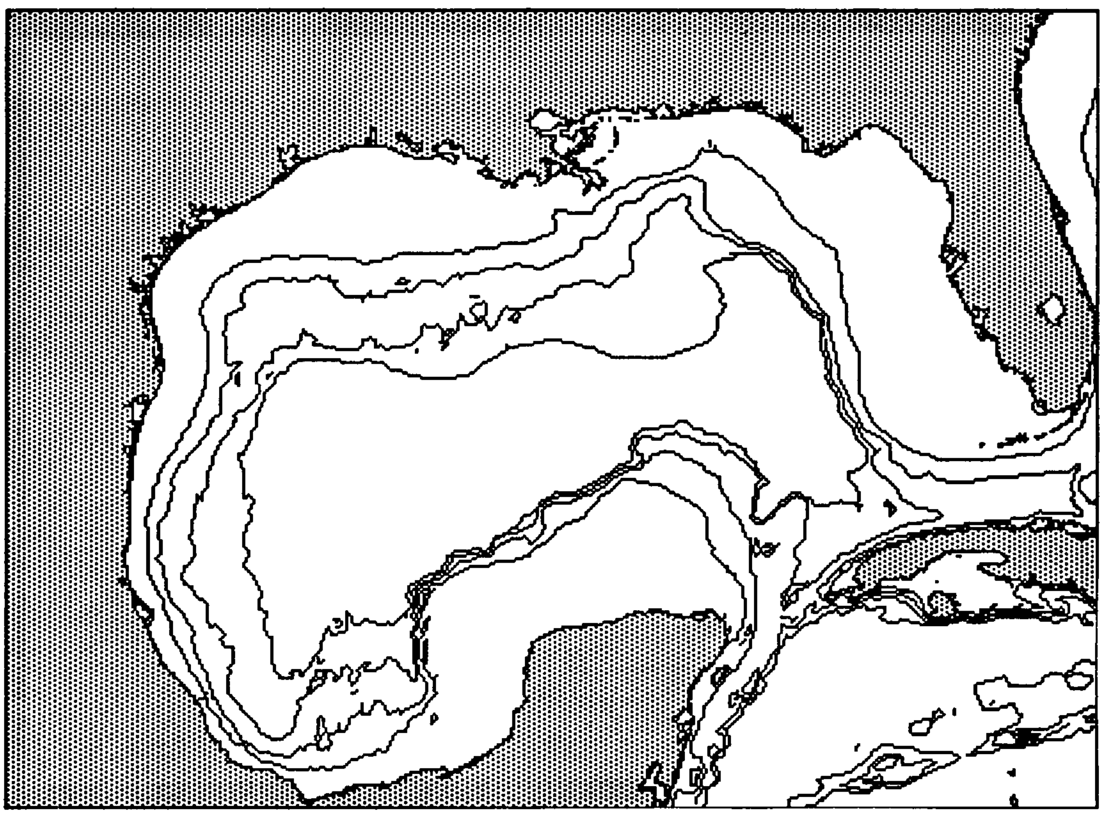
OCS Study
MMS 91-004(

Proceedings: Eleventh Annual Gulf of Mexico Information Transfer Meeting

November 1990



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

OCS Study
MMS 91-0040

Proceedings:
Eleventh Annual Gulf of Mexico Information Transfer Meeting

November 1990

Doubletree Hotel
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SUMMARY

This Proceedings volume presents summaries of the presentations and discussions of the Eleventh Annual Information Transfer Meeting (ITM) held on November 13-15, 1990, 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 introductions by the respective session chairpersons; 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
ARMZ	-	Archaeological Resource Management Zone
AVHRR	-	Advanced Very High Resolution Radiometer
BAT	-	best available technology
bbl• d^{1}	-	barrels per day
BLM	-	Bureau of Land Management
BPT	-	best practicable control technology
BTEX	-	benzene, toluene, ethylbenzene, xylene
cm	-	centimeter
CNG	-	compressed natural gas
COE	-	Corps of Engineers
COTR	-	Contracting Officer's Technical Representative
CTD	-	conductivity, temperature, depth
CWA	-	Clean Water Act
DNR	-	Department of Natural Resources
DOE	-	Department of Energy
DOI	-	Department of the Interior
DOT	-	Department of Transportation
dpm• l^{1}	-	disintegrations per minute per liter
E&P	-	exploration and production
EEZ	-	exclusive economic zone
EPA	-	Environmental Protection Agency
ESA	-	Endangered Species Act
EWT	-	extended well testing
FFPI	-	fossil fuel pollution index
FGCC	-	Federal Geodetic Control Committee
FOSC	-	Federal On-Scene Coordinator
FPSO	-	floating production, storage and offloading units
ft.	-	feet
FWPCA	-	Federal Water Pollution Control Act
FWS	-	Fish and Wildlife Service
FY	-	Fiscal Year
g	-	grams
GEOSAT	-	Geodetic Satellite
GIS	-	Geographical Information System
GOES	-	Geostationary Operational Environmental Satellites
GOM	-	Gulf of Mexico
gpm	-	gallons per minute
GPS	-	Global Positioning System
GTS	-	Global Telecommunication System
ha	-	hectare
HPF	-	Historic Preservation Fund
IMO	-	International Maritime Organization
IR	-	infrared
ITM	-	Information Transfer Meeting
JIP	-	Joint Industry Projects
kg	-	kilogram
km	-	kilometer
LM	-	leasing map
LTL	-	Letter to Lessee
L&WCF	-	Land and Water Conservation Fund
m	-	meter
mA/d	-	milli Amperes per day

ABBREVIATIONS AND SYMBOLS
(cont'd)

mA/h	-	milli Amperes per hour
MAMES	-	Mississippi/Alabama Marine Ecosystems Study
MCSST	-	Multichannel Sea Surface Temperature
mi	-	miles
MIRG	-	Marine Industry Group
mm	-	millimeter
MMD	-	Merchant Marine Documents
MMPA	-	Marine Mammal Protection Act
MMS	-	Minerals Management Service
MOMS	-	Meteorological and Oceanographic Measurement System
NAD	-	North American Datum
NASA	-	National Aeronautics and Space Administration
NCP	-	National Contingency Plan
NECOP	-	Nutrient Enhanced Coastal Ocean Productivity
NEP	-	National Estuary Program
NES	-	National Energy Strategy
NESDIS	-	National Environmental Satellite Data Information Services
NSF	-	National Science Foundation
NGS	-	National Geodetic Survey
nm	-	nautical miles
NMFS	-	National Marine Fisheries Service
NOAA	-	National Oceanic and Atmospheric Administration
NORM	-	naturally occurring radioactive materials
NOS	-	National Ocean Service
NRC	-	Nuclear Regulatory Commission
NTL	-	Notice to Lessee
NTSB	-	National Transportation Safety Board
NWR	-	National Wildlife Refuge
NWS	-	National Weather Service
OCS	-	Outer Continental Shelf
OCSIS	-	Outer Continental Shelf Information System
OCSLA	-	Outer Continental Shelf Lands Act
OHMSETT	-	Oil and Hazardous Materials Simulated Test Tank
OMS	-	Ocean Mapping System
OOC	-	Offshore Operators Committee
OPD	-	Official Protraction Diagrams
OPSP	-	Open Project Selection Process
ORRRC	-	Outdoor Recreation Resources Review Commission
OSC	-	On-Scene Coordinator
OSCP	-	Oil Spill Contingency Plan
OSRV	-	oil spill response vessel
PAH	-	polynuclear aromatic compounds
PCA	-	principle component analysis
pCi/l	-	picocuries per liter
ppb	-	parts per billion
ppm	-	parts per million
ppt	-	parts per thousand
psi	-	per square inch
R&D	-	Research and Development
REC	-	Regional Examination Centers
RLM	-	reef-like mounds
ROV	-	remotely operated vehicle
RRT	-	Regional Response Team

ABBREVIATIONS AND SYMBOLS
(cont'd)

SCORP	-	Statewide Comprehensive Outdoor Recreation Plans
SCS	-	Soil Conservation Service
SHPO	-	State Historic Preservation Officer
SOCC	-	Satellite Operations Control Center
SOOP	-	ships of opportunity
SSH	-	sea surface height
STD	-	salinity, temperature, density
TA&R	-	Technology Assessment and Research
TLWP	-	tension leg well platform
TOC	-	total organic carbon
TOVS	-	Tiros Operational Vertical Sounder
TPH	-	total petroleum hydrocarbons
UPARR	-	Urban Park and Recreation Recovery Program
USCG	-	U.S. Coast Guard
USDA	-	U.S. Department of Agriculture
USGS	-	U.S. Geological Survey
UTM	-	Universal Transverse Mercator
VTS	-	vessel traffic systems
VOA	-	volatile organic analytes
VOSS	-	vessel of opportunity skimming systems
WGS	-	World Geodetic System
XBT	-	expendable bathythermographs

ACKNOWLEDGMENTS

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. Authors are listed by name in the agenda, and again in an index beginning on page 481.

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 as well as the beginning of each session.

Appreciation is extended to the staffs of Geo-Marine, Inc., the Contractor, who handles the logistics for these meetings, and the Doubletree Hotel, who always go beyond expectations to meet the needs of all. Mrs. Patti Knowles of Geo-Marine, Inc., is responsible for the preparation of this Proceedings Volume. Her willingness to accomplish the impossible with the data given to her merits a very special thank you.

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

OPENING PLENARY SESSION

Session: OPENING PLENARY SESSION

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

Date: November 13, 1990

Presentation	Author/Affiliation
Opening Plenary Session: Session Introduction	Dr. Richard E. Defenbaugh Minerals Management Service Gulf of Mexico OCS Region
Information Transfer Meeting Welcoming Remarks and Overview of Current Issues Facing Minerals Management Service	Mr. Chris C. Oynes Minerals Management Service Gulf of Mexico OCS Region
Financial Accounting for the Outer Continental Shelf Lands	Dr. Scott Farrow Council on Environmental Quality
Minerals Management Service/Outer Continental Shelf Program Legislative Outlook	Ms. Jill Martin Minerals Management Service Headquarters Office of Congressional and Legislative Affairs

OPENING PLENARY SESSION: SESSION INTRODUCTION

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 the meeting attendees, and are pertinent to the interests of the Minerals Management Service's (MMS) Gulf of Mexico Outer Continental Shelf (OCS) Regional Office.

ITM INTRODUCTION

The principal purposes of the ITM are (1) to provide a forum for "scoping" topics of current interest or concern relative to environmental assessments or studies in support of offshore oil and gas activities in the Gulf of Mexico OCS Region; (2) to present the accomplishments of the MMS Environmental Studies Program for the Gulf of Mexico, and of other MMS research programs or study projects; and (3) 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 these 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. Presentations are invited through personal contacts between session chairpersons and speakers who have demonstrated knowledge or expertise on the subject of interest. A few presentations are accepted in response to our call for contributed papers.

Meeting support funding is provided through the MMS Environmental Studies Program. All meeting logistical support is provided by a contractor (Geo-Marine, Inc., at this time) and subcontractors selected through the usual Federal procurement process. A proceedings volume is prepared for each ITM, based on presentation summaries submitted by each speaker and on session introductions prepared by session chairpersons.

OPENING PLENARY SESSION INTRODUCTION

The Opening Plenary Session is planned each year to address changing themes, which have included environmental topics, industry technology, offshore resources, marine research, and OCS program issues. This year's Opening Plenary Session was planned as a result of the major changes and challenges that affect the MMS and the OCS Programs.

Our new director, Mr. Barry Williamson, has instituted policy, procedural, and organizational changes. The Congress has had some difficulty developing a Federal budget within the constraints of the Gramm-Rudman-Hollings budget reduction act, which has affected our operating resources. The President has made sweeping policy decisions which affect the OCS Program nationwide.

This year's Opening Plenary Session speakers were invited to share information on some of the current issues we (MMS) face, on some of the financial benefits to the Nation of the OCS oil and gas program, and on some of the recent and pending legislation that will provide even more challenges and opportunities in coming years.

Dr. Richard E. Defenbaugh is Chief of the Environmental Studies Section of the Minerals Management Service Gulf of Mexico OCS Regional Office. His graduate work at Texas A&M University on the natural history and ecology of Gulf of Mexico estuarine and continental shelf invertebrates led to an M.S. in 1970 and a Ph.D. in 1976. He began his career in the Federal service in the Bureau of Land Management's (BLM) New Orleans OCS Office in 1975 and has been involved with BLM/MMS environmental studies and assessment programs since then.

INFORMATION TRANSFER MEETING WELCOMING REMARKS AND OVERVIEW OF CURRENT ISSUES FACING MINERALS MANAGEMENT SERVICE

Mr. Chris C. Oynes
Minerals Management Service
Gulf of Mexico OCS Region

WELCOMING REMARKS

On behalf of the Gulf of Mexico OCS Regional Office of Minerals Management Service (MMS), let me welcome you to the Eleventh Annual Information Transfer Meeting (ITM). Our Regional Director of MMS--Mr. J. Rogers Pearcy--would normally welcome you to this event. Unfortunately, he is unable to be with us today.

We are pleased that you are with us today. This ITM promises to be an exciting three days. Last year we had some 500 attendees. We will probably exceed that number this year. This ITM offers a wide range of subjects on onshore oil and gas development. Through 19 sessions involving 148 speakers we hope to provide you with a wide array of current information, new ideas, new development, and thought-provoking analysis. The sessions we have planned cover a number of issues, including:

- the opening plenary session, with presentations on issues currently facing the MMS, a financial accounting of OCS costs and benefits to date, and an overview of recently passed and pending Federal legislation affecting the OCS program or the offshore industry;

- sessions on new developments in oil spill response and spill response planning, including presentations by Clean Gulf Associates and the U.S. Coast Guard; a panel discussion on recent Federal and industry-sponsored oil spill research; discussions of logistics involved in responses to recent spills (the *Mega Borg* and the *American Trader*) and in oil dispersant use in the Gulf of Mexico; an overview of MMS's program to test industry's capabilities via unannounced oil spill drills; and a panel discussion regarding oil spill contingency planning by Gulf States;

- sessions on findings of recent studies of produced waters discharges in Louisiana coastal areas; on disposal and regulation of naturally occurring radioactive materials (NORMs), which occur in produced waters; and on clearance of drilling or production sites following removal of mobile offshore drilling units or production platforms, a subject of particular controversy with the shrimping industry in the Gulf;

- sessions reporting recent advances in offshore technology, especially in support of deepwater operations in the Gulf of Mexico, including offshore mapping, geologic and geohazard studies, production and transportation issues, and engineering safety and accident control;

- sessions for progress reports by researchers working under MMS funding on a variety of projects, including long-term environmental monitoring at the Flower Garden Banks; a study of effectiveness of various techniques used for management of marshes in coastal Louisiana; studies of the habitats, communities, and ecosystem of the Mississippi-Alabama Shelf; and studies of the social impacts of the offshore oil and gas industry to coastal Louisiana families, institutions, parishes, and other social settings;

- sessions devoted to reports on current technology and recent research to study the distribution, movements, and environmental habitats of sea turtles and whales, using state-of-the-art sonic, radio, and satellite telemetry devices;

- sessions to provide an opportunity for physical oceanographers from the offshore industry, academia, and Federal agencies to share recent research findings, especially of studies to track, analyze, and model Gulf of Mexico eddies;

- sessions of reports by directors of Gulf of Mexico marine laboratories and research facilities, summarizing facilities and current research;

- a session of contributed papers, mostly on studies of echinoderms offshore the Florida panhandle, methods of assessing fish stocks near platforms and minimizing effects of underwater explosives on fish stocks, of studies of dolphins stranded in Texas, and of dolphin behavior near the *Mega Borg* oil spill; and

- a session on the Land and Water Conservation Fund and the Historic Preservation Fund, which are supported by the OCS program and have provided nationwide benefits by providing support for outdoor recreation programs, national parks and seashores, national wildlife refuges, and national forests.

All these sessions promise a full and interesting three days. We are glad you are here to take advantage of them.

OVERVIEW OF CURRENT ISSUES FACING MINERALS MANAGEMENT SERVICE

Another duty has been thrust upon me today. We had hoped that the Director of MMS, Mr. Barry Williamson, might be able to attend our meeting and provide a review of current issues in MMS. Unfortunately, Mr. Williamson's schedule did not allow him to attend our ITM. I will attempt to fill in today with what I hope are some useful observations about current issues facing MMS.

In June of this year President Bush made some far-reaching and fundamental decisions about the direction of the OCS Oil and Gas Program. After a year of careful analysis by his relevant departments and agencies--National Oceanic and Atmospheric Administration, Department of Energy, Environmental Protection Agency, the Interior Department--the President decided to take a number of steps to ensure that offshore oil and gas will be produced in an environmentally responsible manner:

- He removed 99% of the area off California from consideration for leasing for the remainder of the century. Only 87 tracts remain for study.
- Three sales off California and Southern Florida were cancelled.
- He ordered the restructuring of the OCS program, which will soon be reflected in a new 5-year program.
- He also ordered that a study be made of a proposal for sharing OCS revenues with the coastal states.

The Secretary of the Interior, Manuel Lujan, embraced the principles cited by the President and took additional steps. He cancelled a sale in the North Atlantic (or Georges Bank) until the year 2000 and cancelled a sale off the coast of Washington and Oregon.

These decisions will be reflected in the new 5-year leasing program for the period 1992-1997. As you may be aware, development of such a program requires a series of lengthy steps such that the 5-year program will not be finalized until mid-1992. Our next step--issuance of a draft proposed program--will occur soon, perhaps early next month. Consistent with the President's decisions, the draft proposed program will slow the pace of proposed lease sales, will stress an environmentally sensitive program, and will increase the opportunities for close consultation with state governments, the public, and interest groups so that conflicts are minimized.

Another current issue affecting the large number of operations in the Gulf of Mexico OCS is the bonding requirement for companies that conduct operations on the OCS. The MMS has issued in the Federal Register, for review and comment, a proposed regulation to change our bonding requirements. This regulation would require the bonding level to rise from our current level of $50,000 per lease or $300,000 areawide to a higher figure. These bonding levels have not been raised in more than 15 years. A large amount of comments were received, many of them negative. The MMS is now considering a number of options on how it might address this issue.

Finally, I would like to share with you some trends on what is happening in the Gulf OCS regarding oil and gas. Figure 1.1, "Trends in Acres Leased," shows a consistent increase in acreage leased annually from 1986 until 1989, but a slight decrease in acreage leased in 1990. Table 1.1, "Trends in Field Size," shows a consistent decrease in the average size of oil/gas fields discovered over the past four decades, as measured in "Barrels of Oil Equivalent." Figure 1.2, "Trends in Production," shows a very slight decline in the rate of oil production over the period 1986 through 1989, but a slight increase in gas production over the same time period. Cumulatively, these figures indicate that the Gulf remains a major producing area, but that the most promising acreage on the shelf has been explored, and that major fields have been located. Future exploration and development in the Gulf can be expected to focus on smaller or deeper finds on the continental shelf and on the promising acreage in deeper waters of the Gulf.

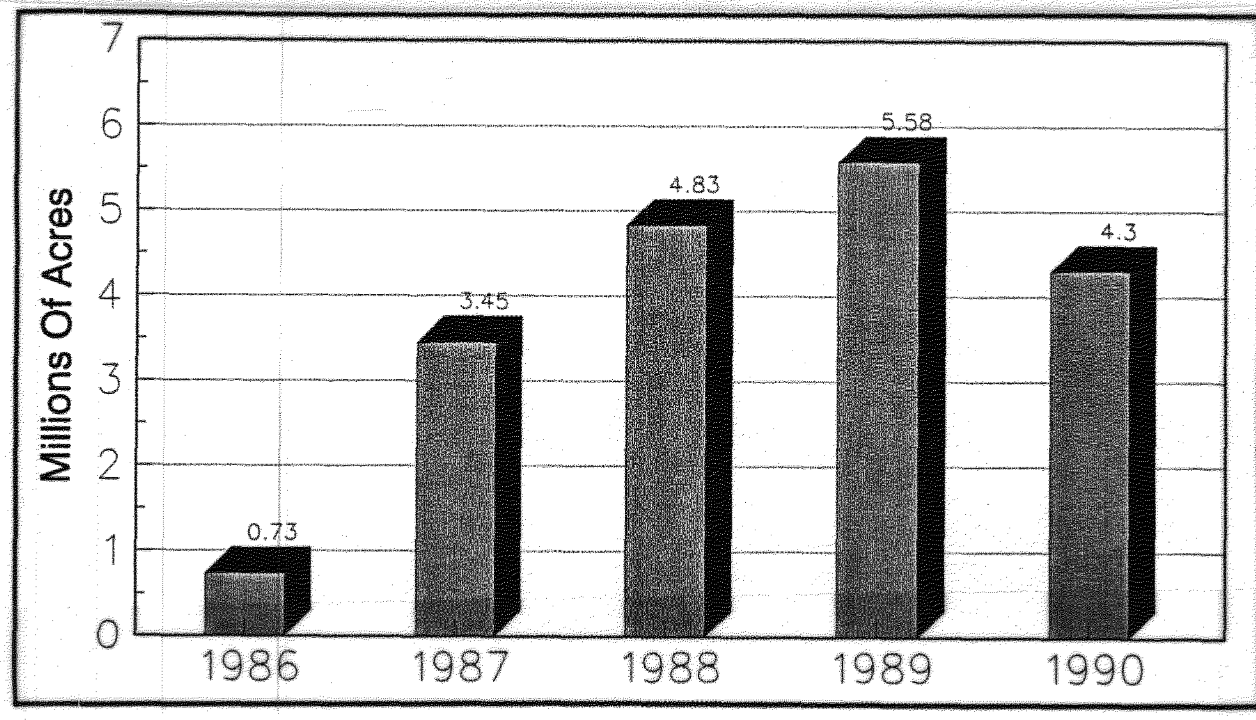

Figure 1.1. Trends in Gulf of Mexico OCS acres leased.

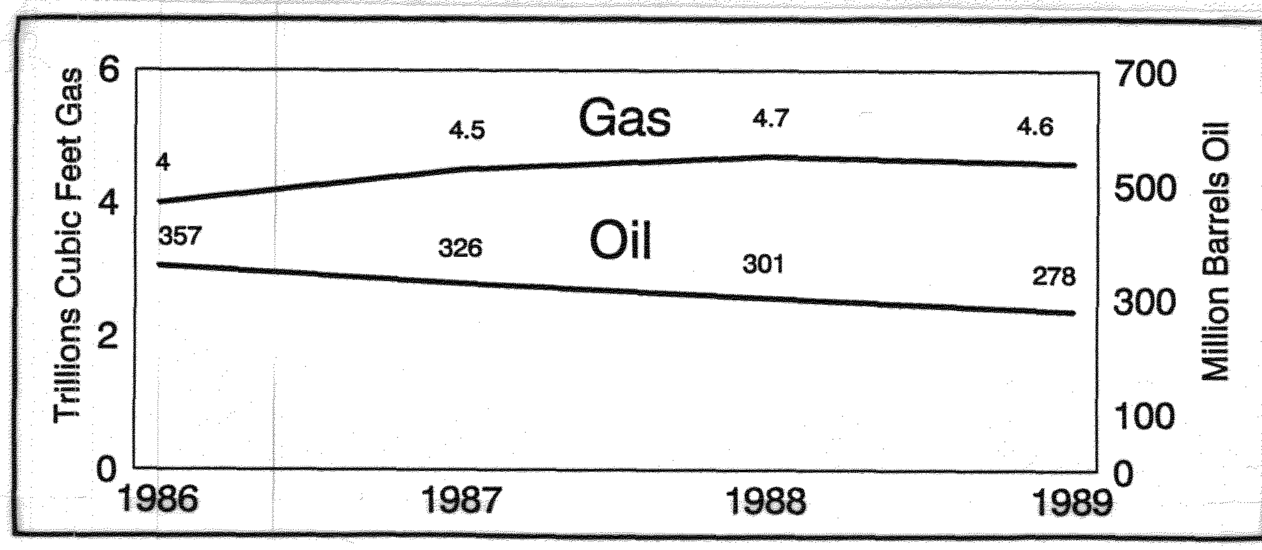

Figure 1.2. Trends in oil and gas production, Gulf of Mexico OCS.

Table 1.1. Trends in Field Size, Gulf of Mexico OCS.

Decade	Average Size Field Discovered
1950's	140 Million BOE
1960's	70 Million BOE
1970's	40 Million BOE
1980's	10 Million BOE

Mr. Chris C. Oynes is the Deputy Regional Director for the Gulf of Mexico OCS Region of the Minerals Management Service. In this role he helps manage all of the Regional Office's functions, including environmental protection, regulation of operations, production and development, and leasing. Mr. Oynes earned his law degree at George Washington University and served for 11 years in the Minerals Management Service Headquarters Offices in Washington, D.C. in OCS leasing and environmental programs.

FINANCIAL ACCOUNTING FOR THE OUTER CONTINENTAL SHELF LANDS

Dr. Scott Farrow[1]
Council on Environmental Quality

Accounting is not the topic that gets the great mass of researchers and policy makers standing up in the aisles. Accounting is however, a powerful tool for management in both private companies and federal agencies where it provides a structure for obtaining and comparing information.

As a guide to obtaining and comparing information, accounting can help fulfill the demanding guidelines of the President's recent Outer Continental Shelf (OCS) decision. In particular, the Minerals Management Service now has time to take a fresh look at the guiding principles for OCS leasing provided by the President in June:

- Adequate information and analysis,
- Environmental sensitivity,
- Resource potential,
- Energy requirements, and
- National security requirements.

Many of these principles, and their tradeoffs, can be addressed in part through an expanded accounting framework that would put the MMS in a leading position among resource management agencies as the United States evolves toward integrating its national income accounts with those of the United Nations.

The most basic change I am suggesting is to integrate the standard income sheet statements--those showing revenues and expenses--with balance sheet statements that are commonplace to private companies who manage natural resources. The MMS is well on its way to that objective. I will demonstrate approximately how such integrated statements might have looked for fiscal year 1987. Following those 1987 statements, I want to push a little bit into less charted territory, specifically how environmental assets might be accounted for in accounting statements for the OCS.

ACCOUNTING STATEMENTS: FISCAL YEAR 1987[2]

While the presentation of integrated income and balance sheet statements is an everyday occurrence in the private sector, federal government accounting is fundamentally different. Governmental accounting devotes little attention to long-lived assets but is instead oriented toward yearly appropriation and revenue cycles. The asset management program of the MMS is fundamentally different than that faced by most agencies and could benefit more than most agencies by integrating financial statements for the year's revenue and income flow with its stock of assets and liabilities.

While I will focus on fiscal year 1987, that year was somewhat unusual for the large role that escrowed elements associated with the 8(g) lands had on the financial statements. In terms of total program receipts, however, fiscal year 1987 started the few years of a downward trend associated with the price declines of 1986 (Figure 1.3).

[1]Views expressed in the article are those of the author and not necessarily the view of the U.S. Government in general or of the Council on Environmental Quality in particular.
[2]This section is based on Farrow, S., J. Broadus, *et al.* 1990. *Managing the Outer Continental Shelf Lands: Oceans of Controversy*. Taylor & Francis. pp. 99-109.

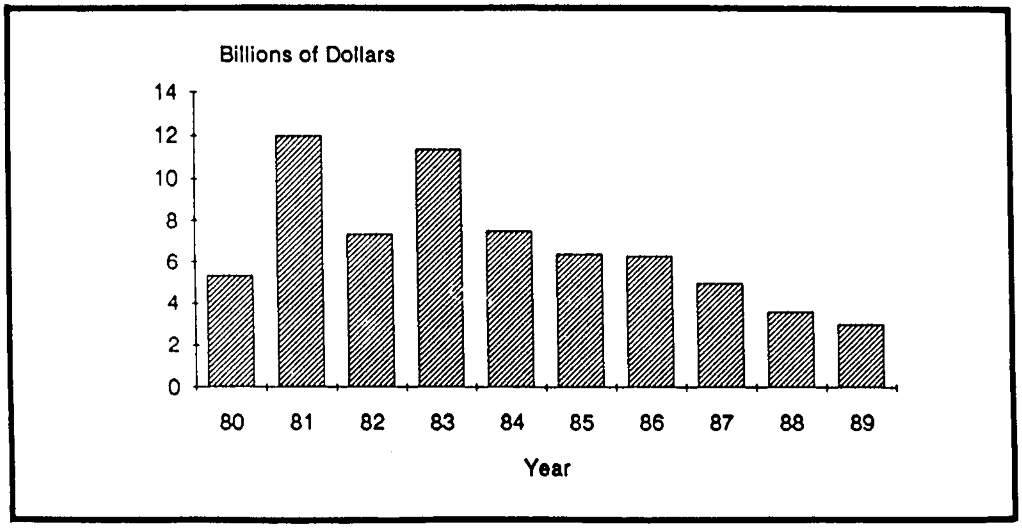

Figure 1.3. Total OCS program receipts and escrow, FY 1980-1989.
Source: USDI, MMS. 1990. Oil and Gas Leasing/Production Program: Annual Report FY 89. MMS OCS Report No. 90-0015. Herndon, Va. xvi + 55 pp.

Income Statement

The program receipts are discussed in more detail in Table 1.2, not only breaking out bonus and royalty payments but also tracking the several insurance funds, the Oil Spill Pollution Fund and the Fishermen's Compensation Fund, which are funded through OCS revenues.

Table 1.2. FY 1987 (millions of dollars).

	Current	Escrow Release	Total*
Bonus and rental	419	1,185	1,603
Royalties	2,316	102	2,418
Interest	0	903	903
Pollution Fund	18	0	18
Fisherman's Fund	2	0	2
Total	2,755	2,190	4,944

*Details may not add to total due to rounding.

Source: Minerals Management Service, *Federal Offshore Oil and Gas Statistics*; U.S. Office of Management and Budget, *Appendix: Budget of the United States, 1989*; Minerals Management Service, *Offshore Oil and Gas Leasing/Production, Annual Report, FY 1987.*

In 1987, bonus and rental payments for lands newly leased totaled $419 million. The release of escrowed bonus and rental payments was $1.2 billion. Royalties accounted for $2.4 billion of which $102 million were funds released from escrow. The several insurance funds collected $13 million with an additional $7 million earned in interest earmarked for those funds. Other interest earned from the funds held in escrow was $903 million. In total, the offshore revenues received by the Minerals Management Service were $4.9 billion in 1987.

Accounting for expenses is equally as important as accounting for revenues. The major expense categories are presented in Table 1.3 for leasing management, resource evaluation, regulation, royalty management, and general administration. The royalty management and general administrative expenses were reduced by 20% to approximately account for the share of expenses associated with onshore royalty collection. The data in Table 1.3 indicate that royalty management is the largest single item at $37 million, followed by regulation at $28 million, resource evaluation at $26 million and the environmental studies program at $23 million. Royalty management and regulation are associated with post-leasing activities while leasing management and resource evaluation extend into pre-leasing activities. Claims on the liability funds and their administration were relatively small with no claims paid through the Oil Spill Pollution Fund in 1987.

Table 1.3. Expenses FY 1987.

Categories	Million Dollars
Preleasing	
Leasing Management	
Environmental Studies	23
Leasing and environmental assessment	16
Resource Evaluation	26
Postleasing	
Royalty Management	37
Regulation	28
Other	
General Administration	21
Claims and administration of funds	1
Total	152

Source: Appendix: *Budget of the United States, 1989*, op. cit.; Minerals Management Service Information Office, detailed tables, *Minerals Management Service Budget: FY 1989.*

In private sector parlance, the MMS would be seen as a cash cow; the Government spent $152 million to net $4.8 billion in revenue. The source of these revenues has been primarily from the Gulf of Mexico with a smaller contribution from Southern California. In the actual Government accounts, no measure of net income, revenues minus expenses, is computed because the majority of revenues are defined to be "undistributed proprietary funds," which are not used to offset costs as possibly implied by a net income calculation. Calculating net income, $4.8 billion in 1987, and tracking its disbursement does, however, provide insight into the uses of the money. Also, because the net income is generated by liquidating a long-term asset--stocks of oil and natural gas--further distribution of net income depends on the size of the long-term assets in the balance sheet.

The Funds Statement

While the source of funds for the MMS is somewhat uninteresting (it is funded entirely out of General Fund allocations to the Department of the Interior) the uses of funds are of substantial interest. In 1987, the $4.8 billion of net income was distributed as in Table 1.4. Eighty percent went directly into the General Fund out of which most Government activities are funded. Seventeen percent went to the Land and Water Conservation Fund (L&WCF) managed by the National Park Service (and then distributed to several agencies and states) to fund recreation projects and new land purchases. The L&WCF is not, however, authorized to spend all of the money transferred to it. This has led to a $5 billion unappropriated balance in the fund at the end of 1987. The National Park Service also received $150 million of the net income for the Historic Preservation Fund, which also carried an unappropriated balance of $1.1 billion at the end of 1987. While I provide a brief review of the distribution of the Land and Water Conservation monies below, I note that several detailed presentations are provided elsewhere in this volume.

Table 1.4. Funds Statement: FY 1987.

Distribution of Net Income	Million Dollars
General Fund	3,800
Historic Preservation	150
Land and Water Conservation	824
Oil and Fishermen's Fund increases	18
Total	4,792

Source: Minerals Management Service, *Federal Offshore Oil and Gas Statistics*; U.S. Office of Management and Budget, *Appendix: Budget of the United States, 1989.*

Land and Water Conservation Fund

The funds spent through the L&WCF and the Historic Preservation Fund are the most visible way in which the benefits of offshore development have been shared among the fifty states and the territories. Because of its larger size, I focus on the Land and Water Conservation Fund. Beginning with legislation in 1965, the L&WCF has been primarily funded by revenues from offshore oil and gas.

The amount actually spent from the Fund has varied widely, however, from just a few million dollars in 1965 to a peak of $800 million in 1978. Legislation required that at least 40% of the expenditures from the Fund be used for federal land acquisition with larger proportions going for federal purposes in recent years. Another portion of the fund is used for supporting recreation at the state and local government level. The history of this funding is presented in Figure 1.4.

Geographically, these funds have gone to local areas all across the United States. Over 85 projects have been funded in New York City alone, while Massachusetts has received over $78 million, an amount exceeded by California, Florida, Illinois, Michigan, New Jersey, New York, Ohio, Pennsylvania, and Texas. Figure 1.5 below indicates the widespread use of the L&WCF at the state level.

The Balance Sheet

The revenues described in previous sections are generated by a shift of assets from long-term assets to current income. The balance sheet categorizes the estimated present value available to the Government for further transactions of this type. Of course, the estimates are based on the technological and economic conditions at a particular time. The balance sheet presented in Table 1.5 focuses on the asset value of the mineral holdings and the long-term assets of the Oil Pollution Fund. Any unobligated balance of current budget authorization and the value of assets such as equipment are not reported.

Table 1.5. The Balance Sheet.

Long-Term Assets	Million 1987 Dollars
Government Securities	103
Leased Tracts	
Developed reserves	18,560
Undeveloped reserves	2,318
Unexplored	6,562
Unleased Tracts	
Unexplored	9,800
Total	37,343

Source: Adapted from Rosenthal, D., M. Rose, and L. Slaski. 1989. The Economic Value of the Oil and Gas Resources on the Outer Continental Shelf. *Marine Resource Economics*.

The first long-term asset is Government securities held by the Oil Pollution Fund totaling $103 million as of the end of 1987. Unsurprisingly, the vast majority of the mineral assets of the Federal offshore program are the currently and potentially leasable lands of the OCS. I will return to the non-mineral assets in a later section. In a recent article, several MMS researchers, Rosenthal *et al.* (1990), estimated the present value of Government receipts that would result given the current technology and a forecast of prices.

There are various categories of uncertainty that are reflected in the balance sheet. Conceptually, Rosenthal et. al (1990), divide the assets managed by the MMS into four categories; leased tracts with developed reserves, leased tracts with undeveloped reserves, leased tracts that have not yet been explored, and unleased tracts. Of course, bonus revenues have already been received on all the leased tracts while both bonus and royalty income represent future income on the unleased tracts. While each category of tracts has different costs, which affect the calculation reported by the authors, each category represents the present value of the lease to the Government. The revenues and costs are discounted at 8% and incorporate an assumed 1% price increase per year from a base of $18 per barrel in 1987.

In present value terms, the expected value of already developed reserves is estimated to comprise almost half the asset value and is estimated to be worth almost $19 billion. Approximately 25% of the asset value is the expected present value of unleased tracts worth almost $10 billion. This contrasts, however, with about $90 billion (nominal) already received by the program.

The balance sheet is, however, clearly sensitive to several sets of assumptions, and the dollar and resource realizations of the program are likely to be very different. Rosenthal et. al. (1990) find that the total value of leases would increase to $61 billion if the 1987 oil price had been $26 per barrel. Alternatively, they estimate that if a 6% discount rate is used the present value of the leases would increase to $51 billion. The suggestion for balance sheet accounting is that a range of numbers could usefully be presented, as well as a supplemental accounting sheet showing the resource estimates that lie behind the estimated values. Furthermore, each financial statement has a geographic area associated with it so that the financial statements could potentially be integrated with geographic information systems.

CONCLUSIONS AND EXTENSIONS

Integrated financial statements as are common in private industry can provide an analytical structure

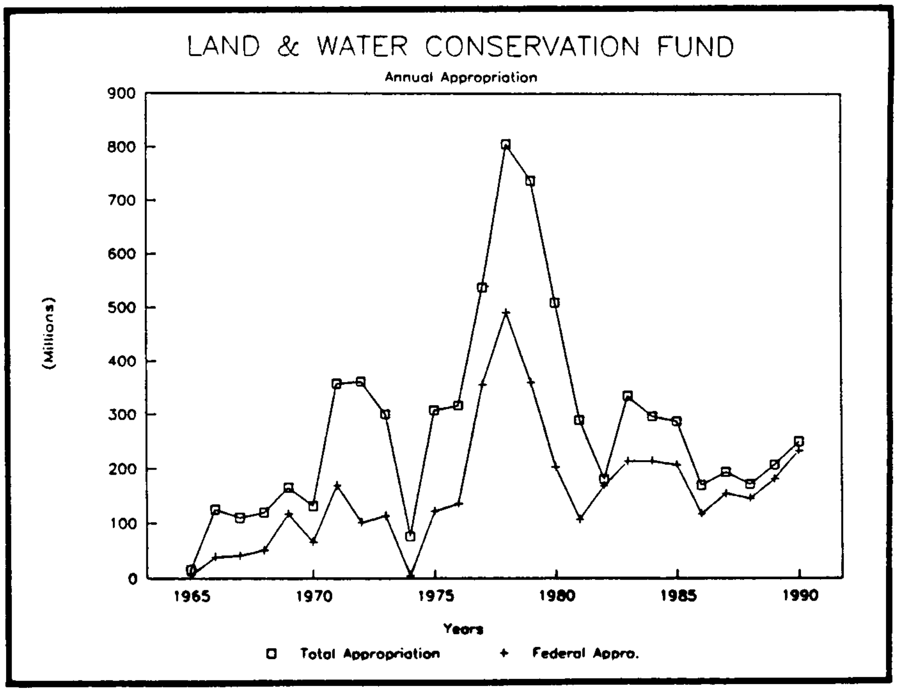

Figure 1.4. Land and Water Conservation Fund, annual appropriations, 1965-1990.

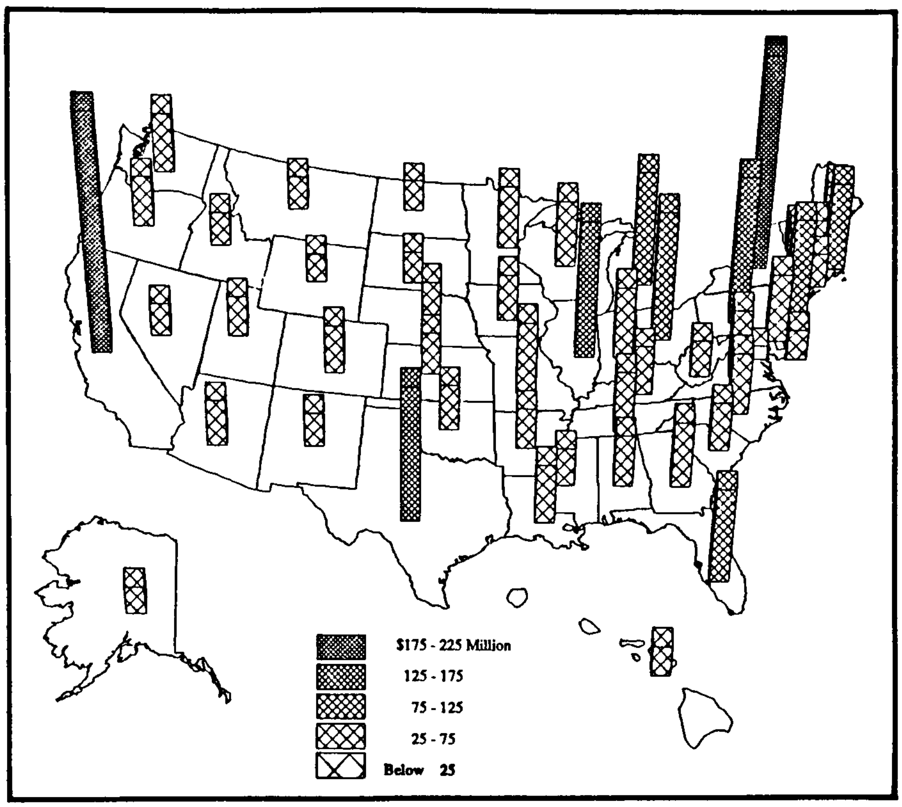

Figure 1.5. Cumulative appropriations to states, Land and Water Conservation Fund.

Source: U.S. National Park Service, ***Annual Report to Congress: Land and Water Conservation Fund Grants-in-aid Program***, Fiscal Year 1987.

for beginning to implement Presidential guidelines on information, resource potential, and environmental sensitivity. It is worth investigating these issues in slightly greater detail.

Resource potential clearly lies behind the balance sheet estimates of asset value with the annual revenues and expenses associated with changes in the balance sheet. Proposals for making U.S. national income accounts consistent with United Nations guidelines may open the door to natural resource accounting of this type. There is a growing awareness, and technical capability, to account for the role that natural resources play in generating the annual national income of a country. The MMS can be a leader in this transition and in the development of so-called satellite accounts for natural resource accounting.

An even more complex task gets to the heart of some OCS controversies. The water column above those energy assets supports a wide variety of economic activities as does the shoreline. A frontier topic in natural resource and environmental accounting, and of central concern to OCS management, is the valuation of all environmental services, particularly those seen as environmentally sensitive.

In fact, the MMS has gone a long way toward thinking about valuing environmental sensitivity. When one considers the meaning of the net social value measures reported in the 1987 five year plan, they represent not only a parallel measure to the Rosenthal et. al. (1990) asset numbers, but also a contingency accounting for environmental damages. The valuation of environmental costs in that document included a litany of direct and indirect costs. While the technical measurement of these costs is likely to evolve substantially given the evolution of natural resource damage assessment methods, they provide an early indication of how the environment can be included in financial statements. One way merely reduces the value of the assets that are being managed. A second way can set up contingency liabilities associated with environmental damage. Further down the road, one may want to consider a comprehensive ocean sector income statement and balance sheet providing for all of the services generated by the ocean environment. While the latter approach may seem grandiose, the debates over OCS management have clearly indicated that energy resource management is inseparable from broader management of ocean resources.

Having waded out into such deep water, I may best separate out a short, medium, and long-term agenda for financial accounting for the OCS program. In the short-term, integrated statements such as those prepared for 1987 can be refined to become a part of the regularly reported offshore statistics. In the medium and longer term, increasing the consistent representation of the interaction between economics, energy, and the environment can help inform the public and the Minerals Management Service in order to achieve the comprehensive balancing required under the OCS Lands Act and reinforced through the recent Presidential guidelines for Outer Continental Shelf leasing.

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Dr. Scott Farrow is the senior economist for the Council on Environmental Quality in the Executive Office of the President. He is on leave from Carnegie Mellon University where he is an associate professor of economics. Dr. Farrow is a member of the OCS scientific advisory committee and recently published a book on managing the Outer Continental Shelf lands.

MINERALS MANAGEMENT SERVICE/OUTER CONTINENTAL SHELF PROGRAM LEGISLATIVE OUTLOOK

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The purpose of this presentation is to provide an outlook of prospective accomplishments of the 102nd Congress. It is impossible to know what will happen during the 102nd Congress, of course, so it is very difficult to project those legislative accomplishments.

For perspective, let us consider influences on the 101st Congress, which concluded on October 28, 1990. This was the first Congress of the 1990's; the first Congress of the Bush Presidency; and also the longest legislative session since 1942 (the early years of World War II). One cause for this lengthy session was the difficulty Congress had in finalizing the Federal budget, but a consequence was more time for legislative business, resulting in a very productive legislative session.

During this time Congress was scandalized, both by the sex affairs of members and by the ethics dilemmas posed by Speaker Jim Wright and the disclosure of the Savings and Loan debacle. During this same time an amazing sequence of world events unfolded, including the end of the cold war era; the demolition of the Berlin Wall; the implementation in the U.S.S.R. of glastnost and perestroika, which resulted in Premier Gorbachev's winning the Nobel Peace Prize; the apparent fall from power of the Sandinistas in Nicaragua; and the overthrow by U.S. forces of Manual Noriega in Panama.

A major influence on Congress seems to be an environmental consciousness that has again resurfaced within the American electorate in the past few years. In 1988 Mr. Bush campaigned to be the "environmental president," pointing out environmental problems in Boston Harbor and other sites. Weather during recent years has been very hot, especially in Washington, leading to air quality problems and discussions of global climate change. A well publicized trash barge cruised the Atlantic and Gulf Coasts seeking a disposal site, and medical wastes littered New Jersey beaches causing beach closings and a public outcry. And then in March 1989 the tanker *Exxon Valdez* caused the Prince William Sound oil spill and a dramatic polarization of public opinion to oppose any activities that might result in oil on the seas, including the offshore oil and gas program.

Many of these influences are reflected in the legislative accomplishments of the 101st Congress. Highlights of special interest to the Minerals Management Service (MMS) or the Outer Continental Shelf (OCS) oil and gas program follow.

OIL POLLUTION ACT
(Public Law 101-380)

The Act is primarily the responsibility of the Department of Transportation (DOT). It does not implement International Protocols and does not pre-exempt existing State oil spill liability programs. Several provisions affect MMS:

- Liability limits for offshore facilities are raised to $75 million for damages, plus unlimited removal costs. Mobile Offshore Drilling Units are treated first as a tanker; after that liability limit is exceeded, they are treated as an offshore facility.

- The MMS will have a role on the Interagency Committee overseeing the research program established by Title VII. The long-term operation of the Oil and Hazardous Materials Simulated Environmental Test Tank (OHMSETT) is "ensured" by this Title.

- Section 1016 (Financial Responsibility) could transfer the responsibility from DOT to MMS for ensuring that parties responsible for offshore facilities maintain evidence of financial responsibility; this transfer is still being worked out. Administrative costs to perform this function should be available from the Oil Spill Liability Fund (Section 1012).

- Section 6003 (Outer Banks Protection) prohibits, for at least one year, any OCS leasing, drilling, and approval of plans and permits offshore North Carolina. Provision calls for establishment of an Environmental Sciences Panel to review the adequacy of current environmental information and to indicate what further information might be needed. A report to the Secretary is required six months after enactment. The President made a strong statement in opposition to this provision when he signed the bill into law; the Administration is seeking repeal of this provision.

- Section 6004 (West Delta Provision) amends the OCS Lands Act, as Amended (1978), to require the Secretary of the Interior to prevent the harmful effects of unrestrained competitive production of hydrocarbons from "common hydrocarbonbearing areas" underlying Federal and State boundaries. The Section also exempts blocks 17 and 18 of the West Delta field offshore Louisiana from the cooperative development provisions listed above, and authorizes sums to be appropriated as may be necessary to provide compensation to the State of Louisiana and its lessees. The Department of the Interior (DOI) appropriations bill, which passed on October 27, 1990, included $4 million for partial payment to the State of Louisiana and State lessees for drainage from oil and gas leases in the West Delta field. However, monies cannot be obligated until the appropriations committees have "conducted a full hearing on the issue."

- Section 8201 amends current section 24(b) of the OCS Lands Act (civil penalties) to give the Secretary the authority to assess civil penalties without allowing time for corrective or remedial action for certain types of violations. It raises the per incident civil penalty fine from $10,000 to $20,000 per day, and requires the Secretary, by regulation, to adjust the civil penalty rate every 3 years to reflect any increases in the Consumer Price Index.

CLEAN AIR ACT REAUTHORIZATION
(Public Law 101-549)

The original Act was passed in 1970 and last amended in 1977. It is comprehensive legislation addressing a range of issues, including tailpipe emissions, air toxics, acid rain, etc. An OCS emissions provision was included in both the House and Senate versions of the bill; the final legislation contained the House provision. Both provisions are:

- The Senate version contained an Administration-backed OCS provision that would retain regulatory authority with DOI; would require regulations developed for areas offshore California to be as stringent as rules applied in adjacent onshore areas; would prohibit discrimination against OCS vs. onshore emissions; and would provide for a Project Emission Reduction Fund to facilitate mitigation.

- The House OCS provision would split responsibility for OCS emissions between Environmental Protection Agency (EPA) and DOI; would require regulations for areas under EPA authority to be the same as rules applied in adjacent onshore areas, for areas within 25 miles of a State; and would provide for delegation to local/state authorities from EPA.

BUDGET RECONCILIATION
(Public Law 101-508)
TITLE VIII AMENDS THE
COASTAL ZONE MANAGEMENT ACT

This legislation reauthorizes the program for five years (through 1995) and makes substantive amendments to Section 307 (Federal Consistency). These amendments are meant to overturn *California vs. Watt* (Supreme Court decision on OCS lease sales). Language will now require any Federal activity (regardless of its location) to undergo consistency certification if it "affects any land or water use or natural resources of the coastal zone." The determination of what activities "affect" the coastal zone is to be construed broadly; this includes direct effects plus indirect effects that could come later in time. No Federal activities are categorically exempted. The President can only exempt a specific activity "if it is in the paramount interest of the United States." During conference, language was added requiring Federal activities to be consistent only with the "enforceable policies" of approved State management plans. The legislation encourages States (through grants) to improve their coastal zone management programs in eight areas, including coastal energy facility siting, and requires States to develop nonpoint source pollution control program from "adjacent coastal land uses."

DOI FISCAL YEAR 1991
APPROPRIATIONS
(Public Law 101-512)

The Appropriations bill included several provisions for OCS moratoria, totalling more than 283 million acres in 8 OCS planning areas:

- No "leasing and related activities" will be allowed for areas placed under restriction in the President's June 26, 1990, statement. These planning areas include: Washington/Oregon; Northern, Central, and Southern California; the North Atlantic; and that portion of the Eastern Gulf of Mexico which lies east of 86'W longitude and south of 26'N latitude.

- A leasing and drilling ban in the North Aleutian Basin planning area.

- A pre-lease and leasing ban on the Eastern Gulf of Mexico Sale 137 area (Florida Panhandle), and on a portion of the mid-Atlantic (a 50-mile buffer from Maryland to the top of the planning area).

Another provision of the bill, regarding "net receipts sharing," will require the deduction of 50% of the administrative costs of collecting mineral leasing receipts prior to distribution of those receipts to States and the Federal Treasury.

ENERGY POLICY AND
CONSERVATION ACT
(Public Law 101-383)

The legislation extends the authority of Title I or Energy Policy and Conservation Act until September 30, 1994; extends the authority for the strategic petroleum reserve (among other things); and extends a prohibition on joint bidding by certain companies for offshore leases until September 30, 1994.

OFFSHORE PIPELINE INSPECTION
(Public Law 101-599)

The legislation amends the Natural Gas Pipeline Safety Act and the Hazardous Liquid Pipeline Safety Act to require:

- Operators are to conduct an initial inspection of each offshore pipeline safety facility in the Gulf of Mexico and report to the Secretary if it is exposed or is a navigational hazard. Operators are required to mark hazards with buoys. For natural gas pipelines, this requirement pertains to pipelines between the high water mark and the point where the subsurface is under 15 ft. of water; for hazardous liquid pipelines, this requirement pertains to all pipelines, other than gathering lines of four inches diameter or smaller.

- The DOT is to establish a permanent systematic inspection requirement. Any pipeline facility that is a navigational hazard must be buried, pursuant to regulations to be issued by DOT.

- The DOT is to establish a program to encourage fishermen and other vessel operators to report navigational hazards involving pipelines.

- The DOT is to conduct a 6-month study regarding methods for determining how deeply underwater pipelines are buried and to research existing marine safety and vessel operational practices relating to underwater pipeline rights-of-way; and to report their findings to Congress.

COASTAL WETLANDS PLANNING, PROTECTION, AND RESTORATION ACT
(Public Law 101-646)

The bill authorizes the Louisiana Coastal Wetlands Restoration Plan, among other things:

- A Federal Task Force is established to determine priority coastal wetland restoration projects that can be completed within a five-year period, and to develop a long-term Wetland Restoration Plan. The Task Force includes the Secretary of the Army, the Administrator of EPA, the Governor of Louisiana, and the Secretaries of Interior, Agriculture, and Commerce.

- Within one year, a list of short-term projects is to be transmitted to Congress, and the restoration plan is to be transmitted within three years. The restoration plan is to integrate the "Louisiana Comprehensive Coastal Wetlands Feasibility Study" and the "Coastal Wetlands Conservation and Restoration Plan" already completed by the State of Louisiana.

- The Secretary of Commerce is authorized, at the request of the Governor, to approve the State restoration plan as an amendment to the State's coastal zone management plan. Corps of Engineers flood control, irrigation, and navigation projects must be consistent with the restoration plan (except emergency projects).

The bill also authorizes Louisiana Coastal Wetlands Conservation Planning. Parallel authority is granted to EPA, the Corps of Engineers, and the Director of the Fish and Wildlife Service to work with the State of Louisiana to develop, review, approve, and evaluate the State's Coastal Wetlands Conservation Plan. This Plan is not mandatory, but if developed, must achieve a goal of "no net loss of wetlands" when regulating development activities.

Finally, the bill authorizes National Coastal Wetlands Conservation Grants. The Director of the Fish and Wildlife Service is assigned the lead role in implementing a national program for 50/50 matching grants to States other than Louisiana for wetlands conservation projects. An allocation of up to $15 million per year is to be provided to the Secretary of the Interior for wetlands conservation projects authorized by the North American Wetlands Conservation Act in coastal States.

This bill was originally to be funded by OCS receipts. That provision was dropped due to Administration opposition; the funding sources now include: a portion of the new 5-cent increase in fuel excise taxes; excise taxes for nonbusiness small motor equipment (which represents a diversion from the Highway Trust Fund); and other monies that are currently deposited in the account.

FLORIDA KEYS MARINE SANCTUARY
(Public Law 101-605)

This bill provides legislation to protect approximately 2,600 square miles around the Florida Keys from ships and oil drilling. The bill would declare the Keys a National Marine Sanctuary and require the development of a comprehensive management plan and a water quality program. It would also prohibit offshore oil drilling and prevent certain large vessels and other ships carrying hazardous materials from sailing through the Keys' waters. Finally, the bill would expand the boundaries of the sanctuary by over a thousand square miles from those contained in the original bill.

ANTARCTIC PROTECTION ACT OF 1990
(Public Law 101-594)

Language of the bill provides that, pending a new agreement among the Antarctic Treaty Consultative Parties, which the Senate has ratified, an indefinite ban is in effect on mineral activities by U.S. citizens or companies in the Antarctic. The bill contains a "sense of the Congress" provision that the Department of State should negotiate a new international agreement with respect to Antarctica to conserve and protect permanently the environment of Antarctica; to prohibit or ban indefinitely mineral activities; and to grant it special protective status as a "land of science." A provision making the National Environmental Policy Act applicable to U.S. activities in the Antarctica was dropped from the bill.

We can only speculate on the legislative accomplishments of the 102nd Congress. Issues that we can expect to be considered, however include:

- Moratoria on OCS activities, including active areas such as the Gulf of Mexico and the Chukchi and Beaufort Sea areas offshore Alaska. Environmental groups have targeted the Flower Garden Banks, the Florida Middle Grounds, a Florida coastal buffer, and scattered topographic highs, especially those offshore Mississippi and Alabama.

- Marine Sanctuaries. Due to the slow progress to date by the Department of Commerce, and their conclusion that some proposed areas were not worthy of sanctuary status, we can expect special interest groups to seek sanctuary status for more areas through the Congress. We can also expect that these designations will carry special provisions to prohibit OCS activities within sanctuary boundaries.

- Revenue Sharing with affected coastal States. The MMS has already been involved in drafting legislation towards this end, and Congressional delegations have their own opinions on legislative language. The outcome is currently uncertain.

- The OCS Lands Act Amendments to consider various revisions to the OCS oil and gas program.

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MINERALS MANAGEMENT SERVICE ENVIRONMENTAL STUDIES FOR THE GULF OF MEXICO: ACTIVE STUDIES PROGRESS REPORTS

Session:	MINERALS MANAGEMENT SERVICE ENVIRONMENTAL STUDIES FOR THE GULF OF MEXICO: ACTIVE STUDIES PROGRESS REPORTS
Co-Chairs:	Dr. Robert M. Rogers Ms. Bonnie LaBorde Johnson
Date:	November 13, 1990

Presentation	Author/Affiliation
Minerals Management Service Environmental Studies for the Gulf of Mexico: Active Studies Progress Reports: Session Introduction	Dr. Robert M. Rogers and Ms. Bonnie LaBorde Johnson Minerals Management Service Gulf of Mexico OCS Region
Long-Term Monitoring on the Flower Garden Banks: Study Design and Field Methods	Dr. Stephen R. Gittings and Mr. Gregory S. Boland Texas A&M University
Mississippi/Alabama Shelf Pinnacle Trend Habitat Mapping Study: A Status Report	Mr. Richard A. Shaul Continental Shelf Associates, Inc.
Distribution, Relative Abundance, and Seasonality of Outer Continental Shelf Cetaceans in the North-Central Gulf of Mexico: July 1989-June 1990	Dr. Keith Mullin, Mr. Wayne Hoggard, Dr. Ren Lohoefener, Ms. Carol Roden, Ms. Carolyn Rogers National Marine Fisheries Service Mississippi Laboratories and Lt. Brian Taggart Office of NOAA Aircraft Operations Center
Application of Archaeological Resource Study Results to Refine the Minerals Management Service Historic Shipwreck Model on the Gulf of Mexico's Outer Continental Shelf	Dr. Richard J. Anuskiewicz and Mr. John R. Greene Minerals Management Service Gulf of Mexico OCS Region
Wetlands Mitigation: A Study of Marsh Management	Dr. Donald R. Cahoon and Dr. Charles G. Groat Louisiana Geological Survey

MINERALS MANAGEMENT SERVICE ENVIRONMENTAL STUDIES FOR THE GULF OF MEXICO: ACTIVE STUDIES PROGRESS REPORTS SESSION INTRODUCTION

Dr. Robert M. Rogers
and
Ms. Bonnie LaBorde Johnson
Minerals Management Service
Gulf of Mexico OCS Region

This environmental studies session was organized to report on the progress of a number of Minerals Management Service (MMS) sponsored marine ecosystem studies and, in one instance, to give an example of how studies information is used in management decisions related to Outer Continental Shelf (OCS) oil and gas leasing.

As oil and gas exploration and development proceeds in the Gulf of Mexico, environmental issues of concern are identified by state and federal agencies and the environmentally concerned public. After prioritizing these technical issues, environmental studies are designed to address the information needs.

Since the inception of the Bureau of Land Management (BLM)/MMS environmental studies program in 1974, approximately $50 million has been spent in the Gulf of Mexico on marine ecological studies. Recently these studies have centered about such environmentally sensitive areas as the Mississippi/Alabama OCS, Flower Garden Banks on the Texas-Louisiana OCS, sea grass communities on the Florida OCS, and coastal wetlands of Louisiana.

Leading off 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 the potential of 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 are essential for documenting the viability of these features.

Sampling on this project is carried out semiannually. Four of the six scheduled cruises have been completed. Monitoring sites have been established on the reefs of the two banks. Each of the two sites has 120 permanent, repetitive photographic stations for observing growth of the dominant coral species; repetitively photographed stations for studying individual coral colonies; and stations for measuring accretionary coral growth. Sample data will be used to assess: (1) coral population levels; (2) temporal variability in coral cover, relative abundance, relative dominance, diversity and evenness; and (3) periodic changes in macrophytic algae cover and abundance of other conspicuous associated organisms.

Mr. Richard Shaul of Continental Shelf Associates, Inc., gave an overview of a recently initiated MMS-sponsored habitat mapping study of the pinnacle trend off the Mississippi/Alabama OCS. The objectives of the study are geologically to characterize pinnacles and significant hard bottoms throughout the study area and then to conduct a biological reconnaissance of the significant features.

The first geophysical survey has been completed under this study. Preliminary interpretations of data indicate that there are several different types of low relief hard bottom areas, a number of pinnacles with relief from 3 to 21 m, and one very significant topographic feature with approximately 55 m relief. The next phase of this project will be the investigation and description of biological communities on selected features. This will be carried out on a biological reconnaissance cruise to be implemented in the spring of 1991. Maps of the geologic features and bathymetry will be produced.

Dr. Keith Mullin of the Mississippi Laboratories of the National Marine Fisheries Service (NMFS) reported on aerial surveys being made of cetaceans on the outer continental shelf of the north-central Gulf of Mexico. The study is a cooperative effort between NMFS, MMS, and the National Oceanic and Atmospheric Administration (NOAA) Aircraft Operations Center. Very little is known about the whales and dolphins in the Gulf of Mexico deeper than 180 m. During these surveys, observations were made on the distribution, relative abundance and seasonality of cetaceans from July 1989 to July 1990. Over 279 sightings of approximately 6,600 whales and dolphins were made.

Dr. Rik Anuskiewicz of the MMS Gulf of Mexico Regional Office gave a presentation on how a particular MMS-sponsored environmental study has been used in management decisions. Specifically he reported on how findings from an archaeological resource study were used to refine the MMS historic shipwreck model on the Gulf of Mexico's outer continental shelf. The study was conducted by Texas A&M University and focused on the management of historic archaeological resources. Results of this study and subsequent MMS interpretations served to refine the high probability zone for the occurrence of OCS shipwrecks. In addition, study recommendations have been made to alter existing historic survey requirements to better evaluate the survey area and provide better protection to the resource.

The final presentation was made by Dr. Donald Cahoon of the Louisiana Geological Survey (LGS). The MMS and LGS in cooperative agreement have recently completed a study of the effectiveness of marsh management as a tool for conservation in the wetlands of Louisiana. The objectives of the study were to determine the degree of monitoring carried on under marsh management plans, the suitability of the data base for evaluating the effectiveness of structural management, and the effectiveness of marsh management in achieving stated objectives. To achieve these objectives, historical files were reviewed and compared.

Changes in habitats were also compared between managed and unmanaged marshes in different environmental settings. Field studies were also carried out with a special emphasis on two areas of extensive structural management, Fina LaTerre Mitigation Bank site in the delta plain and the Rockefeller State Wildlife Refuge and Game Preserve in the Chenier Plain. Details of this study will be provided in the final report and maps which will be available in December 1990.

Dr. Robert M. Rogers is a staff member of the Environmental Studies Section of the Minerals Management Service Gulf of Mexico OCS Regional Office. He has served as Contracting Officer's Technical Representative (COTR) on numerous marine ecosystem studies. Recently, these have included a study of seagrass habitats off Southwest Florida and the Mississippi/Alabama Marine Ecosystems study. Dr. Rogers received his B.S. and M.S. degrees in zoology from Louisiana State University and Ph.D. in marine biology from Texas A&M University.

Ms. Bonnie LaBorde Johnson is a physical scientist in the Minerals Management Service 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.

LONG-TERM MONITORING ON THE FLOWER GARDEN BANKS: STUDY DESIGN AND FIELD METHODS

Dr. Stephen R. Gittings
and
Mr. Gregory S. Boland
Texas A&M University

INTRODUCTION

The summits of the East and West Flower Garden Banks harbor actively growing coral reefs. The coral fauna is dominated by massive head corals. Eighteen species of tropical Atlantic reef-building corals exist on the reefs, or approximately one-third of the reef-building coral species of the Caribbean. No acroporids (elkhorn or staghorn corals) or shallow water gorgonians occur on the reefs. Cover of reef substrates by living coral approximates 50% on the top of each bank. Over 250 species of associated reef invertebrates and over 130 species of fish also exist. Coral cover and growth rates are considered to be comparable to other western Atlantic coral reefs at similar depths (Bright *et al.* 1984).

Environmental concerns on these reefs include the long-term effect of hydrocarbon production activities (platforms are located within 2 km of one bank), discrete and cumulative effects of mechanical impacts caused by ship anchors and ground tackle, and long-term natural change caused by events of unknown origin (e.g., coral bleaching and species-specific mass mortalities). A long-term monitoring program at the Flower Garden Banks, sponsored by Minerals Management Service, is currently being conducted by Texas A&M University. The goal of the program is to address concerns related to both gradual and punctuated degradation of these unique offshore ecosystems. Such data are useful not only from the standpoint of assessing the impacts of industrial activities, but may also be valuable to resource management. The Flower Gardens are scheduled to become a National Marine Sanctuary in the fall of 1990. Recreational use of underwater areas tends to increase following their establishment as protected areas (Tilmant 1987). A long-term data base may allow the identification of impacts caused by this expected increase in recreational use.

The areas of principal focus in the monitoring study are:

- Utilization of existing coral reef research methods to generate data that can be used to document gradual changes in parameters that reflect the health of the Flower Garden reefs;

- Comparison of data on coral populations and coral growth resulting from this study with existing published and unpublished Flower Gardens data;

- Assessment of temporal 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; and

- Consideration of the relationship between outer continental shelf hydrocarbon development activities and environmental sensitivity at the Flower Garden banks, integrating project-generated data with that on mechanical disturbance and chemical contamination of coral reefs.

Discussed here are the field techniques and laboratory methods used to evaluate changes in coral population levels, coral and algae cover, growth rates, and other community characteristics at the Flower Gardens.

METHODS

Field Techniques

During the winter of 1988 and spring of 1989, a monitoring site was established at the East Flower Garden Bank comparable to that established at the West Flower Gardens by Continental Shelf Associates (CSA) in the summer of 1988 (CSA conducted monitoring for Union Oil Co.). This involved:

- implanting eyebolts and marker floats around a 100 m by 100 m study site;

- temporarily installing boundary lines around the sites;

- establishing and producing study site maps indicating the locations of 120 permanent photographic 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 8 m^2 repetitive photographic stations for studying individual coral colonies; and

- implanting and mapping 30 permanent accretionary growth spikes in *M. annularis* coral colonies.

Eyebolts were cemented in 6.5 cm holes drilled using a pneumatic impact wrench and a coring bit at study site corners. To secure the posts, Portland Type II Cement was used with moulding plaster as a catalyst (12:1 ratio). Small subsurface floats are attached to the eyebolts with 3.2 mm stainless steel cable and float approximately 3 m above the bottom. Boundary lines are 0.5 cm polypropylene with knots and loops every 25 m indicating the direction to the nearest corner of the site. The lines, wrapped on extension cord reels, are deployed by divers. Station markers (stainless steel, 3.2 mm diameter nails for encrusting growth stations and 6.4 mm diameter spikes for accretionary growth stations) were installed using pneumatic air hammers with customized heads. The blunt end of nails or spikes were inserted into holes in the hammer heads and driven into reef rock, leaving a specified length of each marker exposed. Repetitively photographed 8 m^2 stations were established using 9.5 mm diameter stainless steel posts. Holes for the posts were drilled to 15 cm depth using a pneumatic impact wrench and 1 cm star drill bit. Stud anchors were welded onto the ends of the posts. After inserting these posts into their respective holes, the diver hammered the top of the post, causing the stud anchor to flare inside the hole. None of the posts has come loose since their installation in early 1989. All stations at both banks were tagged using numbered, plastic, goat ear tags (black on white). Small sections of clear tubing were placed over the markers before the tags were attached with plastic tie wraps, assuring a more secure hold.

Following site establishment, and in October 1989, April 1990, and October 1990, we conducted field work at both banks, and will continue to do so at six-month intervals over a three-year study period.

The study calls for two sampling efforts each year. During each 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 (Figure 2.1). Randomness is achieved by equipping diver teams with slates containing random compass headings and random numbers. The divers are dropped at random locations within the study sites from an inflatable, and go directly to the bottom to start photographing a transect along the first random compass heading. They then kick a random number of times along a second compass heading, and start a second transect along a third compass heading. Two transects are photographed by each diver on each film roll (36 exposure print film).

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/5 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 (Figure 2.2). The border of living coral tissue traverses the approximate center of each printed photograph, allowing measurement of either tissue advance over adjacent coralla or tissue retreat. Divers locate stations and record the order of station photographs on study site maps printed on underwater paper. After photographing a station, divers attach steel paper clips to the nails to indicate to others that the station has been completed. The paper clips rust and become overgrown by algae between sampling trips and are removed periodically.

Slides of each 8 m^2 repetitive photographic station are taken from a height of 2.0 m using a 15 mm wide angle lens and two 225 watt-second strobes. The base of the 2 m post of the T-shaped camera frame is positioned at the point of insertion of the implanted post in the reef. The frame has a bubble level and compass adjacent to the camera to accurately position the camera above the station center before each photograph is taken (Figure 2.3). These devices eliminate camera tilt and twist, respectively, which are the two factors that make repetitive photography notoriously difficult. The bubble level is centered and the compass pointing north before a station is photographed. Repetitive photographs have proven to be nearly identical in terms of area covered and colonies photographed. The sample area approximates eight square meters, which effectively samples the community and allows identification of most colonies at the site.

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. Data are recorded underwater and paper clips are attached to station tags after measurement to indicate completion. Since it is difficult to secure growth spikes so as to completely avoid movement of the spike relative to the coral head, growth measurements will also be made from cores taken from *M. annularis* heads during and at the end of the study. Two cores were taken at each bank in May of 1990 and have yet to be analyzed.

At each reef, two 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 in order to obtain relatively high resolution images. The video transects are taken by a diver from approximately two m above the bottom along 100 m lines tautly strung along the sides of each survey area. Taut lines 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 to 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. Five minute 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. Ryan thermographs were installed on each bank in August of 1990 to record temperature every two hours. Data will be retrieved during each sampling trip.

Laboratory Methods and Data Analysis

Random Transects--Areal coverage of coral and leafy algae is considered the vertical projection of a colony onto the substrate (like canopy cover using aerial photography). 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 are acquired for all coral species and other appropriate organisms (e.g., leafy algae) on the photographs, and observations of disease incidence are documented.

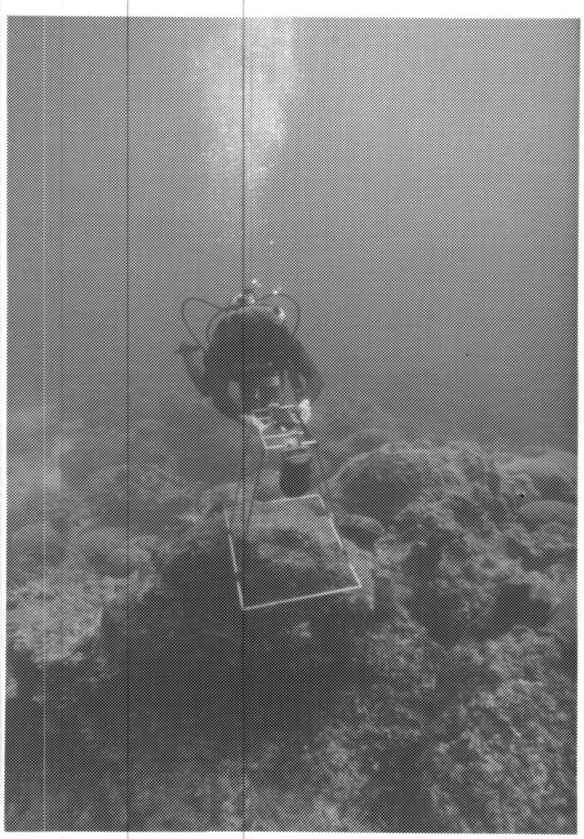

Figure 2.1. Diver photographing a random transect using a framer with attached camera and strobes.

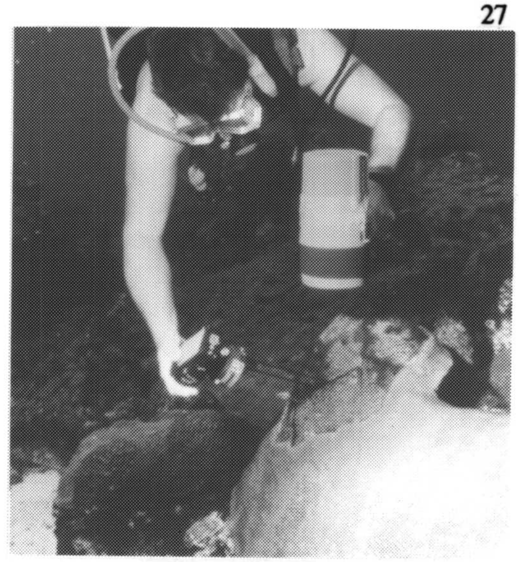

Figure 2.2. Diver taking close-up photograph of an encrusting growth station. (Diopter framer is positioned over two nails adjacent to living tissue and photo is taken normal to the station plane).

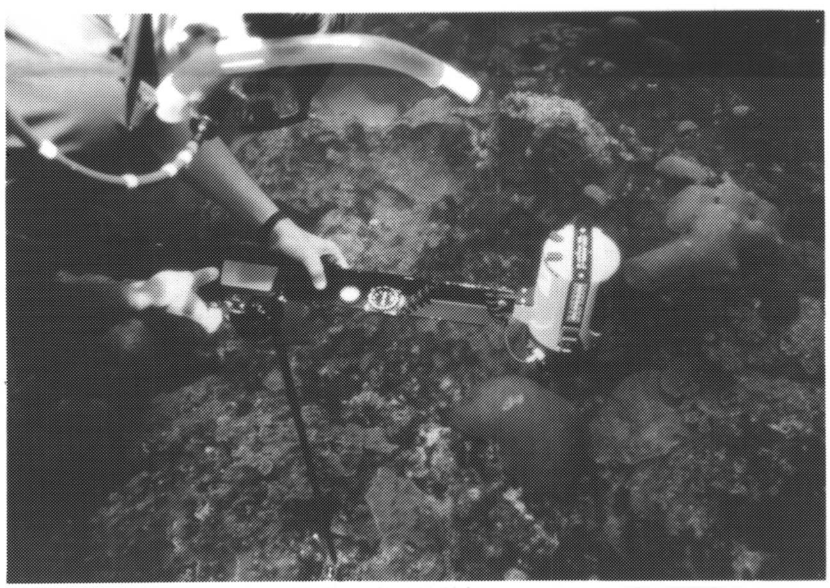

Figure 2.3. Compass and bubble level mounted on the top of the T-frame used to photograph each $8m^2$ repetitive station. (These are used to adjust attitude of unit at each station prior to photography).

Also calculated is the number of colonies of each species, the amount of bare coral substrate (most is actually covered by calcareous or other 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 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 are 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 diagrams (three-coordinate plots). 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*. 1988). The method was useful in determining the deleterious effects of the displacement of coral heads into sandy habitats by the ship.

Repetitively Photographed Stations--Developed color slides will be projected onto a digitizing pad. Individual colony changes between time periods can be determined directly using the digitizer.

Accretionary Growth Stations--Coral growth will be determined for each coral head on which growth spikes are located by comparing sequential measurements. Differences between periods will be evaluated, as will trends through time. Underwater measurement data will be compared to data from high and low density bands in core tissue taken in May 1990 and at the end of the study.

Video Transects--Transcriptions of videotape records will include observations on the general health of the hermatypic coral community and counts of invertebrates and fishes. By estimating physical dimensions along the transects, counts and other observations can be converted to densities (number/m^2). These densities will provide a means for quantitative comparisons between sites, seasons and years. Other information that may be useful to community characterization may include habitat characteristics (cover of sand flats, nature of live coral cover, general health of coral, disease incidence, etc.), patterns of abundance (numbers of individuals, spatial distribution, recruitment or loss of conspicuous reef fish or invertebrates), and relationships between specific taxa and habitats or other biota.

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MISSISSIPPI/ALABAMA SHELF PINNACLE TREND HABITAT MAPPING STUDY: A STATUS REPORT

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INTRODUCTION

The Mississippi/Alabama Shelf Pinnacle Trend Habitat Mapping Study was awarded to Continental Shelf Associates, Inc. (CSA) by the Minerals Management Service (MMS) during August 1990. The area of study is adjacent to an area previously investigated during the MMS-funded Mississippi/Alabama Marine Ecosystems Study and shown in Figure 2.4. The objectives of the study are to geologically characterize pinnacles and significant hard bottoms throughout the study area and then to conduct a biological reconnaissance of the significant features.

METHODS

Two sampling efforts are planned to collect the data needed to meet the objectives of the study. The first, a geophysical characterization survey designed to locate and identify significant topographic and geologic features throughout the study area, was conducted during 12 September - 10 October 1990. A second sampling effort, to identify and characterize the biological communities associated with significant features identified during the geophysical characterization survey, will be conducted during early 1991.

Survey 1 - Geophysical Characterization

The geophysical characterization survey was designed to collect 100% coverage of the study area using side-scan sonar. Side-scan sonar reveals the presence of topographic features as well as distinct sediment textural changes on the surface of the bottom. Subbottom profiler data, which were collected to reveal the presence and thickness of features below the surface of the seafloor, and bathymetric data were collected simultaneously with the side-scan sonar mapping.

The survey was conducted using the R/V *Seahawk*. A Klein 590 side-scan sonar system (100 kHz) with a Klein 532S-101 subbottom profiler (3.5 kHz) was used to conduct the geophysical mapping effort. Navigation was conducted using a Trimble 10X Loran-C/GPS receiver integrated with Seatrac navigational software. Positioning of the towfish was exacted using a Ferranti O.R.E. Trackpoint II system. Bathymetric data were collected simultaneously throughout the survey using an Odum Echotrac Digital Depth Recorder. All side-scan sonar and subbottom profiler data were recorded on digital tape for future review and interpretation. Navigational data and bathymetric data were stored on computer data base for future use.

Survey line spacing was originally planned to be at 1,000 m using a side-scan sonar range of 600 m. Field testing showed that, due to environmental conditions within the study area, 100% coverage could not be attained using the 1,000 m line spacing. To obtain 100% side-scan sonar coverage, survey lines were spaced at 500 m (side-scan sonar range of 300 m) in water depths less than 91 m (300 feet [ft.]) and at 600 m (side-scan sonar range 400 m) in water depths greater than 91 m (300 ft.). Overlap of side-scan sonar coverage was estimated to be approximately 50 m between each survey line. A total of 86 east-west survey lines and 6 north-south tie lines were surveyed. Approximately 2,200 line miles (nm) were investigated during Survey 1.

Survey 2 - Biological Reconnaissance

After review of the geophysical data collected during Survey 1, significant topographic features will be investigated with the intent of characterizing the biological communities present. Features will be relocated with the side-scan sonar and navigational system used during Survey 1. A Phantom HD remotely operated vehicle (ROV) will be used to conduct the biological reconnaissance. Video and still photographic data (qualitative and quantitative) will be collected by the camera systems on the ROV. Voucher specimens of selected biota will be collected using the manipulator arm on the ROV. Additional voucher specimens will be collected by rock dredge and hook and line sampling. All specimens will be identified to the lowest possible taxonomic level to aid identification of biota that appear in photographs and videotapes.

RESULTS AND DISCUSSION

Analysis of data collected during the recently completed geophysical characterization (Survey 1) of the study area is underway. A very preliminary review of the side-scan sonar records and notes made during the field effort indicates that several interesting features are present within the study area

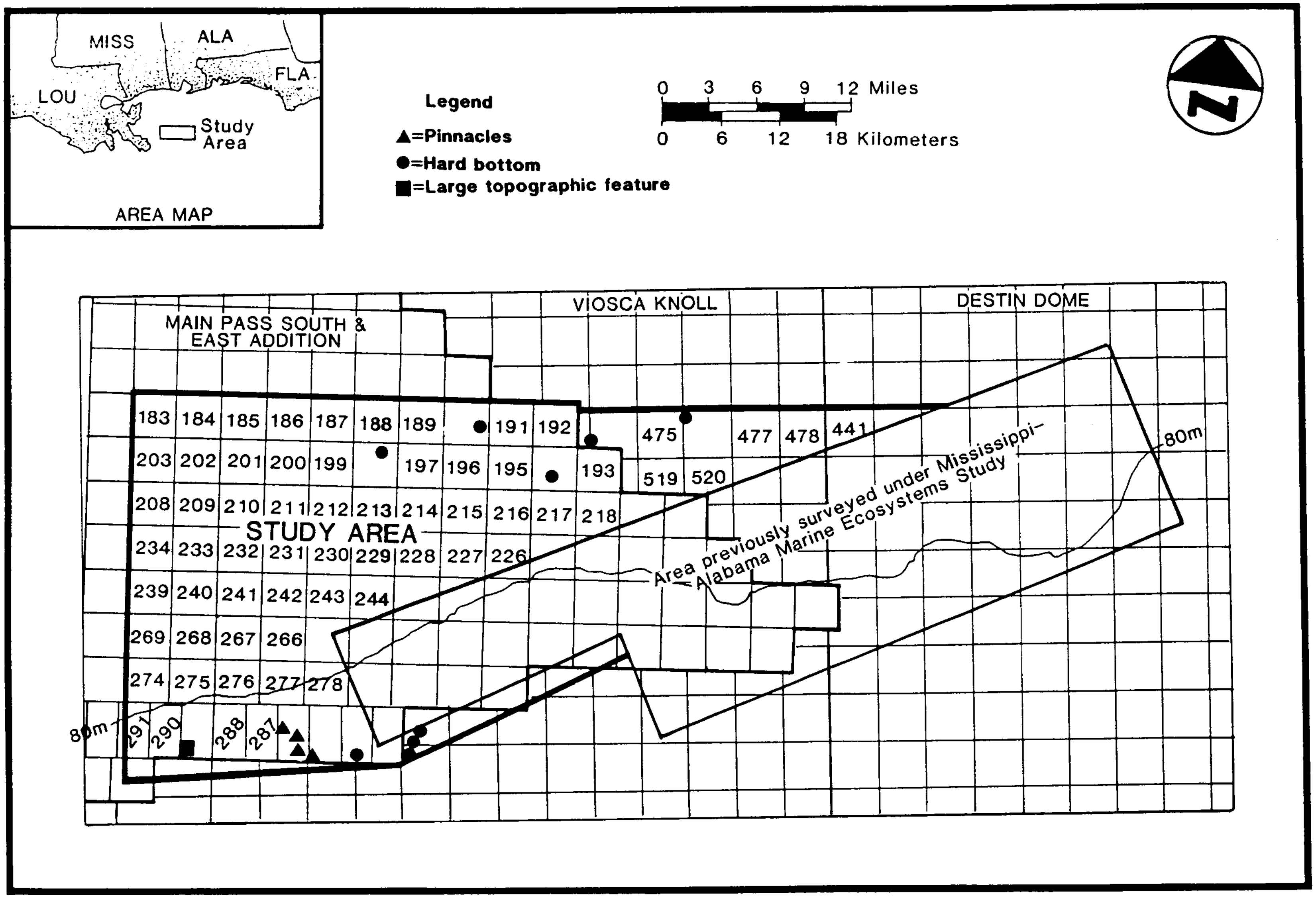

Figure 2.4. Location of topographic features identified during Survey 1.

(Figure 2.4). Several areas of hard bottom have been identified, according to the geophysical and bathymetric data. In the northern portion of the study area several areas of hard bottom have been located, according to the geophysical data. These features appear to be low relief ledges that are present in north-south trends. Other hard bottom areas were also located in the southern portion of the study area, typically in water depths of approximately 91 m (300 ft.). An area of pinnacles located in the southeastern portion of the area investigated during Survey 1 is shown in Figure 2.4. Pinnacles range in size from 3 to 21 m (10 to 70 ft.), occur in water depths ranging from 76 to 107 m (250 to 350 ft.), and are present in a northwest-southeast trend. Over two dozen pinnacles occur within the area. Another very large topographic feature was identified in the southwestern portion of the survey area (Figure 2.4). The base of the feature is in approximately 128 m (420 ft.) of water while the crest of the feature occurs in a water depth of approximately 58 m (190 ft.). This feature has a diameter of approximately 1,500 m and exhibits characteristics of both pinnacle and diapir features located throughout the north central Gulf of Mexico.

SUMMARY

An area on the Mississippi/Alabama shelf was surveyed for significant hard bottom/topographic features using geophysical equipment. Because sampling was only recently completed, data analyses have just been initiated. A very preliminary review of the data collected indicates that several different types of hard bottom are present including low relief hard bottom areas (less than 3 m [10 ft.] relief), many pinnacles with 3 to 21 m (10 to 70 ft.) relief, and one very large topographic feature (approximately 55 m [180 ft.] relief). All the significant topographic features identified by the geophysical data collected during Survey 1 will be mapped. Biological communities present on these features will be investigated and described during the biological reconnaissance effort (Survey 2). A report will be prepared to synthesize the geological and biological data collected during the study. Maps of significant topographic/geologic features and bathymetry also will be produced.

Mr. Richard Shaul has been with Continental Shelf Associates for 10 years. As a senior staff scientist, he has considerable experience investigating the environmental effects of oil and gas activities in the marine and estuarine environment. Mr. Shaul received his B.S. and an M.S. in biological sciences from the Florida Institute of Technology.

DISTRIBUTION, RELATIVE ABUNDANCE, AND SEASONALITY OF OUTER CONTINENTAL SHELF CETACEANS IN THE NORTH-CENTRAL GULF OF MEXICO: JULY 1989-JUNE 1990

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Mississippi Laboratories
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INTRODUCTION

Except for data from strandings (Schmidly 1981) and from aerial surveys by Fritts *et al.* (1983), virtually nothing is known about cetaceans in Gulf of Mexico (Gulf) waters deeper than 180 m. These sources indicate 26 species of cetaceans have occurred in the Gulf.

Fritts *et al.* (1983) used aircraft to survey areas offshore of southern Florida, western Louisiana, and southern Texas. While portions of their study areas included deep water (>180 m), three-fourths of their survey effort was over continental shelf waters (<180 m). They identified nine species or types of cetaceans in the Gulf.

It has been speculated that areas of high sea floor relief may concentrate cetaceans (Collum and Fritts 1985; Payne *et al.* 1986; Kenny and Winn 1986; Selzer and Payne 1988). From July through November 1989, the National Marine Fisheries Service (Mississippi Laboratories), Minerals Management Service and National Oceanic and Atmospheric Administration's (NOAA) Aircraft Operations Center cooperated in conducting a pilot study of cetacean diversity and relative abundance in four areas of high sea floor relief in the north-central Gulf (Lohoefener *et al.* in press). The pilot study was successful. Aerial survey was found to be an efficient method of studying deep-water cetaceans. Cetaceans were found in all study areas and 12 species or types of cetaceans were identified. The objective of our continued research was to expand the area studied to include the waters between (and included in) the 1989 study areas in order to better define the distribution, abundance and seasonality of deep-water cetaceans in the north-central Gulf.

METHODS

Beginning in January 1990, the study area extended from 87° 30' to 91° 00' west longitude. We divided this area into seven study blocks (Figure 2.5). Blocks 1, 3, and 7 overlapped large portions of the 1989 study areas. Block 5 covered only the southern portion of the 1989 Mississippi Canyon area (Lohoefener *et al.* in press). The results of the 1989 portion of the study and those of Fritts *et al.* (1983) indicated that deep-water cetacean sightings were usually in water 200 m or greater in depth. The northern border of the study area was the surface projection of the 180 m isobath. The southern boundary was, for logistical reasons, 46 km south of the northern boundary. Water depths ranged up to 1,900 m.

We used NOAA's Twin-Otter aircraft to study each block two times each month. Poor weather in January and February 1990 prevented us from meeting this goal. 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 at about 204 km/h ground speed. Two observers, one on each side of the aircraft, observed the trackline and adjacent water 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 block, date, time, and location of each data record. Cetaceans were circled in order to make species identifications, to estimate herd size and to document sightings with 35 mm cameras and SVHS video cameras.

RESULTS AND DISCUSSION

In their Gulf study areas, Fritts *et al.* (1983) sighted sperm whales, "beaked" whales, pygmy killer whales, short-finned pilot whales, bottlenose dolphins, Risso's dolphins, "spotted" dolphins, striped dolphins and "spinner" dolphins. From July 1989 through June 1990, we identified 16 species or types of deep-water cetaceans in the north-central Gulf (no surveys were conducted in December).

Bottlenose dolphin (*Tursiops truncatus*)--We sighted 39 herds that averaged 12 dolphins per herd. Bottlenose dolphins were sighted in all of the seven blocks and in each survey month except February and May. Most sightings were in the northern portion of each block. In the Gulf, Fritts *et al.* (1983) did not observe bottlenose dolphins in water deeper than 180 m.

Atlantic spotted dolphin (*Stenella frontalis*)--Herd sizes averaged 26 dolphins in 35 herds sighted. Most herds were sighted in water less than 540 m deep (Figure 2.6). Atlantic spotted dolphins were sighted in six blocks and during every month except January and May.

Pantropical spotted dolphin (*S. attenuata*)--Twenty-two herds that averaged 72 dolphins were sighted during eight months. This species was sighted in all seven blocks. Fritts *et al.* (1983) did not distinguish between species of "spotted" dolphins in their study.

"Spinner" dolphins (*S. longirostris* and *S. clymene*)--During six months and in five blocks, nine herds of spinner dolphins were observed. The mean herd size was 134 animals. Herds occurred in water depths from less than 360 m to greater than 1,080 m.

Striped dolphins (*S. coeruleoalba*)--Fifteen herds were observed and averaged 60 dolphins per herd. Striped dolphins were sighted during six months and in six blocks.

Rough-toothed dolphin (*Steno bredanensis*)--One herd of four was sighted during April in Block 5.

Risso's dolphin (*Grampus griseus*)--Sixty-one herds of Risso's dolphins sighted averaged 13 animals each. Herds were sighted in water from 180 to 720 m deep during nine months and in seven blocks (Figure 2.7). Jennings (1982) reported five Risso's dolphin herds that were sighted in Gulf waters from 200 to 1,800 m deep.

Short-finned pilot whale (*Globicephala macrorhynchus*)--Five herds of pilot whales that averaged 18 animals each were sighted. One herd was associated with Risso's dolphins in August near Block 7. The other four herds were sighted in Block 3 in November. Each herd was located in water greater than 450 m deep.

Killer whale (*Orcinus orca*)--A pod of eight killer whales was sighted on the southern border of Block 4 during May. This pod included a young calf and a mature male.

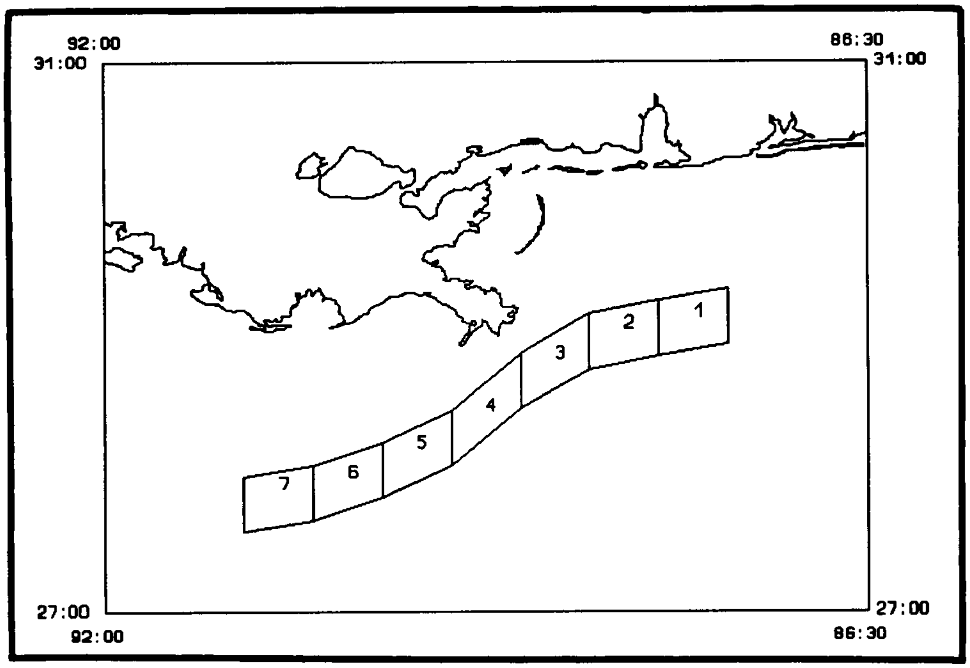

Figure 2.5. Location of the study area and the seven study blocks in the north-central Gulf of Mexico.

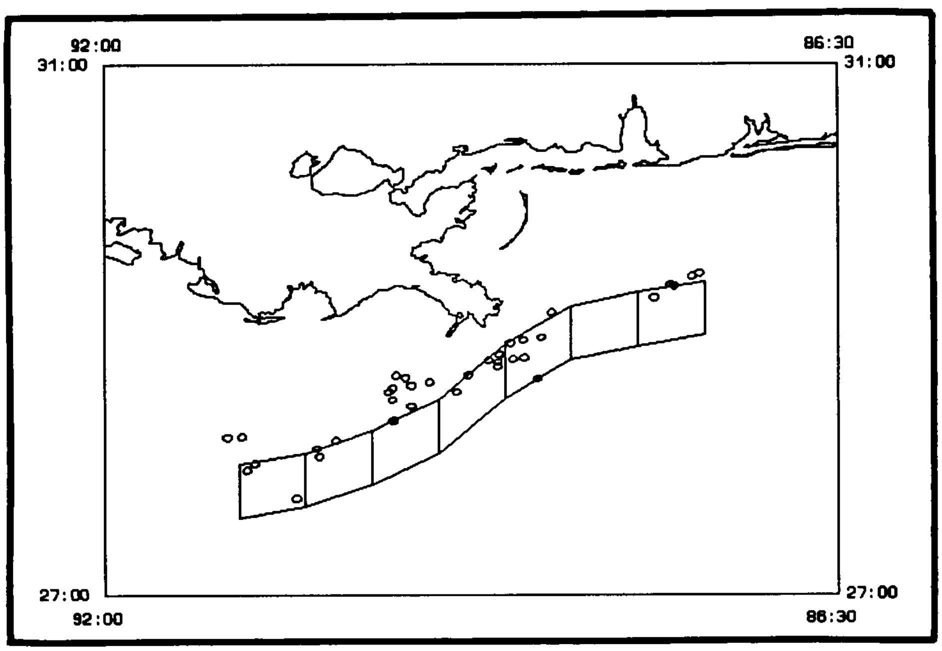

Figure 2.6. Locations (o) of Atlantic spotted dolphin herds sighted from July 1989 through June 1990.

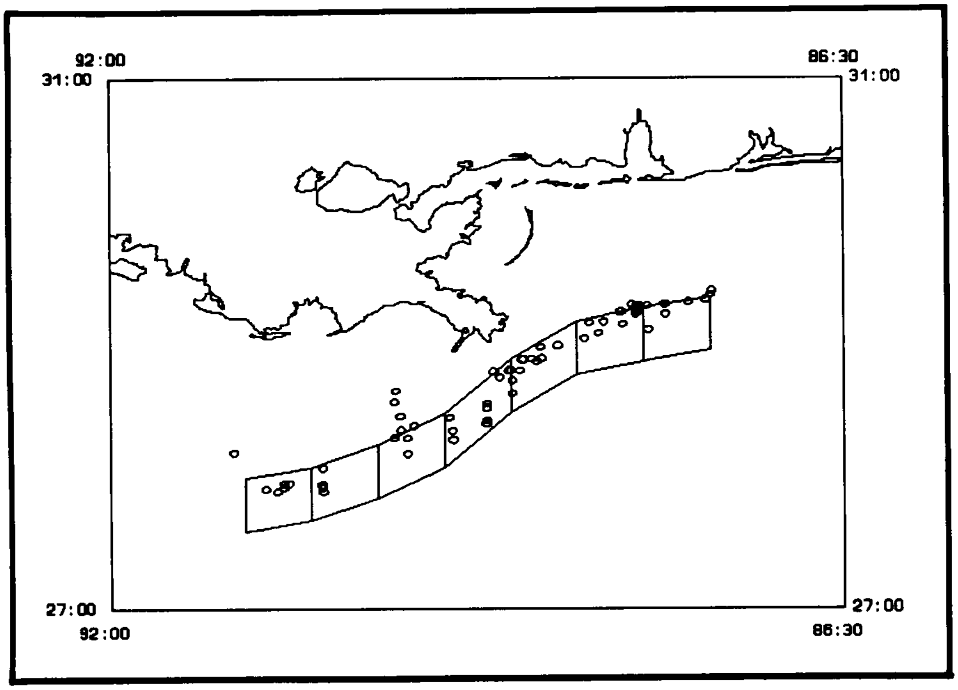

Figure 2.7. Locations (o) of Risso's dolphin herds sighted from July 1989 through June 1990.

False killer whales (*Pseudorca crassidens*)--During August, one herd of three whales was sighted in Block 3 in water about 1,000 m deep.

Pygmy killer whales (*Feresa attenuata*)--During August, we sighted one herd of 25 whales in Block 5 near a group of Risso's dolphins. This herd was located over the west wall of the Mississippi Canyon in water about 300 m deep.

Pygmy and dwarf sperm whales (*Kogia simus* and *K. breviceps*)--Thirty-two herds of these small whales were distributed throughout seven blocks. They were sighted during nine months. Most herds were sighted over the west wall of Mississippi Canyon in and near Block 5. Two whales were typically in each herd.

Sperm whales (*Physeter macrocephalus*)--Sperm whales were sighted 43 times. Herd sizes ranged from one to 11 whales and averaged two whales. Three cow and calf pairs were sighted. Twenty-eight of the sightings were in Block 3 south of the mouth of the Mississippi River (Figure 2.8). Almost all of the sightings were in water from 700 to 920 m deep. Sperm whales were sighted during all months except May. The most sightings were in September and October. Collum and Fritts (1985) reported 17 sightings consisting of a total of 59 sperm whales in the Gulf. Most sightings were in water over 200 m deep. Gulland (1974) thought sperm whales were most common near areas of upwellings and high productivity. Perhaps the area south of the mouth of the Mississippi River, where water depths ranged up to 920 m deep, is an area of high productivity.

Beaked whales (*Mesoplodon* spp. and *Ziphius cavirostris*)--Three species of *Mesoplodon* (*M. bidens*, *M. densirostris* and *M. europaeus*) have been documented from the Gulf. We sighted 11 beaked whales in nine herds. From their shape and white head, four were identified as *Z. cavirostris*. Beaked whales were observed during seven months and in five blocks.

Fin whale (*Balaenoptera physalus*)--During November, in Block 1 in water about 180 m deep, a large baleen whale was photographed and identified as a fin whale.

Bryde's or Sei whale (*B. edeni* or *B. borealis*)--A baleen whale that was either a sei or Bryde's whale was sighted in Block 1 during June.

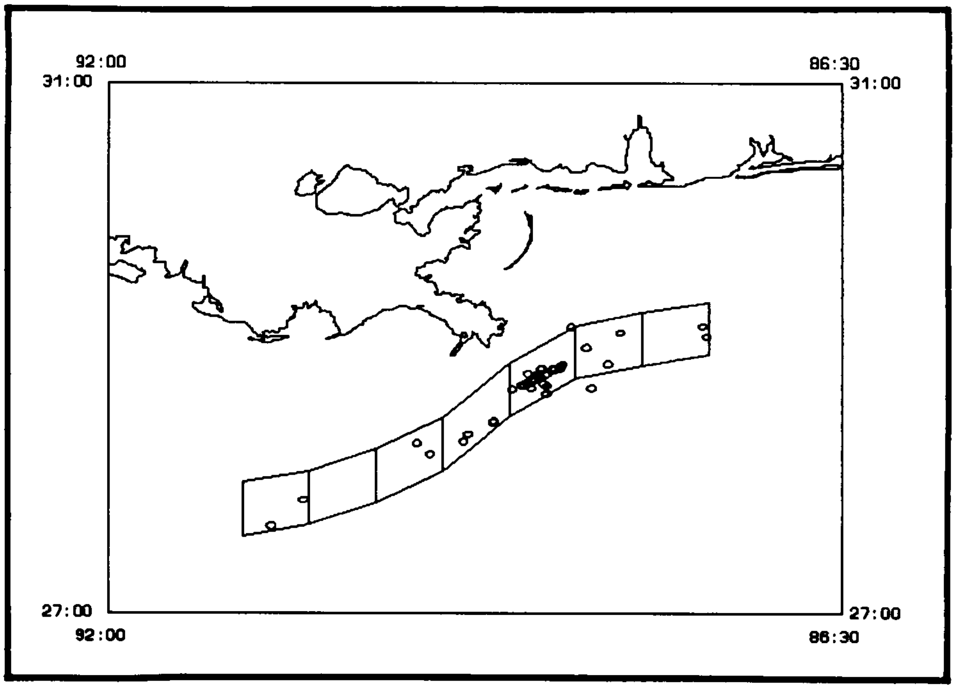

Figure 2.8. Locations (o) of sperm whale herds sighted from July 1989 through June 1990.

SUMMARY

We used aerial surveys to study the distribution, relative abundance and seasonality of cetaceans in the north-central Gulf of Mexico from July 1989 through June 1990. Not counting unidentified cetaceans, we made 279 sightings of over 6,600 whales and dolphins. We identified 16 species or types of cetaceans. Nine species or types were distributed throughout the study area, occurring in five or more of the seven blocks. These included bottlenose dolphins, Atlantic spotted dolphins, pantropical spotted dolphins, striped dolphins, "spinner" dolphins, *Kogia* spp., Risso's dolphins, beaked whales, and sperm whales. All of these species except the striped and "spinner" dolphins also had a wide temporal distribution in the study area; they were sighted during seven or more of the 11 study months.

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APPLICATION OF ARCHAEOLOGICAL RESOURCE STUDY RESULTS TO REFINE THE MINERALS MANAGEMENT SERVICE HISTORIC SHIPWRECK MODEL ON THE GULF OF MEXICO'S OUTER CONTINENTAL SHELF

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INTRODUCTION

The Minerals Management Service (MMS), is responsible for all Outer Continental Shelf (OCS) mineral activities and their potential for impacting natural and archaeological resources. As part of a continuing effort to manage and protect nonrenewable archaeological resources, a study that was conducted by Texas A&M University (TAMU) focused on the management of historic archaeological resources. The results of this study, and subsequent MMS analysis and interpretation, served to refine the high probability zone for the occurrence of historic period shipwrecks located on the OCS in the Gulf of Mexico (GOM). In addition, study recommendations have been made to significantly alter existing historic archaeological survey requirements in order to evaluate better the survey area and provide better protection to the resource. This paper will present the new conceptual shipwreck model offered by the study and discuss recommended changes in the MMS historic archaeological survey requirements.

BACKGROUND

Over 27,000 wells have been drilled in the GOM Federal OCS waters (USDI MMS 1990a). In addition, over 3,600 platforms and more than 30,000 km of pipelines have been installed on the OCS (USDI MMS 1990b). To fulfill its responsibilities for managing archaeological resources, the MMS developed a program to oversee and protect nonrenewable prehistoric and historic resources.

Numerous Federal laws and statutes regulate the MMS archaeological resource management program by providing a public mandate to ensure that exploration and development activities, associated with natural resource development, do not disturb any significant archaeological resources. These laws include the National Historic Preservation Act of 1966, as amended (Public Law 89-665), the National Environmental Policy Act (Public Law 91-190), and the OCS Lands Act, as amended, (Public Law 95-375) (Anuskiewicz and Greene 1990). The OCS Lands Act specifically defines the MMS responsibility for the protection of archaeological resources. It restricts the area of archaeological management to the area affected, directly and indirectly, by activities related to mineral development. A recent Department of the Interior solicitor's opinion stated that the MMS only has the authority to protect archaeological resources on the OCS that may be affected by mineral development.

In order to carry out its mission to protect our nation's archaeological resources on the OCS, the MMS has produced a Manual for Archaeological Resource Protection (MMS 620.1) and an associated Handbook for Archaeological Resource Protection (620.1-H). In compliance with stated policy to update regional baseline studies as new data become available, the Gulf of Mexico OCS Region contracted with TAMU for a regional study that focused on the historic archaeological resources of the northern Gulf of Mexico. This study was to expand and update the initial baseline study for historic archaeological resources originally conducted by Coastal Environments, Inc. (CEI) in 1977.

The 1977 CEI study focused on both prehistoric and historic archaeological resources. The historic aspect of the baseline study utilized mostly secondary literature sources (i.e., published references) to record known shipwrecks that occurred in the northern Gulf of Mexico between 1500 and 1945 A.D. This study compiled a listing of 1,904 reported shipwreck losses. The authors estimated that the total number of significant wrecks in the study area was between 2,500 and 3,000 (CEI 1977). During the course of the study the authors examined several contributing factors to formulate a zone of high probability for the occurrence of historic shipwrecks. These factors included: the nature of shipping, character of vessels, sailing practices, and shipping routes. The CEI high probability zone for ship losses formed the basis of the MMS Archaeological Resource Management Zone 1 (ARMZ1). Between 1980 and Spring 1990 the MMS defined the ARMZ1 as all areas landward of a line of demarcation established as a result of the their study. This line roughly followed the 60 meter (m) bathymetric contour line. All lease blocks located landward of this line had specific archaeological survey requirements invoked under the MMS lease Stipulation 1.

Invocation of the MMS lease Stipulation 1 requires specific geophysical instrumentation and survey parameters that are detailed in the MMS Notice to Lessees (NTL) 75-3 (USDI MMS 1982). The instrumentation package required includes a proton precession magnetometer, dual side-scan sonar, shallow subbottom profiler, and fathometer.

The most significant of these instruments as they pertain to historic shipwreck survey are the magnetometer and side-scan sonar. A dual channel side-scan sonar system is required to record continuous planimetric images of the seafloor. Overlapping coverage must be provided for the entire lease block. The instrumentation vertical beam width must be appropriate to water depth, and horizontal beam width must be tuned for optimum resolution. The magnetometer sensor is required to be towed as near as possible to the seafloor. A distance of six m or less from the seafloor is required for data quality suitable to archaeological analysis. The need for the instrument's proximity to the seafloor results from the relationship between measured gamma intensity and distance from the tow sensor to a ferromagnetic mass. The MMS requires magnetometer instrumentation that can measure the total magnetic field intensity and a sensitivity setting of one gamma or less with background noise levels not to exceed three gammas peak to peak.

A state-of-the-art continuous positioning system is also required and it must be correlated to the annotated geophysical survey records during the remote-sensing survey. The present survey patterns for lease blocks that fall within the MMS high probability area are set at 150 m primary linespacing with cross-tie lines spaced at a maximum of 900 m. Survey patterns for pipelines only require center line survey coverage and at least two parallel offset survey lines spaced 150 m from the center line.

STUDY OBJECTIVES AND RESULTS

As addressed earlier in this paper, the MMS Handbook for Archaeological Resources (620.1) requires that baseline studies be updated as new data become available. The MMS contracted with TAMU to update and refine the 1977 CEI study and to broaden the historic shipwreck data base for the Gulf of Mexico OCS. The objectives of the 1989 TAMU study were as follows:

1. To reevaluate and make recommendations to change, if necessary, the location of ARMZ 1 in the GOM;

2. To determine the relationship between linespacing of magnetometer readings and side-scan sonar and the detection of objects at or below the surface; and

3. To investigate whether remote-sensing data gathered during cultural resource survey in the GOM can be analyzed to discriminate between an archaeological resource and recent debris.

To accomplish these three objectives the study was divided into two major tasks: Task I, evaluation of Archaeological Resource Management Zone 1, and Task II, establishing an interpretive framework to characterize unidentified magnetic anomalies and side-scan sonar contacts (Garrison *et al.* 1989). In Task I the authors utilized primary as well as secondary archival sources to compile a listing of over 4,500 shipwrecks in the northern Gulf of Mexico. The study divided the interval between 1500 A.D. and the present into five major periods that approximate major historic or technological ages. These major periods were identified as the New Spain Period (1500-1699), representing the maritime exploration and settlement of the GOM; the Colonial Period (1700-1803), representing the addition of French and British colonies; the American Period (1803-1865), representing the Louisiana Purchase and the Americanization of the northern GOM; the Victorian Period (1866-1899), representing the post-Civil War increase in maritime activities; and the 20th century (1900-present), representing the modern period change from an agrarian-based economy to an emphasis on petrochemicals and manufacturing.

The TAMU conducted statistical analyses of the over 4,500 shipwrecks and identified areas of high concentrations of loss traps (Anuskiewicz 1989) for ships in the Gulf of Mexico. In the scope of work for this contract TAMU was also asked to examine environmental and geological factors relating to the preservation potential of historic shipwrecks. These factors included bottom sediments, energy zones, and biological and chemical factors. The MMS was not only interested in shipwreck loss traps but was also interested in the preservation potential of a particular wreck, based on its geographic and geologic location. In addition, chronological trends in GOM shipwreck distributions were identified. Spatial analysis, including contour plots and cluster analyses, was performed. Two broad types of high probability areas for the location and preservation of historic period shipwrecks were defined through this study. The first type of high probability area is located proximal to the shoreline. Numerous marine archaeological authors (CEI 1977; Muckelroy 1978; Marx 1971) have recognized that the majority of historic period shipwrecks lie in proximity to the coastline. The TAMU study (Garrison *et al.* 1989) supports the assumption that between 75 and 80% of shipwrecks occur in nearshore waters. The study justified this rationale by citing the relationship between sailing practices, weather, vessel type, and the geographic location of loss traps such as barrier islands. The second type of high probability area, while also located nearshore, centers around historic ports in the GOM as well as certain geologic hazards that exist outside of the nearshore high probability zone.

The study also recommended the creation of high probability search polygons around a centroid specific to each recognized shipwreck that falls outside of the two aforementioned high probability areas. This concept was derived from locational data compiled for each shipwreck in the data base. The majority of archival sources did not provide exact latitudes and longitudes of these shipwrecks. In these cases, descriptive locations were provided which were translated into latitude and longitude using large-scale charts and a digitizer. Presumed accuracy for these individual shipwreck losses falls within a radius of 7.25 km (4.5 mi) from the centroid position.

Task II of the TAMU study established an interpretive framework to characterize magnetic anomalies and unidentified side-scan contacts. The two most important remote-sensing instruments in the conduct of historic shipwreck/shallow hazard surveys are the magnetometer and the side-scan sonar. The utility of side-scan sonar in the search for historic period shipwrecks is principally in areas of the OCS that have a thin sediment veneer over a more indurated paleo-surface. Historic shipwreck debris in those areas would come to rest on the hardened paleo-surface and not be obscured by a blanket of marine sediments. In those areas of the GOM where a significant amount of underconsolidated sediments occur, historic period shipwrecks would likely settle beneath the sediments and provide little or no seafloor relief. The primary instrument for shipwreck detection in this case would be the magnetometer (Stright 1989).

Several authors have commented on the efficacy of 150 m survey linespacing in historic archaeological surveys (cf. Anuskiewicz 1989; Weymouth 1989; Stright 1989; Arnold 1989; Saltus 1989; Clausen and Arnold 1975). All marine archaeologists agree that a 150 m magnetometer survey linespacing interval is insufficient for confident detection of historic shipwrecks on the Gulf of Mexico OCS. Staff MMS archaeologists have developed avoidance zones to be placed around unidentified magnetic anomalies and side-scan sonar contacts that have the potential to be historic resources. These zones were designed to provide protection for the potential historic resources, given a 150 m survey linespacing. In addition, the TAMU study concluded that the 150 m survey linespacing interval is not sufficient to differentiate, at a high confidence level, between modern ferromagnetic debris and potential cultural resources. The study also concluded that, if there is reliance on instrumental data alone, the linespacing interval is critical. Therefore, survey linespacing of 50 m or less was strongly recommended. Assuming a line spacing of 50 m or less, the TAMU study provided some salient instrumental and geophysical characteristics that can be used to differentiate confidently between modern ferromagnetic debris and historic shipwrecks.

The characteristics for anomalies and side-scan sonar patterns of historic shipwrecks are

- multiple peak anomalies or spatial frequency,
- differential amplitude anomalies,
- areal distribution ≥ 10,000 square m,
- long gradients and duration,
- axial or linear orientation of anomalies,
- scour areas associated with anomalies,
- an exposed structure geometrically complex and associated with anomalies, and
- relative locational permanence.

The characteristics for anomalies and side-scan sonar patterns of modern ferromagnetic debris are

- single peak anomalies or no spatial frequency,
- few if any differential amplitudes,
- localized areal distribution ≤ 10,000 square m,
- sharp gradients and short duration,
- random, non-axial orientation of anomalies,
- scour areas with no associated anomalies,
- exposed debris geometrically simple, and
- locational transience.

Other Task II conclusions proved working assumptions generated and used by the MMS Gulf of Mexico OCS Region staff archaeologists in their analyses of archaeological reports. One conclusion was that the detection of magnetic anomalies increases in direct proportion to a decrease in the linespacing interval used in a survey. While this linear trend may be specific to the TAMU study, the inference is that a wider survey linespacing interval results in discovery of fewer ferromagnetic masses by the magnetometer. Another conclusion proved the assumption that development of a lease block increases the number of magnetic anomalies of modern origin.

RECOMMENDED CHANGES IN THE MMS HISTORIC SHIPWRECK MODEL

After receipt of the TAMU study, the MMS GOM Region staff archaeologists undertook an intensive review of the conclusions. A portion of this analysis was conducted with a Geographical Information System (GIS) at Jackson State University in Jackson, Mississippi. The GIS was made available by a cooperative agreement between the MMS and Jackson State University. After analysis of the TAMU study conclusions was completed, the staff archaeologists made several recommendations to GOM regional management to alter the current approach to preserving our nation's historic archaeological resources on the GOM OCS.

1. Replace the current ARMZ1 historic high probability zone with TAMU's refined high probability areas. This change has been adopted by the GOM Region since mid-July of this year. These specific changes result in designating three different types of high probability zones for the occurrence of historic shipwrecks.

    a) The 10 km buffer zone, which extends from the shoreline out to sea for 10 km and only affects Federal waters in Louisiana, Mississippi, and Alabama. This zone acknowledges the relationship between historic period shipwrecks and proximity to the coastline.

    b) Include 21, 0.5-degree square, high probability quadrants centered around specific geological, geographic, and cultural features. This zone acknowledges the relationship between specific features (most notably ports) and historic shipwrecks.

c) Include high probability search polygons (centroid) associated with shipwrecks reported to be outside of the 10 km buffer zone and high probability quadrants. These search polygons are centered on the reported location of the wreck. Until the shipwreck is located, all lease blocks within a 7.25 km (4.5 mi) radius of the centroid location are considered to have a high probability for the occurrence of a particular wreck.

2. Institute a 50 m survey linespacing interval within the refined high probability areas. This change will result in a greater ability to distinguish between potential shipwrecks and modern marine ferromagnetic debris. A further benefit of the increased survey coverage will be a more efficient use of avoidance mitigations. The tighter linespacing will allow the isolation of magnetic anomaly clusters and result in avoidance mitigations with smaller radii. The increase in survey coverage is necessitated by the refinement of the high probability zones.

3. Limit magnetometer surveys (for archaeological purposes) to lease blocks with depths of 60 m (197 ft.) or less. Experience has shown that, in water depths greater than 60 m, it is increasingly difficult to maintain an accurate magnetometer tow sensor height of 6 m or less above the seafloor, as well as sensor position on a survey line. This is due to the interaction between the tow sensor, cable, and towing environment. Questionable data result from these deeper tows. High probability search polygons occurring in water depths greater than 60 m will require archaeological analysis and an archaeological report based on the data generated by a shallow hazards survey at 300 m linespacing interval.

SUMMARY

The TAMU archaeological study has recommended significant changes to the Service's ARMZ1 and the current shipwreck high probability model. The MMS GOM Region supports the recommended changes to the ARMZ1 model. This support was initiated because of the TAMU study and has gained momentum from the staff archaeologists through the GOM Regional Director. The refinement of ARMZ1 will significantly diminish the number of lease blocks on the GOM OCS that require historic archaeological surveys at the 150 m survey linespacing. At the same time, the chances of actually encountering an historic period shipwreck are enhanced due to the specific nature of the refined high probability zones and the new 50 m survey linespacing. The adoption of the 50 m survey linespacing will serve to differentiate better between potential historic archaeological resources and modern marine debris by allowing the recognition and evaluation of clusters of magnetic anomalies that would not have been possible at 150 m survey linespacing. The MMS adoption of the study recommendations makes it possible to provide more efficient and effective protection of our nation's maritime historic archaeological resources on the GOM OCS.

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WETLANDS MITIGATION: A STUDY OF MARSH MANAGEMENT

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INTRODUCTION

A wetlands mitigation study is being undertaken for the Minerals Management Service 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. 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 a report 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 the results of our monitoring analyses.

ANALYSIS OF LANDOWNER MONITORING PROGRAMS

Methods

The objectives of this analysis were to determine: (1) the intensity and quality of monitoring by permittees, (2) the suitability of the data base for evaluating the effectiveness of structural management, and, (3) the effectiveness of structural marsh management in achieving stated objectives. We determined the extent of monitoring by reviewing the permit files of the Louisiana DNR and noting monitoring data submitted by the permittees. The quality of data was determined from the variables measured and the techniques and experimental design used in data collection. We assessed the suitability of the data base for evaluating the effectiveness of structural management by comparing the types and quality of data to the management goals. Management effectiveness was determined by synthesizing all available data.

Results

The monitoring data base on file at the DNR is small in relation to the number of implemented managed areas (9 plans out of approximately 20 fully and 30 partially implemented plans). The intensity of the monitoring programs varies greatly. Some efforts are dedicated to creating long-term data bases; other monitoring efforts have ceased.

The quality of the monitoring programs varies greatly. The monitoring programs focused on measuring plant species composition, water parameters (e.g., level and salinity), and habitat change. However, these variables were rarely measured in a nearby unmanaged marsh for comparison. Also, only one of the monitoring programs provided data on plant growth and no programs provided data on abiotic factors that may affect plant growth, such as water and matter flux, nutrient cycling, sediment distribution and accretion, soil conditions, subsidence, and evapotranspiration.

The ability of the monitoring programs to evaluate the effectiveness of management is limited by the variation in monitoring intensity and quality.

HABITAT CHANGE ANALYSIS

Methods

The objective of this analysis was to measure habitat change in managed and unmanaged marshes in different environmental settings. Sixteen managed sites with an associated unmanaged reference area were selected in both the delta and chenier plains in as many different marsh types as possible. These sixteen sites most likely represent a majority of the fully implemented management plans permitted since 1980. Habitat change was determined by comparing aerial photographic images from 1955/56, 1978, 1981/82/83, 1985, and 1988. Variables analyzed included marsh-to-water ratios, change in marsh type, change in marsh area, and change in habitat diversity.

Results

Marsh management is not consistently effective at increasing marsh acreage, reversing salinity influence on habitat composition, or improving marsh-to-water ratios. When analyzed over the entire interval of management, some managed areas became fresher, or had improved marsh-to-water ratios compared to their unmanaged area while some unmanaged areas showed improvement when compared to their managed area. For example, five managed areas showed improvement in marsh-to-water ratios when compared to their unmanaged areas, while three unmanaged areas showed improvement in marsh-to-water ratios when compared to their managed areas. However, for 50% of the comparisons, there was no difference between the changes occurring at the managed area and those occurring at the unmanaged area.

During the last photographic interval of 1985 to 1988, actively managed marshes sometimes produced improved marsh-to-water ratios (5 of 10 sites), net gains in marsh (2 of 10 sites), and a net change of water to marsh (4 of 10 sites) when compared to nearby unmanaged marshes. Passive management, with very few exceptions, produced no gains in marsh-to-water ratios or marsh acreage.

FIELD STUDIES

Field Sites and Methods

The two areas selected were the Fina LaTerre Mitigation Bank site in the delta plain and Rockefeller State Wildlife Refuge and Game Preserve in the chenier plain. These two areas were selected for study because they represent the two main physiographic provinces of the Louisiana coast and they have numerous characteristics in common. Both of these sites are considered premiere examples of structural marsh management utilizing adjustable water control structures that can alter water levels in the marsh seasonally. Also, each site includes the same marsh type (*Spartina patens*-dominated brackish marsh) in both managed and unmanaged areas. Equally as important as these physical attributes, however, was the fact that the landowners of each site agreed to provide essential logistical support. The managers of the sites provided invaluable support to our field studies in the form of airboats, flatboats, and field personnel (i.e., boat drivers).

At each site we monitored the influence of structural management of water levels on hydrology, production and species composition of emergent vegetation, soil parameters, sediment dynamics, water chemistry, and fisheries. Most of the variables we measured had either not been measured before in a managed marsh or had not been measured simultaneously in both a managed and nearby unmanaged marsh.

Field plots were selected and data collected within managed marsh and nearby unmanaged marsh so that the influence of management on basic ecological processes could be evaluated. All plots were located in marsh areas dominated by *Spartina patens*. Both areas underwent a drawdown in the spring of 1989 during this study. Details of field sampling design are provided in the final report.

Results and Discussion

This synthesis is based on data collected during a drawdown year only. Drawdowns have occurred usually every fourth year at Rockefeller Refuge, while at Fina LaTerre a drawdown has been implemented every year since management was initiated in 1985. For the Fina LaTerre site, the conclusions pertain only to the southern portion of the managed area and the unmanaged reference area south of Falgout Canal.

Management Effects on Physical Processes--Fina LaTerre. Water-level management reduced tidal amplitude and frequency in the southern portion of the managed area. The results of the flux and accretion analysis are consistent with this hydrologic pattern and with each other. The amount of water and matter exchanged with the southern portion of the managed area through the drawdown structure was low compared to that of the unmanaged area, and vertical accretion and matter accumulation were uniformly low throughout this region. Rates of vertical accretion and matter accumulation are not sufficient to keep pace with local rates of relative sea level rise in both the managed and unmanaged areas. Water and interstitial soil salinities in the southern portion of the managed area were equal to or higher than water and interstitial salinities in the unmanaged marsh throughout the entire year. Soils were more reduced in the brackish vegetation zone of the managed marsh during the plant growing season but there was no difference in sulfide concentrations. Three months after commencement of drawdown (May 1989), water levels in the southern portion of the managed area were drawn down to 5-10 cm below marsh level. Analysis of material fluxes and accretionary processes in the northern portion of the managed area is needed in order to understand management effects on the physical processes of the entire management area.

Management Effects on Physical Processes--Rockefeller Refuge. Water-level management reduced tidal amplitude and frequency in unit 4 at Rockefeller Refuge and the results of the flux and accretion analysis are consistent with this hydrologic pattern and with each other. The flux of water and matter, and the rate of vertical accretion and matter accumulation, were greatly reduced in the managed area. Under certain hydrologic conditions, more sediment may flow out of the managed marsh than flows in. Rates of vertical accretion and matter accumulation are not sufficient to keep pace with local rates of relative sea level rise in the managed marsh. In contrast, the unmanaged marsh experienced regular exchange of matter and accretion rates comparable to local relative sea level rise rates. However, substrate conditions were more conducive to plant growth in the managed marsh. Interstitial soil salinity, soil reduction, and sulfide concentrations all were significantly lower in the managed marsh. Water levels were drawn down 20-30 cm below the marsh surface 3 months after commencement of drawdown (May 1989) and 1-2 weeks after 2 of 7 flap-gates were opened for a total of 4 days to allow ingress of shrimp larvae.

Management Effects on Physical Processes--Summary. The impacts of management on hydrology and sedimentology were similar in the southern portion of the Fina LaTerre site and Unit 4 at Rockefeller Refuge. Management was successful at isolating the managed marsh from most local hydrologic influences and controlling and stabilizing water levels at both field sites. In contrast, the unmanaged marshes were influenced by diurnal tidal variations, winter storms, and lunar tidal effects. Consequently, tidally driven flux and accretion were significantly reduced at both managed sites when compared to the unmanaged sites. The implications for sea level rise effects need to be investigated.

Management Effects on Biological Processes--Fina LaTerre. The southern portion of the managed area was still dominated by *Spartina patens* in 1989. The productivity of *Spartina patens* was lower and substrate conditions were more stressful to plant growth in the brackish vegetation zone of the managed marsh. Plant species diversity was the same in both the southern portion of the managed area and the unmanaged area, although more fish species were collected in the unmanaged area. Total biomass of fish was the same for both the southern portion of the managed area and the unmanaged area. The southern portion of the managed area had significantly more individuals of resident estuarine and freshwater species and significantly fewer individuals of marine transient species than the unmanaged marsh.

Management Effects on Biological Processes--Rockefeller Refuge. The productivity of *Spartina patens* was higher and substrate conditions were less stressful for plant growth in the managed marsh compared to the unmanaged marsh. Plant species diversity was also higher in the managed marsh. There were fewer individuals of both marine transient and resident fish species in the managed marsh. Biomass of resident fish species was also lower in the managed marsh. [The reader is referred to the fisheries study at Rockefeller Refuge conducted during 1989 for additional information on fisheries species composition and biomass at Rockefeller Refuge.]

Management Effects on Biological Processes--Summary. Although management effects on hydrology and sedimentology were similar at both sites, management effects on plant growth and stress differed significantly. Growth of *Spartina patens* and plant species diversity were enhanced at Rockefeller Refuge but not in the southern portion of the managed area at Fina LaTerre. The data suggest that the decreased growth rate of *Spartina patens* at Fina was related more to reduced soil conditions than to salinity effects.

Implications of Field Monitoring Results

One of the primary purposes of structural marsh management is to restrict tidal exchange and regulate water levels in order to enhance plant production and consequently improve secondary production of waterfowl and wildlife. A review of the file monitoring data demonstrated that the influence of restricted tidal exchange and regulated water levels on plant growth and the flux of matter into the managed marsh had not been measured before this study. Thus there has been no documentation that the assumed benefits actually occurred. The results of this study of two brackish marsh impoundments indicate that management severely limited both the flux of matter and vertical accretion. The implications of these results for managed brackish marsh in a rapidly subsiding environment are that vegetative growth and organic matter accumulation may be the only means of maintaining marsh elevation. Unfortunately, plant growth may be limited, and organic matter accumulation has been shown to be significantly reduced by management whether or not plant production was enhanced. These findings demonstrate how little is known about the impact of structural management on accretionary and plant growth processes, and ultimately marsh surface elevation. To predict accurately the long- and short-term consequences of using manipulated impoundments in the rapidly subsiding environments of coastal Louisiana, a better understanding of the effects of such techniques on plant growth and marsh accretionary processes must be acquired. Several research topics have been identified and specific issues related to each are discussed below.

Recommendations for Research

Marsh Accretionary Processes--The impact of management on the flux of matter, vertical accretion, accumulation of matter, and plant growth needs to be evaluated for fresh, intermediate, brackish, and saline marsh. In addition, all these variables should be measured during drawdown and non-drawdown years. So far they have been measured only in two brackish marshes and only during drawdown years. These data should be synthesized with data on surface elevation changes in managed and unmanaged marshes.

Plant Growth--The determinants of successful vegetative growth in manipulated impoundments should be isolated by both experimentation and monitoring of natural populations. In particular, the rates of above- and below-ground plant production and plant decomposition should be determined.

Fisheries Access--A sizable body of literature indicates that manipulated impoundments and weir management diminish fisheries access to managed marshes. Future research should be directed at determining the feasibility of retrofitting management structures to allow for ingress and egress of aquatic organisms.

Monitoring Procedures--Standardized monitoring procedures should be developed and used at all managed sites. Standard methodologies should be employed to monitor a prescribed set of variables related to water quality, accretionary processes, substrate conditions, plant growth rates and species composition; and waterfowl, wildlife, and fish production. A standardized monitoring program will facilitate comparison of data collected at different managed sites.

Once data bases of sufficient size have been accumulated, computer models should be developed that, in conjunction with the new monitoring data, can be used to develop management plans with the most appropriate designs and schedules of operation.

Cumulative Impacts--To overcome the lack of knowledge about the cumulative effects of structural management, three approaches are recommended. First, the influence of management on adjacent marshes should be investigated. Pre- and post-implementation data collected from managed and unmanaged areas should be compared to determine the effect of management on neighboring marshes. Second, the interaction of structural water-level management with other management techniques, such as freshwater and sediment diversions, should be determined. Techniques should be developed to capture sediment and freshwater in managed marshes at diversion outfalls; otherwise the managed marsh probably will not benefit from the diversions. Third, regional impacts to sediment distribution, water flows and levels, and marsh health should be determined. Computer models should be developed from the standardized monitoring data bases within a basin to facilitate this analysis.

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 Department of Natural Resources 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. degree from the University of Texas.

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 (with Honors), and an M.S. and a Ph.D. in plant ecology from the University of Maryland.

RECENT SEAFLOOR CLEARANCE ACTIVITIES AT ABANDONED OIL AND GAS STRUCTURE SITES

Session: RECENT SEAFLOOR CLEARANCE ACTIVITIES AT ABANDONED OIL AND GAS STRUCTURE SITES

Co-Chairs: Mr. Felix Dyhrkopp
Mr. Arvind Shah

Date: November 13, 1990

Presentation	Author/Affiliation
Recent Seafloor Clearance Activities at Abandoned Oil and Gas Structure Sites: Session Introduction	Mr. Felix Dyhrkopp and Mr. Arvind Shah Minerals Management Service Gulf of Mexico OCS Region
The Role of the Survey/Sonar Contractor in Locating and Removing Seafloor Debris	Mr. Bill Tink WIMPOL, Inc.
The Impact of Recent OCS Site Clearance Activities on the Oil and Gas Industry	Mr. Michael E. Parker Offshore Operators Committee Fisheries Subcommittee
Panel Discussion: A Case Study Summary of a Site Clearance Operation	Mr. Bill Tink Sonar Company, Mr. Douglas Cochrane Sonar Company, Mr. Michael E. Parker Offshore Operator, Mr. Robert B. Suggs Salvage Company, and Mr. Jimmie Martin Shrimp Trawler

RECENT SEAFLOOR CLEARANCE ACTIVITIES AT ABANDONED OIL AND GAS STRUCTURE SITES: SESSION INTRODUCTION

Mr. Felix Dyhrkopp
and
Mr. Arvind Shah
Minerals Management Service
Gulf of Mexico OCS Region

This presentation was a slide show that reviewed existing Minerals Management Service (MMS) regulations regarding structure removals and site clearance, the history of the development of Notice to Lessees and Operators (NTL) 90-01/03, descriptions of site clearance plans and reports submitted by operators to the MMS, and results of site clearance operations carried out under NTL 90-01/03.

SITE CLEARANCE

Gulf of Mexico Oil and Gas lessees are required by Minerals Management Service (MMS) Regulations 30 CFR 250.112(i) and 250.143(b) to remove all platforms, wellheads, casings, pilings, and other obstructions to a depth of at least 15 ft. below the mud line or to a depth approved by the District Supervisor. Furthermore, the lessees are required by 30 CFR 250.114 and 250.143(c) to verify site clearance by one of the following methods:

1. Drag a trawl in two directions across the location,
2. Perform a diver search around the well bore,
3. Scan across the location with a side-scan or on-bottom scanning sonar, or
4. Use gather methods based on particular site conditions.

Certification of site clearance, which includes the date the work was performed, the areal extent searched around the location, and the search method utilized, must be submitted to the District Supervisor. As required by the lease agreement, clearance of the site by one of the above mentioned methods must be accomplished prior to one year after lease relinquishment, expiration, or termination.

Even though the MMS has regulations in place to prevent trawling obstructions related to Outer Continental Shelf oil and gas exploration, development, or production activities, these obstructions continue to be a problem for Gulf of Mexico (GOM) shrimpers. In the summer of 1987, a series of group discussions was initiated on this issue, with the group consisting of representatives of the MMS, the Offshore Operators Committee (OOC), the Louisiana Department of Wildlife and Fisheries (LDWF), and Louisiana's shrimping industry. Another attempt to address the problem was made in a meeting between the MMS and OOC in August of 1988, from which a survey of site clearance verification methods of five offshore operators subsequently resulted. However, successful resolution of the issue has been elusive, and the problem continues to exist.

At the request of the LDWF, the MMS hosted a meeting of all interested parties on August 18, 1989. Present were representatives of Congressman Billy Tauzin, Senator J. Bennett Johnston, the OOC, the International Association of Drilling Contractors (IADC), the LDWF, the Concerned Shrimpers Association (CSA), the LSU Extension Service, and the MMS. The group discussed the problem in detail, reviewed current site clearance verification technology, and addressed the need for new verification procedures. As a result of those efforts, the MMS formed a committee composed of Representatives of the State of Louisiana, the CSA, OOC, IADC, and MMS to study the problem in detail and develop recommendations as to how it can be successfully resolved. The recommendations made by that committee prompted the issuance of an MMS Notice to Lessees and Operators (NTL) in February of 1990 that provided interim requirements for future site clearance verification procedures. Those requirements were modified after six months of experience were gained, and a new NTL incorporating the modifications was issued in August of 1990. Both the original and present NTLs stipulate the areal extent to be cleared around various types of structures, and that both sonar and trawling methods be employed for verifying the areas are clear of obstructions. The areas are defined as:

A. Exploration/Delineation Wells - A 300 ft. radius around the well bore.

B. Caissons/Well Protectors - A 600 ft. radius around the structure geometric center.

C. Platforms - A 1,320 ft. radius around the platform geometric center.

When the MMS determines that sufficient knowledge has been gained from these activities, revisions will be made to existing MMS Regulations regarding site clearance.

Mr. Felix Dyhrkopp holds a Bachelor's degree in civil engineering from Louisiana State University. He has been employed in the marine field since 1965, approximately half of which was with industry and half with the Minerals Management Service (MMS). He is at present Chief of the Office of Structural and Technical Support located in the MMS Gulf of Mexico OCS Region.

Mr. Arvind Shah holds a Master's degree in civil engineering from the University of Michigan and a Bachelor's degree in civil engineering from University of Baroda, India. He has been in the marine field since 1976, approximately 10 years with the MMS and four years with the U.S. Coast Guard. Previous to that he was employed as a structural engineer with consulting engineering firms for about 15 years. At present he holds the position of structural engineer with the Office of Structural and Technical Support located in the MMS Gulf of Mexico OCS Region.

THE ROLE OF THE SURVEY/ SONAR CONTRACTOR IN LOCATING AND REMOVING SEAFLOOR DEBRIS

Mr. Bill Tink
WIMPOL, Inc.

BACKGROUND

The requirement for clearing sites on offshore leases previously occupied by oil company related activities arose from complaints from the shrimping industry that they were damaging equipment caught in seafloor debris. The cost of repair and the consequent downtime were seriously affecting the livelihood of the shrimpers, and it was obvious from the contents of their damaged nets that the seafloor debris resulted from oilfield exploration and production activities.

The MMS decided that it would introduce procedures to attempt to return the seafloor to its original condition, specifically in those areas where a lease has been relinquished and a platform or caisson removed.

THE STAGES OF A SITE CLEARANCE

When an operator decides that a structure has come to the end of its useful life, he is then obligated to remove it and return the seafloor to its original condition. After removing the topsides and abandoning the pipelines, the jacket then has to be severed from its piles and taken away for scrap, re-use or the rigs-to-reefs program.

After the successful removal, a dive boat equipped with a survey contractor (to relocate the site) and a sonar contractor (to assist the divers in locating objects on the seafloor) are mobilized to the field. All locatable objects are then recovered by the divers. On rare occasions, some of the objects are too big for the diver/dive boat to recover, and a larger vessel with a crane has to be mobilized to assist in the removal.

Once the site has been cleared by divers, a shrimp boat with survey contractor is required to trawl over the entire area to ensure the nets are not fouled by any man-made objects. When the area can be trawled without snagging debris then the field is declared "cleared."

THE SURVEY CONTRACTOR

The co-ordinates of the platform and associated pipelines were established at the time of installation as required by the MMS.

The survey contractor is onboard to ensure that the operations are indeed being carried out over and around the site previously covered by the removed platform.

A typical spread of equipment supplied by the survey contractor has, as its final output a color monitor with the information as shown in Figure 3.1. For the dive boat this includes the site center, pipelines, remaining seafloor structures such as wellheads and templates, and the location of the sonar drops (for a stationary scanning sonar). All of these are shown graphically along with an outline of the boat moving in real time through the field. Tabulations include the location of the boat in latitude and longitude, the distance to a selected target (one of the sonar drop sites), anchor information for a 4-point dive spread, and an indication of the quality of position (shown here as standard error).

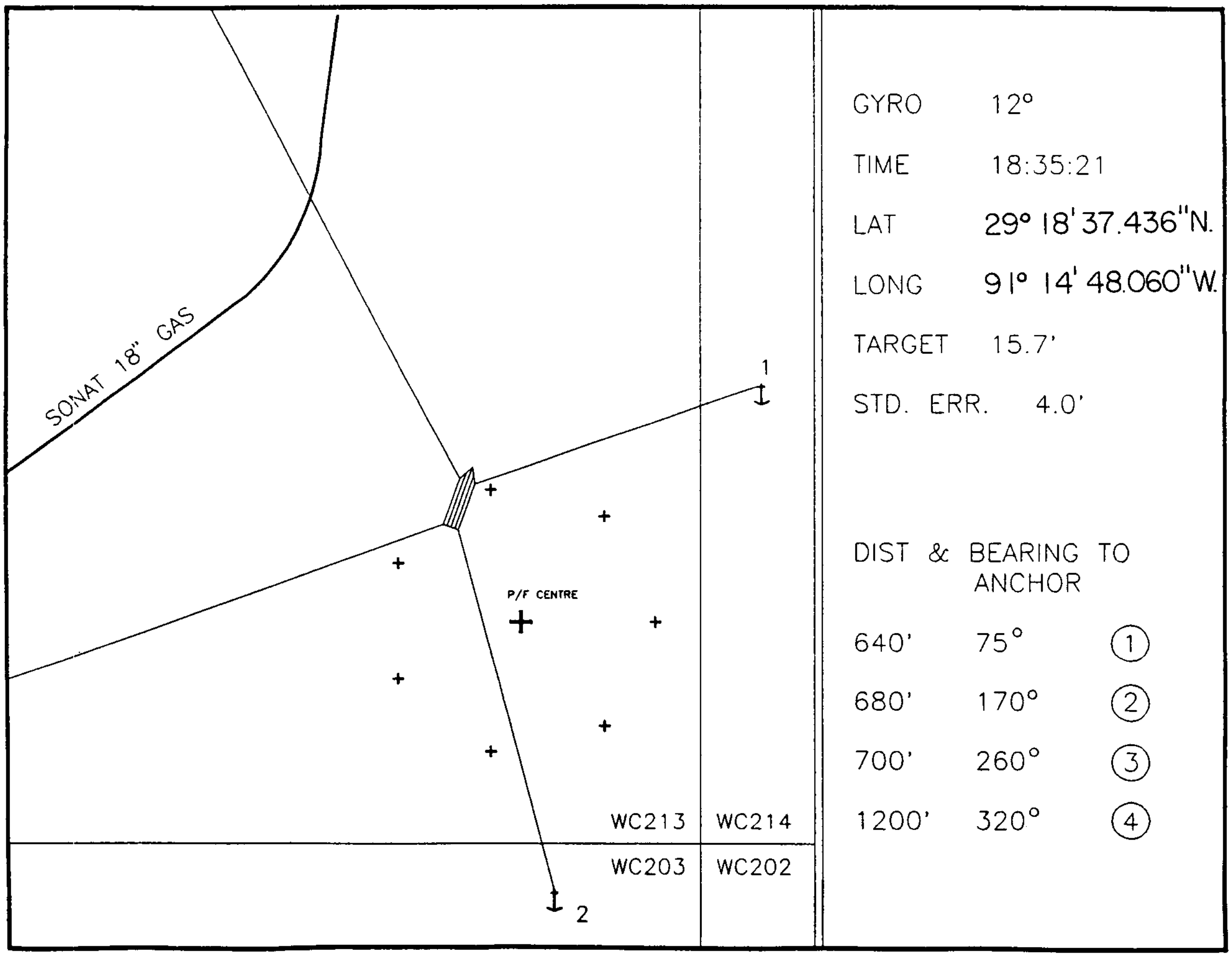


Figure 3.1. Equipment spread.

The locations for the sonar drops are taken from the operator's proposed procedure for clearing the site, which typically includes a plan as shown in Figure 3.2.

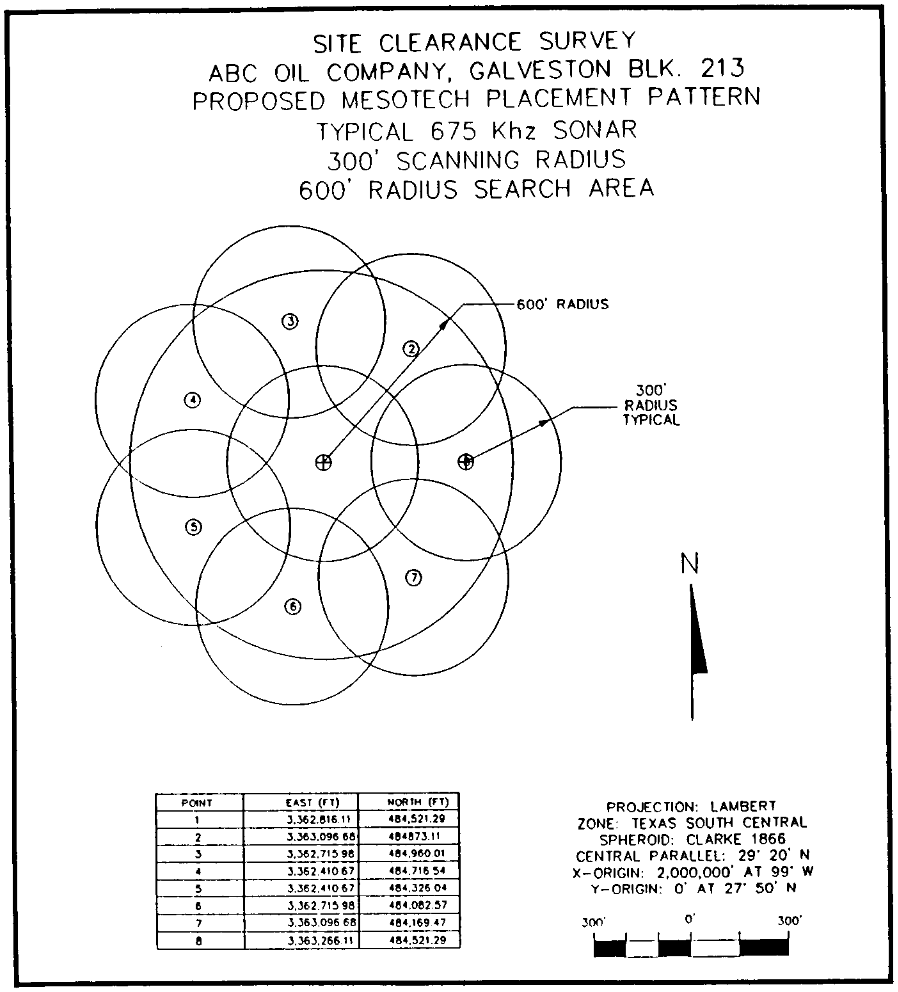
For the shrimp boat, the monitor has information typified by Figure 3.3. This information includes a site center, a survey grid for the trawl lines to be run, and the position of the shrimp boat in real time. Tabulations include course made good, line bearing, speed, position in latitude and longitude, distance to the end of the line, and distance cross course. This is the screen the shrimp boat captain uses for navigating the vessel.

An additional output required for the trawl survey is a hard-copy plotter, which shows the grid lines to be run and the actual path the shrimp boat achieved. This hard-copy assists in highlighting those areas still to be covered by the trawl.

POSITIONING SYSTEMS

There is exaggeration regarding accuracies of survey positioning systems. The equipment currently used by the major survey contractors for most of the offshore work has absolute accuracies on the order of 5 to 10 m; i.e., given a final coordinate on the earth's surface, one should be able to take his boat, navigate it to the same coordinate and be confident he is within 5-10 m of that point.

Any system used incorrectly can have one clearing a site a few miles south of the old jacket site. However, there are a number of ways the oil companies can reduce this risk.



POINT	EAST (FT)	NORTH (FT)
1	3,362,816.11	484,521.29
2	3,363,096 68	484873.11
3	3,362,715 98	484,960.01
4	3,362,410 67	484,716 54
5	3,362,410 67	484,326 04
6	3,362,715 98	484,082.57
7	3,363,096 68	484,169.47
8	3,363,266.11	484,521.29

Figure 3.2. Sonar location plan.

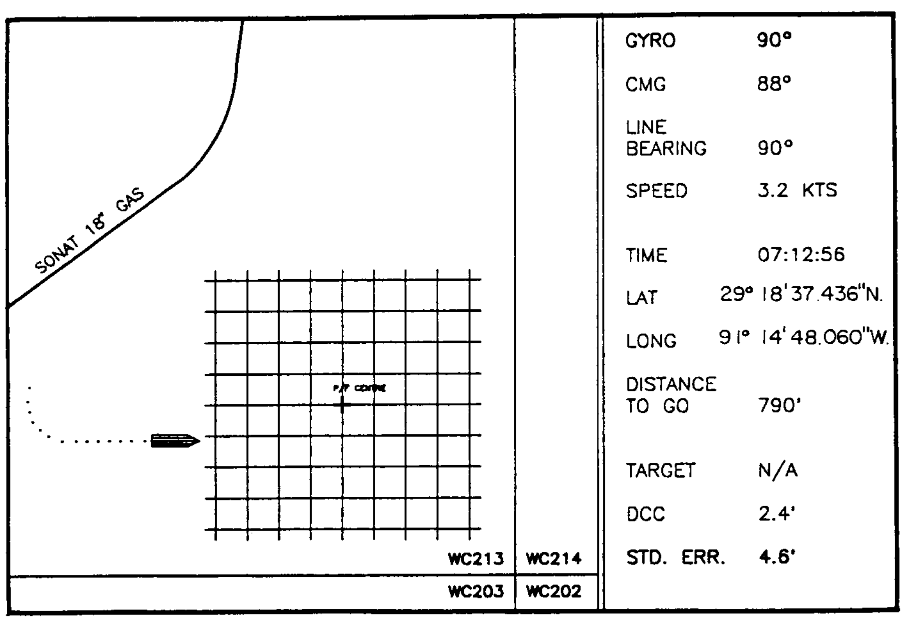


Figure 3.3. Trawling plan.

1. They can make sure their survey contractor has at least one redundant range in his position solution. A quality of fix can then be displayed on the monitor and the oil company representative can be confident he is in the right location.

2. The use of a permanent navigation network will give them the confidence that other people are using this network and the station coordination has been verified over a large number of previous projects.

Navigation systems for general public use such as Loran C and stand-alone GPS are definitely not of acceptable accuracy for this type of work.

SONAR SYSTEMS

By far the most widely used sonar for site clearances (but not the only type) is the fixed-head scanning sonar. This is a device similar, both in use and display, to a boat radar or the radar seen on the weather channel (Figure 3.4). A fixed head with a rotating transducer scans through 360° emitting a 500 to 675 kHz acoustic beam and listens for replies. Any reflections of solid objects appear as a blip on the screen, and a diver can be dispatched to that point to investigate.

FACTORS AFFECTING THE SURVEY

Assuming that quality positioning is provided throughout the clearance, there are additional influences that will have an affect on the efficiency of the operation.

The survey contractor is attempting to lower the sonar and place it on a specified coordinate on the seafloor. Obviously he can set the dive boat over the position but in deeper water and moderate currents, the head and tripod can land on the seabed quite a distance from its intended location. Where is it in relation to where he wants it to be? He can't really be sure without providing additional expensive equipment.

We have seen an instance where the tripod was knocked over and the operator insisted there was a 130 ft. long 'riser' or large diameter pipe on the seafloor and it was moving! Eventually he realized the tripod was lying on its side and he was looking at the bottom of the dive boat.

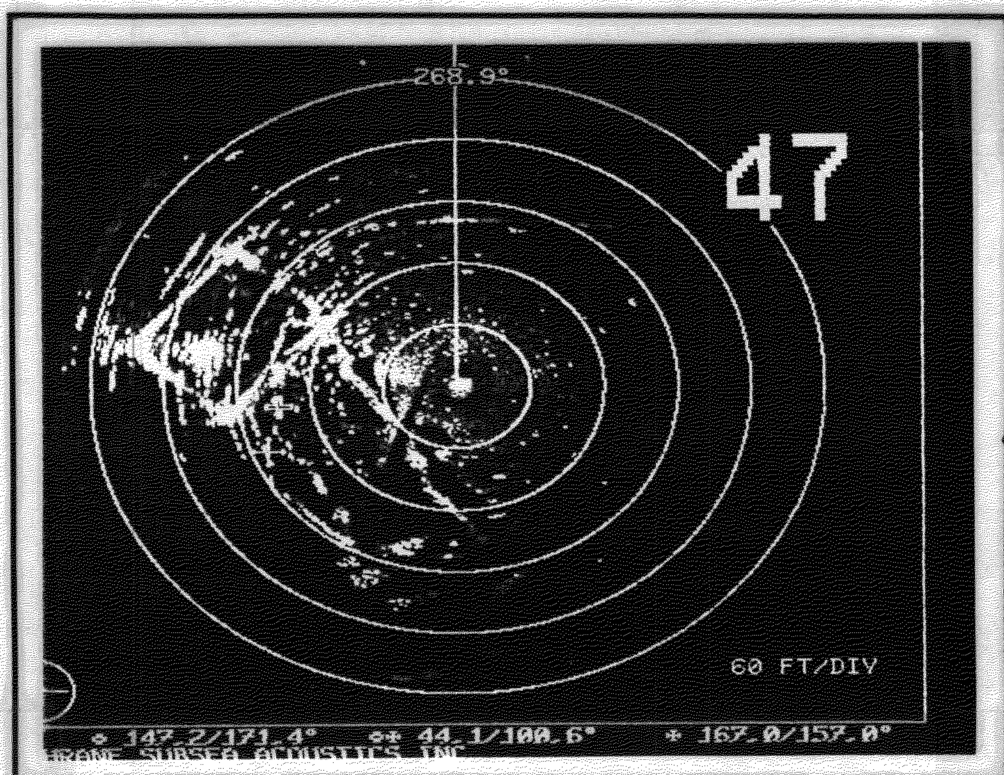


Figure 3.4. Scanning sonar image.

The shrimp boat captain's ability to learn to steer from an electronic real time map of his boat and its surroundings will affect the efficiency of the trawl. Some skippers adapt readily, while others take time to learn this new skill.

In the track plots of the site clearance trawls shown in Figures 3.5 and 3.6, it is apparent that the skills of the two skippers differed considerably. Also, in viewing Figure 3.6, it could be argued that some areas require additional infill. However, this is a track plot of the antenna location on the boat. Depending on water depth, the nets themselves could be 60 to 150 m behind the antenna. The track plot of the nets, if it were available, would be different to that shown in these figures and an attempt to infill the void on the map by running the boat through the area may have little effect on any untrawled portion of seafloor in the area.

FACTORS AFFECTING THE SONAR

Figure 3.7 shows the sonar head and the tripod that supports it above the seafloor. Tripods supporting the head are generally 1.5-3 m high, which places the head in a reasonable position to see out to the range limits of the scanning sonar. However, in soft bottoms there is a tendency for the tripod to sink, thus reducing the effective height of the head. In areas where current is a factor, weights are added to the sonar, and this in turn makes it sink even farther into the mud. The effect of reducing the height of the head is that natural undulations of the seabed cause more shadowing effects and thus reduce the effective range of the sonar.

As operators of this equipment, we have all become accustomed to using 100 m (300 feet [ft.]) as the range for the scanning sonar and to using a 100 m (300 ft.) radius circle to show the area covered by the device. This radius is quoted by the manufacturer as being the maximum range for this frequency. From experience, I would say that very little debris has been detected beyond 60 m, and I'm sure that this has contributed to the volume of debris trawled up in the nets after a field has been declared clear by the sonar operators.

The signal received back at the sonar head is proportional to size, reflectivity and distance, and although an object of a few centimeters in size can be detected close to the head, it takes an object of 2-3 m across to be detected at 100 m.

The age of a field has a bearing on the site clearance procedures. Twenty years ago, everyone was less environmentally concerned and I'm sure more waste materials were discarded over the side of platforms and support vessels than we would like to admit. Over time, this trash buried itself into the seafloor, making it harder or, in some cases, impossible to detect with sonar.

I'm also sure that marine growth has a major impact on detecting seafloor debris. Sound waves reflect best off hard, solid objects. Objects covered with a thick layer of soft, organic growth absorb some of the acoustic energy and may even render the object invisible to sonar.

Bottom conditions will play an important role in the detectability of objects on the seafloor. A piece of grating may stand out quite well against a smooth, featureless mud bottom but when placed against a gravel bottom or one with small sand waves, it will be hard to detect, or even be invisible to the scanning sonar.

REPORT REQUIREMENTS

Our company has now been involved in about 30 site clearances of caissons or platforms and our reports have evolved into the following structure:

1. An introduction giving the client, location of the field, and other service companies involved in the clearance work.

2. A method of operation for all the various phases of the site clearance. This statement enables the client or the MMS to ascertain what equipment was used, how it was deployed, and gives a diary of events showing when the clearance took place.

3. Appended to the main text are a diagram showing the intended coverage of the sonar, the actual drop locations of the sonar head, and pictures of the sonar displays.

4. The next appendix is a tabulation of the trawl lines run by the shrimp boat with a corresponding list of debris collected in the nets.

5. The final part of the report is the track of the shrimp vessel through the site similar to these shown previously in Figures 3.5 and 3.6.

SUMMARY

This presentation is an attempt to give some insight into the role of the survey and sonar contractor in

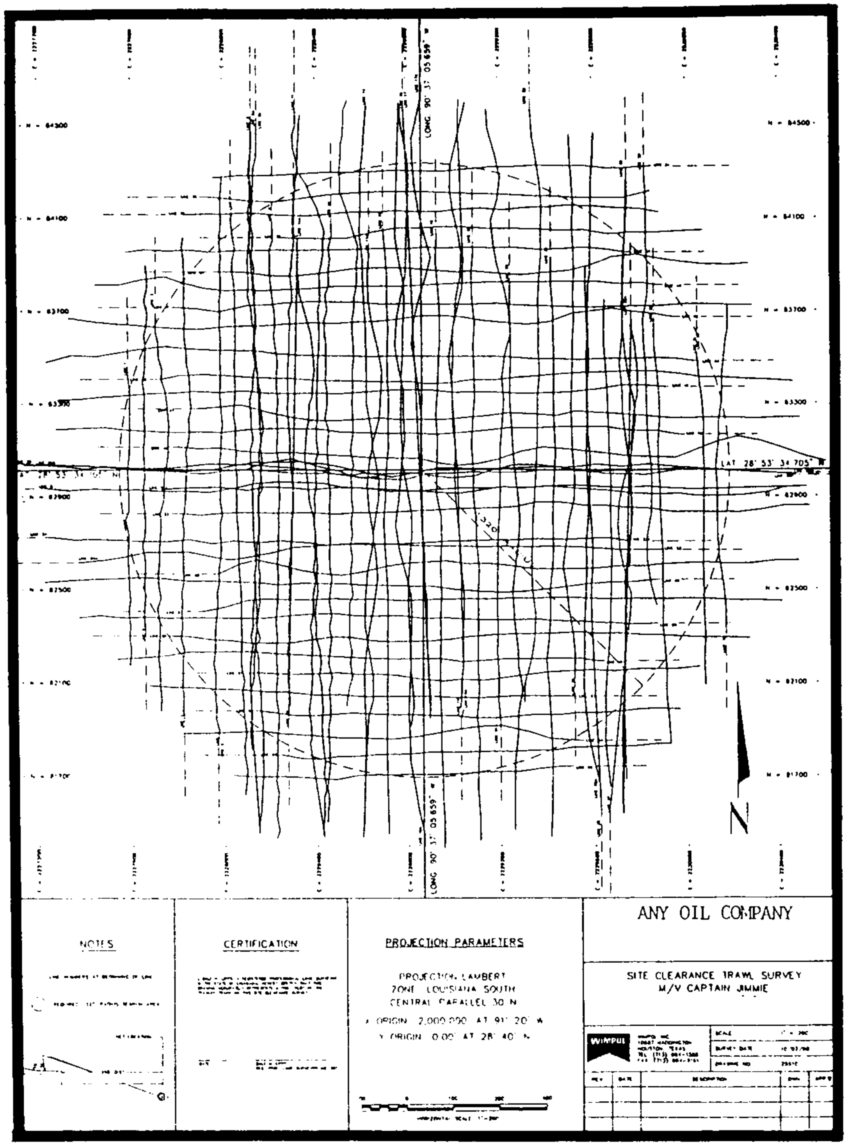


Figure 3.5. Track plots of site clearance trawls (Trawler A).

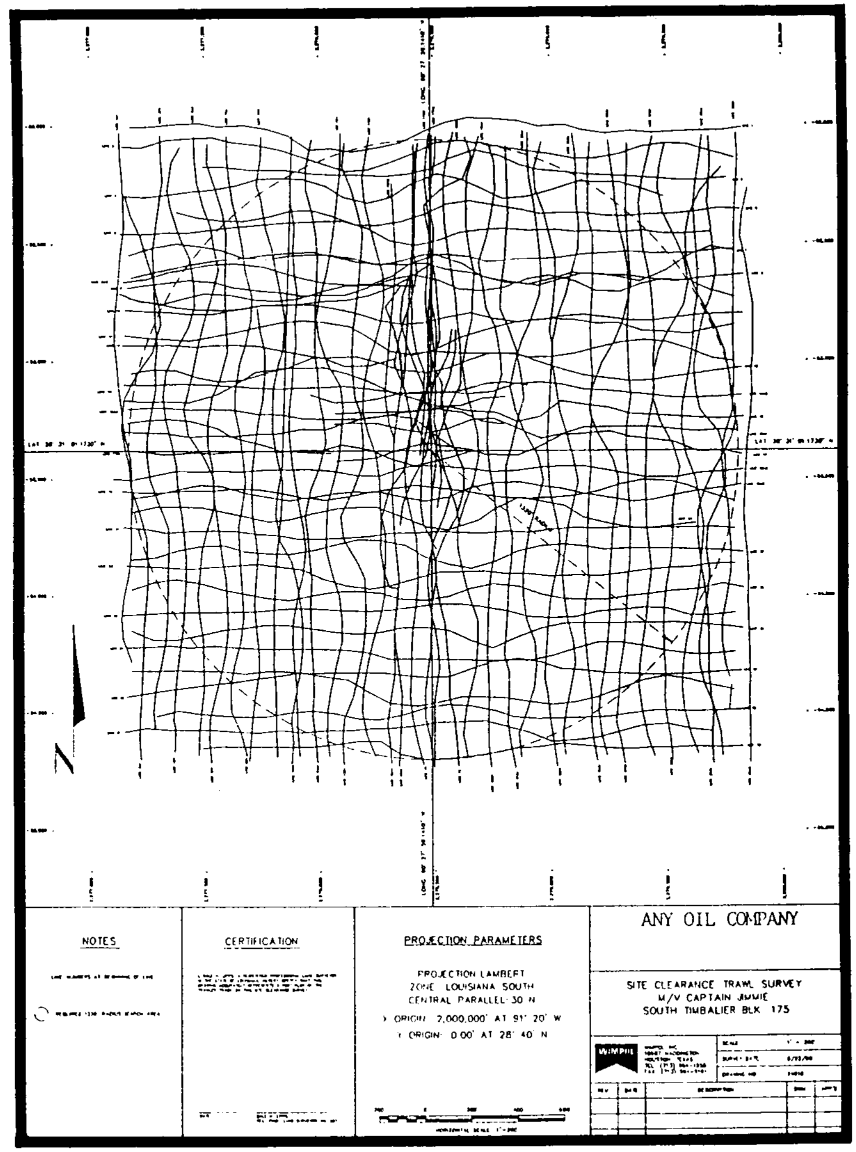


Figure 3.6. Track plots of site clearance trawls (Trawler B).

