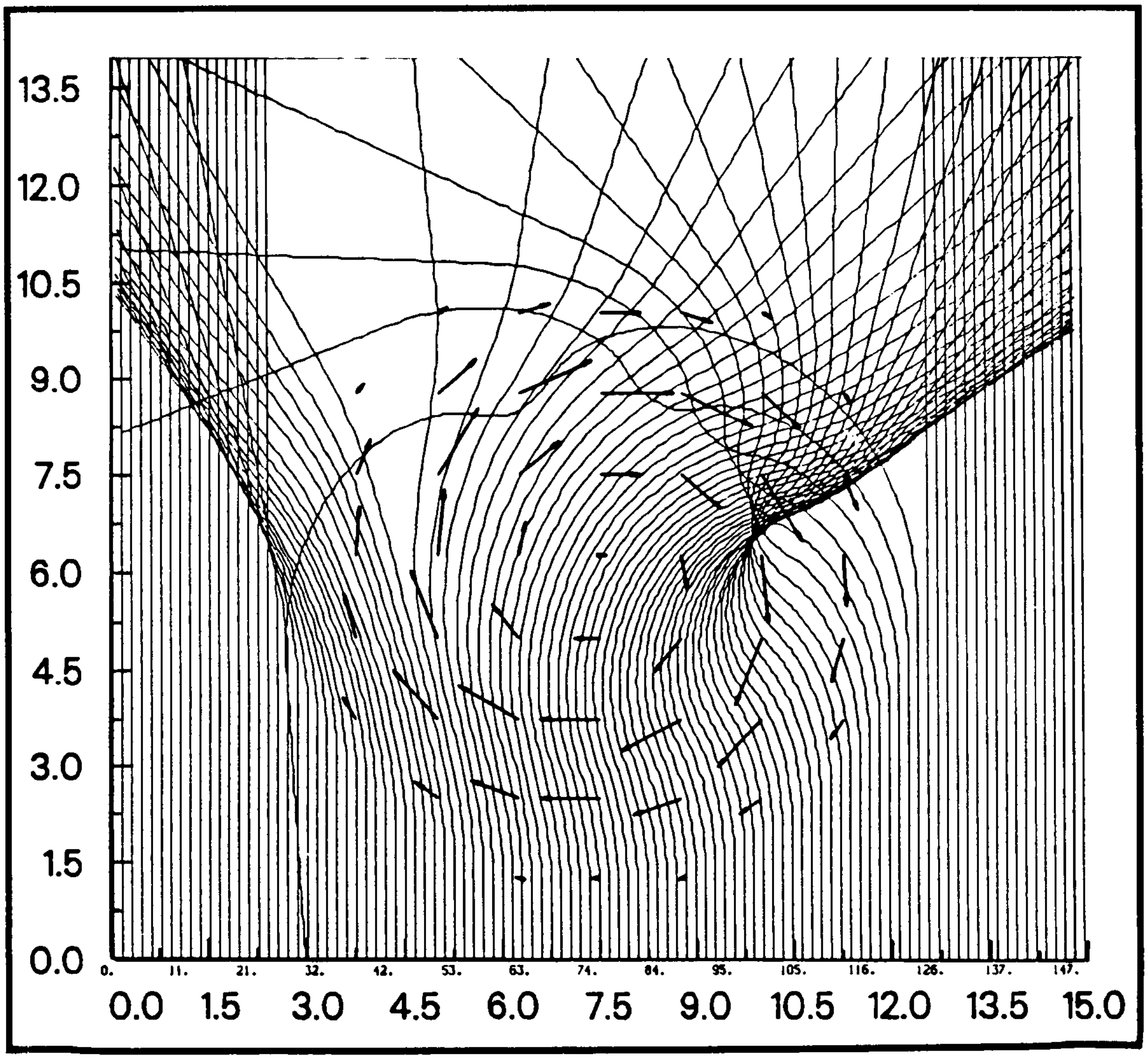

Figure 7.27. **Wave refraction pattern caused by an idealized eddy with maximum tangential speed of** 2.5 ms^{-1}. (From Sheres 1989.)

input data about the surface flow features and the incoming swell.

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ACQUISITION AND ANALYSIS OF POLAR ORBITING ENVIRONMENTAL SATELLITE DATA AT LOUISIANA STATE UNIVERSITY

Dr. Lawrence J. Rouse, Jr.
Coastal Studies Institute
Louisiana State University

In June of 1988, with funding from the Louisiana Board of Regents, the Coastal Studies Institute began operating a facility to acquire and analyze the direct broadcast High Resolution Picture Transmission (HRPT) data from the National Oceanic and Atmospheric Administration (NOAA) Polar Orbiting Environmental Satellites. The facility is equipped with a Terascan[tm] satellite data system operating on a Hewlett-Packard model 9000/825SRX workstation. The Terascan[tm] hardware and software system includes a 1.2 m satellite tracking antenna and receiver, a compact digital tape archiving system, and advanced interactive two and three dimensional image processing software. The SRX monitor (a 3-D solids rendering graphics display) has 32 planes of graphics memory and is capable of displaying an image at a resolution of 1280 by 1024 picture elements.

The data received on the HRPT are from three instruments, all of which are useful for our studies of oceanography of the Gulf of Mexico. The Advanced Very High Resolution Radiometer (AVHRR) is a radiometrically precise, 1.1 km spatial resolution, 5 channel scanning imager providing a 2,800 km by up to 5,000 km view of the earth with each pass captured. The TIROS Operational Vertical Sounder (TOVS) is a multispectral atmospheric sounder which provides the three dimensional temperature and humidity structure of the atmosphere. The third data set received is from the System ARGOS data collection subsystem. These data provide the location of transmitters which can be fixed or attached to such mobile platforms as deer, bears, or drifting buoys. In addition to the location, the short data set that can be transmitted from the surface is also acquired.

From our central Gulf Coast location, we can acquire real-time satellite data from the entire Gulf of Mexico, northern half of the Caribbean Sea, portions of the western Atlantic and eastern Pacific Oceans, as well as the North American continent from Hudson Bay to Panama (Figure 7.28). Seven to nine passes of the HRPT data accumulate daily in the archive that we maintain. More than 2000 passes have been collected in the 18 months since we began operation.

The AVHRR and TOVS have been used by investigators at Louisiana State University (LSU) to observe and quantitatively analyze the spatially large features of the atmosphere, oceans, and land masses. Recent applications have included storm systems, ocean currents, fog formation, and vegetation condition. Some observations, relevant to the topic of this meeting, will be discussed.

One of the advantages of having direct access to all AVHRR data is the ability to view all of the imagery and to see the changes in the surface features of the Gulf of Mexico. The presence, movement, and persistence of fronts, plumes, and eddies along the north central shelf have been observed. An eddy with an apparent westward drift and a diameter of about 100 km has been observed on the shelf south of the Mississippi Barrier Islands. Also east of the Mississippi River delta, another eddy has been observed to persist for at least five weeks. Plumes of water, associated with the impact of Loop eddies on the Mexican shelf, have been observed to extend several hundred kilometers into the Gulf.

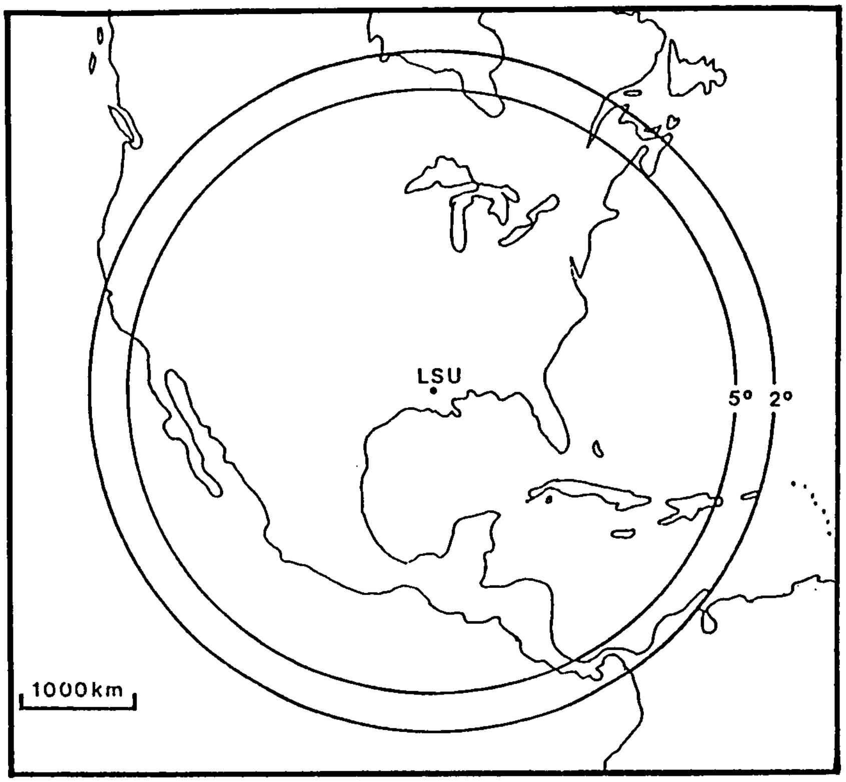

Figure 7.28. Two- and five-degree horizons for the satellite ground station at Louisiana State University. (Imagery can be received from the entire 48 cotiguous states.)

Most of the satellite observations of the oceanography of the Gulf are made in the winter season in the clearer and drier atmospheres associated with the outbreaks of polar continental air. Observations are therefore biased to these conditions and the winter season. In August of 1989, we had the opportunity to observe the Loop current in the summer. Early in the month, we received reports of an eastward flowing four knot current in the Green Canyon area. Initial speculation was that it was a Loop eddy drifting through the region. When the current persisted longer than anticipated, we began an in-depth examination of the AVHRR imagery. An anomalous, weak high pressure system moved through the northern Gulf in the second week of August. We anticipated that the drier and less cloudy atmosphere and the high speed of the current would enable us to see the feature. We were successful in detecting stream lines which we identified as the current. The enhanced imagery indicate that the current was a part of the Loop Current itself and not a detached eddy. In an anomalous path, the Loop Current appears to extend from the Yucatan Strait toward the northwest to the vicinity of the Green Canyon. In the Green Canyon area, the current took a sharp right turn and flowed directly eastward.

We are continuing our monitoring of the Gulf with the AVHRR data and are beginning to process our data archive to extract drifting buoy location data.

ACKNOWLEDGEMENTS

What is presented here is a cooperative and interactive effort with Oscar K. Huh, David Wilensky, and several graduate and undergraduate students in the Earth Scan Lab at Louisiana State University.

Dr. Lawrence J. Rouse, Jr. is an associated professor with the Coastal Studies Institute at Louisiana State University. His interests are coastal circulation and sediment transport processes and application of remote sensing technology to observation of these processes. Dr. Rouse obtained his Ph. D. in physics from Louisiana State University.

MARINE ECOSYSTEMS STUDIES

Session: MARINE ECOSYSTEMS STUDIES

Co-Chairs: Dr. Robert M. Rogers
Dr. Robert M. Avent

Date: December 6, 1989

Presentation	Author/Affiliation
Marine Ecosystems Studies: Session Overview	Dr. Robert M. Rogers and Dr. Robert M. Avent Minerals Management Service Gulf of Mexico OCS Region
Ecological Monitoring Program at the Flower Garden Banks	Dr. Stephen R. Gittings, Mr. Gregory S. Boland, Mr. Brenden S. Holland, and Mr. Kenneth J.P. Delarzes Department of Oceanography Texas A&M University
Southwest Florida Nearshore Benthic Habitat Study	Mr. M. John Thompson Continental Shelf Associates, Inc.
Report on The Minerals Management Service Northern Gulf of Mexico Environmental Studies Planning Workshop, August 15-17, 1989	Dr. Robert S. Carney Coastal Ecology Institute Louisiana State University
National Status and Trends Mussel Watch Program - Gulf of Mexico	Dr. James M. Brooks and Dr. Terry L. Wade Geochemical and Environmental Research Group Texas A&M University
Impact of Offshore Drilling: Florida	Dr. Eugene A. Shinn U.S. Geological Survey
Catastrophic Loss of Seagrasses in Mississippi Sound	Dr. Lionel N. Eleuterius Gulf Coast Research Laboratory

MARINE ECOSYSTEMS STUDIES: SESSION OVERVIEW

Dr. Robert M. Rogers
and
Dr. Robert M. Avent
Minerals Management Service
Gulf of Mexico OCS Region

The Marine Ecosystems Studies session was organized to report on the progress of a number of Minerals Management Service (MMS) marine ecological studies, as well as three studies in related fields of interest. The marine ecological studies series is a large component of the MMS Environmental Studies Program.

These marine studies have provided valuable information on potentially sensitive resources and have been useful in formulating stipulations and mitigating measures for protecting these resources. Recently these studies have addressed such environmentally sensitive areas as the Mississippi/Alabama outer continental shelf and Pinnacle Trend area, the Flower Garden Banks in the western Gulf live bottoms and sea grass communities off South Florida, and the recovery of impacted environments in the vicinity of exploratory drilling sites.

The first speaker in this session was Dr. Stephen Gittings of Texas A&M University. Dr. Gittings is program manager of an MMS sponsored project monitoring the long term health of the East and West Flower Garden Banks. The purpose of this study is to address concerns regarding both gradual and catastrophic deterioration of these unique coral communities. In the light of increased recreational use of these features and the potential effects of oil and gas activities, long-term data base is essential for the identification of input.

The monitoring program at the East and West Flower Garden Banks are carried out twice a year to observe summer and winter conditions. A number of observations were made to evaluate coral reef diversity, growth rates, long term changes in individual coral colonies, accretionary growth, and general community health. Methodologies include stratified random photographic transects, growth monitoring stations, repetitive quadrats, permanent accretionary growth stations, and videotaped transects. At this point in the project two seasonal monitoring efforts have been carried out and analysis completed on the first cruise.

The second speaker was Mr. John Thompson of Continental Shelf Associates, Inc. (CSA). In September of 1987, the MMS contracted with CSA to carry out a habitat mapping project of the Southwest Florida continental shelf. The objectives of this study were to map and inventory seagrass beds using a combination of aerial photography and shipboard groundtruthing, to determine the seaward extent of major seagrass beds, and to classify and delineate major benthic habitats in the study area.

That study effort has been completed with a final report soon to be submitted for distribution. Habitat distributions within 15,294 square miles of the southwest Florida nearshore continental shelf were mapped. Four geomorphically distinct sub-areas were noted (1) the inner southwest Florida continental shelf, (2) Florida Bay, (3) Lower Florida Keys, and (4) Tortugas/Marquesas Reef Banks. In terms of area, the deep-growing seagrass stands of *Halophila decipiens* were the most widely distributed. Seasonality of this seagrass was observed and documented during the course of this study.

The third speaker was Dr. Robert Carney of the Louisiana State University, Coastal Ecology Institute. Dr. Carney has recently served as rapporteur for a workshop sponsored by MMS to plan for three environmental studies scheduled for procurement in FY1990. The meeting was held in New Orleans in August 1989 to discuss (1) Long-term, impacts of Outer Continental Shelf (OCS) oil and gas activities, (2) Texas-Louisiana Marine Ecosystems study, and (3) Chronic impacts of petroleum production activities. Over 100 interested participants representing academia, state agencies, federal agencies, and industry attended the workshop.

Although a proceedings from the workshop is still in the preparatory stage, a number of observations have resulted from the workshop. Some of the major considerations discussed were: (1) the need for rigorous effective and appropriate statistical analysis in large field studies; (2) the importance of linking processes, i.e., productivity, sediment transport, detrital flux, trophic interrelationships, etc., and community structure; (3) the need for innovation components within the structure of larger ongoing projects; and (4) the need for preliminary studies to refine subsequent field sampling and study designs. The proceedings from the workshop is presently being finalized and should be submitted for distribution early in 1990.

The next speaker was Dr. James Brooks of the Geochemical and Environmental Research Group G (GERG) of Texas A&M University. Dr. Brooks reported on the status of the Gulf of Mexico component of the National Oceanic and Atmospheric Administration (NOAA) Status and Trends Mussel Watch program. The purpose of the GERG program is to determine the long-term temporal and spatial trends of selected contaminant concentrations in oysters and sediments in 51 bays and estuaries in the Gulf of Mexico. The accumulations of some contaminants can be quite different in sediments and oysters. Monitored contaminants include, for example, trace metals, tributyl tin, PCBs insecticides and PAHs. Variability in concentrations of contaminants commonly range from 2 fold to 10 fold at different sites. In many cases contaminant levels are difficult to relate to specific point sources. A NOAA re-award to GERG to continue this work will provide comparable data for several years to come.

The next speaker Dr. Eugene Shinn, of the U.S. Geological Survey, described recent investigations of historic exploratory drilling at six sites off southwest Florida, four of which were occupied in the 1960's in the Florida Keys. Once located with magnetometers, the sites were surveyed by diver or manned submersible.

The four older, shallow (5-30 m) Florida Keys sites varied in habitat, ranging from bare sand bottom, to 'live' bottom, to coral reef. The environmental consequences varied depending upon the bottom type and the operational complexities of the drilling. Modifications to the bottom and living resource were generally either short-lived or small in areal extent. For example, a 14-legged jack-up rig in 11 m depth left permanent 5-diameter scars in the bottom, effectively depriving sessile forms of the exposed rock needed for colonization. In other cases pipes, cement mounds and bags, and other debris left by industry, created significant holdfasts for a diverse array of epifauna, and additional habitat for motile invertebrates and fishes. The deeper (53-70 m) sites, occupied in the 1980's, were in live bottom habitat. Discarded material formed habitat for fishes. While no two sites were alike, they share in common a lack of measurable effect from chemical, hydrocarbon, or drilling mud effluent. All environmental effects noted were mechanical in nature, either from debris, or limited crushing or covering the bottom.

The last speaker, Dr. Lionel Eleuterius, head of the Botany Section at the Gulf Coast Research Laboratory, discussed the loss of seagrass habitat in the Mississippi Sound. Vegetated seabottom in 1975 was only about 60% of that recorded in 1969 (4,900 ha). At present seagrass cover is only about 30% of the 1969 figure. Some losses can be attributed to erosion and suffocation during the great hurricane Camille in August 1969, to a massive 1973 freshening of the Sound following an opening of the floodgates of the Bonnet Carré Spillway. Subsequent openings have occurred up until 1983 and the last hurricane affected the area in 1985. During the last 20 years the Mississippi coastal area has grown in human population, industry, oil exploration, processing, transportation, and refining, and miscellaneous discharges into the six rivers entering the Sound. Together, these impacts may interact to induce stress (a weakened physiological condition). Mass die-offs have not been recorded recently. But surveys indicate retardations of growth, changes in reproductive patterns, reductions in the number of seedlings, and relative declines of individual species. *Halophila engelmannii* has not been found since 1972 and *Syringodium filiforme* and *Thalassia testudinum* have nearly disappeared. The dominant *Halodule wrightii* has declined. The causes for these changes have not been identified but they reflect a global decline in seagrasses which may or may not be related.

Dr. Robert M. Avent received the M.S. and Ph.D. degrees in biological oceanography from Florida State University in 1970 and 1973, respectively. His main fields of interest include marine physiological ecology and deep-sea biology. He has pursued investigations on the biological effects of hydrostatic pressure, animal zonation, and reef morphology. He has worked in the consulting industry and for state government. He came to the MMS/Bureau of

Land Management (BLM) in 1981 from the National Marine Fisheries Service.

Dr. Robert M. Rogers is a staff member of the Environmental Studies Section of the MMS Gulf of Mexico OCS Regional Office. His research interests include ecology of meiobenthic organisms and trophic interrelationships. He has been involved with the MMS/BLM environmental studies program since 1977.

ECOLOGICAL MONITORING PROGRAM AT THE FLOWER GARDEN BANKS

Dr. Stephen R. Gittings,
Mr. Gregory S. Boland,
Mr. Brenden S. Holland,
and
Mr. Kenneth J.P. Delarzes
Department of Oceanography
Texas A&M University

INTRODUCTION

The integrity of a coral reef depends upon a substantial cover of living coral tissue, which produces new reef rock, and maintenance of the reef framework. Man, however, has repeatedly caused the destruction of reef framework and coral populations; reef rock is mined for use as building stone, reef flats are blown apart by seismic crews, reefs have been buried beneath causeways, trampled by tourists, crushed beneath shipwrecks, subjected to damage by anchors and ground tackle from boats and ships of all sizes, and silted over or destroyed by dredging activities (see references in Gittings 1988). More subtle stresses, such as eutrophication around tropical reefs by anthropogenic discharges and agricultural runoff, have more recently become evident, especially in Hawaii (Marszalek 1987), and in the Florida Keys (B. Lapointe; presented at Coral Reef Management Workshop, 9-12 June 1988, Marine Resources Development Foundation, Key Largo, Florida).

Deterioration of coral reef communities can be a rapid process, especially during episodes of catastrophic natural or man-induced mechanical disturbance (e.g., hurricanes, blasting, dredging, mining, and shipwrecks). Thermal, oil, chemical, or nutrient pollution may cause gradual deterioration of a coral reef. Similarly, chronic low level mechanical stresses imposed by coral collection, destructive fishing techniques, high levels of diver visitation, or boat and ship activities may also cause the gradual decline of coral populations or coral viability (Tilmant and Schmahl 1983).

Although such impacts are most intense on coastal emergent reefs, submerged reefs far offshore are not immune. In 1985, a portion of Bright Bank, a reef at 37 m depth on the outer continental shelf of the northwestern Gulf of Mexico, was blown apart by misguided treasure hunters (Bright 1986). The nearby Flower Garden reefs, which peak at approximately 18 m depth, are adjacent to commercial shipping lanes. They have been used as offshore anchoring sites by large vessels for decades. Concern over the fate of the Flower Garden reefs in relation to these impacts has been an important factor leading to their nomination for National Marine Sanctuary status.

A long-term monitoring program at the East and West Flower Garden banks is currently being carried out by Texas A&M University. The study serves to address concerns regarding both gradual and catastrophic deterioration of these unique offshore ecosystems. The program will also provide for the augmentation of a data base relating to coral community viability dating from the early 1970's. This is critical in light of the expected Flower Garden National Marine Sanctuary designation (scheduled for spring 1990). Recreational use of underwater areas tends to increase following the establishment of an area as a marine park, preserve, sanctuary, or reef authority (Tilmant 1987). A long-term data base may allow the identification of impacts caused by the expected increase in recreational use. Furthermore, due to differences in the nature of recreational activities and hydrocarbon exploration and production activities, and the nature of the damage potentially wrought through such actions, it may be possible to determine the principal factors leading to any community changes observed in future years at the Flower Gardens.

METHODS

During the early winter and spring of 1989, we established a monitoring site at the East Flower Garden Bank comparable to that established at the West Flower Gardens by Continental Shelf

Associates in the summer of 1988 during field work for Union Oil Co. This involved implanting eyebolts and marker floats around a 100 m by 100 m study site, establishing and mapping 120 permanent stations for monitoring lateral encrusting growth of the corals *Montastraea annularis* and *Diploria strigosa* (60 stations for each species), implanting and mapping 40 permanent posts to mark repetitive sampling stations for studying individual coral colonies, and implanting and mapping 30 permanent accretionary growth spikes in *M. annularis* coral colonies. All stations at both banks were tagged using numbered, plastic, goat ear tags. Following this, and in October 1989, we carried out photographic and video field work at both banks, and will continue to do so at six month intervals over a three-year study period.

The monitoring study calls for two sampling trips each year. During each sampling trip, twenty 10 m stratified random transects are photographed at each of the two study sites. Seventeen immediately adjacent photographs are taken along each transect using a camera framer which describes a 60 by 85 cm area of seafloor.

Each station for monitoring lateral growth of *M. annularis* or *D. strigosa* was established using two 10 cm long stainless steel nails. They are spaced 23 cm apart so that a plus/S diopter framer attached to a 28 mm lens and Nikonos underwater camera can be placed directly over the nails and encompass a repeatable 13.3 by 19.7 cm photographic area. The border of living coral tissue traverses the approximate center of each photograph, allowing measurement of either growth or retreat.

Permanent posts for monitoring changes in individual colonies using repetitive photography were planted in 1 cm diameter holes drilled approximately 15 cm into the reef substrate. A r-shaped camera jig was fabricated that can be attached to the posts at each site. Twelve photos, one taken every 30° around the post, compose a photographic mosaic of a 10 m^2 area. Each photo covers approximately 2 m^2, with the extent of overlap increasing toward the center of the circle.

Due to the many technical problems associated with this technique, the method was modified after the initial sampling effort. We now take single photographs of each station from a height of 2.00 m using a 15 mm wide angle lens. The framer has a bubble level and compass to accurately position the camera above the station center before each photograph is taken. The sample area approximates 8 m^2, which effectively samples and allows identification of most species on the reef.

The spikes used to monitor accretionary growth of corals are implanted in living coral tissue on the tops of coral heads. Growth spikes were driven into heads of the star coral, *Montastraea annularis*. The 20 cm spikes were driven to a depth of 10 cm, leaving approximately 10 cm exposed. The spikes are measured to the nearest millimeter during each sampling effort.

At each reef, a minimum of 2 videotaped transects of 100 m length are flown during each visit to show the general conditions of the coral community at each study site. We use 8 mm video format for relatively high resolution images. The video transects are taken by diver from approximately 2 m above the bottom along 100 m lines tautly strung along the sides of each survey area. They will serve to establish semi-repeatable survey transects that can later be mapped to show distinctive features such as areas of sand, high coral density, diseased or damaged corals, etc., and document gross changes over time.

Light penetration is measured when on station near 1200 hours each day using a Biospherical Instruments QSP 200L Submersible Quantum Scaler Irradiance Meter. Measurements are taken on the surface, at 1 m depth, and near the bottom. Discrete measurements of temperature, salinity, and dissolved oxygen are also obtained daily (near 1200 hours) at 1 m depth and 1 m above the bottom.

DATA ANALYSIS

Random Transects

Areal coverage of coral and leafy algae is considered the two-dimensional downward projection of colonies onto the substrate. Objects on photographs taken along the random transects are outlined using a calibrated planimeter, and area (in cm^2) is automatically calculated. Percent cover data is acquired for all coral species and other appropriate organisms (e.g., leafy algae) on the photographs. Also calculated is the number of colonies of each species, the amount of bare coral substrate (most is actually covered by calcareous or filamentous algae), relative dominance of each coral species (% cover relative to total cover), the frequency of occurrence of each species, species diversity, and evenness.

Encrusting Growth Stations

From developed prints of growth stations, colony borders, distinctive features, and polyp mouth positions are traced onto sheets of mylar drafting material. Minor differences in scale between two sequential mylar traces at a station can be compensated for by projecting one trace onto the other using an image enlarging/reducing map projector. Individual polyp mouth positions can then be matched exactly on the superimposed traces and both colony borders are traced onto the same sheet.

Border lengths, areas of tissue advance, and areas of tissue retreat can then be measured using a planimeter. Standardized statistics generated for each station will be the amount of tissue growth and/or retreat (in cm^2) and the border length over which this growth or retreat occurred. Growth and retreat can be analyzed separately, and data can be combined for analysis of net changes in tissue over time.

Also calculated are the proportions of the total border lengths exhibiting growth, the proportions exhibiting retreat, and proportions exhibiting no change. These will be plotted on ternary plots (three-coordinate plots commonly used by geologists for illustrating sediment characteristics). This technique was first used by our group to study coral growth on coral heads impacted by a freighter grounding in Florida (Gittings et al. in press). The method was useful in determining the deleterious effects of the displacement of coral heads into sand flats by the ship.

Repetitively Photographed Stations

Developed color transparencies will be projected onto a digitizing pad. Coral colony sizes will be calculated at each station using a planimeter. Individual colony changes between time periods can then be determined directly. Other parameters to be compared will be total cover, relative dominance, species frequencies, species diversity, and evenness.

Accretionary Growth Stations

Coral growth will be determined for each coral head on which growth spikes are located by comparing sequential measurements taken from individual coral colonies. Differences between periods will be evaluated, as will trends through time.

Video Transects

Transcriptions from the videotape records will include observations on the general health of the hermatypic coral community and counts of invertebrates and fishes. By estimating elapsed time and physical dimensions along the transects, counts and other observations can then be converted to densities (number/m^2). These densities will provide a means for quantitative comparisons between sites, seasons, and years.

Results from the video tape analyses may include:

- habitat characteristics (% sand flat, rough estimate of live coral cover, general health of coral, etc.) and changes over time;
- patterns of abundance
  - numbers of individuals
  - spatial distribution
  - biomass estimates
  - recruitment of conspicuous reef fish or invertebrates
  - presence/absence data;
- estimates of changes in percent cover for any taxa which could be measured in the same way on more than one cruise; and
- relationships (correlation) of specific taxa to habitats, other biota, or environmental parameters.

DATA INTERPRETATION AND SYNTHESIS

A critical component of this study will be the comparison of the considerable existing knowledge on the Flower Gardens with the data that will result from this study. Some of our objectives are to:

- compare data on coral populations and coral growth resulting from this study to existing published and unpublished Flower Gardens data;

- assess time-dependent change in coral cover, relative abundance, relative dominance, diversity, and evenness over the course of this study and in light of previous estimates of these parameters;

- evaluate the nature and extent of bleaching caused by expulsion of zooxanthellae (as a periodic natural phenomenon or under stressful conditions) and compare these results to the findings of investigators working on other Western Atlantic coral reefs;

- ascertain the apparent extent of human impact on the reefs, especially with respect to mechanical disturbance caused by divers, boat and ship anchors, debris, etc. and compare this with past and currently emerging information on human impacts in other coral reef ecosystems; and

- discuss the relationship between OCS hydrocarbon development activities and environmental sensitivity at the Flower Garden banks, integrating existing data on mechanical disturbance and chemical contamination of coral reefs.

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Dr. Stephen R. Gittings is an Assistant Research Scientist at Texas A&M University interested in coral reefs, hard-bottom ecosystems, and human impacts in these environments. He received a B.S. in biology from Westminster College (1979), and M.S. (1983) and Ph.D. (1988) degrees in oceanography from Texas A&M University.

Mr. Gregory S. Boland is a Research Associate in the Department of Oceanography at Texas A&M University. He received a B.S. in 1974 at Colorado State University and an M.S. degree in oceanography in 1980 from Texas A&M University. His research interests are reef ecology, benthic metabolism, and underwater imaging.

Mr. Brenden S. Holland is a graduate research assistant pursuing an M.S. degree in oceanography at Texas A&M University. He received a B.A. in 1986 from the University of California at San Diego. His research interests are coral reef ecology, coral recruitment, and reproductive strategies.

Mr. Kenneth J.P. Delarzes is a graduate research assistant pursing a doctoral degree in oceanography at Texas A&M University. He received undergraduate and graduate training in botany and zoology at the University of Lausanne, Switzerland (1983-1988). His research interest is coral reef ecology and impacts of long-term water quality changes on coral growth.

SOUTHWEST FLORIDA NEARSHORE BENTHIC HABITAT STUDY

Mr. M. John Thompson
Continental Shelf Associates, Inc.

Habitat distributions within 9,791,000 acres (3,962,417 hectares or 15,294 mi^2) of the southwest Florida nearshore continental shelf were mapped. Within 5,170,000 acres (2,092,299 hectares), habitat distributions were mapped from aerial imagery. In an additional 4,622,000 acres (1,870,523 hectares), habitat distribution patterning were extrapolated from ground survey data.

Four, geomorphically distinct sub-areas exist within this study area: (1) the inner southwest Florida continental shelf, dominated by low-relief hard and soft coral communities and *Halophila decipiens* stands; (2) Florida Bay, dominated by communities of *Thalassia testudinum, Syringodium filiforme*, and *Halodule wrightii*; (3) the Lower Florida Keys, dominated by *Thalassia, Syringodium*, and *Halodule* stands and patch reefs; and (4) the Tortugas/Marquesas Reef Banks, dominated by sand banks and coral reefs (Figure 8.1).

In terms of area, the deep-growing seagrass stands of *H. decipiens* were the most widely distributed habitat surveyed. These seagrass communities covered 3,004,000 acres (1,215,719 hectares) of the inner southwest Florida continental shelf, or 31% of the entire mapped area.

No *Halophila engelmannii* was seen anywhere on the southwest Florida continental shelf during this study. The absence of this species is conspicuous since it has previously been reported from the southwest Florida shelf, and was abundant on the northwest Florida continental shelf (Big Bend area) during studies conducted in 1984 and 1985. No explanation for its absence off southwest Florida during the 1988 sampling period has been advanced.

Halophila decipiens appears seasonally on the west Florida shelf, beginning in late May and early June. These deep seagrass beds grow rapidly and reach a peak standing crop in late September. Following this biomass peak, new blade production drops off and beds begin to deteriorate. Rhizome structure weakens, and these beds are washed away with the onset of severe winter weather.

Halophila decipiens biomass peaked in the 70 to 90 ft (21.3 to 27.4 m) depth range. Deeper than 100 ft (30.5 m), *H. decipiens* began to be replaced by a long-bladed form of *Caulerpa prolifera* in suitable growth substrates. No *H. decipiens* was seen at depths >122 ft (37.2 m).

Mean biomass of *H. decipiens* across the inner southwest Florida continental shelf was 194.0 mg/m^2 in September 1988. Extrapolation from this figure yielded a standing crop estimate of 2,600 tons (2,359 metric tons). The fate of this organic material within the continental shelf ecosystem is not well understood. Very little of it is eaten directly. Some of the disintegrated leaves appear to enter the detrital food chain, while others may be swept off the continental shelf to become a potential food source in deeper waters.

Mr. M. John Thompson is a marine ecologist with Continental Shelf Associates, Inc. He has over 18 years experience as a working marine scientist and is well known for his work with remote sensing and resource mapping of seagrass and coral reef communities.

REPORT ON THE MINERALS MANAGEMENT SERVICE NORTHERN GULF OF MEXICO ENVIRONMENTAL STUDIES PLANNING WORKSHOP, AUGUST 15-17, 1989

Dr. Robert S. Carney
Coastal Ecology Institute
Louisiana State University

A meeting was held on the 15-17 August 1989, in New Orleans, for technical input on three planned Minerals Management Service (MMS) studies in the Gulf of Mexico. These studies are to be a process-oriented ecosystem study in the Texas and Louisiana Outer Continental Shelf (OCS) region (The TexLa Ecosystem Study), a

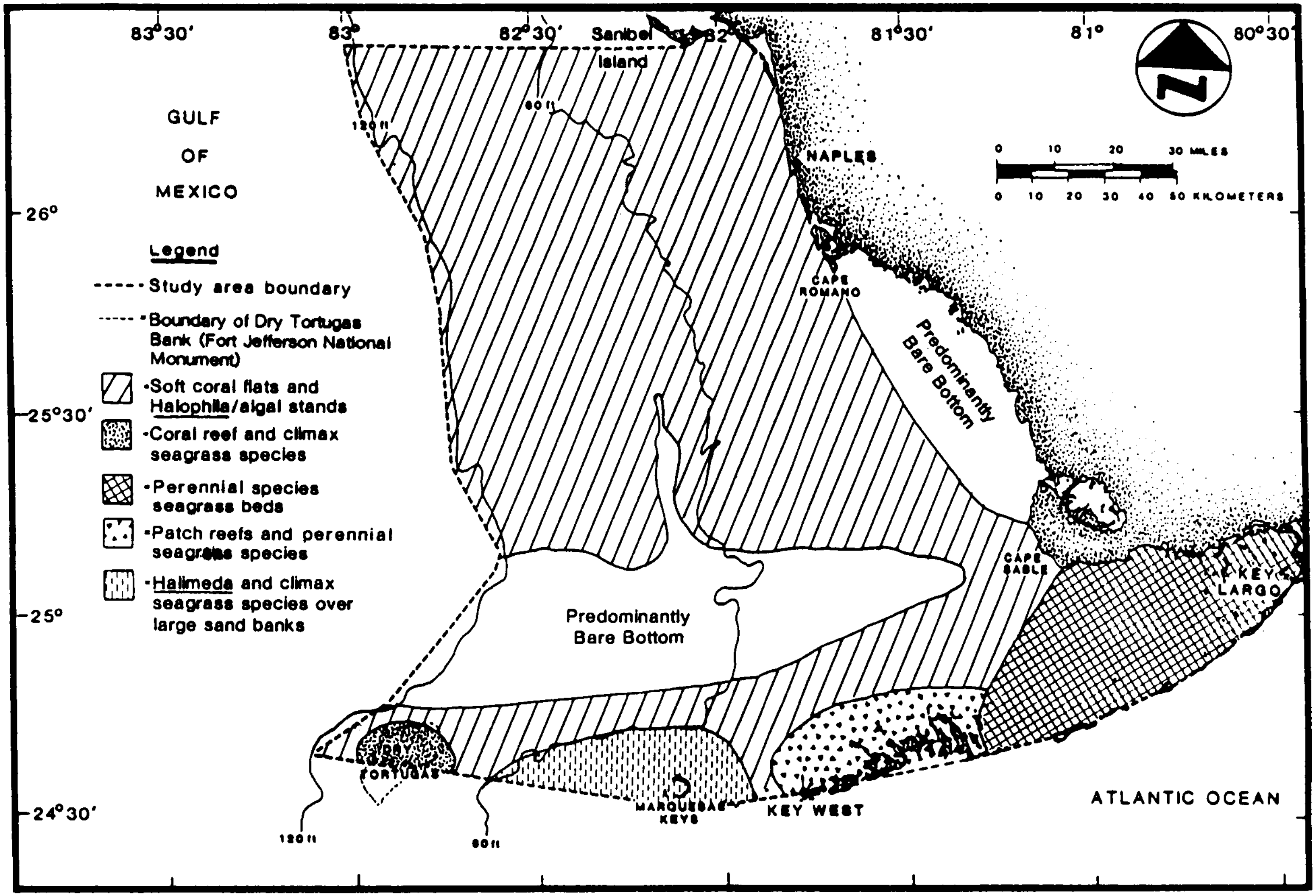


Figure 8.1. Generalized habitat map.

long-term monitoring program designed to understand natural variation throughout the Gulf of Mexico OCS (The Long-Term Monitoring Study), and a study to seek evidence of low-level, chronic impacts possibly associated with established oil and gas activities (Detection of Effects at Long-Term Production Sites).

All three studies face the challenge and obligation to be the initial implementation of new MMS directions stressing process studies, post-leasing activity, and regions of high oil and gas activity. Equally challenging to the participating scientists was the task of proposing obvious and immediate applied value for process studies which have yet to be fully explored as basic research. In spite of the inexperience on both the management and the academic sides, it concluded that all three studies were feasible. New, process-oriented studies can lead to a great improvement in predictive capability in the OCS if fostered and developed carefully.

The TexLa Ecosystem study should consist of an intensive field sampling and modeling effort which examines the benthos, MMS's traditional focus, as part of a larger stem. The Long-Term Monitoring study differs from site characterization studies in that it seeks to understand long-term variation and the relationship among variables. It should be focused upon changes in benthic populations, but include monitoring of the water column and of chemical evidence of changing contaminant levels. The Detection of Effects at Long-Term Production Sites is tasked with resolving the persistent concern but elusive goal of testing for low-level impacts against a background of great natural variation. This project must limit itself to testing specific hypothesized impacts linked to a specific toxin. Components must document the behavior of the candidate toxins in the natural environment and then assess the nature and extent of their toxicity. These two tasks will require both innovative field and laboratory work.

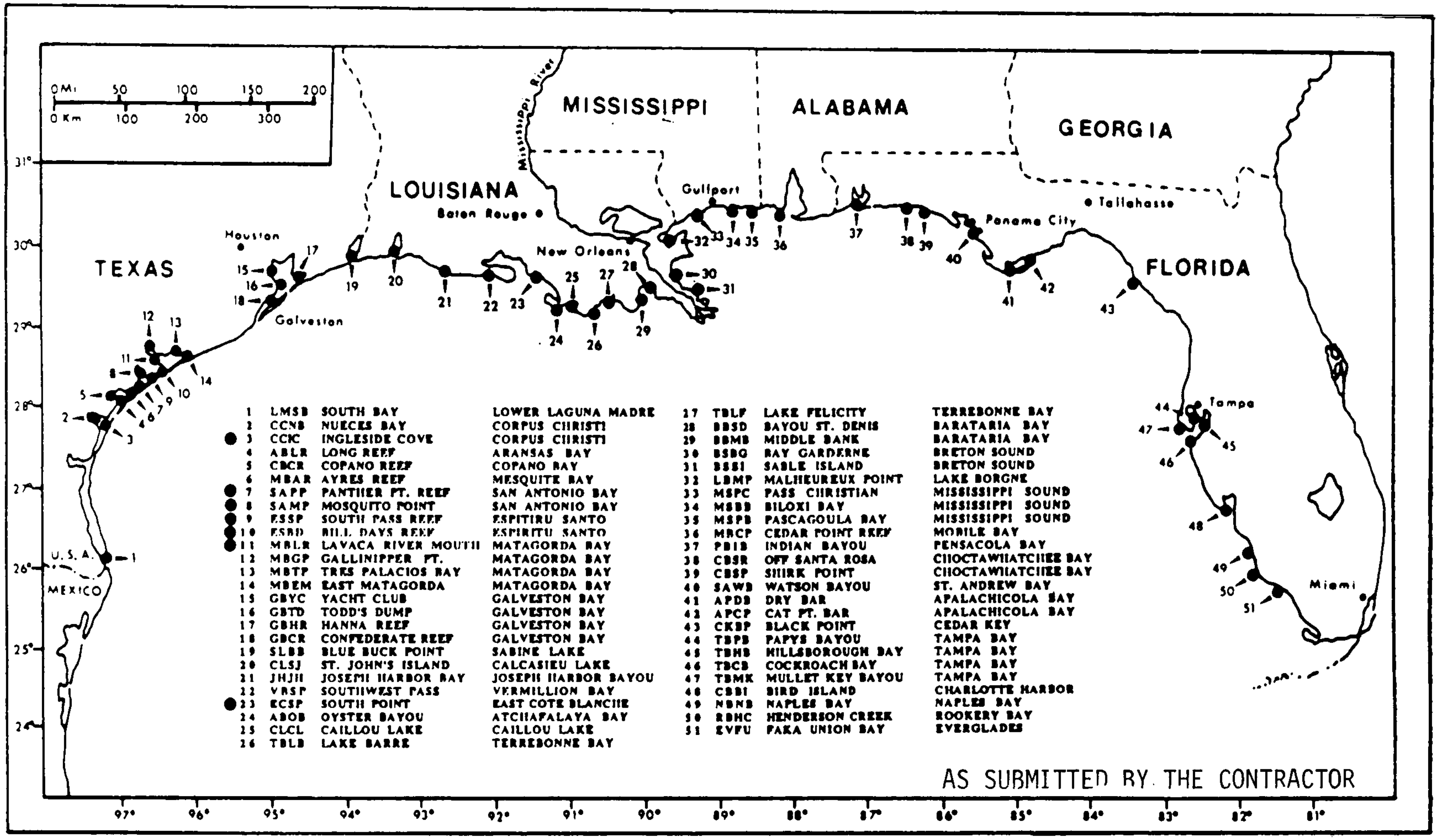
Dr. Robert S. Carney is Director of the Coastal Ecology Institute at Louisiana State University. His major research interests include spatial ecology of benthic systems, ecology of deep-sea megafauna, environmental planning for the deep sea, and effective management of research efforts. He has participated in numerous research projects, particularly of deep-sea fauna and communities; has served on many national-level policy boards, commissions, and scientific review boards; and has served as a National Science Foundation program director for biological oceanography. Dr. Carney received his B.S. in zoology from Duke University, his M.S. in biological oceanography from Texas A&M University, and his Ph.D. in biological oceanography from Oregon State University.

NATIONAL STATUS AND TRENDS MUSSEL WATCH PROGRAM - GULF OF MEXICO

Dr. James M. Brooks
and
Dr. Terry L. Wade
Geochemical and Environmental
Research Group
Texas A&M University

The National Oceanic and Atmospheric Administration (NOAA) Status and Trends Mussel Watch Program was instituted to determine if selected marine contaminants, including PAHs, chlorinated pesticides, and PCBs, are increasing or decreasing over time periods of years. The concentration of the selected trace organics has been measured for three years in oyster samples from 48 to 65 Gulf of Mexico sites. Oysters are valuable sentinel organisms that reflect contamination of an ecosystem on monthly time scales. Oyster samples were obtained at 44 of the total 65 sites during all 3 sampling years. Sediments were also analyzed from each site during at least one of the sampling periods. Sediments reflect long-term (years) contaminant loading of an ecosystem. The sampling sites, removed from known point-sources of contamination, give coverage of Gulf of Mexico coastal areas from southern-most Texas to southern-most Florida (Figure 8.2).

One of the objectives of the Status and Trends Mussel Watch Program is to determine the current status with respect to selected organic contaminants of the nation's coastal zone. A second goal is to determine whether these conditions are improving, remaining the same, or worsening with time.



	No.	Code	Site	Location
	1	LMSB	SOUTH BAY	LOWER LAGUNA MADRE
	2	CCNB	NUECES BAY	CORPUS CHRISTI
●	3	CCIC	INGLESIDE COVE	CORPUS CHRISTI
	4	ABLR	LONG REEF	ARANSAS BAY
	5	CBCR	COPANO REEF	COPANO BAY
	6	MBAR	AYRES REEF	MESQUITE BAY
●	7	SAPP	PANTHER PT. REEF	SAN ANTONIO BAY
●	8	SAMP	MOSQUITO POINT	SAN ANTONIO BAY
●	9	ESSP	SOUTH PASS REEF	ESPITIRU SANTO
●	10	ESBD	BILL DAYS REEF	ESPIRITU SANTO
●	11	MBLR	LAVACA RIVER MOUTH	MATAGORDA BAY
	12	MBGP	GALLINIPPER PT.	MATAGORDA BAY
	13	MBTP	TRES PALACIOS BAY	MATAGORDA BAY
	14	MBEM	EAST MATAGORDA	MATAGORDA BAY
	15	GBYC	YACHT CLUB	GALVESTON BAY
	16	GBTD	TODD'S DUMP	GALVESTON BAY
	17	GBHR	HANNA REEF	GALVESTON BAY
	18	GBCR	CONFEDERATE REEF	GALVESTON BAY
	19	SLBB	BLUE BUCK POINT	SABINE LAKE
	20	CLSJ	ST. JOHN'S ISLAND	CALCASIEU LAKE
	21	JHJH	JOSEPH HARBOR BAY	JOSEPH HARBOR BAYOU
	22	VBSP	SOUTHWEST PASS	VERMILLION BAY
●	23	ECSP	SOUTH POINT	EAST COTE BLANCHE
	24	ABOB	OYSTER BAYOU	ATCHAFALAYA BAY
	25	CLCL	CAILLOU LAKE	CAILLOU LAKE
	26	TBLB	LAKE BARRE	TERREBONNE BAY
	27	TBLF	LAKE FELICITY	TERREBONNE BAY
	28	BBSD	BAYOU ST. DENIS	BARATARIA BAY
	29	BBMB	MIDDLE BANK	BARATARIA BAY
	30	BSBG	BAY GARDERNE	BRETON SOUND
	31	BSSI	SABLE ISLAND	BRETON SOUND
	32	LBMP	MALHEUREUX POINT	LAKE BORGNE
	33	MSPC	PASS CHRISTIAN	MISSISSIPPI SOUND
	34	MSBB	BILOXI BAY	MISSISSIPPI SOUND
	35	MSPB	PASCAGOULA BAY	MISSISSIPPI SOUND
	36	MBCP	CEDAR POINT REEF	MOBILE BAY
	37	PBIB	INDIAN BAYOU	PENSACOLA BAY
	38	CBSR	OFF SANTA ROSA	CHOCTAWHATCHEE BAY
	39	CBSP	SHIRK POINT	CHOCTAWHATCHEE BAY
	40	SAWB	WATSON BAYOU	ST. ANDREW BAY
	41	APDB	DRY BAR	APALACHICOLA BAY
	42	APCP	CAT PT. BAR	APALACHICOLA BAY
	43	CKBP	BLACK POINT	CEDAR KEY
	44	TBPB	PAPYS BAYOU	TAMPA BAY
	45	TBHB	HILLSBOROUGH BAY	TAMPA BAY
	46	TBCB	COCKROACH BAY	TAMPA BAY
	47	TBMK	MULLET KEY BAYOU	TAMPA BAY
	48	CBBI	BIRD ISLAND	CHARLOTTE HARBOR
	49	NBNB	NAPLES BAY	NAPLES BAY
	50	RBHC	HENDERSON CREEK	ROOKERY BAY
	51	EVFU	FAKA UNION BAY	EVERGLADES

Figure 8.2. Gulf of Mexico sampling site locations. (Sites [•] were not sampled all three sampling years.)

The concentrations of selected PAHs, pesticides, and PCBs in sediments and oysters were measured in the Gulf of Mexico in order to provide information on the loading of these contaminants in estuarine areas. This extensive data set for organic contaminants is difficult to summarize. The mean percent changes in oyster concentrations of total PAHs, sum of DDTs (DDE + DDD + DDT), total PCBs, total chlordane (alpha-chlordane + trans-nonachlor), and dieldrin for the 44 sites collected in all 3 years are shown in Figure 8.3. The total PAHs, PCBs, and dieldrin on average were lower in Years II and III compared to Year I. PCBs and dieldrin show a steady decrease among the three sampling years. The sum of DDTs had higher concentrations in Year II and III compared to Year I. Average total chlordane had a higher concentration in Year II and a lower concentration in Year III compared to Year I. Overall the maximum mean percentage change ranged from +54% to -44%.

The general trend for the PAHs are that the concentrations at most sites show little change between the three sampling years. There are, however, exceptions. For example, the oysters from St. Andrew Bay (SAWB) show a steady decrease over the three-year sampling. The mean total PAH concentration decreases from 12,778 to 3,126 to 1,238 ppb. It is possible that there was an unique event at this site, such as a spill of used crankcase oil that caused the initial high concentrations of PAH and with time the environmental levels are decreasing due to dilution and/or degradation of the PAHs. However, even after 3 years this site contains 2 to 3 times higher PAH concentrations than the average Gulf of Mexico site. Another interesting example is Apalachicola Bay, Dry Bar (APDB). The mean total PAH concentrations in oysters were very low in Year I and II (below our reporting level and 8 ppb, respectively) and high in Year III (2,147 ppb). However, the total PAH concentrations for the

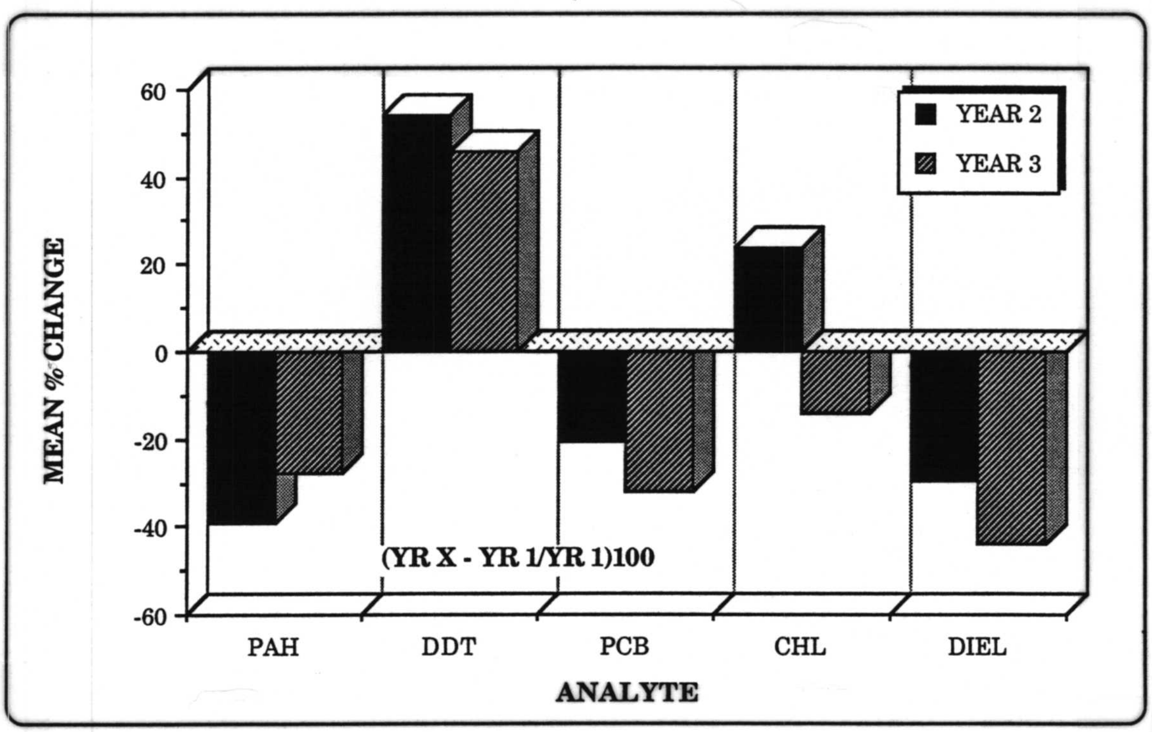


Figure 8.3. Mean percent changes of oyster analyte concentrations.

three replicates from Year III were 3,966, 21 and 2,454 ppb, respectively. The range of concentrations at individual stations at this site, during Year III, overlaps with the Year I and II concentrations. There appears to be a very localized (on the order of 100 m) contamination at this site. Other sites, for example Mississippi Sound, Biloxi Bay (MSBB); Choctawhatchee Bay, Santa Rosa (CBSR); and Barataria Bay, Middle Bank (BBMB) have different patterns. At MSBB we see an increase between Years I and II in the total mean PAH concentrations with a decrease between Years II and III (1,846, 3,659 and 1,131 ppb, respectively). In contrast, the total mean PAH concentrations at CBSR shows a steady increase from Year I to Year III (657, 1,896 and 2,623 ppb), while there is no change in the concentration at BBMB among the three years (1,301, 1,331 and 1,459 ppb for Years I, II and III, respectively).

The 4-ring PAHs are the most abundant aromatic compound in the Gulf Mussel Watch data, accounting for 42 to 60% of the total PAH contents and are similar for oysters and sediments. The 5-ring aromatics account for a very small percentage of the average oyster PAH (2 to 8%) but are a substantial proportion of the sediment PAH (31 to 32%). The 2- and 3-ring PAHs are preferentially concentrated in the oysters. The greater solubility of the 2- and 3-ring over the 4- and 5-ring aromatic compounds may explain the differences observed in the PAH compositions in oysters compared to sediments. Oyster tissue PAH compositions may reflect the PAH that are readily available to the oysters or the PAHs that they preferentially uptake and/or depurate.

The compositions of PCBs and DDTs are different in oysters compared to sediment. While DDD percent of total DDTs are nearly the same in sediments and oysters, there is proportionally more DDT in sediments and more DDE in oysters. This difference may be related to uptake and/or metabolism of DDT compounds by oysters. PCB composition is also different in oysters compared to sediments. Like PAH distributions, the higher molecular weight PCBs are found to be more predominant in sediments while the lower molecular weight PCBs predominate in the oysters. For example, the percentage of the sum of the di-, tri-, tetra- and pentachlorobiphenyls is 72% of the total PCBs in oyster and only 56% in sediments. The average PCB composition in Gulf coast oysters is close to the composition of Aroclor 1254 while the average distribution of PCB homologs in sediments reflects a heavier mixture, e.g., Aroclor 1254 + Aroclor 1260. A more detailed examination of individual PCB congeners is required to determine changes in PCB composition in oysters that may result from uptake, metabolism, degradation, and/or depuration.

The organic contaminant concentrations for Year I versus Year II and III oyster sites from the Gulf of Mexico indicate only minor changes in organic contaminant concentrations with time. There are, however, certain sites where concentrations have changed over the three years. This may be due to secondary input processes at these sites that can provide pulses of input of certain contaminants that increase the normal contaminant loading. Continued sampling of oysters from these and other Gulf of Mexico sites and analysis of the data will allow for further examination of these trends.

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Dr. Terry L. Wade is an Associate Research Scientist in the GERG at Texas A&M University. He is Manager of GERG's Trace Organic Extraction laboratories with expertise in trace organic analysis. He has published over 40 papers on environmental matters.

IMPACT OF OFFSHORE DRILLING: FLORIDA

Dr. Eugene A. Shinn
U.S. Geological Survey

Geological and biological assessment of eight non-productive offshore drill sites off South Florida revealed both positive and negative environmental impacts. Measurable impacts at all sites were of mechanical origin and limited to small areas adjacent to the borehole.

Environments near Key West, where six wells were drilled between 1959 and 1961, include coral reefs, seagrass, live bottom and rippled carbonate sands. Two modern wells off Fort Myers (1981, 1986) were drilled in deep water (53 and 70 m). The deeper site was on a surficial alga/sponge community. Whereas the other was on a relatively barren sand with scattered sponge-encrusted rocky outcrops. Table 8.1 provides additional site data.

Positive impact is limited to the "artificial-reef effect." Abundant debris discarded at sites on rippled sand was encrusted with corals and algae not present before drilling. Numerous species of fish and crustaceans reside among casing, cables, discarded core, and other materials that were routinely dumped overboard before enactment of Outer Continental Shelf (OCS) dumping regulations.

Negative impact resulted where drill rig legs and anchors impacted coral bottom, and at one site the bottom was altered when a barge load of pea gravel was dumped to level the bottom. Approximately one acre of gorgonian and sponge hardbottom was destroyed by the pea gravel. A new community of fleshy algae now grows on the pea gravel. At the same site several dozen bags of cement were piled over the well head. The cement bags support 8 species of corals and provides a habitat for 25 species of fish.

The most severe and long-lasting impact occurred where a 14-legged jackup rig (site OCS 0665 No. I) drilled on coral reef bottom in 1960. In addition to the sand-filled 4.5 m diameter "footprints," two >30 m long anchor scars remain. The total amount of impacted bottom is 406 m² or approximately 1/10th of an acre. Sand in the impacted areas has prevented coral and gorgonian recruitment for the past 30 years. However diversity and numbers of corals and gorgonians in a 10 m² quadrant bordering the borehole are the same as in a control site 1 km from the borehole. No positive or negative impacts could be detected where a floating rig was used to drill on a coral reef. Although all sites may have been initially impacted by drill mud and cuttings, no evidence of their effects could be detected in 1988.

Drill mud and cuttings were not apparent at either of the deep-water sites drilled in the 1980's. Neither cuttings nor drill mud was apparent at OCS G4950 No. I drilled in 70 m of

Table 8.1. Offshore Florida drill site data.

Well Name	Loran C TDs	Lat./Long.	Lease Block	Date Drilled	Rig Type	Water Depth (m)	Well Depth (m)	Lessee
SL 1011 No.2	13887.9 43748.5	24.32.07 82.06.25	State 1011	1961	Barge	5	2,354	California Co.
SL 1011 No.3	13887.9 43748.5	24.32.07 82.06.25	State 1011	1962	Pontoon	5	3,917	California Co.
SL 826Y No.1	13905.4 43729.1	24.37.05 82.02.14	State 826Y	1959	Unknown	5	4,481	Gulf Oil Corp.
OCS 0665 No.1	13845.7 43826.8	24.27.06 82.21.40	OCS Block 28	1960	Jackup	11	4,662	Gulf Oil Co.
OCS 0674 No.1	13826.4 43867.9	24.26.01 82.29.18	OCS Block 46	1961	Jackup	23	2,399	Gulf & Calif. Co.
OCS 0672 No.1	13809.8 43903	24.25.13 82.36.02	OCS Block 44	1961	Barge	20	1,429	California Co.
OCS G4950 No.1	13854.67 30348.52	26.18.37.98 83.42.10.99	OCS Block 622	1986	Jackup	70	3,216	Shell Oil Co.
OCS G3906 No.1	13978.88 30587.78	26.49.27.19 83.24.33.20	OCS Block 144	1981	Jackup	53	3,464	Gulf Oil Corp.

water in 1986, 2.5 years before our observations. The most obvious impact consisted of a 1 m high,, 10 m diameter mound of grout surrounding a 1 m diameter borehole. Large fish lived in the borehole and the site was enveloped by a cloud of small sardinelike fish. Some debris was present, the most obvious of which were dozens of used welding rods.

The other deep-water site (53 m), drilled in 1981, consisted of a 1 m diameter borehole centered on a patch of sponge-encrusted hard-bottom. Two very large groupers occupied the hole and again the area was enveloped in clouds of small fish and schools of 1 m long amberjacks. Debris was less obvious and no grout mound or cuttings pile was present. At both deep sites, the borehole and debris had created an artificial reef.

The purpose of our study was to determine what effects can be predicted during future drilling in tropical environments. We conclude that noticeable damage from offshore exploratory wells drilled on or around coral reefs will be of mechanical origin.

Impacts are caused by anchors and platform legs. Thus impact can be reduced through proper selection of drill sites. Because the only visual evidence of drilling at sites drilled on sandy bottom was caused by discarded debris, I conclude that if no debris is thrown overboard there will be no lasting effect of drilling, assuming no blowouts or drilling accidents. In fact, it would have been impossible to verify six of the eight sites had debris been absent. Because impacts are largely mechanical, it seems likely that offshore wells can be drilled within a few meters of reefs without causing lasting harm.

Dr. Eugene A. Shinn, Project Chief, U.S. Geological Survey, St. Petersburg, Florida, was born in Key West, Florida, and grew up in Miami and the Florida Keys. Dr. Shinn graduated from the University of Miami, then worked as a research geologist in Florida, Holland, the Persian Gulf, West Texas, Houston, and New Orleans, and was an employee of Shell Development Company and Shell Oil Company for 15 years. Dr. Shinn is former Vice President of the Society of Economic Paleontologists and Mineralogists and is a Fellow of the Geological Society of America. His primary research has been in limestone deposition and diagenesis with short forays into coral reef biology and environmental matters. He has dived the Florida Keys' reefs for the past 30 years.

CATASTROPHIC LOSS OF SEAGRASSES IN MISSISSIPPI SOUND

Dr. Lionel N. Eleuterius
Gulf Coast Research Laboratory

Two aspects of seagrass decline are covered in this summary: (1) the reduction in area of seabottom covered by seagrass, and (2) the relative decline and loss of individual seagrass species.

Seabottom vegetated with seagrass in 1975 was about 60% of that recorded in 1969 surveys, where 4,855.8 hectares (12,000 acres) occurred in Mississippi Sound. About 17% or 825 hectares (2,040 acres) were lost to erosion and sand burial caused by Hurricane Camille on 17 August 1969. During 1973 an additional 16% was lost because of prolonged exposure to fresh water discharged through the Bonnet Carré Spillway. This 16% loss amounted to 776.9 hectares (1920 acres) for a total loss of 33%. Loss continued through 1975 until an additional 7% or 339.9 hectares (840 acres) were destroyed and attributed to prolonged exposure to fresh water. The Bonnet Carré Spillway was opened in 1973, 1975, 1979 and 1983. There have been no openings since 1983 and no hurricanes since 1985, so subsequent seagrass destruction and corresponding decline in seabottom coverage have to be attributed to causes other than hurricanes and prolonged exposure to fresh water.

During the past 20 years the coastal area of Mississippi has grown in human population, industry, commercial shipping, oil exploration, oil transport, oil refinery, and used oil processing. Toxic agents from inland areas enter Mississippi Sound by the six local river systems. Toxic agents may have entered Mississippi Sound from waters of the Mississippi River discharged through the Bonnet Carré Spillway, during the four openings over the past two decades. Local oil spills have occurred from used oil "recycling" factories, underwater pipelines, and from ships. If a toxic agent is involved an accumulative effect may be involved, or several toxic agents may react together or in a sequential process that brings great stress upon the plants. Plant stress is a weakened physiological state, which makes the plant susceptible to biotic agents that it may be resistant to normally. Toxic or biotic agents may be involved in the death of seagrasses. However, our surveys do not reveal massive areas of dying seagrass, rather there seems to be a retardation of growth. Stress also causes many plants to go into sexual reproduction. Seed production was abundant in 1986, but no seeds were found to germinate "*in situ*". No seedlings of seagrass were found although many seeds were produced in *Halodule wrightii*. The cause or causes for seagrass decline has not been studied anywhere in the northern Gulf of Mexico, although it is part of a world-wide or global decline. The decline may be part of the global environmental changes presently taking place, and seagrasses need to be carefully studied and given great attention now.

The relative sensitivity or fragility of seagrasses can be seen in the respective declines of individual species. *Halophila engelmannii* is a fragile and delicate seagrass and is probably the most sensitive to change or disturbance, and has not been found since 1972 in Mississippi Sound. *Syringodium filiforme* once the third most abundant seagrass species in Mississippi Sound has completely disappeared except for a small area near the north shore of Petit Bois Island. *Thalassia testudinum* a vigorous, robust species, formally the second most abundant seagrass species has also disappeared, and occurs only in a few small patches in the shallow waters north of Petit Bois Island. A recent oil spill that reached Petit Bois Island poses a threat to these isolated beds of *Thalassia* and *Syringodium*. The most vigorous and prolific seagrass is *Halodule wrightii*. However, even this robust species is not as extensive in area covered as it was just a few years ago. There are about 1455 hectares (3,600 acres) of seagrass in Mississippi Sound at present or about 30% of the area originally covered in 1969, and all of it is essentially *Halodule wrightii*. Many of the "beds" have a sparse coverage of leaves. The cause of sparse leaf production is not known. However, preliminary experimental tank studies indicate that some toxic agent or agents (chemical or biotic or both) is present in the sediment of seagrass beds (Eleuterius and Caldwell, in review A). *Halodule wrightii* plants were placed in aquaria with and without sediment from seagrass beds. After three days seagrass plants placed in the aquaria with sediment were all dead. Those in only seawater lived several months or more. We also tested sand from a local freshwater creek and no death among seagrass plants were noted. Hence our conclusion that something (one or more agents) in the sediment is causing the death of seagrass.

In summary, it is known that hurricanes, fresh water, low water temperatures and sand bar movement are obvious causes of seagrass decline. Now we are faced with an unknown cause of seagrass decline. This cause must be identified and thoroughly investigated, and this needs to be done rather quickly, so that corrective action can be taken to save the existing or remaining seagrasses, and perhaps reestablish them to former areas. Also, the determination of how, or if the seagrass decline here is related to the global seagrass decline now in progress.

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Dr. Lionel N. Eleuterius has been head of the botany section at the Gulf Coast Research Laboratory in Ocean Springs, Mississippi since 1968. He obtained his Ph.D. in botany from Mississippi State University, and M.S. and B.S. degrees in botany from the University of Southern Mississippi. He established the Coastal and Marine Botany program at the Gulf Coast Research Laboratory, and has carried out research on seagrasses since 1968. Dr. Eleuterius carried out the first research project on transplanting seagrasses, which was funded by the Corps of Engineers, U.S. Army, in 1971-1974.

OIL SPILL DISPERSANTS: EFFECTIVENESS AND DECISIONMAKING

Session: OIL SPILL DISPERSANTS: EFFECTIVENESS AND DECISIONMAKING

Co-Chairs: Dr. James J. Kendall
Mr. Charles W. Hill, Jr.

Date: December 6, 1989

Presentation	Author/Affiliation
Oil Spill Dispersants: Effectiveness and Decisionmaking: Session Overview	Dr. James J. Kendall and Mr. Charles W. Hill, Jr. Minerals Management Service Gulf of Mexico OCS Region
Review of the NRC Report on the Use of Dispersants	Dr. John M. Teal Woods Hole Oceanographic Institution
Findings of the MMS-Funded "Dispersant Workshop"	Dr. Thomas W. Duke Technical Resources, Inc.
Dispersant Use Decisionmaking--The MIRG/SLR System	Dr. John P. Fraser Shell Oil Company
Dispersant Use From A Coast Guard Perspective	CMDR Philip Wieczynski Eighth Coast Guard District
Panel Discussion: Dispersant Use in the Gulf of Mexico--Opening Comments	Dr. John P. Fraser Shell Oil Company
State of Florida - Policy on the Use of Chemical Dispersants	Mr. Greg Lee Florida Department of Environmental Regulation
Alabama's Position and Concerns Relating to Dispersant Use in the Gulf of Mexico	Mr. John C. Carlton Alabama Department of Environmental Management
Mississippi's Policy on Dispersant Use in the Gulf of Mexico	Mr. Richard V. Ball Mississippi Department of Environmental Quality
Dispersant Use in the Gulf of Mexico - State of Louisiana	Mr. R. Bruce Hammatt Louisiana Department of Environmental Quality
Dispersant Use in the Gulf of Mexico from the Perspective of the Texas Water Commission	Mr. David Barker Texas Water Commission

Session: OIL SPILL DISPERSANTS: EFFECTIVENESS AND DECISIONMAKING (cont'd)

Presentation	Author/Affiliation
Other Panel Participants*	
State of Florida	Mr. Doug White Florida Department of Environmental Regulation
U.S. Department of the Interior	Mr. Raymond Churan and Mr. Jim Lee Regional Environmental Officers
U.S. Coast Guard	CMDR Philip Wieczynski Environmental Response Port Safety Branch
Woods Hole Oceanographic Institute	Dr. John Teal Advisory Board, Scientific Committee
Technical Resources, Inc.	Dr. Thomas Duke Senior Scientist

*Did not make formal presentations

OIL SPILL DISPERSANTS: EFFECTIVENESS AND DECISIONMAKING: SESSION OVERVIEW

Dr. James J. Kendall
and
Mr. Charles W. Hill, Jr.
Minerals Management Service
Gulf of Mexico OCS Region

Why have a session on Oil Spill Dispersants? To answer this question a few statements were selected from the "Executive Summary and Conclusions" of the report *Using Oil Spill Dispersants on the Sea* (NRC 1989):

> "Concern that chemical dispersants could be toxic to marine life has led to considerable caution in authorizing their use at spill sites."