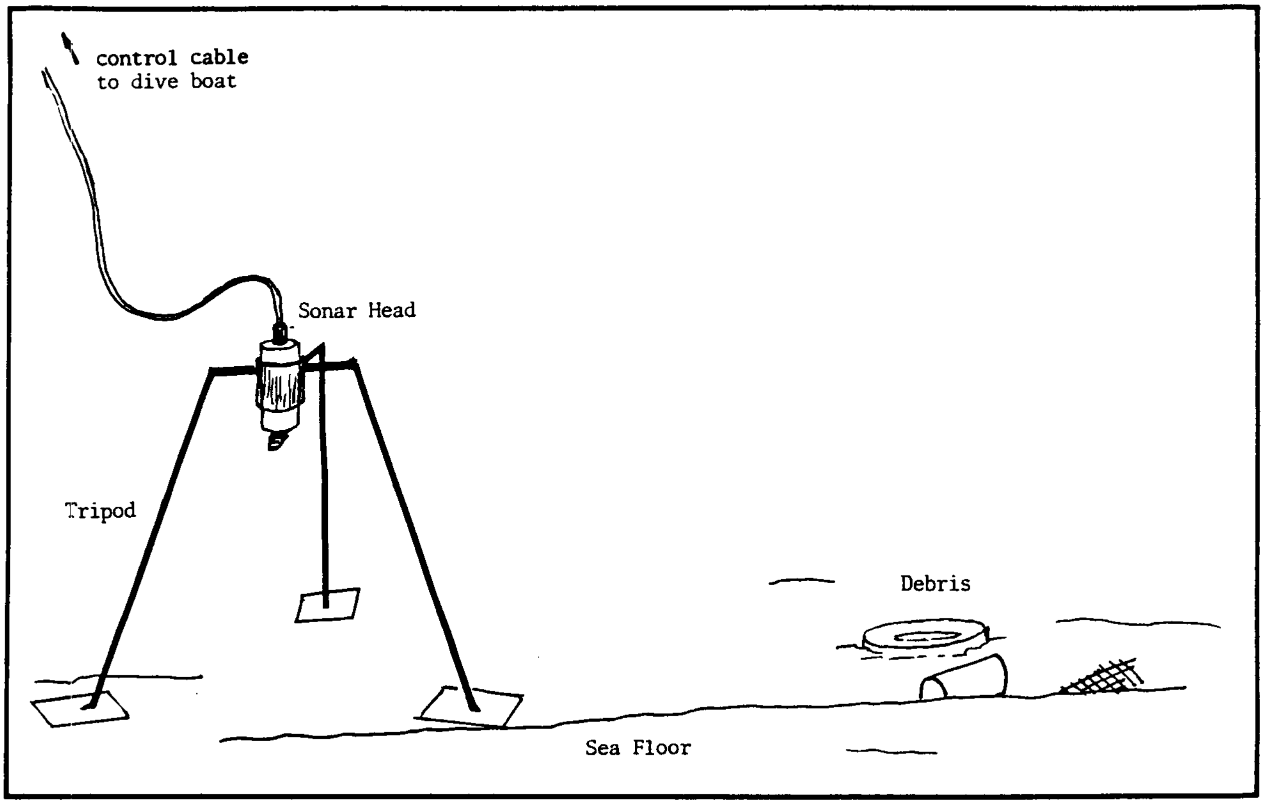


Figure 3.7. Sonar head and support system.

clearing abandoned sites here in the Gulf of Mexico. The procedures in general use, while being far from perfect, are getting the job done and doing it reasonably cost-effectively.

The presentation should also alert the operators and company representatives to some of the pitfalls of the methods used and, it is hoped, this increased knowledge will assist us in completing this work in a more efficient manner.

Mr. Bill Tink is Vice President of WIMPOL, INC. in Houston, where he has been based since WIMPOL was incorporated in 1982. He started as Operations Manager before being promoted to Vice President in 1985. Previously, Mr. Tink was technical manager for the joint venture company IGW based in Abu Dhabi in the Middle East. Earlier experience of offshore operation was gained with Marex on oceanographic projects in the North Sea, South America and Far East. Mr. Tink received his B.E. degree at Sydney University, Australia.

THE IMPACT OF RECENT OCS SITE CLEARANCE ACTIVITIES ON THE OIL AND GAS INDUSTRY

Mr. Michael E. Parker
Offshore Operators Committee
Fisheries Subcommittee

Recent activities by the Minerals Management Service (MMS) have resulted in a significant increase in the amount of time and effort necessary by offshore oil and gas operators to conduct site clearance procedures. The purpose of this presentation is to review the impacts to our industry of this increased effort and offer our perspective on how we feel this effort should proceed.

The MMS's current regulations require that operators remove all platforms to a depth of at least 15 ft. below the mudline and then "verify by appropriate means that the location has been cleared of all obstructions." There are also requirements for operators to certify to the MMS that the location was cleared and to identify the extent of the area surveyed and the method used for the survey.

Historically, operators have surveyed and cleared an area of between 100 ft. and 200 ft. around the perimeter of the base of the structure. Depending on the type of structure being abandoned, different methods have been used. For small platforms, such as exploratory well locations or single well caissons, side-scan sonar was typically used to survey the area. If debris was identified during the survey, divers would be used to recover the debris. For larger platforms, divers would walk the bottom in a predetermined pattern and recover debris within that area and then follow-up with a side-scan sonar survey of the area. In recent years, as the bottom founded side-scan sonar technology came into wider use, many operators have used these systems in conjunction with divers to improve debris location and recovery.

Through 1989, it was the opinion of most operators that these methods were adequate for identifying and removing debris that could be a threat to fishermen's gear. This is not to say that these methods were 100% effective, but when considered against the availability of compensation for damages from Federal and, in many cases, State Fishermen's Gear Compensation Funds, all of which are funded by fees on the oil and gas industry, the total program was felt to be adequate.

As a result of continuing damage to their trawling gear from debris that fishermen felt was largely originating from oil and gas operations, combined with increased difficulty in obtaining compensation for those damages from compensation funds, the fishermen pressed their case with the MMS for improved site clearance procedures. The result was the formation of the MMS Site Clearance Working Group in the fall of 1989.

The working group had representation from the trawling industry, the oil and gas industry, state and local government, and the MMS. The charge of the working group was to work cooperatively, considering the concerns of the parties represented, and develop improved interim site clearance and verification procedures and to generate data that will ultimately be used as a basis for revision of the existing site clearance regulations. Two products have been completed as a result of the successful efforts of the Working Group, MMS Notice To Lessees (NTL) 90-01 and 90-03. It is important to recognize that the NTLs are not intended to be a permanent part of platform abandonment procedures. This, however, is not to say that some of the requirements of the NTLs will not become permanent regulatory requirements, but rather to recognize the purpose of the NTLs.

The first NTL was issued in February 1990 and had a six-month term. This NTL provided detailed site clearance verification procedure requirements, specifying areas of investigation, required the use of bottom founded side-scan sonar for clearance verification and required sites of permanent platforms to be trawled after the sonar verification was complete. In August 1990, the MMS issued the second NTL (NTL 90-03), which superseded NTL 90-01. The NTL 90-03 was fundamentally similar to NTL 90-01; however, it incorporated many improvements based on what was learned under NTL 90-01. Additional types of side-scan sonar equipment were allowed for use, more specific technical requirements were included for sonar equipment, and more specific trawling requirements were listed in NTL 90-03.

The impacts of the NTLs to operators have been significant. We feel we have learned a great deal about site clearance verification methods and their effectiveness but also have a great deal more left to learn before the MMS begins to draft revised site clearance regulations. What we have learned so far is that side-scan sonars have limited capabilities as a tool for detecting debris on the sea floor. We have also learned that trawling vessels and conventional fishing equipment are not well suited to the demands being placed on them by most operators. Before formal rulemaking should begin, we feel there need to be additional data to support the area that is required to be cleared, and more effective technologies (cost and result oriented) need to be developed. Permanent regulations should not be pursued until reasonable, accurate, and cost-effective requirements can be identified.

There are two types of side-scan sonar available for site clearance verification work, bottom founded and towed, each with distinct advantages and disadvantages. The bottom founded side-scan sonar is better suited to location clearance work from a logistical standpoint; however, it is less sensitive and takes more time to cover an equal area than towed side-scan sonar. The limitations of side-scan sonar were not widely known by operators prior to implementation of the requirements of the NTLs. The trawling requirement of the NTLs has shown that side-scan sonar may not detect the presence of objects with 100% accuracy. This detection accuracy is influenced by the skill of the personnel operating the equipment, since interpretation of the results of a sonar scan can often be subjective. From a physical standpoint, if an object cannot reflect the sonar signal, it will not be detected. Things that will cause an object not to reflect a sonar signal can include the shape of the object, the density of the object relative to sea water, the presence of marine growth or silt on the object, or degree of burial of the object.

The use of the trawlers as a verification technique to side-scan sonar has been beneficial, with additional debris being found in many cases. Since it appears that trawling will be a necessary part of site clearance verification for at least the interim study period, we would like to work cooperatively with the trawling industry and the MMS to develop equipment and operating practices that are better suited to the demands of oilfield site clearance operations. Equipment improvements could include stronger lift equipment and use of more cost-effective navigation systems. Operating practices could include provisions for conducting the required trawling on a 24-hour basis and must include improved safety awareness and cooperation. We are particularly concerned about safety issues. A recent National Transportation Safety Board report showed that the fishing industry is the most dangerous industry in the United States with an accident rate of seven times the national average. Trawlers can expect that operators will require strict compliance with their safety programs in the future.

The question of what is the appropriate area to be surveyed during site clearance operations is not answered at this time. Preliminary indications are that the 600 ft. and 1,320 ft. required for templates and platforms may be high. Site clearances conducted under the NTLs indicate that most debris is located near the base of the platform, within a 300 ft. perimeter, with a small debris "plume" extending outward on the side of the platform where vessels are loaded and unloaded. The amount of debris and the area that it is scattered in also appear to be a function of platform age and the activity level at the platform. The documentation requirements of the NTLs should provide the data necessary to better define what the appropriate areas and survey methods are under these different circumstances.

From an operator's perspective, the most significant impact of the NTLs has been increased costs. According to a recent survey of selected operators, the NTLs have increased site clearance costs by 50% to 100%. Since nearly all of the experience to date has been with small platforms (600 ft. radius), it is reasonable to expect these increases to represent the low side of the spectrum of cost impacts. Site clearance costs for larger platforms may see increases of 200% to 400%, since they typically have much higher activity levels than most of the platforms included in the above referenced survey. The survey results also show that the time spent clearing a location is typically greater than the time spent on the actual removal of the platform. This ratio may improve some with time as industry gains experience, but even in the best of situations the NTLs do require significant additional work by operators that result in significant added costs.

In summary, the impacts of the NTLs on operators so far are as follows:

- Side-scan sonar technology has limited applicability as a site clearance verification tool. Operators and equipment suppliers need to work actively at improving the effectiveness of this or other technologies as accurate and cost effective alternatives to the current trawling requirements of the NTLs.

- Trawling appears to be an effective method of detecting debris not otherwise detected. Trawling equipment better suited to "oilfield" applications should be developed and operating practices of vessel operators need improvement, particularly safety program participation and 24-hour trawling operations.

- The MMS should not lose sight of the purpose of the NTLs, which is to generate information to identify reasonable site clearance verification technologies and procedures that can later be used to support a formal rulemaking effort.

- The large added cost seen by operators under the NTLs thus far can only be considered acceptable as long as the requirements of the NTLs are identifying and recovering significant oil and gas industry generated debris that would otherwise not be recovered. As technology improves and the existing requirements are determined to be excessive, the MMS must be prepared to modify the site clearance verification requirements as appropriate.

Mr. Michael E. Parker is a Staff Engineer with Exxon's Offshore Division in New Orleans. Mr. Parker received a Bachelors 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 ia currently assigned as a regulatory and environmental engineer. Mr. Parker is a registered professional engineer in Texas and Louisiana.

PANEL DISCUSSION: A CASE STUDY SUMMARY OF A SITE CLEARANCE OPERATION

Mr. Bill Tink
Sonar Company,
Mr. Douglas Cochrane
Sonar Company,
Mr. Michael E. Parker
Offshore Operator,
Mr. Robert B. Suggs
Salvage Company,
and
Mr. Jimmie Martin
Shrimp Trawler

A panel was convened so that each of the different players in an actual site clearance operation could discuss his company's level of participation. By discussing real experiences, it was felt that interested parties would be better able to understand the capabilities and limitations of the various technologies used in site clearance operations, as well as the problems encountered in carrying out even carefully planned procedures offshore.

Mr. Tink and Mr. Cochrane discussed the successful application of sonar in positioning the diving vessel and directing divers during the clearance operation, as well as providing accurate position locations to the trawl boat as it navigated a predetermined grid pattern. Mr. Suggs provided technical information regarding the diving equipment used and pointed out the value of having employed saturation rather than surface diving techniques. He also discussed some of the possible reasons why certain items were not located by the sonar-directed divers. Mr. Martin gave some statistics on the number and size of items recovered in the trawl, and stated that six nets were torn during the trawling operation. The panel then answered the audience's numerous questions, which covered all aspects of site clearance activities.

Mr. Bill Tink is Vice President of WIMPOL, Inc. in Houston where he has been based since WIMPOL was incorporated in 1982. He started as Operations Manager before being promoted to Vice President in 1985. Previously, Mr. Tink was technical manager for the joint venture company IGW based in Abu Dhabi in the Middle East. Earlier experience of offshore operation was gained with Marex on oceanographic projects in North Sea, South America and the Far East. Mr. Tink received his B.E. degree at Sydney University, Australia.

Mr. Douglas A. Cochrane, Jr., is President and Chief Executive Officer of Cochrane Subsea Acoustics, Inc. and International Subsidiaries, located in Lafayette, Louisiana. He has held this position for the past ten years. Mr. Cochrane received a degree in oceanography from Florida Institute of Technology and has attended the AMA Center for Strategic Planning and Implementation. Between 1974 and 1980, Mr. Cochrane served in various positions ranging from ocean engineer to Vice President, to President and CEO of marine related institutions and companies. He has extensive consulting experience in the areas of international business development as well as strategic planning and implementation.

Mr. Michael E. Parker is a Staff Engineer with Exxon's Offshore Division in New Orleans. Mr. Parker received a Bachelors 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.

Mr. Robert B. Suggs joined AOD in 1985 and has served as the company's Vice-President of Operations since 1986. From 1980 to 1985, he was employed as Vice-President of Operations of Sea-Con Services, Inc., a New Iberia-based diving company. From 1977 to 1980, Mr. Suggs founded and managed Seadive, Inc., a Morgan City-based diving company, which was acquired by Sea-Con in 1980. From 1971 to 1977, he was employed by World Wide Divers, Inc. (which, along with three other diving companies, was merged to form

Oceaneering International, Inc.) as a diver and diving supervisor. He has worked as a diving supervisor in the North Atlantic, Gulf of Mexico, Atlantic Ocean (USA), the Persian Gulf, and the Pacific Ocean (USA). Mr. Suggs attended Oregon State University and studied business administration from 1966 to 1967. He served in the U.S. Navy aboard a nuclear submarine for four years and received an honorable discharge in 1970.

Mr. Jimmie Martin is owner and operator of two shrimp trawlers and three offshore supply vessels. He is a third generation shrimp trawler, having experience and knowledge in operating a trawl vessel, and trawl net construction and repair. In 1976, Mr. Martin ventured into the oil industry, and constructed his first offshore supply vessel. He is a licensed Captain with many years' experience in both industries.

RISK & REWARD: FUELING AMERICA'S RECREATION, CONSERVATION, AND PRESERVATION PROGRAMS THROUGH OCS LEASING

Session: RISK & REWARD: FUELING AMERICA'S RECREATION, CONSERVATION, AND PRESERVATION PROGRAMS THROUGH OCS LEASING

Co-Chairs: Mr. Villere Reggio, Jr.
Ms. Linda Castaño

Date: November 13, 1990

Presentation	Author/Affiliation
Risk & Reward: Fueling America's Recreation, Conservation, and Preservation Programs Through OCS Leasing: Session Introduction	Mr. Villere Reggio, Jr. and Ms. Linda Castaño Minerals Management Service Gulf of Mexico OCS Region
Land and Water Conservation Fund - Impact on State Outdoor Recreation Programs	Mr. Samuel L. Hall National Park Service Recreation Grants Division
Land and Water Conservation Fund - Impact on America's National Parks and Seashores	Mr. Willis Kriz National Park Service Land Resources Division
Land and Water Conservation Fund - Impact on National Wildlife Refuges and Endangered Species	Mr. Villere Reggio, Jr. Minerals Management Service Gulf of Mexico OCS Region, Mr. Larry Coe and Mr. Clyde Schnack U.S. Fish and Wildlife Service
Land and Water Conservation Fund - Acquisition in the Forest Service Southern Region	Mr. Lawrence W. Braddock U.S. Department of Agriculture Forest Service Southern Region
Historic Preservation Fund - Impact on Historic and Cultural Resources	Mr. Stephen Newman National Park Service Preservation Assistance Division
Private Perspective: How a Private Conservation Group Can Help Generate More Acres Per Dollar from the Land and Water Conservation Fund	Mr. Philip G. Ellender The Nature Conservancy of Louisiana

RISK & REWARD: FUELING AMERICA'S RECREATION, CONSERVATION, AND PRESERVATION PROGRAMS THROUGH OCS LEASING: SESSION INTRODUCTION

Mr. Villere C. Reggio, Jr.
and
Ms. Linda Castaño
Minerals Management Service
Gulf of Mexico OCS Region

INTRODUCTION

Exploration, production, and transportation of Outer Continental Shelf (OCS) oil, gas, and sulphur resources entail a degree of environmental risk. The Gulf of Mexico, characterized by the Environmental Protection Agency in 1990 as America's most productive sea, has shouldered the bulk of OCS petroleum and sulphur operations since its first Federal lease sale in 1954. Besides contributing about one-fifth of America's annual domestic energy production, Gulf of Mexico leasing bonuses, production royalties, and rental revenues account for approximately four-fifths of the annual deposits in the Land and Water Conservation Fund. Established by Congress in 1965, this Fund is spent by state and local governments and Federal conservation agencies to acquire and develop recreation, conservation and preservation lands throughout the United States of America. Congress later established the Historic Preservation Fund and also tied its annual appropriations to OCS revenues.

Having celebrated the silver anniversary of the Land and Water Conservation Fund in 1989, the New Orleans OCS office sought an accounting of how OCS revenues spent through the Land and Water Conservation Fund and the Historic Preservation Fund had impacted the establishment, enhancement and preservation of park, recreation, wildlife and cultural resources throughout America in the past 25 years with special emphasis on accomplishments in the 5 Gulf states. Gulf of Mexico lease sale environmental impact statements stress the potential adverse effects of OCS operations on wetlands, parks, beaches, wildlife, endangered species, and cultural resources. The presentations that follow will document how the adverse impacts and short-term risks to coastal and marine environmental resources from OCS leasing have been counter balanced through OCS revenue investment in the permanent expansion, enhancement and protection of America's conservation and recreation estate.

Mr. Villere C. Reggio, Jr., is an Outdoor Recreation Planner with the Minerals Management Service Gulf of Mexico OCS Region. His responsibilities include research, assessment, and reporting on the interrelationship of the OCS oil and gas program with the recreational elements of the marine and coastal environment throughout the Gulf of Mexico region.

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

LAND AND WATER CONSERVATION FUND - IMPACT ON STATE OUTDOOR RECREATION PROGRAMS

Mr. Samuel Hall
National Park Service
Recreation Grants Division

The unique place of the Land and Water Conservation Fund (L&WCF) in America's conservation and recreation legacy can be better understood through a quick history of where the program initiated.

THE FUNDS INCEPTION FROM THE BEGINNING

In 1958, increasing consciousness of public health and environmental issues and an expanding need for recreational space combined into a bipartisan mandate creating the Outdoor Recreation Resources Review Commission (ORRRC).

After three years of research, the ORRRC developed specific recommendations for a national recreation program. The ORRRC emphasized that State and local as well as Federal governments and the private sector were key elements in the total effort to make outdoor recreation opportunities available. Some of the ORRRC's major recommendation's were:

- The United States should establish a national recreation policy to preserve, develop and make accessible to all Americans the resources necessary "for individual enjoyment and to assure the physical, cultural, and spiritual benefits of outdoor recreation."

- All agencies administering outdoor recreation resources, both public and private, should adopt programs designed to make the best possible use of available resources in light of people's needs.

- Each State, through a central agency, should develop a long-range plan for outdoor recreation, to provide adequate opportunities for the public, to acquire additional areas where necessary, and to preserve outstanding natural sites.

- A Bureau of Outdoor Recreation should be established in the Department of the Interior to lead nationwide efforts by coordinating various Federal programs, conducting nationwide planning and assisting other levels of government.

And lastly, the concept of L&WCF and its purpose:

- A Federal funding program should be established to pay for additions to the Federal recreation estate and to provide matching funds to States that would stimulate and assist them to meet the demand for outdoor recreation.

LEGISLATIVE HISTORY OF L&WCF

Largely as a result of ORRRC's work, funding legislation was introduced in 1962 during the second session of the 87th Congress. No action was taken in that Congress, but on February 14, 1963, the President again proposed legislation that would establish a "Land and Water Conservation Fund" to finance new Federal recreation lands and assist States in recreation planning, acquisition and development. The basic purpose of this proposed legislation was to provide a means for catching up with the lag in land acquisition in recognition that the land and water base for recreation was rapidly being lost to development. In fact, the President's proposal specifically provided that development grants for the first 10 years of the Fund program could not exceed 10% of the total amount appropriated each year for State purposes, but the House Interior Committee in reporting H.R. 3846 on November 14, 1963, deleted this provision because land acquisition was not considered a pressing need in the western States. Thus, as it was enacted, H.R. 3846 (P.L. 88-578) permitted the States to use the Fund's monies for development as well as land acquisition. The legislative history of the bill makes it clear that Congress intended the emphasis in the first years of the Fund to be on land acquisition.

Following ORRRC's recommendations, emphasis was placed on planning for future recreation opportunities. In its hearings on the L&WCF bill, Congress defined requirements for Statewide Comprehensive Outdoor Recreation Plans (SCORPs) that would be a condition of State grants.

Recognizing the rapid loss of the land and water recreation base to development, one of the proposed legislation's major purposes was to reduce the lag in recreation land acquisition. The House Interior Committee's report on the bill stated that "During the first years of the program, emphasis will necessarily be on planning and land acquisition activities. It is important that acquisition be undertaken before the land becomes unavailable either because of skyrocketing prices, or because it has been preempted for other uses." The Senate Interior Committee's hearing report addressed the distribution of grant funds. It said that "in providing outdoor recreation resources and facilities for the American people, the greatest emphasis should be given to those areas with large concentrations of people."

Congress clearly indicated that the new Federal program should have a lasting effect on the supply of recreation sites and facilities by requiring that sites be added permanently to the national recreation estate. As a result, Section 6(f)(3) of the Act (H.R. 3846) states unequivocally that grant-assisted areas are to remain forever available for "public outdoor recreation use," or be replaced by lands of equal market value and recreation usefulness.

With vigorous bipartisan support in both Houses of Congress, the bill was passed and signed into law on September 3, 1964, as Public Law 88-578. The Act established a funding source for both Federal acquisition of park and recreation lands and matching grants to state and local governments for recreation planning, acquisition and development. It set requirements for state planning and provided a formula for apportioning annual L&WCF appropriations to the States and Territories. Initially, three sources of revenue to the fund were designated: proceeds from sales of surplus Federal real property, motorboat fuel taxes, and fees for recreation use of Federal lands. The level of funding from fiscal year (FY) 1966 through FY 1968 reached about $100 million per year with small unappropriated balances, but the amount of funding was far short of Congress' expectations.

The unappropriated balances ebbed and flowed annually for the next 10 years ranging from "0" to a high of over $250 million, finally zeroing out in 1977 when the total of over $537 million was provided by appropriations. In the next year the authorization was moved up to $900 million. More about the next few years of authorization/appropriations and the unappropriated balance in a moment. Let's look at some of the nationwide accomplishments that the Fund has achieved since the early days of the program.

L&WCF PROGRAM NATIONWIDE ACCOMPLISHMENTS

Since 1965, the Federal and State "sides" of the Fund have helped to acquire over 5.5 million acres of recreation and park lands including seashores, lakeshores, critical habitats, wild and scenic rivers and national scenic trails.

Almost $4 billion have been appropriated from the Fund for Federal recreation land acquisitions, financing expansion of the National Parks and National Forests into truly national recreation systems. Prior to 1965, almost all Federal recreation lands were located west of the Mississippi, usually in remote or rural areas at some distance from major population centers. Four Federal Agencies at present use the funds from the L&WCF to purchase land. As you can see from the composition of most of this panel they are the Interior Department's National Park Service, Bureau of Land Management, U.S. Fish and Wildlife Service, and the Agriculture Department's U.S. Forest Service. Three of them plus a representative of the Historic Preservation Fund will discuss how their bureaus or offices have used the funds of the L&WCF during this presentation.

For the L&WCF State Grants program, which is run by my Division of Recreation Grants, over $3 billion have been appropriated to the 50 States, the District of Columbia, Puerto Rico, Guam, the Virgin Islands, American Samoa, and the Northern Marianas for planning, acquisition and development of outdoor recreation opportunities. Through FY 1988, a total of 35,000 projects has been approved to support the acquisition of open space for park lands or the development of outdoor recreation facilities. Federal obligations totalling $3 billion have been matched by State and local contributions, for a total L&WCF grant investment of over $6.1 billion.

Of the total number of projects, 9,800 projects have been for the acquisition of over 2,300,000 acres of park land, while 25,000 projects have been for the development of outdoor recreation facilities. Seventy-five percent of the total funds obligated have gone to locally sponsored projects to provide close-to-home recreation opportunities that are readily accessible to America's youth, adults, senior citizens and physically/mentally challenged people. In addition to thousands of smaller recreation areas, grants have helped to acquire and develop new parks of statewide or national significance such as the Allagash Wilderness Waterway (Maine), Liberty State Park (New Jersey), the Willamette River Greenway (Oregon), Platte River Park (Denver), Herman Brown Park (Houston), and Illinois Beach State Park (Chicago).

RELATIONSHIP OF L&WCF AND OCS OIL AND GAS LEASING

After several years of successful operation, it was proposed that Outer Continental Shelf (OCS) mineral leasing receipts be tapped to augment the monies for the Fund. In 1968, P.L. 90-401 raised the Fund's level to $200 million a year for 5 years, beginning in FY 1969, making OCS revenues available to cover the difference between this minimum level and receipts from other sources.

The use of royalties from the offshore oil leasing revenues is based on the idea of recycling the proceeds of natural resources development back into natural resources protection. While a non-renewable resource is being used, renewable resources in the form of conservation and recreation lands are increased and enhanced.

By 1970, growing demands on the Fund led to enactment of P.L. 91-485, which increased the L&WCF again to a $300 million annual level from FY 1971 through FY 1989. This amendment reveals that Congress' perception of needs for the Fund program had expanded in three ways: the State grant program should give more emphasis to urban parks and recreation areas; the grant program should help acquire and develop recreation facilities within urban areas, not just nearby; and the Federal side of the Fund program should also contribute to meeting close-to-home recreation needs.

At present, OCS funds account for 85% of all credits to the fund, if authorized but unappropriated balances are counted. Looking at actual L&WCF appropriations through fiscal 1989, OCS revenues account for 71% ($5.1 billion out of $7.2 billion). Fifteen percent have come from sales of Federal surplus property, which is another type of revenue generated by sales of fixed assets. So the idea of resource reinvestment has worked, and worked well. The petroleum industry can take credit for the fact that its entrepreneurship in offshore drilling has helped to acquire over 5 million acres in Federal, State, and local parks and conservation areas and to develop over 25,000 community and State recreation facilities, even if it didn't originate the idea of dedicating leasing and royalty revenues (not taxes) to conservation.

The Fund's increase in authorized funding to its current level came with enactment of P.L. 95-42 in June 1977, which increased the L&WCF to $900 million for FY 1978 and subsequent years. In that year, unappropriated balance on the Fund was less than $100 million and stayed below the billion dollar mark until 1981 when it started to mount up and state requests for funding went largely unmet. In FY 1990 there was over $7.2 billion available by unappropriated balance in the L&WCF. This represents a 700% rise in the balance in just 10 years.

Since 1965, funding for the grants program has averaged approximately $125 million per year. Recently the annual appropriations have been below this average: FY 1988 and 1989 appropriations totalled less than $17 million each year. The appropriations authority under L&WCF Act was extended by Congress through 2015. At the present rate the unappropriated balance will be $23 billion by the time the law "sunsets." That figure does not take into consideration interest on these funds.

In 1977, Congress also enacted P.L. 95-625, which created, among other things, the Urban Park and Recreation Recovery Program (UPARR), as a complement to the L&WCF program. This program encouraged local governments to rehabilitate existing recreation facilities, demonstrate innovative programs, and plan for overall revitalization of community recreation systems. There have been no appropriations for this program since 1984.

In 1986, Congress, in passing the Emergency Wetlands Resources Act, added a requirement that SCORPs specifically address wetlands issues, needs and priorities. In 1987-88 all States and Territories addressed wetlands in addenda to their SCORP's.

AMERICAN HERITAGE TRUST INVOLVEMENT

The size of the unappropriated balance is seen by many in the recreation and conservation communities as an unfulfilled promise. They point to the bipartisan support for increasing funding authorizations between 1968 and 1975 that was supposed to reflect increased commitment to outdoor recreation. Then they note that current annual funding is below the average for the 1970's, in nominal dollars, without adjusting for inflation. This unfulfilled promise has been the driving force in the establishment of an interest-bearing $1 billion trust fund for recreation. The American Heritage Trust introduced in several congresses has obtained more than 220 co-sponsors in the House and 42 in the Senate. The primary cause of such Congressional support has been the issue that funds set aside for recreation from the OCS royalties have not been used for that purpose. If an interest-paying trust fund were established, the $7.2 billion unappropriated "credit" to the Fund would at least provide a base for $500-$600 million in annual revenue.

FLORIDA SUMMARY AND ACCOMPLISHMENTS

Since 1964 the State of Florida has used $60 million in grants to acquire more than 68,000 acres of land. Florida also used over $32.1 million in development grants to fund 132 projects. The total number of projects for the state in the last 25 years is 257.

Twenty-five years ago, Florida used $2.2 million in L&WCF assistance to purchase a tract of land (then valued at only $9 million) known as "Cape Florida." It was later named Bill Baggs Cape Florida State Recreation Area which was the State's first L&WCF project.

Bill Baggs Cape Florida was also the first state park located within the Miami metropolitan area, the most populated urban area in the State. Located on Key Biscayne and possessing both natural and historic qualities, Bill Baggs Cape Florida State Recreation Area is part of a large barrier island consisting of beach and dunes, as well as beautiful native vegetation and the historic Cape Florida

Lighthouse built in 1826. Located on one of the oldest named places in the United States, Key Biscayne, named by Ponce de Leon in 1513, the Cape Florida Lighthouse is the oldest building in South Florida. Some of the activities at this site include: picnicking, year-round swimming, fishing, boating, nature trails, camping, and historical and archeological sites. Today this L&WCF project is conservatively estimated to be valued at over $50 million.

ALABAMA SUMMARY AND ACCOMPLISHMENTS

Since 1964 the State of Alabama has received more than $833,000 in planning funds. It has used $5.8 million in acquisition funds to acquire more than 10,000 acres of land and over $44.1 million in grants to fund 580 development projects. The total number of projects for the state in the last 25 years is 640.

Looking over the past 25 years since the enactment of the L&WCF program's enabling legislation, the first grant awarded to Alabama was for the construction of an 825-foot fishing pier at Gulf State Park, which today remains one of the State's most attractive and visited Fund-assisted recreation areas.

Since 1966, a total of 6 grants in excess of $1.7 million has been awarded for the development and acquisition of additional land at Gulf State Park. Now encompassing over 6,000 acres with two and one-half miles of prime beach front, the park is known for its outstanding resort/convention complex with its many amenities, beach pavilions, and a fishing pier.

Off the beach and secluded beneath moss-draped live oaks and stately southern pines are other recreation facilities and activities, including an 18-hole golf course, modern campgrounds, cottages, picnic areas, tennis courts, and a freshwater marina for the enjoyment of residents and non-residents alike. Here is but one of the many excellent examples of the recreation benefits realized by Alabama as a result of the L&WCF program.

MISSISSIPPI SUMMARY OF ACCOMPLISHMENTS

Since 1964 the State of Mississippi has received more than $659,000 in planning funds. It has used $4.0 million in acquisition grants to acquire more than 16,300 acres of land and over $32.3 million in development grants for 399 development projects. The total number of projects for the state in the last 25 years is 439.

The first L&WCF project, approved 25 years ago, was Roosevelt State Park. Subsequently, Roosevelt State Park received 9 other L&WCF grants for a total of $726,762 in Fund assistance to date. Roosevelt State Park is only 35 miles from the Jackson metropolitan area and therefore is very heavily used for day use and overnight stays as well as longer vacation periods. It has become an invaluable recreation asset for the citizens of Mississippi and contains a full range of recreation development.

Other projects considered to have had the most impact on recreation development and enjoyment in Mississippi throughout the history of the Fund are:

- The complete rejuvenation of the State Park system whereby 24 State Parks were practically reconstructed with L&WCF assistance.
- The development of the Pearl River Basin Water Park system which extends from north central Mississippi to the Gulf Coast along the Pearl River. Seventeen parks were developed over a fifteen year period in strategic locations on the Pearl River, providing camping, fishing, and float trips for thousands of recreationers each year.
- The Pat Harrison Waterway District developed six large water parks located in south central and southern Mississippi that provide fishing, boating, camping, active and passive recreation, cabins, and several water oriented facilities such as pools, wave pools, and large water slides.

LOUISIANA SUMMARY OF ACCOMPLISHMENTS

Since 1964 the State of Louisiana has received more than $327,000 in planning funds. It has used $14.9 million in grants to acquire more than 73,400 acres of land. Louisiana also used over $42.2 million for 477 development projects. The total number of projects for the state in the last 25 years is 581.

To single out individual projects as exemplary is difficult because, to a town without any recreation facilities, even a small park is special. The wide range of funded projects in the State included acquisition of wetlands, handicapped accessible trails, fishing piers, swimming pools, basketball courts and ballfields, boat ramps, camping and picnicking facilities, and playgrounds.

Many of the 767 L&WCF projects approved thus far are the only public recreation facilities in small towns and, in many cases, the only public recreation facilities in the entire parish. The L&WCF grants are not a luxury in Louisiana. They serve as the bread and butter of park and recreation. The fact that Louisiana has set a high priority on local outdoor recreation opportunities is evidenced by the fact that more than 85% of the L&WCF monies to date have been committed to local park acquisition and construction projects. This is particularly important now, when open space is becoming a premium commodity.

A significant accomplishment has been the opportunity to establish the Louisiana Park Trust Fund which allows all royalties, leases and revenues generated from State Park lands developed or acquired with L&WCF funds to be retained by the Office of State Parks for further acquisition of State and local recreation lands and facilities. Although the fund has not reached the envisioned $100 million ceiling, in a State noted for its mineral wealth, the opportunity still exists.

TEXAS SUMMARY OF ACCOMPLISHMENTS

Since 1964 the State of Texas has received more than $1.1 million in planning funds. It has used $35.9 million in grants to acquire more than 31,000 acres of land. Texas also used over $95.6 million in grants for 792 development projects. The total number of projects for the state in the last 25 years is 891.

Two of the earliest projects that reflect the shoreline nature of the projects that have emanated from the Gulf states were Mustang Island State Park and Armand Bayou Regional Park. The Mustang Island State Park in 1971 used $2.18 million in Fund's monies for the "seashore park site" acquiring 3,965 acres, 6 miles east of Corpus Christi. The State Park is devoted to beach activities such as swimming, surfing, fishing, picnicking, and camping. The interesting feature of this site is that it was financed by a State of Texas Park Bond Issue of 1967 for $75 million.

The Armand Bayou Regional Park was approved in 1974 as a three stage acquisition of 1,203 acres located 25 miles southeast of Houston adjacent to the LBJ Manned Space Craft Center. Using $2.67 million in Federal Funds the Bayou was described as "one of the last natural watersheds in the gulf coast." The "plan" for the Park "would place major emphasis on preserving the natural resources." "Hiking and biking trails, picnic areas, sports, and boating facilities would be the only improvement on the land."

One of the more recent and interesting projects would be the $304,587 spent in Brazoria County to complete its 40-acre regional park in 1989. Brazos River Regional Park, directly on the Gulf of Mexico, has a variety of recreation facilities including a group pavilion with restrooms, an observation tower, playgrounds, 40 picnic tables with grills, a 1-mile trail, a fish cleaning area, 2 picnic pavilions, and support facilities. In this grant, the County's matching share was realized through the donation of the land for the park.

Cameron County received four L&WCF grants and is nearing completion of a master development plan for the 143-acre Isla Blanca Park, on South Padre Island. A total of $768,785 in L&WCF assistance was used to develop large and small shade pavilions, hiking trails, playgrounds, picnic areas, beach improvements, tent and RV campsites, and support facilities necessary to accommodate the influx of vacationers from all areas of the United States, Canada and Mexico. Isla Blanca Park is a popular vacation area for retired citizens living in northern states and Canada. In a unique way, the County's matching share for these grants has been realized primarily through the issuance of certificates of obligation, which are repaid through park revenues.

GULF STATES SUMMARY OF WETLANDS, BEACHES, AND DEVELOPMENT

Since the mid-1960's the region has gained a substantial amount of acreage in two of the most important, and in some ways regionally unique, types of land features it offers--wetlands and beaches.

While the figures we have compiled since the program began are not as "hard" as I would like to use, I can say that I am confident that each state in the region has benefited substantially from the fund in both areas. Below is the information compiled by state in these three different areas:

State	Wetlands (acres)	Beaches (acres)	Development (in $000s)
Florida	36,289	6,051	$171,288
Alabama	638	307	$ 3,032
Mississippi	2,383	367	$ 3,545
Louisiana	24,941	0	$ 14,740
Texas	49,856	3,698	$ 26,385
GULFWIDE	114,107	10,423	$218,990

THE LEGACIES OF THE L&WCF

From an historical perspective, the L&WCF has contributed significantly to the outdoor recreation estate in this region and all across the country over its 25 years of existence. With grants ranging from several thousand dollars for picnic areas to millions for new State park lands and facilities, the L&WCF has had broad impact on outdoor America. Significant also is that a considerable amount of the income going to the Fund has come about through the leasing of offshore oil rights, thus recycling an important natural resource back to public use. While one resource is being used another is being protected.

It is important to note that, in addition to the large number of projects, L&WCF grants have had substantial long-term effects on our overall attitudes and policies toward outdoor recreation. The first legacy of this kind is the notion, basic to the L&WCF Act, that States must assume a leadership role as providers of recreation opportunities. Today, there is clear evidence that the grant program has been successful in encouraging States to take greater responsibility for the protection and development of recreation resources at every level.

The results of State leadership extend beyond simple increases in the size and number of recreation areas. Among other things, they include State actions to establish their own scenic river and recreational trail systems, to recognize the value of recreation resources in stimulating tourism and other economic opportunities, and to provide additional financial and technical assistance to local recreation efforts through State planning, grant, and loan programs. Maryland, for example, has its Program Open Space to acquire key parklands; Texas and Minnesota have dedicated portions of their cigarette taxes to support state and local recreation programs; New Jersey has a Green Acres program that provides loans as well as grants for local acquisition, rehabilitation and development. This legacy extends to the present. In 1988, Californians approved the largest State bond issue in American history, $775 million, for parks and recreation. And California is only one of many states that continue to provide leadership.

Second, when the Fund was established, State recreation planning was essentially non-existent. Statewide recreation planning has come a long way in 25 years, and has given States and their citizens new tools to analyze recreation needs and alternatives in a systematic and responsive way. Indeed, many states now require that local governments develop recreation plans as a condition for any type of Federal or State recreation assistance.

A 1976 amendment to the L&WCF Act, which requires Governors to certify public participation in the SCORP process led to development of the Open Project Selection Process (OPSP) now used by each State to link plan-defined priorities with actual selection of L&WCF projects for funding. These processes ensure that all eligible applicants for L&WCF assistance are aware of the availability of grants and understand the application procedures. By increasing public awareness of the links between State planning and real projects, OPSPs have increased involvement in State recreation policy by citizens at all levels.

The third legacy, and the one with the greatest impact on long-term protection of recreation resources, is the provision of Section 6(f)(3) of the Act that requires all property acquired or developed with L&WCF assistance be maintained perpetually in public outdoor recreation use. Consistent enforcement over the years has ensured permanency of L&WCF's contributions to the national recreation estate. The most tangible evidence of the program in future years will be the tens of thousands of recreation sites across the country that remain available for our children and our grandchildren.

In conclusion, the Land and Water Conservation Fund program is building a permanent legacy for future generations. The source of this legacy will not always be obvious to the thousands of Americans who want places to hike in the woods, play ball, play with their pets, swim in a pool or sit under a tree. But the recreation lands and opportunities supplied and protected by the Land and Water Conservation Fund Act will remain as perpetual monuments to the foresight of its authors and the American people.

Mr. Samuel L. Hall graduated from the University of Houston with a B.S. in political science in 1963. For the past 24 years, Mr. Hall has worked for the U.S. Department of the Interior with the Bureau of Land Management and the Bureau of Outdoor

Recreation and its successor agencies. Currently, he is Chief, Division of Recreation Grants, National Park Service, responsible for administering the L&WCF program as well as the UPARR and Rails to Trails grant programs.

LAND AND WATER CONSERVATION FUND - IMPACT ON AMERICA'S NATIONAL PARKS AND SEASHORES

Mr. Willis P. Kriz
National Park Service
Land Resources Division

The National Park System is composed of more than 350 units designated as national parks, monuments, historic sites, battlefields, seashores, parkways, preserves, recreation areas and several other categories. Included are large, well-known areas readily associated with the National Park System (System), such as Yellowstone, Grand Canyon, and Mount Ranier National Parks, but the System also includes numerous areas not generally thought of in connection with Federal parks: The Statue of Liberty, Independence Hall and the White House, to name but a few.

The System began with the creation by Congress in 1872 of Yellowstone National Park. Sequoia, Yosemite, Crater Lake, Mesa Verde, Glacier, Rocky Mountain, Lassen Volcanic, and other national parks were established in ensuing years. The Antiquities Act of 1906 authorized the President, at his discretion, "to declare by public proclamation historic landmarks, historic and prehistoric structures and other objects of historic or scientific interests" situated on lands owned or controlled by the United States to be national monuments. By 1916, 20 such monuments had been proclaimed, and the need for a separate bureau to administer and coordinate policies and plans for the national parks and monuments had become widely recognized. Accordingly, Congress passed and on August 25, 1916, President Woodrow Wilson signed an act to create the National Park Service. The act provided that "the service thus established shall promote and regulate the use of the Federal areas known as national parks, monuments, and reservations hereinafter specified by such means and measures as conform to the fundamental purpose of the said parks, monuments, and reservations, which purpose is to conserve the scenery and the natural and historic objects and the wildlife therein and to provide for the enjoyment of the same in such manner and by such means as will leave them unimpaired for the enjoyment of future generations" (39 Stat. 535).

The System continued to grow at a modest pace until it reached approximately 200 units by 1960. Beginning in 1961, however, with the authorization of Cape Cod National Seashore, and the authorization of Assateaque, Padre Island, and Point Reyes National Seashores in the following year, expansion of the System began to accelerate. In contrast to most pre-1961 units, which were established primarily from the Public Domain or were acquired and donated by States, the new units encompassed substantial acreages of privately owned land. These units could be developed and opened to the public only after sufficient private lands were acquired to create a manageable unit. Obtaining the funds to pay for the acquisition was difficult, however, because there were competing demands for funding for construction and operation. Thus, in October 1964, the Congress enacted legislation to create the Land and Water Conservation Fund (L&WCF) to provide separate funding for the acquisition of land. Since enactment of the L&WCF, over $2.5 billion have been appropriated to the National Park Service. The money has been used to acquire approximately 86,000 individual parcels of land containing 1,668,000 acres (Table 4.1). The System now totals 80 million acres. The acreage acquired with L&WCF constitutes only a small portion of the total, but in terms of importance to public access and resource protection, that acreage is indispensable.

National Park Service land acquisitions with the L&WCF have had major impacts on national park development and enhancement in all Gulf States except Alabama. In Florida over 600,000 acres have been acquired with over $200 million in L&WCF money. Expansions at Big Cypress National Preserve and Everglades National Park in southwest Florida have been the major beneficiaries. Over 29,000 acres of barrier islands and coastal wetlands along the coast of northwest Florida and coastal Mississippi were acquired with L&WCF appropriations upon the creation of Gulf Islands National Seashore. More than 9,000 acres acquired with $23 million of L&WCF appropriations in coastal Louisiana made the establishment of Jean Lafitte National Historical Park and Preserve a reality. In Texas, most of the 130,000 acres of barrier islands acquired by the National Park Service in establishing Padre Island National Seashore, were

Table 4.1. National Park Service, Purchases by Fiscal Year, Land and Water Conservation Fund.

Fiscal Year	Appropriated	Obligated	Tracts	Acres
1965	$ 4,805,000	$ 1,458,043	83	729
1966	21,367,023	6,386,198	91	3,974
1967	20,189,980	29,863,121	1,391	52,671
1968	32,528,163	29,889,502	2,077	58,522
1969	52,958,100	50,138,206	3,115	98,355
1970	58,370,560	57,662,101	3,805	70,540
1971	96,516,300	68,347,330	1,563	44,651
1972	68,030,000	54,902,553	2,868	68,499
1973	76,789,000	53,231,508	2,127	49,643
1974	910,000	76,826,215	3,924	86,227
1975	80,154,000	73,930,859	3,030	75,412
1976	105,784,000	114,992,318	5,360	149,246
1977	253,304,000	197,607,546	15,847	218,245
1978	367,150,000	386,948,697	17,047	260,555
1979	253,673,000	249,474,342	14,496	122,167
1980	152,928,000	132,224,769	4,205	53,702
1981	65,657,951	102,704,816	701	18,185
1982	123,200,000	75,607,561	494	18,061
1983	86,505,000	104,137,769	299	13,285
1984	122,500,000	109,820,491	723	14,369
1985	125,682,000	78,420,539	660	27,051
1986	6,943,600	80,604,976	583	73,689
1987	109,757,000	61,855,446	362	17,645
1988	40,763,000	65,427,890	587	43,577
1989	52,609,000	50,049,641	390	29,029
1990	67,245,953	55,027,423	277	15,348
1991	103,567,000	0	0	0
Total	$2,549,887,630	$2,367,539,860	85,828	1,668,029

supported with appropriations from the L&WCF. In total over 120 linear miles of Gulf of Mexico beaches, and many thousands of acres of Gulf coastal wetlands, have come under the jurisdiction and stewardship of the National Park Service with money generated through offshore leasing in the Gulf of Mexico.

Mr. Willis P. Kriz is the Chief of the Land Resources Division of the National Park Service, a position he has held for the last 11 years. Among other things, he is responsible for the acquisition of land for the National Park System. He is a Nebraska native and a graduate of the University of Nebraska. He began his Federal career with the U.S. Army Corps of Engineers 31 years ago in Omaha. He moved on to the Park Service 6 years later and has held positions in the San Francisco Service Center; Point Reyes National Seashore in California; and Regional Headquarters of the Western and Southeast Regions. His entire career has been in land acquisition. He was awarded the 1989 Cornelius Amory Pugsley Medal by the American Scenic and Historic Preservation Society for noteworthy advancement of parks at the national level.

LAND AND WATER CONSERVATION FUND - IMPACT ON NATIONAL WILDLIFE REFUGES AND ENDANGERED SPECIES

Mr. Villere C. Reggio, Jr.
Minerals Management Service
Gulf of Mexico OCS Region,
Mr. Larry Coe,
and
Mr. Clyde Schnack
U.S. Fish and Wildlife Service

The Land and Water Conservation Fund (L&WCF) has had a significant impact on the conservation and preservation of wildlife, especially migratory waterfowl and endangered species, both nationally and in the five Gulf States. Nationally, the growth and expansion of about 200 units of the 477-unit National Wildlife Refuge System have been directly affected through the acquisition of approximately 735,000 acres of refuge lands with over $428 million from the L&WCF since 1967. Over 218,000 acres have been purchased with $166 million from the L&WCF on 50 refuges established primarily for the survival and recovery of endangered species.

In the 5 Gulf States 256,000 acres have been acquired with $215 million of L&WCF money on 37 national wildlife refuges (Table 4.2), several of which were established to protect endangered species with critical habitat located in the Gulf region (Table 4.3). Almost two-thirds of the 256,000 acres acquired by the U.S Fish and Wildlife Service with L&WCF money between 1967 and 1989 in the 5 Gulf States constitute wetlands and include 25 miles of coastal beaches (Table 4.4). All of the national wildlife refuges are open to the public and most refuges provide consumptive (hunting and fishing) and non-consumptive recreational opportunities. All refuges offer exceptional environmental education opportunities. The L&WCF-purchased refuge lands, now permanently dedicated to America's conservation estate, are an enduring public benefit directly tied to Outer Continental Shelf leasing and production in the Gulf of Mexico.

The tables submitted by Mr. Larry Coe from the Southwest Regional Office of the U.S. Fish and Wildlife Service detail the L&WCF accomplishments by State and by refuge for States bordering the Gulf of Mexico, and provide specific information on accomplishments by endangered species and selected habitat types. Information on national accomplishments was provided to Minerals Management Service (MMS) by Mr. Clyde Schnack from the Realty Division at Fish and Wildlife Service headquarters. The overview was written and presented by Mr. Villere Reggio, Jr., of MMS, Gulf of Mexico OCS Region.

Mr. Villere C. Reggio, Jr., is an Outdoor Recreation Planner with the Minerals Management Service Gulf of Mexico OCS Region. His responsibilities include research, assessment, and reporting on the interrelationship of the OCS oil and gas program with the recreational elements of the marine and coastal environment throughout the Gulf of Mexico region.

Table 4.2. L&WCF Acquisition in Gulf States, 1967-1990.

Project	Total Acres	Land Cost
ALABAMA		
Watercress Darter National Wildlife Refuge (NWR)	7.10	$ 36,150
Wheeler NWR	121.54	149,700
Blowing Wind Cave NWR	264.00	575,000
Bon Secour NWR	3,917.12	18,576,120
Eufaula NWR	24.19	80,000
Fern Cave NWR	199.23	110,000
6 Refuges	4,533.18	$19,526,970
FLORIDA		
Crocodile Lake NWR	4,165.10	$11,131,110
St. Johns NWR	6,254.95	2,878,323
Florida Panther NWR	24,310.04	10,232,916
Great White Heron NWR	5,091.24	2,758,327
National Key Deer NWR	7,311.85	18,778,803
Lower Suwanee NWR	41,488.77	9,699,560
Cedar Keys NWR	543.00	718,690
Crystal River NWR	46.34	978,600
Ding Darling NWR	54.58	94,550
Hobe Sound NWR	3.72	18,000
Lake Woodruff NWR	23.00	38,970
Pine Island NWR	373.07	1,034,000
Pinellas NWR	14.55	18,000
St. Marks NWR	569.00	185,000
Chassahowitzka NWR	241.93	183,000
15 Refuges	90,491.14	$58,747,849
LOUISIANA		
Lacassine NWR	848.00	$ 559,100
Lake Ophelia NWR	9,414.24	2,618,651
Atchafalaya NWR	15,255.23	11,065,618
Bayou Sauvage NWR	18,000.00	7,750,000
Bogue Chitto NWR	23,187.67	9,966,494
Tensas River NWR	3,125.99	3,358,110
6 Refuges	69,831.13	$35,317,973

(continued)

Table 4.2. L&WCF Acquisition in Gulf States, 1967-1990 (continued).

Project	Total Acres	Land Cost
MISSISSIPPI		
Mississippi Sandhill Crane NWR	17,908.96	$21,033,651
Panther Swamp NWR	3.70	25,000
Bogue Chitto NWR	6,808.08	6,441,836
St. Catherine Creek NWR	6,511.00	2,604,400
4 Refuges	31,231.74	$30,104,887
TEXAS		
Atwater's Prairie Chicken NWR	5,350.88	$ 4,050,949
Anahuac NWR	3,640.85	1,255,226
Aransas NWR	11,502.01	13,500,000
Lower Rio Grande Valley NWR	37,469.33	38,732,190
San Bernard NWR	2,445.74	14,000,000
Santa Ana NWR	69.41	179,750
6 Refuges	60,478.22	$71,718,127
GRAND TOTAL--37 Refuges	256,565.41	$215,415,806

Table 4.3. Endangered Species Refuges in Gulf States Acquired with L&WCF Funds.

Project	Total Acres	Land Cost
Aransas NWR (whooping crane), TX	11,502.01	$13,500,000
Atwater's Prairie Chicken NWR, TX	5,350.88	4,050,949
Blowing Cave NWR (gray bat), AL	264.00	575,000
Crocodile Lake NWR (American crocodile), FL	4,165.10	11,131,110
Crystal River NWR (W. Indian manatee), FL	46.34	978,600
Fern Cave NWR (gray bat), AL	199.23	110,000
Florida Panther NWR, FL	24,310.04	10,232,916
Great White Heron NWR, FL	5,091.24	2,758,327
Mississippi Sandhill Crane NWR, MS	17,908.96	21,033,651
National Key Deer NWR, FL	7,311.85	18,778,803
St. Johns NWR (dusky seaside sparrow), FL	6,254.95	2,878,323
Watercress Darter NWR, AL	7.10	36,150
Totals	82,411.70	$86,063,829

NOTE: The Gulf States refuges in general also provide habitat for other threatened or endangered species such as the bald eagle, American peregrine falcon, red-cockaded woodpecker, Alabama beach mouse, brown pelican, eastern indigo snake, Key Largo wood rat, Schaus swallow-tail butterfly, and the Key tree-cactus, to name but a few.

Table 4.4. Acres of Wetlands and Miles of Beach Acquired with L&WCF Funds.

State	Total Acres Acquired	Wetland Acres[1]	Miles of Beach[2]
Alabama	4,533	1,718	3
Florida	90,491	54,392	7
Louisiana	69,831	59,356	0
Mississippi	31,232	28,543	0
Texas	60,478	19,294	15
Totals	256,565	163,303	25

[1] Estimated
[2] Indicates miles of sandy, recreation-type beaches

LAND AND WATER CONSERVATION FUND - ACQUISITION IN THE FOREST SERVICE SOUTHERN REGION

Mr. Lawrence W. Braddock
U.S. Department of Agriculture
Forest Service
Southern Region

The Land and Water Conservation Fund Act (L&WCF) purchases, in the Southern Region of the U.S. Department of Agriculture (USDA) Forest Service, have acquired for the American public approximately 475,000 acres of outstanding recreation valued lands (Table 4.5). Diversity and variety best describe these lands, which are located in such diverse locations as the highlands of the Smoky Mountains in North Carolina and Tennessee, and the swamplands of northern Florida.

The National Forests in the Eastern United States were primarily formed from lands acquired from private landowners, and in many of those in the South, only half of the lands inside the Forest boundaries are federally owned. The L&WCF purchases have consolidated much of this scattered ownership pattern, resulting in a greatly expanded land base for the enjoyment of a wide variety of developed and dispersed recreation activities. In the South, these lands are the equivalent of a new National Forest, larger in size than the Ocala National Forest in Florida.

The first parcel of land acquired under the authority of the L&WCF Act of September 3, 1964, was the 307-acre Hazard Mill property located adjacent to the South Fork of the Shenandoah River. Purchased for $59,000, this tract became a part of the George Washington National Forest in Virginia, on October 15, 1965. The first recreation area developed on L&WCF acquired lands was also on this tract, when the Hazard Mill Campground was opened for use in late 1966.

Not far to the south from Hazard Mill, the 8,500-acre Hidden Valley property was purchased on November 3, 1965, for $325,000 (about $38 per acre). Also located in the George Washington National Forest, this tract included six miles of frontage on the Jackson River. Included in this purchase was "Warwickton," a brick, two-story house with four interior end chimneys. This National Register of Historic Places dwelling was built in 1858 by Judge James Woods Warwick, a grandson of Jacob Warwick, one of the first settlers in this part of Virginia.

In north Georgia within the Chattahoochee National Forest, a 1967 purchase from the Jacks River Game and Fish Preserve acquired 3,610 acres. Now 2,190 acres of this tract along the Jacks River form a key

Table 4.5. Region 8 Summary, Lands Acquired with Money from Land and Water Conservation Fund Act of 1965.

State	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	Acres Acquired To Date[1]
ALABAMA	43	--	--	20	64	24	27	69	80	3,963	11,197
Arkansas	762	40	--	--	247	200	--	1,554	10,104	8,113	38,158
FLORIDA	55	--	--	--	--	--	95	5	22,117	1,122	41,934
Georgia	--	144	155	--	--	--	--	--	94	23	59,913
Kentucky	646	181	195	825	--	366	[2]24,605	1,288	1,343	1,111	37,990
LOUISIANA	--	--	--	--	--	--	--	--	85	101	1,569
MISSISSIPPI	--	--	--	--	--	--	--	--	--	--	1,104
N. Carolina	40,583	72	1,510	24	1,393	797	871	1,301	1,442	7,260	85,805
Oklahoma	--	--	--	--	--	--	--	160	--	--	11,934
S. Carolina	1	--	--	--	--	--	--	--	340	--	6,559
Tennessee	--	1,766	6	56	857	457	160	378	276	1,100	19,558
TEXAS	39	--	--	--	--	--	--	--	32	--	7,370
Virginia	2,261	364	782	2,060	763	1,498	1,159	5,332	574	1,164	151,014
W. Virginia	--	--	--	--	--	--	--	21	--	--	400
Puerto Rico	--	--	--	--	--	--	--	--	--	--	--
Totals	44,390	2,567	2,648	2,985	3,324	3,342	6,917	10,113	35,487	23,957	474,505
GULF STATES TOTAL											63,174

[1]As of September 30, 1990
[2]4,424 of this acreage is in Mineral Interests (Greenwood Land & Mining Company)

part of the Cohutta Wilderness. Other important L&WCF purchases of private lands have also occurred within the Leatherwood Wilderness in Arkansas, the Clifty Wilderness in Kentucky, and the Beartown Wilderness in Virginia.

The Chattooga Wild and Scenic River, one of the first rivers to be so designated, has several adjacent tracts of lands acquired with L&WCF funds. Located in the States of Georgia, North Carolina, and South Carolina, the Chattooga is not only a favorite of white-water boaters and trout fishermen, but also hikers and horseback riding enthusiasts.

The Appalachian Trail (A/T), a 2,000 mile footpath from Maine to Georgia, was designated a National Scenic Trail on October 2, 1968. Numerous parcels of land have been or are in the process of being acquired on the Chattahoochee, Cherokee, Nantahala, Pisgah, Jefferson, and George Washington National Forests. One of the most scenic of the tracts, acquired in the vicinity of the A/T, is the Hump Mountain tract within both the Cherokee and Pisgah National Forests.

The Highlands of the Roan lie along the backbone of the Smoky Mountains of the Southern Appalachians. This area contains the most extensive area of mountain balds of any location in the Appalachians. Distinctive vegetation and breathtaking, panoramic views characterize this eastern high-country scenic area. The initial federal acquisition was in the 1930's, with L&WCF purchases in the 1970's and continuing in the 1980's.

The Red River Gorge is within the Daniel Boone National Forest in Kentucky. Sandstone arches, rugged cliffs, and peaceful valleys beckon to visitors today, just as they did to Daniel Boone years ago. Numerous L&WCF purchases in the past few years have added significant lands to this outstanding recreational attraction, which also includes the Clifty Wilderness.

Established in 1966, the Mt. Rogers National Recreation Area of the Jefferson National Forest in southwestern Virginia has been greatly enhanced by a large number of L&WCF acquisitions. Extensive recreational use of these lands has been made for recreation developments, hiking and horseback trails, and a multitude of other dispersed recreation pursuits.

Water-oriented recreational lands have been purchased in a number of the southern States. In the national forests of Texas, three reservoirs constructed in the 1960's have been national hot-spots for large-mouth bass fishermen. Key access lands to these surface water giants, Lake Conroe (24,000 acres), San Rayburn Reservoir (114,000 acres), and Toledo Bend Reservoir (181,000 acres), have been acquired with the L&WCF funds.

The newest recreation complex in the Southern Region is the Clear Creek Recreation Area in Alabama, which is located on the Bankhead National Forest next to picturesque Lewis Smith Reservoir. This complex consists of a 125-unit campground, with water and electrical hookups, a picnic ground, a swimming site, and a boat launching site, which are interconnected by 4 miles of hiking and bicycling trails. Constructed partially on lands purchased with L&WCF Funds, this state-of-the-art development is one of the finest in the Nation.

The Ocala National Forest in Central Florida has several enormous, clear, sparkling water springs, each flowing millions of gallons of 72° water per day. One of these, the Salt Springs, along with 10,032 acres, was acquired on February 29, 1979. Not only is this land a sub-tropical paradise for recreational activities, but it is also the home of many water habitat loving birds, such as the osprey. During FY 90, the 512-acre Silver Glen Springs tract was also added to the Ocala.

North of the Ocala River, on the Osceola National Forest, a series of L&WCF purchases are underway to acquire 50,000 acres of remote swamplands, which will unite the existing federal ownership lands of the Osceola National Forest and the Okefenokee National Wildlife Refuge. Home to a diverse variety of wildlife, such as the alligator, white-tail deer, black bear, the endangered red-cockaded woodpecker, and hopefully, in the near future, the reintroduced Florida panther, about 25,000 acres have already been acquired, with the remainder scheduled in the next few years.

These are just a few examples of the magnificent scenic and recreational lands that have been acquired for the use and enjoyment of, not only residents of the South, but for everyone in this great nation of ours. Purchase of lands such as these probably would not have occurred were it not for the money made available by the L&WCF, and in turn, most of the dollars in the L&WCF would not be available were it not for the 90% of the revenues from Outer Continental Shelf leases.

As we begin this 27th year of the L&WCF Act, we are proud of our past accomplishments, but we realize much work remains. A recently completed inventory of privately owned surface inholdings within our 74 units of the National Wilderness Preservation System, indicated that 23 of the wildernesses contained 73 separate private tracts totaling 6.6 thousand acres, and valued at 4.7 million dollars. Examples of other purchase needs exist in other outstanding areas, such as Saline Bayou Wild and Scenic River in Louisiana, Black Creek Wild and Scenic River in Mississippi, Sipsey Fork Wild and Scenic River in Alabama, and Pinhook Swamp in Florida.

We are confident this 27th year will be successful in making available more outstanding recreational lands for the American people, and we look forward to the continued participation that Outer Continental Shelf leasing makes to this critical program.

Mr. Lawrence W. (Bud) Braddock is the Director of Recreation for the Southern Region (R-8) of the USDA Forest Service, headquartered in Atlanta, Georgia. Prior to his current assignment, he was Forest Supervisor of the National Forests in Mississippi from March 1985 until February 1989. During his 28 years with the Forest Service, Mr. Braddock has served in a variety of positions in two Forest Service Regions, including two Job Corps Centers, three National Forest Supervisors' Offices, and eight Ranger Districts.

HISTORIC PRESERVATION FUND - IMPACT ON HISTORIC AND CULTURAL RESOURCES

Mr. Stephen Newman
National Park Service
Preservation Assistance Division

INCEPTION

Beginnings

The National Historic Preservation Act grant programs arise from an interesting history. Federal preservation actions began with natural rather than historic areas: the establishment of Yellowstone National Park in 1872. During the Civil War years, the Government acquired two buildings which are now maintained as historical sites by the National Park Service: Arlington Cemetery and Ford's Theater. The first Federal project in historic preservation was in the Southwest, where commercial looting imperiled the archeological ruins of Indian cliff dwellings and pueblos. A petition to protect these sites was presented to Congress in 1882, but not until seven years later was money appropriated to protect the Casa Grande ruin in Arizona and to preserve the surrounding land.

In the 1890's, increasing protests against the continued vandalizing of archeological sites resulted in passage of the Antiquities Act of 1906. This Act provided penalties for destroying or damaging any historic or prehistoric ruin on public lands and authorized the President to set aside historical places, landmarks and structures as well as other lands of significant natural and scientific value. Thus, for example, Mesa Verde National Park was established as a monument in 1906.

In 1916, Congress authorized the creation of the National Park Service, giving it responsibility for the care and protection of historical natural parks. During its 74-year history, the Service has acquired and maintained a variety of historic buildings, monuments, and sites that are in Federal possession.

The Historic Sites Act of 1935 declared a national policy of historic preservation. It authorized the Secretary of the Interior to initiate a number of preservation programs. A common element for each of the programs was the requirement that all property involved must be of national significance. The National Trust for Historic Preservation in the United States was charted in 1949 with a private sector role in preservation. Its purposes are to facilitate public participation in the preservation of significant historic properties and antiquities, and to receive donations of properties that would otherwise be bequeathed to the Federal Government.

CONCEPT

The National Historic Preservation Act

The grant assistance phase of the Federal historic preservation effort began with Public Law 89-665, the National Historic Preservation Act of 1966. This Act was the first major step to encourage both public and private historic preservation activities, and to support the Federal commitment with a multi-year authorization of funds. The Act recognized the importance of preserving properties of State and local significance, as well as national significance. The House Report (No. 1916) stressed the significance of the legislation: "Notwithstanding the progress which has been made with regard to historic preservation, most existing Federal programs and criteria for preservation are limited to natural and historical properties determined to be 'nationally significant.' Only a limited number of properties meet this standard. Many others which are worthy of protection because of their historical, architectural, or cultural significance at the community, State or regional level have little protection given to them against the force of the wrecking ball. Some of them are not even known outside a small circle of specialists. It is important that many of these be brought to light and that attention be focused on their significance whenever proposals are made in, for instance, the urban renewal field or the public roads program or for the construction of Federal projects or of projects under Federal license that may lead to their destruction...."

Recipients

The 1966 Act was the first major step to encourage both public and private historic preservation activities and to support that commitment with a funding mechanism. Beginning with fiscal year 1968, the Department of the Interior has made matching grants to the 50 States, the District of Columbia, Puerto Rico, the Virgin Islands, Guam, American Samoa, the Trust Territory of the Pacific Islands (since 1986 directly to the Republic of the Marshall Islands, the Federated States of Micronesia, and the Republic of Palau), and to the National Trust for Historic Preservation.

Involvement by Third Parties

States may delegate work responsibilities and funds to third parties through subgrants and contracts. Third parties may be public or private organizations, individuals, universities, or governmental subdivisions. Federal agencies or properties may not receive funds. Survey, inventory, and protection activities may be delegated. Subgrants for restoration can be awarded to all property owners except Federal owners. Tax Act review responsibilities cannot be delegated.

One difference from the L&WCF program, this appropriation is not "no-year" money. Funds may not be reprogrammed after the second year of apportionment.

RELATIONSHIP OF THE HISTORIC PRESERVATION FUND AND OCS OIL AND GAS LEASING

In 1976, amendments to the L&WCF Act created the Historic Preservation Fund (HPF). The HPF was established from revenues due and payable under the Outer Continental Shelf Lands Act. Patterned after the L&WCF, the use of royalties from offshore oil leasing revenues is "recycled" to finance historic and cultural resources.

From 1967 to 1990, almost $474 million have been appropriated for grants to States, beginning in 1978 about $397 million charged to the Fund. Amounts to the Gulf States (through 1990) total: Alabama - $8.9 M; Florida - $11 M; Louisiana - $7.5 M; Mississippi - $6.4 M; Texas - $12.2 M.

Distribution Formula

The Secretary of the Interior determines each participant's share of funds based on an administrative formula. For a number of years the formula was distributed 30% divided equally; 20% divided by population; 50% allocated on the basis of past expenditures. For FY 91, approximately $28 million will be allocated: 89% divided based on a 3-year average of each State's prior allocations; 11% based on a proportion of each State's population and land area to that of all States. A separate "set aside" is allocated to the Pacific Nations and American Samoa.

PURPOSES

Legislative Objectives

The 1966 Act was substantially amended by the National Historic Preservation Amendments of 1980. This legislation reauthorized the HPF through 1987 (later extended to 1992) at a $150 million annual level. It provides a role for local governments through certification at the State and Federal level, and specifies Federal agency responsibilities with regard to historic preservation programs. It revises the structure of the Advisory Council on Historic Preservation.

The 1980 Amendments specify the following requirements (among others):

Citation	Requirements
101b1A	The State program must provide for the appointment by the Governor of a State

Historic Preservation Officer (SHPO) to administer the program.

101b1A The program must provide for the employment or appointment by the SHPO of such qualified staff as may be necessary.

101b1B The program must provide for an adequate and qualified State historic preservation review board designated by the SHPO unless otherwise provided for by State law.

101b1C The program must provide for public participation, including the process of recommending properties for nomination to the National Register.

101b2 The Secretary must determine no less than once every four years whether State programs conform with provisions the Act.

101b3A The SHPO must, in cooperation Federal and State agencies, local governments, and private organizations and individuals, conduct a comprehensive statewide survey of historic properties and maintain inventories of such properties.

101b3B The SHPO must identify and nominate eligible properties to the National Register of Historic Places and administer applications for listing properties on the National Register.

101b3C The SHPO must prepare and implement a comprehensive statewide historic preservation plan.

101b3D The SHPO must administer the State program of Federal assistance for historic resources within the State. (This includes Development as well as Acquisition of historic properties.)

101b3E The SHPO must advise and assist Federal and State agencies and local governments in carrying out their historic preservation responsibilities.

101b3F The SHPO must cooperate with the Secretary, the Advisory Council, Federal and State agencies, local governments, organizations, and individuals to ensure that historic properties are taken into consideration at all levels of planning and development.

101b3G The SHPO must provide public information, education, and training and technical assistance relating to the Federal and State historic preservation programs.

101c1 The SHPO must develop certified local historic preservation programs and assist local governments in becoming certified, and transfer 10% of the HPF allocation to Certified Local Governments.

101d3A The Secretary may provide direct grants for demonstration projects, to minority groups, and other purposes. (In FY 1990, $500,000 was earmarked for direct grants to Indian tribes.)

NATIONAL ACCOMPLISHMENTS

The National Register

The Act authorizes the Department of the Interior to expand and maintain a National Register of Historic Places. The Register today is maintained by the National Park Service; it is a computerized listing of properties that have been nominated and accepted as having historic, architectural, engineering, archeological, or cultural significance, at the national, State, or local level.

The State Historic Preservation Officer

The Act establishes detailed responsibilities of SHPO's, the State officials who administer the NHP program at the State level. Each SHPO is responsible for surveying to identify historic properties, developing a statewide plan for preservation, providing technical assistance to Federal, State, and local agencies and the public, helping local governments become certified to participate in the program, and other activities.

State Review Boards

The Act requires that each program maintain a State Review Board. In the words of the Committee Report for the 1980 Amendments to the Act, Review Boards "function primarily as professional bodies which can objectively evaluate the historic significance of properties and provide professional advice on historic preservation matters." Specific duties of Review Boards are stipulated in regulations. They are to have at least these duties: (1) Review nominations to the National Register and recommend to the SHPO as to whether the property meets the criteria for listing; (2) Participate in appeals to nominations or failures to nominate; and (3) Review and advise on the Comprehensive Historic Preservation Plan and the annual grant application.

Certified Local Governments

The Act provides for the certification of local governments whose historic preservation programs meet prescribed standards, making them eligible for grants-in-aid and technical assistance from the SHPO. Ten percent of each State's annual grants must be transferred to such certified local governments.

Advisory Council on Historic Preservation

The Act creates the Advisory Council on Historic Preservation, an independent agency responsible for advising the President and Congress on historic preservation matters, conducting studies relating to preservation, reviewing Federal agency programs, and reviewing and commenting on agency actions that may affect historic properties. The Council's review process, carried out in cooperation with Federal agencies and SHPOs, is referred to as "the Section 106 process."

Federal Agency Responsibilities

The Act directs Federal agencies to name "Agency Preservation Officers" to coordinate their historic preservation activities, to seek ways to carry out their activities in accordance with the purposes of the Act, to identify historic properties under their jurisdiction, to consider such properties when planning actions that might affect them and to give the Advisory Council an opportunity to comment on such actions, and to document historic properties that cannot be preserved.

Grants-in-Aid

The Act establishes a program of matching grants-in-aid by which the National Park Service assists States and Territories. Grants are used to identify, evaluate, register, or protect historic and archeological resources.

The Secretary of the Interior's Standards and Guidelines for Archeology and Historic Preservation was first published in 1983. The *Standards and Guidelines* are divided into several parts, each dealing with a different aspect of preservation.

The *Standards and Guidelines for Preservation Planning* outlines ways to plan for the protection of historic properties and to establish ways to decide which such properties are worth preserving at the expense of others.

The *Standards and Guidelines for Identification* deals with field surveys, background research, and other methods used to identify properties that might be historic.

The *Standards and Guidelines for Evaluation* outlines ways to evaluate properties to determine whether they are historically significant.

The *Standards and Guidelines for Registration* deals with systems for the formal registration of historic properties in the National Register of Historic Places and in equivalent registers maintained by other governments.

The *Standards and Guidelines for Documentation* addresses how historic properties should be recorded; they are particularly useful when a property must be destroyed or significantly altered, and it is desirable to keep a record of its original appearance, nature, or contents. This portion of the *Standards and Guidelines* is subdivided into Standards and Guidelines for Historical Documentation, Architectural and Engineering Documentation, and Archeological Documentation--the last often called archeological data recovery, salvage archeology, or rescue archeology.

The *Standards for Historic Preservation Projects* are the measures against which acquisition, stabilization, rehabilitation, restoration, and reconstruction projects are measured. These Standards were published by themselves several years before the overall *Standards and Guidelines*, and were integrated into the comprehensive document when it was published in 1983. They are also available as a separate publication, with additional guidance detail.

The *Professional Personnel Standards* outlines the minimum qualifications an individual should have in order to practice one of the "core" preservation disciplines--history, archeology, architecture, architectural history, and historical architecture.

BICENTENNIAL LIGHTHOUSE FUND - $3 MILLION

Congress appropriated $1 million from the HPF in each of fiscal years 1988, 1989, and 1990 to establish a "Bicentennial Lighthouse Fund" in commemoration of the 1789 Lighthouse Act. The appropriation act provided that matching funds be allocated in the same manner and under the same operating requirements as "regular" HPF grants. There was one notable exception. For the first time, States could choose to use some of their funding to assist properties in Federal ownership, and without matching share, Federal owners--the Coast Guard, the Fish and Wildlife Service, the National Park Service itself--are among the governmental and non-profit owners of the 958 contributing resources listed in or officially determined eligible for listing in the National Register of Historic Places in 33 States and (one site in) the Federated States of Micronesia.

The total $3 million appropriation was used for survey and nomination costs directly related to lighthouses and river lights, for preconstruction plans and studies, and for construction work on listed lighthouses and river lights. Some States used the funds to undertake thorough investigations of the extent of the deterioration of numerous lighthouses and to help save some structures from further deterioration. A very positive result of this earmark has been the execution of preservation covenants between the SHPO and property owner whereby the owner agrees to maintain the property for a term of years as a condition of receiving the grant assistance. These covenants help by being an "insurance marker" of sorts against vandalism. The agreements also work to make the resources more visible to the local community and thus to generate post-grant support. The Gulf States projects were as shown in Table 4.6.

TAX INCENTIVES FOR REHABILITATING HISTORIC BUILDINGS

The HPF grants help support SHPO staff who provide "front line" technical assistance and initial review and recommendations for certification of rehabilitations proposed for Federal income tax incentives. These incentives continue to be one of the most successful urban revitalization tools implemented by law. From 1977 through 1989, nearly 21,000 rehabilitation historic buildings have been certified by the National Park Service to qualify for these tax credits. The projects have brought renewed life to business and residential districts, have resulted in new jobs, have increased local and State revenues, and have provided new, high quality housing for families of all income levels. Housing projects account for about half of all four historic rehabilitation projects. Over 100,000 housing units in historic buildings, of which about 17,000 were for low and moderate income units and 51,000 were newly created units, have been assisted through tax incentives.

Since the inception of the tax incentive program in 1976, nearly 21,000 projects, representing an investment of almost $14 billion, have been certified. In the Gulf States for 1989 alone:

State	Certifications of Significance	Certified Rehabilitations	Investment ($ millions)
Alabama	15	18	$ 9.75
Florida	45	37	21.23
Louisiana	40	22	17.98
Mississippi	7	7	0.53
Texas	12	21	10.50
National Total	1,010	994	$927.15

LEGACIES OF THE HPF

Since passage of the 1966 Act, we have witnessed an increasingly strong public interest in and support for historic preservation. The American public has demonstrated growing recognition of the importance of historical, architectural, and archeological values in improving the quality of life in our cities, towns, and rural communities. The public's concern has moved from a narrow interest in individual historic buildings to the need to preserve the sense of identity of America's communities.

In the State historic preservation offices, the SHPOs carry out the National historic preservation program at the State and local level in accordance with standards and regulations published by the Department of the Interior. Historic preservation programs operate in 59 jurisdictions, including 3 Micronesian governments now in Free Association with the United States. Over 500 Certified Local Governments now participate in the program under State auspices.

Far more than just a cooperative program among different levels of government, this program succeeds largely because of the degree to which it stimulates and facilitates citizen initiative and private investment in the goal of preserving our national patrimony. Just one facet of its work, the program of Federal Tax Incentives for Historic Rehabilitation,

Table 4.6. The Gulf States Projects.

State	Site Name and Location	Federal Share
Alabama	1872 Light Keeper's House (Fort Morgan), Baldwin County	$ 10,000
	Light Keeper's House, Phase II, Baldwin County	10,000
	1876 Lighthouse at Mobile Point, Baldwin County	10,000
Florida	Cape Florida Lighthouse Preservation Plan, Key Biscayne, Dade County	$ 15,000
	Ponce de Leon Inlet Oil House, Ponce Inlet, Volusia County	9,814
	Key West Lighthouse, Key West, Monroe County	18,318
	Cape Florida Lighthouse, Phase II, Key Biscayne	30,000
	St. Augustine Lightkeeper's Quarters, St. Johns County	9,000
	Key West Lighthouse Keeper's Quarters, Phase II, Key West	27,395
	Key West Lighthouse, Phase III	22,475
	St. Augustine Light Tower, St. Johns County	15,414
	St. August Light Keeper's House, St. Johns County	2,500
Louisiana	Southwest Reef Lighthouse, Berwick, St. Mary Parish	$ 10,000
	Southwest Reef, Phase II, Berwick, St. Mary Parish	16,375
	Southwest Reef, Phase III, Berwick, St. Mary Parish	14,255
Mississippi	Round Island Lighthouse, Pascagoula	$ 5,000
	Biloxi Lighthouse, Biloxi	5,000
	Round Island, Phase II, Pascagoula	9,500
	Round Island, Phase III, Pascagoula	9,500
Texas	Half Moon Reef Lighthouse, Port Lavaca	$ 580
	Planning study--historic context on Texas Gulf Coast lighthouses, 1845 to 1945	13,646
	Planning study--historic context on Texas Gulf Coast lighthouses, Phase II	11,879

(In addition, $1 million was earmarked from the HPF for a Natchez, Mississippi erosion study.)

has stimulated 21,000 historic building rehabilitations with a total value of over $14 billion.

Mr. Stephen Newman has worked in Federal assistance programs for over 22 years. He has been Chief of Grants Administration for historic preservation grants in the Department of the Interior, National Park Service, Washington, D.C. since January 1977. Prior to this he worked in field operations for the Chicago Regional Office of the Community Services Administration, the anti-poverty Agency. He received a B.A. from the University of Colorado and his M.P.A. from Roosevelt University, Chicago, Illinois.

PRIVATE PERSPECTIVE: HOW A PRIVATE CONSERVATION GROUP CAN HELP GENERATE MORE ACRES PER DOLLAR FROM THE LAND AND WATER CONSERVATION FUND

Mr. Philip G. Ellender
The Nature Conservancy
of Louisiana

THE NATURE CONSERVANCY

Founded in 1951, The Nature Conservancy (TNC) mission is to find, protect, and maintain the Earth's rare species and natural communities by preserving the lands they need to survive. The best way to say who we are is to say who we are not -- we are not an "anti" organization. We work with businesses within the free enterprise system. We are a science and data driven organization. The TNC's accomplishments can be capsulated in the 5.5+ million acres protected in the United States, our 1,200+ private preserves in the United States, and the millions of acres of tropical rainforest protected through country partner organizations and creative debt for nature swaps.

Across the country, and especially in Louisiana, these "protected acres" would not have been possible without the oil and gas industry. In Louisiana the industry includes Amoco, ARCO, Exxon, Freeport McMoRan, LL&E, Mobil, and Texaco. Additionally, the new President and CEO of TNC is John Sawhill, a former Deputy Secretary of the U.S. Department of the Energy and former President/CEO of the U.S. Synthetic Fuels Corporation.

People tend to generalize that if you work for a conservation organization you naturally align against industry. The TNC believes that working together, instead of pitted against one another, our world's conservation goals can be met. There is no such thing as "white hats and black hats;" in reality we all wear "gray hats."

HOW CAN A PRIVATE CONSERVATION GROUP GENERATE MORE ACRES PER DOLLAR FROM THE L&WCF?

Simply put, we drive hard bargains. Non-profit organizations, like TNC, are often successful in obtaining donations and bargain sales. Our ability to be more flexible and promote tax benefits more aggressively allows us to demonstrate to individuals and corporations financial justification for the donation or bargain sale of a piece of property.

According to the U.S. General Accounting Office (9-11-81) between the years 1965 and 1980, 4.5% of federal land acquisitions were done by non-profit organizations. The fair market value of these acquisitions was $162,061,516. After the acquisition and holding expenses of non-profits, the federal cost of acquiring them was $114,055,161 - a savings in excess of over $50 million to the taxpayer.

More recent and specific to TNC, between the years 1979 and 1988, TNC has acquired property with a fair market value of approximately $200 million for the Federal Government. The approximate cost to the federal agencies was $180 million. A $20 million savings to the taxpayer.

Other services that the non-profits provide to the agencies include:

- solving complex title problems;
- ability to move quickly;
- holding prices in a rapidly appreciating market (not true in Louisiana today!);
- acquiring land where there is antipathy toward the Government; and
- solve authorizing legislation constraints.

To the individual citizen or private corporation, TNC relieves the landowner of holding cost, management expense, and can often generate sizable favorable publicity.

EXAMPLES OF PROJECTS DONE BY TNC USING L&WCF FUNDS IN THE GULF COAST STATES

As mentioned earlier, according to a 5-year average (1983-1988) 88.3% of all deposits into L&WCF come from Outer Continental Shelf (OCS) leasing rentals, bonuses, and royalties. The primary fuel for federal conservation has been and is currently OCS production -- it makes sense as one resource is being depleted you conserve another.

Let's run through a few TNC projects in the Gulf Coast region of the United States financed by L&WCF-OCS dollars. I will start with Louisiana, for good reason: (1) I am biased toward Louisiana--the state possesses the greatest "natural wealth" in the entire country; and (2) between the years 1953 and 1987 the OCS off Louisiana's coast produced 92% of all OCS oil and 89% of all OCS gas in the United States (despite the fact that Louisiana has received only 3% of the appropriated dollars from the L&WCF).

Louisiana

In Louisiana one of L&WCF's more recent appropriations was to Lake Ophelia and Grand Cote National Wildlife Refuges in Avoyelles Parish.

Demonstrating TNC's ability to move quickly, we acquired a priority site for the North American Waterfowl Plan for $2.1 million with about a 3-week notice. Monies from the L&WCF are currently reimbursing TNC for this project.

Texas

In Texas, TNC pre-acquired Matagorda Island for the U.S. Fish and Wildlife Service at a cost of $13 million. The 11,502-acre island is one of two remaining undeveloped barrier islands off the coast of Texas. It is the winter home or rest stop for over 250 species of birds including the whooping crane, peregrine falcon, and brown pelican.

Another Texas TNC project financed by L&WCF is Zamora Bend. The 400-acre Zamora nearly encircles the Rio Grande River. Key wildlife protected through this project includes the ocelot.

Alabama

Ruffner Mountain in Alabama is a 600-acre forested woodland within the city limits of Birmingham. Its trails and education programs have opened a world of nature to the inner city population. Ruffner is not an untouched wilderness but is the last undeveloped section of the Red Mountain Ridge.

Mississippi

In Mississippi, Clark Creek Natural Area started as a 427-acre gift of land to TNC from a private company. The gift was used to match L&WCF money to add an additional 166 acres. The area is now managed by the Mississippi Department of Wildlife, Fisheries, and Parks.

Florida

In Florida, the West Indian Manatee finds its home in the Crystal River. The TNC acquired the refuge in 1983, before it was established as a National Wildlife Refuge using L&WCF dollars, which could be described as OCS money.

These are just a sampling, a small handful of cooperative projects--what a private non-profit organization, TNC, has done with the L&WCF.

Mr. Philip Ellender is the Director of Development for The Nature Conservancy in Louisiana. He is a graduate of Louisiana State University with a background in finance. For the past two years, Mr. Ellender has served as a member of the Louisiana State Mineral Board. He has also chaired the Tract Evaluation and the Wildlife and Fisheries Committees.

CONCLUSION

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

Over the past 25 years, more than $7 billion have been invested from the L&WCF in the expansion and enhancement of America's recreation and conservation estate (Table 4.7). Four-fifths of all deposits into the L&WCF have come directly from revenue generated through OCS leasing and production, most of which has occurred off the coasts of Louisiana and Texas. While yearly appropriations (Figures 4.1 and 4.2) have not kept pace with the annual L&WCF authorization of $900 million since 1978, the threat of irreversible environmental degradation has not been manifested on fish and wildlife resources or recreational activity associated with the Gulf of Mexico. It is because of, not in spite of, OCS leasing that lands along the coast of the Gulf of Mexico permanently dedicated to park and recreation use and wildlife conservation have multiplied many times during the 40 years since the advent of Federal OCS leasing.

Mr. Villere C. Reggio, Jr., is an Outdoor Recreation Planner with the Minerals Management Service Gulf of Mexico OCS Region. His responsibilities include research, assessment, and reporting on the interrelationship of the OCS oil and gas program with the recreational elements of the marine and coastal environment throughout the Gulf of Mexico region.

Table 4.7. L&WCF Authorized and Appropriated Balances, Fiscal Years 1965-1990.[1]

FY	AUTHORIZED	UNAPPROPRIATED BAL. AVAILABLE	FEDERAL LAND ACQUIS.* $(000)	STATE GRANTS ADMIN.	STATE GRANTS	RUNNING GRANT SUBTOT.	TOTAL APPROPRIATIONS
1965	$28,398	12,398	5,563	62	$10,375	$10,375	$16,000
1966	$109,717	0	38,429	1,277	$82,409	$92,784	$122,115
1967	$95,007	0	36,207	2,269	$56,531	$149,315	$95,007
1968	$112,951	0	49,093	2,518	$61,520	$210,835	$113,131
1969	$253,000	88,500	116,991	2,571	$44,938	$255,773	$164,500
1970	$200,000	157,400	66,156	3,112	$61,832	$317,605	$131,100
1971	$300,000	100,000	168,226	3,935	$185,239	$502,844	$357,400
1972	$300,000	38,500	102,187	4,313	$255,000	$757,844	$361,500
1973	$300,000	38,500	113,412	4,788	$181,800	$939,644	$300,000
1974	$300,000	262,277	5,480	4,976	$65,767	$1,005,411	$76,223
1975	$300,000	254,785	121,700	5,912	$179,880	$1,185,291	$307,492
1976	$300,000	237,799	135,587	5,660	$175,739	$1,361,030	$316,986
76TQ	$75,988	237,799	30,636	1,427	$43,925	$1,404,955	$75,988
1977	$300,000	0	356,286	6,198	$175,315	$1,580,270	$537,799
1978	$900,000	95,000	490,880	8,426	$305,694	$1,885,964	$805,000
1979	$900,000	257,975	360,776	6,647	$369,602	$2,255,566	$737,025
1980	$900,000	648,781	202,540	6,951	$299,703	$2,555,269	$509,194
1981	$900,000	1,260,188	108,282	6,566	$173,745	$2,729,014	$288,593
1982	$900,000	1,980,261	175,546	4,381	$0	$2,729,014	$179,927
1983	$900,000	2,545,168	220,093	4,381	$110,619	$2,839,633	$335,093
1984	$900,000	3,143,278	226,890	2,081	$72,919	$2,912,552	$301,890
1985	$900,000	3,756,666	213,130	1,629	$71,853	$2,984,405	$286,612
1986	$900,000	4,488,457	120,646	1,570	$45,993	$3,030,398	$168,209
1987	$900,000	5,177,831	175,656	2,270	$32,700	$3,063,098	$210,626
1988	$900,000	5,907,367	150,478	3,419	$16,567	$3,079,665	$170,464
1989	$900,000	6,601,134	186,233	3,300	$16,700	$3,096,365	$206,233
1990	$900,000	7,271,325	210,049 ***	3,260	$16,500	$3,112,865	$229,809
TOTALS	$14,675,061**	7,271,325	4,187,152	103,899	$3,112,865	$3,112,865	$7,403,916

*Includes Admin. for Fed. Land Acq.
**85% of all 'deposits' from OCS revenues
***estimate

[1] Figures based on National Park Service Budget Office Tables and estimates of FY 1990 appropriation levels.

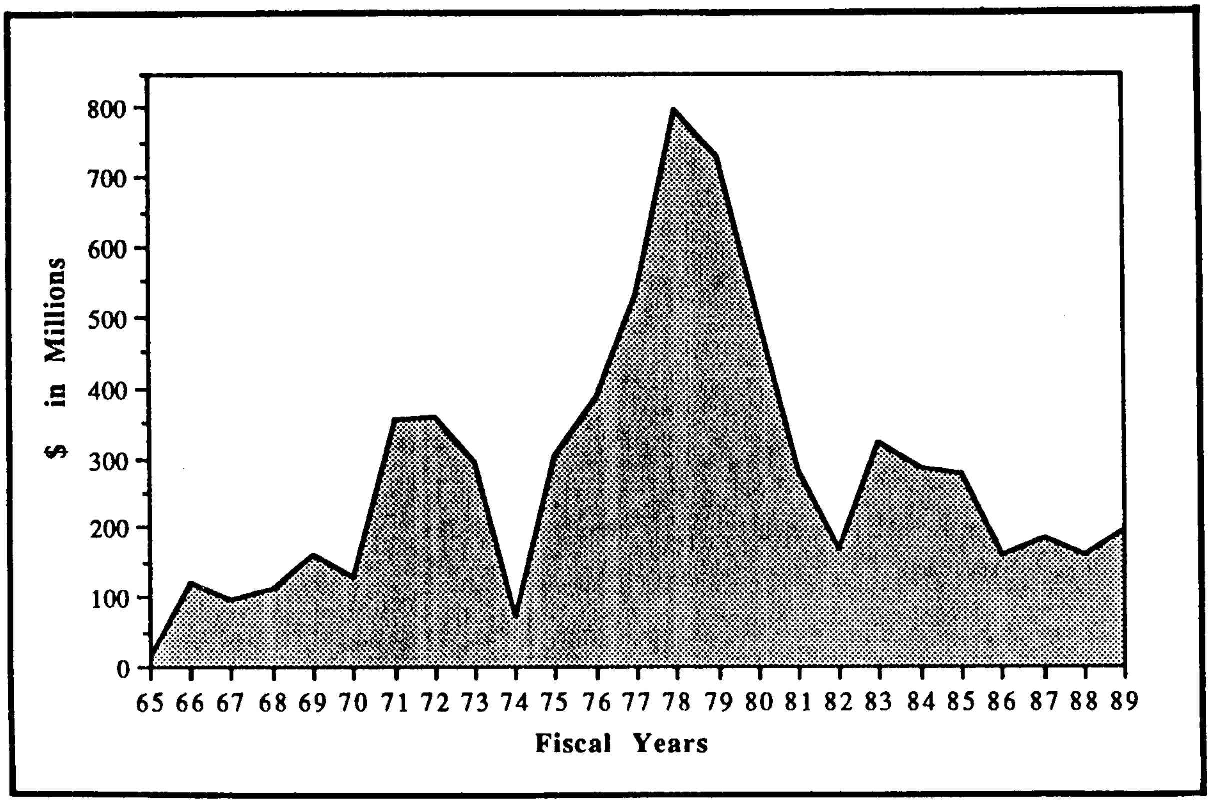


Figure 4.1. Total L&WCF appropriations, 1965-1989.

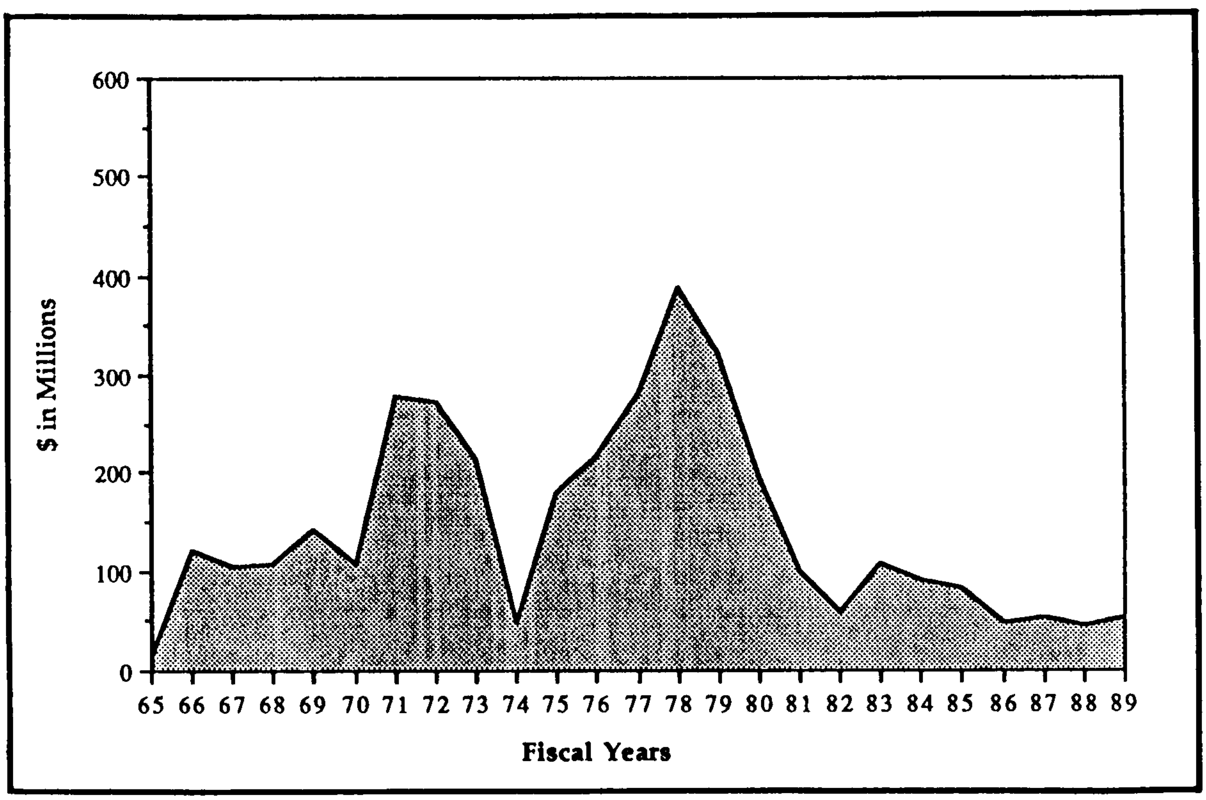


Figure 4.2. Total L&WCF appropriations, 1965-1989, annual appropriations in inflation-adjusted dollars (1965=100%).

CONTRIBUTED PAPERS: OFFSHORE MAPPING AND DEEPWATER OPERATIONS

Session: CONTRIBUTED PAPERS: OFFSHORE MAPPING AND DEEPWATER OPERATIONS

Co-Chairs: Mr. G. Ed Richardson
Ms. Susan Gaudry

Date: November 13, 1990

Presentation	Author/Affiliation
Contributed Papers: Offshore Mapping and Deepwater Operations: Session Introduction	Mr. G. Ed Richardson and Ms. Susan Gaudry Minerals Management Service Gulf of Mexico OCS Region
Update on NOAA Multi-Beam Mapping in the Gulf of Mexico	CAPT Albert E. Theberge, Jr. NOAA, National Ocean Service and CMDR Gerald B. Mills NOAA/NOS/C&GS/OMS/(N/CG224)
Implementation of the North American Datum 1983: A Progress Report	Mr. Paul H. Rogers Minerals Management Service Outer Continental Shelf Survey Group
Deepwater Geohazards and Production Structure Siting, Northern Gulf of Mexico	Mr. Kerry J. Campbell Fugro-McClelland Marine Geosciences, Inc.
Deepwater Pipeline Safety and Risk Assessment	Mr. Philip German J.P. Kenny, Inc. Houston, Texas
Extended Well Testing for Offshore Fields	Mr. Ernest T. Weaver Oceaneering Production Systems
Offshore Technology Research in Support of Deepwater Operations	Mr. John E. Flipse Distinguished Professor of Ocean Engineering Texas A&M University

CONTRIBUTED PAPERS: OFFSHORE MAPPING AND DEEPWATER OPERATIONS: SESSION INTRODUCTION

Mr. G. Ed Richardson
and
Ms. Susan Gaudry
Minerals Management Service
Gulf of Mexico OCS Region

Leasing activities in the Gulf of Mexico from 1985 to 1990 have shown a significant increase in the number of blocks acquired in water depths greater than 200 m. Figure 5.1 shows 38.5% of all leases acquired in the Central Gulf of Mexico Planning Area from 1985 to 1990 were in water depths greater than 200 m. Strikingly, 26.6% of all leases were in greater than 900 m of water. The Western Gulf of Mexico Planning Area shows similar trends with 41.6% of the leases bought from 1984 to 1989 in water depths exceeding 200 m – 21.7% of all of the leases were in water deeper than 900 m (Figure 5.2).

Data in Figures 5.3 and 5.4 show that most of the deepwater leasing activities for the interval 1985 to 1990 in both planning areas have occurred from 1987 to 1990. During the same period, the number of leases acquired in water depths of 200 m or less has remained fairly constant. Clearly leasing in the deeper water areas of the Gulf of Mexico is increasing.

As we explore for and ultimately produce hydrocarbons from the Gulf's deeper waters, innovative mapping, surveying, exploration, evaluation, and production techniques must be developed and refined. Presentations from six speakers in this session addressed some of the advancements in the deepwater arena that will bring us closer to our goal of discovering and producing hydrocarbons in a competitively economic and environmentally sound manner.

Mr. G. Ed Richardson is a Supervisory Environmental Protection Specialist with the Minerals Management Service in the Gulf of Mexico Regional Office. He has 20 years of experience with state and Federal government and with the oil and gas industry. He is currently serving in the Management Development Program. Mr. Richardson received his M.S. degree from Clemson University in microbiology, environmental health, and biochemistry.

Ms. Susan Gaudry, who is originally from the Washington, D.C. area, has almost 20 years of federal service. She started working for the Department of the Interior, Bureau of Land Management, Branch of Contract Operations in 1971, and transferred to New Orleans in 1978 where she worked in the Environmental Studies Section as a Procurement Assistant. In 1982, she was assigned to the Environmental Assessment Section and worked there as an Environmental Assessment Assistant until 1989. She currently works in the Environmental Operations Section as an Environmental Operations Assistant.

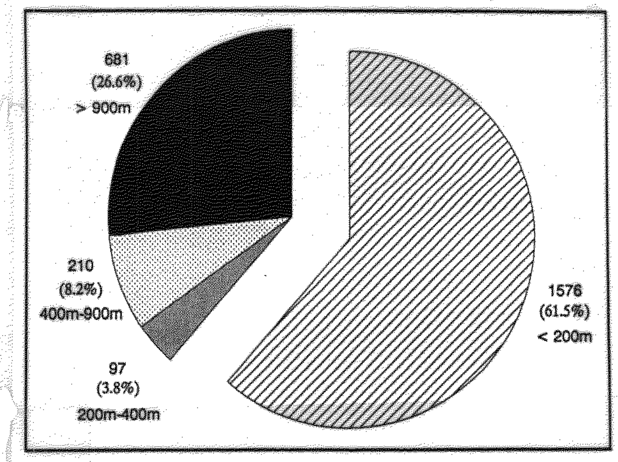


Figure 5.1. CGOM leases by water depth (sales from 1985 to 1990).

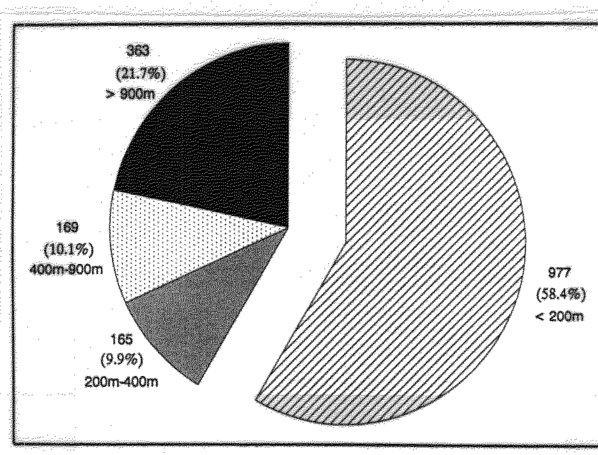


Figure 5.2. WGOM leases by water depth (sales from 1984 to 1989).

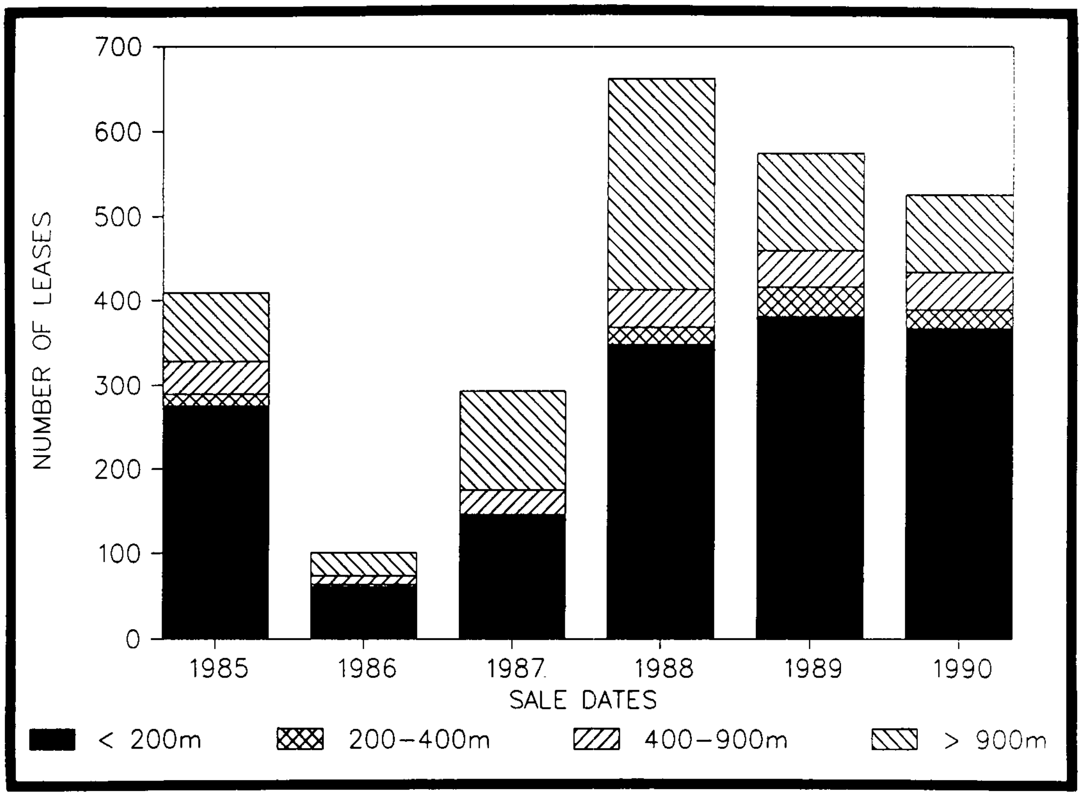


Figure 5.3. CGOM leasing by water depth categories.

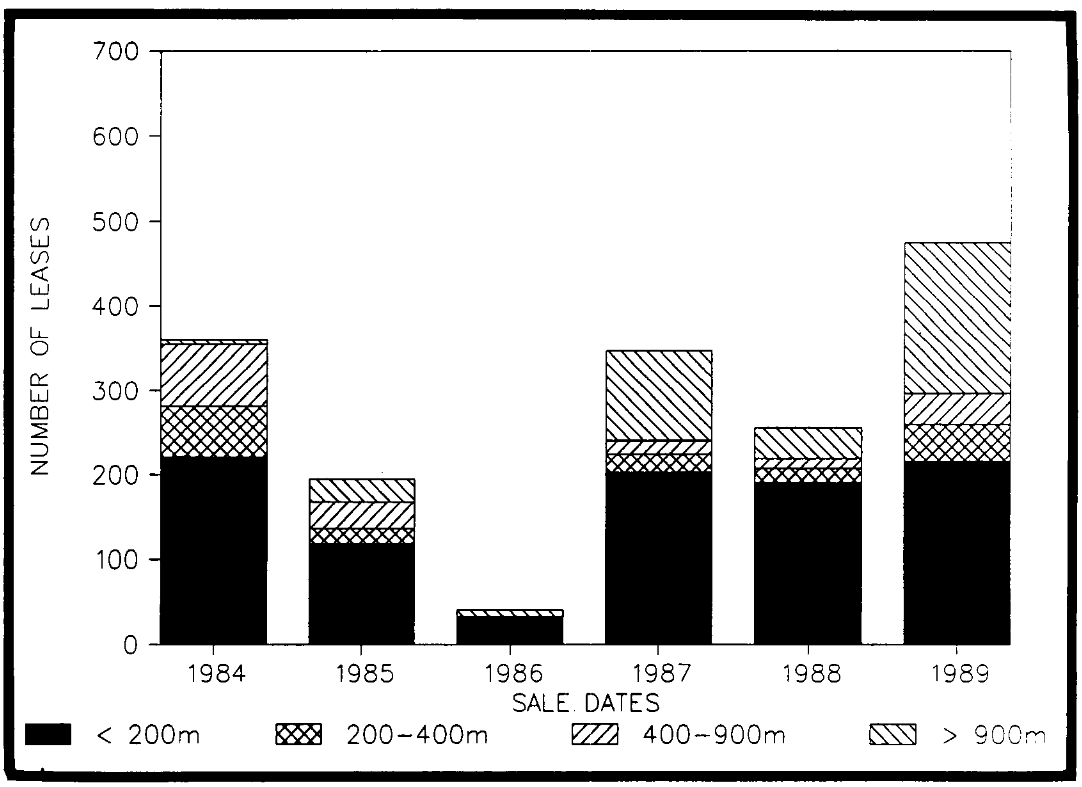


Figure 5.4. WGOM leasing by water depth categories.

UPDATE ON NOAA MULTI-BEAM MAPPING IN THE GULF OF MEXICO

CAPT Albert E. Theberge, Jr.
NOAA, National Ocean Service
and
CMDR Gerald B. Mills
NOAA/NOS/C&GS/OMS/(N/CG224)

INTRODUCTION

The National Oceanic and Atmospheric Administration (NOAA) has been systematically mapping the Gulf of Mexico since early 1988 as part of its multi-beam mapping program of the United States' Exclusive Economic Zone (EEZ). This program is managed by NOAA's Office of Charting and Geodetic Services (C&GS). Sixty surveys covering over 52,424,228 hectares (25,000 square nautical miles) have been conducted by this program using the sophisticated seafloor mapping systems Sea Beam and Hydrochart II. Unprecedented accuracy for large area bathymetric surveys has been attained by the use of satellite-based navigation systems and medium frequency navigation systems for horizontal control. Many multi-beam survey techniques and quality control methods have been developed by C&GS during this project. Large areas of the Gulf of Mexico are being imaged in great detail and many new discoveries are being made. Better management of our Gulf Coast resources and environment will result from this program.

MAPPING PROGRAM

Goals of the Gulf Coast Mapping Program

The NOAA mapping program in the Gulf Coast area addresses seven distinct goals. Attainment of these goals will help all segments of the Gulf Coast oceanic community. These goals are:

- Build the foundation of a Marine Environmental Geographic Information System for solving global and regional change problems.
- Improve targeting of scientific and engineering efforts involving higher cost geophysical investigations, manned submersible investigations and remotely operated vehicle operations.
- Better manage the living and mineral resources of the EEZ.
- Better model the physical oceanography of the Gulf of Mexico including factors affecting water mass movements, acoustic propagation paths, and sediment transport regimes.
- Model geological and geophysical hazards affecting coastal regions and offshore construction.
- Discover and/or define unique or previously unknown marine environments for designation as marine sanctuaries or protected areas.
- Improve and enhance nautical charts and bathymetric maps.

Progress and Accomplishments

The NOAA has mapped over 52,424,228 hectares (25,000 square nautical miles) off the coasts of Alabama, Mississippi, and Louisiana in the Gulf of Mexico with multi-beam sounding systems (Figure 5.5). Four maps have been published to date within this area including Mitchell Dome, Chandeleur Valley, Mitchell Basin, and Researcher Basin. Four additional maps, including Vaca Basin, Orca Basin, Pigmy Basin and Farnella Canyon, are scheduled for publication within the next 6 months. Each of these maps encompasses approximately 3,355,151 hectares (1,600 square nautical miles), contains one-half degree of latitude by one degree of longitude in extent, shows Minerals Management Service (MMS) lease block areas, and includes a three-dimensional view of the map area. All surveyed areas shown on Figure 5.5 not already published are available in preliminary black line copies. To date, NOAA has defined great domes on the upper slope southeast of the Mississippi River Passes (Figure 5.6), Flower Garden Banks Sanctuary, the upper reaches of the Mississippi Fan, large basins on the lower Texas-Louisiana slope (Figure 5.7), lineations running for tens of kilometers in the same area as the basins, and over 402 km (250 miles) of the Sigsbee Escarpment.

Mapping Methods

The NOAA, based on requests from the MMS and the United States Geological Survey, has established the strategy of surveying the Texas-Louisiana Slope from 88 west longitude to the continental shelf break off the coast of Texas as its highest mapping priority

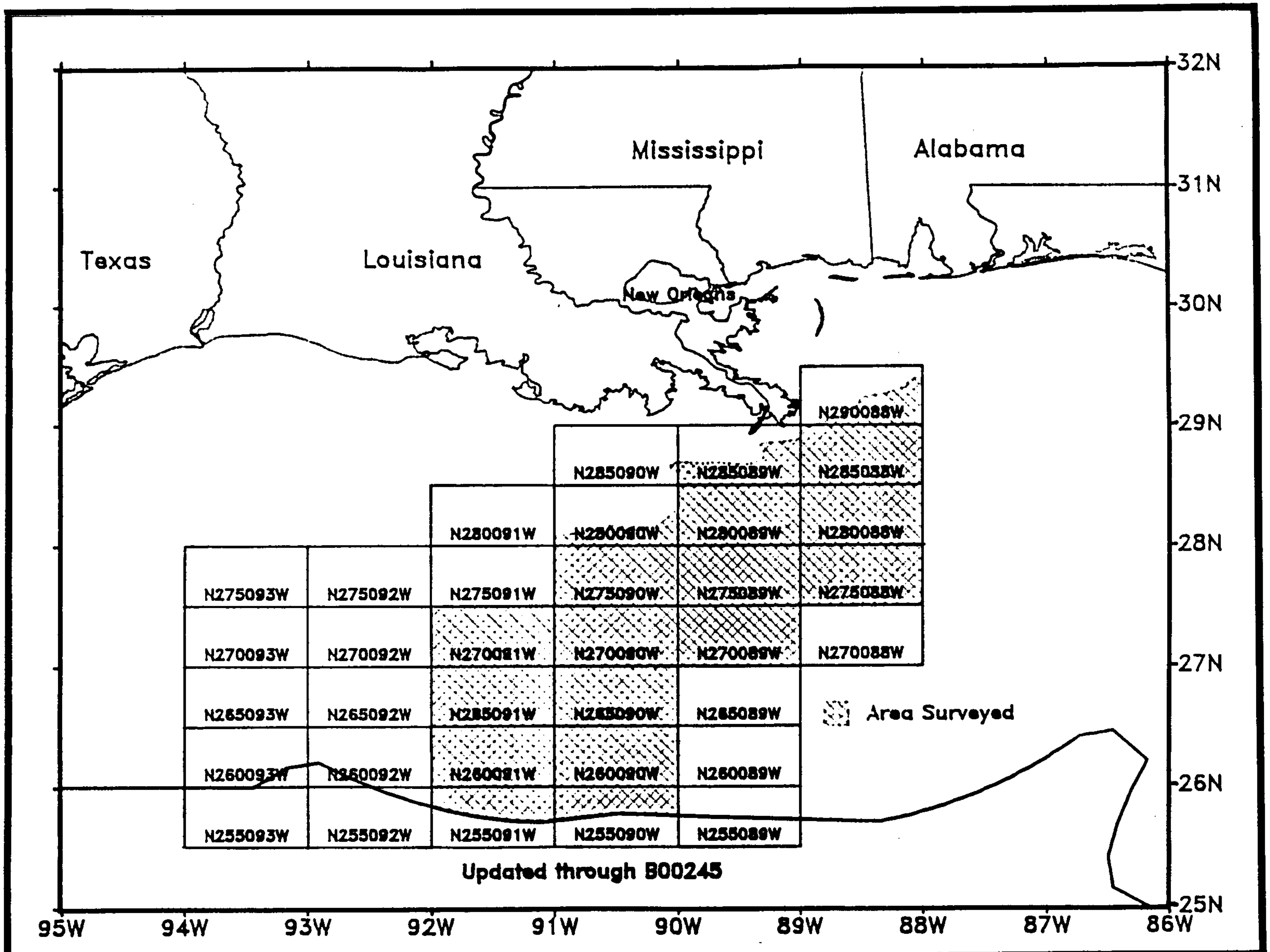


Figure 5.5. Louisiana EEZ bathymetric map index.

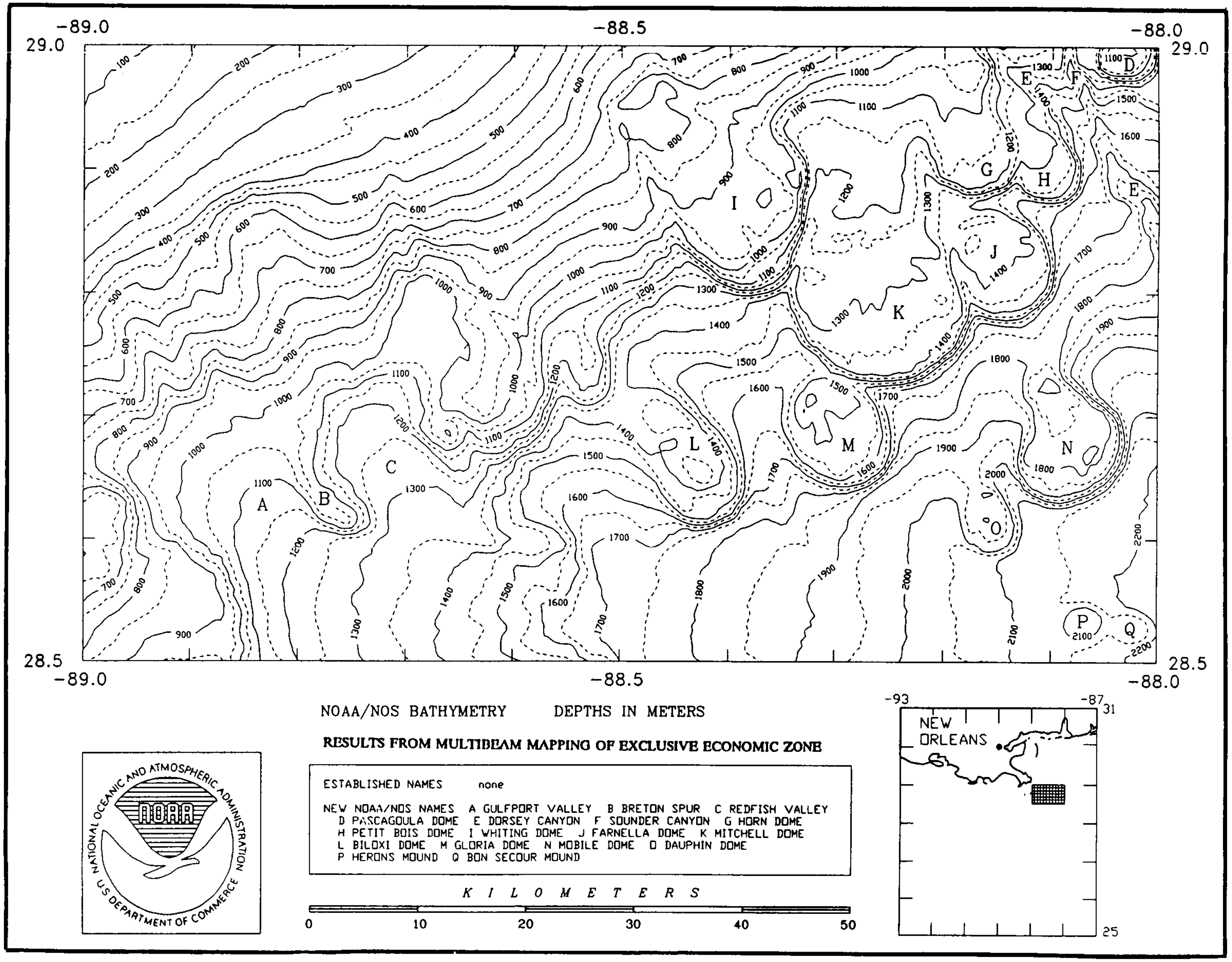


Figure 5.6. Domes on upper slope southeast of the Mississippi River Passes.

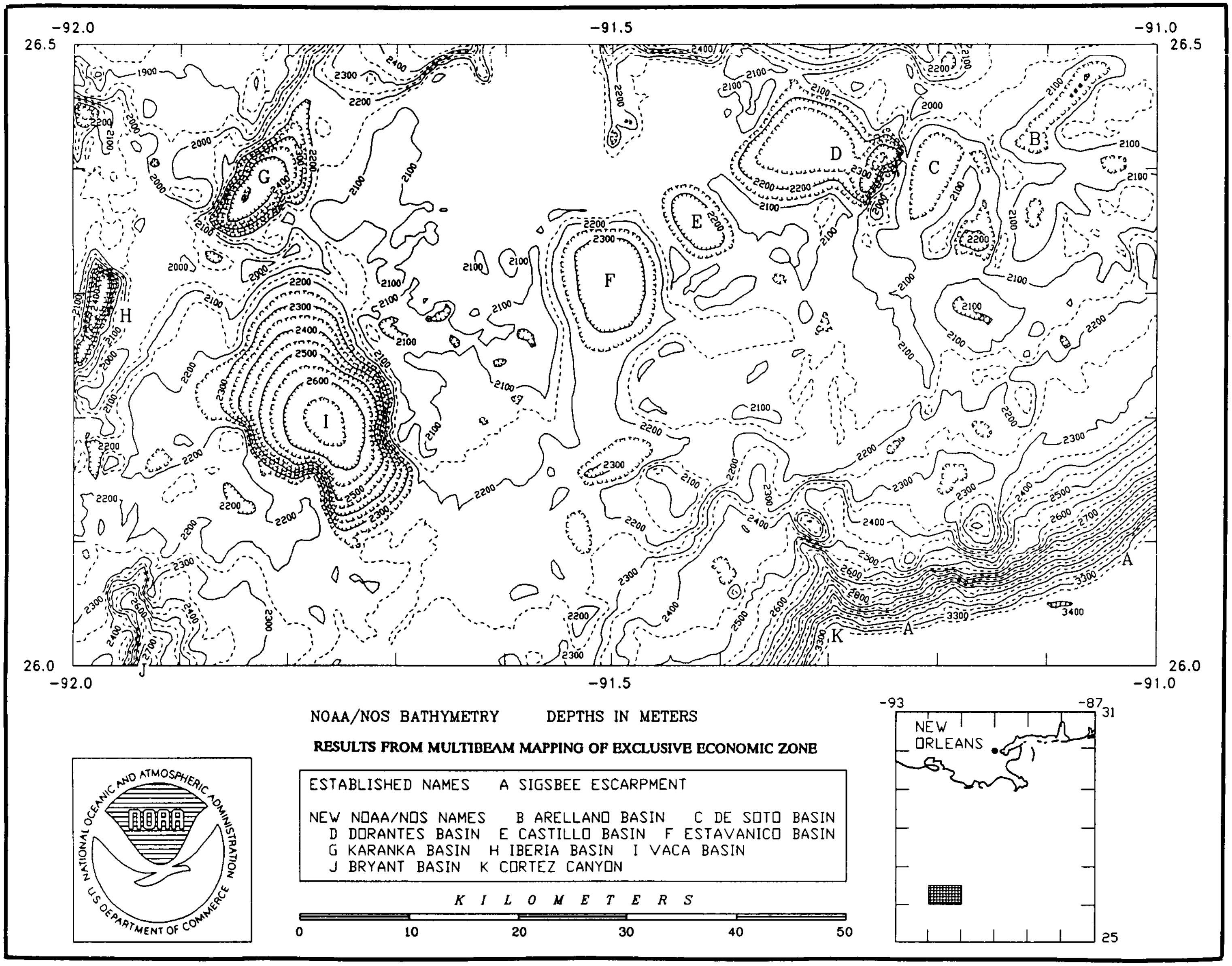


Figure 5.7. Large basins, Louisiana slope.

in the Gulf of Mexico. Surveys are being conducted between the offshore limit of the EEZ and the 150 m isobath (Figure 5.5). Following completion of this area, NOAA vessels will begin to map the area east from 88 west longitude until the entire United States portion of the EEZ in the Gulf of Mexico has been mapped. It will take approximately 4 more years of surveying to complete the entire Gulf at the present rate of progress.

The NOAA ship *Mt. Mitchell* is equipped with Sea Beam, which is a hull-mounted narrow beam, multi-beam sounding system. The NOAA uses this system in water depths between 1,000 m and full oceanic depths. The NOAA ship *Whiting* is equipped with the Hydrochart II multi-beam sounding system, which is normally used between 150 m and 1,000 m water depth. The mission of both ships during survey operations is to attain 100% bottom coverage (i.e., all of the bottom has been ensonified) of the survey area and to maintain International Hydrographic Organization standards for map accuracy. The NOAA strives to maintain navigational accuracy such that 90% of all soundings obtained during EEZ surveys have a horizontal positioning error of less than 50 m and to maintain sounding accuracies within 1% of true depth. To those ends, the John E. Chance STARFIX positioning system has been the only navigation system used by the *Mt. Mitchell* and *Whiting* while operating in the Gulf of Mexico this year. In addition to using the best navigation available in the offshore Gulf of Mexico, swath sonar alignment tests are performed and gyrocompass drift monitored to assure proper swath alignment, and sound velocity tables are periodically updated by conductivity-temperature-depth observations supplemented by daily expendable bathythermographs.

Data Processing

Shipboard data acquisition and processing is accomplished on MicroVAX mini-computers with acquisition software written by the University of Rhode Island Ocean Mapping Development Center working with NOAA's Office of NOAA Corps Operations' System Technology Division. This software allows generation of contour plots, point sounding plots, colored symbol plots, and navigation track plots; all of which aid the field unit in determining whether the data are error free. Once inspection of these various plots assures the bathymetrist of the veracity of the raw data, the ship proceeds to select statistically significant soundings from the total raw data set. This step is required because of the huge size of multi-beam sounding data sets relative to conventional hydrography. A maximum, minimum, and average depth (i.e., that observed depth which is closest to the arithmetical average) are selected for unit areas approximately 250 m on a side throughout the survey area. These representative soundings are plotted to further assure total bottom coverage prior to submitting data to Ocean Mapping Section (OMS) for verification and product generation.

Once the ship has completed its processing and review, data are submitted to OMS for verification. Verification is an independent review of the data to assure that proper procedures were followed during data acquisition, that no errors had occurred during shipboard processing, that no erroneous data had been inadvertently forwarded, and that full bottom coverage had been attained. When a survey has passed the verification stage, it is accepted into the OMS data base. The selected sounding data are then further processed to develop a 250 m XYZ UTM grid. These gridded data are used to develop contour files, three-dimensional imagery, and other specialty products.

Products

Standard National Ocean Service products developed from the gridded data include 1:100,000-scale printed maps, three-dimensional perspective and orthographic plots of each printed map, and the UTM grid on a high density floppy disk. Future products will include: full resolution sounding data (each individual sounding with its accompanying geographic position); variable color contour maps of selected areas; and electronic maps incorporating contours, Loran-C lines of position, bottom characteristics, and MMS lease block diagrams. Other possible products include such items as an atlas of imagery of scientifically interesting "type localities;" slide sets of "type localities" for students and teachers; and videos "flying" through the spectacular scenery of our continental margins. "The Gulf of Mexico," the movie, will be a very real possibility within a few short years.

New maps, blackline copies of preliminary map manuscripts, and revised editions of maps shown on indices will be reflected in the annual NOS publication of *Bathymetric Mapping Products, Catalog 5*. These new maps and copies of Catalog 5 can be ordered by addressing:

Distribution Branch (N/CG33)
National Ocean Service, NOAA
6501 Lafayette Avenue
Riverdale, Maryland 20737
Telephone 301-436-6990

Additional information about bathymetric products may be obtained by contacting:

Graphic Mapping Unit (N/CG2241)
National Ocean Service, NOAA
6001 Executive Blvd.
Rockville, MD 20852
Telephone 301-443-8855.

CAPT Albert E. Theberge, Jr. graduated from the Colorado School of Mines in 1969 with a degree in geological engineering. After a short stint in the U.S. Army, he joined the NOAA Corps. He has had assignments on the NOAA ships *Surveyor*, *Whiting*, and *Peirce* as well as having been chief of party on mobile geodetic and hydrographic crews. CAPT Theberge earned his M.S. in management from the Naval Postgraduate School in 1979. Fixed shore assignments have included project manager of the joint NOAA-DOE Geothermal Mapping Project, liaison to the Scripps Institution of Oceanography Marine Physical Laboratory, and, for the past three years, chief of NOAA's Ocean Mapping Section. At present, he is scheduled to be the Commanding Officer of the NOAA ship *Mt. Mitchell* conducting Seabeam surveys in the Gulf of Mexico.

CMDR Gerald B. Mills graduated from Washington State University in 1967 with a degree in mathematics. After nearly two years with Shell Oil Company as an exploration geophysicist, he joined the NOAA Corps. He has had assignments on the NOAA ships *Pathfinder*, *Mt. Mitchell*, and *Fairweather* as well as having been chief of party on the South Carolina Tidal Datum Planes Project. CMDR Mills earned an M.S. degree in oceanography (hydrography) from the Naval Postgraduate School (NPS) in 1980. Fixed shore assignments have included geophysical data processor with the Marine Geophysics Group, hydrography instructor of the NPS, and Deputy Chief of the Nautical Charting Research and Development Laboratory. He has recently taken over as Chief of NOAA's Ocean Mapping Section.

IMPLEMENTATION OF THE NORTH AMERICAN DATUM 1983: A PROGRESS REPORT

Mr. Paul H. Rogers
Minerals Management Service
Outer Continental Shelf Survey Group

INTRODUCTION

At the preceding Gulf of Mexico (GOM) Outer Continental Shelf (OCS) Region's Information Transfer Meeting (ITM) held in December 1989, a paper was presented outlining the internal process the Minerals Management Service (MMS) was employing to determine if, when, and how the Agency should adopt the North American Datum of 1983 (NAD 83). Since that ITM, the MMS has nearly completed its internal process. The results of the extensive discussions and research are presented here in the form of a draft NAD 83 implementation plan, which will be published shortly in the *Federal Register* (FR).

In addition to the efforts of the MMS NAD 83 Implementation Team, two significant events have occurred between the ITM and mid-August 1990 that facilitated the completion of the internal MMS process. First, the Federal Geodetic Control Committee (FGCC) formally approved three methods for transforming coordinates between NAD 27 and NAD 83 (55 FR 32681, August 10, 1990). This FGCC action curtailed the need to continue a lengthy MMS investigation of the various datum transformation methods. Within the MMS, the most current version of the FGCC-authorized NADCON transformation software will be used for most NAD 27/83 and NAD 83/27 coordinate transformations.

Second, the MMS requested assistance from the National Geodetic Survey (NGS) in developing an Agency-wide draft NAD 83 implementation plan. LCDR Warren T. Dewhurst served as a consultant from July through October, evaluating the MMS offshore program and recommending ways that the OCS Regions could comply with the FGCC mandate to provide for an orderly transition from NAD 27 to NAD 83 to the extent practicable, legally allowable, and feasible (54 FR 25318, June 14, 1989).

DRAFT IMPLEMENTATION PLAN

Accomplishments of the MMS NAD 83 Implementation Team over the last two years and the recommendations of LCDR Dewhurst have resulted in a three-phased draft NAD 83 implementation plan that should minimize transition difficulties. The ultimate goals of the draft implementation plan are (1) for the MMS to remain conversant with its constituencies and (2) to develop a uniform cadastre throughout the OCS. The draft implementation plan has three phases.

Phase I

Conversion to the new datum begins this Fiscal Year, with the initial implementation phase requiring approximately three years to complete in some OCS Regions. Implementation time frames will vary from OCS Region to OCS Region and will be developed on a Region-specific basis.

unknown, that data will be unacceptable. The MMS will notify their constituencies within the oil and gas industries through notices in the *Federal Register* and Notices to Lessees, as well as other mailing lists, to inform the public of this requirement. Further, all permits to perform geophysical surveys will require that the permittee specify the geodetic datum when data are submitted to the MMS.

The end of Phase I, in approximately 1993, coincides with the establishment of a full constellation of Global Positioning System satellites. At that time, it is expected that NAD 83 will be the dominant navigation and positioning system on the OCS.

Phase II

Phase II will solidify the usage of NAD 83 as the primary survey datum for the Agency. Automated systems such as the Outer Continental Shelf Information System (OCSIS) and the Offshore the reference ellipsoid instead of GRS 80. Further, since the offshore program in these areas may not be the same as for the continental United States, a different sized grid (block size) may be used.

TIMEFRAMES

The MMS Regional Directors will determine the timing of regional implementation based on (1) experience gained as regridding proceeds, (2) the current policies regarding leasing, and (3) sales activities. Regridding will proceed on a planning area basis. The time frames listed in the table below are the OCS Regional recommendations for the implementation of NAD 83 within their Regions.

OCS Region	Phase I	Phase II	Phase III
Alaska	present-1992	1992-1993	1993-1996
Atlantic	present-mid 1992	1992	1992-1997
Gulf of Mexico	present-1993	1993-1995	1995-until completed
Pacific	present-1993	1993-1995	1995-until completed

FORTHCOMING EVENTS

Shortly, through a *Federal Register* Notice, the draft implementation plan will be released officially for public review and comment. After the 45-day comment period, the MMS will review and evaluate comments, revising the draft MMS NAD 83 implementation plan as necessary. Once the MMS review and evaluation have been completed, another *Federal Register* Notice will be published announcing the date and location of an MMS-sponsored MMS/Coastal State/Industry forum. At least three days prior to the forum, the MMS NAD 83 Implementation Team will meet to address specific implementation procedures, such as prioritizing the planning areas for conversion to NAD 83. Following the MMS NAD 83 Implementation Team meeting and the forum, a final NAD 83 implementation plan will be submitted to the MMS Director for approval and implementation.

Mr. Paul H. Rogers received his bachelor's degree in geography from the University of Kansas in 1967 and his master's degree from Regent University in 1986. He is currently a Supervisory Cartographer with the Minerals Management Service, OCS Survey Group in Denver, Colorado. Prior to his present assignment, Mr. Rogers was the Acting Lead Bureau Cartographer, Bureau of Land Management (BLM), Washington Office; Chief, Branch of Photogrammetry, BLM, Denver Service Center; Acting Geometronics Group Leader, U.S. Department of Agriculture, Forest Service, Region 10 (Alaska); and a Supervisory Cartographer with the Alaska Department of Highways.

DEEPWATER GEOHAZARDS AND PRODUCTION STRUCTURE SITING, NORTHERN GULF OF MEXICO

Mr. Kerry J. Campbell
Fugro-McClelland Marine
Geosciences, Inc.

The engineering geology of the upper continental slope in the northern Gulf of Mexico is among the most complex of any offshore area in the world. It is far more complex than the engineering geology of the continental shelf with the exception of the Mississippi Delta area where modern mudflows present hazards to exploration and production activities. This deepwater complexity is largely due to the recent and ongoing uplift of numerous salt diapirs and can have an adverse impact on siting and design of petroleum production facilities. Production facilities have been installed recently in water depths of up to 537 m (1,760 ft.) in the Gulf of Mexico, and structures are being designed for much deeper water. These facilities represent investments of hundreds of millions of dollars. A thorough understanding of the shallow geological and soil conditions is needed for the safe and economical development of these deepwater facilities.

GEOLOGIC CONDITIONS

Geologic conditions on the continental slope that can cause engineering difficulties include: (1) steep and potentially unstable slopes of 15 degrees of more (Figures 5.8 and 5.9); (2) irregular, commonly rocky topography (Figure 5.10) with sharp relief ranging

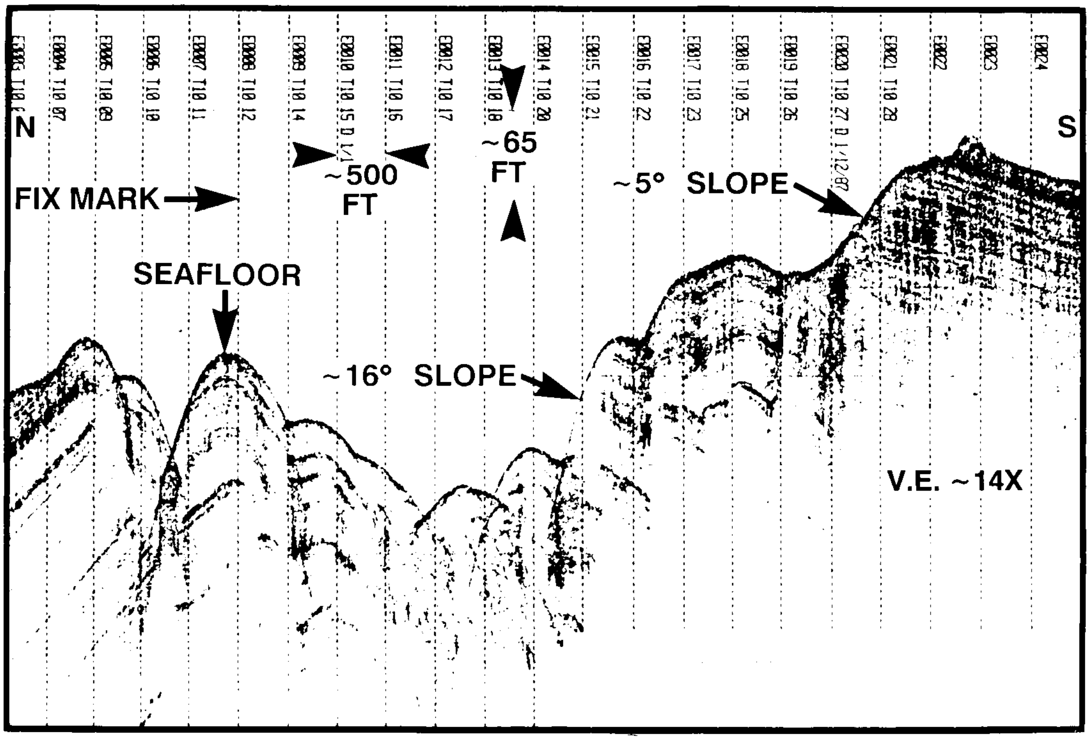


Figure 5.8. Subbottom profiler record showing steep slopes (from Campbell *et al.* 1990).

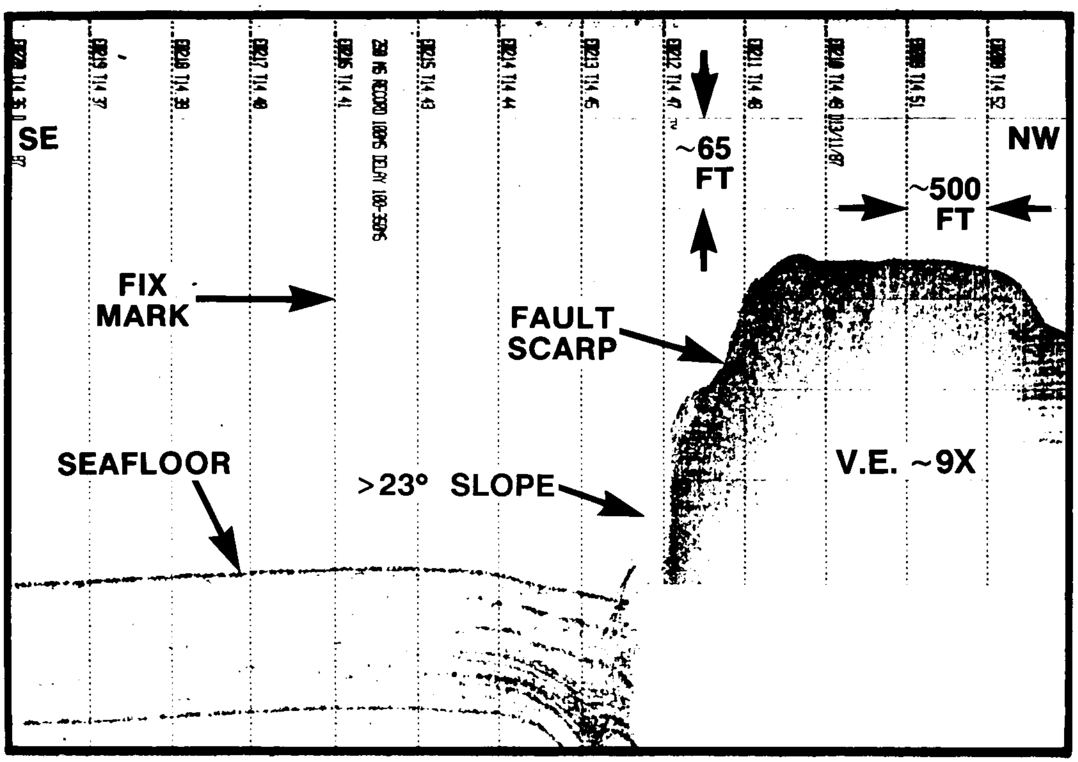


Figure 5.9. Subbottom profiler record showing large fault scarp (from Campbell *et al.* 1990).

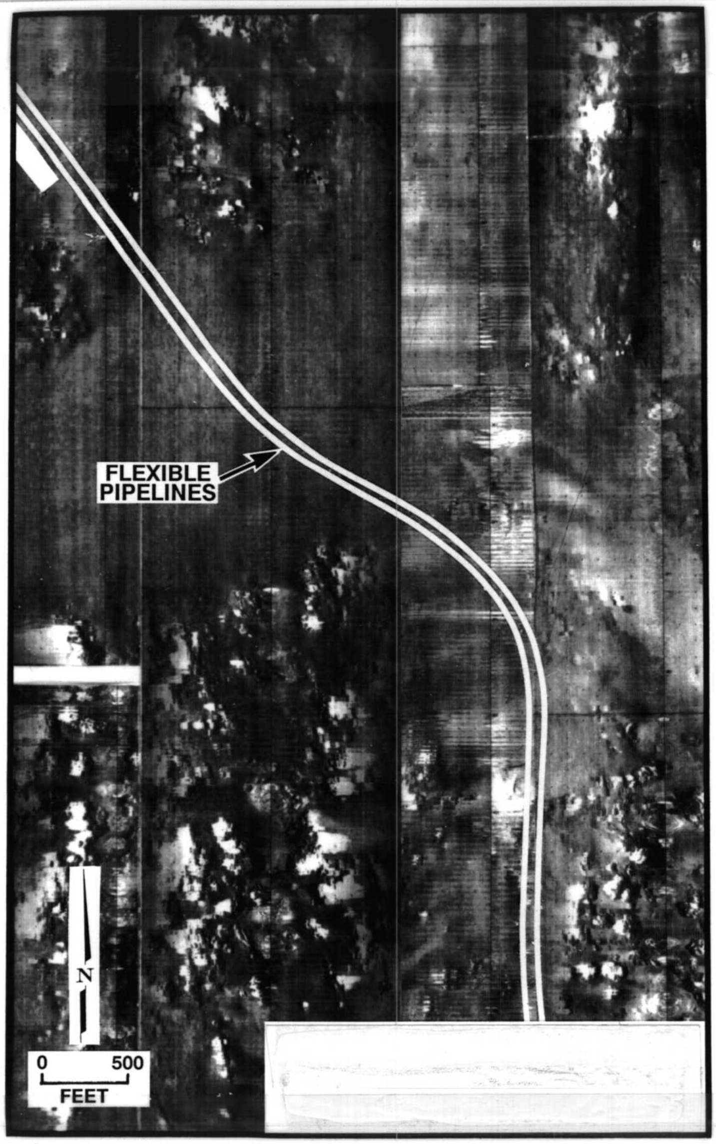


Figure 5.10. Side-scan sonar record showing rocky seafloor (from Campbell *et al.* 1990).

from a meter to several tens of meters that could cause pipeline spanning, damage to pipe coatings, and unfavorable foundation conditions; (3) recently active faults with seafloor scarps ranging up to more than 61 m (200 ft.) high (Figure 5.9) that could also cause pipeline spanning and other problems; (4) both modern and ancient landslides covering large areas; (5) gas hydrates (Figure 5.11; solid, ice-like mixtures of gas and water) that may be subject to reduced shear strength and thaw settlement when heated and that could result in reduced pile capacity; (6) seafloor erosion of tens to hundreds of meters of sediment; and (7) soil conditions ranging from weak, underconsolidated soil to rock.

GEOPHYSICAL SURVEY TOOLS

Deepwater, high-resolution site surveys may require special geophysical equipment and techniques and can be operationally more complex than conventional shallow water high-resolution surveys. Several types of tools are now being used on many deepwater surveys. These tools include narrow-beam water-depth recorder with velocimeter calibration; combined deep-tow side-scan sonar and 3.5-kHz subbottom profiler (with acoustic navigation) to show the seafloor and geologic conditions to penetrations of about 61 m (200 ft.); intermediate-penetration profiler (with minisparker

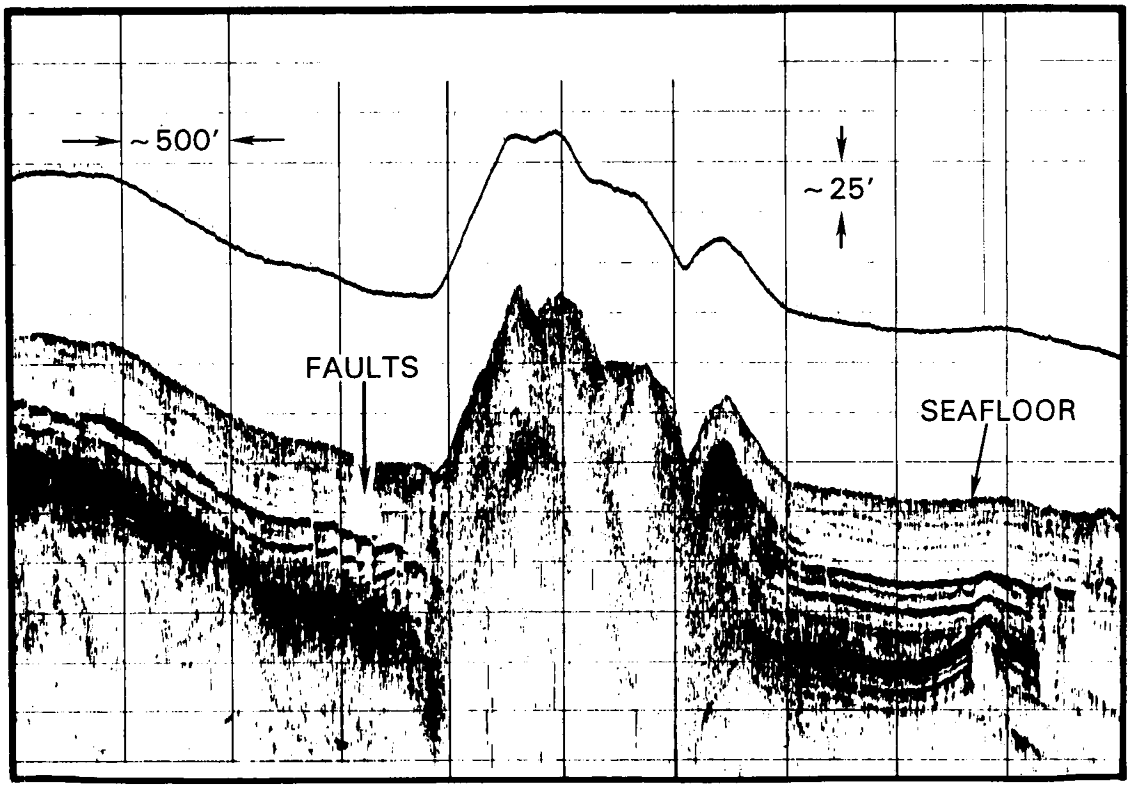


Figure 5.11. Deep-tow subbottom profiler record showing inferred hydrate hill (Courtesy of Shell Offshore Inc.).

or small sleeve-gun array sources, as examples) to show conditions within the foundation zone (to penetrations of about 153 m [500 ft.]); and deep-penetration profiler (sleeve guns with digital recording, for example) to show deep-seated faults, buried landslides, and gassy sediments. Data from these systems allow marine engineering geologists to (1) define water depths and seafloor topography, relationships among soil strata, and potentially troublesome geologic and soil conditions; (2) assess the potential engineering significance of conditions; (3) present results in terms directly useable by design engineers, and (4) provide recommendations for final siting and foundation design.

ACKNOWLEDGEMENTS

This summary is based on a presentation made by K.J. Campbell to the SEG/USN Deep Ocean Technology Symposium in Bay St. Louis, Mississippi, in February 1990; co-authors were E.H. Doyle with Shell Oil Co. and M.J. Kaluza, Fugro-McClelland. The author thanks Shell Offshore Inc. and Conoco Inc. for permission to use the data examples included here.

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Mr. Kerry J. Campbell is Manager of Geology and Geophysics at Fugro-McClelland Marine Geosciences, Inc., in Houston, Texas, and has been with Fugro-McClelland and predecessor companies for more than 16 years. Mr. Campbell has been involved in a wide variety of marine engineering-geological projects worldwide. Recently, he has been involved in assessing deepwater conditions for various engineering projects in the Gulf of Mexico. Mr. Campbell holds B.S. and M.S. degrees in geology from the University of Massachusetts, Amherst.

DEEPWATER PIPELINE SAFETY AND RISK ASSESSMENT

Mr. Philip German
J.P. Kenny, Inc.
Houston, Texas

INTRODUCTION

The Gulf of Mexico is witnessing increased deepwater oil and gas exploration and production. It is anticipated that within the next few years, the Gulf of Mexico will have more deepwater oil and gas activity than any other part of the world.

Deepwater is generally considered to be water depth in excess of 300 m (984 ft.), where working divers are not a practical proposition.

The purposes of this discussion are to raise the question of deepwater pipeline risk and safety, to make qualitative comparisons to shallower water pipelines and introduce a methodology for risk assessment.

INSTALLATION RISKS

It is important to differentiate between installation risks and risks during operation. The consequence of an incident or accident during installation is likely to be limited to cost penalty. The consequence of an incident during operation may have adverse environmental and safety implications as well as any cost impact.

Risk exposure during installation of a deepwater pipeline differs from shallow water pipeline installation on two counts:

- the use of diverless techniques for tie-ins, and
- possible use of less conventional pipeline installation methods.

Use of diverless techniques improves safety by eliminating risk to divers, with the downside risk being the possibility of considerable cost penalty in the event of failure of a diverless system.

Conventional (shallower water) pipelay is by a surface vessel, the pipe adopting an "S" shape between laybarge and seabed. In deeper water the stress levels induced by this method may be excessive, particularly at the "overbend." Two alternatives to conventional pipelay exist:

- towing of prefabricated pipe strings, and
- J-Lay installation.

Towing is well suited to short pipelines and has been successfully employed many times, though some notable failures have occurred.

The J-lay improves on the S-lay by eliminating the highly stressed overbend. Pipe welding is performed in the near-vertical and installation rate may be slow. Several installation contractors are known to have advanced plans for conversion of vessels to J-lay capability.

While J-lay may yet prove to be as reliable as the S-lay technique, it is not common. Pipe towing remains a difficult marine operation, so the risk of problems during deepwater installation must be considered greater than conventional pipelay.

OPERATIONAL SAFETY

To consider the operational safety of deepwater pipelines, it is necessary to examine the modes of failure of offshore pipelines.

Significant offshore pipeline failure modes are listed below:

- internal corrosion,
- dragged anchor,
- dropped object,
- external corrosion,
- fishing gear interaction, and
- environmental (mudslide, spanning, seismic, lateral instability).

The effect of increased water depth on each failure mode is considered below.

> The risk of pipeline failure by internal corrosion is unaffected by water depth.
>
> Dragged anchor damage by unassociated commercial shipping is unlikely to occur in deep water since these vessels do not generally carry sufficient anchor chain length to reach the bottom in deepwater. Dragged anchor damage by vessels working in the oil/gas industry can occur, but this risk is not significantly affected by depth.
>
> The risk of dropped object damage is unaffected by water depth.

External corrosion risk should not increase with increased depth. Sea water oxygen content will be less at greater depths but this factor is not significant.

Fishing gear interaction with pipelines is a problem in the North Sea but not the Gulf of Mexico.

Environmental factors are depth dependent. Seabed topography in the deeper water regions of the Gulf of Mexico differs from the continental shelf. Deepwater seabed topography does not have the soft mud deposited by the Mississippi and exhibits salt diapirs and gas hydrates. However, these hazards are surmountable albeit at increased pipeline construction cost. Once constructed, the deepwater pipeline should be no more at risk than shallower water pipelines. Seabed currents in deeper water are lower and risks due to storm wave conditions significantly reduced.

Finally, pipeline failure statistics indicate that pipe wall thickness is a very significant factor. Thick wall pipelines suffer dramatically fewer failures than thinner wall lines. Pipelines for deepwater will require thick pipewall to withstand installation loading.

The points above compare operational risk and safety of deepwater pipelines to shallower water pipelines. In order to put such discussion in context, it should be noted that pipelines offer the safest means of transport of hydrocarbons. Road, rail, or ship transport is considerably less secure than pipeline transport. Furthermore, offshore pipelines are seen to fail less frequently than overland pipelines.

In conclusion, it is argued here that deepwater pipelines are at least as safe in operation, possibly safer, than conventional offshore pipelines.

The immediate consequences of pipeline failure leading to loss of hydrocarbon are the same for deepwater pipelines as for shallower water pipelines:

- risk to platform due to gas or oil fire/explosion following escape on or near platform;
- threat to shipping due to large gas escape; and
- risk of pollution due to oil release to sea (Note that unlike gas, total oil loss from a ruptured pipeline is usually a very small proportion of pipeline inventory).

However, subsequent repair is very different for deepwater pipelines, requiring specialized diverless techniques. Detailed contingency repair procedures should be developed in advance for all feasible intervention scenarios. Contingency repair equipment may have to be stocked. Any deepwater pipeline repair will take longer to perform and be more costly than conventional offshore pipeline repair.

RISK ASSESSMENT

Conducting a pipeline risk assessment involves the following steps:

- establish best quality, most applicable failure data;
- modify failure data to suit subject pipeline;
- calculate failure probability by each failure mode;
- perform consequence analysis; and
- establish acceptance criteria.

These steps apply to onshore, shallow water, and deepwater pipelines. The difference lies largely in the quality of available failure data. There is a reasonable base of worldwide onshore pipeline failure data, although the quality varies from country to country. Worldwide, offshore pipeline data are quite scarce simply because there are fewer offshore pipelines than onshore pipelines.

Deepwater pipeline failure data are non-existent. The operational risk to deepwater pipelines is expected to be similar to conventional offshore lines. It should therefore be possible to perform a risk assessment based on modified shallow water data.

Mr. Philip S. German is the Chief Engineer with J.P. Kenny, Inc. in Houston, Texas. He has a mechanical engineering degree from Thames Polytechnic in London, England. He has worked on pipeline and subsea production systems in the North Sea, Gulf of Mexico, and Australia.

EXTENDED WELL TESTING FOR OFFSHORE FIELDS

Mr. Ernest T. Weaver
Oceaneering Production Systems

As exploration for hydrocarbons in the Gulf of Mexico takes operators farther offshore and into world record water depths, investments get higher and the risks even greater. With considerable exploration in more than 1,000 m and leases held in 3,000 m of water, the traditional risk/reward balance on investments no longer applies. The geology of these deepwater reservoirs is less understood and the size of investment required for development is such that the risks are often just too great to proceed with development. This presentation addresses a practical and cost effective means of performing multi-well extended well testing (EWT) as a method of evaluating long-term reservoir performance. With the information gathered from EWT, the risks associated with the source of revenue can be minimized and the development scenario better fitted to the reservoir.

The EWT concept consists of a small Floating Production, Storage and Offloading (FPSO) system producing from subsea wells (Figure 5.12). The FPSO would be contracted by operators on a dayrate basis much like a drilling rig contract. Oil, water, and gas would be separated onboard and the oil stored in the vessel's tanks. Oil would be exported either by lightering or shuttling the storage vessel. Depending on production rates, proceeds from the sale of the oil should offset the cost of the testing operation. This arrangement should be selected over a system utilizing a floating drilling rig and storage vessel (Figure 5.13) for the following reasons:

- In the long run, it is inherently more cost effective as it employs only one vessel.
- Deepwater floating drilling rigs are in limited supply and undoubtedly will command significantly higher day rates in the future.
- The EWT system can produce more than one well simultaneously, thereby allowing well interference testing and improved economics.

Extended well testing is not a new concept. It is currently being employed in other offshore frontier areas around the world. However, few operators in the Gulf of Mexico, particularly those in deepwater, have utilized EWT for long-term evaluation of their discoveries. While this system is aimed at deepwater, it should be technically feasible to use it in shallower water depths.

Several Joint Industry Projects (JIP) have been commissioned in recent years to address deepwater extended well testing. Their results have invariably indicated technical feasibility and suggest there is a commercial basis for such a system in the Gulf of Mexico. However, no such system has ever been commissioned. This is largely a result of the following factors:

- While most operators say they would use such a system if it were available, no one contractor is willing to commit the necessary capital without reasonable expectations for return on investment. The classic "chicken and egg" situation prevails.
- Restrictions on flaring of associated gas limit test duration such that long-term productivity cannot be adequately assessed.
- Too much emphasis has been placed on having the EWT system act as an early or marginal field production system. This emphasis has resulted in higher than necessary capital costs and day rates that cannot be supported by typical Gulf of Mexico oil wells during testing.
- Previous studies have largely been made by engineering companies who do not have the resources to put a system into actual operation. Therefore, the systems suggested by these engineering studies have not been translated into an FPSO.

Oceaneering Production Systems (OPS) has determined that there is a need for a cost effective EWT system in the Gulf of Mexico, particularly for deepwater fields. The OPS is committed to providing this service to the industry and has determined that a three-phase approach is the best way to pursue this goal.

Phase I is a JIP that will involve oil companies, experienced hardware suppliers, and engineering firms to perform preliminary engineering analyses to configure the system to meet the technical and economic needs of the operators. It will also address the regulatory requirements of MMS, U.S. Coast Guard, and ABS. The OPS is offering this JIP and will manage this effort as well as perform

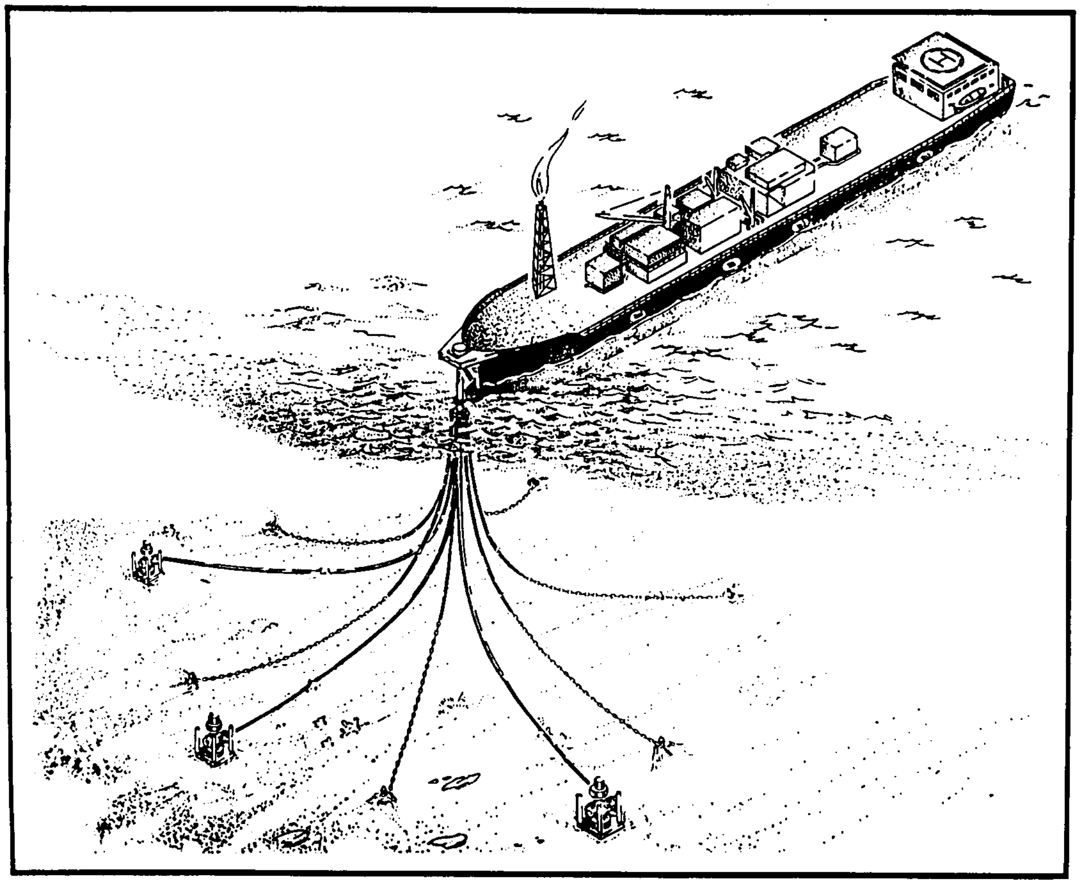

Figure 5.12. Floating production, storage, and offloading system.

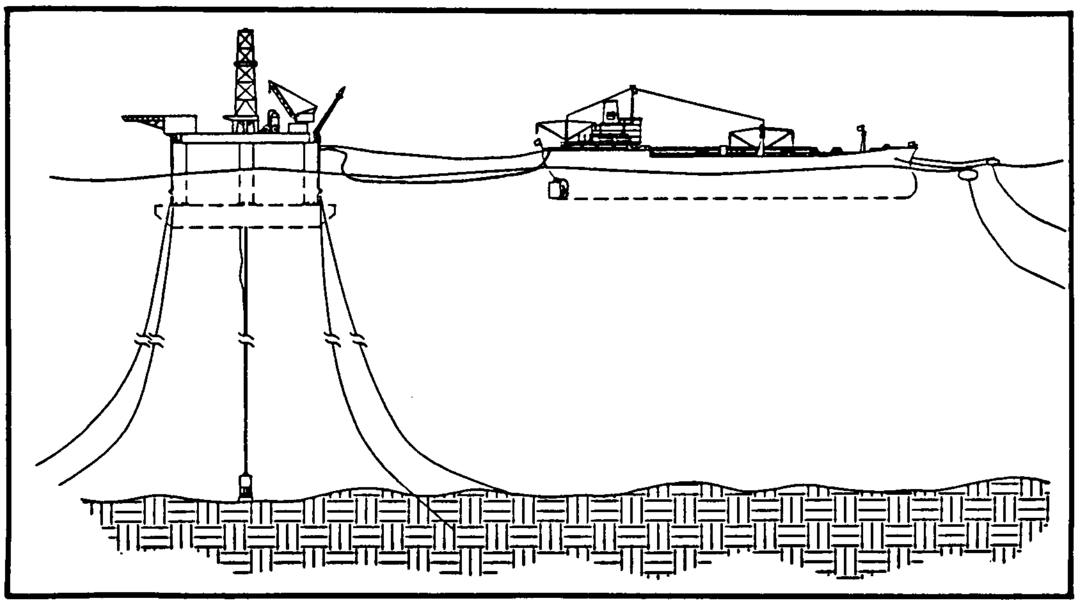

Figure 5.13. Floating drilling rig and storage vessel.

some of the engineering. Subcontractors for Phase I are Mustang Engineering, Omega Marine, Vetco Gray, and Wellstream.

Phase II will involve soliciting contractual commitments from operators for use of the system. If the level of commitment is sufficient, OPS will perform detailed design through experienced subcontractors and will then construct the EWT system.

Phase III is the actual operation of the EWT system. The OPS will own and operate the system and will lease it to operators on a dayrate basis.

The OPS is currently soliciting participants for Phase I of this program. The total budget for Phase I is $357,540. Based on eight participants, the resulting individual cost is $44,693. Commitments for Phase I were requested by December 7, 1990. Project duration is estimated to be six months.

In summary, the EWT is needed for Gulf of Mexico field development. While the need exists, it continues to go unserved largely because no one contractor or operator can justify such a commitment. The OPS has developed an approach to putting an EWT system in operation in the Gulf of Mexico without undue burden on the operator or contractor. The OPS is committed to providing an EWT system and invites interested operators to join in this effort.

Mr. Ernest Weaver is a Project Manager with Oceaneering Production Systems. He has over 35 years of experience of the petroleum industry, which includes employment with Phillips Petroleum, Schlumberger, Houston Systems Manufacturing, Wittaker Survival Systems, and Western Oceanic. Mr. Weaver has a B.S. in petroleum engineering from Louisiana State University.

OFFSHORE TECHNOLOGY RESEARCH IN SUPPORT OF DEEPWATER OPERATIONS

Mr. John E. Flipse
Distinguished Professor of
Ocean Engineering
Texas A&M University

INTRODUCTION

The Offshore Technology Research Center is an academic and research joint venture of the Texas A&M University and The University of Texas at Austin sponsored by the National Science Foundation. The Universities agreed in 1987 to organize and operate a center to perform research, develop knowledge, train students, and interact with industry to develop deep offshore natural resources. Although the effort is directed toward all marine resources, the initial program has focused on the potential of two or more extremely large petroleum provinces believed to exist at depths of 1,800 to 3,000 m (5,906 to 9,843 ft.) in the Gulf of Mexico, an area considered the United States Exclusive Economic Zone as defined by the United Nations Law of the Sea Conference and existing treaties between the United States and other nations. The direction of the program was developed with the guidance of many petroleum and offshore companies and will attempt to meet their five to ten year technology needs for the economical exploration and production of these deep reservoirs.

Based on our experience and strongly guided by the participating companies, six research thrust areas have been identified that could significantly reduce the cost of producing petroleum from the continental slopes but could also enhance the United States capacity to undertake the development of other deepwater natural resources. The six thrust areas are Hydrodynamic Loadings in Deepwater, Structural Integrity of Deepwater Systems, Materials for Ocean Applications, Foundation/Seafloor Engineering, Transport of Mixed Wellhead Fluids, and Fate and Effects of Deepwater Oil Spills. These thrust areas are closely interrelated and form a coherent integrated research program that will require teams of researchers with different backgrounds and expertise. The interaction between the thrust areas is brought about not by any artificial requirements but rather by the nature of the physical phenomena involved.

With strong industry guidance, but limited by the available funding, the initial effort was directed to the first four thrust areas listed above. The offshore industry concerns seem to focus on three major problems, which include deepwater mooring systems, the properties of the deep seabed, and the fundamental knowledge needed to design and build tension leg platforms for economic deep ocean application. Criticism of the linear equations used in the analysis of the hydrodynamic loadings, the discovery and concern regarding gas hydrates in sediments at water depths as low as 600 m (1,969 ft.), and the considerable impact of compliant structure motion on hydrodynamic loading were obvious first problems to approach.

To ensure a useful research program product, basic research in each thrust area is conducted through the establishment of research projects involving teams of principal investigators supported by graduate students with overview provided by industry mentors. The basic plan is to initiate the research project in the first year, continue the work in the second year, and hopefully, move the project at the end of the third year from the research phase to the development phase, which will be conducted by the companies that are members of the Center. We realize that in some cases a third or perhaps even a fourth year will be necessary to complete effectively the research work before it can be passed on to the industry for development.

HYDRODYNAMIC LOADINGS IN DEEPWATER

Offshore structures in very deep water will require a refined knowledge of hydrodynamic forces to prevent prohibitively expensive overdesign. Three-dimensional, nonlinear diffraction theories must be further developed for multi-body, large floating structures in non-Gaussian random seas. Particular emphasis will be focused on large amplitude, slowly varying drift forces. The application of recent advances in nonlinear signal processing and polyspectral techniques to the study of nonlinear responses of moored vessels and tension leg platforms will significantly enhance current capability in nonlinear marine hydrodynamics. Nonlinear interactions between hydrodynamic loadings on slender structures and their dynamic responses is another area that requires further investigation. Advanced computational techniques and experimental studies will be conducted to support modeling efforts. The results will provide an improved capability for predicting hydrodynamic loadings on tendons, risers, and mooring lines.

Techniques will also be developed to generate breaking waves in the laboratory. Experiments will be conducted to investigate wave kinematics and the interaction of extreme transient waves with fixed and floating structures. This experimentation will provide a foundation for developing an advanced numerical technique to model transient extreme waves and wave impact forces. Physical model studies will be conducted to gain insight of the complex nonlinear hydrodynamic phenomena and to verify the analytical and numerical results. The use of advanced digital signal processing techniques should facilitate comparison of model tests with theory and numerical studies.

THE WAVE BASIN FACILITY

In spite of the recent advancements in fluid mechanics, theories of structures, and computational techniques, many offshore engineering problems still cannot be completely solved using only these methods. Physical model tests are frequently needed to calibrate the mathematical models in an iterative mode, thus improving their accuracy. The establishment of the Offshore Technology Research Center and the commitment of the Texas A&M University System to provide 4.5 million dollars to build such a facility has led to the construction of a 3,800 square m three dimensional (3D) wave basin (Figure 5.14). The basin is 46 by 30 by 6 m deep with a pit of 18 m depth near the center of the basin. A multi-segment directional wave generator will create waves up to 1 m high in the basin.

This facility will be a unique asset for our offshore educational and research program and the industry's development program. It will be a major, superbly equipped modem 3D wave tank located in a university setting where skilled scientists and engineers can, on a continuing basis, develop and test the theories and mathematical models necessary for determining hydrodynamic and associated loads on offshore structures while training the next generation of users, teachers and researchers. The design and equipment of the basin reflect recent developments in both Europe and Canada and will be capable of testing any modern deepwater offshore structure. The facility is planned so that it can be expanded with an L-shaped wave maker configuration and increased length, which would permit the testing of offshore multiple module floating platforms suitable for industrial or defense purposes.

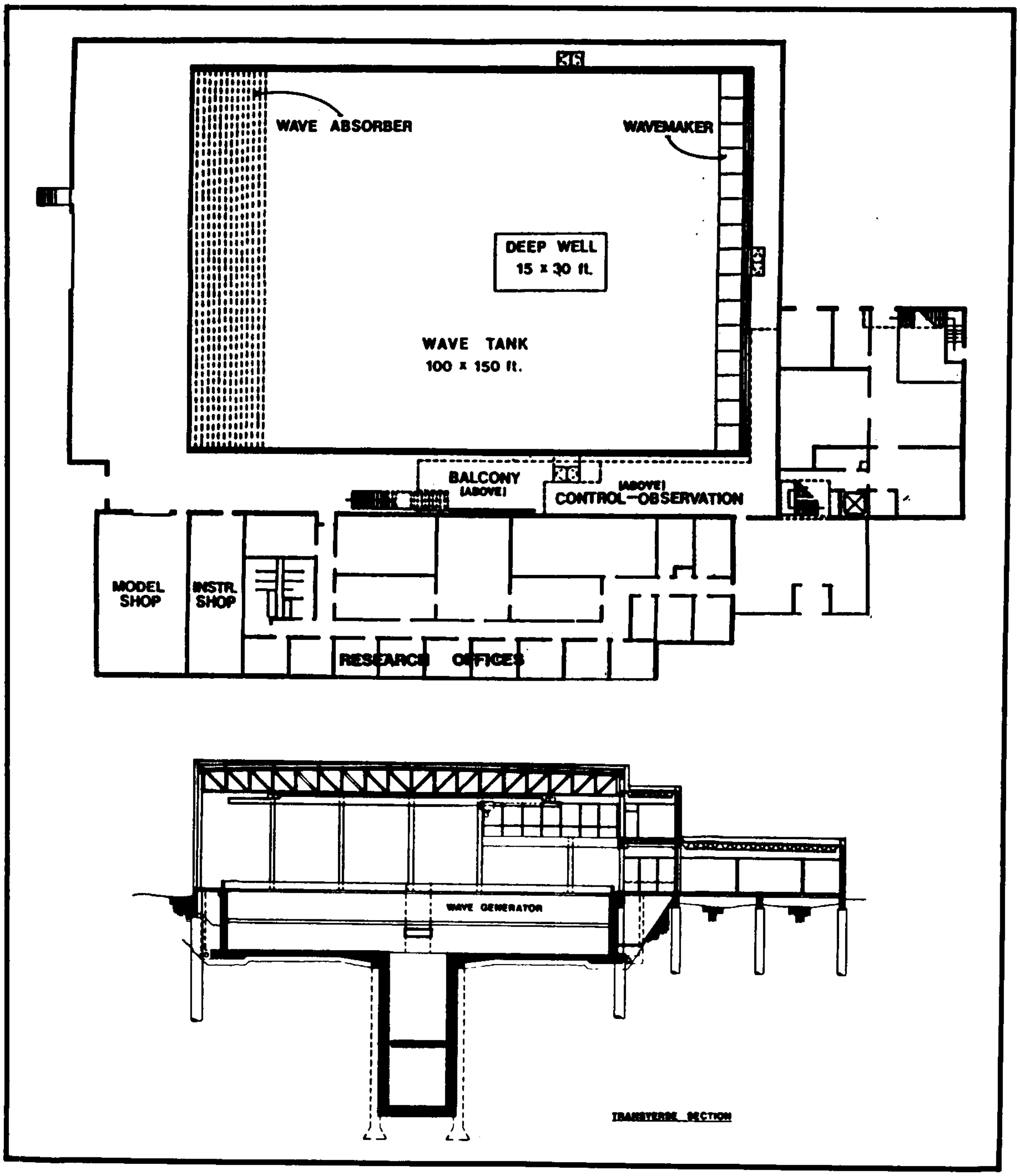

Figure 5.14. Offshore Technology Research Center and wave tank facility.

STRUCTURAL INTEGRITY OF DEEPWATER SYSTEMS

The design of deepwater structures such as tension leg platforms, floating production systems, or compliant structures in general, requires reliable estimation of the motions of the structure under dynamic excitations such as wind, currents, and wave action, and the determination of the stresses in different members (for strength, stability and fatigue considerations). The analysis is complicated by the fact that members of very different sizes are involved. For instance, the members of the hull are of large dimensions requiring in general the use of diffraction theory (linear, approximate nonlinear, or preferably fully nonlinear diffraction) to estimate the motions and forces. Tethers, risers, mooring lines, or cables are, on the other hand, very slender members normally analyzed using Morison's equation. Simplified analyses of tension leg platforms are sometimes conducted studying first the motions of the hull (supported by elastic springs representing the tethers), and then the tethers with a specified motion at the top (the motion of the hull), and the hydrodynamic forces acting along their length. A similar procedure is followed typically in the analysis of risers. More accurate procedures used at present by industry consider the coupled analysis of the hull and the tethers.

There are a number of important topics that need further research to improve the reliability of structural analyses, for instance, the response of large bodies with a fully nonlinear diffraction theory, the drag forces or hydrodynamic damping associated with the motions of these bodies, the validity of Morison's equation and the flow-induced vibrations on slender members, the impact forces caused by breaking waves, and the strength and flexibility of the foundation piles (tension piles for tension leg platforms, anchor piles for cables). The first set of questions is being addressed by the different projects in the hydrodynamics thrust area, while the last is being considered in the project on piles in the Foundations/Sea Floor Engineering area. The Structural Integrity thrust area must provide, therefore, the tools to implement the results of this research in an analysis package and evaluate the effect of new wave force theories and pile models on the performance of the structure. This requires the availability of both sophisticated formulations and computer programs that can account for all nonlinearities with great accuracy, as well as simplified models of an approximate nature, which can be used for extensive parametric (or sensitivity) studies in order to develop a better understanding of behavior.

MATERIALS FOR OCEAN APPLICATIONS

Economic oil production at ocean water depths of 1,800 m (5,906 ft.) will require the application of new materials systems and/or more sophisticated utilization of conventional materials. The weight and reliability of risers and structural attachments from the production deck to the ocean floor (moorings or tension legs) will have a tremendous impact on the design and cost of deepwater hydrocarbon production facilities. The materials thrust area is focusing on the possible application of high performance composite materials in combination with conventional materials fabricated in a novel way that enhances the economics of construction and increases service reliability.

To date, the primary application for high performance composites has been in the aerospace industry. Thus, the long-term durability of such materials in salt water immersion needs to be explored. All polymeric materials absorb some moisture when immersed in water. This absorbed water can degrade the composite in two ways. First, it can plasticize the matrix, reducing the strength of the polymeric material. Second, it can degrade the mechanical integrity of the matrix/fiber interface. The effect of such degradation of the composite system on mechanical properties, particularly fatigue strength, needs to be fully understood.

Development of deepwater petroleum resources poses significant challenges in the construction of seabed linepipe, risers and other flow components, and structures. At depths greater than approximately 900 m (2,953 ft.), pipe must be placed in a vertical, or J-lay, configuration, because of the high bending stresses that would be imposed on the pipe in conventional S-lay techniques used in shallow water. Because the J-lay technique affords one pipe welding and one weld testing station, the welding process chosen for use in J-lay must be fast, reliable, and efficient in order to be economically viable. Dissimilar materials must be welded, as in joints between high strength linepipe and forged risers. Construction of deepwater structures such as platforms, tension legs, and tieback components will require full strength welds in thick cross sections. Welding processes for all deepwater applications must be developed for resistance to hydrogen-assisted cracking and fatigue due to wave and current forces. Finally, welding can be used to join metal couplers (inserts) for composite risers.

It is well known that the ocean environment at depths of 1,800 m (5,906 ft.) can be quite different than that at shallow depths. In particular, the oxygen concentration is often higher and the water temperature is almost always lower at deep ocean depths. The higher oxygen concentration will tend to accelerate the corrosion and corrosion/fatigue process while the lower temperature would tend to retard it. The net effect of these two changes in the ocean environment at great water depths on the corrosion and corrosion fatigue behavior of structural steels needs to be better understood.

FOUNDATION/SEAFLOOR ENGINEERING

The move from the Continental shelf to the slope in search of hydrocarbons has brought a new set of problems to the foundation/seafloor engineering field. Mere extrapolation of shallow water solutions to problems in the deeper waters is seldom an alternative. Often, the reason is new foundation concepts for deepwater structures; in other cases, it is the result of unusual and unforeseen seafloor conditions.

Many of the deepwater structures, such as tension leg platforms, require foundation elements (piles) that are continually in tension with additional vertical and lateral cyclic loads caused by surface wave forces. However, industry knowledge on bearing capacity of long piles has been gained with compression piles and there is virtually no knowledge about tension piles - particularly under repeated loading. New foundation concepts, such as drilled and grouted piles and suction anchors, have only been marginally studied. They require much more research, particularly under repeated loading conditions.

Significant seafloor engineering problems, in the deeper waters include slope instabilities, mass transport of unknown causes, and unusual shear strength conditions. In the latter case, some of the borings conducted in the deep Gulf of Mexico have shown significant thicknesses of weak, under-consolidated clays. At other locations, very sensitive clays have been located; these pose potential hazards for bottom-resting structures because disturbance of the sediments may cause significant loss of shear strength.

Gas hydrates have been detected in shallow drop cores taken throughout the Gulf of Mexico in water depths greater than 500 m (1,640 ft.). Hydrates in the foundation-bearing zone present significant hazards to foundation integrity. First, the bearing capacity of hydrates is unknown. More importantly, the loss of bearing capacity due to hydrate disassociation (thawing) from the presence of nearby hot oil in conductor pipes is a potential problem. Furthermore, in areas where hydrates are actively forming, the expansion of the sediment may cause significant movement of the foundation and consequent loss of bearing capacity.

NEW THRUST AREAS

As in all major research programs, the Offshore Technology Research Center has far more opportunities than resources. The times, industry guidance, and the intellectual curiosity of our research team have led to startup activities in two promising areas. First, a significant expense in deepwater hydrocarbon production is the separation of fluids, gases, and solids from the wellhead products. The facilities for this separation require space on the offshore platform, which increases the total platform size and cost, and multiple pipelines are required to carry the products to shore. In light of impending zero-discharge regulations, waste products from the wellhead (sand, brine, etc.) may also require processing or transport to the shore. It is obviously more economical to transport all wellhead products to a separate processing facility -- either offshore in shallower waters or directly to the shore -- in a single pipeline. However, there are significant difficulties with this approach, including potential blockage of the pipeline by deposition of solids and formation of gas hydrates.

A second challenging opportunity is the potential problem of an environmental accident while producing a deep Gulf of Mexico well. The aim of this effort is not to consider beach cleanup -- which is a technical and emotional issue being handled by numerous researchers --but rather to consider the fate and effects of deepwater oil releases caused by drilling blowouts, pipeline breaks, or tanker spills. Deepwater oil spills require a different strategy that must be addressed quite separately from shallow water spills and beach cleanup. If hydrocarbons are released from a blowout during deepwater drilling operations, the response time will be significant merely due to the large distances from the shore to the blowout locations. Typical alleviation measures, drilling slant holes and injection wells to kill the blowout, may not be suitable alternatives owning to the scarcity of nearby deepwater drilling rigs to carry out these activities. From earlier research on the fate of natural oil seeps in the deepwater Gulf of Mexico, it is not clear that the hydrocarbon products will surface at or near the blowout location. Instead, underwater plumes may be carried great distances by the prevailing currents. Both the surface currents and the deeper currents play an important role in the transportation of spilled hydrocarbons. In areas such as the Gulf of Mexico, knowledge of the loop and eddy currents is necessary to predict the movement of spilled hydrocarbons and to aid in reducing the response time for cleanup.

CONCLUSION

The Offshore Technology Research Center was formally established on October 1, 1988. It presented an opportunity to bring together the many individual research projects funded by the industry and the state government at the two universities in areas pertinent to offshore resource development. In the Center context the investigators in the ongoing research projects have found the cross-disciplinary nature of the program to be stimulating and gratifying in-as-much as the relevance of their particular technical effort is clearly established. The strong industry support suggests that the Center's program is on target and their high level of interaction in both research and teaching provides the technology transfer to which they are entitled. We look forward to continued growth of the program and the opportunity to contribute to international offshore natural resource development.

Professor John E. Flipse has been at Texas A&M University for the past 13 years and currently serves as Director of the Offshore Technology Research Center, a National Science Foundation Engineering Research Center, and a joint venture with the University of Texas at Austin. His industrial and academic experience includes ship design and construction, deep ocean mining, and ocean engineering research. Professor Flipse, a member of the National Academy of Engineering, received his B.S. in naval architecture and marine engineering from M.I.T. and his Master of Mechanical Engineering from New York University.

MISSISSIPPI/ALABAMA SHELF MARINE ECOSYSTEMS STUDY

Session: MISSISSIPPI/ALABAMA SHELF MARINE ECOSYSTEMS STUDY

Co-Chairs: Dr. Robert M. Rogers
Dr. James M. Brooks

Date: November 14, 1990

Presentation	Author/Affiliation
Mississippi/Alabama Shelf Marine Ecosystems Study: Session Introduction	Dr. James M. Brooks Geochemical and Environmental Research Group Department of Oceanography Texas A&M University and Dr. Robert M. Rogers Minerals Management Service Gulf of Mexico OCS Region
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 Ecosystems Study: Physical Oceanography	Mr. Frank Kelly Civil Engineering Department Environmental and Water Resources Area Texas A&M University
Shelf-Slope Exchange - Northeastern Gulf of Mexico	Dr. Andrew Vastano, Ms. Cynthia Lowe, Mr. Charlie Barron, and Ms. Evelyn Wells Department of Oceanography Texas A&M University
Mississippi/Alabama Marine Ecosystem Study: Macroinfauna and Macroepifauna	Dr. Donald E. Harper, Jr. Department of Marine Science Texas A&M University at Galveston
Mississippi/Alabama Marine Ecosystem Study: Fish Taxonomy	Dr. John McEachran Department of Wildlife and Fisheries Texas A&M University
Demersal Fish Food Analysis	Dr. Rezneat M. Darnell and Mr. James D. Simons Department of Oceanography Texas A&M University

(Continued)

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

Presentation	Author/Affiliation
Mississippi/Alabama Marine Ecosystems Study Geological Characterization: Sea Level Effects on Carbonates and Sedimentation	Dr. William W. Sager, Dr. Richard Rezak Department of Oceanography Texas A&M University and Dr. William W. Schroeder Marine Science Program University of Alabama
Biological Characterization of Communities on Topographic Features in the Northeast Gulf of Mexico	Dr. Stephen R. Gittings, Dr. Thomas J. Bright Texas A&M University and Dr. William W. Schroeder University of Alabama
Summary and Synthesis	Dr. Rezneat M. Darnell Department of Oceanography Texas A&M University

MISSISSIPPI/ALABAMA MARINE ECOSYSTEMS STUDY: SESSION INTRODUCTION

Dr. James M. Brooks
Geochemical and Environmental
Research Group
Department of Oceanography
Texas A&M University
and
Dr. Robert M. Rogers
Minerals Management Service
Gulf of Mexico OCS Region

An organizational plan for the Mississippi/Alabama Marine Ecosystem Study (MAMES) was presented and discussed. The MAMES study is being managed by Dr. James 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 three-year study will be completed in late 1990.

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 that operate in regular cyclic fashion versus those that 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, remotely operated vehicle (ROV), 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 thickest (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 compounds (PAH), 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 are possibly explained by a large episodic influx of riverine material followed by slow biological mixing by bioturbation of 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 (Fe) and trace metals compared to shallow water ones, but all were typical of unpolluted Gulf of Mexico shelf sediment. Manganese (Mn) 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 Mn and perhaps other metals. Fish food analyses have been completed for 2,500 specimens representing 42 fish species. 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 Geochemical and Environmental Research Group 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.

Dr. Robert M. Rogers has served as Contracting Officer's Technical Representative 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 Bureau of Land Management/Minerals Management Service environmental studies program since 1977.

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 (PAH), 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:

(1) cyclic--on time frames of 6 months, 1 year, 2 years, and possibly longer. This variation can be explained by either regular inputs (such as seasonal variations) being balanced by either removal processes or dilution events (i.e., aromatic and aliphatic hydrocarbons).

(2) steadily increasing--in this scenario, input continues over time 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).

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

(4) no change--could reflect input equal to removal rate with a relatively constant rate of input, or the time frame of change is greatly in excess of the 2 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 Union College and a Ph.D. in oceanography from Texas A&M University in 1980.

MISSISSIPPI/ALABAMA SHELF MARINE ECOSYSTEMS STUDY: PHYSICAL OCEANOGRAPHY

Mr. Frank Kelly
Civil Engineering Department
Environmental and Water Resources Area
Texas A&M University

The physical oceanography component of the project maintained a cross-shelf array of three current meter moorings in the eastern part of the study area throughout 1988 and added a second array of two moorings on the outer shelf in the central part of the study for 1989. Five semi-annual interdisciplinary cruises collected CTD/Transmissivity, dissolved oxygen, and nutrient data at the 12 primary stations and 5 to 10 supplemental stations. A collateral data set consisting of meteorological, wave, river discharge, water level and satellite infrared observations supplements the time series and hydrographic data.

Large climatic fluctuations, tropical cyclones, outbreaks of intensely cold arctic air, and mesoscale intrusions of warm salty Gulf waters are events (non-periodic processes) that impulsively drive this continental shelf region at various times. The year of 1988 may have been unusual in that all of them did so. The signature of each one in the physical record is clearly detectable, especially the rise in bottom temperature associated with intrusive Gulf waters. The impact on the ecosystem of numerous such physical events acting in concert is unknown. The principal large-scale weather event of 1988 was the severe drought and heat wave. By summer time the Mississippi River reached near record low levels, restricting barge and towboat traffic. The streamflows in the Alabama and Tombigbee Rivers were also unusually low. Although the time series data are limited, they suggest the drought elevated the average salinity of the shelf waters. For example, the average salinity at 10 m at Site A for April through June 1988 was 35.7 ppt; for the same period in 1989 it was 32.2 ppt. During the first week of January 1988, a severe cold wave moved down from Canada, bringing record low temperatures to the Midwest. February and March also featured a couple of memorable cold spells. Later in the year the Northeast and Southeast had their third coldest October of the century (LeComte 1989). Bottom temperatures dropped during each cooling event, but the effect of the cold spells on mean bottom water temperature cannot be determined because of the countervailing influence of intrusions of warm Gulf water.

Tropical Storms Beryl and Keith and Hurricanes Florence and Gilbert influenced the currents and hydrography of the region to varying degrees. Gilbert had the greatest impact despite its southern Gulf track. At Mooring B (60 m water depth) current speed reached 80 cm/s at 10 m depth and 35 cm/s at 57 m depth. The currents flowed southwesterly at both depths and brought warm water from the east where, satellite imagery suggests, a Loop Current filament had extended up DeSoto Canyon. Bottom water temperature was elevated for much of the month of September, reaching a maximum of 24.1°C, the highest bottom temperature recorded at this sight during the two years of observation. The October cold spell reduced bottom temperatures, but an intrusion of warm Gulf water elevated them in November, resulting in the highest mean value of the two-year period, 21.6°C.

The satellite image sequence gathered during 1987-1989 indicates that filaments or plumes that extend northward from the Loop Current are a frequent and persistent influence on the Mississippi/Alabama continental shelf. Vastano *et al.* (in prep) defined the northern extreme of Loop Current intrusions based on continuity with the Loop Current and/or an intrusion-Loop Current temperature difference of less than two degrees. They found intrusive warm waters were observed north of 29.5°N in December 1987; January, March, and May 1988; and February, March, and May 1989 (note that the latitude of Mooring B is 29°37.45'N).

Both Cruise B2, 10-18 March 1988 and Cruise B4, 11-18 February 1989, were conducted during periods of intrusions of Gulf water onto the shelf and provide hydrographic data that complement the satellite thermal imagery. Figure 6.1A shows the subjectively contoured, surface temperature field based on the data collected during Cruise B2. Figure 6.1B shows the satellite infrared (IR) image for 2110 hours (GMT) March 13, 1988, while Figure 6.1C shows the temperature and salinity time-series records collected during March by the bottom current meter at Site A, located in 30 m of water depth. A plume of Gulf water, characterized by higher temperature, salinity and dissolved oxygen values throughout the water column, pushed onto the western portion of the shelf and wrapped clockwise to the northeast. A southwestward return flow, with opposite water mass characteristics, occurred east of the plume. The plume reached current meter Site A briefly on 11 March and then for an extended period beginning 15 March. Bottom temperature rose abruptly by more than 2°C and salinity by about 1 ppt. Clearly, intrusions of Gulf water onto the shelf can displace a major portion of the shelf water for periods of weeks.

Mean near surface flow over the outer shelf and the shelf slope is dominant toward the east and northeast with no clear seasonal variation. Mean bottom flow is directed toward the west and southwest. The current data from the mid-shelf mooring, Site A, show no dominant direction, but there is a slight tendency for eastward flow during the spring and a slight tendency for westward flow otherwise.

The technique of cross-rotary spectral analysis for pairs of vector time series was used to study the coherence between wind stress and currents and between currents at various locations. Wind stress is strongly coherent with the currents at the mid-shelf Site A over the synoptic period band of 2-10 days, but for the deeper moorings the coherence is generally much weaker. Coherence among the currents at the five locations is strong, particularly at periods of 10-15 days and 5-7 days.

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Mr. Frank 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.

SHELF-SLOPE EXCHANGE – NORTHEASTERN GULF OF MEXICO

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Ms. Cynthia Lowe,
Mr. Charlie Barron,
and
Ms. Evelyn Wells
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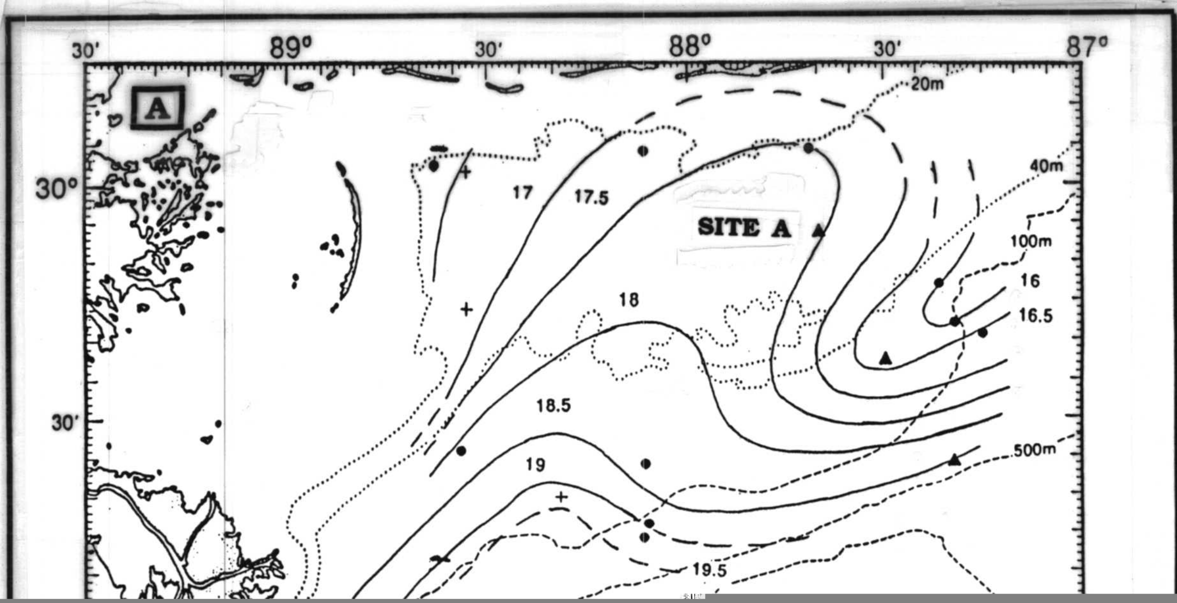
Texas A&M University

Satellite surveillance and analysis during the Mississippi/Alabama Marine Ecosystem Study (MAMES) program monitored the relationship between the waters of the northeastern Gulf of Mexico and the Loop Current from October 1987 to May 1989. This report presents a study that focused on the 1988 image subset to examine satellite-derived surface flow patterns associated with Loop Current Intrusions, Mississippi River outflow, and atmospheric forcing. Episodic shelf and slope water exchanges, transient cyclonic and anticyclonic eddy features, and the penetrations of Loop Current Intrusions and western Gulf waters occurred during these observations.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19.5
16
16.5
20m
40m
100m
500m

Early studies in the eastern and western reaches of the MAMES region inferred the presence of turbulent features and current reversals with drift bottle returns. The perceptions obtained by these means are both verified and modified by MAMES satellite evidence. More recent circulation investigations using drifters, satellites and ships have shown instances of shelf water modification and redistribution during bay-shelf water exchanges and shelf responses to Loop Current Intrusions. The results related in this report present satellite assessments of mesoscale and submesoscale features and flow patterns that were associated with shelf-slope water exchange processes during 1988.

Six sequences have been selected to illustrate flow regimes with patterns showing:

- northeastward flows along the shelf break adjacent to the Mississippi Delta;
- counter-clockwise rotating eddies over DeSoto Canyon;
- seaward, cold water, cross-shelf plumes and paired vortices at the shelf break;
- seaward, cold water plumes over the slope southwest of Cape San Blas;
- penetrations of Loop Current Intrusions from the west and east sides of the MAMES region with formation of clockwise eddies southeast of the Mississippi River Delta by Loop Current Intrusions; and
- formation of counter-clockwise eddies adjacent to the Mississippi River Delta by river outflow waters.

A relatively long-term influence on shelf-slope exchange was exerted by a Loop Current Intrusion south of the MAMES region in the interval between February and May 1988. Figure 6.2 shows four schematic interpretations of the surface water distributions in the eastern Gulf. An intrusion approached the MAMES region during February, established a counter-clockwise rotating eddy south of the Delta, and induced off-shelf transport in western and eastern plumes. The eddy evolved through mid-May and intermittently entrained Mississippi River and shelf waters in accord with the proximity of the western plume to the Delta.

The outflow of the Mississippi River generated an offshore eddy in the fall of 1988. This feature was observed during a five-day interval from November 05-10. Figure 6.2 shows the connection of the eddy south of the Delta to the vicinity of South Pass and Pass a Loutre on November 06, and the flow pattern representing motion over a 24-hour interval between the fifth and sixth. The five days of observation produced four flow patterns and these have been used to estimate movement of the surface waters within the MAMES region. Five-day computed trajectories were based on the flow patterns. These paths demonstrate entrainment into the eddy south of the Delta and the degree to which start positions dictated capture or escape. The eastward motion along the coastline was continuous, inshore of an eddy over the head of DeSoto Canyon, and joined an offshore plume carrying shelf water seaward of the shelf.

Dr. Drew Vastano, Professor and Satellite Group Leader, received his Ph.D. in Physical Oceanography from Texas A&M University in 1967. Dr. Vastano is a member of the American Meteorological Society and the American Geophysical Union. His professional interests include mesoscale ocean circulation and structure long-wave generation, propagation and modification, quantitative satellite analysis of oceanic features and Lagrangian studies of ocean circulation. During the last five years Dr. Vastano has performed numerical studies of tsunami propagation and modification with translating coordinate systems. He assigned particular emphasis on evaluating the tsunami signatures. Dr. Vastano has also concentrated on the analysis and application of satellite data over the last five years. He has made traditional Lagrangian analyses of satellite-traced drifter data and most recently, Dr. Vastano has made numerous analyses of sea-surface flow estimates derived from AVHRR imagery for streamfunction, seasurface topography and vorticity fields. He has also used satellite AVHRR to derive the local and advective time rates of change of heat content in the sea surface layer.

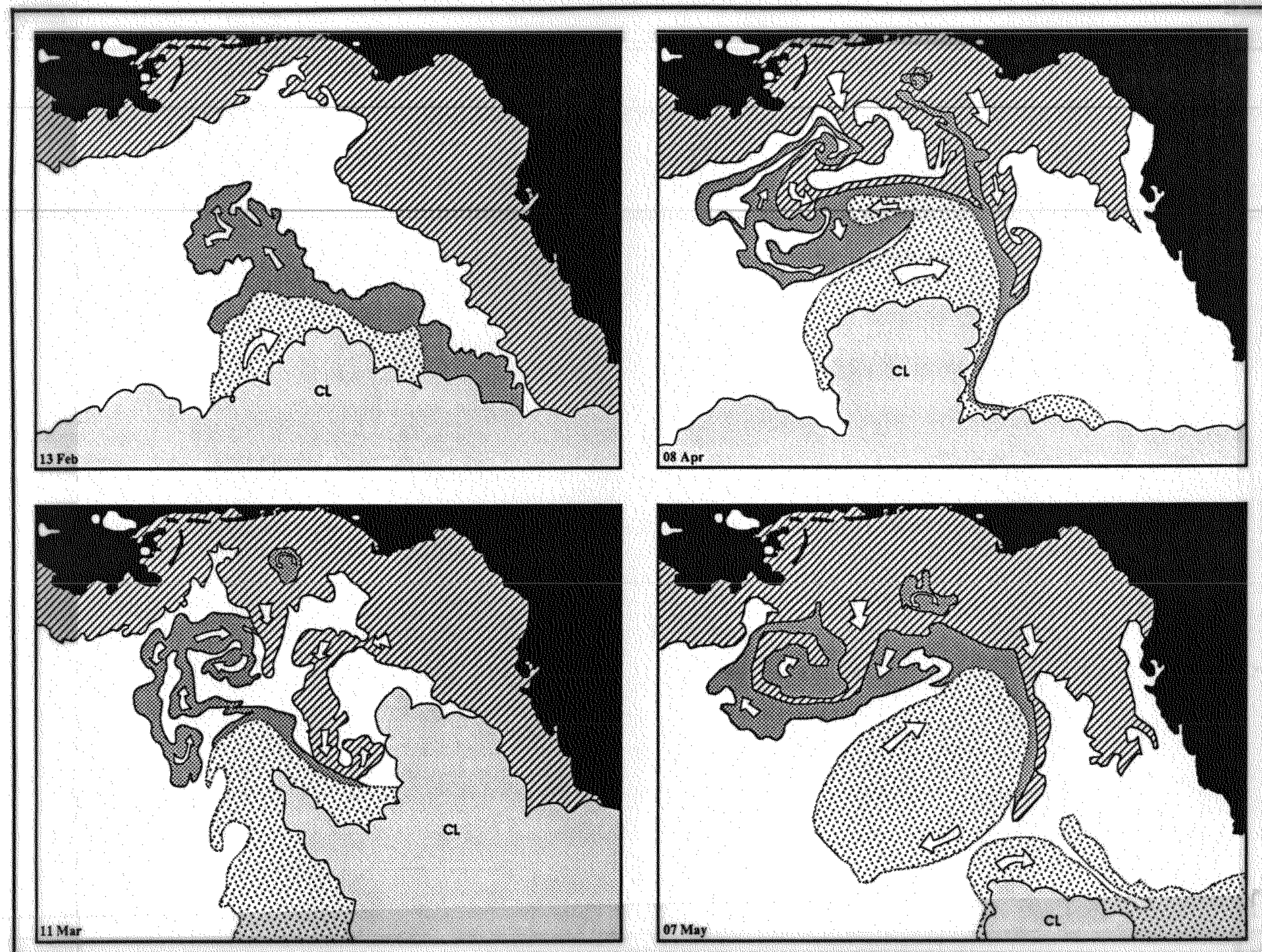

Figure 6.2. Schematic representations of a Loop Current intrusion and associated offshore, shelf water plumes taken from satellite infrared imagery on 13 February, 11 March, 08 April, and 07 May 1988. (Shelf waters are represented by coarse stripe shading, the intrusive waters by fine stripe, Loop Current and Loop Current eddy by course dot, and cloudy regions by fine dot shadings.)

MISSISSIPPI/ALABAMA MARINE ECOSYSTEM STUDY: MACROINFAUNA AND MACROEPIFAUNA

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The Mississippi/Alabama continental shelf has three basic sedimentary regimes that appear to influence the community composition of infauna and, to a degree, epifauna; i.e., coarse sand-coral rubble at stations D2 and D3, very soft mud at stations C3, C4, M4, and D4 (Figure 6.3). The remaining stations have a sandy to sand-shell sediment.

The macroinfaunal communities were dominated by polychaetous annelids. Of these, *Armandia agilis*, the most abundant species, attained very large numbers only during cruise 3 (spring 1988) and was an insignificant member of the community otherwise. The most "stable" infaunal dominant species were *Lumbrineris ernesti* and *Paraprionospio pinnata*. Bivalves and amphipods constituted the second and third most abundant groups. Most of the dominant species have also been reported as dominating assemblages in the western Gulf of Mexico. Abundances of macroinfauna decreased in deeper water on two of the three transects; the *Armandia agilis* population was very large at station C4 in spring 1988 and caused the total abundance to be much higher than at M4 or C4.

Abundances of macroinfauna increased between spring 1977 and spring 1988 and then declined through spring 1989. Cluster analysis of data indicates that the assemblages are influenced by sediment type; the deep stations (200 m depth) formed a cluster distinct from the sand/sand-shell/coarse sand stations.

Macroepifaunal assemblages were dominated by crustaceans, especially penaeid and caridean shrimp and portunid crabs. Abundances of macroinfauna increased between spring 1977 and spring 1988 also, and then declined through spring 1989; the decrease in spring 1989 was extreme as very few organisms were obtained by trawl at any station. There did not appear to be a trend of decreasing abundance from nearshore to offshore.

Cluster analysis indicated that the inshore stations (20 m depth) and the deep stations (150 and 200 m) each formed distinct groups, and the sand-shell/coarse sand bottomed stations in between (D2, D3, and M2) formed a separate cluster.

The heart urchin communities, which were principally located at stations C3 and C4, near the Mississippi River Delta, were comprised of a species complex of the genus *Brissiopsis*, which included *B. alta*, *B. atlanticus*, and two morphs that integrated between the two "species." The urchin populations appeared to be relatively stable from spring 1987 through fall 1988. In spring 1989, the numbers and sizes of urchins were greatly reduced, suggesting that some event had eliminated the adult urchins from the community, and the community was being repopulated by younger individuals.

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MISSISSIPPI/ALABAMA MARINE ECOSYSTEM STUDY: FISH TAXONOMY

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INTRODUCTION

The Mississippi/Alabama continental shelf has long been known for its diverse and productive fisheries resources. Gunter (1963) noted that 23% of the nation's marine fish landings occurred in ports from Pascagoula, Mississippi, to Port Arthur, Texas. The fish assemblage of the area is often considered to be transitional between that of the soft, terrigenous substrata of the northwestern Gulf of Mexico and that of the carbonate substrata off peninsular Florida.

The present study was designed to build on the foundation of historical data and to provide an up-to-date and semi-quantitative picture of the composition and distribution of the fishes of this shelf area to a depth of 200 m. Summer and winter

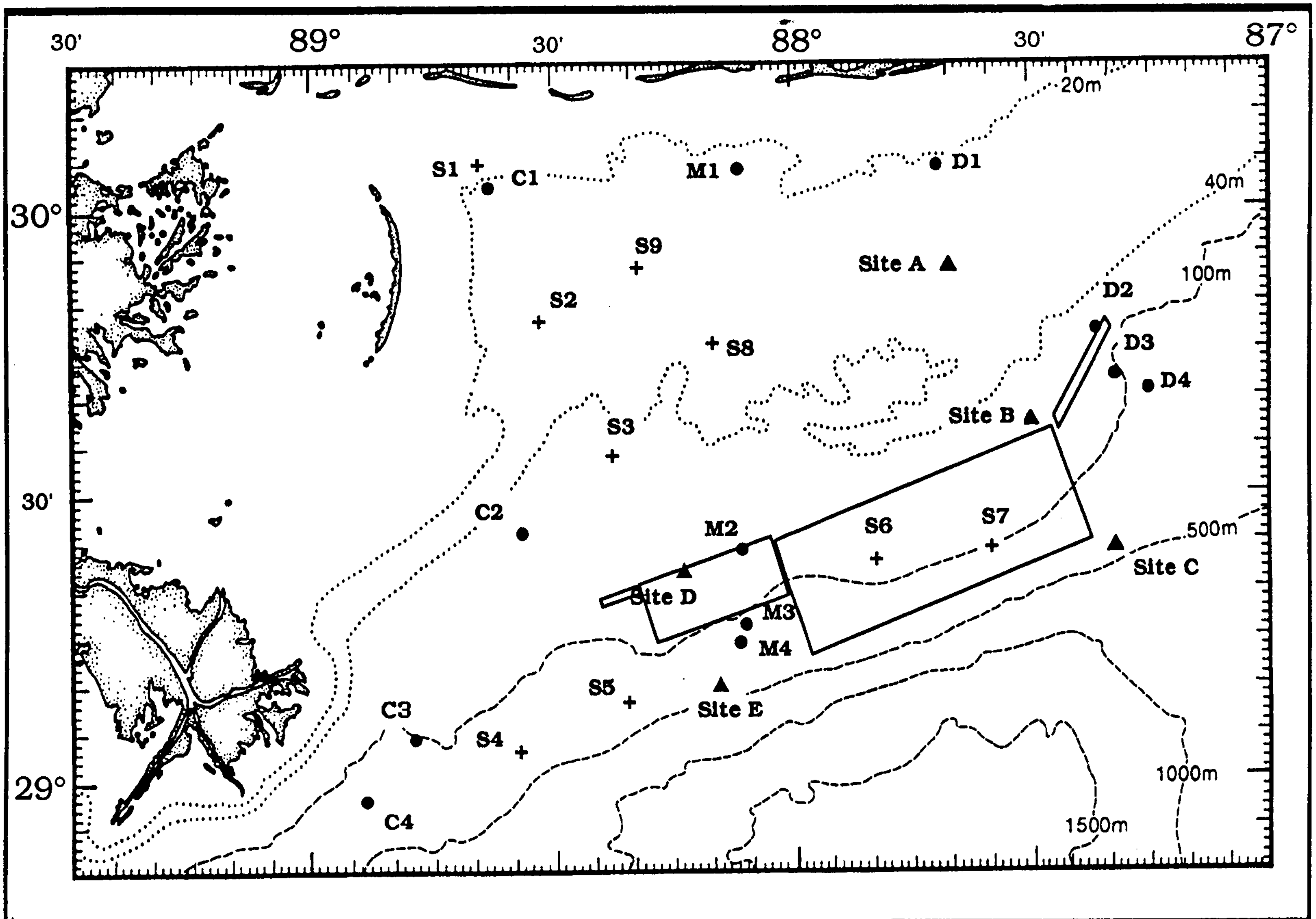

Figure 6.3. Sampling station current meter array locations and the area of geological characterization and topographic features study (map).

surveys along three transects were made with stations at depths of approximately 20, 60, 100, and 200 m The three transects were extended seaward near Chandeleur Islands, off Mobile, Alabama and near DeSoto Canyon. Paired trawl hauls were made at each station, and data were analyzed to determine species composition, species distribution patterns, faunal assemblages and associations of faunal assemblages with physical factors.

METHODS

Field collections were made during three winter and two summer cruises. Despite some bad weather and gear problems, 104 successful trawl collections were made (59 during winter and 45 during summer). All 12 stations were sampled at least 4 times during each season.

Each trawl haul was standardized to a common unit of area to facilitate comparisons. The actual area covered by each trawl was estimated by multiplying the trawl spread by the distance trawled. These estimates were standardized to reflect catch per species per hectare (10,000 m^2). Spread of the trawl was directly observed during special trials at two depths by scuba divers.

Trawl variability was estimated by comparing the 46 sets of paired trawl hauls. Length frequency plots were prepared for the 20 most abundant species. Plots were summarized by cruises and by seasons. Species diversity was computed for stations, transects, depths, cruises, and seasons. The Canberra metric dissimilarity coefficient was used to estimate faunal affinities. Entities were stations in the normal classification and degree of overall similarities between assemblages of fishes were measured. Entities were species in the inverse classification and their presence and/or abundances in collections were the attributes.

RESULTS

Variability of the trawl catches for all 46 paired hauls was a little over one-third of the mean catch. This variation was thought to be due to stormy weather that plagued all of the cruises. Most of the variance was at the deepest stations where winds and currents were the strongest.

A total of 16,182 fish specimens were collected weighing 312.6 Kg. These averaged 323.3 fishes per hectare weighing 6.22 Kg per hectare. The fishes represented 207 species in 68 families. The most speciose families were Bothidae (18 species), Serranidae (17 species), Triglidae (14 species), Ophididae (9 species), Ogcocephalidae, Sciaenidae, and Scorpaenidae (7 species) and Congridae, Synodontidae, Gadidae, Lutjanidae and Cynoglossidae (6 species).

There was no clear pattern of numerical abundance by any species or small group of species. The most abundant species made up 10.3%, the top 5 species made up 30.5%, the top 10 species accounted for 45.1% and the top 20 species comprised 61.0% of the total catch.

Halieutichthys aculeatus, pancake fish, was the most abundant and ubiquitous species. It was captured in high abundance on both winter and summer surveys, and was taken along all transects and at all depths. Length of specimens ranged from 4 to 11 cm and represented 2 age classes, young of the year and one-year olds.

Stenotomus caprinus, longspine porgy, was second in abundance and widespread, but was more abundant at the two inshore stations (20, 60 m). Lengths of specimens ranged from 3 to 19 cm and represented 2 age classes, young of the year and one-year olds.

Syacium papillosum, dusky flounder, was third in abundance and was most abundant at intermediate depths (60 m) along the Mobile Bay and DeSoto Canyon transects. Lengths ranged from 34 to 28 cm and represented several age classes.

Syacium gunteri, shoal flounder, was fourth in abundance and most common at the shallower stations (20, 60 m) along the Chandeleur Islands transect. Lengths ranged from 4 to 24 cm and represented at least 2 age classes, young of the year and one-year olds.

Anchoa hepsetus, striped anchovy, was fifth in abundance and almost entirely limited to the shallowest station (20 m) along the Chandeleur Islands transect. Lengths ranged from 6 to 14 cm and represented 2 age classes, young of the year and one-year olds.

The 20 most abundant species displayed several distributional and temporal patterns within the study area. Several were most abundant at intermediate depths (60, 100 m) along the Chandeleur Islands transect. Two were most abundant at the deepest station along the Chandeleur Islands transect. Several were most abundant at the shallowest station along the Chandeleur Islands transect. One species moved from the deeper stations (100, 200 m) during the winter to the shallowest stations (220, 60 m) during the summer surveys. Two species were most abundant at the inshore stations (20, 60 m) along the Mobile Bay and DeSoto Canyon transects. One species was most abundant at intermediate depths (100 m) along the DeSoto Canyon transect. A majority of the 20 most abundant species appear to be short lived, in that samples consisted of young of the year and one-year olds, and the one-year olds were mature.

The number of species captured at the 12 stations over the 5 surveys ranged from 3 on the fifth survey at station C4 (200 m) to 32.5 on the fourth survey at station C2 (60 m). The average number of species per station was about 20 (range 17.1 to 21.8) for all surveys except for the last survey on which the number of species averaged 11.3 per station.

The number of individuals per hectare captured at the 12 stations over the 5 surveys ranged from 13.7 on the fifth survey at station M1 (20 m) to 1,859.2 on the fourth survey at station C1 (20 m). The average number of individuals per hectare ranged from 91.9 for the fifth survey to 510.9 for the second survey.

The indices of diversity, H', for the 12 stations over the 5 surveys ranged from 1.16 on the fifth survey at station C4 (200 m) to 3.13 on the third survey at station M3 (100 m). The first survey had the lowest mean diversity and the third survey had the highest mean diversity.

The lowest number of species, mean number of individuals per hectare and mean total weight per hectare were lowest for the fifth survey. The fourth survey had the highest average number of species, and the second survey had the highest average number of individuals and highest average total weight per hectare. The third survey had the highest average H' diversity. The deepest stations (200 m) had the lowest average number of species, lowest average number of individuals per hectare and the lowest average total weight per hectare but not the lowest H' diversity. DeSoto Canyon transect had the lowest average number of species, lowest number of individuals per hectare and lowest average total weight per hectare on the winter surveys. Chandeleur Islands transect had the highest average number of species, highest average number of individuals per hectare and highest total weight per hectare on the summer surveys.

The cluster analysis for all five surveys divided the 57 stations sampled (collections) into two major groups (A and B) of 34 and 23 collections, respectively (Figure 6.4). Each of the major groups was in turn subdivided into two major subgroups. Group A has one major subgroup consisting of 19 collections (Subgroup A1) and the other consisting of 15 collections (Subgroup A2). Subgroup A1 includes all of the collections at station 1 along the three transects, in addition to 4 of the 5 collections at station C2. Four of the five collections at station D1 clustered together and were the most distinct of the subgroup. Subgroup A2 consists of all of the collections at stations M2 and D2, and one collection at station C2, in addition to the four collections at station D3. Within Subgroup A2, the collections along the Chandeleur Islands and the Mobile Bay transects, and one station along the DeSoto Canyon transect, clustered together, and the remainder of the collections along the DeSoto Canyon transect clustered together. Group B has two major subgroupings, B1 and B2, consisting of 10 and 13 collections respectively. Subgroup B1 consists of all of the collections at the third stations along the Chandeleur Islands and Mobile Bay transects. Subgroup B2 consists of all of the collections at station 4 along the three transects. The DeSoto Canyon stations clustered together and the Chandeleur Islands and Mobile Bay stations clustered together.

Clustering indicated that depth is important in clustering stations, and that the Chandeleur Islands and DeSoto Canyon transects are more distinct from each other than either is from the stations along the Mobile Bay transect.

DISCUSSION

Trawl samples can, at best, be considered semi-quantitative because of the source of variables inherent in the sampling procedures; i.e., coastal currents, sea state, wind, bottom topography and composition, operation of the ship, trawl winch and trawl, various degrees of clumped distribution among the fish species, location of fishes in relation to the bottom and relative ability of different fish species to avoid the trawl. However, despite these variables, sequential tows, made at approximately the same location in rapid succession, deviated only slightly over one-third from the mean value of the two tows. Further, there is general agreement among surveys and combined seasonal surveys for average number of species, average total number of individuals, average total weight and average H' diversity. The sole exception was the fifth survey, in which the average number of species, average total number of individuals and average total weight were greatly

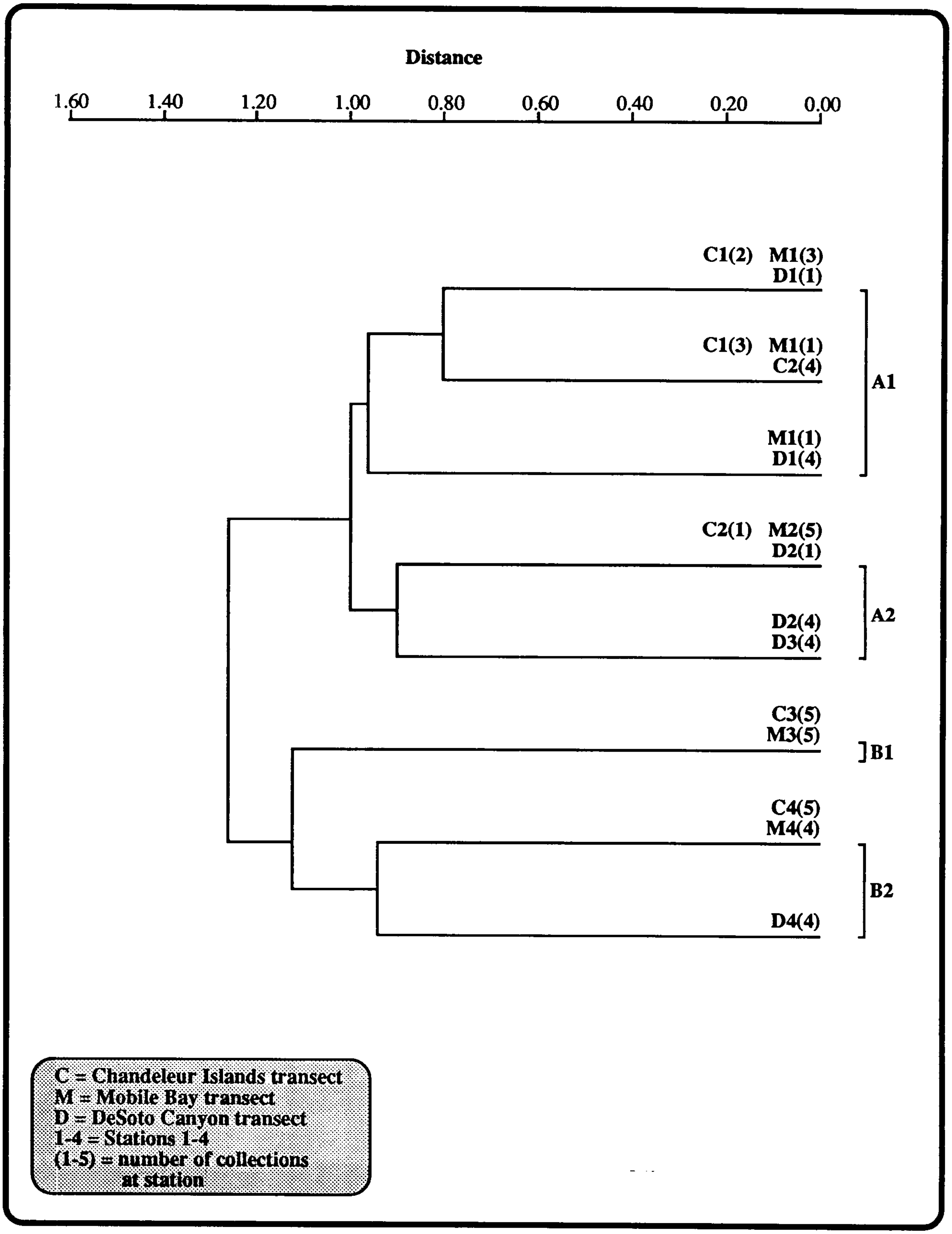

Figure 6.4. Station clusters for all cruises combined.

reduced and the average H' diversity was moderately reduced. The deviations between sequential tows and correspondence among the first four surveys suggest that the lower values for the fifth survey are real, and the result of a major environmental perturbation.

The present study is remarkable because no species or group of species is dominant in abundance, suggesting that more than a single habitat was sampled along the coast of the study area. Other studies of fishes of the continental shelf in the Gulf of Mexico have found that a relatively small number of species are dominant in abundance. Unlike most of the previous studies the present study took place in a transitional area between the soft, terrigenous substrates of the northwestern Gulf of Mexico and the calcarious substrates of the northeastern Gulf of Mexico.

The clustering by stations and by species suggested that depth is a prime factor in distribution of the fishes but also that there is a faunal break between the Chandeleur Islands and DeSoto Canyon transects. The faunal break is supported by reports in the literature and by the lack of dominance of a small group of fish species in the species composition.

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Dr. John D. McEachran has worked at Texas A&M University for 18 years and currently serves as Professor in the departments of Wildlife and Fisheries Sciences and Oceanography. His areas of research interests are systematics and biogeography of fishes of the Gulf of Mexico. Dr. McEachran received his B.A in zoology at Michigan State University, his M.A. in marine biology at the College of William and Mary, and his Ph.D. in marine biology at the College of William and Mary.

DEMERSAL FISH FOOD ANALYSIS

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INTRODUCTION

Among the functional characteristics of ecological systems, none is more basic than the flow of materials and energy through the producer, consumer, and decomposer components. Whereas, this flow is governed in all systems by physical and chemical laws, each system is unique in the way this flow is programmed through the various biological components. The pattern of material and energy flow is referred to as the trophic structure of the system, and the primary means of studying this structure is through the analysis of food habits of the component species.

The present study was designed to examine the trophic structure of the continental shelf ecosystem off Mississippi and Alabama. By focusing upon this limited area and by making repeated collections at regular stations carefully spread throughout the area, it was anticipated that the study would reveal not only the overall trophic picture, but also trends, gradients, and local variations that might be associated with depth, transect, food resource availability, and other factors. In this respect, the study represents a pioneering effort to examine local aspects of the continental shelf ecological system through the medium of fish food consumption. A further goal of the study was to determine objectively the relations of the various collection stations to each other based upon similarities and differences in food group utilization.

All fish specimens examined in the present study were taken by bottom trawls at the regular sampling stations. The 4,675 individual fishes examined represent 28.9% of all fishes taken by trawls during the study. All told, 49 species of fishes were examined. Efforts were made to include 10-20 specimens with food from each available size class and to achieve representation of the different depths and transects inhabited by each species. Space precludes consideration of the food patterns of individual species, and only the broader ecosystem aspects of the results are presented here.

RESULTS

Utilization of the various food groups by all species combined is shown in Table 6.1. Crustaceans made up the bulk of the food (47.5%) followed by fishes (14.4%) and polychaetes (13.2%). Together these three food categories accounted for 75.1% of all the food and 97.4% of the identifiable food items. The remainder included minor phyla, valved mollusks, cephalopods, and organic detritus. Undetermined animal matter constituted 22.8% of the total stomach contents.

Table 6.1. Summary of the Percent Utilization of the Various Food Groups by All Species Combined.

Food Group	Percent
Major Food Groups:	
Minor phyla	0.13
Mollusks (valved)	0.07
Cephalopods	0.62
Polychaetes	13.18
Crustaceans	47.52
Fishes	14.38
Animal matter (undetermined)	22.83
Organic detritus	1.27
Crustacean Groups:	
Small benthic crustaceans	0.75
Calanoid copepods	3.08
Isopods	0.82
Amphipods	9.00
Shrimp	58.61
Lobsters	3.81
Megalopa	2.69
Crabs	10.05
Stomatopods	4.17
Undetermined crustaceans	7.03

Among the crustaceans, shrimp made up over half of the food (58.6%) followed by crabs (10.1%) and amphipods (9.0%). Together these groups constituted 77.7% of all the crustacean material and 83.6% of all the identifiable crustaceans. Additional groups included calanoid copepods, isopods, lobsters, megalopa, stomatopods, and a variety of small benthic crustaceans (ostracods, harpacticoid copepods, cumaceans, and anomurans).

The distribution of the major food groups by depth was examined to determine statistically significant patterns. Polychaetes and crustaceans (particularly the larger mobile species) showed no significant patterns. They appeared to be universally present and were consumed equally at all depths. Cephalopods were eaten in greatest quantity at the shallowest stations, and their utilization decreased regularly with depth. Fishes made up only a small percentage of the food at the shallowest stations, and they peaked at a depth of 100 m. Among the crustaceans, the zooplankton and small benthic species peaked at the shallowest stations and decreased more or less regularly with depth. Benthic microcrustaceans peaked at two depths, 20 m and 100 m, and they were very low at the remaining depths.

The distribution patterns of food intake by transect were also examined. Fishes were consumed most heavily on the Chandeleur transect, zooplankton was taken most abundantly on the Mobile transect, and benthic microcrustaceans were utilized most intensely on the DeSoto Canyon transect. The remaining food groups appeared in about equal abundance on all the transects.

Principal component analysis was employed to determine similarities in food utilization patterns of the different study stations. The analysis revealed that the two shallowest stations on the DeSoto Canyon transect (D1 and D2, Figure 6.3) were greatly different from each other and from all other stations. The two deeper stations on the DeSoto Canyon transect (D3 and D4) clustered together and with the 100-m station of the Chandeleur transect (C3). All the remaining stations on the Chandeleur and Mobile transects formed a single large cluster, but the two shallowest stations (C1 and C2) were somewhat distinct from each other and from the remaining stations within the group.

In overview, the fish populations on this shelf area are very mobile, and each species has independently developed its own particular life history pattern. At first glance the complex community dynamics are bewildering. However, upon careful analysis certain clear feeding patterns emerge. The young of most species inhabit shallower water, and as they mature they move to greater depths. While in the shallows they tend to feed largely upon zooplankton, small benthic crustaceans, and young squids. As they grow and move into deeper water they concentrate upon polychaetes, shrimp, and fishes (according to what is locally available and what they can best capture). Because of its unique hydrographic, sedimentary, and biological characteristics, the DeSoto Canyon region is a unique feeding area. Closer to the Mississippi River Delta, the 100-m depth on the Chandeleur transect is also unique, but the reasons for this are not immediately apparent.

Dr. Rezneat M. Darnell is a professor of Oceanography at Texas A&M University. He has investigated ecosystem composition and dynamics of streams, estuaries, and continental shelves. Recently he has examined the distribution of demersal fish and 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. He has also studied factors responsible for the transport of larval fishes, shrimps, and crabs and has contributed to the understanding of estuarine and marine food webs. Dr. Darnell received his B.S. in biology from Rhodes College (Memphis), his M.A. in biology from Rice University, and his Ph.D. in zoology from the University of Minnesota.

MISSISSIPPI/ALABAMA MARINE ECOSYSTEMS STUDY GEOLOGICAL CHARACTERIZATION: SEA LEVEL EFFECTS ON CARBONATES AND SEDIMENTATION

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INTRODUCTION

Though many sections of the northern Gulf of Mexico continental shelf have been extensively surveyed, topographic and sedimentary features of the Mississippi/Alabama outer shelf were poorly known. Pinnacle-like calcareous structures had been observed near the shelf edge (Ludwick and Walton 1957), but their area-wide distribution could only be surmised. Moreover, the known sediment distribution, a relict sand sheet thought to cover most of the middle and outer shelf and a belt of calcareous reef and interreef facies at the shelf edge (Ludwick 1964), appeared to be suspiciously simple in comparison with sediments elsewhere in the northern Gulf of Mexico (e.g., Curray 1960). The goal of our study was to clarify the picture of geologic features in this area and illuminate their interrelationships using high-resolution geophysical data.

METHODS

During 1987 and 1988 we surveyed 1,620 km^2 of the Mississippi/Alabama outer continental shelf using a 100-kHz side-scan sonar to provide acoustic images of the seafloor and either a 3.5-kHz or 4.0-kHz echo-sounder as a subbottom profiler to probe the upper sediment layers. Survey track positioning was accomplished using either STARFIX satellite or ARGOS radio-triangulation precision navigation. Geophysical data were collected along survey track lines mainly oriented along the shelf-break trend and spaced to allow complete coverage with the side-scan sonar (Figure 6.5). Only in the featureless northern third of the western extension was the side-scan coverage less than 100%. There alternate lines were skipped, yielding 55% coverage. Interesting features were examined in greater detail by four surveys using a narrow side-scan swath-width and covering areas of 0.5-1.0 km^2. Additionally, six tie lines were run oblique to the shelf-break trend to obtain seismic reflection dip-lines with the echo-sounder and a 400-Joule mini-sparker.

Side-scan sonar records were analyzed individually for details and photographically assembled into mosaics 9-14 km on a side to examine larger trends (Laswell *et al.* 1990). Bathymetry data were derived from the echo-sounder profiles and corrected for sound-speed variations using temperature and salinity measurements made near the survey area. A limited amount of ground-truth data was collected using a remotely operated vehicle (ROV) to obtain underwater video and still photographs (27 stations) and a grab or dredge to gather geologic samples (17 stations each).

RESULTS

Seafloor depths in the survey area range from about 48 m on the northern (landward) side to 240-360 m on the southern (seaward) side (Figure 6.6). The shape of the outer shelf is mostly smooth with a gradual decline to the upper slope at about 120 m. Two seaward bulges in the bathymetry contours within the main survey area are the surface expressions of two relict fluvial deltas.

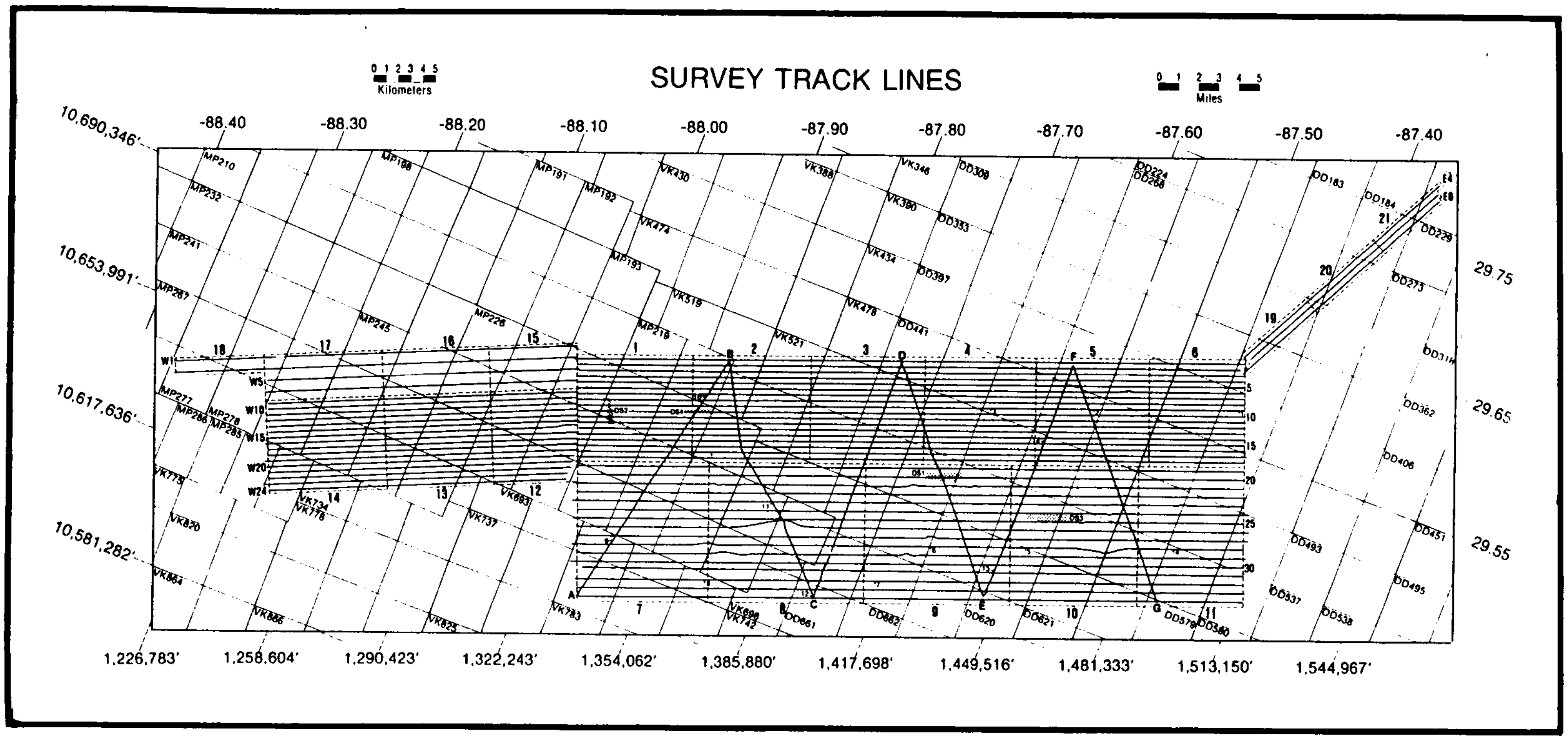

Figure 6.5. Mississippi/Alabama Marine Ecosystem Study geophysical survey ship tracks. (Ship tracks are the heavier lines. Small numbers are line numbers: 1-34 and A-G in the main survey; E4-E6 in the east extension; and W1-W24 in the west extension. Dashed lines denote the boundaries of side-scan sonar mosaics [Laswell *et al.*] Larger numbers are mosaic numbers. Black boxes are locations of detailed surveys. Light squares in the background are OCS leaseblock boundaries.)

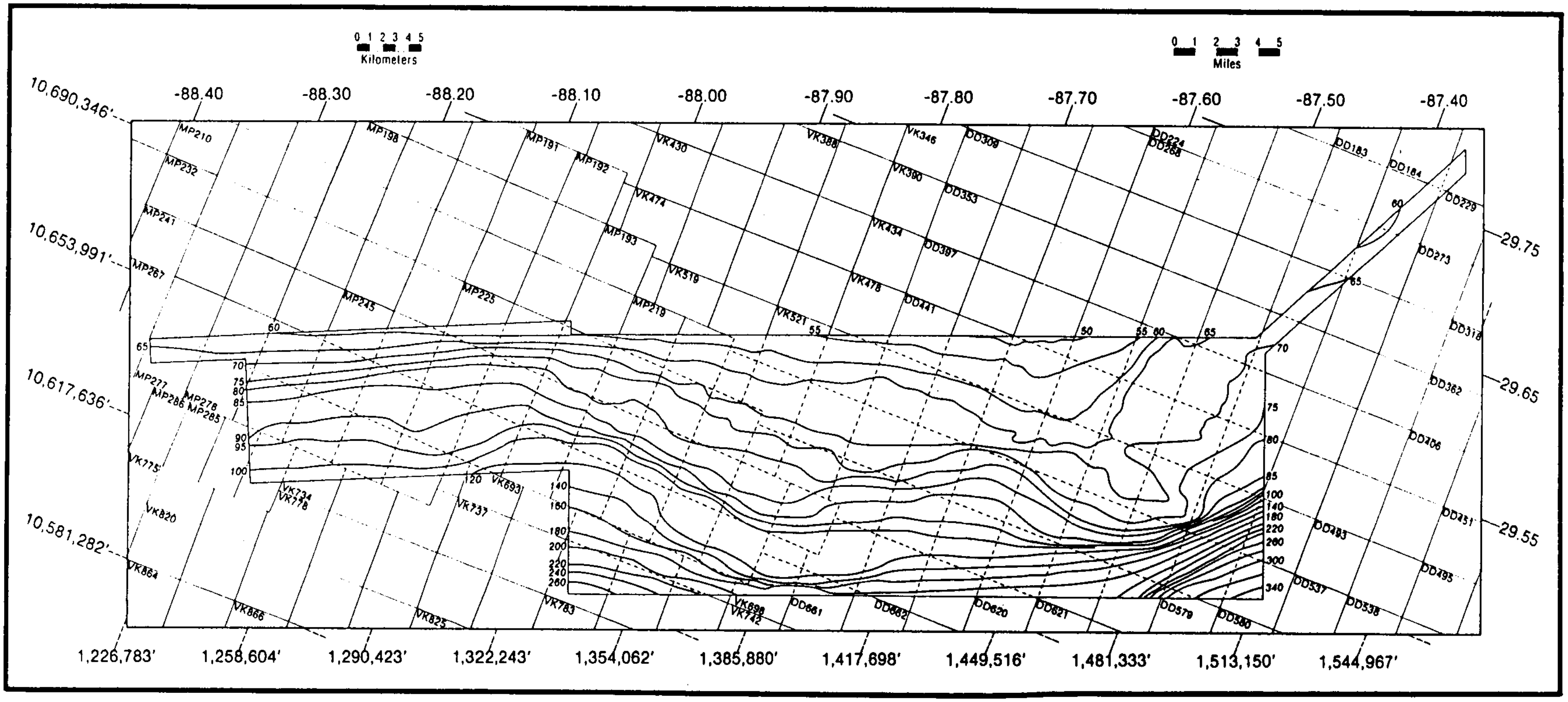

Figure 6.6. Bathymetric contours in the Mississippi/Alabama Marine Ecosystems Study area. (Five meter contours shown to 100 m depth; deeper contours are at 20 m intervals.)

Punctuating the expanses of flat outer shelf seafloor are a multitude of topographic features, divisible into three classes: (1) reef-like mounds (RLM), (2) ridges, and (3) shallow depressions. The depressions are similar to "pock-marks" caused by gas seeps in shelf settings elsewhere (Hovland and Judd 1988). Unlike the other topographic features in this study, their distribution does not appear closely related to sea level.

The RLM are the most widespread and display the greatest variation in size and shape. Found in water depths less than 120 m, they are sometimes isolated, but more often occur in clusters. Most are equidimensional to slightly elongate in plan view. The smallest are 1-2 m in diameter, usually with nearly equivalent heights. Several fields were found containing thousands of small RLM (3,500-7,000 per km^2) with the appearance of patch reefs. The largest RLM are 500-1,000 m in diameter with heights of 3-15 m. Additionally, the RLM display three types of summit morphologies: spire-like ("pinnacles"), flat-topped, and hummocky. Our ground truth studies corroborated previous results (Ludwick and Walton 1957) and imply that the RLM are calcareous bioherms.

Although the RLM appear at most depths, they are mainly concentrated along two isobath bands: 105-120 m and 74-82 m (Figure 6.7). A smaller number of other RLM, not associated with these two groups, are found at depths of 87-94 m in the western survey extension and 60-70 m in the northern part of the main survey.

The second type of topographic feature, ridges, mainly trend along the landward side of the 74-82 RLM band. These features are usually isobath-parallel and have typical widths of tens to hundreds of meters, heights of 1-8 m, and lengths of up to 20 km. Often the ridge is asymmetric with a seaward escarpment. The largest, with a height of up to 8 m, is found in the western part of the main survey area. It bears a striking resemblance to small, modern barrier islands on the Louisiana coast (Penland *et al.* 1988).

Seismic reflection data show two delta lobes within the main survey, one on the east side and one on the west. These deltas have thicknesses of greater than 80 m and 125 m, respectively. Atop each is an unconformity whose erosional nature is indicated by foreset bed truncation on the seaward side of each delta. Interestingly, the RLM are concentrated on the truncated foreset beds at the center seaward edge of each delta, perhaps because these beds provided a suitable substrate for their growth.

The deeper unconformity (A) has an average seaward slope of 0.4° and forms a surface that appears to be continuous across most of the survey area. Only a thin sediment layer, 1-7 m thick, overlies this surface in the western part of the survey. The seaward edge of this unconformity occurs consistently at an average of 126 m and probably delineates the shelf edge during a sea level lowstand. Eastern delta sediments bury A in the central part of the main survey, indicating that the delta is younger. The unconformity atop this delta (B) has a seaward slope similar to A and ranges from 90 to 68 m in depth. Recent sediments deposited atop B are thin and patchy.

Side-scan sonar mosaics showed complex patterns of backscatter (acoustic energy bouncing off the seafloor). Backscatter is primarily a function of sediment texture; for example, sand and gravel usually display strong backscatter whereas that for mud and clay is low. Thus, the backscatter pattern complexity implies a similarly intricate distribution of sediments.

We divided the backscatter patterns into ten different classes (Figure 6.8, Table 6.2). Four classes consist of seafloor with homogeneous reflectivity of varying strengths. Six denote "patchy" patterns of varying forms. The homogeneous backscatter types were (R1) low, (R2) moderate, (R3) moderate-strong, and (R4) strong. Patchy patterns included those with linear trends, (R6) occasional wispy lineations, (R8) large high-backscatter linear features with a consistent trend, and (R9) small high-backscatter linear features with a consistent trend, and those without dominant trends, (R5) large patchy high-backscatter areas, (R7) small patches of high-backscatter, and (R10) strong backscatter seafloor with quasi-linear, randomly oriented trends.

Strong backscatter was usually correlated with RLM and ridges. The RLM cluster between 105-120 m in the western part of the main survey and that between 74-82 m in the eastern part of the survey constitute the largest areas of high backscatter (R4). The strong acoustic echoes appear to come from reef and interreef facies sediments around the RLM. These probably contain large fractions of biologic debris, such as "shell hash." Similar backscatter characteristics occur along the large ridge trending across the northwestern part of the main survey. In this instance, the strong acoustic echoes may be from

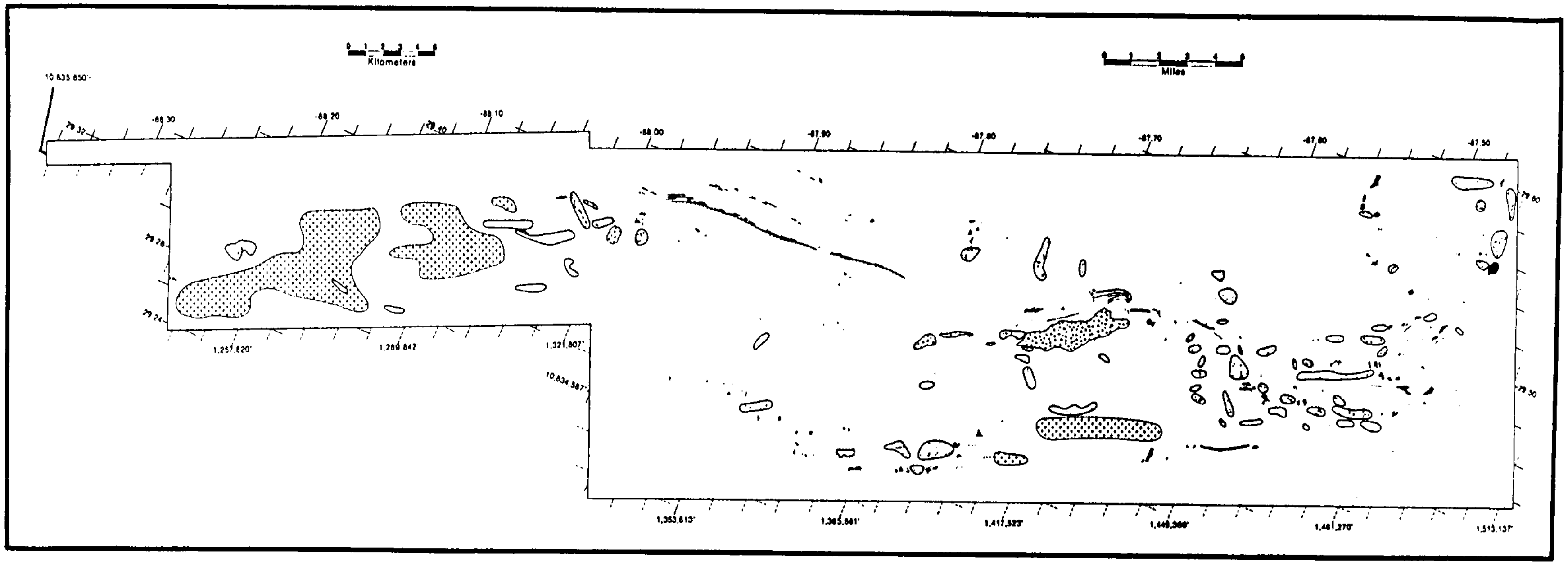

Figure 6.7. Topographic feature locations in the Mississippi/Alabama Marine Ecosystems Study area. (Reef-like mounds [RLM] are shown as black spots; closed contours surround groups of RLM too small to reproduce at this scale. Lines show ridge locations; lines with teeth depict asymmetric ridges with the teeth pointing downhill. Contours with gravel pattern denotes fields of thousands of small RLM ["patch reefs"]. Contours with plus symbols show fields of shallow depressions ["pock marks"].)

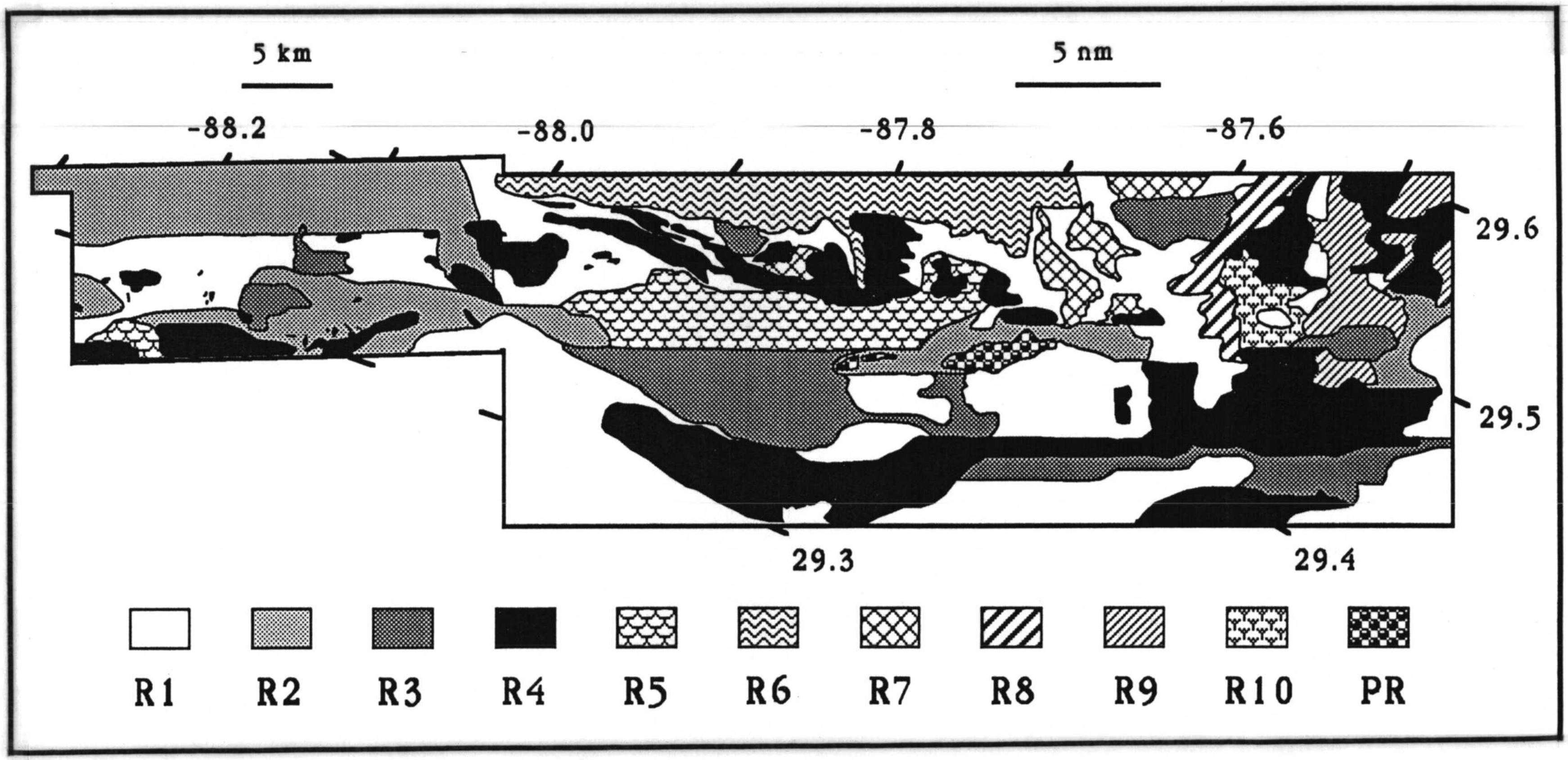

Figure 6.8. Distribution of backscatter patterns within the Mississippi/Alabama Marine Ecosystems Study area. (Pattern key at bottom; pattern descriptions in Table 6.2.)

Table 6.2. Acoustic Backscatter Patterns.*

R1	Low backscatter. Homogeneous light area on side-scan sonar record, usually showing featureless seafloor and yielding a weak seafloor echo.
R2	Moderate backscatter. Homogeneous, often featureless seafloor giving moderate acoustic echo.
R3	Moderate to high backscatter. Homogeneous, often featureless seafloor yielding moderately strong acoustic echo.
R4	High backscatter. Homogeneous, often featureless seafloor giving strong acoustic echo.
R5	Patchy backscatter. Seafloor with discontinuous, but typically strong acoustic echo. Areas of high backscatter are usually equidimensional, hundreds of meters across, and display no preferred trend.
R6	Moderate backscatter with linear high backscatter patches. Seafloor displays predominantly low to moderate backscatter. High backscatter patches are usually lineated, can occasionally be traced between adjacent ship tracks, and often show an overall trend within a limited area. Overall trends, however, are variable.
R7	Mottled backscatter. Seafloor with discontinuous moderate to high backscatter. Areas of high backscatter are usually equidimensional and show no preferred trend and are smaller than those in RS.
R8	Linear backscatter, large features. Predominantly strong backscatter with lanes of lower backscatter. Lineations are subparallel, trending generally northeast. Lineations are wide and long, measuring on average about 150-200 m across and 500-1,500 m in length.
R9	Linear backscatter, small features. Similar to R8 except that linear backscatter features are smaller and shorter, averaging about 50-75 m across and less than about 500 m in length. Area of low to moderate backscatter between features is greater than in R8.
R10	Quasi-linear backscatter, confused trends. Seafloor with varying, but predominantly strong backscatter having characteristics similar to R7-R9. Backscatter features are quasilinear, but do not have coherent trends.

*From side-scan sonar mosaics in Laswell *et al.* 1990.

sand, which is usually the main constituent of barrier islands and longshore dunes.

Patchy backscatter was found primarily in shallow water in the central and landward side of the survey area. In particular, the lineated backscatter features are in water shallower than about 75 m. This depth limitation suggests that the lineated and patchy features may be a result of sorting caused by large storm waves.

SEA LEVEL IMPLICATIONS

Though we have no age data, it appears that the RLM formed after the last ice age because they show no evidence of the subaerial erosion that would have occurred during the last ice age when the shelf was exposed. Furthermore, the living biotic assemblages on these features could not have built them, so they were probably not formed recently at their present depths. Corals or calcareous algae probably formed the RLM, so these features likely grew actively only near sea level, but because of the transgression since the last ice age, they are found all across the outer continental shelf. The concentration of RLM into two isobath bands implies two periods during which conditions for reef formation were particularly good; perhaps the water was clear and warm and sea level was at a stillstand or not rising rapidly. The scarcity of RLM at other depths suggests that each of these periods was followed by times that were not as conducive to reef formation.

The RLM and ridges are distributed in relatively good agreement with independent data showing the rise in sea level since the last ice age (Fairbanks 1989). Figure 6.9 shows our model of the formation of the RLM and ridges and their relationships to sea level. The outer edge depth of unconformity A (126 m) coincides with estimates of the depth of the sea level lowstand during the last ice age (121 + 5 m), which occurred approximately 18 ka BP in radiocarbon years (Fairbanks 1989). This observation implies that A was eroded during the lowstand and that subsequent subsidence has been negligible.

The deeper band (105-120 m) of RLM must have formed during the early part of the deglaciation, a period during which sea level rose slowly (Fairbanks 1989). Later in the early deglacial period, at about 12-13 ky BP, the sea level rise accelerated (Fairbanks 1989). The pinnacle-like spires on the summits of many of these RLM may show that these reefs were building upward rapidly, trying to maintain themselves in shallow water. The shallowest summits of the deeper RLM are at about 90 m, approximately the same depth that the first sediments of the eastern delta spill over onto unconformity A. Perhaps a combination of the rapid rise in sea level with the increased water turbidity caused a cessation in the active growth of these features.

The concentration of RLM and ridges in the 74-82 m isobath band and their association with unconformity B imply that a significant environmental change occurred. Because these features overlie the eastern delta, whose shallowest beds are at 68 m depth, this change must have occurred after sea level reached this depth. According to Fairbank's (1989) sea level curve, this level is approximately coincident with the Younger Dryas cold event (Broecker *et al.* 1988).

Unconformity B can be interpreted as a subaerial erosional feature and suggests that sea level fell by up to 22 m, caused perhaps by a resurgence of the ice caps during the Younger Dryas period. If the ridges had already formed from material scoured from the eastern delta, then their unusual lithification and preservation may have resulted from subaerial exposure and cementation. Obviously, the shallower band of RLM could not have formed until the sea reclaimed the erosional surface after the Younger Dryas. The abundance of RLM at this depth implies that there was a stillstand or that sea level rose slowly. Furthermore, all of the flat-topped RLM occur in this band of features, with summit depths consistently at 66 m. Perhaps these flat tops were caused by a limitation of the reefs' upward growth or a slight drop in sea level.

The sea level curve (Fairbanks 1989) implies another rapid rise in sea level after the Younger Dryas event. This phenomenon is consistent with the fact that the RLM of the shallower isobath band appear to have ceased significant growth and that there are only a few isolated RLM in the portion of the survey shallower than this band.

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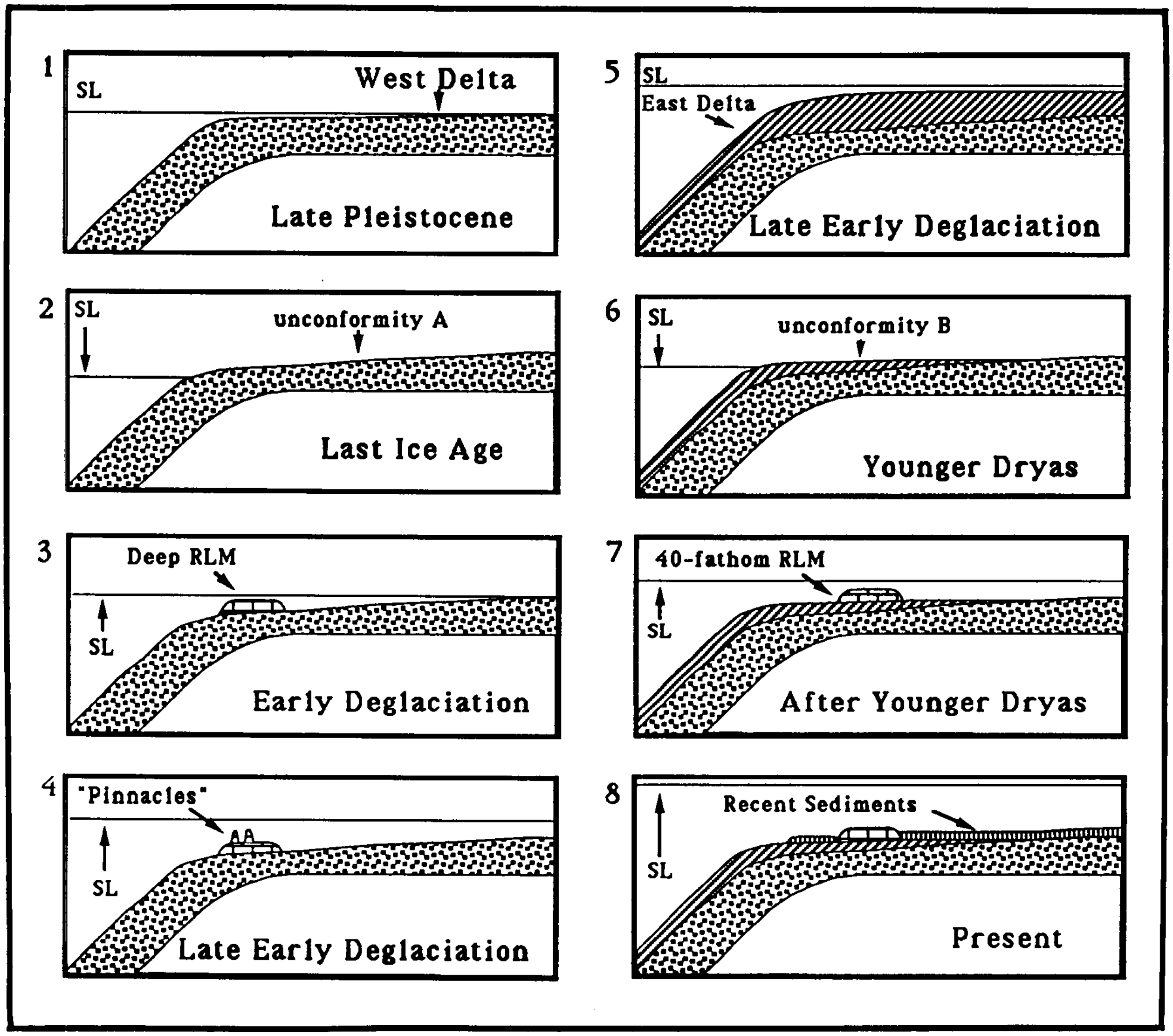

Figure 6.9. Cartoon showing hypothesized effects of sea level on sediments and topographic features in the Mississippi/Alabama Marine Ecosystems Study area. ("SL" shows sea level. Panels on left refer to the western part of the survey area; those on the right apply to the eastern part.)

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BIOLOGICAL CHARACTERIZATION OF COMMUNITIES ON TOPOGRAPHIC FEATURES IN THE NORTHEAST GULF OF MEXICO

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INTRODUCTION

South of Mobile Bay, there are extensive areas of low relief rock outcrops (Schroeder *et al.* 1988). Additional rock features exist on the outer continental shelf (OCS) and continental slope in the northeast Gulf between 73 and 365 m (Ludwick and Walton 1957; Moore and Bullis 1960; Ballard and Uchupi 1970; Shipp and Hopkins 1978). Some hardgrounds in the Mississippi Bight may represent "drowned reefs" or "paleo-reefs" of biogenic origin. Some of these may have begun development on hard substrates provided by authigenic carbonate production (Roberts *et al.* 1988).

Ludwick and Walton (1957) surveyed the OCS between the Mississippi River and Cape San Blas, Florida. They noted a zone of 10-15 m tall "pinnacles," 1.6 km wide and discontinuous with 16-40 km gaps in depths from 73-100 m. These are thought to be calcareous biogenic structures that formed since the last sea level low stand of the Pleistocene. Present-day biotic assemblages were of tropical Atlantic origin and dominated by ahermatypic hard corals (e.g., *Oculina?),* octocorals, and crinoids. Other organisms include antipatharians, various crabs, asteroids, ophiuroids, and fishes commonly associated with hard-bottom habitats elsewhere in the Gulf of Mexico (Continental Shelf Associates [CSA] 1985).

As part of the "Mississippi/Alabama Marine Ecosystem Study," the Minerals Management Service (MMS) requested complete side-scan sonar coverage and selective video reconnaissance within an area of 1620 km^2 on the OCS off eastern Louisiana, Mississippi and Alabama (Figure 6.10). Acoustic surveys showed the area to contain a variety of substrate and topographic feature types (e.g., Laswell *et al.* 1990). Topographic features included isolated low relief formations with relief up to 2 m, isolated moderate (2-6 m) relief and high relief features (up to 20 m relief), clusters of moderate and high relief features, linear ridges several kilometers in length, and clusters of shallow depressions. Horizontal extent of moderate and high relief reef-like mounds ranged from around two to over 700 m.

Particularly interesting among these groups are three feature types: "patch reefs," the pinnacles described by Ludwick and Walton (1957), and flat-topped reefs. Patch reefs are clusters of features, 2-12 m in diameter and 3-4 m tall, occurring in some places in densities of 35-70 per 10,000 m^2. The pinnacles are spire-like features 10-20 m tall, with rugged, often vertical reef faces and jagged summits. By contrast, the flat-topped reefs have similar reef faces, but flat summits up to approximately one kilometer across.

Such hard-bottom areas often contain biological communities of sensitive nature. They can be composed of organisms intolerant of unnatural perturbations that may occur with anthropogenic insult, including excessive sedimentation, eutrophication, and water pollution (Environmental Science and Engineering, Inc., LGL Ecological Research Associates, Inc. and CSA 1987). Such areas, termed "live-bottom areas" by MMS, are defined, in part, as "...those areas which contain biological assemblages consisting of such sessile invertebrates as sea fans, sea whips, hydroids, anemones, ascidians, sponges, bryozoans, or corals...[on]...hard or rocky formations with rough, broken, or smooth topography..." (MMS 1987). We summarize here the results of a biological reconnaissance survey conducted to evaluate the nature and extent of development of live-bottom assemblages inhabiting hard bottoms in the study area, and probable regional ecological controls on community development.

METHODS

Surveys on two cruises in 1988 were conducted at 22 locations within the initial study area (largest rectangle in Figure 6.10) using a remotely operated underwater vehicle (ROV). Surveys in 1989 were conducted on six unique reef and bank features to the west of the initial survey area. At least three of these features are surface manifestations of salt diapirs (Kindinger 1988). The features provided a continuum of topographic relief and habitat complexity (from virtually none to over 18 m vertical relief) over which live bottom community comparisons could be made.

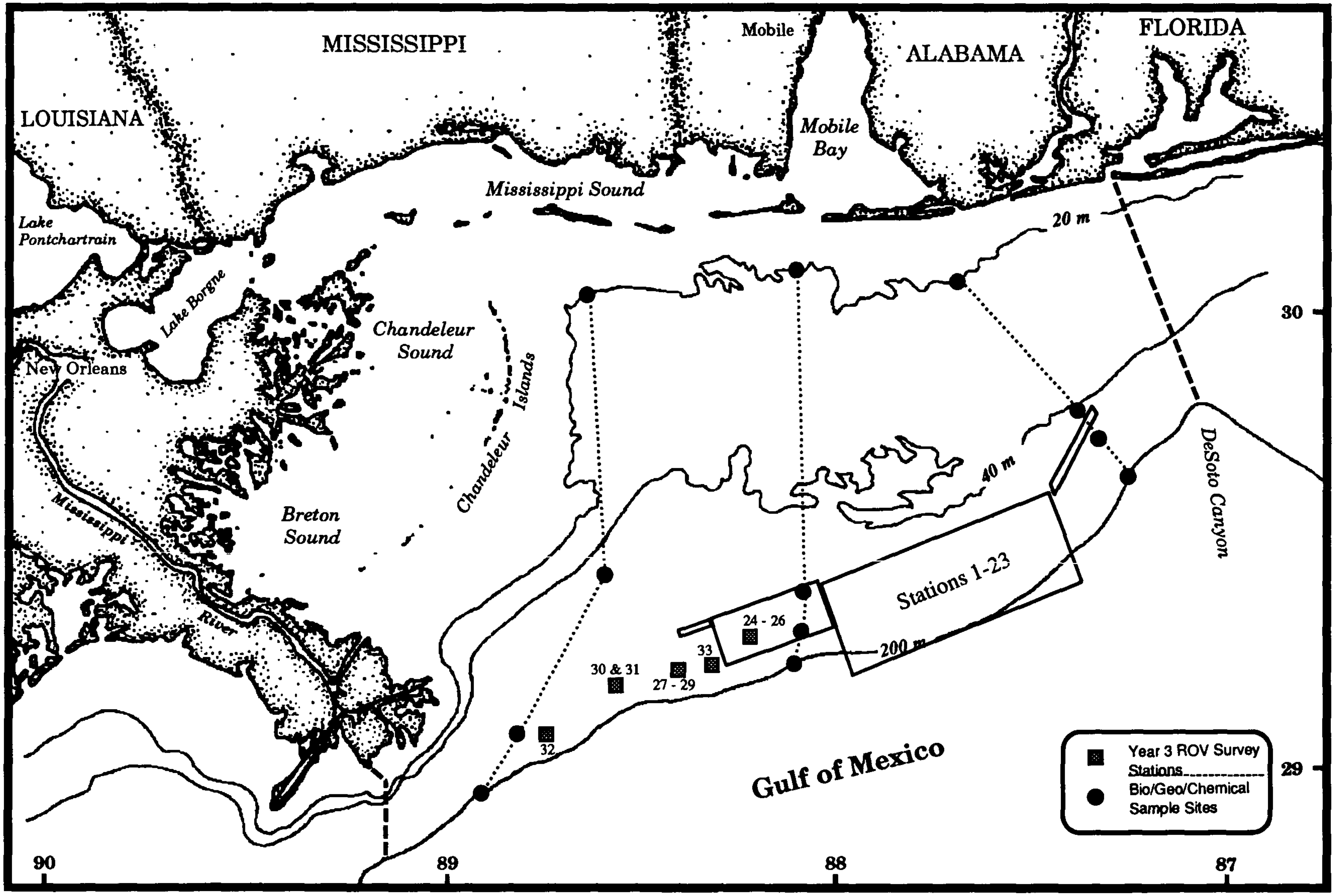

Figure 6.10. Map of Mississippi/Alabama Marine Ecosystems Study area, showing locations of reefs and banks surveyed during 1989 ROV cruise (Stations 24-33) relative to side-scan survey areas and bio/geo/chemical stations.

Data were collected at 27 sites over 28 days using ROV surveys, rock dredges, grabs and hook-and-line fishing. Station descriptions included, among other things, characterizations of habitats, biotic composition, and qualitative descriptors of abundance for each taxon in each habitat type present at stations (some stations contained reef flats, reef faces, low surrounding features, rubble debris fields, and surrounding sandy bottom areas). Complete station descriptions are given by Brooks and Giammona (in prep). Qualitative descriptors for taxa at each station were:

Rare	seldom observed, or a very small percentage of observations at a site; usually only once or twice at any given station, or several times at sites with very high overall abundances.
Occasional	sporadic observations, usually at irregular intervals; generally several observations, or a higher number at stations with very high overall abundances, but not frequent.
Frequent	encountered regularly; common; seen in a large portion of their preferred habitat at a survey site.
Abundant	a regularly encountered species observed in high numbers, representing a high percentage of observations.

Study site comparisons were made both qualitatively, comparing pertinent biotic and abiotic parameters, and semi-quantitatively, by assignment of arbitrary numerical values to qualitative descriptors for each taxon at each survey site (1 for rare, through 4 for abundant). Because biological variability for individual taxa is inherently high, numbers were summed for selected taxonomic groups for community comparisons.

Comparisons were also made between features on the Mississippi/Alabama OCS and other hard-bottom areas, including those on northwestern Gulf salt-diapiric structures and on south Texas relict coralgal reefs, and on other hard substrates in the northeastern Gulf, on the west and east Florida shelf, and on the east coast of the United States.

RESULTS AND DISCUSSION

Biological assemblages on features in the study area (53 to 110 m) were dominated by suspension-feeding, tropical hard-bottom organisms and reef fishes. Epibenthos included gorgonian corals, ahermatypic scleractinian corals, antipatharian corals, sponges, comatulid crinoids, alcyonarians, and oysters (roughly in this order of abundance, though occurrence varied significantly between the sites). Though these features may have been formed by hermatypic invertebrates, present-day substrate production is probably limited to an impoverished calcareous algae population on features cresting above 78 m. Very few hermatypic corals were seen. Features below 78 m are considered completely drowned reefs.

Invertebrate and fish abundance and diversity increased with the amount of exposed hard bottom, substrate roughness, and the complexity of the features (i.e., the number of habitat types available for colonization). Variation between epibenthic development on features is attributable, in many cases, to differences in the potential for sedimentation. Figures 6.11 and 6.12 show that faunal assemblages are of low diversity and depauperate on features with relief less than two m. Both diversity and abundance can be high on some features of 2-6 m relief. All features with relief over 6 m harbor dense assemblages whose composition varies with habitat type. Horizontal reef tops harbor large populations of sponges, tall antipatharian and gorgonian corals, and comatulid crinoids. Vertical or rugged areas are dominated by ahermatypic corals.

Patterns of longitudinal variation are illustrated in Table 6.3 for benthic organisms that dominate most high relief features in the study area. The data suggest that the particular area over which the effects of the Mississippi River plume become limiting for conspicuous hardbottom organisms varies with species. As a group, however, the influence occurs across an area between the westernmost station (32), and Stations 25 and 26, where the sum of taxa frequencies peaks. East of Stations 25 and 26, taxa frequencies vary considerably, but this is likely due to factors other than those influenced by the river. This "Mississippi Threshold," an area with average water quality that is suboptimal for hard-bottom community development, extends east of the river perhaps no greater than 70 km. A comparable area of limited hardbottom community development is much broader to the west of the delta, perhaps limiting hard-bottom development over a distance of some 300 km (Rezak *et al.* 1985, 1990).

Communities on these features contained hard-bottom and fish communities similar to those on the deeper portions of topographic prominences in the

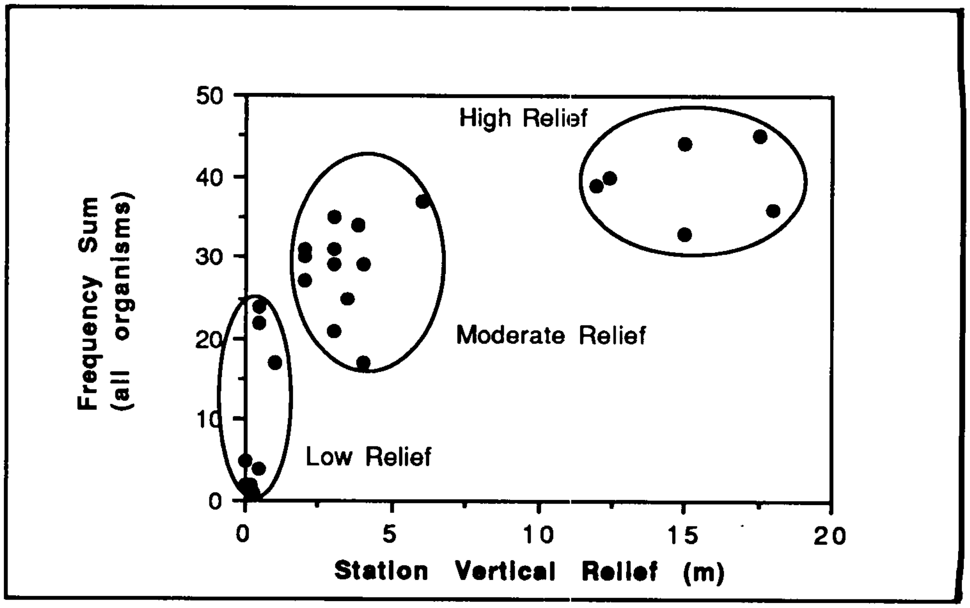

Figure 6.11. Sum of frequency values for all organisms (fish and invertebrates) as a function of vertical relief at stations surveyed in this study. (Ovals surround data points from features with low, moderate, and high topographic relief.)

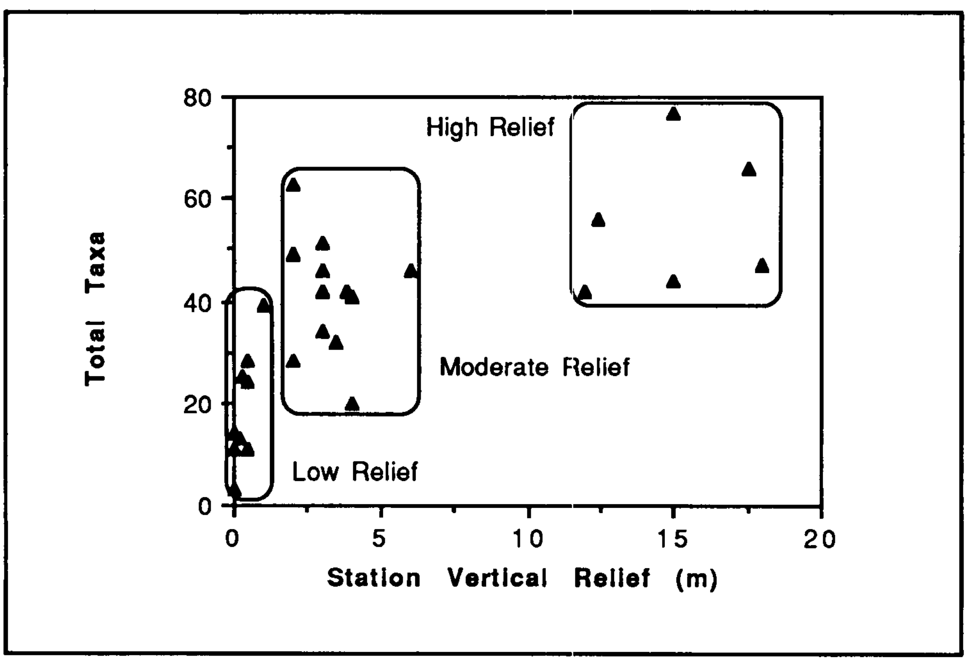

Figure 6.12. Total number of taxa observed at each station as a function of vertical relief. (Boxes surround data points from features with low, moderate, and high topographic relief.)

Table 6.3. Relative Abundance of Selected Invertebrates on the Largest Topographic Features between the Mississippi River and the Eastern Edge of the Hard-Bottom Study Area (blank = absent, • = rare, • • = occasional, • • • = frequent, • • • • = abundant; frequency sum = sum total of the frequency estimates for all selected taxa at each station).

Taxon	**Sta. 32** Sandpile Bank	**Sta. 30/31** Horseshoe Bank	**Sta. 27-29** Mt. Top Bank	**Sta. 33** 36-Fm Ridge	**Sta 25/26** Pinnacles 1 and 2	**Sta. 8/9** West Reefs Area	**Sta.18** Pinnacles	**Sta. 13/14** 40-Fm Fishing Gr.
Distance from Mississippi River	27 km	37 km	50 km	58 km	70 km	90 km	102 km	128 km
Elisella spp.		• •	• • •	• • •	• • •	• • •	• • •	• • • •
Nicella sp.		•	• •	• •	• • •	• •	• • • •	• • • •
Rhizopsammia sp.			•	• • •	• • • •	• •	• • • •	• • •
Oculina? sp.		• •	• •		• • •	• • •	• •	• •
Madrepora carolina					• • • •	• •	• • • •	• • •
White coral clusters		•	• •	• •	• • • •	• • •	• • • •	• •
Encrusting sponges		• • •	• • •	• • •	• • •	• •	• •	• • •
Frequency Sum	**0**	**9**	**13**	**13**	**24**	**17**	**23**	**21**

northwest Gulf of Mexico (Rezak *et al.* 1985) and those on hard substrates at the head of the DeSoto Canyon (Shipp and Hopkins 1978), both of which consist of assemblages predominantly of tropical origin. More specifically, epifaunal species composition is comparable to the deeper portions of the Algal-Sponge Zones, Antipatharian Zones and Nepheloid Zones on outer shelf, midshelf and south Texas banks described by Rezak *et al.* (1985). With some exceptions, their description of the fauna inhabiting partly and completely drowned reefs, which exist at 46-88 m on shelfedge features in the northwest Gulf, is nearly identical to many hard-bottom site descriptions for features on the Mississippi/Alabama OCS. Furthermore, patterns of dominance of fish species suggest more difference between features in the study area and those at the Florida Middle Ground and on the east coast than between the former and the northwest Gulf.

Studies by CSA (1987) on hard bottoms of the southwest Florida shelf resolved communities similar in many respects to those found on features in this study area. Depths of comparable communities, however, were deeper off southwest Florida. These depth differences are probably attributable to such factors as deeper average light penetration on the southwest Florida OCS, warmer water temperatures, and the absence of a nepheloid layer.

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SUMMARY AND SYNTHESIS

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The continental shelf area stretching seaward off the coasts of Mississippi and Alabama and lying between the Mississippi River Delta marshes and DeSoto Canyon is conveniently referred to as the East Mississippi Bight. The western and northern sectors are bounded by barrier islands inside of which lie extensive sounds, bays, estuaries, and marshlands that serve as nursery areas for many shelf species. Review of the technical literature reveals a widespread and dramatic decrease in the environmental quality of these inside waters during the past few decades due to the accumulated activities of human society.

In response to seasonal changes in the physical environment, the biological species of the continental shelf display regular cyclic patterns of spawning, growth, maturation, and migration. However, the area is subject to episodic events that may have catastrophic effects upon the natural populations. These events include major storms, floods, cold snaps, red tide outbreaks, and hypoxic events. All are known to affect populations of the bays and estuaries, but the shelf environment is directly affected only by storms, floods, and red tide outbreaks.

During the past two decades the commercial and recreational fishing effort on the continental shelf has increased severalfold. Simultaneously there has been a dramatic decline in shelf populations of demersal, reef-related, and pelagic fish species. Clearly, unregulated overfishing has played a major role in this decline, but reduction of environmental quality in the bays and estuaries could also be a significant factor.

Results of the present study will be examined and interpreted in light of this historical background.

PHYSICAL ENVIRONMENT

Present evidence indicates that this is a very dynamic area. Water currents are quite active throughout the area, particularly in shallow water near the barrier islands. Although wind stress is the dominating force, induced effects from the Gulf Loop Current are also important. Major storms modify the barrier islands, transport sediments, and stir the bottoms to depths of at least 80 m. As a result, finer particulate material tends to remain in suspension, creating a persistent nepheloid condition.

The primary sources of fine sediments (silts and clays) include the older sedimentary deposits around the Mississippi River Delta as well as freshwater inflow from currently active distributaries of the Mississippi River. Additional fine materials derive from periodic openings of the Bonnet Carre Spillway and subsequent transport through Lakes Pontchartrain and Borgne. Once on the shelf these sediments are subject to resuspension and transport by the active water currents. Sediment samples analyzed during the present study show that sandy sediments predominate throughout the northeastern half of the shelf and that silts and clays predominate throughout the southwestern half of the shelf. Some seasonal changes are evident.

CHEMICAL STUDIES

Potential chemical pollutants, including both trace metals and hydrocarbons, are associated primarily with the finer sediments. Their concentrations tend to be highest in the southwest sector and lowest in the sandy sector of the northeast. Despite heavy chemical pollution of the neighboring bays and estuaries, levels of these chemicals in sediments of the shelf tend to be quite low. Except for deep water stations near the Mississippi River Delta, sediments of the shelf may be considered essentially pollution free.

BIOLOGICAL RESULTS

Benthic infaunal invertebrate populations of the area are characterized by very high species diversity, and their densities are closely associated with sediment types. Highest concentrations (exceeding 1,000 individuals/m^2) tend to be found in association with the coarser sandy sediments, and lowest concentrations generally occur in the finer sediment areas. Large seasonal changes in the density of infaunal animals have been observed, and one anomalously high density occurrence on fine sediments near the Mississippi River Delta was noted.

The demersal fish community was found to be highly diverse and very mobile. Large seasonal changes in local densities and species composition were noted. Statistical clustering techniques reveal that the three shallowest stations on the Chandeleur and Mobile transects display a fairly high degree of faunal similarity. Likewise, during the winter months those species inhabiting the deepest stations (200 m) on all three transects are closely associated with each other. Throughout the shelf area the densities of the demersal fishes were found to be greatly depressed, and the estuary-related species were particularly affected. This differential reduction in populations of estuary-related species argues strongly that the general decline in shelf populations is due both to the decline in quality of estuarine habitat as well as to overfishing of the shelf populations.

Analysis of the food habits of over a quarter of those fishes actually captured reveals that the primary food materials are crustaceans (especially shrimp), fishes, and polychaetes, in that order, and together these three groups make up over 97% of the identifiable food items. Variations in food consumed were noted in relation to depth and transect. Principal component analysis revealed similarities in food consumption patterns at the different stations. Food consumed in the DeSoto canyon area was distinct from that taken on the neighboring Mobile transect. All stations on the Chandeleur and Mobile transects (except Chandeleur Station 3, Figure 6.3) showed a fairly high degree of similarity. On all transects the 20 m stations showed some degree of distinctness. These variations are explained on the basis of food availability, life history stages of the fishes, and other factors.

Topographic prominences (hard bottom "reefs") of the outer shelf were examined in some detail. Distribution patterns of the different feature types were mapped, and biological characteristics of several types were defined. It was found that these features are inhabited by unique communities that show little relationship with communities of the surrounding flat bottom areas. In effect, they represent fragile faunal "islands" semi-isolated in the deep water environment.

MANAGEMENT IMPLICATIONS

1. Despite heavy chemical pollution in the bays and estuaries, the shelf area is basically unpolluted. Hence, any pollution effects of future oil and gas development activities should be readily detectable.

2. The fish communities of the shelf are already devastated, due apparently to deterioration of the estuaries and to overfishing. Future effects of oil and gas developments on the fish communities will likely not be detectable.

3. Due to their fragile nature and unique biological assemblages, the topographic features represent areas of special concern. This is particularly true of the deepwater pinnacles. These features should be protected from the effects of human intrusion.

4. High levels of seasonal and annual variability characterize the physical and biological processes of the shelf in this area. Further studies should be carried out to more clearly define the factors responsible for this variability and the nature of their interactions and to establish more definitive baseline measurements.

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. Recently he has examined the distribution of demersal fish and 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. He has also studied factors responsible for the transport of larval fishes, shrimps, and crabs and has contributed to the understanding of estuarine and marine food webs. Dr. Darnell received his B.S. in biology from Rhodes College (Memphis), his M.A. in biology from Rice University, and his Ph.D. in zoology from the University of Minnesota.

PRODUCED WATERS: FINDINGS OF RECENT STUDIES IN THE COASTAL WATERS OF LOUISIANA

Session:	PRODUCED WATERS: FINDINGS OF RECENT STUDIES IN THE COASTAL WATERS OF LOUISIANA
Co-Chairs:	Dr. James J. Kendall Ms. Gail Rainey
Date:	November 14, 1990

Presentation	Author/Affiliation
Produced Waters: Findings of Recent Studies in the Coastal Waters of Louisiana: Session Introduction	Dr. James J. Kendall and Ms. Gail Rainey Minerals Management Service Gulf of Mexico OCS Region
Introduction to the Minerals Management Service-Funded Study on Produced Waters and Study Site Descriptions	Dr. Nancy N. Rabalais Louisiana Universities Marine Consortium
Findings of the Minerals Management Service-Funded Study on Produced Waters: Chemical Contaminants	Dr. Nancy N. Rabalais Louisiana Universities Marine Consortium Presented by Dr. Jay C. Means Louisiana State University
Findings of the Minerals Management Service-Funded Study on Produced Waters: Biological Assessment	Dr. Nancy N. Rabalais Louisiana Universities Marine Consortium
Review: Findings of the American Petroleum Institute Study on Produced Waters	Dr. Jerry M. Neff and Dr. Theodor C. Sauer, Jr. Marine Sciences Unit Arthur D. Little, Inc.
An Assessment of Produced Water Impacts in Louisiana	Mr. Kerry M. St. Pé, Mr. Patrick Breaux, Mr. Earl J. Eues, Jr., Mr. Richard Guidry Louisiana Department of Environmental Quality Water Pollution Control Division; Dr. Jay C. Means, Mr. Charles Milan Louisiana State University Institute for Environmental Studies; Mr. Matt Schlenker, and Ms. Sherri Courtney Louisiana Department of Environmental Quality
Overview of Current Federal Environmental Regulations Regarding Produced Waters	Dr. Lee B. Gibson U.S. Environmental Protection Agency

PRODUCED WATERS: FINDINGS OF RECENT STUDIES IN THE COASTAL WATERS OF LOUISIANA: SESSION INTRODUCTION

Dr. James J. Kendall
and
Ms. Gail Rainey
Minerals Management Service
Gulf of Mexico OCS Region

Produced waters are waters contained in hydrocarbon-bearing formations that are brought to the surface during the extraction of hydrocarbons (crude oil, condensates, and natural gas). These waters generally have dissolved salt concentrations higher than those of typical seawater, contain dissolved and dispersed hydrocarbons and related non-hydrocarbon organic compounds, and elevated concentrations of certain trace metals and radionuclides. These waters must be separated from the oil and condensates and disposed of by various means. In coastal and marine environments, produced waters may be discharged directly into surface waters. This practice has resulted in a number of studies to characterize the fates and effects of such nearshore discharges. The purpose of this session was to foster the sharing of information regarding recently completed studies on the fate and effects of produced waters and to discuss the future regulation of their discharge.

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. His research interests include the effects of contaminants on the physiology of corals, the behavior of reef animals, and procedures for aquatic toxicity testing. Dr. Kendall has conducted research and monitoring programs in the Gulf of Mexico, Galveston Bay, the Florida Keys, and the Gulf of Eilat, Red Sea. Dr. Kendall received his B.S. in biology from Old Dominion University and his Ph.D. in oceanography from Texas A&M University.

Ms. Gail Rainey is a marine chemist with the Minerals Management Service, Gulf of Mexico OCS Region, Office of Leasing and Environment, Environmental Assessment Section. Her primary expertise and interests include oil spill sources and fate processes and petroleum contamination of coastal and offshore waters. She received her M.S. in marine science (chemical oceanography) from the Louisiana State University.

INTRODUCTION TO THE MINERALS MANAGEMENT SERVICE-FUNDED STUDY ON PRODUCED WATERS AND STUDY SITE DESCRIPTIONS

Dr. Nancy N. Rabalais
Louisiana Universities
Marine Consortium

INTRODUCTION

During the production of crude oil, condensates or natural gas, water that is trapped within permeable sedimentary rock may also be brought to the surface. This water is called formation water, produced water or oil field brine. Of the estimated 1.1 million barrels per day ($bbl \cdot d^{-1}$) of produced water generated on the Gulf Outer Continental Shelf (OCS), a significant portion is piped ashore with the product streams and separated at shore-based or nearshore facilities. Within the State of Louisiana's coastal and estuarine environments, approximately 369,000 $bbl \cdot d^{-1}$ of this volume are discharged into surface waters. Because of the findings of the general study of Boesch and Rabalais (1989) and the increasing need for information useful in the prudent regulation of OCS-related discharges, the Minerals Management Service provided funds for a follow-up study to provide information on more sites than investigated in the first study and to provide greater resolution of the fates and effects of produced waters discharged from these facilities.

STUDY DESIGN

Of the 14 facilities that currently discharge OCS-generated produced waters into coastal environments of Louisiana, 10 discharges in 7 study areas were examined (Figure 7.1). The volumes of discharges in the study areas are larger than most for coastal Texas and Louisiana, and a variety of receiving environments is represented. The volumes of the discharges examined in this study ranged from 3,000 to 106,000 $bbl \cdot d^{-1}$. The receiving environments for these effluents are varied, but include the shallow, nearshore continental shelf; high energy, freshwater distributaries of the Mississippi River delta; and saline coastal environments with moderately to

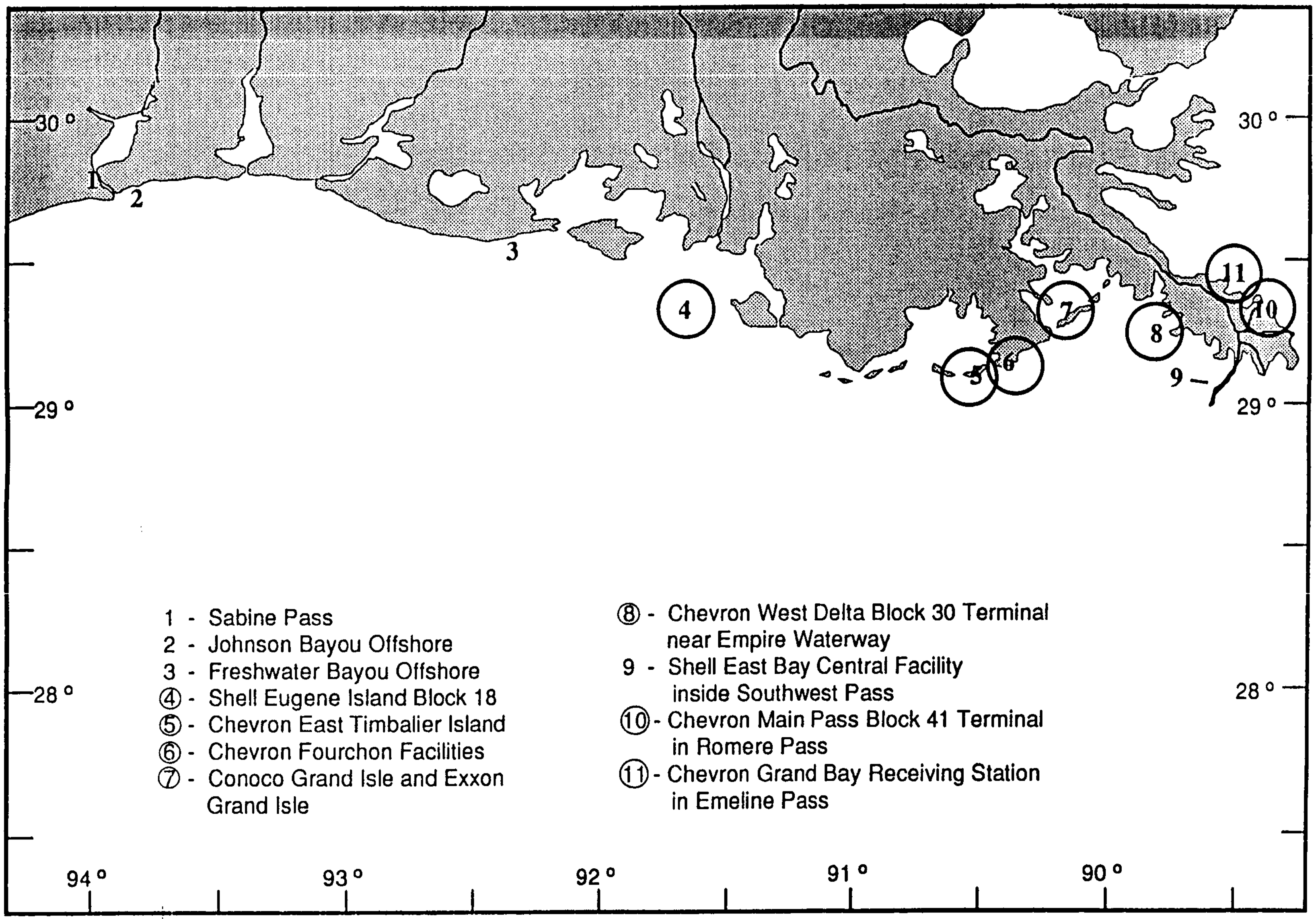

Figure 7.1. Location of OCS-generated produced water discharges in Louisiana state waters with circled numbers indicating areas being studied in the described research program.

poorly flushed waters. This study expanded on the initial assessment of Boesch and Rabalais (1989) with increased temporal and spatial studies of three areas, additional study sites including an abandoned discharge, and additional analytical and field observations (Table 7.1).

COMPARISON OF DISCHARGES

Several factors determine the fate and effects of produced waters on coastal environments and on organisms. These include the volume and the composition of the discharge and the hydrologic and physical characteristics of the receiving environment. Produced water discharges vary greatly in the amounts of organic and inorganic compounds. Similar compounds are found in each of the effluents, but the relative proportions differ with the facility and through time. A comparison of the discharges is given in Table 7.2 with the discharge volumes being totaled for each study site. The mass loadings are calculated from the average concentrations in the various effluents, average daily discharges, and conversion of 1 barrel = 159 liters.

An evaluation of the hydrological and sedimentological characteristics of each study area was made to determine the dilution potential of the environment for the produced water effluents. Dilution of water soluble contaminants would be influenced primarily by the volume of the receiving waters and the current velocity. With the exception of measurements taken on a high spring tide (Empire Waterway) and during a storm (Romere Pass and Eugene Island Block 18 in May 1989), current velocity measurements were assumed to be representative of similar conditions throughout the year. Dispersion of sediment-adsorbed contaminants would be influenced by the bed shear stress, proportional to the slope of the current velocity profile (potential for resuspension and transport), sedimentation rates, and the grain size distribution of the surface sediments.

RECEIVING ENVIRONMENTS

Two environments were characterized as having a high potential for dilution of contaminants: Emeline Pass and Eugene Island Block 18. Mean current velocities reach 9 $m \cdot s^{-1}$ in Emeline Pass, and the coarse-grained, low organic content sediments indicate active sediment transport close to the bed. Eugene Island Block 18 is located in open, shallow, offshore waters adjacent to the Atchafalaya River delta. High freshwater flow influences the area, and the shallow inner continental shelf is expected to be subject to wind-induced events causing resuspension and rapid turnover of surficial sediments. On the other end of the continuum is the Pass Fourchon study site. Current velocities are consistently negligible; potential for sediment entrainment and transport is low. The sediments in the dead-end canal system are sandy muds or muddy sands. Abrupt transitions within the study site are apparent in increasing sand content at the station in closest proximity to the back of the sandy barrier shoreline and at those stations in the more tidally active Belle Pass.

The remainder of the environments were characterized as having a medium potential for dilution of produced water contaminants. Current velocities were strong in Bayou Rigaud and sufficient to resuspend and transport sediments during peak tidal flow. The sedimentary regime, however, indicated periods of high silt content. Alterations in sediment grain size composition would indicate periods of accumulation and periodic resuspension related to storms. A similar situation was found in Empire Waterway. Tidal currents were strong when measured (as noted above on a high spring tide) and indicated that potential for sediment resuspension and transport was high. However, the high silt content of the sediments and the accumulation of contaminants near the abandoned discharge point indicated a depositional environment. Resuspension of sediments and shifts in sediment grain size distribution would be storm related as in Bayou Rigaud. In Romere Pass sediments were sands, but fine-grained, and graded to silts on the northern end of the transect. Resuspension events in Romere Pass would be seasonal and related to the flow of the Mississippi River rather than storm related as in Bayou Rigaud and Empire Waterway. Two hydrological and sedimentary environments can be distinguished at the East Timbalier Island study site. Current velocities, during the single sample period, indicated moderate flushing in the east-west canal where sandier sediments occurred. The north-south access canal was less well flushed, had siltier sediments, and contained higher levels of sediment-adsorbed contaminants.

REFERENCES

Boesch, D.F. and N.N. Rabalais, eds. 1989. Produced waters in sensitive coastal habitats: an analysis of impacts, central coastal Gulf of Mexico. OCS Report/MMS 89-0031, U.S. Dept. of the Interior, Minerals Mgmt. Service, Gulf of Mexico OCS Region, New Orleans, La. 157 pp.

Table 7.1. Study Components and Principal Investigators for this Study.

Principal Investigator (Institution)	Study Component
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 Bioaccumulation

Table 7.2. Comparison of Produced Water Discharges by Study Site. (Study sites arranged in order of decreasing total daily discharges of both OCS- and State-generated produced waters [VOA, volatile organic analytes; PAHs, polynuclear aromatic hydrocarbons].)

Discharge Site	Daily Discharge ($bbl \cdot d^{-1}$)	Number of Discharges	Mass Loadings VOA ($kg \cdot d^{-1}$)	Mass Loadings PAHs ($kg \cdot d^{-1}$)
Bayou Rigaud	145,760	2	98.8	10.5
Pass Fourchon	48,169	3	11.2	3.5
East Timbalier Island	25,558	4	1.2	3.6
Eugene Island Block 18	21,000	1	19.4	1.4
Romere Pass	20,158	2	5.1	3.4
Empire Waterway	10,959	1	2.6	0.9
Emeline Pass	3,693	1	0.5	1.4

Dr. Nancy N. Rabalais is a member of the scientific staff at 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 and was involved in two other large, multi-institutional, multi-disciplinary studies of produced water discharges in coastal environments of the northwestern Gulf of Mexico.

FINDINGS OF THE MINERALS MANAGEMENT SERVICE-FUNDED STUDY ON PRODUCED WATERS: CHEMICAL CONTAMINANTS

Dr. Nancy N. Rabalais*
Louisiana Universities
Marine Consortium

INTRODUCTION

Of the 14 facilities that currently discharge Outer Continental Shelf (OCS) generated produced waters into the coastal environment of Louisiana, 10 were studied. An assessment of the fate and effects of produced water discharges was made along with a detailed analysis of the effluent. The receiving environment was characterized with respect to the hydrographic regime and sedimentary characteristics. Hydrographic profiles, interstitial salinity of surface sediments, and overlying water contaminants were examined to determine the extent of the brine effluent and its chemical constituents. Surface sediments were examined to assess the extent and composition of chemical contamination. Vertical cores provided information on the long-term accumulation of chemicals.

CHARACTERIZATION OF PRODUCED WATERS

Produced waters contain high concentrations of organic compounds, primarily petroleum hydrocarbons but also partially oxidized organics. They also contain elevated levels of several metals, elemental sulfur, and radionuclides. Produced water discharges vary greatly in the amounts of organic and inorganic compounds. Similar compounds are found in each of the effluents, but the relative proportions differ with the facility and with time.

The largest component of the organic load of the produced water effluents in this study was the aliphatic fatty acids and the aromatic acids (Figure 7.2). The acid-extractable compounds are very water soluble and not readily sorbed onto particulate matter; these compounds are less likely to be deposited in sediments, but are more likely to be diluted in the water column. The saturated hydrocarbons were the next highest in concentration; these compounds are the least toxic fraction of crude oil and are very susceptible to microbial degradation. The volatiles and the phenols made up the next largest component of the produced water effluents. Of the volatiles, benzene and toluene composed 75% to 95%. The volatiles and phenols are highly water soluble and, in high concentrations, are acutely toxic to organisms. Their long-term fate, however, is to be diluted and dispersed in the water column. The polynuclear aromatic hydrocarbons (PAHs) were the smallest component of the identifiable hydrocarbons. This fraction, however, is the heaviest, most toxic, and environmentally stable fraction of crude oil. The toxicity of crude oil is a reflection of its aromatic content, primarily the alkyl-substituted naphthalenes and phenanthrenes. The PAHs are the most likely components of produced water discharges to be incorporated into the sediments because of low water solubilities and high sorption coefficients.

The produced water effluents generally had barium, vanadium, and nickel in highest concentrations. Zinc, copper, and chromium were also found in high concentrations in most of the discharges. Water samples were analyzed for a variety of radionuclides. Uranium 238 and thorium 234 activities were below detection levels (<0.5 and <0.8 disintegrations per minute per liter [$dpm \cdot l^{-1}$], respectively). This lack of enhanced uranium and thorium activity indicates that the high radioactivity levels associated with produced waters originate with the radium isotopes and are not supported by radioactive parents of radium which are higher in the decay chain. Produced waters from the sites examined had total radium radioactivities from 304 to 2,312 $dpm \cdot l^{-1}$, which are approximately 150 to 1,150 times higher than natural waters. All discharges sampled had total radium activities in excess of the 111 $dpm \cdot l^{-1}$ activity designated by the Environmental Protection

*As presented by Dr. Jay C. Means

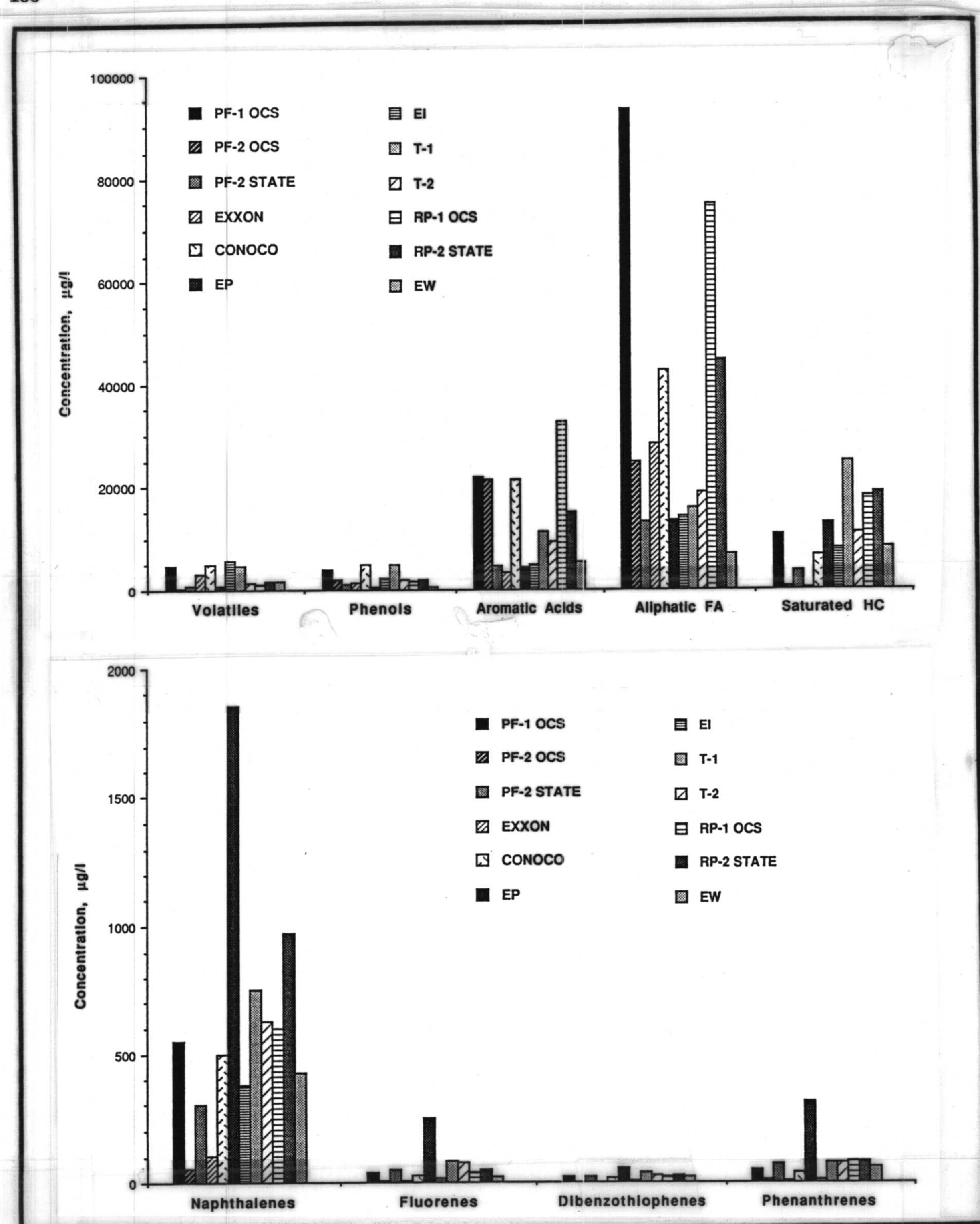

Figure 7.2. Comparison of volatiles, phenols, aromatic acids, aliphatic acids, and saturated hydrocarbons (top) and polynuclear aromatic hydrocarbons (bottom) in 12 produced water discharges from this study (10 discharge OCS-generated produced waters and 2 discharge produced waters from state leases).

Agency (EPA) as hazardous waste. Produced waters from the sites examined had Pb-210 radioactivities ranging from 0.21 to 25.4 dpm • l^{-1}, which are 2 to 254 times higher than natural waters.

DISPERSION OF BRINE EFFLUENT

Because produced water effluents have salinity levels in excess of that of ambient sea water, they may form a dense plume upon discharge into receiving waters. The salt content of the bottom waters may thus be used as a conservative tracer of the plume. A clear density plume was identifiable only at the Pass Fourchon study site and extended up to 800 m from the point of discharge (Figure 7.3). Elevated salinity was found in the bottom water at a single station in the East Timbalier Island study site and was related to the produced water effluent. Otherwise, no clear salinity signals were found that could be attributed to the produced water effluents.

Other tracers of the produced water effluent (volatile organic analytes [VOA] and total radium) are water soluble and are not conservative, but their presence in overlying waters would indicate the extent of the produced water plume to at least the distance they were detected. In the case of VOA, the extent of contamination of the overlying water column by these chemicals was the same for Pass Fourchon (Figure 7.4) and East Timbalier Island as the salinity signal. At Eugene Island Block 18, elevated VOA in overlying waters was detected adjacent to the discharge and to some distance from the discharge whereas an elevated bottom water salinity was not. In a somewhat similar situation at Bayou Rigaud, elevated VOA was detected in overlying waters near a discharge point and at uniformly low levels at several other stations even though a salinity plume was not detected in the bottom waters. Of the five remaining sites, elevated levels of VOA were found only at a single station at East Timbalier Island in a dead-end canal near the discharge point. The lack of flushing at this particular point, compared to the moderately to well-flushed characteristics of the other areas, would account for VOA contamination in spite of the relatively low loadings.

At the Pass Fourchon study site, total radium activity was elevated above background level to a distance of 1,000 m from the discharge point (Figure 7.5). VOA and salinity signals were detectable only within 800 m of the discharge point. Elevated radium levels were detected at Bayou Rigaud, but there was no clear pattern to the distributions. At Eugene Island Block 18, higher total radium (Ra) activities paralleled the elevated levels of VOA. In Romere Pass, total Ra three times above natural levels was detected at RP1000N (450 m from the discharge point) where there were no detectable levels of VOA or elevated salinity. For both the East Timbalier Island and Empire Waterway study sites, total Ra activities were elevated well above background levels throughout the study areas, indicating some level of water column contamination not indicated by the other tracers.

SEDIMENT CONTAMINATION

Substantial contamination of fine-grained sediments with petroleum hydrocarbons of produced water origin was observed at all study sites with the exception of Emeline Pass and the active discharge facility at Empire Waterway. Distance of contaminant effect was determined as the greatest distance where the concentration of the constituent was elevated above background levels or the fossil fuel pollution index indicated petrogenic origin hydrocarbons. Produced water origin PAHs were found to the maximal distances of the study transects at both Bayou Rigaud and Pass Fourchon, 1,300 and 1,000 m, respectively (Figure 7.6). More limited distances of effect were found for alkylated PAHs at Romere Pass (450 m), East Timbalier Island (250 m), Eugene Island Block 18 (250 m), and the abandoned discharge at Empire Waterway (250 m).

The concentrations of hydrocarbons, trace metals and lead 210 (Pb-210) were analyzed for several vertical sediment cores at several of the study areas. Pb-210 activities in the vertical sediment profiles were not appropriate for calculation of sedimentation rates, because some decay in Pb-210 was not present with depth. The profiles obtained indicated either an increase in activity levels with depth or inconsistent variability with depth. We concluded that the profiles were due to several factors including varying input and disturbance of the sedimentary structure by dredging, boat traffic and/or natural events. This explanation is consistent with the hydrocarbon contamination seen in some of the vertical cores, which indicates maxima in produced water origin hydrocarbons in both subsurface and/or with depth in the core. Such non-uniform distributions indicate varying inputs of contaminants to the sediments.

Hydrocarbon concentrations in vertical cores indicated (1) a decrease in overall concentrations with increasing distance from the produced water discharge point; (2) maximal concentrations in the upper sections of the cores at those stations closest

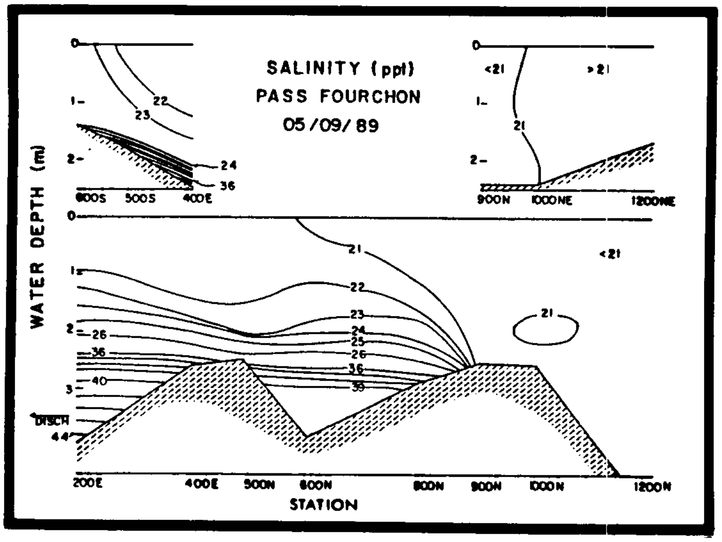

Figure 7.3.

Salinity distribution through the water column at the Pass Fourchon study site, May 1989.

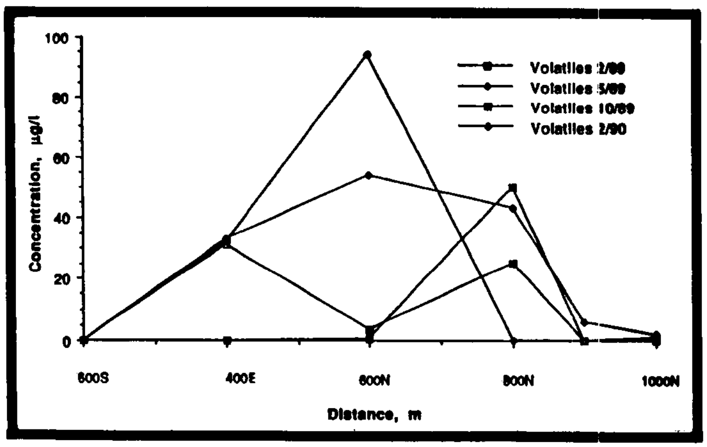

Figure 7.4.

Spatial distribution of volatile hydrocarbon concentrations in Pass Fourchon overlying waters for four sample periods.

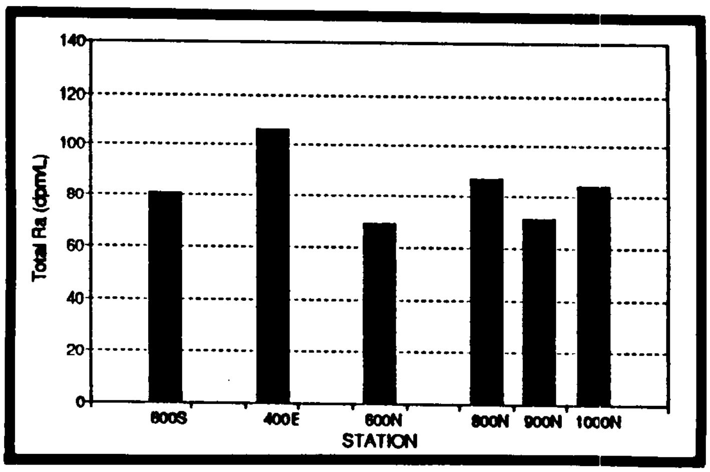

Figure 7.5.

Spatial distribution of total radium activity in Pass Fourchon, February 1989.

Note: Station numbers along the X-axis represent distance (m) north (N), south (S), or east (E) of the discharge point.

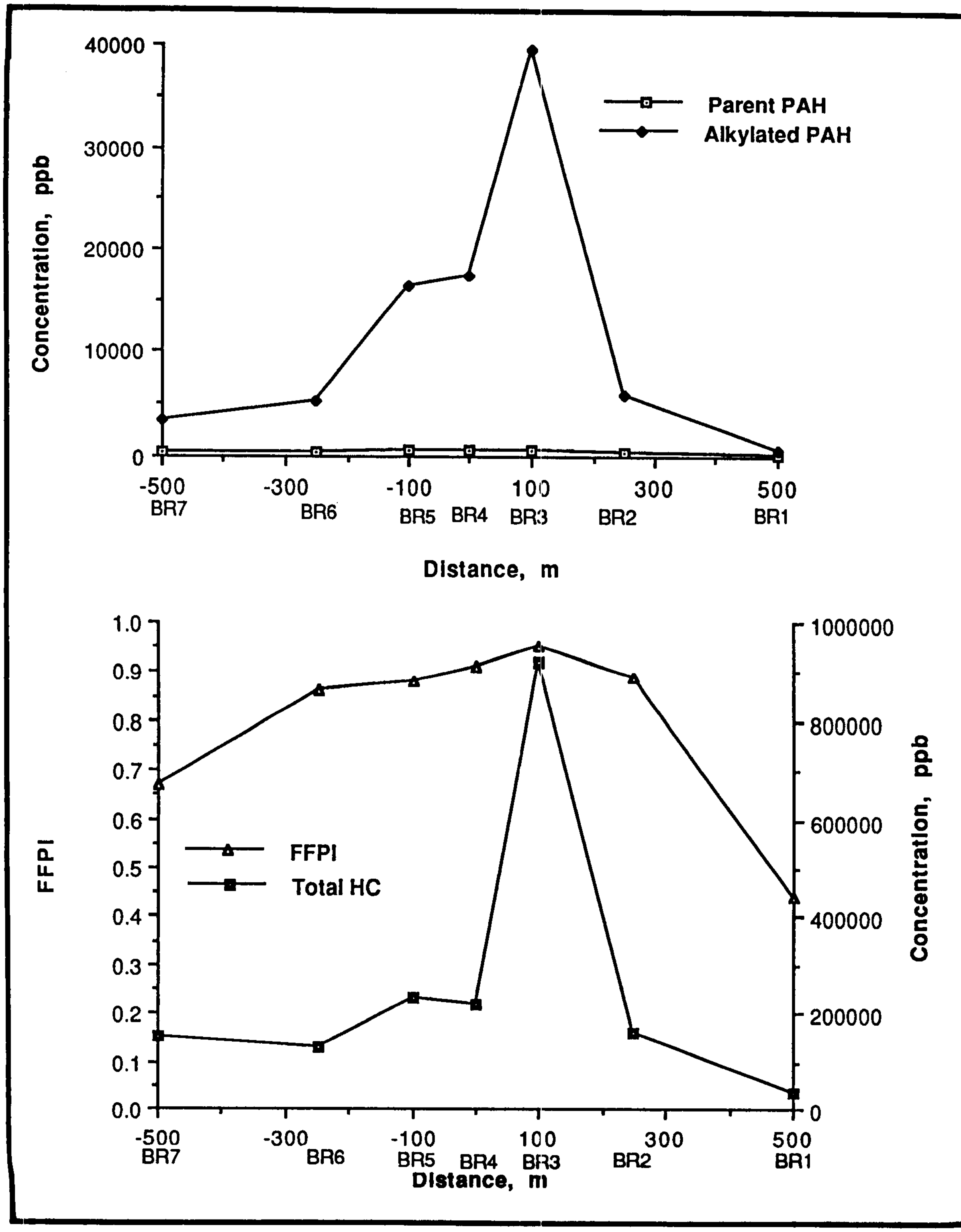

Figure 7.6. Spatial distribution of polynuclear aromatic hydrocarbons (PAH), total hydrocarbon (HC) concentrations, and the fossil fuel pollution index (FFPI) in surface sediments from transect 2, Bayou Rigaud (BR), February 1989. (Stations are plotted in distance (m) from the discharge point at BR4.)

to the discharge point; (3) subsurface maxima and additional maxima with depth in cores separated by lower concentrations in intervening sections, particularly in those closer to the discharge points; (4) very often a weathering of saturated hydrocarbons with depth in the core; and (5) elevated levels of hydrocarbons in the upper sections of vertical cores collected from the distal ends of study area transects usually indicative of pyrogenic hydrocarbon inputs. Changes in concentration of produced water hydrocarbons with depth in vertical cores are related to changes in mass loadings through time, variations in transport and deposition of contaminated sediments, resuspension and transport of contaminated sediments from the area during storm events, and transport of uncontaminated sediments into the area during storm events. The presence of high concentrations of produced water derived hydrocarbons to depths of 25 to 30 cm in a vertical sediment core in some of the study areas, including the abandoned discharge, indicates the long-term accumulation of these contaminants and their resistance to degradation.

Dr. Nancy N. Rabalais is a member of the scientific staff at 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, and was involved in two other large, multi-institutional, multi-disciplinary studies of produced water discharges in coastal environments of the northwestern Gulf of Mexico.

Dr. Jay C. Means is a Professor with Louisiana State University Institute for Environmental Studies and has conducted several studies on produced water. He is a Ph.D. graduate of the University of Illinois in chemistry.

FINDINGS OF THE MINERALS MANAGEMENT SERVICE-FUNDED STUDY ON PRODUCED WATERS: BIOLOGICAL ASSESSMENT

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INTRODUCTION

A previous Minerals Management Service (MMS) funded study on produced waters (Boesch and Rabalais 1989) documented the general nature and extent of environmental contamination and biological effects at three major sites of Outer Continental Shelf (OCS) generated produced water discharges. This study expanded on the initial assessment with increased temporal and spatial studies of three areas, additional study sites including an abandoned discharge, and additional analytical and field observations. Biological impact assessments included benthic community analyses and the bioaccumulation of produced water origin contaminants.

STUDY DESIGN

Two locations (Pass Fourchon and Bayou Rigaud) were selected for seasonal and intense spatial sampling. Additional sites were selected because they represented the range of coastal environments receiving OCS produced waters and because of the size of the present discharges. East Timbalier Island was sampled in the previous study and was sampled once more intensively during this study. Two sites were sampled during high and low flow periods of the Mississippi and Atchafalaya Rivers: Eugene Island Block 18, located offshore of the remnant oyster reefs that demark the lower end of Atchafalaya Bay, and Emeline Pass in the Mississippi River delta. Additional sites were located in Romere Pass and near the Empire Waterway. An abandoned discharge near the Empire Waterway was studied. Bottom sediments were sampled along the same gradients as for sedimentary characteristics and contaminants for benthic macroinfauna.

An additional biological assessment examined the potential impacts of the organic and inorganic contaminants associated with the discharges of produced waters to be accumulated in filter-feeding bivalves. Deployments of oysters were made at known distances from the discharge points in Pass Fourchon and Bayou Rigaud for known periods of time. Deployments were made in April and May for 14 and 27 days, respectively.

RESULTS

The most severely depressed benthic macroinfaunal communities were found within 500 to 800 m of the discharge point in Pass Fourchon (Figure 7.7). Impacts to the benthic communities were observed as far as 700 m in Bayou Rigaud, 300 m at Eugene Island Block 18, 100 m at East Timbalier Island, and within 550 m of the abandoned discharge at Empire Waterway. The impacts of accumulated and residual produced water contaminants adjacent to the abandoned discharge site indicate the persistent effects of these constituents on the benthic fauna and an unknown length of time for adequate recovery of the environment following cessation of the discharge. No effects on the benthic communities were observed in the Emeline Pass and Romere Pass study areas. Both of these environments, however, were normally low in numbers of species and individuals. Impacts on the benthic macroinfauna were consistent across season in the Pass Fourchon and Eugene Island Block 18 study sites. Benthic community impacts were associated with distance from the discharge and levels of produced water chemical constituents in the sediments.

Results from the bioaccumulation studies indicated (1) lower weight gain for those oysters deployed close to the discharge point at Pass Fourchon, (2) increased mortality for oysters during the longer deployment at sites closer to the discharges at Pass Fourchon, (3) accumulation of alkylated polynuclear aromatic hydrocarbons (PAHs) and total hydrocarbons in all oysters above background levels in the first deployment, (4) rapid accumulation of produced water contaminants, (5) variability in accumulation with season and reproductive condition, (6) a decrease in the accumulation of alkylated PAHs and total hydrocarbons in May compared to April, (7) levels of accumulated contaminants above the concentrations of contaminants in ambient sediments, (8) inconsistent results for trace metal accumulations, and (9) limited accumulation of radionuclides. The bioaccumulation studies show the clear potential for uptake and accumulation of produced water origin contaminants by oysters, both in close proximity to the discharge point and to great distances from the discharge.

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REVIEW: FINDINGS OF THE AMERICAN PETROLEUM INSTITUTE STUDY ON PRODUCED WATERS

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INTRODUCTION

There is limited information available regarding the chemical composition of oil well produced water and the effects of chronic discharges of this material on shallow water benthic marine communities. The investigation reported here was designed to determine: (1) if sediments located near platforms that have been discharging produced water into shallow coastal waters for many years contain elevated concentrations of organic and metal contaminants, and (2) if the communities of benthic marine animals resident in the sediments are adversely affected by these chronic discharges.

The design of the study was based on the hypothesis that any significant impacts to the marine environment resulting from more or less continuous discharges of produced water for several years would be manifest as gradients of decreasing sediment contamination and alterations of normal benthic community structure with distance from the produced water discharges.

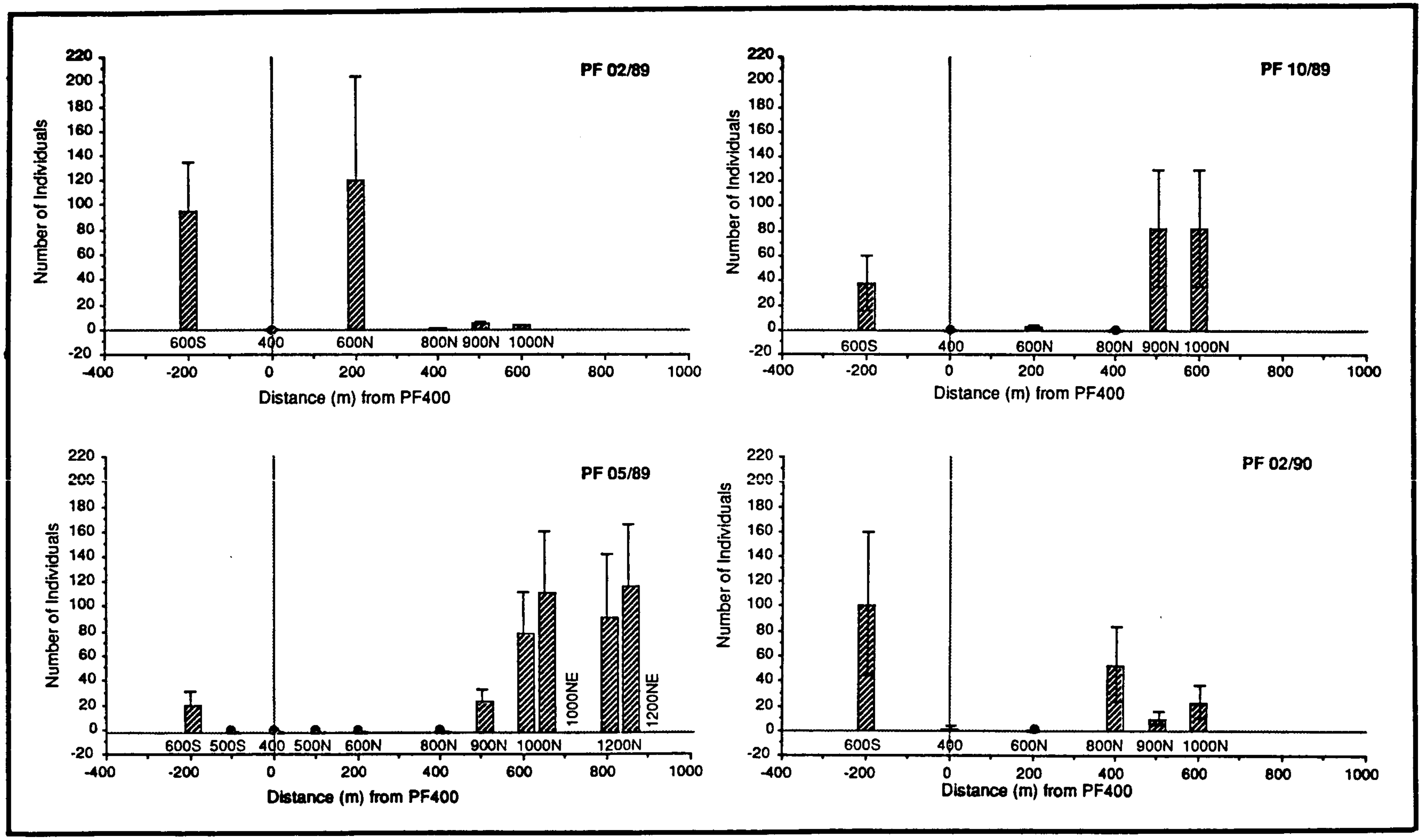

Figure 7.7. Spatial distribution of number of individuals per replicate (mean ± standard error) for Pass Fourchon (PF) for four sample periods: February 1989 (PF 02/89); May 1989 (PF 05/89); October 1989 (PF 10/89); and February 1990 (PF 02/90).

METHODS

Two sites were selected from an initial screening survey of four oil-water separation platforms in less than 20 m of water off the central Louisiana coast. One site, Lake Pelto, Tank Battery No. 1, located in Terrebonne Bay, represented a shallow enclosed estuarine environment; the other site, Eugene Island, Block 105, represented a shallow offshore environment. Two field surveys were performed at each platform, the first in March 1986 and the second in October 1986. On the first survey, 16 stations arranged in a radial array at distances of 20, 100, 300, and 1,000 m from each produced water discharge were sampled. On the second survey, a subset of the stations was resampled.

On both surveys, three sediment grab samples for chemical analysis and six sediment grab samples for biological analysis were collected from each station. The chemistry grab samples were analyzed for sediment grain size, total organic carbon, total saturated and aromatic hydrocarbons, individual n-alkanes, individual two- through four-ring aromatic hydrocarbons and their alkyl homologues, steranes, triterpanes, phenols, and nine metals (barium, cadmium, chromium, copper, lead, mercury, nickel, silver, and zinc). The biology samples were analyzed for sediment grain size and benthic macrofauna, including juveniles retained on a 0.3 mm screen. Produced water samples from each platform were also collected and analyzed for the same analytes as the sediment samples, plus volatile hydrocarbons (methane through the C_3-benzenes).

RESULTS AND DISCUSSION

Produced Water Composition

The average rate of discharge of produced water from the separator platform in Eugene Island, Block 105, is 1,570 barrels/day (250,000 L/day). The discharge was initiated in May 1981. The average rate of discharge of produced water from Lake Pelto, Tank Battery No. 1 is 2,750 barrels/day (437,000 L/day). The discharge was started in the mid-1940's. Water depth at Eugene Island is 7.6 to 8.5 m, whereas Lake Pelto is only 1.8 to 3.0 m.

The average compositions of the produced water from the two platforms (Table 7.3) were similar to that of produced water from other sources. Produced water from both platforms was a hypersaline brine. The concentration of total organic carbon (TOC) in the samples was in excess of 200 mg/L (parts per million:ppm). Only about 10% of this organic carbon was accounted for by hydrocarbons. The rest probably consisted of the uncharacterized nonvolatile soluble organic matter noted by others, mostly organic acids. Phenols and ketones contributed little to the TOC in the samples. The most abundant hydrocarbons in the produce water samples were the monocyclic aromatic hydrocarbons, benzene, toluene, and xylenes. The dominant polycyclic aromatic hydrocarbons (PAHs) were naphthalene and its alkyl homologues. Samples from Lake Pelto also contained phenanthrenes. Concentrations of total steranes and triterpanes were higher than concentrations of total PAHs.

The only metals present in produced water from the two platforms at concentrations substantially (more than a thousand-fold) higher than those in normal seawater were barium, lead, and zinc. High concentrations of barium have been reported in solution in produced water from other sources, and apparently are possible if the produced water contains very low concentrations of sulfate and carbonate. Concentrations of lead and zinc in the produced water samples were quite variable and may have been derived in part from corrosion of galvanized structures on the platform or in the oil-water separator system.

Environmental Impacts

Sediment Contamination

Patterns of sediment grain-size distribution were quite different at stations around the two platforms. At Eugene Island, sediment texture was finest near the platform and became coarser with distance from the platform. At Lake Pelto, the coarsest sediments were located 20 m from the platform with the mean sediment grain size decreasing with distance from the platform. Grain size has important effects on the distribution of both benthic petroleum hydrocarbons and fauna.

Patterns of hydrocarbon distributions in sediments around the platforms tended to parallel those of sediment TOC concentrations. At Lake Pelto, concentrations of total semivolatile hydrocarbons and total PAHs in sediments were highest at one or more stations 20 m from the platform and decreased with distance from the platform. Total PAHs dropped to essentially background values at all stations 300 and 1,000 m from the platform. At Eugene Island, there was a gradient of decreasing concentrations of total semivolatile hydrocarbons in sediments with distance from the platform along most transects. However, concentrations of both

Table 7.3. Mean Concentrations of Several Classes of Organic and Inorganic Compounds in Produced Water from Production Platforms at Eugene Island, Block 105; and Lake Pelto, Tank Battery No. 1 (values in $\mu g/L$ unless indicated otherwise).