> "Dispersed and untreated oil show the same acute toxicity."

From the Coastal Zone Management Newsletter, volume 20, number 30:

> "EXXON is seeking reimbursement from State of Alaska for cleanup costs and damage claims associated with EXXON Valdez oil spill, alleging that the damage was worsened because the state persistently opposed the use of chemical dispersants."

Such concerns and beliefs were the impetus behind this session. It was our intention to present a forum whereby the latest information, concerns, and policies regarding the use of chemical dispersants to mitigate the effects of oil spills could be presented. The session was divided into two segments: (1) individual presentations by noted authorities on dispersants, dispersant use, and decisionmaking; and (2) a panel discussion including representatives of the Gulf of Mexico coastal states, academia, Federal agencies, the U.S. Coast Guard, and industry. Each of the state representatives was also asked to comment on their state's policy on the use of chemical dispersants and on "what is the minimum amount of new information needed that will still permit the consideration of dispersants?"

SPEAKER PRESENTATIONS

The first speaker was Dr. John M. Teal, a Senior Scientist at the Woods Hole Oceanographic Institution. Dr. Teal has served on the Scientific Committee of the Outer Continental Shelf (OCS) Advisory Board since 1978, and as chair for the last two years. The Scientific Committee advises the Director of the Minerals Management Service (MMS) on the feasibility, appropriateness, and scientific value of the MMS OCS Environmental Studies Program. Dr. Teal was also a member of the National Research Council's Committee on Effectiveness of Oil Spill Dispersants which has produced one of the most concise documents dealing with the issue of dispersant use: *Using Oil Spill Dispersants on the Sea* (NRC 1989). The Committee worked for two years on a critical review of the knowledge and effectiveness of spill dispersants. Although the committee was charged with addressing several issues, the primary questions were: do dispersants do any good? and, do dispersants do any harm? As summarized by Dr. Teal, the committee concluded that the use of chemical dispersants can prevent ecological damage from oil spills and should be considered as a first response option along with mechanical cleanup techniques. Also, "the toxicity of the dispersants considered for use in the U.S. and Canada now are low compared with that of the toxic components of spilled oil." Dr. Teals own summary of the report "is that spilled oil should be treated with chemical dispersants if (a) the spilled oil is capable of being dispersed, one has available an effective dispersant, trained applicators, and calibration equipment, and can proceed quickly; (b) the spill is moving toward shore; and (c) the physical setting (water depth, currents, etc.) is such that rapid dilution of the dispersed oil will occur."

During January 17-19, 1989, MMS Gulf of Mexico Region sponsored a workshop entitled "Technical Specifications for Oil and Dispersant Toxicity Testing." The purpose of this workshop was to discuss the latest information on testing the effects of oil, dispersants, and dispersed oil on marine organisms and to recommend to MMS which oils, dispersants, and marine organisms (and their life stages) that should be tested, as well as the methods for testing them. The proceedings of this workshop (Duke and Petrazzuolo 1989) were presented by Dr. Thomas W. Duke. The workshop participants concluded that any toxicological tests conducted need to be with the knowledge that there is already an extensive toxicity database available and that test conditions need to resemble as closely as possible those expected in the field. A general testing scheme was developed reflecting the specializations of the various participants in testing oils and dispersants. Prudhoe Bay, South Louisiana, No. 2 Fuel Oil, and Saudi Arabian Light were recommended as the oils to be tested. The dispersants recommended for testing were: Corexit 9527, Chemlink D609, Finasol OSR7, Cold Clean 500, Slickgone NS, and Gold Crew. The participants also identified the invertebrates, vertebrates, and plants to be tested.

Dr. John P. Fraser of the Shell Oil Company and also a member of the National Research Council's Committee on Effectiveness of Oil Spill Dispersants described a microcomputer-based spill impact assessment system for oil spills in the U.S. Gulf of Mexico. The system was developed by S.L. Ross Environmental Research Ltd (SLR) under contract to the Marine Industry Group (MIRG). The system has been designed to estimate the concentrations of floating and dispersed oil to which organisms would be exposed and then to estimate impacts on the resources at risk so as to allow both spill managers and regulatory agencies to make informed decisions concerning both the benefits and the costs of using and not using dispersants.

Commander Philip Wieczynski, U.S. Coast Guard (USCG), Eighth Coast Guard District, presented the view of dispersants from the USCG perspective. The USCG is the Federal On-Scene Coordinator (OSC) for spill response in offshore waters. With the concurrence of the Environmental Protection Agency (EPA) and the affected state(s), the OSC is authorized to permit the use of dispersants, surface collecting agents, and/or biological additives, provided they are listed on EPA's National Product Schedule. Concurrence is also sought from the Federal trustees who may be affected by the spill, usually the Departments of Interior and Commerce. The OSC may also authorize the use of dispersants without consulting the other agencies during those incidents where lives are threatened. However, the agencies must be notified by the OSC as soon as possible and their concurrence obtained once the threat to human life has subsided. Subpart H of the Regional Contingency Plan for Region VI presents procedures to aid the OSC in authorizing the use of oil spill dispersants in non-life threatening situations.

PANEL DISCUSSION

Opening Comments

Prior to formal statements by the representatives of the Gulf of Mexico coastal states, Dr. John Fraser presented a brief history of dispersants and dispersant use. The uncontrolled use of harsh detergents during the Torrey Canyon spill of 1967 has been cited as causing more damage to the environment than if the chemicals had not been used. As a result, when the Amoco Cadiz accident occurred, the use of dispersants was not permitted in water depths of 50 m or less. A series of legal deliberations resulted, eventually leading to a substantial reduction of the imposed fine--now we have the situation with the Exxon Valdez.

Contingency plans were later developed leading to the acceptance of dispersant data by the EPA. Today, dispersants can only be used with the approval of the OSC, the EPA, and the affected state(s). A recent development has been "A Letter of Agreement" between the State of Florida and the USCG preapproving the use of dispersants in certain situations. While it is a conservative agreement, it does much to expedite the use of dispersants in those instances where they would do the most good. Looking ahead, the next steps should include: formal dispersant use criteria; testing the dispersant use decisionmaking procedures; training conducted under actual field conditions; and training observers to monitor and evaluate situations when dispersants are used.

State Presentations

Mr. Greg Lee presented Florida's policy on the use of dispersants. The State of Florida views the use of dispersants as one of many tools available to reduce the impact of spilled oil along its coastline. Florida was one of the first states to develop general use guidelines and was the first state to sign a limited prior approval agreement with the USCG. The Florida Department of Environmental Regulation has set up a predesignated list of contacts for advisory discussions, utilizes Florida State University's super computer for immediate modeling and forecasting information, and is in the process of implementing the impact assessment model developed by the MIRG and S.L. Ross.

Mr. John C. Carlton presented Alabama's policy on the use of dispersants. The Alabama Department of Environmental Management is the state agency responsible for responding to requests for dispersant usage. Decisions involving the use of dispersants are made on a case-by-case basis. The state's present policy is that within the three mile limit of the state's offshore waters (generally less that 10 m depth) adequate information does not exist to allow dispersant use except possibly where inlets to estuaries are threatened or catastrophic impacts to high use recreational beaches are predicted. Alabama is aware of the interest in having areas "preapproved" for dispersant use and intends to convene meetings with all state and local resource agencies to identify such areas for consideration. However, in an inventory of other Alabama resource agencies which would be contacted prior to any decision, it was found that the information available to them is, at best, incomplete and, at worst, non-existent. The State of Alabama recognizes the need to compile and disseminate pertinent information among its regulatory agencies.

Mississippi's policy on dispersant use in the Gulf of Mexico was presented by Mr. Richard V. Ball of the Emergency Response and Transportation Division of the Mississippi Department of Environmental Quality. Mississippi does not permit the use of dispersants in its waters, and due to the nature of these waters, the authorization for their use is not foreseen in the near future. However, the State of Mississippi does recognize that dispersants may be a useful tool in mitigating oil spills in the open Gulf and fully supports continuing discussions and research in this area.

Mr. R. Bruce Hammatt of the Louisiana Department of Environmental Quality pointed out that while toxicity data concerning oils, dispersants, and dispersed oils on a wide variety of Gulf species would be helpful, realistically it might be prudent to devote the available resources towards studies examining the effects on the critical life stages of selected, commercially important species or "indicator organisms." Mr. Hammatt also stressed that the dispersant issue should not be limited to concerns of toxicity alone. Actual "hands-on" training in the use of dispersants and the monitoring of their efficiency and effects may be needed more than additional toxicity data. The State of Louisiana is presently designing the criteria by which the OSC will have preapproval to authorize the use of dispersants off the coast of Louisiana. While the actual limits and restrictions have yet to be established, the predominantly shallow waters of Louisiana will probably necessitate that any preapproved zone(s) be located beyond the three mile state limit.

Mr. David Barker presented the concerns of the Texas Water Commission (TWC). The TWC believes that additional toxicity data regarding dispersant/oil mixtures will be needed if damages to natural resources are to be assessed. Lists of species were presented which the TWC believes require additional testing, including the testing of eggs and larvae as well as adult life stages. Mr. Barker also suggested that it may not be wise to devote all our research attention and funding to dispersant studies alone. While the purpose of this panel was to discuss dispersant use in the Gulf of Mexico, alternative technologies, such as bioremediation, should also be considered.

OPEN PANEL DISCUSSION SUMMARY

Probably the starting point, or question, for this evaluation should be: How did we ever get into this situation? How is it that we are in the predicament whereby it must be proven that dispersants should be used rather than demonstrating that they should not be used? Why is it that these compounds are not thought of as commonly as the detergents and surfactants in everyday laundry soap?

In spite of the Torrey Canyon incident, the British have a much more open policy regarding the use of chemical dispersants. While the British do not actually endorse the use of dispersants, they do use them in situations where it is believed that they are the best treatment option. In anticipation of a spill, dispersants are available in sufficient quantities and strategically stockpiled. The British have also established guidelines for their use. The U.S. has no such strategy. Furthermore, what is particularly frustrating is that while the EPA does have guidelines for the acceptance of dispersant data, the EPA has no procedure for approving their use. Data is accepted as meeting established

EPA guidelines, but such "acceptance" in no way implies that a dispersant is approved for use. It may be that the dispersant issue is more of an institutional dilemma rather than a data deficiency problem. If so, would it really make any difference to do further dispersant/toxicity testing?

Toxicity Testing

The use of surrogate species was discussed in great detail. Several of the species lists being circulated for further toxicity testing resemble "Noah's Ark." At the MMS workshop on "Technical Specifications for Oil and Dispersant Toxicity Testing" (Duke and Petrazzuolo 1989) it was recognized that not every organism can be tested and in some instances only surrogates will be available. However, whenever such species are used, procedures need to be thoroughly thought out so as to reflect actual field conditions. Furthermore, results from laboratory work utilizing surrogates need to be discussed in terms of the species and the conditions expected in the field. Such information would have particular significance should it be needed during a National Resource Damage Assessment.

A review of the literature will demonstrate that numerous species have already been tested with various contaminants and that comparisons with the real-world have been attempted. However, how much data is enough? While the more data available the better, some restraint needs to be exercised. It is easy to fall into the situation whereby data are continuously collected but never used--decisions are never made. Also, it must be determined up front whether there already is sufficient toxicity data. For example, it was agreed that there already was adequate information on the effects of oil versus dispersed oil on mangrove forests/roots so that under certain circumstances responsible decisions can be made now.

Comparing the toxicity test results of different laboratories and the reproducibility of such tests was also of concern. There is a real problem in that experimental protocols are often not well specified. This has been a consistent dilemma with any type of toxicity testing on a large scale. A good example of this are the drilling mud toxicity tests. These tests have always been, and continue to be, problematic and more changes in protocols and data use/analysis are expected. The procedures for oil and dispersed oil are even more problematic.

There is still no undisputed and well-documented case where dispersants have been shown to have an effectiveness greater than 50%; both a slick and a cloud (dispersed oil) are formed. Here additional toxicity data may be required, particularly that which may be needed for incorporation into a damage assessment. Furthermore, the MIRG model should be based on a 50% dispersion efficiency and not 100% (as has been incorporated into the model).

Finally, whenever laboratory toxicity studies are conducted the key species of an environment, rather than just commercially important ones (or surrogate thereof), need to be considered. Also, the actual exposure of an organism to a substance(s) needs to be well defined; both the concentration and the length of exposure (time) must be taken into account.

Planned Spills

What was repeatedly identified as a critical need was actual training and experience with dispersants in the Gulf of Mexico. At this time it is virtually impossible to get permission to conduct experimental spills in U.S. waters. This is why such experiments are conducted in Norway and Canada. If it were possible to conduct such spills in U.S. waters, direct comparisons between dispersed and undispersed oil could be made; it would be possible to examine the actual effectiveness of dispersants; and actual hands-on training could be conducted. However, the EPA has consistently refused permitting such operations. The EPA will only authorize releases of oil into the environment for research purposes; training is not permitted under such a permit. This was viewed as a serious shortcoming because contingency planning to study accidental spills is difficult and often impossible; plans are made to respond to a spill in one area, but the spill occurs in another.

The Future of MMS Studies on Dispersants

While the Regional Response Team and the Regional Technical Working Group were extremely enthusiastic regarding the toxicological testing of various Gulf of Mexico species, the Scientific Committee of the OCS Advisory Board has questioned whether such information would be of any real value. While the MMS is serious about supporting research on dispersants, it does not wish to make false starts. What the MMS needs from the various organizations and working groups are direct, well defined questions which can be addressed in a scientific study.

CLOSING COMMENTS

In essence, the open discussion arrived at the following general conclusions:

- As for the availability of information on dispersants, it was quite evident that these materials are not in the possession of all of the Gulf states. These materials need to be sought out and studied by the states. It is difficult enough to discuss a topic of this complexity with the appropriate preparation (review/study). States should not expect that these materials will just be sent to them. For example, copies of the NRC report on dispersants and dispersant use (NRC 1989) are still available but must be purchased. However, what did impress a number of people on both the panel and in the audience was that the states were very much open-minded regarding issues involving dispersants.

- As for future studies, the panel participants and the audience pointed out that it took three years to put together what was believed to be a resolution to examine the issue of dispersants and to conduct studies thereof. When it was believed to be complete, the overall concept was so large it was impossible to fund or even to work with. It was particularly frustrating for many in that over the years the same issues are raised again and again.

- A strong point of concern was the issue of practice or test spills. It may be that there are sufficient toxicity data but personnel with the training and the experience to effectively use dispersants are not available. The fundamental question may be: How to get the EPA to permit what is really needed?

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Dr. James J. Kendall is a biologist with the Minerals Management Service Gulf of Mexico OCS Region, Office of Leasing and Environment, Environmental Studies Section. Dr. Kendall's 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's experience in the effects of contaminants on marine organisms and systems began when he developed an *in situ* procedure for testing the effects of offshore drilling muds on the calcification, protein content, and amino acid composition of corals. 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.

Mr. Charles W. Hill, Jr., is a marine biologist with the Minerals Management Service's Gulf of Mexico OCS Regional Office, where he has served in the Environmental Assessment Section for the past 13 years. Mr. Hill is a member of the Coral Advisory Panel of the Gulf of Mexico Fishery Management Council. Mr. Hill has earned M.Sc. in both biology and marine resources management.

REVIEW OF THE NRC REPORT ON THE USE OF DISPERSANTS

Dr. John M. Teal
Woods Hole Oceanographic Institution

The Committee on Effectiveness of Oil Spill Dispersants, convened by the National Research

Council, worked for two years on a critical review of the knowledge and effectiveness of oil spill dispersants. The review used information from the literature and from research workers in this field. The results were published early this year (NRC 1989). The committee members were: J.N. Butler (Chair), L.P. Atkinson, J.P. Fraser, M.J. Herz, C.M. Jones, J.P. Marum, C.D. McAuliffe, R.J. Meyers, L.A. "Skip" Onstad, J.R. Payne, J.M. Teal, and P.G. Wells. They, the Marine Board staff, and numerous other researchers contributed to the results.

"Concern for the possible aesthetic, ecological, and economic impacts of oil spills in the ocean, and the adequacy of technologies for controlling them," by both the U.S. and Canadian governments lead to the review as the report states.

The major questions asked of the committee were stated by them as two sets which ask similar things in different ways and with different implications.

First:

- are dispersants effective--do they remove oil from the surface and disperse it into the water column?
- is the impact of chemically dispersed oil more or less than that of untreated oil?

Second:

- do dispersants do any good?
- do dispersants do any harm?

Ideally there would be a simple answer to all of these. Then decisions about the use of dispersants would be relatively easy. But the answers are not simple, which will come as no surprise. In the words of Merv Fingas (1989), an advisor to the committee, in a review of the report where the second set of questions were addressed:

> "The first, ..., is answered with a resounding "maybe". The reason is that only in a few tests were dispersants shown to be effective;.... The two pages containing this answer are a politician's dream in circumlocution, but the fact remains that there is still no undisputed and well-documented case where dispersants have been shown to have effectiveness values above 50%.
>
> The second major question,..., was answered in a shorter, but similarly circumlocutory manner. The best interpretation of the answer is that dispersants will not cause harm."

The principal conclusion of the report was that the use of chemical dispersants can prevent ecological damage from oil spills and should be considered as a first response option along with mechanical cleanup. The advantages of dispersing oil lie in dispersing the oil before it can strand in sensitive intertidal areas, reducing the damage to birds and mammals that might otherwise encounter the slick, enhance degradation of the oil by making it more available to micro-organisms, and reduce chronic inputs in habitats such as mangroves by reducing the persistence of the oil. But there are a number of caveats that must be considered.

- Proper application of the dispersant to the spill is critical if the chemical is to be effective. The dispersant must get onto the oil rather than the water and in a concentration appropriate to the thickness of the slick. Since thickness can change across a slick, application rates may also have to change across the slick. In short, properly trained people with suitable, calibrated application equipment are required if the effort is to succeed.

- Prompt application of the dispersant is critical. Weathering of a slick rapidly decreases the chances of successfully dispersing it with chemicals. The lighter an oil, the more easily it is dispersed, and evaporation rapidly increases oil density. Photo-oxidation and mousse formation make oil more difficult to disperse and both can occur within hours to days.

- Matching the formulation of the dispersant to the composition of the oil and environmental conditions is necessary for effective dispersal.

With these caveats, it is clear that advance planning is necessary if dispersants are to be used effectively. People must be trained, dispersants available, equipment available and calibrated, and a decision to use dispersants possible within hours after a spill.

The report does not address the question of the effectiveness of presently available dispersants in any depth. The 50% dispersion achieved, referred to above, is certainly useful but leads one to hope that more effective formulations can be developed which are equally benign. (I believe the most important conclusion from the report is that we need better dispersants than are now available). The considerations of the ecological effects of dispersing oil in the report assume effective dispersion.

The toxicity of the dispersants considered for use in the U.S. and Canada now are low compared with that of the toxic components of spilled oils. Most of the toxicity of the dispersed oil is due to the oil and not the dispersant. If oil is dispersed in a sufficient volume of water, its resulting concentration can be low enough to have little effect upon marine ecosystems. There is evidence that, in relation to undispersed oil, degradation of chemically dispersed oil is more rapid and is less likely to adhere to sediments and organisms.

The report makes a series of recommendations about additional research that would be desirable to reach more definitive conclusions. I do not disagree with any of these, but feel that there is enough information to reach some definite conclusions. My own summary of the report is that spilled oil should be treated with chemical dispersants if (a) the spilled oil is capable of being dispersed, one has available an effective dispersant, trained applicators and calibrated equipment, and can proceed quickly; (b) the spill is moving toward shore; and (c) the physical setting (water depth, currents, etc.) is such that rapid dilution of the dispersed oil will occur. I do not see that much will be lost by such a decision, but much could be lost by not making it. If dispersal is unlikely due to the nature of the oil or available dispersants, then trying it will be a waste of time and effort that might be better used in attempts at mechanical recovery. If waters are shallow, enclosed, and poorly exchanged, using of dispersants will expose subsurface organisms to greater concentrations of oil than they might otherwise see and increase environmental damage.

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Dr. John M. Teal is a Senior Scientist at Woods Hole Oceanographic Institution, Woods Hole, Massachusetts.. Dr. Teal has served on the OCS Advisory Board, Scientific Committee since 1978, and as chair for the last two years. The Scientific Committee advises the Director of the MMS on the feasibility, appropriateness, and scientific value of the MMS OCS Environmental Studies Program. Dr. Teal was a member of the National Research Council's Committee on Effectiveness of Oil Spill Dispersants which produced one of the most definitive documents dealing with the issue of dispersant use: "Using Oil Spill Dispersants on the Sea" (1989). Dr. John M. Teal received his Ph.D. from Harvard University.

FINDINGS OF THE MMS-FUNDED "DISPERSANT WORKSHOP"

Dr. Thomas W. Duke
Technical Resources, Inc.

INTRODUCTION

The Minerals Management Service (MMS) conducted a Workshop entitled "Technical Specifications for Oil and Dispersant Toxicity Testing" in New Orleans, Louisiana, January 17-19, 1989. The purpose of the Workshop was to discuss the latest information available on testing the effects of dispersants, oil, and dispersed oil on marine organisms and to recommend to MMS the oil, dispersants, and marine organisms that should be tested, as well as the methods for testing them. Because of present uncertainties regarding the effects of dispersants and dispersed oil on the marine environment, the information from this Workshop could be significant to any study proposed to synthesize existing data on the toxicity of dispersants and dispersed oil to potentially sensitive organisms in the Gulf of Mexico or to any study designed to further toxicity testing.

The objectives of the Workshop were:

- to recommend to the MMS methods for testing the toxicity of oil, chemically dispersed oil, and detergents to marine organisms. The organisms should represent commercial fisheries species, recreational species, sea turtles, corals, seagrasses, and mangroves. In addition, the appropriate life stages for testing should also be considered.

- to identify protocols for testing that are (a) currently available, (b) under development, and (c) those that should be developed.

- to comment on availability of test organisms, match species from a prepared list, and address ecological implications if possible.

METHODS AND RESULTS

The Workshop brought together a group of experts in the fields of aquatic toxicology, marine biology and chemistry, biochemistry, transportation of oil and oil products, and modeling. Criteria for their selection were based primarily on scientific expertise as demonstrated in scientific publications and presentations at professional meetings, knowledge of organisms in the Gulf of Mexico, and knowledge of oil and dispersants. Thirteen experts spoke on subjects of special interest to MMS and served as an Advisory Panel. Others participated in discussions of the papers and in formal working groups. The Workshop consisted of (1) an initial presentation of topical papers or reports by the experts; and (2) organization of participants into four working groups that considered (a) selection of oils and dispersants for testing, and toxicity testing with (b) invertebrates, (c) vertebrates, and (d) plants.

Participants concluded that certain toxicological tests need to be conducted with the knowledge that there is already an extensive toxicity database available. Test conditions should include exposures that resemble as closely as possible those expected in the field, and effect and no-effect levels should be determined.

A general testing scheme was developed by the participants that reflected their experiences in testing oils and dispersants. The participants developed a flow diagram (Figure 9.1) to illustrate the level of testing recommended to evaluate the toxicity of dispersant, oil, and dispersed oil. The testing scheme entails aspects of fate and effects and contains basic ingredients of an aquatic risk assessment. Also, specific marine organisms were recommended for testing purposes.

The Workshop participants agreed that several tiers of testing are required in order to determine the toxicity of dispersants and dispersed oil. The first stage of the proposed testing scheme consists of screening tests. These tests can be conducted in a short period of time (6 to 96 hr), and may or may not result in determination of a concentration that kills 50% of the test population (LC5O).

The next step, definitive tests, usually result in determination of an LC50 or an effective concentration which reduces some physiological indices by half (EC50). Other tiers such as chronic toxicity tests, tests with sediments, micro/mesocosms, and field experiments were also discussed. Formulations of dispersants, often a matter of manufacturer confidentiality, should be known both for proper testing and for the safety of laboratory personnel.

As a result of discussions at the Workshop, participants developed the following findings.

- There are few "standard" toxicity tests designed specifically for testing dispersants, oil, and dispersed oil. However, any standard tests found in the American Society for Testing and Materials standard practices documents and other similar documents can be used if the exposure techniques are modified to accommodate oil and dispersed oil. Furthermore, some methods for testing these chemicals specifically can be found in various scientific articles and reports (relationships among recommended test species, test methods, and level of testing with reference to the flow diagram are illustrated in a table).

- The manner in which organisms are exposed to test chemicals should be consistent, when possible, with the manner in which organisms are exposed in the natural environment. For example, contaminated sediment can be layered over clean sediment

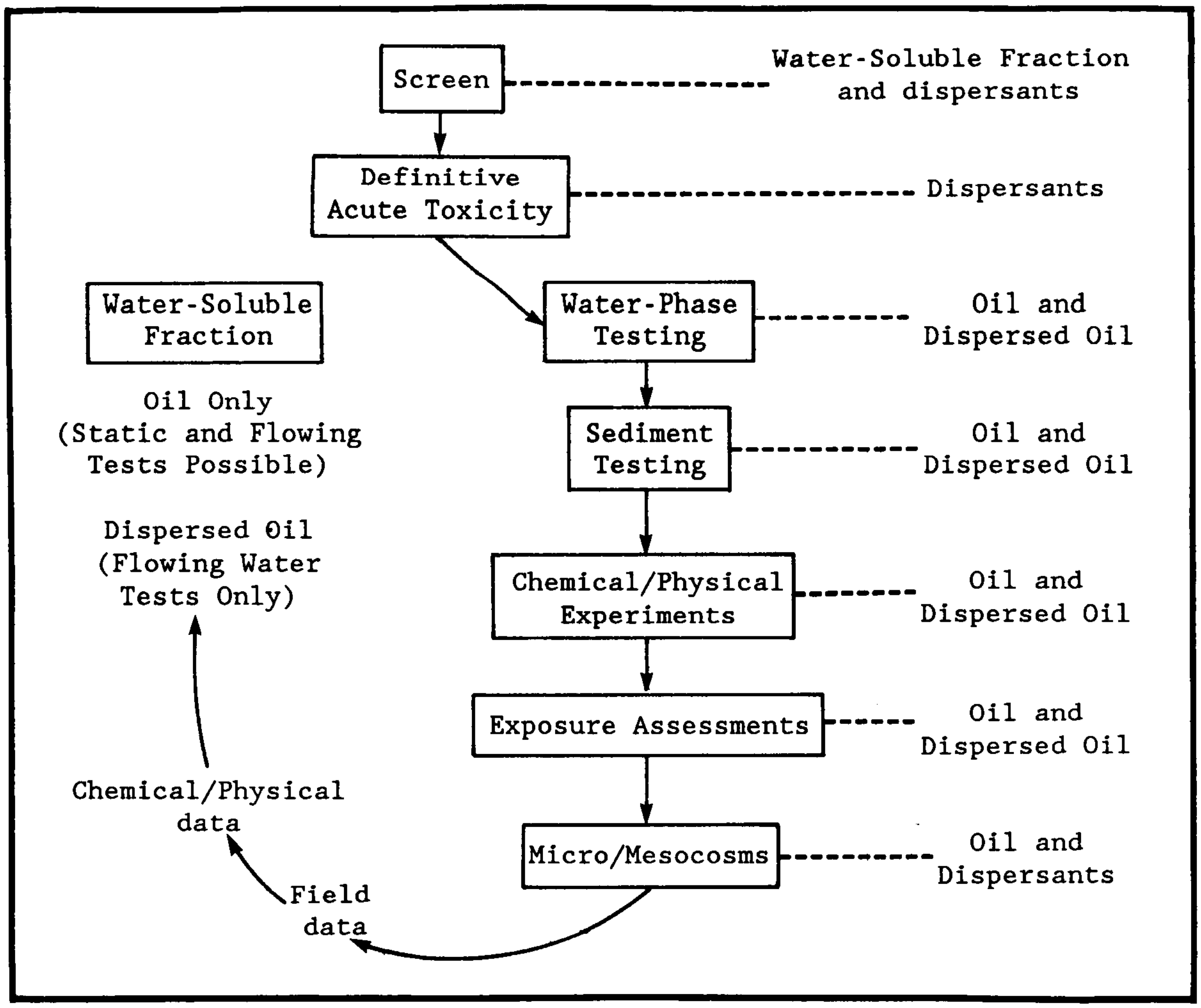

Figure 9.1. A flow diagram for testing dispersants, oil, and dispersed oil.

to test the impact on benthic organisms because this simulates contaminated suspended particulates settling to the bottom in the natural environment.

- The concentration of dispersants, oil, and dispersed oil used in laboratory experiments should include concentrations found in the environment or predicted to be there, and those inducing and not inducing effects. Chemical analysis should be conducted to determine the actual concentrations and, if possible, the composition of the chemicals in the test systems.

- Prudhoe Bay, South Louisiana, No. 2 Fuel Oil, and Saudi Arabian Light were recommended as the oils to be tested.

- The following dispersants were recommended for testing: Corexit 9527, Chemlink D609, Finasol OSR7, Cold Clean 500, Slickgone NS, and Gold Crew.

- Models, such as the MIRG/SLR spill impact assessment model described by Trudel (1989) (also see Fraser this session), should be peer reviewed, "validated," and used as another tool for predicting the impact of oil, dispersed oil, and related chemicals on the environment.

- There is a need for micro/mesocosm studies on the fate and effects of oils and dispersants in marine ecosystems. There is also a need for testing the impact of oils and dispersants on the structure and function of ecosystems in the laboratory and in the field. However, the consensus of the Workshop was that the subject of ecosystem-level testing should be addressed in another forum.

- Test results should be integrated into a risk assessment process in order to obtain a broader view of the fate and effects of the materials involved. One approach is to integrate the results of the proposed hierarchical testing scheme with an ecological risk assessment consisting of hazard identification, effects assessment (water column and sediment), exposure assessment, and risk characterization.

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Dr. Thomas W. Duke is a Senior Scientist at Technical Resources, Inc. in Gulf Breeze, Florida. From 1968 to 1979, Dr. Duke served as the Director of the Environmental Protection Agency's Environmental Research Laboratory in Gulf Breeze, Florida, and then as Senior Research Scientist from 1980 to 1986. His field of interests include ecotoxicology, particularly the effects of contaminants on marine organisms and the environment in which they live. He served recently as co-project officer on a contract with the MMS to conduct a symposium on "Oil and Dispersant Toxicity Testing." The results of this workshop were published in July 1989 as "Oil and Dispersant Toxicity Testing; Proceedings of a Workshop on Technical Specifications Held in New Orleans, January 17-19, 1989." Dr. Thomas W. Duke received his Ph.D. in 1962 in oceanography from Texas A&M University.

DISPERSANT USE DECISIONMAKING-- THE MIRG/SLR SYSTEM

Dr. John P. Fraser
Shell Oil Company

Under contract to the Marine Industry Group (MIRG), a microcomputer-based system has been developed by S.L. Ross Environmental Research Ltd (SLR) to aid in making dispersant use decisions. This system makes detailed numerical estimates of the impacts of dispersed and of untreated oil on populations at risk from an oil spill. With this information, spill response decisionmakers can make informed decisions regarding the use or nonuse of dispersants on any given oil spill in the Gulf of Mexico.

The MIRG/SLR system includes an oil fate model and an oil spill trajectory model. These two models are used to estimate the concentrations of floating and of dispersed oil to which organisms would be exposed.

A large and up-to-date database has been assembled to show the spatial and temporal distributions of species and habitats which might be exposed to oil spills in the Gulf of Mexico. The database was assembled with the cooperation of experts from the state and Federal resource agencies which have responsibility for the Gulf of Mexico.

In development of this database, it was recognized that there are thousands of different species which may be of concern, but that (1) reliable and detailed data are not necessarily available on all, (2) calculations of the impacts of an oil spill on all species is not practical, and (3) many of the species in the Gulf might be grouped and represented by a carefully chosen set of key species. A panel of experts was assembled from Federal regulatory agencies and the regulatory agencies of the five states which have coastlines on the Gulf of Mexico. This panel selected 70 species and habitats which are judged to be reasonably representative of all species and resources in the Gulf and data have been collected on each of these. The resulting database is incorporated into a comprehensive geographical information system which can be used on a microcomputer (personal computer). Algorithms have been incorporated into the system to calculate the impacts of dispersed and of untreated oil from any given spill on the species (populations) and habitats which may be at risk.

When the MIRG/SLR system is used, the output is a tabulation showing the estimated impacts on the resources at risk. Using this information, both spill managers and the appropriate regulatory agencies can make informed decisions regarding the benefits or limitations of dispersant use to mitigate oil spill impacts. An important component of a dispersant use decision is consideration of the relative importance of the resources which may be affected. In the system which has been developed for the Gulf of Mexico, this judgement is made at the time of the spill by the regulatory agencies. However, data on some of the economic and socioeconomic factors involved in a dispersant use decision are included in the system, as an aid to the decision-makers.

The MIRG/SLR system can be used at the time of a spill to aid in making dispersant use decisions. It can also be used as a planning tool to indicate broad areas of the Gulf of Mexico where dispersant use should normally be acceptable. Finally, it can be used as a training tool to show spill managers and others how dispersant use decisions can be made.

Dr. John P. Fraser is an environmental advisor with the Shell Oil Company, Houston, Texas. He has been involved with oil spill response since 1969, initially in research but subsequently (since 1977) in operations. He participated as a committee member in preparation of the report "Using Oil Spill Dispersants on the Sea" released in February 1989 by the Marine Board of the National Research Council. Dr. Fraser is a member of the API Spill Response and Effects Task Force, chairs the MIRG Technical Committee, and is a member of the Dispersant Working Groups of Federal Regions IV and VI. He has been involved as observer, manager, or technical advisor on a wide variety of oil spills including the Shell Martinez spill in 1978 and the Amoco Cadiz, Alvenus, and Ixtoc I spills. Dr. John P. Fraser received his Ph.D. from Cornell University and has been employed by Shell since 1949.

DISPERSANT USE FROM A COAST GUARD PERSPECTIVE

CMDR Philip Wieczynski
Eighth Coast Guard District

The U.S. Coast Guard is predesignated as the Federal On-Scene Coordinator (OSC) for oil spill response in the Coastal Zone. To carry out these responsibilities, it must be familiar with the response tools that are available, one being the use of dispersants. This paper briefly describes the Federal Oil Spill Response Mechanism, the roles of the various levels as they relate to decisions on the use of dispersant, a description of the dispersant use plan for the Gulf of Mexico, and a review of dispersant use following the Valdez spill.

The Federal oil spill response mechanism is organized around national, regional, and local levels. Each level maintains a contingency plan to provide guidance in conducting the response. The National Contingency Plan appears as Part 300 of Title 40 Code of Federal Regulations. It creates a National Response Team (NRT) consisting of representatives from 14 Federal agencies having environmental responsibilities. The NRT is primarily a national planning, policy, and coordinating body that does not respond directly to incidents but provides guidance prior to and assistance as requested during an incident. A National Response Center (NRC) is maintained in Washington, D.C. The NRC maintains a 24 hour watch and allows for one call reporting of oil or hazardous material spills. The NRC relays the spill report information to the OSC who is responsible for the zone where the spill is located.

Regional Response Teams (RRT) are created for each Federal region. Like the NRT, the RRTs are planning, policy, and coordinating bodies and do not respond directly to incidents. Representation on the RRT includes the same

14 Federal agencies as the NRT, plus representatives from the states. An incident-specific RRT may be convened to consider specific issues following a pollution incident. Under these circumstances involved members of the RRT may meet in person or more commonly by telephone conference calls. One issue regularly discussed by an incident-specific RRT is the use of dispersants.

On the local level, the OSC has a responsibility for ensuring proper pollution response and enforcement. The OSC serves as the Person-in-Charge of the Federal response to a pollution incident. The U.S. Coast Guard (USCG) provides OSCs for the coastal zone and the U.S. Environmental Protection Agency (EPA) provides them for the inland zone. Following a report of a pollution incident, the OSC must quickly determine the nature, amount, and location of the pollutant; the potential impact on public health and welfare or on the environment; and the countermeasures necessary to adequately contain, control, or remove the pollutants. He coordinates all Federal containment, removal, and disposal efforts during an incident; monitors cleanup efforts by the responsible party; accesses Federal funds for cleanup where the responsible party is either unidentified or taking insufficient action; and serves as the Federal point of contact for the local response community.

The OSC has a number of resources available to him including assistance from a Scientific Support Coordinator who can prepare spill trajectories and evaluate resources at risk. A USCG Strike Team can respond on scene to mitigate the effects of the spill. The EPA has an Environmental Response Team with expertise in spill response. A Public Information Assist Team is available to coordinate communications with the media during a major incident.

A decision regarding the use of dispersants is but one of many that must be made in the wake of a pollution incident. In view of the time limitations on the effective use of dispersants, however, it must be made quickly. The OSC is authorized to allow the use of dispersants, surface collecting agents, or biological additives, provided they are listed on the National Product Schedule, with the concurrence of the EPA and the state with jurisdiction over the navigable waters polluted by the oil discharge. Concurrence is also sought from the Federal trustees who may be affected by the pollution incident, usually the Departments of Interior and Commerce. For those pollution incidents where lives are threatened, the OSC may authorize use of dispersants without consulting the other agencies, but must notify them as soon as possible and obtain their concurrence once the threat to human life has subsided.

Subpart H of the Regional Contingency Plan for Region VI presents procedures to aid the OSC in authorizing the use of oil spill dispersants in non-life threatening situations (see Appendix to this Session). It was designed to provide a "cook book" approach for dispersant decisionmaking. Each Appendix of Subpart H describes one aspect of the dispersant issue. After collecting information about a spill, the OSC can consult the various tables and lists to develop his plan for handling the situation. From Subpart H, "After determining that (1) the oil spill is likely to impact an environmentally sensitive area, (2) the oil is likely to be dispersible, and (3) dispersant and application equipment are available, the OSC may request dispersant use approval from the RRT." The form to be used for the request is contained in the Subpart. Within six hours of the request, a dispersant use decision shall be made by the EPA and state RRT representatives. If either denies the request, dispersant application shall not be authorized. The RRT for Region VI has been working to identify areas where preapproval for the use of dispersants can be given to the OSC. The RRT also supports a dispersant exercise in the Gulf of Mexico to gain necessary local experience with dispersant application and results.

During the Valdez oil spill, dispersant use became a controversial issue. In the days after the spill several trial applications of the dispersant COREXIT 9527 were made. The initial tests were unsuccessful due to a lack of mixing energy necessary for effective dispersant use. Logistics were also a problem with a limited amount of dispersant, number of aircraft, and applicator problems. By the time the difficulties had been resolved, the bulk of the oil had moved into an area where dispersant use was limited and the weather had deteriorated. The chronology of events pertaining to dispersant use as derived from USCG Pollution Reports and contained in the Report to the President was presented.

In summary, the use of a dispersant, surface collecting agent, or biological additive can be an effective response tool, but each has limitations that must be considered during the decision process. Even when a decision is made to use a dispersant, specific action must be taken to evaluate its effectiveness and damage to the environment.

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CMDR Philip Wieczynski, USCG, is presently serving as Chief, Marine Environmental Response and Port Safety Branch for the Eighth Coast Guard District, New Orleans, Louisiana. He serves as an alternate member of the Regional Response Team for Region VI and as USCG coordinator for Region VI. Prior duty stations include Supervisor of the Marine Safety Detachment in Lake Charles, Louisiana; Marine Safety Duty at USCG Headquarters; and afloat assignments on USCG cutters. He is a 1973 graduate of the USCG Academy and a 1980 graduate of the University of Maryland with a M.S. in chemical engineering.

PANEL DISCUSSION: DISPERSANT USE IN THE GULF OF MEXICO

OPENING COMMENTS

Dr. John P. Fraser
Shell Oil Company

We've come a long way since the Torrey Canyon oil spill of March, 1967. At that time, uncontrolled use of a variety of harsh detergents was blamed for causing more environmental damage than would have been caused by the oil alone. Use of dispersants at the Torrey Canyon spill led directly to development of the restrictive language and emphasis of Annex X of the 1970 National Contingency Plan.

Since that time, extensive research efforts and environmental studies have resulted in significant progress, that is, development of better (more effective and less harmful) dispersants and much greater understanding of their environmental effects. Part of this progress has been reflected in the many papers which have been presented at the biennial Oil Spill Conferences, in the proceedings of the three symposia held by American Society for Testing and Materials (in 1977, 1982, and 1987), and in the recent study by the National Research Council *Using Oil Spill Dispersants on the Sea* (NAS Report). Progress has also taken place in planning for the use of dispersants, as reflected by:

- development of a dispersant use plan in Region VI;
- progress toward development of a dispersant use plan in Region IV;
- the letter of agreement between Florida, EPA, and the U.S. Coast Guard;
- development of dispersant use guidelines in many other states; and
- the MIRG/SLR dispersant use decision-making system.

With the progress already made has come the realization that more work may be needed:

- to define dispersant use criteria more clearly and to convey to both users and regulators better understanding of these criteria;
- to understand more clearly both the opportunities and the limitations of dispersant use;
- to test decisionmaking systems; and
- to train both observers and applicators so that dispersants can be used as effectively as possible.

The purpose of this panel is to review the present status of dispersant use in the Gulf of Mexico, particularly from the perspective of the five states which have coastlines on the Gulf.

There are those who believe that dispersant use is the only way by which oil spills can be mitigated successfully.

- I disagree: There are conditions under which dispersants will not be effective or may be inappropriate. Dispersants are only a tool. However, dispersant use should be authorized without hesitation if such use will minimize ecological impacts.

There are those who fear that dispersant use could lead to severe environmental damage.

- Under most conditions, and especially if they are applied properly, the data which are available today show clearly that dispersant use may actually reduce environmental damage. The key word here is "properly"--if dispersants are not used properly, their environmental effects may indeed be adverse.

There are situations in which no other tool is likely to be effective in mitigating an oil spill. And there are situations in which dispersant use is operationally attractive. In both these situations, dispersant use should receive fair and prompt consideration, without arbitrary and preconceived constraints.

Dr. John P. Fraser is an environmental advisor with the Shell Oil Company, Houston, Texas. He has been involved with oil spill response since 1969, initially in research but subsequently (since 1977) in operations. He participated as a committee member in preparation of the report "Using Oil Spill Dispersants on the Sea" released in February 1989 by the Marine Board of the National Research Council. Dr. Fraser is a member of the API Spill Response and Effects Task Force, chairs the MIRG Technical Committee, and is a member of the Dispersant Working Groups of Federal Regions IV and VI. He has been involved as observer, manager, or technical advisor on a wide variety of oil spills including the Shell Martinez spill in 1978 and the Amoco Cadiz, Alvenus, and Ixtoc I spills. Dr. John P. Fraser received his Ph.D. from Cornell University and has been employed by Shell since 1949.

STATE OF FLORIDA - POLICY ON THE USE OF CHEMICAL DISPERSANTS

Mr. Greg Lee
Florida Department of
Environmental Regulation

Florida was one of the first states to develop general dispersant use guidelines and was the first state to sign a limited prior approval agreement with the U.S. Coast Guard.

Dispersant use is considered for all significant petroleum spills affecting the coastal waters of Florida. The decision to use chemical dispersants is made with the objective of minimizing environmental damage. Immediately upon notification of any significant petroleum spill, the Department of Environmental Regulation (DER) Emergency Response Staff contacts the Regional Response Team and a list of key advisory persons for their input, and begins to determine whether or not dispersant use might reduce the overall impact of the spill in question. It is DER's goal to reach an informed decision within six hours of notification. This could be a very complicated process, because the environmental impact of an oil spill is influenced by such a large number of spill-specific variables, particularly when the spill is near shore and when dilution potential is low. DER has generally adopted Subpart H of the Region VI Contingency Plan to assist in this process.

In addition to input from the key advisory group, the DER is in the process of implementing the Spill Impact Assessment Model developed by the Marine Industry Group (MIRG) and S.L. Ross. This approach estimates the potential impact of the untreated oil spill and compares it with the potential impact of dispersant treated oil. The decision is a tradeoff. While the untreated oil spill poses certain risks to some resources, the use of dispersants may increase the risk to others. The decision is based on the relative effects of untreated and dispersed oil and the relative importance or value of the resources threatened by each option.

The DER is also utilizing Florida State University's Super Computer Computations Research Institute which can provide detailed modeling and forecasting information for a spill in a very short time.

All these activities assist the DER in making the most appropriate choice on a case-by-case basis regarding the use of dispersants in Florida's coastal waters and help to make that decision within the critical time frame.

Florida will continue to refine its overall preparedness to respond to petroleum spills in coastal waters. The use of chemical dispersants is one of the tools we can use in certain situations to reduce the impact of a spill threatening Florida's extensive coastline and the unique subtropical marine habitats that exist in many regions of the state.

Mr. Greg Lee is the Environmental Administrator of the Emergency Response Section of the Florida DER. He has been in this position since 1984 and has been a state representative on the Regional Response Team since 1982. Mr. Greg Lee has a degree in biology from Florida State University.

ALABAMA'S POSITION AND CONCERNS RELATING TO DISPERSANT USE IN THE GULF OF MEXICO

Mr. John C. Carlton
Alabama Department
of Environmental Management

The Alabama Department of Environmental Management (the Department) is the state agency responsible for the various environmental regulatory programs and, as such, has the responsibility of responding to requests for dispersant usage. Currently, the Department evaluates these requests on a case-by-case basis using the information available at the time and in consultation with other resource agencies, as appropriate. Fortunately these requests have been very few and far between. The state's current contention is that within the three mile limit of the state's offshore waters (most of which are less than 10 m) resource agency representatives do not feel that adequate information exists to allow for dispersant use, except possibly where inlets to estuaries are threatened or catastrophic impacts to high use recreational beaches are predicted. Under these conditions dispersant use would be considered if all other prerequisites were met (i.e., availability, sufficient quantities, timeliness of application, etc.). However, the Department is keenly aware of the recent interest in having areas "preapproved" for dispersant use and agrees that a hurried decision, made under the eminent threat of impact, may not be the best informed. Toward this end, the Department intends to convene meetings with all state and local resource agencies in an attempt to "predesignate" areas for consideration of the use of dispersants as a tool in reducing the environmental and economic impact of spill events. The Department applauds the Marine Industry Group (MIRG), API, National Research Council, Minerals Management Service (MMS), and the other Federal agencies' and academia's commitment to provide the information necessary for managers to make ecologically sound decisions.

In preparing for this discussion, the author solicited input from the various state resource agencies which ideally would be contacted prior to the Department approving dispersant use; namely the Alabama Geological Survey/Oil and Gas Board, and the Department of Conservation and Natural Resources-Marine Resources Division. During this exercise it was noted that several individuals within each agency were participating to some degree on various dispersant use projects. The Department, as a member of the Regional Response Team for Region IV, had two individuals involved to varying degrees on the "Dispersant Working Group" and one other individual who participated in workshops held by MIRG/S.L. Ross in developing the "spill impact assessment model." The Alabama Geological Survey has three or four individuals "rotating" on the MMS Regional Technical Working Group and attending the Information Transfer Meetings. The Alabama Department of Conservation and Natural Resources-Marine Resources Division (ADCNR-MRD) provided minimal information to MIRG/S.L. Ross in development of the "spill impact assessment model." To the author's knowledge, the Alabama Department of Economic and Community Affairs, the state's lead coastal zone management agency and provider of economic impact data, has had no involvement on any of the aforementioned projects. It follows that each of these agencies has available to them information which is, at best, incomplete and, at worst, nonexistent and exemplifies the need for a comprehensive compilation of the available data which should be routinely updated. The primary concern was for compilation and dissemination of the available toxicity data which is a prerequisite to determining the amount of "new information" that is needed. In light of the numerous testing methods, there were questions regarding comparability of the toxicity data. Another toxicity data concern expressed by the ADCNR-

MRD was some assurance that as many commercially important species as possible be tested during several life stages and that test procedures emulate natural conditions. Another concern was that the state perceives the need for additional water circulation data (wind driven surface currents as well as subsurface water movement), especially on the shelf areas near shore. The state would not object to MMS requiring oil spill trajectory analyses at all project locations whose target product is oil. This site-specific information is obviously an essential prerequisite to the dispersant use decisions being requested of the states. Also there is some concern that the trajectory analysis techniques are in need of refinement.

Left unattended, these two major concerns and needs will have a significant bearing on the state's ability to confidently predesignate areas where dispersants may or may not be employed.

The state also perceives a need to refine the MIRG/S.L. Ross spill impact assessment model to possibly include: (1) habitat impact and/or some form of ecosystem-level assessment; (2) some means to predict impacts of a treated spill which is less than 100% dispersed; (3) the ability to update toxicity and resource databases to reflect the most current information available.

Some of Alabama's concerns were the subject of the Oil and Dispersant Toxicity Testing Workshop held in January 1989 which resulted in several good recommendations which are worthy of MMS's full consideration.

Mr. John C. Carlton is Chief of the Alabama Department of Environmental Management's Mobile Field Office where he has served in this capacity for 10 years. Mr. Carlton's experience spans a period of 12 years and includes water quality studies and spill response while employed with the Alabama Department of Environmental Management. Mr. John C. Carlton has a B.S. in marine biology from the University of Alabama, Mobile.

MISSISSIPPI'S POLICY ON DISPERSANT USE IN THE GULF OF MEXICO

Mr. Richard V. Ball
Mississippi Department of
Environmental Quality

Mississippi does not permit the use of dispersants in state waters and due to the nature of these waters the authorization for their use is not foreseen in the near future. While we do have concerns regarding the effects of dispersed oil in the state waters of Mississippi, we also feel that dispersants may be a useful tool in mitigating oil spills in the open Gulf.

With this in mind, the State of Mississippi would like to work with its neighboring Gulf States in developing a plan addressing the issues of when dispersants should and should not be used.

Questions concerning the State of Mississippi's policy on dispersant use in the Gulf of Mexico should be addressed to Mr. Richard Ball, Emergency Response and Transportation Division, of the Department of Environmental Quality.

Mr. Richard V. Ball has been On-Scene Coordinator in the Emergency Services and Transportation Division of the Department of Environmental Quality of the Mississippi Department of Natural Resources, Bureau of Pollution Control since 1984. Mr. Ball has responded to over 400 oil and chemical spills from the Gulf of Mexico to the Tennessee state line. He received a B.S. in marine biology in 1983 from the University of South Alabama.

DISPERSANT USE IN THE GULF OF MEXICO-- STATE OF LOUISIANA

Mr. R. Bruce Hammatt
Louisiana Department of
Environmental Quality

The issues surrounding the use of oil spill dispersants off the coast of Louisiana have been discussed repeatedly since 1984 when the M/V Alvenus grounded and released approximately 64,000 barrels of crude oil near the entrance of the Calcasieu Ship Channel. As a result of that incident, as well as several others in the Gulf, the Federal Region VI Regional Response Team organized a "Dispersant Task Force" to identify the primary questions regarding dispersant use and the procedures to be followed to make the appropriate decisions.

A significant amount of time and energy has been spent by the task force members and others in reviewing the available data, including the historical use of various chemical dispersants as well as toxicological studies of impacts of the oils, dispersants, and dispersant/oil mixtures. Many of our original concerns centered around the apparent lack of toxicity data with biological "species of concern." We found, after considerable effort, that there was indeed quite a lot of data available; however, it was suggested by most that specific data on species in the northern Gulf of Mexico were still lacking.

The Louisiana Offshore Oil Port (LOOP) attempted to address some of these concerns by working with the state agencies (principally the Louisiana Department of Wildlife and Fisheries) to design and implement a study on two primary crude oils handled by LOOP and their dispersant of choice. The tests were conducted and as expected, they answered some questions while raising several others.

The Minerals Management Service (MMS) has requested input on the amount of new information needed (in the form of studies) to address our questions concerning the toxicity of dispersants. If we had an unlimited resource to be spend on toxicological studies I would suggest we acquire additional information on a wide variety of species, but I do not view this as the issue of highest priority for Louisiana relative to dispersant usage in the Gulf of Mexico. We have been considering the use of dispersants primarily in the offshore environment not in the nearshore; therefore, I believe we need to concentrate our efforts on the critical life stages of commercially important species or "indicator organisms" of primary interest to the state. Examples of data gaps that we feel should be addressed include the effects of oil dispersant mixtures on the post-larval stages of white and brown shrimp, as well as the effects on the Gulf Menhaden.

Even with such efforts, there will continue to be sincere concerns about whether we should "combat" a major oil spill by spraying additional chemicals on it. I sincerely believe that regardless of how many toxicity tests are conducted, the state will never view the use of dispersants as a cure-all for oil spills off the Louisiana coast.

Regardless of the dispersants or the methodology used, it is accepted by most that some of the spilled oil will reach the shoreline. We do not have extensive areas of sand beaches in Louisiana, nor do we have the rocky habitat that was prevalent in the Valdez area of Alaska. A marsh habitat predominates and with or without dispersants, we need to answer questions on what should be done with the oil that reaches our shoreline. This is an issue MMS should consider for possible study.

I do not feel the issue of training has been addressed adequately. We have been talking about dispersants for years, yet I believe very few people in this audience have actually seen dispersants on oil in the water. We need actual open water training. The Regional Response Team is currently looking at the possibility of holding "real time" training exercises on dispersant spraying in the open Gulf. There are several obstacles and questions that need to be addressed regarding purposefully spilling crude oil in the environment in order to clean it up! This issue is of primary concern and should be looked at by the Federal Government. If this training effort becomes a reality, it should assist us in identifying the types of equipment which would be most effective in monitoring the oil-dispersant plume in the water column as well as training the actual observers who will be directing a dispersant operation.

A decision has been made to identify those conditions necessary to preapprove the use of dispersants off of the coast of Louisiana. While we have not determined the limits nor the restrictions for such a zone, our predominantly shallow waters will probably require any preapproved zone to be located outside the three mile limit in an attempt to keep as much oil as possible out of the nearshore environment.

The intent of this effort will be to give industry the ability to plan for the use of dispersants, at least on a limited basis. We would like to give the On-Scene Coordinator (OCS) the authority to make the decision to use dispersants in a timely and efficient manner.

We have new information and technology to assist us in making the proper decisions in a preapproved zone; for instance, the MIRG/S.L. Ross computer model, and the Sensitivity of Coastal Environments and Wildlife to Spilled Oil Atlas for Louisiana which was recently completed by RPI International, Inc. under contract to the National Oceanic and Atmospheric Administration. We anticipate that the OSC will use such new information and technology.

Proper planning for responding to a major spill is something that has to be done now. This effort should not be postponed until it is too late or until all studies have been planned and completed. We must reduce the time necessary to make the decisions on whether or not to use a dispersant, and ensure that we are knowledgeable about the application and monitoring processes. I believe we must be prepared to use any and all "tools in the toolbox" effectively and in a timely manner to minimize the environmental impacts of petroleum releases into our sensitive coastal waters.

Mr. R. Bruce Hammatt is the Emergency Response Coordinator for the Louisiana Department of Environmental Quality. Mr. Hammatt is the Louisiana representative to the Federal Region VI Regional Response Team, and the department-wide Emergency Response Coordinator in the Office of the Secretary, Louisiana Department of Environmental Quality. Mr. Hammatt is currently in charge of the Section 313 Toxic Release Inventory reports for the state collected under the Federal "Right-to-Know" law. Previously (1979 to 1988), he worked with the Water Pollution Control Division as the Emergency Response Coordinator dealing with all aspects of oil and hazardous materials releases. Mr. Hammatt received his B.S. and M.S. degrees from Louisiana State University with primary courses in wildlife management and chemistry.

DISPERSANT USE IN THE GULF OF MEXICO FROM THE PERSPECTIVE OF THE TEXAS WATER COMMISSION

Mr. David Barker
Texas Water Commission

Following the Minerals Management Service's (MMS) release and publication of the proceedings of a January 1989 workshop on technical specifications for oil and dispersant toxicity testing, there has been an apparent realization of the need to prioritize studies in the face of limited financial resources. The MMS has posed a question to the State of Texas member of the Federal Region VI Regional Response Team (RRT) as follows:

> What is the minimum amount of new information needed that will still permit the consideration of dispersants?

To answer this question, I must digress to some events preceeding the workshop. As indicated in my report, published in the MMS publication OSC Study/MMS 87-0058 (Barker 1987), the RRT formed a workgroup to examine the issue of dispersant use in the Gulf of Mexico. The workgroup prepared a Subpart H to the Regional Contingency Plan which provides for dispersant use decisionmaking and associated actions such as quality control and environmental monitoring. The workgroup has been operating on the rather limited available data concerning the effects of oil, dispersants, or dispersed oil on marine species of the Gulf of Mexico (Ballou and Baxter 1986). Except for the findings of Shuba and Heikamp (1989), this situation appears unchanged. My analysis of the report (MMS 87-0058) indicates that specific data on Gulf species are needed for those situations where the balance of trade-offs are not clear. What do we mean by the balance of trade-offs? We are referring to the trade-offs in expected or reliable predictions of impacts to shoreline and marine environments based on past experience from whole oil versus the questionable marine environmental dangers from dispersed oil. Texas is somewhat unique in that its bays and estuaries are largely protected by barrier islands which have a good sand/shell substrate with a low sensitivity to oil spills. For long stretches, the beach is used for recreational purposes. Local, state, and Federal authorities routinely demonstrate a belief in removal of oil from the beach following a spill. These impacts have been documented time and again. Impacts to the commercial and recreational fisheries are more difficult, if not impossible, to assess with existing data.

The State of Texas has commented to the MMS through the Regional Technical Working Group member concerning our needs that might be addressed through the proposed toxicity studies. These comments were submitted prior to the workshop. Unfortunately, the state was unable to participate in the workshop. As represented by the Texas Parks and Wildlife Department, the state's needs are given as follows:

Red drum	*Sciaenops ocellatus*
White shrimp	*Penaeus setiferus*
Brown shrimp	*Penaeus aztecus*
Turtle grass	*Thalassia testudinum*
Eastern oyster	*Crassostrea virginica*
Spotted seatrout	*Cynoscion nebulosus*
Smooth cordgrass	*Spartina alterniflora*
Gulf menhaden	*Brevoortia patronus*
Red snapper	*Lutjanus campechanus*
King mackerel	*Scomberomorus cavalla*
Pink shrimp	*Penaeus duorarum*

The state is also interested in the additional species in the following listing as proposed by the MMS and we would suggest testing eggs, larvae, and adult life stages (except for vegetation) for any species finally selected by MMS for actual study.

Stone crab	*Menippe mercenaria*
Blue crab	*Callinectes sapidus*
Atlantic croaker	*Micropogon undulatus*
Bay anchovy	*Anchoa mitchilli*
Sand trout	*Cynoscion arenarius*
Sheepshead	*Archosargus probatocephalus*
Snook	*Centropomus undecimalis*
Southern flounder	*Paralichthys lethostigma*
Striped mullet	*Mugil cephalus*
Tarpon	*Megalops atlantica*
Shoal grass	*Halodule wrightii*
Cobia	*Rachycentron canadum*
Crested blenny	*Hypleurochilus germinatus*
Crevalle jack	*Caranx hippos*
Florida pompano	*Trachinotus carolinus*
Mangrove snapper	*Lutjanus griseus*
Sailfish	*Istiophorus platypterus*
Scamp grouper	*Mycteroperca phenax*
Southern kingfish	*Menticirrhus americanus*
Spanish mackerel	*Scomberomorus maculatus*

The state has not had sufficient time to analyze the Proceedings of the MMS workshop, "Technical Specifications for Oil and Dispersant Toxicity Testing" (Duke and Petrazzuolo 1989).

An issue related to any spill, especially a major oil spill, is damage to natural resources and the assessment thereof. Rules governing the assessment of damages have been promulgated by the U.S. Department of Interior (40 CFR, Part 11). I contend that toxicity test data will be needed for dispersant/oil mixtures when a dispersant is used in the spill response phase in instances where damages to natural resources are to be assessed. The point that should be clear is that there is a need for us to find the funds to acquire the needed information. To my way of thinking, it seems to be more of a question of when do you pay, now or later?

With respect to the dispersant use decision, I contend that the state is in a position to decide without any new information. Our decisions will most likely be skewed toward the protection of the marine environment in view of the state's unique shoreline profile. Seasonality will be an important factor in our decision because we will be concerned about organisms and their life stages that would be at risk in a dispersed oil plume. The state has a desire to tailor its own decision process and the Governor of Texas has appointed a standing committee with one of its directives to look into formalizing and documenting this process.

A second question posed by MMS is based on a finding of the National Research Council (1989) that the toxicity of the dispersed oil seems to be due to the toxicity of the oil itself; the dispersant does not increase that toxicity. MMS asks how should this finding be incorporated into decisions to use dispersants? I believe that we should not allow this finding to cause us to overlook the toxicity of the dispersant when it may be ineffective; i.e., when it may disperse into the water column producing an independent pollutant plume and related toxic effects. The National Research Council (NRC) finding is not surprising, in my opinion, as I believe that we have been more concerned for some time about the toxicity of the lighter weight oils. These are the oils that contain a higher portion of volatile, toxic hydrocarbons such as benzene, toluene, and xylene. As opposed to simply considering the toxicity of the dispersant, I think that the NRC finding suggests a need for the decisionmaker to be more concerned about:

- the dispersant effectiveness;
- the nature of the marine environment (the depth of the water and the populations at risk); and,
- the time allowable for weathering of the more toxic components prior to dispersant addition.

While the purpose of this panel was to discuss dispersant use in the Gulf of Mexico, I would like to suggest that alternate technologies, such as bioremediation, may hold greater promise for future use and we may be acting unwisely to devote all of our research attention and funding to dispersant studies.

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Mr. David Barker is the Texas member of the Federal Region VI RRT. He is the supervisor of the Emergency Response Unit of the TWC and has been involved with Texas' spill response program for over 18 years. Mr. Barker was instrumental in developing the *State of Texas Oil and Hazardous Substances Spill Contingency Plan* as well as *Coastal and Inland Spill Response Map Series*, both of which have proven invaluable for deployment of spill response resources and the development of cleanup strategies. Mr. Barker received his B.S. and M.S. from Southwest Texas State University with major and minor courses in biology and chemistry, respectively.

APPENDIX

AUTHORIZATION

SUBPART H REGION VI CONTINGENCY PLAN

AUTHORIZATION FOR USE OF DISPERSANTS
IN NON-LIFE THREATENING SITUATIONS
NATIONAL CONTINGENCY PLAN 40 CFR 300.84 (a)

1. The OSC, when notified of an oil spill shall verify the location, size, source, and other particulars of the spill. Monitoring and tracking of the spill shall commence immediately.

2. The OSC shall immediately notify the appropriate Federal and State agencies in accordance with the OSC's local contingency plan.

3. The OSC shall consult with the NOAA SSC and determine the predicted spill trajectory.

4. Using the charts in Appendix F, Resource Charts and other available information, the OSC and the SSC shall determine if the spill may possibly impact an environmentally sensitive area. If the predicted path is not anticipated to impact an environmentally sensitive area, the OSC and SSC shall monitor the actual spill trajectory until there is no longer any threat.

5. The OSC shall consult Appendix D, List of Oils, and determine if the reported spilled oil may be dispersible. Mechanical cleanup preparations should continue as appropriate. If it is unknown whether the oil is likely to be dispersible or there is reason to believe the information in Appendix D is insufficient or inaccurate, a field evaluation for dispersibility may be warranted using the guidelines listed in Appendix K.

6. The OSC shall verify the availability of sufficient oil dispersant and application equipment listed in Appendix E, Dispersants and Equipment.

7. After determining that (1) the oil is likely to impact an environmentally sensitive area, (2) the oil is likely to be dispersible, and (3) dispersant and application equipment are available, the OSC may request dispersant use approval from the RRT. The EPA representative and the RRT representatives of Texas and/or Louisiana must concur that dispersant use is an acceptable mitigation method.

8. The OSC's request for dispersant use approval shall be transmitted to all appropriate RRT members in accordance with Appendix A, Notifications, and shall contain information listed in Appendix B, Dispersant Use Information Form.

9. Within 6 hours of notification, a dispersant use decision shall be made by EPA RRT representative and the RRT representatives of Texas and/or Louisiana. If either the EPA representative or the affected state RRT representative (s) deny the request, dispersant application shall not be authorized.

10. After receiving approval, the OSC may authorize the application of dispersants upon the spill ensuring the requirements of Appendix H, Quality Assurance and Quality Control, and Appendix I, Environmental Monitoring, will be met.

11. Documentation of the decision shall be included in the OSC's Clean-up Report.

LIST OF APPENDICES AND ENCLOSURES

A Notifications
B Dispersant Use Information Form
C Decision Matrices
D Oils
  1. Transported through the Gulf of Mexico
  2. Produced in the Gulf of Mexico
  3. Dispersibility of Oil
E Dispersant Resources
F Resource Charts
G Toxicity and Effectiveness
H Quality Assurance and Quality Control
I Environmental Monitoring
J MMS Policy
K Field Evaluations for Dispersibility of Spilled Oil
L Training

FISHERIES

Session: FISHERIES

Co-Chairs: Dr. Ann Scarborough Bull
Mr. Richard T. Bennett

Date: December 7, 1989

Presentation	Author/Affiliation
Fisheries: Session Overview	Dr. Ann Scarborough Bull and Mr. Richard T. Bennett Minerals Management Service Gulf of Mexico OCS Region
Status of Gulf Fisheries and Management Activities	Mr. Terrance Leary Gulf of Mexico Fishery Management Council As Presented By Mr. William Perret Louisiana Department of Wildlife and Fisheries
An Overview of the Development of Interjurisdictional Fishery Management Plans by the Gulf States Marine Fisheries Commission	Mr. Larry B. Simpson Gulf States Marine Fisheries Commission
Economic Overview and Changes in the Gulf of Mexico Seafood Industry	Dr. Walter R. Keithly, Jr. Coastal Fisheries Institute Louisiana State University
Ichthyoplankton Dynamics Associated with the Mississippi River Plume/Fronts and a Test of the Linear Food Chain Hypothesis	Dr. Richard F. Shaw, Mr. David L. Drullinger, Mr. James G. Ditty, and Ms. Deborah L. Leffler Coastal Fisheries Institute Louisiana State University
Distribution and Abundance of Larval Yellowfin Tuna, *Thunnus albacares*, about the Discharge Plume of the Mississippi River in September 1987	Dr. Churchill B. Grimes, Ms. Kathy L. Lang, and Mr. John H. Finucane National Marine Fisheries Service
Habitat Conservation: Key Issues in Estuarine-Dependent Fisheries	Mr. Andreas Mager, Jr. and Mr. Donald Moore National Marine Fisheries Service

Session: FISHERIES (cont'd)

Presentation	Author/Affiliation
Effects of Production Platform on Habitat Enhancement and Species Diversification	Dr. Thomas Linton Texas A&M University
The Sport Fishing Institute's Artificial Reef Development Center	Mr. Stephen H. Phillips Artificial Reef Development Center
Conversion of Gulf of Mexico Nonhazardous Ship Generated Wastes into Artificial Reefs Aboard Offshore Platforms	Mr. Dana Larson Rigs to Reefs Company
Factors Influencing the Relative Abundance of Recreationally Caught Fishes near Oil and Gas Platforms in the Northern Gulf of Mexico	Mr. David R. Stanley and Dr. Charles A. Wilson Coastal Fisheries Institute Louisiana State University
Aquariums Without Walls	Mr. Michael E. Parker, P.E. EXXON Company, USA
Development of an Artificial Reef Plan for Texas	Mr. Brett G. Dansby Texas Parks and Wildlife Department
A History and Status of Shrimp Aquaculture	Mr. John Ogle Gulf Coast Research Laboratory
Ranching Redfish	Mr. David Maus Redfish Unlimited

FISHERIES: SESSION OVERVIEW

Dr. Ann Scarborough Bull
and
Mr. Richard T. Bennett
Minerals Management Service
Gulf of Mexico OCS Region

The Gulf of Mexico provides 40% of the commercial fish landings and 33% of the recreational fishing activities in the continental U.S. Landings of all commercial fisheries in the Gulf during 1988 totaled nearly 1.9 billion pounds, valued at about 612 million dollars. Since its inception, the Federal Outer Continental Shelf (OCS) oil and gas program in the Gulf of Mexico Region has been intimately connected with the commercial fishing industry. The practice of and innovations in commercial fishing are of genuine interest to the Minerals Management Service. The thousands of platforms and ancillary structures on the Gulf of Mexico OCS has induced a relationship between fisheries and fossil fuels unparalleled in any other area of the world. For the most part, this relationship has been and continues to be free of major conflicts that plague all other OCS Regions of oil and gas activity. The purpose of this session was to receive and exchange information regarding commercial fishery issues of immediate concern in the Gulf of Mexico. Fourteen presentations were made on topics ranging from fisheries management to artificial reefs.

Mr. William "Corky" Perret, of the Louisiana Department of Wildlife and Fisheries, was first speaker, substituting for Mr. Terrance Leary of the Gulf of Mexico Fishery Management Council. Mr. Perret concentrated on the status of the commercial fisheries stocks in the Gulf of Mexico. The majority of commercial species harvested from the Gulf of Mexico are believed to be in serious decline from overfishing and loss as bycatch. Continued fishing at the present levels may result in rapid declines in commercial landings and eventual failure of certain fisheries. Commercial landings of traditional fisheries, such as shrimp, red snapper, and spiny lobster, have declined over the past decade despite substantial increases in fishing effort. Commercial landings of recent fisheries, such as shark, black drum, and tuna have increased exponentially over the past five years, and those fisheries are thought to be in danger of collapse. Analysis of the present condition of mackerel indicates that management activities have been successful and Spanish mackerel stocks are recovering from overfishing.

Mr. Larry Simpson presented an overview of the Gulf States Marine Fisheries Commission (GSMFC) and the development of interjurisdictional fishery management plans. One important function of the GSMFC is to serve as a forum for the discussion of various problems and programs of marine management, industry, recreation, research, etc., and to develop a coordinated gulf policy to address problems for betterment of the resources and all who are concerned. Interjurisdictional management plans developed by the GSMFC follow the basic format of plans developed by the Gulf of Mexico Fishery Management Council for fisheries in the exclusive economic zone. Compatibility in format and approach to the management of species occurring in state and Federal waters encourages states to adopt fishery management regulations which do not detract from or conflict with the national standards, provisions, and objectives of Federal fisheries management law and plans.

Dr. Walter R. Keithly presented data concerning the economics of the Gulf of Mexico seafood industry. The seafood industry, though diverse and adaptable, is facing an increasingly unpredictable future. Increased competition for limited resources has led to regulations that make investment and expansion decisions difficult. Foreign imports are steadily increasing, driving wholesale prices down and Gulf fishermen and seafood processors out of business. Increasing effort during the 1970's and 1980's in conjunction with a relatively stable deflated value of the Gulf Region finfish and shellfish harvest, especially since the mid-1970's, suggest that the catch per fisherman, expressed in deflated dollars, may be declining. This could translate into declining profits to the fishermen if costs are not likewise declining. There is little reason to expect that costs would be declining.

Dr. Richard F. Shaw presented data from several years of research in the Mississippi River Plume. The annual discharge of the Mississippi River when combined with that of its major distributary, the Atchafalaya River, represents approximately 10% of the volume of the continental shelf waters (less than 100 m depth) of the northern Gulf of Mexico. The river plume's ecological significance is the subject of an ongoing 5-year project. Triplicate Tucker trawl ichthyoplankton collections were taken along hydrographic fronts/convergence zones associated with the river plume during a low river runoff period in July 1987. Relatively distinct ichthyoplankton communities were encountered along transects which paralleled the river plume side versus the oceanic or offshore side of hydrographic convergence zones. Taxa whose distribution overlapped both plume side and oceanic side collections were also encountered. The strength of the salinity gradients observed was not always positively correlated with the larval fish densities collected. The observed frontal systems encountered were very dynamic. One front edge was observed to migrate at a rate greater than one nautical mile per hour. These convergence zones were also quite ephemeral, with formation and relaxation being influenced by tide and wind. A strong or even consistent argument for the existence of a linear food chain was not present.

Dr. Churchill B. Grimes presented data regarding the distribution and abundance of larval yellowfin tuna associated with the discharge plume of the Mississippi River. The National Oceanographic and Atmospheric Administration (NOAA) R/V Oregon II occupied 81 stations along transects of the plume, frontal, and shelf waters during September 1987. Historically, fewer than 50 tuna larvae had been collected in the Gulf of Mexico. To date about half (162) of the NOAA zooplankton samples have been processed and over 900 tuna larvae have been identified. The largest collections of yellowfin tuna ever in the Gulf of Mexico may indicate significant spawning of this species in the Gulf. The numbers, sizes, and ages of larvae collected in relation to their location about the Mississippi River plume may indicate an advantageous situation for larval fish that could dramatically impact their recruitment into the fishery. These results may also be useful in directing other research on tuna larvae.

Mr. Donald Moore reported on habitat conservation efforts in the southeast U.S. The National Marine Fisheries Service (NMFS) is the lead Federal agency responsible for the management of the nation's living marine resources and habitat conservation is a primary concern of the agency. The Habitat Conservation Division (HDC) of NMFS is responsible to conserve fishery habitat. The most important fishery habitats in the nation and especially in the southeast are wetlands. Despite their great importance in the production of fishery resources, wetlands continue to be lost. More than 83% of the annual wetland losses that occur nationwide occur in the southeast. Most of the HDC workload involves review of individual proposals by private and Federal interests to alter wetlands usually at the expense of marine fishery production.

Mr. Stephen Phillips reported on the role that the Sport Fishing Institute (SFI) is playing in the development of artificial reefs. The SFI's Artificial Reef Development Center (ARDC) was created in 1983 because artificial reef development in this country had been undertaken on a "piecemeal" basis due to inadequate management and planning, insufficient funding, and an unreliable supply of reef materials. And most of all, it was hindered by a lack of communication and exchange of information between the states and organizations involved in artificial reef development. One of the major accomplishments of the SFI was to be a major player in the passage of the National Fishing Enhancement Act of 1984. This Act resulted in the writing of the National Artificial Reef Plan. The National Plan has been instrumental in giving artificial reef development some guidelines. From the National Plan, Louisiana got its direction for its highly successful artificial reef program. From early in its existence, the ARDC has been researching topics relevant to prudent artificial reef development such as reef liability, construction materials, economics, siting transportation, and funding, and developed technical reports for those topics.

Mr. Dana Larson explored the concept of upgrading nonhazardous shipboard wastes into artificial reefs and other valuable products aboard Gulf of Mexico obsolete offshore petroleum structures. Preliminary research indicates that the collection of ship-generated wastes at a few selected offshore locations is more economically practical than either (1) retrofitting existing vessels for waste processing or (2) separating ship wastes into separate receiving containers onshore at an estimated 18,000 shorebased terminals. Mariculture ventures associated with the reefs will help offset the problems of natural reef habitat loss, overfishing, pollution, increased demand for fish products, and high levels of U.S. fish imports. Offshore waste conversion facilities will meet both the requirement of the recently adopted Annex V of MARPOL and the long standing objectives of the Department of Health in preventing importation of agricultural threats. If the concept and a demonstration pilot project prove feasible for nonhazardous shipboard wastes, the offshore facilities may be extended to process existing flotsam and jetsam, beach litter and eventually, municipal solid and liquid wastes. These wastes could include gray water, sewage, and associated Exploration and Production wastes. The National Science Foundation's Ocean Enterprise Initiative strongly supports this concept as an example of wiser use of ocean space and resources.

Mr. David Stanley presented conclusions from several years of fishing data collected near oil and gas platforms in the northern Gulf of Mexico. A log book program was initiated to determine the relative abundance of selected fish species around oil and gas platforms off the Louisiana coast. Log books were maintained by 55 anglers and 10 charter boat operators from March 1987 to March 1988. A total of 36,839 fish were caught representing over 46 different species. Principal component analysis (PCA) grouped the 17 most abundant species into reef fish, pelagic fish, bluefish - red drum and Atlantic croaker - silver/sand seatrout associations. Multiple regression analyses were used to compare PCA groupings to physical platform, temporal, geological and angler characteristic variables, and their interactions. Reef fish, Atlantic croaker, and silver/sand seatrout abundances were highest near large, structurally complex platforms in relatively deep water. Spotted seatrout abundances were correlated with the physical parameters of oil and gas platforms although water depth was the dominant factor. Pelagic fish, bluefish, red drum, cobia, and shark abundances were not related to the selected physical parameters of the platforms.

Mr. Michael Parker presented a video entitled "Aquariums without Walls" that gave a description of how and why artificial reefs provide a positive environmental impact. The video also showed how an obsolete oil and gas structure was converted into an artificial reef in the Gulf of Mexico. The construction scenes in the video are of Exxon's High Island A-343 field abandonment. The jacket (underwater) portion of the two structures from High Island were donated to the Louisiana Artificial Reef Program and placed in West Cameron Block 616 in about 300 feet of water. The field abandonment and creation of the artificial reef were completed in December 1988.

Mr. Brett Dansby reported on the status of the artificial reef development plan for the State of Texas. The Texas Parks and Wildlife Department has been involved in artificial reef construction for over 40 years. Since 1947, a total of 68 intentional artificial reefs have been constructed comprising over 1200 acres of bottom in Texas' bays and the Gulf of Mexico. Materials used included: oyster shell; tires; cars; construction rubble; barges; pipes; drilling rigs; and ships. Only 50% of these reefs remained in existence in 1986. The remaining structures were silted over or had been constructed of materials which rapidly eroded or were displaced. The 1989 Texas Legislature enacted Senate Bill 5 which created an artificial reef fund and directed the Texas Parks and Wildlife Department, in conjunction with the Artificial Reef Advisory Committee, to develop rules and guidelines for collection of fees, grants, and donations of money or materials to this fund. Availability of reef building material offered to the Texas Parks and Wildlife Department has never been a problem. Numerous oil companies, interested groups, and private individuals have offered an assortment of materials. However, the problems of placement, marking, maintenance, funding, and transference of liability has not been adequately resolved.

Mr. John Ogle presented information on the aquaculture of shrimp with special emphasis on efforts in the Gulf of Mexico region. Aquaculturists are rearing only 4 of the 342 commercially valuable species of shrimp in the world. Although shrimp had been grown in saltwater ponds in South Carolina in 1947, it was not until 1962 that experimental shrimp pond aquaculture began in the U.S. Research toward culturing shrimp in intensive closed recirculating sea water systems was initiated in 1973 by the National Marine Fisheries Service at Galveston, Texas. Closed-system culture in the U.S. of marine shrimp was attempted commercially in 1979. In 1987, shrimp aquaculture accounted for 26% of the world shrimp production. In 1989, 3.3 million pounds of shrimp were produced by 35 U.S. shrimp farms. This accounted for approximately 10% of the world shrimp production. Competition from foreign producers will require U.S. farms to achieve better survival and higher growth rates, allowing production of at least two crops per year from mainland farms. Concerns over water use, effluent discharge, predator control, and a desire for still greater yields will ultimately take shrimp culture indoors. Intensive closed-system culture is again being practiced by at least five groups in the U.S.

The sessions were completed by Mr. David Maus who presented information concerning the aquaculture of redfish (red drum). Redfish production has two facets: fingerling production and grow-out. Fingerling production necessitates maturation and spawning of broodstock and mechanisms to grow the resultant fry to 2.5 cm size. Grow-out involves growing the 2.5 cm fingerling to market size, which is about a 1 kg fish. Either production involves use of natural resources, primarily water and land. Water use, in most states, requires a permit. Interested parties should inquire about permits to their respective state agencies as early as possible, because the process may take six months or longer. Use of land in terms of site selection will be the single most important factor determining the success or failure of any aquaculture operation. Important site selection factors include: salinity and quality of available culture water, soil type, and elevation.

Dr. Ann Scarborough Bull is a marine biologist in the Office of Leasing and Environment, Minerals Management Service, Gulf of Mexico OCS Region. She received her M.S. and Ph.D. from Louisiana State University, Baton Rouge, and performed her graduate research at the Marine Biological Laboratory, Woods Hole, Massachusetts. Prior to joining MMS, she held positions as a Research Associate in Fisheries at Johns Hopkins University and as a Biologist at the Marine Research Laboratory of the Louisiana Department of Wildlife and Fisheries.

Mr. Richard T. Bennett is a biologist in the Office of Leasing and Environment, Minerals Management Service, Gulf of Mexico OCS Region. He received his B.S. from Mississippi State University and his M.Sc. from the University of Southern Mississippi. Mr. Bennett is involved with environmental impacts of oil and gas operations in the Gulf of Mexico and their effects on fisheries, marine mammals, and endangered species.

STATUS OF GULF FISHERIES AND MANAGEMENT ACTIVITIES

Mr. Terrance Leary*
Gulf of Mexico Fishery
Management Council

The majority of commercial species harvested from the Gulf of Mexico are believed to be in serious decline from overfishing. Continued fishing at the present levels may result in rapid declines in commercial landings and eventual failure of certain fisheries. Commercial landings of traditional fisheries, such as shrimp, red snapper, and spiny lobster, have declined over the past decade despite substantial increases in fishing effort. Commercial landings of recent fisheries, such as shark, black drum, and tuna have increased exponentially over the past five years, and those fisheries are thought to be in danger of collapse.

MACKEREL GULF OF MEXICO AND SOUTH ATLANTIC

Because the historical database for mackerels and other coastal pelagics was inadequate, the Gulf king and Spanish mackerel stocks were overfished without that status being detected scientifically. In order to restore these stocks, significant reductions in harvest levels are required with resultant significant social and economic costs on users. Currently, these fisheries are in the fourth year of a restoration program that is estimated to require 10 years for Gulf king mackerel and a much shorter period for Gulf Spanish mackerel. Scientific data on stock abundance indicates that the restoration program is working for Spanish mackerel and has allowed increased harvest levels. Adequate funding of data collection for this fishery is critical to the restoration of those resources. Much of the detailed data collection allowing annual stock assessment is funded under Marine Fisheries Initiative. Because much of the fishery occurs within waters under state jurisdiction, the success of the management program is dependent on cooperative state programs.

KING MACKEREL
ATLANTIC GROUP

This group recently has been considered fished above the rate of full exploitation based on a number of trends specified in the 1988 stock assessment. In late November 1988, a Federal district judge granted a preliminary injunction enjoining National Marine Fisheries Service (NMFS) from implementing closure of the commercial fishery (scheduled November 23, 1988) and from enforcing zero recreational bag limits (implemented October 17, 1988). Reclosure of the fishery for the final two months (February, March) of the 1988/1989 fishing year will depend on a favorable response to a notice of appeal filed by the Department of Justice on December 27, 1988. Fishing in excess of 1988/1989 TAC, as a result of the court order, may affect the status of this stock.

KING MACKEREL
GULF GROUP

This group has been managed under a rebuilding program since August, 1985. Under restricted allocations, bag limits, and seasonal closures, some signs of recovery are apparent. Spawning stock boimass has exhibited some gains and recruitment is stable at low levels. Since 1980-1981 there has been a marked absence of a strong year class. Strong year classes in the late 1960's and 1970's coincided with historically high catches. There is concern over the possible need for two management units within the Gulf of Mexico and with the possible impact of the increasing Mexican fishery.

SPANISH MACKEREL

Rebuilding programs and restrictive management of Spanish mackerel began in July 1987. Status of stocks as reported in the 1988 Stock Assessment Report indicates that both migratory groups are showing positive signs of recovery. Most of the catch is taken off Florida under state regulations. For the 1987/1988 season, Florida took 75% (7.39 million pounds) of the total catch; 86% of the commercial catch (4.58 million pounds), and 58% of the recreational catch (2.81 million pounds). Capture of 50-80% of the yearly commercial allocation within a period of three weeks by southeast Florida and Florida Keys fishermen may indicate a recovering population. Although recruitment of small fish may have increased, no increases in spawning stock biomass are apparent for the Atlantic group. Increased commercial catches during the past few years in states north of the management area (New England and Middle Atlantic) suggest an expanding population. For the Gulf group spawning biomass and recruitment of small fish appear to have increased.

RED DRUM
GULF OF MEXICO

Based upon the results of data from a major cooperative red drum research program analyzed in a 1987 stock assessment report, the red drum fishery in the Exclusive Economic Zone (EEZ) of the Gulf of Mexico was closed to all harvest on January 1, 1988. The stock assessment concluded that red drum were heavily fished prior to moving offshore to spawn and that those fish less than 12 years of age were poorly represented in the offshore spawning population. Continued harvest of adults would further reduce the spawning stock and increase the risk of a collapse of the red drum fishery. States bordering the Gulf have been asked to increase the level of escapement from nearshore waters to help rebuild the offshore population.

REEF FISH
GULF OF MEXICO

Red snapper is the most important species in the reef fish complex in terms of value and historical landings. According to the most recent data available, red snapper resources in the Gulf of Mexico are severely overfished from both directed and bycatch fisheries. The species is now considered to be in worse condition than was red drum when that fishery was closed to all further harvest in the EEZ. An amendment to the Reef Fish Fishery Management Plan (FMP) is being prepared that will reduce fishing mortality on red snapper. There is insufficient data on most of the other reef fishes to conclude that overfishing is occurring, however, the amendment contains measures designed to prevent overfishing of certain other snappers and several of the important species of groupers.

STONE CRAB
GULF OF MEXICO

The major concern of the stone crab fishery is whether harvest has reached or exceeded maximum sustainable yield. Until recently, the fishery has been expanding in terms of increasing catch within traditional fishing areas and previously unfished or underfished areas. During the last few years, total harvest has declined. Controls on the number of fishermen and gear in this fishery may be the focus of future actions.

SHRIMP
GULF OF MEXICO

The shrimp fishery of the Gulf of Mexico has been under management by the Gulf of Mexico Fishery Management Council since 1981. Two measures in this FMP are the closure of Federal waters off Texas and establishment of the Tortugas shrimp sanctuary off Florida. Both of these measures correspond with state regulations. The Gulf of Mexico shrimp fishery is the most valuable in the U.S., accounting for 80% of the total domestic production. Three species of shrimp dominate the landings: brown, white, and pink. The status of the stocks are: (a) brown shrimp yields are at or near maximum sustainable levels; (b) white shrimp yields are beyond maximum sustainable levels with signs of overfishing; and (c) pink shrimp yields are at or beyond maximum sustainable levels. Yield of the various stocks of shrimp are primarily dependent upon environmental conditions. The continuing decline in the quality and quantity of estuarine and associated habitat due to human development is a major and increasing concern.

This shrimp fishery is also facing a number of other problems: excessive number of vessels given available yields of shrimp; a 10% decline in ex-vessel prices from 1984 levels; increase in interest rates to finance acquisition of vessel and other related equipment; increase in fuel prices; and costs of marine casualty insurance. The cumulative impacts of the environmental and other problems could cause a reduction in available yield and increased reliance on imported shrimp. Imports of shrimp from foreign countries account for 77.5% of domestic consumption. Record levels of pond-raised shrimp are being imported (155,000 tons in the first nine months of 1988). These imports drive the price of shrimp produced by domestic fishermen who find their production costs increasing. The required use of TEDS in the shrimp industry has been the subject of congressional action. Bycatch of finfish is another subject of potential concern as to its effect on those resources.

BUTTERFISH
GULF OF MEXICO

The Gulf Council plans to develop an FMP butterfish in the Gulf of Mexico. This resource is being lightly fished with less than 20% of the estimated safe harvest level being taken. There are significant concerns about the fishery, however, in that some commercial and recreational groups are claiming that butterfish trawlers destroy reef habitat and take large numbers of snappers and groupers. None of these claims have been substantiated. Indeed, a fairly intense onboard observer project indicates that the fishery is relatively clean with little bycatch of any other important commercial or recreational species, and that the trawlers avoid bottoms with corals.

SPINY LOBSTERS
GULF OF MEXICO AND SOUTH ATLANTIC

Biologists believe that the stock is showing signs of growth overfishing. Fishing mortality is high due to the number of undersized lobsters used as attractants in traps and the fact that the number of traps fished exceeds the amount required to harvest the current yield. Fishermen contend that the present fishery practices are optimal for their objectives. Currently, an amendment is under development by the Gulf of Mexico and South Atlantic Fishery Management Councils to merge state/Federal rule-making activities to provide for more compatible regulatory regimes. A study is underway to address the problem of the excessive number of traps in the fishery. Limited entry and other effort reduction measures may be a future consideration.

Mr. Terrance Leary is a Senior Fishery Biologist with the Gulf of Mexico Fishery Management Council and often acts as the Deputy Executive Director. Mr. Leary was born in San Antonio and graduated from the University of Texas. In 1977 he moved to Tampa, Florida to work with

the Council and has been a principal figure in Gulf fishery management. Mr. Leary has the responsibility for the implementation and continuous update of Fishery Management Plans for Coastal Pelagics, Coral, Billfish, and Shrimp in the Gulf of Mexico.

Mr. William S. "Corky" Perret is presently the Administrator for the Marine Fisheries Division of the Louisiana Department of Wildlife and Fisheries. A native of Louisiana, Mr. Perret earned his B.S. and M.Sc. degrees in zoology and fishery science from the University of Southwestern Louisiana. Mr. Perret, representing the State of Louisiana, has worked closely as an appointee to several committees and vice-chairman of the Gulf of Mexico Fishery Management Council.

*Presented by: Mr. William Perret, Louisiana Department of Wildlife and Fisheries

AN OVERVIEW OF THE DEVELOPMENT OF INTERJURISDICTIONAL FISHERY MANAGEMENT PLANS BY THE GULF STATES MARINE FISHERIES COMMISSION

Mr. Larry B. Simpson
Gulf States Marine Fisheries Commission

The Gulf States Marine Fisheries Commission was established by an act of Congress in 1949 as a compact among the five Gulf States. Its charge is to promote the better utilization of marine resources of the Gulf of Mexico.

The commission is composed of three members from each of the five Gulf states. The head of the marine resource agency of each state is an ex-officio member, the second is a member of the legislature, and the third, a citizen who shall have knowledge of and interest in the marine fisheries, is appointed by the governor. The offices of the chairman and vice chairman of the commission are rotated annually between the states.

Regular meetings of the commission are held twice each year on the third Thursday and Friday of March and October. The regular meetings are rotated between the states in order that the commission may better familiarize themselves with the fisheries and coastal areas of the entire Gulf. Special meetings of the commission (subcommittees and technical task forces) are held as needed.

The commission is empowered to recommend to the governor and legislature of the states action on programs helpful to the management of the fishery. The states do not relinquish any of their rights or responsibilities in regulating their own fisheries by being members of the commission.

The basis for any recommendations to the states comes from studies made by experts employed by the states and by Federal resource agencies such as the National Marine Fisheries Service. The commission is also authorized to consult with Federal and state agencies regarding fishery conservation problems. In addition, the commission advises and testifies before the U.S. Congress on legislation and marine policy that affects the Gulf states.

One of the most important functions of the commission is to serve as a forum for the discussion of various problems and programs of marine management, industry, recreation, research, etc. and to develop a coordinated Gulf policy to address them for the betterment of the resource and all who are concerned.

The Interjurisdictional Fisheries Act of 1985 (Title III of Public Law 99-659) established a program to: (1) promote and encourage state activities in the support of management of interjurisdictional fisheries (IJF) resources identified in interstate fishery management plans; and (2) promote and encourage management of IJF resources throughout their range. Enactment of this legislation repealed the Commercial Fisheries Research and Development Act (Public Law 88-309).

Section 8 of the act provides for authorization of appropriations to the three interstate fishery commissions (Gulf, Atlantic, and Pacific) to develop interstate fishery management plans for IJF resources as defined in the legislation.

The basic structure of the IJF management plans follows a format established by a cooperative agreement between the National Marine Fisheries Service (National Oceanic and

Atmospheric Administration, Department of Commerce) and the commission (Figure 10.1). This agreement specifies the tasks that the commission will perform in the organization and formulation of fishery management plans. These tasks include: (1) to identify and prioritize fisheries for regional plan development; (2) to organize task forces composed of the Gulf States Marine Fisheries Commission (GSMFC) existing and newly created committees and subcommittees, representatives of each Gulf State's marine resource agency, and others as deemed appropriate; (3) to provide personnel to assist with plan development and operating procedures; (4) to administer the program; and (5) to provide recommendations of management actions.

The IJF management plans developed by the GSMFC follow the basic format of plans developed by the Gulf of Mexico Fishery Management Council for fisheries in the exclusive economic zone. Compatibility in format and approach to the management of species occurring in state and Federal waters is addressed in Section 5 of the Interjurisdictional Fisheries Act which encourage states to adopt fishery management regulations which do not detract from or conflict with the national standards, provisions, and objectives of Federal fisheries management law and plans.

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TCC → FMC → GS-FFMB → FMC → GSMFC → States for Implementation

↕ ↕

TTF Standing Committees & Outside Review

TTF = Technical Task Force

TCC = Technical Coordinating Committee

FMC = Fishery Management Committee

Standing Committees = Industry Advisory, Law Enforcement & Recreational

GS-FFMB = Gulf State-Federal Fisheries Management Board

GSMFC = Gulf States Marine Fisheries Commission

Figure 10.1. Interjurisdictional Fishery Management Plan Approval Process.

ECONOMIC OVERVIEW AND CHANGES IN THE GULF OF MEXICO SEAFOOD INDUSTRY

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INTRODUCTION

The Gulf of Mexico seafood industry, currently valued in excess of $700 million at dockside, is as complex as it is diverse. The complexity of the industry makes its characterization a formidable task. Fishermen, for example, may choose from and harvest several dozen commercially important species, or may harvest the same species such as shrimp from state inshore, state offshore, or Federal waters. They may further target different species depending upon season, species abundance, relative prices and costs, and other factors.

All of the above suggest that there are considerable variations in the types of boats, gears, and management strategies employed by fishermen. Boats, for example, can range from less than 20 feet to more than 100 feet in length depending upon whether the boat is used for inshore or offshore purposes and the species sought. Trawl, dredge, hook-and-line, traps, and other varieties of gear are all commonly used in the Gulf fisheries. Finally, commercial fishermen range from the "weekend warrior" who may fish as little as a half day over the weekend to those full-timers who travel from port for weeks at a time in search of shrimp, reef fish, and other high-value species.

The commercial seafood industry of the Gulf Region, though diverse and adaptable, is facing an increasingly unpredictable future. Increased competition for the limited fishery resources, by both commercial and recreational interests, has led to an ever increasing array of harvesting regulations. These regulations, while necessary for the conservation of the fishery resources, have been an immediate burden to the commercial seafood industry, making investment and expansion decisions more difficult. Without the regulations, however, stock levels could decline to the point that major displacement in the industry might occur.

Foreign imports of many Gulf landed species are increasing steadily. While providing additional supply to wholesalers and processors, these increasing imports could have potentially negative impacts on the harvesting sector in the form of lower prices. Also, unless used by processors, these increased imports may be of no benefit to the processing sector. Lower prices in conjunction with increasingly uncertain domestic landings make commercial fishing all that more unpredictable.

To analyze possible future changes in the Gulf Region seafood industry, a historical perspective of the industry is provided in the next section of the paper. This historical perspective is followed by a discussion of potential future changes, based upon current and past changes.

HISTORICAL PERSPECTIVE

Commercial landings, imports, and processing are all important components of the Gulf Region seafood industry. As such, they are examined below. The discussion will be general in nature due to space limitations.

Landings

Landings in the Gulf Region currently represent about one-third and one-quarter of the fish and shellfish landed in the U.S. by poundage and value, respectively (Table 10.1). The average annual pounds landed in the Gulf Region during the 1986-1988 period, 2.3 billion lbs., was exceeded only by landings in the Pacific and Alaska Region. Similarly, the value of these landings at dockside, $740 million, was also exceeded only by that observed in the Pacific and Alaska Region, $1.4 billion.

The Gulf Region landings of fish and shellfish have been gradually increasing, as indicated in Table 10.2. Annual 1983-1985 landings, averaging 2.5 billion lbs., exceed the 1968-1970 average landings by one-billion lbs. The 1986-1988 average annual landings of 2.3 billion lbs., while slightly below those observed during the 1983-1985 period, are still higher than those reported during the 1970's.

As with poundage, the current value of the Gulf Region's annual fish and shellfish harvest has been increasing. Valued at $736 million dockside, the 1986-1988 average annual harvest exceeded the 1977-1979 annual catch of $469

Table 10.1. U.S. domestic landings, by regions, 1986-1988 average.

Region	Mill. lbs.	%	$ Mill.	%
Pacific Coast & Alaska	2,624.3	39.1	$1,411.5	45.1
Gulf	2,268.6	33.8	736.5	23.5
Chesapeake	712.9	10.6	146.3	4.7
New England	556.6	8.3	484.9	15.5
Other	543.9	8.2	353.4	11.3
Totals	6,706.3	100.0	3,132.6	100.0

Source: Compiled from data in U.S. Department of Commerce, NOAA, NMFS, Fisheries of the United States (1986, 1987, 1988 issues).

Table 10.2. Annual Gulf Region fish and shellfish landings, 1968-1988.

Year	Pounds	Value	Def. Value[1]
	------------- Mill. lbs. and $ -------------		
1968-1970 avg.	1,532	$148	$134
1971-1973 avg.	1,743	230	182
1974-1976 avg.	1,730	300	186
1977-1979 avg.	1,964	469	236
1980-1982 avg.	1,993	544	201
1983-1985 avg.	2,500	623	201
1986-1988 avg.	2,269	736	216

Source: Compiled from data in U.S. Department of Commerce, NOAA, NMFS, Fisheries of the United States (various issues).

[1]Deflated values were derived by dividing the current values by the Consumer Price Index, 1967 = 100.

million by more than 50% and was almost fivefold the 1968-1970 annual harvest of $148 million (Table 10.2).

After adjusting for inflation, however, little or no growth is seen in the annual value of the Gulf Region fish and shellfish harvest, especially since the mid-1970's (Table 10.2). The 1986-1988 average annual dockside value of $216 million in 1967 dollars, for instance, is less than the $236 million observed during 1977-1979 and only about 20% above the $182 million reported during 1971-1973.

Landings of menhaden, as indicated in Table 10.3, dominate Gulf Region finfish and shellfish production by poundage. Of the 2.27 billion lb. annual Gulf Region 1986-1988 finfish and shellfish harvest, more than three-fourths was menhaden. Shrimp accounted for another 12% of the Gulf Region landings by volume, while blue crabs and oysters represented 3% and 1% of the Gulf Region poundage, respectively,

Table 10.3. Landings of selected Gulf Region commercially important species, 1986-1988 average.

Species	Mill. lbs.	%	$ Mill.	%
Menhaden	1,745	76.9	$70	9.5
Shrimp	262	11.5	482	65.5
Blue Crabs	67	3.0	24	3.3
Oysters	19	0.8	43	5.8
Other	176	7.8	117	15.9
Totals	2,269	100.0	736	100.0

Source: Compiled from data in U.S. Department of Commerce, NOAA, NMFS, Fisheries of the United States (various issues) and unpublished NMFS data.

during 1986-1988. These four species, combined, represent more than 90% of the total commercial harvest in the Gulf Region by poundage.

Though accounting for about three-fourths of the Gulf Region's fish and shellfish production in pounds, menhaden ranks second to shrimp in total dockside value because of its relatively low per pound price. As indicated in Table 10.3, about 65% of the Gulf Region's total finfish and shellfish dockside value is shrimp based while only about 10% is menhaden determined. Adding the dockside values of shrimp, menhaden, oysters, and blue crabs indicates that about 85% of the total value of the Gulf Region finfish and shellfish production can be explained by these four species.

Growth in the landings of these key species, while evident in most cases, has varied considerably among species. Increases in menhaden landings, for instance, have been relatively steady during the 1968-1988 period though landings during the most recent three year period, i.e., 1986-1988, are below those observed during the previous three year period (Table 10.4). By comparison, oyster landings in the Gulf Region have shown little increasing trend with the exception of abnormally large production during 1983-1985 (Table 10.4). Landings of shrimp during the 1986-1988 period, averaging 262 million lbs. annually, are well above the long-run average but are the result of extremely high production in 1986 (304 million lbs.). With the exception of 1986, little growth in the production of shrimp has occurred since the mid-1970's. Shrimp landings during the 1977-1988 period, averaging 242 million lbs. annually, are almost 40 million lbs. above 1968-1976 average annual landings of 204 million lbs. Finally, as indicated in Table 10.4, the annual harvest of blue crabs in the Gulf Region has been rising relatively steadily during the 1968-1988 period, with increased landings being especially apparent in recent years.

Several edible finfish are also of commercial importance to the Gulf Region. The three leading species in terms of dockside value during the 1986-1988 period are snappers, grouper, and yellowfin tuna. Landings of snappers during the 1986-1988 period averaged 7.0 million lbs. ($13.3 million), while grouper landings averaged 8.8 million lbs. ($15.0 million), and landings of yellowfin tuna averaged 10.5 million lbs. ($17.9 million) annually. Two of these three species, groupers and snappers, are thought to be harvested at or beyond optimal biological levels and are increasingly being subjected to regulation and/or potential regulation. Domestic harvest of yellowfin tuna in the Gulf Region is a relatively recent occurrence and little is known of potential levels of harvest. Prediction is complicated because tunas are highly migratory and a single stock can be harvested over a wide range of areas.

Though current statistics on the Gulf-wide basis are unavailable, fishing effort directed at the aforementioned species, and others, is thought to be increasing in most cases. On a state level, the Louisiana Department of Wildlife and Fisheries reports a several-fold increase in the

Table 10.4. Annual landings of selected Gulf Region commercially important species, 1968-1988.

Year	Species			
	Menhaden	Shrimp	Oysters	Blue Crabs
	---------------------------- Mill. lbs. -----------------------------			
1968-1970 avg.	1,064	210	21	31
1971-1973 avg.	1,262	213	18	37
1974-1976 avg.	1,244	189	19	38
1977-1979 avg.	1,504	240	18	42
1980-1982 avg.	1,550	229	20	41
1983-1985 avg.	2,050	238	28	51
1986-1988 avg.	1,775	262	19	67

Source: Compiled from data in U.S. Department of Commerce, NOAA, NMFS, Fisheries of the United States (various issues) and unpublished NMFS data.

number of crab trap licenses issued over the past decade. Similarly, the number of shrimp licenses issued has risen steadily over the past several decades as the state's population increased. If this pattern exists in other Gulf states, commercial fishing activities are probably substantially higher today than in previous decades.

Increasing effort during the 1970's and 1980's in conjunction with a relatively stable deflated value of the Gulf Region finfish and shellfish harvest, especially since the mid-1970's, suggest that catch per fisherman, expressed in deflated dollars, may be declining. This could translate into declining profits to the fishermen if costs are not likewise declining. There is little reason to expect that costs would be declining.

IMPORTS

Because the seafood demand in the U.S. cannot be met by domestic supplies at acceptable prices, imported seafood has historically constituted a significant component of the seafood consumed in the U.S. In fact, it has represented more than half of the total U.S. supply of edible seafood since 1976.

Shrimp imports, which compete with the Gulf Region product, have historically been very high, accounting for more than 50% of the total U.S. supply. As farm-raised shrimp became economically competitive in the early 1980's, however, imports of shrimp into the U.S. proliferated. For example, imports of shrimp into the U.S. averaged 260 million headless lbs. per year during 1977-1979. They increased to 279 million lbs. annually during 1980-1982, increased once again to 432 million lbs. annually during 1983-1985, and rose another 30% to 558 million lbs. during 1986-1988. Overall, U.S. imports of shrimp have more than doubled since 1977 and indications are that imports will continue to rise as countries develop and expand shrimp farming techniques. China and Ecuador, both major producers of farm-raised shrimp, each export about 100 million lbs. to the U.S. These two countries each exported less than 10 million lbs. of shrimp to the U.S. as recently as 1978.

As indicated in Table 10.5, the proliferation of shrimp imports in the 1980's appears to have significantly impacted dockside prices in the Gulf Region. After adjusting for inflation, the 1986-1988 dockside shrimp price, $0.54 per pound in 1967 dollars, is about 20% less than the peak price of $0.70 per pound observed during the 1977-1979 period. If imports continue to rise, as many expect, shrimp prices adjusted for inflation are likely to fall even further.

Adams and Lawlor (1988) have recently provided information which suggests that many of the edible finfish species landed in the Gulf Region will be facing increased competition in the form of imports. Imports of all species of snapper from Latin American countries into

Table 10.5. Gulf Region dockside shrimp prices (head-on) in current and deflated dollars per pound, 1968-1988.

Year	Current Price	Deflated[1] Price
	-------------- $/lb.	----------------
1968-1970 avg.	0.48	0.43
1971-1973 avg.	0.74	0.58
1974-1976 avg.	1.04	0.65
1977-1979 avg.	1.38	0.70
1980-1982 avg.	1.64	0.61
1983-1985 avg.	1.76	0.57
1986-1988 avg.	1.84	0.54

Source: Compiled from data in U.S. Department of Commerce, NOAA, NMFS, Fisheries of the United States (various issues).

[1] Deflated prices were derived by dividing the current prices by the Consumer Price Index, 1967=100.

southeastern ports of entry, for example, have increased from 4.8 million lbs. in 1983 to 14.0 million lbs. in 1987, or about 200%. Grouper imports increased from one-half million lbs. to 8.9 million lbs. during the same period of time. Overall, the total volume of imports of the species analyzed by Adams and Lawlor increased from 17.4 million lbs. in 1983 to 70.4 million lbs. in 1987. This 53 million lb. increase represents annual growth in excess of 13%. It should be noted that shrimp was not one of those species examined by Adams and Lawlor.

Processing

The Gulf Region finfish and shellfish processing activities were valued at about $1.4 billion annually during 1984-1986 compared to $954 million annually during 1978-1980 and $322 million annually during 1969-1971 (Table 10.6). When adjusted for inflation, processing activities in the Gulf Region have been relatively stable averaging $429 million annually during 1984-1986 compared to $438 million annually during 1978-1980, expressed in 1967 dollars. However, the deflated value of processing activities during the 1978-1986 period, averaging $426 million, exceed those observed during the 1969-1977 period, $322 million annually, by approximately one-third.

As one might expect, processing activities by species closely reflect the value of landings by species. Shrimp processing activities dominate receipts from all fish and shellfish processing activities in the Gulf Region, representing 73% of the total value in 1986 (Table 10.7). Menhaden processing activities represent another 8%, while blue crabs and oysters combine for another 8.5% of the Gulf Region processing activities in 1986. All other species contribute just 11% of total Gulf Region processing activities.

It is worth noting that the deflated value of processing activities in the Gulf Region has not been increasing during the 1980's even though imports of shrimp have increased significantly, as previously examined. This is somewhat surprising in light of the fact that shrimp dominate Gulf Region processing activities in value terms. This suggests one of the following: (a) the deflated per pound price of finished processed shrimp has been falling, (b) little of the increased shrimp imports during the 1980's are being utilized by the Gulf shrimp processing industry, (c) imported shrimp are displacing domestic landings in the processing activities, or (d) some combination of the above factors is transpiring.

FUTURE CHANGES

As noted in the introduction, the Gulf Region seafood industry is facing an unpredictable future. Increasing commercial fishing activity

Table 10.6. Current and deflated value of Gulf Region processed fishery products, 1969-1986.

Year	Current Value	Deflated Value[1]
	-------------- $ mill.	--------------
1969-1971 avg.	332	287
1972-1974 avg.	441	327
1975-1977 avg.	606	351
1978-1980 avg.	954	438
1981-1983 avg.	1,182	412
1984-1986 avg.	1,389	429

Source: Compiled from data in U.S. Department of Commerce, NOAA, NMFS, Processed Fishery Products, Annual Summary (various issues).

[1] Deflated prices were derived by dividing the current prices by the Consumer Price Index, 1967=100.

Table 10.7. Gulf Region processed value of selected species, 1986.

Species	Value ($ mill.)	% of total
Shrimp	981	72.9
Menhaden	108	8.0
Blue Crabs	60	4.5
Oysters	54	4.0
Other	142	10.6
Totals	1,345	100.0

Source: Compiled from data in U.S. Department of Commerce, NOAA, NMFS, Processed Fishery Products, Annual Summary, 1986.

can be expected to continue, in the absence of regulation, as population in the Gulf Region increases. Also recreational fishing activities have increased and will likely continue to do so as discretionary income and leisure time rises. Thus increased competition for the limited, and in some cases dwindling, fishery resources can be anticipated. This increased competition suggests an increasingly large and complex set of fishery regulations aimed at reducing effort of both commercial and recreational fishermen. The commercial harvesting sector can anticipate increased regulations of the following type: (1) restrictions on the size of fish taken, (2) seasonal and area closures, (3) gear restrictions, and (4) industry quotas. Finally, limited access to the Gulf Region fisheries, though not currently in place, may be used in the future to control excessive effort.

Increased competition for the limited resources is coming at a time when the commercial harvesting sector is being asked to compete more intensely with comparable imported products. As noted, imports of shrimp, snappers, groupers, and many other Gulf Region type species are increasing. Future increases in these imports can be expected as (a) U.S. demand for high quality seafood increases and (b) foreign countries strive to develop their underutilized resources in an attempt to obtain U.S. dollars. Future increases in imports of finfish species may impact domestic seafood prices in a manner consistent with what has recently been observed in the shrimp fishery.

Finally, it is likely that further processing of the fishery products before export to the U.S. will increase as Latin American and Asian countries attempt to fully capitalize on their respective seafood industries. Such a situation could affect the Gulf Region processing sector in two ways. First, the foreign products may become more directly competitive with products produced by the Gulf Region processing sector. Second, the processing sector may find obtaining sufficient volumes of the raw product increasingly difficult. Either of these cases may lead to significant structural changes in the Gulf Region processing sector.

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ICHTHYOPLANKTON DYNAMICS ASSOCIATED WITH THE MISSISSIPPI RIVER PLUME/FRONTS AND A TEST OF THE LINEAR FOOD CHAIN HYPOTHESIS

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INTRODUCTION

It is generally recognized that density fronts or discontinuities and riverine/estuarine discharge plumes are important sites for energy transfer and intense biological activity with potentially large phytoplankton and zooplankton standing stocks (Simpson and Hunter 1974; Bowman and Esaias 1978; PROBES 1980; Holligan 1981; Incze and Yentsch 1981; Parson et al. 1981). Larval fish aggregations are common in areas of concentrated nutrients and chlorophyll found in oceanic fronts (Hamann et al. 1981) and plumes, i.e., Columbia River (Richardson 1981) and Mississippi Delta (Govoni et al. 1983; Ortner and Hoss 1983). Therefore, any processes or mechanisms responsible for small-scale elevated gradients or patches of microcopepod forage relevant to larval fish searching behavior are crucial for survival. The timing and spatial occurrence of fish spawning tends to take advantage of periods and areas of high productivity (Crisp 1954; Cushing 1967); special predator-prey relationships (Frank and Leggett 1982); and oceanographic features and conditions, which not only affect the distribution and concentration of fish eggs, larvae, and their food, but also their transport, survivorship, and ultimate year-class success (see Norcross and Shaw 1984 for review). Recruitment may be enhanced by "safe sites" (Frank and Leggett 1982) in which physical processes usually insure that biological conditions are stable and favorable for survival (Lasker 1975, 1981). Reproductive success for some species depends upon a "match or mismatch" (Cushing 1972) of the most influential physical and biological factors (Townsend 1983).

As mentioned above, fish with pelagic eggs often reproduce in gyres and fronts (Loeb 1980; Frank and Leggett 1983) thus making areas of upwellings, fronts, and boundary currents among the most productive for fisheries (Garrod and Knights 1979; Mills and Fournier 1979; Bakun and Parrish 1982; Atkinson and Targett 1983). In fact, fisheries production and river runoff correlations have often inferred a simple linear food chain hypothesis (Sutcliffe et al. 1977, 1983; Dickie and Trites 1983). That is, the freshwater discharge affects the nutrient dynamics which increases primary production enhancing zooplankton production, which in turn leads to increased ichthyoplankton survival and fisheries production. Often, however, field observations indicate that the direct food chain argument works only up to the primary production stage; and river runoff linkage to zooplankton and fish do not always appear to be related to trophic dynamics (Colebrook 1978, 1985; Bernal and McGowan 1981; Chelton et al. 1982; Koslow 1984; Sinclair et al. 1985, 1986). The alternative hypothesis is that for the higher levels of the food chain, physical processes often dominate, such as local frontal convergence or large scale circulation processes (Koslow 1984) which determine current strength and the transport and retention of eggs and larvae within the appropriate distributional area for the population (Colebrook 1978, 1985).

The freshwater discharge of interest in this paper is from the Mississippi River, which is the world's fourth largest river. Its annual discharge when combined with that of its major distributary, the Atchafalaya River, represents approximately 10% of the volume of the continental shelf waters of the northern Gulf of Mexico (Dinnel and Wiseman 1986). The ecological significance of the river's plume and its hydrographic fronts to ichthyoplankton dynamics is the subject of an ongoing five-year LaSER project. We present ichthyoplankton density data along with food chain biomass estimates from samples collected during our July 1987 cruise at stations at or near hydrographic fronts associated with the Mississippi River plume. Our ichthyoplankton surface collections were taken during the day along short transects consisting of three Tucker trawl deployments which generated nine replicate samples. Plankton net mesh size was 333 microns and the duration of each surface tow was 3 minutes. On each of the following cruises, sampling was done with a MOCNESS (multiple opening and closing net and environmental sensing system). We are indebted to Quay Dortch for providing the ATP estimates and Michael Dagg (both from LUMCON, Cocodrie, LA) for providing the copepod nauplii and chlorophyll data.

SUMMARY OF RESULTS AND DISCUSSION

Relatively distinct ichthyoplankton communities were encountered along transects which paralleled the river plume side versus the oceanic or offshore side of hydrographic convergence zones. Taxa whose distribution overlapped both plume side and oceanic side collections were also encountered.

The strength of the salinity gradients observed was not always positively correlated with the larval fish densities collected.

The observed frontal systems encountered were very dynamic. One front edge was observed to migrate at a rate greater than one nautical mile per hour. These convergence zones were also quite ephemeral, with formation and relaxation being influenced by tide and wind.

Total larval fish density was compared with mean chlorophyll a (u/g/l), copepod nauplii (#/1), macrozooplankton displacement volumes (ml/m3), and ATP values (ng/l; an estimate of living particulate biomass) from the upper 2 m of the water column. A strong or even a consistent argument for the existence of a linear food chain was not present.

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DISTRIBUTION AND ABUNDANCE OF LARVAL YELLOWFIN TUNA, *THUNNUS ALBACARES*, ABOUT THE DISCHARGE PLUME OF THE MISSISSIPPI RIVER IN SEPTEMBER 1987

Dr. Churchill B. Grimes,
Ms. Kathy L. Lang,
and
Mr. John H. Finucane
National Marine Fisheries Service

Since Fall of 1986 the Panama City and Beaufort laboratories have conducted research cruises to the Mississippi River discharge plume to investigate recruitment mechanisms of important larval fish species occurring there. Yellowfin tuna, *Thunnus albacares*, is one of these species. Our fortuitous collection of a large number of yellowfin tuna larvae has led to our research into the early life history of this species. The purpose of this presentation is to report the occurrence of significant numbers of yellowfin tuna larvae in the Gulf of Mexico, particularly in the area of the discharge plume of the Mississippi River, describe their distribution and abundance in relation to both physical and biological parameters about the plume, and present preliminary results of their ageing and its implications.

Little is known of the early life history or reproduction of yellowfin tuna in the Atlantic Ocean, and particularly in the Gulf of Mexico. Larval distribution data suggests at least some spawning in the tropical Atlantic year round, with most spawning in summer at both higher and lower latitudes. Most spawning was indicated off west Africa and northern South America. Erdman (1968), Goldberg and Herring-Dyal (1981) and others have reported no evidence of reproductive development or spawning in adults off Puerto Rico, the Bahamas, or the U. S. south Atlantic and Gulf of Mexico.

Up until now few young yellowfin tuna have been reported for the Gulf of Mexico. Klawe and Shimada (1959) reported three small juveniles off Pensacola to Mobile in 1,000 fm, and Finucane et al. (1978) sampled extensively off Texas in the mid-1970's but caught only two yellowfin larvae. Extensive SEAMAP sampling in the Gulf of Mexico in 1982 and 1983 collected only about 30 larvae.

From September 2-7, 1987, we occupied 81 stations about the Mississippi River plume. We used a design that sampled plume, shelf, and frontal waters. Stations were about 4-6 km apart along plume transects. Whenever possible, stations were placed at the turbidity front of the plume.

We collected 324 net samples (243 Tucker trawl and 81 neuston), all at the surface. Samples were preserved in 95% ethyl alcohol and returned to the laboratory for sorting and identification. To date, 162 samples have been processed (1:1 neuston and Tucker trawl) from which 978 yellowfin tuna larvae have been preliminarily identified. The identification of these larvae was based on Richards and Potthoff's (1974) description of pigmentation patterns. However, this identification is not conclusive due to possible confusion of yellowfin tuna larvae with those of blackfin tuna, *Thunnus atlanticus*. Clearing and staining procedures according to Potthoff (1983) are underway that should verify the identifications.

Based on the preliminary laboratory analysis, some initial assessments can be made. The yellowfin tuna larvae collected ranged in size from 2.0 - 7.3 mm SL ($\bar{x}$ = 3.96 mm). The smallest larvae were in the yolk sac stage, obviously having been recently spawned. The ageing of these larvae has begun, indicating ages of 3 days for a larva 3.0 mm SL, 7 days for a larva 4.9 mm SL, 11 days for 6.3 mm SL larva, and 14 days for 7.3 mm SL larva.

Other oceanographic measurements were made at the time yellowfin tuna larvae were collected. Water samples were filtered and analyzed aboard ship for chlorophyll a content, and used as an index of primary production. Macrozooplankton displacement volumes were measured from neuston net samples in a graduated cylinder after the ichthyoplankton had been removed. A CTD cast was made at each station and sea surface temperature and turbidity were remotely sensed by NOAA-9 satellite.

Using CTD data collected at each station we constructed temperature and salinity sections for transects. A fairly typical section for a transect where yellowfin larvae were collected shows cooler plume water overlaying warmer, but more saline Gulf water (Figure 10.2). The turbidity front was observed at station 45, while the salinity front extended from about station 45 to station 43. Thus, the frontal region can be characterized as a mixing zone between shelf water and plume water that is about 6-8 km wide. The turbidity front, with a smaller scale of 10-50 m, is usually nested within the frontal region.

There may be a distinct spatial distribution of larvae about the plume. Highest catches (neuston and Tucker trawl) were associated with 31-32% salinities, i.e., around the frontal region (Figure 10.3). Catches along individual transects may give a more exact idea of larval

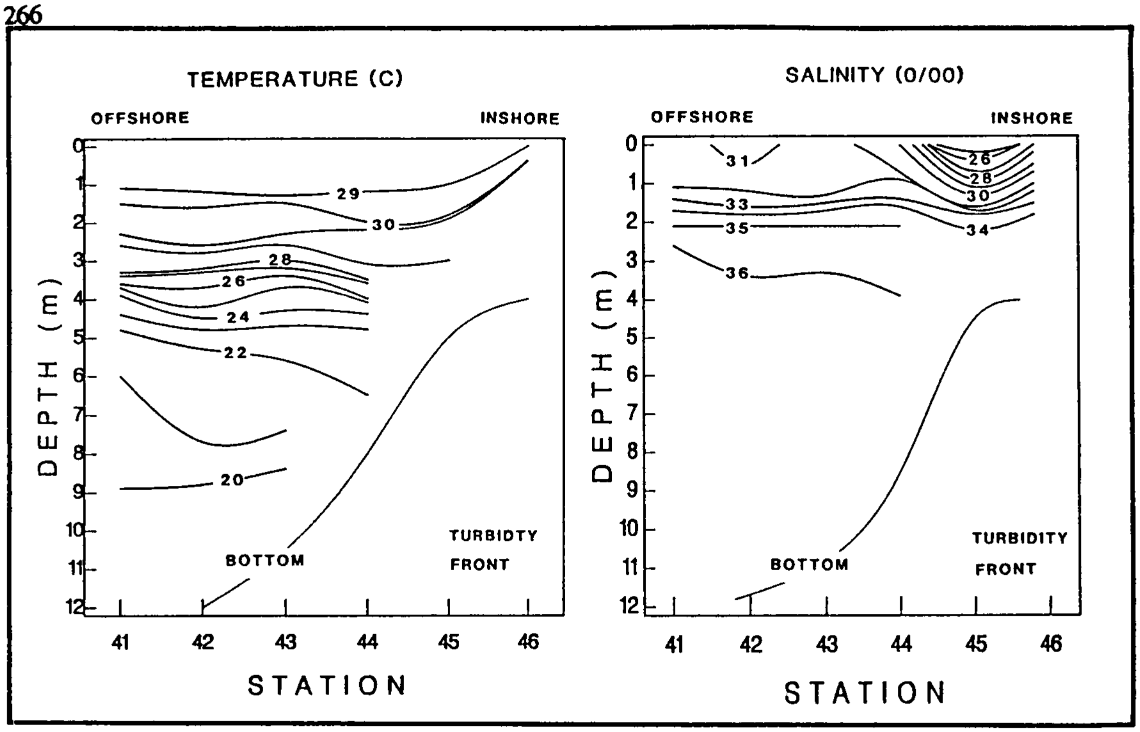

Figure 10.2. Temperature and salinity profiles along a sampling transect directly off the end of Southwest Pass of the Mississippi River.

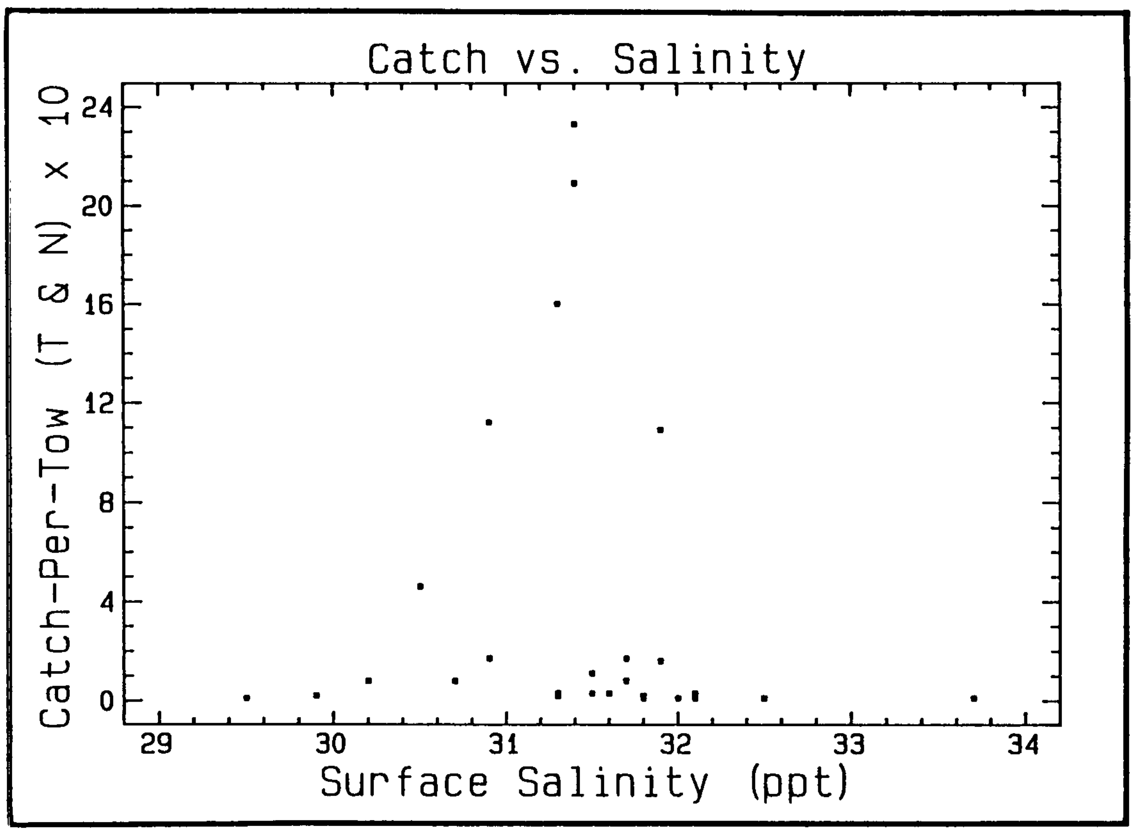

Figure 10.3. Catch-per-tow of yellowfin tuna larvae in neuston tows and Tucker trawls plotted on salinity. (Zero catches are not shown.)

distribution in relation to hydrographic structure of the plume. Along one of the best transects for yellowfin larval catches the data suggests they may have been associated with the shelf or clearwater side of the frontal region (Figure 10.4).

Hydrodynamic convergence could account for the accumulated biomass in the frontal region. A strong density discontinuity is created at fronts by the opposing fresh water plume and saline Gulf of Mexico shelf waters. Horizontal pressure gradients produced within and below the sloping isopycnals of the frontal region are responsible for hydrodynamic convergence, which can be a powerful concentrating mechanism. As surface waters converge planktonic organisms move with converging waters to the front where converging water moves downward. Positively buoyant and surface-seeking organisms accumulate at the surface as they resist downward movement. Surface drifter experiments have measured convergence rates up to about 1.0 m sec^{-1} (Govoni and Grimes, in prep.)

Highest primary and secondary production approximately co-occurred with highest catches of yellowfin tuna larvae (Figure 10.5). However, these parameters (salinity, chlorophyll a, larval catch, and macrozooplankton displacement volume) were not well correlated, individually or multiply, presumably due to the high variances.

The largest yellowfin tuna larvae also occurred in the 31-32% salinity region (i.e., frontal region) as high chlorophyll values, macrozooplankton displacement volumes, and numbers of larvae (Figure 10.6). It is tempting to speculate that these larvae are larger because they are growing faster in the good feeding and growth conditions of frontal waters. Preliminary food studies indicate yellowfin larvae consume mostly zooplankton which are concentrated in the frontal region. In addition, DeVries et al. (in press), have shown that king mackerel, *Scomberomorus cavalla*, grow faster in the Mississippi plume area than other areas of the Gulf of Mexico and the Atlantic Ocean. There is a significant relationship between mean length of yellowfin tuna larvae and macrozooplankton displacement volume (p = 0.011). However, ageing is not complete for these larvae, and therefore we do not know their growth rates.

Although incomplete, this research has already produced some useful information. These largest collections of yellowfin tuna ever in the Gulf of Mexico may indicate significant spawning of this species in the Gulf. The numbers, sizes, and ages of larvae collected in relation to their location about the Mississippi River plume may indicate an advantageous situation for larval fish that could significantly impact their recruitment into the fishery. These results may also be useful in directing other research on tuna larvae.

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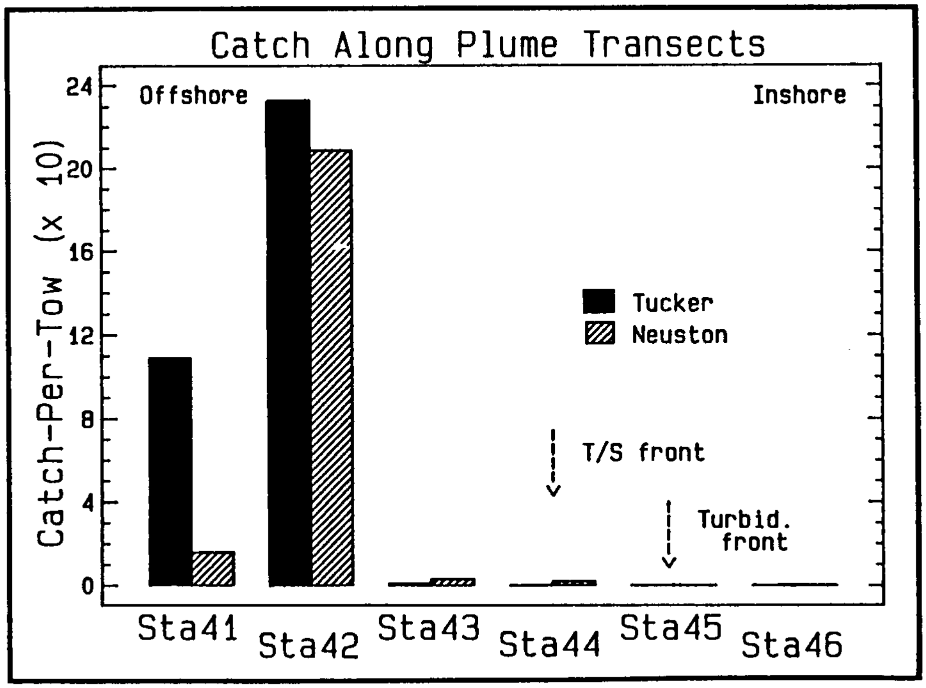

Figure 10.4. Catch-per-tow of yellowfin tuna larvae along a sampling transect directly off Southwest Pass of the Mississippi River.

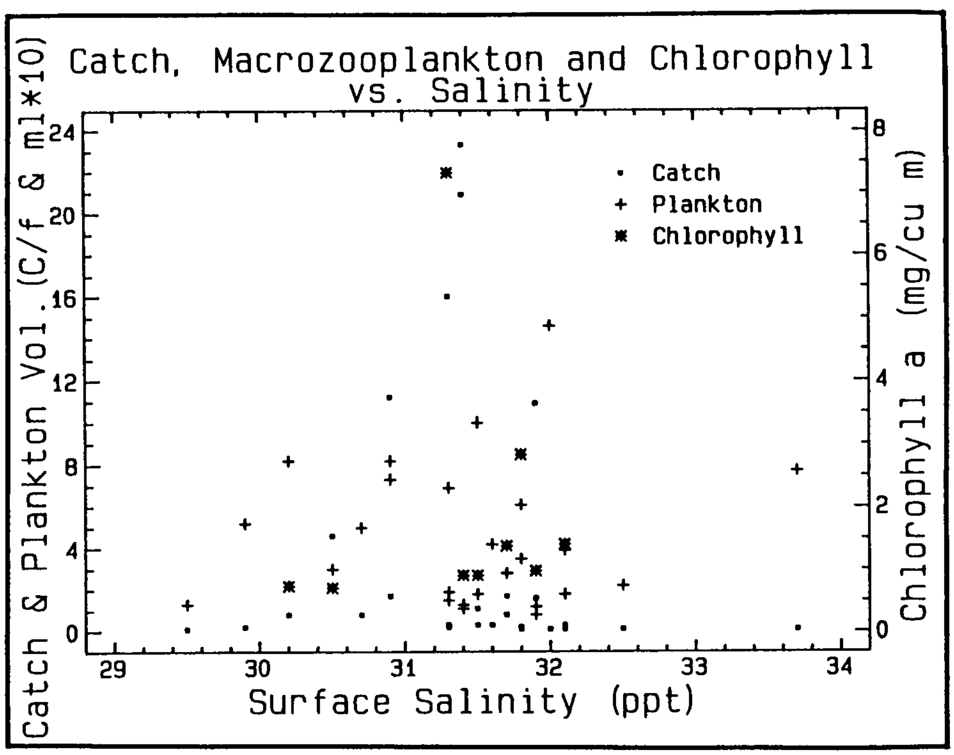

Figure 10.5. Catch-per-tow (neuston and Tucker trawl) of yellowfin tuna larvae, macrozooplankton displacement volume and chlorophyll a plotted on surface salinity. (Data where zero catches occurred are not plotted.)

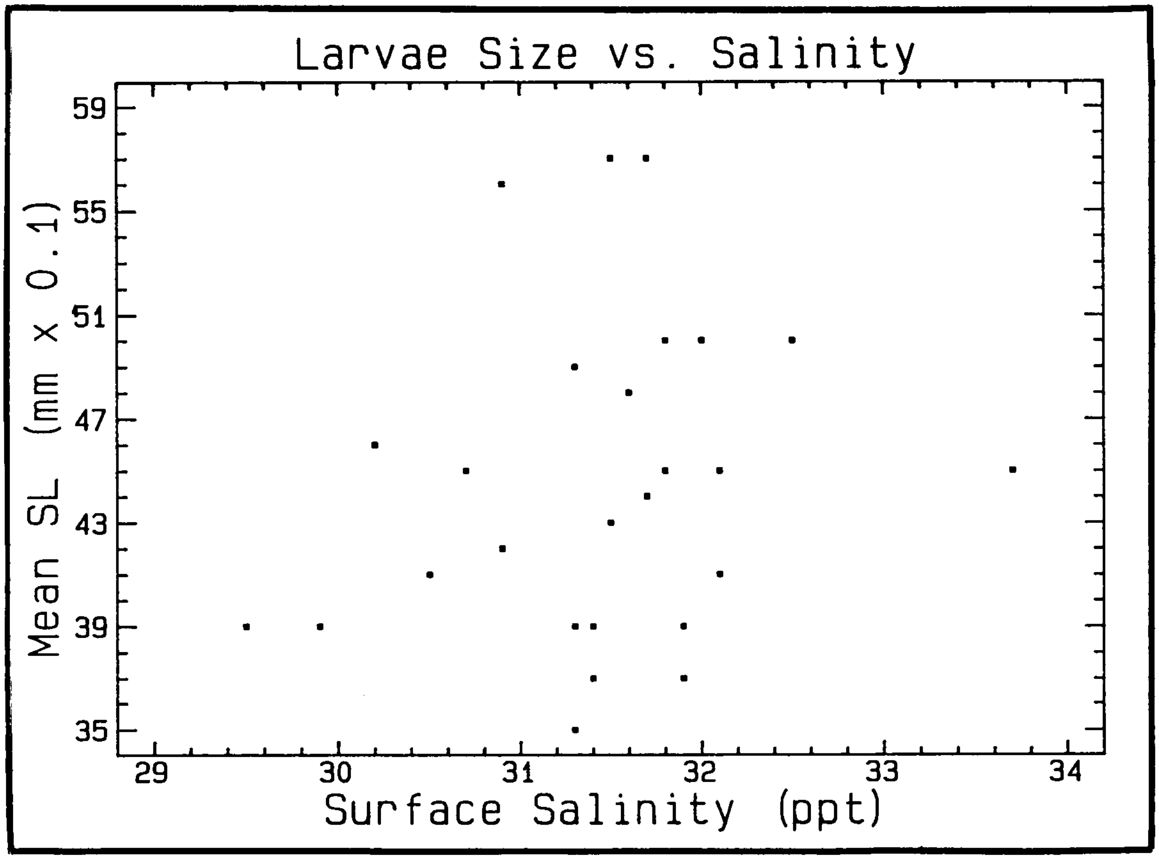

Figure 10.6. Mean standard length of yellowfin tuna larvae per positive station plotted on surface salinity.

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HABITAT CONSERVATION: KEY ISSUES IN ESTUARINE- DEPENDENT FISHERIES

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The National Marine Fisheries Service (NMFS) was established in 1970 under Reorganization Act No. 4 that separated the Bureau of Commercial Fisheries from the Department of the Interior and placed it as the NMFS under the National Oceanic and Atmospheric Administration (NOAA). After leaving the Department of the Interior, NMFS was given the mission to conserve fishery habitat so that recreational and commercial fishery resources of benefit to the people of the U.S. would continue to be produced. In the NMFS Southeast Region, the habitat program is carried out by the Habitat Conservation Division (HCD) for management and the Southeast Fisheries Center for research. The two units coordinate closely to insure that the needs and priorities of both components are met. Our authority to conserve habitat is provided for by the Fish and Wildlife Coordination Act, the Magnuson Fishery Conservation and Management Act, the Marine Protection Research and Sanctuaries Act, the Endangered Species Act, the Marine Mammal Protection Act, the Clean Water Act, and the National Environmental Policy Act.

The NMFS Southeast Region's area of responsibility covers eight states extending from North Carolina to Texas, as well as Puerto Rico and the U.S. Virgin Islands. More than 4,504 kilometers (2,799 miles) of coastline, 48,100 kilometers (29,900 miles) of tidal shoreline, and 300 estuarine systems are located here (Lindall and Thayer 1982). The estuaries contain about 6.96 million hectares (17.2 million acres) of marsh and other estuarine habitat and 2.06 million hectares (5.1 million acres) of intertidal areas comprising about 83% of the coastal wetlands in the coterminous U.S. (Alexander et al. 1986). The total estuarine area for the Gulf states comprises about 5.67 million hectares (14 million acres), including 3.20 million hectares (7.9 million acres) of open-water area and 2.47 million hectares (6.1 million acres) of emergent tidal vegetation (Lindall and Saloman 1977). Submerged grass beds and oyster beds amount to almost 324 thousand and 64 thousand hectares (800 thousand and 159 thousand acres), respectively. The estimates of wetland area for the southeast, however, could be increased by as much as 40% with the addition of seagrasses that presently are poorly mapped (Thayer and Fonseca 1988). This region contains almost all of the nation's mangrove swamps and most of the seagrasses.

Since the wetlands and nearshore areas are such a dominant feature it is not surprising that most of the HCD's efforts are geared toward the conservation of coastal habitats. This approach, however, also is based on findings of our researchers and others that demonstrate the link between these habitats and the production of fish and shellfish (Smith et al. 1966; Douglas and Stroud 1971; Lindall 1973; Turner 1977; Lindall and Saloman 1977; Lindall et al. 1979; Peters et al. 1979; Thayer and Ustach 1981). Simply put, many estuarine-dependent species of fish and shrimp require estuaries during some portion of their life cycle. Typical examples of this relationship is the life cycle of shrimp, which is the most valuable commercial fishery resource in the U.S., and the menhaden which is caught in the greatest quantity. These species deposit their eggs offshore where the young hatch. As larvae they enter estuaries to mature and return to offshore areas as juveniles or adults to breed and complete the life cycle. The estuaries afford protection from predators and also supply abundant food. A major contribution to food supplies occurs from the breakdown of aquatic vegetation. The detritus that is produced is enriched by attached microorganisms (Odum 1970) and utilized directly as particulate or dissolved organic matter or indirectly by feeding on organisms that directly utilize detritus (Hettler 1989).