Compound Class	Eugene Island	Lake Pelto
Total Organic Carbon	220,000	298,000
Total Semivolatile Hydrocarbons (IR)	36,300	25,500
Total Saturates (GC)	28,400	17,100
Total Aromatics (GC)	2,500	3,300
Total Hydrocarbons (GC)	30,900	20,400
Total Targeted n-Alkanes (C_{10}-C_{34})	2,680	606
Total Targeted PAHs (Naph.-Peryl.)	80	142
Total Volatile Hydrocarbons		
(Methane - C_3-Benzenes)	11,300	5,515
Steranes	63	92
Triterpanes	76	80
Ketones	2,230	1,320
Phenols (C_0 - C_4)	2,720	675
Salinity (parts per thousand)	183	150
Metals		
Barium	37,400	11,500
Cadmium	0.32	0.12
Chromium	1.11	0.71
Copper	6.36	0.40
Lead	17.9	1.50
Mercury	0.06	0.07
Nickel	0.40	1.27
Silver	<0.20	<0.20
Zinc	1,200	125

total n-alkanes and total PAHs in sediments were not elevated above apparent background values at any but a few stations in the 20-m ring surrounding the discharge. Sediments from stations 100 to 1,000 m from the platform had relatively uniform concentrations of total n-alkanes and PAHs in the range of 0.3 to 1.6 and 0.02 to 0.16 ppm, respectively. Background concentrations of total hydrocarbons and PAHs in sediments from the northern Gulf of Mexico are in the range of 3 to 70 ppm and 0.4 to 1.1 ppm, respectively. As a general rule, concentrations of total hydrocarbons, n-alkanes, and PAHs were higher in sediments at Lake Pelto than at Eugene Island.

Several hydrocarbon diagnostic parameters and ratios were used to show that, at Eugene Island, sediments from stations 20 m from the platform contained low concentrations of petroleum hydrocarbons in the range of 20 to 90 ppm. Sediments from stations 100 m or more from the platform contained background concentrations of petroleum hydrocarbons. Chronic discharges of produced water at a rate of about 250,000 L/day to inner continental shelf waters with a depth of about 8.5 m have resulted in a low level of contamination of surficial sediments with petroleum hydrocarbons out at least to 20 m but not to 100 m from the platform. Contamination of sediments with petroleum hydrocarbons, even at the 20-m stations, apparently was not sufficient to cause hypoxia of the bottom water or surficial sediments.

At Lake Pelto, sediments out at least to 100 m, but not as far as 300 m, from the platform contained petroleum hydrocarbons, probably derived from produced water discharges. Surficial sediments from 20 and 100 m from the outfall contained 24 to 270 ppm total hydrocarbons. Discharges of produced water at a rate of about 440,000 L/day to a shallow, partly enclosed bay with a water depth of about 2 m have resulted in a low to moderate level of contamination of surficial sediments with petroleum hydrocarbons out at least to 100 m but not as far as 300 m from the platform.

Barium was the only one of the nine metals analyzed that was present in sediments at concentrations substantially higher than expected for uncontaminated sediments from the northern Gulf of Mexico. Concentrations of barium in sediments from most stations were in the range of 500 to 2,000 ppm. There were no gradients of barium in sediments that might indicate that the barium was derived from platform discharges. The excess barium may be from area-wide discharges of barium-laden drilling muds and produced water from many platforms throughout the area and from the Mississippi River outflow.

Effects on Benthic Fauna

The benthic communities at both Eugene Island and Lake Pelto consist of pioneer species characteristic of disturbed marine and estuarine environments. The nature of the disturbance is unclear but appears to be area-wide. At Eugene Island, the disturbance may be periodic hypoxia of the bottom water. Episodes of bottom water hypoxia are known to occur during the summer in waters of the inner continental shelf off central Louisiana. However, no such episodes were documented at Eugene Island during this study. The Mississippi River outflow with its tremendous load of suspended matter and nutrients probably contributes to environmental stress throughout the area.

At both platforms, the benthic fauna were dominated by one or a few species at all stations, even those most distant (1,000 m) from the platforms and presumably unaffected by the produced water discharges. At both locations, the dominant taxon was the capitellid polychaete, *Mediomastus ambiseta*. This and the other dominant taxa are short-lived opportunistic species. Juvenile forms were very abundant in both seasons, representing more than 50% of the total number of individuals of several species at many stations. Despite these faunal characteristics, species diversity was moderate to high at all stations. Benthic communities with similar characteristics have been described by other investigators at several locations in shallow estuarine and coastal waters of the northern Gulf of Mexico. It is probable that benthic community structure throughout the area of this investigation is controlled in large part by factors such as high suspended sediment loads attributable to the Mississippi River outflow and periodic bottom water hypoxia, neither of which is related to discharges from coastal exploration/production operations.

At Eugene Island, benthic faunal density was greatest near the platform and decreased with distance from the platform. However, diversity was lower near the platform than at stations farther away. These trends were due to the fact that the fauna at the inner stations was dominated by *Mediomastus*. Similarity analysis revealed that the benthic fauna of the 4 stations 20 m from the platform were similar to one another and different from the fauna at stations further away. Many of the juveniles present in the spring did not survive until the fall, but were replaced by new juveniles of the same and different species. Diversity and abundance patterns were the same in the spring and fall.

At Lake Pelto, the gradient of decreasing sediment grain size with distance from the platform obscured any gradients that might have existed in the benthic fauna because of impacts of produced water discharges. As a general rule, benthic communities at Lake Pelto were more diverse than benthic communities at Eugene Island. Highest diversities were recorded at stations that had coarse sediments near the platform. There was no clear relationship between distance from the platform and density of benthic fauna.

The relative abundance of the dominant species, *Mediomastus ambiseta*, increased with distance from the platform, whereas the density of another dominant polychaete, *Streblospio benedicti*, was highest at stations near the platform and decreased with distance from the platform. The mean percent juveniles in the total infauna at different stations ranged from 25.2 to 52.9% in the spring and from 24.2 to 35.8% in the fall. However, the juveniles rarely persisted to adult stages and some taxa were replaced by others at different seasons. There was no relationship between percent juveniles and distance from the platform.

Cluster analysis revealed that 2 of the stations at 20 m from the discharge were very similar to one another, but quite different from all other stations. Sediments from these two stations contained the highest concentrations of total hydrocarbons and total PAHs. Diagnostic ratios indicated that a majority of the hydrocarbons in sediments from these stations were from petroleum.

Sediment grain size was the most important parameter contributing to gradients of benthic community structure around the platforms, particularly at Eugene Island. Nevertheless, there is an indication that benthic communities within about 20 m of both platforms were influenced by sediment contamination, probably derived from produced water discharges. Benthic communities located 100 to 1,000 m from the platforms exhibited no evidence of impacts attributable to platform discharges. Thus, relatively minor effects on benthic communities resulting from chronic produced water discharges to shallow estuarine and coastal waters of the northern Gulf of Mexico were restricted to a small area around the platforms.

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Dr. Theodor C. Sauer, Jr. received his Ph.D. in chemical oceanography from Texas A&M University. After several years at Exxon, he moved first to Battelle Ocean Sciences Laboratory and then to the Marine Sciences Unit of Arthur D. Little, Inc. In his 13 years in the marine sciences, he has performed extensive research on the chemistry and fate of organic chemicals in the marine environment and is a collaborator on the development and testing of computer models of the dispersion and fate of drilling muds in the ocean.

AN ASSESSMENT OF PRODUCED WATER IMPACTS IN LOUISIANA

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INTRODUCTION

Produced water is a by-product of the oil production process and is brought to the surface along with petroleum from subsurface formations. Also known as formation water or oil field brine, produced waters associated with Louisiana oil reserves are usually highly saline with ranges of from 50 to 150 parts per thousand (ppt) (Hanor *et al.* 1986).

The recent escalation of research into the environmental effects of produced water discharges is largely due to the increased regulatory concerns of various federal, state, and local agencies. These agencies have directed research efforts towards obtaining the data necessary for reassessing and updating current regulations dealing with produced water discharges.

Within the State of Louisiana, the Louisiana Department of Environmental Quality (LDEQ), Water Pollution Control Division, governs all discharges to surface waters. In 1968 an additional rule was promulgated that prohibited the discharge of oil field brines into freshwater areas, but allowed for their release into " ...normally saline waters, tidally affected waters, brackish waters, or other waters unsuitable for human consumption or agricultural purposes" (LAC 1988).

On November 20, 1985, the LDEQ adopted a water discharge permitting system that required all effluents, including those from the oil and gas industry, to be permitted. Data from the applications submitted by the petroleum industry were summarized in a study by Boesch and Rabalais (1989a). The total volume of produced water discharged into Louisiana waters was almost 2.0 million barrels per day ($bbl \bullet d^{-1}$) at the time of the study.

Presented in this paper is a general summary of the results of a recent study conducted by the LDEQ and the Louisiana State University Institute for Environmental Studies. This study was partially funded by the U.S. Environmental Protection Agency. The original study report, which is presented in more detail, is available from the study coordinator.

STUDY SITES

Four sites in southeast Louisiana were selected for study. Study sites consisted of a single discharge and were located in the Lirette (LRT), Delta Farms (DF), Bully Camp (BC), and Lake Washington (LH) Oil Fields. Three transects, labeled "A," "B," and "C," radiated from each outfall. Eight sampling points were distributed at varying distances from the outfall along the transects. An unaffected reference site (control) was selected for each study site for comparison.

Discharge volumes varied from 462 $bbl \bullet d^{-1}$ at the LRT site to 13,458 $bbl \bullet d^{-1}$ at the DF site. Effluent salinities were considerably higher than receiving stream concentrations, ranging from 139 ppt at the LRT site to 193 ppt at the LRT site. Receiving stream salinities ranged from about 4.0 ppt at the DF site to an average of 23 ppt at the LW site.

HYDRAULIC BEHAVIOR OF PRODUCED WATER EFFLUENTS

Due to their high salinities, Gulf Coast produced waters are generally much denser than Louisiana inland waters. Boesch and Rabalais (1989a) concluded that produced water effluents can act as dense plumes after discharge to estuarine waters. Studies by Boesch and Rabalais (1989a, 1989b) and Armstrong *et al.* (1979) have also shown high concentrations of hydrocarbons in sediments near produced water outfalls.

For chloride analyses, a slotted core tube was used to collect sediment and overlying water samples from each transect point. Overlying water was collected from the core tube at the sediment/water interface (0 level) and at the 10 cm (+10) and 20 cm (+20) levels. Interstitial water was collected also at 10 cm levels (i.e., -10, -20, and -30). Water column measurements were also taken with a commonly used conductivity, temperature, depth (CTD) instrument.

Results from all four study sites indicated that produced water influences on chloride concentrations were more apparent in the sediments than in the water column. At some stations highly elevated sediment chloride concentrations were measured, while no measurable impact in the water column was detected. This suggests that almost no apparent mixing of these discharges is occurring or that any dilution that might occur is insufficient to completely reduce the density differences between the produced water effluent and the receiving water column.

Produced water was shown to penetrate to a depth of at least 30 cm at some stations and there was a strong positive correlation between depth increases and interstitial chloride increases at the most impacted transect points. The trend of steadily increasing sediment chlorinities suggests that a produced water penetration to levels deeper than 30 cm is likely.

Study results also indicate that conventional CTD instruments may not be capable of consistently detecting produced water chloride impacts since much of the effect, at least in poorly flushed systems, may be below the position of the conductivity sensor. A strict reliance on water column salinity readings near produced water effluents might result in the erroneous conclusion that produced waters are completely mixed and quickly dispersed after discharge.

RADIUM 226 ACTIVITIES IN PRODUCED WATER

Produced waters from Louisiana and locations throughout the world have been shown to contain environmentally high concentrations of radium (Ra) (Reid 1984). High Ra-226 levels were detected in all study site effluents and ranged from a low of 355 picocuries per liter (pCi/l) at the Delta Farms site to 567 pCi/l at the Bully Camp site. The variation between site effluent activities is probably due to differences in the mineral composition of the geologic formations from which petroleum is extracted (Kraemer and Reid 1984).

The top 10 cm of sediment from each transect sample point were analyzed for Ra-226. The sediments from the station nearest to the outfalls at the Lirette, Bully Camp, and Lake Washington study sites contained high concentrations of Ra-226 ranging from 182 pCi/g at the Bully Camp transect origin to 533 pCi/g at the Lirette site transect origin.

Ra-226 levels in LRT, BC, and LW sediments located away from the outfalls were lower than transect origin sediments but were still elevated above background levels at most of the transect sample points. Stations indicating Ra-226 activities greater than 5 pCi/g above the background site (reference) were up to 500 m from the outfall.

BIOTOXICITY

Samples of each study site effluent were tested for acute toxicity to mysids and sheepshead minnows. Sediments from a station near each effluent site and each reference site were also tested for acute toxicity using a solid phase procedure.

Each effluent exhibited 96-hour acute toxicities to mysids that were attributed to components other than salinity. The Lirette effluent was the least toxic to mysids with an LC_{50} value of 5.8% effluent. The highest mysid effluent toxicity was 2.6% effluent measured for the Bully Camp discharge. The mean LC_{50} for all effluents was 4.3%.

Effluent toxicity patterns using sheepshead minnows differed from mysid test patterns and sheepshead minnows were shown to be less sensitive to produced water effluents. The 96-hour LC_{50} values for sheepshead minnows ranged from 33.8% effluent (least toxic) at the Bully Camp site to 7.2% effluent (most toxic) at the Delta Farms site. The mean 96-hour LC_{50} value for all effluents used in sheepshead minnow tests was 20.1%.

A solid phase sediment toxicity procedure was used to measure the toxicity of sediment samples to the burrowing amphipod, *Hyalella azteca*. Significant levels of acute toxicity to *H. azteca*, due to a component other than salinity, were measured using this solid phase procedure. The mean mortality rate for all treatment sediments was 73.3% mortality. One reference sediment sample, BC-R, demonstrated a significant mortality rate (28.9%). The remaining reference sites showed no significant mortality.

CHEMICAL CHARACTERIZATION OF PRODUCED WATER IMPACTS

The chemical composition of the four produced water discharges was characterized using gas chromatography/mass spectrometry for the identification and quantification of the organics and inductively coupled plasma/mass spectrometry for the quantification of the trace metals. The produced waters were characterized by high concentrations of volatile hydrocarbons, including benzene and toluene, and semivolatile hydrocarbons such as aliphatic hydrocarbons and a series of alkylated polycyclic aromatic hydrocarbons (primarily naphthalenes and phenanthrenes). The discharges also contained high concentrations of aromatic acids and aliphatic fatty acids. The trace metal content of the four discharges was very variable; however, each was characterized by high levels of barium, ranging from 1,521 parts per billion (ppb) in the Delta Farms produced water discharge to a maximum of 4,644 ppb in the Lirette. Vanadium, a trace metal often associated with oil, was also found in each of the four discharges at variable levels. Some discharges contained significant levels of arsenic and copper. These levels of toxic metals and organics represent a significant negative impact to the receiving waters of natural bayous because of the high volumes of formation waters discharged annually into confined waterways that are often poorly flushed by freshwater flow or tidal exchange. Because of the hydrology of these systems and the particle reactive nature of both the metals and organics being discharged, we would anticipate that these substances would accumulate to high levels within the sediments in the vicinities of the discharges.

ASSESSMENT OF PRODUCED WATER CHEMICAL IMPACTS TO RECEIVING STREAMS

The impacts of produced water discharges on sediment quality varied in each of the areas studied. Major factors determining the degree of impact were (1) discharge rate, (2) quantity and quality of the hydrocarbons and trace metals present in a particular discharge, (3) local hydrology, (4) sediment disturbances (i.e., dredging and boat traffic), and (5) sediment types (organic carbon content and texture). Analyses of sediments collected at the four sites revealed that all four receiving water systems were measurably impacted by the discharges in the region. Concentrations of both aliphatic and alkylated aromatic hydrocarbons characteristic of the discharges, as well as barium, were found at elevated levels above background in the sediments surrounding the outfalls. The areal extent of this contamination expressed in terms of a Fossil Fuel Pollution Index (Boehm and Farrington 1984) or barium concentration was found to extend to the farthest points sampled at each discharge site (approximately 300 m). The continuation of these discharges into these receiving waters will likely result in an increase in both the level and extent of contamination at these sites.

Investigations by Daniels and Means (1989) of the genotoxic potential of produced water indicated that chemicals in produced waters represent a significant genetic risk to embryo and larval stages of fish. In this study a bioaccumulation model applied to the levels of contamination found in the sediments yielded extremely high potential tissue burdens for benthic invertebrates, including edible species. Thus, these chemicals represent both a potential ecological and human health risk.

ACCUMULATION OF ORGANICS AND RADIUM 226 BY OYSTERS

In this study component, caged oysters were used to assess the potential for the uptake of organic contaminants and Ra-226. Oyster cages containing 75 individuals each were placed at the Lirette, Bully Camp, and Lake Washington sites. The Lirette cages were 110 m from the outfall and the Bully Camp and Lake Washington cages were placed 85 and 70 m, respectively, from produced water outfalls. A control was deployed at an unaffected location in Caillou Lake. All oysters remained in place for 30 or 33 days.

All of the oysters exposed to produced water impacts in this study component accumulated both volatile and semivolatile organic compounds. The control site oysters accumulated no volatile organics and only trace quantities of pyrogenic semivolatiles. Total tissue volatiles among treatment site oysters ranged from 3 ppb at the Lake Washington site to 372 ppb at the Lirette Site. Of all volatiles measured, toluene was detected in the greatest quantity. Petrogenic polynuclear aromatic hydrocarbons were detected ranging from 41 ppb at the Lirette site to 319 ppb at the Lake Washington site.

The Ra-226 analysis of caged oyster tissues indicated that oysters growing near produced water effluents may accumulate petrogenic radionuclides. Tissue samples from oysters placed near the Lirette effluent accumulated 3.1 ± 0.3 pCi Ra-226/g of tissue. Oysters placed at the Caillou Lake reference and the Bully Camp and Lake Washington study sites accumulated no measurable radium activities.

Studies with freshwater bivalves by Jeffree and Simpson (1986) demonstrated that these organisms could readily accumulate these pollutants in a linear manner from water containing radium at levels that were much less than those measured for the four outfalls of this study. A complete in-depth study would be needed to assess the full radiological impact of produced waters on oysters. Such a study is recommended since many of these discharges currently exist near commercial oyster harvesting areas.

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OVERVIEW OF CURRENT FEDERAL ENVIRONMENTAL REGULATIONS REGARDING PRODUCED WATERS

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The purpose of this paper is to discuss the direction that environmental regulations are heading at the U.S. Environmental Protection Agency (EPA) from a National and Regional perspective as they relate to oil and gas discharges, particularly produced waters. In light of new EPA National goals focusing on the reduction of toxic discharges and the EPA's new policy on waste minimization, Region 6 is currently developing general permits to regulate the discharges from oil and gas exploration and production facilities.

The Oil and Gas Extraction Point Source Category is currently subdivided into the following five subcategories: offshore (includes territorial seas), coastal, onshore, agricultural and wildlife water use, and stripper. Since there are no nationally promulgated effluent guidelines beyond best practicable control technology (BPT) for these subcategories (40 CFR 435), permits written by the Region implementing more stringent technology based controls must be developed on a best professional judgement basis. The BPT regulations currently limit oil and grease discharges for the offshore and coastal subcategories at 48 mg/l monthly average and 72 mg/l daily maximum; onshore, zero discharge; and agricultural and wildlife water use, 35 mg/l daily maximum. The BPT effluent guidelines for stripper wells are currently deferred.

On July 9, 1986, EPA Regions 4 and 6 jointly issued a general permit (51 FR 24897) that covered all discharges from oil and gas operations in Gulf of Mexico Federal waters (i.e., discharges from facilities greater than 3 miles from shoreline). The permit implements best available technology (BAT) for nonconventional and toxic pollutants and best conventional pollutant control technology (BCT) for conventional pollutants. In addition, the permit was developed using ocean discharge criteria regulations and the best professional judgement of our scientific staff on what discharges could be allowed without harm to the Gulf of Mexico. Produced water discharges are regulated in this permit at a BCT level of control, where oil and grease discharges cannot exceed a 48 mg/l monthly average and a 72 mg/l daily maximum.

Region 6 has recently proposed general permits for the onshore oil and gas subcategories for the states of Louisiana, New Mexico, Oklahoma and Texas (54 FR 35930), August 30, 1989. The final permits are to be published within the next couple of months and will include the zero discharge guidelines requirement for produced waters. Location of the well head is the determining factor as to whether the onshore limitations apply to a particular facility. The transportation of produced waters across subcategory boundaries for the purposes of discharge is also prohibited by these permits (i.e., the discharge of produced waters from the onshore areas into coastal or offshore areas would be prohibited). These permits also apply to wells that become classified as stripper (produce less than 10 bbls of oil per day) after the effective date of the permit.

The Region has recently proposed coastal drilling general permits for the states of Louisiana and Texas (55 FR Part II, 23348, June 7, 1990). Most significantly, these general permits when issued in final form will prohibit the discharge of drilling muds and cuttings within the coastal subcategory.

General permits that cover produced water discharges for Texas and Louisiana coastal waters are currently in the final stages of preparation. The production general permits will propose a zero discharge limit on produced water based on BAT and water quality criteria. The EPA is considering a zero discharge requirement similar to the one advanced by the Louisiana Department of Environmental Quality that would be implemented over a 5-year phase-in period, with the largest volume dischargers scheduled to go to injection first, followed by smaller dischargers over the next several years. Such a plan would provide for all surface produced water discharges being eliminated at the end of the 5-year period.

The economic evaluation for this zero discharge BAT determination is based on a worse-case scenario that shows that the average injection disposal cost after-taxes for produced water to be $0.20/barrel. Wells located over marshes and open water bodies would experience slightly higher disposal costs due to higher costs for platform construction. Disposal costs could increase by $.05/barrel in marsh areas and $.10/barrel over open water. Our model includes very conservative assumptions that all-new injection wells would be required and that existing wells would not be used. As with the onshore general permits, the location of the well head determines if a facility is included in the coastal subcategory. The transportation of produced waters to other subcategory areas for purposes of discharge would also be prohibited. These permits are expected to be completed during the next several months and should be proposed sometime after the beginning of the year.

Beginning in late 1992, EPA Region 6 plans to address facilities that qualify for discharge under the agriculture and wildlife water use subcategory. Because of the limited number of facilities that would qualify under these guidelines and the site specific water quality considerations necessary in permit development, we may take the approach of issuing individual permits rather than general permits.

The EPA Region 6 is currently in the process of characterizing the stripper well subcategory (i.e., number of wells, volume of water discharged, size of operator, current disposal practices, etc.) to help determine appropriate technology and water quality limitations for these dischargers.

On September 15, 1975, EPA promulgated effluent guidelines for interim final BPT requirements at 40 FR 42543, and proposed regulations for BAT and new source performance standards (NSPS) for the offshore subcategory. On April 13, 1979, the EPA promulgated final BPT effluent regulations, but deferred action on BAT and NSPS. On August 26, 1985 the EPA proposed BAT/BCT/NSPS effluent guidelines for the offshore subcategory at 50 FR 34592. The proposed BCT requirement for produced water limited oil and grease discharges to 48 mg/l as a monthly average and 72 mg/l as a daily maximum. The EPA reserved BAT guidelines for produced water in this proposal. On October 21, 1988, EPA published a notice at 53 FR 41356, requesting public comment on new technical, economic and environmental assessment data relating to the development of BAT and NSPS regulations for the offshore subcategory. Now the EPA is currently preparing to repropose effluent guidelines for the offshore subcategory within the next several months and will promulgate final guidelines during 1992.

The following eight options are being considered for produced water discharges at the BAT level of control in the EPA's soon to be published offshore effluent guidelines proposal:

Option 1 Shallow water filtration/deep water BPT control.

Option 2 Shallow water zero discharge/deep water BPT control.

Option 3 Filtration for all discharges.

Option 4 Shallow water zero discharge/deep water filtration.

Option 5 Zero discharge for all water depths.

Option 6 Filtration <4 miles/deep water BPT control.

Option 7 Filtration <6 miles/deep water BPT control.

Option 8 Filtration <8 miles/deep water BPT control.

Of these eight regulatory options considered, options 3, 6, 7, and 8 examine two different levels of filtration technology for produced water discharges, each having its own effluent limitations. The granular media filtration technology, if adopted, would require discharges to meet oil and grease limits of 16 mg/l as a monthly average and a 29 mg/l limit as a daily maximum not to be exceeded. The membrane filtration technology would limit oil and grease discharges to 7 mg/l as a monthly average and 13 mg/l as a daily maximum not to be exceeded.

In summary, environmental regulations for produced water discharges are becoming more stringent as technology based controls become more efficient and as water quality impacts become more apparent. The amount of oil and grease that can currently be discharged could be reduced by as much as 80% or more in the new proposal. At a Regional level, EPA Region 6 will soon propose coastal production permits that will require all operators to cease all surface discharges of produced water. In onshore areas the Region has already proposed zero discharge permits for Texas, Louisiana, Oklahoma, and New Mexico. Final issuance of these permits is expected in the next several months.

Dr. Lee Gibson has worked at the U.S. Environmental Protection Agency for the last three years, currently serving as an environmental scientist in the industrial permits section of the water division, Region 6. He has over 30 years of professional exploration and production experience in the oil industry, both foreign and domestic, as a geologist and stratigrapher in operations, research, and exploration management. Dr. Gibson received his B.A. in zoology and his M.A. in geology from Washington University, St. Louis, Missouri. He has attended Texas A&M University, College Station, Texas (oceanography), the University of Chicago, Chicago, Illinois (ecology), and received his Ph.D. in geology from the University of Oklahoma, Norman, Oklahoma.

MINERALS MANAGEMENT SERVICE
OFFSHORE TECHNOLOGY ASSESSMENT
AND RESEARCH PROGRAM

Session: MINERALS MANAGEMENT SERVICE OFFSHORE TECHNOLOGY ASSESSMENT AND RESEARCH PROGRAM

Co-Chairs: Dr. Maurice I. Stewart, P.E.
Mr. Robert C. Lanza, P.E.

Date: November 14, 1990

Presentation	Author/Affiliation
Minerals Management Service Offshore Technology Assessment and Research Program: Session Introduction	Dr. Maurice I. Stewart, P.E. and Mr. Robert C. Lanza, P.E. Minerals Management Service Gulf of Mexico OCS Region
Overview of Minerals Management Service Technology Assessment and Research Program	Mr. Charles E. Smith, P.E. Minerals Management Service Technology Assessment and Research Branch
Verification Technology for Deepwater and Aging Structure	Mr. Charles E. Smith, P.E. Minerals Management Service Technology Assessment and Research Branch
Blowout Prevention in Deepwater Drilling	Dr. Adam T. Bourgoyne, Jr. Louisiana State University
Blowout Fire Suppression	Dr. David Evans National Institute of Standards and Technology
Engine Exhaust Emission Control Technology	Dr. Robert Wilson Arthur D. Little, Inc.

MINERALS MANAGEMENT SERVICE OFFSHORE TECHNOLOGY ASSESSMENT AND RESEARCH PROGRAM: SESSION INTRODUCTION

Dr. Maurice I. Stewart
and
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Minerals Management Service
Gulf of Mexico OCS Region

As the pace of exploration and development increases in the Outer Continental Shelf, concerns continually arise about technology needs to safely and efficiently develop oil and gas operations. The primary objective of this session was to present an overview of several major research efforts sponsored by the Minerals Management Service that address operational needs for the permitting of drilling and production operations, safety and pollution inspections, enforcement action, accident investigation, and well control training requirements. The major research efforts addressed in this session are verification technology for deepwater and aging structures, blowout prevention in deepwater drilling, blowout fire suppressions, engine exhaust emission control technology, and safety of operations.

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OVERVIEW OF MINERALS MANAGEMENT SERVICE TECHNOLOGY ASSESSMENT AND RESEARCH PROGRAM

Mr. Charles E. Smith, P.E.
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INTRODUCTION

The Minerals Management Service (MMS) of the U.S. Department of the Interior has a mandate to manage the leasing, exploration, development, and the collection of royalties from mineral resources on the Outer Continental Shelf (OCS). In this capacity, the MMS must oversee the development of offshore oil and gas resources and assure that such developments are conducted in a safe, pollution-free manner, using acceptable technology. Through its Technology Assessment and Research (TA&R) Program, the MMS supports an active research program to understand the engineering constraints for operations in hostile frontier environments, especially those related to the structural integrity of platforms and the prevention of pollution.

The research program was initiated in the spirit and letter of the Outer Continental Lands Act, as amended in 1978, which specifies "the Secretary (of the Interior)... shall require, on all new drilling and production operations, and wherever practicable, on existing operations, the use of the best available and safest technologies which the Secretary determines to be economically feasible wherever failure of equipment would have a significant effect on safety, health, or the environment . . . ." The TA&R Program has been given the responsibility for assessing and evaluating technologies proposed for offshore operations. Information derived from the research program is integrated into operations offshore and is used in making regulatory decisions pertaining to the issuing of permits and the reviewing of applications.

The TA&R Program is basically a contract research program, that is, the research is not performed within the agency but is conducted by academic institutions, private industry, and Government laboratories. Studies are performed in cooperation with the offshore industry or with other agencies or governments. This aspect of the Program provides an important multiplier of funding support, but probably of equal importance is the discourse it provides with the industry. The ability to work together to assess a particular technology or the rationale for future technical developments helps both industry and government. Such cooperation and dialogue allow us to understand each other's needs and eliminate possible conflicts or misunderstandings concerning the engineering feasibility of an operational decision. As a result of this dialogue, a valuable exchange of information is provided between MMS and the industry.

RESEARCH PROGRAM

The TA&R Program, established in 1975, is an integral part of the inspection and enforcement mission of MMS Offshore Operations. As such, the Program provides the following services to MMS operations personnel:

- An independent assessment of the technologies applicable to OCS operations,
- Research into the solution of operational problems where technology gaps are determined to exist, and
- A continuing dialogue at the engineering level between the industry, the research community, and the MMS operations personnel.

In this respect, the program is directed toward those technologies that are needed to assure the public that offshore operations are being conducted in a safe and pollution-free manner. The Program does not address the economics of operations, which are within the purview of industry. On the contrary, it specifically addresses operations and functional requirements of MMS personnel as they work with an offshore industry that is moving farther into the hostile environments of the deep ocean and ice-infested Arctic.

In addition to the research program, the MMS also sponsors an Environmental Studies Program (ESP). The ESP is used to gather and develop information needed to predict, assess, and manage the impact of OCS oil and gas leasing activities on the human, marine, and coastal environment. This program sponsors environmental and socioeconomic studies used in the preparation of environmental impact statements for particular lease areas. The TA&R Program, on the other hand, provides a formal technology base for field and headquarters personnel, especially as the oil and gas industry moves into the frontier areas. In short, the two programs can be differentiated in that the ESP is concerned with the effects of operations on the environment, whereas the TA&R Program is concerned with the effects that the environment has on operations.

OPERATIONAL MISSION REQUIREMENTS

The mission of MMS OCS operations can be divided into five broad functional requirements:

- Permit and plan approvals
- Safety and pollution inspections
- Enforcement actions
- Accident investigations
- Well control training requirements

In order to fulfill these requirements, while working with a rapidly growing technology base within the industry, MMS personnel need to avail themselves of the latest research developments. Since the inception of the Program, approximately 150 projects have been sponsored, yielding some 700 technical reports and papers, all of which, with the exception of proprietary studies, are available to the public. The proprietary studies are projects in which the TA&R Program was part of a joint industry research effort where the data and documents produced are held proprietary to the funding participants or their agents for a specified period of time. For the purpose of management, the projects within the research program are categorized in four main sections.

- Well control
- Verification of structures and pipelines
- Engine exhaust emission control
- Oil-spill containment and cleanup

However, for the purpose of budgeting and project review, the four main subject areas are subdivided into the following categories:

- Well-control
- Oil spill mitigation
- Engine exhaust emission control
- Structural dynamics
- Structural inspection and monitoring
- Geotechnical conditions and pipelines
- Arctic environments and ice mechanics
- Materials
- Risk and reliability

Table 8.1 relates the TA&R Program to the broad operational requirements of the MMS. The list illustrates certain mission responsibilities and the research initiatives established to assess and develop usable technology. The requirements and missions are not all inclusive of the research pursued by the Program but they do illustrate the process that is used in the selection of a particular study area for funding. These operational requirements, coupled with insights gained from the industry, are used in conjunction with future leasing plans to plan and develop research efforts. By combining information from all of these sources, the Program strives to select projects to ensure that leasing and development can proceed in a timely manner without technical impediments.

The following sections of this paper will review each of the four major categories of projects and will cite specific investigations to illustrate the type of studies sponsored by the research Program. References 1 and 2 provide a detailed listing of all projects that are currently being or that have been sponsored by the Program in the past. In addition, References 3 and 4 provide short summaries of selected projects.

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VERIFICATION TECHNOLOGY FOR DEEPWATER AND AGING STRUCTURE

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VERIFICATION OF STRUCTURES AND PIPELINES

Safe and economical designs for deepwater platforms require that it be possible to predict accurately the impact of the environment on the structure being contemplated for use. Industry has a long history of experience with fixed leg platforms in water depths up to 600 feet (ft.). However, new designs are using fixed leg platforms in water depths up to 1,500 ft. Also, new types of platforms known as compliant structures (tension-leg platforms, compliant towers, and floating production systems), offer promise for extending platform capabilities significantly further. For these new-type structures, their dynamic response properties must be understood in order to make meaningful fatigue life predictions. Areas of particular interest are problems relating to fluid-structure interaction, the determination of structural response properties, damping and model shapes, and the ability to predict the dynamic response of offshore structures to wave and ground excitation. With the compliant structures, a major need exists to understand riser strumming and to develop a conscientious methodology for their analysis and design. The Technology Assessment and Research (TA&R) Program is funding projects in the following areas to develop a better understanding of the technologies required to approve development plans for deepwater operations:

Table 8.1. Mission Statements versus Research Initiatives.

Mission Titles	Operational Requirement	TA&R Programmatic Response Initiative
1. NO_x Control for OCS Operations	Control or reduce nitrogen oxide air pollution resulting from OCS activities to provide continued leasing and operations.	Provide stimulus for industry, government, and public participation in improving NO_x control technologies by analyzing technologies, devising development plans, organizing workshops and enlisting private industry funding support.
2. Oil spill response for broken ice conditions	Improve capability for containing and cleaning up oil in broken ice fields.	Quantify state of the art in containing and cleaning up spilled oil in areas of broken ice and conduct theoretical and experimental investigations into the application of improved technology.
3. Structural inspection data management modeling	Provide an accurate and detailed knowledge base of the service condition of offshore platforms.	Devise computerized program for retrieving proper structural data required by 30 CFR 250 for optimum analysis, archiving and management decision making.
4. Risk analysis modeling	Determine the applicability of risk analysis as a management tool for OCS operations.	Develop and exercise an OCS operations risk analysis model(s), annotate the usage of the model, and summarize for management the risk analysis language and procedures applicable to MMS operations.
5. Verification of innovative deep ocean facilities	Ensure the integrity of innovative facilities projected for ocean operations.	Analyze and develop the verification technologies and inspection programs needed by MMS for the new technology platforms projected for deep ocean operations.
6. Diverter design and operation	Improve the safety of diverter operations.	Assess the design and operation of state of the art diverters and develop technologies, through theory and experiment, to improve operation safety.
7. Deep ocean well control procedures	Ensure that the safest well control procedures are available for deep ocean operations.	Assess state of the art equipment and procedures for well control and, by theory and experiment, examine the feasibility of applying computer-assisted measurements while drilling.

(continued)

Table 8.1. Mission Statements versus Research Initiatives (continued).

Mission Titles		Operational Requirement	TA&R Programmatic Response Initiative
8.	Platform reverification	Ensure the suitability for service of old or damaged platforms.	Devise philosophies and strategies for assessing degradation and damage, for planning and conducting inspections, and for determining extent of repairs necessary for safe usage.
9.	Earthquake design	Ensure the safety of platforms in earthquake-prone areas.	Conduct seismic event monitoring in earthquake-prone areas; devise forcing functions for design purposes and procedures for verifying safe operation.
10.	Verification of arctic OCS facilities	Ensure the safe operation of facilities subjected to arctic ice.	Determine by theory and experiment the mechanical properties of sea ice and permafrost and the forces exerted on facilities as well as inspection and repair strategies.
11.	Open ocean response for large oil spills	Improve the capability of containing and cleaning up large open ocean oil spills.	Quantify the state of the art for containing and cleaning up large open ocean spills and, by means of theory and experiment, analyze the application of new and innovative techniques.

- Method for Predicting Hydrodynamic Damping for Offshore Structures--A joint industry study to develop improved damping parameters and methods of representing the effects of damping for the analysis and verification of deepwater platforms.

- Response Prediction Techniques for Risers in Sheared Currents--A Joint industry program to assess the global static and dynamic behavior of compliant risers in a shear current.

- Fatigue of High Strength Steels for Innovative Offshore Structures--A joint industry program to assess and characterize the fatigue properties of a variety of new high strength steels under consideration for innovative platforms.

- Wind Loads and Wind/Wave Interaction on Compliant Offshore Structures--A joint industry/Government project initiated to develop improvements in design guidelines and procedures related to the verification of compliant structures subject to strong wind and wave environments.

- Resistance of Tension Leg Platform (TLP) Tendon Steel to the Ripple-Load Effect on Stress Corrosion Cracking--A project to determine the susceptibility of candidate steels and associated weldments for TLP tendons to stress-corrosion cracking in sea water and how this phenomenon might be influenced by the ripple-load effect.

In other areas, the Program is continuing its research to develop the philosophy and procedures for determining the reserve strength and remaining service lives of old and damaged platforms. Six oil companies, the United Kingdom Department of Energy, and the Minerals Management Service are now part of this research on this increasingly important operational problem.

CONCLUSIONS

This paper has highlighted some of the studies being sponsored by the TA&R Program as the industry moves forward to open the deep ocean to offshore oil and gas operations. It has not been possible to present a complete account of all the projects being conducted, such as deepwater foundation concerns, (i.e., drilled and grouted piles and hydrates), deepwater pipeline systems, or oil-spill and containment procedures for both open ocean and Arctic conditions, which must be developed in order to proceed in a safe and reliable manner. A concerted effort is being made by industry, as well as the regulatory agencies, to meet these challenges. Industry has historically demonstrated the ability to develop the required technologies to meet needs arising from a move into new frontier areas of resources. Because of the extensive research being conducted by both Government and industry and the continual accumulation of frontier area experience, the future holds much promise for further developments.

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BLOWOUT PREVENTION IN DEEPWATER DRILLING

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INTRODUCTION

In some marine environments where abnormal formation pressures may be encountered at very shallow depths, conventional blowout prevention equipment and procedures are likely to be of no benefit. This can lead to very severe well control problems when permeable, gas bearing formations are drilled. There have been numerous disastrous blowouts resulting from loss of well control after drilling into shallow, abnormally pressured gas formations. A research well facility at Louisiana State University has been used to study this problem under the sponsorship of the Minerals Management Service (MMS). A number of technical publications have resulted from this work. In this report, those technical contributions will be summarized and concepts will be presented for minimizing shallow gas hazards.

Shallow gas accumulations are always at least slightly abnormally pressured in the upper portion of the reservoir due to the density difference between the gas and the surrounding water. Abnormal formation pore pressures that are approaching the formation fracture pressure are thought to be possible in sand lenses due to gas migration along fault planes from below. Shown in Figure 8.1 is a recently discovered crater (Prior *et al.* 1989) in the floor of the Gulf of Mexico that is thought to be the result of a naturally occurring shallow gas blowout. It was discovered by a Shell Oil Company survey team in 2,176 m (7,139 ft.) of water, about 115 km (71 miles) southeast of the Mississippi River delta. The crater was elliptical in shape, 58 m (190 ft.) deep, 280 m (920 ft.) across, and about 400 m (1,300 ft.) long. Slow seepage of the abnormally pressured gas was thought to be blocked by the formation of gas hydrates in the near surface sediments.

Even when the formation pore pressure is nearly normal, it is generally not feasible to shut-in a shallow gas flow when drilling from a bottom supported vessel. By the time the rig crew can recognize that the well has started to flow, the gas has already traveled a considerable distance up the open borehole. If the blowout preventers are closed, the pressure at the casing seat will generally build to a value exceeding the formation fracture pressure. If one or more fractures reach the surface, the resulting flow can destroy the foundations of a bottom-supported structure and ultimately lead to the formation of a crater. The rig shown in Figure 8.2 eventually collapsed into a large crater in the seafloor.

PREVENTION OF SHALLOW GAS FLOWS

Because of the difficulties in handling gas flows while drilling at shallow depths, considerable attention should be given during well planning to preventing such flows. Seismic surveys can sometimes be used to identify potential shallow gas zones prior to drilling. If localized gas concentrations are detected by seismic analysis, surface well location can reduce the hazards.

When possible, empirical correlations should be applied to the seismic data to estimate formation pore pressures (Bourgoyne *et. al.* 1986). This application will sometimes permit the detection of shallow, abnormal pressure in the marine sediments. When formation pore pressures can be accurately estimated, an appropriate mud density program can be followed to prevent gas from entering the borehole.

In drilling the shallow portion of the well, drilling practices can also impact the blowout risk. Operations that can reduce downhole pressures, such as pulling the drill string from the well, should be carefully controlled to ensure that a pressure overbalance is always maintained in the open borehole. Trip-tank arrangements that keep the well completely full of drilling fluid at all times are better than those that require periodic refilling of the well. Modern top-drive rotary systems permit pumping down the drill-string while pulling pipe and can be used when necessary to eliminate the swabbing effect caused by pipe movement.

Gas-cut drilling fluid can also cause a loss in borehole pressure that can result in a significant reduction in equivalent mud density at shallow depths. Conditions favoring a shallow gas flow due to gas-cut mud become more severe with increasing hole size, increasing drilling rate, and increasing length of uncased borehole. Entrained gas, entering the drilling fluid from the sediments removed by the bit at the hole bottom may reduce the hydrostatic pressure below the allowable safety margin opposite a more shallow sand. This potential problem can be controlled by limiting the penetration rate of the bit. An approximate relationship between penetration rate and loss of borehole pressure was previously presented by Bourgoyne *et al.* (1978). This relationship permits the development of guidelines for an estimated maximum safe drilling rate in the shallow portion of the borehole.

DEVELOPING CONTINGENCY PLANS

Unfortunately, industry is not always successful in preventing the occurrence of shallow gas flows. Historical drilling records since 1965 for the Outer Continental Shelf of the Gulf of Mexico indicate that shallow gas flows have been encountered on approximately 1 well out of every 900 drilled. Shallow gas blowouts have accounted for 25% of all blowouts experienced in this area. In some other offshore development areas of the world, this percentage has been much higher. Thus, contingency plans must be developed to address this possibility.

Since 1975, a diverter system has been required for rigs drilling on the Outer Continental Shelf of the Gulf of Mexico. The function of the diverter system is to divert flow from the well overboard, away from the drilling personnel and rig structure.

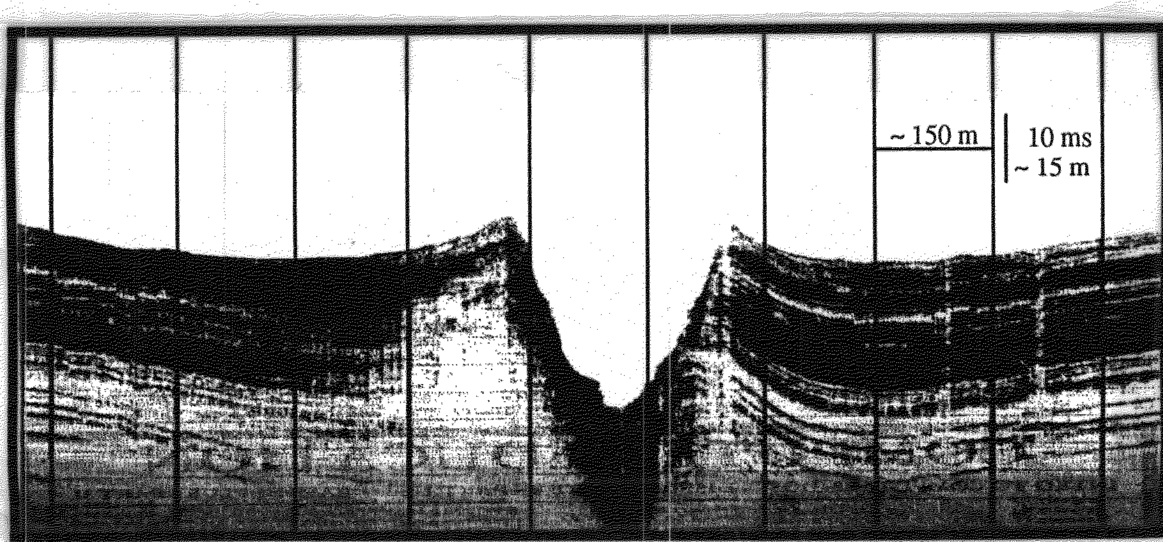

Figure 8.1. Side view of a crater on the sea floor thought to be due to a naturally occurring shallow gas blowout (After Prior *et al.* 1989) (Courtesy of Science Magazine).

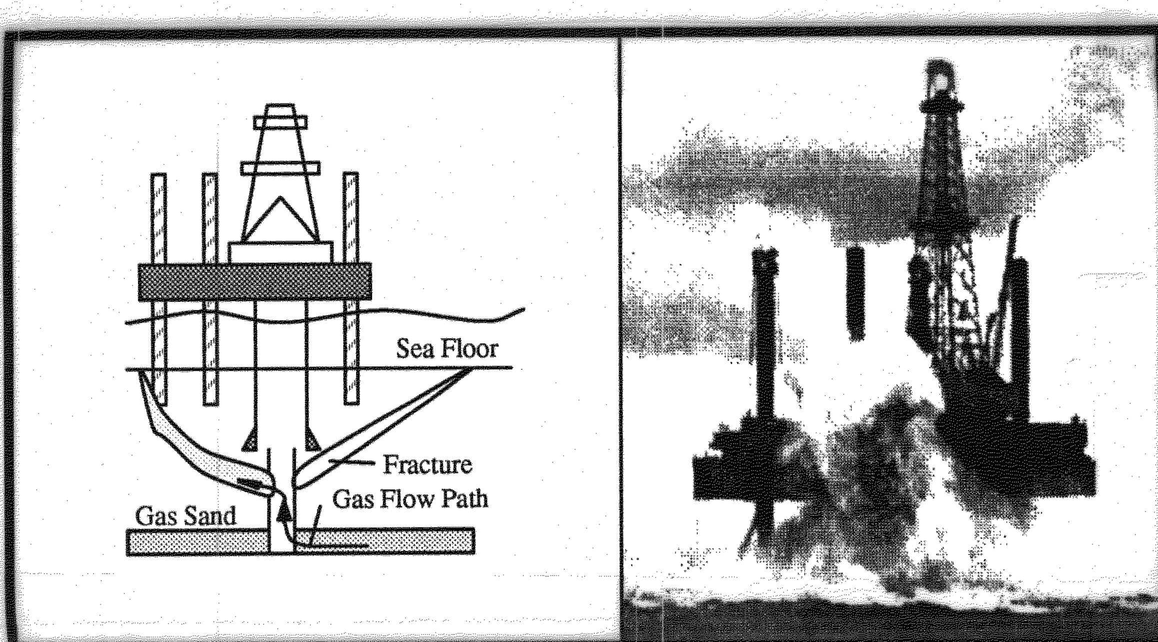

Figure 8.2. Example blowout illustrating the need for a diverter system.

In many cases, after rig construction, diverter systems have been added, which have complicated the placement of vent lines. Further, since diverter systems are not routinely used, special testing and training are needed to ensure maintenance of the diverter components and readiness of the rig crew to handle a shallow gas flow. Records available in the Events File of the MMS indicate a diverter failure rate of approximately 50% during shallow gas flows.

The three most common modes of diverter failure have been

1. a failure of the vent line valve to open;
2. formation fracture due to insufficient vent line size; and
3. erosion.

Divert design criteria have been developed that are directed at overcoming these common modes of diverter failure.

DIVERTER DESIGN

In the past, diverter systems have been designed primarily based on surface pressure considerations. Equations for single phase flow of gas were used to select a vent line size that would result in a maximum acceptable wellhead pressure for a maximum anticipated gas flow rate. It was generally assumed in these calculations that the exit pressure of the vent line was atmospheric pressure. Many offshore rigs were equipped with 0.152 m (6 in.) diverter lines and, until recently, this was considered acceptable practice by many offshore operators and by regulatory agencies. Experience with these systems in the Gulf of Mexico later provided evidence that larger diverter vent lines were sometimes needed.

Beck *et al.* (1987) have suggested an improved diverter system design procedure. They recommend that the final well design should consider the gas reservoir, borehole, casing, and diverter linked together as a single hydraulic system. A systems analysis approach permits the simultaneous calculation of pressures throughout the wellbore and diverter system. Through this type of analysis, it can be determined if a successful diverter system operation can be maintained using the design under consideration. The predicted operating pressures can be used to evaluate the working pressure of diverter system components and the tendency for formation fracture at the casing seat. This approach can be used to determine the minimum safe conductor setting depth for expected well conditions and for the available vent line size. If a practical casing program cannot be achieved with the diverter system available on the rig, then the benefits achieved by increasing the vent line size can be evaluated.

In performing the systems analysis, Beck *et al.* (1986) have shown that the flow at the vent line exit is usually sonic, and the assumption of atmospheric pressure at the diverter exit can lead to large errors. They also showed that near the exit, a significant pressure gradient resulted from fluid acceleration, which could also cause significant errors if ignored. Experimental data was obtained in a model diverter system to permit evaluation of various methods for calculating flowing pressures for single and multiphase flow at near sonic conditions.

The systems analysis is accomplished by defining the pressure change occurring in each system component as a function of flow rate. The calculation is most easily accomplished by starting at the vent line exit, and proceeding stepwise through each component of the flow path to obtain the bottom-hole pressure. The calculation is repeated for several assumed exit pressures or flow rates to define a flow-string resistance curve. An inflow performance equation is used to model the flowing reservoir pressure at the borehole wall as a function of flow rate. The pseudo steady-state flow rate that will be observed during the diverter system operations is determined from the intersection of the flow-string resistance curve and the formation--inflow performance curve.

Beck *et al.* (1987) performed experiments in model diverter systems to measure sonic exit velocities for a natural gas having a specific gravity of 0.64. Data were presented for single and multiphase flow for diverter vent line diameters of 0.0233 m (0.918 in.), 0.0492 m (1.937 in.), and 0.1244 m (4.897 in). These data were used to determine experimental values for the polytropic expansion coefficient, n. Their results have been curve fitted and are shown in Figure 8.3. Note that the measured value of n varied with vent line diameter and gas weight percent (quality) for the range of conditions studied and could be approximately defined by

$$n = 2.8\, d^{0.25} \left[1 + 5.5\, d^{0.5} \left(1 - \chi_g \right)^2 \right] \quad (1)$$

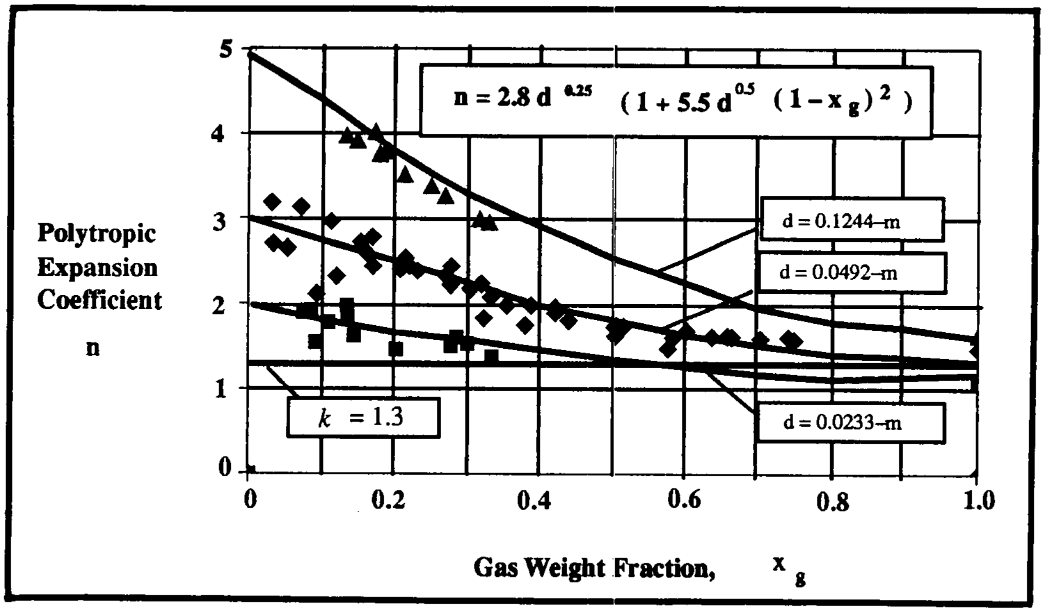

Figure 8.3. Values of polytropic expansion coefficient, n, measured during experimental study of diverter vent line operations.

where the diameter, d, is expressed in meters. The experimentally determined value of n departed significantly from *k*, especially for the largest diameter studied. Recently, experiments have been conducted for diameters of 0.203 m (8 in.) and 0.254 m (10 in.) to verify this correlation.

Flowing Pressure Gradient Calculation

Upstream of the vent line exit, the pressure gradient, $\frac{dp}{dL}$, is given by the expression

$$\frac{dp}{dL} = \frac{\rho g \cos(\theta) + \frac{f \rho \bar{v}^2}{2d}}{1 - \rho \bar{v} \frac{dv}{dp}} \qquad (2)$$

where the first term of the numerator accounts for hydrostatic pressure changes and the second term accounts for frictional pressure losses. The term ρ vdv in the denominator accounts for pressure changes caused by fluid acceleration. In the first term, g represents the acceleration of gravity, and Θ represents the vertical deviation angle of the flow section under consideration. In the denominator, the effect of fluid acceleration between any points 1 and 2 in a section of uniform area was found to be most accurately determined assuming a polytropic expansion model. Use of this model yields

$$\rho \bar{v} \frac{dv}{dp} = \frac{\bar{\rho} \bar{v}^2 \bar{p}^{1/n} \left(p_2^{1/n} - p_1^{1/n} \right)}{(p_2 - p_1)\, p_1^{1/n}\, p_2^{1/n}} \qquad (3)$$

The experimental work performed in this study has shown the acceleration term to be important and this term should not be neglected in diverter design calculations.

Formation Productivity

Resistance to flow is present in the gas reservoir as well as in the flow path to the surface. Since little is generally known about the properties of the gas reservoir causing the unexpected flow, detailed reservoir simulations are not usually justified. However, it is important to take into account turbulence and other factors that become important at high gas velocities. The Forchheimer (1901) equation as adapted for radial, semi-steady state flow in a homogeneous gas reservoir is recommended for use in design calculations for diverter systems. This equation can be arranged to give flowing bottom-hole pressure, p_{bh}, within a well-bore of radius, r_w, due to flow within a circular reservoir of external radius, r_e, and effective thickness, h, and having an average reservoir pressure, p_r. The Forchheimer equation for these conditions is defined by:

$$p_{bh}^2 = \bar{p}_r^2 - \left[\frac{m\bar{T}\bar{z}p_{sc}}{pT_{sc}kh}\ln\left(0.472\frac{r_e}{r_w}\right)\right]q_{sc} - \left[\frac{b\bar{z}M\bar{T}p_{sc}^2}{2Rp^2T_{sc}^2h^2}\left(\frac{1}{r_w}-\frac{1}{r_e}\right)\right]q_{sc}^2 \qquad (4)$$

where the subscript 'sc' denotes standard conditions. The terms in brackets reduce to a constant for a given reservoir. The second term is needed to properly model high-velocity gas flow where the velocity coefficient, b, is determined empirically. Note that once the bracketed terms are reduced to a constant, a relatively simple relationship between gas flow rate and flowing bottom-hole pressure results.

Formation Fracture Pressure

Constant and Bourgoyne (1989) have recommended fracture pressure equations for offshore drilling operations based on Eaton's correlation. The recommended method gives the absolute overburden stress, σ_{ob}, in SI units in terms of the seawater depth, D_{sw}, and the sediment depth below the seafloor, D_s, using

$$\sigma_{ob} = 101{,}300 + 10{,}000\ D_{sw} + 25{,}500\ D_s - 21{,}980{,}000\left[1 - \exp(-0.000279\ D_s)\right] \qquad (5)$$

The minimum expected absolute formation fracture pressure, pf, is then determined from the absolute formation pore pressure, pp, and the overburden pressure, Sob, by

$$P_f = P_p + \left[1 - 0.629\ \exp(-0.00042\ D_s)\right]\left[\sigma_{ob} - P_p\right] \qquad (6)$$

This minimum fracture pressure would correspond to extending an existing fracture in a sandy formation. Higher formation fracture pressures would be expected for fracture initiation and in plastic "gumbo" shale formations. The maximum expected pressure for fracture extension is the overburden pressure given in Equation 6.

Working Pressure of Diverter Components

The systems analysis procedure provides information about the pressures that could be expected on the diverter system components after the well is unloaded and pseudo-steady-state conditions are reached. However, while the drilling fluid is being displaced from the well, the mud in the system behaves as a viscous plug that greatly slows flow through the diverter. This results in a pressure peak occurring when the leading edge of the gas reaches the vent line entrance. The magnitude of the pressure peak depends primarily on the formation pressure and on the amount of mud that remains in the well due to slippage past the gas while the well is unloading. The pressure peak can be substantially higher than the equilibrium wellhead pressure calculated from a systems analysis procedure. This pressure peak is of short duration, typically lasting only a few seconds. If fracturing occurs, it is unlikely that fracture propagation would move very far from the wellbore before the pressure subsides to the equilibrium value. As long as the equilibrium borehole pressure is less than the fracture extension pressure, there is a high probability that the fracture will not propagate to the surface. Thus, it is recommended that the design load at the casing seat is based on equilibrium flowing conditions. However, the design load for surface diverter system components should be based on the pressure peak occurring when the drilling fluid is being displaced from the well.

Santos (Santos and Bourgoyne 1989) performed experiments on a 0.152-m (6 in.) diverter vent line attached to a 382-m (1,252 ft.) well containing 0.178-m (7 in.) casing to study unsteady-state pressure behavior when the well is first placed on a diverter system. In the experiments, the gas entering the bottom of the well flowed through a valve that was controlled by a process control computer that simulated the behavior of a formation. A program was developed for the flow control computer to permit a range of formation productivities to be simulated. Pressures were monitored during the experiments at a number of locations in the well and diverter. Experimental runs were made using a number of different mud systems.

Santos (Santos and Bourgoyne 1989) developed a computer model for predicting the pressures and flow rates observed during a shallow gas flow as a function of both time and position. The program was first verified using the experimental results obtained with the model diverter system. The computer results for peak wellhead pressure matched the observed pressure peaks within an error band of about 25%. The program was then used to simulate a wide variety of field conditions. It was found that the peak wellhead pressure tended to decrease with decreasing formation pressure, decreasing formation productivity, and increasing vent line diameter. For the field conditions studied, the peak wellhead pressure was generally less than 65% of the formation pressure. Also, the time required to unload the well was typically only a few minutes.

Shown in Figure 8.4 are results obtained using the computer model for an example 0.254-m (10 in.) diverter vent. The drilling fluid in the well when the shallow gas flow began was assumed to have a density of 1,116 kg/m^3 (9.3 lb/gal.). Note that it is predicted that the well will unload in about one minute with a peak wellhead pressure of 1,436,000 Pa (208 psi), which is about 34% of the formation pressure. Thus, a working pressure for diverter components of at least this value would be needed. The calculated pressure at the casing seat exceeds the minimum fracture extension pressure of 1,467,000 Pa (214 psi) during most of the first minute but drops to about 496,000 Pa (72 psi) after pseudo-steady state conditions are reached. Similar simulations performed for a 0.152-m (6 in.) diverter vent line gave a peak wellhead pressure of 2,620,000 Pa (380 psi), which was about 63% of the formation pressure.

Diverter Anchors

Some diverter failures have involved the anchor system used to hold the vent line piping in place. The anchor system should be carefully designed to withstand the forces resulting from the moving fluids. The maximum forces on the anchoring system occur when the wellhead pressure reaches its peak value. When telescoping segments or slip joints are used below the annular blowout preventer, a maximum upward force on the wellhead must be resisted that is equal to the peak pressure multiplied by the internal annular cross sectional areas at the slip joint. In computer simulations made by Santos (Santos and Bourgoyne 1989), these forces sometimes reached as high as 1,300,000 N (300,000 lbf) for the field conditions studied. Similarly, a maximum axial thrust distributed along the length of the vent line exists that is equal to the peak pressure multiplied by the internal cross sectional area of the vent line. In addition, at bends in the diverter system, the anchor system must resist a force equal to the mass rate of flow multiplied by the change in the fluid velocity vector at the bend. For a 90° bend, this force is approximately given by the fluid density times the square of the average velocity, $\rho\bar{v}^2$.

Rate of Erosion

Information was collected on 31 wells that encountered shallow gas. Typical locations of erosion type failures are shown in Figure 8.5 for a simplified diverter schematic. Problems tend to occur

1. at bends in the vent line.
2. at flexible hoses connecting the vent line to the wellhead.
3. at valves or just downstream from valves.
4. in the wellhead and diverter spool.

The severity of the erosion problems experienced was greatly affected by the quantity of sand produced by the well. When considerable sand was produced, diverter system component failures started in the bends and valves and progressed back to the wellhead. The entire wellhead and annular preventer were cut from the well in an extreme case. For this well, sand piles of 10 ft. in height were reported on the rig floor after the well bridged.

Bourgoyne (Santos and Bourgoyne 1989) used two experimental set-ups to measure the rate of erosion in various fittings. The first set-up was used for mud/sand slurries. Drilling mud flowed from the right side of a partitioned tank to a centrifugal pump, through 20 ft. of 2 in. inside diameter pipe, through the fitting being evaluated, and then back into the tank. Flow rates were periodically checked by temporarily closing an equalizing line connecting the left and right sides of the tank. Sand concentration in the mud was also periodically checked by taking a sample from the tank.

The second set-up was used for gas/sand and gas/water/sand mixtures. Compressor-supplied air flowed first through a flow control value and 2-in. orifice meter. The flow control value maintained a constant flow rate by means of a process control computer. Sand was added to the flow stream from a 6,000-lb capacity sand blasting pressure pot through a metering valve. The weight of the pressure pot was continuously monitored, and the sand flow rate was determined from the rate of change of weight with time. Water or mud could be introduced downstream of the sand injection point. The mixture then flowed through 56 ft. of 2-in. inside diameter line, through the fitting being evaluated, through a one-foot tail piece, and then exited to the atmosphere.

The fittings evaluated included steel ells, plugged tees, vortice ells, and rubber hoses. The plugged

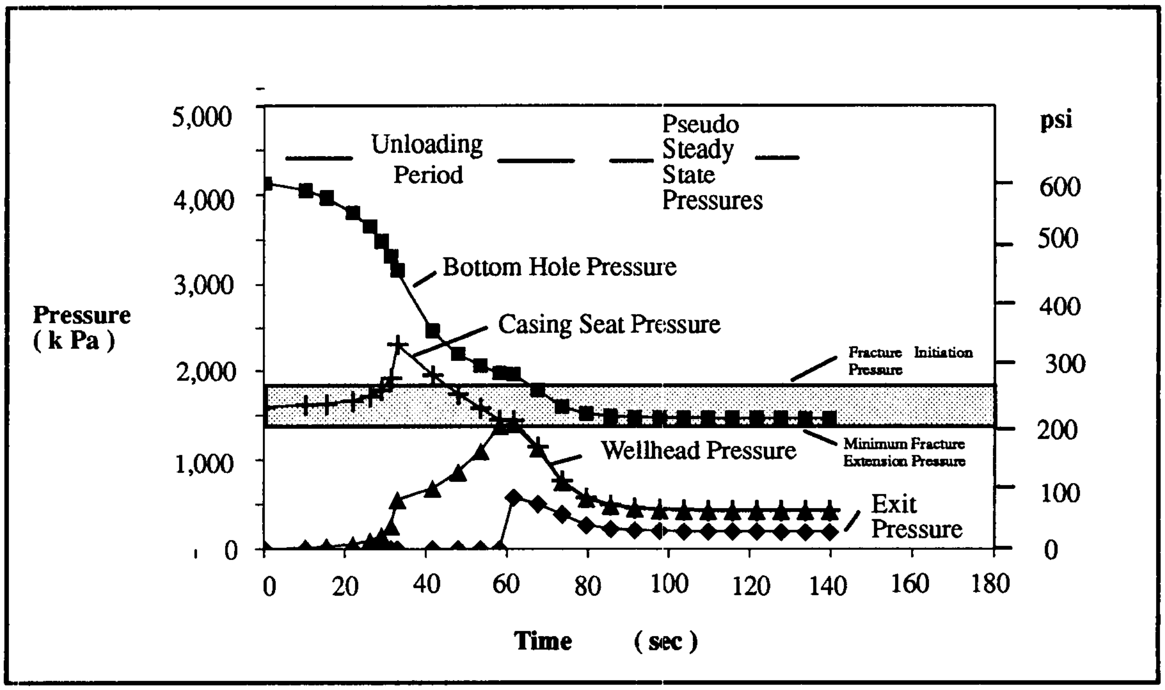

Figure 8.4. Calculated pressure behavior for example 0.254-m (10 in.) diverter vent lines (Santos and Bourgoyne 1989).

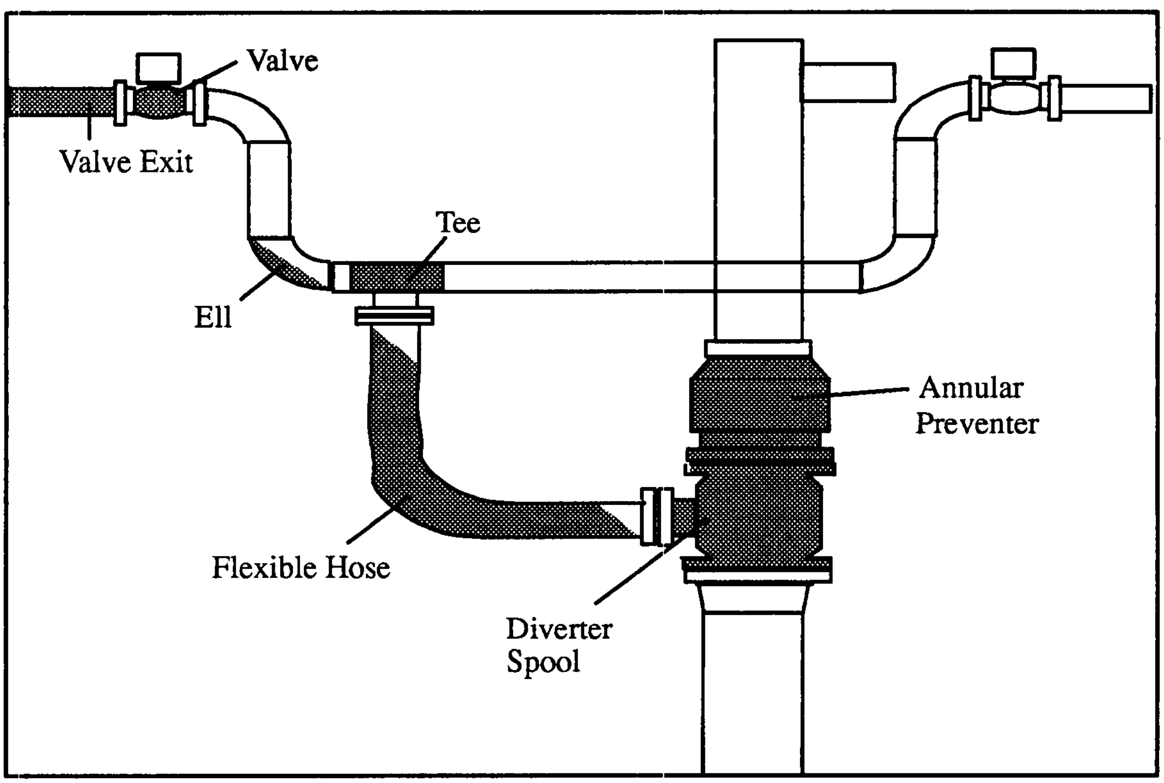

Figure 8.5. Typical locations of erosive wear on diverter system for bottom-supported rig (Santos and Bourgoyne 1989).

tees had only a blind flange on the dead-end portion and did not contain any special lead targets. Weight loss and wall thickness loss were periodically determined during the tests. Wall thickness measurements were made using an ultrasonic method. Thickness profiles were determined along both inside and outside radii of the bends. The locations of the areas of maximum wear are shown for the various fittings and fluid types studied. Data were collected to permit evaluation of sand rate, fluid velocity, fluid properties, and fitting type. The sand used in the experimental tests was No. 2 blasting sand.

Based on the experimental work performed, Bourgoyne (Santos and Bourgoyne 1989) proposed the following equation in SI units for estimating the rate of loss in wall thickness, h_w, with time, t, in a diverter component of density, ρ_s, and cross sectional area, A, flowing abrasives having density, ρ_a, at a volumetric flow rate, q_a, and flowing gas or liquid at superficial velocity, v_{sg} or v_{sl}, and volume fraction (holdup) λ_g or λ_l:

Gas Continuous Phase (Dry Gas or Mist Flow) (7)

$$\frac{dh_w}{dt} = F_e \frac{\rho_a}{\rho_s} \frac{q_a}{A} \left[\frac{v_{sg}}{100 \lambda_g} \right]^2$$

Liquid Continuous Phase (8)

$$\frac{dh_w}{dt} = F_e \frac{\rho_a}{\rho_s} \frac{q_a}{A} \left[\frac{v_{sl}}{100 \lambda_l} \right]^2$$

The accuracy of the proposed calculation method was verified using the experimental data collected. The average error observed was 29%. Currently these equations are being evaluated by collecting erosion rate data in a 6-in. model diverter system.

Plugging

Solids in the drilling fluid tend to settle in the diverter components and can lead to valve malfunctions and vent line plugging. To the extent possible, the diverter system is generally sloped towards its exit to promote draining and minimize the accumulation of solids in the system. In addition, provisions for flushing the system should be made. Clean-out connections with flushing jets should be placed upstream of all valves, bends, and local low spots.

Control System

Control of the diverter vent lines should be achieved by means of valves that can be fully opened to minimize erosion and pressure losses. The diverter control system generally involves pneumatic or hydraulic valve operators and can be operated from remote panels located with the blowout-preventer control panels. It is often advantageous to integrate the diverter control system with the blowout preventer control system. Standards regarding the accumulator unit, which stores the pressurized control fluid needed to operate the valves, should be similar to those adopted for the blowout preventer system. A non-flammable, low freezing-point power fluid should be used in the hydraulic units. The controls should be designed so that the well cannot be closed with the diverter system; i.e., the valves to the vent line should automatically open before the annular sealing device is closed. When multiple vent lines are needed to insure downwind diversion, the currently selected vent valve should open before the other vent valve is closed. Specially designed integral sequencing diverter components have recently become available that provide the annular sealing device with a vent line valve in a single unit (Roche 1986).

Design Considerations for Dynamic Kill

Some operators use a contingency plan that calls for a "dynamic" well control procedure to be attempted as soon as the well is placed on a diverter. The dynamic well control procedure has been described in detail by Blount and Soeiinah (1981). With this method, high-circulating rates are used to increase annular frictional pressure losses sufficiently to cause the bottom-hole pressure to be raised above the formation pressure. Some operators maintain a volume of weighted drilling fluid on location for use in an immediate attempt at a dynamic kill. Other operators plan the use of seawater after the available mud volume has been exhausted. The success of the dynamic well control method is governed primarily by the hole size being drilled, the flow rate and pressure limitations of the available rig pumps and the effective thickness of the gas formation penetrated by the bit before the gas flow is detected. Data that was collected on 28 shallow gas flows occurring in the Gulf of Mexico indicate that in 2 cases the flow was successfully stopped using a dynamic kill procedure.

When a dynamic well control procedure is included in the shallow gas contingency plan, the diverter system design load should be based on the well conditions that will result with the rig pumps operating at the maximum available flow rate. The basic calculation procedure remains unchanged, except that the liquid pumped is added to the formation gas being produced on bottom.

Even when the dynamic well control method cannot be successfully employed using the available rig equipment, there is a high probability that control of the well can be regained through borehole collapse or reservoir depletion. In 25 to 28 shallow gas flow events that occurred in the Gulf of Mexico (90%), the well plugged due to borehole collapse. In 14 cases (50%), flow stopped within a 1-day period. In 22 cases (79%), flow stopped within a 1-week period. However, in one case two relief wells had to be drilled before the well could be brought under control with auxiliary pumping equipment.

Koederitz *et al.* (1987) developed a computer program for determining the flow rate and pressure requirements required to bring a shallow gas flow under control using the dynamic well control method. The program can be used to evaluate the requirements for regaining control using the existing wellbore, or using one or more additional relief wells.

The program developed by Koederitz *et al.* (1987) also determines the maximum pressure experienced at every point in the borehole as the pumping rate is increased up to the value required to bring the well under control. It was found that the maximum pressure at a given point in the borehole does not necessarily occur at the maximum liquid rate. Ideally, the diverter system design would permit any pumping rate up to the kill rate to be maintained without exceeding the fracture pressure.

RECOMMENDATIONS

As a result of the research conducted, the following recommendations are made:

1. Seismic surveys should be made at proposed offshore wildcat-well locations and the data processed for shows of shallow, abnormally pressured gas. However, the operator should recognize that the use of shallow hazard surveys will not always detect the presence of shallow gas formations.

2. Maximum controlled safe drilling rates should be estimated for the shallow portion of a well in which gas-cut mud could occur and increase the risk of a shallow gas flow.

3. A systems analysis design procedure should be employed for proposed wildcat wells to verify the adequacy of the planned casing program for the available diverter system. The systems analysis should consider the possibility of sonic flow velocity at the diverter vent line exit and at restrictions and changes in direction of the flow path.

4. The working pressure of a diverter system should be based on pressure peaks that could be expected during the unloading of the drilling fluid from the well.

5. Bends in diverter vent lines should be avoided whenever possible. When bends are required, a plugged tee or vortice ell should be used.

6. Dynamic well control methods have been successfully used to control some shallow gas flows with available rig pumps. However, a vent line exit monitor should be developed that will detect sonic flow, significant levels of sand production, and provide appropriate warning when these conditions are detected.

7. When shallow gas flows are severe, the diverter system on a bottom-supported drilling vessel should be used primarily to provide time for a orderly rig abandonment.

ACKNOWLEDGEMENT

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BLOWOUT FIRE SUPPRESSION

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STATE RELATIONSHIPS FOR FUEL MIXTURES

Typical oil well blowout and diverter fires involve simultaneous non-premixed combustion of two or more gaseous and liquid fuels. In order to construct state relationships for a variety of possible fuel mixtures using those for pure fuels, a simple mixing rule was devised. This rule involves the assumption that the two or more fuels react with air independent of each other and the products of their individual reactions mix to produce the products of the rule. Measurements of gas species concentrations in four coflow laminar jet diffusion flames burning mixtures of methane and acetylene were conducted. Two gaseous fuels were selected for simplicity, methane to represent the natural gas in oil well fires and acetylene to represent a second fuel component that may have high soothing tendency.

Due to the high soothing tendency of acetylene, a sampling probe/scheme capable of obtaining gas samples in spite of clogging by soot particles was designed. The design relies on the simple principle that the flow that clogs the probe also carries the gas sample. The sampling system consists of a quartz microprobe (250 μm and 350 μm orifice sizes were used) connected to an evacuated (typically to 0.3 atm) and purged (with the carrier gas helium) sampling bulb with an isolation valve. A purge line carrying a small flow of helium is also connected to the probe. The sampling bulb is equipped with an evacuation port, a carrier gas pressurizing line, an absolute pressure gauge and a sampling septum. During operation, the probe is inserted to a desired location within the flame while carrying a small (just to maintain the overpressured) purge flow of helium. The bulb is isolated during this process. Once the probe is at the desired location, the purge flow is shut off and the bulb isolation valve is opened. The pressure inside the bulb is monitored. If the probe does not clog, then the sampling ends when the pressure in the bulb reaches 1 atm and a gas sample is removed for routine chromatography. If the probe clogs, the bulb reaches a constant subatmospheric pressure. At this time, the isolation valve is shut off and a flow of helium is started through the pressurizing valve to bring the bulb pressure to 1 atm. The amount of sample collected is known from the pressure reading at the time of clogging. A sample from the bulb is now removed for analysis. 3The bulb is then evacuated and purged with helium for the next highest soot concentration regions of acetylene/air diffusion flames. To our knowledge, gas sampling within this region has never been possible before.

Measurements of gas species concentrations were taken in a flame burning 27% methane in acetylene with air plotted as a function of local mixture fraction. The concentrations of N_2, O_2, CH_4, C_2H_2, CO_2, and CO were seen to correlate very well. Several measurements were conducted at three different heights from the burner exit and observed to correlate similar to those supporting the laminar flamelet concept for fuel mixtures. If the present measurements for the pure fuels are used, then good agreement between the mixing rule and the data for CO and CO_2 is also observed. These findings have established a convenient method for estimating the major gas species concentrations in flames burning fuel mixtures.

BUOYANT HORIZONTAL TURBULENT DIFFUSION FLAMES

Diverter fires near oil well platforms pose hazards to structures and personnel surrounding them. The flame structure is complicated by the effects of buoyancy turbulence interactions. This flame configuration has received very little attention in the literature. We have developed a parabolic finite difference scheme using a grid that adapts to the jet trajectory as it turns under the action of buoyancy. The predictions of the flame centerline trajectory using the present method compared with measurements (based on visible flame trajectory) for flames with initial Reynolds numbers vary by a factor of 3. The agreement between measurements and predictions is very encouraging.

Measurements of flame surface intermittency using 30 (out of 9,000) randomly selected digitized images show that buoyancy increases the intermittency significantly for all 3 Reynolds numbers. Thus buoyancy-turbulence interactions are expected to be important in this flow and are being addressed.

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ENGINE EXHAUST EMISSION CONTROL TECHNOLOGY

Dr. Robert Wilson
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REDUCING EXHAUST POLLUTION

On the Outer Continental Shelf (OCS), engine exhaust pollution problems are categorized in two ways. For general pollution all of the polluting gases, such as carbon monoxide (CO), sulphur dioxide (SO_2) and nitrogen oxide (NO_x), emanating from all sources are considered for purposes of complying with the California Clean Air Act of September 1988. The Act requires that offending companies use Reasonably Available Control Technology (RACT) to reduce these pollutants to acceptable levels. These RACT technologies, by definition, are available for application usually from the manufacturers of emitting devices.

The second pollution problem, NO_x, as a precursor to ozone, is acute, and current RACT technologies will not suffice for ozone reduction under the new National Air Quality Act as it is envisioned. Leasing will be stifled unless, through a combination of methods (onshore and offshore), NO_x, is reduced to permit the attainment of ozone standards. If improved technology can be applied on the OCS to significantly reduce NO_x, emissions, it is probable that the largest factor constraining leasing off southern California will be removed. Figure 8.6 shows the various sources of NO_x, and the severity of pollution estimated for the Santa Ynez Unit Project. Figure 8.7 shows the Point Arguello field project for the year 1988. Depending upon the kind of offshore operations, the specific types of sources will vary, and an effective control program will have to take them into account. In general, the most important sources are production platform gas turbines, crew and supply boat main (diesel) engines, and exploratory drilling rig diesel engines.

TECHNOLOGY STATUS

NO_x results both from the combustion of fuels containing bound N_2 and from using air, which is 4/5, N_2, as an oxidizing agent. However, by properly controlled combustion (keeping the combustion temperature comparatively low), and or by use of exhaust gas treatment, levels of NO_x, can be held to a minimum. Table 8.2 summarizes the NO_x control measures that are currently used.

CONCLUSION

These control measures, to varying extents, can reduce NO_x levels appreciably. But as exemplified by pollution control levels required for automobiles, environmental demands are ever-increasing and improvements in controls are a continuing requirement. So, too, on the OCS is the need for improvements in exhaust control technology to cope with the ever-increasing power requirements and attendant air pollution.

Table 8.2. NO_x Central Measures Currently Used.

	NO_x Control Technology	Source Applicability
1.	Use of Natural Gas as Fuel Heaters and Boilers Onshore	Platform Gas Turbines
2.	Water/Steam Injection	Platform Gas Turbines
3.	Low NO_x Burners	Heaters and Boilers Onshore
4.	Use of California Certified Engines	Main Diesel Engines (High-Speed)
5.	Precombustion Chamber Design Two Stroke Engines	Stationary, Natural Gas, Spark-Ignited
6.	Injection Timing Retard	Diesel Engines (Crew and Supply Boats)
7.	Turbocharging and Aftercooling	Diesel Engines (Crew and Supply Boats)

Dr. Robert Wilson is the manager of Fuels and Combustion Technology at Arthur D. Little, Inc., in Cambridge, Massachusetts. For the last five years Arthur D. Little, Inc., has performed engine exhaust research and development for the Minerals Management Service related to California offshore projects. Dr. Wilson has a B.S. in aeronautical engineering from Princeton University and a Ph.D. in engineering physics from the University of California.

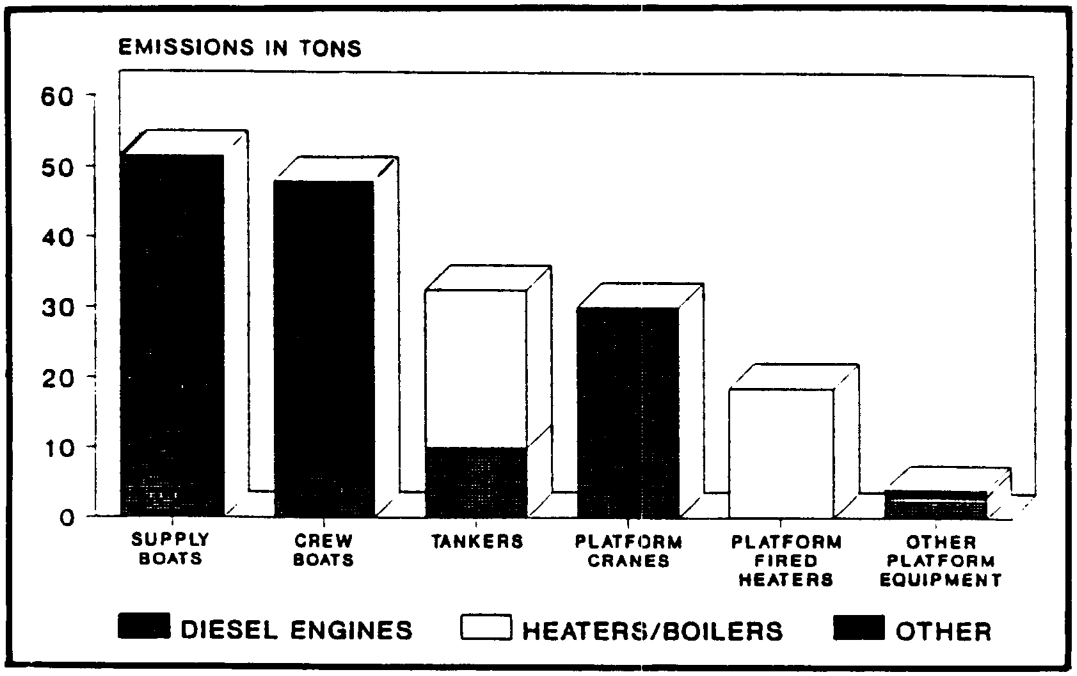

Figure 8.6. Sources of NO_x and severity of pollution estimated for Santa Ynez Unit Project.

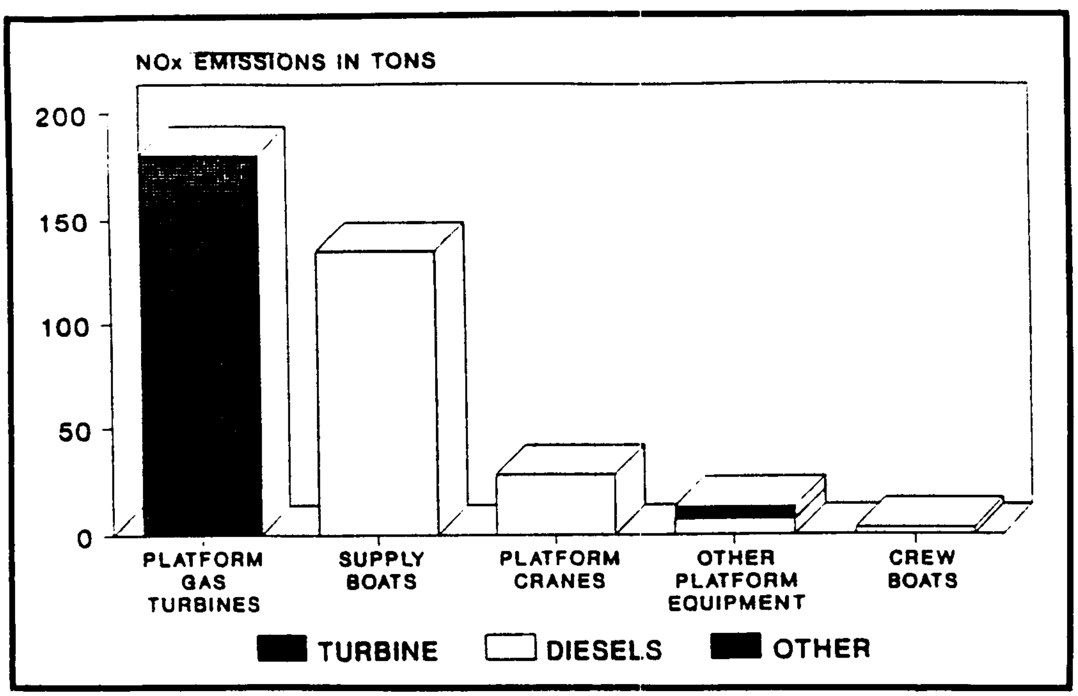

Figure 8.7. Point Arguello Field Project 1988 OCS NO_x emission sources.

ADVANCES IN TELEMETRY, TAGGING, AND
AND TRACKING OF ENDANGERED SPECIES

Session: ADVANCES IN TELEMETRY, TAGGING, AND TRACKING OF ENDANGERED SPECIES

Co-Chairs: Dr. Robert M. Avent
Mr. Patrick Mangan

Date: November 14, 1990

Presentation	Author/Affiliation
Advances in Telemetry, Tagging, and Tracking of Endangered Species: Session Introduction	Dr. Robert M. Avent and Mr. Patrick Mangan Minerals Management Service Gulf of Mexico OCS Region
The Application of Sonic, Radio, and Satellite Telemetry for Studying the Ecology of Juvenile Kemp's Ridley Sea Turtles	Dr. Edward A. Standora State University College at Buffalo and Mr. Stephen J. Morreale Okeanos Ocean Research Foundation
State of the Art Sea Turtle Tracking	Mr. John A. Keinath Virginia Institute of Marine Science College of William and Mary
Assessing Critical Habitats of Whales by Satellite Tracking	Dr. Bruce R. Mate Oregon State University Hatfield Marine Science Center
Ecological Studies on Large Whales Using Telemetry	Mr. Jeffrey D. Goodyear Department of Zoology University of Guelph
Passive and Active Acoustic Detection of Biological Targets	Dr. Coleman Levenson National Oceanographic and Atmospheric Research Laboratory
Progress in the Use of Acoustic Tags in the Tracking of Marine Fish	Mr. William T. Whelan Ocean Communications Systems
Acoustic Tracking Technology	Mr. Don Brumbaugh Sonotronics, Inc.
Advances in Satellite and Radio Location Technology	Mr. Stanley M. Tomkiewicz, Jr. Telonics, Inc.
Capabilities of the ARGOS System	Mr. Christopher Estes Service ARGOS

ADVANCES IN TELEMETRY, TAGGING, AND TRACKING OF ENDANGERED SPECIES: SESSION INTRODUCTION

Dr. Robert M. Avent
and
Mr. Patrick Mangan
Minerals Management Service
Gulf of Mexico OCS Region

INTRODUCTION

The Minerals Management Service (MMS) has the responsibility for the leasing, minerals exploration, and development of submerged Federal lands on the U.S. Outer Continental Shelf.

The Endangered Species ACT (ESA) of 1973, as amended, calls for the conservation of animal and plant species determined to be endangered or threatened. The ESA requires Federal actions (including those of the MMS) to avoid jeopardizing listed species or critical habitats. It also requires interagency consultation on the potential effects of proposed actions on protected species. The Marine Mammal Protection Act (MMPA) of 1972, as amended, specifically protects marine mammals, whether listed by the ESA or not.

Five species of sea turtles have been recorded in the Gulf: the endangered green, leatherback, and hawksbill turtles; the threatened loggerhead; and the highly endangered Kemp's ridley. Mysticete whales seem to be comparatively rare, but odontocetes are represented by a remarkable diversity of species including the endangered sperm whale.

In response to the ESA and MMPA, the MMS Environmental Studies Program has funded protected species studies in the Gulf of Mexico, mostly aerial overflight population characterizations. Two protected species workshops have been funded and convened as well.

As a result of the research priorities for cetaceans and marine turtles suggested at the 1989 workshop, MMS began to consider supporting studies involving radio and acoustic telemetry. The Information Transfer Meeting provided an opportunity to convene manufacturers and researchers who design and use this equipment to present the state-of-the-art technology. In the morning session speakers discussed the application of radio, satellite, and acoustic telemetry to determine the behavior and movements of great whales and marine turtles. In the afternoon, manufacturers and service representatives presented future prospects in equipment improvement, and existing limitations in satellite, acoustic and radio hardware. The afternoon session finished with a critique of the design and implementation of an MMS-sponsored study on marine turtles.

Dr. Robert M. Avent received the M.S. and Ph.D. degrees in biological oceanography from Florida State University in 1970 and 1973, respectively. He has pursued investigations on the biological effects of hydrostatic pressure, shelf physiography, animal zonation, and reef morphology. He has worked in academia, the consulting industry, and state and federal agencies. Coming to the Environmental Studies Section of the Minerals Management Service in 1981, he has coordinated studies of shelf and deep-sea ecology, protected species, and effects of petroleum contamination.

Mr. Patrick Mangan served until December 1990 as the staff specialist for marine mammals and endangered species in the Environmental Assessment Section of the Minerals Management Service, Gulf of Mexico Region. He has also worked for the U.S. Government conducting fisheries and wildlife research in Florida, Colorado, Utah, Minnesota, and the Republic of Kenya. He specialized in freshwater invertebrate ecology and fisheries at the University of Wisconsin.

THE APPLICATION OF SONIC, RADIO, AND SATELLITE TELEMETRY FOR STUDYING THE ECOLOGY OF JUVENILE KEMP'S RIDLEY SEA TURTLES

Dr. Edward A. Standora
State University College at Buffalo
and
Mr. Stephen J. Morreale
Okeanos Ocean Research Foundation

For the past several years we have been using biotelemetry to study the activities of juvenile Kemp's ridley sea turtles in the waters surrounding Long Island, New York (Morreale and Standora 1990). Kemp's ridleys first enter the area during

June, do most of their growing during August and September, and leave the region by early November when water temperatures begin a sharp decline (Burke 1990; Burke *et al.* in press). Telemetry has made it possible for us to study not only the animals' short term movements within the estuaries of Long Island, but also the long-term movements as the turtles emigrate from the region. In addition to tracking, by employing various telemetric techniques we also have been able to monitor specific ecological interactions and behavioral activities of these turtles. Each summer we have tracked up to 10 individual turtles outfitted with telemetry devices, sometimes simultaneously tracking as many as five animals.

We applied radio, sonic, and most recently, satellite transmitters to monitor the turtles' behavior. Recent advances in miniaturization of electronic components and advances in battery chemistry have resulted in smaller and lighter packages with high output signals and extended lives. Perhaps the only application of biological telemetry that has not progressed during the last two decades is in the application of multichannel telemetry; i.e., the monitoring of several physiological or physical parameters from a single device attached to a freely-swimming animal (Standora and Nelson 1977; Standora *et al.* 1982).

The radio transmitters we use operate at a frequency of 164 mHz, weigh approximately 40 grams, and have a life span of four months. These units have a range of 11 km with our boat mounted, 11-element yagi antenna, and a range of 20 km with dual antennas mounted on an aircraft. These transmitters contain no sensors but simply act as locational beacons. Because of the high ionic concentration of sea water, transmissions can only be monitored when the antenna breaks the surface of the water. The radio transmitters are usually attached to the turtle by means of a short tether with a breakaway link to ensure the turtle's survival in the event of entanglement. The transmitting package is made positively buoyant by the addition of external flotation and trails behind the turtle as it swims. Although the unit contains no diving sensor, it is possible to study surface and submergence times by recording periods of signal acquisition and loss. Tether length is critical to the interpretation of such data, as a turtle may be swimming fully submerged although the antenna is exposed.

Since much of the turtles' time is spent below the surface, the additional use of sonic transmitters has enabled us to monitor a much broader range of activities. All sonic transmitters provide precise location and some are equipped with additional sensors for measuring temperature or pressure. The transmitters emit a brief acoustic pulse at approximately 30 kHz and have an interpulse period proportional to the variable being measured; e.g., faster pulse rate as the temperature increases or as the turtle swims deeper. Although sonic transmitters require more power than a traditional radio transmitter and have a shorter range (often less than 2 km depending on ambient noise level) they are extremely valuable because they permit constant monitoring when the animal is at or below the surface. These transmitters also have allowed us to conduct detailed analyses of diving behavior by plotting second-by-second descent and ascent rates. By combining our dive profiles with simultaneous fathometer tracing, we can correlate specific diving behaviors with respect to available water depths. Other physical characteristics of the water column were also monitored at 1-m intervals to correlate these with the turtles' diving behavior. A very important benefit to the use of sonic transmitters is the increased capabilities to locate and recapture study animals. By using submersible acoustic receivers the free-swimming turtles are recaptured at intervals of greater than 14 days for growth rate measurements (Standora *et al.* 1989) and fecal samples are obtained for diet analysis (Burke *et al.* in press).

Turtles are tracked primarily from a 43-foot research vessel that allows us to monitor the turtles' behavior throughout New York waters from July through October. As turtles begin emigration we have followed them for as far as 23 km into the open ocean. Because of inclement late fall weather conditions in the North Atlantic, we have been unable to extend such tracks. It was not until this autumn that satellite transmitters were available in a size suitable for application to the juvenile size class of Kemp's ridleys we encounter in New York. Because these models were experimental, we tested two configurations: a 300-gram unit (90 g in water) that was mounted as a backpack, and a 240-gram towable model that, with flotation, had a positive buoyancy of 75 grams. Two techniques were used to conserve battery power in these units. First, the transmitters had a duty cycle in which the transmitting circuitry operated for only eight hours per day. Second, by the use of saltwater switches, the unit's transmitting circuitry was turned off whenever the transmitter was submerged. With a quiescent current drain of 3 milli Amperes per day (mA/d), an active power consumption of 1.2 milli Amperes per hour (mA/h), and a 1,000 mA/h power supply this unit has a calculated life of 79 days. Actual transmitter life, however, may be longer depending on the turtle's surfacing behavior during the active phase of the duty cycle. Extended periods of submergence will considerably increase transmitter life (Figure 9.1).

For the satellite to receive a transmission, three things must occur simultaneously: (1) the satellite must be orbiting over the proper location; (2) the transmitter must be in the operational window of its duty cycle; (3) the turtle must be at the surface. To determine the appropriate cycle for transmitter activities, we applied our prior knowledge of the turtles' diel diving cycle to increase the probability of reception. With our turtle swimming near 40° north latitude we received three contacts per day for 26% of the days tracked (Figure 9.2). The accuracy of the computed location depends on the quality of the signal received by the satellite and the duration of contact. Location classes are assigned to the computed position, with location Class 3 being the most accurate (within 150 m) and location Class 0 requiring that the quality of results be determined by the user. Approximately half of our receptions were assigned to location Class 0 (Figure 9.3). Groundtruth verification of these positions from our tracking vessel showed the mean error in longitude to be 12.6 km, and for latitude 7.9 km., which may be acceptable for determining global scale migrations. In the process of groundtruthing, we also noted a more serious problem when on numerous occasions the turtle was observed swimming at the surface but the saltwater switch on the backpack model was indicating submergence. Without on-site verification totally erroneous conclusions would have been made concerning the diving behavior of this animal.

In summary, sonic transmitters have the advantage of continuous data transmission with instantaneous sensor data. These units also provide precise locations of submerged animals and are moderately priced; e.g., $550 for depth sensing units. The range of sonic transmitters can be greatly influenced by sea state, thermoclines, and adventitious sounds generated by the biota. Transmitter life for a 145-gram sonic unit with a pressure transducer ranges from four to eight months depending on depth. Radio transmitters are less expensive at approximately $250, are light (40 grams), have excellent range, and last for four months. Disadvantages include difficulty of tracking animals that spend long periods of time submerged, and the necessity of having experienced personnel to effectively and reliably determine positions. Satellite transmitters have the advantage of global coverage and ease of tracking, as only a computer with a modem is required. These transmitters are not as well suited, however, for smaller scale movements and precise behavioral observations. The initial cost of these transmitters is high ($3,000-3,500) as is the cost of satellite time (approximately $4,000 per year under the Global Agreement per transmitter). This must be balanced, however, against the cost of supporting a tracking vessel and crew. Size and reliability have been a problem with early models, although progress is being made in both these areas. One serious consideration with satellite systems is the ease with which they can be applied and the remoteness of the researcher from the animal. Interpretation of data appearing on a terminal screen, where real time interactions of biotic and abiotic factors are usually lacking, is often much different than interpretations based on direct observation in the field.

As no one telemetry system is best for all applications, we suggest the use of double tagging with different types of transmitters, thus combining the advantages of each system. Two important factors contributing to the success of any telemetry project are the field experience of the researchers and the use of an appropriate tracking vessel. It is important that we do not become fixated on technology by using more than is required to obtain the necessary data. Sophisticated instrumentation should not be viewed as an end unto itself, but instead as a tool to achieve desired research goals. It is vital that a project has clearly defined testable hypotheses and is based on sound experimental design. Such an approach allows us to collect a sufficient data base, which is essential for proper management of a living resource.

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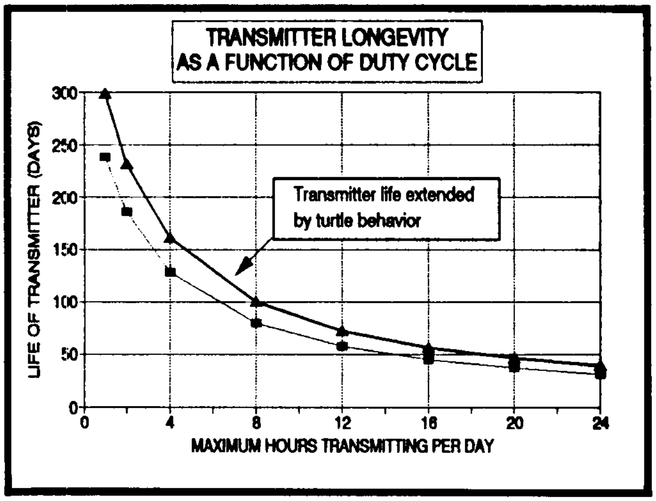

Figure 9.1.

Expected life of the satellite transmitter described in the text (fine line with square symbols). (Solid line with triangles shows longer life which is possible if the turtle would remain submerged for 25% of the operational time.)

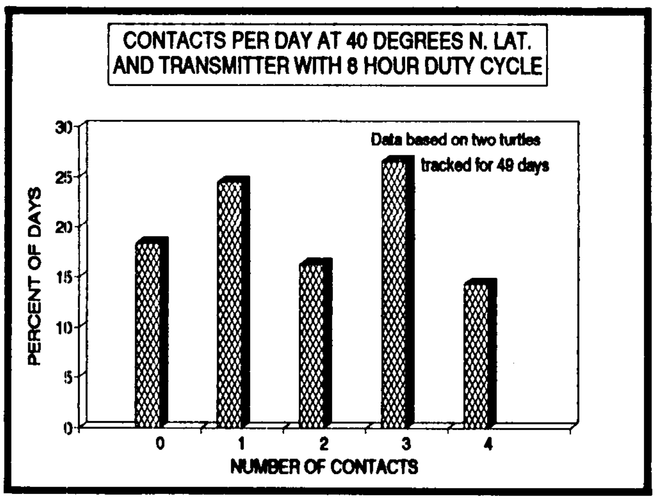

Figure 9.2.

Number of receptions by the satellite per day. (Data are combined for turtles equipped with backpack and towable model satellite transmitters.)

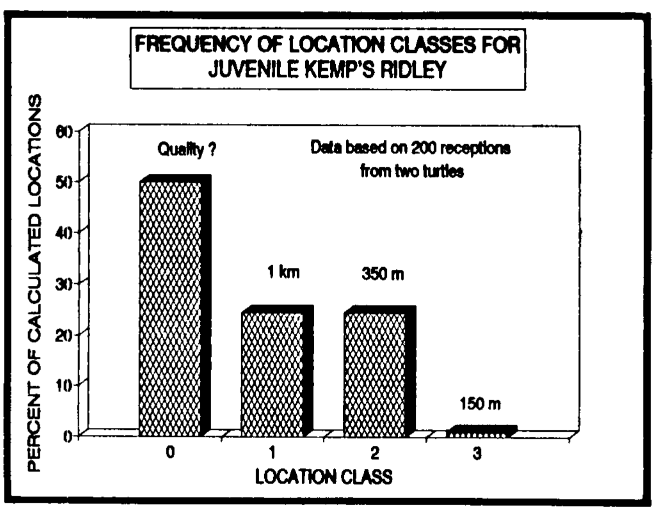

Figure 9.3.

Frequency of calculated locations categorized into the four accuracy classes. (Data obtained from satellite transmitters attached to juvenile Kemp's ridley turtles. Many of the class 0 positions were verified by on-site observations aboard our research vessel.)

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ACKNOWLEDGEMENTS

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Dr. Edward A. Standora has been designing and applying biotelemetry systems for studying vertebrate ecology for over 20 years. He received his B.S. degree from Fairleigh Dickinson University in 1969, his M.A. degree from California State University at Long Beach in 1972, and his Ph.D. from the University of Georgia in 1982. He is currently an assistant professor in the Biology Department at the State University College at Buffalo.

Mr. Stephen J. Morreale has extensive experience conducting research with freshwater and marine species of turtles both in the United States and in Costa Rica. He received his B.A. degree from the State University College at Buffalo in 1979 and his M.A. degree from the same institution in 1983. He is presently the Director of Sea Turtle Research at the Okeanos Ocean Research Foundation.

STATE OF THE ART SEA TURTLE TRACKING

Mr. John A. Keinath
Virginia Institute of Marine Science
College of William and Mary

TELEMETRY SYSTEMS

Knowledge of movements, behavior, and physiology of free-ranging sea turtles is fundamental to understanding their life histories and for formulating appropriate conservation plans. The recent advances in electronic technology have allowed sea turtle researchers to use telemetry to monitor free-ranging sea turtles remotely (Table 9.1).

Three types of systems are currently used on sea turtles: radio, sonic, and satellite telemetry. Radio telemetry utilizes VHF radio frequencies transmitted through air to the receiver, while sonic telemetry uses sound waves to transmit information through water. Satellite telemetry uses UHF radio frequencies to transmit information to satellites, which transmit it in turn to ground stations.

Sea turtles can be tracked at distances up to 30 km with radio telemetry and this method requires the least investment in equipment. Further, because VHF radio waves do not travel through sea water and signals are received only when the transmitter is at the surface, the amount of time the turtle spends at the surface can be measured. The distance a transmitter can be detected is dependent on many factors; e.g., weather conditions, transmitter power, receiver sensitivity, and height and types of antennas used on the transmitter and receiver, but ranges are typically 5-15 km. Because of the small energy requirements of radio transmitters, duration of experiments can be up to 6 months. Minimal receiving equipment (receiver and yagi antenna) costs $2,000, with additional costs for more sophisticated equipment; e.g., improved antennas, microprocessors. Transmitters can be purchased for $100-200 each. Additional housing costs depend on the turtle's contemplated maximum dive depth. Although tracking of turtles from land (Keinath 1986) and airplanes (Byles 1988) has been attempted, a support vessel is usually needed to stay in contact with the turtles for continuous monitoring

Table 9.1. Selected References of Studies Relevant to Sea Turtle Telemetry.

SPECIES	RADIO	SONIC	SATELLITE	REFERENCE
Chelonia mydas	X			Baldwin 1972
green turtle	X			Carr 1967, 1972
	X			Dizon and Balazs 1982
	X			Heath and McGinnis 1980
		X		Ireland 1979
		X		Ireland *et al.* 1978
		X		Mendonca 1983
	X	X		Standora *et al.* 1982
Lepidochelys kempi	X	X		Byles 1988
Kemp's ridley turtle			X	Byles 1989
	X			Mendonca and Pritchard 1986
	X			Timko and DeBlanc 1981
Caretta caretta	X	X	X	Byles 1988
loggerhead turtle			X	Byles and Dodd 1989
	X			Keinath 1986
			X	Keinath *et al.* 1989
	X	X		Kemmerer *et al.* 1983
	X	X		Murphy 1979
	X	X		Murphy and Hopkins 1981
	X			Soma and Ichihara 1977
			X	Stoneburner 1982
	X			Stoneburner *et al.* 1982
	X			Timko and DeBlanc 1981
			X	Timko and Kolz 1982
Dermochelys coriacea	X			Duron-Dufrenne 1978
leatherback turtle			X	Duron-Dufrenne 1987
	X			Keinath 1986
	X	X		Standora *et al.* 1984

over long periods of time, and thus adds to the cost of a project. Unless the turtles are known to be sedentary, around the clock monitoring is necessary to keep in contact with the turtle, requiring additional personnel (Kenward 1987 for a discussion of many practical aspects of radio telemetry).

The range of sonic telemetry is usually less than radio telemetry, but sonic telemetry allows continuous monitoring of the turtle. Except for unusual circumstances, the best reception range of sonic telemetry is 2 km. But the range is heavily dependent on power of equipment, physical characteristics of the water and bottom (e.g., presence of thermocline, shape and type of bottom), and ambient noise. Because of the large amount of energy needed to run all but the simplest sonic transmitters, battery life is usually less than 1 month. Sonic telemetry requires a larger initial investment than radio telemetry; good sonic receivers cost in excess of $7,000, and transmitters are more than $200. Although data from radio telemetry are often limited to location and surface times, sonic transmitters can be monitored continuously and other parameters can be obtained; e.g., temperature and depth. They are measured by varying either the pulse width or the duration between pulses, and equipment is needed to electronically time the signals. Since the receiving range is limited to 2 km, a support vessel is required, thereby increasing cost.

Because of the limited range it is very easy to "lose" a signal. Since VHF radio waves are receivable at "line of sight" distances, researchers usually use both sonic and radio transmitters on a turtle; sonic to obtain specific data, and radio to measure surface durations and to act as a backup location system if the sonic range is exceeded.

Satellite telemetry uses UHF transmitters that transmit signals to a satellite, which in turn relays them to an earth station. The costs of satellite telemetry are three-fold: Transmitters ($3,500), satellite time ($4,000/year, government rate), and data reception costs ($200/month). The ARGOS satellite telemetry system utilizes National Oceanic and Atmospheric Administration (NOAA) Tiros satellites to calculate transmitter location by doppler shift of the transmitter's radio frequency (Kenward 1987), and also allows transmission of digital data collected by transmitter sensors. Data collected by on-board sensors have included water temperature and precise diving/surfacing data (Byles 1989; Byles and Dodd 1989; Keinath *et al.* 1989), and a depth sensitive prototype will soon be available (Byles and Keinath in press). A salt water switch was used to determine dive parameters, and the switch also served to turn off the transmitter while underwater (UHF radiowaves do not travel through seawater) to extend the battery life to over a year of operation. Data are transmitted from satellites to ground stations, and processed and disseminated by ARGOS (Byles and Keinath in press). Data can be accessed via computer and modem, and back up diskettes or print-outs of monthly data can be purchased from ARGOS. Location parameters sent by the transmitter, day and time of reception, and probability of location accuracy are among data received. In contrast to radio and sonic telemetry, which can provide continuous data, the ARGOS system provides only a limited number of daily fixes, depending on latitude (Kenward 1987). Since Tiros satellites are polar orbiting, more fixes are possible at higher latitudes (up to 15 per day) than at the equator (up to seven per day), and since the transmitter is below the surface most of the time, probability of receiving a location is decreased further. Usually two fixes per day have been received from loggerhead turtles tracked off the east coast of the United States (Keinath pers. obs.).

The advantage of radio telemetry is the relatively small investment in equipment, but the limited types of data and costs of support vessels and personnel make radio telemetry expensive for long-term studies. The addition of sonic capabilities requires extra costs for equipment, but the added data gathered may be worthwhile. Further, both systems provide continuous data as opposed to the limited number of data points per day from satellite telemetry. But satellite telemetry economically provides data over a much longer period. A satellite track of a sea turtle over a one-year period currently costs about $10,000, while costs for a ship capable of following a free ranging sea turtle for one year would be $730,000 at $2,000/day (Byles and Keinath in press).

OTHER CONSIDERATIONS

Two general methods have been used to attach transmitters to sea turtles, trailing floats and backpacks. Trailing equipment is buoyant and is attached to the turtle by a line or cable. Backpack style equipment is usually negatively buoyant and is attached directly to the turtle's carapace.

A primary consideration in attaching any instrument to a turtle is the effect upon the animal. Stoneburner's (1982) satellite transmitter units were floating discs 38 cm thick and 76 cm in diameter attached to the turtle by a 33-m cable. These large units (as large as the turtle) likely altered the animal's normal behavior. The effects of the attached instrument should be minimal if results are to be representative of the wild animal. The maximum limit of buoyancy or (submerged) weight of transmitters should be less than 10% of the body weight of the turtle, although a limit of 5% is more desireable for long-term (i.e., satellite) studies (Byles and Keinath in press). If weights are kept below those suggested, size and shape of the transmitters become more important than weight. Low hydrodynamic profiles and small sizes reduce the drag produced by the transmitter. Trailing transmitters should be cylindrical with round or cone-shaped ends. For backpack style attachments, smooth contours conforming to the shape of the carapace are recommended (Byles and Keinath in press).

Trailing transmitters and some backpack style equipment have been bolted through holes drilled through the edges of the carapace, which is possible with all sea turtle species (e.g., Byles 1988; Standora *et al.* 1984; Keinath 1986). Loggerhead turtles have been recaptured years after being tracked, and holes from attachments were clean and seemed to have unaffected the turtle (Keinath pers. obs.). Alternatively, backpack transmitters have been attached with harnesses (Keinath unpublished) and suction cups and silicon sealer (Keinath 1986), although these should be considered for short-term studies only. Backpack transmitters have been attached to the carapaces of hard shelled turtles with fiberglass resins, producing a hydrodynamic shape that presents a low profile for reduced drag and low probability of entanglement in debris or nets.

Two opposing intentions affect attachment design; the need for the transmitter to be attached for the duration of the study and the desire for the transmitter to eventually break free. With equipment attached by lanyards or harnesses, a corrodible link is placed in a strategic location. Magnesium corrodible links are available for short-term (up to 1 week) studies. Ferrous bolts, which corrode in relation to thickness, can be used in longer studies. Turtles that have been at large for 1 year have shed iron bolts of 6 mm. Transmitters attached with resin eventually separate from the scutes over time (over 8 months, Renaud *et al.* in Byles and Keinath in press).

Cryptic colors should be used on transmitters and attachment hardware to prevent predator attraction. Shark tooth fragments were removed from a transmitter housing that was attached to a leatherback with a harness (Keinath pers. obs.), although the turtle was unharmed. It is probable the shark was visually attracted to the red harness.

Fouling of the transmitter and associated hardware should be a concern for long-term studies. A transmitter that was at large for over six months was encrusted to such an extent that it could no longer float. Marine anti-fouling paint should be used to prevent affecting the transmitter's performance and fouling (and associated drag).

Choice of a telemetry system depends on the duration and type of data desired. Both radio and sonic telemetry can provide continuous data on behavior and physiology, but are labor intensive, usually require a support vessel, and are generally limited to less than a month of monitoring. Satellite telemetry provides limited daily data, but for durations over a year. Generally, radio and sonic telemetry provide fine scale data for small time periods and geographic ranges, while satellite telemetry supplies coarse grain data over large periods of time and geographic ranges. Consideration should be given to size, shape, and weight of the transmitter in relation to the turtle, and type and duration of attachment. The desired result of telemetry is gathering data that represent the typical wild animal, and minimization of the effects of the attachment and presence of the transmitter should be a major objective.

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ASSESSING CRITICAL HABITATS OF WHALES BY SATELLITE TRACKING

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Hatfield Marine Science Center

INTRODUCTION

Because whales spend so much time underwater and it is hard to identify specific individuals from a distance, the movements, diving habits and behaviors of most species are poorly understood.

Conventional vessel and aerial survey techniques are good for describing the general seasonal abundance and distribution of some species within the limits of their sampling regime. However, at best, most surveys offer only short segments of behavioral observation and a series of static distribution data. Marvelous findings have come from more detailed observations, including the linkage of known individuals between various parts of the species' range and important reproductive parameters like the female calving interval, weaning and some calf mortality data.

CONVENTIONAL RADIO TAGS

Often what is desired is a more complete understanding of how whales live: how and where they find food, sleep, migrate, mate, and calve. Some questions like frequency and duration of dives can be addressed for short periods of time by direct observation.

With adequate vessel and crew for continuous monitoring, conventional short-range radio tags can be very effective for periods of several days or weeks but are limited to the number of animals that can be monitored at one time due to the short range (3-20 miles) of such tags. The cost of ships and aircraft to relocate tagged whales is often the limiting factor in collecting data from whales tagged with conventional radio tags. However, Watkins and his collaborators have successfully tracked several pelagic species by ship for periods of several weeks that have included significant movements over distances of hundreds of miles.

In 1979, Minerals Management Service (MMS) funded the use of a surface-mounted VHF radio tag to track a gray whale approximately 6,680 km from Mexico to Alaska during a 94-day period (Mate *et al.* 1983). This is the longest distance and longest period of time for tracking a cetacean using conventional radio telemetry, and because this species migrates nearshore, cost-effective monitoring from shore could be accomplished. One such VHF tag stayed attached for 27 months.

SATELLITE-MONITORED RADIO TAGS

In contrast to the logistics and labor of conventional telemetry, satellite-monitored radio tags are more expensive to purchase initially but can be monitored for less than $12/day. Satellite-monitored radio tags are becoming smaller and less expensive. Simple tags costing $4,000 each last year will probably cost $2,000 by 1992. The ARGOS system currently provides the only service available for civilian use to locate specialized transmitters by satellite. ARGOS determines suitably accurate locations daily from transmitters anywhere in the world when enough messages are received during satellite passages overhead (up to 16 minutes). The satellite coverage is better near the poles (28 times/day at latitudes > 75°) than the equator (7 times/day). ARGOS can also collect sensor data that can be helpful in evaluating whale behaviors and the whale's environment.

In 1983, Mate (1985) obtained 10 locations from a humpback whale via a Telonics-built ARGOS transmitter over a 6-day track of 700 km. The animal demonstrated a distinct preference for a convergence area between the Gulf and Labrador Currents, where other humpbacks were known to be feeding. Although the equipment was state-of-the-art, it was large and the attachments were inadequate.

By 1985, transmitters in tethered floats were used to track manatees for 100 days (Mate *et al.* 1988) and have since been used for periods up to 10 months on this species.

In 1987, a pilot whale was tracked with an ARGOS transmitter for 7,600 km and 95 days (Mate 1989), providing important insights into the animal's deep diving habits at night and unusual surface resting patterns at sunrise on a 4-7 day cycle. This is currently the longest distance and duration for tracking a cetacean by satellite or any other form of radio tracking.

In 1989, an adult male North Atlantic right whale was tracked via ARGOS for 1,600+ km during 22 days. It visited every known right whale habitat for that season in just 10 days. Another dramatic discovery was the routine deep diving to the bottom by a species that has been described primarily as a "surface skim feeder." In 1990, 9 right whales were tagged and several moved 3,000-4,000 km in just 6 weeks. Previously unknown habitats included deep water 400+ km from shore and use of the warm Gulf Stream. Wide-ranging distributions were documented.

These studies reinforce the notion that new techniques really do provide new perspectives and that even relatively short duration experiments can change fundamental "understandings" for such poorly known species. These dramatic results included (1) confirmation of male mobility throughout the known breeding range, strongly suggesting the population is a single stock (reproductive unit); (2) demonstration of the animal's use of the entire water column to depths of 300 m; (3) amazing mobility between areas of known concentration (even for females with calves); (4) use of distant and deep offshore regions, which use affirms open water navigational skills (as opposed to nearshore limitations); and (5) on preliminary analysis, a considerable variation between individuals in diving habits.

I believe this technique will be increasingly effective in identifying critical habitats, migration paths and whale behavior as the technology continues to produce smaller, more efficient, sensor-capable, and cost-effective transmitters. Attachments appear to be a limiting factor for the size tags currently in use, but there are encouraging developments for smaller tags and more effective attachments. Tags that can be fully implanted (except for the antenna) are not far away and should stay attached longer. The effectiveness of bio-compatible materials is being examined and deserves more attention. It is probably more important to place a high priority on reliable longer-term tracking for basic distribution data than on the incorporation of exotic sensors at this time. However, the use of even simple sensors adds an enormous amount of information to interpret whale behaviors, movements, and navigation/foraging strategies. For certain types of physiological and behavioral information, even short-term satellite-monitored tags with sophisticated sensors may be the most appropriate method to "characterize" diving, acoustic, and foraging habits. In the future, satellite-monitored radio tags should provide us with an understanding of why whales select specific habitats and what aspects of those habitats make them "critical."

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Dr. Bruce R. Mate is an Associate Professor at Oregon State University, Hatfield Marine Science Center, Newport, Oregon. For 22 years he has studied the distribution and behavior of pinnipeds, sea otters, manatees, and cetaceans. After his doctorate (University of Oregon) on sea lion migrations and a post-doctorate in heavy metal metabolism, he specialized in seasonal distribution and feeding ecology studies. He has developed conventional and satellite-monitored radio tags to track whales thousands of miles to determine migratory routes, critical habitats and diving behavior.

ECOLOGICAL STUDIES ON LARGE WHALES USING TELEMETRY

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Department of Zoology
University of Guelph

INTRODUCTION

The use of telemetry in studies of whales has the potential to provide data and facilitate the acquisition of detailed information on the distributions, stock identification, movements, behaviors, habitats, and ecological requirements of these animals. Telemetry is a broad term that covers many different techniques, each of which has its own unique suite of applications and advantages. The application of each specific telemetry method must be appropriately matched with the scope, desired resolution, and proposed goals of the study.

Similarly, each telemetry method must be matched with the appropriate associated information or techniques. There is a mutual dependency and ultimately, a synergy, between the telemetry and the associated data. Knowledge that this mutual dependency exists is critical to the success of environmental impact studies. In the context of environmental impact studies, the question of "why" animals spend time in certain areas, or why they behave in certain ways must be answered. When properly matched with the study goals and when properly applied, telemetry and associated data collection can approach these types of questions.

In this presentation, I will describe some of the telemetry systems that I have designed or worked with, and how I have applied them in studies of large whales.

DESCRIPTION AND USE OF TELEMETRY SYSTEMS

Remora Tag

In 1980 I participated in a study on the problem of large whales becoming entangled in fishing gear in Newfoundland. A method was needed with which to monitor large whales for several days after their release from entanglement. For this, "remora" suction-attached VHF tags were used (Goodyear 1981). Remora tags are minimally invasive, recoverable at sea, reusable, inexpensive, and deployable from a crossbow. They are constructed of a hollow aluminum tube, which serves as the pressure housing and flotation, a VHF telemetry transmitter, lithium battery, a 1/4 wavelength whip antenna, and a roof-rack suction cup.

The application of these tags on whales in Newfoundland allowed me to learn a great deal about diel movement and dive patterns of humpbacks and to develop an understanding of why and when they were most likely to become entangled in fishing gear.

In my M.Sc. research on humpback whale night behavior (Goodyear 1989a), 10 humpbacks were tagged and followed throughout 24-hour periods from a small motorboat. The use of telemetry made it possible to follow and identify individual whales on a consistent-repeatable basis and to record movements, and surface and dive patterns of whales throughout 24-hour periods. It also made it possible to make close approaches to tagged whales and their associates "at will" so associated data could be collected there.

The remora tag is an inexpensive tool that could be useful for tagging free-swimming whales in ecological studies where short-term (several days) monitoring is desired.

Capsule Tag

In 1985 I was asked to participate in a bowhead whale study that required the use of telemetry (Richardson 1987). Because bowheads commonly break through the ice to breathe, it was necessary to use a tag that penetrated completely below the skin surface. In response, I designed the capsule tag (Goodyear 1985). Capsule tags are stainless steel, bullet-shaped cylinders that contain a VHF transmitter, a lithium battery supply, and an 18-mm diameter X 45 cm long, 1/4 wavelength whip antenna (Figure 9.4). A variety of wildlife telemetry VHF transmitters have been used; only Holohil Systems, Ltd., and Telonics transmitters are recommended. Capsule tags are deployed from a crossbow and penetrate to a maximum of about nine cm leaving only the antenna sticking above the skin surface.

Before capsule tags were used in bowhead studies, their first major application was in migration studies of gray whales (Swartz *et al*. 1987). In that study, 20 gray whales were tagged and followed along the California coast in order to identify diel migration rates and surfacing and dive patterns. The main tracking vessel was a 20-m motorsailor equipped

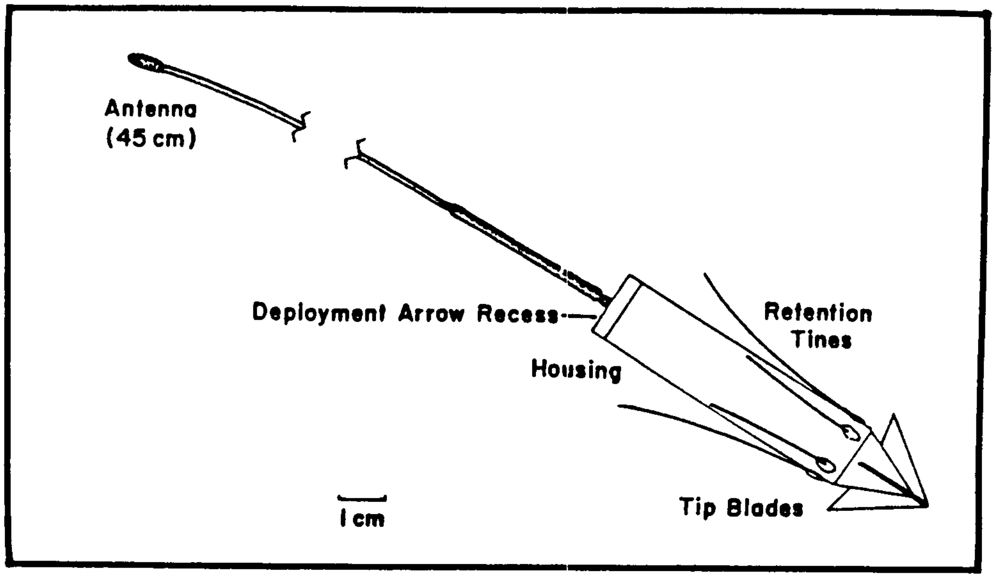

Figure 9.4. Capsule radio tag used on right whales (Goodyear 1985).

with several multi-element Yagi-Uda antennas and two Telonics TR2 receivers. A single engine aircraft equipped with wing mounted antennas conducted some of the radio monitoring. This effort relocated tagged whales as long as 23 days after tagging.

Application of capsule tags in the bowhead studies provided the first successful use of telemetry on that species (Goodyear *et al.* 1987). At the time of the study (1986), the most significant biological information from the telemetry was that a tagged bowhead was relocated 16 days after tagging, after having moved 625 km westward from Canadian to waters off Point Barrow, Alaska. Also significant is that in May of this year, Alaskan Eskimo whalers killed a bowhead whale that contained one of the capsule tags that had been deployed in 1986. Apparently, the tag itself and the surrounding tissue were in good condition. This is the longest known attachment for any telemetry device on whales.

In a four-year study on the diel activity and food requirements of right whales in the Bay of Fundy (Goodyear in prep.) 13 right whales were successfully tagged with capsule tags and monitored for up to 30 days. An 11-m sloop was the principal tagging and tracking platform. The sloop was equipped with tracking gear similar to that used in the graywhale study. From the sloop, whales were easily located from distances to over 20 km. From cliff stations, signals from tagged whales 40 km offshore were received easily. In the one aerial tracking of the study, tagged right whales were located over 60 km away.

Complimentary data that were collected while in close proximity to tagged whales included fine scale distribution and abundance of zooplankton by use of nets, sonar, and remotely operated vehicles (ROV); detailed night observation of tagged whales and their associates using a B.F. Meyers "Dark Invader" model 3000 night vision scope and Sony CCD-V9 video camera; and, observations of whale responses to ships and fishing vessels.

Capsule tags were used successfully in other studies on right whales 100 km off Massachusetts during which similar data were obtained (SCOPEX project, unpublished data).

VHF capsule tags have allowed detailed tracks and surface and dive patterns to be documented for several near and offshore species of large whale. There utility in studies on migration and stock identification of whales would depend on the geographic scale, the species, and location of the study.

Sonic/VHF depth tags

The most basic yet most significant problem in conducting feeding, energetics, or prey studies of whales is the inability to determine when whales are actually feeding. To improve the inference level that whales do feed below the surface, knowledge of their depths of dives and underwater movements contributes significantly to this question. To help solve this problem, I developed another tag (Goodyear 1989b), one which incorporates a sonic and a VHF transmitter and is deployed by a crossbow. The VHF transmitter allows for the long distance monitoring and relocation capability. The sonic transmitter, manufactured by VEMCO, Ltd. (model V3P-HP), produces a pressure-induced pulse rate-modulated 50 kHz signal that allows real-time depth recordings to be made as frequently as once per second. The sonic signal also allows determination of the whale's position relative to the vessel and its general heading and speed underwater. A directional hydrophone is mounted on a pole with a compass rose and aimed at the whale to maintain maximum signal strength.

For use on right whales in my study in the Bay of Fundy, I wanted the tags to release after two to three days so they could be recovered and reused.

To do this, I attached each tag to its anchor with a magnesium link. These links corrode apart after two to three days and release the tag. If a tag is connected directly to its anchor it would probably stay attached to a whale for several weeks. The tags were also designed to float with the VHF antennas pointing up. Once a tag was released from a whale, it was tracked by radio or the sonic receiver and then recovered.

Seven right whales were tagged with sonic/VHF tags. This made possible the detailed recordings of dive profiles (Figure 9.5) and underwater traveling speed and direction of those whales. During close approaches to tagged whales (facilitated by the

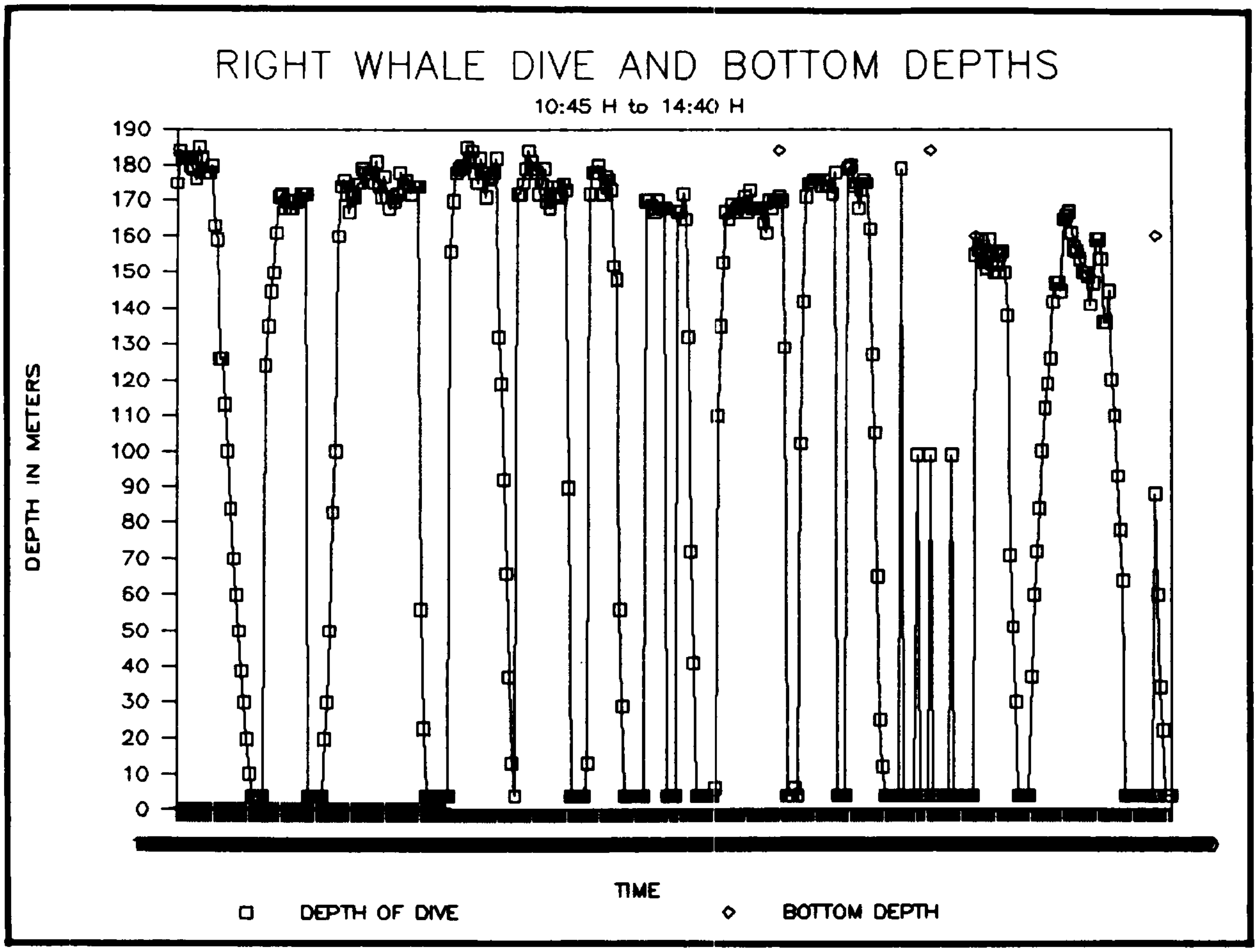

Figure 9.5. Sample depth of dive record of tagged right whale in the Bay of Fundy. (Note the bottom depth marks; whale consistently dove to near the bottom.)

telemetry) fine scale net sampling was conducted in attempts to identify densities of their potential prey.

The sonic/VHF tags worked well in right whale studies. It is likely that they would be appropriate for ecological studies of other mysticetes. However, because the sonic signal that they produce is within the hearing range of most odontocetes, they might not be appropriate for use on those cetaceans.

Availability of an alternative system for telemetering depth of dive that avoids the problem of sonic frequencies overlapping with odontocete hearing ranges would be important. A VHF depth telemetering tag would be ideal, because depth of dive, surfacing and dive patterns, and location of tagged whales could be obtained simultaneously and remotely over substantial distances. The VHF system would best be set up to record depth values from one or a series of dive sequences, then transmit that block of data at a subsequent surfacing.

Satellite Tags

As my research in the Bay of Fundy progressed, it became important to know where right whales migrated to in the winter. For many years Dr. Bruce Mate has worked on the development of satellite systems for marine mammals and has tested them on several species. In 1989, he had some success in applying satellite tags to right whales in the Bay of Fundy (Mate and Nieukirk 1989). In 1990, I decided to contribute and apply satellite tags of my own design with the hope that between our efforts, the mystery of where right whales go in the winter and what they do there, would be dispelled. If tags stayed on whales, my hope was to fly to the locations provided by the satellite so direct observations of their activities could be made.

The tag is about 16 cm (6.5 in. long), 4.6 cm (1.8 in.) high, and weighs about 400 gm (14 oz) (Figure 9.6). The attachment allows the tag to pivot so that direct hits by other whales should flip the tag to the side rather than knock it off. Each tag contains a Telonic's ST6 transmitter that was designed for and registered with the Service ARGOS satellite system. The transmitter is programmed to record, then transmit a series of dive parameters and seawater temperature. The tags are set up to transmit for up to eight months. A VHF transmitter is attached to the tag so tracking of a whale can be done from a vessel at sea. Sea-based tracking will allow close observation of the tag so changes in its attachment over time can be noted and to allow associated data to be collected.

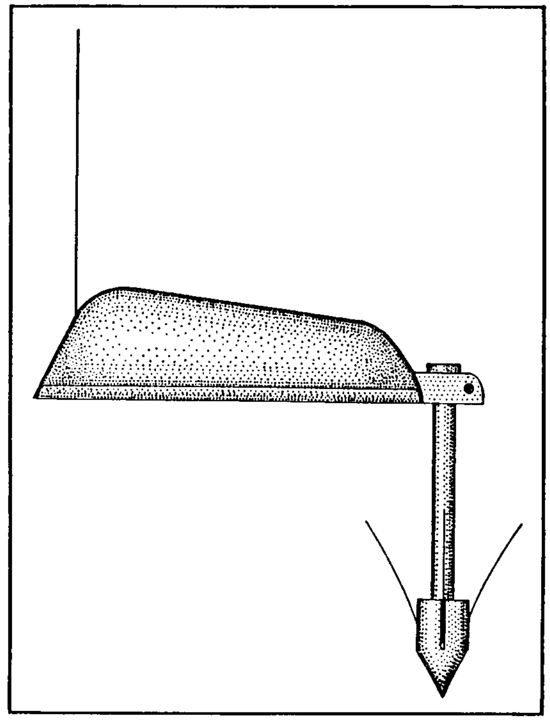

Figure 9.6. Approximate schematic of the new satellite tag for whales (Goodyear, unpublished data).

Satellite data recovery tests from land and sea-based tags were very successful. Field tests of the attachment and housing design were planned by use of dummy "satellite" tags which contained VHF and sonic transmitters. Due to poor weather conditions and a paucity of right whales these tests were passed up. The first trial of this new system was with a functioning satellite tag. The tagging of an adult female right whale went very smoothly. After tagging, monitoring of the tag's VHF transmitter produced strong signals which indicated that the tag was still attached. However, no locations were produced by satellite link.

During the tagging, the whale had been in a very active social group. I assume that the tag was smashed off during continued social activities. Because of the frequent and intensive social activity exhibited by right whales, long-term satellite tracking of this species will require a measure of luck. Reduction in the size of satellite transmitters and their power requirements so tags can be made small enough to fully implant, would solve this problem. Through persistence, however, some tags will make it through the biological battlefield in their present configuration. Application of these tags on other species should be less problematic. With slight modifications to the pressure housing, these tags should be appropriate for use on deep diving odontocetes, such as sperm whales. Next spring, I plan to resume tests and tag several whales with dummy tags. If modifications to the anchor attachment seem necessary, the remaining satellite tags will be modified before they are deployed.

SUMMARY

When properly matched with the study goals, telemetry and associated data can have a synergistic effect in contributing answers to ecological questions and those related to environmental impact. Telemetry is a broad term that encompasses several specific techniques for obtaining data remotely or for providing the opportunity to make observations from close distances. This presentation describes some of my experiences with specific telemetry techniques and their use in several studies on several species of large whale. VHF radio, sonic, and satellite systems were used singly and in combination with non-telemetry techniques to fit specific study designs and goals. Appropriateness of these techniques, how they might be applied in other environmental studies, or how they might be improved, is discussed.

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Mr. Jeffrey D. Goodyear has conducted studies on seven species of large whale with emphasis on diel behavior patterns, migration, and feeding ecology. He has developed several telemetry systems for whales including depth of dive and satellite tags. Mr. Goodyear is finishing his Ph.D. under David Gaskin at the University of Guelph. He received his M.Sc. in marine biology from Moss Landing Marine Laboratories under Bernd Würsig, and B.Sc. in wildlife biology from the University of Massachusetts.

PASSIVE AND ACTIVE ACOUSTIC DETECTION OF BIOLOGICAL TARGETS

Dr. Coleman Levenson
Naval Oceanographic and
Atmospheric Research Laboratory

Techniques for acoustically detecting and counting biological targets are many and diverse. These include use of passive, active and hybrid arrays and individual hydrophones in various configurations. Marine organisms of interest such as whales and turtles are endangered species and are usually migratory, responding to seasonal and physiological conditions. In addition, these organisms spend as much as 95% of their time beneath the surface. Utilization of passive and active acoustic detection is therefore an important method in determining temporal and spatial distribution of these biological targets and is considered with emphasis on marine mammals. Knowledge of the effect of environment and physical parameters affecting sound propagation and thereby detection is necessary and is briefly reviewed. Analysis techniques are discussed along with a general overview of past, present and possible future directions of research to minimize effects of offshore activities to endangered species.

Dr. Coleman Levenson is a senior research scientist with the environmental acoustics group at the Naval Oceanographic and Atmospheric Research Laboratory. He conducts research on acoustic characteristics, distribution and population dynamics of marine organisms that produce and reflect sound. These include long-term studies of both mysticete and odontocete cetaceans conducted from research ships, aircraft and oceanographic towers.

PROGRESS IN THE USE OF ACOUSTIC TAGS IN THE TRACKING OF MARINE FISH

Mr. William T. Whelan
Ocean Communication Systems

In response to a U.S. Fish and Wildlife Service request, efforts were made to investigate the possible reason(s) for continuing unsatisfactory results in their attempts to track the Gulf Sturgeon (*Acipenser oxyrhynchus desotoi*) in the marine environment of Apalachicola Bay, Florida, and the adjacent Gulf of Mexico. Several acoustic tag systems had been used in the estuarine and bay environments with unacceptably small acquisition ranges and little or no effective track lengths. This poor performance frustrated attempts to locate the position of the tagged fish by triangulation.

Theoretical and experimental investigatory field tests were undertaken at Panama City, Florida. The latter were made in the biogenically noisy environment of St. Andrews Bay. These studies identified several significant system design flaws and hardware deficiencies that accounted for the observed poor performance. An improved tag design was implemented that used more effective, lower duty cycle means for encoding of individual tags. This increased code efficiency reduced the battery load. When combined with a simpler, higher efficiency transmitter/transducer combination, the acoustic output from the tag was increased about four-fold for the same battery energy demand. Such an improvement was trivial, in view of the system performance deficit. At least an additional two or three orders of magnitude of system power gain were required for adequate fish tracking performance. This had been deduced from the use of a basic propagation model on a proposed design requirement to establish the minimum acquisition ranges of 1 to 2 miles.

The most significant change made in the attempt to achieve not less than 25 dB (over 300-fold) system improvement was the introduction of a new acoustic receiver designed for operation in the measured environment found in the noisy waters of the local bay. Unfortunately, the most significant possible system improvement could not be implemented. As a result, the work reported here is seriously incomplete and the most significant part of the improvement program is yet to be accomplished.

The results of the short-term improvement program were gratifying, however. The reliable working radius of acquisition for tagged sturgeon was increased to somewhat over two nautical miles. This represented a 60-fold improvement in working range over the average results obtained previously. It also resulted in acquisition of the first meaningful tracks, which displayed fish behavior. These were gratifying following several years of minimum results.

Perhaps, most significantly, the model used to predict performance of the system closely described the actual field data that were obtained and that were correctly predicted the improvements that were realized. Because of this, the propagation model is considered to be quite trustworthy.

Projections based on the system model are especially encouraging. These predict that, when the correct acoustic frequency band is used instead of that currently used, the tag acquisition range should extend to 10 or 20 miles. The tagged fish acquisition area increases as the square of the reception range. Thus, an increase in acquisition range, if it can be purchased without an increase in tag power (which will, also, normally increase as the square of the reception range, unless something drastic is invoked), is probably the most significant of system performance parameters.

Extension of the acquisition range to 2 miles, as reported here, provided a bay and estuary survey area of approximately 20,000 acres. Other than the replacement of the system receiver and a tag efficiency improvement, the cost of the necessary changes to provide the 2-mile range capability was minimal.

The model study results, which predict the 10 to 20 mile radius of acquisition, reflect a significant projection of the system's capability and applicability for marine fish finding and tracking. By increasing the survey area to approximately 270,000 acres for a 10-mile radius and 1,000,000 acres for a 20-mile radius, the applicability of the system to open Gulf searches becomes a reasonable proposition. The required re-engineering of the system in order to accomplish this greater operating range is, not surprisingly, a more significant task than that which has been accomplished thus far.

The predicted availability of the 10- to 20-mile acquisition range is based entirely upon making significant reductions in the "dB per kilometer" absorption coefficient by changes in the operating frequency. This is the "drastic change" referenced above. Such reduction permits a reappointment of the system's available gain between the geometric diffusion loss and the reduced absorption losses. This reduction produces the substantial increase in the range of acquisition.

Operation at greater ranges in the unsheltered Gulf environment and in the deeper and thermally more complex water column will bring more complex propagation. There will also be more noise with which to contend because of the increased wind noise from stronger surface winds and the resulting larger waves that result. The inevitable vagaries of underwater acoustic propagation in the more complex thermal structure will cause greater variability in the results achieved. Despite this inevitable price that Gulf operations will exact, the improved performance threshold would be a significant step forward in this difficult area of fish study.

Mr. William T. Whelan is the owner and founder of Ocean Communication Systems of Panama City, Florida. The company manufactures data systems for free dragging ocean buoys. He has been instrumental in developing telemetry equipment for the marking of Gulf Sturgeon in the Florida Panhandle. Mr. Whelan has directed civilian and military electronic programs since 1942.

ACOUSTIC TRACKING TECHNOLOGY

Mr. Don Brumbaugh
Sonotronics, Inc.

When unobstructed, sound radiates spherically in water, its strength diminishing by 50% or 6 dB each time the range doubles. Range is also affected by the frequency of the signal, background noise, dissolved salts, temperature, and pressure. Absorption loss is directly related to frequency and inversely related to water temperature. Under normal ocean conditions, at 75 kHz this loss is about 20 dB or 90% per kilometer. At 30 kHz, this loss is about 10 dB per km. Operating at lower frequencies, while desirable in the ocean, means large transducers for efficient operation. The maximum efficiency of a radiator occurs at mechanical resonance. This, of course, means larger diameter tags. Operating small rings at frequencies below resonance is done but at a sacrifice in efficiency. The net result is shorter lifetime or reduced range for a given package size.

Background noise is produced by increasing sea state, aquatic noise makers like snapping shrimp, and hydrophone motion. In thermally stratified water, warmer surface waters refract the acoustic signal toward the bottom. A tag below the thermocline can generally be received only directly overhead. The resultant reduction in effective range is predictable, but requires exact knowledge of the thermal profile and the depth of the tag.

The effective range of a tag can be predicted if tag frequency and power are known. Our 18-mm diameter x 100-mm tag has been consistently detected at 4 km in the Bering Straits through 8 m of ice cover, range measured by Loran. In the well-mixed Gulf of Mexico near-coastal waters the same tag has only 1,000-m range. We feel this is due to suspended particulate matter or micro air bubbles. This tag operates at 75 kHz and, for certain, would have better range under all conditions if it operated at a lower frequency at the same power.

Animal size determines tag size, which in turn, determines range and tag life. If one were only tracking very large animals, you could operate with very large tags and not be particular about size and weight. But if you are attempting to track a 20-in. red snapper then you are very aware of the trade offs. Ultra small tags have a life of about 20 days and range to 500 m in sea water. Tags 18 mm diameter x 100 mm have a 3-km range and 2-year life; however, shortening this tag to 75 mm reduces the life to about 300 days with the same range performance. Acoustic tags can also be designed to provide depth, individual coding and hyperbolic location capabilities. Real-time depth tags are small, very accurate and inexpensive. Coded tags can individually identify large numbers of fish on the same frequency. The use of the same frequency speeds data retrieval. Hyperbolic systems are expensive, require omni-directional hydrophones, and have reduced sensitivity. The loss of 25 dB at 75 kHz (94.4%) cannot be improved by amplification without reducing the (Signal+Noise)/Noise ratio. The use of micro-processors has resulted in automatic scanning and data processing. These systems are able to detect tag frequency and pulse interval, eliminate false targets, and make calculations from received data.

The most important part of an acoustic system is the hydrophone. You have to make sure that it is located in the water column far enough down so that it is not exposed at low water or beat upon by waves. The other limit in shallow water systems is to make sure it is not looking at a hill or other obstruction on the bottom. Of course you also want to know that it is pointing in the right direction. Hydrophone cable length is also an important consideration. It must be long enough to lower the hydrophone to be inserted into the water deep enough to avoid obstructions such as the keel of a boat, but not so long so as to be spread across the deck where it can be damaged. Coiling up the coax cable in a diameter less than the forearm will kink it and shorten its life.

In systems of good design, the most frequent failures occur in hydrophone cables (up to 80%). Deployment from fixed platforms, docks, and shore is preferable to boats, facilitates retrieval for inspection and maintenance, and provides greater protection from crushing, abrasion and vandalism. Cable length must be adequate for lowering to sufficient depth to avoid obstacles such as passing ships and should be secured and stowed properly. Improper coiling, kinking or small cuts can result in cable failure. Acoustic gear used for tracking (inexpensive pingers) may also be used for the relocation of remotely deployed systems, or lost or displaced oceanographic equipment.

Mr. Don Brumbaugh is the owner of Sonotronics, a business that specializes in acoustic tracking systems. Previous to that, he was analog design engineering manager at Burr Brown Research Corporation, engineering director for Sensory Systems Laboratory specializing in animal tracking systems, and a Research Project Director at the Lunar & Planetary Laboratory of the University of Arizona. He was educated at RCA Institutes, Pennsylvania State University, and the University of Arizona.

ADVANCES IN SATELLITE AND RADIO LOCATION TECHNOLOGY

Mr. Stanley M. Tomkiewicz, Jr.
Telonics, Inc.

This paper provides a technical overview of the fields of conventional radio biotelemetry and wildlife satellite tracking. Telemetry is defined as the transfer of information from one point to another through the use of various carrier frequencies. This is a simplified definition that certainly does not, in itself, define the complexity of the "art of radio telemetry." The unifying principle in radio telemetry is the "system" concept. The telemetry system is composed of two basic subsystems; first, the transmitting subsystem incorporating the electronics, antenna, power supply, packaging, and the attachment devices. Second, the receiving subsystem includes receiving antenna, receivers, data processing, storage units, and associated power supplies.

System performance is affected by many factors. Range, in particular, is a system level characteristic that can only be determined by considering the specifics of both the transmitting and the receiving subsystems. Moreover, environmental conditions, physiography, and the behavioral and physical parameters of the animal are underlying factors that heavily impact system performance.

TRANSMITTING SUBSYSTEMS

Conventional transmitting subsystems are capable of measuring a number of parameters and transmitting data including temperature, heart rate, activity level, mortality status, and various other parameters.

Selection of the appropriate power supplies for specific applications is critical. Lithium electrochemical systems alone offer over a dozen distinct varieties from which to choose. In addition, mercury- and silver oxide-based electrochemical systems are still used in specific applications. This selection becomes even more complex when secondary power systems such as nickel cadmium or nickel/metal hydride batteries are utilized as intermediate energy storage devices allowing operation of a transmitter from solar cells.

Consideration must also be given to each attachment method as it can directly affect the biology of the animal, as well as the overall system performance. Therefore, careful research and consideration are given to minimizing the biological and physiological impact on the animal, while maximizing system performance. Depending upon these factors, animals are instrumented using any one of a variety of methods of attachment, from the classic collar to a harness, ear tag, leg-mount, implants within the body cavity, to gluing the unit to the fur.

RECEIVING SUBSYSTEM

Protocol receivers reached a theoretical level RF performance several years ago. Therefore, they have not undergone significant redesign, with the exception of modifications to increase production efficiencies and reduce costs. However, the 1990's promise advances to the receiving subsystem by introducing inexpensive microprocessors, contributing significantly to the development of sophisticated automated data acquisition systems. As a cautionary note, however, if this new technology is incorrectly applied, it can adversely affect range performance.

SATELLITE TELEMETRY

Satellite telemetry was the experimental program of the 1980's and, as this technology moves into the 1990's, it promises many new advances. Satellite telemetry technology will advance from being an experimental system to becoming an operational system, foreseeably experiencing an even greater growth in the wildlife field. Size reduction of the overall units and increases in system reliability are bringing this technology into its own. Micropowered microprocessors have cleared the way for an entirely new development in the field of on-board transmitter data collection and more efficient utilization of the location capabilities of the ARGOS system. Sophisticated software now dominates the role of data collection and prolongs operational life.

Mr. Stanley M. Tomkiewicz, Jr. is Director of Wildlife Programs for Telonics, Inc. of Mesa, Arizona. He received his B.S. in biology from Penn State University, and an M.S. in zoology from Arizona State University. He began his work with Telonics in 1976. His early professional work was directed towards the development of implantable telemetry systems for monitoring physiological parameters in unrestrained wildlife.

Mr. Tomkiewicz has since been involved in development of radio telemetry technology for deer, caribou, polar bear, and grey and humpback whales; as well as investigations of techniques for electronic immobilization of wildlife. Current work involves satellite telemetry applications to a wide array of terrestrial and marine mammals, as well as transmitters designed for avian species.

CAPABILITIES OF THE ARGOS SYSTEM

Mr. Christopher Estes
Service ARGOS

The ARGOS system is a satellite-based, data collection and location system primarily reserved for environmental applications. It is the embodiment of a Memorandum of Understanding between the National Oceanic and Atmospheric Administration (NOAA), the French space agency CNES, and the National Aeronautical and Space Administration (NASA). Data collection occurs on the NOAA TIROS spacecraft. All TIROS class spacecraft, NOAA-A through NOAA-M, have, or will carry ARGOS payloads. Service has been continuous since 1978 and is expected to extend beyond the year

2000. The spacecraft launches are timed for least two in simultaneous orbit.

Service ARGOS maintains a list of manufacturers that produce compatible transmitters. Although a variety of sizes, applications, and capabilities are acceptable to the system, all must have a stable transmission of 401.650 mHz (oscillator drift < 4Hz/min). Manufacturers may couple transmitters with any combination of sensors that can send data within a 256-bit message.

The space segment of the ARGOS system is composed of two parts: the Data Collection and Location System (DCLS) and the NOAA spacecraft that carries the DCLS. The spacecraft are in low altitude (833 km or 870 km), circular (eccentricity < 0.05), polar orbits. The orbital period of the spacecraft is approximately 101 minutes (14.1 orbits/day). Orbits in a constant alignment with the sun allow ARGOS to calculate the time of an overflight.

The ARGOS DCLS contains four radio receivers that measure the message's frequency reception time and provide data storage of the reformatted data onboard the satellite. The satellite transmits the data to ground stations in Lannion, France; Wallops Island, Virginia; and Fairbanks, Alaska.

From Wallops Island and Fairbanks, the data are transmitted via geostationary satellite to the NOAA processing center in Suitland, Maryland. The data are sent through the Satellite Operations Control Center (SOCC), which is responsible for the maintenance, programming, and monitoring of the spacecraft. As it passes, an ARGOS computer decodes the data and transmits them to processing centers in Landover, Maryland, and Toulouse, France. When SOCC is finished with the data, they are sent to National Environmental Satellite Data Information Services (NESDIS) for further processing. The NESDIS isolates the ARGOS data and transmits them to the ARGOS processing centers. With this configuration, ARGOS receives each data set twice, once from SOCC and once from NESDIS. This redundancy ensures that the ARGOS system provides complete coverage, in the event that data sets are lost or damaged at either of the NOAA processing centers.

Data from the Lannion ground station are transmitted directly to the French Global Processing Center, and from there to the U.S. Global Processing Center through a 56-kb digital link.

When the data arrive in the ARGOS processing center, they contain the frequency measurement, the time stamp, and the sensor data (if any). The data are analyzed for the transmitter frequencies during the overflight to determine location. During this phase, sensor data are converted to engineering values based on "calibration curves" that are supplied by the users. The two types of processing are done separately because the calculation of location is less predictable than the reception of sensor data. In this case, the sensor data are paired with the previous location of the transmitter. The processing centers also receives messages from transmitters specially equipped for alarm situations, monitor DCLS functions, calculate orbit corrections, and receive weather information for the World Meteorological Organization's Global Telecommunication System (GTS).

The ARGOS users can retrieve data by on-line access, databanks, direct data distribution, or through the GTS. In the summer of 1991, the distribution capabilities will be further enhanced. On-Line access to the data is the most popular method of accessing ARGOS data. Users connect to the ARGOS processing center via TYMNET and interrogate the ARGOS system directly. This method is best for users who have time-critical applications, as the data are available as soon as the processing is complete (typically less than three hours after transmission). The Databank is another popular method of receiving ARGOS data. For applications where time is not a critical element, the Databank is usually sufficient. Databank consists of either a monthly or fortnightly collection of a user's data. The data can be delivered on a variety of media: diskettes (5¼ or 3½), nine-track tape, or hardcopy. This method of distribution allows ARGOS to deliver data directly to the user's computer. If the user's host computer is on SPAN or the Internet, ARGOS can send data on a daily basis as either a file transfer or a mail message. If a user's computer is not on SPAN or the Internet, the ARGOS system can be instructed to deposit information on a remote computer via modem and dialup line. Users who wish to retrieve their data from the GTS may request this processing from ARGOS. For this to work, the transmitter must send messages in one of the WMO code formats. The data are transmitted directly to the GTS as soon as the location and sensor processing are complete.

The process of determining the location of an ARGOS transmitter relies on the doppler effect. The doppler effect is a well known phenomenon that explains frequency shifts as a result of the relative positions and velocities of the creator and receiver of a signal. The simplified formula for computing received frequency is

$$F_r = F_t \left(1 + \frac{|V_r|}{c} \cos A \right)$$

where

- F_r: frequency received
- F_t: transmitter frequency (in the case of ARGOS, 401.650 mHz)
- V_r: relative velocity of satellite to transmitter
  $V_r = V_s - V_t$
- A: angle formed by the speed vector of the satellite and transmitter direction
- c: the speed of light

Since the received frequency (F_r) is measured by the spacecraft, the only unknown element in the equation is A. This angle creates a cone that has the following attributes:

- The apex is the satellite.
- The axis is along a line tangent to the spacecraft's orbit.
- The surface is inclined away from the axis at the angle A.

The altitude of the transmitter must be specified when the platform is introduced to the ARGOS system. If a sphere having a radius of the transmitter altitude is imagined, the cone described above will intersect the sphere in an arc. For each message that the transmitter sends, a new arc can be constructed. The arcs will intersect at two points, one of which is the actual location of the transmitter. To determine the correct location, the system evaluates the measured Doppler effect versus the theoretical Doppler effect at both points (using the least squares method) as well as the last known frequency and last location of the platform.

The ARGOS locates transmitters in three classes of accuracy. The following table describes the distance within which 68% of positions are accurate for the three accuracy classes:

Class	Accuracy
1	1000 m
2	350 m
3	150 m

Criteria for Class 1 location may not be met for animal tracking because the animal's size limits the size and subsequent signal strength. Animals also inhabit areas that are not conducive to a strong signal transmissions (underwater, in narrow valleys, in caves, etc.). For these reasons, ARGOS offers Class 0 location quality. Class 0 locations have no accuracy associated with them; the interpretation of these locations is left solely to the user. To aid in the interpretation of these locations, additional information regarding the performance of the transmitter and other parameters are supplied along with Class 0 location.

To obtain the listed accuracies for the classes of services a number of criteria must be met. The criteria limiting or affecting the three normal classes of ARGOS service include the numbers of messages received per pass, the length of time between first and last signal, angle of line between the transmitter, the satellite, and its path, and the drift of the oscillator from ideal frequency and transmitter velocity. Calculated locations are rejected if the conditions are violated. For example, in Class 3 service, 5 signals are not received in a minimum time of 420 seconds during a pass, or the angle falls outside the range of 5 to 18°.

The number of locations per day usually increases with latitude because the polar orbit provides better coverage at the poles than it does at the equator. The number of times both spacecraft will pass over a transmitter per day varies from 6 to 28 times.

When evaluating the accuracy of Class 0 locations users should consider transmitter altitude, transmitter movement and solar flare activity.

Mr. Christopher Estes has served as the Manager of Production & Operations at Service ARGOS for the past seven months. Prior to this, he worked as a consultant, designing and implementing computer systems for clients in a variety of businesses. Mr. Estes received his B.S. in Technology of Management in Computer Systems Applications from The American University, in Washington, D.C.

NATURALLY OCCURRING RADIOACTIVE MATERIALS

Session:	NATURALLY OCCURRING RADIOACTIVE MATERIALS
Co-Chairs:	Mr. Lars Herbst Mr. Gary Rutherford
Date:	November 14, 1990

Presentation	Author/Affiliation
Naturally Occurring Radioactive Materials: Session Introduction	Mr. Lars Herbst and Mr. Gary Rutherford Minerals Management Service Gulf of Mexico OCS Region
Industry Perspective on Naturally Occurring Radioactive Materials	Mr. W. A. (Buck) Steingraber Mobil Exploration & Producing U.S. Inc.
Regulation of Naturally Occurring Radioactive Materials in Louisiana	Dr. L. Hall Bohlinger Louisiana Department of Environmental Quality
The Status of the State of Texas' Regulatory Effort Concerning Naturally Occurring Radioactive Materials	Mr. Ralph S. Heyer Texas Department of Health Bureau of Radiation Control
The Applicability of Envirocare's Disposal Site in Utah for Naturally Occurring Radioactive Materials	Mr. Kurt M. Higgins Envirocare of Utah, Inc.
Cleaning of Naturally Occurring Radioactive Materials and North Sea Procedures	Mr. Rupert Macnamee Hydrocut/Macnamee Services

NATURALLY OCCURRING RADIOACTIVE MATERIALS: SESSION INTRODUCTION

Mr. Lars Herbst
and
Mr. Gary Rutherford
Minerals Management Service
Gulf of Mexico OCS Region

This session on Naturally Occurring Radioactive Materials (NORM) was organized in an effort to provide an overall update on the issue of NORM. The speakers invited for this session were selected to provide oil and gas industry, regulatory, and service industry perspectives on NORM.

Although there has been much discussion on the issue of NORM over the past few years, several issues such as permitting of NORM decontamination and disposal remain mostly unresolved. However, we hope that the continued discussions and transfer of information between industry and the various regulatory permitting agencies will lead to resolving these issues.

Mr. Lars Herbst and Mr. Gary Rutherford, chairs for this session, once again thank those who presented papers as well as those who participated through attendance.

Mr. Lars Herbst is currently the Drilling Engineer in the New Orleans District Office for Minerals Management Service. He has been involved with the issue of NORM for the past three years as a Staff Engineer in the Technical Assessment and Operations Support Section in the Minerals Management Service, Gulf of Mexico OCS Region. Prior to his employment with Minerals Management Service, he was employed by Schlumberger as a Field Engineer in production testing. He received his B.S. in petroleum engineering from Louisiana State University and is registered in Louisiana as a Professional Engineer in petroleum engineering.

Mr. Gary Rutherford is a geologist in the Minerals Management Service, Gulf of Mexico OCS Region, Leasing and Environment Section. He has been involved with the issue of NORM for the past year. Prior to his employment with Minerals Management Service, he worked seven years in the oil industry, five years of which he was a petroleum geologist with Gulf Oil Exploration and Production Company. He received his B.A. in geology from the University of Tennessee and his M.S. in geology from the University of New Orleans. He is an active member of the American Association of Petroleum Geologists.

INDUSTRY PERSPECTIVE ON NATURALLY OCCURRING RADIOACTIVE MATERIALS

Mr. W. A. (Buck) Steingraber
Mobil Exploration & Producing U.S. Inc.

INTRODUCTION

The presence of naturally occurring radioactive materials (NORM) in oil and gas operations has been recognized since the 1930's, but the phenomenon received only minimal attention in this country until the mid 1980's. At that time regulatory agencies in several of the Gulf Coast States began to focus attention on NORM in the exploration and production segment of the oil and gas industry. Concern was expressed by regulatory agencies that presence of NORM in the workplace could have worker health and safety implications. In addition, the release for unrestricted use of NORM contaminated oil and gas equipment was being questioned from a public health and safety standpoint.

In response to this emerging issue the American Petroleum Institute (API) in 1986 formed an Ad Hoc Committee on NORM. The charge of this ad hoc committee was to investigate the NORM phenomenon in the oil and gas industry and to determine what practices, if any, needed to be implemented to address the potential environmental, health or safety concerns. The ad hoc committee has worked closely with the Conference of Radiation Control Program Directors (CRCPD) in reviewing and commenting on the draft Part "N" Suggested State Regulations For The Control of Naturally Occurring Radioactive Materials. The API Ad Hoc NORM Committee actively supported the efforts of State oil and gas organizations in their negotiations with individual States who were drafting or preparing to draft NORM regulations.

CURRENT INDUSTRY ACTIVITY

The API Ad Hoc Committee on NORM was replaced by the NORM Issue Group in 1989. The issue group is subdivided into four working groups as follows:

1. The State Coordination Task Force;
2. The CRCPD Task Force;
3. The Federal Coordination Task Force; and
4. The Guidance Document Task Force.

These task forces are manned by part-time volunteer technical and legal personnel from API member companies and are supported by full-time API staff. Some of the major task force activities are

- Interface with Regulatory Community;
- Coordination with Other Oil and Gas Organizations;
- Data Collection and Analysis; and
- Guidance Document Development.

Interfacing with the regulatory community involves maintaining liaison with various State radiation control agencies, State oil and gas agencies and Federal regulatory agencies such as the Environmental Protection Agency, Nuclear Regulatory Commission, Department of Transportation, Minerals Management Service, and Bureau of Land Management. In addition, certain regulatory agency task forces or committees such as the CRCPD are active in developing policies and guidance on various NORM issues. The API NORM Issue Group is following the activities of such agencies/organizations on a continuous basis and providing input by reviewing and commenting on proposed policies, guidance and regulations.

The oil and gas industry in this country is very large, both in terms of geographic distribution and numbers of organizations, companies and individuals associated with the industry. The API NORM Issue Group routinely works with and supports the efforts of numerous State oil and gas organizations, including those consisting primarily of major companies as well as independent producers and royalty owner associations. Working with these State oil and gas organizations provides API task force members the opportunity to learn what issues are significant at the local level and how they relate to the nationwide perspective on NORM.

Data collection and analysis are fundamental to API's efforts to understand the NORM phenomenon in the oil and gas industry and to aid in developing sound policies and procedures to address potential environmental, health or safety concerns. The API has published the results of four studies on NORM in the exploration and production segment of the oil and gas industry. The titles of these reports are:

- A National Survey on NORM in Petroleum Producing and Gas Processing Facilities;
- Radionuclides in Produced Water;
- Methods for Measuring NORM in Petroleum Production Equipment; and
- Management and Disposal Alternatives for NORM Wastes in Oil and Gas Plant Equipment.

The management and disposal alternatives report cited above is a significant study and forms the basis for API's guidance on safe disposal practices for oil and gas NORM. The study considered the 4 major types of oil and gas NORM, 12 different disposal methods, and 7 exposure pathways. Radionuclide pathways analysis modeling was performed to determine the Radium 226 or Lead 210 activity level that could be safely disposed of by each of the individual disposal alternatives. The activity levels reported in this study are the result of examining environmental, health and safety concerns in light of existing regulatory standards/limits for radiation exposure and available disposal options.

The API Guidance Document Task force is preparing a NORM guidance document that will cover the following topics:

- Occurrence of NORM
- Prevention of NORM Deposition
- Sampling and Measurement Equipment and Procedures
- Worker Protection Guidelines
- NORM Removal Guidelines
- Surface Storage Guidelines
- Transportation Guidelines
- Equipment/Property Transfer Guidelines
- Disposal Guidelines
- Site Closure

The document is now in its second draft and is scheduled to be finalized for distribution at the end of first quarter 1991.

Additional studies planned for 1991 and 1992 include a NORM Risk Assessment Study, Economic Impact Analysis of CRCPD Model State NORM Regulations, and NORM Activity Levels in the Oil and Gas Industry. Other planned activities include development of training programs for general education on NORM and training to aid in implementing the NORM Guidance Document.

SUMMARY

API and industry data collection and analysis efforts to date reveal the following facts:

- The NORM in oil and gas operations is not predictable with respect to occurrence, quantity or quality, and is found both onshore and offshore;
- Radionuclides of significance are Radium 226 in production equipment as scales, sediment and sludges and Lead 210 in gas plant equipment as a thin film or coating;
- Greater than 99% of the 36,890 external gamma survey measurements taken in 20 states and 3 offshore areas were less than 2 micro Rem per hour (mR/hr) (OSHA limit), and 95% were less than 0.1 mR/hr, therefore minimizing concern over worker health and safety due to ionizing radiation doses;
- Ingestion and inhalation of sufficient quantities of NORM to cause health concerns can be prevented by application of standard industrial hygiene practices at the workplace;
- Concern over radon gas inhalation and internal dose to lungs from daughter products is minimized by following standard closed space entry precautions prevalent in the oil and gas industry due to the presence of hydrogen sulfide, carbon monoxide and oxygen depleted atmospheres often found in tanks and other closed vessels; and
- The NORM wastes can be handled and disposed of on-site at oil and gas operations in a number of ways with no adverse environmental effects or health or safety effects to the workers or the general public.

Mr. W. A. (Buck) Steingraber has worked for Mobil the last 10 years and is currently waste advisor for Mobil Exploration & Producing U.S. Inc. in Dallas, Texas. His primary job responsibility is to implement a uniform waste management program for Mobil's 16 E&P Asset Teams in the United States. He is currently chairman of the API's NORM Issue Group. Mr. Buck received his Bachelors and Masters degrees in geology from the University of South Florida and has completed course work for a Ph.D. in geology from the University of Texas at Austin.

REGULATION OF NATURALLY OCCURRING RADIOACTIVE MATERIALS IN LOUISIANA

Dr. L. Hall Bohlinger
Louisiana Department of
Environmental Quality

The investigation and regulatory control of the impacts of naturally occurring radioactive material (NORM) have largely been overlooked by Federal and State agencies in the past, while stringent controls were placed on X-ray and other man-made sources of radiation. The lack of regulatory controls for NORM has been due, in part, to the fact that the Federal government has limited jurisdiction over NORM, and control was previously left up to the States, which typically did not have adequate programs or staff to deal with the additional problem.

While considerable work has been done by the conference of Radiation Control Program Directors (CRCPD), the U.S. Environmental Protection Agency (EPA), and individual States, much of this work was performed during the late 1970's and early 1980's and many of the recommendations have not been acted on by the EPA or other involved Federal and State agencies. However, there is at this time, a resurgence of interest in NORM by EPA, CRCPD, and some affected State agencies.

Of particular interest to Louisiana is the growing awareness of problems related to the NORM content of produced waters and contamination of equipment and facilities in the oil and natural gas production and support industries. The occurrence of environmentally high concentrations of radioactivity, primarily radium isotopes, in oil field production waters and in precipitates collected from the bottom of oil-water separators and from ditches and pits used for disposal of production waters were first reported in the United States over 30 years ago. The radium levels observed in most saline produced-waters from the Gulf Coast region exceed existing and proposed radium discharge limits applied to other sectors. Recent investigations by the Louisiana Department of Environmental Quality, Radiation Protection Division, have identified radioactive "scale" resulting from the production of oil and associated brines that contained Radium 226 in concentrations of up to 3700 KBqKg.[1] (100,000 pico Curies per gram [pCi/gm]). The scale is formed on the internal surfaces of "tubulars" (piping and equipment) exposed to production waters and can vary considerably in thickness and radioactive concentration. Contamination of soil can occur as scale becomes dislodged and falls from the ends of pipe, and it can become particularly elevated at sites where the scale is actively removed from pipe by reaming, "rattling," or other means used to reclaim the pipe.

On Sunday, December 11, 1988, the *Morning Advocate* in Baton Rouge, Louisiana, began publishing four consecutive days of front-page articles with the titles, "Brine Flowing in Louisiana Waters is Radioactive," "Oil Field Brine Radioactivity New Concern," "Pipes Handled by Oil Workers Discovered to be Radioactive," and "Radioactive Playground Equipment Torn Down." Almost overnight, more consequences of the years of oil production in the State became apparent to the general public.

Concern over the magnitude of the problem, the safety of workers cutting and reaming contaminated pipe and equipment, and the future unrestricted use of NORM contaminated areas has prompted regulatory action to be initiated on behalf of the State. On September 20, 1989, the Radiation Protection Division amended the Louisiana Radiation Regulations under "emergency rule" procedures. The amendments address the "Regulation and Licensing of Naturally Occurring Radioactive Materials." The regulations additionally establish acceptable surface radiation levels for NORM and require worker protection during decontamination of facilities and equipment. It is estimated that over 1,000 facility locations in Louisiana will be subject to the requirements of this amendment. There are certain exemptions to the rule, but in general, any facility with NORM on-site with radiation levels 50 micro Rem per hour (mR/hr) and greater fall under the regulations and general licensure.

In addition to requiring surveys and reporting of NORM contamination, the rulemaking, which became final in October 1989, is expected to provide a data base on the quantity and distribution of NORM contaminated sites and material within the State. Additional efforts are currently underway to characterize the risk associated with different uses of discarded pipe and scale, and to study alternative disposal practices for such materials.

The details of the regulation as well as the impact on the regulated community will be presented along with any data available at that time.

Dr. L. Hall Bohlinger received a B.S. from Southeastern Louisiana University and an M.S. and a Ph.D. from Tulane University in environmental science. Dr. Bohlinger has been involved in state environmental regulatory programs for the past 20 years, the majority being in radiation control. He is a member of Health Physics Society, American Nuclear Society, Air Pollution Control Association, Louisiana Nuclear Society Conference of Radiation Control Program Directors, and currently serves as Vice-Chairman of the Central Interstate Low-Level Radioactive Waste Compact Commission. Currently, Dr. Bohlinger is a Program Manager in the Louisiana Department of Environmental Quality, Radiation Protection Division.

THE STATUS OF THE STATE OF TEXAS' REGULATORY EFFORT CONCERNING NATURALLY OCCURRING RADIOACTIVE MATERIALS

Mr. Ralph S. Heyer
Texas Department of Health
Bureau of Radiation Control

INTRODUCTION AND BACKGROUND

The Texas Department of Health Bureau of Radiation Control (BRC), as well as other state regulatory agencies, has become increasingly aware during the past few years of radiation problems and potential hazards from technologically enhanced naturally occurring radioactive materials (NORM).

The types of NORM problems that many agencies believe need some amount of control are mainly diffuse sources of NORM with low to moderate radiation levels and concentrations of radium, uranium, and thorium. Some examples of sources of NORM are

- radium in drinking water filtration systems (resin beds);
- residuals from mineral extraction such as phosphogypsum tailings from phosphate industries and thorium tailings from chemical extracted tin; and
- radioactive scale buildup on pipes and equipment from the oil and gas industry. The scales trap radium, thus making the deposits a source of contaminated waste.

Requests for use of phosphate fertilizer tails and coal ash for use in commercial products and construction materials (such as roadbeds), as well as the potential for litigation involving radioactive scale containing uranium, thorium, radium, and associated decay products, have shown the need for uniform regulatory standards. Since NORM is not regulated under the Atomic Energy Act by the United States Nuclear Regulatory Commission (NRC), the Conference of Radiation Control Program Directors (CRCPD)--an organization made up of State regulatory personnel--designated a committee to address these areas through model state regulations. Other reasons for the development of the regulations were

- the need for consistency with other regulated industries, since all of the materials and waste associated products mentioned contain concentrations of radium that exceed cleanup levels for uranium mill tailings;
- the need for uniform State regulations throughout the country; and
- to apply U.S. Environmental Protection Agency (EPA) standards for waste and uranium to similar NORM waste.

THE BUREAU OF RADIATION CONTROL REGULATORY INITIATIVES

Although there are several other regulatory agencies and groups that are currently studying the NORM issue, the BRC has proceeded (as has the State of Louisiana) in formulating rules. The BRC's *Texas Regulations for Control of Radiation* (TRCR) Part 46, Draft 1, is similar to the CRCPD, Suggested State Regulations Part N. The BRC's draft rule sets up a regulatory structure similar to that for byproduct material in NRC's Title 10 Code of Federal Regulations--that being Exemptions, General Licenses and Specific Licenses.

The regulations would allow for exemptions based on concentration of NORM, specific activities, and specific products. Specific exempted activities include manufacturing, distribution, use, and disposal of natural potassium compounds not enriched in potassium-40, Brazil nuts (which contain greater than 5 pico curies per gram [pCi/g] radium), phosphate and potash fertilizer, phosphogypsum for agricultural purposes, and building materials that contain NORM not technologically enhanced (such as red brick). Specific exempted products include natural gas and natural gas products, and those products issued under a specific TRCR Part 46 license.

Licenses are of two types--general and specific. The regulations would require that general licenses be issued to cover onsite use of NORM and disposal of waste. The rules under the general license refer to worker protection standards similar to NRC's 10 CER Parts 19 and 20, which include exposure limits and notification provisions. Equipment and soils must be within the specified contamination limits before they can be released for unrestricted use. Examples of acceptable contamination levels are as follows:

	Average ($/100\ cm^2$)	Maximum ($/100\ cm^2$)	Removables ($/100\ cm^2$)
Ra-226, Ra-228 Th-230, and Th-228	100 dpm	300 dpm	20 dpm

Other limits are listed for uranium and other associated daughter products.

Soil limits (above background) are given for radium averaged over any 100 square m as follows:

- 5 pCi/g, averaged over the first 15 cm of soil below the surface, and
- 15 pCi/g, averaged over 15-cm thick layers of soil more than 15 cm below surface.

A specific license, issued only after review and acceptance of a specific application, would be required for the manufacturers and the distributors of exempt products and for persons providing the decontamination of NORM contaminated equipment and facilities. These activities would involve greater potential for worker and public radiation exposure, therefore requiring specific licensure.

One of the BRC's main areas of continued concern is that of diffuse NORM waste disposal. The alternatives currently being discussed are

1. licensed low-level waste disposal facilities for concentrations greater than 2 nano curies per gram (nCi/g);

2. state-licensed waste facilities specifically developed for NORM;

3. uranium mill tailings disposal facilities for NORM with similar chemical and radiological characteristics;

4. Resource Conservation and Recovery Act (RCRA) hazardous waste facilities; and

5. municipal solid waste landfills for low concentration material requiring disposal.

CURRENT ACTIVITIES AT THE BRC

The BRC is continuing to meet with other Texas state agencies, such as the Railroad Commission of Texas (RRC) under the provisions of a Memorandum of Understanding, to discuss and exchange information concerning NORM and to identify potential problem areas. The agencies have most recently identified these areas where NORM may present a concern.

- Produced waters (mainly brines) resulting from drilling in many instances may contain NORM. In Texas, more than 90% of the produced water is reinjected. A few discharge pits are allowed in coastal areas. Lined collecting pits are permitted for emergency collections. Water from these pits is evaporated, and the materials are then injected into the secondary production zone or below. There are currently about 5,800 permitted discharge pits in Texas.

- Tank bottom wastes from oil production facilities do not contain "hazardous" constituents; therefore the wastes are exempt from RCRA requirements. Tank bottoms from oil reclamation plants and petrochemical plants are not exempt. These are considered hazardous waste by the EPA.

- Disposal options allow the disposal of NORM or NORM contaminated tubulars in cased plugged and abandoned wells. These options are reviewed on a case-by-case basis. However, the RRC plugging rules do not allow for plugging in such a manner that the well could not be re-entered. This would limit the extent of the use of this disposal method.

- Water treatment, which is performed at gas plants on water associated with gas production, involves the use of ion exchange resins and could create another potential source of NORM waste.

CONCLUSION

The problems that the TRCR Part 46 and CRCPD Part N address may vary from State to State. Each State should go through its normal rulemaking procedures to implement applicable State regulations. Each State may have a unique set of problems and therefore should modify the CRCPD's Part N as appropriate, the basic framework of the regulations intact.

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NOTE: This paper was previously presented by R. E. McBurney, C.H.P., and E. D. Bailey, P.E., C.B.P., titled "Development of Model State Regulations for the Control of Naturally Occurring Radioactive Materials," at a 1988 Health Physics Society meeting. The information has been modified to reflect current Texas Bureau of Radiation Control activities.

Mr. Ralph S. Heyer has a B.S. in environmental health with a minor in physics from Wright State University in Dayton, Ohio. Previously, he was employed at the U.S. Nuclear Regulatory Commission for 10 years as a Senior Health Physicist performing radioactive material inspections. Currently, Mr. Heyer is the Administrator for the Licensing Branch at the Texas Department of Health, Bureau of Radiation Control in Austin, Texas.

THE APPLICABILITY OF ENVIROCARE'S DISPOSAL SITE IN UTAH FOR NATURALLY OCCURRING RADIOACTIVE MATERIALS

Mr. Kurt M. Higgins
Envirocare of Utah, Inc.

Envirocare owns and operates a facility for disposal of Naturally Occurring Radioactive Waste Materials (NORM). This facility is located 80 miles west of Salt Lake, at the edge of the Bonneville Salt Flats. This location was selected by the U.S. Department of Energy (DOE) and the State of Utah for disposal of 2.3 million cubic yards of 11(e)2 by-product material, generated as a result of the Vitro Uranium Millings operation. This facility was identified as a safe alternative for disposal of radioactive material due to its extreme isolation and geotechnical and hydrological suitability. The operating criteria implemented at the Envirocare facility are the exact duplication of the DOE's design and requirements. In addition, Envirocare's Clive facility has implemented a complete incoming inspection program strictly to verify waste qualifications, segregation, and complete isolation of the waste material of each customer. This is to minimize potentially radioactive products issues, and compaction of the waste during the disposal to ensure long-term structural integrity of the cell.

Envirocare has received NORM waste from a variety of customers, mainly the U.S. Environmental Protection Agency Comprehensive Environmental Compensation and Reliability Act projects and several State programs. Such waste material includes soil and debris generated as a result of clean-up projects, pipe scale and equipment from oil and geothermal industries, process waste from non-licensed facilities and contaminated scrap metal from private firms.

Envirocare's Clive Facility benefits from the most ideal delivery options. This facility is located 2 miles south of the Transcontinental Interstate 80, and it also owns and operates a railroad spur that enters the facility from the Union Pacific Railroad. In addition, Envirocare utilizes an automatic railcar tipper (rollover), which allows Envirocare to receive and dispose in excess of 10,000 tons of material per day.

Due to the unique method of disposal at this facility, which includes individual handling of each container and emptying the content and subsequent compaction, Envirocare can receive waste in virtually any method suitable to the generator as long as it complies with State and Federal Regulatory guidelines. Such options may include steel drums, B-12 and B-25 boxes, polypropolene bags, intermodels and railcars.

Envirocare has provided such a safe disposal alternative at a fraction of the cost compared to the three other existing low-level facilities. The lower cost of operation and disposal is due to a safe and suitable site and lower fees and surcharges by regulatory agencies. Envirocare clearly recognizes the need of reasonably priced and economical disposal operations for the industry and in turn has passed these savings to its customers.

It is also important to note that Envirocare is expected to receive a license for Mixed NORM Waste no later than December 31, 1990. This capability should provide another safe alternative at a reasonable cost for the generator of this classification of waste material.

Mr. Kurt M. Higgins has worked for Envirocare of Utah, Inc. for over two years as Customer Relations Specialist in the Marketing Section of Envirocare's operation. Prior to working for Envirocare he was employed by the Utah Division of State Lands and Forestry for 14 years as Program Specialist for Surface Management and Chief Appraiser for the Division. Mr. Higgins received his B.S. degree in biological science from Southern Utah State College and his M.S. degree in range entomology from Utah State University.

CLEANING OF NATURALLY OCCURRING RADIOACTIVE MATERIALS AND NORTH SEA PROCEDURES

Mr. Rupert Macnamee
Hydrocut/Macnamee Services

I am the Chairman of the Macnamee Group in Aberdeen, a group of companies which has been involved in the North Sea Oil Industry for over

14 years, dealing with high pressure water jetting, industrial cleaning, inspection and ancillary services.

We employ approximately 100 people and feel we have justly deserved our reputation for a professional and safe service. As part of our growth programme we have entered into a joint venture with a Houston-based company specializing in the use of an abrasive and water mix to safely cut metals and other hard substances. This company is called Hydro-Cut. We feel that there will be a great advantage in the exchange of knowledge and services between the two companies and countries.

Macnamee Services has been involved in naturally occurring radioactive materials (NORM) decontamination (called Low Specific Activity Scale/LSA Scale in the United Kingdom) for the past seven years to such an extent that it is now a part of our normal daily routine in the offshore waters of the United Kingdom.

The purpose of this speech is to describe Macnamee Services' procedures for NORM decontamination and disposal on North Sea Platforms and to discuss its relevance to the United States Market.

All workscopes with Ionizing Radiations in the United Kingdom are performed in accordance with an Act of Parliament--the Ionizing Radiations Regulations 1985. The regulations state that every employer must draw up "Local Rules." These are general principles and descriptions of the means of compliance with these regulations. It is therefore my intention to outline the principle points of the 1985 regulations and, where appropriate, to discuss Macnamee Services' "Local Rules" on how to implement the regulation in the actual decontamination workscopes.

Regulation 5 states employers are required to notify the health and safety executive of work with Ionizing Radiations. We, in fact, have achieved a blanket notification with the executive relieving us of the need to inform them of every NORM workscope which was being undertaken.

Regulation 7 requires every employer to take all necessary steps to restrict so far as is reasonably practicable the extent to which employees and other persons are exposed to Ionizing Radiations. It also imposes limits on the doses of Ionizing Radiations which employees and other persons may receive in any calendar year.

Regulation 8 requires that all areas in which persons are likely to receive more than specified doses of Ionizing Radiation be designated as Controlled Areas or Supervised Areas and restricts entry into Controlled Areas to specified persons and circumstances. As discussed under Regulation 7, dose limits are imposed. The limits translated under hourly working limitations to these areas are as follows:

- Supervised Areas will be designated when:

  a. the dose equivalent rate exceeds 2.5μSV/h (micro-sieverts per hour), or

  b. the surface contamination exceeds 2.0 Bq/cm^2 (bequerals per square cm), or

  c. the air concentration exceeds 0.003 Bq/m^3 (bequerals per cubic metre).

- Controlled Areas will be designated when:

  a. the dose equivalent rate exceeds 7.5μSV/h (micro-sieverts per hour), or

  b. the surface contamination exceeds 7.0 Bq/cm^2 (bequerals per square cm), or

  c. the air concentration exceeds 0.01 Bq/m^3 (bequerals per cubic metre).

For Supervised Areas it is simply a case of constant monitoring of an area, open to all personnel with basic or minimal protection, to ensure that no change in levels of Ionizing Radiation occur.

For Controlled Areas, the following would apply in our Local Rules for Entry/Exit procedures:

a. The Controlled Area shall be set up allowing sufficient space to undertake all work and storage involving radioactive material. This shall include both a changing area and a washing facility. In general, this type of area shall be erected by use of habitat materials (tarpaulins, polysheeting) around the vessel entry point or contaminated area for cleaning.

b. Barriers and signs shall be erected to prevent entry of unauthorized personnel.

c. All personnel entering the Controlled Area shall be "classified personnel."

d. All personnel entering the area shall change into the protective clothing provided.

e. All measures shall be taken within the area to avoid irradiation by absorption, inhalation, or ingestion. This shall include the prohibiting of work with any open cuts, and while eating, smoking or chewing tobacco.

f. A person shall be delegated to monitor the access point to Controlled Areas with responsibilities to

   1. log entry of all personnel and equipment into the Controlled Area;

   2. log exit and monitor all personnel and equipment leaving the Controlled Area;

   3. ensure the observance of washing instructions by persons leaving the area; and

   4. ensure the protective clothing provided has been removed before exit from area.

g. On completion of workscope, the Controlled Area shall be thoroughly decontaminated and dismantled. Checks using contamination monitors shall be made and recorded.

Regulation 9 requires the designation of all personnel working in a Controlled Area to be either "Classified" of working under a "Scheme of Work."

As a company policy, we use only "Classified Workers." This means all personnel involved in NORM decontamination shall

a. Undergo yearly ionizing radiation medical examinations;

b. Wear a personal Total Lethal Dose (TLD) badge (Dosimetry);

c. Be registered for dose record keeping through a dosimetry service; and

d. Be fully trained and understand the basics of their workscopes.

Regulation 10 requires the appointment of a Radiation Protection Advisor (RPA).

Since 1985 Macnamee Services has used the National Radiological Protection Board (NRPB) as our RPA. Our RPA's advice is sought for the following:

a. A drawing up and reviewing of Local Rules;

b. Investigation of unusually high exposures and overexposures;

c. Training;

d. Hazard assessment and contingency arrangements; and

e. Calibration of monitoring instruments and dosimetry (TLD badges).

Regulation 11 requires the appointment of Radiation Protection Supervisors.

Radiation Protection Supervisors (RPS's) are used to control any given workscope involving Ionizing Radiation. Our RPS's are chosen only from personnel who have worked with NORM decontamination for at least two years and have undergone further intensive training.

Regulation 12 requires adequate training for personnel involved with Ionizing Radiations.

Our training in the United Kingdom consists of both in-house seminar courses as well as the intensive training by the NRPB. This training is to ensure that all personnel are fully conversant with the requirements of, and methods of compliance with, the regulations.

The training undertaken by the NRPB covers the following points:

a. Radioactivity and how it is arising from Wet Wells;

b. Risks associated with exposure to Radium 226 scale;

c. Health supervision;

d. Safe methods of working;

e. Monitoring instruments;

f. Transport and storage; and

g. Requirements of regulations applied to workscopes.

Regulation 13 requires that doses of Ionizing Radiations received by Classified and certain other specified persons are assessed by one or more dosimetry services approved by the executive and that records of such doses are kept for each person.

We use the NRPB to supply TLD badges, take the readings therefore, and the subsequent recordkeeping. The TLD badges are exchanged quarterly for which we receive a quarterly report in addition to a year-end report. These are then kept for two years.

Regulation 16 requires the need for medical surveillance. The primary purpose of medical surveillance is to ensure, before persons are classified, that they are fit to commence such work and that periodic reviews are made to see that they remain fit. Our review period is one year. A person cannot be a "Classified Person" unless he has been certified fit by an Employment Medical Advisor or appointed Doctor on a health record. We, in fact, use an appointed Doctor.

Regulation 21 covers the transport and moving of radioactive substances, the purpose of which regulation is to ensure that, so far as is reasonably practicable, the substance is kept in a suitable container suitably labelled, while it is being transported.

For transportation, the completion of a Radioactive Substance Transport Form is mandated and requires the following:

a. The nature and quantity of the Radioactive Substance is clearly known and shown.

b. Certain limits are set for maximum dose equivalent rates outside the package as well as maximum surface contamination levels on the external of the package.

c. A guarantee that no leaks of Radioactive Substances can occur.

d. Packages are well marked "Radioactive."

e. The point of origin and destination are clearly marked with the destination point having prior knowledge of its arrival.

Regulation 22 requires the use of washing and changing facilities. As already discussed, this is part of our Controlled Area set up.

Regulation 23 requires that suitable protective clothing be worn, regularly examined, and properly maintained. For our workscopes the following protective clothing would be deemed to be essential:

a. One-piece wet suit or J-suit with elasticated sleeves, legs, and hood, hard wearing and durable;

b. One pair of light overalls for changing purposes;

c. One pair of long rubber gauntlets;

d. One pair of rubber boots with toe protectors;

e. Either a filter mask approved to British Standards or a full face breathing apparatus, depending on requirements;

f. Goggles, face visor, or safety specs depending on the workscope; and

g. A TLD badge.

Regulation 24 requires radiation levels to be monitored and removed in Controlled and Supervised Areas and provides for the maintenance and testing of monitoring equipment.

Constant monitoring is undertaken and also recorded during any given workscope, especially at the exit/entry point to a Controlled Area and of original contamination levels or equipment to be cleaned so that quantity and level of contamination can be assessed for disposal. Regulations require that the calibration of all radiation monitors is undertaken by our RPA's at a maximum of yearly intervals. In practice this is done more frequently, as the instruments tend to be too delicate for their surroundings. Tests can be done to check if the monitors' calibration is accurate by use of a sealed source whose activity has already been determined by laboratory techniques by an authoritative body.

Regulations 25-27 require every employer who undertakes work with Ionizing Radiation to make an assessment of the hazards that are likely to arise from that work. It also requires employers to make contingency plans for dealing with foreseeable incidents.

The contingency plans that we have written into our Local Rules cover the following points:

a. Overexposure to NORM contaminated material;

b. Physical injury to an employee within a Controlled Area;

c. A rapid accumulation of scale buildup in any area other than the one designated as Controlled;

d. A spillage of scale during transfer;

e. A worksite emergency within a Controlled Area;

f. An emergency evacuation of Controlled Area worksite.

Last, but not least, we deal with the disposal of NORM contamination.

Although the disposal of NORM contamination is not directly discussed in the 1985 regulations, we revert to the disposal methods as stated in the 1960 Radioactive Substances Act.

This Act states that any employer wishing to dispose of Radioactive Substances in Scotland must apply to the Scottish Development Department stating the methods they propose to use. The Department shall then study the proposals and either accept or impose restrictions and/or parameters before the application is accepted.

In practice, it is the operators of the platforms or rigs who are responsible for applying to the Department for disposal. The Department has laid down stipulations as to the maximum quantities of disposal from any one given location.

Another stipulation is that the substance to be disposed of must be of a particle size of 1 mm or less and disposed of below the sea level. To achieve this, our procedures call for the use of a direct in line grinder/macerator which is capable of grinding this material to 1 mm or below and deliver for disposal subsea. It works on the principle of a series of cutting discs (approximately 2 rows of 40 discs) which rotate in opposite directions towards each other, at a speed of 100 revs per minute. The unit is fitted with a 1-mm filter, with a backflush through the system available. The unit can either be air or electric driven.

Now that all our parameters have been discussed, a quick word on the cleaning procedure. Our Local Rules will have specific procedures for the decontamination of equipment such as vessels/tanks, production manifolds, tubulars, and valves, etc. This cleaning procedure shall begin with the setting up of the Controlled Area, information on changing facilities and washing facilities to be used.

Entry would only be allowed to highly trained "classified" personnel who are wearing the correct protective clothing. The actual cleaning procedures will be discussed. Cleaning in all cases is achieved using high pressure water or, in some circumstances, high pressure water with grit abrasive injection. This is done to avoid any inhalation hazards of scale dust. During the cleaning process all water (grit) and scale removed shall be collected. If it is cleaning of a vessel, this collection is done naturally by ensuring drains are closed. If it is a tubular or manifold collection is achieved by ensuring the Controlled Area also includes a catchment area to contain all water and scale. The water and scale are then continuously pumped away directly through our grinder/macerator and hence subsea.

This, I am sure you will appreciate, is a very straightforward procedure and can be achieved successfully under any given circumstances.

To summarize, I would like to emphasize the procedures which our company already uses, and which we feel are imperative to follow in any NORM workscope in the United States.

1. Ensuring all notifications and/or licenses are in place.

2. Reducing exposure to a minimum.

3. Ensuring good procedures are clear and precise and are understood by all.

4. Using Supervised and Controlled Areas and all necessary precautions which relate to this.

5. Using only the equivalent of "Classified Workers."

6. Ensuring all personnel are highly trained, and only very experienced personnel used as Radiation Protection Supervisors.

7. Ensuring we have a suitable advisory service.

8. Ensuring the correct personal protective equipment is used and inspected frequently.

9. Ensuring changing facilities and washing facilities are both set up and used successfully.

10. Ensuring that throughout workscopes, monitoring is constant and accurate, and that all monitors are calibrated and maintained to a high standard.

11. Ensuring contingency plans are in place.

12. Ensuring we comply with all disposal and storage precautions which are in place at present.

By using the basics of our Local Rules already set up, we feel that we will provide a much better, safer, and commercially viable cleaning and decontamination service to all clients who require this service.

Mr. Rupert Macnamee is Chairman of Macnamee Group of Companies with offshore experience in the North Sea for the past 14 years. Mr. Macnamee was educated in Edinburgh, Scotland, but is now looking forward to settling down in the United States.

IMPACT OF OFFSHORE OIL EXPLORATION AND PRODUCTION ON THE SOCIAL INSTITUTIONS OF COASTAL LOUISIANA

Session: IMPACT OF OFFSHORE OIL EXPLORATION AND PRODUCTION ON THE SOCIAL INSTITUTIONS OF COASTAL LOUISIANA

Co-Chairs: Dr. Shirley Laska
Ms. Vicki Zatarain

Date: November 14, 1990

Presentation	Author/Affiliation
Impact of Offshore Oil Exploration and Production on the Social Institutions of Coastal Louisiana: Session Introduction	Dr. Shirley Laska Environmental Social Science Research Institute University of New Orleans and Ms. Vicki Zatarain Minerals Management Service Gulf of Mexico OCS Region
Familial Structural Responses to Cyclical Father Absence: The Offshore Family	Dr. Craig J. Forsyth and Ms. DeAnn Gauthier Department of Sociology University of Southwestern Louisiana
Poverty During Boom/Bust Cycles and Social Service Response	Dr. Sarah Brabant As presented by Dr. Robert Gramling Department of Sociology University of Southwestern Louisiana
The Social and Economic Impact of Offshore Oil Extraction and Production on Involved Communities	Dr. Shirley Laska, Dr. Ruth Seydlitz, Ms. Elizabeth Triche, Ms. Karen Bishop Department of Sociology University of New Orleans and Dr. Daphne Spain University of Virginia
The Impact of the Recession in Outer Continental Shelf Activity on the Provision of Public Services by State and Local Government in Coastal Louisiana	Dr. Ralph E. Thayer College of Urban Affairs and Dr. Charles D. Hadley Department of Political Science University of New Orleans
Offshore Leasing Activity as Corporate Strategy	Mr. Charles R. Lambert Department of Sociology University of New Orleans
Common Themes of Social Institution Impact and Response	Dr. Vern Baxter Department of Sociology University of New Orleans

(Continued)

Session: IMPACT OF OFFSHORE OIL EXPLORATION AND PRODUCTION ON THE SOCIAL INSTITUTIONS OF COASTAL LOUISIANA (cont'd)

Presentation	Author/Affiliation
Project Discussion	Dr. Shirley Laska Environmental Social Science Research Institute University of New Orleans and Ms. Vicki Zatarain Minerals Management Service Gulf of Mexico OCS Region

IMPACT OF OFFSHORE OIL EXPLORATION AND PRODUCTION ON THE SOCIAL INSTITUTIONS OF COASTAL LOUISIANA: SESSION INTRODUCTION

Dr. Shirley Laska
Environmental Social Science
Research Institute
University of New Orleans
and
Ms. Vicki Zatarain
Minerals Management Service
Gulf of Mexico OCS Region

The purpose of this session is to present the progress of the Louisiana University Marine Consortium (LUMCON), University of New Orleans in conjunction with the University of Southwestern Louisiana, project on the social implications of the extraction of oil offshore Louisiana. In examining impacts of offshore oil exploration, development, and production on coastal Louisiana, the impacts at various levels of society were explored. The five levels analyzed were (1) the family level, the smallest unit; (2) social service level; i.e., poverty and what various public and private organizations within the community can or cannot do to mitigate these impacts; (3) parish/county level; i.e., what happens to communities, the grouping of individuals and the activities that they participate in at a level where there is organization, structure, and spatial location; (4) level of governmental process, what impact had oil in both boom and bust on State and local community levels; and (5) the oil industry and its changes and how it impacted the lower levels of hierarchy of social institutions.

The first presentation by Dr. Craig Forsyth dealt with the impact of offshore oil exploration and production on the familial structure. Because offshore oil workers' schedules involve cyclical father/husbands' absences, the research explores the familial adaptations to those absences. Types of familial adaptations among offshore oil workers are as follows: Traditional authority occurring about 49% of the time, where the wife takes on both traditional male and female roles during the offshore oil worker's absence, but when he returns, he assumes only the male role, leaving the wife to carry on traditional female tasks. The second adaptation is that of the marginal father, occurring 20% of the time, where the wife has taken on both the traditional male and female roles in both the absence as well as the presence of the offshore oil worker. The third adaptation is that of contingent authority, occurring 17% of the time. The wife has been given the authority to make only minor or emergency decisions in the absence of the offshore oil worker. The offshore oil worker retains all authority and responsibility for the functioning of the family upon his return. The fourth adaptation occurring 7% of the time is that of conflict adaptation, which can be further subdivided into 2 groups: terminal conflict (2%) and habitual conflict (5%). The primary characteristic of families associated with terminal conflict is that the marriage has ended in divorce due to ongoing unresolved conflicts. Those families using the habitual conflict strategy are involved in much ongoing tension and conflict as well, yet the conflict is largely controlled. The fifth adaptation is that of the egalitarian family, occurring 4% of the time. Families using this adaptation have divided the responsibility and authority in the family equally between the parents. The final adaptation is that of the replacement father, occurring 2% of the time. These families live close to relatives, and essentially a male relative "replaces" the offshore oil worker during his absence.

Though nonstandard work schedules may be problematic to the family, adaptations as those described above will result. In some families, the absences necessary for working offshore will come to be defined as appropriate, in others they will not.

The second presentation by Dr. Sarah Brabant discussed poverty during boom/bust cycles and social service response. The time frame for the study, 1970 to 1990, includes the period before the oil embargo, the rapid escalation in the price of crude oil following the embargo, and the subsequent decline in price.

Pre-boom poverty was typical of the underemployed, including the illiterate with menial jobs and lower incomes and the elderly on fixed incomes. During the boom time, those who could not respond with skills never got in on the oil boom. For the elderly poor, boom made poverty even worse while the impact on minorities was mixed. With the nation in a recession, the under and working class migrated to the area. Therefore with the bust, the first to be hurt were those who were the last to come. Previous welfare recipients lost jobs and had to return to food stamps. In addition, a class of people who came to be known as the "new poor" emerged. The common characteristic of the "new poor" was not type of job or income, it was that they had never been poor before.

Some unique aspects of the Louisiana boom/bust cycle with regard to social service response include the following: First, as a result of the Civil Rights movement and the War on Poverty, a number of community-based organizations were already in place prior to the boom/bust period, though it was difficult for these programs to meet the changing flux of poverty. In addition a powerful bureaucratic entity was already in place. This entity, the Roman Catholic Church, served to give both credence and organizational structure to several attempts to serve the poor.

The third presentation by Dr. Ruth Seydlitz was the social and economic impact of offshore oil extraction and production on involved communities. Three types of social impacts were examined: social disorganization, long-term human capital development, and the economic health of communities. Social disorganization of a community or other social unit was measured by suicide and homicide rates. With the changes communities experience with the growth and decline of oil production when it is a significant portion of the economy, it is expected that social disorganization would occur. The enhancement or suppression of long-term human capital is a second way in which it is proposed oil production would impact communities. The two measures that were used to examine this question were high school dropout rates and percent of students going on to college. The third measure of social impact is the economic health of the communities. Three measures of economic health were examined: transfer payments, income, and migration.

Time series analysis indicates that the effects of the oil variables are more likely to be significant in the parishes defined as highly involved in oil and gas activities. The models including oil variables explain more of the variance in the highly involved parishes. Both positive and negative impacts from oil activity are evident. It is important to anticipate such impacts, to understand how they are caused and to determine mitigative actions that might be possible for the negative ones.

The fourth presentation by Dr. Ralph Thayer was the impact of the recession in Outer Continental Shelf (OCS) activity on the provision of public services by State and local government in coastal Louisiana. Many impacts on local government were structural. First, the number of "special taxing districts (or areas)" has proliferated. Parishes indicated that voters preferred "earmarking" increased taxes to specific areas and purposes as opposed to paying into the general fund. Also, parishes and cities report having done everything they could to cut expenses. Layoffs were common, privatization or contracting out was practiced, and all operations were reviewed for possible cutbacks. Virtually all local financial support provided on an optional basis to support social services was eliminated as a matter of necessity. Many local areas have consolidated city-parish operations or even consolidated governments. Where consolidation has not occurred, municipalities and parishes often squabble over municipal plans to annex unincorporated territories to insure that they, not the parish, will have the sales tax collections as these areas develop. Tax competition is on the rise.

Planning and strong central management could paint a different picture for the Louisiana coastal parishes, but this does not seem to be in the offing. Central local authority has been seriously diluted by the proliferation of special districts with their own boards and dedicated sources of revenues. Public understanding of their local government is lessened since the proliferation of special project accounts and districts makes the public focus only on an awareness of "their districts" to the exclusion of others and the general government. Planning is difficult under any circumstances, virtually impossible in a multi-headed non-system.

The fifth presentation by Mr. Charles Lambert pertains to offshore leasing activity as corporate strategy. The U.S. oil industry needs to shrink, and many analysts believe it is still overcapitalized. Industry expansion was driven by high oil prices, the anticipation of still higher prices, and a desire to circumvent OPEC production controls and U.S. price controls. Declining oil demand and economic recession in the early 1980's put many oil firms at risk financially although profits remained relatively high.

Repositioning of integrated multinational oil companies during the 1980's frequently took the form of mergers, asset purchases, stock repurchase and reorganization. A primary goal of many mergers between 1982 and 1988 was to unload low profit assets to increase return on existing assets, and to purchase oil reserves cheaper than drilling for them. A large number of similar mergers involved large integrated independent oil companies that purchased other independents.

When these mergers are considered in light of recent patterns of offshore lease purchases, two types of corporate strategy emerge. One group of companies has concentrated on restructuring for the short-term profitability and pursuit of opportunities outside the Louisiana-OCS region. A second group of companies continues to pursue growth strategies and has maintained or increased its presence in Louisiana-OCS leasing, particularly in deep water exploration.

A third group of companies may be an essential part of the future of Louisiana-OCS activity. These firms include natural gas producers that are expanding leasing activity to position themselves for potentially rich offshore finds, increased demand, and higher gas prices. A final potential for future offshore growth could be investment trusts that show signs of moving into Louisiana-OCS leases.

The sixth presentation by Dr. Vern Baxter was to tie together the previous presentations in common themes of social institution impact and response. The various presentations investigate the interaction of integrated and independent oil companies, federal and state government agencies, and public and private social service providers as they relate to the offshore oil industry as well as the familial adaptations of offshore oil workers and family members to the uncertainties of offshore employment and unemployment. Changes in the international oil industry and in Louisiana offshore oil activity interact with local political conditions and cultural traditions to produce effects on the social institutions and lives of Louisiana citizens. A common theme in the LUMCON research is that it is important to examine local institutions and how they affect and are affected by changes in the global oil industry. State revenue, the system of social service delivery, and overall socioeconomic development in Louisiana are all tied to oil, but existing political traditions, systems of social service delivery, and family adaptation also survive and affect the way global changes affect Louisiana.

The final three presentations were by prominent sociologists active in this area, discussing the project at hand and future implications for Minerals Management Service (MMS).

Dr. Robert Gramling discussed how the structure of the oil industry and the structure of local governments affect social impacts of coastal Louisiana, but also highly important is the Department of the Interior's MMS's policy on leasing. Between 1954 and 1978, an argument can be made that leasing was essentially a closed activity between the Secretary of the Interior and industry. Most of the leasing until the 1960's was in Louisiana and all in the Gulf of Mexico. There were no problems with local population objections since leasing offshore Louisiana was established in the 1920's. In 1969, the Santa Barbara oil spill changed perceptions about the safety of offshore oil in the United States except in the Gulf. The Santa Barbara spill was considered facilitative of NEPA and the 1978 amendments to the Outer Continental Shelf Lands Act (OCSLA). In 1978, the OCSLA was amended and the assessments of effects of leasing on marine, coastal, and human environment were mandated. In 1974, following the 1973 oil embargo, the size of lease offerings was tripled. In 1982, the Secretary of the Interior combined the offshore functions of the Bureau of Land Management and U.S. Geological Survey to form MMS. Further, area-wide leasing was instituted and went into effect in 1983. Leasing is fundamental to social impacts. Much of the United States is now under a leasing moratorium by President Bush until 2000. The domestic leasing program is almost entirely in the Gulf of Mexico. A third structural variable to be entered into analyzing social impacts is the Department of Interior's leasing policy, scheduling of lease sales, and historic leasing.

Dr. William Freudenburg provided context and reactions. Impacts on human environment have not been systematically done. The purpose is not to prohibit development but to foresee negative impacts and mitigate. Four reactions to the LUMCON presentation are (1) promising first steps have been made; (2) on the basis of progress, there are no easy/cheap "fixes"; (3) the agency and the research community need to do more; i.e., focused research task; i.e., applied research to answer specific, narrow questions; (4) the links/conflicts need to be explored focusing on impacts of OCS development on the human environment.

Simple model to do this:

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OCS Activity --> Affected       -------> Impacts
                 o Individuals          (+ and -)
                 o Communities
                 o Regions
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The final speaker, Dr. Harvey Molotch, discussed the challenges of examining social impacts from OCS activity since there are no standard sources from which to begin. There is a need to separate the United States and World versus things local; i.e., the need to define what is distinctive to OCS activities.

Secular trends in the United States since the beginning of the turn of century include expanding public budgets. Cost of development (physical and social infrastructure) has been absorbed by government. In the last decade, however, there has been a sharp cutback in public expenditures, which means that whatever happens, happens at the expense of a community. The community must deal with it. The community can deal with the cost of development through mitigation. Wealth should be drawn from the production process at the time wealth is extracted to minimize the paying for infrastructural cost of that development.

What is part of secular national trends must be isolated from what is peculiarly local. In what ways does development under these circumstances create peculiar problems for localities that perhaps can be mitigated? What about the nature of OCS activities lends them to mitigation? With an extractive industry, you are taking out a non-renewable resource and a bust is inevitable. It is suggested that there be mechanisms in place to provide bonding for lease abandonment; i.e., to remove physical infrastructure; perhaps there is a way to generate an analogous fund to take care of social consequences; i.e., an extra cost of doing business in an extractive industry. Plausible mitigation needs to be specified. In order to provide plausible mitigation, a theory or a set of propositions that can link empirical observations needs to be made.

It is acknowledged that what goes on at the local level in these communities is embedded in national, political, and economic structures. To some degree they must be taken as givens. But out of those givens, particular types of mitigation may be possible to tease out of careful empirical works

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FAMILIAL STRUCTURAL RESPONSES TO CYCLICAL FATHER ABSENCE: THE OFFSHORE FAMILY

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This research explores the familial adaptations to the father/husband's cyclical absences. It involved a sample of 147 offshore oil families.

Before discussing our findings in detail, we must call your attention to the problematic notion of assigning types. Some families will obviously be a good fit, while many more of them will be located on a continuum somewhere close to a specific type. We are not, therefore, saying that each of our families is an exact fit to the type to which they are assigned. Rather, we are saying that their behaviors lean more to those of one type than they do to another. If we created a type to which every family could be matched exactly, we would have 147 types, and the research would be useless. We identified seven types of adaptations to cyclical father absence among families of offshore oil workers (Table 11.1).

The first adaptation identified was that of traditional authority, occurring almost 49% of the time with an n of 72. These families tended to pass the authority back and forth between the parents, allowing both parents active participation in family life. When the offshore oil worker is present, the wife relaxes her authority so that it may embrace his role as decision-maker. However, they are not in an egalitarian relationship. The wife takes on both traditional male and female roles during his absence, but when he returns, he assumes only the male role, leaving her to carry on traditional female tasks. The most important reason for the success or failure of this adaptation lies in the willingness of the mother

Table 11.1. Types of Familial Structure/Adaptations Among Offshore Oilworkers.

Familial Structural Adaptation	N	Percent
Father/Centered	(100)	(68.03)
Traditional	72	48.98
Replacement Kin	3	2.04
Contingent Authority	25	17.01
Role Reversed	(30)	(20.41)
Marginal Father	30	20.41
Egalitarian	(6)	(4.08)
Egalitarian	6	4.08
Conflict	(11)	(7.48)
Terminal Conflict	3	2.04
Habitual Conflict	8	5.44
TOTAL	147	100.00

to relinquish her hold on all of the authority and assume a shared role in the authority of the family.

The second adaptation identified was that of the marginal father, occurring 20% of the time with an n of 30. In this situation, the wife/mother has taken on both the traditional male and female roles in both the absence as well as the presence of the offshore oil worker. She makes all the decisions regarding the family, with no real involvement on the part of her husband, who is treated more as a guest than as an active participating member of the family. His role has been reduced simply to that of "breadwinner." One wife is reported as saying:

> "I've taken on more of the controlling role than he has because he's always kind of left things up to me...[His working offshore] has given him that shadows effect. He's there but he's that shadow in the corner."

In fact, this adaptation is easy to achieve with the occurrence of cyclical father absence and causes one system of authority: that of the wife/mother. Our marginal father is similar to Forsyth and Gramling's "periodic guest," which occurs among merchant seamen. However, because offshore oil workers have schedules that rotate far more frequently that those of merchant seamen, it seems extreme to term the offshore oil worker's stay as "periodic."

The third adaptation identified is contingent authority, which we found to occur 17% of the time with an n of 25. Here, the wife has been GIVEN (by the offshore oil worker) the authority to make only minor or emergency decisions in his absence. Usually, he returns to resume all authority and responsibility for the functioning of the family, and the wife steps back to make no real decisions without first obtaining his stamp of approval. If major decisions must be made during the offshore oil worker's absence, one of two things occur: he is contacted by phone, or the decision is avoided, put off until his return. This is especially true of child discipline, as illustrated by the common threat, "Just wait till your father gets home." That threat in turn yields its own difficulties when the offshore oil worker returns to a list of problems and complaints that he may choose not to deal with. Children in families exercising contingent authority then possess unusually high levels of power as a result.

The conflict adaptation was found to occur 7% of the time with an n of 11. This category is further subdivided into two groups: terminal conflict (n=3) and habitual conflict (n=8). The primary characteristic of families associated with terminal conflict is that the marriage has ended in divorce due to ongoing unresolvable conflict. Usually terminal conflict occurred after having failed at another adaptation. In one family, it appears that the wife was attempting to exercise contingent authority, but the stress proved to be too much for her husband of 14 years.

> "Whenever you get home, you need to unwind, but instead, my wife was always in my ear telling me that when the boys got home I had to get on them for this or that. I hated myself for some of the times I spanked my sons, but she was on me so much, so long about getting them, that I would lose my head for the littlest things they had done. Instead of making our time together quality, I was taking my frustrations out on them."

Those families using the habitual conflict strategy are involved in much ongoing tension and conflict as well, yet the conflict is largely controlled. These partners have "agreed to disagree," and therefore never resolve their problems, nor are they seeking separation or divorce. One woman put it this way:

> "My husband and I have argued for years about finances and disciplining the children...He wants to lay back and do nothing and I want him to get involved...We don't seem to agree on anything, but we're still married."

A fifth adaptation identified among our sample was that of the egalitarian family, occurring 4% of the time with an n of 6. The literature suggests that egalitarian relationships occur only between couples in which both partners are professionals, but our findings show that the literature may have sold the working class short. Offshore oil worker families using this adaptation have divided the responsibility and authority in the family equally between the parents. Unlike the husbands in families using traditional authority, these men assume traditional female tasks while at home--such as the care of infants and children, cooking, cleaning and shopping. All of the families we identified as egalitarian had two wage earners although not all would be considered professionals. In all cases, both spouses were employed full-time, and at least one spouse had a father who was an offshore oil worker or was involved in another father-absent occupation. We believe this is important because negative childhood memories related to the work schedule of the father have inspired these spouses to consciously avoid the same unhappiness from occurring within their families.

The final adaptation identified was that of the replacement father, occurring 2% of the time with an n of 3. These families live close to relatives, and essentially a male relative "replaces" the offshore oil worker during his absence. In all our cases, the male was either the father or brother of the husband, and he would fill in as disciplinarian, handyman, etc. In other words, he filled in for the traditional male role usually occupied by the father. Forsyth and Gramling found this adaptation to be primary in their research with merchant seamen, but we find only an infrequent occurrence among offshore oil workers. We believe this is so because the offshore oil worker returns too frequently to foster such an adaptation. Most of the families interviewed never considered such an alternative because the father would be returning shortly. There were many instances where replacement kin would occur in cases of emergency, but we believe there is little difference in this action and that of shore-based occupations and their families. Also, the increased reliance on kin by dual-career couples is not typically considered to be a replacement kind strategy.

Our findings are consistent with the findings of others, indicating that nonstandard scheduling is a problem for families, and although offshore oilworkers' scheduling is unique, the problems encountered by these families may or may not be. In some families, the absences necessary for working offshore for many reasons (social, interpersonal, economic) will come to be defined as appropriate; in others they will not. Certainly work scheduling is problematic as is obvious simply from the literature on commuter couples and nightworkers. And as the availability, cost and quality of day-care interacts with scheduling--different adaptations will result. This is one set; those identified by Forsyth and Gramling with merchant seamen were another. Ours are similar, but also different because merchant seamen really illustrate only the replacement father and periodic guest adaptations while offshore oil workers' have a wider range of strategies. All are traceable (except perhaps conflict) to these people because of their individual backgrounds. Further research will be systematically looking at these backgrounds quantitatively. Table 11.2 denotes our findings and recommendations on types of stress created by father absence.

A NOTE ON THE EFFECT OF SOCIAL STRUCTURE ON CULTURE

Much has been written about the traditional culture of South Louisiana. Before the drilling for oil offshore began nearly half a century ago, the patterns of life in this culture fit the traditional man concept. One of the characteristics of this traditional culture of Acadiana has been the focus upon extractive economy (fishing, hunting, farming, trapping, etc.), first as an occupation, which facilitated well the lack of, or need for, social mobility. Being self-employed in an extractive occupation allows one to set his own schedule or rather work when he only wants to or needs to.

The greatest intrusion upon this culture has been the drilling for offshore oil. Not only did it bring in more rational views and its accompanying need for social mobility, but it brought with it a unique work schedule. But the demand for offshore oil workers was such that workers were able to quit anytime they wished to participate in their extractive occupation. Offshore oil workers would quit during shrimping season to devote full-time to the occupation they enjoyed. As the offshore rig facilitates fishing, the industry preserved this traditional culture. Another type of scheduling would have destroyed it. With the bust in the oilfield, this ability to quit disappeared. The supply of workers vastly outnumbered the demand; consequently the oil worker could not quit the job for two months and expect to get another job when his recreational job was over.

Table 11.2. Types of Stress Created by Father Absence.

1. Separation from children.

2. Uncontrolled home environment.

   a. The more involved the father is, the higher is this stress.
   b. The less involved the father is, the lower is the stress.

Problem: The less involved the father is, the greater the risk to the family during unemployment.

Problem: Retirement.

RECOMMENDATIONS

Family

Make literature available for families of offshore workers.

Community and Industry

The effect of culture on structure is important to offshore oil. No other culture is so attracted to it. The effect of structure on culture is important to communities. It allows distanced communities to survive. It also allows the culture to exist.

Policy

Need to consider both of these factors (culture and structure).

Examples:

1. Trend to pay in lump sum may affect marginal father.

2. Limiting shrimping has effect on lifestyle, then culture, and may alter structure. Offshore work may no longer be attractive.

Has offshore oil, which was accommodating to this traditional aspect, yet eroded another cultural trait or will culture reemerge when the structure is more accommodating? The past tells us that these cultural traits will disappear, never to return. Only a resurgence of the U.S. oil industry will give us an answer.

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POVERTY DURING BOOM/BUST CYCLES AND SOCIAL SERVICE RESPONSE

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Alexander Godunov, Mikhail Baryshnikov, Rudolph Nureyev--names associated with stages in New York, San Francisco, possibly Chicago, Washington D.C., maybe New Orleans--but Lafayette, Louisiana? Yet between 1982 and 1986, each of these internationally acclaimed ballet superstars appeared on the stage of the Lafayette Municipal Auditorium (now Heymann Center for the Performing Arts) through the auspices of the Fine Arts Foundation. How could this be? The answer is simple--oil.

And oil means money, lots of money. In March of 1981, Lafayette's oil money captured the attention of the New York Times.

> With oil selling at $37 a barrel, and investors consequently rushing to put money into drilling for that oil, once-in-a-lifetime fortunes are being made by those engaged directly in the oil business, and by those capitalizing on the prodigious, oil-induced growth of Lafayette itself (Stevens 1981:4).

By June of 1986, however, oil was selling for $9.39 (Oil and Gas Journal Data Book 1988:1). The boom was over. By summer of 1988, the Fine Arts Foundation was no more (Brabant 1989). In 1989, The New York Times Magazine (King 1989) described Lafayette as "Bad Times on the Bayou." The present research shifts away from front stage Lafayette to the back streets, the world of the poor. How did the fluctuations in oil and gas activity impact poverty? An oft quoted biblical statement suggests that the poor are always with us (cf. Matthew 26:11). Did poverty disappear during the boom? And the bust--what happened then, with respect to needs and response?

The time frame for the study, 1970-1990, includes both the period before the oil embargo, the rapid escalation in the price of crude oil following the embargo, and the subsequent decline in price. Basic need is defined as the necessity of individuals to go outside of kin or informal neighborhood networks in order to obtain food, shelter, or clothing. Four

*As presented by Dr. Robert Gramling

parishes were selected for the study: Lafayette Parish, the administrative center of offshore oil; St. Mary Parish, high blue-collar involvement; Calcasieu Parish, directly impacted by oil and gas but with greater economic diversity; and Ouachita Parish, a parish impacted only indirectly by energy related activity. Data were collected in three ways: in-depth interviews with persons in both public and private settings who work or worked with individuals needing basic assistance; agency statistics; and newspaper accounts. In all, 50 interviews were completed between July 1989 and May 1990. Twenty-nine interviews were conducted in Lafayette Parish, the central focus of the study, six in St. Mary, eight in Calcasieu, and seven in Ouachita. Informants are identified by number only.

PRE-BOOM POVERTY

The majority of the pre-boom poor were the underemployed. "Clients who received food stamps had jobs but did not earn enough money to support them, their families independently of food stamps" (#7); they were "illiterate, those who had menial jobs with lower incomes without any hope of being able to rise above that" (#1). They were the elderly, "who are always with us on the food stamp program" (#6), and "on rare occasions we'd have a working class family that may have had an extreme setback of some kind" (#11). White informants tended to see the poor as predominantly black; black informants tended to see them as mixed. For the most part, however, the pre-boom poor across all four parishes were similar. They were local people, they were uneducated, and they lacked skills.

BOOM TIME

A member of a prominent family commented, "It was really a boom time here in Lafayette for everyone...we all reaped rewards in business and so that just rippled out to everyone. It was a good time all those years" (#50). Not everyone, however, enjoyed the good times. "[For] the people who could respond with skills, it was all right. But there were some people in Lafayette that never had the required skills, and never got in on the oil boom" (#14). For the elderly poor, boom times made poverty even worse. "The cost of living went up...[and] that bled finances" (#45). For those on fixed income and those whose incomes were relatively low, housing was also problematic unless they owned pre-boom. The impact of the boom on minorities was mixed. An informant in Lafayette Parish commented: [the oil industry] did hire a few blacks, but it was just the minimum and the same thing with women...it was only to meet quotas." One in St. Mary Parish remarked, "it was mostly whites who were in the oil industry; a handful, only a handful of blacks who really fought their way in" (#43). The impact on blacks in Calcasieu was more positive. Parish differences may well be attributable to the type of industry. For Lafayette and St. Mary, industry was primarily non-union. Plants in Calcasieu "employed a lot of construction workers" and these workers were unionized; "the unions came in and gave them [blacks] these jobs" (#32).

"As the oil industry made a plea for workers and the word got around that if you go to Lafayette, Louisiana, anybody can get a job, people came from all over. Many of these people had been unemployed for a while and they came on foot, they were hitching rides here. When they came here they were penniless... We had families living in cars. We had people sleeping in ditches. We had people sleeping anywhere downtown and the police would pick them up and try to find a place for them to go" (#14). In the early days of boom, most found work. The manager of Job Services (state employment) recalled that "it was practically impossible to furnish the oilfield people with the personnel that they needed to do what they wanted to do while prices were high... they wanted warm bodies, right. They didn't bother too much about physical exams and things like that" (#47).

In October 1981, National Enquirer described Lafayette as "Boom Town, USA" (Mullins 1981). The nation was in recession, and several informants (#13, #29, #41) felt this article influenced the under and working class, particularly those fleeing the "rust belt." Some hitchhiked in. Others came in "regular cars like a recent model appearing to be in good condition" (#13). Still others came in cars "just barely chug-a-lugging, you know, but they finally made it down here. Yeah, they did have some old beat up vehicles" (#41). "Some were just old cars packed to the – I mean like something you'd see in movies or something, things hanging out the windows it's so stuffed. And trucks. I remember that! Trucks just being loaded down with people's belongings" (#13). There are many stories of those who got jobs, settled down, and then tried to help other newcomers (#48). Some, however, fell into the clutches of the labor camps.

> They'd bring them to the job site, they'd work there during the day and then they'd bring them back to the labor camp at night so they could sleep. When it came time for their pay checks, they owed for the bed they

> slept in at night, they owed for their meals. They wouldn't get a check, you know, they'd work a whole week and then they'd maybe end up with $10 cause naturally they were selling their cigarettes at a higher price than what they paid for them (#2).

The labor camps exemplify the worse case of human exploitation. Even when there was no exploitation, however, hardship stories abound. Families sleeping in cars were common in both Lafayette and St. Mary (#11, #2). Both parishes also saw the emergence of "tent cities" which sprang up on the outskirts of towns as newcomers streamed into the area (#13, #42). Some people resorted to living in "store and locks" (#14). Some slept in the open. "They would sleep next to the air conditioners, wherever there was a closed area, in the corner, in the back of the shrubbery by the church" (#41). There were problems other than housing. "Some families didn't have transportation so that posed another problem" (#13). In addition, the nature of offshore work (cf. Gramling 1989) compounded problems by separating families. Then it was 1982 and the market shifted.

THE BUST

Among the first to be hurt were those who were the last to come. Some came too late to get a job. Others, only recently hired, were the first to be fired. Previous welfare recipients lost jobs and had to return to food stamps. In addition, a class of people who came to be known as the "new poor" was born. Both the backgrounds and the time of emergence of this "new poor" vary across parishes. For St. Mary Parish, the layoffs at McDermott and Avondale in 1982 signalled the end of the boom (#2); for Calcasieu, it was the closing of the petrochemical plants. The "new poor" became evident somewhat later in Lafayette Parish. Like the "new poor" in other parishes, they had made huge salaries in the oil industry. Unlike the others, they were likely to be white-collar and many were highly educated. The bust was a great equalizer. The common characteristic of the "new poor" was not type of job or income. It was that they had never been poor before. Homelessness became commonplace. As the crunch began to affect the middle and upper class, domestic workers lost their jobs (#11, #12). The bust had begun in 1982; by 1986, the boom was over for everyone: the poor, the near poor, the middle class; the rich; and the very, very rich; and then the poor. As one informant put it: "It's affected everybody. I guess that'll be the best way to explain [it]" (#12).

THE AFTERMATH

One of the impacts of the bust often noted in the boom town literature is the loss of population. Although there was some out-migration, it was not as high as the literature would suggest. For some, staying meant changes in living arrangements. Some moved in with relatives, "Everybody's living with everybody. I don't mean sexually, I mean families moving in together" (#11). For some, however, just the opposite took place. "When the oilfield crunch hit back here it took a lot of hard working men and put them into depression. They lost their families because they couldn't keep up their house note anymore" (#40). For other couples, role reversal enabled the family unit to survive. A food stamp worker in Lafayette commented, "I have more men now...receiving food stamps" (#8). Another stated "most of the time it's the woman who's working. Some men will come in, some men still won't come in, so the women will take off" (#9). Workers at other agencies in the parish also report men coming in for help for their families (#16, #48). In July 1989, a local newspaper reported "a modest recovery" (O'Donell 1989:19). Unemployment rates were down, employment was up. Comments from those who work with the poor, however, reflect a picture that is not so optimistic. "All of these jobs that are available now here are part-time. That means you're offered nothing" (#12). The cultural prescription against moving away from family may be creating a new Appalachia. One informant when asked "What has oil done for this area?" responded: "Well, it made it and then it broke it" (#18).

COMMUNITY RESPONSE

Many characteristics ascribed to other areas impacted by extractive industries apply to the three oil/gas impacted parishes presented in this research. These include rapid population growth, increased cost of living, inability of traditional systems; i.e., kin or neighbors, to meet basic needs in crisis situations and the suddenness and unexpectedness of the bust (cf. Gulliford 1989). There are, however, some unique aspects of the Louisiana boom/bust cycle, particularly with regard to social service response.

First, as a result of the Civil Rights movement and the War on Poverty, a number of community-based organizations were already in place prior to the boom/bust period. This presence proved to be extremely important. The structure, scope, and guideline limitations and constrictions of national organizations; e.g., Salvation Army, often made it difficult, if not impossible, for these programs to meet the changing flux of poverty.

In addition, there was a second factor unique to Southern Louisiana. Programs inaugurated and carried out by individuals, regardless how good intentioned and well meaning, are often doomed to failure. Sheer physical and emotional exhaustion is often a problem. In addition, new programs are highly susceptible to destructive criticism on the part of those with other agendas. Lafayette, St. Mary, and Calcasieu were unique in that a powerful bureaucratic entity was already in place. This entity, the Roman Catholic Church, served to give both credence and organizational structure to several attempts to serve the poor. In addition, the Civil Rights movement of the late 1960's created networks between Protestants and Catholics that facilitated both the development of programs and subsequent networking.

No matter how good the programs or how dedicated the workers, it takes money. The presence of two federally funded programs, Food Stamps and Federal Emergency Management Administration, were critical. The individual pain brought about by the bust should not be minimized. It was terrible. Without these programs, however, it would have been even worse.

MAJOR FINDINGS

1. Poverty is associated with both the boom and the bust periods.

2. Poverty across the boom/bust cycle is characterized by heterogeneity.

3. The creation of poverty continues after the boom/bust cycle is complete.

4. The impact of the boom/bust cycle in southern Louisiana was ameliorated by factors unique to the time period and area.

IMPLICATIONS

1. Carefully controlled leasing of mineral rights could minimize social costs both to individuals and to communities. Massive growth inevitably ties local economics to the vicissitudes of the commodities market. Leasing less area over longer periods of time would result in more stable economic and employment conditions.

2. Communities impacted by offshore drilling of mineral rights should be monitored. This monitoring should include but not be limited to cost of housing, cost of food, and changes in food stamp eligibility determinations.

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THE SOCIAL AND ECONOMIC IMPACT OF OFFSHORE OIL EXTRACTION AND PRODUCTION ON INVOLVED COMMUNITIES

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The State of Louisiana and its offshore waters have been increasingly involved in the exploration, production and use of oil and gas throughout the mid-20th century until very recently. Involvement has included the economic activities required to locate and extract these fossil resources. Workers at all levels of the occupational hierarchy have had to be hired to plan, manage and implement these activities, which include the manufacturing of the needed equipment, the use of the equipment for exploration and production, the transport of the resources to on-land points of use and finally to process them either for use as an energy resource--gasoline--or as a raw material for petrochemical manufacturing.

Such economic activities are not accomplished without related activities occurring in the other realms of the society. The economic activities occur in particular locations--communities situated within particular counties of particular states. These units must each adjust to the changed and enhanced economic involvement with the resource. All social institutions within them are likely impacted by an economic activity when the magnitude of it is sufficient, especially when its relative magnitude vis a vis other economic activities in the same area is great. Government, education, social services, religious organizations, recreational, and of course other economic activities such as retail trade, housing and services all must adjust. Likewise, the individual members of the local society are affected as are the smaller social units such as families, social groups and neighborhoods.

Some of these effects of oil activities on the other realms of the society are clearly evident and require little study to understand. Sheer demand for more housing for workers coming to the area seeking employment is an obvious impact. However, other impacts require closer scrutiny because of the complex and less than obvious way in which they respond to the enhanced economic activity (even obvious impacts require examination of specific dimensions such as the timing of the impact, the distribution of the impact, the differences of the impact for offshore extraction as opposed to onshore, the effect of advance/decline phases of the extraction activity, the areal extent of the impact, etc. Further, less obvious is the differential manner in which particular aspects of the economic activity affect other parts of the society. And, there is the difficulty in ascertaining the mechanisms by which the oil activities have their impact. This paper (1) examines three important ways in which offshore oil activity might affect communities involved with them and in so doing (2) explores these less obvious aspects of the impact process.

SOCIAL IMPACTS

Three types of social impacts have been examined: social disorganization, long-term human capital development and the economic health of communities. Social disorganization of a community or other social unit is evident when individuals or groups are not functioning normally; i.e., when the usual expectations within the various life realms are not realizable for the members of the community. When this occurs tensions mount that result in a reaction on the part of individuals or groups. Two measures of such social disorganization are suicide--when the individual determines that problems are not solvable in another manner rather than to remove himself permanently--and homicide--when the individual resorts to violence either to accomplish his goals or because of frustration in not being able to. With the changes communities experience with the growth and decline of oil production when it is a significant portion of the economy, it is expected that social disorganization would occur.

The enhancement or suppression of long-term human capital is a second way in which it is proposed oil production would impact communities. One argument would be that the heightened economic activity accompanying oil production encourages the youth of the community to remain in school in order to take full advantage of such opportunities. The opposite argument would be that job opportunities would dissuade students from believing that they need additional education. The two measures that we used to examine this questions were high school dropout rates and percent of students going on to college.

The third measure of social impact is the economic health of the communities. While it would be expected that growth in oil production would contribute to the economic health of communities involved, it may be more problematic than would be expected. The oil activity may impact various aspects of the economic health of a community differentially. Also, the economic health of the community may vary over the phases of exploration and production. Three measures of economic health were examined: transfer payments, income and migration. Transfer payments included income maintenance including Aid to Families with Dependent Children and unemployment insurance.

OIL INVOLVEMENT

Three independent variables were chosen as indicators of the oil industry activity: average price per barrel in constant dollars, Louisiana offshore oil production (in barrels) and Louisiana Division Outer Continental Shelf exploratory wells (actual number of wells). These measures may vary in terms of the type of economic impact they reflect: increases in jobs, increases in state and local revenues, etc.

DATA

Louisiana parishes involved in oil and gas activities were used for this analysis. They were compared with a group of Louisiana parishes not involved. Two criteria were used to determine which parishes were highly involved and which were minimally involved: (1) the percentage of people working in the parish who were employed in oil and gas extraction, manufacturing and wholesale trade in 1978, 1981, and 1984 and (2) the percentage of total income of the parish residents that came from wages and salaries from oil and gas activities including processing in 1984. The twelve parishes with the highest average rank were considered highly involved parishes and the 11 with the lowest average rank were defined as minimally involved.

METHODS

Time series analysis was done using multiple regression with the lag of the dependent variable included to account for autoregression, which is common in time series analyses. In addition, the graphs comparing the involved and minimally involved parishes were examined to see how changes in the oil activity were associated with changes in the social variables.

RESULTS

Time series analysis indicates that the effects of the oil variables are more likely to be significant in the highly involved parishes and the models, including oil variables, explain more of the variance in the highly involved parishes. Also, production is more related to social impacts than is price or wells.

For social disorganization the graphs suggest that increases in oil activity are socially disruptive. Suicide rates in the highly involved parishes surpassed those of the minimally involved parishes when at least one of the oil variables is at a high level. Homicide rates in the highly involved parishes increase in the year immediately following a peak in at least one of the oil variables. Thus, social disruption, as measured by homicide rates may be only temporarily disruptive.

High production, when not accompanied by high prices and large numbers of wells, increases long-term human capital, especially in the most involved parishes. The percentage of students completing high school increases during times of high production. When production is high, the percentage of students seeking higher learning is higher in the most involved parishes.

Indicators of economic health are less stable but at more favorable levels in the most involved parishes. Welfare dependency, as indicated by transfer payments, is lower in the highly involved parishes as long as oil activity is at a high level, especially high prices and a large number of wells. Per capita income is higher in the highly involved parishes but rises and falls with the levels of oil activity, particularly price and the number of wells. Net migration is also strongly affected by oil activity but only in the highly involved parishes. Increases, particularly in price and number of wells, increase in migration while decreases in the same measures stimulate rapid migration out of these parishes. Involvement in the oil industry increases the economic health of the highly involved parishes but only as long as the industry is highly active.

IMPLICATIONS

Both positive and negative impacts from oil activity are evident. It is important to anticipate such impacts, to understand how they are caused and to determine mitigative actions that might be possible for the negative ones.

FINDINGS

1. Social disorganization is increased by high levels of oil industry activity.

2. Long-term human capital is increased by increases of production but may actually be decreased by high prices and high numbers of wells.

3. Economic health of both involved and uninvolved parishes is helped by production but high prices and high numbers of wells only help the highly involved parishes.

IMPLICATIONS

It is necessary to address the negative social consequences of oil involvement and ways they might be mitigated.

It is important to understand the ways in which the negative impacts may be caused by different aspects of oil involvement.

It is important to consider ways in which the positive effects of oil activity can be enhanced in order to counteract the negative effects.

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THE IMPACT OF THE RECESSION IN OUTER CONTINENTAL SHELF ACTIVITY ON THE PROVISION OF PUBLIC SERVICES BY STATE AND LOCAL GOVERNMENT IN COASTAL LOUISIANA

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Louisiana, since the time of Governor Huey Long (1928-1932), has developed an intergovernmental system with the Governor at the center of the stage, fiscally and otherwise. With the large amounts of oil and gas severance tax revenues coming to the State, he had the ability to ensure local support of his policies by spending generously in local districts at his discretion. The State provided a wide range of services, many in the health and welfare field (e.g., old age pensions) that were not available in other States without Louisiana's revenue base.

Over the same period of time, the legislature kept the units of local general purpose government (parishes and municipalities) from having or exercising real home rule powers. These restrictions, many of them constitutionally embedded, have not only limited local government initiative, but, especially in the field of local taxes, have kept the local governments in a subordinate position to that of the State. This is true even now, although the State adopted a "new" constitution in 1974 to replace a very obsolete 1921 version. Despite the presence of a textbook statement on home rule (Article VI), the new constitution carried forth longstanding restrictions on local government revenue-raising ability.

As a result, the local governments in Louisiana have traditionally provided only the most basic and non-controversial of public services, mainly physical facility construction (roads, bridges, drainage systems) or mandated regulatory functions (courts, police and fire, coroner, assessor). Louisiana did have social services at the local level, but they were provided directly by the State (Charity Hospital) or indirectly by the State through contract to private providers such as church or non-profit groups. As they were able or inclined, some of the local governments made small appropriations to these type organizations in recognition of the need that they were meeting, but the initiative in social services has been almost exclusively that of the State.

So long as the severance revenues kept increasing, the situation was near idyllic: low personal taxes and a variety of services. When the oil bust hit, however, the bubble burst. State revenues declined over $1 billion in 3 years, only partially offset by $700 million in new taxes in 1984. Local government revenues dropped as well: many of the coastal parishes received proportional severance revenues remitted by the State. Public services at the local level began to show signs of stress as the State retrenched to meet its constitutional obligation of a balanced budget. The State, commencing in 1986, balanced its budget by "temporarily" suspending exemptions for food and drugs from the State sales tax. These exemptions remain in force in 1990 and are slated for renewal in 1991. Local units of government were impacted and there was concern as to the nature and extent of the damage.

In an attempt to determine just what had been the governmental and service provision impacts of the oil crisis on Louisiana units of local general purpose government, requests for information were sent to each coastal parish through the planning body for the parish. The same requests were sent to both selected cities and municipalities using the same channels. Many local purpose governments have skeletal staffs; to ensure that the request for information was completed, personal contacts in the planning and economic development were used to get a good response rate. About 70% of the parishes and 4% of the municipalities responded. The following summarizes the reported impacts.

Many impacts on local government were structural. First, the number of "special taxing districts (or areas)" has proliferated. Parishes indicated that voters preferred "earmarking" increased taxes to specific areas and purposes as opposed to paying into the general fund. These project funds now exist in great profusion and exercise oversight over parks, libraries, recreation facilities, drainage districts, sewer districts, fire protection districts, and on and on. The local general fund is increasingly forced to subsidize these funds at year's end, a classic example of "the tail wagging the dog." Earmarking revenues has greatly limited the amount of discretionary monies available to the local elected officials. Increasingly, parish and city officials preside over a diffuse administrative structure where some funds are well-supplied and others run dry and need help but inter-fund transfers of funds are controversial and often legally blocked from occurring.

Parishes and cities report having done everything they could to cut expenses. Layoffs were common; privatization or contracting out was practiced, especially in solid waste management; and all operations were reviewed for possible cutbacks. Virtually all local financial support provided on an optional basis to support social services was eliminated as a matter of necessity. Many local areas have consolidated city-parish operations or even, as in Houma-Terrebonne, consolidated governments. Where consolidation has not occurred, municipalities and parishes often squabble over municipal plans to annex unincorporated territories to ensure that they, not the parish, will have the sales tax collections as these areas develop. Tax competition is on the rise.

Planning and strong central management could paint a different picture for the Louisiana coastal parishes, but this does not seem to be in the offing. Central local authority has been seriously diluted by the proliferation of special districts with their own boards and dedicated sources of revenues. In fact, it often occurs that the special districts pay better than does the local unit of general purpose government and hires away some of the more talented and able local government personnel. Public understanding of their local government is lessened since the proliferation of special project accounts and districts makes the public focus only on an awareness of "their districts" to the exclusion of others and the general government. Planning is difficult under any circumstances, virtually impossible in a multi-headed non-system.

Louisiana coastal parishes stand on the verge of having more monies pumped their way as wetlands restoration monies from the Federal government and increased severance tax revenues seem all but assured. Much of this will doubtless be wasted on physical projects of dubious merit without much consideration of other alternatives, especially in the area of social services where local governments have not been comfortable or well established anyway. Recommendations as to a cure would be difficult to encapsulate. A look to our sister State of Florida, which now mandates local planning, which is then summarized and coordinated on a regional and State basis in furtherance of State objectives, including a strong environmental protection function, would be a good place to start. Such initiative is not likely to emanate from the State government at the highest levels after so many generations of "laissez faire" and in the face of threats by companies to leave the State if regulated to that degree. The Federal government cannot mandate such planning, but it might look to the discontinued 701 planning assistance efforts of yesteryear as a model whereby planning might be assisted by a Federal conditioning of fund receipt on the presence of such planning.

FINANCIAL IMPACTS

- Local governments completely unable to make up financial void left by State's fiscal retrenchment and end of revenue sharing.
- Overtaxed general funds at local level are being used to subsidize increasing number of project specific categorical funds.
- Centralized control over number of project funds and their rate of expenditure is very questionable.
- Many capital projects shelved since 1984 now being built especially since creation of dedicated State highway trust fund.
- Any discretionary money left is largely devoted to local economic development: good interparish coordination lacking.
- "Earmarking" of revenues via creation of special taxing districts is accelerating due to voter acceptance of idea.
- Parish municipality competition for tax base is accelerating.
- Local governments are all but inactive in the provision of social services.
- State greatly reduced its expenditures on social services.

ORGANIZATIONAL IMPACTS

- Central executive control at local government level is eroding as special districts and project activities have great control over their revenues and expenditures.
- Consolidation of governments is a viable option, but the fiscal benefits of consolidation not sufficient to offset deficits.
- "Row Offices" (coroner, courts, sheriff, etc.) impacted much less greatly by reduced revenues than general fund activities.
- Planning at local level now more equivalent to capital improvements programming rather than consider alternative futures.
- Social service provision almost exclusively in the hands of private providers at local level. Little local funding.
- Accountability to public for expenditures is lessened due to diffusion of governmental oversight to projects districts.

SOCIAL IMPACTS

- Outmigration from state and coastal zone will result in loss of one Congressional seat in reapportionment.
- School dropout rate unacceptably high.
- Massive need for environmental betterment to offset years of drilling and exploitation activity.

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OFFSHORE LEASING ACTIVITY AS CORPORATE STRATEGY

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The offshore Gulf is an important oil producing region that is close to refineries and pipelines that serve the huge U.S. market. Despite the geographical advantages of the Gulf of Mexico, decisions that govern petroleum exploration and production in the region are made by companies that operate within the larger political economy of worldwide energy. Recent changes in the international energy picture include increased control of oil reserves by producer nations followed by a period of higher oil prices (1973-1981), and then a fall in prices, beginning in 1982 and accelerating in late 1985. Oil prices remained low until Iraq invaded Kuwait in 1990.

The U.S. oil industry needs to shrink, and many analysts believe it is still overcapitalized (Jensen 1986; Financial World Staff 1990:35). Industry expansion, including big exploration and production budgets between 1974 and 1984, was driven by high oil prices, the anticipation of still higher prices, and a desire to circumvent OPEC production controls and U.S. price controls. Declining oil demand and economic recession in the early 1980's put many oil firms at risk financially although profits remained relatively high (Jensen 1986:326).

Repositioning of integrated multinational oil companies during the 1980's frequently took the form of mergers, asset purchases, stock repurchase and reorganization. A primary goal of many mergers between 1982 and 1988 was to unload low profit assets to increase return on existing assets, and to purchase oil reserves cheaper than drilling for them, with the anticipation that higher oil prices would eventually increase their value (Adelman 1986; Financial World Staff 1990:38). Mergers of this type include Texaco's purchase of Getty Oil in 1983, Mobil's purchase of Superior Oil in 1986, and BP's purchase of SOHIO in 1987 (Van Lear 1989:149). The largest oil merger ever, Chevron's purchase of Gulf Oil for over $13.2 billion in 1984, and Chevron's purchase of Tenneco's offshore holdings in 1988, also fall into this category (Mack 1989:52). A large number of similar mergers involved large integrated independent oil companies that purchased other independents. Examples include Occidental Petroleum's purchase of Cities Service, Philips purchase of General American in 1983 and Aminoil in 1984, Sun Oil's purchase of Exeter in 1984, and Amoco's purchase of Dome Petroleum in 1987 (Van Lear 1989:149).

When these mergers are considered in light of recent patterns of offshore lease purchases, two types of corporate strategy emerge. One group of companies, including Exxon, Marathon, Amoco, and Mobil has concentrated on restructuring for short-term profitability and pursuit of opportunities outside the Louisiana-Outer Continental Shelf (OCS) region. High levels of debt and concern about corporate takeovers may motivate the retrenchment in the Louisiana-OCS positions of some companies. Exxon in particular has reduced its U.S. exploration and production budget by 31% since 1985 (Welles 1990). Exxon spent an average of $228 million per year on Louisiana OCS leases from 1978 to 1984, and only an average of $21 million per year since 1985. At the same time, Exxon has spent $15.5 billion to repurchase stock and strengthen per share earnings (Welles 1990:72).

Shell, CONOCO/Dupont, Chevron, and Atlantic Richfield are examples of companies that continue to pursue growth strategies and have maintained or increased their presence in Louisiana OCS leasing, particularly in deep water exploration. Deep water drilling costs far exceed onshore or shallow water costs. Deep water drilling technology developed in the North Sea is now used in the Gulf of Mexico. Shell has been the most active company, spending three times as much money on offshore leases in the past three years as the second largest leaser (SOHIO/BP), leasing 38% of deep-water (over 1,500 ft.) acreage in the Gulf (MMS 1978-1990; Biesada 1990).

A third group of companies may be an essential part of the future of Louisiana-OCS activity. These firms include natural gas producers (e.g., CNG) that are expanding leasing activity to position themselves for potentially rich offshore finds, increased demand, and higher gas prices. A final potential for future offshore growth could be investment trusts that show signs of moving into Louisiana-OCS leases.

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Mr. Charles R. Lambert spent 35 years in the petroleum industry worldwide. As a District Representative for the Universal Oil Products Company, he served all major and independent refiners on the Gulf Coast. After six years as Plant Manager for the South Hampton Company, he became operating manager of Tenneco's Chalmette, Louisiana refinery. Mr. Lambert received his M.S. degree in sociology from the University of New Orleans in 1990.

COMMON THEMES OF SOCIAL INSTITUTION IMPACT AND RESPONSE

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It is our contention that the 1986 crude oil price collapse was the proximate cause of decisions by oil companies to reduce lease activity, drilling, and oil production in the Outer Continental Shelf (OCS) of the Gulf of Mexico. The collapse of offshore oil activity contributed to widespread unemployment and reduced investment in oil service and related activities central to the Louisiana economy. Our research explores the effects of the decline of offshore oil activity in the Gulf of Mexico on the social institutions of Louisiana. We analyze the Gulf of Mexico region within its macroeconomic and political context so that relevant industry and organization level strategies and contingencies can be properly examined. The various presentations investigate the interaction of integrated and independent oil companies, Federal and State government agencies, and public and private social service providers as they relate to the offshore oil industry. The familial adaptations of offshore oil workers and family members to the uncertainties of offshore employment and unemployment will also be addressed.

The 1986 oil price collapse culminated one stage of an unfolding transformation of the political economy of world oil and is part of an ongoing restructuring of the world political and economic order since 1970. The centrality of oil company investment strategies and U.S. government regulation and foreign policy concerns in producing countries was undermined by OPEC nationalism and subsequent nationalization of oil concessions that temporarily shifted control of oil supply and price to OPEC. The interaction of representatives of oil producing and consuming nations, multinational energy corporations, and U.S. independent oil companies contributes to subsequent restructuring in the oil industry worldwide. Changes in the distribution and extent of investment in offshore oil activity in the Gulf of Mexico are among the consequences of that restructuring.

Changes in the international oil industry and in Louisiana offshore oil activity interact with local political conditions and cultural traditions to produce effects on the social institutions and lives of Louisiana citizens. A common theme in our research is that it is important to examine local institutions and how they affect and are affected by changes in the global oil industry. State revenue, the system of social service delivery, and overall socioeconomic development in Louisiana, are all tied to oil, but existing political traditions, systems of social service delivery, and family adaptation also survive and affect the way global changes affect Louisiana.

It is especially important to assess the ways macroeconomic and political relations and organization level strategies interact with individual strategies and actions at the household or familial level. Individual aspirations are affected by change in the oil industry. Offshore oil workers perform dangerous and difficult jobs that can provide ample material rewards and high levels of job satisfaction. But economic cycles and industry restructuring can interrupt the flow of opportunities and rewards available from offshore employment. We address the ways offshore employment affects family interaction and well being, and the question of how unemployment of offshore workers affects family adaptation.

The oil industry is affected by the structure and dynamics of international finance, the international state system, and consumer demand for gasoline; and seriously affects all manufacturing industries, transportation firms, and utilities that depend on a stable flow of energy at a reasonable price. The degree of complexity and interdependence implied here makes clear the problematic nature of macro organizational interactions and the need to investigate the specific historical and cultural circumstances of economic development and change. The collapse of oil prices in 1985 had severe effects on all Louisiana social institutions, but the deeper causes of the collapse and a key to understanding its long-term consequences lie in the restructuring of the oil industry and the world political economy since 1973.

Restructuring of the American oil industry has featured centralization of management, finance, and business services, and the use of computer technology to reduce the number of field operating units. The result is streamlined organizations with fewer personnel in regional divisions like New Orleans and exploration and production districts like Lafayette, Louisiana. Oil industry restructuring has involved mergers that reflect the advance of a finance conception of control where the firm is seen as a bundle of assets that are managed to produce the maximum short-term profit. Mr. Lambert's presentation highlighted the various strategies of oil companies based on leases purchased since 1978. Certain firms (e.g., Exxon, Marathon, Cities Service, Mobil) have pulled back from purchase of Louisiana-OCS leases and spent money on other opportunities and on stock repurchase and debts accrued from mergers. Another group of firms (e.g., Shell, Chevron, Atlantic Richfield) have pursued a growth strategy that involves continued Louisiana-OCS activity. Overall, in the context of changes in the overall governance structure of the oil industry, predatory mergers and financial practices of investors in the United States may have exacerbated the disruptive effects of restructuring in the domestic oil industry on the purchase of offshore leases and continued development of OCS reserves. The continued expansion of foreign majors (e.g., Shell and BP) suggests that the national business culture of the United States may have created the unique pattern of mergers and company restructuring that characterize the oil industry here since 1982.

It is well known that the spatial distribution of employment and population are strongly affected by economic development (Gordon 1984). Economic development in Louisiana throughout most of the twentieth century is closely associated with the petroleum industry. Direct employment by Louisiana offshore oil producers in 1984 was estimated at 19,668, while the total number of Gulf offshore contract employees was 97,386 (Centaur 1986:2-103, 3-9). The ripple effect of direct employment and expenditure through the Louisiana economy is tremendous, and makes it clear that petroleum is the major industry in Louisiana.

Dr. Seydlitz's presentation analyzed the effects of oil and gas activity on a variety of demographic and social variables in a sample of Louisiana parishes that are strongly and weakly affected by the petroleum industry. Findings are complex, yet they suggest that oil industry involvement is associated with differential effects over time of oil prices, exploratory offshore drilling, and offshore oil production on indicators of social disorganization (suicide, homicide), and human capital development (high school dropout rates). Dr. Seydlitz outlined how, since 1956, high levels of involvement in the oil industry increase economic health of parishes when levels of exploratory drilling, price, and production are high or increasing. But each peak in an oil variable is associated with increased homicide rates in highly involved parishes; social disorganization is generally increased by high levels of the oil variables. Rapid economic change is disruptive of social life, but perhaps even more severe are the negative effects of declines in economic activity on population, employment, tax revenues, and local social service delivery.

The government intervenes in important ways to help organize and manage economic activity, and to legitimate existing institutions. The American government grew in size and scope after the great capitalist crisis of the 1930's. In the process, the importance of the State grew with respect to the economy and the organization of personal life. Redistribution of wealth and power through progressive taxation and the legalization of collective bargaining reduced overt conflict among labor, capital, and government. Regulation of oil production and prices by the states was instituted to stimulate economic growth and stabilize relations between American multinational and independent oil companies (Prindle 1981; Moran 1987). The modern welfare state was created and institutionalized, including programs to aid dependent children and provide social security (Piven and Cloward 1971). Government loan guarantees (Federal Housing Administration, GI Bill) and subsidies of interstate highway construction promoted suburbanization of the population and integrated the population through expanded working class consumption of houses, cars, and petroleum products (Ashton 1984).

The devaluation of the dollar in 1971, the Arab oil crisis of 1973, and the withdrawal of the United States from Vietnam are often cited as indicators of U.S. decline from worldwide dominance, and prominent causes of the worldwide recession of 1973-1975. Concurrent changes in technology, communication, and the international division of labor contributed to increased internationalization of economic activity and the centrality of multinational corporations as conduits of trade. The globalization of capitalism since World War II raises questions about the ability of the national state or competitive markets to organize and manage national economies. Between one-half and three quarters of American overseas trade is transactions within rather than between corporations. This is particularly true among multinational oil companies that produce and transport their own crude oil and crude oil purchased from competing companies or national oil companies; and then either refine and market the crude through a subsidiary or affiliate, or sell it to another company to refine and sell.

After the oil price shocks of 1973-1974, OPEC countries recycled increased oil revenue through United States and foreign banks in the Euro-currency, Euro-bond, and Euro-credit markets, which fueled a $260 billion lending boom to developing countries around the world. Bank capital flowed out of the United States, both to avoid American bank reserve laws and to secure higher interest rates available from credit hungry developing nations. The resultant inflation and the second oil price shock (1979-1980) hurt the U.S. economy. The government reacted to the financial crisis of high inflation, stagnant profit levels, and slow growth in the late 1970's by increasing interest rates and passing legislation to deregulate banks. The economic recession of 1981-1982 then created a crisis in the international financial system that hurt the U.S. economy.

The response of the Reagan administration to inflation and recession in 1981-1982 was a rejection of Keynesian demand maintenance policies like progressive taxation and redistributive social spending, and a movement to deregulate the economy, reduce real tax rates, and cut social spending. The idea was to enhance savings and place more money in the hands of investors to stimulate economic growth. Oil prices were decontrolled in 1981 and regulation of the nation's banks and savings and loans (S&Ls) was relaxed. Pressure has increased on State and local governments to maintain services the Federal government can no longer cover. In Louisiana, change in Federal policy was accompanied by the refusal of State government to continue traditionally high levels of per capita government spending, particularly funding of local services (e.g., many educational expenses, supplemental pay for policemen and firefighters).

Professor Thayer elaborates State and local conditions within which these macroeconomic and political changes play themselves out. Legislative attacks on executive power in Louisiana during 1970's and 1980's, and efforts to shift from oil and gas severance taxes to other sources of revenue undermined efforts of local government units to raise revenue necessary to handle increased demands on their shrinking budgets. Political traditions like opposition to local property taxes proved resilient to efforts at fiscal reform attempted by Governor

Roemer and his coalition. The solution has been expansion of special local and regional districts that dedicate tax money to transportation, education, flood control, and tourism.

Social service delivery at the local level is required during periods of expansion and decline in market driven resource extraction. Dr. Brabant shows how a combination of public and private sources of social welfare delivery serve the Lafayette, Louisiana area. Particularly the existence of a network of Church funded agencies and other private programs served the needy during periods of boom and bust in the local economy. Existence of local social service institutions mediates the negative impact of withdrawal of Federal and State funding of social services in Lafayette parish.

Family adaptation to the vicissitudes of offshore employment can be connected to instability of industrial employment as exacerbated by industrial restructuring as oil companies try to buffer themselves from uncertain market conditions. Families must make difficult choices between the immediate and potential long-term economic benefits of offshore employment, and the intrinsic occupational and personal hardships. Greater material rewards of offshore employment cause many men to choose offshore employment and then ask their families to adapt to the offshore lifestyle. Subsequent declines in opportunity create new problems that demand another kind of adaptation--adaptation to unemployment, inferior employment, more wives working, and adult children moving in with their parents. Again, the ability of many families in South Louisiana to adapt successfully is connected to local traditions of father absence to work in the fishing industry. Local culture mediates the effects of macroeconomic and national political processes on Louisiana families.

1. The effects of expansion and contraction of Louisiana OCS activity on Louisiana social institutions must be analyzed in the context of fundamental changes in the domestic and international oil industries as they occur within the global process of economic and political change.

2. The actual effects of Louisiana OCS activity on Louisiana social institutions are tempered and fundamentally depend on local economic, political, social, and familial traditions.

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Dr. Vern Baxter is Associate Professor of Sociology at the University of New Orleans. He received his Ph.D. in sociology in 1984 from the University of Wisconsin-Madison. Research interests include formal organizations, political economy, and social change. Research projects include a study of technological change and labor relations in the U.S. Postal Service, an analysis of interorganizational regulation of intercollegiate athletics by the National Collegiate Athletic Association, and a paper on regional holding companies in the electric utility industry.

PROJECT DISCUSSION

Dr. Shirley Laska
Environmental Social Science
Research Institute
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and
Ms. Vicki Zatarain
Minerals Management Service
Gulf of Mexico OCS Region

The final three presentations were by prominent sociologists active in this area, discussing the project at hand and future implications for the Minerals Management Service (MMS).

Dr. Robert Gramling discussed how the structure of the oil industry and the structure of local governments affect social impacts of coastal Louisiana, but also highly important is the Department of the Interior's MMS's policy on leasing. Between 1954 and 1978, an argument can be made that leasing was essentially a closed activity between the Secretary of the Interior and industry. Most of the leasing until the 1960's was in Louisiana and all in the Gulf of Mexico. There were no problems with local population objections since leasing offshore Louisiana was established in the 1920's.

In 1969, the Santa Barbara oil spill changed perceptions about the safety of offshore oil in the United States except in the Gulf. The Santa Barbara spill was considered facilitative of NEPA and the 1978 amendments to the Outer Continental Shelf Lands Act (OCSLA). In 1978, the OCSLA was amended and the assessments of effects of leasing on marine, coastal, and human environment were mandated. In 1974, following the 1973 oil embargo, the size of lease offerings was tripled. In 1982, the Secretary of the Interior combined the offshore functions of the Bureau of Land Management and U.S. Geological Survey to form MMS. Further, area-wide leasing was instituted and went into effect in 1983. Leasing is fundamental to social impacts. Much of the United States is now under a leasing moratorium by President Bush until 2000. The domestic leasing program is almost entirely in the Gulf of Mexico. A third structural variable to be entered into analyzing social impacts is the Department of Interior's leasing policy, scheduling of lease sales, and historic leasing.

Dr. William Freudenburg provided context and reactions. Impacts on human environment have not been systematically done. The purpose is not to prohibit development but to foresee negative impacts and mitigate. Four reactions to the Louisiana Universities Marine Consortium presentation are (1) promising first steps have been made; (2) on the basis of progress, there are no easy/cheap "fixes"; (3) the agency and the research community need to do more; i.e., focused research task; i.e., applied research to answer specific, narrow questions; (4) the links/conflicts need to be explored focusing on impacts of Outer Continental Shelf (OCS) development on the human environment.

Simple model to do this:

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OCS Activity --> Affected        -------> Impacts
                 o Individuals             (+ and -)
                 o Communities
                 o Regions
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The final speaker, Dr. Harvey Molotch, discussed the challenges of examining social impacts from OCS activity since there are no standard sources from which to begin. There is a need to separate the United States and World versus things local; i.e., the need to define what is distinctive to OCS activities. Secular trends in the United States since the turn of century include expanding public budgets. Cost of development (physical and social infrastructure) has been absorbed by government. In last decade, however, there has been a sharp cutback in public expenditures, which means that whatever happens, happens at the expense of a community. The community must deal with it. The community can deal with the cost of development through mitigation. Wealth should be drawn from the production process at the time wealth is extracted to minimize the paying for infrastructural cost of that development.

What is part of secular national trends must be isolated from what is peculiarly local. In what ways does development under these circumstances create peculiar problems for localities that perhaps can be mitigated? What about the nature of OCS activities lends them to mitigation? With an extractive industry, you are taking out a non-renewable resource and a bust is inevitable. It is suggested that there are mechanisms in place to provide bonding for lease abandonment; i.e., to remove physical infrastructure. Perhaps there is a way to generate an analogous fund to take care of social consequences; i.e., an extra cost of doing business in an extractive industry. Plausible mitigation needs to be specified. In order to provide plausible mitigation, a theory or a set of propositions that can link empirical observations needs to be made.

It is acknowledged that what goes on at the local level in these communities is embedded in national, political, and economic structures. To some degree they must be taken as givens. But out of those givens, particular types of mitigation may be possible to tease out of careful empirical works

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Dr. Shirley Laska teaches sociology at the University of New Orleans. She is currently Associate Professor of Sociology and Director of the Environmental Social Science Research Institute there. Her areas of interest and research are urban and environmental issues. Dr. Laska received her B.S. from Boston University and her Ph.D. from Tulane University.

Ms. Vicki Zatarain is an Economist in the Minerals Management Service, Gulf of Mexico OCS Regional Office of Leasing and Environment. She holds a B.S. in marketing and an M.A. in economics from the University of New Orleans and a B.A. in computer information systems from Tulane University. Prior to employment with the Minerals Management Service, she was an economist with the New Orleans District of the U.S. Army Corps of Engineers and a teacher of computer information systems. Her current research and analysis center on regional economic impacts associated with offshore oil and gas activity as well as design and maintenance of in-house leasing data bases.

NEW DEVELOPMENTS IN OIL SPILL RESPONSE AND RESPONSE PLANNING

Session: NEW DEVELOPMENTS IN OIL SPILL RESPONSE AND RESPONSE PLANNING

Co-Chairs: Ms. Darice Breeding
Mr. Dennis Chew

Date: November 15, 1990

Presentation	Author/Affiliation
New Developments in Oil Spill Response and Response Planning: Session Introduction	Ms. Darice Breeding and Mr. Dennis Chew Minerals Management Service Gulf of Mexico OCS Region
Update of Clean Gulf Associates' Spill Response Planning	Ms. Belinda V. Breaux ARCO Oil and Gas Company
Provisions of the Oil Pollution Act of 1990: U.S. Coast Guard Perspective	CAPT John E. Lindak U.S. Coast Guard
Coast Guard Oil Spill Response Research and Development for the 1990's	CAPT Donald S. Jensen U.S. Coast Guard Research and Development Center
Oil Pollution Research at U.S. Environmental Protection Agency	Mr. Kurt Jakobson Office of Research and Development U.S. Environmental Protection Agency
Results from Selected Oil Spill Response Research by the Minerals Management Service	Mr. Edward Tennyson Minerals Management Service Headquarters, Herndon, VA
In Situ Burn Research	Dr. David Evans National Institute of Standards and Technology
The Risk of Oil Spills from the Transportation of Petroleum in the Gulf of Mexico	Ms. Gail Rainey Minerals Management Service Gulf of Mexico OCS Region
Response for *Mega Borg* and Galveston Bay Oil Spills	CDR Philip Wieczynski U.S. Coast Guard
Logistics of the American Trader Oil Spill	LT John Meehan U.S. Coast Guard
Dispersant Use Logistics in the Gulf of Mexico	Dr. Gordon P. Lindblom Consultant
Minerals Management Service Unannounced Oil Spill Drill Program	Mr. Joseph R. Hennessey Minerals Management Service Gulf of Mexico OCS Region

(Continued)

Session: NEW DEVELOPMENTS IN OIL SPILL RESPONSE AND RESPONSE PLANNING (cont'd)

Presentation	Author/Affiliation
Update of Florida's Oil Spill Contingency Planning	Mr. John H. Holmead III Florida Marine Patrol Northwest Region
Update of Alabama's Oil Spill Contingency Planning	Mr. John C. Carlton Alabama Department of Environmental Management
An Update on Oil Spill Preparedness Activities in the State of Louisiana	Mr. R. Bruce Hammatt Louisiana Department of Environmental Quality
Update of Texas' Oil Spill Contingency Planning	Mr. David Barker Texas Water Commission

NEW DEVELOPMENTS IN OIL SPILL RESPONSE AND RESPONSE PLANNING: SESSION INTRODUCTION

Ms. Darice Breeding
and
Mr. Dennis Chew
Minerals Management Service
Gulf of Mexico OCS Region

In light of all of the recent tanker spills that have occurred in the U.S. coastal waters since the *Exxon Valdez* incident in March 1989, much effort has been expended from the national to the local level in assessing the adequacy of the country's spill response planning and response capabilities. In addition, the implementation of the recently enacted Oil Pollution Act of 1990 could greatly alter the country's existing oil spill response planning structure and response capability.

The mission of the Minerals Management Service (MMS) offshore program, as set forth in the Outer Continental Shelf (OCS) Lands Act, is "to balance orderly energy resource development with the protection of the human, marine, and coastal environment." Efforts to prevent oil spills and to provide a rapid and effective spill response capability on the infrequent occasions when spills from OCS operations do occur are necessary to fulfill MMS's stated mission. In response to this mandate, the MMS maintains a comprehensive oil spill program that includes contingency planning, training, announced and unannounced response drills, equipment, spill reporting, spill databases, and research.

This session was initiated to gain information that will be used to enhance the MMS oil spill contingency planning program. Recent information was solicited for these sessions on the following topics: (1) the status of State and Federal spill contingency planning, (2) ongoing and recently initiated plans for conducting federally sponsored oil spill research and development, (3) provisions of and plans for the implementation of the Oil Pollution Act of 1990, (4) the outcome of recent major spill response efforts, (5) initiatives underway by the Gulf of Mexico OCS oil and gas operator's oil spill response cooperative, and (6) the logistic considerations necessary for effective dispersant use. Another equally important focus of these sessions was to share information that has been gained as a result of the MMS unannounced oil spill drill program.

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.

Mr. Dennis Chew is a biologist with the Environmental Operations Section of the Minerals Management Service, Gulf of Mexico OCS Regional Office. He holds an M.S. in biological sciences and has worked as a marine biologist in the Gulf area since 1970, specializing in wetlands and fisheries. His responsibilities include review of oil spill information for exploration and development plans of action in the Gulf.

UPDATE OF CLEAN GULF ASSOCIATES' SPILL RESPONSE PLANNING

Ms. Belinda V. Breaux
ARCO Oil and Gas Company

Clean Gulf Associates (CGA) has embarked on a major capital program to assure adequate response capabilities to member companies' oil spills in the Gulf of Mexico. This program is part of an ongoing process of assessing and upgrading response capabilities according to the needs of members. Additions to the CGA stockpile include 4 identified boats equipped for ocean skimming, 18,000 ft. of open ocean boom, and 9,000 ft. of shoreline protection boom. In addition, modifications that result in improved response times and operability of equipment have been made to existing equipment. Further, studies are underway to investigate other potential areas of improvement.

BACKGROUND OF CGA

The CGA is a spill cooperative established in 1972 by 33 oil and gas exploration and production companies then operating in the Gulf of Mexico. Current membership includes 131 offshore oil and gas companies. The purpose of the organization is to establish a plan for containing and cleaning up oil spills of members involved in operations offshore.

The organization has purchased and maintains a stockpile of offshore oil spill cleanup equipment for use by member companies and provides operations manuals and training on the use of the equipment for each member company. Funds needed to maintain CGA are divided between the member companies based on a formula that takes into consideration each member's oil production. The amount and type of equipment stockpiled are predicated on the potential needs of the membership. The equipment is intended to handle the likely drilling or production spills, with worst case being a blowout situation. Equipment stockpiles are maintained at strategic locations throughout the Gulf coast.

Membership in CGA is limited to oil and gas operators in the Gulf of Mexico. Only companies engaged in the exploration and production of oil and gas within the given boundaries of the Gulf are allowed to be members; therefore, pipeline companies, marine transportation companies or other users of the Gulf are not members of CGA but may have access to CGA equipment through their oil and gas affiliate companies. Non-members may use CGA equipment upon approval by the Executive Committee. In fact, the largest spill response in which CGA equipment has ever been utilized was the *Mega Borg* spill, summer 1990. The CGA was in the process of adding to the equipment inventory prior to the *Mega Borg* incident, but experience gained in this event will be used to modify existing equipment in order to optimize performance.

The CGA is guided through the efforts of a full-time Executive Director and a voluntary Executive Committee made up of executives from nine member companies. Assisting the Executive Committee are the Legal, Accounting, Operations, and Technical Subcommittees as well as Ad-Hoc committees that are formed as needed. Halliburton Services, Inc. serves as the contractor to purchase and maintain the equipment, to provide supervisory personnel, to provide training, and to perform certain administrative functions. There are nine full-time Halliburton personnel dedicated to CGA, serving as Marine Supervisors and mechanics in addition to two administrative persons.

The initial equipment inventory in 1972 included one high-volume open-sea skimmer, one fast-response over-the-side skimmer, one shallow-water skimmer, 1,000 ft. of boom, and miscellaneous smaller items. At the beginning of 1990, the current CGA stockpile included the HOSS barge, 12 fast-response units (FRU's), 6 boat spray systems, 6 helicopter underslung sprayer systems, 39,875 gallons of dispersant, 3 self-propelled shallow water skimmers, several smaller skimmers and hand-held skimmers, 5,000 ft. of 36-inch nearshore boom, a communications system, a portable biological and chemical field sampling unit, a waterfowl rehabilitation station, bird scare guns, sorbent material, and miscellaneous accessory equipment. The current assets of CGA are on the order of $7.8 million, with a replacement cost of $14 million.

NEW EQUIPMENT

In February, 1990, CGA began consideration of certain upgrades to the stockpile. In order to keep in step with the needs of operators in the Gulf and to continue to improve upon our response capabilities, CGA has embarked on a major capital program. The additions to the CGA stockpile that are currently in progress include four skimming systems to be mounted on existing identified offshore service vessels (ID boats), open ocean boom, and shoreline protection boom. Further, a study has recently been initiated to assess the needs for adding two shallow-water skimmers to CGA's inventory.

An identified (ID) boat is a utility vessel under charter to an oil company in the Gulf on which skimming equipment is mounted by CGA for use by member companies as a first response to a spill in the area. The concept of mounting skimming equipment on dedicated vessels was considered, but the idea of mounting the equipment on a vessel that is operating offshore in critical oil-producing regions actually results in an improvement in response times over the shore-based dedicated boat.

The first ID boat has already been equipped and the legal and accounting issues are currently being resolved. The vessel is the MV *Cecilia C* owned by Gilbert Cheramie Boats, Inc., and currently under long-term contract to Shell Offshore, Inc., in the South Timbalier area. A skimming system including a crane, power pack, outrigger and boom, GT-185 skimmer (design rating 200 gpm), and 2,100-gallon oil separator are skid mounted on the vessel. There is also 500 ft. of Expandi 4300 open ocean boom stored on the vessel to be used for containment in conjunction with the skimming operations. A member company having a spill would call the Halliburton dispatcher for release of the ID boat and upon approval by a member of the Executive Committee or the Executive Director, Shell would release the vessel to respond to the spill. The ID boat would be the first responder to the incident until the CGA FRU reaches the location. Then the ID boat would be returned to service for Shell. The second and third ID boats are currently under fabrication with the CGA skimming equipment scheduled to be installed during December and January. A fourth boat is planned for the first quarter of 1991. Each of the ID boats will require an initial investment of approximately $400,000.

Another major investment by CGA is the purchase of 18,000 ft. of Expandi 4300 open ocean boom. Between 1,500 to 3,000 ft. of the boom will be stockpiled at each of the CGA bases. The total cost of the boom, including accessory equipment, is about $2.1 million. The basis for choosing the Expandi boom was that it is compactly stored and is easily deployed and retrieved. The boom can be deployed off the back of a workboat to contain an area of floating oil for subsequent skimming. As mentioned previously, an additional 500 ft. of Expandi boom will be located on each of the ID boats for rapid deployment at a spill site.

In addition to the open ocean boom, the Technical Subcommittee is in the process of selecting a shoreline protection boom. Approximately 9,000 ft. of the shoreline protection boom are to be purchased at a cost of approximately $300,000. The type boom being considered is a tri-compartment boom with two water-containing sections on bottom and an air-filled section above. The purpose of the boom is to isolate an oiled section of beach from a clean or biologically sensitive area to protect the adjacent areas from being oiled.

Another planned addition to the CGA stockpile is additional shallow water skimmers. A study to assess the needs for additional shallow water skimmers is currently being initiated. The criteria for choosing the type of skimmers will be determined as a part of this study. Depending on the study results and the approval by the Executive Committee, additional shallow water skimmers will be procured for the CGA stockpile.

EQUIPMENT MODIFICATIONS

In addition to the aforementioned items, several modifications to spill response equipment have been made that will significantly improve response capabilities. Modifications and improvements are made within CGA when situations and experience warrant. Many of the following modifications were made at the recommendation of operators after use of the equipment at either a training exercise or during a spill response.

Fast Response Units

Selected FRU's have been mounted on trailers to allow immediate deployment to a selected location. This change in procedures can reduce the time required to respond to an offshore spill by one to two hours, which was the amount of time previously required for locating trailers and moving the FRU with a yard crane at some CGA bases.

The manifold on the FRU pump - skimmer line has been modified to allow repairs and maintenance to be done while the equipment is offshore on a job. Previously, most repairs had to be done onshore, thus requiring the boat to leave the field. This modification results in a significant improvement in equipment operation.

Spare Parts Trailer

Another minor item that should significantly improve CGA dependability on a spill is the purchase of two spare parts trailers. These trailers will be used to stock frequently needed and difficult-to-locate parts and will accompany equipment as it leaves the CGA bases.

Dispersant Boat Spray System

The fabrication of storage boxes for the boat spray system will allow the spray bars to be stored in a partially assembled state, reducing the time required to install the system on a member's boat from 1.5 hours to about 30 minutes.

Also included on the list of assignments to the Technical Subcommittee is the assessment of the dispersant boat spray system for needed modifications based on dispersant application criteria. Input from dispersant experts will be sought by the committee in making recommendations for improving the spray system.

HOSS Barge

The HOSS barge was put in service in 1985, but until the *Mega Borg* incident this past summer, had never been in use during an oil spill. Experience gained during the spill has led CGA to begin some modifications to the barge. One modification that has already been implemented is an improved attachment system for the filter belts. Other items still under study include an emergency shelter area for crew, reduction of labor needs by changing the type of boom used, and improved communication and navigation systems.

Skimming Time

Another area of planned improvement is to investigate and incorporate methods for increasing the total number of hours per day that skimming operations can be conducted. Currently, skimming operations are limited to the daytime; however, CGA will be investigating ways to extend operating hours into the night. Some of the ideas to be considered include state-of-the-art tracking of oil slicks and improved illumination. The use of the Expandi boom in conjunction with the GT-185 skimmers will also be a method of extending skimming time throughout the night.

Communications Systems

An ad hoc committee has been authorized to assess the needs for communications systems for use by member companies in spill response. Experts from several oil companies will be sought to participate on this committee to develop a proposal for the upgrade of the CGA communications equipment.

BIOLOGICALLY SENSITIVE AREA MAPS

The CGA has been investigating possible sources for updating and improving on the maps of biologically sensitive resources located along the Gulf coast. A comparison of available and currently developing computerized systems that would also provide trajectory and dispersant decision making capabilities is being reviewed by an ad hoc CGA committee. A final recommendation has not yet been made by the committee.

AGREEMENTS WITH OTHER SPILL COOPERATIVES

The CGA has been pursuing agreements for sharing of assets between the other spill cooperatives in the Gulf, namely the Louisiana Offshore Oil Port (LOOP) and Marine Industries Group (MIRG). The LOOP has some small skimmers, but of primary interest to CGA is access to aircraft under contract to LOOP for dispersant application. The CGA and LOOP are discussing an arrangement for the sharing of the aircraft and the HOSS barge. The MIRG actually has minimal equipment but has developed through consultant S.L. Ross a computer model for dispersant use decision making that includes trajectory analysis for chemically dispersed and undispersed oil and a comparison of the biological effects on species within the predicted area for landfall. The MIRG and CGA have been discussing various arrangements whereby CGA could obtain use of the S.L. Ross model.

SUMMARY

In summary, CGA is continuing to assess its spill response capabilities based on member company needs and is making appropriate modifications and additions to the equipment stockpile. Significant new equipment purchases have been made in the past year and are underway for the near future. These include the new ID boats, open ocean boom, shoreline protection boom, and shallow water skimmers. Modifications to existing equipment are also made as indicated by the needs and experiences of member companies. Opportunities for cooperative efforts with other spill groups will continue to be sought out.

Ms. Belinda V. Breaux has been employed by ARCO Oil and Gas Company for the past six years and is currently the Supervisor of the Regulatory Compliance and Environmental Department in the Southern District. She is also serving as chairman of the Technical Subcommittee of Clean Gulf Associates and has been a member of the committee since 1986. Ms. Breaux received a B.S. in chemical engineering from Lamar University in 1981.

PROVISIONS OF THE OIL POLLUTION ACT OF 1990: U.S. COAST GUARD PERSPECTIVE

CAPT John E. Lindak
U.S. Coast Guard

Historically, the tasking of federal agencies has changed as the result of new legislation developed in reaction to a significant event. On the oil pollution front, for example, the first Oil Pollution Act of 1961 was in response to a national awareness of the damage done to the marine environment by oil pollution. In 1972, Congress amended the Federal Water Pollution Control Act (FWPCA) and developed the Ports and Waterways Safety Act, in light of the environmental damage from a number of vessel pollution incidents including the grounding of the *Torrey Canyon*. In 1977 the FWPCA was amended again to be more effective and renamed the Clean Water Act. The Port & Tanker Safety

Act that followed was developed after the explosion of several tank vessels in U.S. ports. Most recently, the *Exxon Valdez* and other events, including the *Mega Borg* spill offshore Galveston in June of this year, brought about the new Oil Pollution Act of 1990 (OPA90).

This new legislation will result in increased federal oversight of oil transportation. Specifically, it requires

a. New vessel construction requirements,

b. New crew licensing and manning requirements,

c. Enhanced facility/vessel contingency planning requirements,

d. Broader enforcement authority,

e. Enhanced response capability,

f. New research and development programs,

g. Increased penalties,

h. Increased financial responsibility for the spiller, and,

i. Establishment of a billion dollar trust fund to cover cleanup costs and damage not compensated for by the spiller.

More directly, the new legislation requires that the U.S. Coast Guard (USCG) organize a "District Response Group" and a "District Advisory Staff" to assist in response activities and contingency planning. It directs the U.S. Environmental Protection Agency and the USCG to develop "Area Response Committees." These are organizations defined by the legislation and headed by the Federal on-scene coordinator. They will include Federal agency and local and State government representatives with a charge to develop contingency plans for their areas. A new "National Response Unit" will work on training and logistical support for spill response and maintain a national inventory of response equipment. All tank vessels and facilities are required by OPA90 to have approved response plans for worst case spills. It requires that these plans be exercised regularly. In addition, all tank vessels and facilities are required to carry some response equipment. The exact amount will be determined during the rule making process. New USCG Buoy Tenders will be equipped with oil spill response equipment. The penalty provisions have been increased for civil and criminal violations for pollution. The Interagency Coordination Committee for Oil Pollution Research was defined by OPA90, and the USCG has been designated as the lead agency. Further, the increased emphasis on the use of chemical agents (dispersant and bioremediation) is cause for the development of new laboratory test procedures by this committee with the possibility of an applied test program.

This legislation will impact on several USCG programs and will require a significant increase in personnel to support its implementation. The Marine Safety program will have to implement the new double hull requirements; conduct a study to determine the economical and technological feasibility for single hull vessels to have structural or operational features that would provide the vessel with substantial environmental protection; establish minimum plate thickness requirements for tank vessels; and develop requirements for tank overfill alarms, tank level or pressure monitoring and vessel spill response equipment. The USCG has been directed to evaluate foreign manning standards to determine if they are equivalent to U.S. standards or to determine if international standards are acceptable to our government. Foreign vessels not in compliance with manning standards acceptable to the United States will not be allowed to enter U.S. waters unless under force majeure and the USCG is assured that they do not pose a threat to the environment. Crew members on tank vessels cannot work more than 15 hours in any 24-hour period or more than 36 hours in any 72-hour period. Mandatory drug testing of all applicants for Licenses, Certificates of Registry, or Merchant Marine Documents (MMD) will have no significant increase, as this program is already in place. However, as a result of the new five-year period of validity for MMDs and Certificates of Registry, the workload at USCG Regional Examination Centers (REC) will increase. Accessing the National Register of Drivers to look for previous incidents of alcohol abuse will also add to their workload. Review of applications for clemency due to the good record of individuals previously found to have problems with alcohol or illegal drug abuse and the increased emphasis on oil spill investigations to determine if the casualty was a result of inadequate manning, equipment, vessel or facility operations manuals, vessel or facility contingency plans and/or substance abuse will impact the workload of USCG Headquarters, the local RECs and the investigation departments at USCG Marine Safety Offices.

Significantly, in response to the *Exxon Valdez* grounding, the legislation mandates that a new study to determine where Vessel Traffic Systems need to be established and/or expanded. This study requires a specific focus on Prince William Sound.

In the past several years, the USCG has been tasked with additional responsibilities, including the enforcement of various MARPOL Annexes, increased emphasis on maritime drug interdiction, additional inspection programs, new readiness responsibilities (an example of which was the breakout of Reserve Fleet vessels in support of Operation Desert Shield) and increased tasking of USCG resources in support of major oil spill cleanup operations. Previously, these increased responsibilities were met without additional personnel. OPA90 authorizes an increase of some 360 new USCG billets and the financing of new response equipment. With the personnel and equipment increases authorized under the OPA90 and the support of the public and industry, we will strive to meet the challenges presented in the oil spill arena during the 1990's.

CAPT John E. Lindak is at present serving as the Chief, Marine Safety Division, Eighth U.S. Coast Guard District, New Orleans, Louisiana. This district extends from St. Marks, Florida, to Brownsville, Texas, and includes seven U.S. Coast Guard Marine Safety Offices. He serves as the Co-Chair of the Region VI Regional Response Team. CAPT Lindak is a graduate of the U.S. Coast Guard Academy and the University of Maryland with an M.S. in chemical engineering.

COAST GUARD OIL SPILL RESPONSE RESEARCH AND DEVELOPMENT FOR THE 1990's

CAPT Donald S. Jensen
U.S. Coast Guard
Research and Development Center

INTRODUCTION

On March 24, 1989 the *Exxon Valdez* ran aground on Bligh Reef in Prince Williams Sound producing the largest oil spill in U.S. history. Several reports have analyzed the *Exxon Valdez* spill and called for upgrades in oil spill response strategy and technology. This call was repeated by Congress in the comprehensive Oil Pollution Act of 1990. The U.S. Coast Guard (USCG) concluded that additional effort was necessary to revisit research and development (R&D) efforts of the past, and implement an updated R&D strategy to improve the USCG's capability to deal with catastrophic spills.

DETERMINING TECHNOLOGY NEEDS FOR SPILL RESPONSE

To define areas better where response capabilities are inadequate and where further R&D efforts could upgrade these capabilities, the Marine Environmental Protection Division at USCG Headquarters convened a workshop on August 7-8, 1989, to review and analyze response operations conducted during the *Exxon Valdez*, the *World Prodigy*, and the *Presidente Rivera* spills. Spill response planning and management, initial response, containment, cleanup and disposal, and damage assessment functions were addressed. Of the 50 capability shortfalls identified, 32 were handed off to the R&D program for further effort. The need for further efforts in the spill planning and management area was identified and can be summarized as the need to (1) compile accurate and accessible information for decision support, (2) refine contingency planning methodology, (3) validate contingency plans, and (4) upgrade spill response training programs. In the initial response area the need to (1) improve surveillance capability to stabilize a damaged tanker and (2) remove, contain, or dispose of the oil on or near the ship was identified. In the containment, cleanup, and disposal area, the need to (1) improve mechanical recovery, (2) improve shoreline cleanup, (3) define chemical countermeasures technology, and (4) develop a capability and protocol for *in situ* burning of oil was identified. The needs identified for further effort in the damage assessment area included the need to (1) develop damage assessment protocols and (2) develop a system for long-term effects monitoring.

NOTE: The views expressed in this paper are the author's alone, and should not be construed to reflect the views of the USCG, the Department of Transportation or any other government entity.

CURRENT COAST GUARD OIL SPILL R&D PLAN 1990-1995

Given the output of the August 1989 workshop with the USCG On-Scene Coordinators (OSC), and the feedback obtained from a September 1989 interagency workshop on oil spill R&D held at the USCG R&D Center, USCG R&D set about devising an oil spill R&D strategy for the 1990's. This program has been further modified according the mandates and direction of the Oil Pollution Act of 1990. The program focuses on four major areas: spill planning and management, spill surveillance, tanker countermeasures, and spill countermeasures and cleanup.

Spill Planning and Management

This portion of the USCG R&D effort recognizes the potential improvements in spill response capability that could be gained through better contingency planning, better training, and more rapid and better informed decision making, particularly during catastrophic spills.

A fundamental element will be to analyze USCG spill response strategy and operations during recent spills to define a more effective organizational structure for catastrophic spills. Requirements will be identified for a catastrophic spill management system including databases and a Decision Support System (DSS).

This requirements analysis will lead to development of a standardized methodology for risk assessment and contingency plan development and review. Contingency plan methodologies developed for other purposes (e.g., nuclear power plant accidents) will be reviewed to determine applicability for spill response. Current USCG field unit contingency planning methods will also be studied to determine requirements. The ultimate goal will be the development of a computerized expert system approach including tools for scenario development and risk assessment, databases for contingency planning, decision matrices for predicting required response actions, and analytical models for examining the adequacy of spill response resources. Database development efforts are currently underway with National Oceanic and Atmospheric Administration, Environmental Protection Agency, and Minerals Management Service (MMS), and will be coordinated with other agencies interested in the development, maintenance, and use of these databases. Currently being considered are

1. historical database capturing knowledge from past spills,
2. technical experts database,
3. oil properties and behavior database,
4. environmental effects database,
5. chemical countermeasures (dispersants) database,
6. sorbent materials database,
7. cleanup equipment capabilities database,
8. logistics planning database, and
9. health and safety database.

In the area of spill response training, a technology assessment effort will investigate available methodologies and technologies, such as interactive video training modules that could enhance resident and field training. Another study will investigate advanced methodologies and systems for operations simulation and evaluation (such as those used by the Department of Defense and Federal Emergency Management Agency) to determine applicability to the Regional Response Team/OSC simulation exercise program. The study will specifically look at how these tools could be used better to structure, document and analyze the exercises and provide a quantitative measure of readiness.

Additional efforts include investigation of innovative systems and technologies for transmitting information, and determining the position and status of resources employed during spill response (e.g., use of satellites for tracking spill response units). Also included is a study to investigate and analyze the health and safety issues associated with spill response and the development of protocols for insuring personnel protection.

Spill Surveillance

In responding to any large spill, it is essential that the OSC know the location, areal coverage, and general physical condition of the oil to deploy cleanup resources effectively and protect environmentally sensitive areas. To provide this information, a 24-hour, all weather surveillance capability is required. This program element will focus on the development, test and evaluation, and implementation of an upgraded oil spill remote sensing capability in the USCG. Two approaches will be taken; the first will be the integration of this capability into a multi-mission successor to the current single mission AIREYE system. A comprehensive study is underway to determine USCG mission requirements for airborne (aircraft or satellite) surveillance and to explore technologies currently available (specific sensors and platforms).

An analysis will then be performed to define a system configuration based on optimized multi-mission performance, cost, and availability. Once the defined system is approved by the various USCG program managers, efforts to design, build, test, and evaluate a prototype platform/sensor package will proceed. A parallel approach will support the ongoing development of the next generation of oil specific sensors such as the laser fluorosensor and laser thickness sensor currently underway in Canada.

Tanker Countermeasures

This portion of the project recognizes that the best response strategy is to eliminate or minimize the threat of pollution at the source. The *Exxon Valdez* response demonstrated this as 80% of the cargo was off-loaded from the vessel using the USCG-developed, air deliverable, anti-pollution system (ADAPTS). This prevented a much greater environmental disaster from occurring.

It is recognized that the money saved by ADAPTS over the years, in value of recovered oil and prevention of costly cleanup efforts, has more than paid for the entire USCG pollution response R&D program. With this in mind, a significant emphasis is being placed on tanker countermeasures. The goal here is to develop a suite of integrated technologies to assess rapidly the degree of damage and resulting stability of the polluting or potentially polluting vessel, to contain product in the vessel, transfer product to another vessel, and to inhibit the spread of product away from the source.

Two studies are underway to define better the R&D efforts in this area. The first is being conducted by the National Research Council's Marine Board under USCG sponsorship. This study is investigating oceangoing tanker designs; it will recommend rules and standards to improve hull resistance to penetration during collisions and groundings and reduce outflow of oil should the hull be penetrated. The second study is being conducted by the USCG R&D Center to assess the USCG National Strike Force (NSF) capability to stabilize and off-load damaged tankers and identify where systems and equipment can be upgraded.

To support tanker damage survey operations, a technology assessment effort will investigate in-tank and remote (electromagnetic and acoustic) methods of determining oil/water interface levels in tanks, the nature of the hull damage, and the integrity and strength of the vessel structure as a result. Improvements to ADAPTS, such as lighter weight and smaller pumps, prime movers, couplings, and hoses and techniques and equipment for easier transport and deployment will be investigated.

Following a review of the recommendations and guidance from the Marine Board study, another effort will investigate the development of systems that can be built into tankers and activated by the crew following a casualty to prevent or minimize the loss of oil. An earlier study (Ross 1983), indicated that tanker self-help countermeasures suffered from technological constraints. However, given the high potential payoff in this area, this technology must be revisited. Such systems will include vacuum systems to introduce a negative pressure in the tank head space to slow the leaking of oil, redundant piping and high volume transfer systems (similar to ADAPTS) to allow for rapid cargo transfer despite damage and loss of ship's power, onboard plugging and patching equipment, in-tank gelling agents, and automatically deployed spill containment systems. In addition, the feasibility of in-tank flexible membranes will be investigated to prevent leakage in the event of small punctures and cracks.

Finally, experience gained from the deliberate destruction of several vessels in Alaskan waters indicates that in some cases destruction of the vessel is a viable option. This effort will assess the tools for carrying out *in situ* destruction operations; review the legal, safety, and environmental issues; and develop a decision support guide for the OSC.

Oil Spill Countermeasures and Cleanup

This portion of the R&D program will seek to improve the USCG's overall capability to recover the spilled oil and mitigate its impact. Several studies have been undertaken to assess the current capability and define areas where further R&D work can improve this capability.

An initial study took a comprehensive look at the alternative system approaches to recovering spilled oil including modular, air-deployable systems as currently used by the USCG National Strike Teams; dedicated skimming vessels; vessel of opportunity skimming systems (VOSS) for USCG vessels; and pre-positioned spill response barges such as those employed by cleanup cooperatives. A second study surveyed USCG National Strike Team recovery systems and commercially available systems and equipment to see if the recovery process could be de-bottlenecked through improved viscous oil pumping, debris handling, and oil-water separation.

Once promising systems and pieces of equipment have been identified, test and evaluation will follow to see which of these can be integrated into the current NSF inventory. Also, innovative techniques for oil/water and emulsion separation and improved techniques and equipment for temporary storage of recovered oil will be investigated. Several interesting prospects for oil/water separation have already been identified. Possibilities for temporary storage include lighter weight, easier to deploy dracones; lightweight (Zodiac type) containment barges for very viscous oil and debris; and pre-staged rigid hull, conventional barges.

A feasibility and system definition study is currently being conducted to identify portable VOSS systems that can be rapidly installed on the USCG harbor buoy tender replacement. This is a follow-on study to a previous system definition study for the coastal buoy tender. Once these specific systems have been identified and acquired, efforts will proceed to verify system capability and delineate engineering design details that must be considered in the buoy tender acquisition.

The USCG is also joining with the MMS, U.S. Navy, Environment Canada, and potentially other government agencies to develop standard test protocols for oil spill cleanup equipment and to provide support for reactivation and operation of the Oil and Hazardous Materials Simulated Test Tank (OHMSETT) facility in Leonardo, New Jersey. Candidate systems and equipment, including both commercially available systems and equipment, to define best available technology and innovative techniques requiring follow-on R&D will be identified for test. This test and evaluation process may include at-sea testing of systems and equipment that have performed well at OHMSETT.

An option for the recovery of smaller spills, spills in confined areas, and for shoreline protection is the use of sorbents. A survey is underway to identify available products on the market and compile a user database of product characteristics and effectiveness, application techniques, and disposal techniques, which will ultimately be incorporated in the DSS.

The USCG R&D is participating in an interagency effort to study the viability of *in situ* burning as a response technique. Parameters such as oil type, temperature, degree of weathering, and emulsification will be studied and the production and dispersion of airborne contaminants will be characterized. The effort includes a series of mesoscale tests (2,000-3,000 gallons of oil) at the Fire and Safety Test Detachment in Mobile, Alabama, followed by at-sea burns (15,000 gallons) in a cold water location (possibly Newfoundland) and a warm water location (probably Louisiana). In addition to providing funding and the test facility, the USCG will provide logistics support for the Louisiana at-sea burn. Concurrently, a study will be initiated to define the legal, environmental, and safety issues associated with *in situ* burning and to develop a decision protocol for the USCG OSC. Parallel efforts by other agencies will investigate technologies such as the addition of chemical additives and water spray injection to reduce the smoke and particulates from burning.

Although the USCG does not intend to develop additional oil spill chemical countermeasures (dispersants, gels, elastomers and surfactants), it will monitor the efforts planned by other agencies. The USCG OSC must have concise and accessible information on the effectiveness, toxicity, and application requirements for these chemicals to decide if a particular chemical can be used in a specific spill situation. A study is underway to collect and analyze all available information on effectiveness, toxicity, application procedures, product availability, and past experience at actual spills for all chemical products currently listed in the National Contingency Plan Product Schedule. This information will be formatted and verified for completeness and accuracy, and compiled in a maintainable computer database that will become part of the DSS.

CONCLUSION

As a result of recent major spills, USCG R&D has identified a number of areas where oil spill response technology needs to be improved. In cooperation with other government agencies and industry, a long-term R&D effort is being formulated to address these needs. The final level of success will depend on the limits of the technology itself, but also on the continued level of national interest and funding for R&D in this area. Although it is unlikely that any level of R&D can insure complete recovery of a spill of *Exxon Valdez* proportions, an aggressive, revitalized R&D program in oil spill response should reduce the threat of catastrophic spills in the future and ensure a far more effective response should such spills occur.

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OIL POLLUTION RESEARCH AT U.S. ENVIRONMENTAL PROTECTION AGENCY

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During the early 1970's, the U.S. Environmental Protection Agency (EPA) sponsored a major oil spill research and development (R&D) program in conjunction with the U.S. Coast Guard (USCG). This research was primarily aimed at developing and demonstrating mechanical devices that could be deployed, following a spill, to contain and remove the spilled oil. This program, which produced a variety of technologies, continued at a reduced level until 1987 because other priorities commanded the available resources. At that time, it was decided that continuing the effort at the level of funding available would produce little new information.

The Ashland spill in January 1988 and the *Exxon Valdez* incident in 1989 highlighted the shortcomings of the spill control equipment used and of the remedial measures taken. These incidents emphasized the need for development of new oil pollution control technology and procedures for the objective assessments of the environmental risks associated with both the spill and the cleanup activities.

The Alaska oil spill demonstrated that the nation's capacity to respond to large spills on a short-term basis is limited. The United States borrowed equipment from several nations, including the USSR and Mexico. Several of the constraints were logistic; however, mechanical and chemical response techniques for recovering oil and for remediating the contaminated environment suffered from inadequate scientific and engineering knowledge.

Shortly after the spill in Price William Sound, EPA initiated the Alaska Bioremediation Project. The objective of this project was to demonstrate the feasibility of augmenting, in an environmentally safe manner, shoreline cleanup by accelerating natural microbial oil degradation processes through the application of fertilizers. Results of field activities in 1989 proved that bioremediation was feasible, but indicated the need for further study.

In 1990, the project addressed three additional needs. First, it assessed the risks and benefits associated with Exxon's application of oleophilic fertilizer to 415 subdivisions (approximately 34 miles) of oiled shoreline. Second, the project is seeking to advance the understanding of the science of bioremediation as it applies to oil spill cleanup. Third, a range of commercial products is being assessed for their applicability to shoreline cleanup.

To date, results on risks and benefits are very encouraging. Results of toxicity testing have shown no toxicity associated with fertilizer application. Specifically, there has been no significant difference between survival of mysids, which are shrimp-like crustacea, maintained for 96 hours in seawater taken from treated and untreated segments of shoreline. A single application of fertilizer has been shown to increase the rate of oil biodegradation by two to three times over the rate on an untreated shoreline. This accelerated rate has been sustained for several weeks, even after nutrient concentrations return to background levels.

Research pursuant to advancing the understanding of bioremediation is ongoing. Projects are investigating the optimal concentrations of fertilizer needed to maximize degradation of oil, more effective strategies for delivery of nutrients to microbial populations, and improved analytical procedures for the determination of oil degradation. Preliminary results indicate that the maximum fertilizer concentration tested, 500 grams per square m, has produced the highest level of microbial activity.

Two commercially available products not previously evaluated for effectiveness on the Prince William Sound shoreline are being field tested. These products were judged the most promising by an expert panel assembled for EPA by the National Environmental Technology Applications Corporation of the University of Pittsburgh. The panel reviewed information that was provided by 39 vendors, as well as data collected by the our laboratory on 10 of the products. The two products selected for field testing contain naturally occurring microbes.

Another lesson that has been learned over the past 20 years, and which was reinforced by the two major recent spills, is that no single Federal agency has the expertise or resources to handle all aspects of oil spill prevention, containment, and cleanup. The overall objective of EPA's oil pollution research program is to provide the On-Scene Coordinator (OSC) at a spill on inland waters with the scientific and engineering data required to choose the most cost-effective and environmentally sound option for dealing with a spill under a variety of conditions and to do so within very limiting time constraints. These options include technologies for removing oil, as well as methodologies for determining the effectiveness of the removal process and the potential environmental damage caused by the process. This data, together with the methodology for determining the potential environmental risk associated with the spill itself and the cleanup process, will provide the OSC and other decision-makers with the information needed to determine whether or not to attempt a cleanup operation and at what point to terminate the cleanup.

The EPA's oil pollution research program will focus on four areas. These are (1) development of biological and chemical cleanup techniques, (2) development of cleanup operation monitoring techniques, (3) development of mechanical cleanup techniques for inland spills, and (4) development of methodologies for environmental risk assessments. A short summary of the proposed research in each area is shown below.

BIOLOGICAL AND CHEMICAL CLEANUP TECHNIQUES

Research to determine the effectiveness of chemical and biological processes for cleaning beaches and shorelines affected by a spill is a major component of the proposed research. This research includes the development of protocols for evaluating the efficacy and toxicity of a variety of chemical and biological agents designed to be used under various conditions to remove oil spilled into the water or from beaches, marshes and shorelines. Upon completion of these protocols it will be possible to evaluate commercially available products as part of the listing procedures provided for in the National Contingency Plan, and to have this information available to the OSC at the time of a spill.

In addition to the development of the protocols and their validation under field conditions, research is needed to provide the scientific underpinning for the use of these types of materials. This research must include a laboratory to determine how the degradation process takes place as well as an examination of the products of the degradation process. Engineering research is also required to optimize the application methods to be employed under various geographic conditions.

CLEANUP OPERATION MONITORING TECHNIQUES

Consensus has not been reached to determine when the cleanup operation begins to produce more environmental damage than the spill itself. The monitoring of a cleanup operation requires an understanding of the processes that affect oil spill behavior. To provide this information, research will be performed to refine and validate microcosm models used to assess impacts of spills in different environments. This research will eliminate the need for testing each type of cleanup technique in each different environment. In addition, research is required to provide response personnel with simplified analytical tools to monitor the progress of a cleanup operation. These include the identification of benchmark oil components that are easy to measure, the development of biological indicators to assess cleanup effectiveness, as well as improved methods for chemical analysis in the field.

MECHANICAL CLEANUP TECHNIQUES FOR INLAND SPILLS

The National Contingency Plan gives EPA the responsibility for providing an OSC on oil spills in inland waters. Although most of the technology and information needed to remediate these spills is similar to that required for coastal environments, one unique requirement has been repeatedly demonstrated. Mechanical oil spill containment devices used on the high seas or in coastal environments fail when used on fast flowing rivers and streams usually found inland. Research is therefore required to develop and demonstrate effective techniques for controlling the spread of oil in streams moving at a rate of more than one knot. In addition, research is required to demonstrate technologies suitable for removing oil spilled into bodies of water that are either partially or entirely covered with ice.

ENVIRONMENTAL RISK ASSESSMENT

The circumstances surrounding the recent series of oil spills have underscored the inadequacy of current risk assessment methods for estimating the effects of oil spills on public health and the environment. The EPA research will complement the efforts being undertaken by the National Oceanic and Atmospheric Administration. Specifically, research will be conducted to develop improved methodology for assessing the risks to human health and the environment from oil spills (real and hypothetical) into sensitive areas. In addition, methodologies must be developed to determine the economic damages caused by such spills. For critical estuarine areas, studies will be conducted to allow the prediction of the potential impact of a spill before it occurs. This information will be developed for various spill scenarios involving different types and quantities of oil spilled and different locations within the estuary. This information, together with information in existing fate and transport models, will be provided in the form of an impact assessment protocol that can be used to update local contingency plans and in the event of an actual spill.

Much has been learned during the twenty years since the Santa Barbara oil spill, which initiated EPA's original oil spill research program. A great deal of the hardware in use today resulted from this research and that sponsored by other Federal agencies such as the USCG. Events of the past two years, however, have pointed out that there is still a great deal of work to be done in order to provide the scientific and engineering know-how required to deal with spills under a variety of conditions. Congress recognized this need when they wrote the Oil Pollution Act of 1990, which was signed by President Bush on August 18th. It is now up to all of us to provide the answers so that we will be prepared when the next big spill occurs.

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RESULTS FROM SELECTED OIL SPILL RESPONSE RESEARCH BY THE MINERALS MANAGEMENT SERVICE

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INTRODUCTION

Recent large oil spills from tankers have reaffirmed the need for continuing technology assessment and research to improve oil-spill response capabilities. The Minerals Management Service (MMS) remains a lead agency in conducting these studies. This paper discusses MMS concerns, as reinforced by the acceleration of its research program in 1990. It briefly describes assessment of the current state-of-the-art technology for major aspects of spill response, including remote sensing, open-ocean containment, recovery, *in situ* burning, chemical treating agents, beachline cleanup, and oil behavior and the reactivation of the Oil and Hazardous Materials Simulated Environmental Test Tank (OHMSETT) facility.

A number of factors have to be considered in the evaluation of the adequacy of spill response. These include sea-state and weather conditions, type of oil, size of spill, elapsed time from spill to response, presence of ice, and level of response effectiveness. Readiness includes the siting of sufficient equipment and trained personnel to address spill response issues. A major aspect of preparedness is the state-of-the-art technology of existing equipment and procedures, including capabilities for detection, containment, recovery, disposal, alternative responses; e.g., chemical treating agents and *in situ* burning.

DETECTION

Practical oil spill detection is still done by visual observation, which is limited to favorable sea and atmospheric conditions and is not possible in rain, fog, or darkness. Airborne remote sensing packages have been developed using side-looking radar, infrared and ultraviolet/false color cameras. These systems are not resources usually available to responders.

The MMS research (Tennyson 1988) has produced a method of specially tuning shipboard navigational radar to track oil spills under all, except extremely rough, sea conditions. This technique has been used successfully on three successive oil spills.

This detection technique has been successful in locating spills as small as 5 barrels out to a distance of 12 nautical miles. It depends upon harmonic resonance of X-band radar as a result of back scattering from short (approximately 5 cm) wavelength wave trains. These waves occur at sea in wind velocities from approximately 3 knots up to hurricane force winds. In repeated trials offshore Nova Scotia in 1987, the presence of significant breaking seas coupled with large swells (above 1.5 m) obscured the slick. It is unclear whether this was a wave-induced phenomenon or whether the small slicks were rapidly dissipated and no longer detectable. Fog and rain had no effect on detection. There is an apparent correlation between slick thickness and the radar image. As the slicks dispersed to sheen thickness, the radar imagery became less distinct.

Before the radar technique can become a reliable operational tool, additional research is necessary to correlate slick characteristics; e.g., slick thickness and sea conditions with the radar presentation. The completion of an MMS/Esso Research Ltd., Canada, and Environment Canada (EC) research effort to design and evaluate an airborne laser thickness sensor for oil slicks will help provide additional information.

The airborne laser thickness sensor for oil slicks has been thoroughly evaluated in the laboratory, and a system potentially can be made flyable within the next 2 years. Airborne remote sensing packages cannot discriminate between areas of a slick that are thick enough to recover and portions too thin for reasonable response effort. Observations indicate that slicks do not dissipate uniformly at sea. The majority of the oil remains in small areas of concentration compared to the total area of the slick. Future studies will address the airborne sensor's capability to transmit rapidly the location and configurations of the thicker portions of the slick to the responder in real time.

Existing remote sensing packages routinely indicate false slicks as potential oil slicks. This problem may be overcome when weather conditions are good allowing the joint use of side-looking, airborne radar and ultraviolet and infrared sensors. Visual confirmation of oil remains the most common detection technique. Still, fresh oil, freshwater inflows, seaweed, tidal riplines, debris etc., can be mistaken for oil slicks.

The EC began a research project, which MMS joined in 1987, to develop a system that could be transported in small twin engine aircraft and could discriminate between spurious targets and those containing oil. It has been proven in the laboratory that the airborne laser fluorosensor can distinguish between biogenic and petrogenic oil. This system also appears to have potential for identifying oil on shorelines and in broken ice conditions. This technique uses lasers and should offer a significant increase in detection capabilities. The MMS anticipates that an experimental system will be flyable within the next 18 months.

CONTAINMENT

Capabilities for using open ocean booms to contain oil are unquantified in waves over 2 to 3 ft. Yet these wave heights are often exceeded on the Outer Continental Shelf (OCS). Conventional knowledge indicates that containment booms will not effectively operate in wind speeds over 15 to 20 knots or at tow speeds exceeding 1/2 to 3/4 knots. During MMS/EC experimental oil-spill operations conducted off the coast of St. John's, Newfoundland, oil was successfully contained by booms towed with the wind, instead of against it, in contravention of conventional practice. This new technique resulted in successful slick containment in winds up to 35 knots and at tow speeds up to 1.4 knots (Tennyson and Whittaker 1988).

Currently, there are more than 30 different boom designs in use in the OCS. The relative capabilities of these booms have not been properly quantified for lack of a standardized testing technique or protocol. The MMS, the EC, the U.S. Coast Guard (USCG), and the Environmental Protection Agency initiated the development of an extensive test protocol in 1985 that would rate the performance of containment booms without requiring the intentional spillage of tens of thousands of gallons of oil as is the current international practice. This protocol was evaluated and verified off the coast of Newfoundland in 1987 (Nash and Hillger 1988). Standard nonpolluting test procedures are being devised to evaluate the performance of each containment boom in a wide range of sea states.

RECOVERY

Several offshore skimmers of differing oil retrieval concepts have been evaluated at OHMSETT and elsewhere in realistic offshore conditions. Additional testing of conventional systems would be of minimal value. However, MMS, EC, USCG, and the American Petroleum Industry are jointly searching for innovative skimmers for evaluation. One such skimmer, based upon a Finnish prototype, appears to have significant potential for oil recovery in a wide range of broken ice conditions. This device makes use of proven ice-handling techniques, efficiently contacting the oil slick with minimal ice movement. Negotiations on testing this skimmer are continuing.

CHEMICAL TREATING AGENTS

Chemical treating agents involve 11 major categories of treating agents including sorbents, solidifiers, gelling agents, sinking agents, surface washing agents, dispersants, biodegradation agents, biodegradation enhancers, de-emulsifiers, burning agents, and herding agents. The MMS and EC began in 1987 to develop a better understanding of the mechanism of dispersant action.

This task was undertaken because of the controversy over the field effectiveness of dispersants and because laboratory effectiveness measurement protocols did not yield reproducible data. Laboratory tests were normalized using more realistic oil to water ratios and allowing a settling time prior to the effectiveness evaluations. This new test yielded reproducible (within 5%) results and was used to evaluate a range of crude oils and products with commercially available and experimental dispersants (Fingas *et al.* 1990). Table 12.1 shows the results of this research.

When oil to water ratios of 1 to 1,000 and settling times of 10 minutes were used with traditional laboratory effectiveness protocols (including the Labofina, Mackay, and the Swirling Flask), techniques showed reproducible results for most of the oils listed in Table 12.1.

Additional research on an emulsion inhibitor and a visco-elastic agent has been conducted by MMS and EC (Gershey and Batstone 1988), both in the laboratory and at sea. Both treating agents were successful. The demulsifier significantly inhibited the formation of emulsions or broke up emulsions while the oil was on the ocean surface. Demulsifier was used at concentrations ranging from 250 to 4,000 ppm. The visco-elastic agent also performed well in the laboratory and at sea. Laboratory and tank tests indicated that under certain conditions skimmer recovery rates could be increased by an order of magnitude. At sea, emulsion formation was inhibited and the adhesive character of the oil increased by concentrations of 1,000 to 10,000 ppm. Both treating agents modified the characteristics of the oil to enhance significantly its recoverability and ability to burn *in situ*.

The MMS and EC are continuing research to identify and evaluate other chemical treating agents.

IN SITU BURNING

The major advance in spill response has resulted from joint research begun in 1983 to determine the limiting conditions for burning oil on the surface of the open ocean. This effort was conducted at the OHMSETT facility in Leonardo, New Jersey. Prudhoe Bay, Amuligak, and several other crude oils were evaluated to determine the effects of selected physical variables including slick thickness, weathering, sea state, wind velocities, air and water temperatures, degrees of emulsification, and degrees of ice coverage. All of the oils tested burned with 50 to 95% removal ratios, as long as emulsification had not occurred. Effects of ice coverage from less than 30 and up to 98%, wind speeds from calm to 50 knots, and water temperatures from -1° to 13°C were minimal to the outcome. Weathered, but not emulsified, oils burned with a higher percentage of removal than did the fresh oils. This was unexpected but appears to be a function of increased viscosity as weathering occurs.

Having seen the success of this research, MMS began to explore how major burns affect air quality. A joint research effort with EC began in 1985 to quantify burn products and to model the behavior of the products as a function of time and cooling. This research was conducted under contract by the National Institute of Standards and Technology. The modeling uses a Department of Defense "Nuclear Winter" computer model, which addresses the behavior of the smoke plumes from numerous fires in a defined area (Evans 1988). Continuing analyses

Table 12.1. Results of Research on Dispersant Use.

Oil	Dispersant	Effectiveness (percent) Average	Pre-mixed	1 drop	2 drop
ADGO	C 9527	61	61	82	41
ADGO	CRX-8	39	61	31	26
ADGO	ENER 700	59	76	53	47
ADGO	DASIC	8	11	7	5
Amauligak	C9527	45	50	36	49
Amauligak	CRX-8	50	61	51	37
Amauligak	ENER 700	62	65	62	59
Amauligak	DASIC	28	23	40	22
Amauligak	DREW	0	TL	TL	TL
Amauligak	C 9550	0	TL	TL	TL
Amauligak	BQ	60	72	52	57
Amauligak	II	0	22	TL	TL
Arabian light	C 9527	17	31	16	3.3
Arabian light	CRX-8	9	15	8.6	4.8
Arabian light	ENER 700	22	16	27	23
Arabian light	DASIC	33	24	36	40
Arabian light	BQ	42	28	54	43
ASMB	C 9527	33	42	28	28
ASMB	CRX-8	45	57	43	35
ASMB	ENER 700	51	68	51	35
ASMB	DASIC	24	18	27	28
ASMB	DREWLT	0	TL	TL	TL
ASMB	C 9550	0	TL	TL	TL
ASMB	BQ	79	81	82	73
ASMB	II	18	49	5	0
ASMB	WELLAID 3315	14	8	12	21
ASMB	BP1100WD	12	6	14	17
ASMB	BP1100X	12	6	14	17
Atkinson	C 9527	39	59	31	27
Atkinson	CRX-8	31	67	19	7
Atkinson	ENER 700	73	79	75	66
Atkinson	DASIC	49	33	61	53
Avalon J-34	C 9527	11	18	7.5	8
Avalon J-34	CRX-8	5	7.6	5.3	3.3
Avalon J-34	ENER 700	11	15	12	7
Avalon J-34	DASIC	16	8	18	21
Avalon J-34	BQ	10	11	11	7.1
Avalon zone 4	C 9527	10	14	10	5.7
Avalon zone 4	CRX-8	7	14	4.2	3.1
Avalon zone 4	ENER 700	7	14	4.2	3.1
Avalon zone 4	DASIC	30	12	40	38
Avalon zone 4	BQ	13	16	14	10
Bent Horn	C 9527	17	12	17	21
Bent Horn	ENER 700	23	10	18	42
Bent Horn	DASIC	35	14	43	48
Bunker C	C 9527	1	2.3	1.1	1
Bunker C	CRX-8	2	3.8	1.3	0.9
Bunker C	ENER 700	1	0.9	1.9	0.8
Bunker C	DASIC	2	2.1	2.9	0.5
Bunker C	BQ	1	1.4	1.4	0.8
Bunker C light	C 9527	1	0.6	1	0.4
Bunker C light	CRX-8	1	0.7	0.9	0.7
Bunker C light	ENER 700	1	0.7	2	1.5
Bunker C light	DASIC	1	0.6	1.7	1.3
Bunker C light	BQ	2	1.6	2.6	0.8
California crude (11.0)	C 9527	1	0.5	1.1	0.9
California crude (11.0)	CRX-8	1	2.3	1.2	0.8
California crude (11.0)	ENER 700	1	1.4	2.7	0.8
California crude (11.0)	DASIC	1	0.2	2.2	0.8
California crude (11.0)	BQ	1	0.4	2.2	1.7
California crude (15)	C 9527	1	1.3	0.7	0.3
California crude (15)	CRX-8	1	0.4	0.8	0.6
California crude (15)	ENER 700	1	0.9	0.9	1
California crude (15)	DASIC	2	0.8	3	3.3
California crude (15)	BQ	1	1.4	1.3	0.8
Cohasset	C 9527	95	88	100	98
Cohasset (11.2%)	C 9527	96	88	99	100
Cohasset (25.6%)	C 9527	88	75	92	97
Cohasset (28.1%)	C 9527	90	74	97	100
Cold Lake bitumen	C 9527	2	1.9	2.3	0.4
Cold Lake bitumen	CRX-8	1	1.1	2.1	0.6
Cold Lake bitumen	ENER 700	1	0.9	1.4	0.4
Cold Lake bitumen	DASIC	1	1	1	0.3
Cold Lake bitumen	BQ	1	1.1	1.5	0.3
Endicott	C 9527	7	17	2.3	2.8
Endicott	CRX-8	8	20	1.3	2.4
Endicott	ENER 700	6	10	2.4	6.4
Endicott	DASIC	14	8.1	15	18
Endicott	BQ	13	18	6.9	13
Endicott (7.5% w)	C 9527	3	3	3	3
Endicott (7.5% w)	CRX-8	4	5	3	3
Endicott (7.5% w)	ENER 700	6	4	6	9
Endicott (7.5% w)	DASIC	4	1	1	11
Endicott (7.5% w)	BQ	6	4	6	7
Endicott (11.7% w)	C 9527	2	2	2	2
Endicott (11.7% w)	CRX-8	2	2	3	2
Endicott (11.7% w)	ENER 700	6	2	9	6
Endicott (11.7% w)	DASIC	3	1	3	4
Endicott (11.7% w)	BQ	4	1	6	6
Federated	C 9527	25	41	24	11
Federated	ENER 700	40	41	56	22
Federated	DASIC	38	23	55	35
Federated	BQ	64	66	85	42
Hibernia	C 9527	6	13	1.9	1.8
Hibernia	CRX-8	6	14	2.6	2
Hibernia	ENER 700	10	7.3	10	14
Hibernia	DASIC	14	8.6	18	16
Hibernia	BQ	9	7.8	12	6
Hibernia	WELLAID 3315	4	3	4	4
Hibernia (15.4%)	C 9527	4	6.1	2.3	2.5
Hibernia (15.4%)	CRX-8	3	5.8	1	2
Hibernia (15.4%)	ENER 700	8	5	11	7.5
Hibernia (15.4%)	DASIC	7	1	8	11
Hibernia (15.4%)	BQ	5	4	6	4
Issungak	C 9527	66	70	93	35
Issungak	CRX-8	60	58	75	47
Issungak	ENER 700	62	51	79	57
Issungak	DASIC	51	31	60	61
Issungak	BQ	77	77	69	84
Lago Medio	C 9527	5	9.5	3.6	1.5
Lago Medio	CRX-8	5	13	1.8	1.4
Lago Medio	ENER 700	13	11	21	5.9
Lago Medio	DASIC	15	4.1	18	24
Lago Medio	BQ	18	22	25	6.3
Mousse Mix	C 9527	6	9	5	3
Mousse Mix	CRX-8	9	15	8	5
Mousse Mix	ENER 700	14	10	19	13
Mousse Mix	DASIC	17	9	22	20
Mousse Mix	BQ	18	25	17	12
Mousse Mix	II	6	15	3	0
Norman Wells	C 9527	36	51	40	17
Norman Wells	CRX-8	43	60	38	30
Norman Wells	ENER 700	51	73	26	53
Norman Wells	DASIC	26	19	33	27
Norman Wells	DREWLT	0	TL	TL	TL
Norman Wells	C 9550	0	TL	TL	TL
Norman Wells	BQ	77	83	80	68
Norman Wells	II	0	33	TL	TL
Panuk	C 9527	96	95	95	97
Panuk	CRX-8	78	100	62	71
Panuk	ENER 700	96	93	97	99
Panuk	DASIC	40	44	38	37
Panuk	BQ	100	100	100	99
Panuk (47.4% w.)	C 9527	99	96	100	100
Panuk (53.2% w.)	C 9527	99	96	100	100
Prudhoe Bay	C 9527	13	19	13	7
Prudhoe Bay	CRX-8	13	23	9	6
Prudhoe Bay	BQ	32	43	29	24
Prudhoe Bay	ENER 700	35	48	26	31
Prudhoe Bay	DASIC	11	14		18
Prudhoe Bay (1989)	C 9527	7	13	5.8	2.5
Prudhoe Bay (1989)	CRX-8	7	15	3.2	3.9
Prudhoe Bay (1989)	ENER 700	10	15	3.1	13
Prudhoe Bay (1989)	DASIC	14	11	18	13

(continued)

Table 12.1. Results of Research on Dispersant Use (cont'd).

Oil	Dispersant	Effectiveness (percent) Aver-age	Pre-mixed	1 drop	2 drop
Prudhoe Bay (1989)	BQ	15	25	4.8	16
Prudhoe Bay (1989)	WELLAID 3315	4	3	5	3
Prudhoe Bay (89) (7.6% w)	C 9527	6	9	3	5
Prudhoe Bay (89) (7.6% w)	CRX-8	6	13	3	3
Prudhoe Bay (89) (7.6% w)	ENER 700	16	8	25	16
Prudhoe Bay (89) (7.6% w)	DASIC	16	12	19	18
Prudhoe Bay (89) (7.6% w)	BQ	19	29	18	10
Prudhoe Bay (89) (14.5% w)	C 9527	4	5	4	3
Prudhoe Bay (89) (14.5% w)	CRX-8	4	8	2	3
Prudhoe Bay (89) (14.5% w)	ENER 700	8	4	6	14
Prudhoe Bay (89) (14.5% w)	DASIC	10	2	14	13
Prudhoe Bay (89) (14.5% w)	BQ	9	7	15	5
South Louisiana crude	C 9527	31	53	19	21
South Louisiana crude	CRX-8	36	55	33	19
South Louisiana crude	EVER 700	48	31	75	37
South Louisiana crude	DASIC	42	27	50	50
South Louisiana crude	BQ	62	71	80	35
Synthetic crude	C 9527	63	77	88	25
Synthetic crude	CRX-8	41	49	41	34
Synthetic crude	ENER 700	61	69	69	45
Synthetic crude	DASIC	25	23	30	21
Synthetic crude	BQ	55	89	42	34
Terra Nova crude	C 9527	16	29	13	6.5
Terra Nova crude	CRX-8	11	22	5.2	6.5
Terra Nova crude	ENER 700	28	21	38	24
Terra Nova crude	DASIC	40	19	58	44
Terra Nova crude	BQ	40	40	53	27
Transmountain blend	C 9527	8	14	6	3.1
Transmountain blend	CRX-8	8	13	5.3	6.6
Transmountain blend	ENER 700	28	17	43	25
Transmountain blend	BQ	19	25	18	15
Used motor oil	C 9527	33	42	31	27
Used motor oil	CRX-8	31	39	31	23
Used motor oil	ENER 700	36	47	32	30
Used motor oil	DASIC	29	29	27	31
Used motor oil	BQ	36	42	41	24

Notes:
- Premixed—reflects the largest amount dispersed at a dispersant to oil ratio of 1:25.
- 1 drop—reflects largest amount dispersed at a dispersant to oil ratio of 1:10. Test measures how oil/dispersant combination functions with real application.
- 2 drop—reflects largest amount dispersed at a dispersant to oil ratio of 1:10, delivered in 2 drops. Test measures the herding effect of the oil dispersant combination when compared to the 1-drop test.
- BQ and II are experimental dispersants made by EETD.
- TL—too low to measure.

of airborne pollutants indicate that dioxins, furans, and polynuclear aromatic hydrocarbons (PAH) are not generated as a result of combustion. The PAH compounds in the oil are partially destroyed or converted to higher molecular weight compounds that are less acutely toxic (Evans *et al.* 1989). The next phase of this research is to evaluate the scaling effects on efficiency, pollutant loading, and airborne plume behavior. This phase is scheduled for the winter of 1990 with at-sea verification in 1991-1992.

Results indicate that within certain constraints, *in situ* burning should be considered as a primary response strategy especially in remote areas where logistics play a key role in limiting conventional response capabilities.

OIL CHARACTERIZATION

Oil properties, which significantly affect spill response, change rapidly after initial contact with the ocean surface. Physical properties (pour point, viscosity, density, water content, etc.) change rapidly as a result of evaporation, photo-oxidation, emulsification, sediment loading, adhesion to debris, and others. The MMS joined with EC in 1986 to evaluate the effects of the most significant weathering phenomena. Of particular interest were the more exotic oils, such as the heavier oils produced offshore of California. Significant changes in physical properties of these and other oils have been reported (Bobra 1989a,b).

OHMSETT

The MMS, with cooperative support from the USCG and EC, has initiated a major effort to refurbish facilities and reinitiate research at the OHMSETT facility. This open-air test tank has the capability of testing oil recovery equipment in oil and in repeatable wave conditions while towing. Approximately 95% of the performance data on recovery equipment was generated at OHMSETT. The facility will be used to evaluate and develop new and innovative oil-spill response strategies.

SHORELINE CLEANUP

The MMS began in 1986 with EC to develop a matrix analysis program to evaluate various beachline cleanup techniques. Both the effectiveness for cleaning various shoreline types and the effects of the cleanup techniques on the survival of biota and natural restoration of the shoreline community were studied. A matrix analysis has been developed and priorities have been assigned to shoreline types. We are continuing attempts to obtain the necessary permitting. Field research is expected to be initiated in 1992 to address the issue of the level of oil cleanliness and what effect the level of cleanliness will have on natural restoration of the beaches.

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Mr. Edward Tennyson has been involved in oil spill response and research since servicing the U.S. Coast Guard from 1967-1971. Mr. Tennyson's first spill was a blowout on Chevron's Main Pass 41 platform in 1970. He served in the capacity of On-Scene Coordinator for that spill. Mr. Tennyson holds an M.S. degree from George Washington University and has done additional graduate research. Mr. Tennyson has served as Project Manager for the Minerals Management Service in oil spill response since 1981.

IN SITU BURN RESEARCH

Dr. David Evans
National Institute of
Standards and Technology

Presentation discussed in previous summary (Tennyson).

Dr. David Evans is a group leader with the National Institute of Standards and Technology. He received a B.S. degree in fluid and thermal science from Case-Western Reserve University and an M.S. and a Ph.D. in mechanical engineering from Harvard University. He is head of the Fire Suppression Research Group at National Institute of Standards and Technology, a group that studies the dynamics and performance of suppression systems and develops predictive methods for suppression system performance. Dr. Evans is the principal investigator for safety studies in offshore drilling funded by the Minerals Management Service, including studies of oil spill combustion and blowout fire suppression.

THE RISK OF OIL SPILLS FROM THE TRANSPORTATION OF PETROLEUM IN THE GULF OF MEXICO

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Minerals Management Service
Gulf of Mexico OCS Region

The transportation of crude oil and petroleum products by pipeline, barge, and tanker in coastal and offshore waters of the Gulf of Mexico is a major source of oil spills to this region. At any one time, oil is being moved through Gulf waters by three major oil transport operations: import and export activities, waterborne shipping of oil between Gulf terminals, and domestic offshore oil production. These operations have resulted in 91 oil spills greater than 1,000 barrels during the last 17 years. The following assessment analyzes both the modes of transport and the types of operations to determine their risk of spill occurrence.