Nationally about 70% of commercial fishery resources are estuarine dependent (NMFS 1984). In the Gulf of Mexico, however, estuarine-dependent species exceed 90% of the commercial catch (Thompson and Arnold 1971). Nationally at least 48% of recreational fishery resources are estuarine dependent (Peters et al. 1979). In the Gulf of Mexico, 70% of recreational fishery resources rely on estuaries or nearshore coastal habitats (Lindall and Saloman 1977). These resources provide significant economic and social benefits. Commercial fisheries contribute $5.5 billion annually to the national economy while recreational fishermen spend more than $13.5 billion per year to pursue their sport. In 1988, 0.86 billion kilograms (1.9 billion pounds) of fish and shellfish worth in excess of $700 million dockside were landed in the Gulf of Mexico (NMFS 1989). Recreational fishermen spent $3.4 billion in the southeast during 1985 (Schmied and Burgess 1987). In addition to food production, wetlands and coastal habitats provide many other useful benefits such as storm protection, flood prevention, erosion protection, aesthetics, waterfowl and furbearer production, recreation, and other benefits, but these values are largely unquantified. Some economists have provided some estimates of values that are as high as $203 thousand per hectare per year ($82 thousand per acre per year) (Gosselink et al. 1974).

Despite their great importance in the production of fishery resources, wetlands continue to be lost. The reasons are varied, but man-induced perturbations account for a significant amount of the coastal wetland loss rate estimated nationally at 7,300 to 8,100 hectares (18,000 to 20,000 acres) per year. In states such as Louisiana the loss rates are much higher and from the 1950's to the 1970's approached 104 - 129 square kilometers (40-50 square miles) per year (Scaife et al. 1983). This is due to a number of factors such as subsidence, erosion, sediment depletion, saltwater intrusion, and possibly sea level rise. In fact more than 83% of the wetland losses that occurred nationwide were in the southeast (Hefner and Brown 1985).

NMFS is the lead Federal agency responsible for the management of the nation's living marine resources and habitat conservation is a primary concern of the agency. Based on this concern the NMFS developed a Habitat Conservation Policy in 1982. This policy established 12 Implementation Strategies that would be used to conserve habitat. Unfortunately, the NMFS cannot adequately do everything suggested by the 12 strategies because many are labor intensive and require fairly large commitments of funds. Accordingly, the HCD in the southeast has determined that based on the size of the staff and funds, the habitat conservation goals of the agency could best be met by concentrating on the first four strategies, i.e., (1) implement joint region and center planning, (2) increase research effort, (3) involve Fishery Management Councils, and (4) influence other agencies, especially the fourth which calls for direct involvement with the wetland regulatory and civil works programs of the Corps of Engineers (COE). We are the only Federal agency in the southeast that reviews all of the permit proposals to alter coastal wetlands. Other agencies have had to scale back due to funding, manpower limitations, and other priorities. We review more than 56% of all permit requests and Federal projects handled by NMFS in the entire U.S. and since 1981 have reviewed more than 35,000 water development projects, both private and Federal.

Most of the HCD workload involves review of individual proposals to alter wetlands by private and Federal interests. Last year alone, these entities proposed to alter about 146 thousand hectares (360 thousand acres) of wetlands. More than nine years of NMFS data collection reveals that the more than 8,356 projects proposed to alter more than 656 thousand acres of wetlands between 1981 and 1988 (Mager and Thayer 1986; Mager and Ruebsamen 1988). Involvement by NMFS could potentially have conserved as much as 146,000 hectares (360,000 acres) with mitigation of nearly 69,000 hectares (170,000 acres).

Most of the area proposed for alteration results from proposals to impound marshes, especially in Louisiana, for marsh management and waterfowl production; usually at the expense of marine fishery production. Much of the area proposed for alteration, however, includes very small projects that eventually result in a piecemeal loss of large amounts of wetlands. The pressure to develop wetlands will not decrease because of the large number of people that are moving to the coast and will compete for space and other services afforded by wetlands. By the year 2000, researchers say that 80% of the U.S. population will live within 80 kilometers (50 miles) of the ocean (Edwards 1989).

In addition to direct coastal habitat modification, other priority habitat issues in the southeast include water diversions, coastal eutrophication, mitigation techniques and strategies, chemical loading, pathogen introduction, and cumulative effects of the foregoing issues individually and cumulatively. These issues are being addressed to varying degrees by NMFS and other NOAA components in their research and management programs. The NMFS also is working to address the President's goal of no-net-loss of wetlands and is developing an agency policy and strategy for implementation. An additional key issue for the near future will be the effects of global warming and resultant sealevel rise on wetlands and ultimately the fishery resources that the agency oversees.

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THE SPORT FISHING INSTITUTE'S ARTIFICIAL REEF DEVELOPMENT CENTER

Mr. Stephen H. Phillips
Artificial Reef Development Center

The Sport Fishing Institute's Artificial Reef Development Center (ARDC) was created in 1983 because artificial reef development in this country had been undertaken on a "piecemeal" basis due to inadequate management and planning, insufficient funding, and an unreliable supply of reef materials. And most of all, it was hindered by a lack of communication and exchange of information between the states and organizations involved in artificial reef development.

Like the Sport Fishing Institute (SFI), the ARDC has three basic goals: service, research, and education. One of the major accomplishments of the SFI was to be a major player in the passage of the National Fishing Enhancement Act of 1984. This Act resulted in the writing of the National Artificial Reef Plan. The National Plan has been instrumental in giving artificial reef development some guidelines. From the National Plan, Louisiana got its direction for its highly successful artificial reef program. From early in its existence, the ARDC has been researching topics relevant to prudent artificial reef development such as reef liability, construction materials, economics, siting transportation, and funding, and developed technical reports for those topics. There are several topics that should be of interest to reef developers nationwide, including the Gulf of Mexico.

NEW MATERIALS

In the past 10 years several reef projects around the country have used the ash waste product from the combustion of coal and oil as a reef material. Studies in New York, Delaware, and Florida have shown that their test ash reefs do not significantly affect the organisms associated with the reefs and that any toxic chemicals associated with the ash are bound up relatively tightly inside the block.

Oil and coal ash pilot artificial reef projects give some credibility to the idea of using waste materials as a reef material. However, new projects, such as one proposed by Mr. Dana Larson, Vice-President of Rigs-to-Reefs, Houston, Texas, will use other types of waste materials in reefs. In New York, researchers with the State University of New York propose using incineration ash for reef material.

We have a trash crisis on our planet. As our population continues to grow, trash fills up our landfills making that mode of disposal ever more expensive. Other parts of the country burn their trash, however, the opening of new incinerators always comes at the cost of local opposition--rightfully so in their eyes--nobody wants trash burnt in their backyard.

Another alternative to waste management is ocean disposal. Lets face it, artificial reef development at times is a form of waste management. When the popular media discusses reef development, it still is occasionally described as junk disposal. However, reef developers have come a long way, there are new prefabricated materials designed for select species; there have been four international reef conferences with a fifth planned in southern California in 1991; four states have reef plans and three more are writing plans (including Texas).

The Gulf will see the coming of some of the "new" materials. Are they a threat to fisheries or reef development in the Gulf? Presently no, but in the future it would be wise for reef enthusiasts to a keep a careful eye on these new initiatives. It has taken us decades to discover what materials make for productive, stable artificial reefs.

While the use of waste materials for reef materials is laudable, it is important that we do not confuse waste disposal and reef development. Waste refers to those materials that contain elements that have a potential deleterious effect in their original "unblocked" form. The ash block studies mentioned above only address short term biological effects. What happens in the long term? Will the contaminants bound up in these blocks become bio-available? What about during storm events--will the blocks stand up to long term ocean forces? These questions must be answered.

Those that are on the ground floor of reef-development administration, such as state reef coordinators, at times have no voice in the determination of materials that should and should not be used. In other words, they are told what materials to use from their superiors. This is an important reason why all of us need to communicate when controversial reef development issues come up. If an upper level state administrator hears that a specific reef material is not worthwhile, maybe he will decide not to use that material.

This is one of the reasons that the ARDC publishes "REEF BRIEFS"--to act as a forum for artificial reef information. This is also why the Gulf States Marine Fisheries Commission is forming an artificial reef subcommittee.

MITIGATION

When a natural marine environment, such as a salt marsh, is dredged or filled as part of a bay or port development project, artificial reefs are sometimes considered as an out-of-kind and off-site form of mitigation. For example in the Gulf region, a concrete artificial reef was used during 1988 to mitigate for damages caused by a chemical spill in Tampa Bay.

Discussions with participants in several mitigation projects reflected an attitude of "we had to get something for the destruction of valuable marine habitat, and artificial reefs seemed a good choice." However, the majority of reef coordinators do not approve of using artificial reefs as mitigation for the destruction of productive natural habitat, and would prefer not to participate in such a project in the future (Jim Murray, person. comm. 1988). The bottom line is that one cannot trade shoreline and inshore habitats for offshore deep water artificial reef habitats and still sustain a fishery.

Out-of-kind off-site mitigation using artificial reefs, while supplying reef developers with employment opportunities, are fraught with complications. Mitigation reefs cannot replace natural habitat especially nursery habitat such as mangroves and salt marshes. Our capability to imitate nature using reefs is limited at best. We also are not in the position to lose any more of our wetlands. We need our wetlands if we wish to keep a sufficient biomass of fish for recreational and commercial users. Alternatives are needed for reefs in mitigation cases.

As alternatives to reefs in mitigation, the creation of artificial wetlands could be considered. There are now companies that specialize in wetlands creation/restoration. If, for example, Louisiana was faced with a potential mitigation, wetlands restoration might be a proper choice to repair past problems caused to wetlands by channelization and rising sea levels.

COMPARATIVE MONITORING METHODS

The ARDC and Florida Sea Grant have received preliminary grant approval from the National Marine Fisheries Service for a two phase project that will update and expand the ARDC Profiles database and develop comparative reef monitoring methods.

The ARDC Reef Profiles database is a computerized catalog of information on coastal state artificial reef programs and permitted reef sites in U.S. waters. This includes sites where active reefs already exist and sites where reefs have been permitted and are simply awaiting suitable materials. The present database, current through October 1986, includes information on the 23 coastal states and 401 artificial reef sites.

One objective of the upcoming Profiles project will be to update and expand the database with current artificial reef information. For example, since 1986 over 100 new artificial reef projects have been constructed in Florida alone. In addition, profiles will be placed on a computer modem so that reef data will be easily accessible to a larger audience. A DBASE III program will be set up so that individual states can download and edit their own files. Another objective of this project is to develop a consistent application of reef monitoring practices. This portion of the project will be undertaken by Joe Halusky, Donald Pybas, and Dr. William Seaman of Florida Sea Grant.

Methods for reef site assessment or post-construction evaluation vary from state to state, and locally within states. Data from individual sites are therefore not as useful as they might be, due to incompatibility with other locations. It is hoped that from this project a consistent list of measurements of pre- and post-reef construction characteristics as well as a set of procedures for using them reliably will be developed. Both the Atlantic and Gulf States Marine Fisheries Commissions, their member states and others, will be requested to assess the monitoring techniques and variables to be used in the monitoring study. It is hoped that a consensus will be reached among those who monitor reefs and that consistent monitoring techniques will be used across state boundaries.

Also of interest regarding this study is that the monitoring is based upon the volunteer monitoring program developed by the Jacksonville Scubanauts under the direction of Joe Halusky. Reef coordinators often do not have sufficient funds to carry out proper pre- and post-monitoring of their reef projects.

In Florida, Sea Grant Extension has succeeded in training volunteer divers to undertake reef monitoring. In this project, the volunteer monitoring will be expanded to other parts of Florida to verify the ability of trained citizen groups to support scientific observation. It is hoped that the volunteer monitoring example from Florida will be used in other parts of the country. This project will be completed in early 1991.

In conclusion, Texas is developing a reef plan and Louisiana has realized a successful state program, reef development in at least two states is proceeding well. In Florida, the Jacksonville office of the Army Corps of Engineers has issued a statement to the effect that the Corps will only issue a permit for an artificial reef if the applicant demonstrates the reef material is unambiguous, the responsibility for maintenance for the reef is clearly established, and that the applicant has the financial ability to assume liability. Florida reef development will now be shifted from the private sector to state and local governments.

Mr. Stephen Phillips received his B.S. degree in biology from Baldwin-Wallace College in 1979 and his M.S. degree in fisheries science from Oregon State University in 1987. He spent two years in Guatemala with the Peace Corps and has worked for the Oregon Department of Fish and Wildlife, Oregon State University, Environmental Protection Agency, and National Marine Fisheries Service. He joined the Sport Fishing Institute in 1987 as a Research Specialist in charge of the Artificial Reef Development

Center. In May of 1989, Mr. Phillips became the Managing Director of the Fish America Foundation, which is administered by the Sport Fishing Institute.

CONVERSION OF GULF OF MEXICO NONHAZARDOUS SHIP GENERATED WASTES INTO ARTIFICIAL REEFS ABOARD OFFSHORE PLATFORMS

Mr. Dana Larson
Rigs to Reefs Company

SUMMARY

This paper explores the concept of upgrading nonhazardous shipboard wastes into artificial reefs and other valuable products aboard Gulf of Mexico (GOM) offshore petroleum structures. Preliminary research indicates that the collection of ship-generated wastes at a few selected offshore locations is more economically practical than either (1) retrofitting existing vessels for waste processing or (2) separating ship wastes into separate receiving containers onshore at an estimated 18,000 shorebased terminals. Mariculture ventures associated with the reefs will help offset the problems of natural reef habitat loss, overfishing, pollution, increased demand for fish products, and high levels of U.S. fish imports. Offshore waste conversion facilities will meet both the requirement of the recently adopted Annex V of MARPOL and the long standing objectives of the Department of Health in preventing importation of agricultural threats. If the concept and a demonstration pilot project prove feasible for nonhazardous shipboard wastes, the offshore facilities may be extended to process existing flotsam and jetsam, beach litter, and eventually, municipal solid and liquid wastes. It is hoped that the concept's "push - pull" economic engine, fueled by fees provided by producers of maritime waste and by profits from mariculture ventures, will help reduce existing flotsam and future overboard dumping. As costs for waste management increase, the incentive to pollute also increases unless the product becomes too valuable to discard. "Subsidies" from other sources such as Rigs to Reefs donations from platform owners and local governments may assist the concept in the early stages of implementation. If the conversion of ship generated wastes proves feasible in the GOM, it may also prove applicable to other uses and locations. Specially selected platforms could process wastes from offshore platforms, drilling rigs, and supply, support, and service vessels. These wastes could include gray water, sewage, and associated Exploration and Production wastes. The National Science Foundation's (NSF) Ocean Enterprise Initiative strongly supports this concept as an example of wiser use of ocean space and resources.

ANNEX V OF MARPOL

In 1973, the International Maritime Organization recognized the growing problem of marine pollution by overboard disposal of shipboard wastes. They adopted the International Convention for the Prevention of Pollution by Ships, better known as the MARPOL treaty for Marine Pollution. The treaty, amended in 1978, has five clauses involving pollution issues from oil and hazardous chemical dumping to solid waste disposal at sea. Annex V, concerning the dumping of plastic debris by ships, had to be ratified by at least 15 of the world's countries controlling at least 50% of the shipping fleet tonnage in the world. In late 1987, both the U.S. and Russia ratified the treaty. Their combined tonnages put the treaty in force.

Annex V of MARPOL 73/78 basically does the following (Figure 10.7):

- prohibits the ocean disposal of all plastics;
- prohibits the disposal of other floating garbage within a specified distance of the nearest coastline; and
- designates certain "special areas", possibly including the GOM, where no garbage dumping is allowed except comminuted food wastes at least 12 miles from shore.

Regulation 2 of MARPOL states, "The provisions of this Annex shall apply to all ships."

MARINE PLASTIC POLLUTION ACT

On December 30, 1987, President Reagan signed into law PL 100-200, including Title II, the Marine Plastic Pollution Research and Control Act of 1987. It is the national implementing

Garbage Type	All Vessels Except Offshore Platforms & Associated Vessels		Offshore Platforms & Assoc. Vessels***
	Outside special areas	In special areas**	
Plastics - includes synthetic ropes and fishing nets and plastic bags	Disposal prohibited	Disposal prohibited	Disposal prohibited
Floating dunnage, lining and packing materials	Disposal prohibited less than 25 miles from nearest land	Disposal prohibited	Disposal prohibited
Paper, rags, glass, metal, bottles, crockery and similar refuse	Disposal prohibited less than 12 miles from nearest land	Disposal prohibited	Disposal prohibited
*Paper, rags, glass, etc. comminuted or ground	Disposal prohibited less than 3 miles from nearest land	Disposal prohibited	Disposal prohibited
Food waste not comminuted or ground	Disposal prohibited less than 12 miles from nearest land	Disposal prohibited less than 12 miles from nearest land	Disposal prohibited
*Food waste comminuted or ground	Disposal prohibited less than 3 miles from nearest land	Disposal prohibited less than 12 miles from nearest land	Disposal prohibited less than 12 miles from nearest land
Mixed refuse types	****	****	****

* Comminuted or ground garbage must be able to pass through a screen with a mesh size no larger than 25 mm.

** Special areas are the Mediterranean, Baltic, Red and Black Seas, and Persian Gulf areas.

*** Offshore platforms and associated vessels includes all fixed or floating platforms engaged in exploration or exploitation and associated offshore processing of seabed mineral resources, and all vessels alongside or within 500m of such platforms.

****When garbage is mixed with other harmful substances having different disposal or discharge requirements the more stingent disposal requirements shall apply.

Figure 10.7. MARPOL 73/78 Annex V, Summary of Garbage Disposal Requirements.

legislation for MARPOL'S Annex V. Among other things, it requires that:

- certain ports and terminals shall provide separate facilities for oil, noxious liquid substances, plastics, and other ship generated wastes;
- ships may be denied entry to those ports and facilities that are required to have adequate reception facilities but which do not; and
- certain ships may be required to maintain refuse record books and shipboard management plans and may be inspected.

As before, the Department of Agriculture's Animal and Plant Health Inspection Service (APHIS) has the mission of preventing foreign pests, insects, and pathogens from entering the U.S. The agency does not allow ships from foreign ports to enter U.S. ports unless food wastes and food containers are either sterilized by steam or incinerated and the residue transported to an approved U.S. Department of Agriculture landfill.

Proper disposal of wastes, even nonhazardous wastes, is expensive and getting more expensive. The National Solid Wastes Management Association has made estimates for the planning, acquisition, development, and monitoring costs of building a typical 100 acre, 20 year double liner landfill with 30 years of monitoring that meets current regulatory requirements. Even without other waste management costs such as bonding or insurance, transportation costs, tipping fees, etc., the average cost per acre to dispose of nonhazardous wastes is about $870,000 or about $20 per square foot. A typical tipping fee in 1988 was $20.36, up 51.6% from 1986.

ARTIFICIAL REEFS

The productivity of reefs can vary significantly depending upon many factors including reef design, location, configuration, orientation, water quality and parameters, preferred species, age class, etc. The Artificial Reef Development Center of the Sport Fishing Institute researched their files to determine the productivity of artificial reefs. The Japanese have been able to produce 16 to 20 kilograms of fish mass per cubic meter per year. From artificial reefs produced since 1972, the Japanese now produce more than the entire North Sea catch.

In contrast:

- Per capita fish consumption is currently about 17 pounds per person and is projected to increase to 40 pounds by the turn of the century.
- About 80% of U.S. fish consumption is imported. Fish products are the third greatest U.S. import product exceeded only by illegal drugs and oil.
- All U.S. fisheries of primary commercial and recreational interest are being harvested at or beyond their limits to sustain their population.
- Fish products are the only edibles not Federally inspected.

POTENTIAL EXTENDED APPLICATIONS

If the enhancement of shipboard wastes into artificial reefs, plastic lumber, beach stabilization devices, etc. proves feasible on a pilot project basis, the scope of the raw material basis could be enlarged. A logical first extension would be the collection of ocean flotsam and jetsam as it periodically collects along rip tides and wind winnows. The collecting devices could be existing oil skimming barges. Another extension would be the enhancement of debris collected on beaches. A third extension would be the use of nonhazardous household trash from adjacent coastal municipalities. A fourth extension would be the use of processed sewage sludge.

CONCERNS

The many advantages of converting wastes into durable assets are self evident. Some concerns about the concept are:

- current lack of start-up funds,
- liability,
- fears of pollution,
- unknown costs of collecting and processing garbage and wastes at sea,
- risks of mariculture venture,
- platform structure maintenance ,
- final disposal/fate of offshore facilities,

- infringing upon the vested interests of the status quo,
- lack of lead entity, and
- regulatory maze.

OCEAN ENTERPRISE CONCEPT

In 1983 the area for potential economic development in the U.S. was almost tripled by Presidential Proclamation of a 200 nautical mile Exclusive Economic Zone (EEZ). This zone added 3.9 billion acres of marine territory to U.S. economic jurisdiction, but the EEZ has not yet produced any new activities or economic benefits of significance. Unless the U.S. actively encourages the development of new or underdeveloped resources and uses in the ocean, the economic potential of the EEZ will not be realized. This inactivity contrasts sharply with offshore developments in countries such as Japan and France which are rapidly exploring and exploiting new uses of their maritime territories.

The NSF sponsored a workshop in February in which the Ocean Enterprise (OE) Concept, Program, and several possible projects (including this Annex V waste enhancement concept) were presented. Fundamentally, the OE concept is a way of overcoming the concerns and constraints that seem to be inhibiting the developments of the resources and uses of the EEZ. Some ocean projects or developments fail to advance because of the perception that high risks are involved; the funding cannot be found to demonstrate the commercial viability of a new ocean technology; and some because of uncertainties and risks associated with the regulatory framework, public perception about ocean use, and the possible exposure to intervener judicial challenges. These are all examples where scales of time, risk, and/or magnitude are too great for one sector (of government, industry, or academia) to bridge the No Man's Land alone (Figure 10.8). A mechanism to bridge this gap between research and development requires a larger, more integrated effort with private/public sharing of funding to support special development activities. A possible organization chart for the OE concept is shown as Figure 10.9. Figure 10.10 depicts a proposed Structure for an OE Waste Treatment Project such as the upgrading of Annex V wastes.

Mr. Dana Larson is Vice President of the Rigs to Reefs Company of Houston, Texas. He has had a long term interest in converting environmental problems into environmental assets. Mr. Larson was the first to suggest the conversion of redundant gravel islands in the Beaufort Sea into North American Migratory Bird refuges. Mr. Larson was the cocreator of the concept of harvesting mussels from oil platforms in the Santa Barbara Channel off California, was recognized by Department of the Interior Secretary William Clark as the "Father of Rigs to Reefs", and played an influential role in the establishment of the first preplanned Rigs to Reefs project in the Gulf of Mexico in 1979. Mr. Larson has a B.S. in geology from the University of Michigan, a M.B.A. from the University of Michigan, and lacks a thesis for a Masters in oceanography from the University of Houston.

FACTORS INFLUENCING THE RELATIVE ABUNDANCE OF RECREATIONALLY CAUGHT FISHES NEAR OIL AND GAS PLATFORMS IN THE NORTHERN GULF OF MEXICO

Mr. David R. Stanley
and
Dr. Charles A. Wilson
Coastal Fisheries Institute
Louisiana State University

A log book program was initiated to determine the relative abundance of selected fish species around oil and gas platforms off the Louisiana coast. Log books were maintained by 55 anglers and 10 charter boat operators from March 1987 to March 1988. A total of 36,839 fish were caught representing over 46 different species.

Principal component analysis (PCA) grouped the 17 most abundant species into reef fish, pelagic fish, bluefish-red drum, and Atlantic croaker-silver/sand seatrout associations. Multiple regression analyses (MRA) were used to compare PCA groupings to physical platform; temporal, geological, and angler characteristic variables; and their interactions. Reef fish,

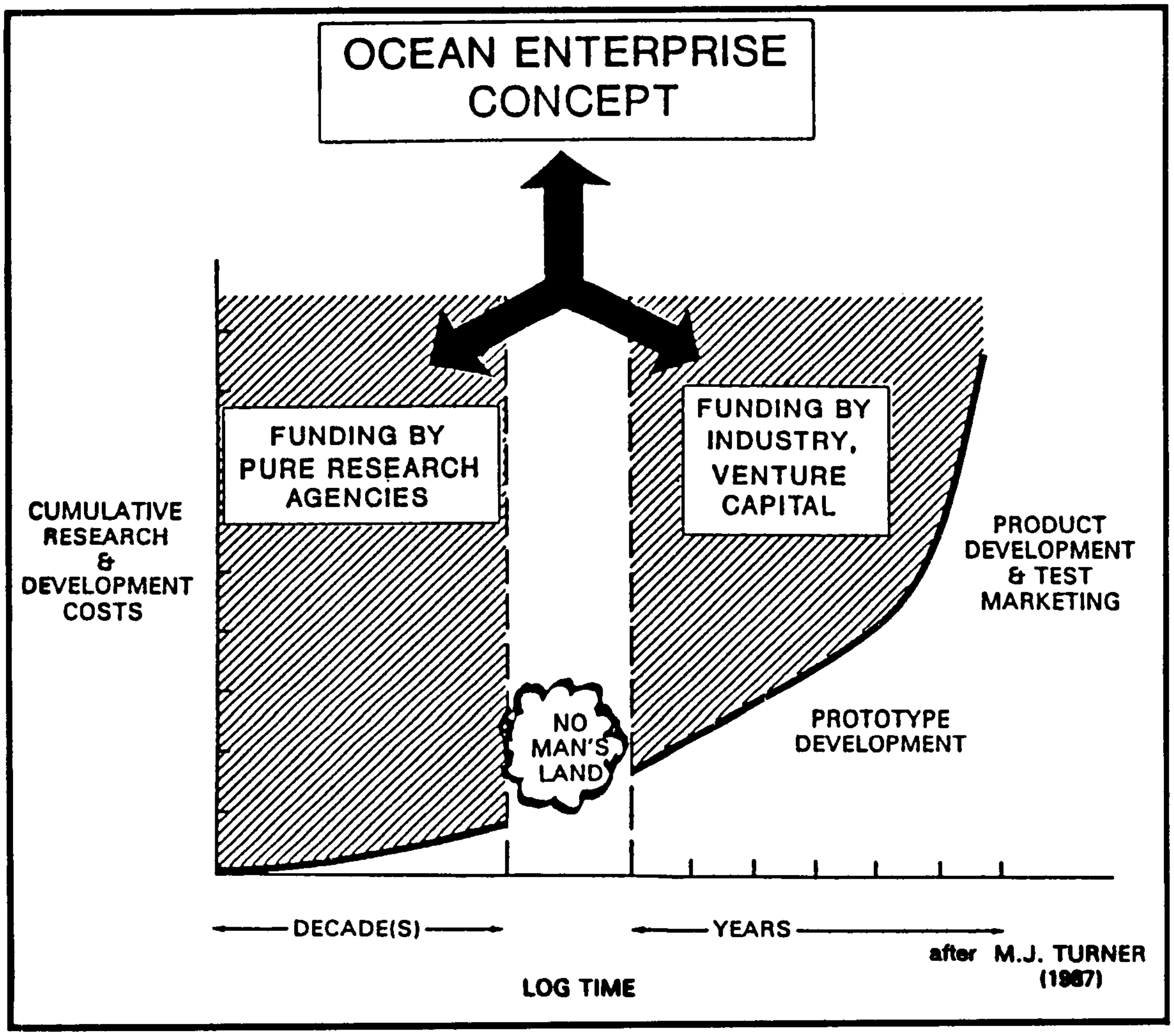

Figure 10.8. The Ocean Enterprise concept to bridge the NO MANS LAND gap.

Atlantic croaker, and silver/sand seatrout abundances were highest near large, structurally complex platforms in relatively deep water. Spotted seatrout abundances were correlated with the physical parameters of oil and gas platforms although water depth was the dominant factor. Pelagic fish, bluefish, red drum, cobia, and shark abundances were not related to the selected physical parameters of the platforms.

INTRODUCTION

Sportfishing off Louisiana is concentrated around oil and gas platforms with over 70% of all recreational angling trips in the Exclusive Economic Zone (more than 3 miles from shore) occurring around platforms (Reggio 1987). All of the 3,700 oil and gas platforms off the coast of Louisiana are thought to act as artificial reefs and contribute to Louisiana's designation as a fishing "paradise."

Gallaway (1985) estimated that oil and gas platforms constitute 28% of the known hard substrate off Louisiana and Texas and since the nearest natural hard bottom habitat is approximately 92 km from shore, the structures provide the only source of hard bottom habitat close to shore (Sonnier et al. 1976). These unique artificial reefs extend throughout the entire water column, consequently they effect not only benthic and demersal fishes, but also pelagic

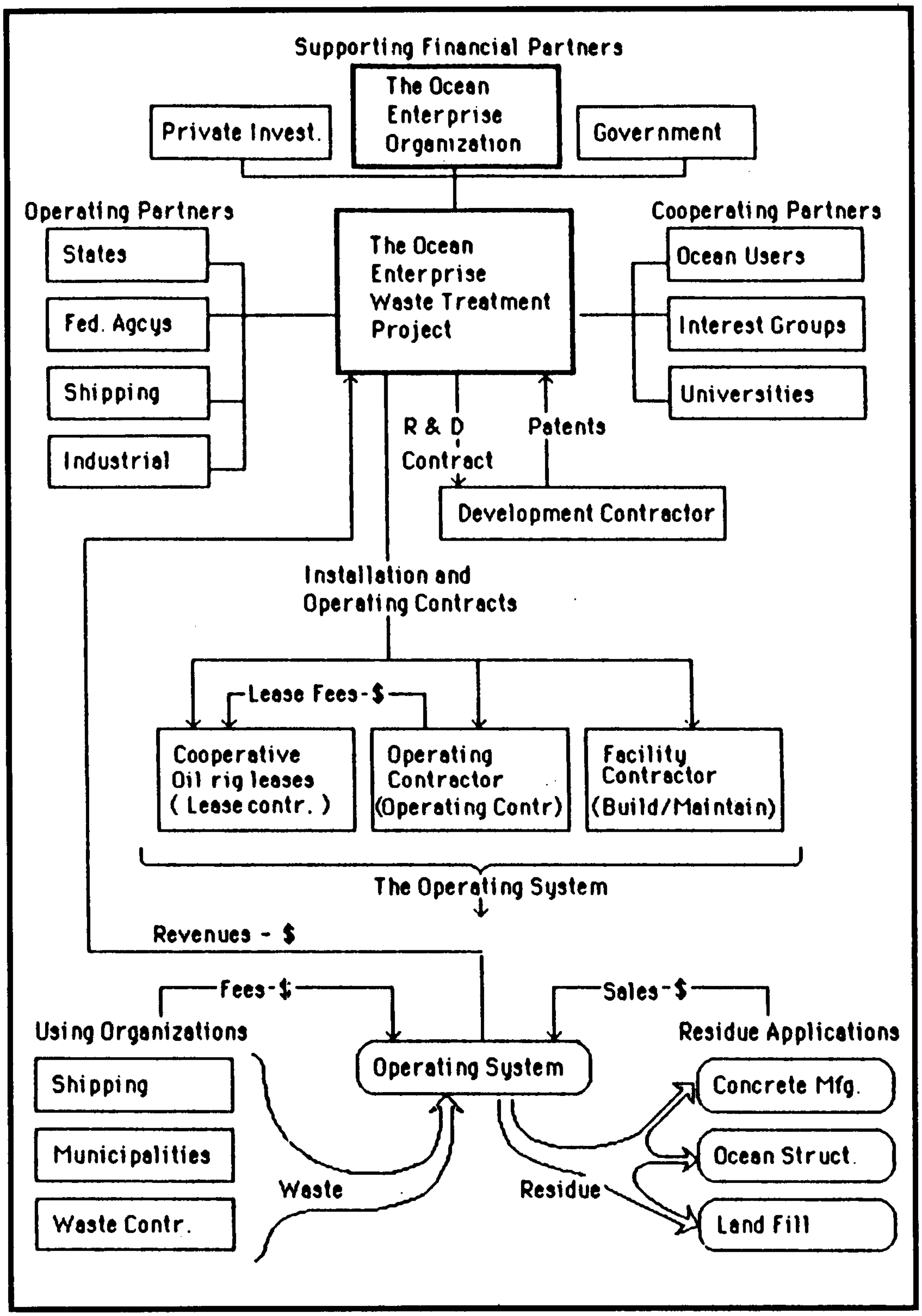

Figure 10.9. A proposed structure for an Ocean Enterprise waste treatment project.

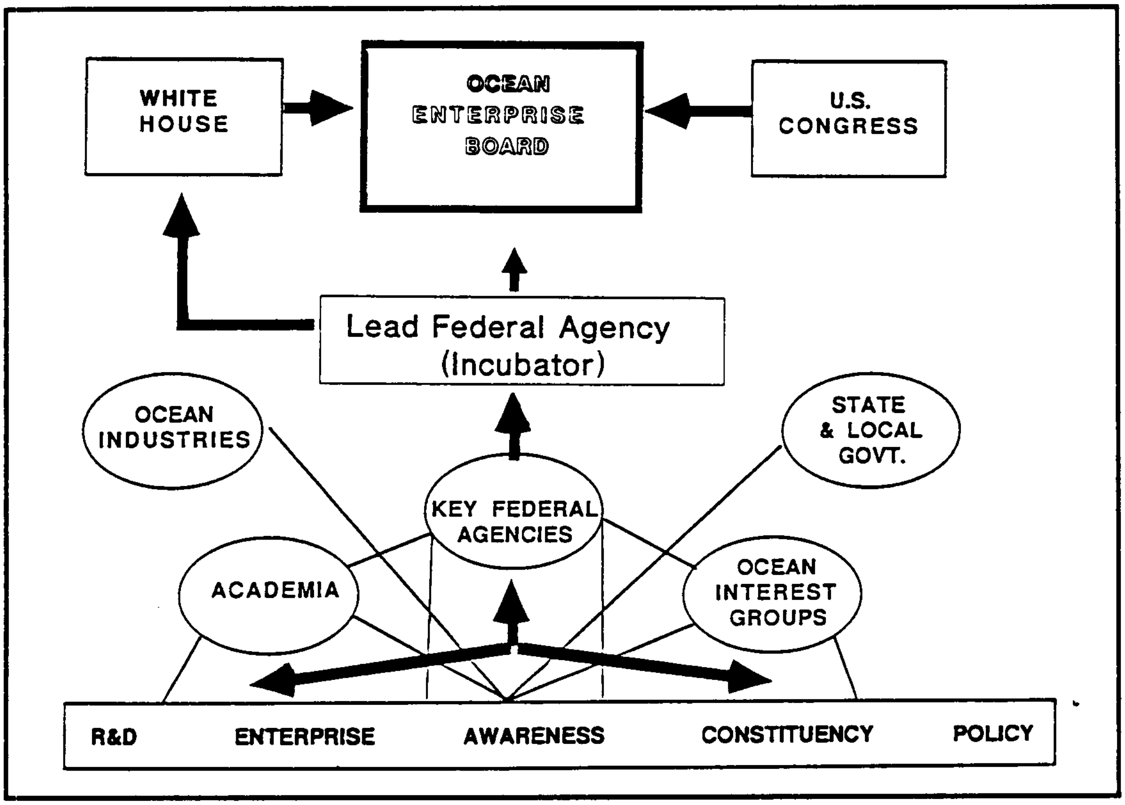

Figure 10.10. Proposed Ocean Enterprise Organization.

fishes (Gallaway et al. 1981; Continental Shelf Associates 1982).

Artificial reefs have been reported to concentrate scattered fishes and/or elevate secondary production by increasing the growth and survival of new individuals. However, the trophodynamics of these systems are poorly understood (Bohnsack and Sutherland 1985). For example, although many species of fish around oil and gas platforms are trophically independent of the structure, they may use the platform for other purposes (e.g., shelter, protection from predation, spawning, and orientation) (Gallaway et al. 1981; Continental Shelf Associates 1982).

There are few techniques to test the success of artificial reefs. A method of testing the effectiveness and community structure of fish near an artificial reef is to track the number and species of fish caught over time. By using CPUE (catch per unit effort) as a measure of relative abundance of fish, the effects of an artificial reef such as an oil or gas platform can be assessed.

The objective of this study was to determine if a relationship exists between selected oil and gas platform physical parameters, geological parameters, angler characteristics, and temporal parameters with the relative abundance of selected fish species around oil and gas platforms off the coast of Louisiana.

MATERIALS AND METHODS

Between September 1986 and March 1987, 120 recreational anglers were solicited from fishing clubs across Louisiana to maintain log books. In addition, 23 charter boat operators volunteered to maintain log books. Log book data were collected from March 1987 to March 1988. Due to the difficulty of identifying some fish species, snapper other than red snapper, groupers, sharks, and silver and sand seatrout were classified as other snapper, groupers, sharks and silver/sand seatrout, respectively.

CPUE, defined as the number of fish caught/angler hour, was transformed by ln(CPUE+1) to approximate the normal distribution of the catch data (Pennington 1983).

PCA was used on the individual fish species as a data reduction technique. The PCA transforms the original set of variables into a smaller set of orthogonal linear combinations that account for a major portion of the variance in the original set.

Stepwise MRA were performed with spotted seatrout ln(CPUE+1) and the component scores of each PC on the angler characteristics, meteorological, temporal, geological, and physical data and their interactions (predictor variables) (Table 10.8).

RESULTS AND DISCUSSION

A total of 55 anglers and 10 charter boat operators returned log books with usable information, a 45.8% and 43.5% return rate, respectively. The participants fished at 467 different oil and gas platforms a total of 1,196 separate times catching 36,839 fish representing over 46 different species.

A five factor PCA explained 45.7% of the variance of the original data set. The first factor was defined as a reef fish factor which included high positive loadings for greater amberjack, grey triggerfish, grouper, other snapper, and red snapper and a negative loading for spotted seatrout. The pelagic fish factor consisted of positive loadings for dolphin, king mackerel, little tunny, and Spanish mackerel and a negative loading for spotted seatrout. The third factor was composed of high positive loadings of Atlantic croaker and silver/sand seatrout. The fourth factor was comprised of high positive loadings of bluefish and red drum. The fifth consisted of positive loadings for cobia and sharks and a high negative loading for blue runner.

A MRA with each PC and ln(CPUE+1) spotted seatrout was utilized to examine the relationships between the abundances of the various species of fish and the temporal, meteorological, angler, physical, and geological variables (Table 10.8).

As evidenced by the relationships identified by the MRA, many factors influence species abundances around oil and gas platforms in the northern Gulf of Mexico. Reef fish, Atlantic croaker, and silver/sand seatrout were most abundant around large oil and gas platforms (mean volume enclosed 150,000-250,000 m^3) with complex construction in relatively deep water (e.g., 70-100 m). However, these species were not abundant at the largest platforms in very deep water implying that a species specific optimal structure size and depth may exist. Spotted seatrout were also abundant near small oil and gas structures although depth was the dominant factor affecting their abundance; spotted seatrout abundances were highest in water depths less than 10 m and near small, unmanned platforms. Since the attraction of pelagic fishes, bluefish, red drum, cobia, and sharks is likely based on optical stimuli there was little or no relationship between their abundances and physical platform characteristics. These species are presumed to be transient residents, therefore their abundances were associated with temporal and angler characteristic variables.

Age of the structure was not a significant factor in explaining fish composition or abundance around oil and gas platforms. It is possible that the platforms in the study may have been fully colonized, since colonization could take as little as 15 months in the northern Gulf of Mexico (Lukens 1981) and the platform ages ranged from 8 months to over 30 years.

Season was an important factor affecting the abundances of fish around oil and gas platforms. Smith (1979) and Lukens (1981) reported large fluctuations in species composition and abundance around natural and artificial reefs in the northern Gulf of Mexico and based on our results this includes fish populations around oil and gas platforms off the Louisiana coast. Higher abundances of spotted seatrout were found in the spring and summer while pelagic fish abundance increased over time suggesting abundance was related to water temperature as indicated by Fable et al. (1981). Temporal variation in reef fish abundances were mixed; however they appeared lowest in the summer with no clear pattern over the remainder of the study period.

Overall, fishing power for cobia, shark, reef fish, and pelagic fish was not equal as fishermen with larger vessels and sophisticated electronics had access to deeper water and were better able to locate fish. The exception was spotted seatrout

Table 10.8. Temporal, meteorological, angler, physical, and geological variables and their interactions used in the multiple regression analysis.

Variables	
<u>Angler</u>	<u>Physical</u>
Fishing method	Structure age
Boat length	Number of crossmembers
Boat Hp	Number of legs
Presence of echosounder	Number of wells
Presence of LORAN	Water depth
Presence of graph recorder	Submerged surface area
	Volume of water enclosed
	Structure manned
	Structure in production
<u>Geological</u>	
Mean sediment size	
<u>Interactions</u>	<u>Temporal/meteorological</u>
Boat length * Hp	Linear date
Quadratic structure age	Quadratic date
Structure age * number of legs	Cubic date
Structure age * number of crossmembers	Wind speed
Structure age * submerged surface area	Wind direction
Number of legs * number of cross members	Air temperature
Number of legs * number of wells	
Number of legs * enclosed volume	
Number of legs * submerged surface area	
Structure manned * structure in production	
Water depth * volume of water enclosed	
Water depth * submerged surface area	
Submerged surface area * volume of water	

as large vessels with sophisticated electronics were not required to capture this species due to their high abundance in shallow water. Geological and meteorological variables were not significant predictors of fish abundance around oil and gas platforms.

The physical construction of oil and gas platforms precludes the sampling of the associated sport fish populations using traditional methods (e.g., gill nets, trawls, etc.). Based on the results of this log book program, the collection of CPUE data over long periods of time may be an effective technique of monitoring the catchable fish populations associated with artificial reefs. Although the data supplied by the log books is an index of relative abundance of fish susceptible to angling and is biased towards larger individuals, it provides a valuable source of data which is otherwise difficult to obtain.

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Dr. Charles A. Wilson is an Associate Professor of Fisheries at the Coastal Fisheries Institute, Louisiana State University, Baton Rouge, Louisiana. Dr. Wilson's principal research interest involves age and growth of marine fishes. Dr. Wilson earned a Ph.D. degree in fisheries science from the University of South Carolina.

AQUARIUMS WITHOUT WALLS

Mr. Michael E. Parker, P.E.
Exxon Company, U.S.A.

The conversion of obsolete oil and gas production platforms into permanent artificial reefs provides a unique opportunity for oil and gas producers to make a positive environmental impact of the installation of offshore structures, the creation of an artificial reef, virtually permanent. Exxon has had a continuing interest, and has actively participated in developing both Federal and state artificial reef programs for many years. Programs like the Louisiana Artificial Reef Program have proven to be environmentally desirable and economically attractive options for recycling obsolete oil and gas platforms.

Early on in the planning process of our High Island A-343 "A" and "B" artificial reef project we recognized the opportunity this project presented for "spreading the word" on the benefits of artificial reefs. This opportunity coupled with Exxon's participation in the New Orleans Aquarium of The Americas led to the production of this video presentation entitled "Aquariums Without Walls." Exxon is currently working with the New Orleans aquarium to develop a version of this video for use as part of an artificial reef exhibit.

The video gives a description of how and why artificial reefs provide a positive environmental impact and also shows how an oil and gas structure is converted into an artificial reef. The construction scenes in the video are of Exxon's High Island A-343 field abandonment, which was completed in December 1988. The jacket portions of the two structures were donated to the Louisiana Artificial Reef Program and placed in West Cameron Block 616 in about 300 feet of water.

Mr. Michael E. Parker is a Staff Engineer with Exxon's Offshore Division in New Orleans. Mr. Parker received a Bachelor's degree in civil engineering from the University of Texas and a Master's degree in ocean engineering from Texas A&M University. Since joining Exxon in 1978, Mr. Parker has held a variety of drilling and production operations assignments and is currently assigned as a regulatory and environmental engineer. Mr. Parker is a registered professional engineer in Texas and Louisiana.

DEVELOPMENT OF AN ARTIFICIAL REEF PLAN FOR TEXAS

Mr. Brett G. Dansby
Texas Parks and Wildlife Department

Artificial reefs are structures or systems of structures placed in waters for the purpose of enhancing fishery resources. Man has used artificial reefs to attract aquatic organisms for several centuries. As coastal populations and fishing pressure increases, the demand for additional artificial reef sites will continue to increase.

The Texas Parks and Wildlife Department has been involved in artificial reef construction since 1947 (Crowe and McEachron 1986). A provision in Section 12.016 of the Parks and Wildlife Code gave the Department statutory authority to construct or contract for the construction of artificial reefs in the coastal waters of Texas, or in international or Federal waters adjacent to the coastal waters of Texas. Since 1947, a total of 68 intentional artificial reefs have been constructed comprising over 1,200 acres of bottom in Texas' bays and the Gulf of Mexico (Crowe and McEachron 1986). Materials used included: oyster shell; tires; cars; construction rubble; barges; pipes; drilling rigs; and ships. Only 50% of these reefs remained in existence in 1986. The remaining structures were silted over or had been constructed of materials which rapidly eroded or were displaced.

Availability of reef building material offered to the Texas Parks and Wildlife Department has never been a problem. Numerous oil companies, interested groups, and private individuals have offered an assortment of materials that would otherwise be difficult to dispose of. However, the problems of placement, marking, maintenance, funding, and transference of liability has not been adequately resolved.

In addition to intentionally constructed artificial reefs, Texas has over 2,000 unintentional reefs in the form of: piers and docks; jetties; oil and gas well shell pads; offshore petroleum platforms; and open water spoil areas that cover over 40,000 acres of bottom area (Crowe and McEachron 1986).

LIBERTY SHIPS

The most noteworthy contribution to artificial reef development in Texas began in 1973 with the adoption of Texas Senate Resolution 102 mandating the acquisition of Liberty Ships for deployment as artificial reefs. The Texas Coastal and Marine Council (TCMC), in conjunction with the Texas Parks and Wildlife Department acquired title to 12 of the 42 available Liberty Ships. The major impetus for development of Liberty Ship reefs was based on the strong historical interest by recreational fishermen combined with a steady increase in the coastal population of Texas (Texas Coastal and Marine Council 1984). Although funding for the Liberty Ship program was limited, salvage from the acquired vessels generated $432,000 and allowed the Texas Coastal and Marine Council to meet Federal requirements while also maintaining navigational aids on several sites for a short interval (Texas Coastal and Marine Council 1984). When the Marine Council was disbanded in 1985, title, maintenance, and marking responsibilities of the Liberty Ships and the proposed Flower Garden site were transferred to the Texas Parks and Wildlife Department. The permit for the Liberty Ship reefs is renewable and can be amended to allow petroleum structures to be added on condition that certain size, placement, and marking criteria can be met.

SENATE BILL 5

The 1989 Texas Legislature enacted Senate Bill 5 delegating general duties to the Texas

Parks and Wildlife Department to create a state Artificial Reef Plan to promote, develop, maintain, and monitor artificial reef potential in the Texas Territorial Sea (out to 9 nautical miles) and in the Exclusive Economic Zone adjacent to Texas waters (out to 200 nautical miles). Senate Bill 5 mandates the Texas Parks and Wildlife Department to establish an advisory committee, serve as permittee for artificial reefs, plan and review private permit applications, coordinate with state and Federal agencies, conduct public hearings, oversee maintenance, construction and placement requirements, and develop rules and guidelines concerning collection of fees, grants, and donations to the Artificial Reef Fund.

The final goal of the Artificial Reef Plan is to establish artificial reefs that enhance and conserve fisheries resources, facilitate use and access by recreational and commercial user groups, minimize conflicts, minimize risks (e.g., environmental, personal, public health, and property), be consistent with international and national fishing laws, not create unreasonable obstructions to navigation, and to use the best scientific information available to achieve this goal.

As directed by the Legislature, the Texas Parks and Wildlife Commission appointed a nine member Texas Artificial Reef Advisory Committee to advise and make recommendations to the Commission on details and specifications of the plan. The Committee consists of members from the following organizations:

	Organization	Member
1.	A saltwater sports fishing group	Irby Basco
2.	An offshore oil and gas company	Win Thornton
3.	The Texas Tourist Industry	Eugene Dilbeck
4.	The General Land Office	Greg Pollock
5.	A shrimping organization	Harris Lasseigne
6.	A Texas diving club	Jim Morrison
7.	The Attorney General's office	Jim Mattox
8.	A Texas university	William Fisher
9.	An environmental group	Sharron Stewart

Senate Bill 5 creates an artificial reef fund and directs the Texas Parks and Wildlife Department, in conjunction with the Artificial Reef Advisory Committee, to develop rules and guidelines for collection of fees, grants, and donations of money or materials to this fund. Although the Texas Parks and Wildlife Department may accept financial assistance from outside sources, this bill stipulates no general revenue funds may be expended. The possibility exists a donor funded program may not generate funds needed to maintain artificial reefs perpetually, and, at this time it is unclear how long-term funding sources will be provided.

Other pertinent sections of Senate Bill 5 include removal of liability from the state or person who has transferred title of construction materials to the state. However, construction materials must meet applicable requirements of the National Fishing Enhancement Act, the U.S. Department of Interior, and all applicable permits before complete removal of liability. It is believed the liability question will ultimately be resolved in a court of law.

The Texas Parks and Wildlife Department was directed by Senate Bill 5 to complete the artificial reef plan on or before September 1, 1990. The Texas Parks and Wildlife Department Staff has been preparing the plan since June, 1988, in accordance to the Texas Parks and Wildlife Department's six-year plan.

MANAGEMENT CONSIDERATIONS

The debate among artificial reef authorities continues to center on whether artificial reefs increase biomass or merely concentrate available biomass. There is evidence that artificial reefs attract fish, but many experts believe that placement of additional structures could prove detrimental to areas where fish stocks are overfished (Osburn et al. 1988). For example, red snapper, a major reef fish in Texas' offshore waters, is currently overfished. Management efforts that concentrate this species and, therefore, increase its vulnerability to angling can only serve to harm the population. At this time few management measures regulating fishing on artificial reefs are in effect. However, Phillips (1988) recommends an assortment of management strategies that can be implemented by reef managers to control fishing on artificial reefs including: user specific reefs; reef rotation; construction of additional reefs; additional access sites in conjunction with new reefs; reef stamps; user group education; catch and release; and Special Management Zones (SMZ's). Considering the relatively shallow depth of the shelf region off the Texas coast combined with the fact that most artificial reef sites will probably be sited in Federal waters, SMZ's appear to be a promising management strategy.

DISCUSSION

The relatively shallow offshore region along the Texas Gulf coast creates additional reef management problems. First, it is difficult to place artificial reefs where they can be utilized by all user groups. Marking constraints, bottom composition, storm and wave energies, water clarity, and interference with shipping and national defense may require most reefs to be located beyond the distance most recreational anglers are willing to travel. Second, user conflicts among the three major user groups could create additional management concerns since the presence of one group usually limits access of the remaining groups (Phillips 1988). And third, due to the economic importance of shrimping grounds along the Texas coast, limiting the removal of valuable bottom area available for shrimping must also be taken into consideration.

In conclusion, scientific evidence available at this time is mixed on the benefits of artificial reefs relative to the long-term management of the fisheries for reef fish. The need for further research and study of artificial reefs is imperative if these questions are to be resolved.

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Mr. Brett Dansby is currently employed as a Biologist II in the Coastal Fisheries Branch of the Texas Parks and Wildlife Department and is responsible for conducting recreational and commercial creel surveys and aquatic habitat analysis in the Lower Laguna Madre bay system. Mr. Dansby was born and reared in Pasadena, Texas and in 1986 obtained a B.S. degree in wildlife and fisheries science with a major in fisheries ecology from Texas A&M University. Mr. Dansby was one of the original authors assigned to the Texas Artificial Reef Plan in May of 1988.

A HISTORY AND STATUS OF SHRIMP AQUACULTURE

Mr. John Ogle
Gulf Coast Research Laboratory

PAST

The aquaculture of marine shrimp is a fairly recent activity (Table 10.9). Of 342 commercially valuable species of shrimp in the world, aquaculturists are rearing only four. Shrimp were first spawned in the laboratory in 1933 and by 1939 larvae had been reared. Hatchery technology had been developed in Japan by 1964 and in the U.S. by 1966. However, complete control of the life cycle was not achieved until 1975 when captive maturation was attained. Although shrimp had been grown out in saltwater ponds in South Carolina in 1947, it was not until 1962 that experimental shrimp pond aquaculture began in the U.S., Japan, and Ecuador. The first commercial farms were constructed in 1967 in the U.S. and in 1969 in Ecuador. Shrimp farming in the R.O.C. (Taiwan) began in 1968 and the first feed mill was constructed in 1977. Shrimp farming in the P.R.C. (China) began

Table 10.9. Timeline: Aquaculture of marine shrimp.

Year	AQUACOP[1]	China	Taiwan	Japan	Ecuador	USA
1933				Lab Spawning		
1939				Lab Rearing		
1947						Growout
1962				Pond Culture	Pond Culture	Pond Culture
1963				Japanese method (Artemia)		
1966						Galveston Method (algae)
1967			1st Farm (spawn *P. monodon*)			1st Farm (spawn *P. vannamei*)
1968		Experiment Station				
1969					1st Farm	World Aquaculture Society Formed
1970				Shigueno Tanks		1st Hatchery
1972						1st Raceway
1973						*P. vannamei* grown (closed circulation)
1974	Captive Maturation (*P. vannamei*)					ERL Aquacell[1]
1977			Commercial Feed (developed)			
1978		1st Hatchery				
1980		1st Farm				
1981						MCE[1]
1982						Laguna Madre Farm[1]
1985						paddlewheel, SFP (developed)
1986					Top World Production	
1987			Industry Peak			

[1] Commercial Company

with an experiment station in 1968 and led to the first commercial farms in 1978. Production from these early farms was several hundred pounds per acre. Research toward culturing shrimp in intensive closed recirculating sea water systems was initiated in 1973 by the National Marine Fisheries Service at Galveston, Texas. Closed-system culture of marine shrimp was attempted commercially in 1979.

PRESENT

Today consumption of seafood is at a record high of 2.3 pounds per capita with shrimp comprising 15%. In 1987 approximately 555 million pounds of shrimp were consumed in the U.S. The U.S. shrimp fleet caught approximately 350 million pounds with the remainder being imported from Ecuador, Mexico, P.R.C. (China), R.O.C. (Taiwan), and India. Shrimp aquaculture accounted for 26%

of the world production. In 1984 approximately 487,000 pounds of shrimp were produced on U.S. shrimp farms. In 1989 3.3 million pounds of shrimp were produced by 35 U.S. shrimp farms. Yields of several thousand pounds per acre are being routinely achieved. Supplemental aeration by paddlewheels and increased water exchange has led to experimental yields as high as 14,000 pounds per acre per crop with three crops possible in Hawaii. Energy consumption ranges from 533 to 2,636 pounds of production per horsepower input (Table 10.10). Water consumption ranges from 1,395 to 13,368 gallons per pound of production (Table 10.11).

FUTURE

The increasing yields and number of farms have created a greater demand for seed (postlarvae) to stock. The quantity and quality of seed produced domestically is currently unpredictable and cannot meet U.S. requirements. Competition from foreign producers will require U.S. farms to achieve better survival, higher growth rates allowing production of at least two crops per year from mainland farms. Concerns over water use, effluent discharge, predator control, and a desire for still greater yields will ultimately take shrimp culture indoors. Intensive closed system culture is again being practiced by at least five groups in the U.S.

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Mr. John Ogle is a research associate with the Gulf Coast Research Laboratory, Ocean Springs, Mississippi. He received his B.S. in zoology from Texas A&M University at College Station, Texas and a M.S. in wildlife and fisheries from Texas A&M University Marine Laboratory at Galveston, Texas. He has been involved with aquaculture for almost 20 years. He currently manages an experimental recirculating sea water system for maturation of a marine shrimp.

RANCHING REDFISH

Mr. David Maus
Redfish Unlimited

Redfish production has two facets: fingerling production and grow-out. Fingerling production necessitates maturation and spawning of brood-stock and mechanisms to grow the resultant fry to 2.5 cm size. Grow-out involves growing the 2.5 cm fingerling to market size, which is about a 1 kg fish.

Either production involves use of natural resources, primarily water and land. Water use,

Table 10.10. Energy use in shrimp farming.

	hp/acre	lb/acre	lb/hp
O.I.	13.5	7,194	533
La Pesca	4.0	3,407	841
Amorient	8.0	8,000	1,000
Waddell	3.2	4,843	1,499
Orca	2.6	5,200	2,000
Taiwan	4.5	9,968	2,215
Wolf Point	0.8	2,109	2,636

Table 10.11. Water use in shrimp farming.

	Actual			Equivalent	
	lb/acre	gal water	gal/lb	pond size acres	production lb/acre
Texas	1,032	14,115,822	13,368	14.4	71.6
South Carolina	5,999	24,438,750	4,074	25.0	239.9
Amorient	14,361	50,246,070	3,499	51.4	279.4
M.C.E.	150,000	209,181,576	1,395	213.9	701.3

Corn 2,040 gal/lb Beef 996 gal/lb

in most states, requires a permit. Interested parties should inquire about permits to their respective state agencies as early as possible and begin the process as soon after site selection as possible, because the process may take six months or longer. Use of land in terms of site selection will be the single most important factor determining the success or failure of any aquaculture operation.

In redfish production, site selection is determined by the type of production which will be undertaken; i.e., fingerling production, grow-out, or both. Important site selection factors include: salinity and quality of available culture water, soil type, and elevation.

Any production scheme which includes fingerling production must have on-site pristine seawater quality water of 30-35 parts/thousand (°/₀₀) salinity. This salinity is necessary to cycle and spawn the broodstock and to incubate and hatch the eggs. Grow-out, on the other hand, is possible in hard freshwater to 50 $^{\circ}/_{\circ\circ}$ plus salinity.

Soil type is important because if ponds are to be built from soil on site, the soil must contain at least 20% clay to prevent high seepage rates. Clay soil is very important in grow-out production in ponds, because relatively large acreages must be constructed to produce large poundages of fish. Soil type is not as critical to fingerling production, however, since less acreage is required and therefore, it may be cost effective to line ponds with plastic or bentonite to prevent seepage.

The elevation of the site above sea level is important because if ponds are to be drained by gravity, the pond bottoms must be above sea level. Water can be pumped out of ponds, but this is very expensive and may make production costs prohibitive. Elevation is important for both fingerling production and grow-out. It is more important for fingerling production, because fingerlings don't tolerate seining, so ponds need to be drain-harvested. Grow-out ponds, on the other hand, can be in production for years without draining, so the ability to drain them is not as critical.

Redfish production begins with the collection of wild broodstock which are placed in tanks in photo-period temperature-controlled rooms. They are placed on a 150-day cycle which is a compression of the normal year. When the controlled cycle reaches fall, which is when the fish spawn in nature, they spawn in the tanks. The fertilized eggs float to the surface and are skimmed off by an egg collector. The eggs are removed from the egg collector and enumerated in a graduated cylinder using the standard of 1,000 eggs/ml. The eggs are then placed in a cone bottom, 2,000 liter incubator where they hatch in 24 hours. The fry are held for 40 hours post-hatch to give their mouth parts time to develop and then they are placed outside in fingerling ponds. The fingerling ponds have been prefertilized 10-15 days prior to stocking in order to stimulate the food chain and provide the zooplankton that the fry need for survival and growth. About 12 days after stocking, the fingerlings are fed salmon starter to supplement the zooplankton. From 35-45 days after stocking, the fingerlings are harvested at a 2.5-5 cm size. At this point, the fingerlings can be transferred directly to grow-out ponds, but production is significantly more predictable if these fish are moved into tanks and grown to 7.5-10 cm before they are transferred to ponds. Grow-out of a 10-15 cm fingerling to one kg+ at our Palacios, Texas facility can be accomplished in 6 to 7 months. After reaching harvestable size, the fish are seined from our ponds and marketed through seafood markets, restaurants, grocery stores, and wholesalers at an average price of about $2.50/lb for whole fish.

Mr. David Maus has been the Manager of Redfish Unlimited since its inception (about three years), and was responsible for the design and construction of the facility. Previous to managing Redfish Unlimited, he was employed by the Texas Parks & Wildlife Department for three years at a production marine fish hatchery. Mr. Maus has a B.S. in marine biology and a M.S. degree in aquaculture.

OIL SPILLS IN TROPICAL ENVIRONMENTS

Session: OIL SPILLS IN TROPICAL ENVIRONMENTS

Co-Chairs: Dr. James J. Kendall
Mr. Charles W. Hill, Jr.

Date: December 7, 1989

Presentation	Author/Affiliation
Oil Spills in Tropical Environments: Session Overview	Dr. James J. Kendall and Mr. Charles W. Hill, Jr. Minerals Management Service Gulf of Mexico OCS Region
Panama Oil Spill: Biological Effects	Dr. Brian D. Keller, Dr. Jeremy B.C. Jackson, Dr. John D. Cubit, Dr. Jeffrey D. Brawn, Dr. Kathryn A. Burns, Dr. Roy L. Caldwell, Dr. Norman C. Duke, Mr. Stephen D. Garrity, Mr. Hector M. Guzman, Mr. Karl W. Kaufmann, Dr. Sally C. Levings, Dr. Michael J. Marshall, Dr. Richard Steger, and Mr. Ricardo C. Thompson Smithsonian Tropical Research Institute
Effects of the Panama Oil Spill: Hydrocarbon Chemistry	Dr. Kathryn A. Burns Bermuda Biological Station for Research
Project Overview: Panama Oil Spill	Dr. Robert S. Carney Coastal Ecology Institute Louisiana State University
Effects of Oil Spills on Mangroves and Other Wetlands	Dr. Howard J. Teas University of Miami
Effects of Oil Spills on Seagrasses	Dr. Michael J. Marshall Continental Shelf Associates, Inc.

OIL SPILLS IN TROPICAL ENVIRONMENTS: SESSION OVERVIEW

Dr. James J. Kendall
and
Mr. Charles W. Hill, Jr.
Minerals Management Service
Gulf of Mexico OCS Region

Why have a session on Oil Spills in Tropical Environments? On April 27, 1986 at least 8 million liters of medium-weight crude oil spilled from a ruptured storage tank into the Bahia Las Minas on the Caribbean Coast of Panama. This is the greatest amount of oil spilled directly into a sheltered coastal habitat in the tropical Americas (Jackson et al. 1989). What makes this spill of special interest is that it occurred quite "literally" on the door steps of the Smithsonian Tropical Research Institute's Galeta Laboratory. Here, resident and visiting scientists have been studying the ecology of the Bahia Las Minas and the adjacent areas for over 15 years.

For those of us working in the Gulf of Mexico, this spill is of particular interest because many of the coastal environments and the species affected may be very similar to those of the Gulf. Almost immediately, the Minerals Management Service and the Smithsonian Tropical Research Institute (STRI) began discussions as to a strategy to study the effects of the spill; shortly thereafter, plans for a five-year-study were finalized. The objectives of this project are to document long-term changes in spatial and temporal distribution and abundance of populations and communities of the region which may result from the spill, and to understand, ecologically, the processes which cause the observed changes.

During this session a series of papers were presented describing the studies being conducted in Panama. Papers of a more general nature were also presented addressing the ecological/biological effects of oil spills as they may be applied to the coastal tropical and subtropical environments of the Gulf of Mexico. The first speaker, Dr. Brian D. Keller, the STRI project manager, presented an overview of some of the biological components of the study: subtidal reef corals, mangrove forests, mangrove roots, and reef flat communities.

The 1986 oil spill in Bahia Las Minas, Panama resulted in an immediate and unexpected mortality and injury to subtidal corals. This was in stark contrast to widely held assertions that corals are not affected by oil floating on the surface. However, as the study progresses, and as new data are examined, it is becoming increasingly more difficult to distinguish between oiled and unoiled (control) areas. Interestingly, this difficulty is not the result of recovery at the oiled reefs, but rather a decline in coral cover at the unoiled reefs. Such a deterioration in the health of apparently unimpacted corals has been observed in other regions of the Caribbean (Dr. Eugene Shinn, personal commun.).

Other difficulties in defining long-term impacts from short-term data have also been encountered. During the spill, oil accumulated along the seaward margin of reef flats. Massive mortality of reef-flat organisms occurred at each low tide when organisms in these areas were smothered by crude oil. Again, as the study progresses, what appears to be natural phenomena complicated the analyses. The fauna and flora of the reef flat areas at Galeta have been monitored for over 15 years and these data are used to compare abundances before and after the spill, particularly the natural mortalities occurring annually during reef flat exposures. Based on the long-term records, the most extreme exposures of the reef flats since 1974 occurred in 1988, two years post-spill. The mortalities suffered by the reef flat organisms after the 1988 exposures were greater overall than that observed following the 1986 oil spill. While such comparisons must be made with caution due to the spatial differences of the mortalities on the reef flat, the necessity of the long-term data (both pre- and post-spill) is emphasized.

These discrepancies underlie the importance of detailed, long-term studies and the dangers inherent in extrapolating from short-term (acute) observations. For example, long-term impacts to coral reefs must be discussed in terms of 10's of years and thus requires the appropriate baseline (long-term) data.

Mangrove forests fringe the shore of the Bahia Las Minas, and trees died soon after the oil spill along over 20 km of the shoreline. Detailed studies of the mangrove forest are just now beginning and will include detailed mapping of the deforestation from aerial photographs and surveys, monitoring of primary production, and studies of the primary consumers.

The studies of the mangrove roots are well advanced. Immediately following the spill, mangrove roots and their epibionts (encrusting algae and sessile invertebrates) were coated with oil and soon died. Three types of studies are being conducted: percent cover of epibionts, community development and persistence, and the recruitment of epibionts onto wood dowels (surrogate mangrove roots). The algal-invertebrate community still differs between oiled and unoiled sites over three years after the spill.

Dr. Kathryn Burns, of the Bermuda Biological Station for Research, is the Scientist-in-Charge of the hydrocarbon analyses for the Panama Oil Spill Study. These chemistry studies are intended to be the basis for constructing a model for the rates of degradation and the rates of dispersion processes of spilled oil in tropical environments. These studies will also provide dose estimates of toxic aromatic hydrocarbons and their oxidation products to correlate with the biological studies in the long-term assessment. Results of the analyses of coral samples collected five months after the spill have documented that corals take up petroleum hydrocarbons in proportion to the level of exposure (Burns and Knap 1989). The data have also shown that exposure to the oil affected the lipid biochemistry of the corals. Such a disruption of lipid biosynthesis could have a cascading impact on other components of the coral reef ecosystem which depend on the corals for food and protective substrate.

Hydrocarbon analyses of sediment samples confirmed the relative severity of oiling at the various study sites determined visually (see Jackson et al. 1989). Analyses from cores taken from heavily oiled mangrove sediments have shown that in some instances oil had penetrated in high concentrations. However, gas chromatography analyses have shown that even in heavily oiled areas, these oil residues are extremely weathered (degraded). The important conclusion from these preliminary analyses is that the rate of degradation of oil in tropical ecosystems is much faster than has been observed in temperate areas. While some areas (e.g., mangrove sediments) may remain significant sources of contamination for sometime to come, the oil being released may be highly modified compared to that originally spilled.

Dr. Howard Teas of the University of Miami reviewed the distribution of the principal wetlands of the Gulf of Mexico: seagrasses, mangroves, and saltmarsh grasses. These wetlands stabilize shorelines and provide the habitat and the energy (primary productivity) supporting the major fisheries resources.

Dr. Teas reviewed the basic physiological and morphological adaptations of the mangroves species found along the Gulf coast and how these attributes are pertinent to any discussion of the effects of spilled oil on mangrove communities. These adaptations included the abilities to obtain low salinity water through their subsurface roots, even while growing in saline environments, and to grow in anaerobic soils using "snorkel" like systems which supply oxygen to subsurface roots. Damage to either of these systems by spilled oil may lead to the death of the plant. The death of mangroves (and for that matter saltmarshes) may lead to erosion and the loss of productivity and habitat which may seriously impact economically important fishery resources.

The use of chemical dispersants has been shown to spare some mangroves from the adverse effects of oil spills. Dr. Teas recommended that, because of the many years required for the regrowth of mangroves, the dispersion of oil be considered as an option for the treatment of oil spills which threaten mangroves. For mangroves and saltmarsh grasses which are killed by oiling, replanting should be conducted as soon as possible. Techniques for replanting saltmarsh grasses are well known and have been carried out at a number of sites in conjunction with coastal erosion programs. The largest post spill restoration of mangroves reported to date was carried out in Panama at the site of the 1986 oil spill (Teas et al. 1989). Almost all of the approximately 75 hectares of the oil killed mangrove forest was replanted.

The damage to seagrass communities by spilled oil was reviewed by Dr. Michael Marshall. Historically the effects of oil spills on grassbeds have been overlooked since, in most instances, only small portions of the beds have ever been killed. It was assumed that oil slicks floating on the sea's surface had little if any effect on these subtidal communities. Dr. Marshall reviewed the older anecdotal evidence suggesting that oil has little effect on grassbed communities and the more recent evidence suggesting that spilled oil can significantly impact seagrass communities.

After the Panama spill, a heavily oiled intertidal grassbed was destroyed. Following the decay of the flora, sediments were washed away exposing the bare rock platform. While such mortality was not observed for subtidal seagrass meadows, the landward-most edges have receded several meters since the spill. While these meadows have, for the most part, remained intact, various infaunal groups were strongly affected by the oiling. These included polychaetes, amphipods, tanaids, brachyurids, and sipunculids (see graphs in Jackson at al. 1989). As such, Dr. Marshall believes that the monitoring of the effects of oil spills on grassbeds requires that all components of the community be examined. For example, highly diverse assemblages of small animals are associated with *Thalassia* meadows. While many of these small animals are juveniles of commercially important species, other faunal components of the community may have an equally important role serving as links between the commercial species and the primary productivity of the seagrass meadows. Of particular concern to Dr. Marshall were the potential effects of the large quantities of oil (presumably originating from the Bahia Las Minas spill) buried within the sediments of the seagrass meadows and mangrove forest. While these oil residues may be extremely degraded by processes of evaporation, dissolution, microbial, and photodecomposition (as noted by (Dr. Burns), Dr. Marshall contends that "the effects of weathered oil, in various stages of chemical decomposition, on grassbed fauna are unknown."

While Dr. Robert S. Carney was not the final speaker of this session, his comments are best incorporated into the concluding thoughts of this overview. Dr. Carney is the chairman of the Scientific Review Board (SRB) for the Panama Oil Spill Study. The SRB provides scientific advice and criticism, and reviews experimental designs, data, and reports as the project progresses. As such, he and the other members of the SRB have the unique opportunity to view the project in its entirety, and not "miss the forest because of the trees." As pointed out by Dr. Carney, the study being conducted in Panama covers all the major components of the ecosystem and is unique in its attempt to integrate the chemical effects of the spill with those of the biological components. As such, the framework exists to effectively understand, biologically, ecologically, and chemically the processes causing the observed changes. However, as was duly noted by several participants, direct comparisons between the environments and the species of Panama with those of the Gulf of Mexico must be made with caution. While individual species and environmental parameters may be comparable on a one-to-one basis (under certain specific instances), ecosystems and habitats consist of multitudes of species and series of interconnected pathways and environmental parameters. Comparisons, even when made with great caution, need to be made between the cumulative results of the individual elements and not merely between individual components.

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PANAMA OIL SPILL: BIOLOGICAL EFFECTS

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In April 1986, over 8 million liters (50,000 barrels) of medium-weight crude oil spilled from a ruptured storage tank into Bahia Las Minas on the Caribbean coast of Panama (Cubit et al. 1987, Cubit et al. 1988, Jackson et al. 1989). The bay is located near the Atlantic entrance to the Panama Canal and the city of Colon, and has a history of exposure to various kinds of pollution and stress. These include effects from the construction of the Panama Canal and the city of Colon starting over a century ago, sedimentation from erosion caused by decades of deforestation, industrial operations (a petroleum refinery, an electrical generating plant, and an out-of-use cement plant), an oil spill in 1968, and increasing contamination from growing towns adjacent to the bay. In addition to these types of localized environmental effects, the Caribbean region has recently experienced large-scale natural phenomena, such as coral bleaching (e.g., Lessios et al. 1983) and the mass mortality of the sea urchin *Diadema antillarum* in 1983 (Lessios et al. 1984) with the subsequent growth of algae on the reefs.

Nevertheless, the 1986 oil spill in Bahia Las Minas had strong effects on intertidal and subtidal populations and communities (Jackson et al. 1989). The purpose of the on-going studies in Panama is to monitor the fate of the spilled oil and any longer-term biological effects resulting from the spill. A considerable amount of the spilled oil remains in mangrove sediments. This appears to be the main source of oil slicks in Bahia Las Minas, which still occur over three years after the spill.

A coastal reserve of the Smithsonian Tropical Research Institute (STRI) at Punta Galeta was heavily oiled. Previous studies, particularly of reef flat populations and communities at Punta Galeta, provide long-term baseline data for assessing biological effects of the spill. Pre-spill surveys had been conducted in other environments and some additional pre-spill/post-spill comparisons can be made. However, certain effects of the spill must be inferred from comparisons of oiled and unoiled areas.

We briefly discuss findings to-date of studies of subtidal reef corals, mangrove forests, epibiota on mangrove roots, reef flat populations and communities, and subtidal seagrass communities. Chemical analytical findings will be presented elsewhere in these Proceedings (K. Burns). It is important to note here that these chemical analyses corroborate visually assessed categories of oiling (heavy, moderate, and none) (i.e., Jackson et al. 1989).

SUBTIDAL REEF CORALS

Visual estimates of cover are made annually at 12 reefs (6 heavily oiled, 2 moderately oiled, and 4 unoiled), using square-meter quadrats along 4 transects from the shallowest to the deepest part of each reef. Six of these reefs (one heavily oiled, one moderately oiled, and four unoiled) were surveyed before the spill

(1985). In August 1986, four months after the spill, live coral cover at a depth of 0.5-3 m had declined dramatically at the heavily oiled reef and somewhat at the moderately oiled reef, but not at the unoiled reefs (Jackson et al. 1989). At a depth of 3-6 m, coral cover dropped only at the heavily oiled reef. Surveys of all 12 reefs in 1988 and 1989 show that live coral cover has subsequently converged at heavily oiled, moderately oiled, and unoiled reefs at both depths, but not because of recovery of corals at oiled reefs. Instead, live coral cover has declined at unoiled reefs for unknown reasons.

Visual estimates of recent injuries (white skeleton devoid of coral tissue) are made quarterly at the 12 reefs along 100 square-meter transects at depths of 0.5-1 m and 1-2 m. Soon after the spill, recent injuries to corals were far more severe at heavily oiled reefs than at moderately and unoiled reefs. This was particularly evident at the shallower depth. Also, the dominant reef-building coral, *Siderastrea siderea*, was injured more frequently than two other common species, *Porites astreoides* and *Diploria clivosa*. About 1.5 years after the spill, levels of injury had declined.

Skeletons of head-forming corals, such as *Siderastrea siderea*, *Porites astreoides*, *Diploria strigosa*, and *Montastrea annularis*, contain alternating high- and low-density bands. In Panama, as at other localities, this banding pattern is annual. For corals collected from heavily oiled reefs, growth during the year of the spill (1986) was the lowest observed over the last 10 years. For three of the four species (the exception was *Siderastrea siderea*), mean growth at heavily oiled reefs during 1986 was significantly lower than the mean for the previous nine years.

MANGROVE FORESTS

Intensive studies of mangrove forests were not initiated until 1989. They will include detailed mapping of deforestation from aerial photographs and surveys, monitoring of primary production, and studies of the primary consumers.

Forests fringing the shore are dominated by *Rhizophora mangle*. Trees died after the oil spill along over 20 km of the shore in Bahia Las Minas. Although adult trees were killed, some *R. mangle* seedlings survived the spill. In addition to tens of thousands of planted seedlings and propagules (Teas et al. 1989), there has also been substantial natural recruitment by *R. mangle* since the spill. Seedling survival and growth are being monitored. Studies of primary production and consumption are designed to examine sublethal effects of the spill on forest dynamics adjacent to deforested areas.

MANGROVE ROOTS

Aerial roots of *Rhizophora mangle* extending into the water in three different habitats (open coasts, channels and lagoons, and rivers and streams) provide substrata for algae and sessile invertebrates. These epibiota were surveyed before the spill (1981-82) and have been monitored quarterly since August 1986, four months after the spill. Three types of studies are being conducted. Percent cover is measured on randomly selected roots extending at least 20 cm into the water, but not attached to the bottom. Community development and persistence are monitored on a cohort of marked roots that was entering the water in August 1987, approximately 15 months after the spill. Finally, recruitment is measured on wooden dowels suspended in the water every three months.

Rotted roots are more frequent at oiled sites than at unoiled sites in all three habitats. This deterioration decreases the availability of roots for epibionts at oiled sites.

Mangrove roots in the three habitats are encrusted by different assemblages of epibionts. At open coast sites, space is occupied mainly by foliose and crustose algae, and sessile invertebrates (mainly hydroids, tunicates, and sponges). Roots were coated with oil soon after the spill, and percent cover of algae and invertebrates at oiled sites were much lower than at unoiled sites. Oiling has decreased greatly with time, and by 1.5 years after the spill, little oil was found on roots at open coast sites. Nevertheless, the algal-invertebrate community still differs between oiled and unoiled sites over three years after the spill.

The oyster *Crassostrea rhizophorae* is the dominant organism on mangrove roots in channels and lagoons. It suffered extensive mortality at oiled sites soon after the spill. Some oil still occurs on mangrove roots and appears on dowels at oiled sites over three years after the spill. Recruitment by *C. rhizophorae* has generally been low at both oiled and unoiled sites. Percent cover of oysters on mangrove roots converged at oiled and unoiled sites less than two years after the spill, partly because of a decrease in oysters at unoiled sites.

The false mussel *Mytilopsis domingensis* dominates mangrove roots in rivers and streams. It virtually disappeared from roots at oiled sites soon after the spill. Considerable oil still occurs on roots and appears on dowels at oiled sites over three years after the spill. There has been virtually no recruitment by *M. domingensis* at oiled sites and the assemblage has not recovered at all after over three years.

REEF FLAT COMMUNITIES

Populations of sea urchins and communities of algae and sessile invertebrates have been monitored on the reef flat at the STRI's marine laboratory at Punta Galeta for a number of years prior to the 1986 oil spill. This database is being used to compare abundances before and after the spill. After the spill, two unoiled sites and a second oiled site were established for comparisons. Data from these additional sites have shown that patterns observed at Punta Galeta are typical.

During the spill, sea level was at its seasonal low and oil accumulated along the seaward margin of reef flats. Organisms in this zone were smothered by crude oil at each low tide for many days after the spill. As a result, mortality of reef-flat organisms was greatest along the seaward margin.

The sea urchin *Echinometra lucunter* has been monitored monthly at the Galeta reef flat since 1978 and its numbers dropped at the seaward edge of the reef flat immediately after the spill. No such decline was measured farther inshore, away from the zone of heaviest oiling. While the numbers of this sea urchin have been highly variable through time, its decline after the spill was the largest recorded for this time of year.

Populations of gonodactylid stomatopods occur in intertidal beds of the seagrass *Thalassia testudinum*, and were studied before the spill, from 1979 until 1983. They live in cavities in coral rubble and fight aggressively for the limited supply of holes. Cavities are especially limiting for large individuals, and individuals of all sizes are forced to occupy cavities that are smaller than preferred. After the spill, two oiled and two lightly oiled sites used in the earlier studies were selected for semi-annual monitoring. Initially, there were significantly fewer large gonodactylids, particularly females, at the oiled sites. This selective die-off apparently occurred because females move into very shallow water to reproduce at the time of year that the spill occurred. As a result, surviving animals moved into larger cavities at oiled sites than before, carried fewer wounds and injuries, and grew faster. This initial shift in characteristics of populations at oiled sites diminished through time. Seagrass at one of the oiled sites died after the oil spill. About two years later, the matrix of dead rhizomes was breaking up and sediments were eroding. This erosion continued, and most of the seagrass habitat disappeared within three years of the spill. In addition, there has been exceptionally low post-larval recruitment of stomatopods at all sites since the spill. The spatial scale and cause of this change are not known.

Coverage of algae and sessile invertebrates were measured frequently at the seaward edge of the Galeta reef flat during 1983 and 1984 (less frequent measurements date to 1970), and quarterly measurements were started less than two months after the spill in 1986. The dominant space occupier in this zone is the foliose alga *Laurencia papillosa*. Immediately after the spill, nearly all organisms were killed where oiling was heaviest. This die-off was the most extreme observed, compared with mortalities after annually occurring reef flat emersions during the previous 15+ years. The microalgal bloom after the spill was much greater than usual.

The most extreme emersions of reef flats in continuous records since 1974 occurred in 1988, two years after the spill. The mortalities observed for most of the sessile organisms after these exposures were greater overall than those observed after the 1986 oil spill. However, unlike the die-off following the oil spill, which was concentrated at the seaward margin of the reef flat, the die-off after the 1988 emersions was greatest farther shoreward. Microalgal blooms after both die-offs were greatest where mortality was highest, i.e., low on the shore after the oil spill and high on the shore after the 1988 emersions. It is possible that aspects of the reef-edge community affected by the oil spill, such as grazing activity or allelopathic effects, had not returned to normal two years after the spill.

The seaward edge of the reef flat was the main habitat on the reef flat for corals, nearly all of which died after the spill. They have not recovered after over three years. The zoanthid *Palythoa* also has not recovered, although *Zoanthus* has. Poor recovery by certain sessile invertebrates may be due to the persistence of microalgae and the seaward spread of *Laurencia papillosa* into this most seaward zone after the spill. If rates of accretion at the seaward edge of the reef flat are depressed as a result, hydrographic and, therefore, biological processes over the entire reef flat may be affected.

SUBTIDAL SEAGRASS COMMUNITIES

Findings will be presented elsewhere in these Proceedings (M. Marshall). Epifauna and infauna were monitored for two years after the spill at oiled and unoiled sites. It appears that different invertebrate taxa responded in different ways to the spill (decrease, no change, or increase).

CONCLUSION

The 1986 oil spill in Bahia Las Minas caused an unexpectedly severe die-off of subtidal corals, as well as extensive mortality in intertidal populations. This may have been partly due to the large volume of the spill, and weather and sea conditions at the time of the spill, which confined the spilled oil mainly within Bahia Las Minas. The degree and distribution of intertidal oiling were determined also by the extreme low tides which characteristically occur at the time of year of the spill (Cubit et al. 1989).

Another surprising finding was the substantial reduction in coral cover at unoiled control sites during the years following the spill. This observation underscores the need for long-term monitoring in order to evaluate variation associated with a particular event (such as the oil spill) against naturally occurring variation. A similar pattern of reduced abundance of oysters on mangrove roots in unoiled channels and lagoons has also been observed since the spill, and the extreme exposure of reef flats in 1988 further support the importance of long-term monitoring.

Intensive monitoring programs, such as this one, may reveal patterns in distribution and abundance correlated with a particular event, such as an oil spill. However, understanding such patterns requires investigations of ecological processes, as well.

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Dr. Jeremy Jackson is chief scientist and collaborates with the study of subtidal reef corals. Scientists-in-charge of studies are: Dr. Kathryn Burns (hydrocarbon analyses, Bermuda Biological Station for Research, Inc.), Mr. Hector Guzman (subtidal reef corals), Dr. Norman Duke (mangrove forests), Mr. Stephen Garrity (mangrove roots, reef flat gastropods), Dr. John Cubit (reef flat communities and echinoids), Dr. Roy Caldwell and Dr. Rick Steger (reef flat stomatopods, University of California, Berkeley), and Dr. Michael Marshall (subtidal seagrass communities, Continental Shelf Associates, Inc.). Mr. Karl Kaufmann is the data manager. Dr. Jeffrey Brawn and Dr. Sally Levings are data analytical consultants. Mr. Ricardo Thompson is chief technician for the Environmental Sciences Program at Punta Galeta.

EFFECTS OF THE PANAMA OIL SPILL: HYDROCARBON CHEMISTRY

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The key component in assessing the impact of a chemical spill in the environment is to relate the observed biological changes with the presence of the toxic chemicals. Oil is a complex mixture of many hundreds of chemicals, most of which are hydrocarbons of various configuration. Crude and refined oils have been documented to be toxic to all components of marine ecosystems when exposed in catastrophic spills. The Bahia Las Minas oil spill of over 8 million liters of medium weight crude oil onto the Caribbean coast of Panama was documented to cause massive mortalities in mangrove, seagrass, and coral reef ecosystems (Jackson et al. 1989). Up to the time of this spill, the popular belief was that oil was not directly toxic to tropical reef ecosystems, except in cases of direct oiling in the intertidal zone or where dispersants transported oil to subtidal reefs. This Long Term Impact Assessment was thus launched with major studies in all three types of tropical coastal ecosystems. The objectives of the hydrocarbon chemistry program are to interface with the ecological studies to provide chemical evidence of exposure levels, to determine the variability of contaminating oil within habitats, and to study the diagenetic fate of the oil in terms of correlating the composition of residual fractions of the oil with the long term impact and recovery studies.

No single analytical method can be used to determine all of the components of oil in environmental samples in sufficient detail to address all of these objectives. Methods range from relatively inexpensive semi-quantitative optical techniques such as ultraviolet fluorescence spectroscopy (UVF) selectively sensitive to the aromatic hydrocarbons, through quantitative but less specific methods such as flame ionization gas chromatography, to extremely sensitive, selective, and expensive techniques such as gas chromatography/mass spectrometry (GC/MS). A sampling program necessary to meet the statistical requirements for characterizing the study sites was developed and a hierarchical analytical scheme providing the replication necessary to meet the requirements, and yet provide the analytical detail necessary to determine compositional details relevant to toxicity was implemented. Further details on the analyses and statistical protocols used in this study may be found in Burns and Knap (1989) and Jackson et al. (1989). Sampling was concentrated on substrates which would serve as long term reservoirs of oil in the coastal environment as well as provide information on toxic doses in each ecosystem. Analysis of samples collected in 1986 are complete. A second major sampling effort was carried out in 1988/1989 two years into the study.

The first analytical priority was to establish a dose response relationship between reduction in coral growth rate, physiological damage, and exposure to oil based on the content of hydrocarbons in the coral tissues. Results of analysis of oil in corals collected in 1986, five months after the oil spill, confirmed that corals take up petroleum hydrocarbons in proportion to the level of exposure from contaminated seawater (Burns and Knap 1989) (Table 11.1). Levels of petroleum hydrocarbons in coral tissues correlated with coral death and stress (Jackson et al. 1989). In addition to providing preliminary evidence that analysis of coral tissue could establish quantitative dose/response relationships with the biological measurements of damage, the data provided preliminary evidence for the effects of the oil on the lipid biochemistry of the corals. This was shown by a change in the lipid to protein ratios of oiled versus non-oiled corals. This observation agrees with other studies of the effects of oil on coral reproduction and energetics. Disruption in lipid biosynthesis is expected to have cascading impact on other components of the coral reef ecosystem which depend on the corals for food and protective substrate. With this rationale, the impact of the oil on the lipid composition of the coral tissues will be assessed in addition to oil content as part of the long term assessment study.

Analysis of surface sediments in mangrove, seagrass, and coral reef ecosystems confirmed the relative severity of oiling at the various study sites determined visually. Oil in mangrove sediments reached 25% of the dry weight in heavily oiled areas. The oil extracted from the heavily oiled mangrove sediments was used to construct the calibration curve for the UVF determinations. This proved more quantitative than using the original, unweathered oil as the calibration standard when results were compared with GC analysis. As will be shown below, this is due to differential rates of weathering of the aromatic and aliphatic hydrocarbons. Mangroves were classified as heavily oiled when sediment concentrations ranged from thousands to hundreds of thousands ug/g dry wt, as moderately oiled in the 1,000 ug/g range, as lightly oiled in the hundreds, and as unoiled in the less than 100 ug/g dry wt range (Table 11.2). The scales for the seagrass sediments were thousands for heavily oiled, hundreds for moderately oiled, and less than 100 ug/g dry wt for lightly to unoiled. The carbonate sediments of the coral reefs retained an order of magnitude less oil in their relative classifications. These rankings were later confirmed by the biological data.

Depth cores in the mangroves taken in 1986 showed that despite heavy oil concentrations in surface sediments, only in exposed seaward areas had oil penetrated in high concentration to deeper layers. This situation had changed by the second sampling conducted in 1989 where oil was observed to have penetrated to deeper core layers down channels created by rotting mangrove roots.

The variability in spatial distributions of oil was demonstrated with the replicate UVF analysis of surface sediments. For samples analyzed both by UVF and the more quantitative GC procedure there was significant correlation between the results (Figure 11.1). Thus either method can be used to rank exposure levels based on sediment oil content.

GC analysis indicated that even in heavily oiled mangroves, the oil residues were extremely degraded by the processes of evaporation, dissolution, and microbial and photodecomposition within 5 months after the oil spill. Figure 11.2 contrasts the GCs of the original oil with oil in seawater suspended in the water flowing off of heavily oiled mangroves in 1986. The low boiling hydrocarbons are missing and the resolved alkanes had been degraded leaving a pattern of residual high boiling, unresolved hydrocarbons with the bimodal distribution characteristic of highly degraded crude oils. Sediments even in heavily oiled, anoxic mangroves were also highly degraded. Figure 11.3 shows the concentrations and patterns in surface and deep mangrove sediments in 1986.

Table 11.1. Oil content in coral tissues estimated as unresolved saturated hydrocarbons. (Concentrations of petroleum hydrocarbons expressed as mg URE/g lipid, protein to lipid ratios, and overall assessment of severity of reef oiling based on tissue analysis of reef building corals. URE is the GC signal generated by the complex mixture of hydrocarbon residues which cannot be resolved into individual peaks. This is a conservative estimate of "petroleum" hydrocarbons in samples.)

Reef (Genus)	URE mg/g lipid	Protein / Lipid	Oiling Severity
Palina West			Unoiled
Siderastrea	1.0	4.6	
Agaricia	0.3	2.5	
Narajos South			Light-Moderate
Siderastrea	1.4	4.3	
Agaricia	0.4	2.6	
Galeta Channel			Heavy
Siderastrea	2.5	4.2	
Agaricia	2.8	4.5	
Payardi North			Very Heavy
Siderastrea	5.1	6.1	
Agaricia	8.3	6.4	

Table 11.2. Oil content in surface sediments collected 5 months after Bahia Las Minas oil spill (ug/g dry wt).

Ranking:	Heavy	Moderate	Light	Unoiled
Mangroves	>200,000 to >2,000	<2,000	<1,000	< 200
Seagrass	>2,000	<2,000	< 100	--
Coral Reefs	< 300	< 200	< 50	--

The surface residues are in an intermediate stage of degradation with a few alkanes still visible in the saturated hydrocarbons fraction and many resolved peaks in the aromatic fraction. The bottom sediments showed an even more degraded residue. All of the other oiled mangrove, seagrass, and coral reef sediments had patterns ranging between these extremes. Mass spectrometry analysis confirmed that the volatile aromatic hydrocarbons were missing from the sediments collected five months after the spill. The important conclusion from this preliminary data set, is that the rate of degradation of oil residues in tropical ecosystems is much faster than has been observed in temperate areas. Reaching this level of degradations requires on the order of one to two years in temperate salt marshes.

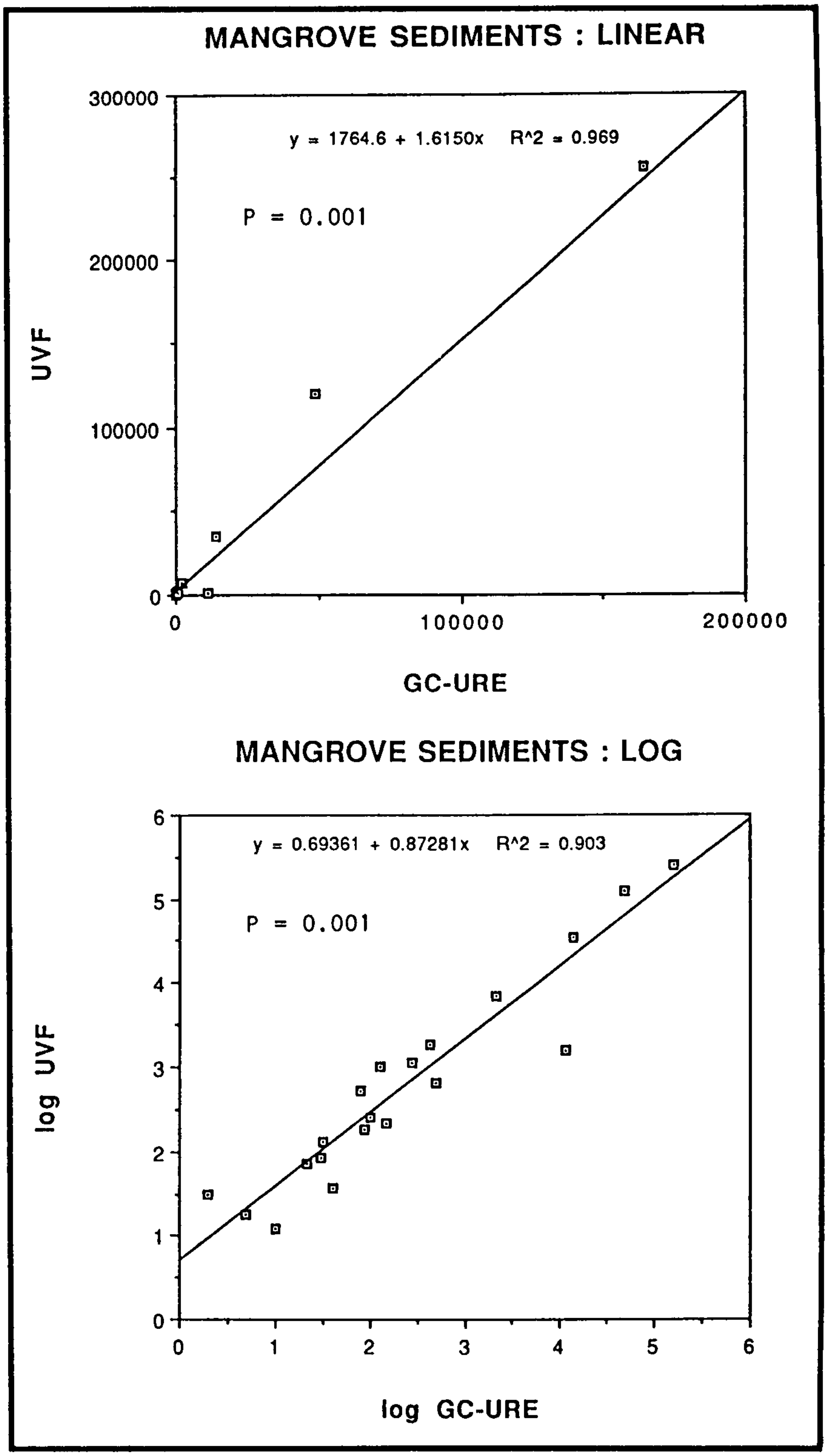

Figure 11.1. Relationship between petroleum hydrocarbons determined by gas chromatography and ultraviolet fluorescence spectroscopy. (Units are ug/g dry wt [top] and Log ug/g dry wt [bottom]. P is the level of significance.

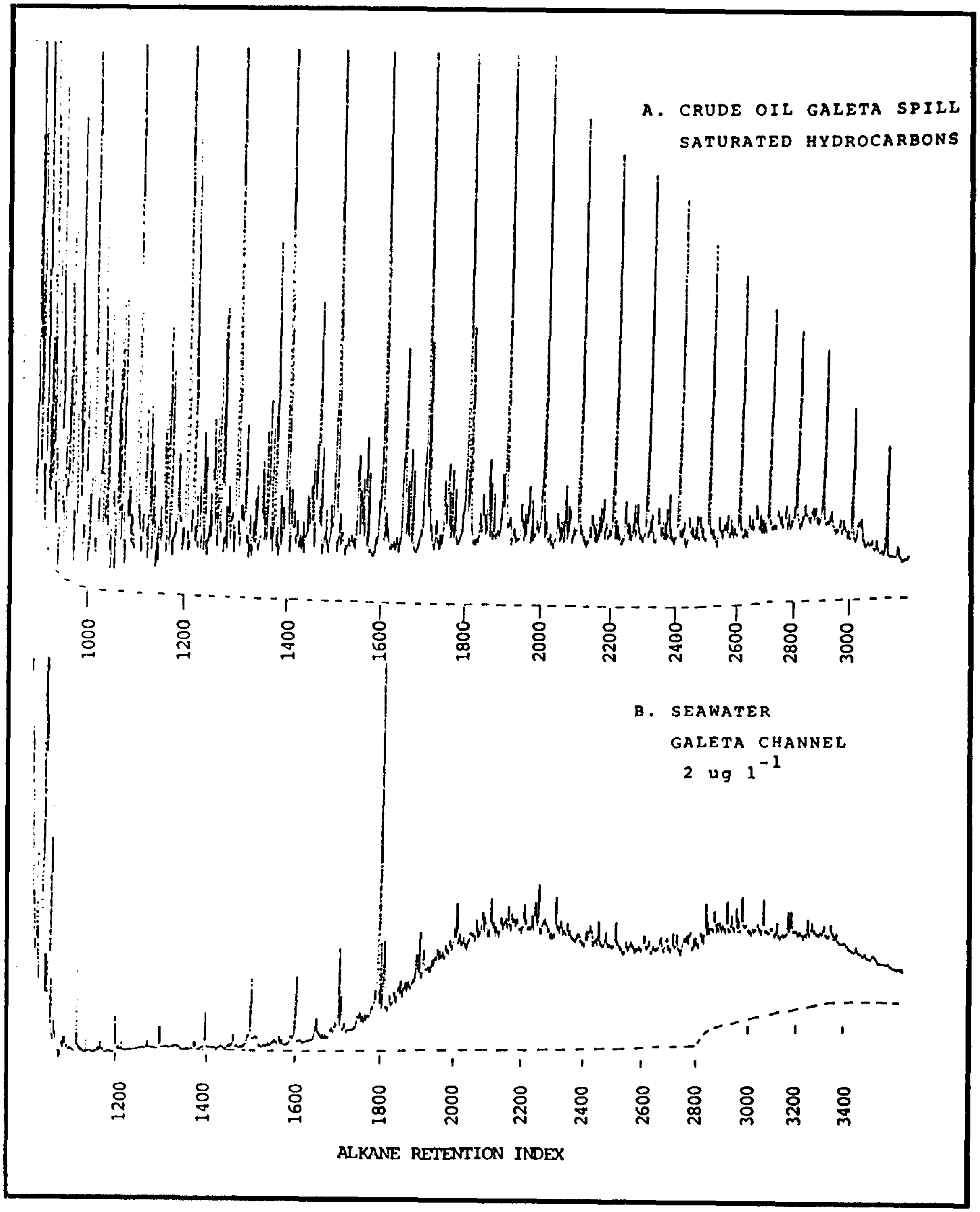

Figure 11.2. Gas chromatograms of saturated hydrocarbons in Galeta crude oil and suspended in seawater near mangroves in Galeta Channel, September 1986.

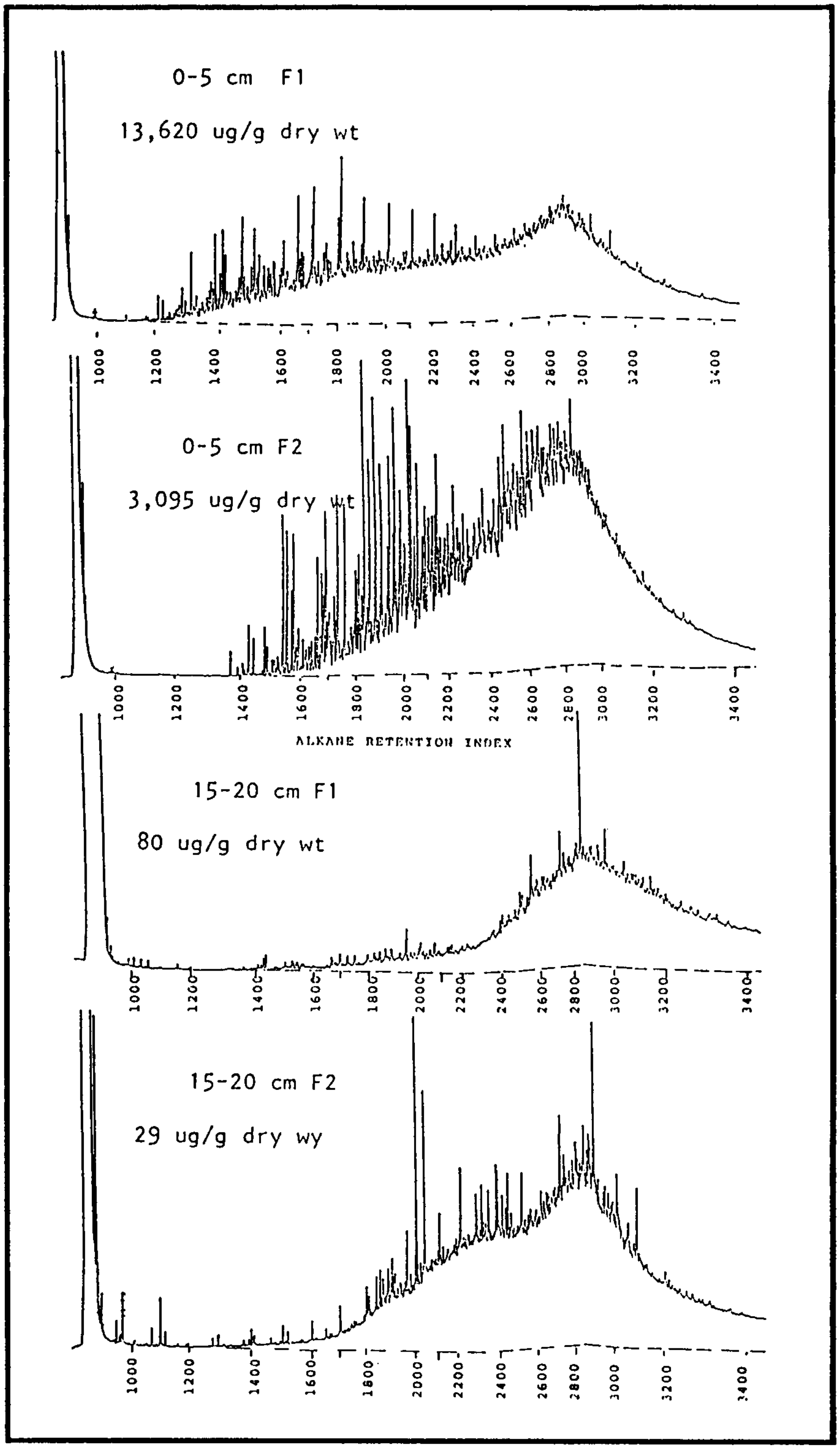

Figure 11.3. Gas chromatograms of F1 saturated and light aromatic hydrocarbons and F2 aromatic hydrocarbons in mangrove sediment cores. (Station LRRN, September 1986.)

While the mangroves will remain significant sources of contamination to the offshore seagrass beds and coral reefs as the oil is flushed out during storm events, the oil being released is highly modified in composition compared to the originally spilled crude. The traditional indices of degradation such as the ratio of isoprenoid to n-alkane peaks is not applicable to this study. Oil residues were so degraded even five months after the oil spill that the more sophisticated methods of petroleum identification based on stable biomarkers visible by selected ion monitoring in GC/MS analysis were necessary for positive identification of some of the samples back to the Galeta crude.

To illustrate this point further, the UVF spectra of the aromatic hydrocarbons for the same cores (Figure 11.3) indicate that as the oil weathers, the relative contribution of the smaller ringed aromatics with emission maximum at approximately 370 nm decreases relative to the contribution by the heavier ringed structures with emission maximum at approximately 410 nm (Figure 11.4). This phenomenon could be due to the dissolution of the more soluble lighter aromatics, or to the production of compounds with longer emission wavelengths. Fractionation of the residues into hydrocarbon classes by high performance liquid chromatography and then reanalysis by UVF shows both processes are operating (Figure 11.5). The degraded oil residues in the surface sediments of heavily oiled mangroves showed a larger contribution of compounds fluorescing at higher wavelengths in the fractions containing the oxidation products of the aromatic hydrocarbons F4 and F5 (Oxygenates). Since these compounds have different spectral emission bands than the original oil, it is necessary to calibrate the UVF analysis with similar compounds. An oxygenated PAH standard will be used to estimate the content of O-PAHs in selected samples.

The questions for the long term assessment are thus focused not only on the amount of residual oil in the mangrove and other sediments, but also on the composition of this residue and how it relates to toxicity in the ecosystem. The little toxicity data on oxygenated PAH which exists to date, indicates that the oxidation products are at least as environmentally hazardous as the parent hydrocarbons (discussed in Widdows et al., in press). Thus, the UVF determinations will be crucial in estimating the total dose of toxic hydrocarbons and products from oiled sediments. This will be semi-quantitative information on fractions not easily analyzed even by GC/MS methods.

Oil residues in bioindicator organisms such as the mussels and oysters that are recolonizing the mangroves are being measured on a quarterly basis. Bivalves tend to selectively absorb the lighter aromatic hydrocarbons while the nearby sediments show the heavier components. An example of the GC patterns seen in oysters compared to sediments for station MACN is shown in Figure 11.6. This was the only site that was significantly contaminated by a heavy fuel oil residue in addition to the Galeta Crude in 1986. No living bivalves were found in the mangroves heavily oiled in 1986, so a similar comparison could not be made. Bivalves are extremely useful indicators of oil contamination in the water column, in the sublethal concentration range (Burns and Smith 1981). Thus they will be useful in continued ranking of dose levels, although in the lightly to moderately oiled areas, the ranking based on sediments and bivalves may vary slightly due to the differential solubility of hydrocarbons and the selective bioaccumulation phenomenon. It is expected that the bivalve chemistry data will correlate with the biological measures of growth, reproductive success, and survival not only of the bivalves themselves, but of the populations of other organisms recolonizing mangrove roots.

In summary, the aims of these chemistry studies are: (1) to construct a model for the rates of degradation and dispersion processes of contaminating oil hydrocarbons in tropical environments compared to similar models derived in temperate regions; and (2) to provide dose estimates of toxic aromatic hydrocarbons and their oxidation products to correlate with the biological studies in the long term assessment of the Bahia Las Minas spill.

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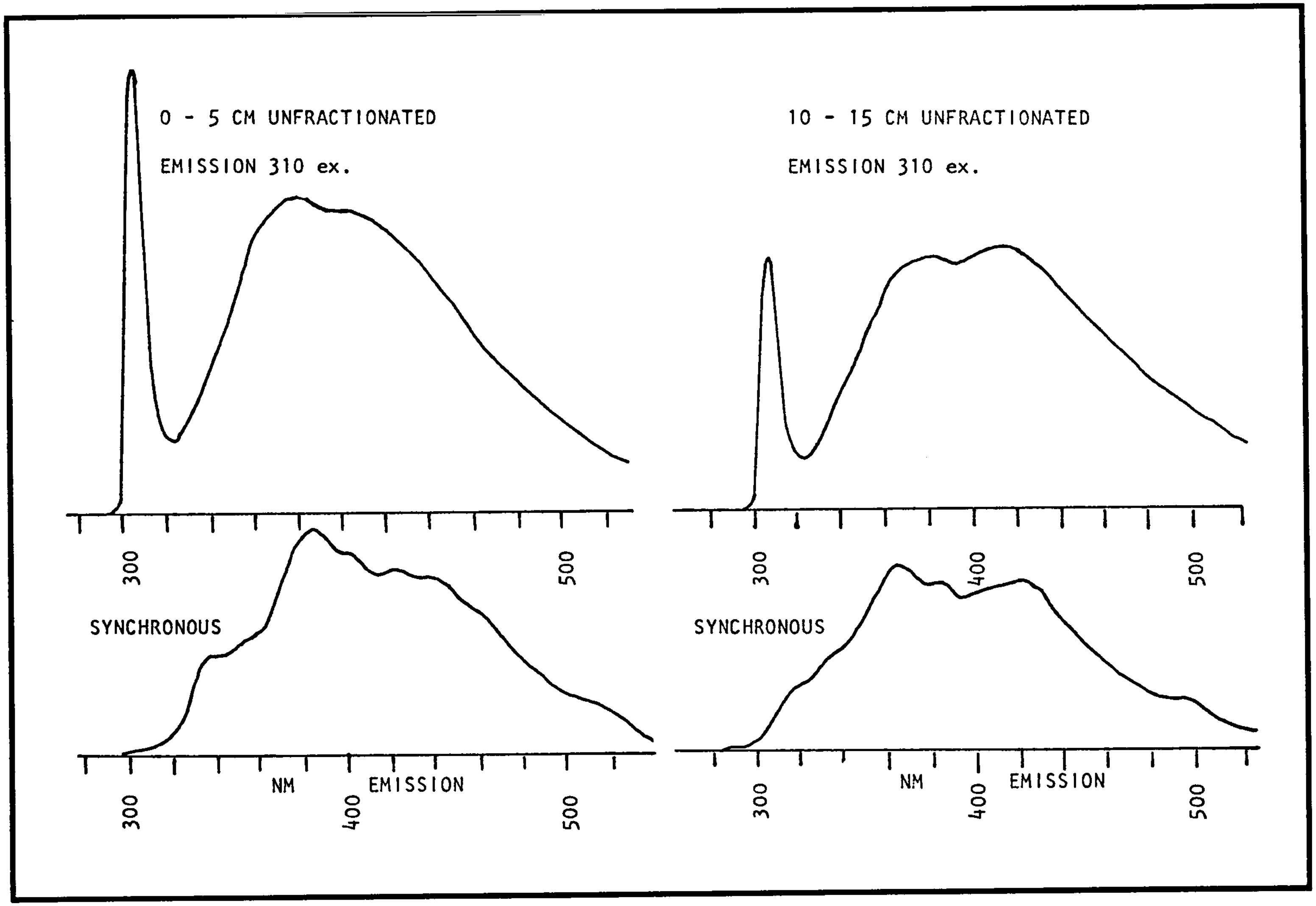

Figure 11.4. Emission and synchronous excitation/emission spectra of aromatic hydrocarbons extracted from mangrove sediment cores. (Station LRRN, September 1986.)

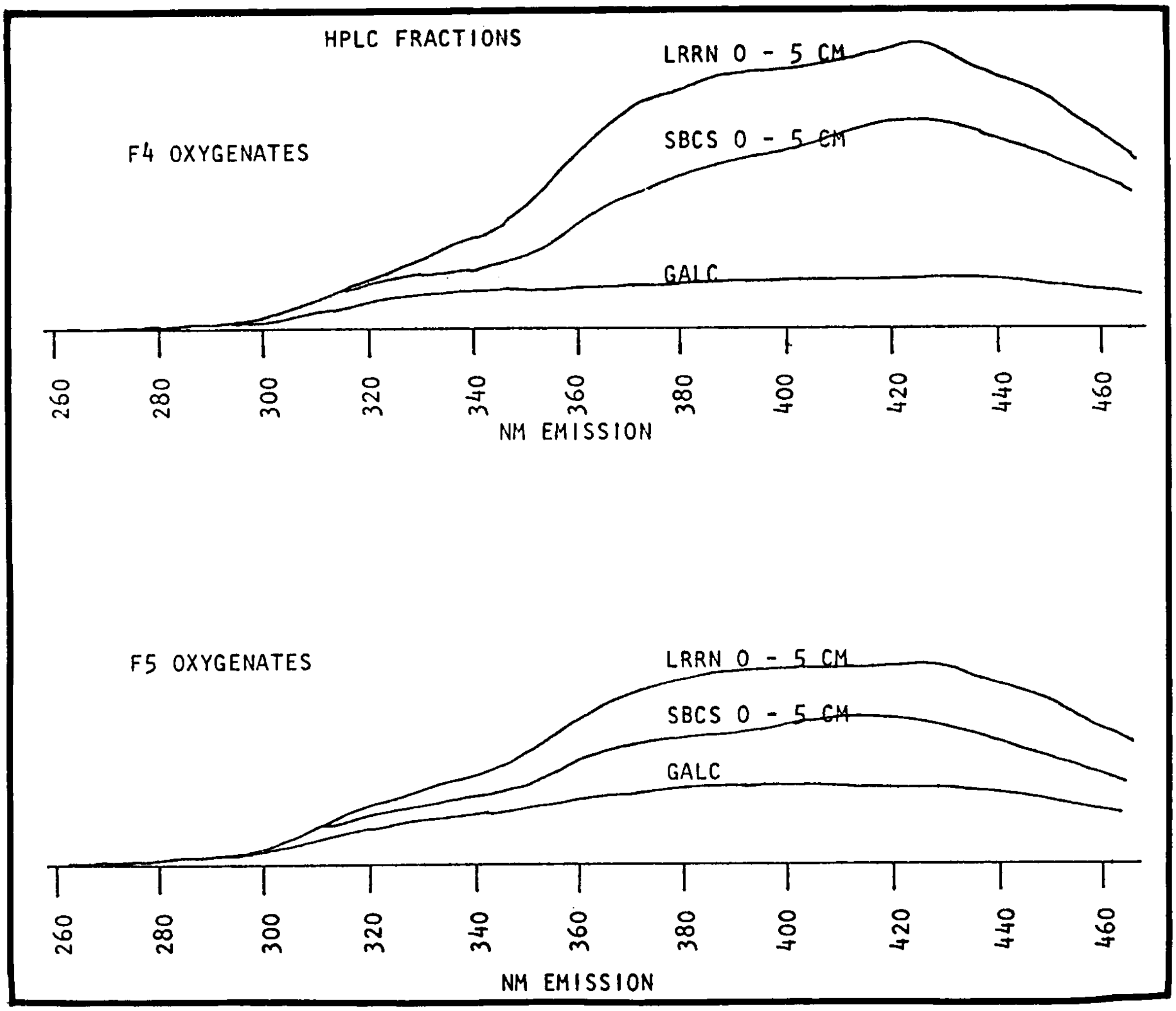

Figure 11.5. Synchronous UVF spectra of GALC and extracts of mangrove sediments.

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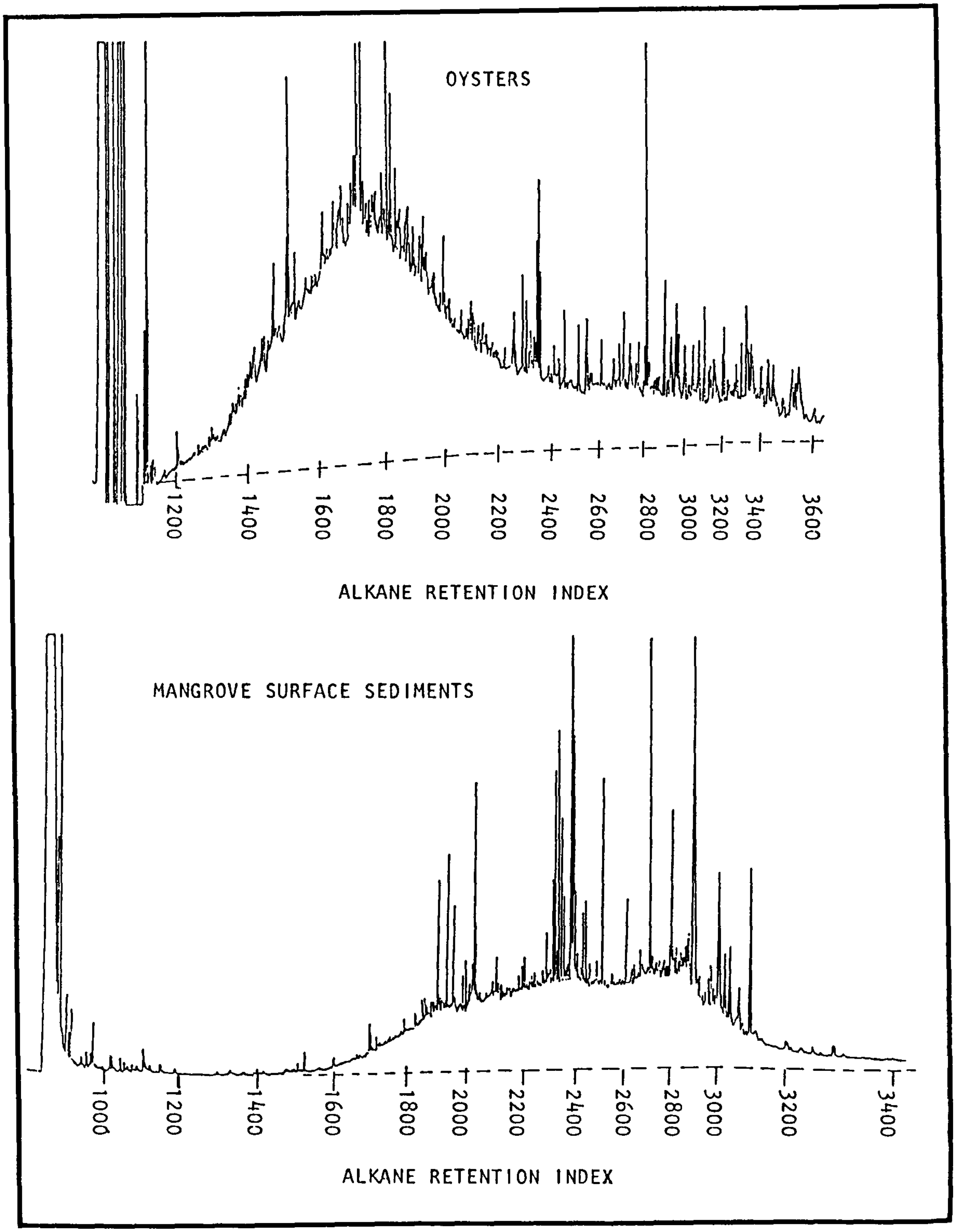

Figure 11.6. Saturated hydrocarbon gas chromatograph traces.

in Monaco and is currently an associate scientist at the Bermuda Biological Station for Research. Dr. Burns has been the chair of the IOC/UNESCO Group of Experts on Methods, Standards, and Intercalibration's subgroup on Organic Contaminants since 1982. Dr. Burns is Scientist-in-Charge of the hydrocarbon subproject of the Panama Oil Spill study being conducted by the Smithsonian Tropical Research Institute for the Minerals Management Service.

PROJECT OVERVIEW: PANAMA OIL SPILL

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The Bahia Las Minas Oil Spill Study is unique among Minerals Management Service (MMS) programs in two aspects which need to be acknowledged prior to application of the findings to management concerns. First, and most importantly, it is what might be called a surrogate study. MMS is supporting this project well outside of the U.S. Outer Continental Shelf (OCS) to take advantage of a spill in an environment with some similarities to South Florida. Second, it is a true process study in the spirit of MMS announced intentions to emphasize such studies (see Aurand 1988).

The use of surrogates is an excellent idea. While most of the U.S. is a temperate climate; oil and gas operations are and will continue to be considered in both U.S. arctic and tropical-subtropical environments. Management information needs for these environments can often be efficiently obtained through projects in other countries having similar coastal climates. However, use of surrogates should also include an explicit and well planned effort to establish the exact similarity to the U.S. region of concern. In this case, Panama is similar to South Florida in some ways but differs in others. The Bahia Las Minas study is producing results which have already had an influence upon concerns in South Florida (e.g., National Research Council 1989), yet there has been no effort thus far to determine the full applicability of these results.

Fortunately, the Bahia Las Minas study is a process-oriented study. Whatever the differences between Panama and Florida in terms of fauna and flora, basic processes in mangroves, coral reefs, and grass beds are fundamentally similar. As a consequence, comparison between the two systems should be easy to make, and the limits of applicability fully disclosed.

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EFFECTS OF OIL SPILLS ON MANGROVES AND OTHER WETLANDS

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INTRODUCTION

The principal wetland vegetation of the Gulf of Mexico generally consists of the submerged seagrasses and emergent mangroves and saltmarsh grasses. The coastal wetlands of the Gulf are valuable because they provide the primary productivity that is the source of energy for ecosystems responsible for the major economic species of finfish and shellfish. They are also important because they stabilize shorelines and provide habitat for a variety of species.

Mangroves are the trees and shrubs that grow along low energy tropical and subtropical marine shorelines of the world. Mangroves are a botanically diverse group that have in common only that they can grow successfully in saline environments that are hostile to upland plants. Three species of mangroves are found along parts of the shore of the Gulf of Mexico: *Rhizophora mangle*, the red mangrove; *Laguncularia racemosa*, the white mangrove, and *Avicennia germinans*, the black mangrove. The red, white, and black mangroves grow along southern peninsular Florida, extending as far north as Cedar Key (Davis 1940), where they are killed by cold every few years. From Tampa northward all three species of mangrove are found to be progressively smaller in stature. The black mangrove, more cold tolerant than the other two species, has been reported to extend in Florida as far as Ile de Chien at the western end of Appalachee Bay (Sherrod and McMillan 1985). Black mangroves are found in Louisiana from the Mississippi River delta westward along the Texas and Mexican coasts. All three species are found in Mexico south of La Pesca, 300 km south of the Texas border. Although black mangrove propagules are washed ashore on the islands of Mississippi Sound, the species has not become established, apparently because of the frequency and severity of cold winter conditions (Sherrod and McMillan 1985). Similarly, viable red mangrove propagules are found along Texas beaches, but no naturally established plants have been observed from this beach drift. Planted red mangroves at South Padre Island reached reproductive size before being killed by the subfreezing conditions in December of 1983 (Sherrod et al. 1986).

Mangroves are able to outcompete saltmarsh grasses along southern and central peninsular Florida, but saltmarsh grasses, which have much greater cold tolerance than mangroves, are increasingly the dominant emergent vegetation form farther north where mangroves are limited by temperature. As Harshberger (1914) noted, mangroves are found in areas of tropical coasts that would be occupied by saltmarshes on temperate shores. The dominant saltmarsh grass species are *Spartina alterniflora*, smooth cordgrass, which extends the length of the Gulf coast, and *Juncus roemerianus*, the black needle rush, which is an important component of the saltmarshes along the northern central Gulf.

The Gulf of Mexico is subject to heavy traffic by ships carrying a wide range of crude oils and refined products as well as being the site of extensive oil drilling and production operations. Although numerous oil spills have occurred in the Gulf, there have, fortunately, been no spectacular large spills that have killed mangroves.

This report will cover effects of oil on mangroves, mangrove protection and restoration, with minor reference to oil effects on saltmarshes. Seagrasses are the topic of a paper in this series by another author.

OIL AND MANGROVE PHYSIOLOGY

Historically, mangroves were derived from land plants that developed adaptations to live in a saline environment where the soils are anaerobic. The internal cellular milieu of mangroves is not much more saline than that of other land plants. Mangroves are able to grow in saline environments because they can obtain low salinity water through their subsurface roots which have membranes that exclude much of the salt of seawater. Mangrove root membranes function like the industrial reverse osmosis membranes that are used to obtain potable water from seawater. The energy for the industrial process is provided by high pressure pumps. In mangroves the energy for deriving low salinity water from seawater is solar energy, which operates through evapo-transpiration

(Scholander 1968). Red mangroves have relatively more efficient root membranes than do the black and white mangroves, but the latter two species have salt excretion glands on their leaves by which they rid themselves of salt passed by their less efficient root membranes. Metabolic energy is involved in the excretion of salt by the salt glands (Scholander 1968).

The root membranes of mangroves are readily damaged by light oils, especially those with a high content of aromatic hydrocarbons. Membranes damaged by oil allow salt to enter the plant, which probably accounts for mangrove mortality following spills of light oil. It has been found that red mangroves that were exposed to sublethal amounts of oil showed increased amounts of sodium from seawater in their leaves (Page et al. 1985).

Root membrane damage requires contact of the oil with subsurface roots. In one spill, aviation jet fuel was floating on the water and in contact with red mangrove prop roots for a period of hours. No damage was done to the trees; because the oil did not reach the soil and therefore did not penetrate to the subsurface roots. However, there was extensive mangrove mortality at a site several km distant, where the same jet fuel soaked into the soil (Teas unpublished).

Anaerobic soils pose a special problem for mangroves. Ordinary land plants obtain the oxygen they require for their roots by diffusion through the soil. Mangroves, which grow in anaerobic soils, have special adaptations to supply oxygen to their subsurface roots. All three Gulf species of mangroves have snorkel systems which connect the subsurface roots to openings (lenticels) above the soil. In the red mangrove the lenticels are located on the prop roots; on the white mangrove they are found on pneumatophores and the lower trunk; and on the black mangrove they are on the pneumatophores. Pneumatophores are finger-like vertical projections from subsurface lateral roots; they are exposed to the air at low tide. The lenticel openings to the atmosphere are covered by clusters of microscopic waxy spheres that allow air to penetrate at low tide, but, because of surface tension, exclude water at high tide. Simple diffusion of air from the lenticels to the tips of subsurface roots, which may be a distance of one to two meters, could not occur rapidly enough for the roots to survive. However, the mangrove subsurface roots are provided oxygen by air that enters through the lenticels. The flow of air to the roots is caused by the negative pressure that develops from oxygen uptake in the roots. The carbon dioxide formed metabolically in the roots is approximately 60 times as soluble as oxygen and diffuses into the surrounding water.

The lenticel openings which allow air to reach the roots have been characterized as the "Achilles heel" of mangroves (Odum and Johannes 1975). If lenticels become covered by viscous oil, such as heavy crude oil, Bunker C fuel oil, or weathered oil, the oxygen supply of the subsurface roots may be blocked and the roots may die of asphyxiation. Red mangroves have been killed experimentally by coating their prop roots (and thus all their lenticels) with petroleum jelly (Teas unpublished).

EXAMPLES OF EFFECTS OF OIL ON MANGROVES

The Gulf mangrove species are sensitive to oil. Mangroves of all three species were killed by the Refineria Panama spill on the Atlantic coast of Panama in 1986 (Teas unpublished), and by a small spill within Tampa Bay from the vessel Howard Star (Lewis 1983).

As Macnae (1968) noted, often when mangroves are clearcut or removed, mangroves do not become reestablished at the site. One of the factors involved is the change of substrates. When mangroves die their near-surface roots die and no longer hold sediments. This may result in erosion of shorelines so that they become unsuitable for mangrove reestablishment.

Another effect of oil killing mangroves is that fallen branches, trunks, and prop roots may restrict the normal distribution of waterborne propagules that would initiate regeneration of the forest. Such inhibition of propagule distribution was noted in St. Croix by Lewis (1983) where little regeneration had occurred seven years after the vessel Santa Augusta spill. At the Refineria Panama spill site, successful replanting was carried out six months post spill and beginning natural regeneration was observed approximately two years post spill (Teas et al. in press).

THE ROLE OF DISPERSANTS IN GULF OIL SPILLS

Mangroves have been shown to be protected from spilled oil if the oil is dispersed before contact with the trees. Teas et al. (1987) and Ballou et al. (1989) reported sparing of red mangroves in experimental plots by dispersing oil. Lai and Feng (1985) found reduced mortality in *Avicennia* mangroves in Malaysia from dispersed compared to undispersed oil, and Wardrop (1987) reported reduced defoliation of *Avicennia* mangroves where the oil was mixed with dispersant before application to the trees. The *Avicennia* mangroves in Malaysia and Australia are other species of the Genus, but are closely related to the Gulf of Mexico black mangroves. The mechanism of mangrove sparing by oil dispersion appears to be that the dispersed oil is flushed out by the tides rather than (as undispersed oil) making lethal contact with the mangroves root membranes or coating lenticels (Lai and Feng 1985).

Because of the value of mangroves for their primary and secondary productivity and for shoreline protection, coupled with the long period of time for mangroves to regrow (20 or more years), dispersants should be considered for use in Gulf oil spills that threaten mangroves, especially where dense stands of mangroves are involved.

RESTORATION PLANTING OF MANGROVES

Hand planting of mangroves is a long established procedure in silviculture. It was recommended by Watson (1928) for accelerating regeneration of clearcut mangrove forests. It has been little used for mangrove restoration after oil spills, although Lewis and Haines (1980) reported having planted 6.15 ha of mangroves in St. Croix, a portion of which was to restore mangroves killed by the Santa Augusta oil spill approximately seven years earlier.

The largest post oil spill restoration planting reported to date was that carried out in Panama at the site of the 1986 Refineria Panama spill. Teas and co-workers (Teas et al. 1989a; 1989b) reported tests on a variety of techniques for replanting red mangroves in the oiled substrate of killed mangrove forests. Replanting experiments were initiated at six months post spill when considerable oil was still present in the soil. A successful technique that was developed was planting red mangrove nursery grown seedlings or propagules in holes filled with upland soil. This upland soil protected the young roots from early contact with oiled soil, provided the roots an opportunity to grow deeper into the soil where the oil content was lower, and provided time for the oil to weather to a less toxic form before the roots grew into oiled soil. Almost all of the approximately 75 ha of the oil killed mangrove forest at the site of the Refineria Panama spill was replanted.

SALT MARSHES AND OIL SPILLS

Saltmarshes often act as oil traps because they occur at low energy sites where they are protected from wave and current action and because the thick vegetation offers a large surface for oil absorption. Oil spills sometimes kill smooth cordgrass marshes. Evidence suggests that oil may interfere with oxygen passage through the plant into the roots (Baker 1979). Techniques for saltmarsh establishment are well known; they have been carried out at many sites in conjunction with coastal erosion programs.

RESEARCH NEEDS

Although black and white mangroves are killed by oil spills, there have been few tests of their sparing by dispersion of oil. Especially needed are tests with all three species using relatively non-toxic dispersants which might be more acceptable because of reduced impact on other species.

SUMMARY

The wetlands of the Gulf of Mexico consist of seagrasses, saltmarsh grasses, and mangroves. The lower temperature limits restrict plant size and species distribution. Mangroves, which grow with their roots in saline anaerobic soils, have root adaptations by which they exclude salt from entering the plants. Mangroves also have special "snorkels" that operate through lenticels on prop roots or pneumatophores that provide oxygen to their subsurface roots. Oil can kill or stress mangroves by damaging root membranes or by blocking lenticels. Oil also inhibits passage of air to the roots of saltmarsh grasses (Baker 1979).

Oil killing of mangrove forests and saltmarshes may induce erosion and cause loss of productivity and habitat that seriously impact economically important fishery resources as well as threatened and endangered species.

Dispersion of oil has been found to spare some mangroves from oil killing. It is recommended that, because of the many years required for the regrowth of mangroves, the dispersion of oil be considered for treatment of oil spills that threaten mangroves.

Techniques are available for replanting mangroves and saltmarsh grasses. It is recommended that after oil killing of these communities they be restored as soon as possible by replanting.

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EFFECTS OF OIL SPILLS ON SEAGRASSES

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The damage to seagrass communities by oil spills has usually been dismissed as insignificant. It has been assumed that oil slicks floating on the sea's surface would have little if any effect on subtidal grassbeds. Here the older anecdotal evidence suggesting that oil has little effect on grassbed communities and the more recent evidence which suggests that spilled oil can significantly impact seagrass communities is reviewed.

Chan (1976) reported that oil clingage (a mixture of oil and water), pumped from the tanker Garbis near the Marquesas Keys, Florida, floated over grassflats during high tides between Boca Chica Key and Little Pine Key, without noticeable effects on *Thalassia testudinum*, *Syringodium filiforme*, or *Halodule wrightii*. However, empty but still articulated shells of *Pinctada radiata*, a pearl oyster common in Keys' grassbeds, accumulated on beaches soon after the Garbis incident. The mass mortality of these organisms was attributed to the oil. No other observations were made in the subtidal grassbeds.

Diaz-Piferer (1964) reported the "degeneration" of *Thalassia* meadows resulting from the 1962 spill from the Argea Prima, but described neither the magnitude of the damage nor the depth ranges of the grassbeds. Panamanian grassbeds were oiled in 1968 with fuel oil from the tanker Witwater but the effects of this oiling were not examined (Rutzler and Sterrer 1970). Crude oil from the tanker Zoe Colocotonis caused *Thalassia testudinum* leaves to blacken and to eventually be shed (Nadeau and Bergquist 1977). Plant rhizomes were apparently not killed since new seagrass growth was seen in the oiled areas within 10 months of the spill. While infauna were not significantly affected, various larger invertebrates were killed and quickly washed ashore.

The only other reports of oil damages to seagrass communities are those to French *Zostera marina* beds oiled by the Amoco Cadiz spill (den Hartog and Jacobs 1980; Jacobs 1980) and to *Thalassia* meadows oiled by the rupture of a refinery tank in Panama (Jackson et al. 1989; Marshall and Batista, In prep.). In each incident, changes in plant biomass were monitored and infaunal and epifaunal assemblages intensively sampled. The most noticeable differences between prespill and postspill grassbeds (France) and unoiled and oiled grassbeds (Panama) were large decreases in the abundances (France) and the virtual absence (Panama) of several orders of small crustacea and all classes of echinoderms.

While a heavily oiled intertidal grassbed was destroyed in Panama, this was not the case in France. In Panama, after the dead intertidal grassbed decayed, sediments were washed away exposing a bare rock platform. Seagrass leaves, in the oiled subtidal grassbeds of both France (at 0.5 to 4.0 m below MLWN) and in some areas of Panama (from approximately 0.75-2.0 m depth), blackened and were shed. No seagrass mortality was observed in France but the landward-most edges of heavily oiled, subtidal seagrass meadows in Panama have receded several meters since the spill (Marshall, personal observation). Seagrass biomass samples, from randomly selected sites within each grassbed, have not yet been fully processed to ascertain whether seagrass biomass was affected by the oiling.

In Panama, the infaunal groups which seem to have been most strongly affected by the oiling included polychaeta, amphipoda, tanaidae, brachyura, and sipunculida (see graphs in Jackson et al. 1989). Bivalvia, gastropoda, and ophiuroidea were not found to be significantly different in abundance between oiled and unoiled sites. However ophiuroids and other echinoderms were virtually absent from oiled grassbeds during the first two years of monitoring. Paguroidea became more abundant in oiled grassbeds and, as noted by Jackson et al. (1989), this is the first time that such an oiling effect has been recorded for certain infaunal groups in seagrass meadows. Epifaunal groups which may have been negatively affected by oil, as suggested by their distribution patterns across oiled and unoiled grassbeds, included amphipoda, certain species of shrimp, and grassbed-resident fishes (including scarids [parrot fish], gobies, and blennies). Since these observations were based on comparisons between oiled sites and unoiled sites it was necessary, in order to determine if there was a definite initial impact, to follow temporal changes in abundances by long-term post-spill surveys in order to monitor "recovery." If there is no convergence in community composition then it will be difficult to define the extent of the "initial" impact. Post-spill surveys were conducted bimonthly from September 1986 through January 1987 and then quarterly from January 1987 through April 1989.

The preliminary results of the studies underway in Panama suggest that oil can significantly impact *Thalassia* meadow communities. This is particularly true for intertidal and shallow, subtidal grassbeds. Grassbeds in areas adjacent to reef crests or near other areas where waves break may be exposed to oil-in-water emulsions entrained by the action of breaking waves. Most tanker spills occur during inclement weather when sea states would most likely facilitate the formation of emulsions (Bak and Elgershuzien 1976).

Suspended sediment and organic matter concentrations may also be elevated during rough weather or during rainy seasons. Oil droplets commonly adhere to such materials and sink (The International Tanker Owners Pollution Federation LTD. 1986). Since one of the ecological roles of seagrass meadows is that they trap fine particles of sediment (Zieman 1982) they may also act as traps for these sinking oil droplet/sediment particles.

In Panama, large quantities of oil were buried within the sediments of seagrass meadows as confirmed by hydrocarbon analyses (see paper by Burns this session) and by the formation of surface slicks whenever the sediments were disturbed. Dissolved hydrocarbon fractions may be very toxic but their residence time in grassbeds should be very short (when flushing rates are high) as compared to the sedimented oil fractions. Oiled sediments within mangrove forests may also be a major source of chronic hydrocarbon pollution for nearshore tropical seagrass meadows. In Panama, slicks originating from oil buried in mangrove sediments, are still frequently seen floating over seagrass beds and coral reefs.

Historically, it may be that the effects of oil spills on grassbeds have been overlooked since, in most cases, only small portions of the seagrass beds have ever been killed. The monitoring of the effects of oil spills on grassbeds requires that all components of the community associated with the seagrasses be monitored. Highly diverse assemblages of small animals are associated with *Thalassia* meadows. While many of these small animals are juveniles of commercially important species (Rutherford et al. 1989), the other, noncommercially important species may be of an equal value since they are the link between the commercially important species and the primary productivity of the seagrass meadows (Carr and Adams 1973; Leber 1983; Marshall 1985).

FIELD EXPERIMENTATION

An API dispersant project (Ballou et al. 1987) conducted in the Laguna de Chiriqui, Panama, has been the most comprehensive field experiment to date on the effects of oil and dispersed oil on the fauna and flora of mangroves, seagrasses, and coral reefs. Each habitat was monitored in pre- and post-treatment sampling programs. The purpose of the project was to determine whether the use of chemical dispersants would reduce or intensify the adverse impacts of oil spills upon sensitive tropical environments. The experimental approach was intended to simulate a "severe, but realistic, worst-case scenario" of two large spills of fresh crude oil in nearshore waters: one treated with a chemical dispersant and the other left untreated. The dispersant treatment utilized a protocol that is not recommended in present day dispersant-use strategies. Dispersants are typically used only on oil slicks far offshore and over deep water. That this procedure is not always followed was demonstrated when about 21,000 liters of Corexit 9527 were used to treat oil slicks located just offshore from the Bahia Las Minas, Panama, in an area of shallow coral reefs, seagrass meadows, and tropical mangrove forests (Cubit et al. 1987).

The API dispersant project used Prudhoe Crude oil and a commercial nonionic glycol ether-based dispersant concentrate. The experiment was directly applicable to the experimental site and to the region because Prudhoe crude oil is pumped via a pipeline across Panama from tankers in Puerto Armuelles, on the Pacific coast, to the tankers in Laguna de Chiriqui, on the Atlantic coast. (In November 1989, a spill of 400 to 500 barrels of crude oil from a pipeline break at the Petroterminales de Panama, S.A. was released into the Laguna de Chiriqui and oiled mangroves and threatened seagrass meadows and subtidal reef corals [Hector Guzman, personal commun., 1989, STRI]).

In the API experiment, both the seagrass meadows treated with either dispersed or undispersed crude oil showed reductions in seagrass densities. However, while the oil-only treated seagrass test areas remained lower than pretreatment levels, the areas treated with the dispersed oil returned to higher than pretreatment densities. Sea urchin abundances decreased rapidly in the dispersant treated site but declined more slowly in the oil-only treated site. Comparisons of infaunal densities were obscured by high intrasite variability.

The preliminary results of the Bahia Las Minas oil spill study (Jackson et al. 1989) suggest that other factors not considered in the API study (e.g., oil-in-water emulsions formed in high surf zones and the trapping of large amounts of oil in mangrove forest sediments) may greatly increase the damage done to subtidal seagrass meadow communities by crude oil. The results of the API experimental study might be applicable only to spills which occur in protected lagoons, or on shallow open coastlines during calm periods, when and where emulsions are not likely to be formed.