Data have been compiled from a number of published and unpublished sources that include the U.S. Department of Energy, Energy Information Administration (USDOE/EIA); the U.S. Army Corps of Engineers, Waterborne Commerce Statistics Center (USCOE); the Louisiana Offshore Oil Port (LOOP); the U.S. Department of the Interior, Minerals Management Service, Environmental Policy and Programs Division, Washington, D.C., (USDOI/MMS, Wash. DC) and the Gulf of Mexico OCS Regional Office (USDOI/MMS, GOMR); the U.S. Coast Guard (USCG); and the Port of New Orleans. The term "petroleum products" refers to a variety of hydrocarbon compounds derived from the processing of crude oils. Such products include unfinished oils, liquefied petroleum gases, aviation gasoline, kerosene, fuel oils, petrochemical feedstocks, special napthas, asphalts, etc. Data are presented in million metric tons and in million barrels. The conversion factor used was 7.36 barrels per metric ton. It is noted that there are inherent problems in converting barrels to tons because of the different specific gravities of different oils. Original data were received both in metric tons and barrels, depending on source. Data from USDOE, the most frequently analyzed, were provided in barrels.

Figure 12.1 shows the relationship of the major oil transport activities occurring in the Gulf during 1987. This figure presents a mass balance consideration of oil moving in the Gulf at any one time in order to understand the major activities influencing oil-spill occurrence. The year 1987 is reasonably representative of the last five years. Not included in the mass balance consideration is the volume of oil piped from onshore oil production to coastal processing facilities. The risk of spillage from barging this oil in coastal waters, however, is accounted for in the intra-Gulf oil movement. There is no record of spills greater than 1,000 barrels occurring from coastal production and related piping operations in the Gulf states; therefore, the contribution of these activities to oil spill risk is considered very small. Table 12.2 provides the data depicted in Figure 12.1. Crude oil accounted for 68% of all oils moved through Gulf waters, while the importation of crude oil (39%) represented the largest volume of any oil type moved through the Gulf from any one activity. Total volumes of both crude oil and petroleum products transported in the Gulf by import-export operations and brought into the Gulf from Alaska represented over 50% of oil transported (57%). The intra-Gulf, coastwise movement of petroleum products and crude oil accounted for the next largest single activity transporting oil in Gulf waters (29%). This activity is often overlooked when oil movement in the marine environment is accounted for. Domestic offshore production, often considered a major concern regarding oil spills, accounted for only 14% of the volume of oil transported through Gulf waters in 1987.

The accompanying figures provide more detailed information describing each of the major oil transportation activities occurring in the Gulf. Many of the figures are generalized maps of the Gulf with arrows and bars indicating oil movement. The arrow orientation indicates the general direction of the oil movement, and the width of the arrows is proportional to the volume of oil moved. The bars indicate the landfall of the oil shown moved by the arrows, the height of the bars being proportional to the volume of oil landed. Landfalls can be either pipeline terminals or ports of entry.

CRUDE OIL IMPORTS AND EXPORTS

Figure 12.2 depicts the amounts and routes of import and export petroleum operations occurring in the Gulf of Mexico from 1985 to 1988. On an average, 117 million metric tons (862 million barrels) of crude oil were imported annually into the Gulf of Mexico during this time period. This volume represents around 63% of all crude oil imported into the United States. About 16% of this volume was not

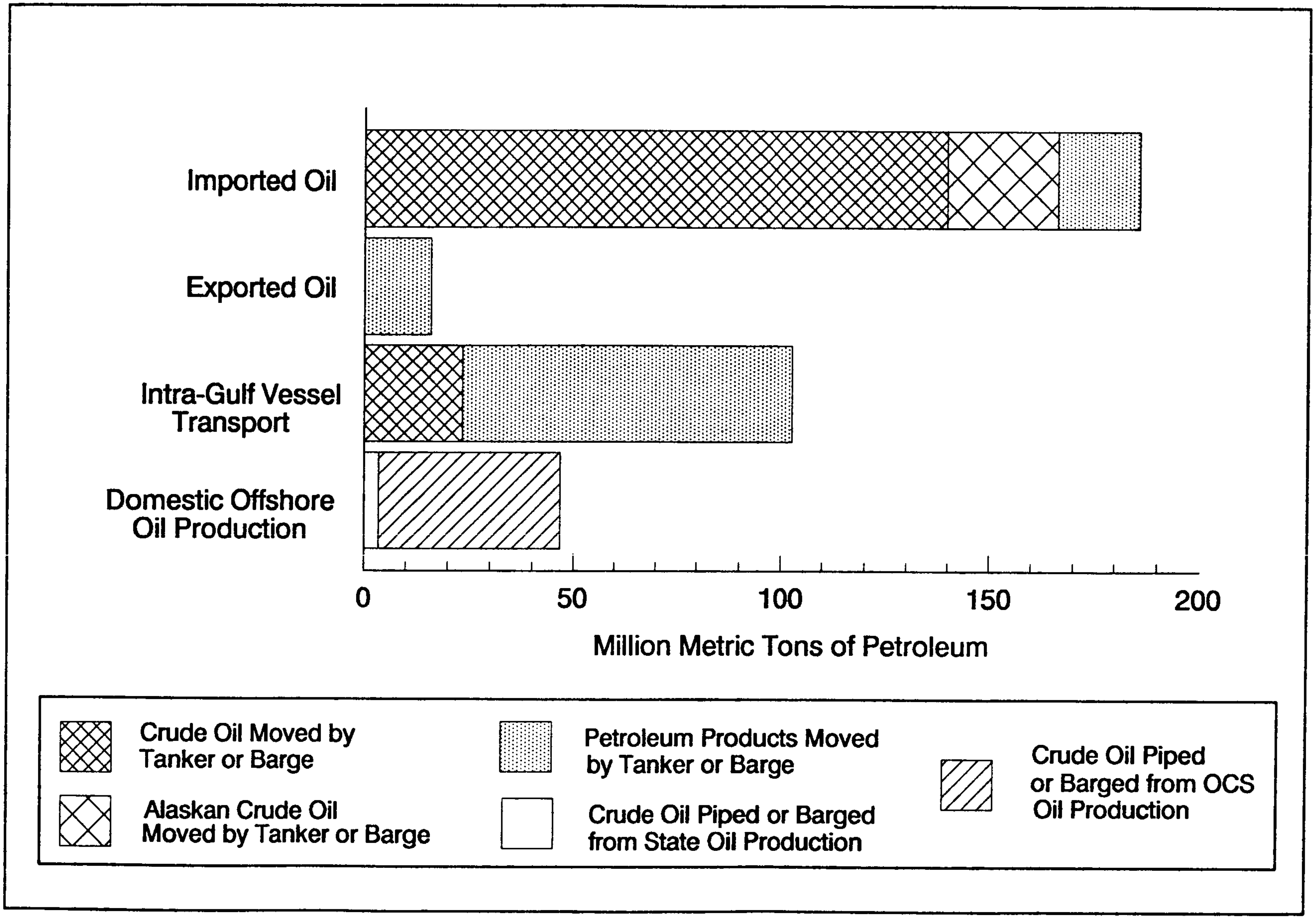

Figure 12.1. Volumes of crude oil and petroleum products moved through Gulf of Mexico waters from major oil transport activities, 1987.
Sources: Compiled from data in USCOE, Waterborne Commerce Statistics Center, 1989; USDOE/EIA, Petroleum Supply Annual 1987; USDOI/MMS, Gulf of Mexico OCS Region, Unpublished data, 1990b.

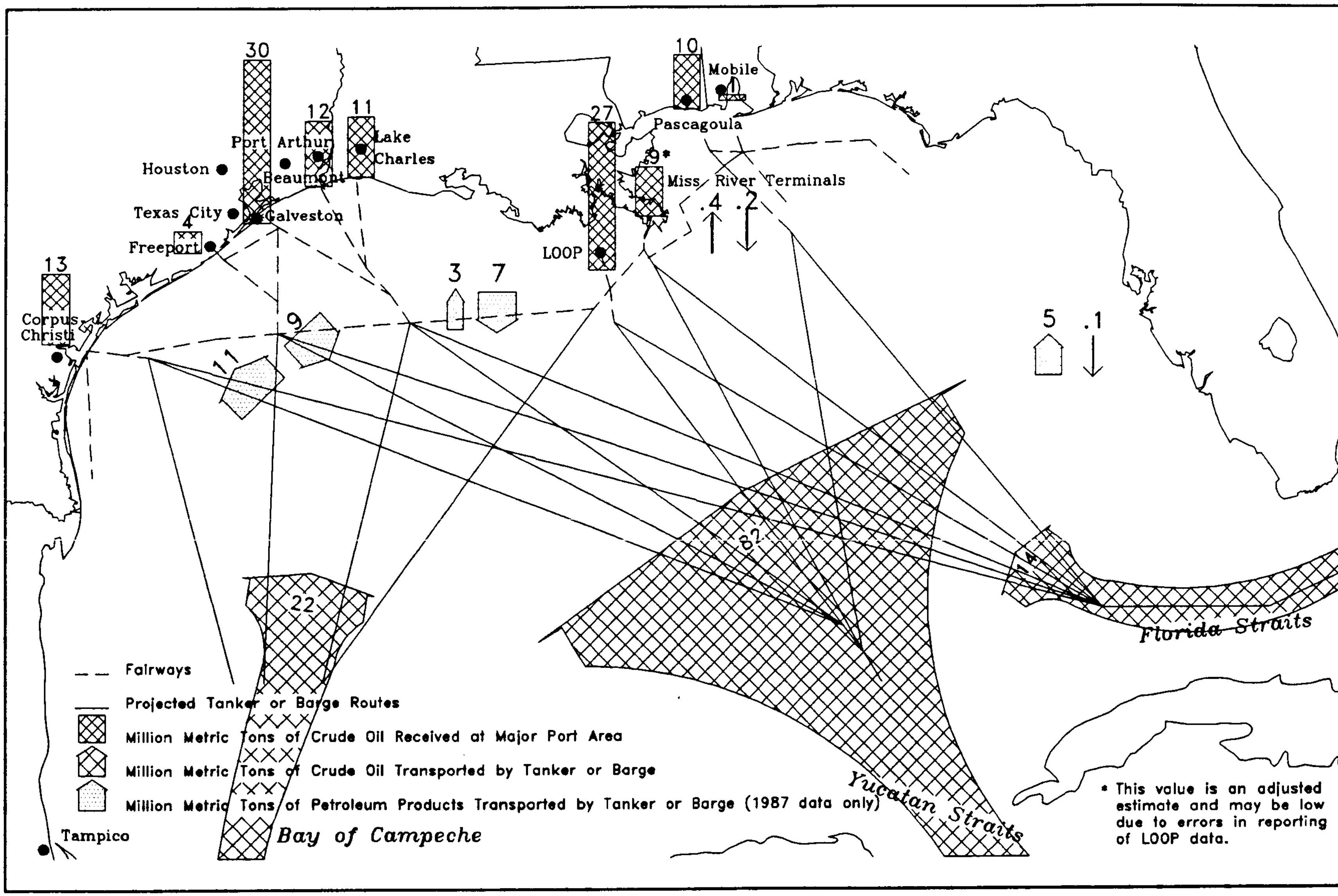

Figure 12.2. **Volumes and routes of import/export oil vessel movement - annual average 1985 - 1988.**

Sources: Compiled from data in LOOP, personal communication 1990; Port of New Orleans, personal communication 1990; USCOE, Waterborne Commerce Statistics Center 1989; USDOE/EIA, Petroleum Supply Annuals 1985-1988; USDOE/EIA, Unpublished data 1990a.

Table 12.2. Volumes of Petroleum Transported in the Gulf of Mexico from Major Activities, 1987.

Activity	Million Metric Tons	Million Barrels	Percent of Total
Crude Oil			
Import	139.5	1027	39%
Alaskan "Imports"	26.7	197	8%
Oil Production			
Federal Offshore	45.2	333	13%
State Offshore	3.7	27	1%
Intra-Gulf Movement	23.9	176	7%
Total Crude Oil	239.0	1,760	68%
Petroleum Products			
Imports	19.5	144	6%
Exports	15.8	117	4%
Intra-Gulf Movement	79.4	588	22%
Total Petroleum Products	114.7	849	32%
TOTAL ALL OILS	353.7	2,609	100%

Source: USDOE/EIA 1990; USDOE/EIA 1988; USCOE 1989.

processed in the Gulf region but transported out for processing elsewhere. Most crude oil not processed along the Gulf is transported by pipeline to north-central U.S. refineries; a small amount is transported into the Atlantic by tanker or barge. Figure 12.2 also includes the amount of crude oil brought by tanker or barge into the Gulf through the Yucatan Channel from the Pacific Ocean. It is assumed that this oil is primarily Alaskan crude. During the time period of 1985-1988, 25 million metric tons (184 million barrels) were "imported" annually into the Gulf from Alaska.

Tanker routes depicted on Figure 12.2 are estimates based on the assumption that the vessels will follow the shortest distance between the country of origin and the receiving port. Historically, specific routes taken by tankers are usually left to the discretion of the vessel captains. In general, most tankers carrying crude oil enter the Gulf through the Yucatan Channel and leave through the Straits of Florida. Tanker captains preferentially choose the Yucatan Channel to avoid the Loop Current that exits through the Straits of Florida. Assuming that only European countries and countries bordering the Mediterranean will use the Straits of Florida, it is estimated that approximately 70% of the oil will be transported into the Gulf through the Yucatan Channel, 18% through the Bay of Campeche (Mexican oil only), and 12% through the Straits of Florida. The newly promulgated Oil Pollution Act of 1990 requires a closer watch on tanker oil movement and volumes. This scrutiny should expand information regarding tanker routes in the Gulf.

Figure 12.3 compares the annual volumes imported into the Gulf for the years 1981-1989. There has been a sharp increase in the volume of oil brought into the Gulf in the last few years. In 1989, 190 million metric tons (1,398.7 million barrels) of crude oil were imported into Gulf waters. This amount is 2.7 times greater than volumes imported into the Gulf in 1985. Figure 12.4 depicts the scale of crude-oil imports that occurred in 1989.

The Gulf States import crude oil primarily from 35 countries. Except to Canada, crude oil is not

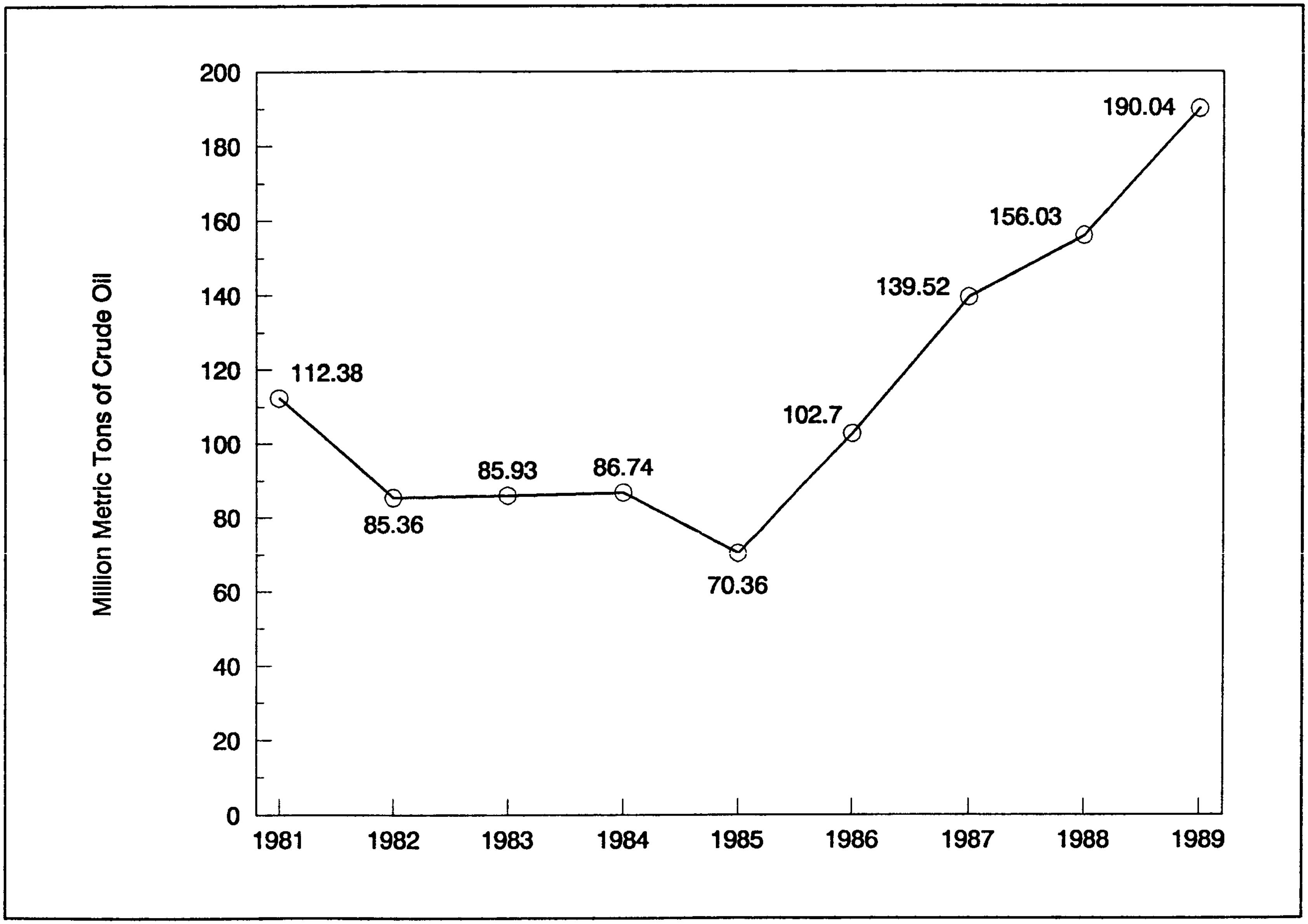

Figure 12.3. Annual volumes of crude oil imported into the Gulf of Mexico, 1981 - 1989.
Source: USDOE/EIA, Petroleum Supply Annuals 1984 - 1989; USDOE/EIA,Unpublished data, 1990a.

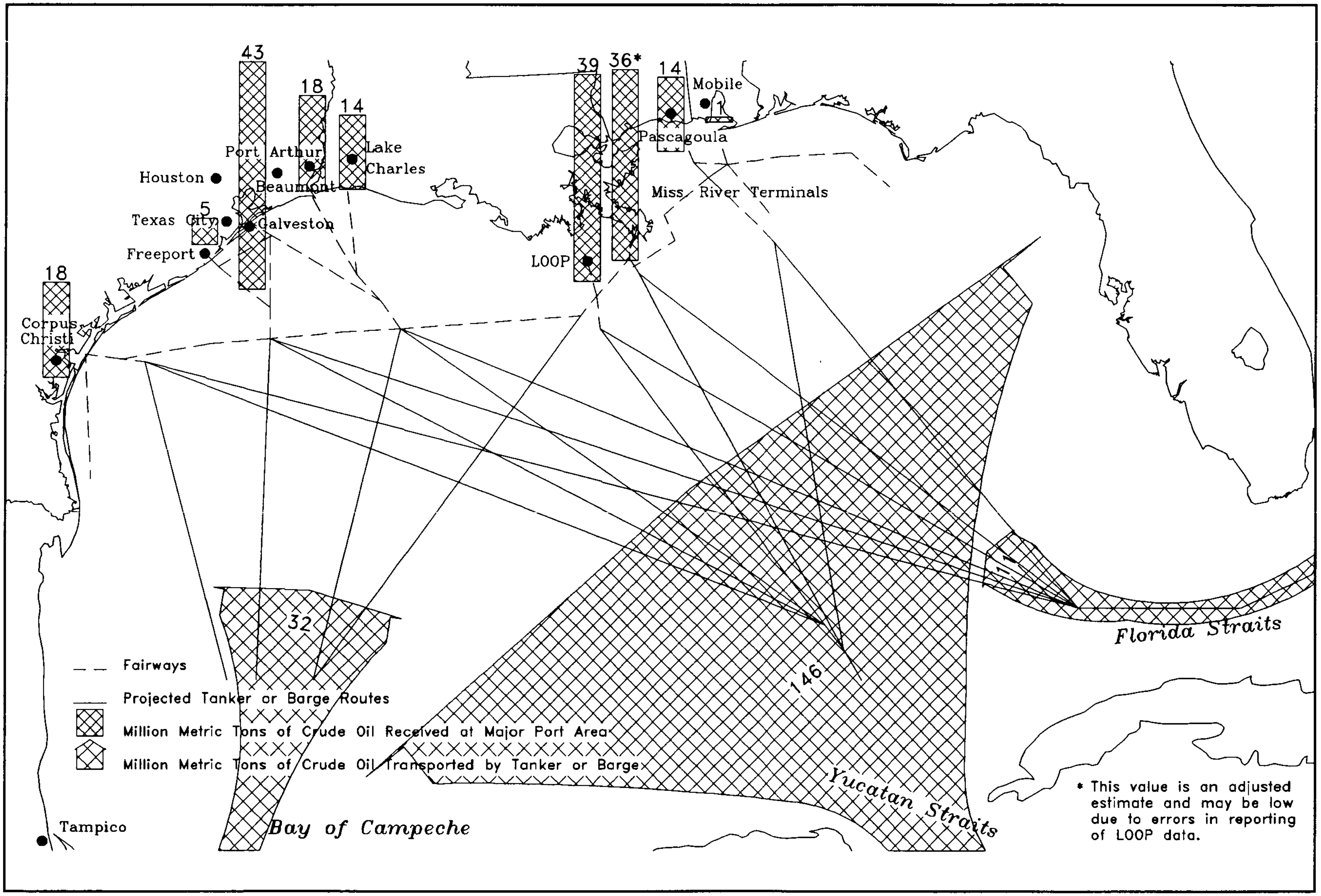

Figure 12.4. Volumes and routes of import crude oil vessel movement - 1989.

Sources: Compiled from data in USDOE/EIA, Petroleum Supply Annual 1989; USDOE/EIA, Unpublished data, 1990a.

exported from the United States. Such exportation is generally prohibited by law. Figure 12.5 shows the percentage of oil from the major countries, as well as Alaska, exporting oil for processing in the Gulf region between 1987 and 1989. The largest quantities of crude oil were received from the Arab OPEC countries, primarily Saudi Arabia, Iraq, and Kuwait, followed closely by the non-Arab OPEC countries (these include Ecuador, Gabon, Indonesia, Iran, Nigeria, and Venezuela). The OPEC sources made up almost 62% of all foreign sources. In 1989, Iraq and Kuwait exported 17% of the foreign oil received in the Gulf region, compared to only 5% in 1987; however, considering the current situation in these countries, these percentages are expected to change significantly in the future.

The ports of entry of imported crude oil and the relative volumes of oil are indicated by the bars mapped on Figure 12.2; Table 12.3 provides actual statistics. Several ports are combined on Figure 12.2 into three major port systems, the Mississippi River Port System, the Galveston-Houston-Texas City Area, and the Port Arthur-Beaumont area. Oil may be unloaded directly at facilities at receiving ports or at marine terminals located in the vicinity of these ports. The Louisiana Offshore Oil Port (LOOP) is the only operating offshore port in U.S. waters. Supertankers unload at three moorings located about 19 miles off the Louisiana coast. The oil is then piped to shore where it can be stored or moved through an extensive pipeline system.

From storage facilities or terminals located near major receiving ports, imported oil is then usually shipped to nearby refineries. At present there are 20 refineries operating in Louisiana, 16 of which are located in the coastal zone; and 36 refineries operating in Texas, 20 of which are located in the coastal zone. These refineries either report being completely shut down or are operating at capacity. Oil may also be barged or piped to more distant refineries, such as from Louisiana terminals to Texas refineries. Such secondary coastal oil movement activities are discussed later. Oil may also be piped out of the area. For example, the Capline Pipeline located at St. James, Louisiana, carries imported oil long distances. (The St. James terminal is included as part of the Mississippi River port system.)

PETROLEUM PRODUCTS IMPORTS AND EXPORTS

Data on petroleum product imports are maintained by both the USDOE/EIA and the USCOE. According to USDOE/EIA 1985-1988 data, the volume imported annually through the Gulf is 21 million metric tons (155 million barrels). Because USCOE waterborne commerce statistics include information not found in the USDOE/EIA data, the destination of imported petroleum product by waterway, these were the data used. A compilation of data by state was completed for 1987. In that year, 19.5 million metric tons (144 million barrels) of petroleum products were imported by Gulf states (Figure 12.2). Table 12.4 provides volumes of petroleum products imported and exported in the Gulf of Mexico by state. The volume of petroleum products exported from the Gulf region is somewhat less than volumes imported (Figure 12.2). The following countries have historically received the majority of U.S. exports: Canada, Japan, Virgin Islands, Taiwan, and Mexico.

VOLUMES AND ROUTES OF CRUDE OIL TRANSPORTED FROM OCS OIL PRODUCTION

The volumes and routes of oil transported to Gulf states from domestic, federally supervised oil production operations on the Outer Continental Shelf (OCS) from 1985 to 1988 are depicted in Figure 12.6. This information was compiled from data maintained at the MMS, GOMR. The total volume transported annually during this time period from OCS platforms to shore is 43.84 million metric tons (324.43 million barrels). Unlike imported oil volumes, the amount of oil produced on the OCS has shown no significantly increasing trend; in fact, the annual amount produced peaked in 1972. The amount of oil produced on the OCS in 1989, 37 million metric tons (272 million barrels), was lower than the previous 4-year average (44 million metric tons).

Historically, most (about 98%) of the oil produced on the OCS has been transported by pipeline, the rest by barge. Between 1985 and 1988, an average of 2.7 million metric tons (20.1 million barrels) of OCS crude oil was piped into Texas annually; and 40.4 million metric tons (298.7 million barrels) of OCS crude oil made landfall in Louisiana. There are 94 land-based terminals receiving OCS oil transported to shore by either pipeline or barge, 14 in Texas and 80 in Louisiana. At present, there is no tanker transport of OCS oil in the Gulf of Mexico. As of October 1990, there were 86 major oil pipeline systems and 50,942 miles of pipelines transporting OCS crude oil ashore. State oil development operations are often tied into these pipeline systems. About 10% of OCS oil is produced on leases in the

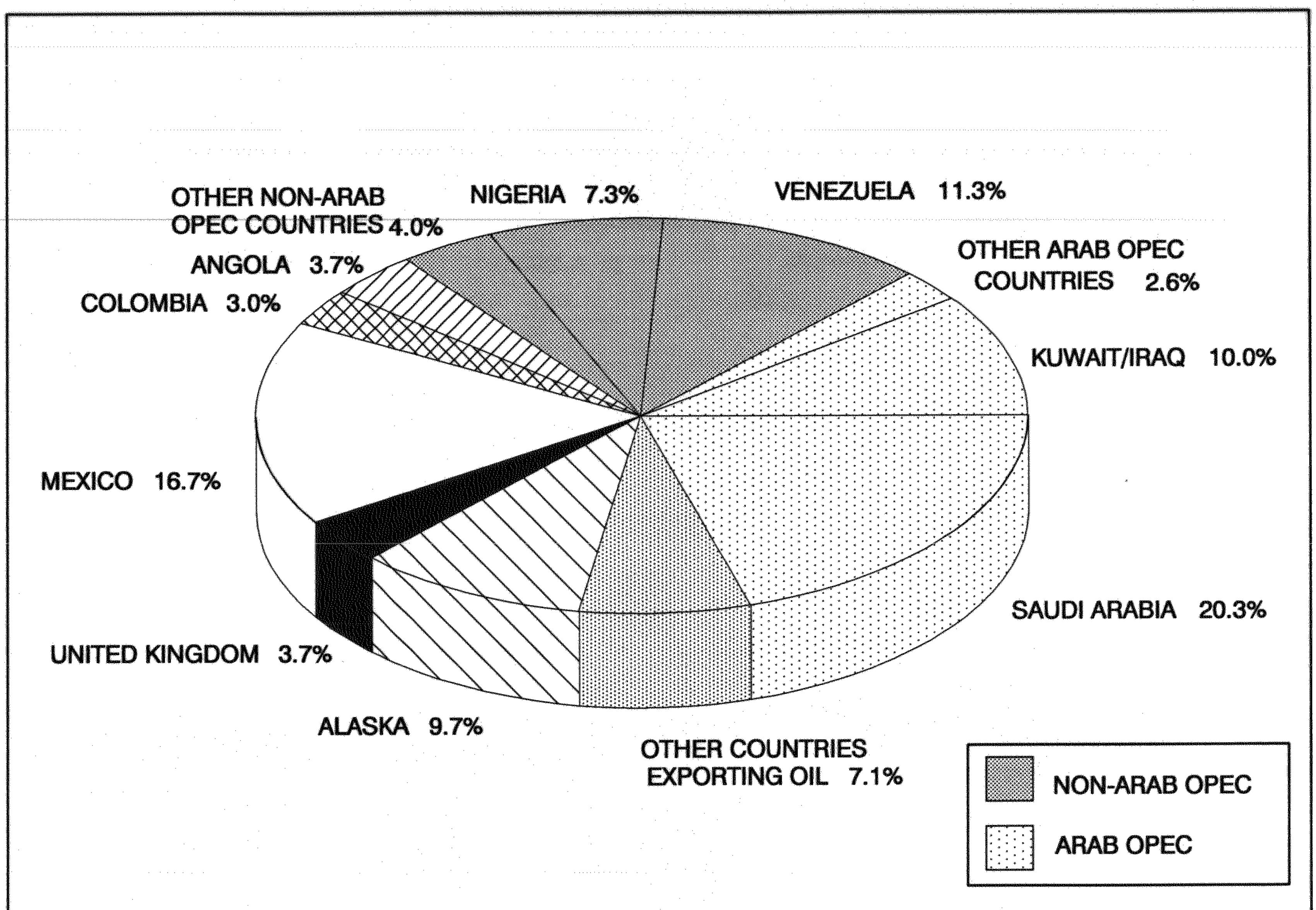

Figure 12.5. Imports of crude oil into the Gulf of Mexico by country of origin - annual average 1987-1989 (includes tankered Alaskan crude).
Sources: Compiled from USDOE/EIA, Petroleum Supply Annuals 1987-1989.

Table 12.3. Volume of Oil Imported into the Gulf of Mexico by Port of Entry Annual Average, 1985-1988.

Receiving Ports of Entry	Million Metric Tons	Million Barrels	Percent
Corpus Christi	13.2	97.3	11%
Freeport	3.7	27.3	3%
Houston	14.4	106.0	12%
Galveston	11.5	84.3	10%
Texas City	3.7	26.9	3%
Port Arthur	6.6	48.7	6%
Beaumont	5.2	38.3	4%
Lake Charles	11.2	82.5	10%
Miss. River Ports*	9.3**	68.7**	8%**
LOOP	27.3	200.5	23%
Pascagoula	10.5	77.0	9%
Mobile	0.7	4.8	1%
TOTALS	117.3	862.3	100%

*Includes Baton Rouge, Good Hope, Gramercy, New Orleans, and St. Rose, La.
**This value is an adjusted estimate and may be low due to errors in reporting of LOOP data.

Source: LOOP, personal communication 1990; Port of New Orleans, personal communication 1990; USCOE 1989; USDOE/EIA, Petroleum Supply Annuals 1985-1988; USDOE/EIA, Unpublished data 1990a.

Table 12.4. Volume of Petroleum Products Imported and Exported in the Gulf of Mexico by State, 1987.

IMPORTED			EXPORTED	
Million Metric Tons	Million Barrels	State	Million Metric Tons	Million Barrels
0.35	2.6	Alabama	0.15	1.1
0.03	0.2	Mississippi	0.00	0.0
3.29	24.2	Louisiana	6.89	50.7
4.51	33.2	Florida	0.05	0.4
11.31	83.2	Texas	8.80	64.8
19.49	143.4	TOTALS	15.89	117.0

Source: USCOE 1989.

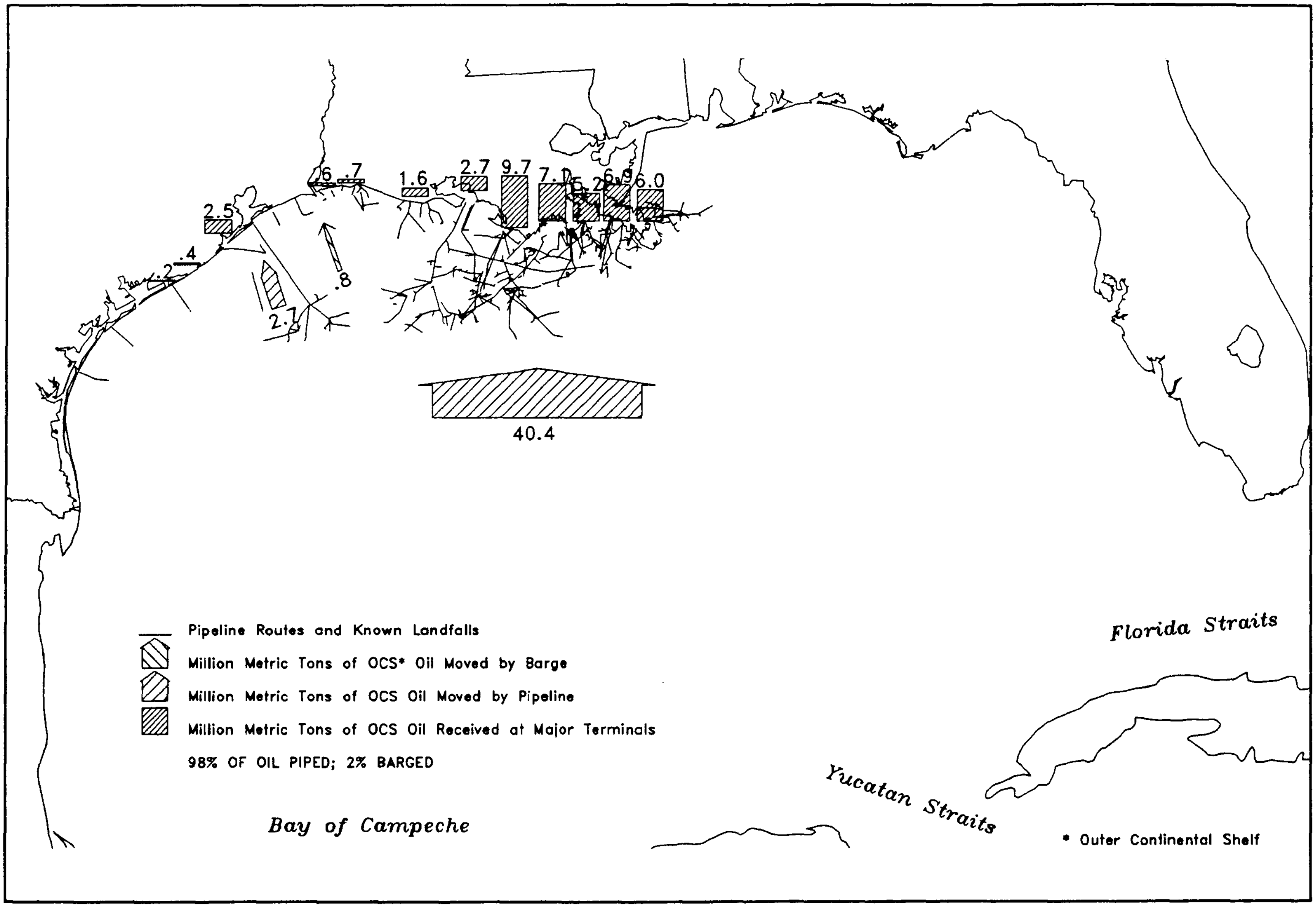

Figure 12.6. Volumes and routes of OCS oil operations - annual average 1985 - 1988.
Source: Compiled from USDOI/MMS, Gulf of Mexico OCS Region, Unpublished data, 1990b.

Western Gulf Planning Area, but only about 6% of this oil is piped to Texas.

The largest pipeline systems make landfall at terminals located along the Louisiana coastline. The largest pipeline system comes ashore at a terminal in Gibson, Louisiana, in Terrebonne Parish, east of the Atchafalaya River Delta area. This system annually carries 8.4 million metric tons (62 million barrels). The next largest system makes landfall near Caillou Island near Timbalier Bay, Louisiana; several large pipeline systems also make landfall on nearby South Timbalier Island. Grand Isle is the next largest terminal, receiving oil from two major pipeline networks. A number of terminals located on the bird's foot of the Mississippi River receive, together, 12.9 million metric tons (95 million barrels) annually, greater than any of the above terminals.

Between 2% and 3% of the oil produced on the Gulf OCS is barged ashore rather than piped. The percent of oil barged has changed very little since the 1950's, when barging operations first began. Between 1985 and 1988, 0.76 million metric tons (5.63 million barrels) of oil were barged annually to shore terminals from OCS platforms. As of January 1989, OCS operators of 86 lease blocks located in Federal waters transported oil to shore by barge rather than by pipeline. Historically, operators of a total of 179 leases are using or have used barges to bring crude oil to shore terminals. Usually, an operator decides at the start of production whether or not to barge the oil. All of the lease blocks where barging is currently taking place are located fairly close to shore. There are 10 shoreline terminals known to receive barged oil from either Federal or State offshore operations. The MMS does not regulate barging operations and, therefore, there are no data on locations of landfalls from specific leases. Through contact with barging companies, it was learned that, because the oil is sold on the spot market, the barge systems carrying the oil may transport it from the same lease to different land terminals at different times.

PROJECTIONS OF FUTURE VOLUMES OF CRUDE OIL TRANSPORTED IN GULF WATERS IN THE YEAR 2007 FROM OCS OIL PRODUCTION AND FROM IMPORT AND EXPORT OPERATIONS

The volume of crude oil transported through Gulf waters will continue to increase to meet the energy demands of this country. Therefore, crude-oil imports are expected to continue to rise from present levels. Figure 12.7 depicts projections of future volumes and modes of transport of crude oil to be transported through Gulf waters from OCS production and import operations in the year 2007. This year was chosen because MMS has projected it as the peak year for future OCS oil production (USDOI 1990a). Projections of the amount of imported crude oil were derived from USDOE/EIA estimates of U.S. total crude-oil imports. If it is assumed that 63% of U.S. imported oil will continue to be transported into the Gulf of Mexico, then 306 million metric tons (2.26 billion barrels) of crude oil are projected to be imported in the year 2007 through Gulf waters. This volume is more than twice the amount imported into the Gulf in 1987; that is, imports will have doubled in 20 years. The implications for oil-spill risk from such large volumes are obvious.

The amount of oil transported in the Gulf from OCS oil production is expected to remain consistent with present levels. The MMS estimates that 45.9 million metric tons (338 million barrels) of crude oil will be produced in the year 2007 on the OCS. Of this amount, 2.59 million metric tons will be shuttle-tankered, and 1.32 million metric tons will be barged to shore facilities. The vast majority will be carried by the ever-expanding pipeline network, 42.04 million metric tons (310 million barrels). Figure 12.7 shows the general locations projected for these three modes of oil transport - pipeline, barge, and tanker - associated with OCS activities. Because of a recent trend to a much higher level of leasing in deep-water blocks not located in proximity to the existing oil pipeline system, some future transportation of OCS oil by tanker is projected to occur. Further, most economically recoverable oil located in the eastern Gulf is expected to be tankered to central Gulf of Mexico terminals.

VOLUMES OF PETROLEUM TRANSPORTED BY INTRA-GULF OIL VESSEL MOVEMENT

A large volume of crude oil and petroleum products is transported within the Gulf by tankers and barges moving between land-based terminals or port storage facilities. Twenty-nine percent of all oil movement in the Gulf is accounted for by transport of the oil either between or within Gulf states. Figure 12.8 depicts the general directions and amounts of both crude oil and petroleum products that were moved within the Gulf during 1987; Table 12.5 provides the data in more detail. These data are compiled from waterway maritime activity statistics (USCOE 1989).

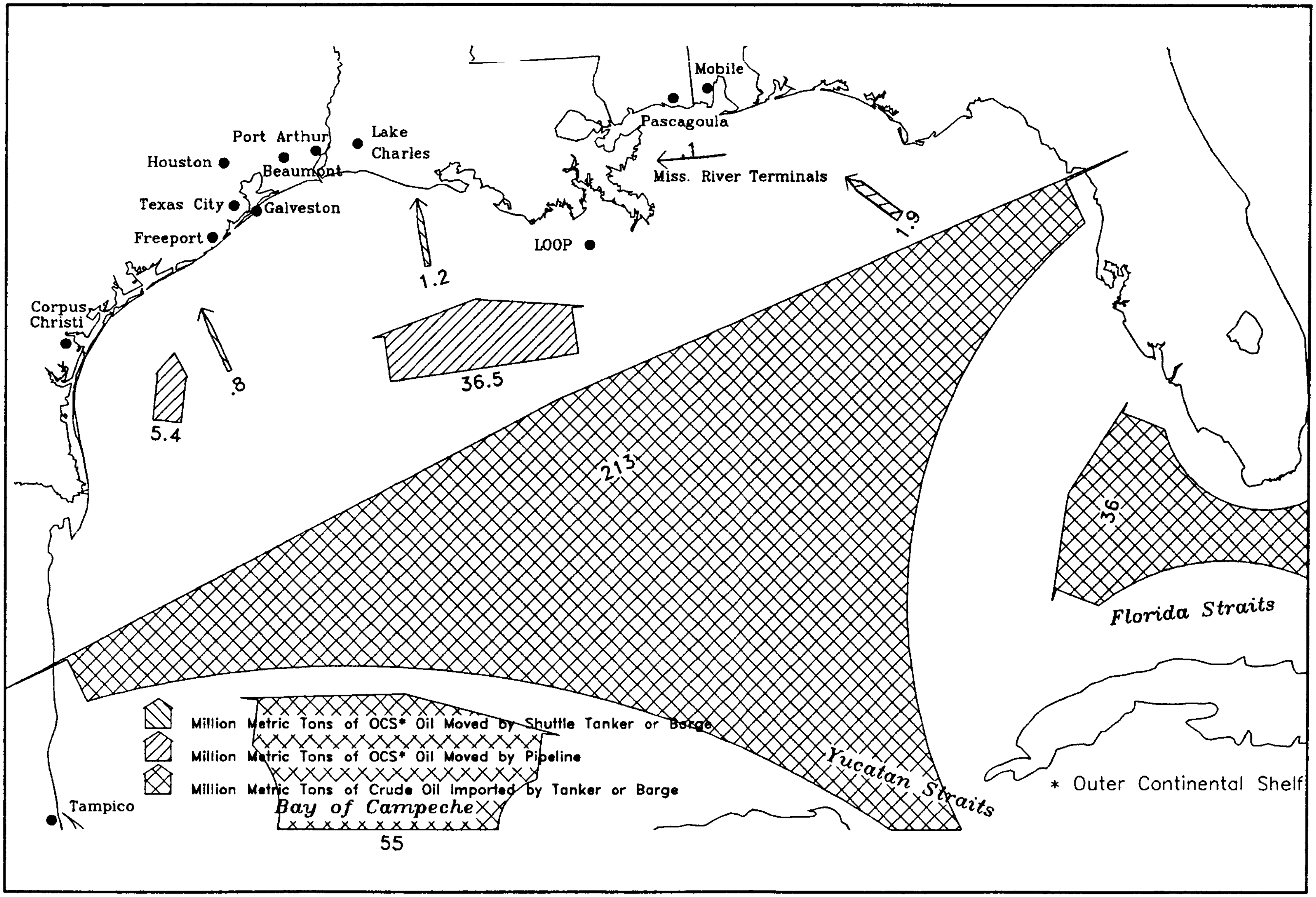

Figure 12.7. Projected volumes of crude oil movement from OCS oil production operations versus import tankering - year 2007.

Sources: Compiled from data in USDOI/MMS, Gulf of Mexico OCS Region, EIS 131/135/137, 1990a; USDOE/EIA, Unpublished data, 1990b.

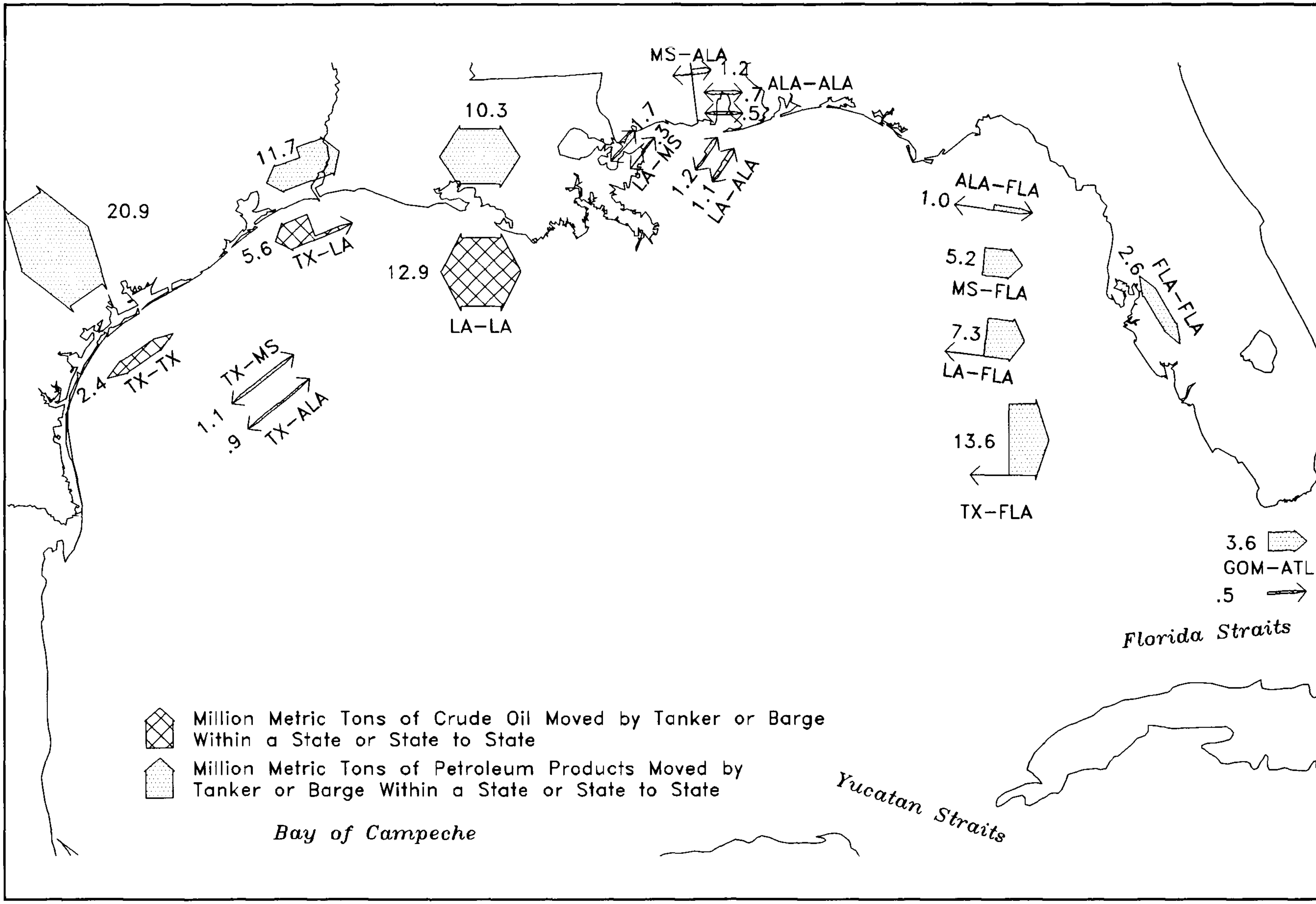

Figure 12.8. Volumes and routes of intra-Gulf oil vessel movement - 1987.

Source: Compiled from USCOE, Waterborne Commerce Statistics Center, Unpublished data, 1989.

Table 12.5. Volumes of Petroleum Transported in Gulf Waters by Intra-Gulf Oil Vessel Movement, 1987.

	Million Metric Tons	Million Barrels
Crude Oil		
Within Alabama	0.47	13.46
Within Louisiana	12.90	94.94
Within Texas	2.40	17.66
Alabama to Louisiana	0.74	5.45
Louisiana to Alabama	0.94	6.92
Louisiana to Mississippi	0.26	1.91
Mississippi to Louisiana	0.06	0.44
Louisiana to Texas	4.98	36.65
Texas to Louisiana	0.64	4.71
Texas to Mississippi	0.02	0.15
Petroleum Products		
Within Alabama	0.72	5.30
Within Florida	2.59	19.06
Within Louisiana	10.30	75.81
Within Mississippi	0.10	0.74
Within Texas	20.88	153.68
Alabama to Florida	0.96	7.07
Florida to Alabama	0.02	0.15
Alabama to Louisiana	0.36	2.65
Louisiana to Alabama	0.85	6.26
Alabama to Mississippi	0.14	1.03
Mississippi to Alabama	1.06	7.80
Alabama to Texas	0.50	3.68
Texas to Alabama	0.37	2.72
Florida to Louisiana	0.03	0.22
Louisiana to Florida	7.23	53.21
Florida to Mississippi	0.02	0.15
Mississippi to Florida	5.22	38.42
Florida to Texas	0.01	0.07
Texas to Florida	13.54	99.65
Louisiana to Mississippi	1.35	9.94
Mississippi to Louisiana	0.33	2.43
Louisiana to Texas	4.85	35.70
Texas to Louisiana	6.87	50.56
Mississippi to Texas	0.55	4.05
Texas to Mississippi	0.54	3.98

Source: USCOE 1989

Routes between states are not known, but it is assumed that, since the oil is moved by tanker or barge, transport occurs directly in Gulf waters, along the Gulf Intracoastal Waterway (GIWW), or between connecting waterbodies. Petroleum movement within a state may not occur along the Gulf coast but, as in the case of Texas, could simply be between two ports along a river. Only 0.5 million metric tons of crude oil are transported out of the Gulf of Mexico by vessel from Gulf ports to Atlantic refineries.

In the calculation of oil-spill risk, these operations have not always been considered, the focus being on import-export operations versus domestic oil production. Although the original source of oil must be either from domestic production or from importation, such transport operations of the oil are separate activities from when the oil is either originally shipped into a port of entry or piped to a marine terminal. For example, OCS-produced oil could be piped to shore terminals, then later barged from these coastal facilities; or OCS oil barged ashore could be piped to a different facility, combined with both state-produced oil and imported oil, then barged to another state.

Because Florida receives no crude oil and has no Gulf coast refineries, a substantial amount of petroleum products is tankered or barged there from other Gulf states to meet its inhabitants' energy demands. Twenty-seven million metric tons (199 million barrels) of petroleum products were shipped into Florida during 1987 from other Gulf states (most of this oil is transported around the Florida Keys to Atlantic waters before making landfall) (USDOE/EIA 1987). If this state-to-state oil volume is added to the 4.5 million metric tons of petroleum products imported into Florida and the 2.6 million metric tons shipped between Florida's ports, the total oil movement in Florida waters by tanker and barge operations in 1987 is 34.1 million metric tons. Projections of oil that would be produced in Federal waters and transported through or near Florida waters by the offshore oil industry are much less. The maximum volume of crude oil projected to be produced in the Eastern Gulf during any one year (peak year 2007) is only 2 million metric tons. Estimates of total economically recoverable oil existing in the Eastern Gulf (50 million metric tons (370 million barrels) (USDOI 1990a) are only one and a half times the amount of oil shipped into Florida's waters in 1987 alone. Florida's greatest exposure risk to oil spills is clearly from vessel transport of petroleum products.

OIL SPILLS

Large spills of greater than 135 metric tons (1,000 barrels) occurring from offshore pipelines, platforms, tankers, and barges from 1974 to July 1990 are mapped on Figure 12.9. The spill statistics were compiled by the MMS Environmental Policy and Programs Division in Washington, D.C. This office maintains a database on crude oil spills occurring since 1974 from OCS oil development operations and worldwide tanker operations.

There have been 9 spills greater than 1,000 barrels that have occurred from Gulf of Mexico offshore oil production since 1974 (through July 1990), one from Mexican oil exploration, the others from OCS operations. Table 12.6 lists all historic major spills that have occurred from Gulf of Mexico OCS oil exploration and production operations since records have been kept. Of these 20 known large spills, 8 have occurred since 1974 and are mapped on Figure 12.9. Two of these were from platform mishaps; the others were all from pipeline breaks mainly due to anchor dragging. There has not been an OCS platform spill since 1980. Based on MMS statistics, the average size of spills of greater than 1,000 barrels occurring from OCS oil development is 18,000 barrels for platform spills (6,000 barrels median size), and 25,000 barrels for pipeline spills (7,000 barrels median size). In the Bay of Campeche, near Mexico, a blowout of the *Ixtoc* oil well resulted in the largest documented spill in history. Approximately 0.5 million metric tons (3.3 million barrels) of oil spilled. This spill is mapped on Figure 12.9 in the bottom left-hand corner.

Figure 12.9 also maps the locations of the 82 tanker and barge spills greater than 1,000 barrels occurring in the Gulf region between 1974 and July 1990. Only nine of these occurred outside of the coastal areas of the Gulf states. The vast majority are centered in the major port areas and along the Intracoastal Waterway and the Mississippi River where terminals are located. The major cause of the spills (45% of the incidents) was collisions in restricted waterbodies. Figure 12.10 is a bar graph that breaks down the spill locations by state. Table 12.7 displays the number of spills by type of oil and by source and average size in barrels.

The largest spill in the Gulf of Mexico from tanker operations was the result of the *Burmah Agate* tanker fire, which spilled around 255,000 barrels of crude oil near the Galveston, Texas, coast. This spill was approximately the same size as the *Exxon*

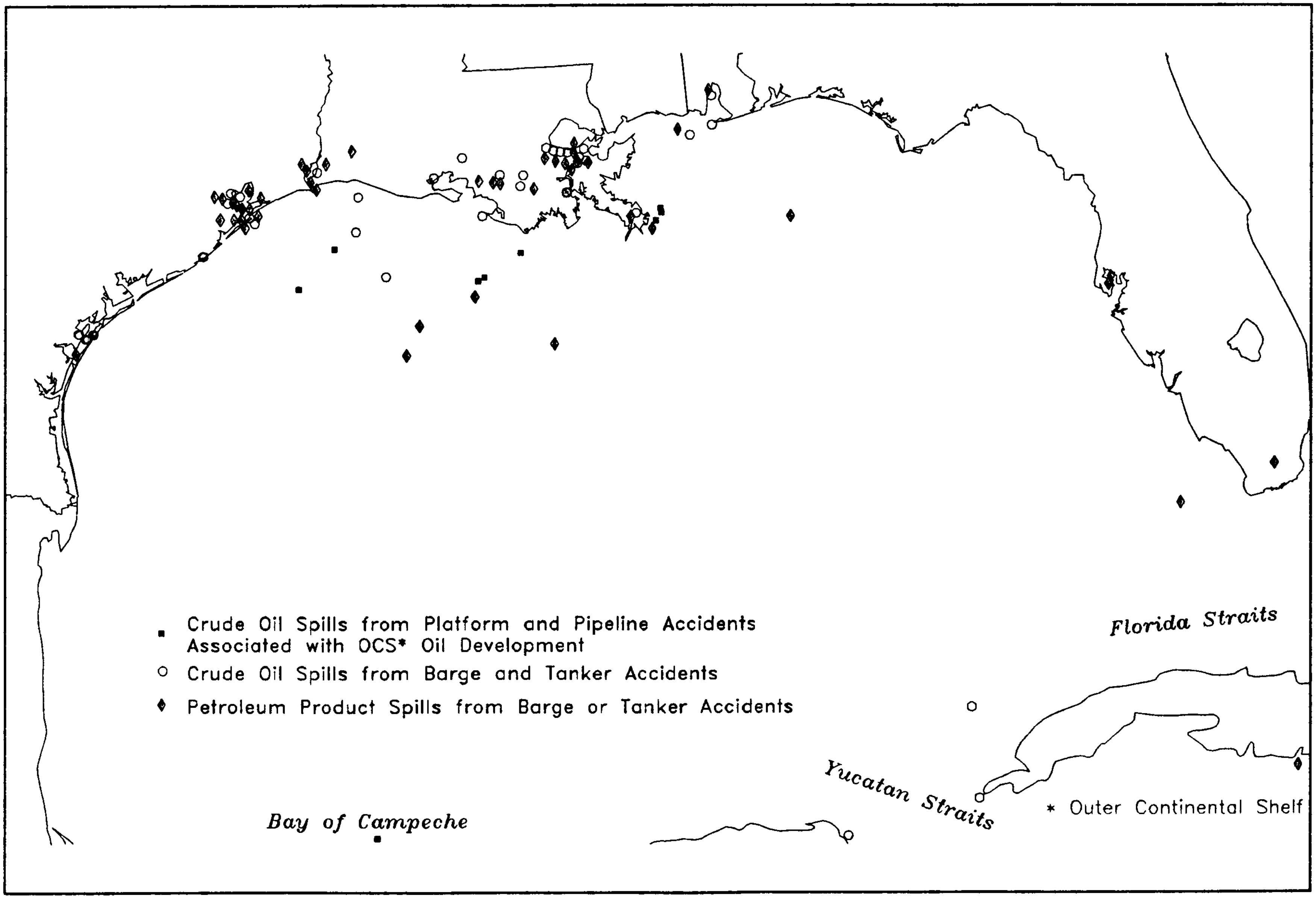

Figure 12.9. Oil spills ≥ 135 metric tons (1,000 barrels) that have occurred in the Gulf of Mexico or its coastal waters during the time period 1974 to July 1990.
Source: USDOI/MMS, Wash.,DC., Unpublished data base, 1990.

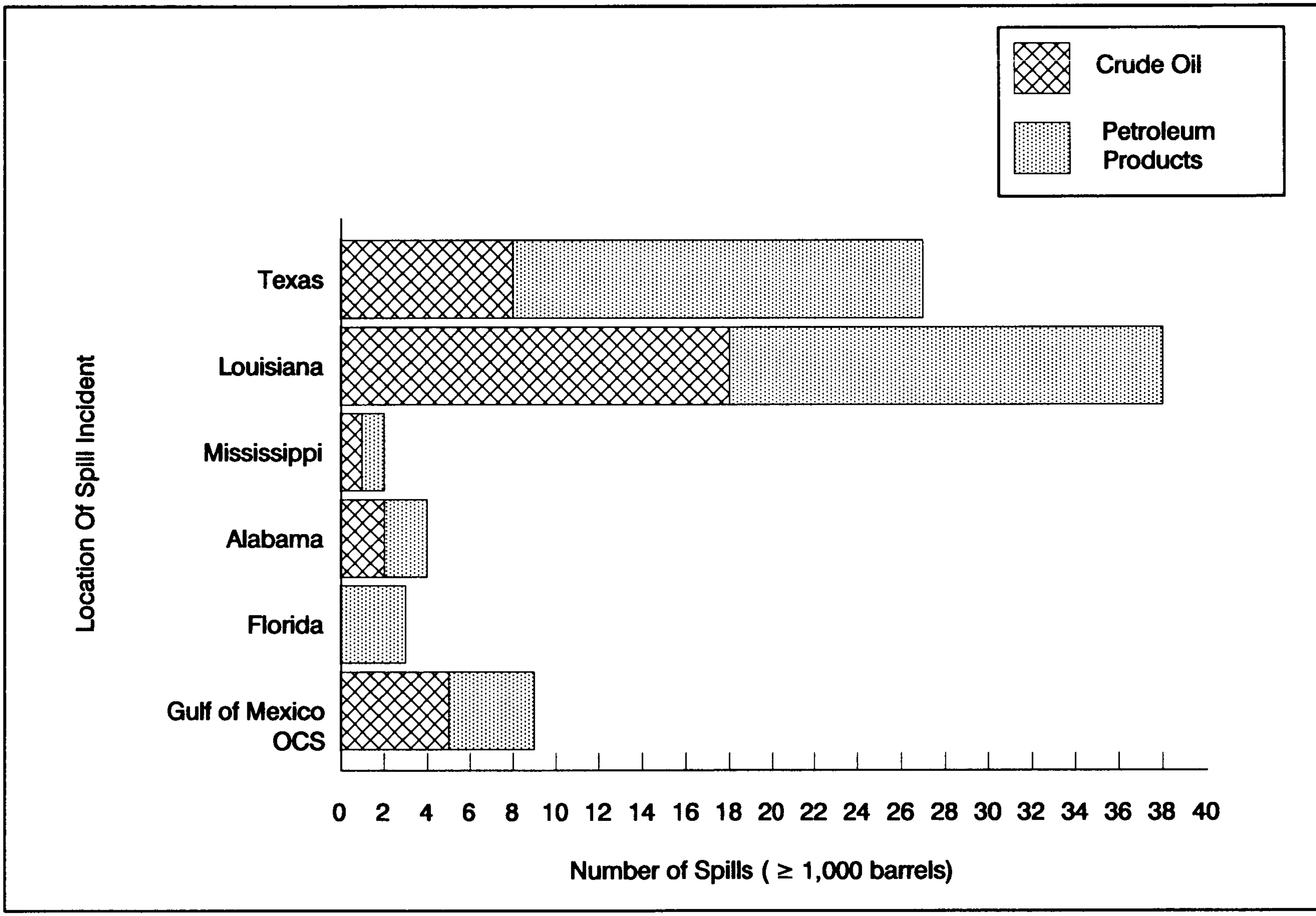

Figure 12.10. Locations of oil spills (1,000 barrels or greater) occurring in State waters or the Gulf of Mexico Outer Continental Shelf from barge and tanker accidents (1974 to July 1990).

Source: Compiled from USDOI, MMS, Wash.,D.C., Unpublished database, 1990.

Table 12.6. Oil Spills of 1,000 Barrels or More from Activities Associated with Oil and Gas Development on the Gulf of Mexico Outer Continental Shelf.

Date	Location	Spill Size (Barrels)	Cause
		PLATFORMS	
8 April 1964	Eugene Island 208	2,559	Collision
3 October 1964	(5 platforms)	11,869	(Hurricane) Blowouts
19 July 1965	Ship Shoal 29	1,688	Blowout
16 March 1969	Ship Shoal 72	2,500	(Weather) Collision/Blowout
10 February 1970	Main Pass 41	30,000	Fire
1 December 1970	South Timbalier 26	53,000	Blowout
9 January 1973	West Delta 79	9,935	Storage Tank Spill
26 January 1973	South Pelto 23	7,000	Oil Storage Barge
23 November 1979	Main Pass 151	1,500 diesel fuel	Collision/Rough Seas
13 November 1980	High Island 206	1,456	Storage Tank Spill
		PIPELINES	
17 October 1967	West Delta 73	160,638	Anchor damage
12 March 1968	South Timbalier 131	6,000	Anchor damage
11 March 1969	Main Pass 299	7,532	Anchor damage
12 May 1973	West Delta 73	5,000	Corrosion Leak
17 April 1974	Eugene Island 317	19,833	Anchor dragging
11 September 1974	Main Pass 73	3,500	Hurricane
18 December 1976	Eugene Island 297	4,000	Shrimp Trawl Drag
11 December 1981	South Pass 60	5,100	Anchor damage
7 February 1988	Galveston A-2	15,576	Anchor damage
24 January 1990	Ship Shoal 181	9,000-16,000	Initial estimates, spill still under investigation

Source: USDOI/MMS, Wash., D.C. 1990.

Table 12.7. The Numbers and Average Size of Crude Oil and Petroleum Product Spills Occurring in the Gulf of Mexico Area from Tanker and Barge Accidents (1974 to July 1990).

Number of Tanker Spills	Average Size (Barrel)	Number of Barge Spills	Average Size (Barrel)
19 crude oil	31,564	15 crude oil	5,339
16 petroleum product	11,358	32 petroleum product	7,615
35 total		47 total	

Source: USDOI/MMS, Wash., D.C. 1990.

Valdez. Much of this oil burned before reaching land.

These data on oil spills can be used to determine the risk of oil-spill occurrence. The MMS Environmental Policy and Programs Division in Washington, D.C., has developed an oil-spill rate that gives the likelihood of oil spills of 1,000 barrels and greater occurring in association with the production and transportation of offshore oil on the OCS and worldwide import crude oil operations. (Worldwide tanker statistics show that, between 1974 and 1989, there have been 188 spills greater than 1,000 barrels from tankers--62 of these spills occurring in port, 94 in restricted waters, and 32 in open waters.) Using these statistics, MMS estimates spill occurrence rates per billion barrels produced or transported. These rates are presented in Table 12.8. Because information is not available on the volume of oil barged, no spill rates can be calculated. Considering the frequency of recent tanker spill occurrences, it is surprising that, using the exposure variable of volume of oil handled, the spill rate from OCS development is similar to the spill rate from import tankers. However, knowing that, in the Gulf of Mexico during 1989, oil imported was five times the amount produced on the OCS, it is clear that it is the sheer volume of oil transported by tankers that results in such a frequency of spills from tankers.

An examination of the locations and frequency of historic spills in the Gulf of Mexico shows that the majority of the spills occur near terminals and are caused by the coastal barging of petroleum products. Nearly as many spills occur from the movement of tankers in coastal waters. Activities associated with these movements include either the import of oil by tankers approaching docking facilities or by the intra-Gulf transport of petroleum between terminals or port facilities. In predicting the risk of oil spills, the mode of transportation (pipe, barge, or tanker) rather than the type of activity or source of the oil (imported oil versus domestically produced) is the critical factor. More in-depth knowledge about the routes, the modes of transport, and the number of times that a given oil volume is transported before refining is needed to provide a better understanding of the risk of oil spills. The Oil Pollution Act of 1990, recently promulgated, has provisions for an examination of coastal oil transport. Section 207(a) of the Act requires the President to conduct a study on improved methods for the prevention of oil spills in restricted waters and similar portions of bays, estuaries, and nearshore waters, and report its results within one year to congress. It is hoped that this effort will result in a reduced risk of oil spills from vessel transport in coastal areas of the Gulf of Mexico in the future. No matter what the outcome of the study, however, considering the tremendous amount of crude oil projected to be needed in the future to meet our energy demands, oil spills will continue to occur.

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Table 12.8. Oil Spill Rates Associated with OCS Oil Development and Import Tanker Accidents--Number of Spills (1,000 Barrels or Greater) per Billion Barrels of Oil Handled.

Spills (1,000 Barrels or Greater) per Billion Barrels of Oil Handled

From OCS Oil Development		From Import Tankers	
		At Sea	
Platform	.60	Restricted Waters	.69
		Open Waters	.23
Pipeline	.67		.92
All Spills	1.27	In Port	.45
		All Spills	1.37

Source: Anderson and LaBelle 1990; USDOI/MMS, Wash., D.C. 1990

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RESPONSE FOR MEGA BORG AND GALVESTON BAY OIL SPILLS

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On June 8, 1990, just before midnight, the Norwegian tanker *Mega Borg*, anchored 57 miles southeast of Galveston, Texas, suffered an explosion in the pumproom, killing 4 crewmen and causing a major fire in the pumproom and engineroom of the vessel. At the time of the casualty, the vessel had approximately 37.5 million gallons of light Angolan crude oil on board. Over the next 8 days over 3.9 million gallons were lost, either into the water or consumed by the fire.

The *Mega Borg* response eventually involved two different operations; firefighting and pollution response. Each involved unique problems requiring coordination. Initially, a rescue operation was conducted by vessels removing most of the crew members from the burning ship. Within a few hours a number of commercial and U.S. Coast Guard (USCG) vessels had arrived on scene. The 210-ft. USCG Cutter *Steadfast* assumed the role of On-Scene Coordinator and remained on scene supervising the firefighting until the fire was extinguished six days later.

Within a few hours the Federal On-Scene Coordinator (FOSC), Captain T. C. Greene, Commanding Officer of Marine Safety Office, Galveston, Texas, made a request to the Regional Response Team (RRT) for the use of dispersant. At that time no oil had leaked from the vessel and the request was intended to address the high possibility that substantial oil could be lost from the vessel. Within 6 hours, the RRT had approved the dispersant request for the area located within a 5-mile radius around the vessel. Preparations were then made to conduct aerial spraying of dispersant onto any spilled oil. Over 55,000 gallons of the dispersant COREXIT 9527 were staged in Houston. Eventually over 11,300 gallons of the dispersant were used in the response. Water samples were taken as part of a dispersant application environmental monitoring program and the results are pending.

To fight the fire, offshore supply vessels were modified with deck-mounted pumps and fire monitors. The initial firefighting effort focused on keeping the hull of the ship cool to prevent further spreading of the fire. The large volumes of water used in this effort eventually caused oil to be carried overboard during the night of June 10th. For the next several days the fire raged throughout the stern of the vessel and occasionally spread to the oil on the water around the vessel. On June 14th an application of foam was successful in bringing the fire under control.

Pollution response operations lasted almost two weeks. The oil on the open waters of the Gulf of Mexico was first collected using skimming barriers, the Clean Gulf Association's High Volume Open-Sea Skimming System (HOSS) barge, Mexican skimming vessel *Ecopemex*, U.S. Navy skimmers, and various other support vessels. Fortunately, most of the slick dissipated and the only land impact occurred as a result of tar sheets that landed on the beaches of Southwest Louisiana. At that point, the response shifted to a beach cleanup operation.

During the response, the FOSC dealt with foreign consular offices, Federal agency heads, State agency heads including the Governor, Mexican Navy dignitaries, and local government leaders. Over 500 U.S. Coast Guardsmen from 52 units participated in the response along with 8 USCG vessels. The total cost of the Federal response exceeded 4.5 million dollars, not including the salvage and other costs borne by the owner.

Media from all over the world covered the fire and the response. Over 30 different media agencies were represented including television, press services, radio, newspaper, and magazines. The FOSC provided at least one daily press conference during the response. At times the media seemed to besiege the USCG offices.

After completion of the *Mega Borg* response, life at the Marine Safety Office in Galveston had barely returned to normal when they were faced with their second major pollution incident. On the afternoon of July 28, 1990, the Greek tanker *Shinoussa* outbound from Houston collided with an inbound tow consisting of three tank barges loaded with catalytic feedstock, a petroleum product similar to #5 oil. One of the three barges sank and one was heavily damaged from the collision, resulting in a spill of over 700,000 gallons of oil. The sunken barge came to rest along the edge of the narrow channel, resulting in the closing of the busy Houston Ship Channel until August 4.

The barge owners accepted responsibility for the spill and commenced a cleanup and salvage operation. They performed these operations until August 2 when they notified the FOSC that they had reached their limits of liability and were suspending operations. At that time the cleanup operation was federalized, meaning that Federal pollution funds were used to finance the cleanup.

Once again the FOSC was faced with a major pollution response and salvage operation that brought national attention to the issue of oil spill response. The shallow nature of most of Galveston Bay limited skimming operations and presented many challenges. The sensitivity of Galveston Bay led to consideration of alternative cleanup techniques and a request was made for the use of a bioremediation agent. The RRT approved the use of bioremediation in areas of the bay where mechanical recovery would not be viable and with the provision that an effective monitoring program be implemented.

Application of the bioremediation agent was made on August 4 in a marshy area in the northern portion of Galveston Bay. The site was selected by a team consisting of USCG, U.S. Environmental Protection Agency (EPA), Texas Water Commission, and National Oceanic and Atmospheric Administration representatives. A section of the marsh was boomed and four control sites were isolated. Two of the four sites were treated and water sampling was conducted in the four sites over the next four days to evaluate the effectiveness of the bioremediation application. The samples are at present being evaluated by the EPA at their laboratory in Edison, New Jersey.

These two incidents brought much national attention to the problem of oil spills. They occurred as Congress was deliberating new Oil Spill legislation initially drafted as a result of the grounding of the *Exxon Valdez* in Prince William Sound. Shortly after these incidents Congress passed the Oil Pollution Act of 1990, which was signed into law by President Bush on August 18, 1990.

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LOGISTICS OF THE AMERICAN TRADER OIL SPILL

LT John Meehan
U.S. Coast Guard

Text not available for publication at this time due to legal restraints.

LT John Meehan received a B.S. degree in forestry in 1979 from the University of Maine and is currently pursuing an MBA. LT Meehan has served in the USCG since 1980. He spent his first five years of service as an Aviation Electronics Tech at the USCG Airbase in Mobile, Alabama. In 1985, LT Meehan was selected for Officer Candidate School. Upon completion, he served as a manager for the USCG Auxiliary Program. LT Meehan's present assignment is with the Marine Environmental Response Division at the MSO/Group, Los Angeles-Long Beach. This division responds to some 400 oil spills a year as well as hazardous chemical incidents within the Captain of the Port Zone. As the Marine Environmental Division Chief, LT Meehan rewrote the USCG local contingency plan and served as cleanup manager for the *American Trader* spill that occurred in February 1990.

DISPERSANT USE LOGISTICS IN THE GULF OF MEXICO

Dr. Gordon P. Lindblom
Consultant

INTRODUCTION

A dispersant application on an oil spill, in common with any mechanical operation, requires that all the proper equipment has been tested and that it and all supplies are readily available or easily and quickly transportable to the spill site. Proper bases for operations on land, sea, and in the air are also required. Finally, trained personnel for the many tasks associated with the response action are essential. Without these requirements, a successful response is not possible. This presentation reviews the critical nature of the logistic requirements and the current situation on the U.S. Gulf Coast.

The term "logistics" refers to the equipment, supplies, and personnel necessary for starting and maintaining a particular job, process, or operation. It also includes associated items such as inventory ensurance and transportation, mechanical maintenance, communication and training. Every action that might be necessary for the control of oil spills requires a logistic function, and no proposed response capability can be considered in a state of readiness until this function is addressed and implemented. Simply put, unless a detailed logistic effort has been part of the plans for a given response method, no effective capability for use of that method really exists (Lindblom 1979)

Unfortunately, an incorrect perception that certain response methods are simpler to activate and control results in poor planning for them. The use of chemical dispersants is the most obvious case in point. While almost all response groups worldwide claim the ability to mount a dispersant response, the truth is that very few really have it. They fail in most or all of the logistic terms mentioned above--equipment and maintenance, training of personnel, and inventory control. Such inadequacy has resulted in another false perception--that dispersants are ineffective--when it is difficult to find instances where their use has been properly prepared for or the application properly carried out.

CURRENT GULF CAPABILITY

The Gulf Coast of the United States at present has limited dispersant response capability. Only eight spraying systems for workboats are available in the area, and several of these units require extensive upgrading. Spraying from aircraft is much more efficient, but the entire Gulf has limited access (at this time) to only three airplanes and to only one helicopter spray system, which only a few helicopters are equipped to use. Of course, in an emergency, other aircraft with adequate systems could be brought in on contract, if they are available.

Clean Gulf Associates (a consortium of oil producing companies) has six dispersant spray units for use from large workboats. These systems were designed by Halliburton around 15 years ago, according to technology available at that time, and are still maintained by them (Allen 1977). However, they need some redesign and calibration to bring them up-to-date. The current operating pressure is too high, the volume of water pumped is excessive, and there is no adequate variable control of dispersant flow. Overall, the systems are very large, requiring several palettes of heavy equipment to be loaded aboard the vessel with use of forklifts and winches. Installation requires several workers, and usually takes about 4 hours. This stands in strong contrast to much newer portable units that are available and can be easily moved and rigged by only two people. Clean Gulf has recently developed a single large box to contain much of the necessary equipment and claims that time of installation can now be reduced to 2 hours or less.

The Louisiana Offshore Oil Port (LOOP) has two of its workboats equipped with spray systems, one of which is a complete portable unit built in England, while the other has booms of LOOP's design. These systems have been calibrated and dosage control charts prepared.

The LOOP also has an exclusive stand-by charter contract (including crew) for use of two aircraft (a DC4 and a DC3), now based in central Florida. These are fully equipped for spraying, and the systems have recently been completely overhauled and calibrated to provide for controlled spraying of dispersants.

The Marine Industry Response Group (MIRG) is another offshore operator's organization with aerial spraying capability. The MIRG owns one-half of an ADDS (Airborne Dispersant Delivery System) unit together with the Clean Caribbean Cooperative (CCC). The ADDS unit is stored with the CCC stockpile in Ft. Lauderdale, Florida. It requires charter of a C-130 Hercules airplane for deployment, and also a Biegert Aviation ADDS operating crew.

The following paragraphs address the various logistic concerns mentioned earlier and point out the reasons and needs for each.

APPLICATION EQUIPMENT

Dispersant spray equipment is obviously the most important requirement. Without adequate application units, there can be no dispersant response. Aerial application is preferred because of its speed, quicker turn-around time between missions, and much better visibility for assessment of results. Airplanes are readily a necessity. Although it was once thought that helicopters could be effectively employed, this has not proved to be so, except for rapid response relatively close to a land base. There is a limitation in both capacity and speed, but a well-planned and managed helicopter response in areas near a land base could still often be more valuable than boat application, particularly if the boat is large and relatively difficult to maneuver.

All spraying equipment must be calibrated and dosage charts provided for operation and for informing response authorities. Calibration will identify the adequacy of the system to perform under various conditions, such as pressure, type and arrangement of nozzles, speed, and swath width. Equipment that has not been calibrated should not be used. Almost all failures of dispersant operations can be traced to problems with equipment and its use. Currently, the ASTM, in its Committee F-20, is developing several standards for dispersant application equipment, including design requirements, calibration and testing, and use. These will be added to 17 other F-20 standards already issued on dispersant operations.

There have been many equipment problems that have caused inadequate treatment to occur (Lindblom 1986). These include improper or malfunctioning pumps or nozzles, high fluid pressure or volume, causing misting or fogging and off-target drift (in both boat and aerial units), or (in boat units) a high spray velocity that causes the chemical to be pumped through the oil slick without effect. A common mistake on helicopter or airplane units is to orient the nozzles to discharge directly down, rather than aft. In such a case, the wind shear is far too high and only very small droplets survive. Many examples could be given of inadequate or damaged pumps, educators, nozzles, and booms, and of poorly designed systems, which are unfortunately still held by some response organizations in the United States and elsewhere.

CHEMICAL SUPPLY

Adequate and continuing dispersant supply is another obvious critical requirement for effective planning. Many stockpiles of dispersants are held by response organizations around the country. In the Gulf Coast area the largest is Clean Gulf's supply of 628 drums, 538 of which are held in Houston, Texas; 80 in Panama City, Florida; and 10 in Grand Isle, Louisiana. An additional 100 drums are held in tanks for shipboard use. Others along the coast hold fewer than 20 drums, and LOOP has about 50. Exxon Shipping still maintains about 1,000 drums at the Houston Intercontinental Airport, originally stocked there during the *Valdez* spill, and Exxon Chemical Company continues to maintain their 200-drum stock, as well as raw materials for immediate manufacture of an additional 200 drums. Perhaps the major reason for the lack of preparedness by local bases on the coast is the uncertainty of whether dispersant use would be allowed at a given spill. This situation seriously hinders planning and also capability and is due to regulatory groups still holding to outdated and disproven views about the effectiveness and safety of dispersant use, and thus are unlikely to give rapid permission for a dispersant response. This issue clearly overshadows all others, since the absence of a dispersant supply immediately eliminates all discussion of its use.

All dispersants are not alike, nor can they all be used in the same way, so it is important that any mixed stock be compatible. Some cannot be effectively used from aircraft because, due to low density and viscosity, they form a cloud of droplets of very low volume median diameter, and therefore excessive drift. Most hydrocarbon-based dispersants (of density less than 0.95 and viscosity less than 10 cst) are of this type and produce a droplet spectrum in which over 80% of the droplets are less than 50 microns in diameter (Lindblom and Cashion 1983).

Hydrocarbon solvent-based dispersants also lose effectiveness if diluted in water, such as in certain boat applications, and should not be used with equipment requiring this. However, it is not uncommon to find that response base managers do not even know the type of chemical they have in stock or its limitations.

OTHER AIRCRAFT

Auxiliary aircraft are particularly important for a dispersant application, and also must be provided for in response plans. These aircraft are used for reconnaissance, direction, and monitoring of the operation. Most important is the direction aircraft, sometimes called the "spotter" aircraft. Its function is to direct the spraying operation in the air by radio communication to the spray aircraft or boats. A member of the response team, specially trained for this function, must be in the cockpit of the helicopter or airplane used, and in direct communication with the crew of the spray plane. Directions are given for compass heading and for ordering, starting and stopping of the spray on each pass over the slick, for maneuvering into position for subsequent passes, and also to order adjustments in dosage and pump rate. During and between spray runs, the direction aircraft can observe the results as the operation proceeds. A second aircraft might be designated as another observer craft, but it is not desirable to have more than three aircraft in the area involved in a low-level operation. Helicopters are generally not recommended for direction service because of their relatively short range, but might serve adequately if the application were within about 20 miles of shore, and the spill were not over 10,000 barrels (about 6 square miles), and provided that 2 pilots were not required (thus freeing a seat for the director of the operation). If at all possible, it is highly recommended that the "spotter" aircraft should be a high-performance twin-engine airplane with a range of 3-4 hours. Such planes as the Mitsubishi MU-2, the Aerostar, and the Twin Otter are particularly good. Each has good visibility, excellent communications equipment, and room for other observers, officials, or photographers. Each is very fast, allowing for rapid positioning when directing aircraft such as a C-130 or a DC-4, thus greatly outperforming any helicopter.

TRAINING AND MAINTENANCE

Finally, provision for personnel training and drill and for regular maintenance of equipment, including deployment and testing of communications, needs to be part of any contingency plan. All equipment should be inspected for damage and deterioration in storage, and repaired as necessary. Dispersant spray systems should be fully exercised at least twice a year, and a calibration check made, and pumps, educators, and nozzles should be inspected in detail at least every two months.

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Dr. Gordon P. Lindblom was employed by Exxon for 29 years in several of the corporation's technical and research organizations. He retired from Exxon in 1986, but continues to be professionally active as a consultant to the industry on oil spill matters, such as contingency planning, training, design and calibration of equipment for dispersant use, and on-site response at spill incidents. His experience in these areas covers 15 years in over 20 countries and at several major spills, including *Ixtoc I*, *Hasbah 6*, *Patmos*, *Exxon Valdez* and *Mega Borg*. He received his B.A. and M.S. from the University of Minnesota, and his Ph.D. in biochemistry and microbiology from Michigan State University.

MINERALS MANAGEMENT SERVICE UNANNOUNCED OIL SPILL DRILL PROGRAM

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BACKGROUND

On May 30, 1989, the Minerals Management Service (MMS) notified all active operators of offshore leases in Federal waters that the MMS would soon begin conducting Unannounced Oil Spill Containment Drills to test the operator's spill response preparedness. It was anticipated that five or six such exercises would be held each year. On June 26, 1989, the MMS informed the active operators that four different types of drills or exercises had been developed and that they could be held anytime after July 1, 1989.

TYPES OF MMS OIL SPILL RESPONSE DRILLS

Table Top Simulation

In accordance with 30 CFR 250.43, operators of Outer Continental Shelf (OCS) leases are required to provide their Oil Spill Response Operating Teams (OSROT) with annual hands-on training classes and drills in the deployment and operation of oil spill response equipment. Where feasible during these exercises by randomly selected operators, the MMS may initiate a "Table Top" drill. In this type of exercise an MMS monitoring team would present a scenario involving one of the operator's facilities and then observe the OSROT's simulated and/or actual responses. In addition to drills held in conjunction with annual training classes, unannounced "Table Top" drills may be initiated periodically by the MMS at the offices of randomly selected companies.

Mobilization

In this type of unannounced drill, the MMS monitoring team presents a randomly selected operator with a scenario involving one or more of the operator's facilities. The minimum expected response to the scenario is that the operator assemble that portion of their OSROT required to operate Clean Gulf Associates' (CGA) equipment at the appropriate CGA base, procure a boat, and load the fast response system (FRS). All other actions outlined in the operator's approved Oil Spill

Contingency Plan (OSCP) may be simulated. Travel time to the scene and the time to deploy the response equipment are estimated, taking into account the distance to be traveled and the sea state.

Mobilization and Deployment

This type of unannounced drill is identical to the mobilization-only drill through the point of loading of the FRS aboard the boat. A member of the MMS monitoring team travels with the FRS to the site of the simulated spill or to another predetermined suitable location and monitors the deployment of the FRS by the OSROT.

Equipment deployment may not always be limited to the FRS. In some exercises it may be decided to have the operator activate the High Volume Open Sea Skimmer (HOSS) as part of the response effort.

The object of the above two types of unannounced drills is to test how rapidly and effectively an operator can assemble and deploy clean up and/or containment personnel and equipment. Although other activities such as conducting helicopter or boat reconnaissance, assembling an advisory committee, or transporting backup personnel and equipment may be simulated, operators will not be discouraged from actually performing these types of activities.

Announced Catastrophic

In this type exercise the MMS participates with the U.S. Coast Guard, other Federal and State agencies, and a volunteer or selected operator in an announced "Table Top" Simulation of a large spill. Although this simulation does not require the mobilization or deployment of any personnel or equipment, the exercise helps familiarize the MMS, the on-scene coordinators, and the Regional Response Team with the decision-making and coordination that are necessitated by large and extraordinary oil spills.

STEPS IN CONDUCTING AN UNANNOUNCED DRILL

Predrill

The selection of an operator to participate in an unannounced drill is made randomly, but such factors as the number of oil producing facilities and the volume of oil production are considered before the final choice is made. Once an operator is chosen to participate in a drill, that operator's OSCP is reviewed for familiarization, and his current operations; i.e., the number and locations of his offshore activities, type and volume of production, are reviewed. Based on the review of the operator's current activities, an appropriate location is chosen and a spill scenario is developed.

Scenarios are designed to elicit a desired response from the operator, that is, what containment or clean up equipment will be deployed to protect what resources? To achieve this response, fictitious weather conditions are used to produce a trajectory of the spill. These fictitious weather conditions are provided to the operator during the drill. Real time (actual) weather conditions are not to be used during the drill.

Four of the five unannounced drills conducted to date were carried out during normal business hours. The fifth was initiated during the early evening. While it is more convenient to carry out a mobilization or a mobilization and deployment drill during normal business hours, the position of the MMS is that, just as an actual spill can occur at anytime, an unannounced drill may be held at anytime.

The MMS notifies other agencies such as the local Coast Guard Marine Safety Office and the National Response Center of the planned drill. One reason for this notification is, in the event that the operator fails to state that the call is being made as part of a drill, the agency will be aware that particular operator will be participating in an unannounced drill conducted by the MMS. Having been previously notified, the agency may then inquire of the operator if the call is being made in conjunction with a drill.

During Drill

During the drill one or more of MMS's monitoring team members are dispatched to the operator's spill response command center to observe the response activities there. Arrival of the team member(s) at the command center is timed to coincide with the arrival of the team member at the spill site. Most drills are planned to have the initial notification of the simulation delivered to the field; i.e., at the location of the fictitious spill. This is done by a team member who presents a copy of the spill scenario to the operator's representative at the spill location. Concurrently with or shortly after notification is received by the field and the command center, one or more of MMS's monitoring team members arrive at the CGA equipment base that, by scenario design, is the most logical for the operator to choose. Here these team members observe such things as time of notification, equipment requested, time to load equipment, and time of departure of the equipment from the base. The MMS monitoring team leader remains at the Regional Office and serves as the MMS point of contact for the operator. The team leader receives the initial call from the operator that a spill drill is in progress and customarily provides the operator with periodic weather and spill location updates. The team leader also receives progress reports from the team members at the command center and the CGA base. The team leader may at times also simulate the roles of other government agencies during the drill.

Post Drill

After conclusion of a drill, the MMS monitoring team members discuss among themselves and with the operator's and CGA representatives, as appropriate, the strong and weak areas of their responses. Exemplary responses are acknowledged and recommendations for improvement are offered when warranted. Upon their return to the office, all members of the MMS monitoring team meet and review the drill and discuss their respective observations from each location. A written critique of the drill based on the observations of the team members is prepared. A written summary of this critique is furnished to the operator.

DRILLS CONDUCTED TO DATE

Chevron U.S.A.
July 25, 1989

Scenario

A large fishing vessel struck the D and E platform complex at South Timbalier Block 27. The vessel struck the leg supporting a 240 cubic meter (m^3) (1,500 barrels [bbls]) oil storage tank, causing the tank to rupture and spill 159 m^3 (1,000 bbls) of crude oil into the Gulf. The collision also damaged an incoming pipeline and it began leaking about 1.6 m^3 (10 bbls) per minute. The estimated loss from the pipeline before the leak was noticed was 39.8 m^3 (250 bbls).

Analysis

Chevron was able to procure a vessel, load a fast response unit (FRU), and was prepared to depart the shore base in 6 hours and 10 minutes, which compares favorably with the 6 hours estimated in its Regional OSCP.

Union Exploration Partners
October 24, 1989

Scenario

An oil storage tank on Platform F at Eugene Island Block 32 began leaking oil during the night through a split in a seam after a weld gave way. Approximately 398 m^3 (2,500 bbls) leaked into the Gulf.

Analysis

The Oil Spill Response Coordinator was, by coincidence, offshore at the site of the spill and chose to coordinate the response from there rather than designate an alternate at the command center or appoint a liaison between himself and the response team. Union was able to procure and load out an FRU in the very commendable time of 2 hours 15 minutes. However, travel time from the chosen shore base to the spill site was 12 hours, and the company had the means available to transport an FRU from another shore base to the leading edge of the spill in less than 6 hours.

Shell Offshore Inc.
February 1, 1990

Scenario

A well being worked over at Platform A, Mississippi Canyon Block 194, blew out at 7 p.m. and began flowing uncontrollably.

The estimated rate of flow was approximately 24 to 32 m^3 (150 to 200 bbls) per hour. The scenario was designed to determine Shell's ability to respond effectively to a nighttime oil spill by utilizing the means at their disposal as defined in their regional OSCP.

Since this drill was conducted at night, rather than have Gulf of Mexico OCS Region personnel act in the roles of personnel from the MMS regional and district offices and State and Federal agencies, Shell was instructed to follow their OSCP. Prior to the drill, the monitoring team leader had informed all the appropriate parties and agencies of the impending drill.

Analysis

Shell's oil spill response personnel were well prepared to make appropriate response decisions in an orderly and timely manner. Shell's initial spill response headquarters in One Shell Square is well equipped with the necessary communications system, appropriate spill tracking maps, and recordkeeping equipment to coordinate the various activities that are required for an effective response to a spill from exploration or production operations in the Gulf. The types and amounts of response equipment obtained or simulated to be obtained were appropriate for the spill scenario.

Shell was able to procure two boats to mobilize the HOSS barge much quicker than anticipated. However, the time required to procure several of the vessels for the FRU was greater than anticipated.

From this and previous drills, it appears that boat procurement times are longer and equipment load-out times are shorter than estimated.

Conoco, Inc.
April 12, 1990

Scenario

At 10:15 a.m., during routine drilling operations at Well No. 2, Destin Dome Block 56, it was discovered that a split in a diesel fuel tank aboard the ODECO drilling rig *Ocean Titan* had released approximately 31.8 m^3 (200 bbls) of diesel fuel into the gulf.

Analysis

The oil spill response vessel the *Joey D* was moored to a buoy approximately one-half mile from the *Ocean Titan*. The oil spill response equipment aboard the *Joey D* included one FRU, 1,500 ft. of 4300 "Expandi" boom, and a small inflatable boat with outboard motor. A full crew was aboard the *Joey D* to deploy the equipment.

The onsite FRU was deployed in 30 minutes; however, Conoco chose not to deploy the 1,500 ft. of "Expandi" boom on the *Joey D* due to the sea conditions (4 to 6 ft.) at that time. For the same reason, Conoco did not deploy the 200 ft. of sorbent boom located at the rig site. The sorbent boom would be particularly effective in the event of a diesel spill.

Conoco located a sufficient amount of dispersant and equipment necessary for its use in a short period of time. However, it is the opinion of the monitoring team that the dispersants would not be necessary nor very effective, considering the size and type of oil spilled.

Conoco's Accidental Discharge Emergency Preparedness Team (ADEPT), which assembled in the New Orleans office, and the onsite personnel were well prepared and quite efficient in their duties. Good communications were established and maintained between the *Ocean Titan* and the team. Several hand-held, two-way radios, which proved to be necessary and effective, were used for communications between the *Joey D*, the surveillance helicopter, the tool pusher, the drilling foreman, and the rig's safety technician.

The consensus of the monitoring team was that Conoco was prepared to respond adequately to a spill of this type, but the adverse weather conditions limited their actions, thereby limiting the scope of the drill.

Kerr-McGee Corporation
August 7, 1990

Scenario

A 4-inch oil transfer line ruptured near Platform C, Ship Shoal Block 33, causing a loss of approximately 79.5 m^3 (500 bbls) of crude oil.

Analysis

Kerr-McGee (KM) handled the response effort admirably despite the fact that their primary response coordinator and his two alternates were out of town attending a meeting requested by MMS Headquarters personnel. The field was notified of the simulated spill by MMS Houma District personnel at 9:03 a.m., and the KM spill response operations center in Lafayette, Louisiana, was notified by the field at 9:20 a.m. The spill scenario was accurately relayed from the field to the operations center. The KM emergency response phone system at the operations center was activated by 9:30 a.m. All mandatory and courtesy notifications were made by 11:15 a.m. Timely requests for weather observations were made throughout the drill. The KM team first considered the use of dispersants at 10:55 a.m., but did not begin filling out the request until 12:20 p.m.

The FRUs were procured timely and from the appropriate spill base locations. Alternate equipment procurement scenarios were properly considered by KM. Estimated response times of 7-1/2 hours from Morgan City and 14 hours from Intracoastal City were within the accepted range.

SUMMARY OF DRILL OBSERVATIONS

Pros

1. Overall OSCP Worked

   The OSCP's call for an orderly response to an oil spill event, and the operators who have participated in the drills, have all demonstrated this capability.

2. Teams and Coordinators Know Their Responsibilities

   The unannounced drill program has demonstrated that the Response Coordinators are, generally, properly educated about the consequences of a spill and about the resources available to mitigate these consequences. Team members generally showed evidence of being well trained to carry out their individual responsibilities.

3. Response Times to Mobilize Were Within the Limits Projected by the Operators

   In each drill the containment and cleanup equipment and the trained personnel to operate the equipment were ready for transportation to the drill site within the times projected by the operator.

4. CGA's Equipment Was Functional

   Of the five unannounced drills conducted to date, two involved deployment of the CGA equipment. In each case the equipment was assembled and deployed without any significant problems. There were no problems associated with loading or transporting the equipment during any of the drills.

Cons

1. Communication Between the Field and Oil Spill Response Center Can Be Improved

   There have been instances, not necessarily during these drills, where inaccurate information was given to the response center by the field, or important details about a spill were completely overlooked by the field when reporting to the response center. If a response is to be designed to accommodate a particular spill, those preparing the response must be provided accurate information about the spill.

2. Dispersant Use Form Needs to Be Available

   Operators' response teams have not always had the forms needed to request approval to use dispersants readily available during a drill, nor have the response coordinators had a prior knowledge of the oil properties of their companies' production. Copies of the dispersant use request form should be available in the command centers along with a listing of the characteristics of the oil(s) produced at the operator's facilities. Having the form available allows it to be completed and submitted expeditiously, which may provide the time needed to protect sensitive resources.

3. Spill Trajectories Need to Be Updated More Frequently

   One spill trajectory will not necessarily be sufficient to predict where the slick will impact unless the spill occurred in very close proximity to shore. Trajectories should be run as frequently as necessary dependent upon changing weather and current conditions. Having an accurate forecast of shoreline impact allows for a determination of the shoreline areas that should be protected.

4. Vessels Not Under Contract Should Be Considered

   Always look for the quickest vessel of opportunity. Operators should not limit their search to only those vessels under contract to themselves. Depending on their location and status, contract vessels may not always be able to provide the fastest response. There could be vessels available near a CGA base that could be loaded and dispatched to the spill site before a contract vessel could arrive at the CGA base.

5. Operators Should Have a Checklist of OSCP Requirements

   Each operator should develop a checklist of the major items to be considered when responding to a spill. Development and use of such a checklist help to ensure that all of the appropriate response actions are taken more quickly than if, alternatively, the OSCP itself must be gone through section by section at the time of a spill.

6. Use All Resources Available for Response

   In times of emergency, divisions of a company should not consider themselves as autonomous, self-sufficient entities. The resources of other divisions may be able to respond more quickly than those of the affected division. Additionally, other operators in the area may be able to assist with personnel or equipment, and this possible source of assistance should not be overlooked.

7. Obtain a Spill Trajectory as Quickly as Possible

   The initial estimate of where the spill is going will determine the type and magnitude of the initial response. If one doesn't know what areas and resources might be impacted, one cannot know what equipment will be needed to protect those areas and resources.

8. Know the Equipment

   The Response Coordinator and appropriate members of the response team should know the capabilities and limitations of the response equipment and the specifications of the support equipment required to be used with the response equipment. For example, the HOSS barge is not intended to function as a movable skimmer; an FRU on a vessel with a 10-foot draft cannot function in 8 ft. of water.

Mr. Hennessey is an 18-year veteran of the Minerals Management Service and its predecessor, the Conservation Division of the U.S. Geological Survey. At present he is the Unit Supervisor of the Exploration and Development Plans Unit in the Regional Office for Field Operations, Gulf of Mexico OCS Region. Prior to his present assignment he served for 14 years as the District Drilling Engineer in the New Orleans (Metairie) District. Mr. Hennessey worked as a Field Engineer for an oil industry service company for 6 years after earning a B.S. in physics from Southeastern Louisiana University.

UPDATE OF FLORIDA'S OIL SPILL CONTINGENCY PLANNING

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HISTORY OF FLORIDA'S POLLUTANT SPILL PREVENTION AND CONTROL ACT

The Florida Legislature first enacted oil spill legislation in 1970. No sooner did this legislation become effective, than it was challenged in Federal Court as being unconstitutional. The basis of this challenge was a provision that created unlimited liability on the part of a spiller regardless of whether or not a spill was intentional. The U.S. District Court ruled in 1971 that the law was indeed unconstitutional and issued a temporary restraining order enjoining Florida from enforcing it. The State appealed the order and in 1973 the U.S. Supreme Court overturned the lower court's ruling.

In 1974, Chapter 376, Florida Statutes, the "Pollutant Spill Prevention and Control Act," was amended to establish limits of liability for oil spill cleanup at $14 million or $100 per gross registered ton for a vessel, whichever is the lesser, and $8 million for a terminal facility. However, these limits only applied to accidental spills and not to spills that were the result of a willful act or gross negligence and only applied to cleanup cost. Damage liability continued to be unlimited.

As part of this act, the 1974 Legislature created the Florida Coastal Protection Trust Fund and established a $35 million cap. The fund was financed primarily by a two-cents-per-barrel excise tax on pollutants when first produced in Florida or imported into the state. Pollutants were defined as petroleum products, pesticides, ammonia, chlorine and derivatives thereof, but liquefied petroleum gas, medicinal oils, lubricants, and waxes were excluded. In 1980 the fund capped at $35 million and the tax was suspended.

The trust fund was established to be used by the Florida Department of Natural Resources (DNR) as a nonlapsing revolving fund to provide a mechanism to have financial resources immediately available for cleanup and rehabilitation after a pollutant has been discharged, to prevent further damage by the pollutant, and to pay for damages.

In 1989 the Legislature raised the cap to $50 million and provided that the interest earned on the fund after it reaches $30 million shall first support the administrative expenses, personnel expenses and equipment costs of the Department relating to enforcement of ss. 376.011-376.22, Florida Statutes, with the remaining interest split equally between the Save Our State Environmental Education Trust Fund and the acquisition of coastal recreational lands and lands for improving beach access.

The balance in the trust fund as of October 31, 1989, was $28.7 million. The two-cents-per-barrel transfer tax was activated July 1, 1989, pursuant to action taken by the 1989 Legislature to raise the cap to $50 million. It is estimated that the annual revenue from the tax will be approximately $6 million and the fund is projected to cap at $50 million by July 1994.

COASTAL SPILL RESPONSE PROCEDURAL SUMMARY

Pursuant to the National Oil and Hazardous Substances Pollution Contingency Plan, the Federal Region IV Response Team is immediately activated in response to a major spill into the coastal waters of Florida. The team includes representatives of five Federal departments and six southeastern States. The nearest U.S. Coast Guard (USCG) Captain of the Port is designated as the Federal On-Scene Coordinator responsible for directing the overall spill response efforts. Upon activation of the Regional Response Team, the State Response Team is activated and its manpower and resources made available to the Federal On-Scene Coordinator.

In accordance with Federal and State laws, the identified spiller is given the opportunity to assume financial responsibility and initiate a timely and effective cleanup. If the spiller assumes this responsibility, the basic role of the USCG and the state is to monitor and evaluate the cleanup efforts constantly and to assess the damages. If the spiller declines to accept financial responsibility or does not react or perform in a satisfactory manner, the USCG assumes responsibility for the cleanup operation through the use of third party contractual agreements.

In the event that Federal funds are exhausted or there are third party damage claims or additionally needed cleanup efforts resulting from the spill, the Florida Coastal Protection Trust Fund is activated pursuant to s. 376.11, Florida Statutes.

The Florida Coastal Pollutant Spill Contingency Plan is a coordinating document for State involvement that sets forth procedures for spill response, identifies all potential participants and equipment, sets out time frames and basically establishes a comprehensive framework for decision making that leads to hands-on cleanup. The plan is updated annually because of the involvement of so many State and Federal agencies, districts, city and county governments, cleanup cooperatives, third party contractors and changing disposal sites. Individual addresses and phone numbers are kept current in order for the plan to be a guideline for spill response at any given time. This plan is in direct support of the Atlanta Region IV Federal Regional Response Team. A copy of this plan may be obtained from the DNR's Division of Law Enforcement, 3900 Commonwealth Blvd., Room 704A, Tallahassee, Florida 32399.

1989 LEGISLATIVE INITIATIVES

The 1989 Legislature appropriated $2.3 million from the Florida Coastal Protection Trust Fund for the acquisition of spill response equipment, the development and implementation of a pollution response training program, and the establishment of four regional coordinators in the DNR. Actions undertaken as a result of the 1989 Legislature include the following:

1. The purchase of oil spill response equipment to be prepositioned at 12 port locations in the state. This program component is being implemented through a grant from the DNR to the Jacksonville Port Authority. This equipment will include 19 skimmer vessels and 48,000 ft. of heavy duty containment boom. All of this equipment will be trailerable for rapid deployment to any point in the State. Through the implementation of this program component, Florida will effectively double the amount of available spill response equipment in the State. The anticipated completion date for this program component is December 31, 1990. Funding for this initiative totaled $1.7 million.

2. The development and implementation of a comprehensive pollution response training program. This program component is being administered through a grant from the DNR to the Florida Community College at Jacksonville. The primary objective of this training initiative is to develop a well-trained force of first responders, who will be immediately available to combat a major coastal pollutant spill in their

area. As part of this program, 15 Florida Marine Patrol front-line personnel received specialized oil spill training during October 1989. Final completion of the entire training program has a target date of November 30, 1990. Approximately 1,000 first responder personnel will have been trained at that time. Funding for this initiative totalled $395,000.

3. The establishment of four regional response coordinator positions within the Florida Marine Patrol. These positions have been established in Panama City, Tampa, Miami, and Jacksonville. These coordinators work with the pollution prevention and response activities of the various ports, spillage control organizations, third party contractors and the U.S. Coast Guard on the development and maintenance of better pollution response capabilities. The funding for this program component totalled $198,014.

SPILL RESPONSE TASK FORCE LEGISLATION

In 1989 the Florida Legislature created a Spill Response Task Force consisting of twelve members appointed from the following sources: Florida DNR, Florida Department of Environmental Regulations, U.S. Coast Guard, ports, spillage cooperatives in the State, groups advocating the protection of the environment, the petroleum industry, one State senator, and one State representative.

The Spill Response Task Force was directed to

1. Investigate and evaluate Florida's readiness to respond to oil and hazardous material spills in coastal waters with regard to

   (a) Prevention, including pilot training and certification, channel markings, safety regulations, and other prevention factors.
   (b) Containment of spilled material.
   (c) Removal of spilled material.
   (d) Cleanup and disposal of waste and residual material from spills.

2. Determine the existence of or need for a coordinated plan, and what elements the plan should contain, to implement prevention, containment, removal, and cleanup of oil and hazardous material spills.

3. Meet with parties that have some responsibility in the prevention of and response to oil and hazardous material spills to receive comments and input relative to the task force's investigations.

4. Consider in its investigation the capabilities and spill response program of the U.S. Government.

5. Compile and review current inquiries, recent and ongoing studies, and legislation pertinent to spill response readiness.

6. Submit to the Speaker of the House of Representatives, the President of the Senate, the minority leaders of the House of Representatives and the Senate, and the Governor by February 1, 1990, a report that clearly states recommendations necessary to improve the State's readiness to prevent, contain, remove, and clean up petroleum and hazardous material spills in coastal waters. The task force shall recommend in its report the designation of an existing or proposed governmental entity to be a central review and coordinating body for inquires into and studies on spill response readiness. In addition to specific recommendations, the report shall include legislation needed to implement the recommendations.

Public notice of all five Spill Response Task Force meetings was given and they were open to the public.

CHAPTER 90-54 LAWS OF FLORIDA POLLUTANT SPILL PREVENTION AND CONTROL

The 1990 Florida Legislature enacted a comprehensive package of initiatives designed to substantially improve oil spill prevention and response capabilities in the state. The following is a brief overview of the provisions contained within these new amendments to the law:

- Transfers the registration and licensing of bulk product facilities from the DNR to the Department of Environmental Regulation.

- Establishes a mandatory system whereby all vessels transporting pollutants as cargo in State waters must have adequate financial security to insure for needed oil spill cleanup.

- Requires oil handling waterfront facilities including marinas to have immediate access to needed oil spill containment and cleanup equipment. This requirement does not apply to facilities handling only gasoline.

- Increases the safety regulation of large vessels by requiring ship specific oil spill contingency plans and the booming of heavy oil product transfers. Also, guidelines are to be established for each Florida port; these will provide for minimum vessel bottom clearances and for the controlled movement of vessels entering and leaving State ports.

- Establishes stronger requirements to regulate vessel pilots better.

- Establishes a network of civil penalties for those individuals who violate Florida's oil spill prevention and control laws.

- Raises the cap on the Florida Coastal Protection Trust Fund from $50 million to $100 million. This action will only take effect if the U.S. Department of Interior approves offshore oil drilling in waters off Florida's coast.

- Increases the limits of liability for an oil spill by a vessel from $14 million or $100 per gross ton to $50 million or $625 per gross ton, whichever is less. These limits will also increase for terminal facilities from $8 million to $25 million.

- Establishes a program to create minimum construction and installation standards for large aboveground pollutant storage tanks. Included in this Department of Environmental Regulation program will be the testing of these tanks to insure for their structural integrity.

Mr. John H. Holmead joined the Florida Marine Patrol as one of four regional oil spill prevention coordinators when the positions were first established in October 1989. His Northwest Region consists of the coastal portions of the Florida panhandle. Mr. Holmead received his B.S. degree in business and public administration from the University of Maryland. He retired from the U.S. Coast Guard as a Captain with 30 years' service prior to embarking on a new career with the Florida Marine Patrol.

UPDATE OF ALABAMA'S OIL SPILL CONTINGENCY PLANNING

Mr. John C. Carlton
Alabama Department of
Environmental Management

Partly in response to the *Valdez* incident, but primarily as part of the Alabama Department of Environmental Management's (ADEM) on-going planning efforts, a review of the ADEM *Oil and Hazardous Materials Spill Contingency Plan* was commenced in January of this year. This plan describes how the ADEM functions internally and is designed to be a dynamic document providing guidance to employees during emergency situations and serving as a reference source for emergency response contacts. The overall State response mechanism for hazardous material spills is set forth in the *Alabama Emergency Operations Plan* (EOP). This plan is maintained by the Alabama Emergency Management Agency, which was designated as the State's coordinating agency--pursuant to Executive Order 40--and includes fairly detailed lines of authority and areas of responsibility for each State agency. It also establishes a toll-free reporting number for calls placed within the State and establishes the State Hazardous Materials Task Group (HMTG), which serves as an ad hoc interagency coordinating body to plan and recommend procedures for the State response to hazardous materials incidents. The plan also establishes the State Hazardous Materials Response Team and predesignates the State On-Scene Commander during specific incident types. The role of the ADEM under this plan, in part, is to (1) act as the technical advisory agency in identifying and directing the containment, treatment and removal of hazardous materials threatening or affecting water or air quality as authorized by Alabama's environmental laws and regulations; (2) recommend the type of treatment, storage or disposal facilities for hazardous materials and advise the responsible party on proper disposal methods for hazardous materials spills; (3) act as the primary operational agency in the containment and cleanup of hazardous material spills in State waters; (4) act in coordination with other response elements as the authority on the use of chemical dispersants in combating a hazardous materials incident; (5) provide a representative to serve as vice-chairman of the HMTG on a rotating basis with Department of Public Safety; (6) coordinate activities between the State and the U.S. Environmental Protection Agency

(EPA) and/or U.S. Coast Guard (USCG); and (7) provide a representative to the State Emergency Operations Center as necessary.

In addition to these response-oriented responsibilities, the EOP establishes the role of each State agency, pursuant to Executive Order 4, under S.A.R.A. Title III. The ADEM's role is to (1) maintain jurisdiction over chemical releases as outlined by law; (2) serve as the repository for the list of chemicals and hazardous chemical inventory forms; and (3) provide public access to the chemical lists, forms, or other information as prescribed in Title III.

The EOP, as is readily apparent, is designed to cover hazardous material incidents and does not specifically address oil spills. This plan, however, has been implemented for petroleum spills occurring from landbased facilities and transportation accidents impacting waterways and has proven to be very effective. Portions of the EOP allude to the fact that the ADEM is the primary State response agency to oil spills occurring from waterborne transportation impacting State waters. The ADEM reporting procedures for oil spills in State waters are primarily through the National Response Center, USCG, and/or EPA, since there are currently no State statues or regulations requiring direct notification. Each of these Federal Agencies maintains a listing of the ADEM contact telephone numbers for each of the three geographical response regions. Each ADEM region utilizes a local beeper and/or answering service to notify response team members after normal workhours. The response team consists of several employees in each office who rotate being primarily on call with one or more individuals designated as secondary (backup) responder. The level of responsibility ADEM is commensurate with the severity of the incident and maybe as uninvolved as remaining on stand-by up to a full scale on-scene response with sampling teams and equipment. This is where the previously mentioned *Oil and Hazardous Material Spill Contingency Plan* provides guidance to employees in assessing the appropriate level of response and ensuring that any other necessary State/Federal notifications are made. The draft of the revised plan establishes an in-house mechanism through which the on-scene representative can access the wide variety of technical expertise within the ADEM and establishes procedures for requesting additional State/Federal agency resources. There are also provisions requiring that each branch office maintain a notebook containing specific contacts for Federal, State and local governmental response agencies, waste disposal facilities, cleanup contractors, commercial analytical laboratories, adjacent State response agencies, and waste disposal facilities.

As indicated earlier, this plan is an internal working document for employees and is not intended to duplicate the Region IV Regional Response Team (RRT) contingency plan, but rather to complement it and ensure that it is implemented. The ADEM has been, and will continue to be, an active member of the RRT and its various working groups and continues to enjoy a good working relationship with both the EPA and USCG. Historically, the ADEM has relied on USCG response to oil spills within the coastal area, providing technical advice and on-scene representatives when requested or as necessary to ensure the maximum protection of the State's natural resources.

This notwithstanding, the Alabama Legislature passed Act 90-741 creating the "Spill Response Task Force." This group is charged with assessing the existing State capabilities to respond to oil and hazardous material spills within the coastal area of Alabama, determining the need for a comprehensive response plan, reviewing the existing spill prevention factors, and making recommendations to the Governor and Legislature by January 1991. To date, the Task Force has held two meetings and made good progress in assimilating the necessary background information. Pending the completion of the Task Force report, its recommendations, and how it is received by Alabama lawmakers, there may be some changes in Alabama's oil spill contingency planning and response procedures.

Mr. John C. Carlton is Chief of the Alabama Department of Environmental Management's Mobile Branch and has served in that capacity for 11 years. He has a Bachelor of Science degree in marine biology from the University of South Alabama. Mr. Carlton's experience spans a period of 12 years and includes water quality studies and spill response while employed with ADEM. He is a member of the Gulf of Mexico Program Technical Steering Committee and Toxic Substances and Pesticides Subcommittee and a member of Alabama's Coastal Waters Initiative's Science and Technical Committee. Mr. Carlton is also participating in Alabama's Oil and Hazardous Materials Spill Task Force.

AN UPDATE ON OIL SPILL PREPAREDNESS ACTIVITIES IN THE STATE OF LOUISIANA

Mr. R. Bruce Hammatt
Louisiana Department of
Environmental Quality

This presentation summary will concentrate on updates of the following four major areas concerning oil spill contingency planning in Louisiana: (1) an update of the State oil/hazardous materials emergency notification regulations, (2) the issue of oil spill preparedness and response activities, (3) the Governor's Oil Spill Task Force, and (4) recent developments regarding the use of oil spill dispersants off the coast of Louisiana.

Act 200, which was passed in the 1989 State Legislature, required the Louisiana Department of Environmental Quality (DEQ) and the Louisiana Department of Public Safety and Corrections to consolidate the existing dual reporting system for State notifications of emergency chemical releases and to develop a "one-stop shopping" concept for emergency chemical releases. Several changes that were being made at the State and Federal levels relative to Comprehensive Environmental Compensation and Liability Act (CERCLA) reportable releases dictated that the process would take a little longer than anticipated. These changes included major revisions of the reportable quantities and name changes for many chemicals and compounds.

The Louisiana DEQ has met with several industry representatives and other State agencies and is developing the one-stop shopping idea as required by law for those incidents defined by our regulations as being environmental emergencies. At this time, we are anticipating the Department of Public Safety and Corrections, Office of State Police, will man the 24-Hour Louisiana Emergency Hazardous Materials Hotline (504) 925-6595. They will be responsible for notifying all other State agencies regarding these reported emergency incidents as appropriate. We anticipate that the new regulations will be published in the April 1991 issue of the Louisiana State Register.

The *Exxon Valdez* and *Mega Borg* incidents, as well as several other major incidents occurring around the nation in the last two years, have obviously required those of us dealing with oil spills at the State level to reevaluate our preparedness posture. I believe most coastal and many inland States will be considering substantial changes as a result of these catastrophic oil spill incidents. In Louisiana, two bills dealing with this issue were introduced in last year's legislative session. The two bills were quickly consolidated into a single coordinated bill.

The resulting bill was debated extensively by the Natural Resources Committees of both Houses. Most of the discussions centered around the level of funding and the source of the funds necessary to carry out the provisions of the Act. Other heated debates centered around the membership and size of the oil spill commission, which was to be established to help guide and coordinate the overall State effort on preventing, preparing for, and responding to major oil spills. The legislature was not able to reach a consensus on any of these issues and, as a result, the bill was withdrawn in the closing days of the legislative session.

Governor Roemer later established an Oil Spill Prevention and Contingency Task Force by Executive Order BR-90-9. The responsibilities of the Task Force include

(1) Determining the needs and resources of the State and industry for responding to oil spills;

(2) Determining the response capabilities of the State, and the potential for cooperative interstate or regional response;

(3) Determining the potential for better coordinated interaction among Federal, State, institutional, local, and private entities during a given spill response;

(4) Formulating training plans;

(5) Preparing a statewide oil spill prevention and contingency plan;

(6) Encouraging industrial and environmental participation and support;

(7) Identifying long-term and emergency funding sources;

(8) Recommending needed legislation and regulations; and

(9) Undertaking any other action that the Oil Spill Task Force deems appropriate.

The Task Force members were appointed by the Governor and include three Chairmen of the House and Senate Natural Resource Committees; the Secretaries of the Departments of Environmental Quality, Natural Resources, and Wildlife and Fisheries; the Governor's Executive Assistants for Coastal Activities and Environmental Affairs; the Assistant Director of the Office of Emergency Preparedness and three members to serve at large. These three members include a private attorney, the president of the Louisiana Offshore Oil Port, and State Representative Ted Haik, the author of the oil spill bill discussed in the State Legislature. The Task Force has received input from a number of private industry representatives as well as the U.S. Coast Guard (USCG) and State response personnel. On September 30, 1990, a recommendation was sent to the Governor with unanimous support from the Task Force. These recommendations were to designate the DEQ as the lead State agency in charge of oil spills and to request that the Governor designate an individual to be in charge of oil spills as a coordinator of major spill events.

There have been several important issues discussed in detail by the Task Force, which I feel will be addressed in the near future. They include the issue of third party liability; preplanning on response actions including interstate compacts or agreements and other issues such as boom deployment and protection of critical resources; the use of oil spill dispersants, burning, and bioremediation; encouraging Federal and State cooperation with oil spill drills where we would actually add oil to the water's surface; and natural resource damage assessment.

On the issue of third party liability, we have encouraged the adoption of a policy that is basically identical to that recommended by the newly created Marine Spill Response Corporation. This would be a "good samaritan" concept similar to that already existing in the State for hazardous materials. This is a very important issue if we are going to have the cooperation we need with the private response organizations during a major incident.

The issue of interstate cooperatives or agreements will also have to be seriously considered. The *Mega Borg* incident of last summer made this very clear. This incident occurred well off the coast of Texas, but some of the oil impacted Louisiana's shoreline. There was a lot of controversy regarding this incident and its effects on Louisiana's resources. It also occurred while our Legislature was in session. This brought an unusual amount of attention to the incident and also "encouraged" a significant amount of misunderstanding about the incident and the response. We need to ensure that actions taken in one State do not put an undue burden on our neighboring States.

Louisiana prepared a pre-approval package on the use of oil spill dispersants and submitted it to the USCG and the U.S. Environmental Protection Agency (EPA). The package included a mechanism for individual companies to prepare and submit their requests in a standardized format to the Region VI Regional Response Team. It also identified a zone where the State would consider pre-approval for the use of dispersants. After a review and approval process, the pre-designated Federal On-Scene Coordinator would then be able to make an immediate decision during an incident on whether dispersants would be allowed to be used.

We had received very favorable reports on our proposed process from the USCG and EPA before the National Contingency Plan (NCP) was modified. The changes relative to dispersant pre-approval in the NCP now require us to get concurrence from the U.S. Departments of Interior and Commerce instead of USCG and EPA. As of the date of this presentation, we have not received comments from these two agencies.

While all of these efforts were proceeding, Louisiana Offshore Oil Port submitted a dispersant pre-approval proposal to the USCG Marine Safety Office in Morgan City. The plan tracked the process which we submitted to the Federal agencies. As of the date of this presentation, I am glad to say that it appears the request will be approved in the near future. Some modifications will have to be made, but we believe this approval will send a clear message to all parties that the State is sincere in its efforts at protecting its resources and is willing to work cooperatively to achieve these goals.

In closing, we believe the overall intent of the update on contingency planning in Louisiana will be to complement the newly enacted Federal Oil Spill Law. We are not interested in reinventing the wheel, but we do want to ensure the State's interests are being protected. We believe any package that goes into the legislature in 1991 will be looked at in a more favorable light than 1990's. We recognize the bulk of the natural resources at risk in the Gulf of Mexico are probably off Louisiana's coast since we have the bulk of the oil production and transportation adjacent to our coastline.

We believe there are still a number of issues to be resolved relative to oil spill prevention, preparedness and response. We have had a number of major oil spills in Louisiana in recent history. We feel we have handled them in a fair manner, but we nevertheless realize we need to progress much further before we can say that we have a viable oil spill contingency effort in this state.

Mr. R. Bruce Hammatt received his B.S. and M.S. degrees from Louisiana State University with primary courses in wildlife biology and chemistry. He is the Emergency Response Coordinator for the Louisiana Department of Environmental Quality and has been the State's representative on the Federal Region VI Regional Response Team for several years. He is the State contact for all matters pertaining to Section 313 of the Emergency Planning and Community Right To Know Act of 1986 and is also involved in oil and hazardous materials planning for the State.

UPDATE OF TEXAS' OIL SPILL CONTINGENCY PLANNING

Mr. David Barker
Texas Water Commission

INTRODUCTION

The State as represented by its lead agency for administering the spill response program, Texas Water Commission (TWC), has been involved in spill contingency planning since the late 1960's. Every few years since that time, the State's plan has been updated and improved. The current plan was published in October 1988 and the next update is planned to coincide with some proposed rulemaking anticipated to occur early in 1991. Pertinent sections in the plan address spill notification requirements, recommended initial response actions, the spill response organization, extent of cleanup and restoration, chemical agents or other additives and disposal. As a supplement to the plan, the State prepared a series of spill response maps in the early 1980's. The maps depict environmental sensitivity and logistical features pertinent to protective measures and cleanup strategies. All information depicted on the maps is supported by textual information. The separately bound text provides information regarding emergency notifications, logistical data for each county, and species descriptions. The maps for the coastal region were updated in 1989.

As a component of the State's plan, the TWC administers the Texas Spill Response Fund and contracts with the State Department of Highways and Public Transportation and private entities for spill cleanup. Spills cleaned up by the TWC include those where the responsible party is unwilling or unable to respond, responding inadequately, or where the source is unknown. The TWC encourages and cooperates in the response by other authorities such as local and Federal government responders and industry groups or cooperatives. However, the TWC is authorized to take independent action to deal with unaddressed State concerns.

RESULTS

An oil spill contingency plan is only as good or strong as the capabilities to back it up. The TWC is dedicated to providing a meaningful effort as evidenced by its being the only State agency in the United States whose spill response personnel were specifically authorized and fully funded by the National Oceanic and Atmospheric Administration (NOAA) and sent to work in Alaska on the cleanup of Prince William Sound following the *Exxon Valdez* spill. The TWC was the agency responsible for the State's response to two recent major oil spills on the Texas Coast, the *Mega Borg* and the Apex barges incident. Many other good things may be said about the State's plan but there is one thing very wrong. The State oil spill response program is grossly underfunded. Local capability is limited or nonexistent. As a result, there is almost total reliance on the responsible party and the Federal government for the provision of capability.

In view of recent experience with spills on the Texas Gulf Coast, the Governor's Oil Spill Advisory Committee that was established on May 25, 1989, is calling for the State to commit itself to developing a strong independent response capability under State control. The committee met for the eighth time on October 26, 1990. Significant new issues identified and actions taken by the committee are listed as follows:

1. In recognition that the current balance of the Texas Spill Response Fund is alarmingly low and the fund has never been big enough to develop a comprehensive oil spill preparedness and response program, the committee has recommended that the fund be raised to an authorized level of $50 million, or an amount

determined by the legislature. Options that are not mutually exclusive identified by the committee to raise the fund are

- appropriate import/export fees,
- direct appropriation,
- fines and penalties, and
- other sources of financial aid including Federal assistance.

Without regard to priority, the following needs have been identified for the lead agency's attention under the enhanced fund:

- acquisition and maintenance of equipment to ensure an immediate response to spills,

- research and development,

- enforcement of rules and regulations,

- training exercises and personal protection and safety, and

- other measures developed by the lead agency to implement a comprehensive spill response and preparedness program.

2. Following a motion that a single agency should be recognized as having lead responsibility and be identified to implement an oil spill preparedness and response program as funded by the next session of the State legislature, the committee has recommended the TWC as the lead agency.

3. Other recent committee action includes recommendations for the lead agency to refine an inventory of materials and equipment available for response to spills in Texas and to provide for a State on-scene command post and joint information center. Further, the committee has recognized the need for a Navigation Safety Task Force made up of representatives from industry, government, academia and other interests to evaluate spill prevention issues.

4. The committee is also encouraging and supporting the idea that industry restudy the economic, environmental and operational feasibility of constructing an offshore oil terminal (deep water port) on the Texas Coast.

With respect to the existing program, approximately 1800 spills are reported to the TWC annually. A breakdown by material spilled indicates that oil accounts for about 48% of the spills, hazardous substances comprise 50% and other pollutants make up the remaining 2%. By consolidation of the spill preparedness and response program, the TWC is able to maximize the level of protection provided by the State government in environmental emergencies. The program is necessarily integrated with other TWC regulatory and legislative programs. With statutory authority and work experience in water quality and industrial and hazardous waste control, TWC has the necessary technical expertise to respond to spills, assess damages and pursue necessary enforcement. The TWC has drafted detailed rules, under its existing legislative authority, to address spill reporting requirements, allocation of the responsibilities for spill response, cleanup standards, enforcement measures, contingency planning, deed recordation, penalties and other important spill response issues.

The TWC is advocating that industries along the Texas Coast, with State and local government support, should be authorized by law to establish spill preparedness and response cooperatives under State supervision to provide a speedy and effective first response capability for spills. When these cooperatives are established, they should be authorized by law to receive revenue from the enhanced Texas Spill Response Fund and to substitute for State capability for the area, provided they are established, maintained and operated according to State standards and under State supervision. For areas not served by a qualified cooperative, the TWC should be authorized by law to establish fully staffed and funded centers containing stockpiles of equipment in sufficient quantities to ensure rapid and effective response to spills. Such centers should utilize standby contracts as much as possible to minimize the number of full-time State employees needed to maintain full capability. Further, coastal counties, port authorities and industries, along with State resource agencies and citizen groups, should be authorized by law to establish regional spill response districts under State supervision to facilitate site specific contingency planning and response.

SUMMARY

The TWC is a State agency of long-standing experience in contingency planning and response to spills. With enhanced funding, the TWC will provide a proven, professionally and scientifically sound spill response capability to fully respond to all spills of oil, hazardous substances and other pollutants independent of the responsible party and the federal government.

Materials identified in this presentation and further information on the State's program may be obtained by writing to the TWC, P.O. Box 13087, Capitol Station, Austin, Texas 78711-3087.

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 Texas Water Commission and has been involved with Texas' spill response program for about 20 years. Mr. Barker was instrumental in developing the *State of Texas Oil and Hazardous Substances Spill Contingency Plan* as well as the 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.A. from Southwest Texas State University with major and minor courses in biology and chemistry, respectively.

PHYSICAL OCEANOGRAPHY

Session:	PHYSICAL OCEANOGRAPHY
Co-Chairs:	Dr. Murray L. Brown Dr. Alexis Lugo-Fernández
Date:	November 15, 1990

Presentation	Author/Affiliation
Physical Oceanography: Session Introduction	Dr. Murray L. Brown and Dr. Alexis Lugo-Fernández Minerals Management Service Gulf of Mexico OCS Region
Presentation of Award	Mr. J. Kenneth Adams Minerals Management Service Gulf of Mexico OCS Region
A Short History and Representative Current Measurements of Nelson Eddy	Mr. Stephen P. Koch Exxon Production Research Company
An Overview of the Loop Current's Movement in 1989 from Enhanced National Ocean Survey Frontal Analysis Charts	Mr. Jeffrey N. Cox and Dr. Curtis C. Ebbesmeyer Evans-Hamilton, Inc.
U.S. Navy Tests of Sonobuoy-Size Oceanographic Buoys	Dr. Robert L. Pickett Naval Oceanographic and Atmospheric Research Laboratories and Mr. A. C. MacAdam METOCEAN Data Systems Limited
Quiet Eddy, 1990	Mr. Ken J. Schaudt Marathon Oil Company, Mr. John Lamkin National Marine Fisheries Service, Dr. George Z. Forristall Shell Development Company, Dr. Cort Cooper Chevron, Dr. D. C. Biggs Texas A&M University, Dr. Wilton Sturges Florida State University, Mr. Jeffrey D. Hawkins Naval Oceanographic and Atmospheric Research Laboratories, Dr. T. J. Berger and Dr. Peter Hamilton Science Applications International Corporation, and Mr. James W. Feeney Horizon Marine, Inc.

(Continued)

Session: PHYSICAL OCEANOGRAPHY (cont'd)

Presentation	Author/Affiliation
Benefits of NOAA-11 Channel #3 in Detection of Mesoscale Eddies in the Gulf of Mexico During Summer	Mr. Jeffrey D. Hawkins, Mr. Douglas A. May, and Dr. Robert L. Pickett Naval Oceanographic and Atmospheric Research Laboratories and Mr. Fred Abell, Jr. Sverdrup Technology, Inc.
Ring Monitoring in the Gulf of Mexico Using GEOSAT Altimetry	Dr. Donald R. Johnson Naval Oceanographic and Atmospheric Research Laboratories and Dr. Robert R. Leben Department of Aerospace Engineering and Sciences University of Colorado
Gulf of Mexico High Resolution Mean Sea Surface Determined from Satellite Altimetry	Mr. Myung-Chan Kim, Dr. Che-Kwan Shum, and Dr. Byron D. Tapley Center for Space Research University of Texas at Austin
A United States-Mexico Cooperative Study of a Cold-Core Ring in the Western Gulf of Mexico	Dr. D. C. Biggs Texas A&M University Department of Oceanography, Dr. M. M. Crawford University of Texas Center for Space Research, Dr. David Salas de León UNAM Instituto de Ciencias del Mar y Limnología, Mexico Mr. Octávio Salas Flores and Ms. Sílvia Escoto Hidalgo SEMAR Dirección General de Oceanografía Naval, Mexico
Nutrient Enhanced Coastal Ocean Productivity	Dr. Donald K. Atwood and Dr. Gary L. Hitchcock NOAA Atlantic Oceanographic and Meteorological Laboratory

(Continued)

Session: PHYSICAL OCEANOGRAPHY (cont'd)

Presentation	Author/Affiliation
Formation, Movement, and Thermal Structure of Double Vortices in the Northeastern Gulf of Mexico	Dr. Charles K. Eleuterius, Dr. John P. Steen, Mr. G. Alan Criss, Dr. James T. McBee, Mr. Richard S. Waller Gulf Coast Research Laboratory and Mr. Rex Herron National Marine Fisheries Service
National Weather Service Modernization Purpose	Mr. Billy J. Crouch National Weather Service Slidell Forecast Office
Overview of the GULFMEX Project: A Study of Return Flow in the Gulf of Mexico	Mr. G. Alan Johnson National Weather Service Slidell Forecast Office
Application of the Sandia Ocean Modeling System to the Gulf of Mexico Circulation	Dr. David E. Dietrich Ecodynamics Research Associates, Inc.

PHYSICAL OCEANOGRAPHY: SESSION INTRODUCTION

Dr. Murray L. Brown
and
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The general theme of the first Physical Oceanography session at the 1990 Information Transfer Meeting, while not explicitly listed in the program, was "Eddies in the Gulf of Mexico." Nearly every paper touched on this subject, although it was not planned. There are two likely reasons: highly interesting results are beginning to appear from the industry/agency/academic studies of "Eddy Nelson" in the summer of 1989, and generally increased interest in the Gulf as a testing area for mesoscale observations. It was apparent, also, from the technical contents of the papers that considerable exchange of data occurs in the Gulf community, especially regarding eddy behavior and location. The session was particularly appropriate, in view of plans for the Minerals Management Service-sponsored "Texas-Louisiana Physical Oceanography Program" (LATEX Program), which will continue many of the research themes discussed here.

Dr. Murray L. 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, Bureau of Land Management and Minerals Management Service. At present, he is project officer for the Minerals Management Service physical oceanography study series and has special interest in information management.

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A SHORT HISTORY AND REPRESENTATIVE CURRENT MEASUREMENTS OF NELSON EDDY

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The Loop Current offered a unique challenge to industry in August 1989 when it surged to the northwest and detached a large eddy. That eddy impacted Green Canyon and Mississippi Canyon drilling operations for nearly two months. Although Nelson Eddy was costly to those drilling operations, its size and intensity also provided an opportunity for acquisition of valuable current and temperature data to aid industry's study of these features. This paper presents a brief review of current profile data acquired by Exxon Company, U.S.A., during August and September 1989 in support of a Green Canyon drilling operation.

The 1989 history of the Loop Current was somewhat unique even before its August movement. The presence of the Loop Current's northerly front near Green and Mississippi Canyons was known as early as February (Barker *et al.* 1990). Satellite data taken throughout the first half of the year indicated little, if any, movement of the front. The Loop's position throughout that half of the year was at about the 5-10% frequency position based on frontal analyses of data from 1976-1984 (Vukovich and Hamilton 1989).

Shortly after Nelson Eddy first impacted a drilling operation at Green Canyon 166, Exxon initiated a current and temperature measurement program to provide a real-time capability of monitoring the feature. The measurement equipment involved an acoustic Doppler current profiler (ADCP) and expendable bathythermographs (XBT), with a Loran system as the position reference. The ADCP relies on reflected acoustic signals from within the water column to obtain absolute current speed and direction data. The XBT's measure temperature profiles, which can be correlated with historic data to infer current features.

Nelson Eddy's impact on Green Canyon drilling locations contained three distinct phases of severity. The most severe currents were observed from late July to late August and began shortly after the passage of Hurricane Chantal. Chantal's northerly track was just west of Green Canyon. For the next

2 weeks, minimal current speeds--below 0.4 knots (kts) at the 45 m depth level--were observed at most drilling locations in the eastern half of Green Canyon. Thereafter, a period of increasing current speeds--up to a maximum of 1.4 kts at 45 m depth on September 25--was observed. The return to normal Gulf of Mexico background current levels occurred by October 1.

During the August severe current phase, Exxon's measurements indicated a consistent band of 2.2-2.7 kts surface current moving eastward between the 500 and 1,000-m depth contours in the eastern half of Green Canyon. Also during that time frame, the western edge of the Eddy was measured and visually observed at 27.8°N and 91.1°W. The direction of the current in the western edge was essentially due north. Measurements made along northward running transects during this time period indicate the current profile may be modified due to bottom topography in water as deep as 500 m.

During early September, current speeds as high as 3.6 kts were measured, but to the southeast of the early maxima and to the southeast of Green Canyon. The data suggest that the Eddy had either moved to the east or had rotated clockwise about its center of rotation. In the final phase of the measurements, the measured current maximum was only 2.6 kts and was located south and west of the previous maxima. Drifting buoy and other industry data confirmed that the eddy was translating to the southwest by early October.

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AN OVERVIEW OF THE LOOP CURRENT'S MOVEMENT IN 1989 FROM ENHANCED NATIONAL OCEAN SURVEY FRONTAL ANALYSIS CHARTS

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and
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During 1989 the Loop Current penetrated northward into the Gulf of Mexico sufficiently to disrupt offshore oil exploration activities at a number of deep water drilling sites south of Louisiana and Texas. The Loop Current generated several associated features over the course of the year, the largest and strongest (in terms of currents) of which was Nelson Eddy. While measurements of the Loop Current and its associated features were conducted by numerous companies, government agencies, and individual investigators, these measurements were most heavily concentrated during July-September, depending upon details of the water property and velocity structure of the Loop Current events. To understand the evolution of the Loop Current and features that it generates, the scientific community has relied primarily upon satellite imagery and the National Ocean Survey (NOS) Oceanographic Analysis charts, derived from this imagery, for interpretations of frontal positions and the edges of Loop Current features. During those months of good satellite imagery (primarily October - early May), these provide perhaps the best means of visualizing and tracking the Loop Current's foray into and retreat from the northern Gulf.

Reviewing each individual satellite image and NOS oceanographic analysis map is very informative, yet it can still be difficult to follow the oceanographic changes that occur. To understand better the evolution of the Loop Current events during 1989, we have obtained, digitized, placed into Gulfplot format, and enhanced the NOS oceanographic analysis maps depicting the physical oceanographic frontal events in the Gulf of Mexico for all of 1989. From this presentation, the evolution of the Loop Current's northward penetration, eddy shedding, and shelf water interactions are more easily pictured and understood.

METHODS

All NOS oceanographic analysis charts for 1989 were obtained and frontal features associated with the Loop Current and its eddies were digitized. Features depicting coastal cold fronts or the coastal boundary layer were not digitized so as to more clearly display the Loop Current related features.

The charts were digitized using a Kurta digitizing tablet attached to an IBM compatible PC. Special software was written to transform the X-Y grid of the tablet into latitude and longitude for the Gulf of Mexico, thereby allowing each frontal feature within the charts to be assigned actual latitude and longitude values. The software also allowed for digitization of frontal information from non-uniform size charts. The frontal events were digitized at the resolution of the tablet, or 1,000 points per inch (approximately 5 points per km). To allow input of these files into a graphics enhancement program, the data were reduced by a factor of 10 using a running average technique. Displayed data density is therefore approximately one value every two km.

Enhancement of each chart was performed using CorelDraw. First, frontal positions on each chart were imported into a basemap of the Gulf of Mexico. Next the open southern boundary of the Loop Current was artificially connected to allow for highlighting of the Loop Current feature. Eddies were also highlighted for easier identification. One chart per week (Thursdays) was then selected for the presentation. The digitized, but not color enhanced, version of all frontal charts in Gulfplot format is also available on disk.

RESULTS

The Loop Current began 1989 far to the north, with its northern edge drawn at approximately 28° north latitude. During this time the Loop Current lay southeast of the Mississippi River delta and always to the east of 90° west longitude. It maintained this position until mid-February when its northern edge was identified at near 29° north and began to move westward between 26 ° and 27 ° north in what appears to be the initial formation of Nelson Eddy.

Nelson Eddy's formation date appears to have been difficult to interpret, as the charts from February 23rd through June 1st show Nelson Eddy as still attached to the Loop Current. In several of these charts Nelson Eddy appears to be connected by a thin band, whereas in other charts it appears more as an extension of the Loop Current itself. It is also interesting to note the large variety in shape and position of the frontal features from week to week during this time period. April 20th and 27th (Figure 13.1) are good examples of this. Whether or not the large differences in frontal positions and shape occur due to rapid movement of the frontal positions or to difficulty in precisely locating Loop Current features from satellite imagery is unknown, however these differences indicate field measurements are critical for proper interpretation of precise frontal locations.

Nelson Eddy became well established as an independent feature by mid-June even though its position and size during June varied considerably within the charts. At this time the northern boundary of the Loop Current was located at approximately 24.5° north latitude. Unfortunately Nelson Eddy's location could no longer be interpreted from satellite imagery after June, and the Loop Currents northern edge disappeared after July 6th.

Satellite imagery became interpretable again at the end of October at which time the Loop Current again reached northward of 25 ° north latitude. Nelson Eddy is essentially not seen on the charts. By years end the Loop Current had reached 27° north latitude and appeared headed for creation of a new eddy for 1990.

SUMMARY

Loop Current related features on the NOS oceanographic analysis charts have been digitized, placed into Gulfplot format, and enhanced with a computer graphics program to enable a better visualization and understanding of 1989 events within the Gulf of Mexico. The charts depict clearly how the Loop Current started the year far to the north (28° north latitude) and later formed Nelson Eddy. The changes in both frontal shapes and positions between weeks is much greater than expected. Whether or not this is due to rapid frontal changes or difficulties in interpreting satellite imagery alone is unknown, however it does point out the need for field measurements when precise positioning of frontal events is critical. The charts have been made available to the Gulf marine community through the GULF.MEX bulletin board.

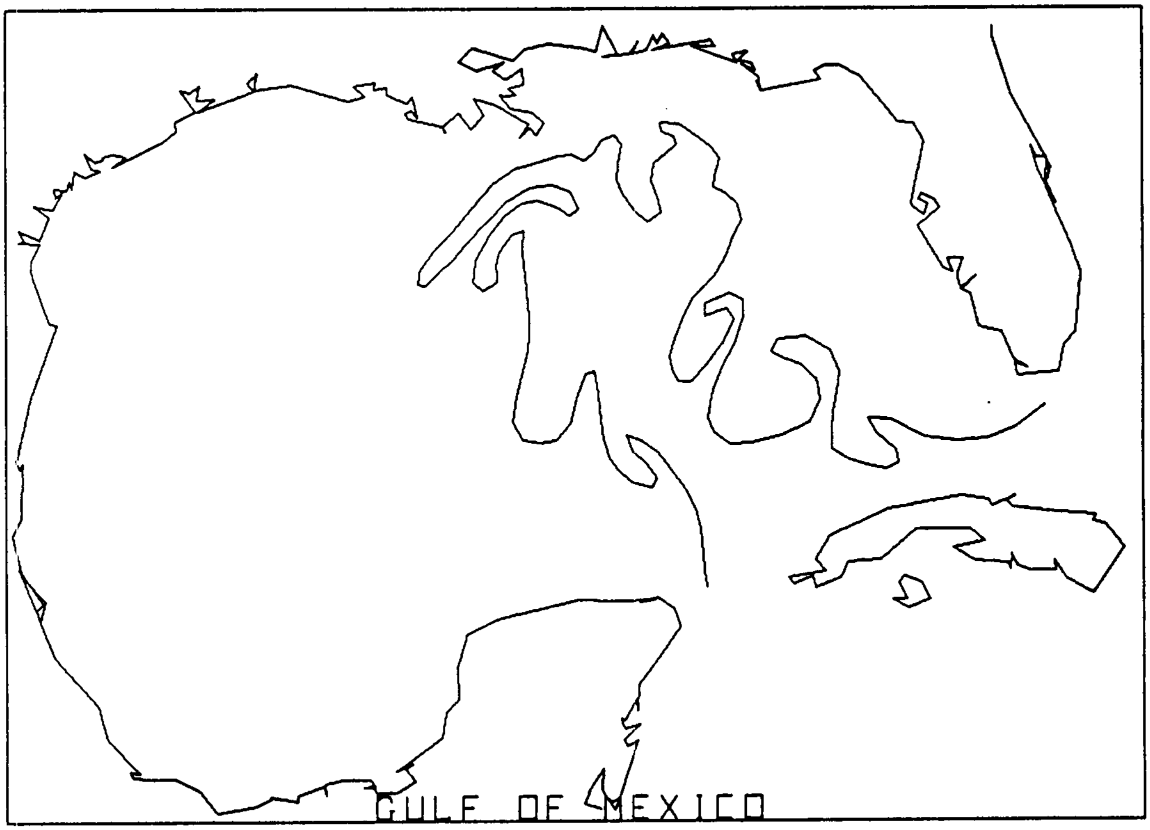

Figure 13.1. Loop Current on April 27, 1989. (GULFPLOT digital chart by Evans-Hamilton, Inc. from National Oceanic and Atmospheric Administration analysis.)

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U.S. NAVY TESTS OF SONOBUOY-SIZE OCEANOGRAPHIC BUOYS

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ABSTRACT

The Navy is developing sonobuoy-sized, air-deployed, satellite-tracked, drifting data buoys. The buoys send 10-min averages of air pressure, air

temperature, and water temperatures. Water temperatures are at 0, 5, 10, 20, 30, 50, and 100 m below the surface.

The buoys have two purposes. First, they collect and relay data from remote or violent-weather areas. Second, they help interpret near-surface current patterns by their drift tracks.

Last year, the Navy tested 60 of these buoys. Tests were in the Gulf of Mexico, Mediterranean, Northwest Pacific, and Northeast Atlantic. Results showed buoy sensors are reasonably accurate. However, subsurface sensors do not survive for the three-month design lifetime. Although surface sensors rarely failed within three months, one-third of subsurface sensors typically failed within one month.

INTRODUCTION

Buoy Uses--Remote Data and Circulation

The U.S. Navy uses drifting buoys for gathering data in inaccessible areas and for interpreting surface currents.

As remote data stations, buoys have to be both expendable and rugged. They should also deploy easily from either ships or aircraft. The Navy uses them in regions where heavy weather has driven out traffic or in regions where there is no traffic. In either case, buoys are never recovered or repaired. Both the U.S. Coast Guard (Thayer *et al.* 1988) and the Navy (Pickett 1989b) are testing such buoys.

Another buoy application is in circulation studies. The buoys can help predict motions of sonobuoy arrays (Pickett and Burns 1987; Burns and Pickett 1988) and can provide data to prime models. They are also valuable in interpreting satellite images (Pickett *et al.* 1984).

As remote data stations, the buoys work well. However, in circulation studies, they have limitations. Satellite-derived positions are several hours apart and only accurate to about 0.3 km (Pickett *et al.* 1983). In addition, wind introduces drift errors (Pickett 1989a). Hence these buoys can accurately track only large-scale, strong currents in light to moderate winds.

Weather Buoy--Worked Well

Last year we tested a weather buoy designed to meet the above needs (Pickett 1989c). These buoys relayed 10-min averages of air pressure, air temperature, and sea-surface temperature via satellite. They were expendable, with a design lifetime of three months. The buoy package is a standard sonobuoy container (36 inches long, 4.9 inches diameter, 25 lbs) (Figure 13.2). They cost $2,750 each and can be launched from either ships or aircraft.

From aircraft, the buoy launch envelope was 300 to 30,000 ft. altitude, and 0 to 300 kts air speed. A self-deploying parachute slowed descent, and a seawater-switch activated the buoy. The switch caused the sonobuoy container to fall away, a flotation collar to inflate, and an antenna to pop up. The container, attached to the bottom of the buoy with a 100-m cable, acted as a drogue.

Once the buoys were in the water, the data were satellite-relayed about every three hours at 30°N and more frequently at higher latitudes. Service ARGOS, the data-processing company, gathered the satellite data from several receiving stations around the world. Next, the company converted the data to standard units and formats. Finally, they loaded the converted data on international weather networks. Weather facilities around the world received the buoy's data within a few hours. Figure 13.3 shows the buoy's data format sent over the networks.

Many Navy facilities, however, no longer rely on the above data-relay system. They can receive buoy data directly and more quickly with their own satellite-receiving stations.

Our tests of this buoy uncovered two major problems. First, lifetimes were less than three months. Second, buoys failed at aircraft launch speeds above 250 kts.

We traced lifetime problems to the flotation-collar gas. Carbon dioxide either reacted with, or diffused through, the collar fabric. When we changed the gas to nitrogen, lifetimes increased to three months.

Higher-speed launches required some redesign and an external wind-flap support. With these changes, the buoy then survived launches up to 300 kts.

After we fixed the above two problems, the buoys passed all our tests. The Navy then bought several hundred and used them operationally around the world.

Figure 13.2. A fully deployed buoy (cut open to show insides). (The surface unit is on the right, and the launch container on the left. The surface unit houses the air-pressure port and air temperature sensor in a white knob at the top [above the antenna]. The sea-surface temperature sensor is at the bottom of the surface unit. The subsurface temperature cable is still on the spool at the bottom of the launch container. All electronics [data sampling, averaging, transmitter] are on five circular boards at the bottom of the surface unit. Above these boards is the power stack of C-cell batteries.)

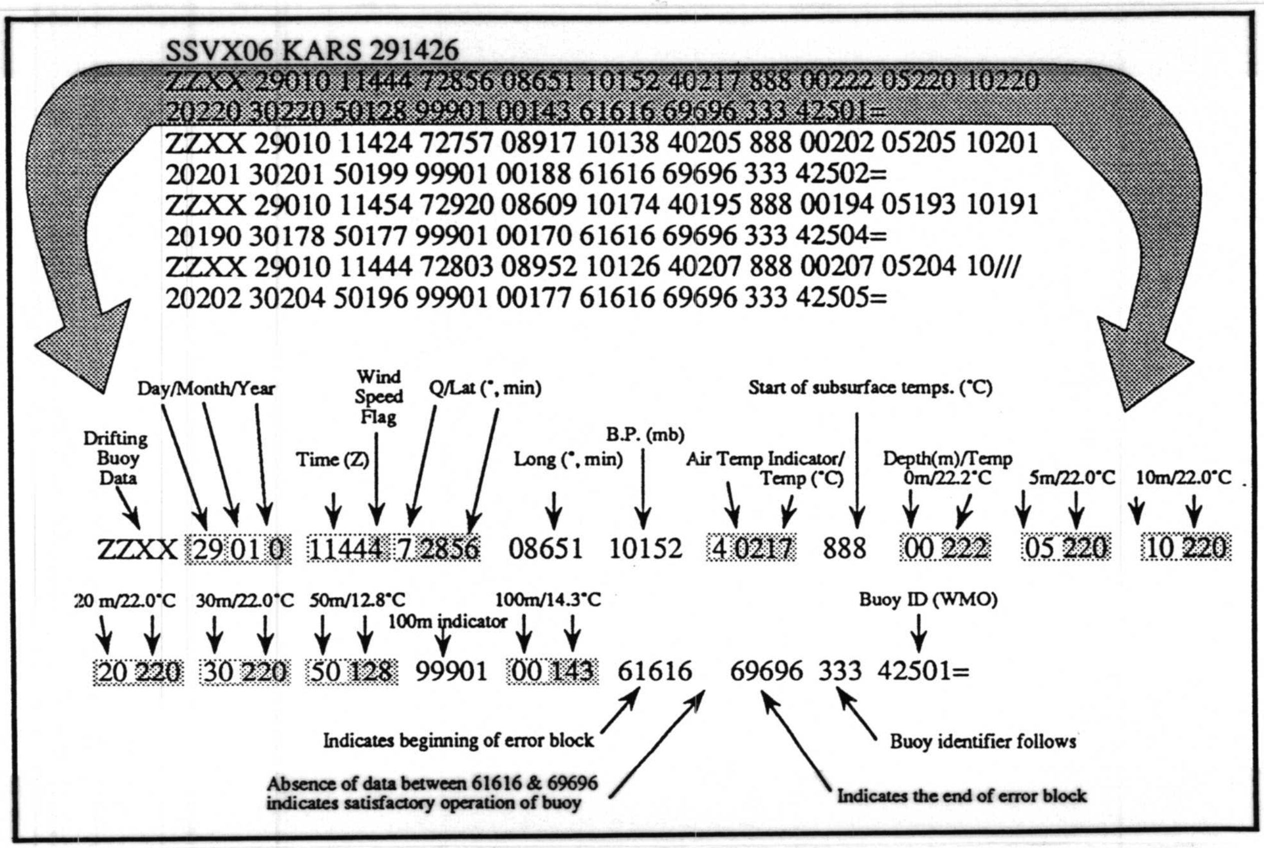

Figure 13.3. A sample message from a buoy. (The first line of each message begins with the SSVX06 KARS identifier followed by the day and time [GMT]. Typically one message contains data from all buoys in an area. The second line starts with ZZXX, which separates data from each buoy. The next two words are the date and time of the data. The rest of the words are: latitude, longitude, air pressure, air temperature and, finally, the subsurface temperatures.)

Improved Buoy--Subsurface Temperatures

This year, we began testing an extended version of the same buoy (Figure 13.2). The new buoys cost $4,000 each. Packaging and launching are unchanged. The major difference is that the drogue line now contains temperature sensors. Hence in addition to the same surface sensors, the new buoys also measure 10-minute averages of seven levels of water temperature. The seven levels are 0, 5, 10, 20, 30, 50, and 100 m below the surface.

The addition of the temperature cable also required three minor design changes. First, the external container falls away, rather than becoming a drogue. This is done to avoid possible sensor-cable damage. Second, the cable has an end-weight to keep it more vertical. Third, the bottom of the cable has a pressure sensor to measure cable tilt.

FIELD TESTS

Lake Michigan--Accuracy Tests

The first at-sea test of the subsurface-sensor buoys was in Lake Michigan. The lake was chosen for three reasons. First, there was a moored weather station at its center. Second, the lake had a strong thermocline within the 100-m length of the temperature tail. Third, the lake offered a better chance of recovering the buoys than the open ocean.

To check sensor accuracy, we deployed two buoys by ship on 7 September 1989 beside the weather station. We recovered the buoys on 26 September. During this drift period, one buoy remained within 35 km of the station, but the other drifted 70 km away.

Details of this accuracy test are in McCormick *et al.* 1990. In general, the results showed all buoy surface sensors compared well with the weather station's data. The buoys' subsurface temperatures also compared well to a conductivity-temperature-depth instrument. Figure 13.4 is a sample of these comparisons.

Buoy surface water temperatures are warmer because the buoy only measures 0.5 m below the surface. By contrast, the weather station measures 1 m below the surface (note near-surface, temperature slope in last panel). Similarly, buoy air temperatures are higher because they are closer to the water surface (1 m instead of weather station's 5 m). Allowing for these differences, buoys sensors seem reasonably accurate.

Although buoy-sensor accuracies were close to specifications, subsurface-sensor lifetime was not. All subsurface temperature sensors on both buoys failed within two weeks. As a result, we stopped the test and recovered the buoys for analysis.

Studying the condition of the recovered buoys, we made three changes to the subsurface cable. First, we molded the thermistors directly into the cable, instead of a less-protected breakout system. Second, we added a stronger, load-bearing bushing between the buoy and the top of the cable. Third, we added a tripod suspension above the bottom weight to strengthen the attachment and reduce spinning.

Gulf of Mexico--Air Launch

After the above redesign, we shifted testing to the Gulf of Mexico. In this series, we also added the rigor of aircraft deployment.

For the first test, two buoys were air dropped in November 1989 at the same location in the northern Gulf of Mexico. We then compared the first 10 days of surface data from the buoys before they drifted apart. The object was to test if high speed launch and water impact altered sensor accuracy. We calculated differences between simultaneous buoy measurements of air pressure, sea surface temperature, and air temperature.

The above test showed the mean and standard deviation of the air pressure differences were 0.3 mb and 0.4 mb. The mean and standard deviation of sea surface temperature differences were 0.1° and 0.1°C. For air temperature, the mean difference was 0.0°C and the standard deviation was 0.1°C.

Although the above data show all surface sensors survived air launch with no loss of accuracy, subsurface sensors on both buoys soon developed problems. Bottom pressure sensors failed within in a few days. In addition, one subsurface temperature sensor on each buoy failed within a week.

To develop better statistics on subsurface failures, we air-launched 17 more buoys in the Gulf. Minor changes followed each drop as we tried to increase subsurface-sensor lifetimes. None of these changes was very successful. By the time we finished these drops, bottom-pressure sensors still failed in a few days and subsurface-temperature sensors in a few weeks. Eventually, we managed to recover three of these failed buoys for analysis.

While we analyzed these recovered buoys, we also ran pressure tests on a subsurface-temperature cable. We put the tail of an operating buoy in a seawater pressure tank at a pressure equivalent of 200-m depth (twice the operating depth). After two weeks, all subsurface sensors still operated. We concluded seawater pressure alone was not causing early failures.

After studying the three buoys recovered from the Gulf of Mexico, we tried a new, less-permeable potting compound for the cable sensors. We also reduced the size of the bottom weight to reduce cable stress.

Engineers at the Naval Avionics Center had already suggested reducing the bottom weight. A stress-simulation model run at the Naval Oceanographic Office confirmed their suggestion. The model showed the bottom weight was heavy enough to stress the conductors inside the cable in steep seas. In addition, the bottom pressure sensor never recorded significant cable lift on buoys at sea. As a result of the above suggestions, models, and observations, we reduced the end weight from 2 to 1.5 lbs.

Operational Tests--Buoys Pass

While completing the above redesigns, we tested some more buoys in military operations. The object was to find out if there were any special problems associated with military applications anywhere in the world.

During late 1989 and early 1990, Navy aircraft launched three buoys off Iceland and four in the Mediterranean. The Air Force also launched two in the northeast Pacific.

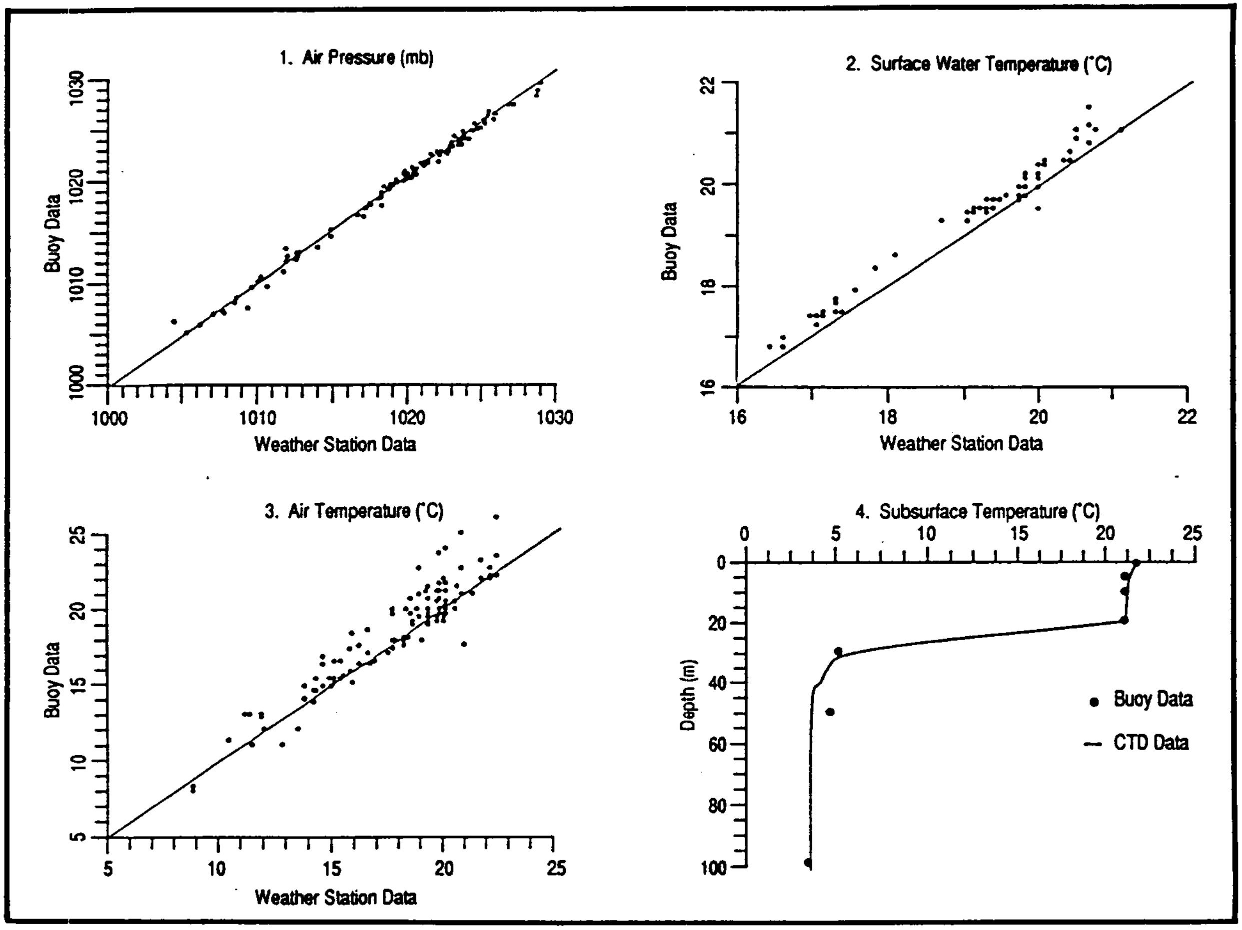

Figure 13.4. Air pressure and water and air temperature comparisons in September 1989 in Lake Michigan (from McCormick *et al.* 1990). (A weather station at the buoy launch site provided the surface reference data. A conductivity-temperature-salinity instrument provided the subsurface reference data.)

All these tests were successful. All buoys survived deployment, provided necessary data, and lasted throughout the operations (a week or two). We also discovered by accident that our subsurface sensors seem to survive longer in cooler waters. The reason for this is unclear.

Figure 13.5 shows the subsurface-sensor lifetimes on the four operationally buoys air launched in the Mediterranean Sea in February 1990. Although the mean lifetimes did not reach the 90-day design goal, they were greater than any group of buoys we tested so far.

Gulf of Mexico Again--Cables Fail

In January 1990, we dropped six buoys with new potting and lighter end weights in the Gulf. Figure 13.6 shows the survival rate for these buoys. In general, lifetimes are shorter in the Gulf of Mexico than the Mediterranean. Further, the 100-m sensors failed very quickly (10 to 15 days).

Still more changes followed the above tests. The latest redesign included all previous improvements, plus three new ones. First, we moved the bottom pressure sensor 0.5 m below the bottom temperature sensor. This was done so we could make 100-m temperature sensors exactly like the upper ones. We hoped they would then match the reliability of the upper sensors. The second change involved electronic improvements to reduce potential voltage spikes that could damage circuits. Finally, we reduced the end weight once again from 1.5 to 1.0 lbs to reduce cable stress further.

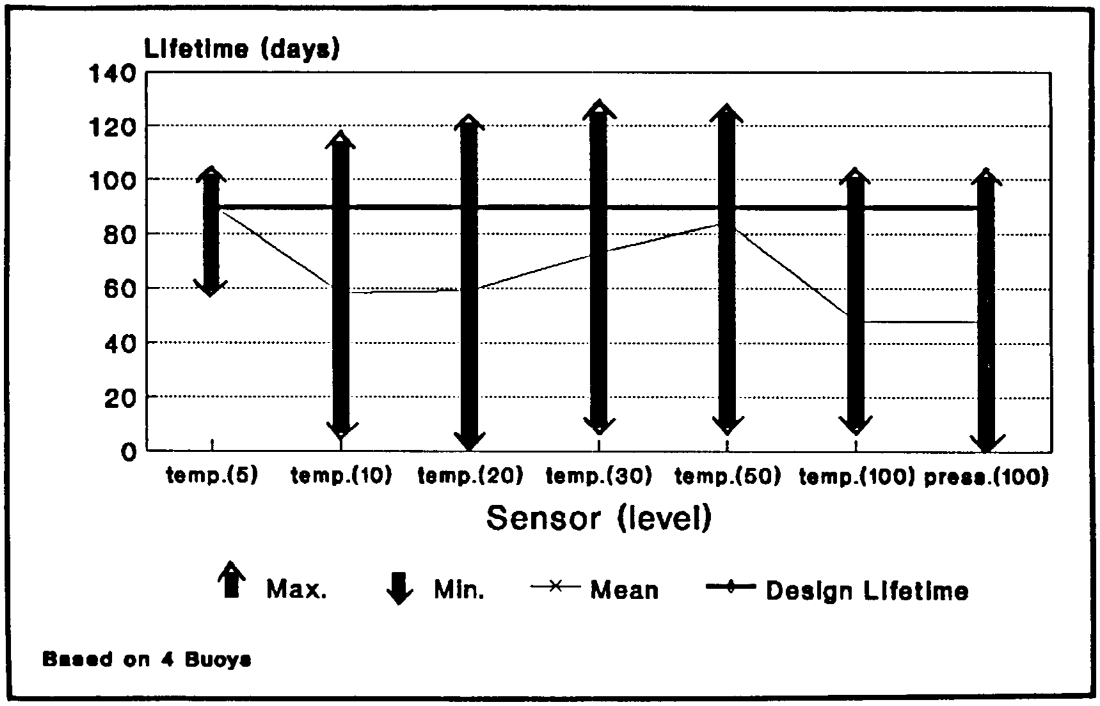

Figure 13.5. Survival rates for buoy subsurface sensors - February 1990. (The figure covers four buoys launched in the Mediterranean Sea during February 1990. The vertical bars extend from the minimum to the maximum sensor lifetime at each depth. The flat line near the top is the design goal of 90 days. The other line connects the mean sensor lifetime for each level. There is a large range in sensor lifetimes among buoys. However, these subsurface sensors in the cool Mediterranean lasted longer than any others.)