Dissolved oil concentrations in the API study may have been realistic but the total amount of oil used could not possibly have the same effects as a large spill. After large spills, many thousands of barrels of oil may be trapped within, and slowly released from, heavily oiled mangrove forests. Following a major oil spill in the tropics or subtropics, seagrass meadows may be re-oiled many times whenever weathered oil washes out of oiled mangrove forests. The effects of weathered oil, in various stages of chemical decomposition, on grassbed fauna are unknown. Judging from the differing results of the Panama/API experimental oil spill study (and 18 months of follow-up studies) (Ballou et al. 1987) and those of the Bahia Las Minas, Panama, accidental oil spill (Jackson et al. 1989; Burns and Knap 1989; Cubit and Burgett in review; Guzman et al. in review; Marshall and Batista, In prep.) it would be very difficult to design and implement realistic field experiments. A realistic design for a tropical oil spill would necessitate the application of weathered oil to corals and seagrasses over a period of many months or even years (Guzman et al., in review).

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Dr. Michael J. Marshall is a senior scientist and benthic ecologist with Continental Shelf Associates, Inc. Dr. Marshall is the Scientist-in-Charge of the seagrass subproject of the Panama Oil Spill Study being conducted by the Smithsonian Tropical Research Institute for the Minerals Management Service. Dr. Marshall's research interests include the ecological interactions of organisms in complex communities and in the recovery of such communities after natural and manmade perturbations. Dr. Michael J. Marshall received his B.A. in biology from the University of South Florida and his M.S. and Ph.D. degrees in zoology from the University of Florida.

CURRENT OFFSHORE INDUSTRY TECHNOLOGY

Session: CURRENT OFFSHORE INDUSTRY TECHNOLOGY

Co-Chairs: Mr. G. Ed Richardson
Mr. Jake Lowenhaupt

Date: December 7, 1989

Presentation	Author/Affiliation
Current Offshore Industry Technology: Session Overview	Mr. Jake Lowenhaupt, Mr. G. Ed Richardson, and Mr. Mark Rouse Minerals Management Service Gulf of Mexico OCS Region
Deepwater Surveys	Mr. Rob Floyd and Mr. Jim Sides John E. Chance and Associates, Inc.
360° Color Scanning Sonar Coupled with MOCKINGBIRDS	Mr. Douglas A. Cochrane, Jr. Cochrane Subsea Acoustics, Inc.
Extending Pipeline Installations from 2500 to 5000 Foot Depth	Mr. R.J. Brown R.J. Brown & Associates
Floating Production Systems	Mr. Joe W. Key Key Ocean Services, Inc.
Deepwater Drilling and Development Advancements	Mr. Andrew F. Hunter Conoco, Inc.

CURRENT OFFSHORE INDUSTRY TECHNOLOGY: SESSION OVERVIEW

Mr. Jake Lowenhaupt,
Mr. G. Ed Richardson,
and
Mr. Mark Rouse
Minerals Management Service
Gulf of Mexico OCS Region

The offshore oil and gas industry is advancing its technology on many fronts, but by far its biggest challenge is the deepwater environment where many of the newer leases are located. Governmental regulatory agencies, such as Minerals Management Service (MMS), must deal with new approaches to the exploration and production of oil and gas. The MMS has adapted by offering tracts with longer lease terms and recently modified the time requirement between operations to keep leases in effect. Industry has continued to purchase leases in increasingly deeper water and has drilled and made discoveries on some of this acreage. Bold new approaches are necessary to produce these discoveries in a competitive economic and environmentally sound manner.

The oil industry must devise ways to find and produce oil and gas from leases in ever deeper water. The deepwater leases usually go hand-in-hand with more distance from shore which also poses problems for production operations. Presentations were heard from six speakers on five topics about offshore operations in deepwater.

Messrs. Rob Floyd's and Jim Side's discussions on "Deepwater Surveys" focused on new sonar applications for offshore deepwater surveys. Their topic included the advantages and disadvantages of utilizing "bottom-towed" sonar systems versus "surface-towed" systems. Deep-towed systems operate within 100 feet of the bottom and are used over relatively flat topographies, utilizing lower frequencies to obtain a greater swath of coverage. One of the newest deepwater subsea sonar systems, TAMU2, has a variable swath coverage from 200-400 m up to 40 kilometers. Positioning accuracies of these systems are between 5 and 15 m.

Mr. Doug Cochrane's discussion on "color scanning sonar" examined the application of static versus dynamic sonar systems and the development of a 360 degree static color scanning sonar system. This system operates similar to radar and may be utilized for such applications as bottom debris clearance verification, locating well heads and lost objects, and monitoring operations.

Mr. R.J. Brown discussed many facets of deepwater pipelining including the feasibility of reuse with relocation. He talked about the Green Canyon Block 29 project where flowlines were installed and connected in water depths to 2,400 feet (ft). The procedures for pipe towing, positioning, and tying-in wellheads and manifolds at the 5,000 ft depth were discussed. Pressurization to prevent collapse of pipe manufactured by conventional process was discussed.

Mr. Joe Key presented a discussion on floating production systems. Mr. Key addressed the problem of economically producing hydrocarbon from the deeper offshore water depths. He discussed the smaller, marginal deepwater fields of 10 to 25 million barrels which necessitate mobile production facilities. Mr. Key discussed the available alternatives before proposing Floating Production, Storage, and Offloading units known as "FPSO". He described the FPSO components and the tanker size necessary to produce any field. Two key ingredients to success are the turret mooring and the high pressure, multi-product fluid swivel. The advantages of this system as well as its safety features were discussed.

Mr. Andrew Hunter made the session's last presentation on deepwater drilling and development advancements and the outlook for producing hydrocarbons within the economic constraints of the world prices. He predicted the development of deepwater prospects over the "Continental Slopes" for the next 50 years. In discussing the site specific needs of an uneven slope area, he used the Conoco Jolliet Field development as an example. This project used existing infrastructure to improve its economics. The key to the Green Canyon Block 184 operations is the use of a lightweight tension leg well platform (TLWP) in 536 m of water. The tension leg principle allows the wellheads to be located above the water. The 12,000 metric ton unit is arranged into a drilling template, foundation template, mooring system, and surface vessel. The TLWP is one answer to deepwater development with oil prices less than $20 per barrel.

The presentations made at this session were all concerned with deepwater operations. The engineering effort to design practical and feasible methods for discovering and producing hydrocarbons within the economic framework of world prices was discussed. Regulatory constraints were recognized for safe and environmentally responsible operations.

Mr. Jake Lowenhaupt is a petroleum engineer on the staff of the Regional Director of the MMS, Gulf of Mexico OCS Regional Office. He has served in line and staff positions relating to offshore operations. Mr. Lowenhaupt received his B.S. degree in petroleum engineering from Louisiana State University.

Mr. G. Ed Richardson is a supervisory environmental protection specialist and unit supervisor in Environmental Operations with the MMS, Gulf of Mexico OCS Regional Office. He has 17 years experience with state and federal governments and with the oil and gas industry. Mr. Richardson received his M.S. from Clemson University in microbiology, environmental health, and biochemistry.

Mr. Mark Rouse is an oceanographer with the MMS, Gulf of Mexico OCS Regional Office. Mr. Rouse works in the Environmental Assessment Section evaluating the impacts of the Federal OCS oil and gas program on the offshore and coastal environments. Mr. Rouse received his B.S. degree in oceanography from Lamar University and has done graduate work through Louisiana State University and Florida Institute of Technology. Prior to his work with MMS, he held positions with Seiscom Delta, Mobil, and the Ocean Surveys Division of the U.S. Naval Oceanographic Office.

DEEPWATER SURVEYS

Mr. Rob Floyd
and
Mr. Jim Sides
John E. Chance and Associates

Presentation Summary
Text Not Submitted

Mr. Jim Sides is Vice President of John E. Chance and Associates of Lafayette, Louisiana. He has worked as a geophysicist for some 20 years.

Mr. Rob Floyd is an underwater archeologist for John E. Chance and Associates and specializes in remote sensing applications.

360° COLOR SCANNING SONAR COUPLED WITH MOCKINGBIRDS

Mr. Douglas A. Cochrane, Jr.
Cochrane Subsea Acoustics, Inc.

The Cochrane 360° color scanning sonar system is state-of-the art in seafloor imaging technology. The system has evolved over the years from navy obstacle avoidance sonar and side-scan sonar. Today it is the standard and is used for many applications.

This system contains a number of components along with various options to satisfy a variety of application needs. The major components are:

- the sonar processing unit;
- video tape recorder;
- encoder/amplifier;
- RGB CRT monitor;
- underwater cable;
- the underwater transducer (sonar head);
- tripod; and
- power supply.

OPERATION

The principle operation of the color scanning sonar is similar to sonar in general. That is, a sound signal is sent out and reflected off of a target. Computer processing allows the data to be displayed in a number of convenient formats. The most common is the Polar Mode. Two cursors can be moved around the screen and are used to make precise measurements for range and bearing from the sonar transducer to each cursor and between the two cursors.

The underwater transducer is mounted in the tripod and lowered over the side of the vessel to the seafloor. The head sits about 4 ft above the seabed. A stepper motor inside the head turns the transducer 360 ° as it sends and receives its signal. These data are telemetered to the surface RGB monitor via a four conductor SO type cable. Data are first processed, sent to the monitor, run through the encoder/amplifier, and recorded on a common VHS video recorder.

After the sound signal is sent out from the transducer, it hits the target and some of the signal is reflected. The computer assigns a color to the signal depending on the strength of the return signal. This is displayed on the RGB monitor. One hundred twenty-eight colors are used.

The sonar can be used in water depths ranging from a few ft to 3,000 ft. Extended depth transducer housing can extend capabilities to 6,000 ft.

Data are displayed in a number of formats but the most common is the Polar Mode. This is a circular picture similar to the format of the weather radar. Radar-like range rings are displayed to provide visual representation of objects/targets seen on the screen in relation to the sonar head. A compass and moveable cursors (2 each) provide range and bearing measurements to a resolution of 0.1° and 0.1 ft.

APPLICATIONS

The 360 ° color scanning sonar has many applications. Some of the most common applications that are related to the offshore oil and gas industry are:

- Minerals Management Services bottom clearance surveys;
- rig positioning;
- mapping pipelines near rigs and structures;
- debris clearances around salvaged platforms;
- locating lost objects; and
- monitoring diver/remote operated vehicles (ROV) operations.

The most common application involves using the sonar for bottom clearance surveys. The sonar provides an ability to "see" the immediate bottom area around the rig or platform. Debris on the bottom is depicted on the screen. The cursors are used to measure the size of objects and to help identify them. A diver or a ROV can also be seen on the screen as they move out to the object. It is particularly useful to be see the diver/ROV in relation to the rig and the objects on bottom. This expedites the work of recovery as well as providing a safety aid never before available.

Using the 360° color scanning sonar on the rig as it moves onto a location allows the rig mover to see the legs of the rig converge on a well stub and avoid other seafloor equipment as well as debris (e.g., pipelines, valves, etc.).

In many cases, pipelines and flow lines near a rig or production platform are presumed to be laid straight per construction drawings. However, in reality, they are often not laid as straight as intended. This sonar provides a method of real-time mapping.

When a platform is salvaged after years of operation, debris is often found on the seafloor around the area. The 360 ° color scanning sonar can be used to map the debris and aid divers/ROV's during recovery of the obstructions.

Objects as small as a coffee can are visible on the sonar screen. The cursors allow us to measure the size of the object and aid in identification. Items lost overboard can be found and recovered quickly.

Adding the visual capability to "see" the diver/ROV in relation to the rig with audio communication between diver and surface tender, provides an ultimate safety aid. Surface supervisory personnel maintain visual and audio contact with the diver and, if he gets into trouble, another diver can be directed to him.

Before the 360° color scanning sonar, surface personnel had to rely on what the diver says he can see or feel to determine what is on bottom. Determining precisely where objects were on the bottom was difficult. Side-scan sonar helped to a degree, but near the rig or platform, it was impractical. It is too risky to tow a "fish" very close to such a structure.

MOCKINGBIRDS

The newest innovation in the 360 ° color scanning sonar is the use of subsea acoustic MOCKINGBIRDS. These small electronic devices can be placed on an object on the seafloor to provide an unmistakable image on the screen. This is useful when objects are partially buried. The MOCKINGBIRD hears the sonar signal and responds at the same frequency. This enhances the return signal.

MOCKINGBIRDS are most useful for rig moves and marking pipelines. They are much easier to install than sonar reflectors. Their image display is much more definitive. MOCKINGBIRDS can also be attached to the diver's belt as well as to the ROV.

This brief description of the 360 ° color scanning sonar and the new subsea acoustic MOCKINGBIRDS is intended to provide an overview of the sonar system and its capabilities. In its short history, it has proven to be a great innovation for monitoring subsea work. Additional applications arise every day.

Mr. Douglas A. Cochrane, Jr., is President of Cochrane Subsea Acoustics, Inc., and International Subsidiaries with headquarters in Lafayette, Louisiana. Mr. Cochrane received his degree in oceanography from Florida Institute of Technology.

EXTENDING PIPELINE INSTALLATIONS FROM 2500 TO 5000 FOOT DEPTH

Mr. R.J. Brown
R.J. Brown and Associates

Considerable research and development is being expended for installation of gas and oil transportation systems in deep water frontier areas. As exploratory wells are completed in deeper waters, questions continue to arise as to the feasibility and costs for installation of various pipeline transportation systems. The deepest to date has been Placid's Green Canyon Block 29 project in which flowlines have been installed and connected to a template and wellheads in water depths to 2,400 ft. In the same field, an export gas and oil pipeline system has been installed and connected in a maximum depth of 1,540 ft. This paper describes the next step in the evolution to the 5,000 ft depth utilizing existing techniques and innovative technology. The latter part of this paper includes the potential recovery and reuse of Placid's existing lines. Also included are discussions of modifications to methods used by Placid, and procedures for pipe towing, positioning, and tying-in wellheads and manifolds for extensions to the 5,000 ft water depth.

INTRODUCTION

Now that the Placid pipelines have been successfully installed and connected the next and obvious step is to look beyond the 2,400 ft water depths. The next bench mark level is 5,000 ft. For understanding the complexities in the various methods of pipeline installation, a review of several techniques are discussed in this paper. These methods include: various lay, reeling, and towing techniques. The laying techniques (Figure 12.1) are subdivided into: conventional, third generation, dynamic positioned, "J" lay, reeling, and vertical lay. The towing techniques include: bottom, mid-depth, surface, and near surface. Each method has its own characteristics, advantages, and disadvantages and can be utilized in many different locations and under varying conditions. The purpose of this paper is to define some of the technical limitations and commercial implications for the various techniques.

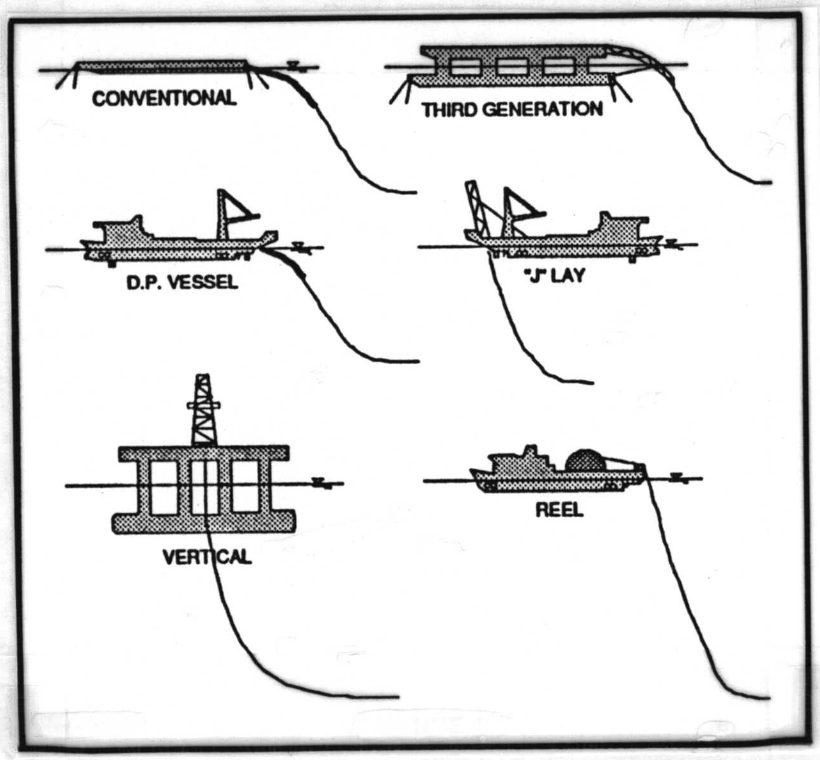


Figure 12.1. Six types of lay equipment that work from the sea surface.

As installations are being conducted in deeper water depths, the pipeline's structural qualities for resisting collapse are becoming more important. There is a definite depth restriction, which obviously depends on design criteria utilized. Whether collapse initiation, propagation, or critical collapse depth criteria are used, there is a limit as to pipe wall thickness which can be commercially manufactured. Unless new approaches evolve, methods of installation are definitely limited in terms of pipe diameter, wall thickness, and depth. One approach which has been utilized on several installations is the use of internal pressure to prevent pipe collapse thus increasing the depth limit for installing lines. This is limited, however, to towing techniques. The fact is, for a fixed wall thickness, the larger the diameter of the pipe, the less water depth in which it can be installed unless additional collapse resistance measures are taken.

SURFACE INSTALLATION TECHNIQUES

Surface installation techniques involve equipment that assemble pipe on the surface, and by advancing the vessel, lowers the suspended pipeline to the seabed. Obviously, in deeper water, the longer the suspended pipe length, the more time required for the pipe to reach its touchdown point on the seabed. In the case of the 5,000 ft depth, suspension time can be as much as 24 hours depending on which laying technique is employed and the production rate associated with that method.

The surface installation methods discussed herein are shown in Figure 12.1 and are in various stages of development. The conventional laybarge has a long history of pipeline installations with sizes ranging up to 56 inches and smaller lines to water depths of 1,400 ft. The first conventional laybarge was developed on the U.S. Gulf Coast during the mid-1950's and was the primary method utilized until the third generation lay vessels emerged in the early 1970's. The main differences between these two methods are, hull configurations, stability, stingers, mooring system, and pipe makeup procedures. In general, the third generation has a production rate approximately 40% faster than the conventional laybarge, and has the capacity to lay in twice the water depth. A more recent innovation has been the development of a high performance, dynamically positioned (DP) conventional lay vessel with innovative methods of pipe transfer and an improved efficiency in laying pipe. At least two contractors are developing "J" lay technology using both conventional barges and a ship shape with a sloped ramp on the stern of the vessel. These techniques have considerable promise for extending the laying depths to 5,000 ft for smaller diameter pipe sizes.

Another method that has its own special technique of pipe make-up for flowlines and small transmission lines is the reel barge. This technique has been quite active in this specialized portion of the market. The technique was first used during World War II for unspooling flowlines between England and France to transfer fuel to the Allies on the Continent. The method of operation involves making pipe up on shore and spooling it onto a large drum, on a vessel. The vessel transports the pipeline to the work site for off-spooling onto its final location.

Another concept which is in an early stage of development is the vertical lay method. It is presently being studied by at least one company and utilizes a semi-submersible drilling vessel. The method is similar to the "J" lay technique except that pipe is deflected around a vertical bending shoe at the base of the semi-submersible.

TOWING TECHNIQUES

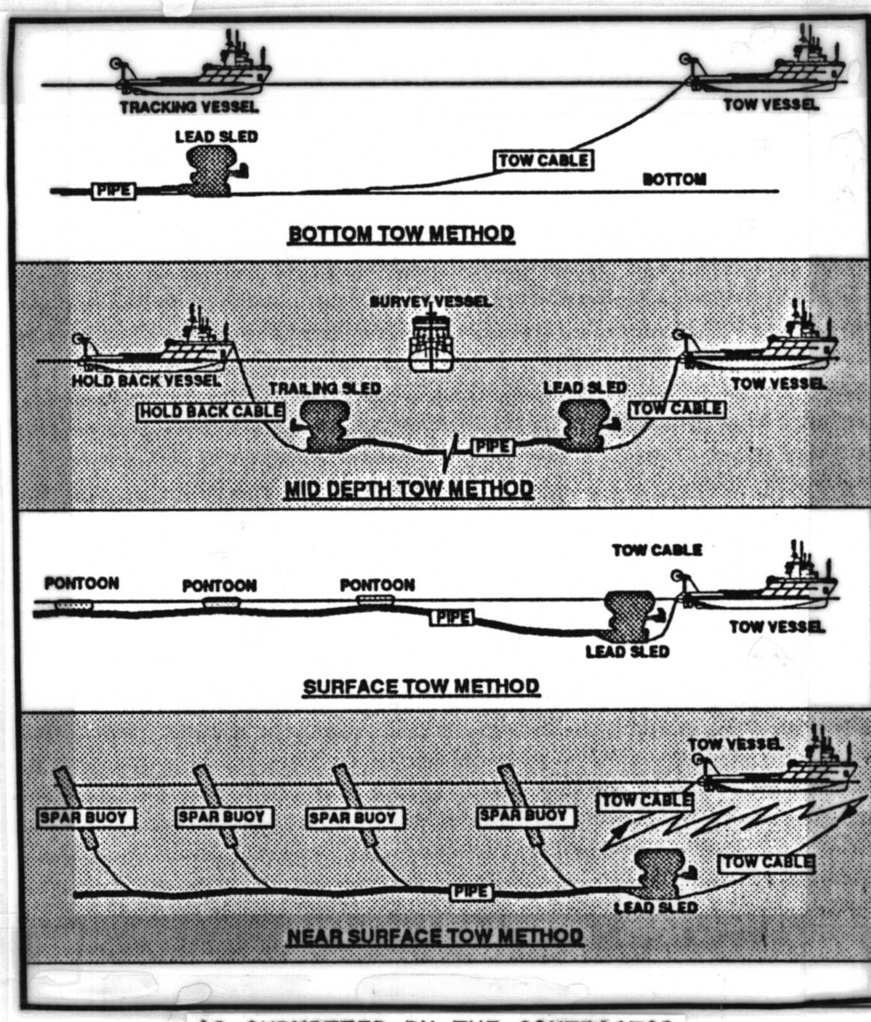
Figure 12.2 depicts four towing techniques which include "on bottom" where pipe is towed on the sea bed by a single vessel with a tracking vessel maintaining position above the lead sled for determining the three dimensional position of the sled. In very deep waters, the lead sled is sometimes lifted off the bottom and towed at an elevation of as much as 500 ft above bottom with up to 8,000 ft of suspended pipe from sled to touchdown point. This type of operation is very useful when lines are being towed into their final location and precise positioning is required for final tie-in at a subsea well or manifold position. With precision of weight control achieved in the pipe manufacturing process for Placid's installation, towing single 16 mile lengths are feasible using a single towing vessel. Longer pipe sections require additional towing equipment and rigging. The primary disadvantage of this method is the extensive route survey required to establish an acceptable low risk tow route.

The "mid-depth" tow carries pipe between two vessels in lengths up to 3 miles. This system works best where lines are relatively short and tow distances are long. A minimum amount of survey data are required except for detailed survey information on bottom conditions in launching and final position areas.

The "surface" tow method has been used successfully for pipelines crossing bays, and recently several companies have experimented with some deep water applications including towing of tendons for tension leg platforms. Like the "mid-depth" tow, a pipeline is limited in length by virtue of its exposure to sea state and traffic conditions.

The "near surface" tow method is similar to the "surface" tow method having similar length and survey requirements.

Pipe towing techniques began in the latter 1940's when pipe strings were made up on shore and pulled on the surface and on the bottom. These installations included many outfall lines, and river and bay crossings. The longest tow to date was a 19 mile length of 32 inch pipeline pulled from the Island of Khargu to Ganaveh on the mainland of Iran in 1960. During the middle 1970's when pipe laying equipment in the North Sea was limited, pipeline installations were very expensive. Because of this pipe lay equipment shortage, bottom towing of lines for long distances was initiated. Tow distances of up to 250 nautical miles were achieved. In the latter 1970's, the "mid-depth" tow method became attractive for pipeline lengths up to three miles and many bundled pipelines were installed using this technique. Experimental works have been for "near surface" tow method in which spar buoys are used on the pipe to maintain its depth at 50 ft below the surface. As described earlier, each of these methods have their own advantages and disadvantages. The project engineer is required to look at specific situations on a case-by-case basis to determine which tow technique is more attractive technically, within acceptable risk levels and offers the most cost effectiveness.



AS SUBMITTED BY THE CONTRACTOR

Figure 12.2. Four types of towing methods--bottom tow, mid-depth tow, surface tow, and near-shore tow.

DEEP WATER PIPELINE DESIGN

To date, most pipelines have been installed in relatively shallow water depths utilizing a conservative external pressure design (based on propagation pressure) to establish minimum pipe wall thickness. The propagation depth is the water depth at which external pressure is sufficient to cause a collapse to propagate after some form of buckle or dent has deformed the circular properties of the pipe. In other words, if a line is being installed to 500 ft depth with a 400 ft water propagation depth then, if collapse is initiated, the pipe collapse will propagate horizontally until the 400 ft water depth is reached. The initiation depth is greater than propagation depth and as long as a dent or buckle does not initiate collapse, the pipe can be safely laid to this depth. After a pipeline has been installed and the pipe is not being flexed or stressed, critical collapse depth, with a safety factor, should govern. This depth is considerably greater than either initiation or propagation pressures. For example, Figure 12.3 is a plot of four collapse pressures (propagation, initiation, critical with 50% longitudinal stress, and critical with no longitudinal stress) for 12, 18, and 24 inch pipe. From these data, it can be seen that once a pipeline is safely in its final position, critical collapse depth far exceeds initiation and propagation depths.

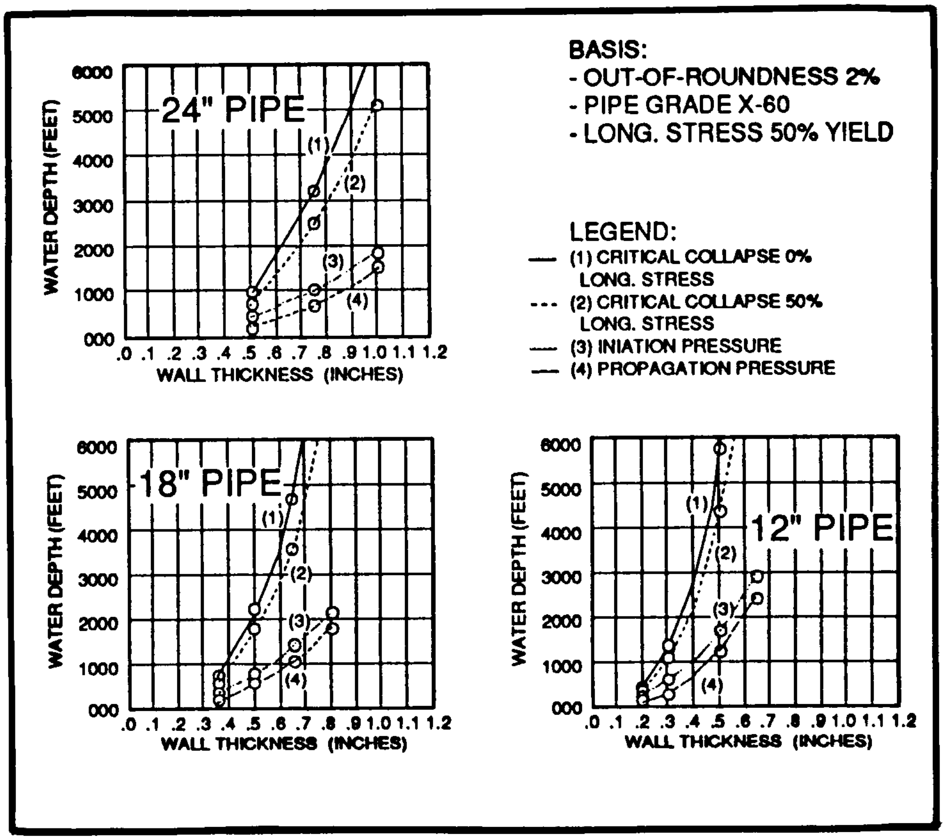


Figure 12.3. A graphical presentation of initiation, propagation, and critical collapse depths for 12-inch, 18-inch, and 24-inch pipe.

Therefore for very deep waters, the project engineer must use additional collapse resistance items such as buckle arrestors and/or internal pressurizing. If pressurizing is used and if there is a possibility of evacuating the line (for gas operations) then the engineer should be able to rely on use of critical collapse criteria for deeper operations. If the line is for oil service, the problem is lessened by virtue of maintaining the line filled with oil with its internal hydrostatic head. With the gas case, this problem can be solved by operating the system within pre-established procedures that do not permit depressurizing the line.

MATRIX COMPARISON OF METHODS, DEPTH, AND COSTS

Figure 12.4 depicts a matrix comparison of various types of installation methods along the abscissa at the top of the figure. The vertical columns represent each pipe lay method with towing techniques grouped into a single column. This comparison is prepared for water depths ranging from 0 to 5,000 ft shown along the left ordinate. Three pipe diameters for 12, 18, and 24 inch are shown for each method as described in Figure 12.3. The relative costs, shown along the right ordinate are for installations in the Gulf of Mexico. In this matrix there are only two valid cost comparison figures which include conventional and bottom tow methods. The other costs do not include mobilization from outside the Gulf of Mexico. In the case of "J" and vertical lay, this equipment is in various stages of development or not available. The narrow vertical bars, within the columns, represent pipe sizes of 12-inch (white) bar, 18-inch (black), and 24-inch (cross-hatched) bar. The maximum laying depths can be read from the top of the vertical bars along the left hand ordinate for each pipe size. In the Gulf of Mexico area, the maximum depths completed by conventional laybarges has been 1,500 ft. The

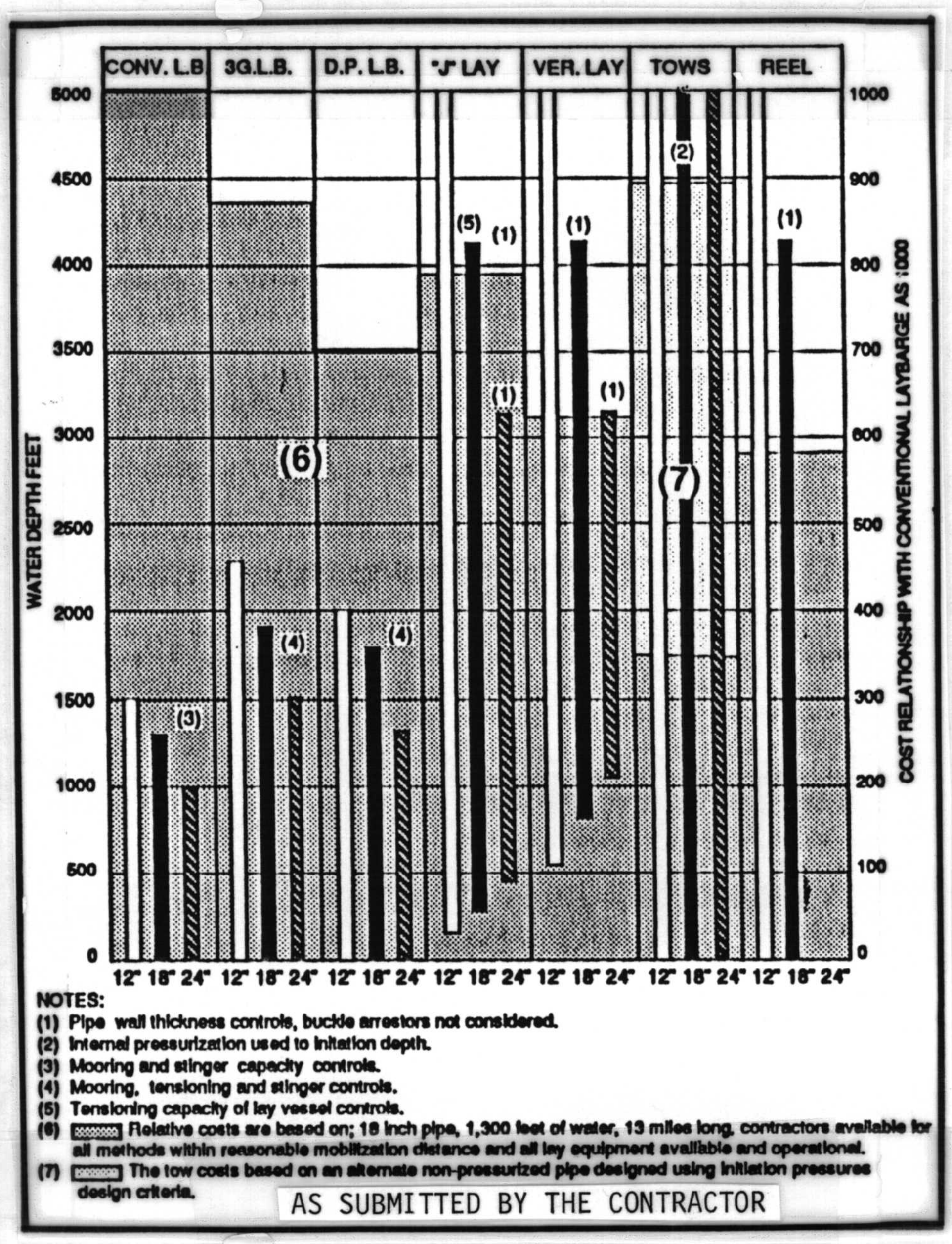


Figure 12.4. A matrix comparison of various pipe installation techniques in terms of maximum and minimum water depths for 12-inch, 18-inch, and 24-inch pipe.

third generation laybarge is capable of extending these depths to 2,300 ft. There is, however, some difference with laying capacity of third generation laybarges. The horizontal pipe makeup semis are less adept at curving pipe to a greater departure angle, therefore, sloped ramp type semis are able to achieve greater departure angles and extend depths as shown on Figure 12.4. The conventional laybarge, as presently developed, is limited by mooring and stinger capacity. The DP lay vessel exceeds current capacity of conventional laybarge but has less depth capacity than the third generation type. The "J" lay and vertical lay equipment far exceed the laying depths of conventional, third generation, and DP lay vessels. They are, however, limited in shallower waters because of the steep departure angle and the vertical height required to provide sufficient distance to deflect the pipe into a horizontal position. The reeling method has potential for deep installations for pipe sizes of 12 and 18 inch. The upper limits, noted as "(1)", are maximum wall thickness that pipe suppliers can manufacture on a commercial basis. The tow methods are grouped into a single column and have capacity to be installed to 5,000 ft depth provided internal pressure is utilized for resisting collapse. The alternative, without internal pressure, is to use a heavier wall thickness in the pipe, then the upper limits for tows are similar to "J" and vertical installation equipment. For towing, this has the disadvantage of increasing pipe materials cost and limits the length of tows unless pontoons are used. The use of pontoons is expensive. However, it can be employed to extend length of tow and avoid intermediate tie-ins.

EXAMPLE OF MATRIX INSTALLATION AND COST COMPARISON

To understand the matrix comparison in Figure 12.4, three examples have been chosen to demonstrate use of this matrix. It is assumed that various types of equipment are available for the methods as shown on Figures 12.1 and 12.2 within reasonable mobilization distance, and that all lay equipment is operational.

The first example is an 18-inch line in 1,300 ft of water, and 13 miles in length. Referring to the laying depth portion of the chart, left ordinate, we see that all methods are acceptable and within laying capacities. Using the abscissa on right hand side for cost relationship, the conventional laybarge is shown as 1,000 and is the basis for comparison. From this, the third generation laybarge is 87% of the cost; the DP laybarge is 70%; "J" lay is 79%; vertical lay is 62%; tow method with pressure is 35%; tow method without pressure is 89%; and finally, reel barge is 58%. As described earlier, this matrix is prepared for the Gulf of Mexico, therefore, the conventional laybarge and pressurized tow are the only valid figures. The costs for the third generation laybarge and the DP laybarge do not have mobilization costs included in their figures. Depending on their location, mobilization cost is additive. The "J" lay and vertical lay are even more nebulas because of their various stages of design and development making it difficult at this time to place a monetary value on their completion, and their costs for mobilization, start-up, and operation. For the reel barge, however, a closer estimate is possible except for mobilization costs which, in all probability, would be from the North Sea area.

The second example is based on the installation of an 18-inch line in 3,500 ft of water, and 13 miles in length. The only equipment capable of installing this type of pipeline is "J" lay, vertical lay, tows, and reel equipment. Each cost when compared to the "J" lay method is: 80% for vertical lay; 50% for tow with pressure; and 75% for the reel method. The only valid cost within this comparison is the towing method which is considered to be technically feasible and available at this time. The "J" lay method is feasible but equipment is not currently available. This equipment could become available within one year upon the signing of a contract with Allseas in Europe. The same consideration applies to the vertical lay method. The reel method is capable of executing the installation but is 30% higher in cost when compared to the towing technique (excludes mobilization costs to the Gulf of Mexico).

The third example is for an 18-inch line in 5,000 ft of water, and 13 miles in length. The only obvious method available at this time is the towing technique with internal pressurization. This is mainly limited by commercially available pipe being pressurized to resist collapse.

NEW AND REUSE OF EXISTING LINES

The first method of reuse shows a line which could be relocated for use with a new well. The line is shown along the upper portion of Figure 12.5 from the Block 100 manifold on the left to a well on the right side of the figure. In this case, the objective is to disconnect from the well and reposition the line some 7 miles southwest into Block 100. This single end method for redeployment is for one end only and consists of the following work elements. The mating sled is disconnected from the well and its 12 inch pontoon deflooded. The line is repositioned into its tow-in original straight line position. The towing bridle is then reconnected to the sled and the tow vessel repositioned with approximately 4,000 ft of towing cable deployed. The vessel takes an easterly heading away from the well and manifold. The vessel applies a 90 ton load on the cable and spools in 4,000 ft of cable until the sled reaches the surface. The 16 inch casing is lifted off the seabed for some 12,000 ft. With

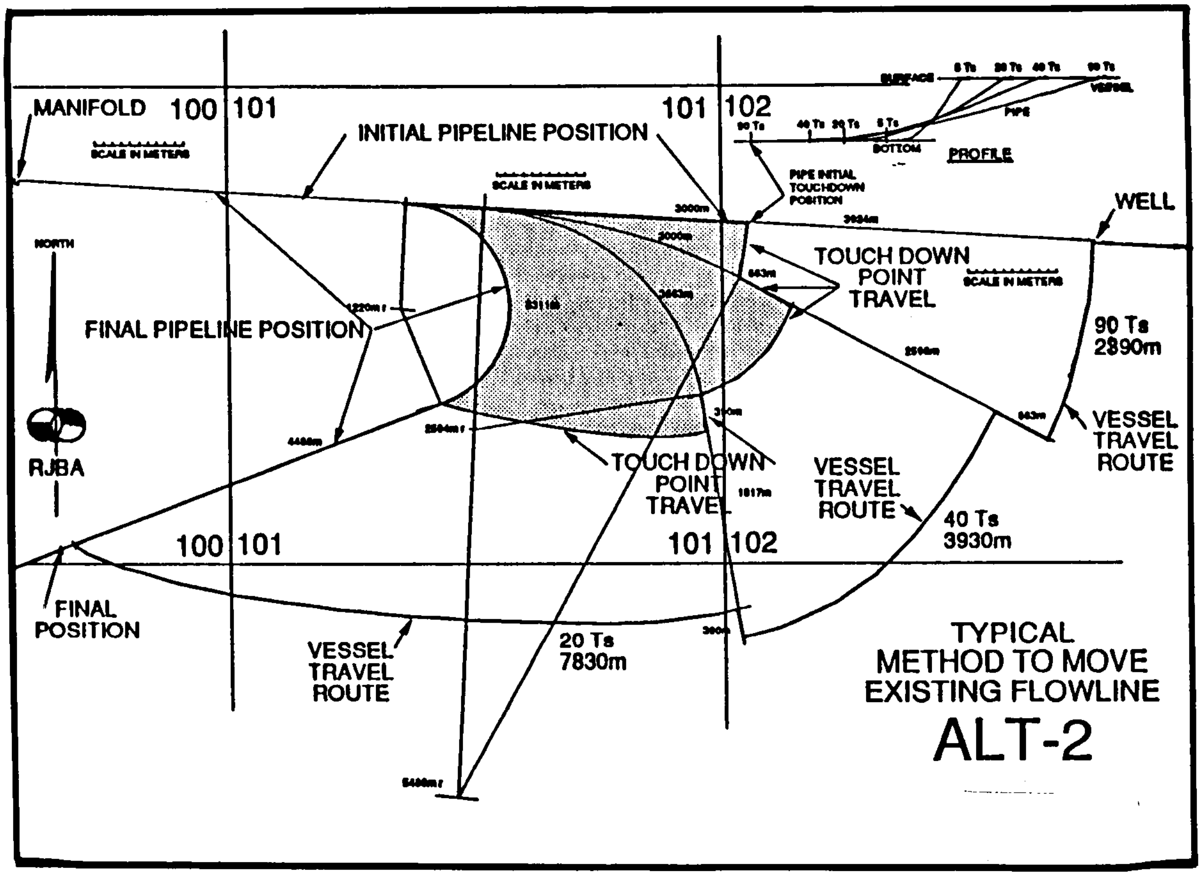


Figure 12.5. Repositioning of a 7-mile pipeline in which the pipe end is moved a distance of 7 miles.

the casing in this position, the vessel moves in a southerly direction approximately 10,000 ft and the pipe deflects, sweeping the bottom back some 21,000 ft from the sled. The pipe moves laterally over the seabed sweeping the bottom for approximately 8,500 ft. At this point, the vessel reduces its load on the pipe from 90 to 40 tons backing down the tow line approximately 1,500 ft. The pipe touchdown point advances 1,500 ft in the direction of the vessel. The vessel again deflects laterally, in a southwesterly direction until the pipes touchdown point is within Block 101 area. The vessel then slacks down the tow line to 20 tons and deflects laterally in a westerly direction until the sled on the pipe end has reached its final location within the Block 100 area. At this point, the vessel slacks down the tow line completely and disconnects from the sled. The total sweep area limits are defined by the shaded area shown on Figure 12.5 so that a detailed survey can be completed to determine that this area is clear of obstructions. After the pipe end repositioning is complete and confirmed, the location for drilling the well is re-established by employing a 1:200 scale model to determine the precise position coordinates and bearing for the well. The well can then be drilled, the well completed, pipeline connected diverless, and started up. This method of installing the line prior to a well being drilled has been completed at 2,400 ft depth and is a proven technique.

The same procedure can be used for an existing well, where the pipe end is towed and placed in a predetermined target area. The line is then deflected laterally employing the deflect to connect method for a diverless tie-in. This is basically the same system that Placid used successfully for its installation.

The second method of reuse is to remove the entire pipeline by disconnecting both ends, repressurizing pontoons on both ends, undeflecting both ends, and connecting either end to the sled for retowing the line to its new location. If the new location is in water depths less than the initially designed 3,000 ft, no additional pressurizing of casing or pontoon is required. Should the plan require the pipeline at 5,000 ft depth, then reentry into casing and pontoons are required so that lines can be pressurized to a higher level to resist pipe collapse. This reentry process has been successfully completed on one of the Placid lines at the 2,300 ft water depth, when one 12-inch pontoon was inadvertently flooded.

EXTENDING INSTALLATION DEPTHS FOR TOW METHOD

The question of extending installation for the towing technique primarily involves adding pressure at some position along the towing route and modifying existing towing equipment. If there is sufficient wall thickness in the pipeline, casing for bundled lines, and pontoons, pressurization can be completed in the surf zone. These activities are completed prior to initiating the tow from near shore to its final location. If pipe wall thickness and safety factor used for pressurizing near shore is not sufficient, towing of pipe to a depth of approximately 2,000 ft is required to permit additional pressurization. From the overall cost standpoint of the towing method, additional costs are required for pressurizing and extra rigging for towing equipment. Figure 12.6 shows towing configuration and equipment which includes additions to tow wire, number of pendant wires, and spooling winches on the towing vessel to extend the tow to 5,000 ft depths. For example, tow wire is increased from 6,000 ft to 8,000 ft, number of 600 ft pendants from 14 to 26, and spooling winches from 3 to 6. A first conservative estimate of cost increase to extend from 2,500 ft to 5,000 ft depth is an additional 10% in overall cost. Obviously, additional engineering is required for further refining of these elements.

CONCLUSIONS

The conclusions are listed in brief statements in what the author considers to be their order of importance.

1. It is technically feasible to install, and connect, single or bundled pressurized pipelines for sizes up to 24 inches in diameter, at depths of 5,000 ft at this time by towing techniques.

2. The maximum bottom towed lengths with a single vessel to the 5,000 ft depth is 15 miles. Greater lengths require an additional vessel and rigging.

3. The mid-depth tow method of pipeline installation is capable of installing single and bundled pipelines up to 24 inch in diameter, 3 miles long to the 5,000 ft depth.

4. Installation by the reeling method are feasible for line sizes up to 12 inch at 5,000 ft depth, at this time.

5. Within one year of signing a contract, the "J" lay system could be available for installing a single 12-inch line in 5,000 ft of water.

6. For gas transmission lines, procedures should be developed for operating systems under a minimum prescribed pressure so that after installation, the line is not depressurized.

7. Using initiation and propagation collapse criteria for establishing pipe wall thickness limits manufacture of pipe sizes larger than 12 inch at this time by conventional pipe manufacturing process. However, a special pipe-rolling manufacturing technique is possible but at considerable additional costs.

8. When considering installation of lines in very deep water for pipe sizes shown in this paper, revision in design criteria is necessary, along with the use of buckle arrestors and/or pressurizing the pipe.

9. A new design criteria should be developed using a dual criteria for pipe collapse, initiation, propagation, during pipeline installation and critical collapse depth data for the pipeline's lifetime operation.

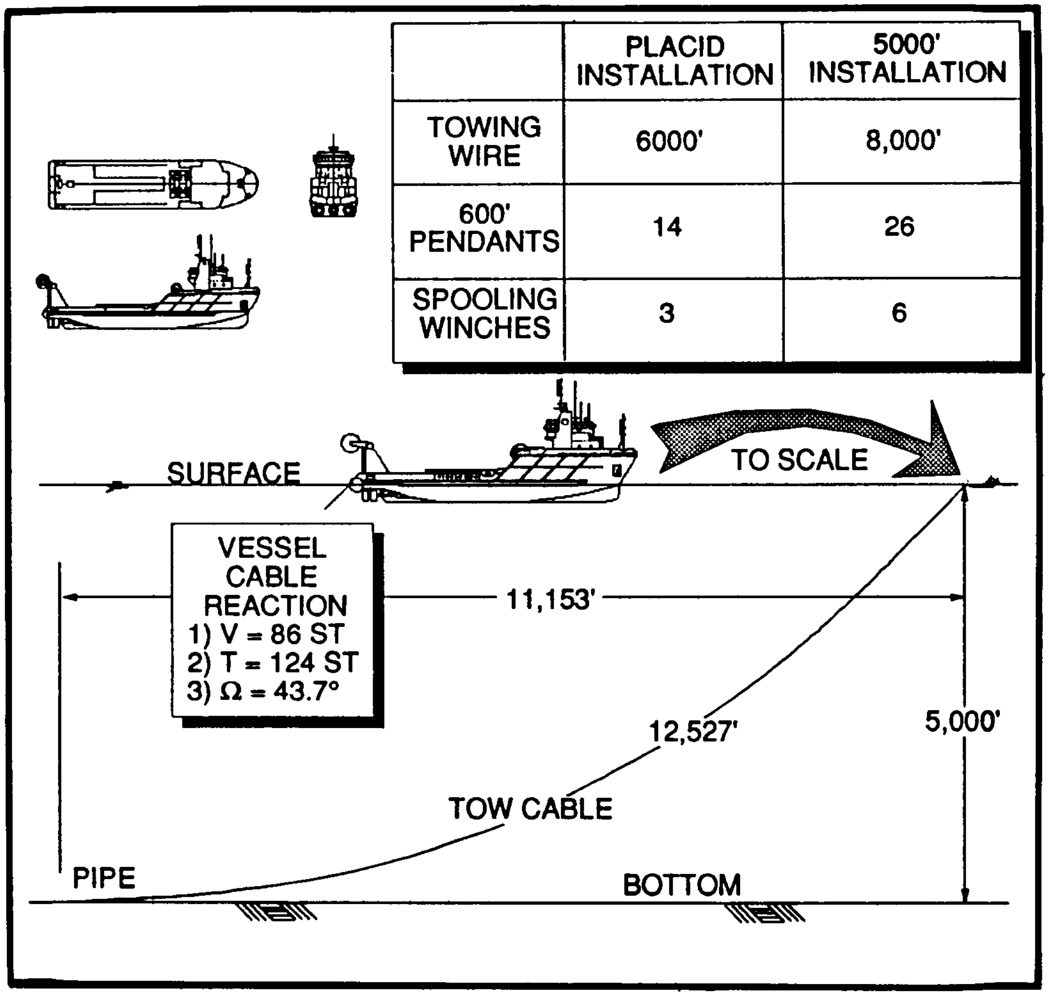


Figure 12.6. Bottom-tow pipeline equipment defining additional rigging required for extending from a depth of 3,000 feet to 5,000 feet.

10. For all pipe sizes in this paper, none of the conventional "horizontal pipe barge" makeup systems are viable to the 5,000 ft water depth.

11. For a project similar to Placid but in deeper waters, the bottom tow technique is 50% lower in cost when compared to lines installed using surface equipment.

12. The method for extending bottom tow to greater depths involves either additional pressurizing at the beach during launching, or at an intermediate water depth enroute.

13. Reuse of single and bundled pipelines is feasible when designed and installed by bottom towing technique using low load deflect to connect procedures.

14. For a 7-mile cased bundled flowline, the end can be disconnected, redeflected into a straight line, and moved for reuse elsewhere at distances up to 7 miles from the disconnection point. This is possible when the bottom sweep survey confirms that there are no obstructions within the area.

15. For bottom towing of single and bundled lines to the 5,000 ft depth, it is necessary to extend tow line length from 6,000 to 8,000 ft, increasing pendants from 14 to 26, and spooling winches from 3 to 6.

16. Utilizing initiation and propagation design criteria for D/t of 24, critical collapse depth is approximately five times greater.

Pipe Collapse Formula

$$P_p = 6\,\sigma_Y\left({}^{2t}/_{fD}\right)^{2.5}$$

$$f = 1+\left({}^{POR}/_{100}\right)$$

$$P_i = 6\mathrm{x}10^5\left({}^{t}/_{fD}\right)^{2.064}$$

$$\delta = {}^{P}/_{Pcr} + \epsilon/_{Cer}$$

$$R = D/t \qquad d = (R)(POR)$$

$$F = \sqrt{(1+d^2)}-d$$

$$\sigma_E = 23.55 \times 10^6/(R-1)^2$$

$$Y = \sigma^Y/\sigma_E \qquad \epsilon_{CR} = {}^{.5}/_R$$

$$Pcr = (2/R)(\sigma_E\sigma_Y)/\sqrt{(\sigma_E^2 + \sigma_Y^2)}$$

$$\delta = F\sqrt{(1+\gamma^2)}/\sqrt{(1+\gamma^2)(F^2)}$$

POR = Percent Out-Of-Round
σ_Y = Min Yield Stress
t = Pipe Wall Thickness
D = Pipe Diameter
P_P = Propagation Pressure
P_I = Initiation Pressure
δ = Critical Collapse Depth
σ_E = Longitudinal Stress

Mr. R.J. Brown has worked in the offshore pipeline industry for 36 years, and established R.J. Brown and Associates in 1969. He holds a B.S. degree in civil engineering from Ohio University (1950) and an M.S. degree in civil engineering from Stanford University (1963). He is a partner in the firm and serves on the Board of Directors of the Swiss, United Kingdom, American, Canadian, Malaysian, and Singaporean groups. Mr. Brown pioneered the development of the third generation laybarge, new and innovative methods of pipeline installation and connection, and pipeline stabilization through jetting and plowing. In 1985, Mr. Brown received the American Society of Civil Engineers' Stephen D. Bechtel Award for outstanding achievements in pipeline engineering. In 1986, he was named "Pipeliner of the Year" by the Pipeliner's Club of Houston.

FLOATING PRODUCTION SYSTEMS

Mr. Joe W. Key
Key Ocean Services, Inc.

During the past 20 years, there have been many significant changes in the offshore oil and gas industries. There has been a major shift from onshore to offshore production, there has been a significant decline in the offshore production of oil and gas in the U.S., and there has been a shift from water depths less than 600 feet (ft) to more than 2,000 ft. These changes have necessitated innovative solutions to economically produce the deep water reserves. A tanker-based Floating Production, Storage, and Offloading (FPSO) unit is one option which will take on greater significance during the next decade.

BACKGROUND

During the past two decades, the offshore oil and gas industry has undergone major changes. The price of oil has gone from \$3 per barrel, up to \$40 per barrel, down to \$9 per barrel, and back up to \$20 per barrel. The production trends have been equally dramatic.

In 1969, only 15% of the world's oil production was from offshore areas. This ratio increased to more than 28% in 1985, and still remains at nearly 26%. In 1972, only 9% of natural gas came from offshore production, with an increase to more than 21% in 1984, and now it stands at about 16% of the total gas production.

In 1972 the four major offshore oil producers were Venezuela, the U.S., Saudi Arabia, and the United Arab Emirates. Venezuela has dropped from 28% to 7% of the world's production and the U.S. has dropped from 19% to only 8%. Saudi Arabia has been very volatile, ranging between a high of 23% and a low of only 10%. The United Kingdom has moved from zero production to the number one spot with 17% of the total offshore production. Mexico is now the number two producer of offshore oil, with 11% of the total production.

In 1977, the U.S. produced 61% and the United Kingdom produced 19% of the offshore gas. Now the U.S. only produces 34% of the world's offshore gas. It would be normal to assume that the percentage of U.S. production of offshore oil and gas has fallen because of the huge discoveries in the North Sea and other areas of the world. Offshore production of oil in the U.S. has dropped from 1.7 million barrels per day in 1972 to only 1.1 million barrels per day in 1988. Likewise, similar trends have occurred for natural gas production in the U.S., with a peak of 15.2 billion cubic ft per day in 1981, and only 10.4 billion cubic ft per day in 1988.

The statistical data for the preceding figures came from the Oil and Gas Journal Energy Database.

There has been one other major trend in the Gulf of Mexico during the past two decades. As indicated by Figure 12.7, there has been a major shift from shallow water to deep water. Exploration drilling depth records have increased from 1,300 ft to 7,560 ft. In 1968, the tallest fixed platform was in 340 ft of water. That platform is dwarfed by the Bullwinkle platform recently installed in a water depth of 1,300 ft. Conoco now is producing from their tension leg platform in about 1,760 ft of water. Placid has produced wells with their semi-submersible based Floating Production System, which is located in a water depth greater than 1,500 ft, with subsea satellite wells in a water depth of about 2,240 ft.

This move into deep water has presented many major technical and economic challenges to the offshore industry. Figure 12.8, which was extracted from the December 1988 issue of Offshore Magazine, shows the economic impact and the reasons why alternatives to fixed platforms are essential. Additionally, many of the deepwater leases are highly fractured, leaving many small marginal fields with 10 to 25 million barrels of recoverable reserves, and short field lives of 5 to 7 years. These marginal fields often will dictate the utilization of mobile production facilities which can be moved from one field to another. This will allow the capital expenditures to be amortized over two or three of these marginal fields.

TYPES OF MOBILE PRODUCTION FACILITIES

Basically, there are four types of mobile production facilities, including jack-up units, semi-submersible units, tension leg platforms, and tanker or barge based units.

Due to the existing infrastructure of pipelines and the relatively low costs of fixed platforms for water depths less than 250 ft, jack-up production units probably will not have a major role in the Gulf of Mexico. The use of semi-submersible based floating production systems is proven worldwide and is a good solution if the field is near existing pipeline facilities. Tension leg platforms will be used widely in the Gulf of Mexico to facilitate frequent workover of wells. The remaining portions of this paper will be devoted to a discussion of tanker based FPSO.

FPSO COMPONENTS

A complete offshore facility, from wellhead to offloading, will include:

- wellheads;
- production risers;
- well control equipment;
- tanker, including accommodations, power supply, utilities, cranes, crude storage, offloading pumps, and personnel safety equipment;
- production/process equipment;
- gas disposal equipment;
- mooring system; and
- tanker offloading system.

TANKER SIZE

The availability of crude sales lines, environmental conditions, anticipated production rates, and travel distances for shuttle or export tankers will determine the minimum storage and tanker size. For most fields, tankers should be in the range of 75,000 DWT to 150,000 DWT.

TURRET MOORING

Key Ocean Services (KOS) is now marketing a new generation of uni-turret mooring system. It is suitable for a wide range of water depths (50 to 1,200 m) and can be installed in many different tanker sizes (75,000 to 300,000 DWT) without the delay of custom engineering and design.

In operation, the uni-turret simply allows the vessel in which it is installed to rotate (or weathervane) so that environmental forces against it are minimized.

FUNCTION	1968	1989
Exploration Drilling	1,300	7,560
Fixed Platforms	340	1,300
Tension Leg Platforms	N.A.	1,760
Offshore Production	340	2,240

Figure 12.7. Maximum water depths (feet).

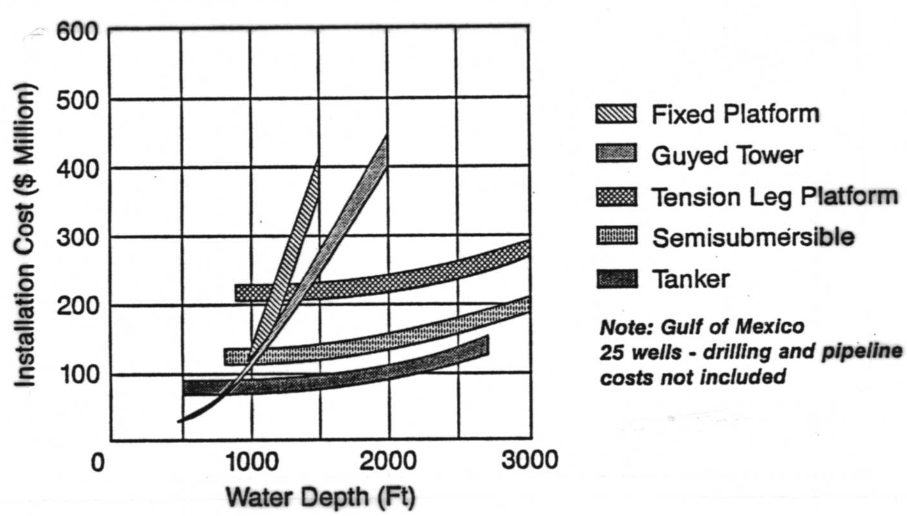


Figure 12.8. Cost estimates for development systems in various water depths.

With the uni-turret mooring system, the risers, manifold, the multi-product fluid swivel, and all the mooring system components are readily accessible for maintenance and repairs.

HIGH PRESSURE, MULTI-PRODUCT FLUID SWIVEL

With the introduction of the KOS multi-product fluid swivel, a reliable high pressure swivel now exists. It provides more lines, higher throughput, and greater operating pressures for gas and water injection than other previous swivels.

KOS can fabricate a swivel with the specific features needed to produce any field. For example, six or more products can be handled in the following manner:

Quant.	Diam. (in.)	Operating Pressure (psi)	Test Pressure (psi)
2	12	3200	4800
2	8	3200	4800
1	6	3200	4800
1	4	3200	4800

Significant improvements in seal and sealing surface technology has made it possible for KOS to offer a reliable multi-product fluid swivel suitable for high pressures and corrosive materials.

PRODUCTION AND PROCESS FACILITIES

You must have efficient process facilities that can function with the normal pitch and roll of a floating tanker.

Theoretically, if the tanker heads directly into the waves, there will be no roll. However, in practice, head seas will generate small roll motions due to the directional scatter of the waves. Roll motions will not cause production shut-in for waves that are within ± 30 from the bow or stern of a tanker. Allowable pitch motions will not be exceeded for a tanker-based FPSO.

Internal baffles in the production equipment are provided to extend normal operational limits. Several vendors, using data from motion simulators, can design and manufacture high quality processing equipment with the proper "internals" for the anticipated crude characteristics. Continuous operation, without production shut-in due to excessive roll or pitch, can be achieved with a tanker based FPSO.

The production facilities are sized to meet the needs of a specific field, but typical facilities will include:

- well production and test manifold;
- 1st stage production separator;
- 2nd stage production separator;
- test separator;
- flare system, including flare scrubber;
- produced water treatment equipment; and
- tanker offloading pumps.

For some fields, water injection or gas injection facilities will be required.

FLOWLINES AND RISERS

KOS normally utilizes flexible pipe for flowlines and risers to provide maximum flexibility to adjust to changing conditions. This minimizes the equipment needed to compensate for roll, pitch and heave.

ADVANTAGES

A tanker based FPSO has several advantages over a semi-submersible based floating production system. These include:

- deck space;
- deck load capability;
- stability; and
- oil storage (1 to 2 million barrels of oil).

This gives the option of using conventional oil and gas pipelines, or using a shuttle tanker to transport the produced crude oil.

TANKER OFFLOADING

There are two primary methods used for offloading from a permanently moored storage tanker to a shuttle tanker.

"Breasting," or a side-by-side arrangement, requires the least capital expenditure but is more weather sensitive than the "Tandem," or end-to-end, system. Both techniques have been used successfully for many years. The side-by-side offloading is used extensively in the Gulf of

Mexico as we offload our huge volumes of imported oil into shuttle tankers. Those offloading operations have not created unusual pollution or oil spill problems.

Offloading through a pipeline is accomplished through the multi-product fluid swivel into a flexible pipe riser which connects to the pipeline.

SAFETY

About a dozen tanker based FPSOs have operated worldwide for several years. Apparently, none have encountered major safety problems, nor have they had any significant oil spills.

Historically, the major cause of oil spills from tankers has been running the tanker aground. Obviously, that is not a factor with an FPSO since it will stay on location in water depths of 500 to 3,000 ft, and be empty of oil when it moves from one field to another. Moreover, the risk of collision is greatly reduced since the fixed location of the FPSO can be shown on all navigation charts. The remote location is also helpful in mitigating any potential damage from an oil spill since the FPSO will be more than 100 miles off the Louisiana or Texas coasts. Naturally, the FPSO will have oil spill booms or similar containment equipment onboard in order to respond to emergency situations.

SUMMARY

Tanker based FPSOs give the industry a state-of-the-art option for producing deep water fields in the Gulf of Mexico.

Mr. Joe W. Key is the President of Key Ocean Services, Inc., which is an offshore production contractor with headquarters in Houston, Texas. He is a Fellow of the American Society of Civil Engineers, and a Fellow of the Society of Naval Architects and Marine Engineers (SNAME). He was the 1983 recipient of SNAME's Blakely Smith Medal, which has been awarded to only six individuals. He also was the Program Chairman for the 1989 Offshore Technology Conference.

DEEPWATER DRILLING AND DEVELOPMENT ADVANCEMENTS

Mr. Andrew F. Hunter
Conoco, Inc.

Today, industry is well on its way to establishing the basic technology required for deepwater oil and gas production. The challenge is to evolve the technology under the economic constraints of world oil prices.

What is "deepwater"? Today's answer in terms of production platform capabilities, is 400 m to 600 m. Ask the same question in 1999 and the answer will likely be 1,200 m to 1,800 m.

Exploratory drilling has already taken place in water depths beyond 2,000 m. If oil is found in commercial quantities, development will naturally follow within 5 to 10 years.

However, development and operating costs must be competitive with other sources of supply, if we are to succeed in maintaining an indigenous energy source for the U.S.

Obviously, as prudent operators, protection of the environment is of prime consideration in any development plan. As engineers, our task is to develop systems which are no less efficient than their shallow water counterparts, while maintaining the high level of safety inherent with that type of operation.

For the last 50 years, the vast majority of offshore developments have been on the "Continental Shelves," out to 200 m of water. The next 50 years will see the development of deepwater prospects over the "Continental Margins," or "Continental Slopes."

"Slope technology" has its own unique set of problems associated with a contoured seafloor and, in the Gulf of Mexico, soft bottom conditions.

Unlike flat bottom locations shallow water, one must engineer the production system to suit the site specific needs of the deepwater block.

A typical example of this technique is Conoco's Jolliet Field development on Green Canyon Block 184.

Taking advantage of the existing infrastructure of shallow water platforms and pipelines, economics can be greatly improved. By tying into this infrastructure, we can get the oil and gas to the onshore market.

Sometimes this is the only way to provide satisfactory economics for a deepwater development. Conoco's solution to the problem was to install a lightweight tension leg well platform (TLWP) on Green Canyon Block 184 in 536 m of water, and transfer the produced oil/water and gas to a central production platform on Green Canyon Block 52, in 200 m of water, for final processing and pipeline transfer to shore.

Conoco has developed this tension leg principle as a means to economically keep the wellheads above the water, in a manner similar to that found on shallow water platforms. We believe the TLWP is one of the best ways to provide economic surface real estate for deepwater. Once in production, well maintenance and operating costs are similar to those on shallow water fixed platforms.

A tension leg platform is simply an inverted pendulum, supported on the surface by the excess buoyancy built into the unit. In the case of the Jolliet TLWP, the overall weight of the unit is 12,000 metric tons. However, the displacement (the volume below the waterline) is 16,500 metric tons. This difference of 4,500 metric tons between buoyancy and weight is distributed as tension over the 12 tendons, each tendon carrying 375 metric tons.

The "tension leg principle" is merely the application of "Archimedes Principle" to an offshore structure.

The motions of the TLWP, under the influence of wind, waves, and current, are mainly lateral. The parallelogram formed by the tendons in the offset condition, causes the TLWP to "sit down" in the water, but the deck remains horizontal.

The TLWP has four basic components: a drilling template, a foundation template, the mooring system, and the surface vessel itself.

For the Jolliet Field, the drilling template was installed in 1987 to permit predrilling of the wells.

The foundation template was installed in 1988 and secured to the seafloor with 16-1.5 m diameter piles driven 100 m into the seafloor.

The structural framing of both templates was arranged to match the 4° sloping bottom, and special jacking mechanisms were attached to provide means to level the structures if necessary.

The mooring system is perhaps the most unique feature of the TLWP. Each tendon was built in one piece like a long pipe (600 mm outside diameter). Apart from the heavy end connectors which attach onto the foundation and the floating vessel, each tendon is neutrally buoyant, permitting them to be floated out and towed to the site.

At the site, they were sequentially upended and attached. Once all tendons were in position, the unit was fully deballasted and the tendon pretension established.

The TLWP vessel, using 6,500 metric tons of high strength steel, was fabricated in Singapore in one piece. It took one year to build, six weeks to outfit and six weeks to dry-tow it to the Gulf of Mexico.

The unit was installed in July 1989, all 20 production wells were hooked up and production started in November 1989.

The TLWP is not the only answer to deepwater development, but it has stirred the industry by showing what can be done with oil prices less than $20/bbl.

Several other companies are following Conoco's lead in proposing tension leg technology solutions to their deepwater problems. We see a bright future for this type of development.

Mr. Andrew F. Hunter is currently manager for Conoco's Jolliet Project. He has responsibility for the conceptual design, preliminary and final design, and its construction and installation. He holds a Mechanical Engineering degree in marine systems design and is a chartered engineer, a Fellow of the Institute of Marine Engineers, member of the Institute of Fuels, and holds 14 patents on T&P related systems.

ENVIRONMENTAL MONITORING:
GULF OF MEXICO OCS PROGRAM

Session: ENVIRONMENTAL MONITORING: GULF OF MEXICO OCS PROGRAM

Co-Chairs: Mr. Lester Dauterive
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ENVIRONMENTAL MONITORING: GULF OF MEXICO OCS PROGRAM: SESSION OVERVIEW

Mr. Lester Dauterive
and
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The Minerals Management Service (MMS), Gulf of Mexico Outer Continental Shelf (OCS) Regional Office of Leasing and Environment, is responsible for ensuring compliance with applicable environmental laws for its plan and permit actions. An assessment is made of the specific effects of postlease oil, gas, and sulphur operations which include exploration drilling; development, production, and transportation operations; structure removal; and site clearance. A program has been established to monitor the effects of those operations on certain other uses and resources of the OCS.

The MMS reviews and prepares evaluations of environmentally-related monitoring and survey activities, including biological surveys for topographic features, and the presence of live bottom and chemosynthetic communities; air quality; and structure removals. The MMS also encourages the conversion of selected obsolete oil and gas structures to artificial reefs on the OCS to enhance recreational and fishing opportunities in accordance with predetermined guidelines and goals.

The purpose of this session was to present the MMS requirements, mitigation, and a summary of findings for the monitoring/evaluation of data collected for topographic features, live bottom areas, chemosynthetic communities, air emissions, and structure removals. An overview of the implementation and monitoring of Louisiana's Artificial Reef Program was also presented.

Mr. Charles Hill, a biologist with the MMS Gulf of Mexico OCS Region, presented the first topic concerning monitoring of topographic high features. Specifically, this presentation dealt with the requirements and results obtained through monitoring efforts since 1974. There are 44 topographic features which the MMS, in consultation with the U.S. Fish and Wildlife Service and other interested parties, have determined to be worthy of a biological stipulation which requires the lessee to take protective measures, or restrict operations to protect the biota of the feature. Mr. Hill discussed the history of the biological stipulation, monitoring efforts, and techniques used in the Gulf of Mexico.