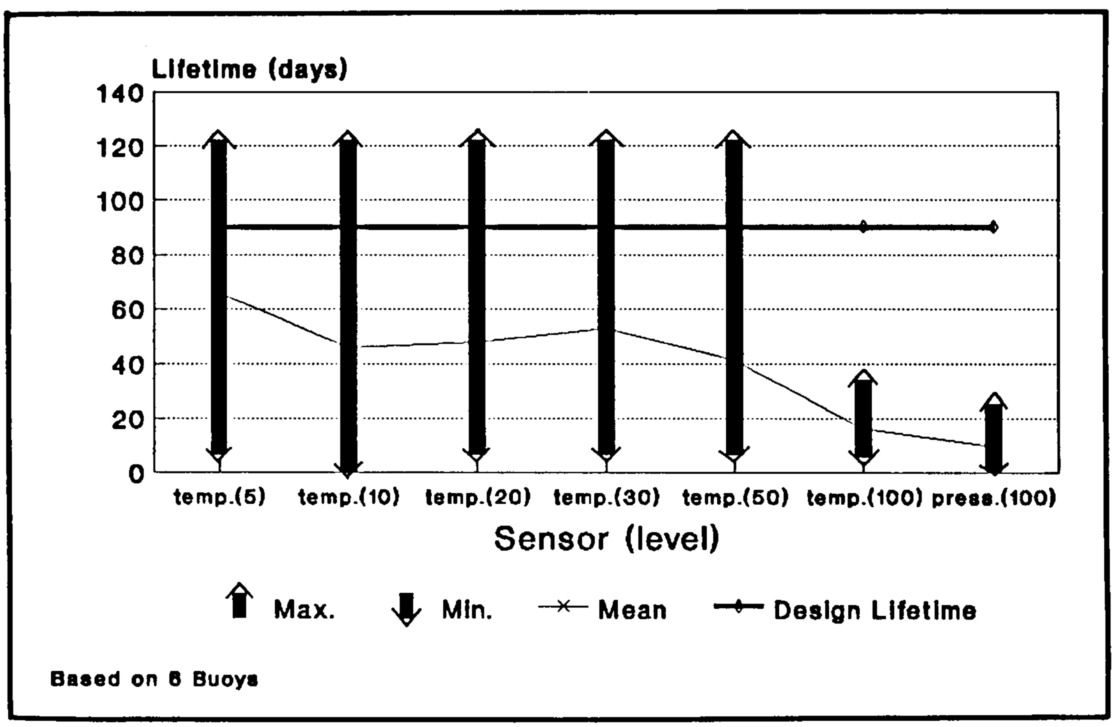

Figure 13.6. Same as Figure 13.5, except data are for six buoys launched in winter 1989-1990 in Gulf of Mexico. (Lifetimes were less than in the Mediterranean Sea.)

We dropped 10 of these latest buoys in the Gulf in August 1990. One buoy did not deploy, but Figure 13.7 shows the survival of the other nine. In spite of all of the above improvements, the subsurface-sensor lifetimes actually declined, averaging only about 20 days. Our only explanation is that increasing water temperatures increase failures faster than we are improving the buoys.

DATA FLOW

Communications--Getting Bugs Out

Along with the above survival problems, we also uncovered communication problems during the above tests. First, buoy messages had parts cut off. Service ARGOS had to fix their automatic data-processing programs. Second, Navy facilities were not receiving some messages. This was a routing problem at the gateway to the international weather networks. Third, the Fleet Numerical Oceanography Center did not have programs in place to receive buoy-subsurface data. Fourth, after any buoy sensor failed, there was no way to remove its bad data from the weather network.

Eventually we solved all the above communication problems. In addition, we installed an automatic editor (Teague *et al.* 1986) in the data stream at Service ARGOS. During data processing, the editor automatically checks for bad data. If any sensor fails the tests, the editor switches to a missing data code.

Data Display--Software Help

Navy facilities quickly ran into problems dealing with our large quantities of buoy data. Since every buoy sends about 70 observations per day (9 sensors, 8 data relays), the output from a group of buoys is large. Six of our Gulf buoys, for example, sent more subsurface temperatures over the networks than the rest of the world combined.

As a result, the facilities needed easy-to-use methods to extract (from the format shown in Figure 13.3) and display buoy data. In response, we wrote and

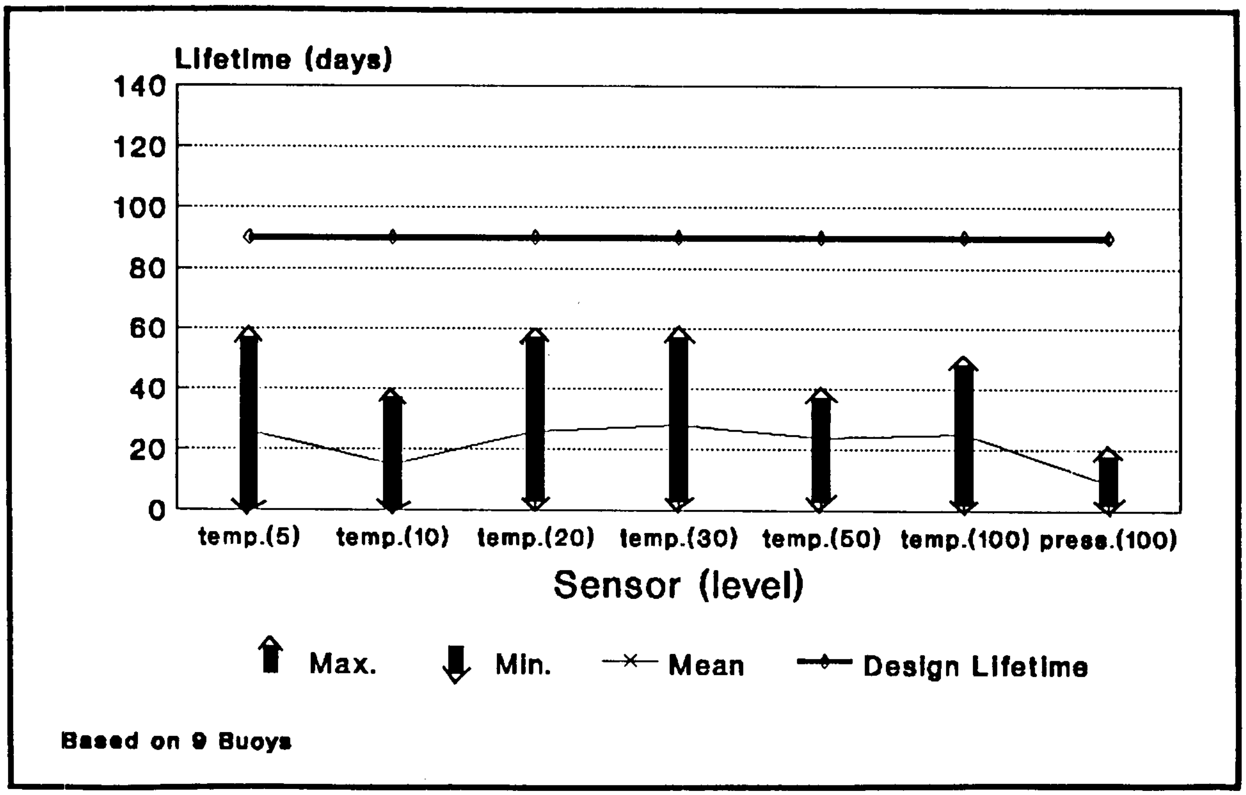

Figure 13.7. **Survival rates for buoy subsurface sensors - summer 1990. (The figure covers nine buoys launched in the Gulf of Mexico during summer 1990. The vertical bars extend from the minimum to the maximum sensor lifetime at each depth. The flat line near the top is the design goal of 90 days. The other line connects the mean sensor lifetime for each level. Lifetimes were the shortest yet in this warm water.)**

sent them a series of programs to capture and display buoy data.

SUMMARY

In Lake Michigan, buoy sensors compared well with the reference weather station. After aircraft launch into the Gulf of Mexico, buoy sensors also compared well with each other.

Although buoy sensors were accurate, subsurface sensors failed before their three-month design lifetime. One-third of all subsurface sensors failed within about 30 days. At present, these early failures are our major problem.

In addition, we have two minor problems. First, there are occasional bad barometers. In the recent lots of buoys we tested, about 20% of the barometers were not within specifications (± 0.1 mb).

Second, after tail sensors fail, their output drifts. Typically they drift in and out of reasonable bounds. This drifting allows bad data to go through the editor and over the networks. Ideally, once a sensor fails, if should go to an out-of-range value and stay there.

We hope to fix the above three problems soon. A better understanding of tail failures, barometer tests, and internal software changes should lead to solutions for the above problems. In our next series of tests, for example, we will load buoys with diagnostic sensors to detect cable problems. Also, we will continue to try to recover buoys at sea to analyze failures.

Once we solve the above problems, we plan to extend the subsurface cable from 100 m down to 300 m. The result of these efforts should be a buoy with accurate sensors that lasts three months at sea. Such a buoy would satisfy both Navy requirements. It could provide data in remote or dangerous regions, as well as estimates of near-surface currents.

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QUIET EDDY, 1990

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During the summer of 1990, the Loop Current pushed northward south of the Mississippi Delta, where a diverse range of eddies and other circulations was formed. The major eddy formed at this time was nicknamed Quiet Eddy. Although the surge and eddy separation occurred during the summer months, when atmospheric moisture generally precludes tracking of these features by satellite imagery, the surge northward and eddy formation were well documented through hydrographic surveys and drifting buoys. Additionally, the fine structure of the Loop Current/Eddy fronts is revealed by cool water upwelled near the region of strongest currents.

Throughout the late spring and summer, the general circulation of the Gulf was defined by the drifting buoys deployed. During May and June, additional details of the circulation were revealed by Expendable Bathythermographs (XBTs) deployed during the National Marine Fisheries Service Ichthyoplankton Surveys, as well as other satellite-telemetered XBTs. During July, the routine satellite-telemetered XBTs and drifting buoy data were supplemented with an XBT and acoustic Doppler current profiler transect across the Loop Current.

After high currents entered the deepwater lease areas in August, detailed hydrographic and current sampling began. These surveys, combined with the buoy and satellite data, give a detailed picture of the separation of the eddy from the Loop Current.

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Mr. Jeffrey D. Hawkins has worked in the Remote Sensing Branch at the Naval Oceanographic and Atmospheric Research Laboratories for the past 10 years and is now the head of the Applications Development Section. His areas of research interest focus on the use of satellite-derived sea surface temperatures, sea ice, and sea surface height for Naval applications. Mr. Hawkins received his B.S. and M.S. in meteorology from Florida State University.

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Mr. James W. Feeney is president of Horizon Marine, Inc. He manages the "Eddy Watch" and "Ocean Response to Hurricanes" programs for the offshore oil industry and conducts other ocean current studies, aerial surveys, and other physical oceanographic efforts.

BENEFITS OF NOAA-11 CHANNEL #3 IN DETECTION OF MESOSCALE EDDIES IN THE GULF OF MEXICO DURING SUMMER

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INTRODUCTION

Monitoring the Loop Current and mesoscale (50-350 km) warm and cold core eddy positions in the Gulf of Mexico year round has taken on enhanced interest as our understanding of the Gulf's physical oceanography and its impact on a diverse set of industrial and scientific disciplines matures. Early sporadic hydrographic cruises were supplemented in the late 1970's and early 1980's with satellite infrared (IR) imagery from the Geostationary Operational Environmental Satellites (GOES) and various versions of the present National Oceanic and Atmospheric Administration (NOAA) Advanced Very High Resolution Radiometer (AVHRR). The synoptic IR views helped immeasurably by permitting mapping of the major mesoscale features via their sea surface temperature (SST) signatures.

The early work of Ichiye (1962), Cochrane (1972) and others was then enhanced considerably when imagery began to fill in the time-space void inherent in Gulf ship surveys. Information pertaining to the cycle of Loop Current penetration, eddy shedding and drift of resultant warm core eddies westward to the Texas shelf rapidly revised earlier speculation and brought us to a new level of viewing the dynamics of the Loop Current System.

Several drawbacks remained while utilizing IR imagery to detect Gulf mesoscale features. Cloud contamination often eliminated this valuable resource for time spans lasting weeks when poor meteorological conditions prevailed. Summertime conditions, including solar heating, reduced the SST gradients associated with all features, requiring the capability to measure relative and absolute SSTs to the accuracy of 0.25°C and better in order to view the faint surface signatures.

Early NOAA and GOES sensors were limited in the number of spectral channels and digitization levels, restricting the ability to remove the contaminating effects of water vapor that can reach 8-10°C in magnitude. This problem was answered in part by the 1981 operational implementation of the AVHRR five-channel sensor. Figure 13.8 illustrates the atmospheric windows through water vapor that channels 3, 4, and 5 use to view the SSTs. Particular attention should be placed on the enhanced transmissivity of channel #3 in relation to both 4 and 5. Clearly, water vapor will have the least distortion in this spectral band.

Most attempts in tapping this channel for its superior ability to "see" through atmospheric water vapor were thwarted as one sensor after another suffered serious noise degradation shortly after launch. Various "quick fixes" were tried, but nothing short of "outgassing" the entire AVHRR sensor would decrease the noise level to acceptable levels and then only for a short time. Fortunately, this has not been the case for the NOAA-11 AVHRR, and full use of three IR bands with 10-bit digitization (0.12°C thermal sensitivity) has been possible since its launch in November 1988.

The summer of 1989 was then the first opportunity to incorporate noise-free multi-channel SST (MCSST) algorithms in an attempt to map weak Gulf SST patterns. However, for some unknown reason, no concerted effort was focused on this task by those groups carrying out Gulf ocean feature mapping. The NOAA was creating global MCSSTs with channel #3 information, but the resultant 14-km SST maps have several drawbacks when not appropriately enhanced. This lack of interest is amazing in hindsight, but most groups had been lulled into what we will call the channel #3 noise syndrome.

During this past summer, Naval Oceanographic and Atmospheric Research Laboratories (NOARL) upgraded its SST algorithms to match the new Cross Product SST (CPSST) now operational at NOAA. Investigations compared the results from each individual channel with the 4-5 MCSST and 3-channel CPSST images. Considerable success was readily achieved in consistently locating the Loop Current boundary as it stretched northward into the Gulf. The NOARL was simultaneously receiving requests from several groups wishing to know if an eddy had been shed in early summer. We therefore intensified our efforts to map mesoscale features as

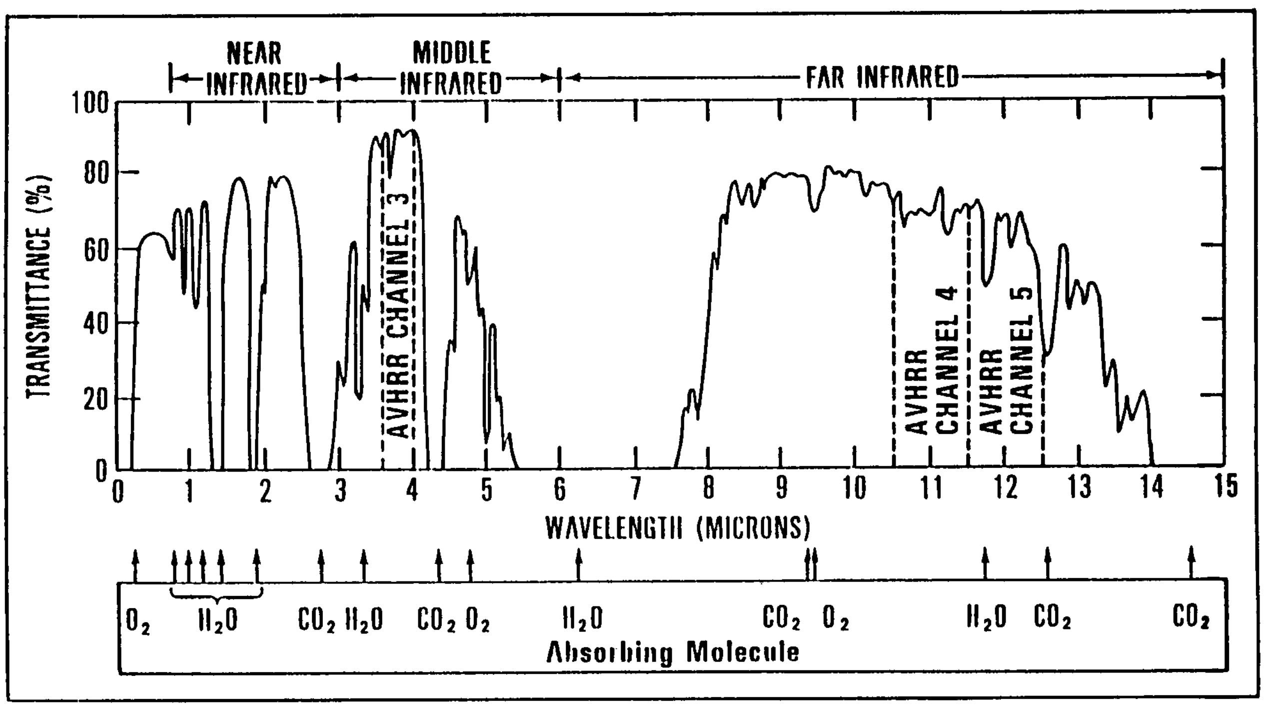

Figure 13.8. The percent transmittance of radiant energy as a function of wavelength for a wide spectral range, including the three AVHRR channels used for creating sea surface temperature retrievals.

the onset of the "worst" timeframe for IR sensing, during July and August, occurred.

August 12 and 19 3-4-5 MCSST and CPSST imagery dramatically illustrated the advantages inherent in channel #3. A huge, elliptical warm core eddy was noted separating from the Loop Current, with the major axis extending nearly 400 km to the north and the minor axis to the east-west about 250-300 km. The SST gradient surrounding the edge was 0.5°C, difficult to find in any type of objectively contoured SST product. However, standard image processing techniques easily produced detectable patterns that matched well with expendable drifting buoys (Pickett 1989) entrained within the warm core eddy's anticyclonic circulation.

Figure 13.9 was selected to best illustrate inherent advantages channel #3 has over #4 and #5. Since grey scale IR images with very small gradients reproduce poorly unless using the best of photographic paper, we have resorted to presenting a profile of SSTs along 27.3°N, going from 89.1°W and 83.5 °W. This horizontal cross section of temperature (°C) versus distance (km) graphically demonstrates the relationships between all three AVHRR channels and the final three-channel CPSST product. Please note that NO offset has been applied to any of the values.

The relative comparisons of channels 3, 4 and 5 can be expected in part from Figure 13.8, but the magnitude of the temperature separations between the individual calibrated channels is dramatic. This is due to the extremely moist conditions. Channels #4 and #5 mirror each other with a nearly constant 2°C offset. Both exhibit a 1°C SST gradient near location A, then show a decline of 2°C, followed by a gradual rise of the same magnitude distributed over some 200 km.

Channel #3 SSTs differ markedly from these profiles. The sharp gradient at 50 km is reduced to minor significance and is replaced with a weaker feature at 100 km. Channel #3 has neither the large decrease or rise seen in both #4 and #5 between 50 and 350 km and instead has a 0.5°C gradient located in the middle of what was a flat SST region. A look at the imagery puts these observations into context:

1. All the major SST changes in channels #4 and #5 are water vapor related and an analyst would be hard pressed to find any features of note using either channel.

2. These water vapor boundaries are directly linked to atmospheric fronts that are largely mitigated with channel #3.

3. The SST signals appear in channel #3 that have little or no visualization in channel #4 and #5.

4. Front and eddy mapping without channel #3 would be basically useless in this example, even when using a 4-5 MCSST product. Please note channel #3 is limited in daytime use to the anti-solar (view away from sun) AVHRR side.

The CPSST profile illustrates the depressed signal still existing in channel #3. An offset of nearly 3.5°C exists between the two and they mirror each other well except for the enhanced gradient at the 100 km mark. This absolute SST value has been shown to have a global RMS error of 0.6 °C (McClain 1990) when compared to accurate drifting buoys over a range of from 0 to 35°C. The profile gradients (Figure 13.9) relate directly to the edge of "Quiet" eddy on the left and a small cold core cyclonic eddy near 375 km.

When viewed in the context of an image, even these small gradients of 0.5°C or less make it possible for experienced analysts to extract valuable mesoscale feature information. The human eye is great at pattern recognition and, when combined with image processing software, can make even very weak signals useful for a variety of applications.

CONCLUSIONS

Early efforts to use Gulf of Mexico infrared imagery during the summer months were marginal at best due to the water vapor attenuation in the channels available. Pieces of frontal segments could be vaguely viewed, but typically not enough was visible to extract a viable map of the ocean mesoscale field. This has changed dramatically with the advent of a noise-free AVHRR channel #3.

A three-channel SST algorithm was applied to a suite of images from July to October to track one huge warm core eddy (Quiet Eddy) and then later used to map a smaller warm core eddy (Lolita) that pinched off in the east-central Gulf and remained there for over a month. The Loop Current was mapped much farther to the east and south than usual and did not repenetrate to its "normal" position until after the smaller eddy had shed.

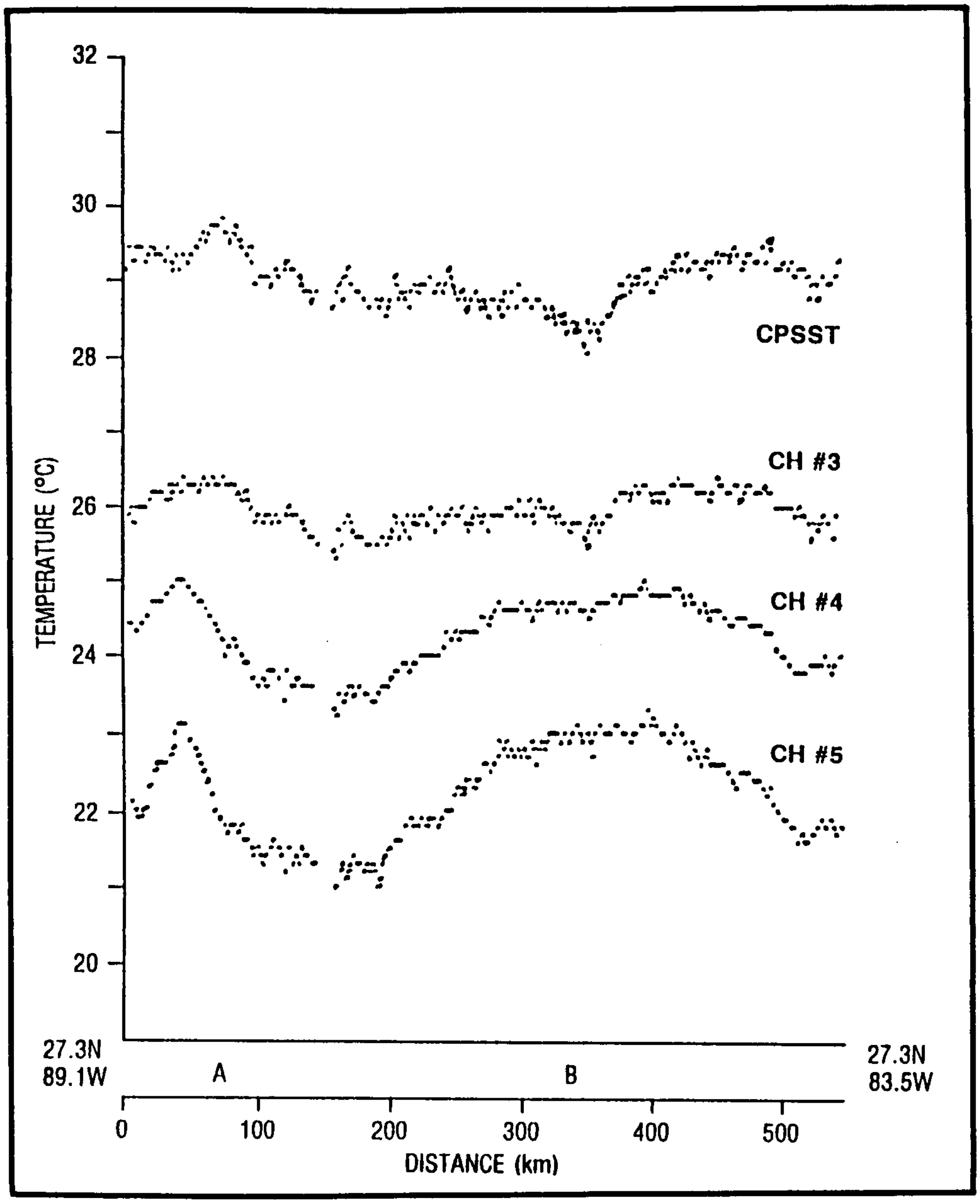

Figure 13.9. Sea surface temperature profile across a portion of the Gulf exhibiting the apparent SSTs in AVHRR channels 3, 4, and 5 plus the atmospherically corrected CPSST values.

Efforts to use this relatively new resource via objectively analyzed SST maps will likely not succeed, since the gradients are so small and are buried in the natural noise inherent in summertime SST patterns. This problem can be remedied by "bogusing" the fronts and eddies in manually by a method similar to that used operationally at the Fleet Numerical Oceanography Center (Fox *et al.* 1990).

A noise-free channel #3 on the NOAA AVHRR sensor has added significantly to the overall capability to monitor the Loop Current and the warm and cold core eddies that dominate the circulation in the Gulf of Mexico. The atmospheric window it uses is more transparent to the debilitating effects of water vapor (Figure 13.8). It will be interesting to see how nearly year-round IR imagery (within in the confines of cloud limitations) fills in our knowledge data gaps of the Loop Current System.

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Mr. Jeffrey D. Hawkins has worked in the Remote Sensing Branch at the Naval Oceanographic and Atmospheric Research Laboratories for the past 10 years and is now the head of the Applications Development Section. His areas of research interest focus on the use of satellite-derived sea surface temperatures, sea ice and sea surface height for Naval applications. Mr. Hawkins received his B.S. and M.S. in meteorology from Florida State University.

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RING MONITORING IN THE GULF OF MEXICO USING GEOSAT ALTIMETRY

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INTRODUCTION

The U.S. Navy's GEOdetic SATellite (GEOSAT) recently completed four and three-fourths years of service, obtaining an unprecedented set of sea level measurements covering the global ocean. Launched in March 1985, with a primary mission (classified) of mapping the marine geoid, this altimetric satellite occupied a non-repeating orbit at approximately 800 km altitude and 108° inclination. For the following 18 months, GEOSAT sampled a dense network, covering the earth up to +72° latitudes, with average crosstrack resolution of about 4 km and alongtrack resolution of about 7 km. In October 1986, the satellite was maneuvered into an exactly repeating orbit of 244 revolutions (near 17 days - Exact Repeat Mission, ERM), which continued until January 1990, when the altimeter ceased functioning.

In this study, we have used altimeter data from the first (geodetic) mission to determine its utility in monitoring Loop Current-shed rings in the Gulf of Mexico. Comparisons were made between altimeter-derived sea surface height (SSH) anomalies and combinations of Advanced Very High

Resolution Radiometer (AVHRR) imagery, satellite tracked drifters and hydrography. Encouraged by the success of this effort, we have begun melding the time series of SSH from the geodetic mission with SSH from the ERM in order to obtain a data set of SSH topography anomalies in the Gulf of Mexico covering four and one-third years.

METHODS

Although absolute sea level measurements obtained by GEOSAT during the geodetic mission are classified, crossover point differences are not. Crossover point differences are formed by subtracting sea level measurements made at the intersections of ascending and descending ground tracks. After proper orbital and geophysical corrections, including removal of tides, this difference represents real ocean dynamic height changes that occurred between the times of overpass along the two tracks. An important advantage of the crossover point difference method is that differencing eliminates the relatively large (but temporally unchanging) marine geoid, and, hence, also eliminates both the requirement for repeat track orbits and the need for classification. However, it should be emphasized that the method only gives SSH anomalies, not absolute values of sea level.

Using a method developed by Fu and Chelton (1985), time series of SSH were calculated at grid points in the Gulf of Mexico from crossover point differences. The differences were partitioned by location into overlapping diamonds of 3° latitude by 3° longitude, centered on each grid point, and biases (vertical offset referred to an arbitrary height) of each track were found by least squares fit to all tracks within each diamond. These biases were then organized into time series according to the time of passage of the satellite along each track. The resulting time series represents characteristic dynamic height (SSH) anomalies for that particular grid point, regardless of where the track occurred within the diamond. In order to partially ameliorate the effect of this spatial "jumping" within the diamonds, a temporal filter (low pass with 1/2 amplitude at 50 days) was applied to the series. But this also reduces the maximum amplitudes and the sharpness of gradients. SSH topographic anomaly maps were produced from the time series for sequential dates in order to follow events across the Gulf.

Several satellite-tracked drifting buoys were available during the geodetic mission for comparison with the altimeter data. In order to make this comparison, surface current vector anomalies were computed from the SSH anomalies in the following manner: surface current vector components were first calculated between each two adjacent grid points, based upon the instantaneous SSH difference between those two points and the assumption of geostrophic balance. Then, from a four-sided box of such adjacent grid points, the resulting four current components were vector averaged into a single vector, characterizing the center of the box.

RESULTS DURING 1985/1986

An example of SSH topographic anomalies in the Gulf of Mexico is shown in Figure 13.10 for the 29th of August 1985 (Year Day 241). Three known rings were present in the Gulf at this time: ring "A" (Fast Eddy), ring "B" (Hot Eddy) and ring "G" (Ghost Eddy). Tracks of two different drifting buoys are superimposed on the topography for comparison.

Referring to Figure 13.10, it seems fairly clear that the center of swirl of the drifters matched the ring centers, as identified by SSH anomalies, to within the resolution allowed by grid size; i.e., about 75 km. Further comparisons at different locations and with other drifters confirmed this estimate of resolution. However, current speed amplitudes, calculated from the SSH topography, were only about 30%-50% of the actual drifter speeds. This reduction is attributed to the method of SSH retrieval, the low pass filter and the fact that SSH amplitudes represent anomalies about the mean topography, not actual heights. This amplitude reduction could also be seen in a comparison with (somewhat limited) ship surveys of hydrography.

The Loop Current on YD 241 is represented in Figure 13.10 as a topographic low centered just north of the Yucatan Straits. This cyclonic motion is a reversal from the ambient anticyclonic curvature and indicates that the Loop Current anomaly is weaker at this time than its average for the whole period. From sequential maps (not shown here), the Loop Current can be observed to grow slowly in amplitude until the last two months when a rapid intrusion occurs and a new ring is formed.

Figure 13.11 show a sequence of five current vector maps, at 15 day intervals, covering the generation of ring "G." The name "Ghost" Eddy was applied to this ring since it seemed to have appeared from nowhere. In the sequence, shown in Figure 13.11, ring "A" can be clearly distinguished in the central Gulf. This ring migrates toward the west at a speed of 3-4 cm/s. At the same time, a feature, which we are

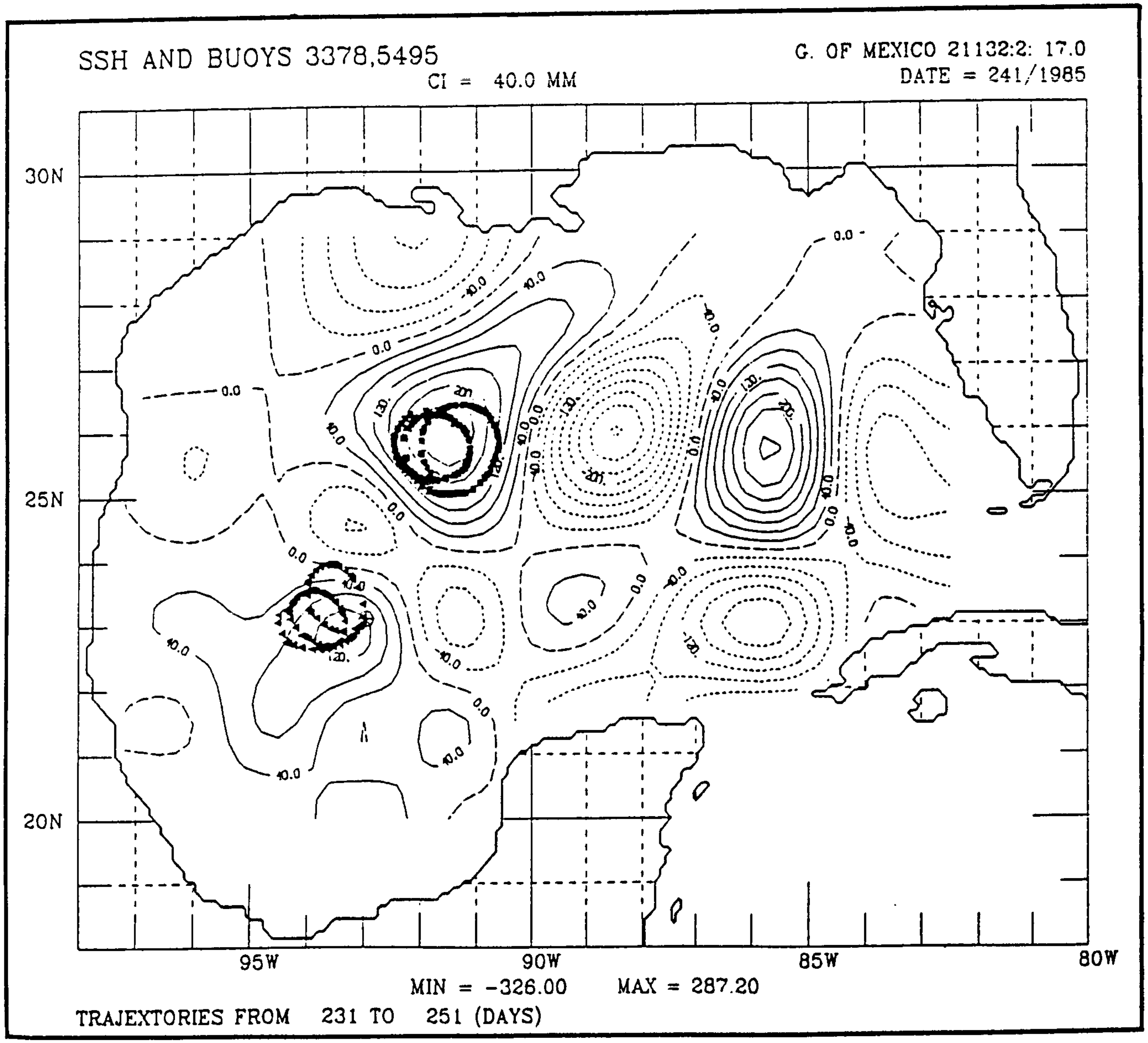

Figure 13.10. The SSH anomaly topography for day 241/1985 with two drifting buoy trajectories superimposed. (The SSH amplitude is given in millimeters [from Johnson *et al.* 1990]).

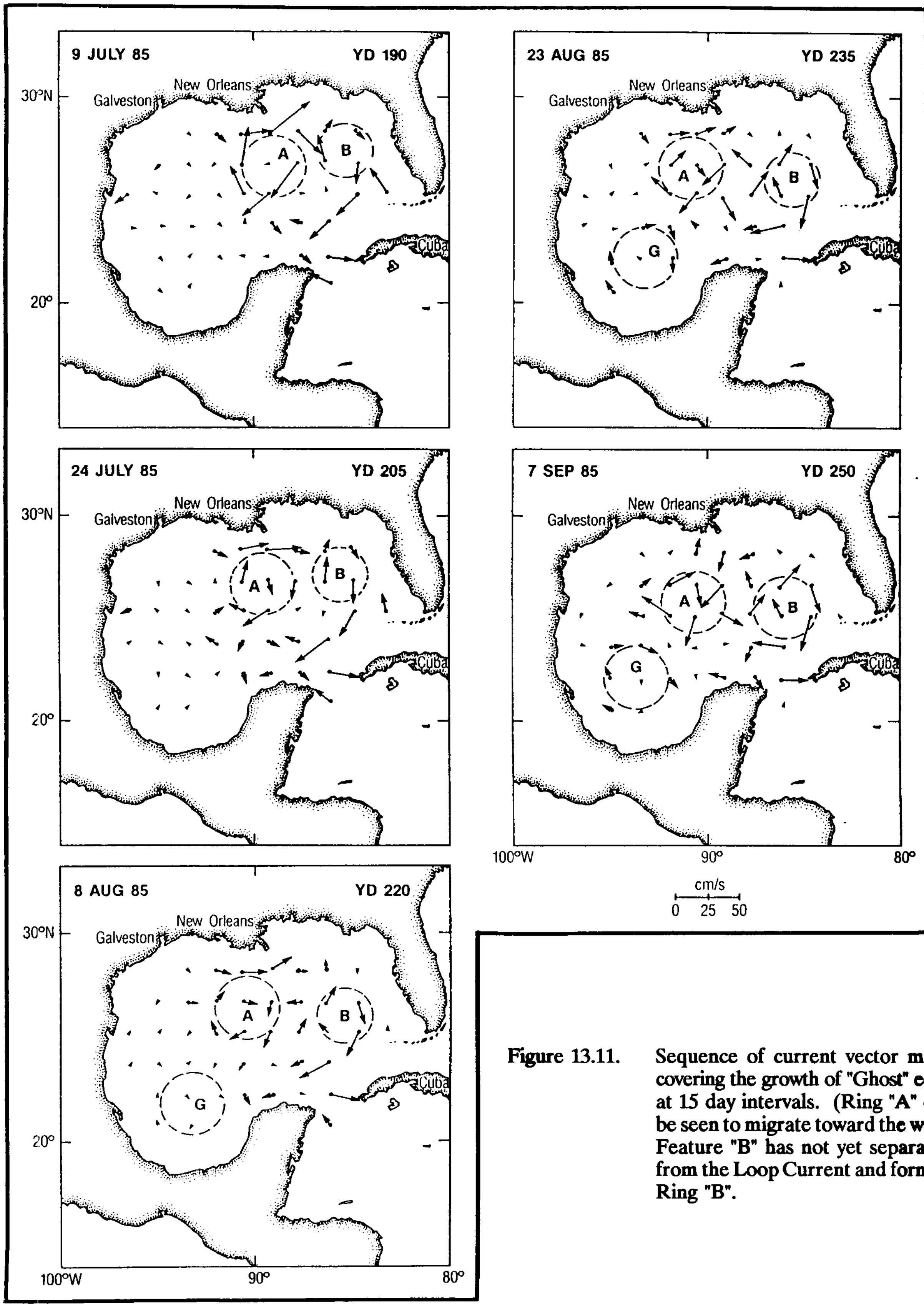

Figure 13.11. Sequence of current vector maps covering the growth of "Ghost" eddy at 15 day intervals. (Ring "A" can be seen to migrate toward the west. Feature "B" has not yet separated from the Loop Current and formed Ring "B".

calling "B," appears in the northeast corner of the Gulf. In subsequent panels, this latter feature can be traced in a southward movement until it reaches the location where rings are commonly detached from the Loop Current. At that time it begins to migrate toward the west.

From these examples, covering only the first mission of GEOSAT, it seems apparent that altimetry can be a valuable tool, capable of monitoring rings and other features in the Gulf of Mexico. Correct amplitude information from altimetry will need additional effort. But the real payoff may occur when we have been able to generate long time series of SSH topography, and are then able to develop relational statistics for prediction improvement.

PROGRESS IN DEVELOPING LONG TIME SERIES

In order to produce a time series data set for the Gulf of Mexico that covers the entire GEOSAT mission, we have melded time series from the geodetic mission (crossover point differences) with time series from the Exact Repeat Mission (collinear differences). The method has been previously applied to study the large scale meridional transport in the equatorial Pacific (Miller and Cheney 1990) and was described in detail in Milbert *et al.* 1990.

Crossover point differences were obtained that covered the first year of the ERM as well as the geodetic mission. This one-year overlap with the collinear data set offered an opportunity to compare the methods of time series extraction. The differences from the collinear data had been corrected for orbit error using a tilt and bias adjustment prior to obtaining crossover point differences. An example of raw biases computed from crossover point differences within a 2° box centered at 25° N, 90° W is shown in Figure 13.12. The +'s represent each arc bias. Optimal interpolation with a 30-day decorrelation time produced a smooth representation of the time series as shown by the dashed line.

Calculating the collinear time series is a straightforward process, much simpler than the crossover adjustment technique that must be used for nonrepeating orbits. Alongtrack height anomalies from the first 60 exact repeat cycles of GEOSAT were calculated and corrected for orbit error using a tilt and bias adjustment. In order to achieve a correspondence with the crossover point biases, all anomaly data from each pass of the altimeter over the 2° box were averaged to obtain a bias for that arc and time. The raw arc biases are shown in Figure 13.12 as dots. These biases were optimally interpolated to produce the smooth time series represented by the solid line in Figure 13.12. Clearly, the two time series match quite well in the one-year overlap. In addition, the scatter of the individual observations about the smooth curves was also similar. In order to meld the two time series for the final presentation, we used a linear combination of the optimally interpolated crossover point and collinear solutions over the interval of overlap, with the crossover solution weighted more at the beginning of the overlap and the collinear solution more at the end.

In Figure 13.13, we have computed the 4-1/3 year long time series at longitudes 87°W - 95°W along two lines of latitude: 26°N and 24.5°N. Shading of the positive anomalies allows the easy identification of Loop Current shed rings and their propagation to the western Gulf. We can identify at least six rings in the GEOSAT record: "A" (Fast Eddy), "B" (Hot Eddy), "C" (Crazy Eddy), "D" (Lazy Eddy), "E" (Eddy Murphy) and "F" (Oggie Eddy). Each ring migrates westward and southward with similar speeds. As the rings disappear from the 26°N line, they begin to appear on the 24.5 °N line, demonstrating their southward component of migration.

Although these figures demonstrate clearly that altimetry can be a remarkable tool for monitoring shed rings from the Loop Current in the Gulf of Mexico, the real work of analysis is just beginning. Opportunities for future altimetry work will expand considerably with the launches of the ERS series, TOPEX/POSEIDON and the possible GEOSAT Follow-On series of altimeters.

ACKNOWLEDGEMENTS

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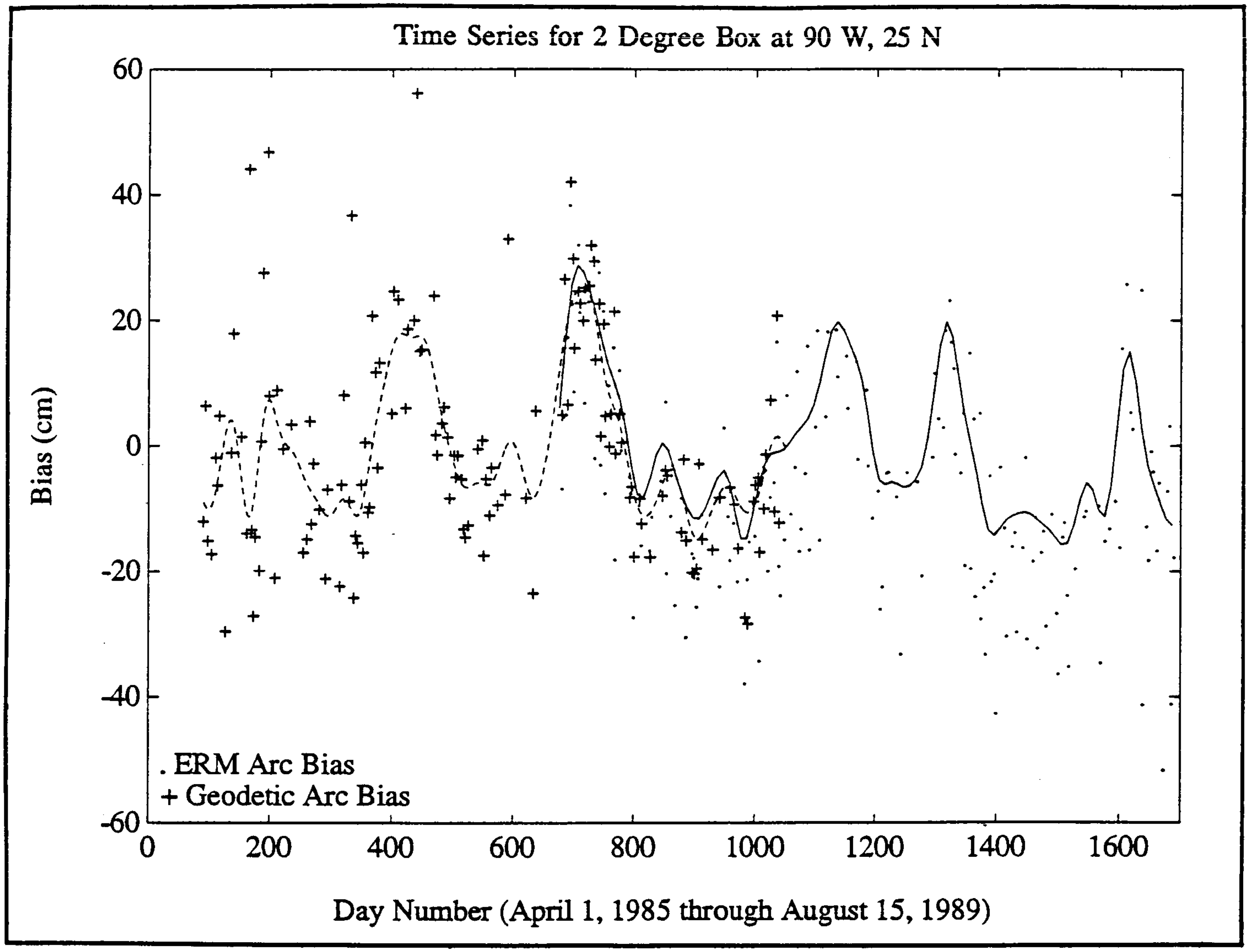

Figure 13.12. **The SSH time series in a 2°x 2° box, centered at 90°W/25°N. (The +'s represent raw biases from crossover point differences for the first 2-1/2 years and the dashed line represents optimal interpolation of this series with a 30 day decorrelation. The dots represent raw biases for the final 2-3/4 years and the solid line represents optimal interpolation. Notice that there is a one year overlap between the two series which is then adjusted by a weighting scheme.)**

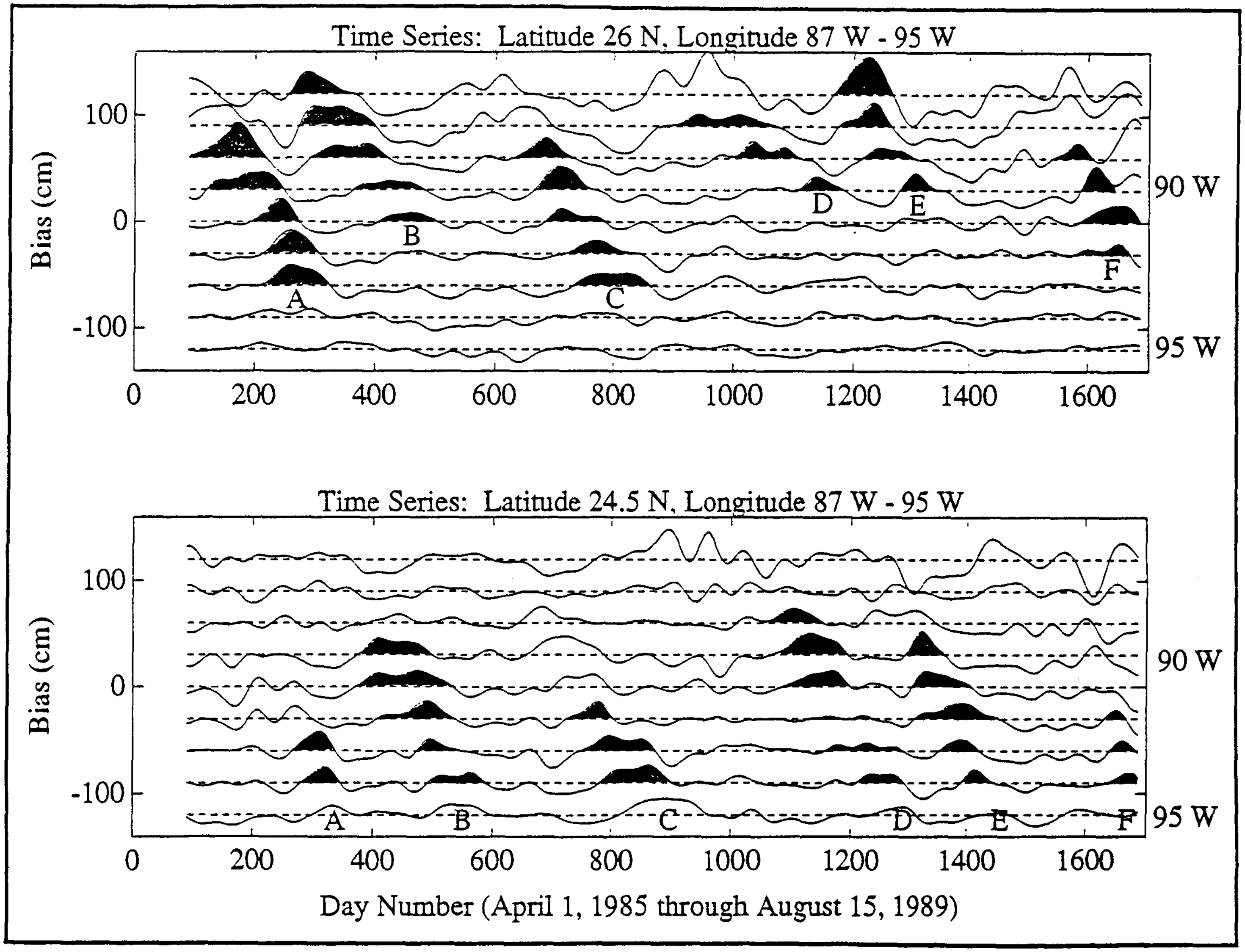

Figure 13.13. **Time series for indicated meridians at 26°N (upper) and 24.5°N (lower). (Six Loop Current spin-off rings can be followed in their western migration. The rings disappear from the northern latitude line as they appear on the southern latitude line, showing a southward component to their migration.)**

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GULF OF MEXICO HIGH RESOLUTION MEAN SEA SURFACE DETERMINED FROM SATELLITE ALTIMETRY

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INTRODUCTION

We are interested in developing a stable surface interpolation technique to combine optimally both sea surface height and deflection of vertical (slope) measurements to determine high resolution mean sea surface (marine geoid). The sea surface height and slope measurement types can include those inferred by satellite altimetry and those obtained by ship gravimetric measurements. These measurements can be noisy, irregularly distributed and with sparse coverage in certain regions. The primary objective of this research is to develop an efficient and accurate surface interpolation technique to compute mean sea surfaces by optimally combining scattered sea surface height and slope measurements collected by satellite altimetry missions and other inhomogeneous data types.

The so-called surface spline interpolation is an efficient method for the global interpolation of scattered data. The fitting function is represented by a combination of the fundamental solutions of iterated Laplacian and some low degree polynomial terms accompanied by associated constraints (for the underlying mathematical formalism, see Meinguet 1979, 1981, 1984). The constraints play a role of damping out excessive oscillations in the fitting function. The technique is a natural generalization of the one-dimensional smoothing polynomial spline interpolation to higher dimensions. As it will be shown in the next section, this technique is an improvement over the biharmonic spline interpolation algorithm (Sandwell 1987) for the determination of regional mean sea surface using satellite altimeter data.

To filter out noise and to average data over several passes, we reduce the number of model parameters of the fitting function to an appropriate quantity. The algorithm results in solving an overdetermined linear system with linear homogeneous equality constraints. A technique of square root free Givens transformation was used to solve this linear system. For computational efficiency, the target area is divided into subareas whose boundary regions are overlapped with neighboring subareas.

This technique is applied to 51 days (three 17-days repeat orbits) of GEOSAT height data and 2 years of averaged GEOSAT slope data (averaged over 44 repeat orbits) along with 69 days of SEASAT slope data for computation of a high resolution (0.125° by 0.125°) regional mean sea surface, which includes the Gulf of Mexico region. The resulting mean sea surface is compared with another high resolution geoid determined from the OSU89B spherical harmonics gravity field model complete to degree and order 360 (Rapp and Pavlis 1990). The GEOSAT sea surface heights used were obtained using precise orbits computed in a terrestrial reference frame determined by satellite laser ranging (Shum *et al.* 1990) and using an improved Earth's gravity field model, PTGF4A (Shum *et al.* 1989). The origin of the SLR-determined reference frame is known to differ from the center of mass of the Earth by less than 5 cm (Schutz *et al.* 1987). Although the surface interpolation technique has been applied to Gulf of Mexico region in this study, it can be extended to any region of the world and globally.

One of the applications for the establishment of absolute sea surface height measurements is to enable the feasibility of monitoring of sea level changes using satellite altimetry. The availability of an accurate and high resolution mean sea surface in the Gulf of Mexico region will enable more accurate determination and prediction of eddy movements and will enhance other research areas to study physical oceanography in the Northwestern Gulf of Mexico region.

APPLICATION TO SATELLITE ALTIMETRY

The GEOSAT altimetric satellite launched by the U.S. Navy in March 1985 was maneuvered into an exact repeat mission (ERM) with a repeat period of 17.05 days in November 1986 for the study of mesoscale oceanographic features. Figures 13.14a and 13.14b present the repeated GEOSAT and SEASAT (respectively) ground tracks in the region, which includes the Gulf of Mexico. The surface spline interpolation technique was applied to this region to obtain a high resolution regional mean sea surface. We assume that the region is flat so that longitude and latitude can be considered as Cartesian coordinates.

The sea surface height data employed in this study were reduced from three separate 17-day orbits beginning November 17, 1986; December 21, 1986; and January 7, 1987. The sea surface heights were computed by $h_{ssh} = h_{sat} - (h_a + c)$ where h_{sat} is the height of the satellite, h_a is the observed altimeter measurement and c is the sum of corrections to the altimeter data (Nerem *et al.* 1990). These computations are performed relative to the 1979 IUGG-adopted reference ellipsoid. The satellite heights are based on precise orbits (accurate to 20 cm rms) of 17-day continuous time span computed for the GEOSAT ERM using the University of Texas gravity field model PTGF4A (Shum *et al.* 1989, 1990).

Figure 13.15 presents three collinear sea surface profiles along the repeated ascending ground track AA' as shown on Figure 13.14a. The closeness of collinear profiles reflects the accuracy of orbits while discrepancies result from orbit errors (primarily due to uncertainty of the Earth's gravity field) and dynamic oceanographic phenomena. A set of one per second height data (number of heights = 26,810) was generated from these three sets of profiles.

The sea surface slope data employed in this study were reduced from two years of averaged slope profiles, which were obtained by averaging the individual along-track slope profiles from 44 GEOSAT repeated cycles. A set of two per second slope data (number of slopes = 23,986) was generated from these averaged slope profiles. Also included is a set of one per second SEASAT sea surface slope data (number of SEASAT slope data = 41,306) with data time span of 69 days (during the period July - October 1978) of SEASAT profiles. A relative weight of 0.25 was assigned to the SEASAT slope data as oppose to the unit weights used for GEOSAT slope and height data.

We divided the region into 1/8° by 1/8° size grid elements. At most, one model parameter is assigned on each grid element. When the grid elements do not contain measurement(s), no model parameter is allocated. Hence the gaps between ground tracks as well as land areas contain no model parameter. And we locate each model parameter at the center of the corresponding grid element. This procedure results in 7,101 active grid elements (each contains at least one measurement hence a model parameter) out of 38,912 grid elements in the whole target region. For the computational efficiency, we divided the region

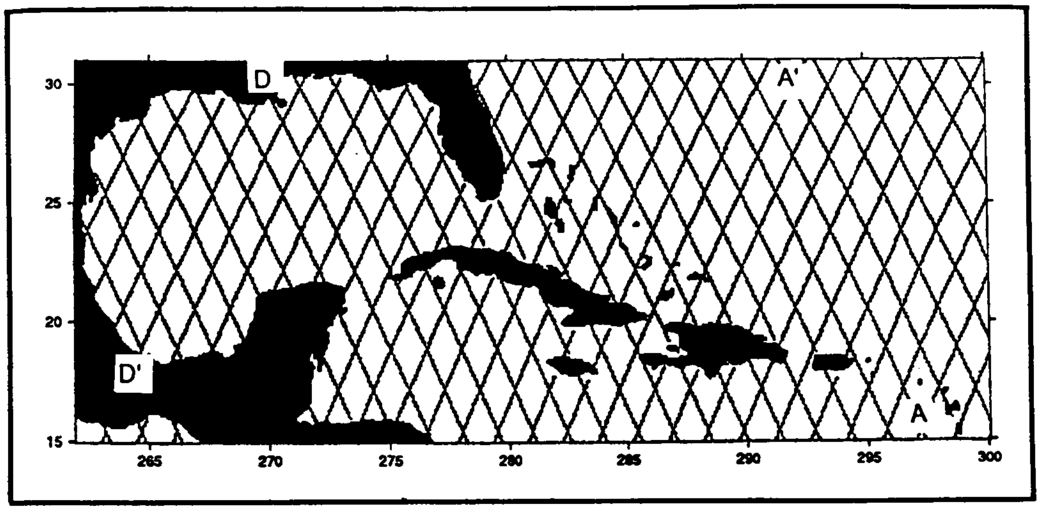

Figure 13.14a. GEOSAT ground tracks.

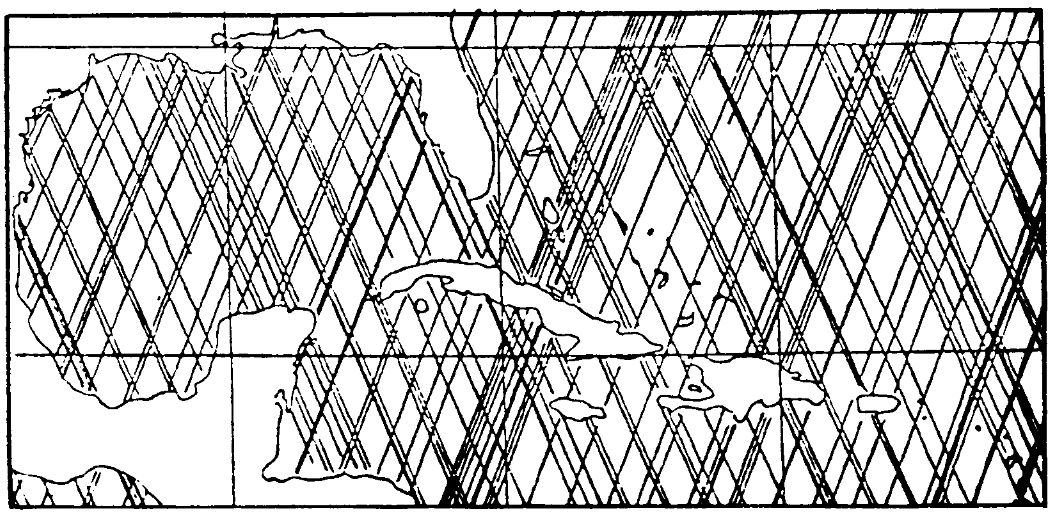

Figure 13.14b. SEASAT ground tracks.

into 18 subareas of same size with latitude range 16/3° and longitude range 38/6° and made the areas overlap by extending each margin by 10% (this increases the virtual area by 44%). The average number of model parameters in subareas is 523.

After finding the unknowns of each subareas, the surface was computed with 1/8° by 1/8° intervals. Figure 13.16a and Figure 13.17a show contour maps of the resulting GEOSAT and GEOSAT + SEASAT high resolution regional mean sea surfaces respectively. Residuals of the surface fitting were computed to assess the accuracy of the solution. Figure 13.18 presents the residuals of height data along the sea surface profiles AA' as shown on the Figure 13.14. Nonzero mean value of residuals reflects the influences of other profiles (our interpolation algorithm is a global interpolation). Figures 13.19a and 13.19b present residual histograms for the heights and slopes of the GEOSAT mean sea surface, respectively. Since the interpolation is a least squares data fitting process, regional ephemeris errors and time dependent oceanographic phenomena that produce profile differences will tend to be averaged, and the RMS of residuals presented in Figures 13.19a and 13.19b includes the orbit errors and dynamic oceanographic phenomena as well as errors due to interpolation.

Another assessment of accuracy evaluation was performed by comparing the mean sea surfaces with another high resolution geoid (Figure 13.16b) computed by OSU89B spherical harmonics (degree and order 360) gravity field model. Figures 13.16c

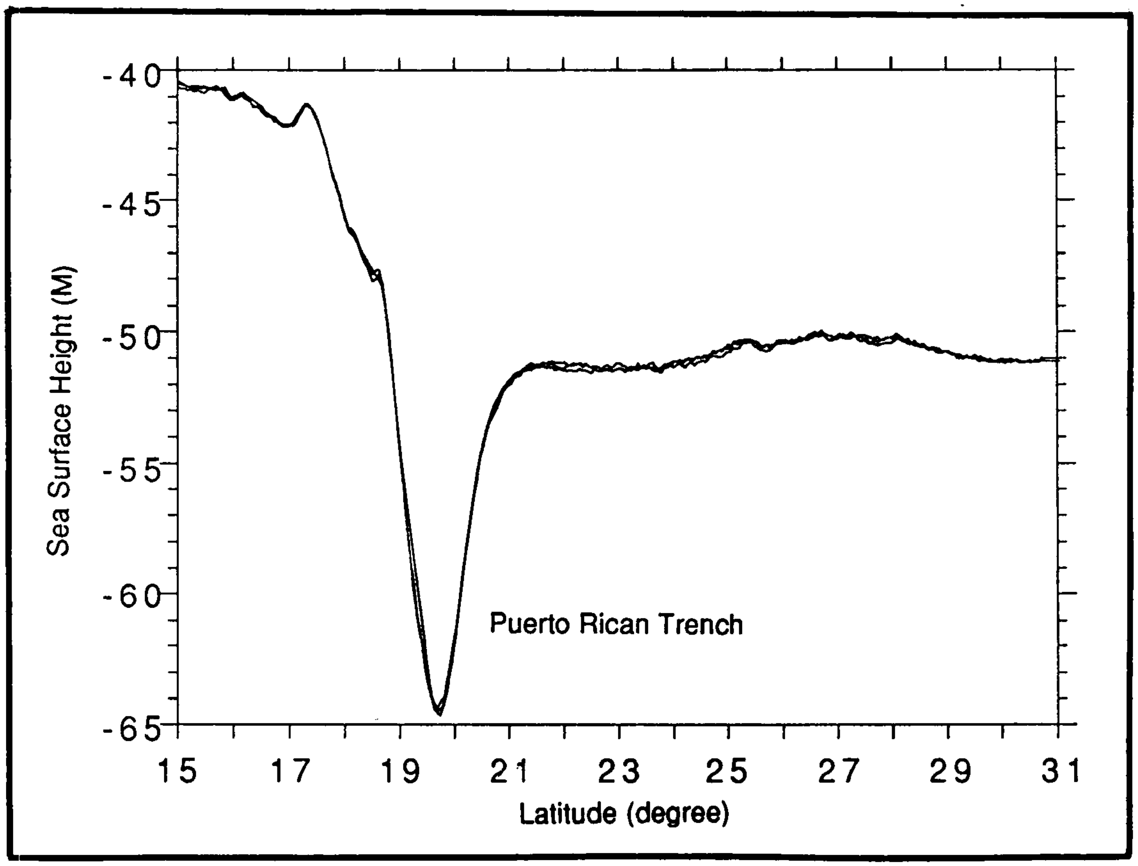

Figure 13.15. Three GEOSAT collinear sea surface profiles (A-A' on Figure 13.14a) based on PTGF4A orbits.

and 13.17b show contour maps of the differences between GEOSAT - OSU89B and (GEOSAT + SEASAT) - OSU89B, respectively. Although the contour maps show the Caribbean region, the RMS values of the differences that were computed for the northwestern Gulf of Mexico region are 69 cm and 63 cm, respectively. Considering large gaps (comparing to the interpolation resolution) between repeated ground tracks, no significant variations of differences occur in the Gulf of Mexico region and northeastern region of the Caribbean. This suggests that these gaps are naturally filled with the surface spline function. In the southern Caribbean region, the Puerto Rican trench dominates the discrepancies and several small islands of differences are visible (Figure 13.16c). The SEASAT slope data allowed additional 7,230 grid elements to be filled, resulting in smaller (comparing Figure 13.17b to Figure 13.16a) differences in certain regions. The remaining discrepancy may be in part due to the fact that the mean sea surface developed in this study has higher spatial resolution (0.125°) than that of the OSU89B model.

SUMMARY

A technique to compute mean sea surface based on altimeter measurements both in terms of absolute sea surface heights and slope measurements has been developed. The surface spline interpolation algorithm can accommodate different types of data, (heights and slopes) suppressing noise, averaging several profiles from single or multiple satellites, maintaining smoothness and has a complete analytic expression. We applied this interpolation technique for the Gulf of Mexico mean sea surface computation with the primary objective to verify the technique. The resulting regional mean sea surface has an RMS discrepancy of 63 cm with the geoid determined from OSU89B spherical harmonics gravity model.

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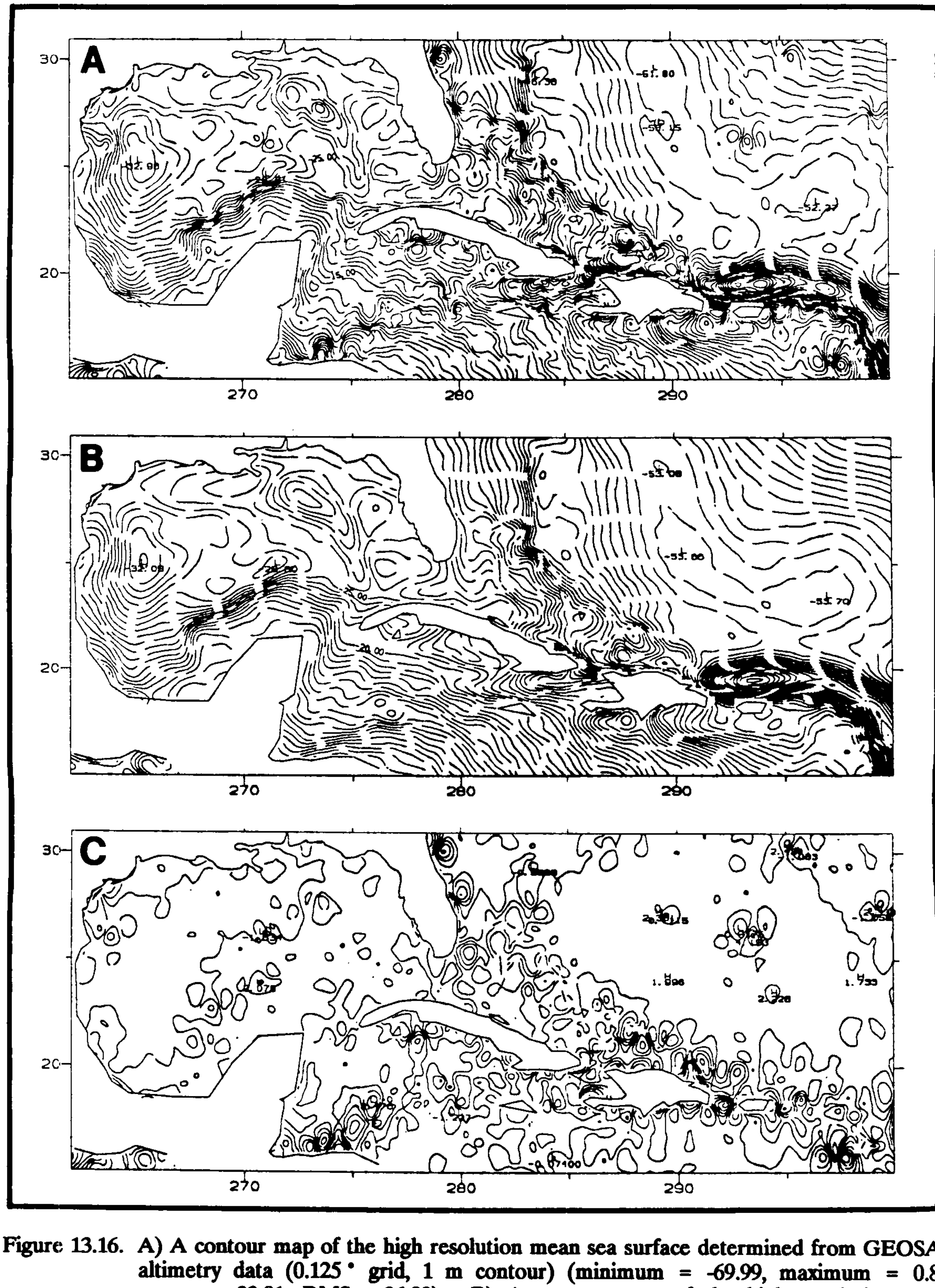

Figure 13.16. A) A contour map of the high resolution mean sea surface determined from GEOSAT altimetry data (0.125° grid, 1 m contour) (minimum = -69.99, maximum = 0.89, mean = - 33.81, RMS = 36.83). B) A contour map of the high resolution geoid determined from OSU89B gravity field model (0.125° grid, 1 m contour) (minimum = -70.23, maximum = -0.37, mean = -34.64, RMS = 37.68). C) A contour map of the differences: GEOSAT - OSU89B (0.125° grid, 1 m contour) (RMS sea surface differences in NW Gulf of Mexico = 69 cm).

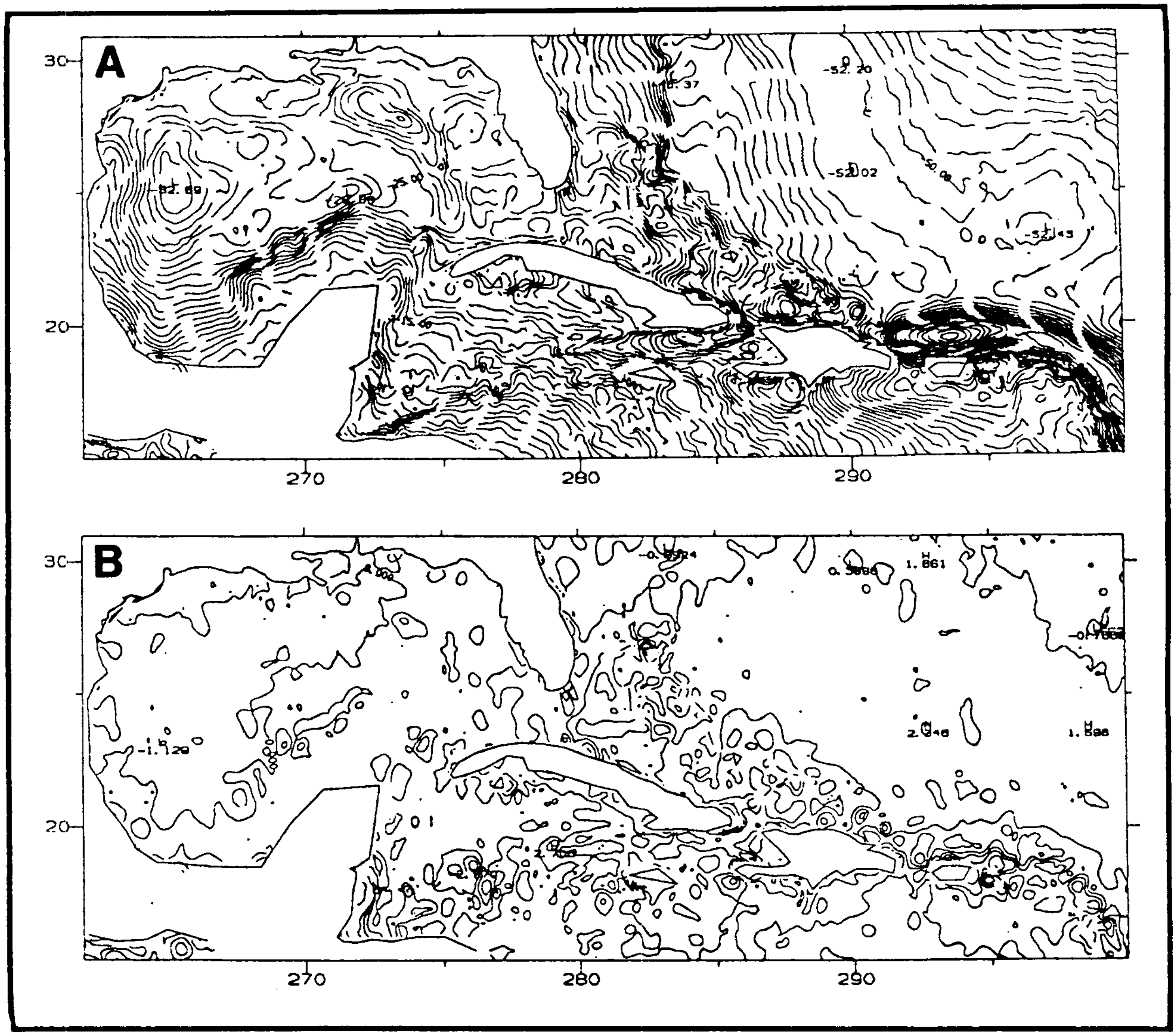

Figure 13.17. **A) A contour map of the high resolution mean sea surface determined from (GEOSAT + SEASAT) altimetry data (0.125° grid, 1 m contour) (minimum = -70.55, maximum = -0.37, mean = -33.76, RMS = 36.78). B) A contour map of the differences: (GEOSAT + SEASAT) -OSU89B (0.125° grid, 1 m contour) (RMS sea surface differences in NW Gulf of Mexico = 63 cm).**

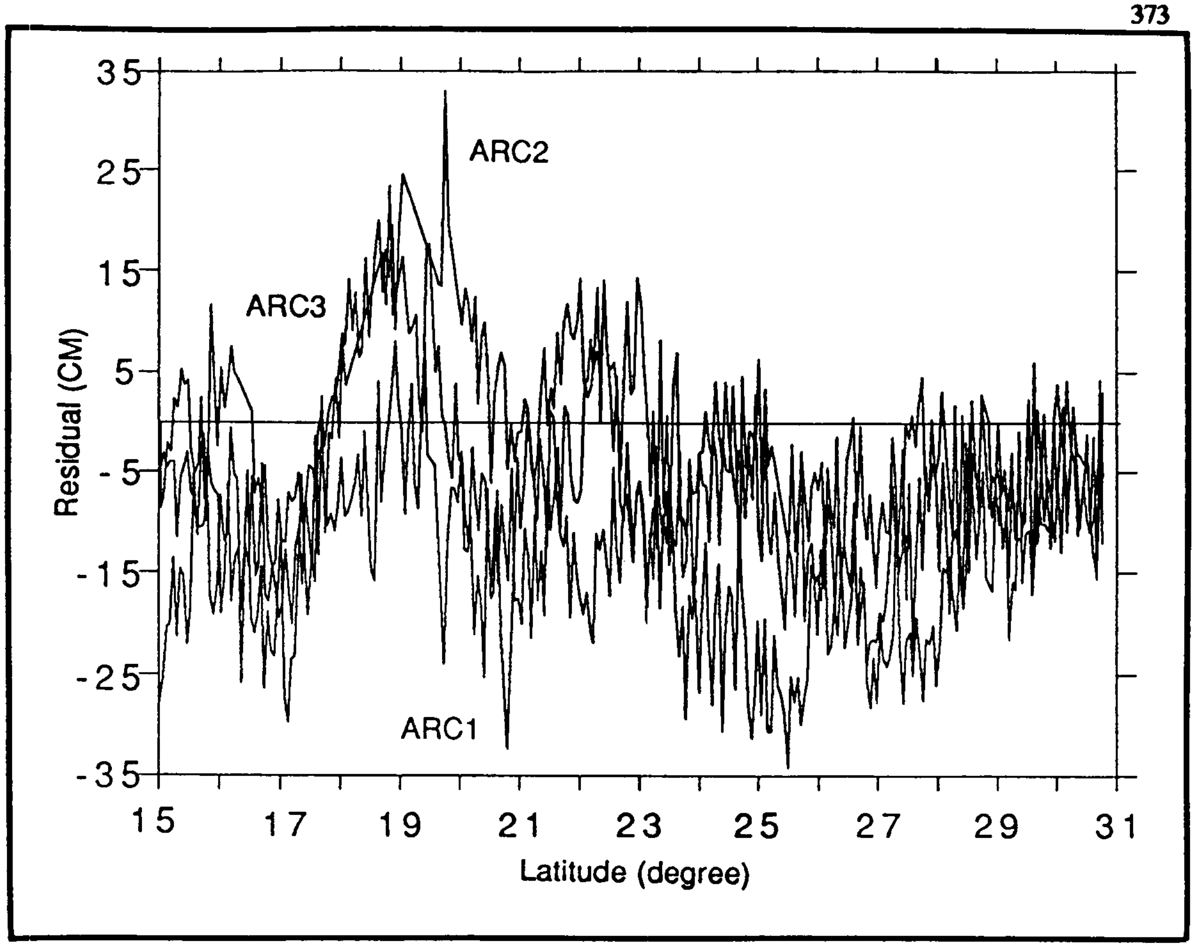

Figure 13.18. Residuals between three GEOSAT collinear sea surface profiles (A-A' on Figure 13.14a) and the interpolated sea surface.

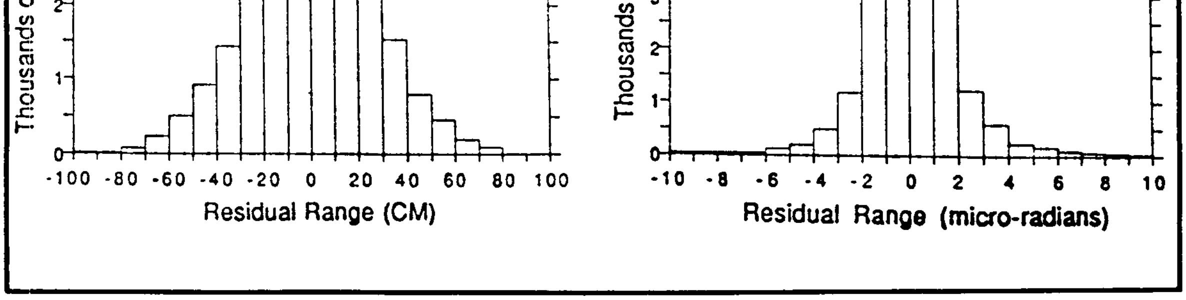

Figure 13.19. A) A histogram of residuals of GEOSAT sea surface height data. B) A histogram of residuals of GEOSAT sea surface slope data.

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A UNITED STATES-MEXICO COOPERATIVE STUDY OF A COLD-CORE RING IN THE WESTERN GULF OF MEXICO

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INTRODUCTION

At last year's Minerals Management Service (MMS) Gulf of Mexico Information Transfer Meeting, summary hydrographic data from an 11-19 November 1989 *Gyre* cruise were presented. The objective of that presentation was to illustrate the parameters that are monitored during the multi-year, repeated hydrographic surveys of the northwest Gulf of Mexico continental shelf and slope fielded three times a year from R/V *Gyre* since 1987 (Biggs

1989). For this year's presentation, we present a multidisciplinary characterization of the cyclonic circulation feature (cold-core ring) that *Gyre* cruise 89G-15 surveyed.

Cruise 89G-15 was the third "ring" cruise in an ongoing TIGER-AMIGO (Texas Institutions Gulf Ecosystem Research - Analysis Multidisciplinario de Investigaciones en Golfo Occidental) program, which is a five-year, cooperative project between Texas A&M University (TAMU) and Mexico's Dirección General de Oceanografía Naval. As on previous ring cruises in Fall 1987 (87G-11) and Fall 1988 (88G-05), United States and Mexican researchers worked together at sea to survey the field area. However, cruise 89G-15 was the first ring cruise in which our at-sea work was guided by same day insights of the mesoscale circulation provided by satellite-imagery interpretation. Beginning in early November, the University of Texas Center for Space Research (UT-CRS) monitored Advanced Very High Resolution Radiometer data collected by NOAA-11 from morning and afternoon passes over the northwest Gulf of Mexico. An example of an image that was processed by UT-CSR and sent via FAX service to the ship on 10 November (the day before R/V *Gyre* sailed) is presented as Figure 13.20a. This is annotated with the location of hydrographic stations made on 89G-15 to illustrate the dominance of eddy-like features in the surface circulation field. Note the surface expression of an elliptical area of cool (<25°C) surface temperature about 210 km x 120 km in size that was centered near 26°N and 95°W and bounded to the north, east, and south by warmer (>26°C) water.

PHYSICAL OCEANOGRAPHY

Eight conductivity/temperature/depth instruments (CTDs) and 30 expendable bathythermograph (XBT) stations made over the continental slope delineated the eastern, southern, and northwestern boundaries of the region of cool surface temperature and showed it had a cold core subsurface: the 15°C isotherm shoaled from greater than 200 m at ring periphery to a depth of only 112 m at 26°10'N and 94°57'W (TAMU 1989). Computation of the dynamic topography relative to 800 db indicated the center of this elliptical ring stood 20-25 cm lower than the periphery (Figures 13.20b and 13.21). Using the 800 db as an isobar reference level of no motion, geostrophic calculations indicate that near surface currents set counterclockwise around the periphery of this feature, at velocities of 30-50 cm sec^{-1}, causing mass transports (in the upper 800 m) of 3-5 Sverdrups. A publication detailing these calculations is in preparation by Salas de León *et al.* Data from acoustic Doppler current profiler, averaged at 5-minute intervals and decimated for display purposes, support the geostrophic calculations. They confirm that cyclonic currents of speeds of about a knot ($\sim 52\ cms^{-1}$) were present in the upper 100 m along most of the cruise track (Figure 13.22a).

Because the western periphery of this cold-core ring was at or near the shelf-slope break, it entrained cool, low salinity surface water from the south Texas shelf. This entrainment is best seen in summary plots of underway temperature and salinity data (Figures 13.22b and 13.22c), which indicate that the coolest and freshest surface water was found near ring periphery, where it was coincident with regions of highest near-surface current velocities.

PLANKTON BIOMASS AND PRIMARY PRODUCTIVITY

Within the cold-core ring, we collected zooplankton standing stocks in the upper 200 m that were somewhat higher than those collected over the surrounding slope. Wet displacement volumes of zooplankton in meter net collections ranged from 7-10 mls per 100 m^3 in the ring, compared to just 5-7 mls per 100 m^3 outside the ring. The highest surface chlorophyll concentrations were associated with the cold ring as well. Within the zone where surface salinity and surface temperatures were lowest, chlorophyll ranged 0.13 - 0.22 μgl^{-1}, whereas over the rest of the continental slope outside the ring, the chlorophyll concentrations averaged only 0.10 μgl^{-1} or less (Figure 13.22d). By contrast, integration of chlorophyll from surface to 100 m was less variable, averaging 17 ± 2 mg m^{-2} over the continental slope at stations in water depths greater than 500 m, both inside and outside the eddy. Such integrations are subject to seasonal as well as interannual variations. Although integrated chlorophyll in this survey was similar to those measured over the NW continental slope in October 1988 (19 ± 4 mg m^{-2}), it was only about half as great as integrated chlorophyll in November 1987 (39 ± 6 mg m^{-2}).

Two light bottle-dark bottle ^{14}C uptake experiments carried out on subsequent days within the cold-core "ring" show that primary production there averaged 96 and 111 mg m^{-2} h^{-1}. This is markedly higher than the production rates of only 15-23 mg m^{-2} h^{-1} (0.2 g m^{-2} day^{-1}), which were measured in a warm-core ring over the NW continental slope over the Gulf of Mexico (Biggs 1990). However, the flux of

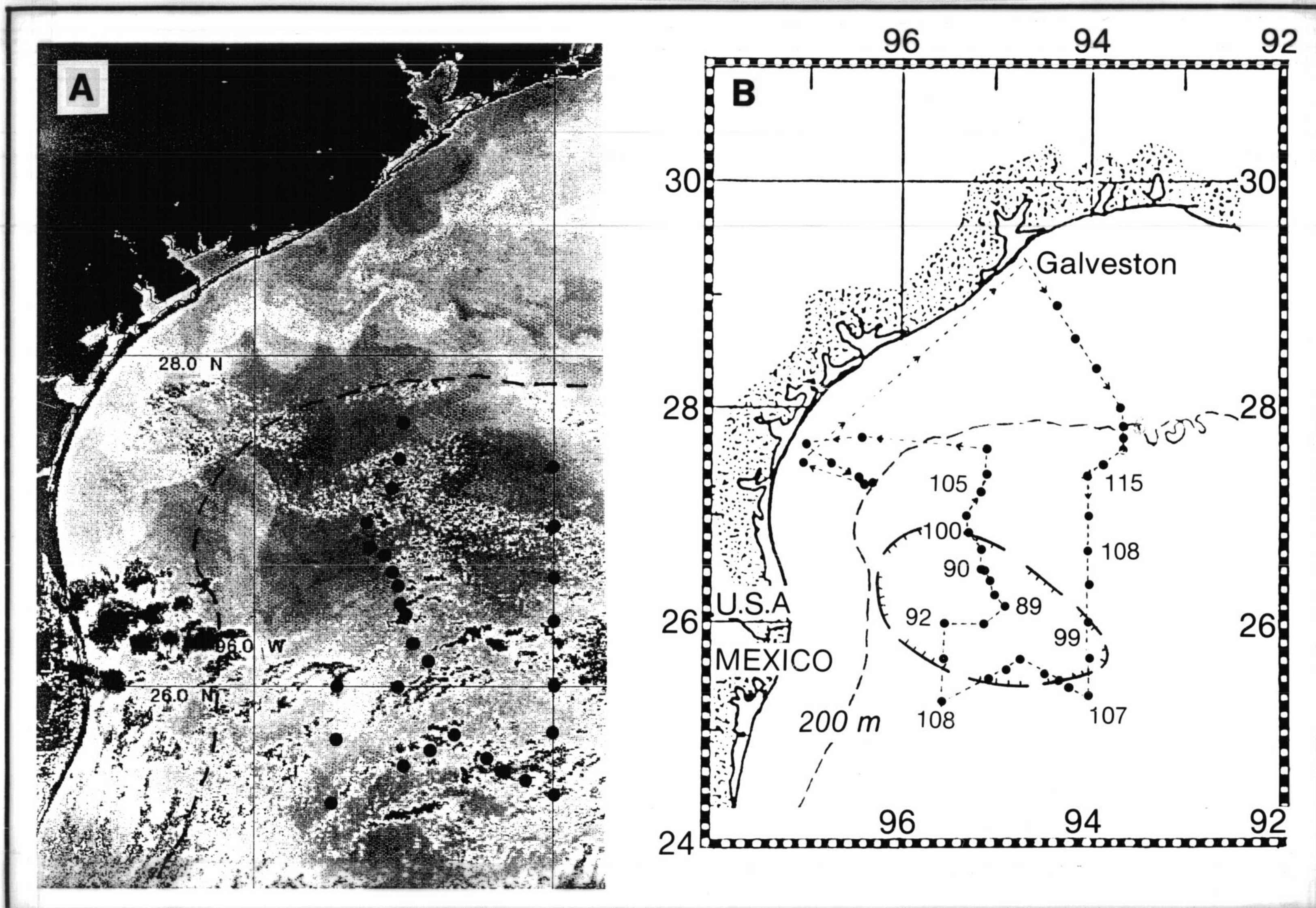

Figure 13.20. A) Sea surface temperature map of the NW Gulf of Mexico, from NOAA-11 overflight at 14:04 CST on 10 November 1989. (Dots show the location of CTD and XBT stations made 13-16 November.) B) Local geopotential anomaly (in dynamic cm relative to 800 db reference level), calculated using XBT data as well as CTD data. (Salinity was splined to each XBT temp:depth datum using the T:S relationship of the nearest-neighbor CTD station).

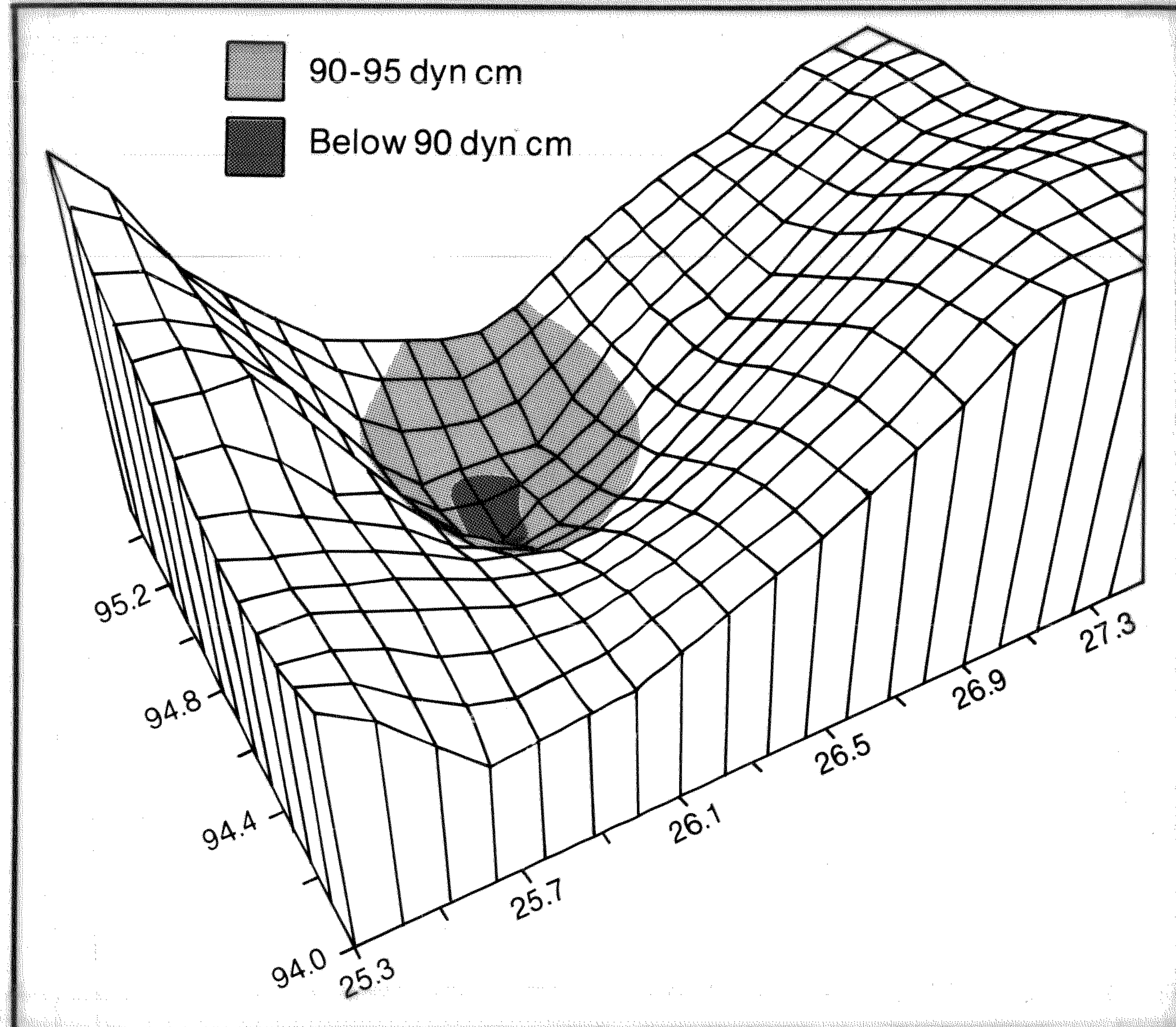

Figure 13.21. Computer plot of the local geopotential anomaly data of Figure 13.20B, extrapolated by UNIMAP software to predict dynamic topography for the 5 x 10^4 km^2 region 25.3–27.5 °N and 94.0–95.5 °W.

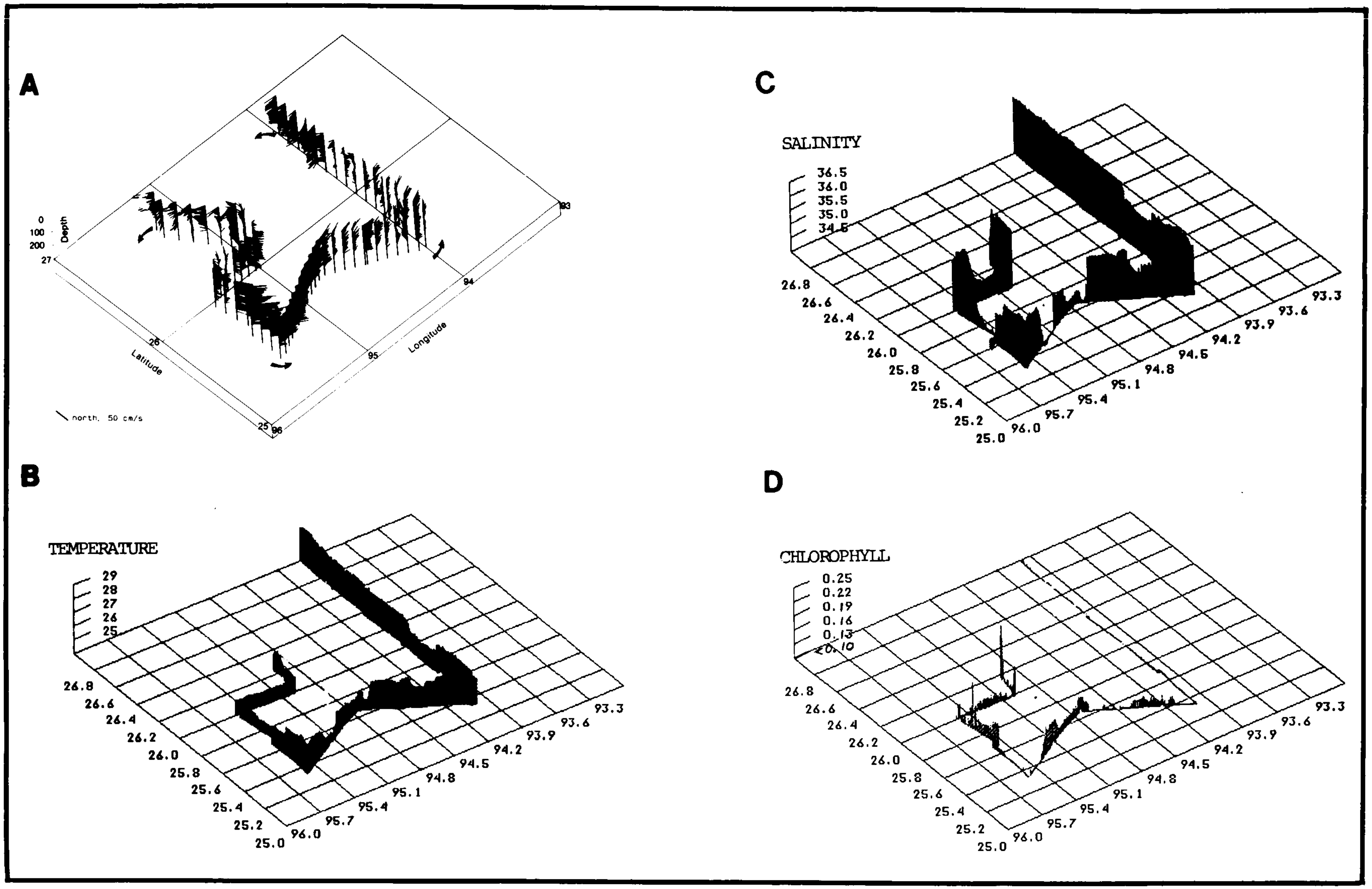

Figure 13.22. Computer plots of underway data collected on cruise 89G-15: A) Near-surface currents measured by ADCP; B) surface temperature; C) surface salinity; D) surface chlorophyll.

particulate organic carbon from near-surface waters of the cold-core "ring" was not as high as might have been predicted from its high rate of primary productivity. A sediment trap allowed to drift for 13 hours at a depth of 75 m within the cold-ring intercepted a mass flux of only 1.6 mg/0.17 m^2 (17 mg m^{-2} day^{-1}), of which 25% was particulate organic carbon. Such low mass and carbon fluxes are surprisingly similar to those intercepted in October 1988 within a Gulf of Mexico warm ring (Biggs 1990).

ONGOING RESEARCH ON COLD-CORE FEATURES

On 23 February 1990, a cold "ringlet" some 50 km in diameter was evident in remotely sensed sea surface temperature images of the northwest corner of the Gulf of Mexico, following the passage of an atmospheric cold front. Within this feature, which was centered just seaward of the shelf-slope break at 27°20'N and 95°30'W, surface temperature was 1.3°C cooler than the adjacent slope. Fortunately, R/V *Gyre* was operating in this area to support an NSF-sponsored geological oceanography program, and five days later, during R/V *Gyre* cruise 90G-05, a CTD/rosette multisampler station was occupied within this feature. Both the vertical distribution of chlorophyll and its primary production were measured. Results will be reported in a subsequent publication (Biggs *et al.* in preparation).

We are planning that a fourth TIGER-AMIGO ring cruise will be fielded in March or April 1991. Its focus will be to survey regions of cyclonic circulation over the NW continental slope, between 93°-96°W and 25°-28°N. We anticipate that "Quiet Eddy," a warmcore ring which separated from the Loop Current in summer 1990 and is drifting gradually westward, will have entered our TIGER-AMIGO field area by the spring of 1991. If recent paradigms are correct, as the remnant(s) of this warm ring interact with the shoaling bathymetry of the continental slope in the NW corner of the Gulf, transfers of vorticity may cause companion cold-core features to "spin up" about ring periphery (Lewis and Kirwan in press).

ACKNOWLEDGMENTS

The TAMU funds the shiptime and provides partial salary for technical specialists in a Department of Oceanography pool comprised of autoanalyzer technicians, electronics technicians, and other marine technicians who support each of the TIGER Training and Research cruises of R/V *Gyre*. A cooperative agreement 14-35-0001-30501 with the MMS supports the at-sea participation of four TAMU technicians and the preparation of technical reports to archive and share the hydrographic data (TAMU 1989). The MMS also provided the Sippican T7 XBTs that we deployed on cruise 89G-15. Fercan Kalkan of the TAMU Department of Geophysics produced Figure 13.21, using the UNIMAP 3D software package available from UNIRAS; David Murphy of the TAMU Technical Support Services Group reduced the underway data and wrote the software to produce Figure 13.22.

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NUTRIENT ENHANCED COASTAL OCEAN PRODUCTIVITY

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In 1990 the National Oceanic and Atmospheric Administration (NOAA) began a study of the Mississippi-Atchafalaya River (MAR) Outflow region as the initial study under the Nutrient Enhanced Coastal Ocean Productivity (NECOP) component of the NOAA Coastal Ocean Program. The key objectives of the NECOP program are to determine quantitatively the degree to which coastal primary productivity has been enhanced in areas receiving high anthropogenic nutrient inputs, the subsequent impact on water quality (especially dissolved oxygen demand) and living resources, and the implications of such productivity on global carbon budgets as they relate to climate change. The Mississippi-Atchafalaya River Outflow was chosen as the initial NECOP study site because it fulfilled major criteria for such selection. A clear indication of impacts by anthropogenic nutrient inputs is that inputs in the Mississippi River have tripled since the mid 1950's, with a demonstrable impact of the enhanced production on coastal environmental quality; i.e., 8,000 to 10,000 square km of bottom hypoxia exist on the shelf west of the Mississippi-Atchafalaya Outflow. This impact affects renewable resources of significant value in the MAR, for example, the highest tonnage U.S. fishery (Gulf menhaden), the highest value U.S. fishery (shrimp), and the highest value U.S. fin fishery (Gulf menhaden).

A research program has been defined that addresses several key questions to elucidate our knowledge of the nutrient inputs on the northern Gulf of Mexico. First, several groups are trying to determine if an historical record exists within the sedimentary record that indicates that the productivity of Shelf waters has increased on time scales commensurate with the historical record of anthropogenic nutrient loading. Second, oceanographers are trying to determine the temporal and spatial scale of physical and biological variability in the MAR Outflow and the northern Gulf of Mexico, in particular, they are concerned with the production rate, distribution, and fate of biogenic carbon in the river, and in estuarine plumes and on the shelf on seasonal-to-annual time scales. The objective of this research program is to determine quantitatively if the increased nutrient loading in the Mississippi-Atchafalaya Outflow has contributed to the occurrence of hypoxic conditions on the northern Gulf of Mexico shelf and to quantify the effect of the MAR and similar systems on global carbon budgets.

This research program has four multi-investigator components: retrospective analysis, productivity of the Shelf/Plume System, hypoxia research and modeling, and carbon flux studies. Modeling efforts are contained in several components. In the first year the NECOP Program funded 15 proposals representing 3 NOAA Labs and 7 academic institutions. Project abstracts are available from the NECOP program office at NOAA/Atlantic Oceanographic and Meteorological Laboratory (AOMIL). From July 17 to August 10, 1990, a multi-ship effort was conducted involving the N/S *Baldrige*, R/V *Gyre*, and R/V *Pelican*, with overflights for ocean color from a NASA Lear Jet, using either a NASA/Ames AOCI color scanner or NASA/NSTL CAMS color scanner. The program is now structured as cooperative with NASA and the Minerals Management Service Gulf of Mexico physical oceanography program, all of which address to some degree the NECOP project objectives and research questions.

In addition, a data management plan has been put into effect in cooperation with NODC and that will provide users' access to historical data sets, as well as provide PC-based data tracking, archival, and retrieval. This function is located at AOML in Miami, Florida.

Dr. Donald K. Atwood and Dr. Gary L. Hitchcock work at the Atlantic Oceanographic and Meteorological Laboratory of the NOAA. Dr. Atwood is the Program Manager of the NECOP research program. Dr. Hitchcock is the Operations Manager for the program.

FORMATION, MOVEMENT, AND THERMAL STRUCTURE OF DOUBLE VORTICES IN THE NORTHEASTERN GULF OF MEXICO

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Dr. John P. Steen,
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Dr. James T. McBee,
Mr. Richard S. Waller,
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INTRODUCTION

An interdisciplinary study of eddies in the northeastern Gulf of Mexico was initiated in the winter of 1987 to investigate the role and potential impact of eddies on the distribution and fate of eggs, zooplankton, and larvae in the waters over the continental shelf, slope, and upper continental rise. The presence of eddies over the continental shelf/slope in the northeastern Gulf of Mexico has been reported based on analyses of water column temperature and salinity data (Drennan 1968), investigations employing numerical simulation (Hurlbert and Thompson 1980), and observations via satellite imagery (Herron pers. comm. 1987). Numerical simulations of Gulf circulation (Thompson pers. comm. 1989) showed frequent formation of eddies along the continental slope in the vicinity of DeSoto Canyon; these either moved across the shelf and dissipated or impinged upon the shelf where they lingered for a time before moving into the open Gulf. Eddies that form over the continental shelf/slope and draw and entrain waters from the shelf may be important mechanisms in the northeastern Gulf for cross-shelf material transport; e.g., nutrients, pollutants, eggs, zooplankton, and fish larvae.

METHODS AND RESULTS

Marine scientists from the Gulf Coast Research Laboratory (GCRL) and the National Marine Fisheries Service planned and initiated an investigation of eddies in the northeastern Gulf of Mexico in 1987. While monitoring Advanced Very High Resolution Radiometer (AVHRR) imagery of sea surface temperatures from the National Oceanic and Atmospheric Administration's satellites during the winter of 1987-1988, formation of paired vortices south of Mobile Bay and Pensacola, Florida was observed on January 27, 1988. The R/V *Tommy Munro*, with marine scientists from GCRL aboard, was dispatched to study the phenomena. Locating stations within and on the peripheries of the eddies was facilitated by real-time acquisition and near real-time processing of satellite AVHRR imagery. After selecting sites for initial hydrographic stations based on geo-referenced and processed AVHRR thermal imagery, the oceanographer at the land-based satellite receiving station relayed the station positions to the scientific party aboard the research vessel. Coordinates for additional hydrographic stations were relayed to the vessel as quickly as satellite imagery from subsequent passes was received and processed.

The sequence of AVHRR imagery of sea surface temperatures spanning the period January 27 - 29, 1988, shows the development of twin eddies centered at approximately 29°30'N latitude. The satellite imagery depicts a tongue of seaward-directed shelf water encountering a band of warm Gulf water. The band of warmer, saltier Gulf waters encircled the cooler, less saline shelf waters, forming oppositely rotating vortices. The cooler shelf waters became the core waters of both vortices.

The west member of the vortex pair rotated anti-cyclonically while the east member rotated cyclonically. During the period that the eddies were tracked via satellite imagery, the pair moved northeasterly at an average translation speed of 0.5 $kmhr^{-1}$. As the vortex pair became better developed, their shape at the sea surface changed from elliptical, with minor and major axial dimensions of 72 km and 120 km, respectively, to circular with diameters of approximately 52 km.

Two transects were made by the research vessel, one through each of the eddies, to obtain temperature profiles of the water column, measure surface salinities, measure surface water chlorophyll-a concentrations, and collect plankton samples. The transect through the west eddy along 88° W longitude formed a chord that passed through only the outer region of the eddy core. Temperatures of surface waters were between 16.5°C and 20.0°C with the lower values occurring within the eddy core and shoreward over the continental shelf. Contour charts of temperature cross sections depict a 100-m thick layer of 20°C Gulf water extending shoreward dipping beneath the eddy core and rising again shoreward of the core. The 19°C - 17°C isothermal surfaces rise seaward of the shelf break and reach the sea surface, forming the shoreward side of this eddy. Along this transect through the eddy, the thermal structure indicates that the eddy did not reach a depth greater than 50 m.

The second transect bisected the other member of the vortex pair. Surface water temperatures measured were between 17.0°C and 18.6°C with the cooler temperatures associated with the core water. The temperature cross section of the water column, again, indicated that the eddy did not extend beyond a depth of 50 m.

The relationships of zooplankton composition/density and chlorophyll-a concentrations to the different source waters comprising these vortices have been discussed previously (Steen *et al.* 1988).

Cloudy skies prevented the continued tracking of the vortex pair via satellite beyond January 28, 1988. Later satellite imagery did not reveal any recognizable signatures of the double vortices. Because of the role these phenomena may play as mechanisms for material transport across the shelf, marine scientists at GCRL have continued to investigate the occurrence of eddies in the northeastern Gulf. Eddies may prove to have a profound impact on fish recruitment in this region of the Gulf of Mexico.

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Dr. Charles Eleuterius has worked at Gulf Coast Research Laboratory for the past 25 years and has been head of the Physical Oceanography Section for the last 20 years. His areas of research interest are estuarine and shelf hydrodynamics. Dr. Eleuterius received his B.S. in mathematics and M.S. in statistics from the University of Southern Mississippi, completed course work toward a Ph.D. in physical oceanography at Texas A&M University in 1971, and received his Ph.D. from the University of Southern Mississippi in 1987.

Dr. Rex Herron has worked for the National Marine Fisheries Service, Mississippi Laboratories, for the past five years as an Ecologist-Remote Sensing Specialist. He was recently detailed as NOAA's Coordinator to the Gulf of Mexico Program Office at the John C. Stennis Space Center in Mississippi. Dr. Herron received his B.S. in physics and M.S. in biology from Tennessee Technological University and his Ph.D. in fisheries and wildlife ecology from Utah State University.

Dr. John Steen has worked at the Gulf Coast Research Laboratory for the past 15 years and is an Associate Biologist in the Ecology Section. His research interests include plankton populations and physical transport processes in shelf and estuarine waters. Dr. Steen earned a B.S. in biology from Mars Hill College, an M.A. in biology from Appalachian State University, and a Ph.D. in biology from the University of Mississippi.

Mr. Alan Criss has worked at Gulf Coast Research Laboratory for 12 years. His areas of research interest are remote sensing applications to the physical oceanography of continental shelf/slope and estuarine regions. Mr. Criss received his B.S. in biology from Union University in Jackson, Tennessee. He is currently pursuing an M.S. degree in remote sensing technology with an emphasis in marine sciences through the University of Southern Mississippi.

Dr. James T. McBee has worked at Gulf Coast Research Laboratory for the past 15 years as an estuarine ecologist. His research interests include estuarine and shelf transport processes. Dr. McBee received his B.S. from Texas A&M University, his M.S. from Humboldt State University, and his Ph.D. from Texas A&M University.

Mr. Richard Waller has worked at Gulf Coast Research Laboratory for the past 23 years and holds the position as Associate Biologist in the Fisheries Section. His research interests are in fisheries assessment and fisheries recruitment oceanography. Mr. Waller received his B.S. in biology from Alabama College.

NATIONAL WEATHER SERVICE MODERNIZATION PURPOSE

Mr. Billy J. Crouch
National Weather Service
Slidell Forecast Office

The modernization and associated restructuring of the National Weather Service (NWS) (Figure 13.23) shall assure that the major advances that have been made in our ability to observe and understand the atmosphere are applied to the practical problems of providing weather and hydrologic services to the Nation.

AUTOMATED SURFACE OBSERVING SYSTEMS

Automated surface observations will relieve staff from the manual collection of surface observations. Over 1,500 automated surface observing systems across the nation (Figure 13.24) will provide data on pressure, temperature, wind direction and speed, runway visibility, cloud ceiling heights, and type and intensity of precipitation on a nearly continuous basis. This is a cooperative effort with the Federal Aviation Administration (FAA). The Department of Defense (DOD) is considering joining this effort and providing additional observation capability.

NEXT GENERATION WEATHER RADARS

Using Doppler radar technology, this next generation weather radar (NEXRAD) system will observe the presence and calculate the speed and direction of motion of severe weather elements such as tornadoes and violent thunderstorms. The NEXRAD will also provide quantitative area precipitation measurements important to flood forecasting. These capabilities will increase the accuracy and timeliness of NWS warning services. A national network (Figure 13.25) of 160 NEXRAD systems will improve the uniform coverage of the Nation over the present-day radar network. The DOD and FAA will operate 39 of these radars and the NWS will operate 121 radars in the network.

SATELLITE UPGRADES

The new satellites will have separate instrumentation that allows simultaneous image and sounding data to be observed and transmitted to ground stations. This GOES 1-M system will provide visible and infrared imagery as frequently as every six minutes during severe weather over selected areas of the Nation.

NATIONAL CENTER ADVANCED COMPUTER SYSTEMS

Present-day Class VI computers will be replaced with Class VII computers, which have processing capabilities an order of magnitude greater. This will allow improved models with greater spatial resolution to be run more frequently and support the warning and forecast operations at each office.

ADVANCED WEATHER INTERACTIVE PROCESSING SYSTEM

The Advanced Weather Interactive Processing System (AWIPS) will be the nerve center of operations in each weather office. The AWIPS will receive high resolution observational data and centrally prepared analysis and guidance products. The integration of these data represents the data base from which all warning and forecast products will be prepared. The system includes NOAAPORT, a satellite communications capability that interconnects weather offices for exchange of data. The NOAAPORT will also deliver a wide range of products, such as oceanographic and environmental data, to external users including other government agencies, universities, private research organizations and business interests.

Mr. Billy J. Crouch is the Meteorologist in Charge and Area Manager of the Weather Service Forecast Office for New Orleans located in Slidell, Louisiana. He has considerable experience as a forecaster, meteorologist, and manager with the Weather Service in the Gulf of Mexico area. Working assignments since the 1950's included Texas, Louisiana, and Alabama. He also has worked in Alaska, the Canadian Arctic weather station, and as a forecaster with the U.S. Air Force. He holds a B.S. in meteorology from Florida State University

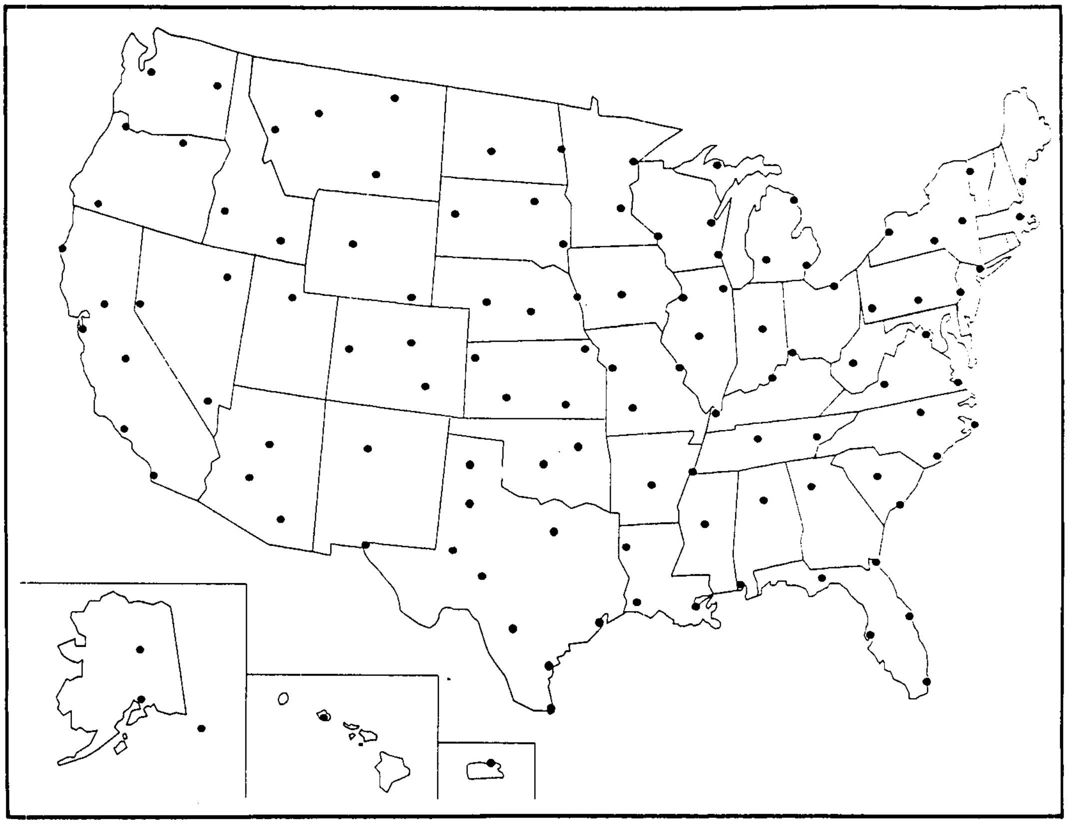

Figure 13.23. Location of Weather Forecast Offices in the United States and Territories.

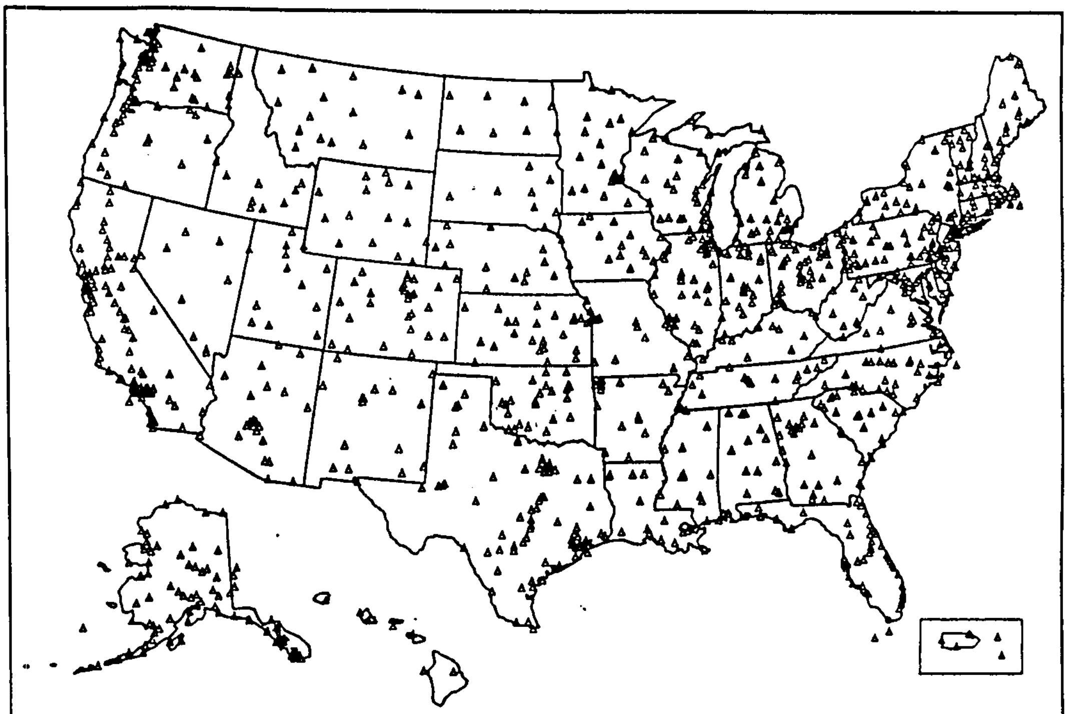

Figure 13.24. Location of Automated Surface Observing Systems (ASOS) in the United States.

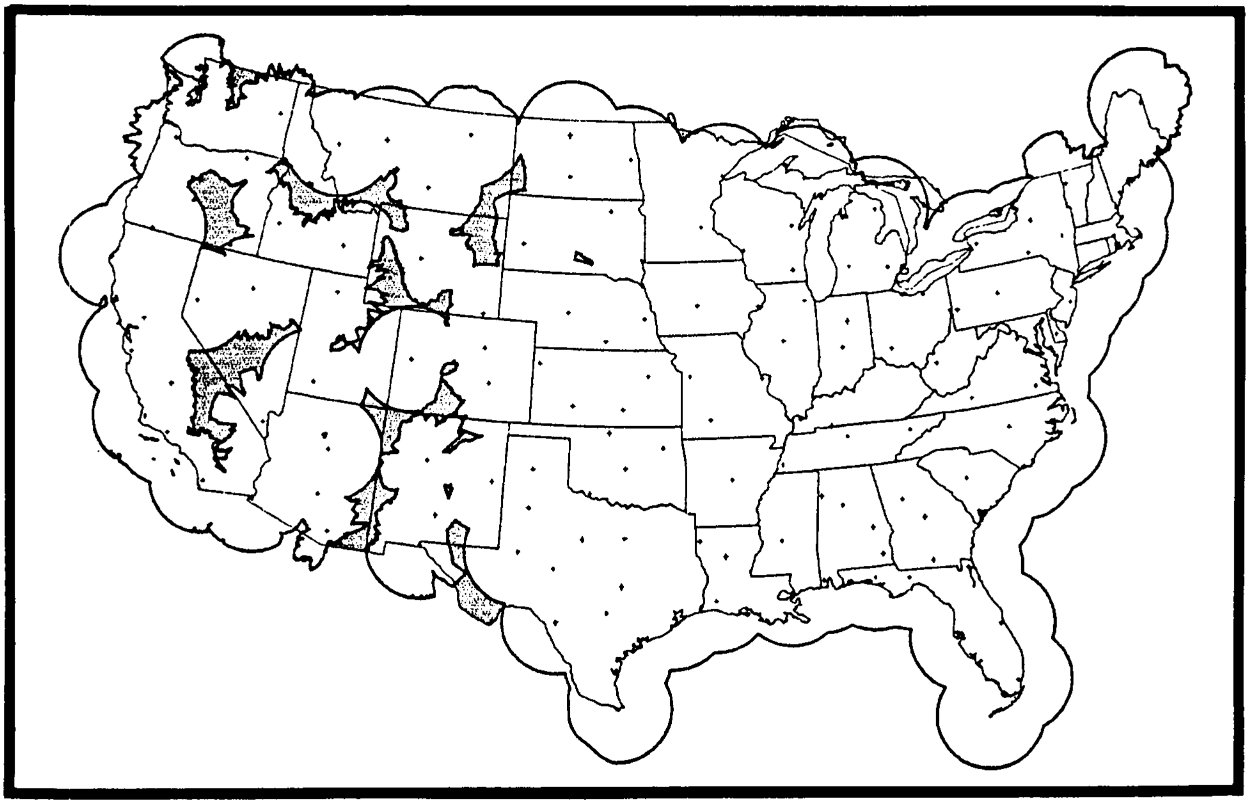

Figure 13.25. Location and total coverage (at 10,000 ft. elevation) of the Next Generation Weather Radars (NEXRAD).

and attended the Management Training Center at Tulane University, New Orleans.

OVERVIEW OF GULFMEX PROJECT: A STUDY OF RETURN FLOW IN THE GULF OF MEXICO

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INTRODUCTION

The GULFMEX project is a joint effort between the National Severe Storms Laboratory (NSSL), National Severe Storms Forecast Center (NSSFC), and National Weather Service Forecast Offices in San Antonio, Texas, and Slidell, Louisiana. The initial experiment was conducted in February and March 1988. The main purpose of this continuing study is to collect observational data that would help to develop conceptual models of storms, air masses (and their modification), return flow patterns, and properties over the western and central Gulf of Mexico and adjacent coastal areas.

The Gulf of Mexico is the primary source of water vapor for both general precipitation and severe storms in the central United States. Further, sea fog and stratus clouds are a major aviation hazard in the northern Gulf especially during the winter and early spring months. Several years of observational data over the northern Gulf were analyzed and graphical forecast aids were developed for the purpose of improving the aviation forecasts.

Slidell's forecast staff participated in the GULFMEX project from November 1989 to April 1990. Data were collected on the various types of air masses that affected the Gulf, the prevailing synoptic patterns, return flow weather and performance of models in predicting the return flow. The timing and characteristics of the return flow are very important for our area of forecast responsibility, which includes public, aviation, and marine.

BRIEF SUMMARY OF NATIONAL SEVERE STORMS LABORATORY GULFMEX EXPERIMENT

During February and March 1987 a limited field experiment was conducted over the Gulf of Mexico to gather data on two phenomena: air mass modification over the Loop Current and return flow characteristics of modified polar air returning to the southern United States (Lewis *et al.* 1989).

During this experiment several characteristic return flow patterns from the Gulf into the southern United States were identified (Figure 13.26), as well as several types of air masses returning across the Gulf (Figure 13.27) (Lewis and Crisp 1989). Ten years of climatological data of return flow events were tabulated and are presented in Table 13.1 (Lewis and Crisp 1989).

METHODS USED BY THE FORECAST STAFF AT SLIDELL

During the period of November 1989 to April 1990, observational data from surface aviation weather reports (SAWRS) from the northern Gulf were evaluated as well as surface observations from land based stations. Additional data sources included satellite imagery, radar observations, radiosondes, buoys, C-MAN, and sea surface temperature analyses (SST's). Upper air analyses were used to identify the prevailing upper air pattern.

In an effort to collect important data on various meteorological parameters during return flow events, an operational checklist was developed for use by the forecasters. The checklist was used in each event, and some 25 return flow events were documented this past season.

RESULTS

Various parameters such as types of air masses entering and then returning north across the Gulf, synoptic patterns, transport of moisture in the return flow, and performance of numerical models in predicting the return flow were summarized. The results were forwarded to NSSL, NSSFC, NMC, and other offices.

Four types of sea fogs were identified during the analysis of SAWRS and SST's in the northern Gulf for two sessions. Figure 13.28 is an example of a typical synoptic pattern during winter with return flow of warm and moist air over a colder sea surface in the northern Gulf. Several graphical forecast aids were developed to improve the aviation and marine forecasts across the northern Gulf and immediate coastal sections (Figure 13.29). Sea fog and stratus clouds are a major aviation hazard in the northern Gulf. Over 700 helicopter flights are conducted daily to and from offshore oil platforms. On a daily basis, over 35,000 persons work in the Gulf in support of the oil industry, most of who are transported by helicopters.

CONCLUSIONS

To enlarge our data base, the GULFMEX study will be continued by the Slidell forecast staff this coming season. Few changes will be made to last year's checklist. In a few years NSSL may conduct GULFMEXII project in the Gulf. This will depend on the combined results of the data collected from 1989-1990 and 1990-1991. Aviation and marine forecasts prepared for the northern Gulf by the Slidell forecasters should improve this coming winter season if the graphical aids for forecasting sea fog and stratus clouds are used. Navigation interests are greatly affected by low surface visibilities due to dense sea fog as well as aviation operations.

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Mr. G. Alan Johnson is a Forecaster-in-Charge (meteorologist) with the National Weather Service Forecast Office in Slidell, Louisiana. His areas of research interest are studying the various types of weather associated with return flow from the Gulf of Mexico. These include severe storms and heavy rainfall in the lower Mississippi Valley, winter storms, and dense sea fog and stratus clouds across the northern Gulf in winter. Mr. Johnson received his B.S. in meteorology from the University of Texas at Austin, Texas, with some graduate work from the University of California at Davis, California.

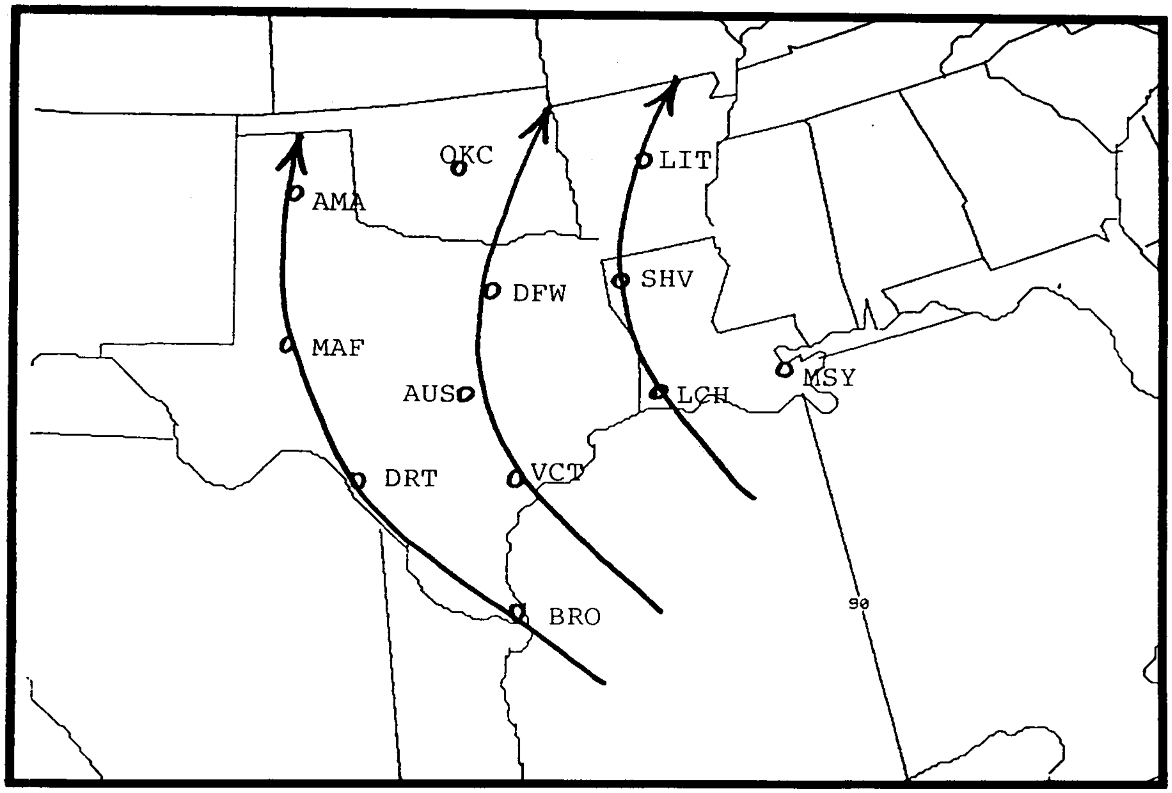


Figure 13.26. Characteristic return flow patterns (Lewis and Crisp 1989).

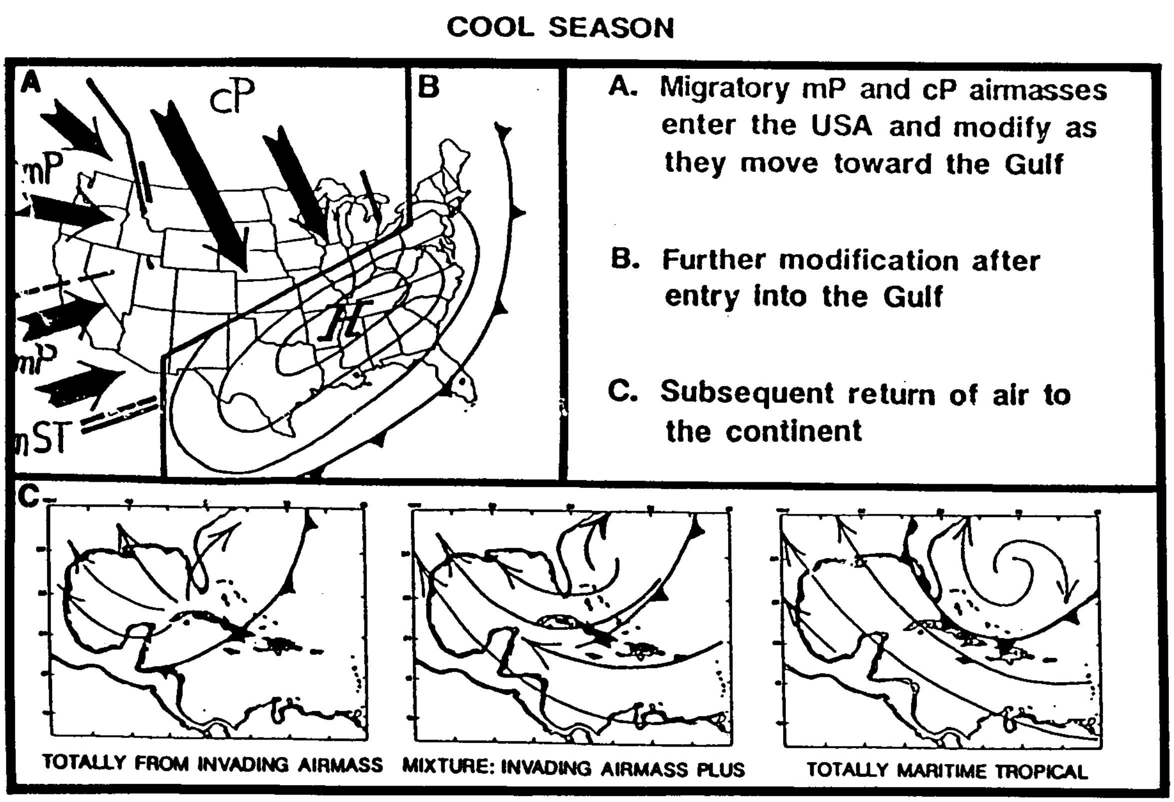


Figure 13.27. Types of air masses returning across the Gulf (Lewis and Crisp 1989).

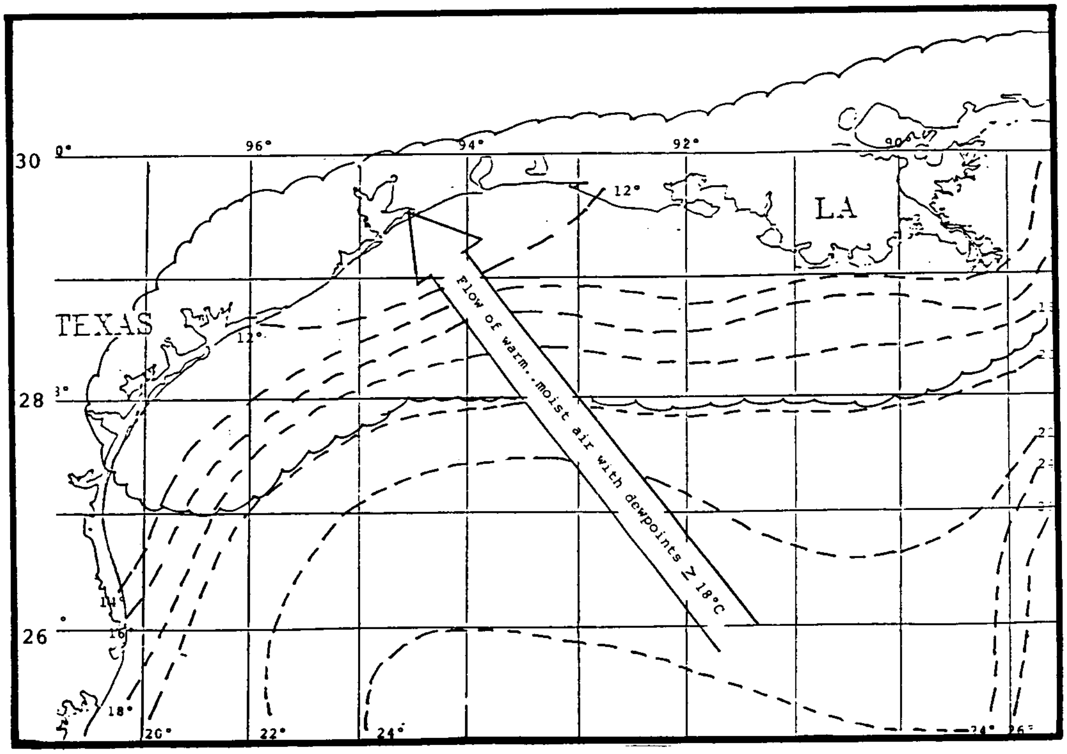


Figure 13.28. Typical synoptic pattern during the wintertime when sea fog and stratus are more prevalent. (Scalloped area outlines area of sea fog and/or stratus; dashed line is SST's.)

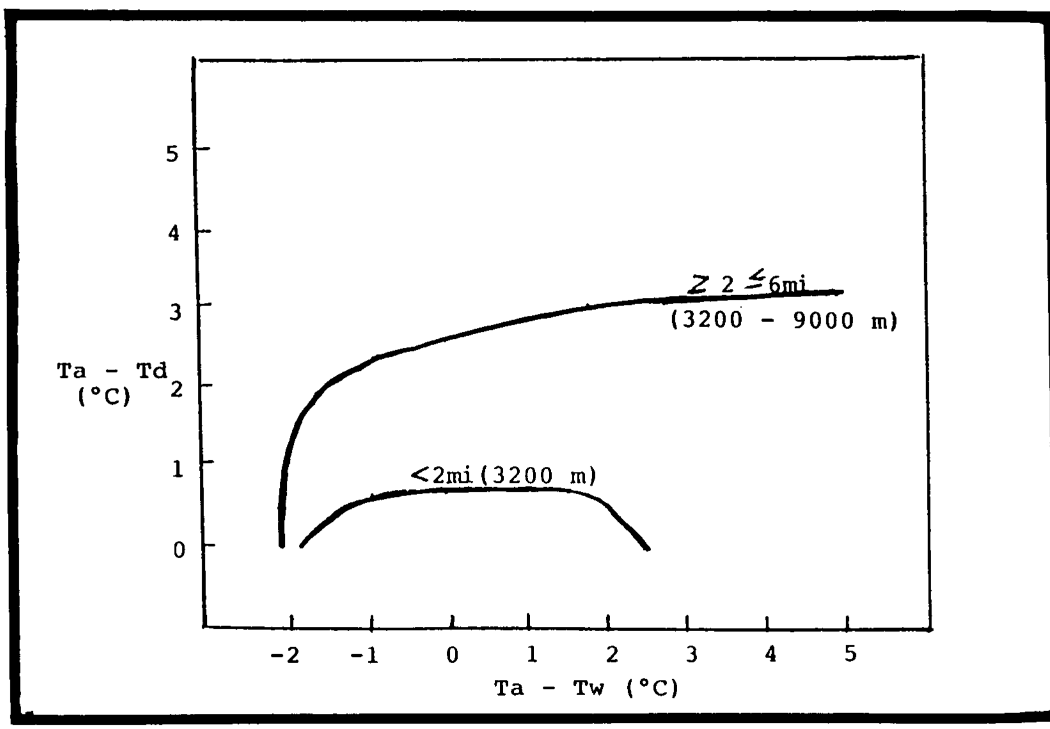
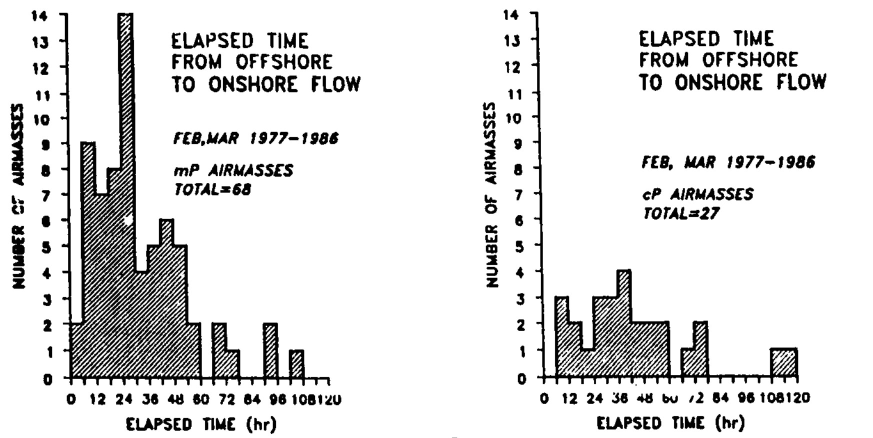


Figure 13.29. Example of a graphical forecast aid for use in forecasting surface visibility associated with sea fog (cooling). (T_a equals air temperature, T_d equals dew temperature, and T_w is the sea surface temperature.)

Table 13.1. Climatological Data of Return Flow Events for the Period of February and March, 1977-1986 (Lewis and Crisp 1989).

FREQUENCY OF RETURN FLOW



MOST RETURN FLOW EVENTS STARTED WITHIN 30H AFTER ONSET OF OFFSHORE FLOW. MAXIMUM FREQUENCY AT 24-30H AVERAGE NUMBER OF RETURN FLOWS: 6.8	ELAPSED TIME VARIED ALMOST UNIFORMLY FROM 0.5 DAY TO SEVERAL DAYS. RANGE REFLECTS LARGE VARIANCE IN PENETRATION OF COLD AIR INTO THE GULF. AVERAGE NUMBER OF RETURN FLOWS: 2.7

NOTE: THERE WERE SEVERAL EVENTS IN WHICH CONSECUTIVE AIRMASSES ENTERED THE GULF WITH NO RETURN FLOW BETWEEN THEM. THERE WAS AN AVERAGE OF 1.5 OF THESE EVENTS IN FEB. AND 0.8 EVENTS IN MAR.

APPLICATION OF THE SANDIA OCEAN MODELING SYSTEM TO THE GULF OF MEXICO CIRCULATION

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Ecodynamics Research
Associates, Inc.

INTRODUCTION

During the early 1980's, the Department of Energy sponsored the Subseabed Waste Disposal Program, a multi-faceted program for assessing environmental impacts of possible waste disposal in the ocean depths. The focal point was Sandia National Laboratories in Albuquerque, New Mexico. This program sponsored the development of the Sandia Ocean Modeling System, called SOMS, during 1984 and 1985. The SOMS is described by Dietrich *et al.* (1987).

The SOMS is a fully conservative, partially implicit ocean and lake modeling system. It uses a fully Eulerian frame with an Arakawa "c" staggered grid. It uses a separate boundary-fitted three-dimensional boundary layer submodel, which includes a Mellor-Yamada level 2.5 turbulence closure scheme (Mellor and Yamada 1982). The boundary layer submodel is coupled to an overlying free-stream submodel by pressure gradient and flux matching at their interface. The interface is a prescribed distance from the modeled basin bottom, such that the boundary layer submodel contains the turbulent bottom boundary layer. This approach is motivated by boundary layer theory and is designed for bottom boundary phenomena over general topography, including continental shelf regions.

Recently, we added a more accurate treatment of the Coriolis terms and demonstrated its effectiveness for a prototype ocean problem in a grid convergence study (Dietrich *et al.* 1990). The results show that the new approach is as accurate with 20-km resolution as conventional methods used on the Arakawa "c" grid are with 10-km resolution. Such grid convergence demonstration is an important part of model validation (Roache *et al.* 1986; Roache 1989) that has been overlooked by other modelers and is an ideal approach for model comparison.

The SOMS has addressed lake (Zuur and Dietrich 1990) and open ocean circulations (Zuur pers. comm. 1990) and a cold filament observed in the continental shelf boundary layer (Ezer 1989). Here, we describe results of its application to the Gulf of Mexico.

This spring, we applied SOMS to a rectangular flat bottom idealization of the Gulf of Mexico (Dietrich and Lin in prep.). Our goal was to make a benchmark comparison, using only two levels of vertical resolution with the widely recognized two-layer Navy model results (Hurlburt and Thompson 1980, 1982; hereafter, HT). Our results show that properly designed two-level Eulerian models can realistically address baroclinic effects as well as barotropic effects in the Gulf of Mexico. This striking and significant result is explained by Dietrich and Lin (In prep.).

RESULTS WITH REALISTIC TOPOGRAPHY

Recently, we applied SOMS to the Gulf of Mexico with actual topography from the NCAR data set. To model the inflow through the Yucatan Strait, we included the northern part of the Caribbean Sea in our simulation (Figure 13.30). We used 8 vertical levels and 20-km horizontal resolution.

Three runs were made. The first two are driven by a steady, latitudinally uniform geostrophic inflow into the Caribbean from the east, south of Cuba. In the third, a western boundary current inflow is added, entering the modeled northern Caribbean region from the south. Wind driving is not included.

Run 1 covers two full eddy shedding periods, during 18 months. The top level (200 m thick) eastern inflow is 27.5 Sverdrups (34.4 cm/sec) during this period, with 5.0 Sverdrups (0.4 cm/sec) inflow uniformly distributed in the remaining 7 levels below. In all but the top level, the inflow temperatures are uniform, with a stratification of 2°C per km, starting with a level 2 temperature of 10°C. Top level inflow temperatures are determined using a geostrophic thermal wind relation, starting with the warmest value (24.9°C) adjacent to the southern boundary of Cuba and integrating southward. This warmest value reflects a reduced gravity parameter equal to 3.0 cm/sec-sec.

During run 1, the thermal wind relation gives about a 15° latitudinal temperature range at the top level inflow. Although this is not realistic and yields very weakly stratified southern inflow, it gives the strong upper and weak lower level inflows necessary to get vortex shedding by the Gulf of Mexico Loop Current with steady inflow. We report results of this somewhat unrealistic run 1 only to compare with run 2.

During run 2, the next 12 months, the top level eastern inflow is weakened by 10%. Although the Loop Current vortex oscillates and shows signs of being on the verge of eddy shedding, no eddy shedding occurs. When compared to our flat bottom results (Dietrich and Lin in prep.), the results from run 2 show that Loop Current eddy shedding is inhibited by bottom topography, as explained by HT, although it has little effect on the natural 290-day gestation period. The results of run 2 also suggest that the Loop Current might generally barely be on the verge of eddy shedding. Thus, inflow time variations might be important, even though the HT mechanism based on absolute vorticity conservation dominates.

In retrospect, by extending the modeled region southward, one could get the necessary inflow into the southern Caribbean while maintaining more realistic horizon density gradients. Like runs 1 and 2, such inflow would tend to form a concentrated Caribbean western boundary current. Such boundary current allows a concentrated upper level northward flow, without the unrealistically large horizontal density gradients needed for a concentrated surface current in deep water regions.

However, modeling such a large region is beyond the reasonable capability of our present workstation. The present calculations used most of its central memory and took about 40 hours cpu per model year. Its computing speed is about 1/500 of a modern supercomputer. Thus, instead of modeling the southern Caribbean, in run 3 we reduced the eastern top level inflow to 12.5 Sverdrups and added a 12.5 Sverdrup western boundary current inflow (about 82 cm/sec) into the modeled northern Caribbean region. Inflow is into the westernmost

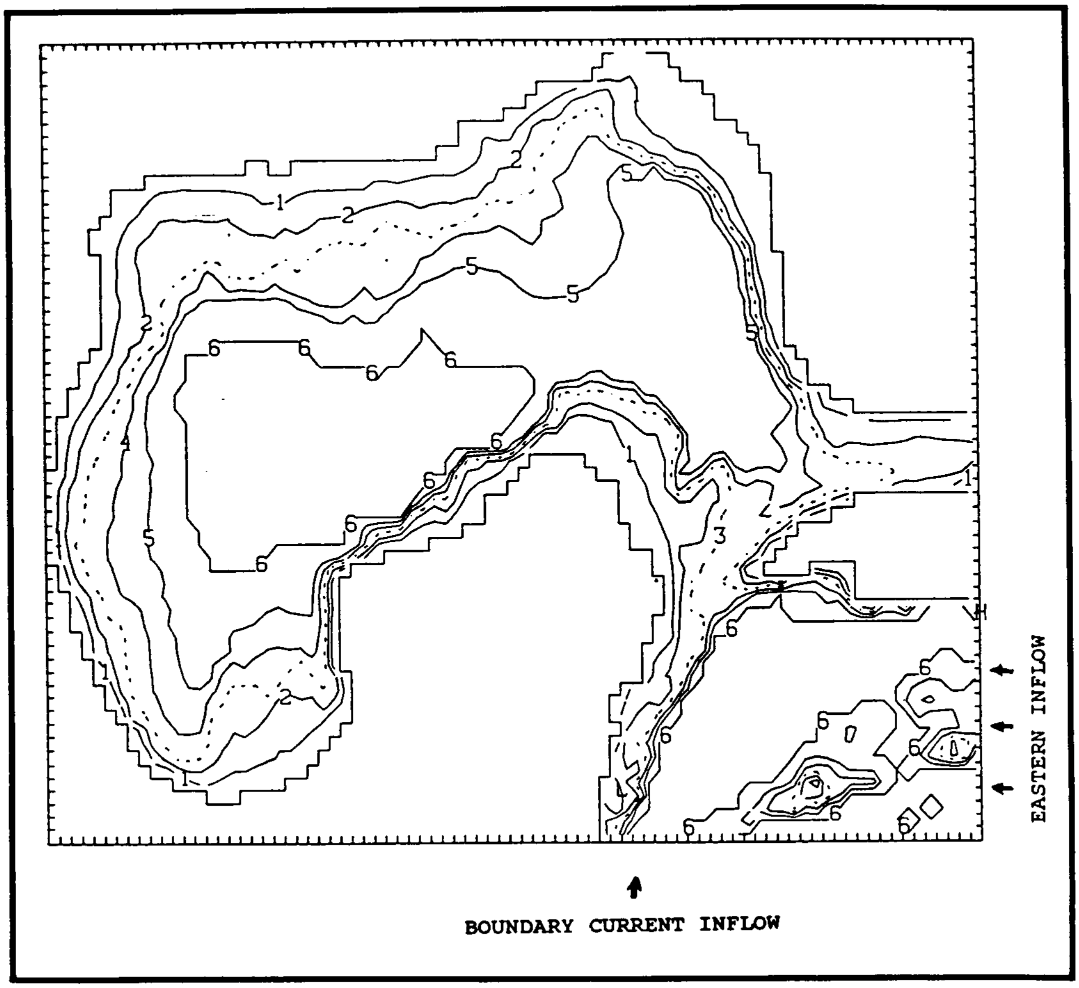
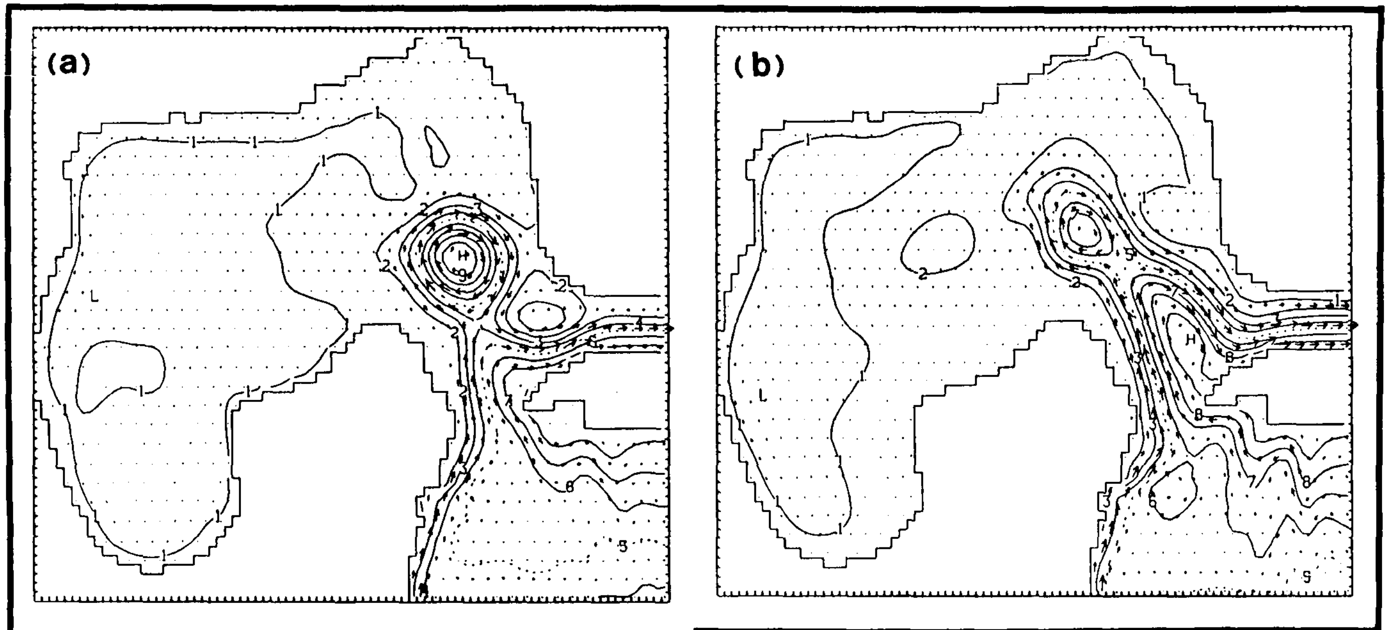


Figure 13.30. Gulf of Mexico and Northern Caribbean Sea bottom topography modeled by SOMS. (Each tic mark represents 20 km. The model top level boundary staircase approximation is also indicated. Actual NCAR data set depths are used, truncated at 3.5 km deep. The contour interval is 483.3 m.)

two top level zones and into the westernmost level two zone. Since the level two zone is 449 m thick, a little more than half of the 12.5 Sverdrup inflow is into level two. The transports of about 14 and 12 Sverdrups, respectively, through the top two levels of the Yucatan strait, compared to about 20 and 10 Sverdrups used in run 2. In spite of the increased level two inflow, the 14 and 12 Sverdrups result in an eddy shedding regime with more realistic eastern Caribbean inflow temperatures.

Runs 1 and 2 show a strong western jet flow through the Yucatan Strait, with maximum speeds typically 120-190 cm/sec. Run 3 has maximum speeds of 90-120 cm/sec through the Yucatan Strait. A computer-generated movie from run 3 will be shown. Copies are available on request.

Figure 13.31 shows plots of the run 3 eddy shedding sequence. The Loop Current extends to the northern region of the Gulf of Mexico at times during the eddy shedding cycle. Just before eddy separation, the Loop Current pinches together at a "saddle point" in the pressure field, reflecting the HT eddy shedding mechanism. This pinching results in a transient closed cyclonic eddy on the Florida side of the pinched region, associated with boundary current separation during the pinching. The "recirculation" on the east side of this eddy decreases with increasing horizontal diffusivity. Most of the time, a closed circulation occurs inside the Loop Current. Comparing these results with those of run 2 suggests that vorticity generation by bottom drag in the western boundary current region (Figure 13.32) increases northward Loop Current penetration and favors eddy shedding. These details



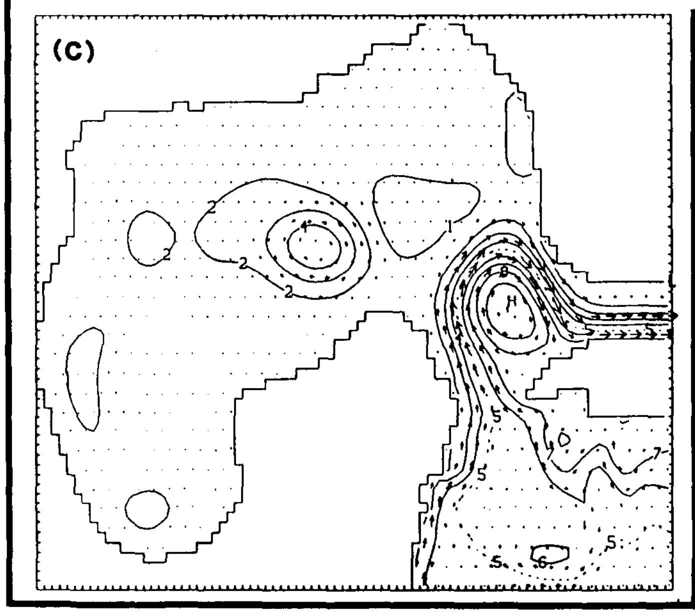


Figure 13.31. Run 3 results: top level (depth = 100 m) pressure and velocity at days 420, 480, and 540. (Extrema of longitudinal [u] and latitudinal [v] velocity are given in cm/sec. Equivalent surface elevation ranges are given in cm.)

(a) Day 420
dh=58 cm; u: -76.1 to 84.4; v: -77.4 to 82.2

(b) Day 480
dh=54 cm; u: -64.8 to 79.3; v: -62.3 to 78.1

(c) Day 540
dh=67 cm; u: -54.8 to 92.8; v: -74.0 to 77.0

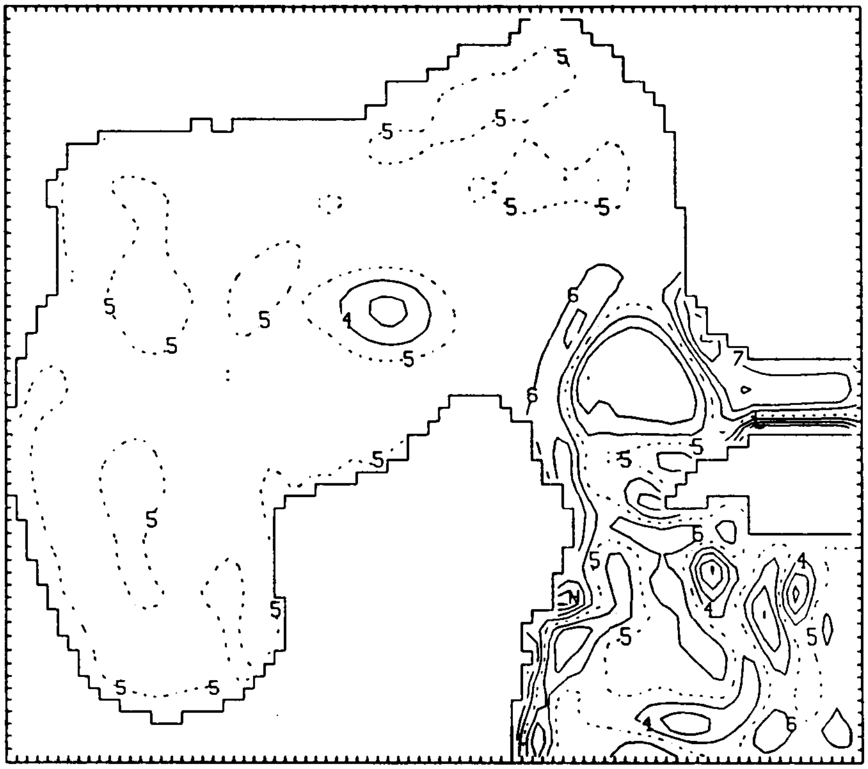


Figure 13.32. Run 3 results: top level vorticity at day 540 (min = -2.97 E-05; max = 2.83 E-05).

do not detract from the fundamental importance of the HT mechanism, but suggest there are other significant effects.

FINAL REMARKS

Results from a fully Eulerian model (SOMS), calculated in 0 (100) hours on a workstation with 1/500 the computing speed of modern supercomputers, compare favorably with theory, other model results, and observations in the Gulf of Mexico. Having been designed for bottom boundary phenomena over general topography, using more accurate treatment of the important Coriolis and pressure gradient terms than previous models, and having been validated by a grid convergence test in a prototype ocean problem, SOMS is a validated, accurate model applicable to the entire Gulf circulation, including the continental shelf boundary region. We strongly encourage comparison of SOMS with other models.

ACKNOWLEDGEMENTS

I warmly thank Drs. Harley Hurlburt, Kirk Bryan, and Charles Lin for help and encouragement on this work, and Mr. Thierre Renault for providing the NCAR data set for the modeled region. This work was partly supported by grants from the Natural Sciences and Engineering Research Council of Canada, and the Department of Fisheries and Oceans.

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Dr. David Dietrich is vice-president of Ecodynamics Research Associates, Inc., and is interested in numerical model design and application to environmental problems. Dr. Dietrich received his B.S. in mathematics from North Central College, and his M.S. in meteorology and Ph.D. in geophysical fluid dynamics from Florida State University.

GULF OF MEXICO MARINE LABORATORIES: AN OVERVIEW OF CURRENT RESEARCH

Session: GULF OF MEXICO MARINE LABORATORIES: AN OVERVIEW OF CURRENT RESEARCH

Co-Chairs: Dr. Richard E. Defenbaugh
Dr. James Kendall

Date: November 15, 1990

Presentation	Author/Affiliation
Gulf of Mexico Marine Laboratories: An Overview of Current Research: Session Introduction	Dr. Richard E. Defenbaugh and Dr. James Kendall Minerals Management Service Gulf of Mexico OCS Region
Overview of Southern Association of Marine Laboratories	Dr. Thomas D. McIlwain Gulf Coast Research Laboratory
Research Overview for Mote Marine Laboratory, Sarasota, Florida	Mr. James K. Culter Mote Marine Laboratory
Research Overview for Florida Institute of Oceanography	Dr. Sandra L. Vargo Florida Institute of Oceanography
Research Overview for Florida Department of Natural Resources, Marine Research Institute, St. Petersburg, Florida	Mr. Brad Weigle Marine Research Institute Florida Department of Natural Resources
Research Overview for University of South Florida, Department of Marine Sciences, St. Petersburg, Florida	Dr. Peter R. Betzer Department of Marine Sciences University of South Florida
Research Overview for the Florida State University Marine Laboratory, Tallahassee, Florida	Dr. Nancy H. Marcus Florida State University
Research Overview for Alabama Marine Environmental Sciences Consortium, Dauphin Island Sea Lab, Dauphin Island, Alabama	Dr. Kenneth L. Heck, Jr. Alabama Marine Environmental Science Consortium
Research Overview for University of Southern Mississippi, Center for Marine Science, Stennis Space Center, Mississippi	Dr. George A. Knauer Center for Marine Science University of Southern Mississippi
Research Overview for Gulf Coast Research Laboratory, Ocean Springs, Mississippi	Dr. Thomas D. McIlwain Gulf Coast Research Laboratory
Research Overview for Louisiana Universities Marine Consortium Laboratory, Chauvin, Louisiana	Dr. Michael Dagg Louisiana Universities Marine Consortium
Research Overview for Louisiana State University, Department of Oceanography and Coastal Studies, Baton Rouge, Louisiana	Dr. R. Eugene Turner Louisiana State University

(Continued)

Session: GULF OF MEXICO MARINE LABORATORIES: AN OVERVIEW OF CURRENT RESEARCH (cont'd)

Presentation	Author/Affiliation
Research Overview for Lamar University, Center for Coastal and Marine Studies, Beaumont, Texas	Dr. Thomas S. Bianchi and Dr. David Bechler Lamar University
Research Overview for Texas A&M University at Galveston, Texas	Dr. Andre M. Landry Texas A&M University-Galveston
Research Overview for the Texas Parks and Wildlife Department, Perry R. Bass Marine Fisheries Research Station, Palacios, Texas	Mr. Paul C. Hammerschmidt Marine Fisheries Research Station Texas Parks and Wildlife Department
Research Overview for the University of Texas at Austin, Marine Science Institute, Port Aransas, Texas	Dr. Paul A. Montagna and Dr. Robert S. Jones Marine Science Institute University of Texas at Austin
Research Overview for Corpus Christi State University, Center for Coastal Studies, Corpus Christi, Texas	Dr. Jennifer Smith Prouty Center for Coastal Studies Corpus Christi State University
Research Overview for the University of Texas-Pan American, Coastal Studies Laboratory, South Padre Island, Texas	Dr. Frank W. Judd Coastal Studies Laboratory University of Texas-Pan American

GULF OF MEXICO MARINE LABORATORIES: AN OVERVIEW OF CURRENT RESEARCH: SESSION INTRODUCTION

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

The Southern Association of Marine Laboratories (SAML) is an organization composed of the executive officers of marine laboratories located in the southeastern quadrant of the United States, Bermuda, and some Caribbean Islands. The SAML meetings regularly include presentations by representatives of research-funding agencies regarding their research programs and agendas. Our office was invited to participate in such a meeting held at the Louisiana Universities Marine Consortium laboratory in November 1989. As a result of that meeting, this Information Transfer Meeting (ITM) session was developed as a means for mutual information sharing between Gulf Coast SAML member institutions and the Minerals Management Service (MMS). Our goal was to synopsize in brief fashion current Gulf-wide marine laboratory-based research, to understand the variety of research planning mechanisms employed, and to provide an opportunity for SAML members to become familiar with MMS issues and research programs.

Following initial discussions with Dr. Mahadevan, who served as SAML president at the time, and who was very supportive of our proposal for this session, we invited participation by the Director (or the Director's representative) of each SAML member institution along the Gulf Coast. All were supportive, and all but two were able to arrange to participate. Also, one non-SAML institution requested participation in the session.

Each institution was invited to share information with the ITM audience on its facilities, and to focus on three topics:

- to provide an overview of current research;
- to describe the means used by each institution to plan future research needs; and
- to present highlights of ongoing or recently completed research that would be of interest to the ITM audience.

The agenda was structured so that the institutional presentations began with Mote Marine Lab, located in south Florida, and proceeded geographically around the rim of the northern Gulf to end with a presentation by University of Texas-Pan American, which is located in south Texas.