The stipulation has been modified over the years. A conclusion of a 1987 Biological Monitoring workshop was that shunting is effective and there was no need to continue extensive monitoring efforts. After the 1987 review of the stipulation, a Notice to Lessees and Operators (NTL) (No. 89-01) was promulgated by the MMS which gave the lessee the option to follow the old stipulation or the new NTL. Mr. Hill stated that valid conclusions can be drawn from the stipulation-required monitoring efforts and from other pertinent studies.

The second speaker was Mr. Ted Stechmann, a biologist with the MMS Gulf of Mexico OCS Region, who presented an overview of the monitoring of live bottom areas in the Gulf of Mexico. Live bottom areas are scattered in small patches throughout the Eastern Gulf Shelf. The MMS has consulted with the U.S. Fish and Wildlife Service and the State of Florida to determine what type of lease stipulation would be needed to protect these communities from adverse effects from oil and gas operations. Mr. Stechmann discussed in detail the requirements of the live bottom stipulation and measures which the MMS may adopt to protect live bottom areas. In conclusion, a summary of the results of five monitoring programs was presented including Charlotte Harbor Block 144, Gainesville Block 707, Destin Dome Block 167, Charlotte Harbor Block 622, and Pensacola Block 996.

Mr. Ken Graham, a biologist with the MMS Gulf of Mexico OCS Region, gave the next presentation concerning monitoring of chemosynthetic communities. Chemosynthetic communities are groupings of tubeworms, clams, and other organisms that are found at hydrocarbon seep locations on the Gulf of Mexico Continental Slope. Studies have concluded that these animals are widely scattered across the Central and Western Gulf of Mexico.

Mr. Graham presented a video of documented chemosynthetic communities found in Green Canyon Block 185. The MMS has adopted an NTL (No. 88-11) which formalizes the requirements for the protection of these communities. Mr. Graham discussed in detail the requirements imposed on the operator for organism protection and concluded with important questions that need to be answered in order for the MMS to effectively manage and protect these sensitive communities.

Mr. Elgin Landry, a meteorologist with the MMS Gulf of Mexico OCS Region, presented a discussion of MMS requirements for monitoring offshore air emissions. The MMS reviews OCS proposals to assure that emissions of nitrogen oxides, carbon dioxide, volatile organic compounds, total suspended particulates, and sulphur dioxide from offshore operations do not significantly affect onshore air quality pursuant to the Clean Air Act of 1970, as amended. Application of an exemption formula and modeling requirements were discussed in detail for individual facilities. The MMS has also used the Offshore and Coastal Dispersion Model (an in-house modeling study) to assess cumulative impacts to assure that the mandate of the OCS Lands Act is being followed and to require control strategies if any sources of pollution were determined to be significantly impacting on the air quality of any state. None of the OCS proposals have exceeded the exemption formula to date for individual facilities or in the cumulative assessment.

Mr. Rik Kasprzak, the Coordinator of the State of Louisiana's Artificial Reef Program, discussed the Program's implementation and monitoring. Mr. Kasprzak discussed the importance of platform structures in not only meeting the energy needs of the nation, but also for their role in supporting bountiful fishery harvests. According to Mr. Kasprzak, over 75% of all offshore recreational fishing trips are destined for one or more of these structures. Louisiana took measures to preserve and improve fishing opportunities associated with these structures by establishing the Louisiana Artificial Reef Initiative in 1985. In 1987, the Louisiana Senate and House Natural Resources Subcommittees approved the Louisiana Artificial Reef Program. Mr. Kasprzak next discussed the conversion of three platforms donated by Oxy Corporation, Chevron, and Mobil Exploration/Exxon Corporation. A significant component of the present Program concerns monitoring of reef sites to address liability and biological issues. According to Mr. Kasprzak, monitoring and assessment of artificial reef materials is an integral part of any reef program.

The final speaker was Mr. Richard Bennett, a biologist with the MMS Gulf of Mexico OCS Region, who discussed endangered species and marine mammal protection during offshore structure removals in the Gulf of Mexico. Mr. Bennett addressed the regulatory mandate for and number of structure removals since the inception of the leasing program in the Gulf of Mexico. As a result of concern over loss of sea turtles in South Texas, the MMS requested a Section 7 Consultation with the National Marine Fisheries Service for structure removals involving the application of explosives. In concluding, Mr. Bennett identified the precautionary measures which have been used since 1987 to lower the risk of injury or death to sea turtles or marine mammals during explosive structure removals. Since the imposition of these measures, there has been no evidence of harm or death to these animals.

Mr. Lester Dauterive is a Supervisory Environmental Protection Specialist in the MMS Gulf of Mexico OCS Regional Office of Leasing and Environment. Mr. Dauterive received his B.S. in biology from the University of Southwestern Louisiana and M.S. degree in environmental science from McNeese State University. Mr. Dauterive is the MMS Diving Officer and has been involved with the Gulf of Mexico Program for Environmental Monitoring throughout his 17 years with the MMS.

Ms. Bonnie LaBorde Johnson is a physical scientist in the MMS Gulf of Mexico OCS Regional Office of Leasing and Environment. She holds a B.A. degree in geography from the University of New Orleans. Her current area of involvement centers on coastal zone management and environmental issues related to offshore oil and gas operations.

MONITORING TOPOGRAPHIC HIGHS: REQUIREMENTS AND RESULTS

Mr. Charles W. Hill, Jr.
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INTRODUCTION

The concern for the coral reef-related biological communities on the 44 mostly shelf-edge topographic features was described. Above 85 m, these communities are essentially unique in the Gulf of Mexico, exhibiting coral reef and reefal associated communities which, because of this uniqueness and interest to the public and for research, required protection from potential damage from oil and gas operations. Lease stipulations have been developed which place certain operational restrictions on oil and gas operations designed to provide that protection, including the shunting of drilling fluids to within 10 m of the bottom and monitoring to detect any impacts to these important biota. In addition, Minerals Management Service (MMS) reviews all plans for oil and gas activities to ensure compliance with the stipulations and to impose additional environmental protection measures if necessary. Monitoring reports required by the stipulation are reviewed for completeness and, where appropriate, may lead to modifications of future monitoring requirements. In this review, 18 monitoring reports of 35 wells, 24 of which were shunted, were examined.

STIPULATION

The history of the stipulation was described. Essentially, in 1973-1974 impacts from the discharge of drilling fluids were unknown, and the stipulation was developed to determine such impacts, if any. Although the stipulation has changed in minor ways since then, the essential features remain: the establishment of a No Activity Zone, based on the 85 m isobath (100 m at the Flower Garden Banks), and zones of various distances (1,000 m and 1, 3, and 4 nautical miles, as appropriate), in which certain operations restrictions or requirements would obtain; if monitoring was required, a qualified reef ecologist would be required to conduct the monitoring effort, and a monitoring report would have to be submitted to MMS. As MMS gained new information as a result of these efforts (or through other means, such as the Outer Continental Shelf [OCS] Environmental Studies Program of the MMS), the stipulation was modified as necessary. Recently, a Notice to Lessees (NTL No. 89-01) was promulgated allowing lessees to follow the requirements of the latest version of the stipulation, rather than the other requirements of their lease (where appropriate).

MONITORING

The fate of the discharged drilling fluids (using barium as a tracer, since it is not considered a pollutant), and the effects (qualitative--photos and TV), were often measured. Pre-, during-, and post-drilling measurements were made. The following elements were often a part of the monitoring efforts:

- techniques--current meters, sediment traps, sediment cores, photos, TV, remotely operated vehicles;
- analysis--statistical (some), before-after comparisons, best professional judgement;
- results--distances fluids detected, area covered by settling, effects on biota, shunting versus non-shunting;
- outside comparison--National Academy of Science study, models; and
- criticisms--not scientific, weak or no statistics, differing methods, varying levels of quality, difficult to compare with other work.

With regard to the criticisms, it should be noted that the monitoring studies were never intended to be full blown scientific studies; they were, as mandated by the stipulation, designed simply to determine the effects of a particular operation on a particular biotic environment. This they have done. However, general conclusions regarding impacts and the efficacy of the stipulations have been possible, and have been largely confirmed by other studies.

MONITORING REPORTS

MMS reviewed the reports, and, where necessary, could modify the lessee's operations;

results were also used to help design the next activity or monitoring effort, to evaluate effectiveness of the stipulations, and to aid in modifying the stipulations.

SHUNTING

The shunting of drilling fluids to very near the bottom is acknowledged as a trade-off: wide dispersion and dilution throughout the water column by not shunting versus concentrating the fluids (cuttings and muds) in an area or layer away from biota of concern by shunting. However, shunting has been shown to be very effective in doing the latter; materials placed in that nearbottom layer do not later find their way to the tops of the banks where the biota of concern are located.

CONCLUSIONS

From the stipulation-required monitoring efforts and from other pertinent studies, the following conclusions can be drawn:

- Transmissivity approaches background at 1,500 m from the drill site.
- There is in general a dispersion of 10^6 within 2,000 m from the drill site.
- Drilling effluents are generally not detectable beyond 1,000 m of the drill site.
- Elevated levels of trace metals in surficial sediments are only evident in immediate (i.e., less than 1,000 m) area of drill site.
- Toxic effects of drilling muds observed in laboratory experiments are only at concentrations far exceeding those observed in the field.
- Water-based drilling fluids are essentially non-toxic.
- Acute damage to marine fauna is not observed except very close to the discharge point.
- Juvenile lobsters and flounders exposed to drilling fluid-contaminated sediment and food accumulate no more barium and chromium than those exposed to uncontaminated sediments alone.
- No substantial reduction in benthic abundance will occur greater than 1,000 m from the discharge point.
- Drilling effluents shunted into the near-bottom water layer will remain in that layer; physical conditions in the vicinity of topographic features ensures that currents, and their entrained particulate materials, will flow around the features, not up onto the features.
- The coral *Acropora cervicornis*, when exposed for 24 hours to 100 ppm whole drilling muds, did not suffer any mortality; when exposed to 500 ppm whole drilling muds, 100% mortality resulted. Neither of these concentrations is likely to occur in the field.
- Plume tracking studies of the lighter fraction have shown transmissivity to be the only hydrographic parameter altered beyond the immediate vicinity of the discharge source.

Mr. Charles W. Hill, Jr., is a biologist with the MMS, working in the Environmental Assessment Section in the Gulf of Mexico OCS Region. He holds Master's degrees in biology and marine resources management. He has been employed by the MMS for 13 years, concerned largely with issues involving benthic ecology. He also serves on the Coral Advisory Panel of the Gulf of Mexico Fishery Management Council.

MONITORING LIVE BOTTOM AREAS: REQUIREMENTS AND RESULTS

Mr. Ted Stechmann
Minerals Management Service
Gulf of Mexico OCS Region

The Final Regional Environmental Impact Statement, published in January 1963, defines live bottom areas as "those areas which contain biological assemblages consisting of such sessile invertebrates as sea fans, sea whips, hydroids, anemones, ascidians, sponges, bryozoans, seagrasses, or corals living upon and attached to naturally occurring hard or rocky formations with rough, broken, or smooth topography or whose lithotope favors the accumulation of turtles and fishes. The available evidence indicates that these areas are sparsely scattered in small patches throughout the eastern Gulf shelf." The existence of live bottom areas on the Florida shelf have been known for some time and are important in at least two respects. They have intrinsic value as a very productive habitat for a wide variety of organisms, including algae, sponge, and corals; and they provide habitat for a number of commercially valuable fish species. For these reasons, the Minerals Management (MMS) consulted with the U.S. Fish and Wildlife Service (FWS) and the State of Florida to determine what sort of lease stipulations were needed to protect these communities from adverse effects resulting from oil and gas operations. As a result of these consultations, all current leases in the eastern Gulf in water depths of 100 m or less, and many leases in water depths up to 200 m have a live bottom protective stipulation.

The live bottom stipulation, as originally conceived, states that "prior to any drilling activity or the construction or placement of any structure for exploration or development on this lease, including but not limited to well drilling and pipeline and platform placement, the lessee will submit to the Office of the Regional Director (ORD) a bathymetry map, prepared utilizing remote sensing and/or other survey techniques." This map must include interpretation for the presence of live bottom areas within a minimum of 1,820 m radius of a proposed exploration or production activity site.

If it is determined that the remote sensing data indicate the presence of hard or live bottom areas, the lessee must submit to the ORD photo-documentation of the sea bottom near proposed exploratory drilling sites or proposed platform locations. For activities in water depths greater than 70 m, this photo-documentation is required regardless of the remote sensing data interpretation. Furthermore, south of 26 ° north latitude (Howell Hook and Pulley Ridge lease areas) photo-documentation is required regardless of both water depth and remote sensing data interpretation.

If it is determined that live bottom areas might be adversely impacted, then the ORD will require the lessee to undertake any measure deemed economically, environmentally, and technically feasible to protect live bottom areas. These measures may include, but are not limited to, the following:

- the relocation of operations to avoid live bottom areas;
- the shunting of all drilling fluids and cuttings in such a manner as to avoid live bottom areas;
- the transportation of drilling fluids and cuttings to approved disposal sites; and
- the monitoring of live bottom areas to assess the adequacy of any mitigation measures taken and the impact of lessee-initiated activities.

Monitoring the impacts of nearby oil and gas activities on the biota of a live bottom, while not of itself providing protection for that specific operation, will add to our knowledge of such impacts for use during that and subsequent operations; if any impacts are detected by the monitoring program, other protective measures may be instituted for that operation, including moving the activity farther away from the live bottom.

As a result of a Department of the Interior (DOI) workshop of MMS and FWS biologists, the live bottom stipulation for the Gulf of Mexico was revised. The 1,820 m radius requirement was decreased to 1,000 m. This change was decided upon because numerous previous monitoring results throughout the Gulf indicated that impacts to biota as a result of drilling operations could not be detected at a distance from the drill site of greater than 300 m. This revision first appeared for the Eastern Gulf in the Final Environmental Impact Statement (FEIS) for lease sales 113/115/116, published in October 1987.

Since the stipulation first went into effect, photo-documentation surveys have been conducted in a number of blocks in the Eastern Gulf of Mexico. As a result of these surveys, the MMS has determined that monitoring of live bottoms would be required for only three exploratory drilling activities in the Eastern Gulf. In addition, two live bottom monitoring programs were requested by the State of Florida to address their concerns related to exploratory drilling. In each case, the operator contracted with Continental Shelf Associates, Inc. (CSA) of Jupiter, Florida to conduct the monitoring program.

A brief summary of the results of these five monitoring programs follows. The first three were MMS live bottom stipulation-required.

- CSA conducted a monitoring program for Gulf Oil Company in Charlotte Harbor Block 144. The report, filed in 1981, indicated that hard bottom outcrop and associated live bottom within 200 m of the drill site showed no signs of burial and no visually detectable impacts from drilling operations.

- In 1985 and 1986, a monitoring program was conducted for Shell Offshore Inc. in Gainesville Block 707. The program was conducted to determine drilling impacts on extensive seagrass beds which existed in the area. Post-drilling surveys showed an absence of all seagrass within 300 m of the drill site. Smothering by drilling effluent was assumed to be the causative factor. Seagrass recovery was hampered by the passage of Hurricane Elena in August of 1985, which destroyed what seagrasses remained in the area. However, the following year, the seagrass standing crop within 300 m of the drill site was approximately equivalent to predrilling biomass, indicating almost complete recovery.

- Since March of 1989, CSA has been conducting a monitoring program in Destin Dome Block 167 for Chevron U.S.A. Inc. to assess drilling impacts to what were considered at the time "marketable quantities" of the Calico Scallop, *Argopectin gibbus*, in the vicinity of the drill site. The first post-drilling cruise, conducted in August, found that the scallop population had been significantly reduced. However, there was no evidence to show a correlation between drilling activities and scallop mortality. By the time the cruise was conducted, the Calico Scallop industry off the West Florida coast had all but disappeared, the result, according to several boat captains in the Panama City area, of over-fishing by the scallop industry. A third cruise, conducted in November 1989, seemed to confirm this conclusion. During a total of 18 dredges at and surrounding the drill site, only two juveniles and no adult scallops were collected.

The following monitoring programs were requested by the State of Florida:

- During May-June 1986, a monitoring program was conducted in Charlotte Harbor Block 622 by CSA for Shell Offshore Inc. The survey was designed to detect gross changes such as mass mortality of epifauna, bleaching of coralline algae, and disappearance or reductions in cover of foliose algae. A post-drilling photographic survey detected coarse particles suspected to be drill cuttings within about 50 m of the drill site, and a light dusting of fine sediment (probably drilling muds) on some transects, mostly within 500 m of the drill site. There were no obvious impacts on benthic organisms.

- A monitoring program was conducted in Pensacola Block 996 during 1988 for Texaco Producing Inc. The program, which consisted of photo-documentation and surficial sediment sampling, was designed to assess impacts to identified live bottom in the vicinity of the proposed drill site. Post-drilling surveys indicated no large scale biological mortality occurred as a result of the activity. Coverages of most taxonomic groups observed prior to and after drilling appeared to agree between the reference area and within 2,000 m of the drill site.

Experience with the stipulation to date shows that it is indeed working to identify and protect live bottom areas. It should also be remembered that any oil and gas resources present under such live bottom areas could be recovered using directional drilling techniques.

Mr. Ted Stechmann is a biologist with the MMS Gulf of Mexico OCS Region, Office of Leasing and Environment. He holds a B.S. degree in biology from the University of Southern Mississippi. His areas of interest include biological resources, particularly live bottom areas of the eastern Gulf of Mexico.

MONITORING CHEMOSYNTHETIC COMMUNITIES: REQUIREMENTS AND RESULTS - CHEMOSYNTHETIC COMMUNITIES NOTICE TO LESSEES AND OPERATORS NO. 88-11

Mr. Ken Graham
Minerals Management Service
Gulf of Mexico OCS Region

Chemosynthetic communities are groupings of tubeworms, clams, and mussels found at hydrocarbon seep locations on the Gulf of Mexico Continental Slope. The organisms derive their energy from seeping gas and oil in a process known as chemosynthesis.

When these animals were first discovered, Minerals Management Service (MMS) was concerned that they were so rare that they could be endangered. Subsequent research work indicated that the animals were widely scattered at various seepage sites across the central and into the western Gulf of Mexico.

Investigators next discovered that some seep areas supported very dense and complex chemosynthetic communities. The presentation included some video highlights of the "Bush Hill" site, located in Green Canyon Block 185. The video footage emphasized the density and diversity of animals found at "Bush Hill," as well as the indications of hydrocarbon seepage which could be observed there. It is these dense chemosynthetic communities that MMS is concerned about protecting from the impacts of oil and gas activities.

The Notice to Lessee and Operators (NTL) No. 88-11 formalized the requirements for protection of dense chemosynthetic communities that were already being imposed on oil and gas lessees and operators on a case-by-case basis. It applies to all operations of Gulf of Mexico leases in water depths greater than 400 m. The provisions of NTL No. 88-11 are summarized as follows.

- Operators must delineate seafloor areas which would be disturbed by their proposed operations.
- Operators must interpret their geophysical information (and other pertinent information that is available) for the presence of geological phenomenon which could support chemosynthetic communities.
- MMS will review the proposed activities to determine if dense chemosynthetic communities could be impacted. If they could, the following protective measures may be imposed on the operator:

  1. The operator would be required to modify the plan to avoid impacting these areas.
  2. The operator must furnish further information such as photo or video surveys to determine if dense chemosynthetic communities can actually be found there.
  3. Other measures could be required for protecting or monitoring the impacts to these communities.

Although no impact monitoring has been required for chemosynthetic communities, two plans for oil and gas activities were received in the summer of 1989 in which the operators performed video surveys. Information about the equipment and methods used to conduct these two surveys was provided. Video highlights of what was found in the two blocks (Mississippi Canyon Block 28 and Garden Banks Block 300) were presented. Results of the two surveys indicated that the proposed operations were unlikely to impact any dense chemosynthetic communities.

In order for MMS to more effectively manage and protect dense chemosynthetic communities, further information is needed. Some questions that need to be answered include the following:

- What is the ecological significance of dense, "Bush Hill" type communities for the continental shelf and overall Gulf of Mexico ecosystems?

- How common (or rare) are dense chemosynthetic communities across the Gulf of Mexico Continental Slope and what is the extent of their geographic distribution?

- How ephemeral (or permanent) are dense chemosynthetic communities and the hydrocarbon seeps that support them under natural conditions?

- Are there any characteristics of dense chemosynthetic communities which would make them easily detected by remote sensing techniques or make their locations accurately predicted?

- How quickly do chemosynthetic communities recover from physical impacts such as anchor scars?

- How are seeps and the chemosynthetic communities that are supported by them affected by oil and gas production from reservoirs which supply hydrocarbons to the seeps?

Mr. Ken Graham is currently employed as a biologist by the MMS, Gulf of Mexico OCS Region in New Orleans, Louisiana. Prior to that time, he worked as a biologist for the Jacksonville District, U.S. Army Corps of Engineers. He received a B.A. degree in biology from Luther College and a M.S. degree in botany from North Dakota State University.

MONITORING OFFSHORE AIR EMISSIONS: REQUIREMENTS AND RESULTS

Mr. Elgin Landry
Minerals Management Service
Gulf of Mexico OCS Region

The requirements and results of monitoring air emissions from oil and gas and sulphur operations in the Outer Continental Shelf (OCS) were presented in this session.

The Outer Continental Shelf Lands Act (OCSLA), as amended, requires the Secretary of the Interior to proscribe regulations (Section 5 [a] [8]) for compliance with the national ambient air quality standards pursuant to the Clean Air Act (CAA) of 1970, as amended, to the extent that oil and gas and sulphur activities authorized under the OCSLA significantly affect the air quality of any state.

The Department of the Interior (DOI) promulgated final rules (30 CRF 250.57, March 7, 1980 now found at 30 CFR 250.44, 30 CFR 250.45, and 30 CFR 250.46 effective April 1, 1988) regulating air emissions in the OCS. The Gulf of Mexico Region is charged with assuring that emissions of nitrogen oxides, carbon dioxide, volatile organic compounds, total suspended particulates, and sulphur dioxide from offshore operations do not significantly affect onshore air quality pursuant to the CAA.

Several tiers of regulations apply to offshore air emissions. The initial review concerns an exemption based on a distance formula designed to screen an application for compliance with a significant amount of emissions at the site of the operation.

If a violation of the allowable amount of emissions offshore is found, the operator must use an approved air quality model to determine if these emissions will significantly affect an onshore area as defined by 30 CFR 250.44, 30 CFR 250.45, and 30 CFR 250.46.

If the modeling results determine that a significant effect would be felt onshore, controls must be installed to reduce the emissions. This presents the occasion for monitoring and for the lessee/operator's reporting of the findings. Additional monitoring of the meteorological data is also required at this stage. Another cause for monitoring would be when a situation in which an operator determined the offshore air emissions is based on the use of controls at the initial stage of calculations. Monitoring would be required at that stage to determine if the controls are effective.

The procedures discussed above were for individual facilities. The DOI rules envisioned a program by which the Minerals Management Service (MMS) would periodically assess the cumulative impacts from OCS facilities to ensure that the mandate of the OCSLA was being followed and to require control strategies if sources were significantly impacting the air quality of any state. In this regard, a modeling study was conducted in-house. The study utilized the official model, the Offshore and Coastal Dispersion Model, required by the MMS. The input consisted of emissions from 85 platforms with 195 point sources in an area within 38 miles offshore Lafourche, Jefferson, and Plaquemines Parishes, Louisiana. The results of the study determined that the maximum concentration at the shoreline was 1.83 micrograms per cubic meter. The NAAQ standard is 100 micrograms per cubic meter.

As of this date, over 5,000 Exploration Plans and/or Development Operations Coordination Documents have been reviewed. None of the emissions exceeded the distance exemption formula. Therefore, there has been no occasion thus far for any official monitoring procedures or reports.

Mr. Elgin Landry has been the staff meteorologist of the MMS Gulf of Mexico OCS Regional Office since the inception of the air quality regulations for the OCS in 1980. Mr. Landry earned a B.S. in meteorology from Penn State. His duties include pre- and post-lease environmental reviews.

THE IMPLEMENTATION AND MONITORING OF LOUISIANA'S ARTIFICIAL REEF PROGRAM

Mr. Rick A. Kasprzak
and
Dr. Charles A. Wilson
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Louisiana's offshore oil and gas industry began in 1947 when the first well was drilled out of sight of land south of Terrebonne Parish. Today over 4,500 offshore oil and gas platforms have been installed supplying over 25% of the U.S.'s production of natural gas and 10% of its oil (Reggio 1989).

In addition to meeting the nation's energy needs, these structures also form one of the world's most extensive de facto artificial reef systems. For over 40 years fishermen from Louisiana and neighboring states have recognized the bountiful fishery harvests that exist beneath these structures. These platforms are so popular as fish havens that over 75% of all offshore recreational fishing trips are destined for one or more of these structures (Witzig 1986). Louisiana has taken steps to preserve and improve the fishing opportunities associated with these structures.

Federal regulations and international treaties require that platforms be removed within one year after the lease has been terminated. Over 470 platforms had already been removed by 1986 and at that time it was estimated that 2,500 platforms were expected to end their primary life as an oil and gas structure by 1996 (NRCMB 1985). The removal of these structures is a major expense to the oil and gas industry, a loss of vital fishery habitat for many marine species, and a loss of favorite fishing spots.

In 1985, some Louisiana citizens became concerned about the inevitable removal of offshore oil and gas structures (Reggio et al. 1986) and formed the Louisiana Artificial Reef Initiative (LARI). LARI was a unique blend of federal, state and university representatives, members of various recreational and commercial fishing interests, and representatives of Louisiana's oil and gas industry. Modeling state legislation after U.S. Senator John Breaux's National Fishing Enhancement Act, LARI members developed the Louisiana Fishing Enhancement Act (Act 100) to provide the authority to develop a comprehensive artificial reef program for Louisiana. Signed into law on June 25, 1986, Act 100 established Louisiana's Artificial Reef Development Program and outlined the duties of the participating agencies. Act 100 gave the State of Louisiana the authority to act as permittee for the reef sites (Louisiana Department of Wildlife and Fisheries) as well as the responsibility for siting, maintaining, and enhancing artificial reefs (Louisiana Geological Survey and Coastal Fisheries Institute at Louisiana State University) in both State and Federal waters off Louisiana's coast utilizing, but not limited to, retired oil and gas structures.

Since the Louisiana Artificial Reef Program was approved by the Louisiana Senate and House Natural Resources Subcommittees in 1987, three artificial reef sites using the underwater support structures (platform jackets) from four obsolete platforms and one entire production platform have been established off Louisiana. The first reef was created in October 1987 when Oxy Corporation (formerly Cities Service) donated the jacket of a large eight-pile structure. Since the 3,500 ton jacket was already in one of the eight pre-determined planning areas, the jacket was toppled in place in 238 feet (ft) of water south of Marsh Island, Louisiana (Thornton and Quigel 1989).

Chevron followed suit 10 months later, toppling one of its former production platforms 28 miles off the southeast coast of Louisiana. Again, the structure was in a pre-approved planning area and was toppled in place in 102 ft of water (Kasprzak 1989).

Louisiana's third reef was a cooperative effort between Mobil Exploration and Producing and Exxon Corporation. Since the jackets of petroleum platforms scheduled for removal were not in a planning area, the participating companies had to transport the jackets from offshore Texas to offshore Louisiana. Exxon towed two jackets 27 miles from their High Island location to the West Cameron planning area where they placed them within the permitted reef site. Mobil removed and transported the jacket of its Mustang Island A-90-A platform 200 miles from a location off Corpus Christi, Texas to the established reef site. Each company also has an actively producing platform within the State-permitted site scheduled for abandonment within the next few years. These will likely be toppled in place once the lease is terminated and slated for removal.

In addition to providing, transporting, and deploying the reef material, the participating companies also donated half their savings realized through participation in the program. These funds were placed in the legislatively protected trust fund for further reef development and maintenance and monitoring of the existing artificial reefs.

A significant component of Louisiana's Artificial Reef Program is the responsibility of monitoring the reef sites. Our monitoring program has liability and biological components which were established to maintain and improve the Program. As part of obtaining a Corps of Engineers permit for artificial reef development, the permit holder is responsible for monitoring the reef site to insure permit compliance (Stone 1985). This includes, but not limited to, ensuring the reef remains buoyed, when necessary, and to monitor the structural integrity and location of the reef material.

Buoy inspections can be done visually from the surface to verify they are on location. Inspection of the buoy anchoring system can be performed with SCUBA in waters less than 120 ft or with a mechanical remote operating vehicle (ROV) in greater depths. For example, inspection of the buoy at ST-128 in August 1989 revealed it to be heavily fouled with marine growth which caused it to ride 1-2 ft lower than normal. Although a structural failure in the anchoring system of our WC-616/617 buoy prevented its inspection, the buoy once retrieved, demonstrated very little fouling even though it was in the water approximately the same amount of time as the buoy in ST-128. This may be due in part to the distance offshore (120 miles versus 28 miles) or the difference in depth (310 ft versus 103 ft).

Assessment of the location and condition of reef material will help determine the degree of deterioration, rate of subsidence, and rate of movement. An initial position is determined so that the reef materials can be accurately charted for navigational purposes and enable fishermen to find them. They are periodically verified to assure the reef managers and regulatory agencies that the material has not shifted or exhibited any major movement. Accurate measurements of the clearance over the top of the reef provides reef managers with subsidence estimates. Measurements taken approximately one year after deployment indicated the structure at ST-128 had not moved from its original location but subsided approximately 6-8 ft (Dauterive 1989). Accurate diver verified depth measurements on our SMI-146 and WC-616/617 reefs have not been made. Measurements taken using a fathometer and ROV indicate the structure is still on location and the clearance over the top of the reef has not significantly changed (Kasprzak 1987; Palmer 1989, pers. comm.).

"Tidal fluctuations, temperature changes, current flow, marine biota, and the salty marine environment all contribute to the deterioration of man-made reef materials" (Lukens et al. 1989). However it has been shown that oil and gas structures are very durable in the marine environment. It was estimated that with the present cathodic protection and the thickness of the steel used in construction, the reef at SMI-

146 will take over 300 years to deteriorate (Thornton and Quigel 1989). A visual inspection by SCUBA of the structure at ST-128 revealed that severe deterioration had occurred in the lower portions of the jacket over the approximate 30 years prior to toppling, however, very little deterioration was evident in the upper portion of the structure which was above the water prior to toppling.

Biological monitoring to determine the effectiveness of artificial reefs is another component of a comprehensive reef program (Lukens et al. 1989). A visual inspection of the ST-128 reef revealed both young and adults of many species of marine reef fish and provided evidence that ST-128 was acting as a recruitment site for many species of reef fishes (Dauterive 1989). A qualitative analysis of both the pelagic and reef fish populations prior to, immediately, and one year after toppling the structure, indicated that toppling the structure in place had little to no effect on the community structure of the reef site. An ROV survey by Mobil of its former platform in August 1989, approximately nine months after transportation and placement, were inconclusive (Palmer 1989, pers. comm.). The apparent lack of fish on this structure may have been due to the fact that the structure had not become fully recruited or there was insufficient light and poor visibility preventing accurate visual assessment. Lukens (1980) indicated it took approximately 15 months for artificial reefs to become fully recruited.

Future biological monitoring plans include the application of a dual-beam hydroacoustic system, ROV, and side-scan sonar. With the advent of dual-beam hydroacoustic systems, target strengths of free swimming fish can be measured and used to calculate the number and size of fish detected. An estimate of abundance can be extrapolated once the total volume sampled can be determined (Burczynski and Dawson 1987). With this system we hope to define the area of influence around typical oil and gas structures and assess their subsequent re-use as artificial reefs, provide biomass estimates of various species of fish associated with oil and gas platforms and artificial reefs, and determine factors influencing variations, and document behavioral patterns of selected fish species relative to oil and gas platforms and artificial reefs in the northern Gulf of Mexico. The use of this equipment will lead to a better understanding of the community structures of oil and gas structures and artificial reefs.

The ROV and side-scan sonar will aid us to monitor our deeper reef sites when it's not practical to monitor them with SCUBA. The side-scan sonar will be used to physically mark the position of the reef and to determine whether or not the reef is breaking up and drifting off location. The ROV will enable us to visually inspect the reef to determine deterioration, subsidence rates as well as inspect buoy mooring systems for defects which occur over time.

Monitoring and assessment of artificial reef materials is an integral part of any artificial reef program. It is an activity which is critical in evaluating the effectiveness of artificial reefs in attracting and maintaining fish populations and it contributes to the long-term effectiveness of reef materials by providing reef managers with information on the suitability of bottom types and materials.

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Mr. Rick Kasprzak received a B.S. degree in zoology from Loyola College, Baltimore, in 1975. Since 1987 he has been coordinator of Louisiana's Artificial Reef Program for the Department of Wildlife and Fisheries at Louisiana State's Coastal Fisheries Institute. Prior to that he was employed by the Louisiana Department of Wildlife and Fisheries as a district supervisor in the Marine Finfish Section. His research interests include: artificial reef development and their impact on the community structure of fishes, resource management, as well as fisheries ecology and population dynamics.

Dr. Charles Wilson earned a B.S. from Hampden-Sydney College in Virginia in 1976, M.S. and Ph.D. from the University of South Carolina (1980, 1984). He, with Virginia Van Sickle, established the Louisiana Artificial Reef Initiative in 1984 and has been an active participant in the evolution of the State program. He is an Associate Professor in the Marine Sciences Department of the Coastal Fisheries Institute at Louisiana State University. His research interests include: artificial reef development and their impact on the community structure of fishes, age and growth of fishes, and mariculture.

ENDANGERED SPECIES AND MARINE MAMMAL PROTECTION DURING OFFSHORE STRUCTURE REMOVALS IN THE GULF OF MEXICO

Mr. Richard T. Bennett
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Gulf of Mexico OCS Region

INTRODUCTION

The first oil and gas lease sale on Federal Outer Continental Shelf (OCS) lands in the Gulf of Mexico was held in 1954. Since that historic sale, there have been 67 other oil and gas lease sales in the Gulf of Mexico Region. Approximately 26,684 wells have been drilled on these leases through December 1988. From 1953 through 1988 approximately 4,220 oil- and gas-related structures have been installed and 576 have been removed on the Federal OCS. The National Research Council (1985) projected that approximately 2,600 of the oil- and gas-related structures in use today will be removed by the year 2000 (Figure 13.1).

REQUIREMENTS FOR REMOVALS

In compliance with the 1958 Continental Shelf Convention, the U.S. agreed to completely remove any installations (structures/platforms) that are abandoned or disused on the OCS. According to Section 22 of the current oil and gas lease form (MMS-2005 [March 1986]), lessees are required to remove all devices, works, and structures from the lease block within a period of one year after termination of the lease. In compliance with 30 CFR 250.112(i), all obstructions must be removed at least 15 feet (ft) below the mud line. The lessee must also verify that the site has been cleared of obstructions per one of the procedures listed in 30 CFR 250.114.

Prior to 1986, explosive contractors had few requirements during structure removals; cost considerations determined explosive methodologies. The common practice was to buy the cheapest explosive available, prepare a linear or ring-shaped bulk charge, emplace, and detonate the charge. Since delays are very costly in salvage operations, "overcharging" (using more explosives than necessary) was the common practice to ensure successful severing of the structure's pilings and well tubulars (DeMarsh 1987).

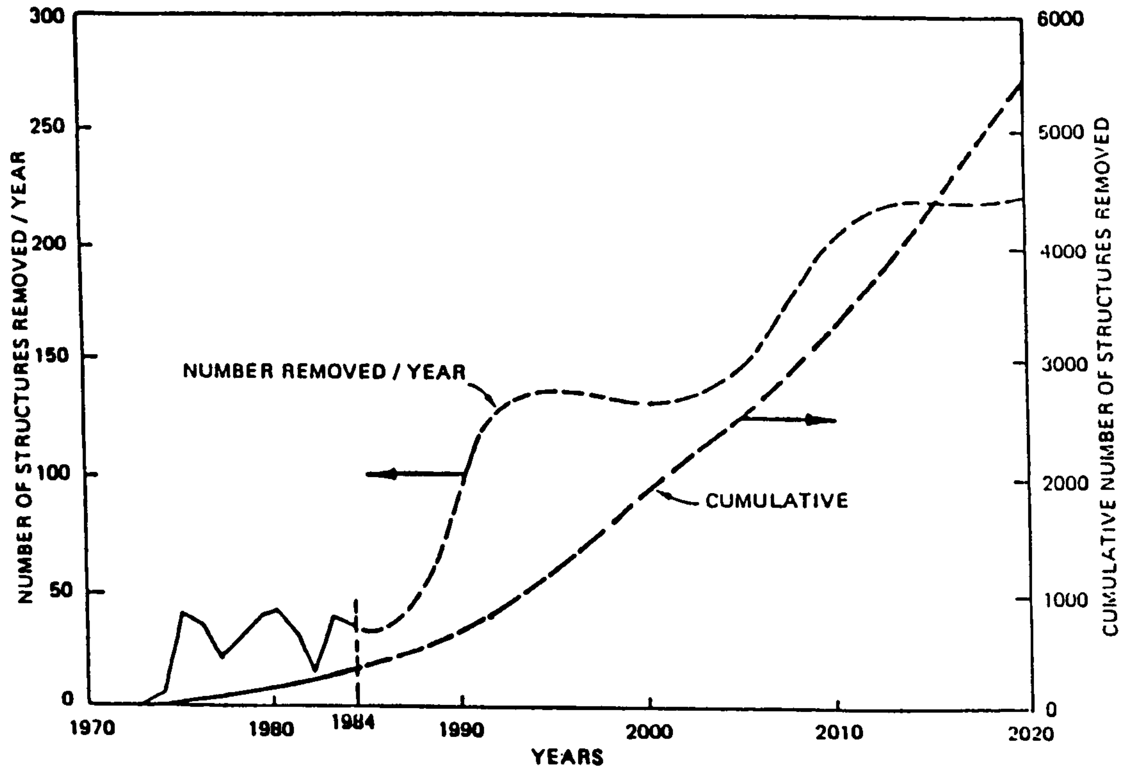
ENDANGERED/THREATENED SPECIES AND PROTECTED MARINE MAMMALS IN THE GULF OF MEXICO

In April 1986, the Regional Director of the Minerals Management Service (MMS) Gulf of Mexico OCS Regional Office, received a letter from the Director of National Marine Fisheries Service (NMFS) Laboratory in Galveston, Texas, that expressed concern regarding two major stranding events--one in the fall of 1985 and the second in the summer of 1986. Dead marine turtles and other animals were associated with these stranding events along the beaches of the upper Texas and southwestern Louisiana coasts. Coincidentally, a number of structures in state territorial waters had been removed. The NMFS suggested that a correlation may exist between the explosive removal of structures and the stranding of sea turtles and other animals.

The Regional Director of the Gulf of Mexico OCS Regional Office responded to these concerns and sent a letter to all lessees and operators in August 1986 requesting that the office be notified 30 days in advance of any plans to remove structures. Since the Regional Director determined that explosive structure removals may affect threatened and endangered species, he sent a second letter to all lessees and operators requesting additional information to facilitate interagency consultations under Section 7 of the Endangered Species Act (ESA), as amended. Each proposed explosive structure removal or group of explosive structure removals then underwent Section 7 consultation procedures.

In November 1986, the MMS and NMFS agreed to procedures to facilitate and expedite formal consultations under Section 7 of the Endangered Species Act with respect to removing oil and gas structures in the Gulf of Mexico using explosives. Between November 1986 and March 1988, 34 expedited consultations were initiated and 30 opinions received because of the enhanced effort provided by MMS and NMFS. It was suggested in March 1988 by MMS to NMFS that there be a category of removals which represent a "standard" removal operation. In all of the expedited consultations initiated for structures with less than eight piles and four conductors removed, using charges less than 40 pounds, the Incidental Take Statements was virtually identical. Personnel from the NMFS and MMS met on April 14, 1988, to evaluate the feasibility of engaging in a generic consultation under the ESA for specific categories of OCS oil and gas structure removals in the Gulf of Mexico from which a generic consultation was formulated. A "generic" Section 7 Consultation handles approximately 90% of the explosive removals. Approximately 100+ structures may be scheduled for removal next year.

Since 1986, the MMS has received 333 applications for structure removals (both explosive and nonexplosive methodologies). Ninety-six explosive removals and 79 nonexplosive removal applications have been approved as of November 21, 1989.



Sources: Historical data from Minerals Management Service and industry sources; forecast developed by committee based on assumptions described in the text.

Figure 13.1. Structures removed and to be removed--Gulf of Mexico.

CONCLUSIONS

The following precautions required by the MMS and NMFS have been very effective in lowering the risk of injury or death to sea turtles and marine mammals from explosive structure removals. Since the imposition of the mitigative measures, there has been no evidence to indicate that any of the explosive structure removals since the summer of 1987 have injured or killed a sea turtle or marine mammal.

- Qualified observer(s) must be used to monitor the area around the site before, during, and after detonation of the charges.
- On the day of blasts, a 30-minute aerial survey must be conducted within one hour before and one hour after the detonation.
- If any sea turtles are observed in the vicinity of the structure (within 1,000 yards of the site) before detonating charges, the blast must be delayed until steps are taken to remove them.
- Detonation of explosives must occur no sooner than one hour following sunrise and no later than one hour before sunset.
- During all diving operations, the diver must be instructed to scan the subsurface areas surrounding the structure site for turtles and marine mammals.
- Charges must be staggered to minimize the cumulative effects of the blast.

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Mr. Richard T. Bennett is a biologist in the MMS Gulf of Mexico OCS Region, Office of Leasing and Environment. Mr. Bennett received his B.S. degree from Mississippi State University and his M.S. degree from the University of Southern Mississippi. Mr. Bennett is involved with assessing environmental impacts of oil and gas operations in the Gulf of Mexico and their effect on fisheries, marine mammals, and endangered species.

NORTH AMERICAN DATUM CHANGES

Session: NORTH AMERICAN DATUM CHANGES

Co-Chairs: Mr. Douglas Elvers
Mr. J. Homer Benton

Date: December 7, 1989

Presentation	Author/Affiliation
North American Datum Changes: Session Overview	Mr. Douglas Elvers and Mr. J. Homer Benton Minerals Management Service Gulf of Mexico OCS Region
The Transformation of Positional Data from the North American Datum of 1927 to the North American Datum of 1983	LCDR Warren T. Dewhurst National Geodetic Survey
Minerals Management Service and the Implementation of the North American Datum 1983: A Status Report	Mr. Paul H. Rogers Minerals Management Service OCS Survey Group
Offshore Navigation Requirements: Improvements to be Gained by the NAD 27 to 83 Transformation	Mr. Harold Spradley National Ocean Industries
The Relationship of the NAD 27 Datum to Leasing on the OCS and the Impact of Changing to the NAD 83 Datum	Mr. Dave M. Groce Texaco, Inc.
Navigation and Positioning for Offshore Installations	Mr. Phil Stutes John E. Chance and Associates, Inc.
Positioning Requirements for Platforms and Pipelines for NAD 27 to 83 Conversions	Mr. Joe Culp Texaco, Inc. Offshore Operators Committee
North American Datum Changes: Panel Session	Mr. Douglas Elvers and Mr. J. Homer Benton Minerals Management Service Gulf of Mexico OCS Region, Mr. Paul H. Rogers Minerals Management Service OCS Survey Group, Mr. Harold Spradley Satellite Positioning Corporation, LCDR Warren T. Dewhurst U.S. Department of Commerce NOAA, and Mr. Dave M. Groce Texaco, Inc.

NORTH AMERICAN DATUM CHANGES: SESSION OVERVIEW

Mr. Douglas Elvers
and
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Gulf of Mexico OCS Region

With the vastly improved surveying equipment and satellite positioning systems now in use it became evident to the geodesists that the shape of the earth was slightly different from that envisioned in 1927 when the North American Datum of 1927 (NAD 27) was implemented. Therefore in 1983 a new datum was initiated. On December 6, 1988, the Federal Geodetic Control Committee (FGCC), stated to the extent practicable, legally allowable, and feasible, all civilian Federal agencies using or producing coordinate information should provide for an orderly transition from NAD 27 to North American Datum of 1983 (NAD 83).

All leases, pipeline right-of-ways, and development work located in the Gulf of Mexico Region are described on official leasing maps or protraction diagrams. These locations, such as a lease block, are defined by X and Y coordinates.

All of the existing leasing maps and protraction diagrams coordinates are currently referenced to the NAD 27. The purpose of holding this session was to identify the latest information available from the National Geodetic Surveying conversion of offshore coordinates from the NAD 27 to that of NAD 83. In addition, we wanted input from the oil and gas industry on problems they foresaw on implementing a conversion. There is considerable geodesy, and leasing expertise within the various oil companies and survey companies that operate offshore in the Gulf.

The following statements are an attempt to summarize this session. It must be pointed out that even by extending this session beyond the time limit by one hour, there were a number of unanswered questions and there was no general consensus among the participants on a number of key issues.

- The NADCON conversion has been adopted by the FGCC.
- Map regridding in the Gulf would probably cause heavy administration burdens on Minerals Management Service (MMS) and industry.
- The surveying personnel in industry are aware of NAD 83 and the problems that could arise from interchanging NAD 27 and 83 coordinates without proper conversion.
- Industry and government agree that NAD 83 is an improved datum.
- Industry and MMS will have to work closely in implementing NAD 83 data.

This session was timely and the exchange of information was useful to both the MMS and the oil and gas industry. The MMS appreciates the participation of the speakers and those in attendance.

A panel discussion closed the session. The fact that the FGCC had adopted NADCON the day of our meeting caused additional intensity and electricity to the panel session. About 50 participants attended and few were too bashful to make comments or ask questions.

Some industry representatives were concerned that NADCON would (due to extrapolation from Geodetic Reference System shoreline data) be sacrificing accuracy for convenience in the deep water offshore. Landsmen's representatives were concerned that changes might create acreage or boundary changes that could legally cloud their existing leases and complicate production and royalty accountings. Recommendations were made to test NADCON and particularly describe which datum, projection, and central meridian was used to identify future mapping. The feeling was that many of the potential problems and ongoing concerns could be alleviated by a better understanding of NADCON and why these changes were taking place. Some uncertainties seem to be perceptions of accuracies and small differences for offshore that are difficult to determine.

Several participants felt that NADCON was workable, and that MMS would not create changes for "sake of change" concerning lease datum year of origin. Further information transfer on the subject and certain assurances from MMS were felt to be desirable.

Mr. Douglas Elvers has worked 31 years in Federal surveying, mapping, and environmental programs. His early years were spent on geophysical surveying, navigation, and mapping for the U.S. Navy and the Coast and Geodetic Survey (now National Ocean Survey NOAA) from the Arctic Circle to Antarctica. During the past 17 years Mr. Elvers and his staff have produced environmental documents and maps in the Gulf of Mexico and the Atlantic that generated for MMS a total of 28 Environmental Impact Statements which supported 41 oil and gas lease sales and one sulphur/salt lease sale.

Mr. J. Homer Benton is the Deputy Regional Supervisor in the MMS, Gulf of Mexico OCS Region, Office of Leasing and Environment. His responsibilities include the overall management and direction of that office's offshore lease sales program, which encompasses the supervision of activities necessary for the preparation of required pre- and post-lease environmental and socioeconomic analyses, lease sales, lease issuance, and lease maintenance. Mr. Benton holds a B.S. in forestry management from Mississippi State University and has held positions in resource management under the Bureau of Land Management in Oregon, Colorado, and Wyoming. Mr. Benton has held positions in the offshore oil and gas program in the Atlantic OCS Region, Headquarters, and the Gulf of Mexico OCS Region.

THE TRANSFORMATION OF POSITIONAL DATA FROM THE NORTH AMERICAN DATUM OF 1927 TO THE NORTH AMERICAN DATUM OF 1983

LCDR Warren T. Dewhurst
National Geodetic Survey

ABSTRACT

A constancy in geodetic datum must be maintained when comparing or mixing coordinate data from varying sources. Correct relationships cannot be realized unless all coordinates are in the same system of units and within the same datum. A large quantity of ground survey and feature coordinates are referenced to the North American Datum of 1927 (NAD 27), including coordinates associated with offshore lease blocks managed by the Minerals Management Service. NAD 27 has been replaced as the official North American geodetic datum by the North American Datum of 1983 (NAD 83). A potential for datum inconsistency confronts the land survey and offshore industries. The potential for misunderstanding and error is great.

A rapid and sufficiently accurate transformation methodology has been developed which can be used to transform large quantities of existing coordinate information between NAD 27 and NAD 83. This methodology, employing modeling of datum shift information and straight-forward interpolation, represents a distinctly new and different approach to the problem. Results indicate that the transformation procedure itself will introduce no more than 15 cm of positional error for the majority of the coterminous U.S. Remote regions, especially offshore areas, where geodetic control is either sparse or nonexistent may experience less accurate results, but seldom in excess of 1 m. The transformation method has been programmed in standard FORTRAN 77 for use on a multitude of computing platforms, including IBM PC compatible microcomputers. This program, known as NADCON, is available from the National Geodetic Survey (NGS) to assist the user community with datum transformations. It is intended to facilitate and ease the transition from NAD 27 to NAD 83.

BACKGROUND

The NAD 83 represents the single most accurate and comprehensive geodetic survey datum in the history of the U.S. The NAD 83, historically the third official U.S. datum, supersedes the NAD 27. The NAD 83 provides a consistent datum for the country, at a higher level of accuracy.

What were the problems with NAD 27? What makes this new datum preferable to use? These questions are often asked, largely due to the fact that the "old" datum has proven useful for so long.

There are several fundamental reasons why the geodetic reference system for the U.S. required reconsideration. Increasing demands by the surveying community, the introduction of highly accurate electronic measurement systems, and the advent of satellite tracking systems such as Doppler and the Global Positioning System all contributed to the identification of weaknesses in the NAD 27. Discrepancies between existing control and newly established surveys predicated the establishment of an entirely new datum rather than a "repair" to NAD 27. The arguments articulating the necessity for a new datum are well documented by Whitten and Burroughs (1969), Whitten (1971), and the National Academy of Sciences (1971). In summary, NAD 27 suffers from (1) an outmoded and obsolete mathematical representation of the Earth, (2) inconsistencies arising from partial adjustments of data on a regional basis, and (3) limitations due to outdated survey instrumentation. These inconsistencies needed to be reconciled to provide a consistent datum from coast to coast and between neighboring nations within North America (Schwarz, In press).

DIFFERENCE BETWEEN NAD 27 AND NAD 83

The differences between NAD 27 and NAD 83 arise from a difference in the assumed coordinate systems as well as the approach taken in the calculation of coordinate values. Figure 14.1 shows the total magnitude of the shifts between these datums for the coterminous U.S.

The largest discrepancies can be attributed to the choices in reference ellipsoids (of revolution) for each datum. Reference ellipsoids or spheroids, a geometric approximation for the Earth, are necessary for the definition of coordinate systems. NAD 27 depends upon an early approximation, known as the Clarke Spheroid of 1866, while NAD 83 relies upon the more exacting Geodetic Reference System of 1980 (GRS 80). Datum differences attributed to differences in ellipsoid can be in excess of 100 m in amplitude. The Clarke Spheroid of 1866 was designed to optimize or fit the shape of the coterminous U.S., while GRS 80 is global in extent. GRS 80 was made possible due to advances in satellite tracking technology and modeling. The primary advantage of GRS 80 is that it facilitates the computation of correct geometric relationships on a global as well as a continental scale. GRS 80 is a geocentric ellipsoid, indirectly employing the Earth's center of mass in the specifications for the coordinate system; the center of the reference ellipsoid is defined as the Earth's center of mass. The Clarke Spheroid of 1866 employed a specific coordinate pair, as well as a geometric relationship (orientation), in order to define the survey datum. The coordinate pair for a station known as MEADES RANCH in Kansas served as the origin, rather than the Earth's center of mass.

In addition to discrepancies caused by differences in the definition of coordinate systems, small differences or local distortions (on the order of 10 m) arise from differences in adjustment and survey methodologies. Coordinate values referenced to NAD 27 were obtained in layers, with accurate geodetic networks serving as a framework for less accurate observations.

The NAD 27 was performed prior to the advent of digital computers and all of the computations and data assimilation were done manually. A large-scale, totally comprehensive adjustment of all horizontal control data within the U.S. represented an impossible task.

In contrast, NAD 83 represents the simultaneous consideration of all geodetic survey information; a layered computational approach was not utilized. This ensured that observations connecting stations were all related, regardless of survey date, instrumentation, or relative accuracy. Appropriate weighing and mathematical modeling guaranteed that the "mixed" observations were properly considered. Optimal coordinates, in a least squares sense, resulted for the NAD 83 adjustment. This adjustment process resulted in consistency between political

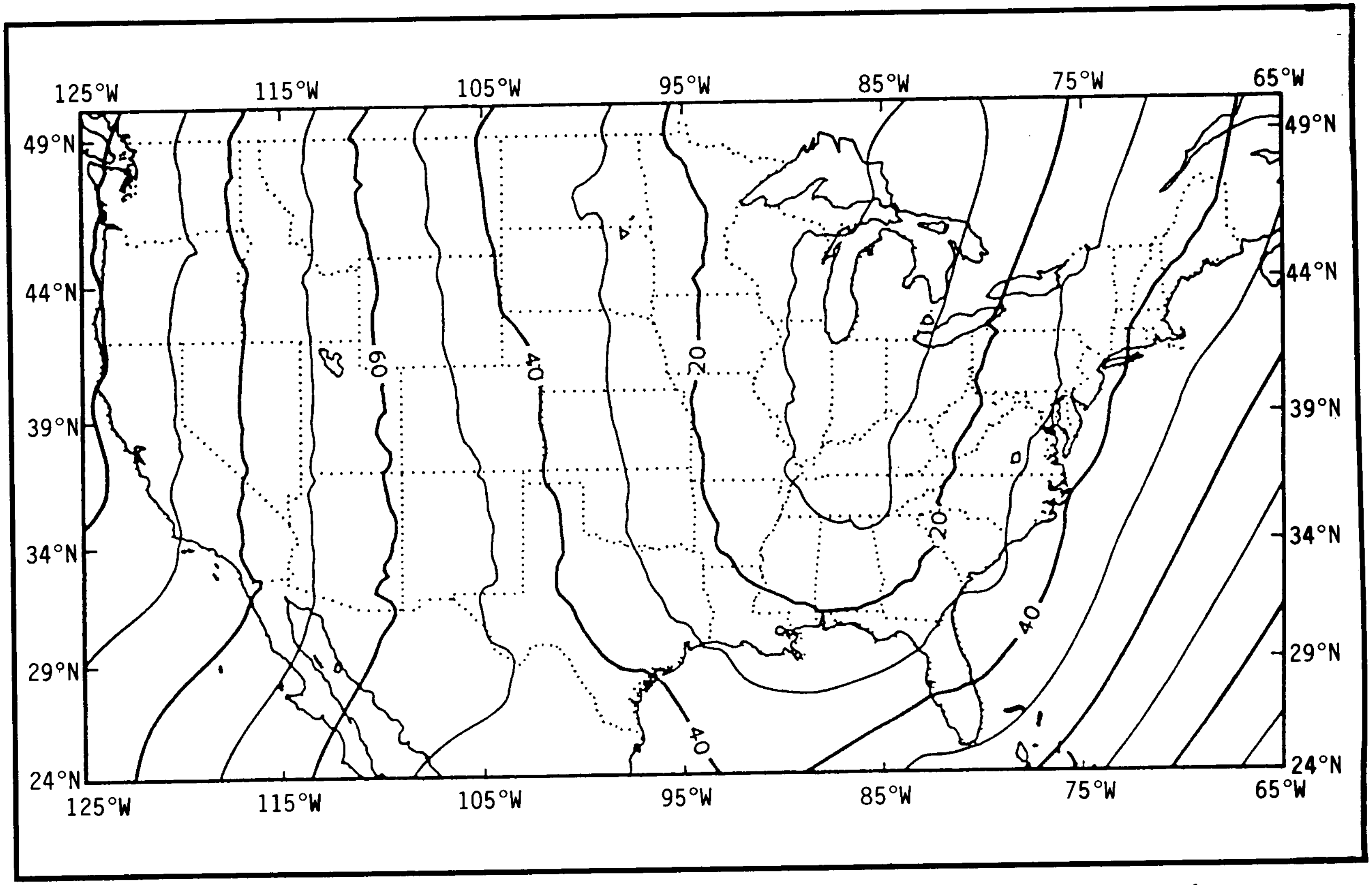

Figure 14.1. Contour map of the coterminous United States showing the magnitude (meter) of total shift between NAD 27 and NAD 83.

boundaries as well as within surveys of differing origin.

The digital computer, as well as advances in higher mathematics, permitted the simultaneous adjustment of all observations and the resolution of all unknowns for NAD 83.

DATUM TRANSFORMATIONS

Several different methods for transforming coordinate data are well accepted in the geodetic and surveying communities. All of these rely upon a closed form expression relating coordinate systems from one datum to another. These approaches are thus all analytical and exact.

Unfortunately, the differences between NAD 83 and NAD 27, as mentioned above, consist of more than a mere difference in the coordinate systems. Local distortions, implicit within NAD 27, are evident and require correction.

A transformation can be accomplished in curvilinear (geodetic) or in rectangular space. For a geodetic coordinate this becomes:

$$\phi_{NAD\ 83} = \phi_{NAD\ 27} + \Delta\phi$$

and

$$\lambda_{NAD\ 83} = \lambda_{NAD\ 27} + \Delta\lambda. \quad (1)$$

From the above it is clear that this procedure is only possible if the datum shifts, $\Delta\phi$ and $\Delta\lambda$, are known or estimated.

To satisfy the demanding applications within the Federal surveying and mapping communities, NGS developed a least-squares approach that relies upon actual and observed coordinates expressed in both NAD 27 and NAD 83. Since these coordinates are the same as used in the actual definition of NAD 83, and are known to millimeters, a much more accurate transformation is possible. A computer program, known as "LEFTI," implements the approach (Vincenty 1980). In areas of good geodetic coverage, accuracies of one m or better are possible. The approach, however, requires geodetic expertise to use and access to valid geodetic data. In addition, the application of different geodetic control data within the program will yield different results, depending on the accuracy of the control data and its spatial distribution relative to the unknown points. This method is therefore suitable for experts when good control data are available.

In addition, several private concerns have developed independent methodologies for the transformation of data within local areas. These "home brew" methods often optimize the transformations within a particular area, such as the Gulf of Mexico, while sacrificing transformation accuracy elsewhere in the U.S.

In brief, several different methodologies have been developed, but none satisfies the majority of users who are perceived to be naive about most matters concerning geodesy.

A NEW METHOD - NADCON

Recognizing that not all users of coordinate data are expert geodesists and that a transformation methodology should yield consistent results, NGS developed another approach to the problem (Dewhurst 1989). Many users require a simple, yet accurate, method for transforming coordinate data. This intuitive method utilizes a homogeneous subset of first- and second-order horizontal control data. These data represent the best available data (e.g., most accurate) associated with the establishment of NAD 83.

A method was designed that could satisfy the majority of users, providing a uniform methodology for the Nation and minimizing the technical confusion concerning the application of NAD 83. In particular, the method was designed for (1) simplicity, (2) accuracy (1 m or better was the target accuracy), (3) completeness, and (4) availability (low cost). The overall goal was, again, to stabilize the technicalities of the transformation between datums and facilitate the application of NAD 83 within the U.S. This new approach should greatly simplify the computational task, minimize costs, and eliminate technical ambiguities from the decisionmaking process.

As mentioned above, the new method is intuitive; it is analogous to interpolating values between contour lines on a map. In essence, a gridded data set of standard datum shifts is prepared and a simple interpolation routine provides estimates of values at non-nodal points. The preparation of the gridded values remains the difficult aspect, a task done by NGS. The actual application of the processed data is accomplished by the user in an application program known as "NADCON."

To reiterate, the new method is a two-step process: the development of gridded data sets (essentially the $\Delta\phi$ and $\Delta\lambda$ of equation 1), and the estimation to non-nodal points. The gridded data sets are prepared using a technique known as "minimum curvature" (Briggs 1974; Webring 1981). This approach mathematically minimizes the total curvature, or rate of bending, associated with a smooth surface describing the shift values between datums.

Minimum curvature has its origin within mechanical engineering, geophysics, and the mathematics of finite differences. The differential equations pertaining to the deformation or bending of plates form the basis for the method.

This approach is unique in application within geodesy. The particular differential equations are known as biharmonic and their solutions are cubic splines. Mathematical boundary conditions require that the curvature at the edges of the surface describing the shift values be zero, thus achieving a smooth depiction throughout the surface. Continuity is also achieved; large erroneous offsets are not permitted between regions. Total as well as local smoothness is thus maintained.

Figures 14.2A and 14.2B show the shift values in terms of arc seconds for the coterminous U.S. These contour maps represent the surfaces that result from the application of minimum curvature. Note that the shift values (estimates) vary continuously without large gaps or offsets.

NADCON - ACCURACY AND SPEED

Ideally, the best and most general test of validity would be a comparison of NADCON estimates with independent truth data. However, independent data are scarce. Therefore, overall accuracy can be defined as an extension of precision, or the ability of the NADCON estimation process to replicate the original data used in the modeling.

In addition, a comparison can be made to other geodetic or survey data of a lesser accuracy, such as third-order data. This comparison does result in an independent verification of the process.

Table 14.1 provides a summary of accuracy tests. This table reveals that NADCON can replicate the original first- and second-order data to within approximately 15 cm within the coterminous U.S. In addition, a comparison with third-order data reveals that transformations with an accuracy of better than 50 cm are probable. Note that the comparison with third-order may be independent but also somewhat misleading; third- and lower-order geodetic data are often of dubious quality and the accuracies highly variable. These independent comparisons must be viewed cautiously and probably represent a worst-case situation.

The accuracy of a transformation will depend upon the accuracy of the original survey data and the control used; no transformation will improve the overall accuracy of the coordinates. A third-order position cannot be improved to second-order by a datum transformation.

Again, NADCON will not, nor will any procedure, improve inferior data. Users must always be aware of the limitations inherent with the accuracies of the original data. At the very least, however, NADCON will not further complicate the situation by falsely distorting relationships. Scale and azimuth will be preserved and rendered properly within a NADCON-produced NAD 83 framework.

Transformation procedures must be fast enough to accommodate the transformation of a complete database in a reasonable length of time. NADCON has been successfully employed to transform a database containing more than 150,000 coordinates, a subset of TIGER data for the Denver, Colorado region, in less than 30 minutes on an IBM 80386-based microcomputer. Remember, the conversion process occurs only once; repeated computations are unnecessary. Additional transformations are only necessary when different NAD 27 data become available. Thus, the conversion to NAD 83 may only involve a few hours of computational time.

CONCLUSIONS

The advantages of NADCON are numerous:

- simple to use, requires no particular expertise;
- available at little expense;
- accurate for most applications;

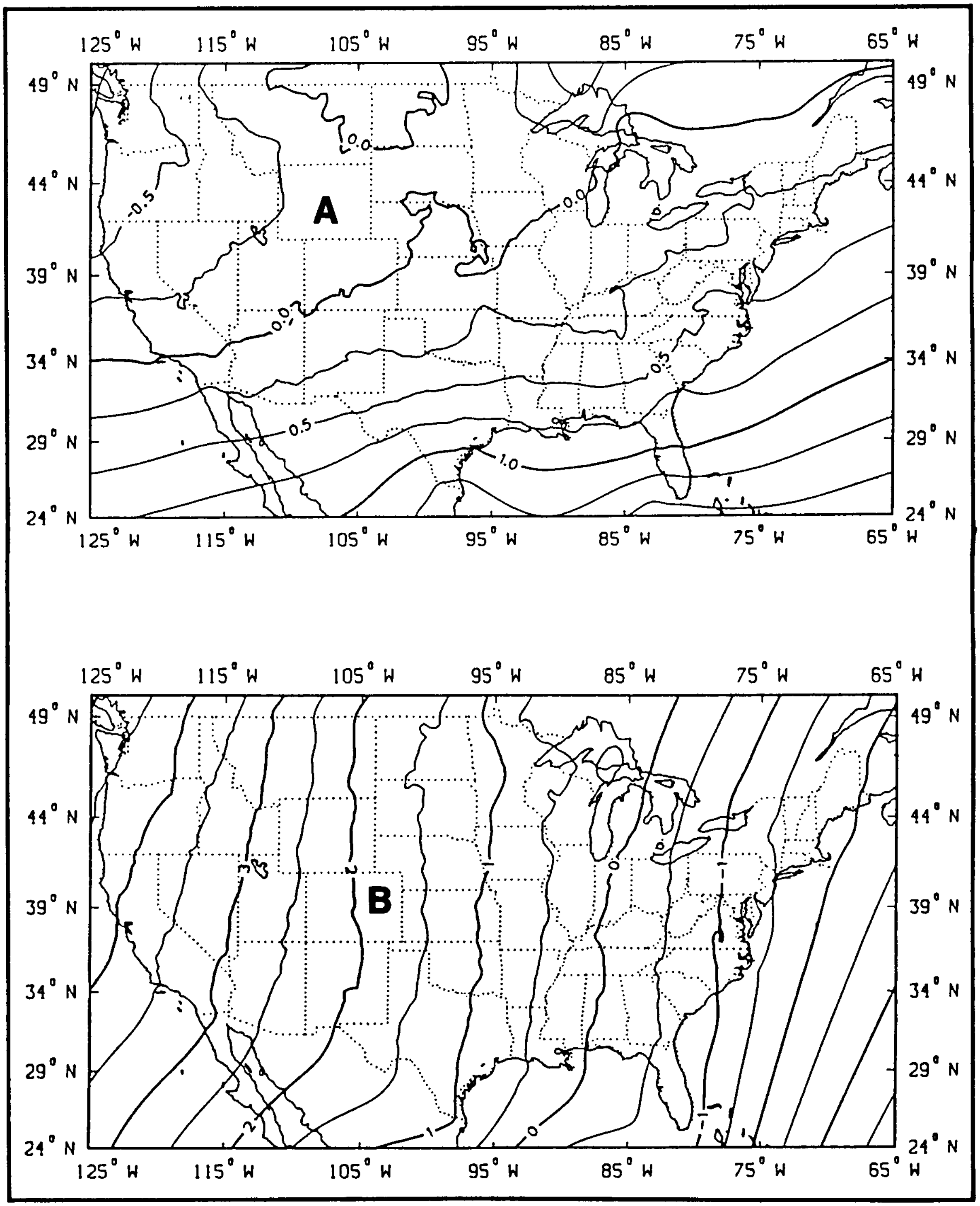

Figure 14.2. (A) Latitude shift (arc seconds) for the coterminous United States.

(B) Longitude shift (arc seconds) for the coterminous United States

Table 14.1. Accuracy results with NADCON.

No. of Comparisons	No. of Outliers	Estimates Within 1 m (%)	Latitude Mean Residual (m)	Latitude Standard Deviation (m)	Longitude Mean Residual (m)	Longitude Standard Deviation (m)
FIRST ORDER						
33,280	90	99.7	0.002	0.145	0.001	0.131
SECOND ORDER						
81,803	240	99.7	-0.001	0.162	0.002	0.149
THIRD ORDER						
42,070	1,765	96	0.009	0.454	0.010	0.446

- officially sanctioned and developed by NGS;
- consistent and continuous datum for the U.S., no discontinuities (e.g., smooth); and
- written in portable FORTRAN computer code--adaptable to other platforms.

The disadvantages of the method relate mostly to the nonexactness of the mapping between the two datums, not with the transformation approach itself. As previously addressed, NAD 27 and NAD 83 do not exactly map into one another. The estimation of shift data in regions of sparse coverage, such as far out at sea, is a difficult problem. No technique is sufficiently capable of providing estimates where no original data exist. Some information must be available for any technique to work.

However, NADCON provides transformations in all areas. The quality of these transformations is directly related to the quality and coverage of the first- and second-order geodetic control incorporated within the NAD 83 adjustment. Users should expect the accuracy of a transformation to decline in inverse proportion to the distance away from good control. For example, the transformation of coordinates that are tens to hundreds of miles at sea can be expected to be no better than 1 to 5 m while the transformation of data within the coterminous U.S. land mass can be expected to be much better than 1 m.

In all, the usage of any technique must be weighed with due regard to the advantages and the disadvantages. Any decisions, however, must reflect the overall objective; in this case, the transformation of data from NAD 27 to NAD 83. More esoteric and perhaps accurate methods could be designed. However, NADCON is probably sufficient for most applications.

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LCDR Warren T. Dewhurst, a member of the NOAA Corps and a registered professional engineer, serves as Administrative Officer and Technical Advisor to the Chief, National Geodetic Survey. He received his B.S. in geophysics from the Colorado School of Mines, a M.E. in mechanical engineering from the Catholic University of America, and a Ph.D. in geophysics from the Colorado School of Mines. He recently developed NADCON, an approach and computer program that transforms coordinate information from the NAD 27 to the NAD 83.

MINERALS MANAGEMENT SERVICE AND THE IMPLEMENTATION OF THE NORTH AMERICAN DATUM 1983: A STATUS REPORT

Mr. Paul H. Rogers
Minerals Management Service
OCS Survey Group

In mid-August, shortly after the Minerals Management Service (MMS) published "Notification Regarding Datum Reference" in the Federal Register (54 FR 31737, August 1, 1989), an employee in the legal department of one of the major oil companies called the Outer Continental Shelf (OCS) Survey Group. That person had been surprised by the notice, since an industry spokesman at the July 1988 National Ocean Industries Association (NOIA) meeting stated that MMS had begun using North American Datum 1983 (NAD 83) coordinates offshore. For example, one visual aid displayed at that meeting stated: "In 1987, the MMS began to use NAD 83 [sic] coordinates for defining the boundaries of offshore concessions."

The information presented at that NOIA meeting relative to MMS and NAD 83 was premature. The datum conversion environment is dynamic, especially offshore; like some other Federal agencies, MMS was then, and is now, learning about and assessing the ramifications associated with adopting NAD 83.

Although the OCS Survey Group had been informally investigating the potential impact of NAD 83 on the agency for some time, the MMS formalized the effort earlier this year. In March, the Deputy Associate Director for Offshore Leasing established a NAD 83 Implementation Team under the lead of the OCS Survey Group. Late April 1990 has been set as the target date for the Implementation Team to present its findings and recommendations to management. Until a formal NAD 83 implementation plan is adopted, the MMS will still use the North American Datum 1927 (NAD 27) as the official referencing datum for the offshore cadastre.

THE OCS SURVEY GROUP

When the MMS was created in 1982, the OCS Survey Group was transferred to the new agency from the Bureau of Land Management (BLM). Although it is organizationally a part of the Branch of Sales Activities in the Washington Office, the OCS Survey Group is located in Denver, Colorado.

The unit's primary function is the development and maintenance of the OCS cadastre, including various offshore projected boundaries and areal measurements, which forms the foundation for MMS leasing activities. The cadastre, with its roughly 1.7 million coordinate pairs, is shown on approximately 500 Leasing Maps (LM's) and Official Protraction Diagrams (OPD's) of the contiguous 48 states and Alaska and 15,000+ Supplemental Official OCS Block Diagrams

(Split Blocks). Eventually an additional 300 OPD's will be needed to depict the area covered by the Exclusive Economic Zone (EEZ), Hawaii, and the U.S. Pacific and Caribbean dependencies (Naito 1987).

THE PROBLEM

Over 95% of the geographic source data used by the OCS Survey Group for salient point determination and subsequent boundary computations/projections is derived from data gathered by other Federal surveying and mapping agencies. These agencies (primarily the National Ocean Service and the U.S. Geological Survey) have implemented NAD 27 to NAD 83 conversion plans for their surveying and mapping products.

If switching from NAD 27 to NAD 83 were as easy as converting English measurements to metric or converting latitude and longitude to state plane coordinates, the conversion process for MMS would be relatively simple. However, the two datums are basically incompatible. Therefore, as James Morgan (Senior Staff Navigation Specialist, Chevron Geosciences) has observed (Morgan 1987):

> In the near future, all operating companies in North America will need to decide on one of the following options.
>
> - NAD 27 position data from active areas will need to be transformed to NAD 83 positions before combining, in a database or on a map, these data with newly surveyed data referenced to NAD 83; or
>
> - All new NAD 83 position data will need to be transformed to NAD 27 positions before placing the data in databases or on maps referenced to NAD 27.

For years, the OCS Survey Group has been using NOS information on pre-NAD 27 datums by transforming that data to NAD 27. Currently, we are using the same procedure when NAD 83-based geographic information must be used. Thus, prior to December 6, 1988, the two options Morgan indicated would be available to industry were available to MMS. However, on that date the U.S. formally adopted NAD 83 as its official civilian horizontal datum. That action by the Federal Geodetic Control Committee states, "... to the extent practicable, legally allowable and feasible, all civilian Federal agencies using or producing coordinate information should provide for an orderly transition from NAD 27 to NAD 83." Thus, it would appear that Morgan's second option is no longer viable for the MMS without a preponderance of evidence justifying why NAD 83 can not be adopted. Then, assuming that NAD 83, in some form, will be adopted by the MMS, the major problem becomes how to implement it uniformly throughout the OCS without adversely affecting the offshore mineral leasing program.

In late 1988, industry began requesting that the MMS adopt NAD 83 and provide them with NAD 83 coordinates. To honor this request the MMS must develop two compatible NAD 83 implementation plans--long and short range. The long range plan will be developed early next year by the agency's NAD 83 Implementation Team. Additional information on the long range plan can be found in Rogers and Morehouse (1989). The short range plan is primarily the responsibility of the OCS Survey Group and deals with the transformation of existing NAD 27 coordinates into their NAD 83 values.

TEST TRANSFORMATION OF THE OCS CADASTRE

The OCS cadastre has two main parts, the projected offshore boundaries and the grid; each part is independently developed. The offshore boundaries are based upon mean lower low water salient points, which are frequently selected in concert with the affected state. Using a series of precise computer programs, the various offshore boundaries (State Seaward Boundary, Limit of 8(g) Zone, EEZ, etc.) are projected seaward from the shoreline. This process becomes more complex for states like Florida and Texas where the historic coastline also must be considered.

The cadastre grid depicted on OPD's uses the pure mathematics of the Universal Transverse Mercator Grid System. It is independent of the survey grids used onshore in the adjacent coastal states. The cadastre grids depicted on LM's off the coastal portions of southern California and the nearshore areas off the Louisiana and Texas coastlines are based upon the State Plane Coordinate System of the particular state.

Computer programs merge the projected boundaries and the cadastre grid and produce a draft plot of the Split Blocks.

From the OCS Survey Group's perspective, the ideal NAD 27/83 transformation program for projected boundary coordinates should:

- not adversely affect existing leases;
- not adversely affect offshore boundaries (e.g., fixed (court) decree lines and international boundaries);
- maintain projected boundary relational integrity (e.g., 3-mile line, 8(g) line, and other lines) with each other and the cadastre;
- be universal in application (all MMS OCS Regions, Hawaii, the U.S. dependencies in the Pacific, and Caribbean, and out to at least the EEZ boundary);
- be Public Domain software, developed/evaluated and tested in cooperation with the National Geodetic Survey (NGS); maintained by NGS; available to the public through NGS; and meet Federal data exchange standards (e.g., PL 100-409);
- be simple to use; does not require "experts" and/or "major" decisions;
- be capable of transforming large databases/data files;
- be capable of using existing databases/data files;
- provide "real-time" results (i.e., results within minutes);
- be transportable (i.e., not tied to a particular computer system);
- be accurate (forward and inverse) and meet MMS requirements;
- be dependent upon the NGS control network.

The ideal transformation program for cadastre grid coordinates would have all of the same characteristics except for the last one. It should be independent of, and not influenced by, the NGS control network.

To date, the OCS Survey Group has been investigating four transformation programs: NADCON4, developed by NGS; Least-squares Fitting Transformation Interpolation (LEFTI), developed by NGS; PCCS-WB349G (transforms coordinates three dimensionally; although significant for onshore transformations, it is much less significant for offshore) developed by BLM; and a Molodensky (formula)-based program developed by MMS. None of these transformation programs meet all of the characteristics for the ideal. For example, NADCON4 is influenced by the control network when transforming the cadastre grid; LEFTI and the PCCS-WB349G require experts and/or major decisions to be made by the user; and the Molodensky-based transformation is extremely difficult to use.

It has been assumed that transformation programs should provide similar results. However, the <±20 m (±65.6 feet) results obtained from the Molodensky-based program seemed excessive when compared to the results generated by the other three. The NGS indicated that unless the control parameters are perfect, a Molodensky-based program can compute with errors of that magnitude offshore (W. Dewhurst 1989, pers. comm.).

A comparison of the NAD 27/83 shift computations among the other three programs seems to support the "similar result" assumption. Depending upon the desired level of accuracy, there is fairly good agreement for the transformed values of 15-minute latitude/longitude grid ticks on the Mississippi Canyon OPD:

	Latitude	Longitude
NADCON4/PCCS-WB349G	±0.6 m (±2.0 ft)	±0.6 m (±2.0 ft)
NADCON4/LEFTI	±1.1 m (±3.6 ft)	±4.2 m (±13.8 ft)
LEFTI/PCCS-WB349G	±1.2 m (±3.9 ft)	±3.8 m (±12.5 ft)

The Mississippi Canyon OPD is one of nine MMS NAD 83 test areas. Other OPD test areas are Beechey Point off Alaska, Santa Maria off California, and Currituck Sound off Virginia/North Carolina. Five LM areas are being tested; California Map 6A, Louisiana Maps 2/2A, and Louisiana Maps 9/9A. Identical tests are being conducted for each of these OPD's and LM's. In addition, NGS has indicated that NADCON5 will be available soon and this program will also be tested.

PRELIMINARY CONCLUSIONS FROM TESTING

Two major conclusions can be drawn from the research conducted to date. First, as NAD 83 literature indicates, coordinate transformation from one datum to another does not produce exact coordinates, especially offshore (Rogers and Morehouse 1989). Coordinate transformations involve a fitting process, and the accuracy of transformed coordinates depends upon the accuracy and reliability of the input data.

For example, a transformation program that can compute to an accuracy level of ±1 foot may develop less accurate computations when changes are made to the control parameters, the number of computational iterations, the number of degrees of the polynomial, or when questionable or less reliable coordinate values are used.

Since datum coordinate transformation programs do not compute exact coordinates, MMS, with input from industry, other Federal agencies and coastal states, must determine what level of accuracy is acceptable. When converting from NAD 27 to NAD 83 and vice versa, what latitude is acceptable: ±1 foot?; ±15 feet?; ±1 m?; ±3 m?; etc.?

The second conclusion that may be drawn is that datum transformations do not affect the physical positions on the earth, including leaseholds. Although cadastre grid lines, projected boundaries, and latitude/longitude grid ticks appear to have changed, they have not. The referencing system being used has been changed; therefore, only the graphic depiction has changed.

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Mr. Paul H. Rogers received his B.S. degree in geography (1967) from the University of Kansas. Mr. Rogers is currently a Supervisory Cartographer with the MMS OCS Survey Group in Denver, Colorado. Prior to his present assignment, Mr. Rogers was the Acting Lead Bureau Cartographer, BLM (Washington Office); Chief, Branch of Photogrammetry, BLM, Denver Service Center; Acting Geometronics Group Leader, USDA, Forest Service, Region 10 (Alaska); and a Supervisory) Cartographer with the Alaska Department of Highways.

OFFSHORE NAVIGATION REQUIREMENTS: IMPROVEMENTS TO BE GAINED BY THE NAD 27 TO 83 TRANSFORMATION

Mr. Harold Spradley
National Ocean Industries

Presentation Summary
Text Not Submitted

Mr. Harold (Hal) Spradley has worked as a geodesist for 30 years with the Defense Mapping

Agency. Since 1973, Mr. Spradley has worked in Houston, Texas primarily in solving surveying and mapping problems for the petroleum industry. Mr. Spradley is author of the text, *Surveying and Navigation for Geophysical Exploration* (1984). Mr. Spradley is president of GPS Technology Corporation with offices in Houston and London. Mr. Spradley is also chairman of the Navigation of Positioning Standards Subcommittee of the National Ocean Industries Association.

THE RELATIONSHIP OF THE NAD 27 DATUM TO LEASING ON THE OCS AND THE IMPACT OF CHANGING TO THE NAD 83 DATUM

Mr. Dave M. Groce
Texaco, Inc.

The intention of this paper is to present an overview of some of the possible impacts on leasing and lease administration which may be the result of changing from the North American Datum (NAD) 27 to NAD 83. In order to do this, the leasing process will be reviewed; the dependent relationship of existing leases and the present mapping and coordinate system will be discussed; restrictions affecting the exploration for and the development of oil and gas, and mineral resources will be discussed; and some of the problems of implementing the datum change to NAD 83 will be discussed. In order to simplify the area of discussion, this paper will focus its attention on the Federal waters of the Gulf of Mexico.

There have been approximately 9,400 Federal leases issued on the Outer Continental Shelf of the Gulf of Mexico. Some of these leases date back to the mid-1930's. Presently, there are more than 5,500 active leases in this region. The economic life for many of these leases could very well last fifty years. With such a large number of active leases, a change in the datum and the mapping system could be catastrophic.

By law [43 U.S.C. 1337(b)] a tract, for which an oil and gas lease is issued, shall consist of a compact area not exceeding 5,760 acres. Generally, tracts or blocks defined by the Official Protraction Diagram are 5,760 acres; tracts or blocks defined by the Texas (Lambert) Plane Coordinate System are 5,760 acres; and tracts or blocks defined by the Louisiana (Lambert) Plane Coordinate System are 5,000 acres.

The Minerals Management Service (MMS) issues a notice of oil and gas (or sulphur) lease sale. The notice provides that the blocks or bidding units which are offered for lease are defined by the leasing maps or protraction diagrams of a specific date. These maps and diagrams are based on the NAD 27 datum. Bids are submitted to the MMS for the blocks or bidding units which are described by the leasing maps or protraction diagrams. The lease which is issued is defined as covering a specific block or bidding unit. Therefore, any change to the leasing map or protraction diagram may have an impact on the areas which are described by existing leases.

If existing leases are redescribed based on a new datum, there is a possibility that the acreage calculations for the leased area may change. Lease payments, rentals, and minimum royalties are calculated for a lease, generally, at $3.00 per acre or portion thereof. If the NAD 83 acreage calculation of an existing lease is greater, even for the smallest calculable increase, than that which is specified in the body of the lease instrument, the amount of the rentals or minimum royalties due for the existing lease may increase. Additionally, if the acreage calculations are increased for an existing lease due to the change to NAD 83, are retroactive lease payments due to the MMS? Will the MMS ratify the existing leases or issue new leases covering the same area?

Rights to leases may be transferred to qualified lessees with the approval of the MMS. Either record title or operating rights to a segment of the leasehold are passed. If the leasehold is severed, either horizontally or vertically, operating rights are assigned to the entire tract or aliquot portions thereof. If the cadastral system used does not provide for rectangular tracts or blocks, or if existing leases are redescribed to some other tract configuration, the transfer of operating rights to a lease may be complicated by describing portions of irregular polygons.

Operations on a tract or block under lease may be limited for several reasons. By regulation, lease wells may not be completed for production within 500 feet of the lease boundary. The change from NAD 27 to NAD 83 may require the lessee to seek a waiver of the regulation from the MMS to continue producing a well with a completion within 500 feet of the NAD 83 lease boundary. Operations on a tract or block may be prohibited due to the location of shipping fairways and for areas of biological or historical significance or for other environmental reasons. NAD 83 may have an impact, due to the change in lease description, on the area described by the lease which is clear of any operational restriction, such as a no-drill area or an area which requires shunting or monitoring of drilling effluents. Operations on a leasehold may be restricted due to the operations of the Department of Defense (DOD). Coordination with the DOD and the lessee is required for specific areas. NAD 83 may impact these areas defined for military operations. These operating restrictions are specified by the lease and the regulations are referenced to the present cadastre based on NAD 27.

Other items for consideration include lease pipelines and pipeline right-of-ways; and state, Federal, and international boundaries, and demarcations relative to the tiering of oil prices or revenue sharing between state and Federal governments as described by the 8g line. The naming of wells and fields, and the description of tracts or blocks as defined by unit agreements, operating agreements, or such other agreements between lessees, may be impacted as a result of changing from NAD 27 to NAD 83. These items are referenced to specific blocks or leases which are defined by the leasing map or protraction diagram.

As can be seen, the conversion from NAD 27 to NAD 83 will have a significant impact on the administration of the existing leases. Consideration needs to be given to working closely with representatives of the MMS and the lessee and operator of oil and gas, and sulphur leases in the Gulf of Mexico. Appropriate methods need to be defined to maintain the integrity of the present leasing system while seeking improved methods for data positioning on the outer continental shelf. The energy industry only gets the opportunity to discover hydrocarbons and other minerals on public lands by means of the "Lease". If the integrity of the lease is reduced, industry assumes a greater risk of being able to claim title to the substance produced.

Mr. David M. Groce is employed by Texaco, Inc. in its Eastern Regional Office, Offshore Exploration Division, located in New Orleans. He is the Staff Land Representative for the Company Properties-Central and Eastern Gulf of Mexico group, and is responsible for administering Texaco's Federal oil and gas leases which are located east of East Cameron Area, East Cameron Area, South Addition, and Garden Banks. Mr. Groce is a Certified Professional Landman and is a Director for the Petroleum Landmen's Association of New Orleans. Mr. Groce acquired his B.S. in general business administration from the University of New Orleans.

NAVIGATION AND POSITIONING FOR OFFSHORE INSTALLATIONS

Mr. Phil Stutes
John E. Chance and
Associates, Inc.

Presentation Summary
Text Not Submitted

Mr. Phil Stutes

NORTH AMERICAN DATUM CHANGES: PANEL SESSION

Members:

Mr. Paul H. Rogers
Minerals Management Service
OCS Survey Group,
Mr. Harold Spradley
Satellite Positioning Corp.,
LCDR Warren T. Dewhurst
U.S. Department of Commerce
NOAA,
and
Mr. Dave M. Groce
Texaco, Inc.

Chairing Questions:

Mr. Douglas Elvers
and
Mr. J. Homer Benton
Minerals Management Service
Gulf of Mexico OCS Region

Question - Can the conversion from North American Datum 1927 (NAD 27) to North American Datum 1983 (NAD 83) be done piecemeal or should it be done all at once? For all map areas?

Paul Rogers: NAD 83 change is dynamic. Prior to preparing the March paper, the U.S. Geological Survey (USGS) was going to convert en masse at the turn of the century, then USGS changed their policy and now they will convert to NAD 83 as they remap the areas. If a temporary hiatus is caused between sheets (1:24000), then so be it. When you talk about converting en masse, that is a tough situation handling about 2 million points or more-probably taking until the turn of the century or 10 years. It is more likely that the conversion can be made on a sale area-by-sale area basis. That is feasible--en masse is a large task, 10 years--it can go either way.

Dave Bornholdt: I get stuck with the policy end of it and have the dubious distinction of taking these issues forward to management for resolution. Paul mentioned that the decision paper will be available in April 1990. Some of these questions, like the time table for conversion, will be passed to upper management in Washington. We hope to get some of these decisions but it will be a little while yet before we do.

Question - Homer Benton: I think, since we have representatives from industry here it would be good to ask them when they think the conversion (NAD 27 to NAD 83) should be implemented. What time period would be realistic for the conversion from NAD 27 to NAD 83?

Hal Spradley: I need to put on my National Ocean Industries Association (NOIA) hat. Each company will make its own decision on when and how they should perform the mapping data base conversion. However, the ability to make that change means that you have the transformation information available to make that change. In our recommendation to Minerals Management Service (MMS) on behalf of NOIA, we would ask if we could separate the mathematical portion of the datum transformation away from all of the other policy aspects such as whether boundaries have to be straight line on one or another map projection as opposed to having a definition that allows one point in an existing latitude/longitude to be converted in its equivalency to a latitude/longitude on a new datum. It would seem that one of these operations is more straightforward than all of the other policy issues and it would at least give us an opportunity to transform coordinates of those corners and any intermediate boundary points that would need to be transformed in order to keep those acreages the same. Somehow, a few million data points no longer scares me in this age of computers, as it would have back in abacus times, when we started. If the conversion were done on some sort of a scale it would seem that it would take no more than a weekend rather than a 10 year project, if we are only talking about the mathematical conversion. Implementing this into the diagrams could take many months longer in time. Being able to issue the lists so that each operating company could have both sets of numbers, so that they could make a choice, would make this implementation go a lot faster.

Paul Rogers: That's basically the conclusion that we have come to from March until this time. We have two separate problems. The short term problem is basically how do we provide industry with the ability to use a dual coordinate database. We want to divorce that from the implementation problem which is longer term. We have to involve two other agencies in the implementation phase, the USGS and National Geodetic Survey (NGS). We are going to impact their schedules for their production products. If we want to do a total implementation "en masse", we are looking at a long term job, but like Hal is saying--if you want a NAD 27-NAD 83 conversion we are very close to saying, "this is what you should do" ....

Question - Homer Benton/from audience: If a survey is conducted in the Gulf today, should the contractor use NAD 27 or NAD 83?

Hal Spradley: A contractor doesn't use the datum in the sense of having a natural home for the navigation system that is being used. Most of the major navigation is operated relative to a system from which we measure ranges from points on shore and ranges from satellites in space and we compute a position. It is only secondary that that becomes a part of the datum, when we use the coordinates of those reference stations from which we measured the ranges. If those shore stations have coordinates which we insert in our computation programs using the NAD 27 values, then those positions come within the NAD 27 datum. If we insert the coordinates for those stations in NAD 83 then that same survey will have positions in NAD 83 datum. The systems themselves (used for calibration) if we are talking about government furnished satellite signals are WGS "84"; the changeover of the GPS system from WGS "72" to WGS "84" took place in January 1987, the changeover of the transit satellite system from WGS "72" to WGS "84" took place on January 27, 1989. So we have a mixture of signals which go into the calculation of the position of a drillship or seismic vessel. These are normally calculated on some other system and then transformed to North American Datum of whichever year is appropriate.

Question - Homer Benton/from audience: Using satellite positioning, if I hired two different survey companies to locate a rig in GA300 and Company #1 set up their differential base station in New Orleans and Company #2 set up their differential base station in Brownsville, Texas would the distortions of the offshore navigation from the two stations be different using NAD 27 vs. NAD 83?

Warren Dewhurst: If the two base stations were both on the same national geodetic reference systems (NGRS), and I would assume that they would be, then it would all depend on the transformation technique that was used. If the differential GPS measurements were done and tied into those NGRS stations then you should get the same number regardless of who did the survey. That is one of the purposes of the NGRS in the first place, to provide that kind of consistency. That would be the case if they used NAD 83. If they used NAD 27, then most likely they would get a different number. The difference between those two coordinate values may be 10 m or so--that is approximately the expected undulation that is superimposed on the differences between the two ellipsoids in the Gulf of Mexico, or in the conterminous USA.

Question - Homer Benton/from audience: Will all block boundaries stay where they physically are in the Gulf of Mexico or just those already leased?

Paul Rogers: That requires a two part answer. One, if you remember back to the lease document projected on the screen, the corners do not move (period) but there were two items of information missing on the lease document. One was the date of the OPD. "It just cited an OPD"; OPD's have a history of being changed over time. To not cite the OPD date is a critical omission--that is a personal opinion I'm not trying to speak for MMS here. Something signed off on in the Bureau of Land Management (BLM) days may or may not be the same as in the 1989 version of the OPD. The other omission was no reference to the year of the datum. If one or both of them was there, then you would be tied to a specific set of coordinates. The diagram that is in the 50 page report shows what happens (and it is exaggerated too--bear that in mind) when a lease block or a number of leases on NAD 27 abuts a regrid. We have a couple of options on how to implement NAD 83--do we regrid or do we transform the grid? That is yet to be determined, but a regrid will create overlays and hiatuses on a temporary basis between the NAD 27 and NAD 83 grid, and that's a decision that management is going to have to wrestle with. One of the questions that has been kicked around recently--Is 5,760 acres that gospel, and would royalties change on a NAD 27 lease if it goes to a NAD 83 lease? My guess on that would be no. Have we broken the law if we exceed 5,760 acres slightly? My answer would be no.

Dave Groce (comment): The law specifically sets out 5,760 acres as the maximum (OCS Lands Act).

Dave Bornholdt (comment): I think one interesting point is that the lease form specifies "approximately 5,760 acres" and I have asked for something in writing on this from our Solicitor's office.

Question - Dave Groce: That leaves several questions; does the lessee have to go back and pay additional rentals and royalties in arrears if acreage should increase?

Paul Rogers: We have a situation which is analogous to what the State Department has encountered on international boundaries. The decision has been made that the official coordinates for those boundaries are maintained on the datum for which they were enacted. If there was a treaty in 1987, it will be based upon NAD 27. However, after a cutoff time from that point forward, the official coordinates will be based on WGS 84 (NAD 83).

Warren Dewhurst (comment): For all interests and purposes, WGS 84 and NAD 83 are one and the same.

Homer Benton (comment): Warren, a number of people would like to have your address to obtain the NADCON program.

Warren Dewhurst (comment): Write to NOAA, 11400 Rockville Pike, Rockville, Maryland 20852, Attention: Warren Dewhurst.

Question - Audience: Warren, do you know that there is a flyer out from MMS.

Warren Dewhurst: Yes, I do. The flyers were released on November 28th and shipping will begin on January 2.

Question - Homer Benton: Shell has evaluated NADCON for use offshore. It has found that NADCON causes systematic errors greater than 3 m in areas where Shell is currently operating in NAD 27. Elsewhere in the Gulf these errors are larger. This is a nuisance, since they are avoidable. For offshore Alaska, East and West Coasts, these errors are even greater--20 m. We have our doubts as to the suitability of NADCON for universal offshore use. "How can NADCON be suitably tested?" "How can its integrity be guaranteed, especially off of Alaska?" "Why is the universal method necessary now, if the MMS has not published its time table?" "Can numerical improvements be made in the NADCON future releases?"

Warren Dewhurst: NADCON has been tested by a number of individuals--the number exceeds 1,000. I know for a fact that I have shipped over 100 data test copies of what is considered NADCON IV and, subsequent to that, others have been distributed. Some of those have gone to Alaska. Alaska has been given its own set of programs and provided feedback to me, which led to some improvements to NADCON. In Alaska, the errors have been reduced by a factor of 2. "That's a major improvement!" The prerelease version of NADCON had a standard deviation of a residual of around 1 m. The current distribution of NADCON has a standard deviation of around 35 cm. "So, that's an improvement." Whatever number of copies were sent out, very few people have responded negatively to this. All of those have been operators out in far regions--where there are no NAD 27 or few NAD 83 values to work with. When I developed NADCON, I did it based on reality--I did it based on what was in the NGRS--I didn't make up any data. Whatever was there I modeled. Anyone can come up with a transformation technique which optimizes certain areas, such as the Gulf of Mexico. What NADCON does is to provide a uniform perception as to what the differences are between the 2 datums for the entire nation. NGS perception as to what those differences are are reflected within the code. Shell's perception as to what those differences are may be different from NGS. Hence my dialogue with NOIA was to get some consensus within the offshore community. This is your area. NGS doesn't have any brass disks stuck in the bottom of the Gulf of Mexico.

If your perceptions about the differences in those two datums is legitimate and available, then it can be considered in a modeling effort. There is another issue here, one of timeliness. I began a dialogue with NOIA last spring. I was under a lot of pressure from various agencies and groups to have NADCON available to the general public. Besides the offshore community, there were a number of operators onshore that wanted this product. It is important for the nation to have a tool to make these sort of transformations. I agree, there are problems. One of the questions here, "Can improvements be made to NADCON in future releases?" Anything is possible--yet, I don't see it as being likely. If NOIA, as a corporate unit, had come to NGS with some points for checking and showed that this was their perception of the differences between the two datums in question, then NGS would have checked, verified, and included these points in their model. This did not happen. Today the Federal Geodetic Control Committee (FGCC) has labeled NADCON as the official federal definition for calculating the differences between the two datums. That should answer the three questions.

Question - Homer Benton/Audience: Should there be representatives of industry associated with the MMS/NAD implementation team or has MMS decided to use NOAA (NGS) only in this capacity?

Dave Bornholdt: I would guess that we have principally considered this as an MMS/NGS problem, but this an interesting suggestion. If industry is interested in joining the implementation team, I could pursue this.

Question - Roger Lott (British Petroleum): I'm worried by the discussion of some of Dave Groce's concerns that may have been dismissed by technical experts. The Landsmen side of the problem shows a general perception that something horrible is happening here. That may be a misperception. We as surveying experts need to educate the user community and any non-geodetic experts as to what these changes are all about.

Hal Spradley suggested that there is no reason why block boundaries should be changed. Conceptually, he's right. What worries me is that I've never actually heard a formal MMS statement that this is so. Dave Groce's fears are real fears but technically they can be laid to rest since this is principally an issue about numerical descriptions concerning a "black art" science that may not be well understood.

MMS needs to make a firm statement that this datum change can happen easily by converting new (NAD 83) coordinates to block corners (as Hal Spradley has mentioned), but this will not change lease boundaries. It is important to label the system and finalize the datum (so latitude and longitude can become unique) on the protraction diagrams.

MMS should make it a policy that they will always qualify the protraction diagrams as to the NAD datum, qualify all coordinates, and properly describe the boundary areas.

Paul Rogers: My presentation specifically states that MMS will identify which datum is mapped (NAD 27 or NAD 83). However, this also should follow as vice versa. Information coming in from industry should identify if the survey is registered to NAD 27 or NAD 83, whichever is appropriate.

Hal Spradley: If we use corner points and decide there is a straight line grid between these points, we get into problems with grid definitions. Grids have historically been an integral part of the definition of these protraction diagrams. If we define intermediate points within the block boundaries, we can reduce the differences in the block acreage between the datums.

Dave Groce (comment): I question any change in the lease form and unless MMS will issue further ratifications of lease or other assurances, I would continue to be concerned.

Dave Bornholdt (comment): One of the concerns that we have recognized is that the legal rights to the lease are maintained regardless of which datum is being used.

Hal Spradley (comment): In my testing of NAD 27 and NAD 83, in general, NAD 27 has not been as accurate at the shoreline as NAD 83. NAD 27 has twists or wrinkles in the old datum of 20 m in magnitude in some areas and even with all of the readjustments by NGS for NAD 83, there were some 1 m residuals. Throughout all of this--if we extrapolate either NAD 27 or NAD 83, offshore it will represent and magnify some of these residual differences. In the case of NAD 27, in general, those showed one part in 100,000. For tests of NAD 83, the differences was one part in 250,000 (a more accurate system). NAD 27 in fact does <u>not</u> <u>exist</u> 200 miles offshore--except as a hypothetical datum. The big problem later on with extrapolating NAD 27 to NAD 83 for far offshore, may be that NAD 27 coordinate conversion to NAD 83 can become academic.

Warren Dewhurst (comment): It becomes a matter of perception when converting the datums. If the user community can determine what they perceive the difference to be (for far offshore) and can define these differences to NGS with a uniform voice, then NGS can commence to check these differences out. So far we have not been told anything real in these terms, with this uniform voice.

Question - Byron Lambert (Amoco): I understand that there is a vertical datum that will be adjusted in about a year. Will that change NADCON in any way?

Warren Dewhurst: No! No! No! You fellows are a rough audience!! [Laughter]. Yes, there is a vertical datum in the works. It is called NAVD 88; it will be different from NAVD 29. It is designed to convert the elevation benchmarks. The commencement of this readjustment has not yet been defined. The magnitude of the numbers will be small. It is likely that I will have to develop this program called NAVCON.

Henk Kripsen: Will this also be for offshore? [Laughter].

Warren Dewhurst: Would you like them for offshore, Henk? [Laughter]. You'll have to tell me what they should be!

Audience Question: What is the chance that NADCON may be updated, augmented, or modified in the future?

Warren Dewhurst: Hal Spradley and I may differ on this, but it is simply a matter of perception on the need for this. Yes, there is always some possibility that NADCON could require a modification but it is my professional belief that the probability for this is very low. In order for a modification of NADCON to take place, every federal agency that voted to accept NADCON would then have to be convinced of the need to change NADCON again. The probability of this (in the federal system) is very low/very slim! I was not able to attend the last Federal Geodetic Control Committee (FGCC) meeting since I am down here, but I have recently talked to the chairman of the FGCC. What occurred at the last meeting was a ratification of three options available to the federal surveying community in the adjustment of NAD 27 to NAD 83.

1. The first option is to readjust existing NAD 27 observations into the NAD 83 framework using NADCON.

2. The second option is to reobtain positioning data using modern positioning equipment, such as the equipment presented by Phil Stutes (John Chance & Associates) at this meeting, that obtains the NAD 83 position directly and use that new "83" position rather than attempt a NADCON conversion.

3. The third option, available to people that have coordinate data, is to use NADCON as a methodology and compute gridded data estimates from these existing coordinates.

Paul Rogers: Does everybody know who is represented in the FGCC? Audience replied that they would like to know this.

Paul Rogers: The FGCC is made up of the Departments of Agriculture, Commerce, Defense, Energy, Housing and Urban Development, Interior (MMS is represented by the USGS), Transportation, the Army Corps of Engineers, National Aeronautics and Space Administration, BLM, and the International Boundary Commission. These agencies make up the FGCC which is chaired by Rear Admiral Wesley Hull.

Question - Audience: Since the FGCC has endorsed NADCON, the MMS/NGS implementation team does not have the freedom to use any other method besides NADCON? That's not a decision for them to make?

Dave Bornholdt: I think that is a fairly safe assessment.

Question - Ken Adams: Would Paul Rogers clarify or further explain figure 5 in his paper? This would help us understand better what we are up against for the NAD conversions for existing and future leases.

Paul Rogers: The assumptions that we made when starting on this paper late in 1988 were the same that we have made today: "We are not going to touch the leases that are out there now ... somebody already owns them--don't mess with them." It is just like this analogy on land; my property in Jefferson County, Colorado is still the same piece I own when I bought it on NAD 27. It is still the same piece on NAD 83 and there has been no change. If we want to hold a lease sale under NAD 83 that adjoins existing NAD 27 leases, we can transform the NAD 27 lease grid into NAD 83. The blocks will no longer be square and they cut into a new NAD 83 grid. Earlier I said that we have two options available to us. One is to regrid, which comes from the best expert opinions that we can get out of USGS and NGS, or we can transform the existing NAD 27 grids into NAD 83. That has its own set of ramifications. (Further technical discussion on problems that the implementation team will need to address in Denver next week followed here).

Question - Ken Adams: I would like to get some industry reaction on these two options in terms of problems and in terms of administration of your leases.

Audience: It sounds like the corners do move on the new lease grid. (Rogers: only if you regrid). It sounds like that's what you propose. (Rogers: that's what I propose).

Hal Spradley: Remember his (Rogers) last example with the shape of different projections. The area of the original lease and the corners have not moved, but the essential difference on NAD 83 is that he would probably use a different projection. Particularly it would have a different spheroid. In a different projection, depending on how extreme you want to be, in scale factors (the particular alignments of central meridians), those things can take different directions, if assigning grid north to the top is required. The choice is totally in the use of the projection and where you choose your central meridian. If we regrid a new area or create a grid (in an existing lease area?), the alignment problems that we encounter come more from a different choice in a projection, rather than in a different spheroid or datum.

Ken Adams: What conflicts do you have between existing leases under NAD 27 and a new lease grid under NAD 83? That's where we really need industry input on how would we go about administrating such a problem.

Dave Groce: There is a lot of reference to the current NAD 27 grid system in terms of field names, well logs, etc., to the current area and block. Then, to jump into a totally new grid system after all that history ... I can't see the workability in all these changes.

Roger Lott: [Stepped to a chart board to draw a description of a regridding option and possibly using a metric grid.]

Hal Spradley (comment): Don't mess with the local culture too much now! [Laughter].

Homer Benton (comment): We would try to avoid certain administrative nightmares!

Hal Spradley (comment): Computers can handle some of these problems that are being presented. To allay one fear--if the central meridian of a grid projection is chosen on the same longitude, then there needs to be no essential difference in orientation of a grid projection for a datum change. There may be distance and scale difference because of the (new) spheroid but at least orientation (changes) would not become one of the problems. We could do it (change orientation) if we were just perverse and wanted to create problems, but that's not necessary. If we choose the same central meridian, then the grid can be maintained in the same orientation.

Audience: But the boundaries won't be exactly in the same place.

Hal Spradley: The boundaries won't be exactly in the same place, but the primary directions will be the same.

Warren Dewhurst: There's no difference between UTM described on a Clarke's 1866 spheroid and one described on a WGM 84. The central meridians are exactly the same--the orientation does not change--you won't have that kind of skewed grid that Roger Lott just drew.

Roger Lott: That was, of course, exaggerated.

Hal Spradley: But this creates more fears than are necessary at this time.

Question - John Scipher (McMoran Oil & Gas): If we change a 5,760 acre block from NAD 27 to NAD 83, how much of an acreage change could we expect?

Hal Spradley and Paul Rogers: Maybe the size of a postage stamp. We are talking acreage changes well after the decimal point.

John Scipher: From strictly economic standpoints then, this accuracy may be overemphasized. From the legal standpoint, we may have another hypothetical problem. (Summarized).

Dave Groce: If you have a 500 million barrel (oil) field, you are going to want to retain every last tenth or hundredth of an acre in unitization.

Roger Lott: We don't think unitization will even come into this, in anyway whatsoever, and the boundaries that we have now will remain.

Douglas Elvers: Yes, it would be very difficult to say that a block leased under NAD 27 would suddenly be altered under NAD 83, and MMS is coming toward this problem as rapidly as they can. A new NAD 83 lease may be slightly different in acreage if converted back to the NAD 27 datum but a 1983 lease would be under its datum. A 1927 lease should stay under its datum, just as it was purchased by Dave Groce's company (as they would want it to remain a lease under the 1927 datum).

Hal Spradley (statement): I think that is a straightforward rule (just for the comfort factor). "A lease is a lease in the datum in which the transaction takes place," any other description of it is for mapping purposes; that is, those leases issued in the old datum are defined in that datum for as long as the lease continues to be renewed as a piece of property. So that it also can be described (a 1927 datum lease) with full accuracy in NAD 83 for mapping and database purposes, those leases issued under a 1983 datum can be back referenced to NAD 27 for mapping and database purposes. It should clearly be the rule that contracts as of the date of issuance retain the form under the datum it was issued. In that form there is no problem of being "shortchanged". What we are talking about is a need for both (1927 and 1983) coordinate systems for a period of time so that industry can chose either system for mapping and database purposes.

Dave Groce: We have leases that will be economic for more than 50 years ... and hopefully could last for another 50 years ...

Hal Spradley: And that definition of that lease, if it was established under the 1927 datum, would continue until the lease was terminated--the oil runs out.

Douglas Elvers: And if you gave up that lease, even after 50 years, MMS could then choose to release it (to someone drilling deeper) under NAD 83. But I would presume that MMS would be reluctant to change an old lease to a new datum (or grid) until the old lease was terminated.

Question - Bill Parish (Shell Offshore): It was said that NADCON was developed on reality--reality was NGRS, which stops at the beach. Reality for the offshore operators are the OPD's, yet these government agencies are advocating the use of NADCON to convert NAD 27 to NAD 83 offshore which is a pure extrapolation. We have established NAD 27 100--200 miles offshore to improve the algorithm; yet, I see there's a great deal of hesitation to use these steps.

Warren Dewhurst: NADCON was based on (modelling of) actual triangulation data. When there was offshore navigation data from the Coast Guard or other agencies or sources, all of these values that were made available to us were included in the model. There are no buoys for offshore (Parish--we have platforms offshore). Yes, you have platforms 100 miles offshore--there were formats made available to submit that data to NGS by the FGCC. Submission of such offshore data to NGS for inclusions in the NGRS could have improved the large offshore area model. Shell or other companies may have submitted some of that data. Yes, there is extrapolation for miles and miles out there and even with another 1,000 points we would still have an area of extremely sparse coverage. If I used strictly Shell's data and Texaco came by later and said "my coordinates don't agree with your coordinates," then Shell's reality would be a difference in perception of Texaco's reality. The fact that you have consistently seen a 10 m difference offshore ... that assures me that there is a difference in our computations, but at least we can predict what that difference should be. If there is a unified voice from offshore users and an additional submission of data for offshore, then that would help me to understand any difference that would exist. But I based the NADCON model on NGRS data.

Douglas Elvers: An additional call for questions was made. The panel was thanked for doing a fine job and the meeting was closed. This meeting was videotaped and a summary follows.

SUMMARY

The fact that the FGCC had adopted NADCON the day of our meeting caused additional intensity and electricity to the panel session. About 50 participants attended and few were too bashful to make comments or ask questions.

Some industry representatives were concerned that NADCON would (due to extrapolation from GRS shoreline data) be sacrificing accuracy for convenience in the deep water offshore. Landsmen's representatives were concerned that changes might create acreage or boundary changes that could legally cloud their existing leases and complicate production and royalty accountings. Recommendations were made to test NADCON and particularly describe which datum, projection, and central meridian were used to identify future mapping. The feeling was that many of the potential problems and ongoing concerns could be alleviated by a better understanding of NADCON and why these changes were taking place. Some uncertainties seem to be perceptions of accuracies and small differences for offshore that are difficult to determine.

Several participants felt that NADCON was workable and that MMS would not create changes for "sake of change" concerning lease datum year of origin. Further information transfer on the subject and certain assurances from MMS were felt to be desirable.

Mr. Paul H. Rogers received his B.S. degree in geography (1967) from the University of Kansas. Mr. Rogers is currently a Supervisory Cartographer with the MMS OCS Survey Group in Denver, Colorado. Prior to his present assignment, Mr. Rogers was the Acting Lead Bureau Cartographer, BLM (Washington Office); Chief, Branch of Photogrammetry, BLM, Denver Service Center; Acting Geometronics Group Leader, USDA, Forest Service, Region 10 (Alaska); and a Supervisory Cartographer with the Alaska Department of Highways.

Mr. Harold (Hal) Spradley has worked as a geodesist for 30 years with the Defense Mapping Agency. Since 1973, Mr. Spradley has worked in Houston, Texas primarily in solving surveying and mapping problems for the petroleum industry. Mr. Spradley is author of the text, *Surveying and Navigation for Geophysical Exploration* (1984). Mr. Spradley is president of GPS Technology Corporation with offices in Houston and London. Mr. Spradley is also chairman of the Navigation of Positioning Standards Subcommittee of the National Ocean Industries Association.

LCDR Warren T. Dewhurst, a member of the NOAA Corps and a registered professional engineer, serves as Administrative Officer and Technical Advisor to the Chief, National Geodetic Survey. He received his B.S. in geophysics from the Colorado School of Mines, a M.E. in mechanical engineering from the Catholic University of America, and a Ph.D. in geophysics from the Colorado School of Mines. He recently developed NADCON, an approach and computer program that transforms coordinate information from the NAD 27 to the NAD 83.

Mr. David M. Groce is employed by Texaco, Inc. in its Eastern Regional Office, Offshore Exploration Division, located in New Orleans. He is the Staff Land Representative for the Company Properties-Central and Eastern Gulf of Mexico group, and is responsible for administering Texaco's Federal oil and gas leases which are located east of East Cameron Area, East Cameron Area, South Addition, and Garden Banks. Mr. Groce is a Certified Professional Landman and is a Director for the Petroleum Landmen's Association of New Orleans. Mr. Groce acquired his B.S. in general business administration from the University of New Orleans.

Mr. Douglas Elvers has worked 31 years in Federal surveying, mapping, and environmental programs. His early years were spent on geophysical surveying, navigation, and mapping for the U.S. Navy and the Coast and Geodetic Survey (now National Ocean Survey NOAA) from the Arctic Circle to Antarctica. During the past 17 years Mr. Elvers and his staff have produced environmental documents and maps in the Gulf of Mexico and the Atlantic that generated for MMS a total of 28 Environmental

Impact Statements which supported 41 oil and gas lease sales and one sulphur/salt lease sale.

Mr. J. Homer Benton is the Deputy Regional Supervisor in the MMS Gulf of Mexico OCS Regional Office of Leasing and Environment. His responsibilities include the overall management and direction of that office's offshore lease sale program, which encompasses the supervision of activities necessary for the preparation of required pre- and post-lease environmental and socioeconomic analyses, lease sales, lease issuance, and lease maintenance. Mr. Benton holds a B.S. in forestry management from Mississippi State University and has held positions in resource management under the BLM in Oregon, Colorado, and Wyoming. Mr. Benton has held positions in the offshore oil and gas program in the Atlantic Region, Headquarters, and the Gulf of Mexico Region.

AGENDA

Tenth Annual
Minerals Management Service, Gulf of Mexico OCS Region
Information Transfer Meeting

Session I

OPENING PLENARY SESSION

Co-Chairs: Dr. Richard Defenbaugh, Mr. Ruben Garza

December 5, 1989

INTERNATIONAL BALLROOM

9:30 - 9:45 a.m.	Mr. Ruben Garza Geo-Marine, Inc. Dr. Richard Defenbaugh MMS, Gulf of Mexico OCS Region	Welcome, Introductions, and Announcements
9:45 - 10:00 a.m.	Mr. J. Rogers Pearcy Regional Director MMS, Gulf of Mexico OCS Region	Agency Welcome
10:00 - 10:45 a.m.	Dr. Rezneat Darnell Department of Oceanography Texas A&M University	Descriptive Studies: Merits and Utility to Decisionmakers
10:45 - 11:30 a.m.	Dr. Robert Carney Center for Wetland Resources Louisiana State University	Processes Studies: Merits and Utility to Decisionmakers
11:30 - 11:35 a.m.	Dr. Richard Defenbaugh	Closing Remarks, Adjourn
	Lunch Break	

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Session II.A

WETLANDS CONCERNS

Co-Chairs: Dr. Norman Froomer, Mr. Dennis Chew

December 5, 1989

CRESCENT BALLROOM "A"

1:30 - 1:40 p.m.	Dr. Norman Froomer MMS, Gulf of Mexico OCS Region	Welcome, Introductions, and Announcements
1:40 - 2:05 p.m.	Dr. Donald Cahoon Louisiana Geological Survey	Marsh Management and Wetlands Mitigation
2:05 - 2:30 p.m.	Dr. Ed Pendleton and Dr. Mary Watzin U.S. Fish and Wildlife Service	Overview of USFWS Coastal Louisiana Wetlands Initiative
2:30 - 2:55 p.m.	Dr. Harry Roberts Louisiana State University	New Physical Process Research on Wetlands Loss in Louisiana
2:55 - 3:10 p.m.	**Refreshment Break**	
3:10 - 3:35 p.m.	Dr. Irv Mendelssohn Louisiana State University	Long-Term Recovery of a Brackish Marsh from an Oil Spill in Coastal Louisiana
3:35 - 4:00 p.m.	Dr. James Webb Texas A&M University	Effects of Spilled Oil on Smooth Cordgrass
4:00 - 4:20 p.m.	Dr. Nancy Rabalais Louisiana Universities Marine Consortium	Fate and Effects of Produced Water Discharges in the Northern Gulf of Mexico
4:20 - 4:25 p.m.	Dr. Norman Froomer	Closing Remarks, Adjourn

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Session II.B

OIL SPILL RESPONSE, I

Lead Chair: Ms. Darice Breeding
Co-Chair: Mr. Michael Joseph

December 5, 1989

CRESCENT BALLROOM "B"

1:30 - 1:35 p.m.	Ms. Darice Breeding MMS, Gulf of Mexico OCS Region	Welcome, Introductions, and Announcements
1:35 - 2:00 p.m.	Mr. Bob Meyers Bob Meyers and Associates	Exercising the Oil Spill Contingency Plan/Computer Enhanced Crisis Management Simulation Exercises
2:00 - 2:25 p.m.	Mr. Don Smith Environmental Protection Agency	Emerging Technologies for Sorbent Use
2:25 - 2:50 p.m.	Mr. Skip Onstead Clean Seas	Lessons Learned from Clean Sea's Response to the Pac Baroness Sinking
2:50 - 3:15 p.m.	Dr. Mark Reed Applied Science Associates, Inc.	Satellite-Tracked Surface Buoys for Simulating Oil Spill Trajectories: Test in Alaska and the North Sea
3:15 - 3:30 p.m.	**Refreshment Break**	
3:30 - 3:55 p.m.	Dr. Jerry Galt National Ocanographic Atmospheric Administration	Real-Time Trajectory Modeling of a Spill Event
3:55 - 4:20 p.m.	Admiral John Costello PIRO Implementation, Inc.	Description and Status of the American Petroleum Institute's Petroleum Industry Response Organization
4:30 - 4:35 p.m.	Mr. Michael Joseph	Closing Remarks, Adjourn

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Session II.C

GULF OF MEXICO ISSUES AND INITIATIVES
(CONTRIBUTED PAPERS)

Chair: Dr. Richard E. Defenbaugh
Co-Chair: Mr. Ted Stechmann

December 5, 1989

ROSEDOWN ROOM

1:30 - 1:35 p.m.	Dr. Richard E. Defenbaugh MMS, Gulf of Mexico OCS Region	Welcome, Introductions, and Announcements
1:35 - 2:00 p.m.	Dr. Pulak Ray MMS, HQ Office, Offshore Resource Evaluation Division	OCS Hydrocarbon Production in the 1990's: The Role of the Gulf of Mexico
2:00 - 2:25 p.m.	Dr. Semoon Chang University of South Alabama	An Economic Model for Artificial Reefs with Special Reference to the Use of Obsolete Oil and Gas Platforms
2:25 - 2:45 p.m.	**Refreshment Break**	
2:45 - 3:15 p.m.	Dr. R. Eugene Turner Dr. Nancy N. Rabalais Louisiana State University Louisiana Universities Marine Consortium	Long-term Changes in the Mississippi River and Impact on the Continental Shelf Ecosystem
3:15 - 3:45 p.m.	Dr. Ren Lohoefener National Marine Fisheries Service	Deepwater Cetaceans in the North Central Gulf of Mexico
3:45 - 4:15 p.m.	Dr. Fred Kopfler EPA Gulf of Mexico Program Office	EPA Gulf of Mexico Program's Mobile Bay Demonstration Project
4:15 - 4:45 p.m.	Ms. Patty Debenham Center for Marine Conservation	Education and Awareness: Keys to Solving the Marine Debris Problem
4:45 - 4:50 p.m.	Dr. Richard E. Defenbaugh	Closing Remarks, Adjourn

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Session III.A

MISSISSIPPI/ALABAMA SHELF MARINE ECOSYSTEMS STUDY

Co-Chairs: Dr. Robert Rogers, Dr. Robert Avent

December 6, 1989

MADEWOOD BALLROOM "B"

8:30 - 8:35 a.m.	Dr. Robert Rogers MMS, Gulf of Mexico OCS Region	Welcome, Introductions, and Announcements
8:35 - 8:55 a.m.	Dr. James Brooks Texas A&M University	Introduction
8:55 - 9:15 a.m.	Dr. Mahlon Kennicutt Texas A&M University	Chemical Characterization
9:15 - 9:30 a.m.	**Refreshment Break**	
9:30 - 9:55 a.m.	Mr. Frank Kelly Texas A&M University	Physical Oceanography Characterization
9:55 - 10:25 a.m.	Dr. William Schroeder Dauphin Island Sea Lab	Geological Characterization
10:25 - 10:55 a.m.	Dr. Stephen Gittings Texas A&M University	Pinnacle Trend Characterization
10:55 - 11:15 a.m.	Dr. Donald Harper Texas A&M University	Biological Characterization
11:15 - 11:35 a.m.	Dr. Rezneat Darnell Texas A&M University	Program Synthesis
11:35 - 11:40 a.m.	Dr. Robert Rogers **Lunch Break**	Closing Remarks, Adjourn

Tenth Annual
Minerals Management Service, Gulf of Mexico OCS Region
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Session III.B

OIL SPILL RESPONSE, II

Lead Chair: Ms. Darice Breeding
Co-Chair: Mr. Michael Joseph

December 6, 1989

CRESCENT BALLROOM "B"

8:30 - 8:35 a.m.	Ms. Darice Breeding MMS, Gulf of Mexico OCS Region	Welcome, Introductions, and Announcements
8:35 - 9:00 a.m.	Mr. Mike Ryan Environmental Protection Agency	Recovered Oil Disposal Options, Regulations and Considerations
9:00 - 9:50 a.m.	Panel Discussion by State Representatives: Regulations Governing Disposal of Recovered Oil and Oiled Debris Mr. Greg Lee, Mr. Doug White - Florida Department of Environmental Regulation Mr. Bruce Hammatt - Louisiana Department of Environmental Quality Mr. John Carlton - Alabama Department of Environmental Management Mr. Richard Ball - Mississippi Department of Environmental Quality Mr. David Barker - Texas Water Commission	
9:50 - 10:05 a.m.	**Refreshment Break**	
10:05 - 10:30 a.m.	Dr. Bela James Continental Shelf Associates Mr. Jim O'Brien O'Brien's Oil Pollution Service	Contingency Planning for Exploration Activity
10:30 - 10:55 a.m.	Mr. Parag Gandhi Mr. Mark Ploen Ajat Shaw, Inc.	State of the Art Oil Spill Response Equipment
10:55 - 11:20 a.m.	CWO Fred Gonzales U.S. Coast Guard Atlantic Area Strike Team	Evaluation of Oil Spill Response Methodology Used During the Cleanup of the Exxon Valdez Spill
11:20 - 11:25 a.m.	Mr. Michael Joseph **Lunch Break**	Closing Remarks, Adjourn

Tenth Annual
Minerals Management Service, Gulf of Mexico OCS Region
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Session III.C

ALTERNATIVE ENERGY: NOW AND THE FUTURE, I

Co-Chairs: Mr. Bill Johnstone, Ms. Linda Hunter

December 6, 1989

ROSEDOWN ROOM

8:30 - 8:40 a.m.	Mr. Bill Johnstone MMS, Gulf of Mexico OCS Region	Welcome, Introductions, and Announcements
8:40 - 9:20 a.m.	Ms. Cherri Langenfeld Department of Energy	Progress Toward a National Energy Strategy for the United States
9:20 - 9:45 a.m.	Mr. Mike Shelby Environmental Protection Agency	An Assessment of Recent Alternative Fuel Proposals
9:45 - 10:00 a.m.	**Refreshment Break**	
10:00 - 10:45 a.m.	Dr. Mike Canes American Petroleum Institute	Future of Oil and Gas as it Relates to Alternative Energy
10:45 - 11:30 a.m.	Dr. Richard Tabor Massachusetts Institute of Technology	How Can You Have an Energy Policy in a Market Economy?
	Lunch Break	

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Session III.D

PHYSICAL OCEANOGRAPHY, I

Co-Chairs: Dr. Murray Brown, Dr. Alexis Lugo-Fernandez

December 6, 1989

MADEWOOD ROOM "A"

8:30 - 8:35 a.m.	Dr. Murray Brown MMS, Gulf of Mexico OCS Region	Welcome, Introductions, and Announcements
8:35 - 9:00 a.m.	Dr. Evans Waddell Science Applications International Corporation	Overview of Year 5 Physical Oceanography Study
9:00 - 9:25 a.m.	Dr. Bill Wiseman Louisiana State University	Analysis of Louisiana Shelf Currents
9:25 - 9:50 a.m.	Dr. Peter Hamilton Science Applications International Corporation	Analysis of Slope and Eddy Currents Offshore Louisiana
9:50 - 10:05 a.m.	**Refreshment Break**	
10:05 - 10.05 a.m.	Dr. Fred Vukovich Research Triangle Institute	New Atlas of Front Locations in the Gulf of Mexico
10:30 - 10:55 a.m.	Dr. Jim Lewis Science Applications International Corporation	Analysis of Drifting Buoy Trajectories from Year 5
10:55 - 11:25 a.m.	Dr. Alan Wallcraft Jaycor, Inc.	Circulation Modeling Study
11:25 - 11:50 a.m.	Dr. Doug Biggs Texas A&M University	Hydrographic Surveys in the East Breaks Area
	Lunch Break	

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Session IV.A

MARINE ECOSYSTEMS STUDIES

Co-Chairs: Dr. Robert Rogers, Dr. Robert Avent

December 6, 1989

MADEWOOD BALLROOM "B"

1:30 - 1:35 p.m.	Dr. Robert Rogers MMS, Gulf of Mexico OCS Region	Welcome, Introductions, and Announcements
1:35 - 2:00 p.m.	Dr. Stephen Gittings Texas A&M University	Long-Term Monitoring at the East and West Flower Garden Banks
2:00 - 2:25 p.m.	Mr. John Thompson Continental Shelf Associates, Inc.	Southwest Florida Nearshore Habitat Mapping Study
2:25 - 2:50 p.m.	Dr. Robert Carney Louisiana State University	Summary of the Northern Gulf of Mexico Environmental Studies Planning Workshop
2:50 - 3:05 p.m.	**Refreshment Break**	
3:05 - 3:30 p.m.	Dr. James Brooks Texas A&M University	NOAA Status and Trends Monitoring Program
3:30 - 3:55 p.m.	Dr. Eugene Shinn U.S. Geological Survey	Environmental Recovery at South Florida Drilling Sites
3:55 - 4:20 p.m.	Dr. Lionel Eleuterius Gulf Coast Research Laboratory	Catastrophic Loss of Seagrasses in Mississippi Sound
4:20 - 4:25 p.m.	Dr. Robert Rogers	Closing Remarks, Adjourn

Tenth Annual
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Session IV.B

OIL SPILL DISPERSANTS: EFFECTIVENESS AND DECISIONMAKING

Co-Chairs: Dr. James Kendall, Mr. Charles Hill

December 6, 1989

CRESCENT BALLROOM "B"

1:30 - 1:35 p.m.	Dr. James Kendall MMS, Gulf of Mexico OCS Region	Welcome, Introductions, and Announcements
1:35 - 2:05 p.m.	Dr. John M. Teal Woods Hole Oceanographic Institution	Review of the NAS Report on the Use of Dispersants
2:05 - 2:35 p.m.	Dr. Thomas Duke Technical Resources, Inc.	Findings of the MMS-Funded "Dispersant Workshop"
2:35 - 3:00 p.m.	Dr. John Fraser Shell Oil Company	MIRG Dispersant Use Decision Model
3:00 - 3:30 p.m.	CMDR Philip Wieczynski U.S. Coast Guard	Dispersant Use: A Coast Guard Perspective
3:30 - 3:45 p.m.	**Refreshment Break**	
3:45 - 4:55 p.m.	Panel Discussion: Dispersant Use in the Gulf of Mexico	

Dr. John Fraser - Shell Oil Company
CMDR Philip Wieczynski - Environmental Response, Port Safety Branch, U.S. Coast Guard
Mr. Greg Lee, Mr. Doug White - Florida Department of Environmental Regulation
Mr. Bruce Hammatt - Louisiana Department of Environmental Quality
Mr. John Carlton - Alabama Department of Environmental Management
Mr. Richard Ball - Mississippi Department of Environmental Quality,
Mr. David Barker - Texas Water Commission
Dr. John Teal - Woods Hole Oceanographic Institution
Dr. Thomas Duke - Technical Resource, Inc.
Mr. Raymond Churan, Mr. Jim Lee - U.S. Department of the Interior, Regional Environmental Officers

4:55 - 5:00 p.m.	Dr. James Kendall	Closing Remarks, Adjourn

Tenth Annual
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Session IV.C

ALTERNATIVE ENERGY: NOW AND THE FUTURE, II

Co-Chairs: Mr. Bill Johnstone, Ms. Linda Hunter

December 6, 1989

ROSEDOWN ROOM

1:30 - 1:35 p.m.	Mr. Bill Johnstone MMS, Gulf of Mexico OCS Region	Welcome, Introductions, and Announcements
1:35 - 2:20 p.m.	Mr. James Bruce Energy and Natural Resource Committee, U.S. Senate	Outlook for Alternative Transportation Fuels - A Congressional Perspective
2:20 - 3:00 p.m.	Mr. Nicholas Fedoruk Energy Conservation Coalition	Potential from a National Energy Efficiency Policy
3:00 - 3:15 p.m.	**Refreshment Break**	
3:15 - 4:00 p.m.	Mr. Bill Harris U.S. Council for Energy	Role of Nuclear Energy in America's Future
4:00 - 4:05 p.m.	Mr. Bill Johnstone	Closing Remarks, Adjourn

Tenth Annual
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Session IV.D

PHYSICAL OCEANOGRAPHY, II

Co-Chairs: Dr. Murray Brown, Dr. Alexis Lugo-Fernandez

December 6, 1989

MADEWOOD ROOM "A"

1:30 - 1:35 p.m.	Dr. Murray Brown MMS, Gulf of Mexico OCS Region	Welcome, Introductions, and Announcements
1:35 - 2:00 p.m.	Mr. Ken Schaudt Marathon Oil Company/ EJIP Consortium	Industry Projects/Eddy Nelson Surveys
2:00 - 2:25 p.m.	Mr. Ray Canada National Data Buoy Center	Meteorological and Oceanographic Monitoring System (MOMS)
2:25 - 2:50 p.m.	Dr. David Moran U.S. Navy David Taylor Laboratory	Navy-Sponsored Deep Ocean Research Island
2:50 - 3:05 p.m.	**Refreshment Break**	
3:05 - 3:30 p.m.	Dr. Frank Muller-Karger University of South Florida	NASA-Sponsored Coastal Zone Color Scanner Data Archive
3:30 - 3:55 p.m.	Dr. David Sheres University of Southern Mississippi	Studies of Surface Wave-Mesoscale Feature Interactions
3:55 - 4:20 p.m.	Dr. Larry Rouse Louisiana State University	New Remote Sensing Facility
4:20 - 4:25 p.m.	Dr. Murray Brown	Closing Remarks, Adjourn

Tenth Annual
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Session V.A

FISHERIES, I

Lead Chair: Dr. Ann Scarborough Bull
Co-Chair: Mr. Richard Bennett

December 7, 1989

MADEWOOD BALLROOM "A"

8:30 - 8:35 a.m.	Dr. Ann Scarborough Bull MMS, Gulf of Mexico OCS Region	Welcome, Introductions, and Announcements
8:35 - 9:00 a.m.	Mr. Corky Perret Louisiana Department of Wildlife and Fisheries	Status of Gulf Fisheries and Management Activities
9:00 - 9:25 a.m.	Mr. Larry Simpson Gulf States Marine Fishery Commission	Interjurisdictional Fisheries Act Program of the Gulf of Mexico
9:25 - 9:50 a.m.	Dr. Walter R. Keithly Louisiana State University	Economic Overview and Changes in the Gulf of Mexico Seafood Industry
9:50 - 10:05 a.m.	**Refreshment Break**	
10:05 - 10:30 a.m.	Dr. Robert Shaw Louisiana State University	Interaction of the Mississippi River Plume and Larval Fish
10:30 - 10:55 a.m.	Dr. Churchhill Grimes National Oceanographic Atmospheric Administration	River Influence Recruitment to Commercial Fisheries
10:55 - 11:20 a.m.	Mr. Donald Moore National Oceanographic Atmospheric Administration	Habitat Conservation: Key Issues in Estuarine-Dependent Fisheries
11:20 - 11:45 a.m.	Dr. Thomas Linton Texas A&M University	Effects of Production Platform on Habitat Enhancement and Species Diversification
	Lunch Break	

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Session V.B

OIL SPILLS IN TROPICAL ENVIRONMENTS

Co-Chairs: Dr. James Kendall, Mr. Charles Hill

December 7, 1989

MADEWOOD BALLROOM "B"

8:30 - 8:35 a.m.	Dr. James Kendall MMS, Gulf of Mexico OCS Region	Welcome, Introductions, and Announcements
8:35 - 9:15 a.m.	Dr. Brian Keller Smithsonian Tropical Research Institute	Panama Oil Spill: Biological Effects
9:15 - 9:50 a.m.	Dr. Kathryn Burns Bermuda Biological Station for Research	Effects of the Panama Oil Spill: Hydrocarbon Chemistry
9:50 - 10:05 a.m.	**Refreshment Break**	
10:05 - 10:20 a.m.	Dr. Robert Carney Louisiana State University	Project Overview: Panama Oil Spill
10:20 - 10:50 a.m.	Dr. Howard Teas University of Miami	Effects of Oil Spills on Mangroves and Other Wetlands
10:50 - 11:20 a.m.	Dr. Michael Marshall Continental Shelf Associates, Inc.	Effects of Oil Spills on Seagrasses
11:20 - 11:25 a.m.	Dr. James Kendall	Closing Remarks, Adjourn
	Lunch Break	

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Session V.C

CURRENT OFFSHORE INDUSTRY TECHNOLOGY

Co-Chairs: Mr. G. Ed Richardson, Mr. Jake Lowenhaupt, Mr. Mark Rouse

December 7, 1989

ROSEDOWN ROOM

8:30 - 8:35 a.m.	Mr. Jake Lowenhaupt MMS, Gulf of Mexico OCS Region	Welcome, Introductions, and Announcements
8:35 - 9:00 a.m.	Mr. Rob Floyd and Mr. Jim Sides John E. Chance and Associates, Inc.	Deepwater Surveys
9:00 - 9:25 a.m.	Mr. Doug Cochrane Cochrane Subsea Acoustics, Inc.	Color Scanning Sonar Systems with Mockingbirds
9:25 - 9:50 a.m.	Mr. Joe W. Key Key Ocean Services, Inc.	Floating Production Systems
9:50 - 10:15 a.m.	Mr. Howard Wright R. J. Brown & Associates	Deepwater Pipelining
10:15 - 10:30 a.m.	**Refreshment Break**	
10:30 - 10:55 a.m.	Mr. Andrew Hunter Conoco, Inc.	Deepwater Advancements
10:55 - 11:00 a.m	Mr. Jake Lowenhaupt	Closing Remarks, Adjourn
	Lunch Break	

Tenth Annual
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Session VI.A

FISHERIES, II

Lead Chair: Dr. Ann Scarborough Bull
Co-Chair: Mr. Richard Bennett

December 7, 1989

MADEWOOD BALLROOM "A"

1:30 - 1:35 p.m.	Dr. Ann Scarborough Bull MMS, Gulf of Mexico OCS Region	Welcome, Introductions, and Announcements
1:35 - 2:00 p.m.	Mr. Stephen H. Phillips Sport Fishing Institute	Sport Fishing Institute's Artificial Reef Development Center
2:00 - 2:25 p.m.	Mr. Dana Larson Private Consultant	Converting Annex-5 Waste into Fishing Reefs on Obsolete OCS Platforms
2:25 - 2:50 p.m..	Mr. David Stanley Louisiana State University	Factors Affecting Fish Abundance Near Platforms in the Gulf of Mexico
2:50 - 3:05 p.m.	**Refreshment Break**	
3:05 - 3:40 p.m.	Mr. Michael E. Parker EXXON Company, USA	Angel Reef: From Texas to Louisiana
3:40 - 4:05 p.m.	Mr. Brett Dansby Texas Parks and Wildlife Department	Development of a Texas Artificial Reef Plan
4:05 - 4:30 p.m.	Dr. John Ogle Gulf Coast Research Laboratory	Status and Potential of Shrimp Mariculture
4:30 - 4:55 p.m.	Mr. David Maus Redfish Unlimited	Redfish Ranching
4:55 - 5:00 p.m.	Dr. Ann Scarborough Bull	Closing Remarks, Adjourn

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Session VI.B

ENVIRONMENTAL MONITORING: GULF OF MEXICO OCS PROGRAM

Co-Chairs: Mr. Lester Dauterive, Ms. Bonnie LaBorde Johnson

December 7, 1989

MADEWOOD BALLROOM "B"

1:30 - 1:35 p.m.	Mr. Les Dauterive MMS, Gulf of Mexico OCS Region	Welcome, Introductions, and Announcements
1:35 - 2:05 p.m.	Mr. Charles Hill MMS, Gulf of Mexico OCS Region	Monitoring Topographic Highs: Requirements and Results - Topographic High NTL 89-01
2:05 - 2:35 p.m.	Mr. Ted Stechmann MMS, Gulf of Mexico OCS Region	Monitoring Live Bottom Areas: Requirements and Results
2:35 - 3:05 p.m.	Mr. Ken Graham MMS, Gulf of Mexico OCS Region	Monitoring Chemosynthetic Communities: Requirements and Results - Chemosynthetic Communities NTL 88-11
3:05 - 3:20 p.m.	**Refreshment Break**	
3:20 - 3:50 p.m.	Mr. Elgin Landry MMS, Gulf of Mexico OCS Region	Monitoring Offshore Air Emissions: Requirements and Results
3:50 - 4:20 p.m.	Mr. Rick Kasprzak Louisiana Department of Wildlife and Fisheries	Monitoring Louisiana Artificial Reef Sites-Offshore Oil and Gas Structures
4:20 - 4:50 p.m.	Mr. Richard Bennett MMS, Gulf of Mexico OCS Region	Monitoring Platform Removals: Requirements and Results
4:50 - 4:55 p.m.	Mr. Les Dauterive	Closing Remarks, Adjourn

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Session VI.C

NORTH AMERICAN DATUM CHANGES

Co-Chairs: Mr. Douglas Elvers, Mr. Homer Benton

December 7, 1989

ROSEDOWN ROOM

1:30 - 1:35 p.m.	Mr. Douglas Elvers MMS, Gulf of Mexico OCS Region	Welcome, Introductions, and Announcements
1:35 - 1:50 p.m.	LCDR Warren Dewhurst National Geodetic Survey	Transformation of Positional Data from the NAD 27 to the NAD 83
1:50 - 2:05 p.m.	Mr. Paul Rogers Office of Special Mapping Minerals Mangement Service	Status of MMS Tasks and Conversion Planning: National Data Base Systems
2:05 - 2:20 p.m.	Mr. Hal Spradley National Ocean Industries	Offshore Navigation Requirements: Improvements to Be Gained by the NAD 27 to 83 Transformation
2:20 - 2:35 p.m.	**Refreshment Break**	
2:35 - 2:50 p.m.	Mr. Dave Groce Texaco, Inc. Petroleum Landmen's Association	Effect of Record Keeping and Lease Administration After the NAD 27 to 83 Conversion
2:50 - 3:15 p.m.	Mr. Phil Stutes John E. Chance and Associates, Inc.	Navigation and Positioning for Offshore Installations
3:15 - 3:30 p.m.	Mr. Joe Culp Texaco, Inc. Offshore Operators Committee	Positioning Requirements for Platforms and Pipelines for NAD 27 to 83 Conversions
3:30 - 4:45 p.m.	Mr. Homer Benton MMS, Gulf of Mexico OCS Region	Introduction to Panel Discussion: Considerations for Implementation of NAD 83 on the OCS Leasing Program
4:45 - 4:50 p.m.		Adjourn

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