Presentations at the ITM session were successful at sharing information on Gulf-wide research facilities, projects, and findings. Research planning was revealed to be generally driven by pragmatic forces, including institutional mission, capabilities and interests of faculty, and availability of support funds from institutional, grant, or contract sources.

We appreciate the participation of these institutions, and the time, effort, and expense of the individuals representing them.

Dr. Richard E. Defenbaugh is Chief of the Environmental Studies Section of the Minerals Management Service, Gulf of Mexico OCS Region. His graduate work on the natural history and ecology of estuarine and continental shelf invertebrates at Texas A&M University led to an M.S. in 1970 and a Ph.D. in 1976. He began his career in the Federal service in the Bureau of Land Management's (BLM) New Orleans OCS Office in 1975 and has been involved with BLM/MMS environmental studies and assessment programs since then.

Dr. James Kendall is a biologist with the Environmental Studies Section of the Minerals Management Service, Gulf of Mexico OCS Region. He received his B.S. in biology from Old Dominion University; his Ph.D. in oceanography from Texas A&M University; and did post-doctoral research at the Marine Biological Laboratory of the Hebrew University of Jerusalem, Israel. Dr. Kendall has conducted and participated in research and monitoring programs in the Gulf of Mexico, in Galveston Bay, in the Florida Keys, and in the Gulf of Eilat, Red Sea.

OVERVIEW OF SOUTHERN ASSOCIATION OF MARINE LABORATORIES

Dr. Thomas D. McIlwain
Gulf Coast Research Laboratory

The southern United States is one of the fastest growing regions in the country as more and more people move to the sunbelt seeking jobs, a warmer climate, and a more pristine environment.

Chief among the region's many natural assets is its coastal wetlands, which comprise almost 90% of the nation's total estuarine wetlands from Chesapeake Bay to Texas. These wetlands provide critical habitat for most of the commercially and recreationally valuable fish and shellfish species found in the region.

The economic value of marine and estuarine species harvested in and near the coastal waters from Chesapeake Bay through the southern states and Caribbean annually exceeds $1 billion dollars. The value of saltwater recreational fishing, while more difficult to measure, undoubtedly has an even greater economic impact on the region.

Yet, less than 35% of Federal research dollars available for marine studies currently is allocated to the southern states. Because of the increasing pressure on marine resources in the region, research on coastal and offshore resource areas is of paramount importance.

Marine laboratories of the South play a key role in supporting the research necessary to protect the coastal environment. They also provide a vital link between scientists and resource users and managers.

Because of the diversity of problems and concerns facing researchers and resource managers in the region, the Southern Association of Marine Laboratories (SAML) was formed in 1985 to provide a concerted approach to coastal marine research.

The overall goal of SAML is to promote the development and maintenance of a strong marine research program in the southeast United States and to promote regional research initiatives.

In an effort to address the overall goal of the organization, the following objectives are being addressed:

- Promote the wise use and conservation of marine and coastal resources,
- Promote the importance of marine research and education to the economy and to society,
- Promote research initiatives related to marine and estuarine resources of the southeast,
- Promote a forum for resolving problems common to marine laboratories in the region, and
- Promote cooperation and unity among the member organizations to increase the effectiveness of their work.

Since the organization's inception in 1985, the membership has grown to its current size with 41 members from Chesapeake Bay to Texas, including Bermuda, Puerto Rico, and the U.S. Virgin Islands (Table 14.1). Current officers of the organization are: President, Dr. Kumar Mahadevan, Mote Marine Laboratory, Sarasota Florida; President-Elect, Dr. Thomas D. McIlwain, Gulf Coast Research Laboratory, Ocean Springs, Mississippi; Secretary, Dr. Ken Haddad, Florida Department of Natural Resources, St. Petersburg, Florida; Treasurer, Mr. Kris Fulton, Gulf Coast Research Laboratory, Ocean Springs, Mississippi. Board Members: Dr. George A. Knauer, University of Southern Mississippi/Center for Marine Science, Stennis Space Center, Mississippi; Dr. Anthony H. Knap, Bermuda Biological Station for Research, Inc., Bermuda; Dr. Judy P. Stout, Dauphin Island Sea Laboratory, Dauphin Island, Alabama.

The organization meets twice yearly, usually at one of the member laboratories, alternating between the East and Gulf coasts. Meetings are organized around both internal and external agenda items. External agenda items include addresses to the membership by representatives of agencies who traditionally fund the type of research conducted in member laboratories. These addresses enable the general membership to keep abreast of current research thrusts by the funding agencies. For example, at our most recent meeting held in Washington, D.C., representatives from all Federal agencies who are now funding research in coastal ocean research were invited to participate actively in the meeting. This participation gave SAML members the opportunity to obtain indepth information on each funding agency's specific area

Table 14.1. Southern Association of Marine Laboratories Members.

Benedict Estuarine Research Laboratory*
Bermuda Biological Station for Research, Inc.
Chesapeake Biological Laboratory*
College of Charleston
Corpus Christi State University
Dauphin Island Sea Lab
Duke University Marine Laboratory
Fairleigh Dickinson University
Florida Department of Natural Resources
Florida Institute of Oceanography**
Florida Institute of Technology
Florida State University
Gulf Coast Research Laboratory
Harbor Branch Oceanographic Institution
Horn Point Environmental Laboratory*
Lamar University
Louisiana Universities Marine Consortium
Mote Marine Laboratory
National Marine Fisheries Service**
Old Dominion University*
Savannah State College
Skidaway Institute of Oceanography
Smithsonian Environmental Research Center*
South Carolina Wildlife & Marine Resources Dept.
Texas A&M University at Galveston
Texas Parks and Wildlife Department
U.S. Environmental Protection Agency**
University of Florida - Marine Laboratory
University of Florida - The Whitney Laboratory
University of Georgia Marine Institute
University of Miami
University of North Carolina - Chapel Hill
University of North Carolina - Wilmington
University of Puerto Rico
University of South Carolina
University of South Florida
University of Southern Mississippi
University of Texas - Marine Biomedical Institute*
University of Texas - Austin
University of Texas - Pan American
Virginia Institute of Marine Science*

* Membership in the process of being approved
**Associate Members

of interest in coastal ocean research. It also provided an opportunity for the members to design a strategy for developing research initiatives between individual laboratories or individual researchers within individual laboratories.

Internal agenda items usually are designed to address management issues and problems common to most or all members. Internal agenda items have included boat operations, diving safety and operation, fund raising, overhead recovery, organizational structure, teaching assistantships, and faculty incentive programs.

This type of interaction between member laboratory executive officers has resulted in a greater awareness of the broad expertise and capabilities available in the region's marine laboratories. Tremendous camaraderie has developed between the members leading to numerous joint research initiatives. The membership has served to make our national elected officials more aware of the natural resources of our region and of the needs of the research/educational community to address these needs.

A major need identified by the organization is the lack of minorities in the marine sciences. With funding from the National Science Foundation (NSF), SAML has sponsored four workshops across the Southeast with predominantly minority institutions to develop a means of recruiting minority students into the marine sciences. The result of the workshops has resulted in the formation of an organization of predominately minority institutions, Minority Institutions Marine Science Association, which is dedicated to increasing minority participation in the marine sciences. The SAML has secured additional funding from NSF to implement the strategies for increasing minority participation in the marine sciences that were identified in the four minority workshops.

Dating back to the organization of the Southern Association of Marine Laboratories, there has been an effort underway to organize a national organization that would advocate the needs of marine laboratories nationally. At a recent meeting in Woods Hole, Massachusetts, on November 2-3, 1990, the National Association of Marine Laboratories (NAML) was formed. This organization will be a coalition of regional organizations, such as SAML. Currently there are three regional organizations that will form NAML. They are as follows:

1. Pacific Association of Marine Laboratories (PAML)

2. Southern Association of Marine Laboratories (SAML)

3. Eastern Association of Marine Laboratories (EAML)

The NAML and each regional organization will be incorporated as a 501(c)(3) nonprofit organization. The PAML and EAML are currently in the organizational stages.

Executive Committee members of these three regions will also serve as directors of the NAML Board. The NAML will be responsible for advocating the cause and needs of marine laboratories nationally, while the regional organizations, such as SAML, will promote regional initiatives. This organizational structure will allow all marine laboratories to speak with a single voice when deliberating marine issues. The NAML will also be able to work closely with other advocates of marine issues, such as the Council on Ocean Affairs and the National Association of State Universities and Land Grant Colleges Marine Division. It is believed that this organizational structure will specifically and effectively represent the interests of marine laboratories, large and small, and advocate the development and maintenance of a strong marine research program in the United States.

Dr. Thomas D. McIlwain has worked at the Gulf Coast Research Laboratory for the past 24 years and currently serves as its Director. Dr. McIlwain is the President-Elect of the Southern Association of Marine Laboratories. His areas of research interest are marine fisheries management and biology and ecology of the fishes of the Gulf area. Dr. McIlwain received his B.S., M.S., and Ph.D. in zoology from the University of Southern Mississippi. He has been intimately involved in fisheries management and fishery development in the Gulf for the past 12 years.

RESEARCH OVERVIEW FOR MOTE MARINE LABORATORY, SARASOTA, FLORIDA

Mr. James K. Culter
Mote Marine Laboratory

HISTORY

Mote Marine Laboratory (MML) is an independent, nonprofit research organization dedicated to excellence in marine sciences and education. Now celebrating its 35 year of operation, MML began in 1955 as the Cape Haze Marine Laboratory at Placida, Florida, founded by William and Alfred Vanderbilt. The first director was Dr. Eugenie Clark who initiated the Laboratory's reputation in shark research. The Laboratory moved to Siesta Key in Sarasota, Florida, in the early 1960's. The Vanderbilt family's support waned and the William R. Mote family stepped in as major benefactor to help the fledgling laboratory back on its feet. Two interim directors, Dr. Sylvia Earle (1966) and Dr. C. M. Breder, Jr. (1967), served the Laboratory until the appointment of Dr. Perry W. Gilbert, a world renowned expert in shark biology and behavior. In 1967, the name was changed to the Mote Marine Laboratory in honor of Mr. William R. Mote and Ms. Elizabeth Mote Rose, major benefactors to the Laboratory.

The Laboratory moved to much larger modern facilities at the present location on City Island, Sarasota, in 1978. Donations from many foundations and friends of the Laboratory provided for the construction for the modern laboratory as well as the Mote Marine Science Aquarium, a public museum and aquarium facility. Dr. William H. Taft became the new director and expanded the Laboratory's mission to include coastal ecology and environmental pollution problems while enhancing research programs in marine and biomedical studies.

Dr. Kumar Mahadevan, a biological oceanographer, currently serves as Executive Director and Dr. Richard Pierce, a marine chemist, as Director of Research. The Laboratory has gradually grown from a small biological station to a marine sciences research laboratory with a permanent staff of over 65 employees.

AREAS OF RESEARCH AND CURRENT PROGRAMS

Research areas are divided into seven programs: Aquaculture, Biomedical, Chemical Fate and Effects, Coastal Resources, Environmental Assessment and Enhancement, Marine Mammals and Sea Turtles, and Shark Biology. In addition, the Laboratory has a public education and outreach program through the Marine Science Aquarium. All areas of research frequently involve cooperative research with visiting investigators from other institutions.

AQUACULTURE AND FISHERIES ENHANCEMENT

This program focuses on basic and applied research important to protection and management of estuarine and coastal fisheries. A cooperative program with the Florida Department of Natural Resources conducts research on the basic aquaculture requirements of snook and redfish. The goals of this program are to develop the methods necessary for large scale production of fishes for the purpose of enhancement of declining populations of important Florida fish stocks. Nutrient dynamics of fingerling production ponds were also studied, with findings resulting in new management procedures.

Other recent and ongoing fisheries aquaculture studies include a demonstration that redfish can be grown successfully in mineralized freshwater that is available throughout most of Florida, identification of juvenile snook nursery habitats along coastal Southwest Florida, and assessment of recreational fisheries of Sarasota Bay.

BIOMEDICAL

The Biomedical Research Program utilizes marine organisms as sources of research materials and as comparative animal models for studies designed to contribute basic knowledge toward a better understanding of biomedically related problems in higher animals. Of particular interest is the use of sharks and skates as research animals. Some highlights of this program include the following:

- Purification and characterization of active proteins from shark cartilage processed through use of high pressure liquid chromatography instrumentation, allowing further investigation of cartilage protein-induced inhibition of capillary blood vessel growth as well as inhibition of protein degradation (proteolysis). The potential for the shark cartilage-derived proteins to inhibit the vascularization of tumors and, thereby, limit the input of nutrients to the transformed cell could result in a therapeutic means of controlling tumor growth that would not be accompanied by harmful side effects of the host.
- Chemical exposure studies utilizing direct-acting carcinogenic agents such as methylazoxymethanol acetate (MAM-Ac) to evaluate acute and chronic effects on DNA modification and tumor formation. A lack of tumors is consistent with historic, observed data indicating an ability of sharks and skates to resist tumor formation from potent cancer causing chemicals.
- Preliminary studies of shark and skate macrophages.

CHEMICAL FATE AND EFFECTS PROGRAM

This program investigates the fate (distribution, persistence) and effects (toxicity) of pollutants and natural biotoxins in the marine environment. Ongoing and recent projects include the following:

- Studies of the toxicity of mosquito larvicides to non-target marine organisms during actual field applications in coastal wetlands were designed by the Chemical Fate and Effects program. The goals of this project are to assess pesticide impact and assist in the development of environmentally sound methods of mosquito control.
- Studies on the biomagnification of toxic chemicals in marine organisms, such as accumulation of red tide toxins in fish.
- For a number of years the program has studied the mechanism of aerosol suspension of red tide toxins in the nearshore zone, resulting in respiratory irritation.

COASTAL RESOURCES PROGRAM

The Coastal Resources Program (CRP) conducts research necessary for effective resource management in Florida. The research involves field studies to gather new information to analyze or synthesize existing data, as well as policy-level decisions for resource management, where scientific issues (e.g., sea level rise) are involved. At present a major focus of the Program is the Sarasota Bay project of the National Estuary Program (NEP). Recent and current projects include wetlands assessment and mapping of the Sarasota Bay system for the NEP. A related project, also for the NEP, is the development of a baywide segmentation scheme useful for management purposes. Studies on the Florida coastal river systems continue to be an important aspect of the CRP. Studies include the development of an hydrologic model as well as a biotic characterization for the Myakka River and participation in the development of a management plan for the Loxahatchee River basin.

ENVIRONMENTAL ASSESSMENT AND ENHANCEMENT PROGRAM

The Environmental Assessment and Enhancement Program focuses on basic and applied research on human-related disturbances of the environment. Studies identifying the impacts of pollution and other disturbances on aquatic fauna and flora are important aspects of the program. The overall goal is to conduct scientific research that will lead to the preservation, conservation and enhancement of our natural resources. Major study areas of this program include benthic ecology, environmental assessment, environmental chemistry, fisheries biology and ichthyoplankton/fish migration.

The program has extensive involvement in the NEP Sarasota Bay project, including a bay bottom habitat assessment, which is mapping subtidal habitats with strong emphasis on nonvegetated bottom types and their role in turbidity problems. The study will also examine relative proportions of bay bottom that have been disturbed by human activities versus the natural or undisturbed bay bottom.

Three beach restoration projects are currently underway, involving the design and implementation of monitoring programs.

A multidisciplinary project involving the effects of thermal discharge on an estuarine seagrass meadow is in progress and involves thermal plume delineation, sedimentology, benthic infauna, seagrass health evaluation, and algal distributions.

The water quality laboratory of MML is involved in many projects, including well water analysis, evaluation of aquatic sediment metal concentrations, and monitoring of surface water and nearshore waters for a Navy submarine base.

The Fisheries Program is conducting research on king mackerel stocks in the southern Gulf of Mexico and port surveys of commercial fishing fleet catches. In addition, ichthyoplankton samples are being processed from the Loxahatchee River (East Florida coast) and stomach content analyses of larger fishes from the same location are being performed.

MARINE MAMMAL PROGRAM

The Marine Mammal Program provides opportunities to study dolphins, manatees and whales. The primary goal is to generate knowledge for the enhancement and protection of marine mammals.

The program conducts aerial surveys of the Florida west coast population of manatees. In addition, studies will soon begin to study hearing in the Florida manatee.

Dolphin populations are being monitored in the Indian and Banana Rivers complex on Florida's east coast for the National Marine Fisheries Service.

The program participates in the National Marine Mammal Stranding Network, and in 1989 responded to 18 strandings of bottlenose dolphins. In late summer of 1990, two captive bottlenose dolphins were introduced to the wild after an acclimation period at MML.

SEA TURTLE CONSERVATION AND RESEARCH PROGRAM

The purpose of the program is to provide information on the population of the loggerhead sea turtle nesting on the barrier islands between Tampa Bay and Charlotte Harbor. By identifying preferred nesting beaches and mortality factors, it is anticipated that management decisions will result in stabilizing and perhaps increasing loggerhead populations. The program has been involved in monitoring surveys for dredging activities for pass maintenance and beach restoration. In addition, nests are occasionally moved and artificially incubated when beach erosion or severe storms threaten to destroy nesting areas.

RESEARCH PLANNING

The Executive Director and Director of Research have final authority on types of research conducted at MML. Periodic reviews of the long-term goals and mission of the Laboratory are conducted by eminent scientists from around the country at the request of the Board of Directors. Review findings, together with the input of the Directors and Laboratory, are utilized to formulate broad policy. Within this policy, and subject to the approval of the directors, MML scientists have the freedom to pursue any research that relates to the established programs. Funding is largely dependent on obtaining research contracts and grants.

Mr. James K. Culter has worked at Mote Marine Laboratory for 11 years. He is a Staff Scientist in charge of the Environmental Assessment/Benthic Ecology program. Areas of interest include benthic invertebrate ecology, seagrass ecology, and long-term turbidity monitoring. Mr. Culter received his B.A. and M.A. in marine biology from the University of South Florida, Tampa.

RESEARCH OVERVIEW FOR FLORIDA INSTITUTE OF OCEANOGRAPHY

Dr. Sandra L. Vargo
Florida Institute of Oceanography

The Florida Institute of Oceanography (FIO) is an administrative umbrella organization of the State University System of Florida representing the geographically dispersed marine science research and education community in Florida. The consortium members are the nine public universities, the private University of Miami, Florida Department of Natural Resources, and the Florida Sea Grant College. The FIO's mission is two-fold: (1) developing, implementing, and managing oceanographic education and research programs, and (2) providing, operating, and maintaining ship and shore facilities required for these programs.

In fulfilling its first mission, the FIO provides a forum for initiating and coordinating research considered important to the State institutions and agencies responsible for conservation and management of the marine environment. This forum is accomplished by utilizing the wealth of expertise of the FIO's membership and other educational and research organizations. In the past, the FIO has responded in a reactive mode to research opportunities and has coordinated and managed a broad range of programs funded by State and Federal sources. Just a few examples are the following:

1. Spatial and Temporal Variation of Crude Oil Residues in Continental Shelf Waters Offshore Western Florida - State of Florida

2. Predictions through Satellite Data of Hydrocarbon Transport after an Oil Spill - State of Florida

3. Effects of Petroleum on Marine Turtles - Minerals Management Service (MMS), U.S. Department of Interior

4. Florida Atlantic Coast Transport Study - MMS, U.S. Department of the Interior

Under the leadership of John C. Ogden, who became Director in September 1988, the FIO has taken an increasingly proactive role in developing research goals and programs, assembling the required scientific expertise, and obtaining the necessary funding. An example of this proactive role is the SEAKEYS program funded by the John D. and Catharine T. MacArthur Foundation.

The FIO has long recognized the value of sustained ecological research. This research is necessary for understanding the functioning of ecosystems and for distinguishing natural variability from man-induced impacts. This research must be done on a time and geographic scale appropriate to the ecosystem in question. Funding cycles rarely encompass the time course of natural phenomena such as storms, diseases, and oceanographic-atmospheric events such as ENSO and processes such as global warming trends and sea level rise. Additionally, research at a single site cannot be extrapolated to draw conclusions about the broader system as a whole.

These considerations of scale have led to an integrating concept in Florida. This concept is based on the design of Florida's water management districts, which were determined by hydrological zones. The goal of this design was to manage water resources in a manner appropriate to the geographic scale of the resource. The FIO proposes to extend this concept to coastal ocean management with management zones based on biological and physical factors (Figure 14.1), allowing for common research methodology and a coordinated management strategy.

In initiating this plan the FIO has targeted two areas in Florida for pilot studies - the West Florida Shelf and the Florida Keys reef tract. The West Florida Shelf program is in the preliminary stages, and program design will be developed at a workshop to be sponsored by the FIO in April-May 1991 with State funding. The need is apparent when one considers the high productivity of the region (including periodic red tides with major ecosystem impact), its great areal extent, and the relative paucity of information available. The major studies in the region were funded by MMS to evaluate potential environmental impacts of oil and gas exploration and production activities in the region. These studies were primarily descriptive in nature and not process oriented. In addition, there was no linkage between the water column and the benthos.

The FIO has received funding for this program in the Florida Keys from the John D. and Catharine T.

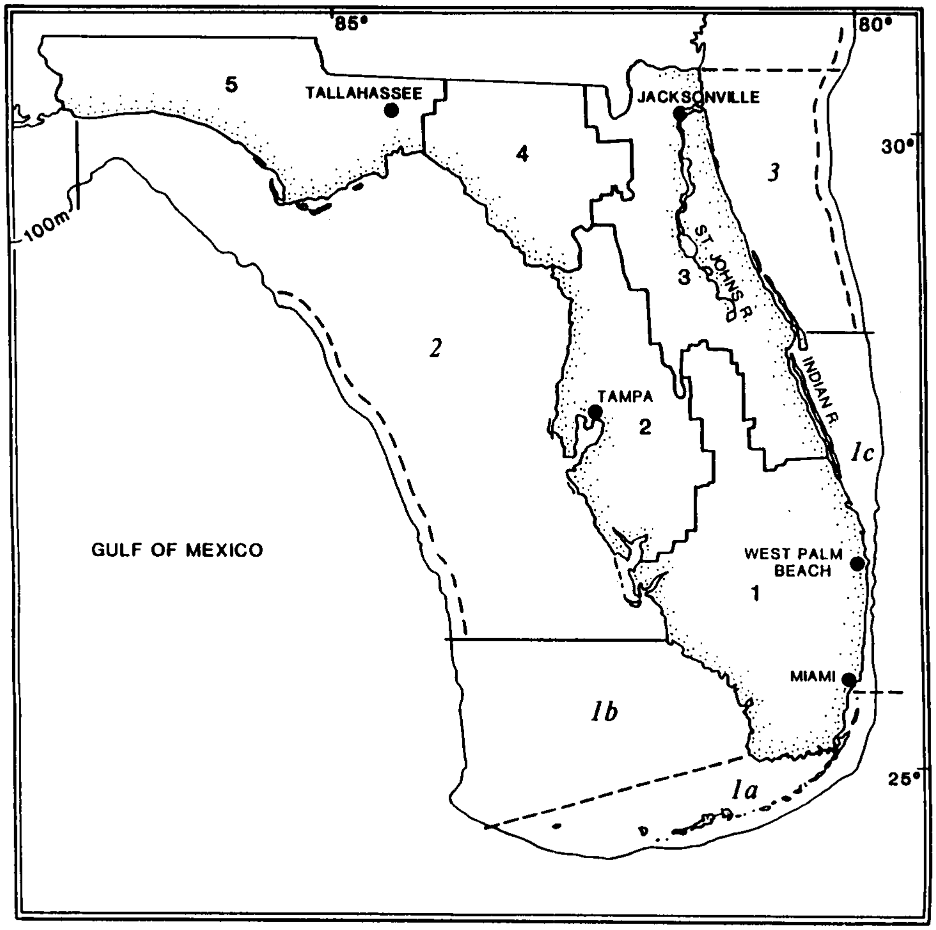

Figure 14.1. Hypothetical Coastal Management Districts.

MacArthur Foundation with supplemental funding from the State. Titled SEAKEYS, the program will focus on the reasons for the decline in live coral coverage along the reef track in the past 10 years, keeping in mind that the reef tract is the downstream element in a mosaic of ecosystems commencing at Lake Okeechobee. At least four hypotheses have been advanced to date to account for the decline of live coral and are as follows:

1. nutrification due to agricultural runoff and increased population,

2. input of trace metals and pesticide from the same sources,

3. stress from the coral bleaching events in 1983 and 1987, and

4. some combination of the above.

The research team has designed a program taking into account the time and geographic scales necessary to evaluate these various hypotheses. The establishment of five core research sites (Figure 14.2) is central to the program. Initial plans are to utilize the National Oceanic and Atmospheric Administration Marine Sanctuary system and other protected areas where possible. The planned sites are Fowey Rocks, Key Largo Marine Sanctuary (Carysfort Reef), Sombrero Reef, Sand Key, and the Fort Jefferson National Monument (Pulaski Shoal). The Fort Jefferson station will be funded cooperatively by MMS, National Data Buoy Center (NDBC), and Florida Department of Natural Resources (FDNR). Additionally, FDNR will fund a station in Florida Bay and MMS will fund a buoy on Cay Sal Bank in support of the Straits of Florida program. Each of these sites will be subject to long-term continuous monitoring of environmental parameters such as incident and submarine irradiance, air temperature, wind speed, tide and wave height, water temperature at several depths,

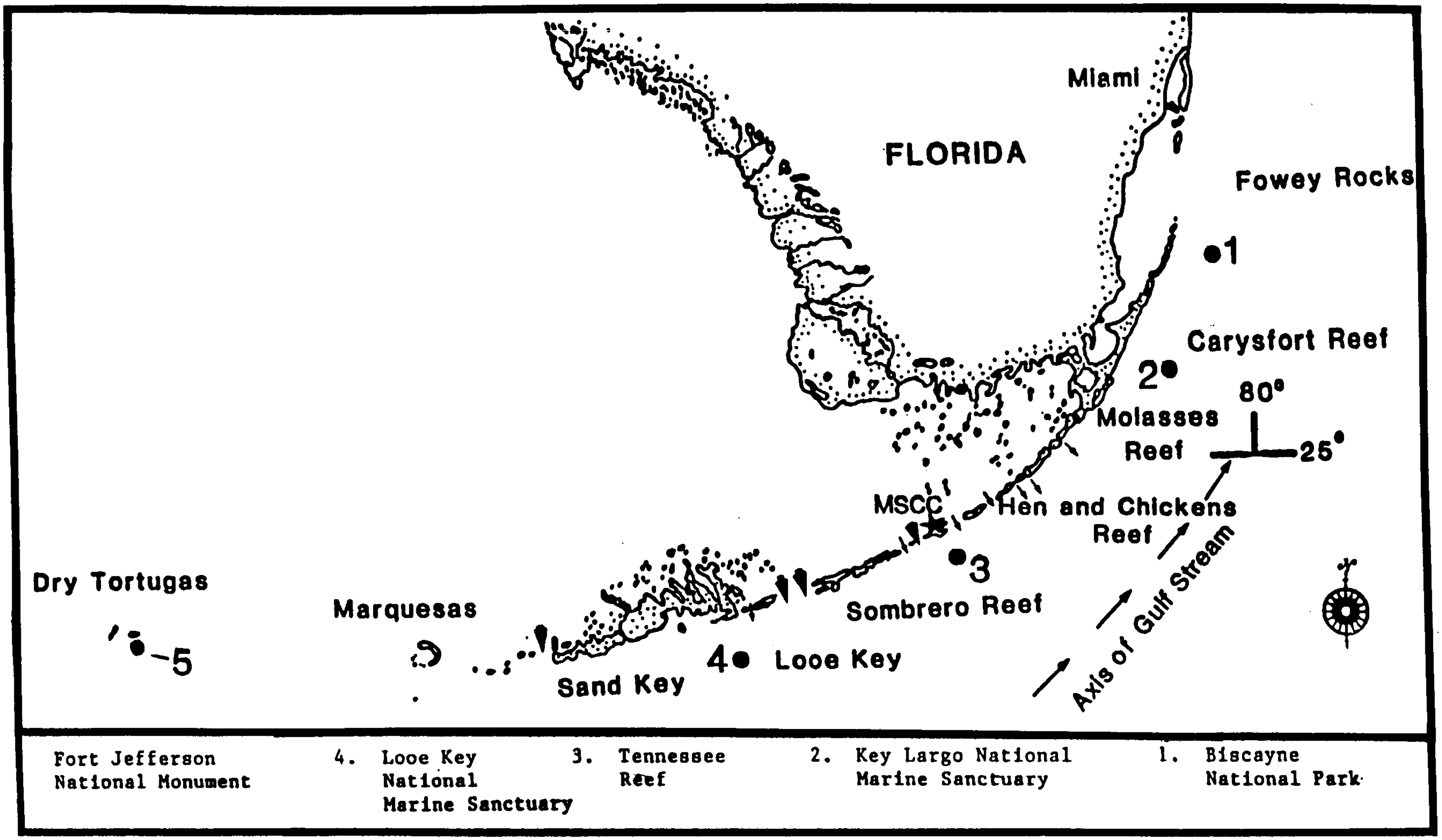

Figure 14.2. General locations of Core Sites along the Florida Keys reef tract. (Water flow from Florida Bay out toward the reef tract is shown by the arrows. The size of the arrows denotes the relative volume of the flow.)

fluorescence (chlorophyll a), turbidity, and conductivity. These monitoring stations will be automated and data transferred by satellite transmission to the NDBC for quality control and then to the main support facility at Keys Marine Laboratory on Long Key, roughly midway in the chain of islands. The data will be used to establish long-term trends along the geographic scope of the reef tract and as support information for the more site-specific studies designed to fill in known data gaps.

Four site-specific studies are planned to fill these data gaps and are as follows:

1. Water circulation and transport (N. Smith, Harbor Branch Oceanographic Institution)--The water circulation and transport studies will focus on quantifying water exchange (tidal and non-tidal) between Florida Bay and the reef tract. Secondarily, net transport from the island chain to the reefs will be determined.

2. Coral reef dynamics (J. Porter, University of Georgia; W. Jaap, Florida Department of Natural Resources)--The coral dynamics portion will use photographic recording of quadrats to determine long-term changes in coral coverage and growth. This will build on an existing five-year library for Key Largo and Looe Key. The process will be automated to make it more suitable for management purposes.

3. Ecological and physiological indicators of coral health (A. Szmant, University of Miami)--This portion of the program will evaluate a variety of factors influencing coral growth such as incidence of disease, biomass of zooxanthellae, and recruitment. Coral growth will be measured directly using Alizarin Red techniques.

4. Nutrient dynamics (A. Szmant, University of Miami)--The integrated effect of increased nutrients will be assessed using settling tiles (caged and uncaged) to determine the growth of macroalgae. Additionally macroalgae will be plotted in selected quadrats at the core sites and assessed quarterly to determine seasonal and longer term trends.

While the environmental monitoring stations and site-specific studies will provide much needed information to develop management strategies for the Florida Keys reef tract, none of these strategies will be effective without broad-based public support. It is quite likely that any effective management will involve further restriction of activities on the reef. Therefore, we have incorporated in this program a means of public education via a videotape explaining the relationship of the reef to the larger seascape and how man's activities affect this ecosystem.

In conjunction with the SEAKEYS program the FIO has also participated in the Caribbean Coastal Marine Productivity (CARICOMP) program. This is a Caribbean-wide network. To foster this network the FIO, funded by NSF, will co-host with UNESCO a workshop on environmental monitoring techniques in December 1990 at Discovery Bay Marine Laboratory, Jamaica. Thirty to forty scientists from over twenty regional marine research institutions will attend to discuss and conduct field trials for a suite of standardized physical (temperature, salinity, light attenuation, and suspended solids) and biological (community structure and growth rates of principal species) measurements. The CARICOMP program is directed at an understanding of long-term coastal ecosystem change through comparative ecosystem studies at the geographic scale of the Caribbean and adjacent waters.

The second portion of the FIO mission is to provide, operate, and maintain the ship and shore facilities and equipment necessary to support these programs. The intent of the Florida Board of Regents in establishing the consortium was to prevent costly, duplicative funding of facilities that would not be utilized fully by a single institution. The FIO operates two oceanographic research vessels in support of the State's programs. The 71-ft. R/V *Bellows* and the 110-ft. R/V *Suncoaster*. Both are designed for general oceanographic research with equipment provided either from the State oceanographic equipment pool maintained by the FIO (conductivity-temperature-depth recorders [CTDs], expendable bathythermographs [XBTs], precision depth recorder [PDR], Niskin bottles, dredges, trawls, current meters, acoustic releases, etc.) or by the individual researcher in the case of more specialized equipment.

In addition to the sea-going facilities, the FIO, in cooperation with the Florida Marine Research FIO of the Florida DNR, operates the Keys Marine Laboratory (KML) on Long Key. Although KML currently provides basic dormitory, laboratory, and classroom facilities, it is the intent of both institutions to develop this as a combined full service marine research and education center over the next five years. This will be a major support facility for research programs on the Florida Reef Tract and Florida Bay in the future.

Dr. Sandra L. Vargo has worked at the Florida Institute of Oceanography since 1980 and is currently Assistant Director. She develops, coordinates, and manages multi-investigation, multi-institutional research and education programs for the Florida Institute of Oceanography. Dr. Vargo received her B.S. in zoology and chemistry from the University of Miami; her M.S. in marine science from Rosensteil School of Marine and Atmospheric Science; and her Ph.D. in oceanography from the University of Rhode Island.

RESEARCH OVERVIEW FOR FLORIDA DEPARTMENT OF NATURAL RESOURCES, MARINE RESEARCH INSTITUTE, ST. PETERSBURG, FLORIDA

NOTE: No text of Mr. Weigle's presentation was submitted for publication. The following information has been excerpted from an informational flyer distributed with Southern Association of Marine Laboratories materials.

The Florida Marine Research Institute (Institute) is located at Bayboro Harbor, just south of downtown St. Petersburg, Florida. It is charged by State Statute [Section 370.02(2)(b)] to conduct research necessary for marine resource management decisions. The Institute has responsibilities for marine fisheries and marine ecology research, marine habitat research and restoration, endangered and threatened species recovery programs, and a marine fish stock enhancement research program.

Research at the Institute encompasses studies in nine broad, interrelated programs.

- Fishery Stock Assessments to determine population abundance, migration, dispersal patterns, and other aspects of selected species stocks for management options and decisions;

- Fisheries Statistics to obtain recreational and commercial fisheries catch and effort data by area, gear, and user; to monitor juvenile and subadult abundance and recruitment;

- Life History Studies to identify developmental stages of certain fishes and invertebrates and determine spawning, age at reproduction, age of entry into fishery, sex ratios, nursery areas, and feeding strategies;

- Coastal Hydrography and Red Tide Studies using satellite remote sensing to evaluate coastal processes such as hydrological and biological features; to forecast recruitment of larval fishes into nearshore waters and the occurrence of noxious plankton blooms;

- Culture and Rearing of Marine Animals to artificially spawn and rear selected species for life history data; to refine culture technologies; to assess the cost/benefits of stocking selected estuarine-dependent species, particularly fishes, into Florida's estuaries and nearshore waters;

- Habitat Characterization and Restoration Studies to develop techniques for supplying seagrasses, mangroves, and saltmarsh plants for coastal vegetation restoration; to document coastal habitat loss; to assess the feasibility of determining carrying capacity of a system;

- Benthic Community Studies to document assemblages of organisms and distribution patterns; to assess human influence on Florida's coral reefs;

- Endangered and Threatened Species Recovery Programs to permit and coordinate marine turtle and marine mammal activities and study population dynamics; and

- Marine Animal Health and Contamination Assessment to develop a reference collection of normal tissue, document and describe disease events, and analyze diseases in closed systems.

The main facility in St. Petersburg consists of three laboratory buildings, a dock, and storage compound for trailered vessels and vehicles. Tanks with recirculating artificial seawater systems, computer facilities, TEM and SEM microscopes, vertebrate and invertebrate reference collections, and various analytical and research equipment are housed at the facility.

Library holdings include more than 38,000 reprints, 6,000 books, and 1,700 journal titles. Computer facilities consist of mainframe processing on an IBM-4381 minicomputer housed at Department of Natural Resources in Tallahassee, Florida. A direct 9,600-band link to the Institute with a 32-port controller allows multi-user access. Approximately 130 microcomputers exist as either stand-alones or workstations. A 32-bit Gould 32/27 minicomputer comprises a rastor-based image processing and geographic information system.

Research vessels include the R/V *Herman Cortez II*, an 85 ft. steel-hull trawler; the 35 ft. R/V *Bonnie E*; and the 34 ft. R/V *Allmand*; plus 30 small boats, most trailerable.

The Port Manatee Stock Enhancement Research Facility consists of 12 one-acre experimental production ponds. Field stations with special research goals are located at Ft. Myers (manatees), Marathon (queen, conch, spiny lobsters), Stuart (sea turtles), and Tequesta (finfish, manatees, and habitat).

The Florida Marine Research Institute is not an academic institution, but scientific staff members serve as graduate advisors or guest lecturers at area universities and colleges and serve on many international, national, regional, and state councils, committees, boards, and panels. Senior research and management staff consists of more than 60 individuals, about a third of whom hold doctoral degrees.

For further information, please contact:

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Florida Marine Research Institute
100 Eighth Avenue SE
St. Petersburg, Florida 33701
(813) 896-8626 FAX (813) 823-0166

RESEARCH OVERVIEW FOR UNIVERSITY OF SOUTH FLORIDA, DEPARTMENT OF MARINE SCIENCES, ST. PETERSBURG, FLORIDA

NOTE: Dr. Betzer was not able to participate in the Information Transfer Meeting session due to a schedule conflict. The following information has been excerpted from materials provided by Dr. Betzer.

The Department of Marine Science at the University of South Florida offers M.S. and Ph.D. degrees in marine science with specializations in biological, chemical, geological, or physical oceanography. The department's academic and research curricula provide an ideal forum for investigating phenomena that span disciplinary boundaries while also providing a solid background in basic oceanography. More than 80 students are actively pursuing degrees in the department on a wide variety of topics. Study areas range from estuarine and nearshore systems to remote areas of the Pacific, Atlantic, and Indian Oceans, as well as the Arctic and Antarctic. Graduate instruction is presently provided by 23 full-time faculty. Three additional faculty will join the staff by 1991. Departmental operations are supported by 30 technical and clerical staff members.

The department's location on Bayboro Harbor allows immediate access to Tampa Bay and the Gulf of Mexico. Bayboro Harbor is home port to the R/V *Bellows* (71 ft.) and the R/V *Suncoaster* (110 ft.) operated by the Florida Institute of Oceanography (FIO) for the entire state university system. The department's principal building (82,000 sq. ft.) is shared with the FIO, and is immediately adjacent to the Florida Marine Research Institute, the research arm of the Florida Department of Natural Resources (DNR). There are currently more than 120 full-time employees at the Marine Research Institute including 19 doctoral-level personnel. Beginning in the fall of 1988, the St. Petersburg Campus has become home to the Center for Costal Geology of the United States Geological Society (USGS). The Center for Coastal Geology will maintain a staff of approximately 30. The proximity of four major research facilities at the Bayboro Campus (Marine Science, DNR, USGS, FIO) makes our campus a highly interactive and diverse research community.

The Marine Science Department's specialized laboratories include those for trace-metal analysis, physical chemistry, organic and isotope geochemistry, optical oceanography, satellite imagery, radioisotope geochemistry, sedimentology, micropaleontology, physiology, benthic ecology, water quality, microbiology, ichthyology, planktology, and geophysics. The department has a large flume facility for interdisciplinary boundary-layer studies. Major items of equipment include an ISI (DS-130) scanning electron microscope, a Finnigan MAT-250 isotope ratio mass spectrometer, high-resolution gas chromatographs, a combined GC-mass spectrometer, UV-Visible spectrophotometers, flame and graphite furnace atomic absorption spectrometers, multichannel autoanalyzer systems, X-ray diffraction systems, a Mössbauer spectromer, an ORE Geopulse high-resolution continuous seismic reflection profiling system, and an EG&G side-scan sonar system.

Approximately 15 state-supported assistantships are available each year for beginning students. In addition, approximately five fellowships are available each year from community sources. Most of our students are supported by the research grants of individual faculty.

A brief synopsis of the faculty and their research follows:

- Peter R. Betzer, Professor and Chairman, Ph.D., University of Rhode Island, 1971. Chemical oceanography, chemical tracers, pollutant transfer, particle fluxes, role of organisms in modifying chemistry of seawater.
- Norman J. Blake, Professor; Ph.D., University of Rhode Island, 1972. Ecology and physiology of marine invertebrates, inshore environmental ecology and pollution, reproductive physiology of molluscs and crustaceans.
- John C. Briggs, Professor; Ph.D., Stanford University, 1952. Systematics and behavior of marine fishes, marine zoogeography.
- Robert H. Byrne, Professor; Ph.D., University of Rhode Island, 1974. Chemical oceanography, physical chemistry of seawater, ionic interactions, marine surface chemical, oceanic CO_2 system chemistry.
- Kendall L. Carder, Professor; Ph.D., Oregon State University, 1970. Physical Oceanography, ocean optics, suspended particle dynamics, instrument development, ocean remote sensing.
- John S. Compton, Assistant Professor; Ph.D., Harvard University, 1986. Diagenesis of marine sediments, low-temperature and sedimentary geochemistry, sedimentary petrology, paleoceanography.
- Larry J. Doyle, Professor; Ph.D., University of Southern California, 1973. Marine geology, sedimentology, sediments and sedimentary processes of the continental margins.
- Kent A. Fanning, Professor; Ph.D., University of Rhode Island, 1973. Chemical oceanography, pore-water geochemistry, nutrients in the ocean, marine radiochemistry.
- Boris Galperin, Associate Professor; Ph.D., Technion-Israel Institute of Technology (Israel), 1982. Physical oceanography, turbulence theory, application of renormalization group methods to geophysical turbulence, mixed layers, numerical modeling of mesoscale oceanographic systems.
- Giselher R. Gust, Professor; Ph.D., Universität Kiel, FRG (West Germany), 1975. Physical oceanography, benthic boundary-layer flows, geochemical fluxes across the sediment-water interface, biological-hydrodynamical interactions, instrument developments.
- Pamela Hallock-Muller, Professor; Ph.D., University of Hawaii, 1977. Micropaleontology, paleoceanography, carbonate sedimentology, coral reef ecology.
- Albert C. Hine, Professor; Ph.D., University of South Carolina, 1975. Carbonate sedimentology, coastal sedimentary processes, geological oceanography, sequence stratigraphy.
- Thomas L. Hopkins, Professor; Ph.D., Florida State University, 1964. Biological oceanography, marine plankton and micronekton ecology, oceanic food webs.
- Frank E. Muller-Karger, Assistant Professor; Ph.D., University of Maryland, 1989. Biological oceanography, remote sensing, regional and global plankton productivity, nutrient cycles.
- David F. Naar, Assistant Professor; Ph.D., University of California, San Diego (Scripps), 1989. Marine geophysics and plate tectonics, microplate and midoceanridge processes, seafloor remote sensing, investigation of time dependent plate tectonic phenomena using molten wax.
- John H. Paul, Associate Professor; Ph.D., University of Miami (Florida), 1980. Marine microbiology and genetics, gene transfer mechanisms.
- William M. Sackett, Distinguished Professor; Ph.D., Washington University (St. Louis), 1958. Marine organic and isotope geochemistry.
- Joseph J. Torres, Associate Professor; Ph.D., University of California, Santa Barbara, 1980. Biological oceanography, deep-sea biology,

bioenergetics of pelagic animals, comparative physiology.

- Edward S. Van Vleet, Professor; Ph.D., University of Rhode Island, 1978. Chemical oceanography organic geochemistry, molecular biomarkers, hydrocarbon pollution.

- Gabriel A. Vargo, Associate Professor; Ph.D., University of Rhode Island, 1976. Biological oceanography, phytoplankton ecology and physiology, nutrient dynamics.

- John J. Walsh, Distinguished Professor; Ph.D., University of Miami (Florida), 1969. Continental shelf ecosystems, systems analysis of marine food webs, global carbon and nitrogen cycles.

- Robert H. Weisbert, Professor; Ph.D., University of Rhode Island, 1976. Physical oceanography, equatorial ocean dynamics, estuarine and nearshore circulation studies.

- Raymond R. Wilson, Assistant Professor; Ph.D., University of California, San Diego (Scripps), 1984. Ichthyology, deep-sea ecology, fisheries biology.

For further information, please contact Dr. Peter Betzer, Chairman; Department of Marine Science, University of South Florida; St. Petersburg, Florida, 33701-5016.

RESEARCH OVERVIEW FOR THE FLORIDA STATE UNIVERSITY MARINE LABORATORY, TALLAHASSEE, FLORIDA

Dr. Nancy H. Marcus
Florida State University

INTRODUCTION

The Florida State University administers a coastal facility at Turkey Point, Sopchoppy, Florida and an academic diving program on the main campus of the university in Tallahassee, Florida. Its purpose is to provide high quality space and support for research and educational programs, and ready access to marine and freshwater environments.

COASTAL FACILITY

The Turkey Point laboratory was constructed in 1968. It is situated in the Alligator Harbor Aquatic Preserve, at the transition of the Appalachicola River estuary to the west and the Ochlocknee River, salt marshes and seagrass meadows to the east. A diverse array of marine, estuarine, and freshwater habitats exists within easy reach of the laboratory. Human development along this coastline is minimal and waters are pollution free.

The laboratory provides easy access to undisturbed major nursery and offshore adult habitats of significant sport and commercial fisheries, including gag grouper, seatrout, redfish, and black sea bass. The extensive seagrass beds and saltmarshes and their constituent populations are not available in many other areas, especially in the Panhandle. The pollution-free location of the laboratory makes it ideal for conducting experimental work on marine, estuarine, and freshwater organisms.

On-site facilities include a research building with 16 laboratories, an adjoining administration, library, computer, and classroom building, a maintenance shop and dive locker, a trailer for office space, a 60-m long concrete dock and fueling station, 4 efficiency apartment buildings, a 3-bedroom residence house, a house trailer, an accessory administration and classroom building, 3 greenhouse research buildings, a semi-enclosed seawater wet table area and a large recirculating seawater raceway, 3 controlled (temperature and light) environmental rooms with seawater capabilities, and several storage areas.

A variety of research vessels is maintained at the laboratory, including 16-ft. aluminum skiffs, two 28-ft. pontoon boats, a 20-ft. Privateer, and the 47-ft. multi-purpose research vessel *Nectes*. The *Nectes* has a range of about 300 miles and can carry a scientific party of 5 for multi-day trips and 12-member classes for 1-day cruises.

ACADEMIC DIVING PROGRAM

The Academic Diving Program maintains a full-service dive locker with more than 100 scuba tank sets, 50 regulators, and other dive accessories. Special gear includes training and facilities for mixed gas diving, KMB full-face masks, underwater cameras, and a towable diving sled. All of the gear is maintained by a dive technician. Courses in basic diving and the application of diving to research are offered along with specialized workshops.

RESEARCH AND ACADEMIC PROGRAMS

The pursuit of research and educational programs through the facilities of the Florida State University Marine Laboratory is encouraged. Research programs are currently being conducted by faculty, staff, and students from the Departments of Biological Science, Chemistry, Oceanography, Meteorology, Geology, Anthropology, and Movement Science at Florida State University. These projects include studies of the zooplankton, benthic infaunal, and benthic macro-invertebrate populations of nearby waters, the role of coastal wetlands in supplying greenhouse gases, the reproductive biology of grouper, and the neurophysiology of sharks. Educational programs include the highly successful Saturday at the Sea program, which enables secondary school students to learn about the marine system first hand. Outside users from various public and private institutions utilize the facilities. The Harbor Branch Oceanographic Institution has been operating a model oyster hatchery and grow-out facility, and the Caribbean Marine Research Center has been conducting studies on the early life history stages of *Tilapia* and striped bass. The Bureau of Archeological Research is looking for evidence of early human activities at various springs in the region. Two agencies of the State of Florida, the Department of Environmental Regulation and the Department of Natural Resources, maintain offices at Turkey Point.

Dr. Nancy Marcus was a staff scientist at the Woods Hole Oceanographic Institution for 10 years. She has worked at the Florida State University since 1987 and serves as Director of the Florida State University Marine Laboratory. She is also an Associate Professor of Oceanography. Her areas of research interest are the ecology and evolutionary biology of marine zooplankton. Dr. Marcus received her B.S. in biology from Goucher College and her Ph.D. from Yale University.

RESEARCH OVERVIEW FOR ALABAMA MARINE ENVIRONMENTAL SCIENCES CONSORTIUM, DAUPHIN ISLAND SEA LAB, DAUPHIN ISLAND, ALABAMA

Dr. Kenneth L. Heck, Jr.
Alabama Marine Environmental Science Consortium

INTRODUCTION

The Marine Environmental Sciences Consortium (MESC) is Alabama's marine science research and education center. Founded in 1971 by the Alabama legislature to maximize the marine research capabilities of Alabama institutions of higher learning, MESC has grown to include 21 colleges and universities. As the focal point for marine programs in the State, MESC is funded independently by the Alabama Educational Trust Fund and as such is part of the State's system of higher education. Teaching and research activities of the MESC take place principally at the Dauphin Island Sea Lab (DISL), a facility located on the north-central coast of the Gulf of Mexico in the small town of Dauphin Island, Alabama.

The DISL consists of a 36-acre campus on the east end of Dauphin Island near the western entrance to Mobile Bay. Included on the campus are a 7,000-square foot laboratory building, which satisfies the nutrient chemistry, chemical ecology, larval ecology, benthic ecology and marsh/seagrass space requirements, and also contains two classrooms and a small museum. A separate building houses an 8,000-gallon recirculating seawater system, a 10-m flume and a 3,000-square foot wet laboratory that provides an environment for maintaining animals and experimenting under investigator-controlled conditions of light and temperature. Two additional 1,500-square-feet lecture/lab teaching buildings support the educational program. The administration building is connected to a library facility that houses 4,500 volumes and 600 periodical titles. Two 84-person dormitories provide housing for undergraduates while a 12-unit apartment building houses graduate students and visiting investigators. Thirteen three-bedroom houses are available for summer and visiting faculty. A fully equipped cafeteria also operates on the campus. Additional support is provided by a well-equipped shop, a complete dive locker, and a diver training pool.

The MESC maintains two research vessels at the DISL: the *A.E. Verrill*, a 65-ft. steel hull vessel equipped with laboratory and sleeping quarters for 8; and the 41-ft. fiberglass hull *Deborah B.* designed for day trips in near-shore waters. Seven other smaller boats provide support for the research activities at the DISL.

At present, 10 MESC faculty are at the DISL year-round, and this resident faculty is complemented by three postdoctoral research associates and adjunct faculty from the MESC member institutions. Academic and research activities are fully supported by an on-site business and purchasing office, research and data processing technicians, research vessel crew and plant operations and fabrication staff.

Data base development at DISL has become a central source of information on estuarine and marine habitats in the northeast Gulf of Mexico and the major source of information for the Alabama and western Florida region. Data bases of particular value, because of their duration and/or uniqueness (e.g., meteorological records, resource inventories, and marine invertebrate museum) are discussed in more detail below. In the past, information exchange with new and visiting researchers has been accomplished through publications in the primary literature, a series of technical reports and personal interaction. Recently, computerized data base management has been applied successfully to the DISL museum collection. This year, in conjunction with our ongoing National Science Foundation Facilities award, we are upgrading the means by which visiting and outside investigators obtain information on local and regional environments through the initiation of a data management plan that incorporates both computer access to data bases and complete library archiving of relevant data and reports.

The DISL has established and maintained long-term meteorological records and extensive collections and inventories of the local biota in support of ongoing research activities. Meteorological observations at the DISL site date to the 1950's, and since 1974 the Sea Lab has maintained a meteorological station on site, and wind speed and direction are continuously monitored, while air and water temperature, salinity, and rainfall are monitored daily. In addition, National Oceanic and Atmospheric Administration (NOAA)/National Ocean Survey (NOS) has operated a continuously recording tide station at Dauphin Island since 1966. Their entire data set is available from NOS and much of it (1973-1988) is stored on tape at DISL. These data have been summarized in periodic reports (Schroeder 1976, 1978; Schroeder *et al.* 1979, 1980; Schroeder and Wiseman 1985) and are available for general use by the scientific community.

RESEARCH GOALS AND PROGRAMS

The long-term research goals of the MESC are (1) to develop new theory and improved understanding of the mechanisms structuring nearshore ecosystems, and (2) to apply this knowledge to the management of the nation's aquatic and coastal resources through multidisciplinary studies of coastal waters and their adjoining landscapes. The MESC has consciously decided to focus its resources on nearshore and shelf waters because of the proximity of pristine local shallow water habitats and the challenging questions remaining to be addressed in these habitats.

Historically, the faculty at the DISL have concentrated on descriptive studies of salt marshes, soft bottom community structure, and hydrographic processes in and around the Mobile Bay estuary. These studies have provided a substantial data base for the present focus. Similarly, studies on the Outer Continental Shelf have established benchmark information on biological community structure, hydrography, and sediment chemistry and texture. These studies have provided a substantial data base from which a more process-oriented research program has evolved.

In support of its evolving research goals, MESC has taken major steps toward improving the research environment at the DISL. In 1988, the MESC finalized a new five-year plan that charts the direction of short-term growth and development of research activities. This document completes a process that began in 1986 with an expanded commitment of MESC resources to the research program at the DISL. In support of this plan, ongoing enhancements to the program include (1) the addition of four new faculty members and the planned addition of two further faculty lines; (2) the upgrade of the physical plant; and (3) acquisition of new, state-of-the-art research instrumentation.

As an outgrowth of the historical research emphasis of the DISL, the present programmatic focus is on (1) the dynamics of production in estuarine environments with emphasis on the marsh, submerged aquatic vegetation, and open water ecosystems; and (2) shelf processes, emphasizing production on "hard bottoms," and energy coupling between the estuary and the shelf.

In the area of estuarine productivity, we are concentrating on the processing and transfer of energy through the dominant types of local nearshore habitats. This work involves measurements of both primary and secondary production and nutrient regeneration, studies of predator-prey and plant-animal interactions, and the recruitment and transport dynamics of planktonic and sessile fauna and flora in a variety of localities (Alabama's estuarine ecosystems, Belize, and St. Joseph Bay, Florida). A central theme in this work is an attempt to understand how variation in physical, chemical and biological processes interact to regulate the structure and function of estuarine ecosystems.

Turning to studies on the shelf, ongoing and future investigations are focused on the dynamics of water movement and sediment transport, larval transport and retention, and planktonic production. Efforts are also focused on the inter-relationships of these factors with the composition and productivity of invertebrates and fishes associated with "hard bottom" benthic communities. A major thrust of these studies is to understand how the westerly-moving turbid, nutrient-rich plume exiting Mobile Bay affects larval transport and reinvasion of the estuary, and also how productivities in areas receiving the plume might be affected by this large supply of nutrient-rich water.

REFERENCES

Schroeder, W.W. 1976. Physical environment atlas of coastal Alabama. Pub. No. MASGP-76-034. Miss/Ala Sea Grant Consortium, Ocean Springs, Miss. 325 pp.

Schroeder, W.W. 1978. Physical environment atlas of coastal Alabama. Pub. No. MASGC 76-034-(1977's). Miss/Ala Sea Grant Consortium, Ocean Springs, Miss. 62 pp.

Schroeder, W.W. and R. Horton. 1980. 1979 meteorological data, Dauphin Island, Alabama. Rept. No. 80-001, Dauphin Island Sea Lab, Dauphin Island, Ala. 25 pp.

Schroeder, W.W., R. Horton and L. Lutz. 1979. 1978 meteorological data summary, Dauphin Island, Alabama. Report No. 79-001 Dauphin Island Sea Lab, Dauphin Island, Ala.

Schroeder, W.W. and W. Wiseman. 1985. An analysis of the winds (1974-1984) and sea level elevations (1973-1983) in coastal Alabama. Publ. No. MASGP-84-024, Miss/Ala Sea Grant Consortium, Ocean Springs, Miss. 102 pp.

Dr. Kenneth Heck has worked at the Alabama Marine Environmental Science Consortium since 1986 and at present serves as Research Director. He is also a Professor in the Department of Biological Sciences and is on the staff of the Coastal Research and Development Institute at the University of South Alabama. His research interests are in marine ecology with special emphasis on the role of seagrasses in coastal ecosystems. Dr. Heck received his B.S. in biology from the University of West Florida and his M.S. and Ph.D. in biology from Florida State University.

RESEARCH OVERVIEW FOR UNIVERSITY OF SOUTHERN MISSISSIPPI, CENTER FOR MARINE SCIENCE, STENNIS SPACE CENTER, MISSISSIPPI

Dr. George A. Knauer
Center for Marine Science
University of Southern Mississippi

PROGRAM OF STUDY

The University of Southern Mississippi (USM) has been given the leadership role in marine science by the Board of Trustees of State Institutions of Higher Learning. To accomplish this goal, the USM in 1985 established the Center for Marine Science (CMS) at the John C. Stennis Space Center (SSC), located near Bay St. Louis, Mississippi.

The CMS offers multidisciplinary master's and doctoral programs in biological, geological, and physical oceanography, and marine chemistry.

The USM also administers the Gulf Coast Research Laboratory (GCRL) in Ocean Springs, Mississippi, an agency widely recognized for its diversified marine science educational, research, and service programs.

The continental shelf/open-ocean emphasis of CMS is enhanced by GCRL's primary focus on Mississippi's estuarine and coastal environments. The cooperative mission of these previously independent organizations, coupled with the naval oceanographic expertise available at SSC, enables USM to offer a comprehensive academic program for graduate students in marine science.

The CMS offers courses during both the fall and spring semesters, while GCRL schedules graduate and undergraduate classes during the summer. Students who wish to enter the degree program should apply for admission as soon as possible after the fall semester because a limited number of graduate stipends are available on a competitive basis to qualified students.

RESEARCH FACILITIES

The CMS at present occupies offices and laboratories in Building 1105 and Trailers 242 and 246 located in SSC's central area. Our program is developing rapidly, and we have a considerable array of research equipment available, including spectrophotometers, analytical balances, high pressure liquid chromatographs, research grade dissecting microscopes, epifluorescence and phase contrast microscopes, fluorometers, carbon-nitrogen analyzers, liquid scintillation counters, deep-sea camera systems, mooring systems, conductivity/temperature/depth instruments, sediment traps, and various computer systems for data reduction, manipulation, and graphics. Construction of a clean laboratory and phytoplankton culture facility is underway.

Students may interact with SSC marine scientists from many disciplines who have state-of-the-art equipment ranging from gas chromatograph/mass spectrometers to scanning electron microscopes. Students may wish to interact with those marine-oriented faculty located on the main campus in Hattiesburg, who also have well-established programs and laboratories. The departments of biological sciences and geology have programs of study with marine emphasis.

The GCRL scientific staff represents expertise in analytical and environmental chemistry, botany, ecology, geology, microbiology, toxicology, microscopy, parasitology, physical oceanography, invertebrate zoology, systematic zoology, fisheries, fisheries management, and aquaculture.

The GCRL's Ocean Springs and Biloxi campuses offer excellent facilities and instrumentation to support these areas of study. The Ocean Springs campus has a student dormitory. Additionally, the Laboratory supports a research fleet that includes the R/V *Tommy Munro*, a 97-ft. oceanographic research vessel.

Field studies, in addition to classroom and laboratory expertise, are an integral part of the GCRL summer program. Students with instructors who have extensive field knowledge, have an unique opportunity to observe plants and animals in their natural habitats.

Many of the Center's faculty have ongoing research grants through the division of ocean sciences of the National Science Foundation and, therefore, have access to research vessels operated by the University National Oceanographic Laboratory System. Graduate student participation in at-sea research is highly encouraged.

Center faculty and students are becoming increasingly involved in new global-scale studies to determine elemental cycles and the flux of particulate material and gases through the world ocean. These studies are truly interdisciplinary and require interaction among scientists of all areas of oceanography. Additionally, CMS is developing a research program in remote sensing of the oceans using sensors such as synthetic aperture radar, altimeters, and Advanced Very High Resolution Radiometer. Research into fundamental problems is conducted in the Gulf of Mexico and Gulf Stream region.

RESEARCH PROGRAM

The research of both faculty and students at CMS is funded in part by several agencies including the National Science Foundation, the Office of Naval Research, the Naval Oceanographic and Atmospheric Research Laboratories (NOARL, formerly NORDA), and the National Oceanic and Atmospheric Administration. Active research projects at CMS cover diverse topics including:

- The development of *in situ* camera systems to measure the abundance and flux of marine snow aggregates.
- Microbial dynamics and relation to physical and chemical oceanographic processes.

- Studies of the sources, fate, transport, and deposition of marine snow in the Black Sea and Lake Baikal.
- Time-series studies of primary production and particulate organic carbon and nitrogen fluxes.
- Free-floating sediment traps in the Sargasso Sea near Bermuda.
- Biostratigraphy and paleoenvironmental analysis of neogene marine sciences.
- Remote sensing of the evolution of fronts and eddies.
- Wave-current interactions and their effect on remote sensing.
- Acoustic reverberation from the sea floor.

REGULAR ON-SITE
ADJUNCT FACULTY

- R. A. Arnone, M.S., Georgia Tech., 1974. Adjunct Professor, NOARL. Research interests: remote sensing, ocean optics.
- J. D. Boyd, Ph.D., Texas A&M University, 1986. Adjunct Professor, NOARL. Research interests: mesoscale oceanography and use of aircraft in oceanography.
- M. R. Bradley, Ph.D., University of Virginia, 1977. Adjunct Professor, PSI. Research interest: applied mathematics.
- P. Fleischer, Ph.D., University of Southern California, 1970. Adjunct Professor, NOARL. Research interests: marine sediments and depositional processes.
- Z. R. Hallock, Ph.D., University of Miami, 1977. Adjunct Professor, NOARL. Research interests: ocean circulation, mesoscale variability, geophysical fluid dynamics.
- B. J. Little, Ph.D., Tulane University, 1983. Adjunct Professor, NOARL. Research interests: chemistry and microbiology of corrosion.
- R. L. Miller, Ph.D., North Carolina State University, 1984. Adjunct Professor. Research interests: biological oceanography, remote sensing, image processing, statistics, microcomputers, and software development.
- H. T. Perkins, Ph.D., MIT/Woods Hole Oceanographic Institution, 1970. Adjunct Professor, NOARL. Research interests: waves and tides; statistics and time series analysis; theory of ocean circulation.
- K. D. Saunders, Ph.D., MIT/Woods Hole Oceanographic Institution, 1971. Adjunct Professor, NOARL. Research interests: variability of currents and internal waves in the upper oceans, geophysical fluid dynamics.
- A. V. Stiffey, Ph.D., Fordham University, 1981. Adjunct Professor, NOARL. Research interests: environmental science and microbiology.
- J. D. Thompson, Ph.D., Florida State University, 1974. Adjunct Professor, NOARL. Research interests: dynamic oceanography, numerical modeling, remote sensing.
- D. K. Young, Ph.D., University of Hawaii, 1966. Adjunct Professor, NOARL. Research interests: structure and function of marine communities.

REGULAR FULL-TIME
FACULTY

- V. L. Asper, Ph.D., MIT/Woods Hole Oceanographic Institution, 1986. Assistant Professor, CMS. Research interests: production, distribution and fate of large particle sediment traps; deep-sea camera systems.
- C. A. Brunner, Ph.D., University of Rhode Island, 1978. Associate Professor, CMS. Research interests: paleooceanography, taphonomy, biostratigraphy and global climatic change.
- S. P. Dinnel, Ph.D., Louisiana State University, 1988. Assistant Professor, CMS. Research interests: physical oceanography, estuarine-shelf processes, coastal circulation.
- R. R. Goodman, Ph.D., University of Michigan, 1958. Research Professor, CMS. Research interests: underwater acoustics, physical oceanography, ocean engineering.
- G. A. Knauer, Ph.D., Stanford University, 1972. Professor and Director, CMS. Research

interests: primary productivity, pelagic energy flux, trace metals in marine waters and organisms.

- S. E. Lohrenz, Ph.D., MIT/Woods Hole Oceanographic Institution, 1985. Assistant Professor, CMS. Research interests: microbial dynamics, comparative studies of phytoplankton and bacteria, physical-biological interactions.

- T. D. McIlwain, Ph.D., University of Southern Mississippi, 1978. Professor, CMS. Research interests: fisheries management, biology of estuarine fishes including life history and population analysis, culture of fishes and invertebrates.

- D. G. Redalje, Ph.D., University of Hawaii, 1980. Assistant Professor, CMS. Research interests: phytoplankton physiological ecology and biochemistry, mass culture of microalgae.

- D. Sheres, Ph.D., Scripps Institution of Oceanography, 1980. Associate Professor, CMS. Research interests: wave-current interactions and remote ocean sensing.

- A. M. Shiller, Ph.D., Scripps Institution of Oceanography, 1982. Assistant Professor, CMS. Research interests: trace element geochemistry, carbon dioxide system, estuarine geochemistry.

Dr. George A. Knauer received his Ph.D. from Stanford University in 1972. Dr. Knauer has been Professor and Director of the Center for Marine Science since 1985. His research interests include primary productivity, pelagic energy flux, and trace metals in marine waters and organisms.

RESEARCH OVERVIEW FOR GULF COAST RESEARCH LABORATORY, OCEAN SPRINGS, MISSISSIPPI

Dr. Thomas D. McIlwain
Gulf Coast Research Laboratory

INTRODUCTION

The Gulf Coast Research Laboratory (GCRL) is Mississippi's institution of higher learning for research, education, and service in the marine sciences. Now under the administration of the University of Southern Mississippi (USM), GCRL provides full-time, year-round marine research; professional marine science education; public education pertaining to the marine environment; assistance and advisory services to Mississippi's fisheries and seafood industries; professional and technical support to governmental regulatory agencies; and advisory services and assistance involving coastal problems to state, city, and county governmental entities.

The GCRL is affiliated with 59 colleges and universities in Mississippi and 14 other states to provide academic training in the marine sciences to the students in these institutions. Formal lectures and regular courses are offered primarily in the summer and, on occasion, night courses for in-service science teachers are offered during the academic year. The summer teaching faculty includes visiting professors, in addition to the GCRL faculty.

The Graduate Research Program provides facilities, training, and supervision to resident graduate students working on master's and doctoral degrees in various fields of marine science. Graduate students typically complete their basic course requirements at the USM main campus; the USM Center for Marine Science (CMS), at Stennis Space Center, Mississippi; or on the main campus of one of the other 59 affiliated institutions, before their residency at the Laboratory.

LABORATORY HISTORY

The GCRL was created in 1947 as a summer institute by the Mississippi Academy of Sciences. In 1950 the Mississippi Legislature chartered the Laboratory and placed it under the control of the Board of Trustees of State Institutions of Higher Learning. In 1988 GCRL was placed under the administrative control of the University of Southern Mississippi.

The Laboratory is located on 45 acres on the shores of Mississippi Sound in Ocean Springs, Mississippi. The Biloxi, Mississippi, campus, where the Laboratory's J. L. Scott Marine Education Center and the oceanographic research vessel *Tommy Munro* are located, comprises an additional 16 acres. Both facilities are located in a richly productive estuarine area that serves as a nursery area for many commercial and recreation seafood species.

SENIOR SCIENTIFIC PERSONNEL

The senior scientific staff is composed of 20 personnel, 18 of who have Ph.D. degrees. Key personnel and their area of expertise are listed below.

- Dr. Thomas D. McIlwain, Director, Fisheries
- Dr. Harold D. Howse, Director Emeritus, Microscopy
- Dr. David W. Cook, Assistant Director, Microbiology
- Mr. William J. Demoran, Oyster Biology
- Dr. Charles K. Eleuterius, Physical Oceanography
- Dr. Lionel N. Eleuterius, Marine Botany
- Dr. William E. Hawkins, Microscopy
- Dr. Richard Heard, Invertebrate Biology
- Dr. Jeff M. Lotz, Aquaculture
- Dr. Joanne Lyczkowski-Shultz, Larval Fish Biology
- Dr. Julia S. Lytle, Environmental Chemistry
- Dr. Thomas F. Lytle, Analytical Chemistry
- Dr. James T. McBee, Coastal Ecology
- Dr. Ervin G. Otvos, Geology
- Dr. Robin M. Overstreet, Parasitology
- Mr. Allison Perry, Fisheries Assistance
- Dr. Stuart Poss, Systematic Zoology
- Dr. John P. Steen, Coastal Ecology
- Dr. Sharon H. Walker, Marine Education
- Dr. William W. Walker, Toxicology

ADJUNCT FACULTY

- Dr. R. B. Channell, Professor, Biology Department, Vanderbilt University, Nashville, Tenn.

- Dr. J. I. Jones, Executive Director, Mississippi-Alabama Sea Grant Consortium, Ocean Springs, Miss.

- Dr. P. M. Biesiot, Department of Biology, University of Southern Mississippi, Hattiesburg, Miss.

CURRENT RESEARCH PROGRAMS

The GCRL has a variety of expertise for investigating the Gulf of Mexico waters. The research staff conducts year-round, full-time applied and basic research in various fields that are reflected in the following sections.

- Analytical Chemistry--Investigates a broad range of issues from determination of nutritional components of Gulf fishes to determination of chemical and physical properties of organotins under bioassay conditions. In addition, investigates inorganic pollutant levels in resident organisms and determines movement of anthropogenic wastes through the northern Gulf estuaries.

- Botany--Research on plant life of Mississippi's estuaries, marine ecosystems, sand beaches and dune habitats, with concentration on the systematics, physiology and ecology of tidal marsh plants, sea grasses and sand dune species.

- Ecology--Conducts research on the rate of photosynthesis by phytoplankton in relation to the concentration of chlorophyll and other plant pigments; the composition of the phytoplankton community and light intensity; and examines benthic community structure.

- Environmental Chemistry--Investigates the seasonal and biological variabilities in fatty acid content of Gulf finfish and crustaceans; assays fatty acid mixtures used in biomedical research; investigates nutritive properties of various food materials for shrimp aquaculture; and examines various indigenous plants for ability to interact with polynuclear aromatic hydrocarbons.

- Oyster Biology--Studies the population dynamics of major oyster reefs in Mississippi Sound.

- Fisheries/Aquaculture--Monitors commercially and recreationally important finfish and shellfish from the northern Gulf region and generates data sets used to provide stock assessment information to various State and Federal management agencies, also documents life histories of various species. Fisheries has an extensive aquaculture research program aimed at parasites and diseases and spawning marine shrimp; development of culture technology for various finfish species, including red drum, striped bass, and Tilapia.

- Geology--Conducts interdisciplinary studies of bottom-sediments of Mississippi coastal water bodies; conducts field surveys of beach accretion-erosion cycles; conducts detailed investigations of Pleistocene-Holocene geological history of coastal plains of inshore and nearshore Gulf areas.

- Invertebrate Zoology--Conducts ecological surveys of local invertebrate fauna, including extensive baseline studies on Mississippi barrier islands.

- Microbiology--Studies the microflora of seafoods concerning product quality and public health. Other studies are conducted on bacterial pathogens of aquaculture species, autochthonous estuarine pathogens, and indicator bacteria in the estuarine environment.

- Microscopy--Conducts research on histological and ultrastructural aspects of organs, tissues, and cells of marine and freshwater organisms, possibly resulting from effects of carcinogens and other environmental toxicants.

- Parasitology--Studies various aspects of parasites and diseases of marine and estuarine animals, such as taxonomy, morphology, life histories, ecology, pathology, and public health.

- Physical Oceanography--This group teams with the researchers at CMS to conduct research on estuarine hydrodynamics and physicochemical processes and characterization of estuaries, air-sea interaction, hydraulic processes in marshes, and dynamics of estuarine fronts, continental shelf circulation and cross-shelf processes.

- Systematic Zoology--Research on taxonomy, systematics, and distribution of sub-tropical and tropical marine and estuarine fishes.

- Toxicology--Studies the fate and disposition of xenobiotics in natural environments, including assessment of degradation rate kinetics, effects on degradation rate of environmental parameters and geographic site, comparison of laboratory systems to field evaluations in predicting environmental fate of various chemicals, and assessment of toxicity concerning degradation of parent compounds using indigenous fish and crustaceans. Additional research is focused on the effect of pollutants on developing aquatic communities.

In support of this extensive research effort, the Laboratory maintains the Gunter Library that contains 26,000 cataloged reprints, 10,000 books, and 1,000 journal titles. Additional research support facilities include the Ichthyology Research Collection, which contains about 20,410 catalogued lots of fishes representing over 200,000 specimens comprising 251 families and 2,700 species. The Laboratory also maintains a Water Analysis Laboratory and the William M. Shoemaker Toxicology Laboratory to support its extensive research effort.

Additionally, the Laboratory operates a fleet of research vessels, including the oceanographic ship *Tommy Munro*, which has an overall length of 98 ft., beam of 25 ft., and draft of 12 ft. This vessel carries an ABS certification for operation in all oceans.

Besides the extensive research effort outlined above, the Laboratory operates the J. L. Scott Marine Education Center located on the Biloxi, Mississippi, campus. The Center is the Laboratory's main public-use facility and provides living and static displays of flora and fauna in the aquarium room and lobby. The large public aquarium area is designed to inform the public of the diversity and importance of our estuarine and marine environment. Through this Center the Laboratory offers "Project Marine Discovery," a unique field-trip program for kindergarten through high school students during the academic year and summer months. Once a month throughout the year, a program called "An Evening at the Aquarium" is held. This is a family-oriented lecture program aimed at informing the public about current issues relating to the marine environment.

Dr. Thomas McIlwain has worked at the Gulf Coast Research Laboratory for the past 24 years and currently serves as its Director. Dr. McIlwain is currently the President-Elect of the Southern Association of Marine Laboratories. His areas of research interest are marine fisheries management and biology and ecology of the fishes of the Gulf area. Dr. McIlwain received his B.S., M.S., and Ph.D. in zoology from the University of Southern Mississippi. He has been intimately involved in fisheries management and fishery development in the Gulf for the past 12 years.

RESEARCH OVERVIEW FOR LOUISIANA UNIVERSITIES MARINE CONSORTIUM LABORATORY, CHAUVIN, LOUISIANA

Dr. Michael Dagg
Louisiana Universities
Marine Consortium

Presentation Summary text not submitted.

RESEARCH OVERVIEW FOR LOUISIANA STATE UNIVERSITY, DEPARTMENT OF OCEANOGRAPHY AND COASTAL STUDIES, BATON ROUGE, LOUISIANA

Dr. R. Eugene Turner
Louisiana State University

Presentation Summary text not submitted.

RESEARCH OVERVIEW FOR LAMAR UNIVERSITY, CENTER FOR COASTAL AND MARINE STUDIES*, BEAUMONT, TEXAS

Dr. Thomas S. Bianchi
and
Dr. David Bechler
Lamar University

INTRODUCTION

Lamar University's Center for Coastal and Marine Studies (CCMS) is located on Pleasure Island, Port Arthur, on the upper Texas coast along the shore of the Sabine-Neches estuary. The center was recently established in 1989 to serve as a base for research and teaching functions in the Marine Sciences program at Lamar University. In particular, the departments of biology, geology, and civil engineering have been most active conducting research on the Sabine-Neches estuary. For example, in biology alone there have been 23 master's theses as well as some publications and reports on research related to this coastal ecosystem. The primary focus of CCMS is to continue research on nearshore coastal processes that will provide essential information for making sound ecological management decisions in the future.

Low-salinity systems such as the Sabine-Neches estuary are unique when compared to the other hypersaline systems on the lower Texas coastline. Unfortunately, most of the studies to date have concentrated on the hypersaline estuaries in the state. In regard to our recent membership in the Southern Association of Marine Laboratories, we are particularly interested in providing an opportunity for scientists from other institutions to work in collaboration with CCMS scientists on this predominantly fresh-water estuarine system. In the following section we provide information on some ongoing projects associated with CCMS and other affiliated departments.

SYNOPSIS OF CURRENT RESEARCH PROJECTS

Behavior and Life-History studies

David Bechler of the biology department has been conducting research on the behavioral ecology of estuarine crustaceans and fishes. Specifically he has examined agonistic and reproductive behaviors of common estuarine organisms. He is particularly interested in life history traits such as longevity, fecundity, frequency of spawning, and the spatio-temporal periodicity of reproduction. Past work has involved the reproductive and behavioral biology of the goby, *Gobiosoma bosci* and agonistic behavior of the xanthid crab, *Rhithropanopeus harrisii*. Currently he is working on the effects of differential foraging on weight gain and fecundity in the Atlantic croaker, *Micropogon undulatus*. Other preliminary work involved the discernment of biological and physical factors that control spawning behavior in *G. bosci*.

In another project Dr. Bechler is examining the physicochemical and biological parameters influencing the spatio-temporal distribution of the anchovy, *Anchoa mitchelli*, in the Sabine-Neches

*Presented as hand-out at the Information Transfer Meeting estuary. By taking this new approach he hopes to be able to develop a better understanding of how various environmental factors control the distribution and abundance of crustaceans and fishes in estuarine systems.

Biogeochemical Dynamics of
Food Webs in Estuarine Ecosystems

Having recently arrived in the biology department at Lamar University, Thomas S. Bianchi has begun some preliminary research that examines the food web dynamics of benthic and pelagic systems in the Sabine-Neches estuary. More specifically, he will be using plant pigments (i.e., chlorophylls and carotenoids) as tracers of inputs of organic matter sources to the estuarine food web. In conjunction with the Environmental Chemistry Laboratory and Chromatography Institute at Lamar University, he will be using state-of-the-art techniques such as high pressure liquid chromatography (HPLC) to determine the relative trophic importance of these different source materials to benthos and fishes in the Sabine-Neches estuary.

In another project, Dr. Bianchi is collaborating with Paul Buonora of the chemistry department, where they will investigate carbon dynamics of decomposing organic matter sources from the Sabine-Neches estuary using Nuclear Magnetic Resonance and HPLC. More specifically, they will examine the structural changes in carbon bonding and plant pigments during the decay of different resources collected from the estuary. Then, they will examine how carbon bonding and pigment composition relate to the heterotrophic breakdown of recalcitrant and labile carbon sources.

Toxicological and Environmental Studies

Richard C. Harrel and his graduate students in the biology department have been studying community structure of macrobenthos in the Neches River and the Taylor Bayou estuaries, adjacent marshes, and upstream waters for over 20 years. These long-term data sets provide rare and useful information for evaluating environmental stability based on populations that are primarily controlled by stochastic processes. Emphasis has centered on effects of industrial and municipal effluents, oil spills, methods of oil spill clean-up, and dredging of the navigation channel. Other studies have been conducted on the toxicity of heavy metals, herbicides, and pesticides on local aquatic organisms. Current research is centered on laboratory and field investigations on the use of *Rangia cuneata*, the brackish water clam, as a biomonitor of toxic substances in Gulf coast estuaries and inland waters.

Epidemiological Studies

Madelyn D. Hunt of the biology department has studied seroepidemiology of cholera in Gulf coastal Texas. Titers of vibriocidal antibodies were studied in different segments of the population in regard to exposure to seawater and shellfish. The results indicated that an endemic focus of infection with *Vibrio cholerae* occurs in the area. Future studies will focus on clean-up of hydrocarbon wastes by bioremediation.

Historic and Current Shoreline Erosion

A study of historic coastal position in the upper coastline from 1930 to 1990 was begun in 1986 by Donald E. Owen of the geology department at Lamar University. The study site is located between Texas Point at Sabine Pass and Sea Rim State, Texas. Historic aerial photography (first flown during 1930) and ground and aerial observations during the past five years provide the data base. Hurricanes are an important contributor to shoreline erosion in the study area, and observations have been made after the three hurricanes since 1986. However, processes such as subsidence, sea-level rise, and sand starvation are more important. Since 1930, shoreline recession has averaged 5 m per year, although greatly variable during hurricane years.

Paleoecological Studies

James W. Westgate of the geology department at Lamar University has three ongoing projects involving the paleoecology of the Texas coastline:

- Fossils found at Laredo, Texas indicate that a *Nypa* mangrove community existed on the Texas coast about 42 million years ago. Pollen, spores, and plant megafossils provide evidence for the presence of a lycophyte, seven ferns, a conifer and at least 10 species of angiosperms including *Nypa*, the mangrove-forming palm. Biogeographic distributions of these fossil taxa indicate that the deposit was formed in a tropical estuary with salinities of about 10 parts per thousand. The waters were wave sheltered and warmer than 24°C.

- Beach samples from Baffin Bay, Texas, have yielded a micro-mammal fauna represented by teeth and bones of rodents and insectivores. The beach sediments are primarily whole and broken shells of small marine bivalves and gastropods which live in hypersaline waters in Baffin Bay. Additional beach samples are being processed to enlarge the mammalian fauna. This taphonomic analysis is intended to shed light on the anomalous occurrences of fossil terrestrial mammal remains in marginal marine deposits.

- Excavation of drainage canals through deposits of the pleistocene Beaumont Formation near Lyford, Texas, exposed remains of numerous individuals and nesting sites of the giant gopher tortoise, *Gopherus hexagonatus*. Tortoises were buried in the flood plain-levee complex of the Rio Grande River during a sea level high stand. The deposit is 12,000-60,000 years old. Additional specimens are being collected to help indicate the cause of mortality, refine the age of the deposit, and help clarify the history of sea level rises on the south Texas shoreline.

SUMMARY

The aforementioned research activities at CCMS represent the early stages of a growing marine science program at Lamar University. The current research interests in land-margin ecosystems by the National Science Foundation, Sea Grant, and other funding agencies, demonstrate the need for coastal research facilities. Because of the inter-disciplinary approach needed to conduct successful research at the ecosystem level it is necessary for regional laboratories to communicate and thus insure collaborative efforts. This Information Transfer Meeting has provided an excellent opportunity for different regional institutions to exchange ideas and thereby encourage the collaborative effort needed for successful work in the Gulf of Mexico.

Dr. Thomas S. Bianchi is an assistant professor in the biology department at Lamar University. His areas of research interests are biogeochemical dynamics of marine food webs and ecosystem ecology. Dr. Bianchi received his M.A. in ecology and evolution at State University of New York, Stony Brook, and his Ph.D in marine sciences from University of Maryland.

Dr. David Bechler is an associate professor in the biology department at Lamar University. His areas of research interests are behavioral and life-history strategies of estuarine crustaceans and fishes. Dr. Bechler received his M.S. in biology at Northeast Louisiana University and his Ph.D in biology at St. Louis University.

RESEARCH OVERVIEW FOR TEXAS A&M UNIVERSITY AT GALVESTON, TEXAS

Dr. Andre M. Landry, Jr.
Texas A&M University - Galveston

INTRODUCTION

Texas A&M University at Galveston (TAMUG) is the marine and maritime component of the Texas A&M University (TAMU) System. The University provides academic instruction in seven marine and maritime-related degree programs leading to the Bachelor of Science degree; there are cooperative graduate degree programs at both the master and doctoral level with the Departments of Oceanography, Biology, and Wildlife and Fisheries Sciences at TAMU at College Station.

The University has two campuses - the 100-acre Mitchell Campus on Pelican Island and the 3-acre Ft. Crockett Campus on Galveston Island. An additional 15,200 sq. ft. of space are occupied by University researchers at the National Marine Fisheries Service Laboratory at Ft. Crockett. Galveston and Pelican Islands are located at the mouth of Galveston Bay with access to the Gulf of Mexico only minutes away.

RESEARCH PROGRAMS

Research at TAMUG is housed under two administrative units, the Texas Institute of Oceanography (TIO) and the Coastal Zone Laboratory (CZL). Although each unit has its own administrative responsibility (e.g., funding), there is some overlap among their constituent research programs. A brief description of these administrative units is given below.

The TIO, established under the auspices of the TAMU System, is directed by Dr. William J. Merrell, President of TAMUG. The TIO provides services for all research institutions in Texas. Its mission (1) provides focus for research on the Gulf coast, (2) assures scientists at Texas universities of suitable multi-user facilities, (3) provides research and technological base for development of marine-related businesses in the State of Texas and Gulf of Mexico, (4) facilitates management and coordination of academic marine research programs of Texas, and (5) facilitates management of regional Federal programs.

The CZL is a TAMUG-based administrative entity under the direction of Dr. C. S. Giam. The CZL has two main functions: (1) administer and coordinate all research at TAMUG, and (2) report on all TAMUG research activities and funding to the Texas Coordinating Board.

Research at TAMUG is housed in four major program areas. These program areas include (1) Coastal Processes, (2) Texas Shelf Processes, (3) Marine Policies and Management, and (4) Climate Change in Texas. There is considerable variation in the degree of research development across these four program areas. Consequently, the primary focus of this presentation will be on research within the best established program, Coastal Processes. However, a brief description of the other three research programs is warranted prior to discussion of Coastal Processes.

The Texas Shelf Studies Program incorporates research efforts concentrating on basic research in physical, biological, chemical and geological oceanography, geophysics, and ocean engineering in Gulf of Mexico offshore and other deepwater environments. The TIO plays a vital role in this program by providing researchers access to the latest technology for analyzing water, sediment and core samples and vessel time to collect these samples.

The Marine Policies and Management Program facilitates research providing marine policy for coastal zone management, risk assessment from which seafood safety regulations may be developed, and environment/ecosystem educational outreach programs targeted to State and Federal agencies and legislative bodies. Examples of research projects under this program include factors affecting recreation/tourism in the coastal zone, impact of science on environmental policy and the economic consequences of this policy, oil prices and the U.S. economy, and humanities and life along the coast.

Research in the Climate Change and Texas Program is attempting to determine how human activities and natural forces are influencing climate. The TAMUG is fortunate to have a MACSAT real-time satellite imaging computer system for monitoring weather and ocean temperatures. The TIO is working with TAMU at College Station to establish a university-wide Center for Advanced Climate Studies to provide a focus for systematic research on the physical basis of climate changes, its prediction, and related policy issues.

The best developed research program area at TAMUG is the Coastal Processes Program. This program provides an umbrella of research focused primarily on Galveston Bay and vicinity. Specific research interests included in the Coastal Processes umbrella are (1) Marine Chemistry and Toxicology, (2) Physical Oceanographic Processes and Modeling, (3) Galveston Bay Information Center, and (4) Marine Life Sciences.

Research projects in marine chemistry and toxicology are of dual purposes, namely understanding (1) transport and transfer processes and toxicological effects of organic pollutants and (2) transport and transfer processes of trace metals and radionuclides. Dr. C. S. Giam directs TAMUG's research efforts in organic pollutant processes and toxicological effects. Constituent research projects have developed a routine facility to characterize highly complex mixtures of organic pollutants in all media at parts per billion and parts per thousand concentrations. This level of sensitivity is essential for monitoring chronic low level pollution. The Giam research group is also interested in using biochemical and physiological responses in animals as indicators of environmental pollutants. They have focused on identification of marine fish species that are sensitive to effects of carcinogens and on detection of early changes through DNA-adducts that are indicative of long-term effects. Dr. Giam has been correlating laboratory observations with results from field studies in an attempt to identify "field sensitive species." Lastly, the Giam team is investigating the atmospheric transfer of anthropogenic (man-made) pollutants from industrial complexes to the world's oceans.

The trace metal and radionuclide research team is headed by Dr. Peter Santschi. This research effort is targeting four specific objectives. The first of these is geochronology and tracer applications in water and sediments, including studies of climate change using alpha-, beta- and gamma-counting and mass spectrometry of primordial, cosmogenic and anthropogenic nuclides. A second research objective is determining the self-cleaning capacity of natural water bodies, with particular emphasis given to mechanisms of solute-particle and sediment-water interactions. Thirdly, Dr. Santschi's group is assessing the importance of chemical speciation in bioaccumulation and bioavailability of trace metals in coastal waters of Texas. Lastly, the dynamics and characteristics of sedimentation and water circulation are being studied. Model development plays an important role in Dr. Santschi's trace metal/radionuclide studies.

The Physical Oceanographic Processes Program incorporates research projects designed to develop computer models of Galveston Bay processes. Several researchers, including Drs. Robert Whitaker, Doug Klein, Thomas Schmalz, Jerry Hite, Fred Schlemmer and Joseph Szucs, are directing various modelling efforts. The objectives of this modelling program include (1) pollutant diffusion in Galveston Bay, (2) flow patterns and tides in the Bay, (3) circulation model of the Bay, (4) boundary-fitted orthogonal grid system for the Bay, (5) temporal and spatial scales of variation in physical properties in the Bay, and (6) population genetics. One nearly completed project is a calibrated model examining circulation, salt-flux mechanisms and maintenance of the salt balance in Galveston Bay. This model will be capable of predicting velocity and salinity fields as a function of wind, freshwater inflow, tides and topography.

In addition to the modeling studies, all material on Galveston Bay is being compiled and cataloged in the Galveston Bay Information Center located at TAMUG. This center provides a bibliography and special reference collection of Galveston Bay literature and media for use by the scientific community and general public. Currently, the bibliography contains 3,200 resources. The Information Center is scheduled to open in February 1991.

Another well-developed research component of the Coastal Processes Program is the Marine Life Sciences. Constituent research areas within the Marine Life Sciences are threefold: (1) endangered species, (2) mariculture and seafood safety, and (3) ecological sciences. The TAMUG's endangered species research program is currently targeting marine mammal and sea turtle stocks. To this end, TAMUG has initiated a Marine Mammal Research Program consisting of a core of five researchers with expertise in various facets of marine mammal biology. Dr. Bernd Würsig, a behavioral ecologist, is Director of this program. Other core researchers include Drs. William Evans, an acoustician; Randy Davis, a physiologist; Graham Worthy, a physiological ecologist; and Raymond Tarpley, a veterinarian and anatomist. Collectively, this group is involved in research activities that include (1) energetics, growth and nutritional factors of cetaceans; (2) advanced remote sensing techniques based on bioacoustics; (3) causes of mortality in stranded bottlenose dolphins; and (4) behavioral ecology of deep water marine mammals.

The other endangered species component of the Marine Life Sciences area is sea turtle natural history. Research efforts involve collaborative efforts between Drs. Andre Landry and Ray Sis and the National Marine Fisheries Service Galveston Laboratory. Targeted investigations within the sea turtle research program include (1) natural history of nearshore Gulf and Texas estuarine stocks, (2) causes of mortality in stranded sea turtles, and (3) necropsy protocol and criteria for determining cause of death. Turtle netting surveys and tag-release recapture experiments are being deployed to define natural history of nearshore stocks. Aerial surveys have been initiated to document nesting activity along Texas beaches and occurrence in nearshore waters. Additional natural history and mortality information have been generated by the necropsy of stranded carcasses.

The mariculture and seafood safety research element of the Marine Life Sciences is targeted to oyster biology and pathogens associated with oysters. Drs. Sammy Ray, Leonard DiMichele, Donald Lewis, and John Schwarz are principal investigators of research projects involved with the following objectives: (1) evaluation of coal combustion by-products as oyster reef substrate; (2) development of hatchery techniques to produce fast-growing, disease resistant strains of oysters; (3) determining feasibility of commercial production of cultchless oysters; and (4) detection and identification of a naturally occurring human pathogen, *Vibrio vulnificus*, associated with raw seafood.

The third constituent research program area under Marine Life Sciences is ecological sciences. This research element is targeted toward a broad-based approach to benthic and fisheries ecology. The benthic ecology section is led by Dr. Donald Harper, whose research projects aim to understand (1) long-term trends in benthic species composition and population dynamics and (2) effects of natural and man-made perturbations on benthic ecosystems. Drs. Andre Landry, James Webb, and William Wardle, plus research colleagues from the National Marine Fisheries Service Galveston Laboratory, conduct the majority of fisheries ecology research. Objectives of these research efforts are two-fold: (1) age and growth of commercial/recreational species and (2) role of wetlands as habitat for fisheries species.

Dr. Andre Landry, Jr. is an Associate Professor and Deputy Director of Texas A&M University's Galveston Marine Laboratory. His research interests include fisheries ecology and sea turtle biology. Dr. Landry received his B.S. in zoology from Tulane University, and his M.S. and Ph.D. in wildlife and fishery science from Texas A&M University.

RESEARCH OVERVIEW FOR THE TEXAS PARKS AND WILDLIFE DEPARTMENT, PERRY R. BASS MARINE FISHERIES RESEARCH STATION, PALACIOS, TEXAS

Mr. Paul C. Hammerschmidt
Marine Fisheries Research Station
Texas Parks and Wildlife Department

INTRODUCTION

The subject of my presentation at the 11th Annual Minerals Management Service Information Transfer Meeting is current research at the Perry R. Bass Marine Fisheries Research Station (MFRS). The station was originally established as a marine finfish hatchery. It has evolved over the last 20 years into an important and respected marine research station.

Organizationally, the MFRS is under the direction of the Coastal Fisheries Branch and the Fisheries Division of the Texas Parks and Wildlife Department (TPWD).

The TPWD is Texas' principal wildlife and fisheries resource management agency. Consequently, the Coastal Fisheries Branch is responsible for providing information and making management recommendations, derived from our data analyses, to the TPWD Commission regarding the State's saltwater fishery resources within the bays and estuaries and out to nine nautical miles in the Gulf of Mexico.

The scope of this responsibility covers the coastal fisheries conducted in Texas' 4 million acres of salt water by about 20,000 commercial fishermen and an estimated 1.6 million recreational fishermen, which have a minimum economic impact of $1.9 billion annually.

CURRENT RESEARCH

The Coastal Fisheries Branch conducts fisheries research under three broad programs.

The first is Resource Monitoring. This program is designed to monitor routinely fisheries resources using bag seines, gill nets, beach seines, oyster dredges and otter trawls. The data gathered from these fishery-independent survey techniques provide long-term trend information on relative abundance, species size distribution, and population condition. Tag returns provide data on age, growth, movement and mortality. The standard routine survey techniques have proven invaluable in assessing the impacts of periodic environmental events like the freezes, the red tides, and recently, oil spills.

The second program is Harvest Monitoring. This program routinely surveys both recreational and commercial fishermen. Direct fishery-dependent interviews of fishermen and a self-reporting program provide us with long-term trend data on fishing pressure and harvest. Socioeconomic data are also obtained and are important in assessing the value of a particular fishery as well as the economic impact of major environmental events and/or changes in harvest regulations.

The third program, Marine Culture and Enhancement, involves my shop, the Perry R. Bass Marine Fisheries Research Station. My staff and I are responsible for conducting the types of research that require a little more controlled environment, either tanks, ponds, or laboratory. The majority of projects at the MFRS are partially funded by the U.S. Fish and Wildlife Service through the Sportfish Restoration Program, or fully funded by the State of Texas.

The MFRS is probably most well known for its pioneering research on red drum spawning in captivity using temperature/photoperiod manipulation and pond culture of larvae. The culmination of this research has been the construction of one, and soon two, State marine fish hatcheries, as well as the development of a large-scale red drum restocking program across the State. Red drum spawning technology is also being used by several commercial red drum hatcheries.

Current spawning and rearing research at the MFRS continues with red drum and includes spotted seatrout, snook, tarpon, and oysters. We have had good success in spotted seatrout spawning with the publication of a spawning and pond culture manual.

The mysteries of snook spawning continue to remain a mystery. Our tarpon project is currently a capture and maintenance program. We have been successful in maintaining tarpon in captivity, but currently do not have the facilities to hold mature individuals. The goal of our oyster project is to investigate ways to reestablish an oyster fishery in Corpus Christi Bay. It is progressing well with successful spawns obtained in the laboratory. We are gathering additional information about the Corpus populations through a spat set study we have just started.

Because the ability to distinguish groups of organisms from each other is essential to proper management of the resource, a major portion of our research involves investigations into fishery stock identification. Our research involves both physical and biochemical identification of stocks of various marine species.

Research in the biochemical arena includes the following:

- Assessment of Red Drum Mitochondrial DNA (MtDNA)--This series of studies is designed to compare the frequency of haplotypes of mitochondrial DNA in red drum juveniles and adults from the south Atlantic and Gulf of Mexico. Very simply, mitochondrial DNA is inherited solely from the female parent. Distinctive characteristics of this DNA may vary from stock to stock. These characteristics are very precise and are identifiable through complicated biochemical and analytical procedures.

  Dr. John Gold of Texas A&M University heads the projects that are variously supported by Marine Fisheries Research Initiative (MARFIN) and Sea Grant funds. The analyses are being conducted at Texas A&M. The MFRS staff, as well as resource and harvest personnel, have and are collecting many of the red drum samples needed for this study. Dr. Gold and his staff are conducting the MtDNA analysis.

- Allozyme investigations of Red Drum--This study compares the frequencies of allozymes and their variants in red drum juveniles and adults collected throughout the Gulf. Simply, we look at individual enzyme systems in which the enzyme molecule can take different forms yet perform the same function. These different forms (or alleles) are genetically determined by the fish's parents. Analysis of the frequency of occurrence of rare and common forms of these enzymes gives an indication as to how genetically similar or different groups of fish are from one another.

  The procedure involves extracting the proteins from tissue samples and placing them on a specially prepared starch gel. An electric current is run through the gel, causing the proteins to migrate. The distance they migrate through the gel is dependent upon the molecule's electric charge and weight. The gel is then sliced and stained for specific enzymes and the pattern of protein migration is determined. To date, MtDNA and allozyme analyses of red drum indicate that there is possibly one stock between the Atlantic and Gulf.

  In the process of conducting the allozyme analysis, four enzyme systems were discovered that carry alleles rare enough to allow development of a selective breeding program. These systems can be resolved simply from fin clip tissue. We are currently in the process of procuring red drum and examining them for these rare alleles. Most fish that carry the rare allele are heterozygous for that trait. In other words, they posses one gene that produces the common form and one that produces the rare form of the enzyme. Breeding these heterozygous fish together will result in offspring homozygous for the rare allele, meaning both genes result in the rare form of the enzyme.

  The offspring from this cross will undergo comparative biochemical, culture, growth and survival investigations. Once they are determined sound, the fish will be stocked into selected Texas bays for evaluation of the impact of a stocking program.

  We know the natural frequency of occurrence of this mark in the wild population. Therefore, any change in this frequency will be an indication of the presence of stocked fish in the population as determined by our bag seines and gill nets or in the creel of our recreational fishermen. We will have a direct assessment of the impact of our stocking program.

- Allozyme Investigations on Spotted Seatrout--A similar allozyme analysis was conducted on spotted seatrout from throughout the Texas coast. Generally, the analysis reveals a single stock throughout Texas with an interesting clinal increase in the frequency of occurrence of one allele from upper through lower coast. Further, one enzyme system found in spotted seatrout exhibited a rare allele that can also be resolved from fin clips. We are now pursuing a selective breeding program for spotted seatrout as well.

- Allozyme Investigations on Eastern Oysters--Allozyme investigations have also been conducted on Eastern oysters from Texas as a step toward identifying the range of stocks and as part of our program to reestablish an oyster fishery in Corpus Christi Bay. This study revealed that the oysters that live in high salinity South Bay in the lower Laguna Madre may be considered a different race from those found in the upper Laguna Madre northward along the Gulf coast. Those throughout the lower Laguna Madre are generally similar.

- Marine Finfish Polyploidy--We are currently investigating procedures for inducing polyploidy in marine finfishes using pressure, chemical and thermal shock induction. Animals that are polyploid have more than one set of chromosomes and will be easy to detect through DNA analysis. Additionally, it is theorized that these fish will not only be sterile, but will grow to a larger size than their normal diploid counterparts. This has not been investigated in marine fishes. We are in preliminary stages of experimentation. We wanted to work with spotted seatrout, but they were difficult to obtain. Our initial studies were conducted on red drum using thermal shock. Currently we have no positive results.

- Isoelectric Focusing Library--Another project at the MFRS is to compile a library of protein patterns generated via the technique of isoelectric focusing. Structural proteins are extracted from tissues such as muscle, eye lens, and so on and applied to acrylimide gels. Like the starch gels, an electric current is run across the gel. As the proteins reach their isoelectric focusing point, they stop moving. The pattern that develops following staining is unique to the species sampled.

  We are currently finishing a library on sciaenid finfishes and on penaeid shrimps. The work on penaeids has already been useful in positively identifying the "strange shrimp" found in the Brownsville shrimp channel as *Penaeus vannamei*, an exotic shrimp raised in aquaculture operations in Texas. We hope to eventually have diagnostic gels for all Texas marine finfishes and shellfishes when the project is over.

Research projects in stock identification using physical characteristics are as follows:

- Chemical Marking--We are also involved in evaluating methods to create a visible chemical mark in large numbers of hatchery reared fingerlings that will be stocked into the wild. Currently we have experimented with the antibiotic oxytetracycline (OTC), which chemically binds with calcium. So, when a fish grows, the OTC is incorporated into bone structure including spines, scales and otoliths. When OTC is illuminated with ultraviolet light, it fluoresces, thereby showing that we had treated the fish with OTC at one time in its life.

  We have seen major success with some experimental red drum, and we have completed the first phase of a project designed to pinpoint the optimum concentration and soak times of OTC on striped bass. The success of this project will give us yet another method for assessing the impact of our stocking programs.

- Optical Imaging--We are also involved in developing the use of our optical pattern recognition system in order to separate stocks of spotted seatrout among bay systems. The system works by comparing shapes of otoliths and annuli distances on scales of fish from different bay systems. The premise is that both scales and otoliths grow with the fish and that fish's growth is controlled by its environment. The aquatic environments are different among bay systems; therefore, there may be differences in shapes of the hard parts among these fish.

  The same premise can be held for fish reared in a hatchery situation. Since the environment in a pond can be controlled somewhat, either by temperature, salinity, feeding rates, stocking densities, etc., we should be able to "mark" a group of fish with a characteristic growth pattern that can be recognized by our OPRS system.

  Using several different parameters such as otolith shape, scale annuli distances, etc., my staff has been able to identify spotted seatrout from different bay systems with 70 to 80% accuracy. New software for the OPRS system promises to fine tune our methodology and analyses.

- Cold Tolerance Characteristics of Red Drum-- Another project we are actively pursuing is determining if there are strains of red drum that exhibit greater cold tolerance than those on the Texas coast. We have captured and reared red drum from South Carolina and compared their spawning, growth and cold tolerance with native Texas fish and found them to be similar.

  This year we have captured red drum from North Carolina near Cape Hatteras in hopes of repeating the experiment with these fish. One bonus in our studies between the Texas and North Carolina fish was that we were able to successfully rear red drum from fertilized egg to mature spawning adult completely in captivity.

SUMMARY

The various projects summarized in this talk are designed to address questions and problems relative to fisheries resource management. The staff at the Perry R. Bass MFRS, along with all of Coastal Fisheries and the Texas Parks and Wildlife Department, strive to stay on the leading edge of marine fisheries research and to provide the people of the State of Texas with the best information available by which the Department's commissioners manage our fishery resources.

Mr. Paul Hammerschmidt graduated from the University of California, San Diego, with a B.A. in biology and from Texas A&M University with an M.S. in fisheries science. He has been employed with the TPWD for the past 16 years. Beginning his career as a technician, he is currently Research Director of the Perry R. Bass Marine Fisheries Research Station, a position he has held since September 1988.

RESEARCH OVERVIEW FOR THE UNIVERSITY OF TEXAS AT AUSTIN, MARINE SCIENCE INSTITUTE, PORT ARANSAS, TEXAS

Dr. Paul A. Montagna
and
Dr. Robert S. Jones
Marine Science Institute
The University of Texas at Austin

The purpose of this presentation is to give an overview of The University of Texas at Austin Marine Science Institute facilities, describe how research is planned, and present highlights of research findings during the last year.

OVERVIEW OF PROGRAMS

The Marine Science Institute (Institute), with continuous usage by a resident research staff since 1946, is the oldest marine laboratory on the Texas Gulf Coast. After a modest beginning with a series of wooden structures, The University of Texas at Austin has invested steadily in the facility including major modern steel-and-concrete laboratory construction phases in 1961, 1973, and 1974 (Table 14.2). The latest building complex, completed in 1983, comprises an auditorium, meeting rooms, library, and visitors center. The current staff includes 15 faculty and research scientists (Table 14.3), 10 additional research staff, and 45 permanent supporting staff.

Active research programs in several marine science disciplines including the physiology, biochemistry, and ecology of marine plants and animals; biological, chemical, and physical oceanography; geochemistry; mariculture; biochemical toxicology; and environmental monitoring have been established at the Institute for many years.

The Department of Marine Science is the academic counterpart of the Institute and has faculty members located both in Austin and at the Institute. Courses are taught in both localities and graduate research is concentrated at the Institute.

The Institute is located in the town of Port Aransas, Texas, at the north end of a barrier island beach, Mustang Island, and adjacent to Aransas Pass, which connects the Gulf of Mexico with an extensive system of estuarine lagoons. The site is within a few

Table 14.2. University of Texas at Austin - Marine Science Institute Research Facilities.

- 72 Beachfront Acres plus Marina
- 83,000-sq.-ft. Laboratory
  - Two buildings
  - Library: 8,000 books, 37,000 serials
  - Auditorium
  - Visitors Center
- 10,000-sq.-ft. Wet Lab
- 7,000-sq.-ft. Dormitories
- 26,000-sq.-ft. Fisheries and Mariculture Laboratory
- Apartment Complex: 6 units
- Cottage Complex: 10 units
- Fleet:
  - 105-ft. *Longhorn*
  - 57-ft. *Katy*
  - 32-ft. *Armstrong - Jefferson*
  - 25-ft. *Sonny Mac - AMC*
  - 25-ft. *Kleberg - Jefferson*
  - 21-ft. *Jefferson*
  - 18-ft. Jon boat
  - 18-ft. Monarch
  - 16-ft. Whaler
  - 13-ft. Whaler

Table 14.3. University of Texas at Austin - Marine Science Institute Resident Senior Staff - Research Interests.

Marine Ecology:	
Ron Benner	Microbiology: Organic Matter Degradation
Ed Buskey	Zooplankton: Bioluminescence
Ken Dunton	Botany: Macrophyte Physiology
Lee Fuiman	Ichthyology: Larval Behavior
Robert Jones	Ichthyology: Habitats
Paul Montagna	Benthos: Community, Populations
Curtis Suttle	Phytoplankton: Nutrient Cycling, Viruses
Marine Biology:	
Jim Cameron	Crustacean Physiology
Peter Thomas	Fish Endocrinology, Toxicology
Mariculture:	
Connie Arnold	Fish Spawning, Egg Development
Joan Holt	Larval Fish Feeding, Development
Chemistry:	
Pat Parker	Organic Geochemistry
Dick Scalan	Organic Geochemistry
Terry Whitledge	Nutrients, Instruments
Hydrography:	
Tony Amos	Tides, Currents and Weather

hundred meters of the Gulf beach. The location provides access to a wide range of marine and estuarine habitat types, and in spite of increased development in the past two decades, the Institute remains in a relatively pristine environment. In addition, the regions to the north and south comprise one of the largest lagoon systems in the world and span a rainfall gradient that produces a salinity gradient ranging from nearly fresh at the Louisiana border to extremely hypersaline at the Mexican border. The region is also the center of economically important fisheries, gas and oil production, and is becoming a center for marine-related tourism.

OVERVIEW OF FACILITIES

The Institute's 83,000-sq.-ft. headquarters on 72 acres of beach front land consists of a series of interconnected buildings containing laboratories, offices, library, museum exhibit halls, classrooms, a visitors center, auditorium, seminar rooms, and workshops. All laboratories are air-conditioned and supplied with air, natural gas, deionized water and filtered seawater, and have approved chemical waste-disposal facilities. A 10,000-sq.-ft. wet laboratory is supplied with filtered running seawater. An additional 7,000-sq.-ft. of wet lab are set up for fish studies. Other buildings on the grounds of the Institute include 9,500 sq. ft. of dormitories (70 beds), a cafeteria, physical plant complex, garages, greenhouses, walk-in freezers, and several outdoor pool/habitat tanks. A five-acre boat basin/marina provides quick access for research vessels to both the bay systems and Gulf of Mexico. A well-equipped pier laboratory affords direct research access to fluxes in the Aransas Pass ship channel connecting the Gulf with the bays.

A mile west of the main building complex, the Fisheries and Mariculture Laboratory occupies 26,000 sq. ft. of buildings on 10 acres adjacent to the ship channel. The University of Texas shares this space with Texas A&M University (TAMU), which operates a shrimp mariculture facility complementing the finfish work of the Institute.

The Institute Library contains over 8,000 books and 37,000 bound volumes of journals. An on-line computer system provides access to bibliographic and abstract services nationwide, and interlibrary loans are obtained from all major State and university libraries. Remote job-entry terminals in the Institute's computer laboratory provide direct access to The University of Texas at Austin Computation Center's mainframe computer system. A reference museum of catalogued material contains over 5,000 specimens.

The R/V *Longhorn* is the largest of the Institute's research vessels. The ship was modified in a major refit in 1986 to give her an overall length of 105 ft. The *Katy* is a 57-ft. fiberglass trawler used in bay operations and is augmented by a fleet of small research vessels. Four-wheel drive and other vehicles are available to provide access to coastal habitats.

The Institute is an organized research unit of The University of Texas at Austin. The Institute director reports to the Executive Vice-President and Provost of The University of Texas. The Institute receives an operating budget annually and it is based on a two-year advanced budget approval by the State legislature. Most research funds are based on grant and contract research.

Brochures are regularly mailed to many institutions describing the summer course program and opportunities for graduate studies. The brochures contain information about facilities at the Institute. Collaborative research with colleagues from other institutions who come to the Institute as visiting investigators is a major means of communicating the nature of these facilities to others. The Institute's funded postdoctoral program and student output further expand communications. The University of Texas and TAMU have recently established a committee on marine programs appointed by the presidents of the two institutions. Scientists from TAMU already collaborate with Institute scientists, share facilities at the Fishery and Mariculture Laboratory, and are currently negotiating a lease agreement to allow TAMU to build additional marine research facilities on the Institute campus. Other correspondence and contacts made at national and international meetings help augment communication with colleagues about the facilities available at the Institute.

The Institute is a permanent, year-round facility, and so is used full time by its resident staff. Visiting investigators are encouraged to make use of the Institute's facilities. In addition to research usage, the Institute serves as a marine educational center for the region. Courses are taught in residence during the summer sessions, typically involving 3,550 graduate and undergraduate students from Texas and other states. Graduate students reside in Port Aransas for thesis and dissertation research, supervised by one or more of the resident faculty, sometimes in collaboration with Austin faculty members. As part of the Continuing Education function of the University, a large number of outside groups, primarily high school and college classes, visit the Institute during the year. The total number of visitors to take advantage of the Marine Education Services program now exceeds 10,000 annually. Hands-on teacher workshops are also provided.

PLANNING AND HIGHLIGHTS OF CURRENT RESEARCH

The Institute is dedicated to the three primary functions (education, research, and service) of a major university as they apply to the Texas coastal zone. Because the Institute is an organized research unit, its primary emphasis is in both basic and applied research and aimed at understanding the biological, chemical, and physical processes that govern the coastal zone ecosystem. Geographically, this includes the unique bays and estuaries of Texas as well as the adjacent continental shelf in the Gulf of Mexico. Data provided by faculty and research scientists not only add to the general body of knowledge in marine science, but also provide baseline data for the wise utilization and management of the coastal zone for development of new economic opportunities in harmony with retention of a healthy marine environment.

The Institute addresses its service obligation by operating as a facility and research resource for State and Federal agencies, as well as for private industry and the general population, in solving specific problems relating to the marine environment. The publications of the Institute scientists, faculty, and students provide valuable reference data for making decisions involving environmental impact, water quality control, and fisheries management. The Institute's interdisciplinary team of scientists possesses the specialized equipment and expertise necessary to tackle a wide variety of problems as they emerge such as the impact of an Ixtoc type oil spill in the coastal zone, the effect of freshwater reservoir management on the water quality and fishery resources of a Texas estuary, the solution of problems related to the rearing of red drum in mariculture, the effect of maintaining fish passes between the bays and the Gulf of Mexico, or the maintenance of fisheries production in deteriorating habitats.

Specific operational objectives of the Institute are to provide an integrated research facility with modern laboratories for marine research; to operate research vessels and a boat-shore facility with supporting marine gear for use by The University of Texas at Austin and State and Federal agencies, as appropriate; and to operate student dormitories and service facilities as needed for support of both the research and educational missions.

On-going research projects at the Institute are of a broad, interdisciplinary, and diverse nature reflecting the individuals of faculty and staff. They include the following:

- Molting and shell formation in blue crabs, leading to an understanding of the hormonal control of calcium uptake;
- Mechanisms for excretion of ammonia in crabs, fish, sharks and rays, which are important in understanding gas exchange and acid-base regulation in all four groups;
- Behavior, nutrition and growth of vertically migrating phytoplankton. These studies also aid in the development of models predicting outbreaks of red tides;
- Isolation and research on marine viruses and the phytoplankton species they infect;
- Study of the physiology of microalgae with the development of improved methods for measuring primary production and interpreting results;
- Utilization of modern equipment to investigate the behavior and distribution of zooplankton, including larval crustacean and fishes;
- The occurrence, distribution and transport of red drum and other sciaenid eggs and larvae in the Gulf of Mexico, Aransas Pass, and Redfish Bay-Aransas Bay systems;
- Investigations into the transport of energy from the microbial community to higher consumers in estuarine and continental shelf food chains;
- Production ecology of marine plants including seagrasses and salt marsh vegetation;
- Environmental impacts on coastal wetlands. The data are also useful in determining the value of plant habitats in supporting coastal marine food webs and as nursery grounds for many species of shrimp, fishes, and waterfowl;

- Long-term effects of oil and gas production on continental shelf benthos;

- Biological effects of natural hydrocarbon seeps;

- Geochemical studies dealing with the geological fate of marine organic matter. This includes the study of how organic matter is preserved in sediments to form a record of life and climate, and the origin of petroleum and gas;

- Research on chemical ecology involving the use of stable isotope ratios to study food chains, the impact of river-carried organic matter on marine life in Texas bays and estuaries, natural vs. artificial diets in shrimp mariculture; in an interdisciplinary, multi-university study of Bering Sea productivity; and in the recycling of elements transported upstream by runs of Pacific salmon;

- Automated techniques are being developed to investigate complex recycling of nutrients in the sediments and water column environments;

- Biology of red drum, red snapper, spotted seatrout, pompano, and dolphin including: larval and juvenile dynamics, nutrition and biochemistry, reproductive physiology; disease and stress physiology; and natural habitat studies;

- A pilot plant to demonstrate the feasibility of growing the selected species in commercial ventures or in natural population enhancement;

- The RNA/DNA ratios and protein synthesis in fish tissue are used to measure the state of health in mariculture-hatched species and evaluating the success of artificial diets;

- The sources and identities of hormones controlling successive stages of gonadal growth and maturation in economically important marine fishes is being studied. A new steroid hormone was recently discovered that had not previously been identified in fishes. The role this steroid plays in maturation is being investigated;

- The effects of several model pollutants on ovarian function in marine fishes is being studied to develop indices of impaired reproductive function in wild populations of fish that can be used as early warning indicators of deterioration in the marine environment;

- An interdisciplinary study of the impact of inflow of freshwater on the Lavaca, Guadalupe and Nueces estuaries;

- An interdisciplinary ecosystem study on how fisheries production is maintained in the nutrient limited Laguna Madre;

- Cooperative efforts with the National Marine Fisheries Service and the Texas Department of Parks and Wildlife include: assistance in the release of Kemp's ridley sea turtles from the "Headstart program;" overcoming spawning problems and increasing efficiency in fish hatcheries; handling mammal and turtle strandings; and studies on the effect of currents on the migration of the Texas shrimp population;

- Bay circulation and exchange processes are being studied and long-term measurements of bottom currents on the continental shelf are being made to aid in understanding various coastal processes: transport of sediments offshore following storms; the movement of commercial fishery species out of the bays and into the Gulf of Mexico in the summer. Hydrographic studies are also being conducted to observe the effects of reopening a barrier island pass (Cedar Bayou); and

- Long-term studies are investigating the rapidly increasing accumulation of trash and hydrocarbon compounds on Texas barrier island beaches and the impact of this problem on the recreation industry and marine bird populations.

As a result of this research activity, the Institute provides scientific leadership and an operational base for the Gulf of Mexico scientific community.

Dr. Paul Montagna has worked at the University of Texas at Austin Marine Science Institute for the past four years and is at present an Assistant Professor in the Department of Marine Science and Research Scientist at the Institute. His area of research interest is benthic ecology. He has participated in oil seep and Outer Continental Shelf monitoring programs in the Arctic and Pacific Oceans. Dr. Montagna received his B.S. in biology from State

University of New York, Stony Brook, an M.S. in biology from Northeastern University, and a Ph.D. in biology from the University of South Carolina.

Dr. Robert Jones has worked at the University of Texas at Austin Marine Science Institute for the past six years and is at present a Professor and Chairman in the Department of Marine Science and Director of the Marine Science Institute. His area of research interest is fisheries ecology. Dr. Jones received his B.S. and M.S. in zoology from the University of Texas, and a Ph.D. in zoology/marine science from the University of Hawaii.

RESEARCH OVERVIEW FOR CORPUS CHRISTI STATE UNIVERSITY, CENTER FOR COASTAL STUDIES, CORPUS CHRISTI, TEXAS

Dr. Jennifer Smith Prouty
Center for Coastal Studies
Corpus Christi State University

The Center for Coastal Studies at Corpus Christi State University was established in 1984 as a unit of the university's College of Science and Technology, to administer and monitor grants with outside agencies. The center facilitates coastal ecosystems research and contract studies focused on the Laguna Madre, Nueces/Corpus Christi Bay Complex, and the Padre/Mustang barrier island chain. Dr. John W. "Wes" Tunnell serves as Director of the center.

The Center for Coastal Studies is based in the Center for Environmental Studies and Services on campus; this building also houses offices of the university's National Spill Control School, the U.S. Fish and Wildlife Service (USFWS), Ecological Services Division, National Wetlands Research Center, and National Fisheries Contaminant Research Center, Texas Parks and Wildlife Department (Resource Protection Division), and the Minerals Management Service.

This paper will describe highlights of current research involving the Center for Coastal Studies. The center is at present involved in several contract studies with the USFWS Ecological Services Division and the National Wetlands Research Center; these studies employ university graduate and undergraduate students to assist USFWS personnel in the field and laboratory. In some cases these studies also serve as the basis for biology graduate student theses.

In 1989 the USFWS Ecological Services Division contracted with the Center for Coastal Studies to study the reestablishment of fauna in an estuarine mitigation area and compare it to a nearby natural *Spartina alterniflora* marsh. The 13-month study, recently completed, involved monitoring an 80-hectare (200 acre) deep, shallow, and emergent estuarine habitat created in 1988 in the nearby Nueces River Delta as mitigation required of the Port of Corpus Christi for wetland losses associated with deepening of the Corpus Christi Ship Channel. Biology graduate student Barbara F. Ruth conducted the research and used it as the basis for her graduate thesis. Ruth determined that opportunistic benthic invertebrates, juvenile fish, and shellfish use the mitigation site, as do shorebirds and migrating ducks. However, faunal use in the mitigation site is seasonally uneven, while the seasonal cycles in the natural marsh are more predictable. Ruth did not study the establishment success of marsh vegetation; another firm evaluated this aspect.

The U.S. Army Corps of Engineers recently contracted with the Center for Coastal Studies to monitor this mitigation site an additional two years. Biology graduate student John Adams will conduct the study to determine the long-term success of faunal reestablishment; it will serve as the basis for his graduate thesis.

In 1989 the USFWS Ecological Services Division contracted with the Center for Coastal Studies for a two-year study to determine the source of biological productivity associated with serpulid worm reefs in Baffin Bay, Texas, and the geologic history of the now-inactive reefs. The upper Laguna Madre and Baffin Bay complex are notable for their abundant finfish population, despite the hypersalinity of their waters.

This study will attempt to delineate the association of gamefish with the reefs, to determine the extent of primary production by epiflora on the reefs, and to describe the associated reef faunal community. Additionally, this study will attempt to determine historically when the reefs were actively growing. Results of this study will provide necessary baseline information useful to the USFWS to evaluate the impact of future proposed development in the Baffin Bay complex. Biology graduate student Billy B. "Beau" Hardegree is conducting this ongoing study as the basis of his graduate thesis.

Since 1988 the USFWS Ecological Services Division has contracted with the Center for Coastal Studies, which provided students to serve as field workers, in an ongoing wetlands creation, enhancement, and restoration opportunities initiative along the southern and middle Texas coast and in selected inland sites. The Soil Conservation Service, Nueces County Agricultural Stabilization and Conservation Service, Texas Parks and Wildlife Department, Texas A&M Research and Extension Center, and other organizations also provided assistance. Project workers contacted district and range conservationists for information on the area hydric soils, natural depressions, farmed wetlands, and landowners with an interest in wetland preservation. Field workers then visited selected properties and contacted private landowners with potential involvement in this project. The field workers provided landowners with information about the Conservation Reserve Program, North American Waterfowl Management Plan, and other appropriate programs, and with information about technical and financial assistance available.

The potential exists for wetlands creation, enhancement, and restoration in the southern and middle Texas coastal plain. Landowners in these areas more widely accept participation in the North American Waterfowl Management Plan because it provides more flexible assistance. Lack of funding to share construction costs with private landowners has hindered several proposals.

The USFWS Ecological Services Division recently contracted with the Center for Coastal Studies for site characterization of a margin of Cayo del Oso, Corpus Christi, known as the "Blind Oso." Cayo del Oso is a small secondary bay marginal to the larger Corpus Christi Bay. The Blind Oso site has been considered for possible habitat enhancement as a mitigation site 4 times in the past 12 years. The study, to begin in 1991, will delineate historical changes and present habitat usage of the Blind Oso. Biology graduate student Theresa Barrera will conduct the study; it will serve as the basis for her graduate thesis.

The USFWS National Wetlands Research Center has also contracted with the Center for Coastal Studies, which is currently providing students to serve as workers for an ongoing study of waterfowl feeding and behavior in Laguna Madre and adjacent freshwater ponds. Students are also helping National Wetlands Research Center personnel gather information on seagrass epiphytes at specific sites throughout Laguna Madre. This is an outgrowth of an earlier, completed study of seagrass distribution in Laguna Madre that also employed university students as research assistants. Currently, biology graduate student David Hicks is conducting a study for the National Wetlands Research Center to determine the recovery of upper Laguna Madre seagrass communities from a December 1989 freeze; this study will serve as the basis for his graduate thesis.

In the past, the Center for Coastal Studies has contracted for work with other offices and agencies as well, such as the Texas Water Commission and the National Park Service. Work has involved both university faculty and students. During the 1989-1990 academic year, over $53,000 was dispersed to support 13 students as research assistants. In addition to financial support, these contracts provide students with invaluable practical experience in coastal research. Possible future contracts may involve numerous other agencies, including the Texas Parks and Wildlife Department and the Minerals Management Service.

Dr. Jennifer Smith Prouty has worked at Corpus Christi State University since 1983. She is at present an associate professor in geology and serves on the Administrative Council of the Center for Coastal Studies. Her research interests include modern coastal processes and geologic evolution of Quaternary barrier island complexes. Dr. Prouty earned her A.B. in geology from Vassar College, her M.S. in geology from Yale University, and her Ph.D. in geology from the University of Georgia.

RESEARCH OVERVIEW FOR THE UNIVERSITY OF TEXAS-PAN AMERICAN, COASTAL STUDIES LABORATORY, SOUTH PADRE ISLAND, TEXAS

Dr. Frank W. Judd
Coastal Studies Laboratory
University of Texas-Pan American

INTRODUCTION

The University of Texas-Pan American Coastal Studies Laboratory is located on a 1.8-hectare tract of land in Isla Blanca Park, South Padre Island, Texas. The laboratory has approximately 715 square m of enclosed space and 307 square m of semi-enclosed space. It includes a classroom with seating for 45, 2 teaching laboratories (seating for 36 and 24), 5 small research labs (average size 9.3 square m), a shop, 2 offices, 2 restrooms with showers and lockers, a pantry, a garage, and a public display area. A seawater system was installed in 1987.

A public display area contains representative species of fauna and flora of the Laguna Madre, Gulf of Mexico, and South Padre Island. The laboratory is open for public visitation 1:30 to 4:30 p.m., Sunday through Thursday. Admission is free. Organized school groups, civic and other groups should arrange to visit Monday through Friday 7:30 a.m. to 12:00 noon. Courses offered through the University of Texas-Pan American at Edinburg and the University of Texas-Pan American at Brownsville are scheduled each semester at the Coastal Studies Laboratory. Both institutions have B.S. and M.S. degree programs in biology. Students may develop degree plans that emphasize marine biology.

This paper provides (1) an overview of current research at the Coastal Studies Laboratory, (2) summaries of recent findings, and (3) a description of the means used to plan future research.

OVERVIEW AND HIGHLIGHTS

During the past five years 70 persons have used the Coastal Studies Laboratory in their research. Fifteen were from the University of Texas-Pan American at Edinburg and four were from the University of Texas-Pan American at Brownsville. Forty-three persons were from other institutions or agencies in Texas. Eight researchers were from Louisiana. Utilization of the lab by students and faculty is hampered by lack of dormitory facilities.

Current research by faculty and students from the University of Texas-Pan American focuses on the coastal ecosystems of southern Texas and northern Mexico. Research projects in progress include the following:

- the role of disturbance in determining community structure and development of vegetation of barrier islands;
- the resistance and resilience of barrier island vegetation;
- the use of remote sensing techniques to monitor the distribution and abundance of black mangrove, *Avicennia germinans*, on the Texas coast;
- the use of aerial photography to determine the distribution and abundance of oyster reefs in shallow bays;
- the community ecology of South Bay - a State estuarine sanctuary; and
- the demography of the Texas tortoise, *Gopherus berlandieri*.

Other projects involve investigations of the fish and crustacean communities of the lower Laguna Madre and the factors that determine the critical thermal minimum of fish.

Natural disturbance is an important force driving population and community dynamics and barrier islands are paradigms of disturbance-dominated ecosystems. Indeed, barrier islands are formed, shaped, and moved by hurricanes. We studied changes in nearshore vegetation on South Padre Island, Texas, over a 14-year period and provided information on the recovery of vegetation from Hurricane Allen in 1980 until it was again impacted by Hurricane Gilbert in 1988. In eight years, species richness was equal to or greater than pre-hurricane values. Similarly, in eight years, percent cover on the primary dunes was close to pre-hurricane values. Conversely, vehicular traffic in the backshore retarded recovery of vegetation, and values for species richness and percent cover remain low. After Hurricane Gilbert (1988) total cover reached its lowest value in 14 years in 1989.

We used color-infrared (CIR) aerial photography to assess the extent of vehicular damage in the secondary dune and vegetated flats zone of South Padre Island and investigated the effect of known intensities of all-terrain vehicle traffic in this zone. Vehicular damage decreased from 18% of the dune area at the northern town limit to 6% of the dune area 6 km north of the town. Up to 20 passes over the same track with an all-terrain vehicle (ATV) failed to produce a set of bare tracks similar to those evident in CIR aerial photographs. All traces of ATV tracks resulting from 1, 5, 10, and 20 passes over the same tracks were healed within a year.

We also used CIR aerial photography (and ground truthing) to document the distribution and abundance of black mangrove, *Avicennia germinans*, along the Texas coast. Black mangrove had a red to dark red CIR image response that made it easily distinguishable from other vegetation, soil, and water. Computer-based image analyses of CIR film positive transparencies showed that black mangrove populations could be quantified accurately. This technique can permit "percent area estimates" of black mangrove that can be used to monitor changes in its distribution over time.

South Bay in Cameron County is the southernmost bay area on the Texas coast. It covers approximately 1,416 hectares and ranges in depth from a few centimeters to a meter. Salinities range from 35 to 42 parts per thousand except when lower salinities result from heavy rains. South Bay has been designated a State Estuarine Sanctuary, but biological information is lacking for most of its communities, including the oyster reef community. In 1989, we provided the first map of oyster reefs in South Bay using CIR aerial photography. Approximately 90% of the 153 reefs were concentrated in the southwestern quadrant of the bay. We hypothesized that the proximity of tidal channels that create high flushing rates as the tide changes may be responsible for the concentration of reefs in this area. We now seek information on the factors that determine the distribution of oyster reefs in the bay.

Egg production by the Texas tortoise, *Gopherus berlandieri*, was studied by X-raying marked (and telemetered) females in the field in Cameron County, Texas, throughout two reproductive seasons. There was no evidence for any female producing multiple clutches, but females retained portions of their clutch for up to 39 days and partitioned the laying of their single clutch in time and space.

MEANS USED TO PLAN FUTURE RESEARCH

Future research directions are decided largely by individual choice. Constraints that are important are (1) availability of grant support, (2) availability of physical resources, and (3) expertise of principal investigators. The most important determining factors are interest and expertise of the principal investigator. Most of our faculty hold full professor rank and have research programs that have been ongoing for many years. These scientists have established lines of investigation and usually do not embark on totally new lines unless it involves collaboration with another scientist.

Dr. Frank W. Judd has worked at The University of Texas-Pan American for the past 19 years. At present he serves as Director of the University's Coastal Studies Laboratory and as Professor in the Department of Biology. His areas of research interest are in barrier island community ecology and vertebrate population ecology. Dr. Judd received a B.S. in biology from Midwestern State University and an M.S. and a Ph.D. in zoology from Texas Tech University.

CONTRIBUTED PAPERS: MARINE BIOLOGY

Session: CONTRIBUTED PAPERS: MARINE BIOLOGY

Co-Chairs: Mr. Gary D. Goeke
Mr. Patrick Mangan

Date: November 15, 1990

Presentation	Author/Affiliation
Contributed Papers: Marine Biology: Session Introduction	Mr. Gary D. Goeke and Mr. Patrick Mangan Minerals Management Service Gulf of Mexico OCS Region
Echinoderms Associated with a Rhodolith Community on the Alabama Outer Continental Shelf: Management Considerations for a Unique Environmental Setting	Dr. Thomas S. Hopkins and Dr. John F. Valentine Marine Environmental Sciences Consortium Dr. James B. McClintock, Dr. Ken R. Marion, and Dr. Stephen A. Watts Department of Biology University of Alabama
Variation in Reproductive Patterns in Echinoderms from the Northern Gulf of Mexico	Dr. James B. McClintock, Dr. Stephen A. Watts, Dr. Ken R. Marion, and Dr. Gottfried Schinner Department of Biology and Dr. Thomas S. Hopkins Marine Environmental Sciences Consortium University of Alabama
Secondary Production: Differential Arm Loss in Two Sympatric Species of Sand Stars	Dr. Thomas S. Hopkins and Ms. Meredith W. Cornett Marine Environmental Sciences Consortium Dr. James B. McClintock, Dr. Ken R. Marion, and Dr. Stephen A. Watts Department of Biology University of Alabama

(Continued)

Session: CONTRIBUTED PAPERS: MARINE BIOLOGY (cont'd)

Presentation	Author/Affiliation
Hydroacoustic Assessment of Abundance and Behavior Patterns of Fish Associated with an Oil and Gas Platform off the Louisiana Coast	Mr. David R. Stanley and Dr. Charles A. Wilson Coastal Fisheries Institute Center for Wetland Resources and Mr. Curtis Cain Mobil USA Inc.
Estimation and Minimization of Underwater Blasting Effects on Fish and Wildlife Assemblages	Dr. Gary L. Thomas University of Washington and Dr. Percy Washington GAIA N.W. Inc.
The Occurrence of Heavy Metals in Selected Tissues of the Atlantic Bottlenose Dolphin (*Tursiops truncatus*) Stranded Along the Texas Coast: A Preliminary Analysis	Ms. Elsa M. Haubold Department of Veterinary Anatomy, Dr. B. J. Presley Department of Oceanography, and Dr. Raymond J. Tarpley Department of Veterinary Anatomy Texas A&M University
An Investigation of Dolphin (*Tursiops truncatus*) Deaths in East Matagorda Bay, Texas, in January 1990	Dr. W. George Miller Naval Ocean Systems Center
Bottlenose Dolphin Reactions to the *Mega Borg* Oil Spill	Dr. Bernd Würsig and Ms. Mari A. Smultea Marine Mammal Research Program Texas A&M University at Galveston

CONTRIBUTED PAPERS: MARINE BIOLOGY: SESSION INTRODUCTION

Mr. Gary D. Goeke
and
Mr. Patrick Mangan
Minerals Management Service
Gulf of Mexico OCS Region

The Minerals Management Service solicited from the research community contributed presentations pertaining to individual research results. The response to this open call was successful with several speakers identifying efforts that display the diversity of marine researchers who attend the Information Transfer Meeting. The following papers present research results that range from echinoderm reproductive patterns to marine mammals to the effects of underwater blasts on benthic communities.

Mr. Gary D. Goeke has an M.S. in marine biology from the University of South Alabama in Mobile and has worked for various private, State, and Federal agencies. He now works in the Environmental Assessment Section of Leasing and Environment for the Minerals Management Service, Gulf of Mexico OCS Region, and maintains an active research interest in crustacean taxonomy and marine ecology.

Mr. Patrick Mangan served until December 1990 as the staff specialist for marine mammals and endangered species in the Environmental Assessment Section of the Minerals Management Service, Gulf of Mexico OCS Region. He has also worked for the U.S. Government conducting fisheries and wildlife research in Florida, Colorado, Utah, and Minnesota, and for the Republic of Kenya. He specialized in freshwater invertebrate ecology and fisheries at the University of Wisconsin.

ECHINODERMS ASSOCIATED WITH A RHODOLITH COMMUNITY ON THE ALABAMA OUTER CONTINENTAL SHELF: MANAGEMENT CONSIDERATIONS FOR A UNIQUE ENVIRONMENTAL SETTING

Dr. Thomas S. Hopkins,
Dr. John F. Valentine
Marine Environmental
Sciences Consortium,
Dr. James B. McClintock,
Dr. Ken R. Marion,
and
Dr. Stephen A. Watts
Department of Biology
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INTRODUCTION AND OBJECTIVES

Collard and D'Asaro (1973) developed a scenario for community associations in a variety of habitats in relation to depth and substrate in the eastern Gulf of Mexico. Lyons and Collard (1974) further delineated the eastern Gulf of Mexico into the (a) West Florida Shelf - Florida Keys to Cape San Blas - because the existing knowledge was greater, and (b) Alabama-Mississippi Shelf - Cape San Blas to the region known by the authors. Furthermore, the authors delineated depth zones for the West Florida Shelf as follows: Zone I - Shoreward Zone (0-10 m); Zone II - Shallow Shelf Zone (10-30 m); Zone III - Middle Shelf I Zone (30-60 m); Zone IV - Middle Shelf II Zone (60-140 m); Zone V - Deep Shelf Zone (140-200 m).

In 1974, the Bureau of Land Management/Minerals Management Service began a series of studies that included macroepifaunal communities of both regions of the eastern Gulf of Mexico. The biotopic relations of fauna to substrate of Zone III (Middle Shelf Zone I category) were reported by Hopkins (1975). The descriptions of faunal relations of Middle Shelf I, Middle Shelf II, and Deep Shelf Zones were reported by Hopkins (1979). In addition to those National Technical Information System publications, the Florida Marine Research Institute has published a series of monographs (Memoirs of the Hourglass Cruises), research reports, and refereed articles about the fauna and flora of the western Florida shelf. The fishes of the MAFLA area have been described by Shipp and Bortone (1979), and the fishes to be expected at our study areas have been listed by Nestor (1978).

Gilbert (1983) has presented an ecological and zoogeographically oriented study of the molluscan epifauna reported by Hopkins (1975, 1979) and collected from four of the five depth zones created by Lyons and Collard (1974). Of particular use to this study are the provincial zoogeographic categories that will be used later in this report. These are as follows:

- Carolinian Restricted (CLR)--Organisms recorded with a southern range limited to north of mid-Florida on either side of peninsular Florida and whose northern range is limited to Cape Hatteras, North Carolina.

- Carolinian Eurythermic (CLE)--Organisms recorded with a major distributional range extending along the eastern seaboard from around Cape Hatteras, North Carolina, south to either side of mid-peninsular Florida, northern Gulf of Mexico, and with recorded occurrence in the Caribbean.

- Biprovincial (BIP)--Organisms that are recorded as so wide ranging throughout the Carolinian and Caribbean area preclude a distributional preference.

- Caribbean Eurythermic (CRE)--Organisms with a distributional record centered within the Caribbean and having extensions into the northern Gulf of Mexico or up the eastern seaboard north of mid-Florida, and southern extensions into the south Atlantic south of Brazil.

- Caribbean Restricted (CRR)--Organisms with a distributional record limited in the north to south of mid-Florida on either side of peninsular Florida and limited in the south to north of central Brazil.

- Gulf of Mexico Restricted (GMR)--Organisms not recorded from outside the Gulf of Mexico.

With the recent development of hypotheses on the prospects for global warming, we propose that there is value in affirming and understanding the abundance and distribution of the fauna of the northcentral eastern Gulf of Mexico (an area bounded on the east by Cape San Blas and bounded on the west by the eastern edge of the Mississippi delta).

The objectives of this report are threefold: (1) to document the occurrence of species with warm or cooler water affinities (present and/or recently recruited), (2) to document echinoderm substrate relationships, and (3) to document echinoderm depth distributions in relation to salinity and temperature fields. This information should be of use to ecologists of future generations as they detect the arrival and survival of species whose biological functions were thought to be tied to seas warmer or cooler than those of our central Gulf coast.

METHODS

Positional location was determined by LORAN C and converted to latitude and longitude by a computer software program. Plots of gear start/stop locations were made on expanded scale charts for Stations 3 and 5. Bathymetry was recorded on videotape (VHS) along with LORAN C values and reviewed upon return. Figure 15.1 shows the sampling sites in relation to Mobile Bay, Alabama.

In late 1988, we made reconnaissance visits to seven sites based on bathymetry. For ecologically parsimonious reasons, we established three stations based on differing substrate and the total community of animals present. In the initial two efforts, we deployed both a Capetown Dredge (Hopkins 1979) and a 30-ft. semi-balloon trawl (Shipp and Bortone 1979) equipped with extra skids and tickler chain to increase weight. After several comparative efforts, it was concluded that the trawl was more manageable, covered a wider track and increased the catch/unit effort using a standardized 30-minute bottom time for towing distance.

RESULTS

Station A

The substrate at Station A is classified as MAFLA Quartz Sand Sheet (Doyle and Feldhausen 1981), but the area is also known to have low rocky outcrops, scattered artificial reefs, and patchy sediment distribution over a relatively flat bottom (Schroeder *et al.* 1988). We have encountered large and small shell fragments overlying the bottom in the study area, and this habitat may in turn provide cover, concealment, or substrate for bryozoans, coelenterates, crustaceans, foraminiferans, molluscs, nematodes, polychaetes, and poriferans. Ongoing *in vivo* food habit studies of the sand stars *Astropecten*

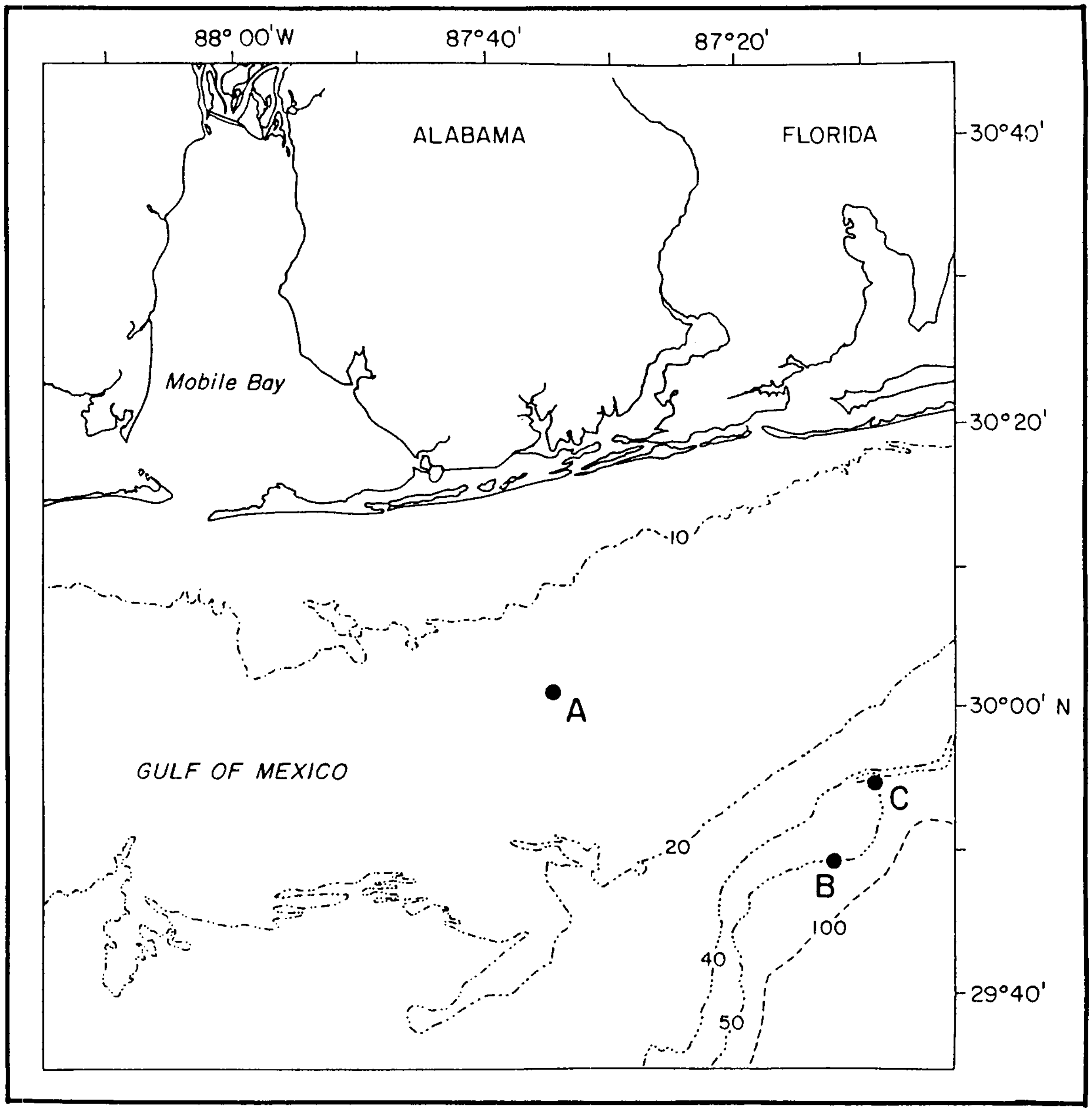

Figure 15.1. Map showing the location of the three echinoderm collection sites (A, B, C) in the northern Gulf of Mexico. (Depth is given in fathoms.)

articulatus and *Luidia clathrata* provide evidence that the above mentioned groups play a major role in the food web of these species. The 18 species of echinoderms associated with this station are representative of those encountered in similar depths on comparable substrate throughout the MAFLA tract (offshore Mississippi to offshore Charlotte Harbor, Florida) (Hopkins 1979). The dominant stellaroids associated with this station are *Astropecten articulatus* and *Luidia clathrata;* the dominant ophiuroids are *Ophioderma brevispinum* and *Ophiolepis elegans.* Recruits of the regular urchins, *Arbacia punctulata* and *Lytechinus variegatus,* the irregular urchins, *Clypeaster prostratus* and *Encope aberrans,* along with the stellaroid *Echinaster paucispinus,* have been found consistently, but not in large numbers.

Station B

The epi-substrate at Station B is a feature of the 90-m contour that occurs irregularly along the

MAFLA shelf from Charlotte Harbor, Florida (Hopkins 1979). Whereas the relatively hardpacked surficial layer is MAFLA Quartz Sand Sheet, the sand is carpeted with rhodolith structures *(sensu* Focke and Gebelein 1978). The size of these biolithified structures ranges from 5 to 10 cm in diameter, and the structures have enhanced surface areas as a result of epiphytic and epizootic calcareous growth and lithophagy by the bivalve *Barbatia cf. cancellaria.* These holes are often modified by the hermit crabs *Cancellus cf. ornatus* and *Pylopagurus* sp. At this same site, we have collected well preserved fossil specimens of the hermatypic coral *Manicina areolata* and more recently the massive encrusting hermatypic coral *Dichocoenia cf. stellans.* Overall, the rugose nature of this habitat appears to be attractive to the recruitment of echinoderm species in substantial numbers. Amongst the 32 species of echinoderms from Station B, the dominant stellaroid echinoderms are *Anthenoides piercei, Echinaster modestus, Echinaster cf. brasiliensis,* and *Tosia parva.* The dominant ophiuroid, echinoid, crinoid, and holothuroid echinoderms are *Astroporpa annulata, Stylocidaris affinis, Comactinia meridionalis,* and the highly cryptic *Psolus tuberculosus,* respectively. Of particular note is the presence of the euryalous ophiuroids *Astrocyclus cf. caecilia* and *Asteroschema intectum*, which are associated with a rather diverse octocorallian/antipatherian community structure comprised of 6-8 species.

Station C

The substrate at Station C is probably the underlying MAFLA Quartz Sand of Station B. Even though it is 10 km distant, and at the same depth, it is depauperate in species numbers by comparison. Station C is dominated by large numbers (70-100/0.9 km haul) of *Clypeaster ravenelii* (Vernon *et al.* 1990). Only occasionally do we find the stellaroid *Echinaster modestus* in any number.

DISCUSSION

Although the MAFLA data for the West Florida Shelf (Hopkins 1979) involved four different years of collections, the actual number of stations sampled did not reveal the diversity of echinoderm fauna that existed west of Cape San Blas, and thus, it never really filled the void that Lyons and Collard (1974) noted. Hopkins and Valentine (1982) reported on the case for depth zonation of echinoderms from the eastern Gulf of Mexico. Those data, along with Gilbert (1983), who reports on molluscs, clearly show that the depth zone concept has validity for individual phyla.

From the standpoint of hydrographic observations, the area in which we have worked has experienced some large scale seasonal and annual (+ 4°C and 10 parts per thousand) differences in surface parameters. We can safely speculate that these conditions would very likely affect planktotrophic larval recruitment of tropical species. In contrast, we found solid evidence, the presence of young individuals, that species whose center of greatest abundance is the Caribbean Sea do arrive and survive in our study area, and are reproductively active (Hopkins *et al.* 1990).

At Station A, we encountered sixteen species of echinoderms that have eurythermic distributions. Considering the periodic cold air masses from the north, and cold water masses from the south, we believe that this number makes a significant contribution to the community structure on a sandy/shell fragment substrate in 30 m depth. For example, on-going *in vivo* food habit and secondary production studies (DISL) and *in vitro* food habit studies (UAB) indicate that *Astropecten articulatus* and *Luidia clathrata* are playing a major role in the food web of this community. Ongoing efforts at the DISL indicate these two stellaroids are discriminate predators. Secondary production studies indicate they contribute biomass energy to the community through arm loss to predators as yet unidentified (Hopkins - these proceedings; McClintock *et al.* 1990). The other major feature of their community role is the indirect evidence that they potentially contribute to the planktonic food web through spawning and recruitment back to established populations.

Our findings at Station B are significant in view of the MAFLA data; e.g., we report the largest species number of any 90-m contour station of the MAFLA tract from offshore Mississippi to offshore Charlotte Harbor, Florida (Hopkins 1979). Surely Cape San Blas is not a limiting factor for the larvae of this faunal group. Over 75% of the fauna have their greatest affinity with water masses of the Caribbean seas. There seems little doubt that the combination of this unique epi-substrate, coupled with seasonally favorable hydrographic conditions, makes this station a veritable refugia for echinoderms with cosmopolitan, Carolinian, and Caribbean affinities. In contrast, the Carolinian attribute is limited to one species (3%); however, the remaining 22% have relatively cosmopolitan distributions. The total species number (32) for this 90-m station greatly exceeds all other 90-m MAFLA sites sampled over a 3-year time scale (1975, 1976, 1977). As indicated, we have established reproductive periodicity for some of these animals and established the fact that some spawn in the winter season, an unexpected event.

If we contrast the faunal differences of Station C to Station B, we propose that neither depth nor hydrography is responsible for the remarkable species makeup. We do propose that the rhodoliths forming an epi-substrate can well be the major attractive feature of the echinoderm community at Station B.

In conclusion, the northeastern central Gulf of Mexico has a zoogeographically diverse echinoderm fauna with a larger than expected species number, which is apparently associated with substrate. The fauna is distinctly distributed with depth between 30 m and 90 m and has less than 10% commonality in species composition with depth because of the strong Caribbean component at 90 m depth.

APPLICATION OF INFORMATION TRANSFER TO MMS AND GAS/OIL INTERESTS

1. This study supports the value of small scale reconnaissance and follow-up of specific habitat studies in the Gulf of Mexico.

2. The "rhodolith habitat" we are studying supports a unique biological community of warm water faunal origin. It is the first of its kind on record in the Northern Gulf of Mexico, and it needs protective consideration as a habitat of particular concern.

3. The area containing the rhodoliths is a potentially unique historic geological site because of (a) the suspected age of the rhodoliths and (b) the recovery of a massive fossil, *Dichocoenia stellaris*, and scattered fossil *Manicina areolata* (hermatypic controls). These fossil hermatypes will be important in characterizing the area and its relation to hermatypic reef structures that may have existed in the area in the relatively recent geological past.

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Dr. Thomas S. Hopkins received a Ph.D. in marine biology from Scripps Institution of Oceanography in 1967. He has been a principal investigator/chief scientist on four separate Bureau of Land Management/Minerals Management Service contracts. He is a Professor of Marine Science, Marine Science Program, Dauphin Island Sea Lab, Dauphin Island, Alabama.

Dr. John F. Valentine received a Ph.D. in biology (marine science) from the University of Alabama in 1989. At present he is a marine research scientist at the Sea Lab, responsible for co-directing National Science Foundation and National Science Foundation EPSCoR research. The research focuses on the effects of herbivory and bioturbation on seagrass habitats.

Dr. James B. McClintock received a Ph.D. in biology from the University of South Florida, Tampa, Florida. His major focus in marine ecology has been in the area of ecological energetics and predator prey defenses. He is an Assistant Professor of Biology at the University of Alabama, Birmingham, Alabama.

Dr. Ken R. Marion received a Ph.D. in zoology from the University of Missouri. Although trained as a vertebrate field ecologist, he has been affiliated with the Dauphin Island Sea Lab and directed graduate students in marine biology. He is a Professor of Biology at the University of Alabama, Birmingham, Alabama.

Dr. Stephen A. Watts received a Ph.D. in biology from the University of South Florida, Tampa, Florida. His major focus is on cellular processes in marine invertebrate animals with emphasis on secondary metabolites and reproductive processes. He is an Assistant Professor of Biology at the University of Alabama, Birmingham, Alabama.

VARIATION IN REPRODUCTIVE PATTERNS IN ECHINODERMS FROM THE NORTHERN GULF OF MEXICO

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INTRODUCTION AND OBJECTIVES

Reproduction is a fundamental trait in an organism's life history. Consequently, the wide variety of modes reproduction takes is of great importance. In marine invertebrates, reproduction is typically divided into direct and indirect methods (Thorson 1950; Giese and Pearse 1974). Direct development may involve brooding or broadcasting of small numbers of large lecithotrophic non-feeding embryos, whereas indirect development is characterized by the release of large numbers of small planktotrophic feeding larvae (Strathmann 1971, 1977; Mileikovsky 1971). Little information is available on developmental modes and the timing of gametogenesis in echinoderms from the Gulf of Mexico. Such information is critical to understanding factors that regulate the distribution and abundance of these dominant macroinvertebrates (Hopkins *et al.*, this issue).

Biogeographic patterns of developmental modes have been proposed for marine invertebrates. Brooding of lecithotrophic embryos is thought to have its highest incidence in polar latitudes, while broadcasting of planktotrophic larvae is thought to be most common in temperate and tropical latitudes (Thomson 1876; Thorson 1950; Arnaud 1974; Jablonski and Lutz 1983; Pearse *et al.* 1991). This proposed biogeographic pattern in the incidence of developmental mode in marine invertebrates is termed "Thorson's Rule." However, recent studies have shown that, in contrast to these predictions, pelagic lecithotrophy predominates in Antarctic benthic marine invertebrates (Pearse 1981). These findings indicate that more information is needed on modes of reproduction among groups of marine invertebrates from different latitudes before broad generalizations concerning geographic patterns of developmental mode can be made.

Most marine invertebrates have seasonal reproductive cycles (Giese and Pearse 1974). This appears to be the general rule for members of the Echinodermata with either planktotrophic or lecithotrophic modes of development (Pearse 1981; Emlet *et al.* 1987). However, with few exceptions the environmental variables that regulate and synchronize the gametogenic cycle remain to be identified. Seawater temperature has been demonstrated to modulate seasonal reproductive cycles in several marine invertebrates occurring in areas with seasonal temperature fluctuations (Giese and Pearse 1974; Watts 1986). More recently, studies have revealed that gametogenesis, growth and feeding may be under photoperiodic control in echinoderms (Pearse and Eernisse 1982; Pearse *et al.* 1986; McClintock and Watts 1990). The hypothesis that photoperiod or temperature may serve to synchronize gametogenic cycles in echinoderms from the Gulf of Mexico has received little attention.

The objectives of this research program are to examine and compare aspects of reproduction and other important demographic features of many of the most abundant echinoderms in offshore waters of the Gulf of Mexico. These objectives include an assessment of modes of reproduction (planktotrophy vs. lecithotrophy, brooding vs. broadcasting, demersal vs. pelagic larval development), the allocation of materials and energy to reproduction (gamete production) in species with contrasting modes of reproduction, the timing and exogenous control of gametogenesis and gonadal and somatic growth, and temporal patterns of spawning and juvenile recruitment. The present paper summarizes work to date on modes of reproduction and timing of gametogenesis in echinoderms from the northern Gulf of Mexico.

METHODS

Echinoderms were collected from three sites located off the coasts of Alabama and Florida (Figure 15.1). The substrate characteristics and depths of these sites are presented in Hopkins *et al.* (this issue). Echinoderms were collected approximately monthly from November 1989 to August 1990 using either a Capetown dredge or a 30-foot semi-balloon trawl. Seawater temperatures were recorded at each collecting station. Ten individuals of each species were placed immediately on ice and returned to the laboratory at the University of Alabama at Birmingham. Individuals were then weighed and dissected into their primary body components. In order to determine a gonadal index, the wet weight of the intact gonad was measured and divided by the total body wet weight x 100. Sub-samples of testes and ovaries were placed in Bouin's fixative, and tissues were sectioned and stained for histological analysis.

RESULTS AND DISCUSSION

The reproductive modes of those echinoderms examined are presented in Table 15.1. Five of the eight asteroids examined had planktotrophic modes of reproduction, producing large numbers of small planktotrophic larvae. Histological analyses revealed egg sizes of approximately 100-130 μ in diameter, indicative of planktotrophy. The two *Echinaster* spp. and *Tosia parva* had large (520-820 μ diameter) eggs, reflecting a lecithotrophic mode of reproduction. Fecundity of these three species was low when compared to the planktotrophic species. The three echinoids and the single ophiuroid examined all had planktotrophic modes of reproduction. Of the 12 species examined, a total of 8, or 75%, produced large numbers of small eggs, which develop as planktotrophic larvae. These observations are in accordance with the predictions of Thorson's Rule, which postulates that low latitude species will have a higher incidence of planktotrophy than high latitude species. Recent studies have revealed that high latitude polar fauna are indeed characterized by high levels of lecithotrophy, although many of these species do not brood their yolky embryos, in contrast to the predictions of Thorson (Pearse 1981).

Sufficient gonadal samples were collected from five asteroids and one echinoid to allow an assessment

Table 15.1. Modes of Reproduction of Echinoderms from the Northern Gulf of Mexico.

Species	Collection Site	Larval Nutritive Mode	Egg Size	Fecundity
Asteroidea				
Luidia clathrata	A	Planktotroph	Small	High
Astropecten articulatus	A	Planktotroph	Small	High
Anthenoides piercei	B	Planktotroph	Small	High
Goniaster tesselatus	B	Planktotroph	Small	High
Tosia parva	B	Lecithotroph	Large	Low
Chaetaster nodosus	B	Planktotroph	Small	High
Echinaster modestus	B	Lecithotroph	Large	Low
Echinaster braziliensis	B	Lecithotroph	Large	Low
Echinoides				
Stylocidaris affinis	B	Planktotroph	Small	High
Clypeaster ravenelii	C	Planktotroph	Small	High
Clypeaster prostatus	C	Planktotroph	Small	High
Ophiuroidea				
Astroporpa annulata	B	Planktotroph	Small	High

of both the timing and magnitude of annual gametic production. Reproductive maturity was evaluated both on the basis of the gonadal index and histological examination of the gonads. The sand stars *Luidia clathrata* and *Astropecten articulatus* were reproductively mature in the winter (November) of 1989, while peak gonadal indexes were generally lower in magnitude and postponed to the spring of 1990. The asteroid *Anthenoides piercei*, collected from rhodolith substrates, was reproductively mature in the late fall and winter of 1989, while few mature gametes were noted in the fall, winter, spring, or summer of 1990. Two additional asteroids collected from cobble substrates, *Tosia parva* and *Echinaster modestus*, had peak reproductive indexes during summer months (July and August) in 1989, while producing few gametes in the summer of 1990. The only echinoid examined, *Clypeaster ravenelli*, had consistently high gonadal indexes, particularly in winter and spring months. Gonad indexes for this species were high in part due to the presence of nutritive cells within the gonads, a characteristic condition common in echinoid gonads. Histological analyses indicated that this echinoid is a winter spawner, as gonads were swollen with mature gametes during both the winters of 1989 and 1990.

The reproductive cycles of all the asteroids examined varied markedly over the years 1989 and 1990. Gamete production occurred in all species in 1989, but was either delayed or absent during 1990. This pattern is noteworthy, as most echinoderms show repeated annual peaks of reproduction (Giese and Pearse 1974). One possible explanation is that minimum seawater temperatures were a full 5 °C lower in the northern Gulf of Mexico during the winter of 1990 (15 °C) compared to the winter of 1989 (20° C). Temperature has been shown to affect the magnitude and timing of gametic development in some echinoderms (Giese and Pearse 1974). Most of the species examined in the present study are at the extreme northern limit of their geographic distribution and may therefore be particularly vulnerable to temperature depression. Low temperatures may not only decrease the rate of gametogenesis, but could influence local levels of food availability. Levels of nutrient availability have been shown to influence gametic production in echinoderms (Lawrence 1985). If this is the case, then periodic cessation of gamete production may be a common occurrence during cold years in these species. This would suggest that recruitment events would be episodic and correlated with warm years. In addition to temperature, recent studies have indicated that the timing of gametogenesis in echinoderms can be regulated by photoperiod. McClintock and Watts (1990) found that even in a tropical echinoid (*Eucidaris tribuloides*), the timing of gametogenic cycles may be influenced by day-length. It is possible that reproductive cycles of echinoderms in the northern Gulf of Mexico are mediated by both temperature and photoperiod.

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SECONDARY PRODUCTION: DIFFERENTIAL ARM LOSS IN TWO SYMPATRIC SPECIES OF SAND STARS

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OBJECTIVES AND HYPOTHESES

This study is part of a larger synecological approach to the community structure of a shellhash-sand biotype located in approximately 30-m seawater off the coast of Alabama (Station A, Figure 15.1). In this portion of the study, we are seeking to determine if there is evidence to suggest that there is differential arm loss in two species of sympatrically occurring sea stars, *Astropecten articulatus* and *Luidia clathrata*. If there is differential arm loss (or amounts of regeneration), we can proceed with new hypotheses concerning (a) mechanisms of arm loss, (b) energy required for regeneration, and (c) energy provided to the community as potential biomass for consumers. The two species are well adapted for their occurrence together on mud, sand, shell fragment, and mixtures of the foregoing, substrates throughout the MAFLA tract (Hopkins 1979).

At the outset, we proposed the following null hypotheses:

- H_o^1: There is no significant difference in the mean value of R (R = distance from center of oral disk to tip of arm) in the sampled population of *Astropecten articulatus* and *Luidia clathrata*.

- H_o^2: There is no significant difference in the mean value of r (r = radius of oral disk) in the sampled population of *Astropecten articulatus* and *Luidia clathrata*.

- H_o^3: There is no significant difference in the mean seasonal value of R and r in the sampled population of *Astropecten articulatus* and *Luidia clathrata*.

- H_o^4: There is no significant difference in the total number of individual animals regenerating in the sampled population of *Astropecten articulatus* and *Luidia clathrata*.

- H_o^5: There is no significant difference in the total numbers of individual arms regenerating in the sampled population of *Astropecten articulatus* and *Luidia clathrata*.

MATERIALS AND METHODS

The two sand stars, *Astropecten articulatus* (Paxillosida: Astropectiniidae) and *Luidia clathrata* (Platyasterida: Luidiidae), have a relatively biprovincial distribution along the eastern Atlantic and Gulf of Mexico coastlines in shallow water (Downey 1973). *A. articulatus* exhibits a rather distinct color pattern of purple paxillae whose circumference is rather sharply set off by bright orange superomarginal plates. Although it is capable of burrowing, it has been found to be a surface dweller during daylight hours. We have used a color variety of *L. clathrata* in this study and designated it "Tricolor." This designation comes from its prominent brown central stripe bounded by adjacent pale and bright orange paxillar stripes. (The more typical gray form with black stripe is predominant nearshore and in Mobile Bay.) Both *A. articulatus* and *L. clathrata* were collected simultaneously at Station A by use of a 9-m semi-balloon trawl towed by the R/V *Verrill* using Loran C for navigational positioning.

We performed standard statistical procedures on the parameters R, r, and numbers of arms regenerating per individual. We used these data for the development of size frequency distributions. Chi Square Goodness of Fit were used to determine abundance relations and other potential patterns we encountered in the regenerating populations study. A non-parametric Mann-Whitney U Test was used to evaluate the relationship between the numbers of *A. articulatus* and *L. clathrata* showing one or more arms in the regenerative mode.

RESULTS

We have been able to examine 369 individuals of *Astropecten articulatus* and 251 individuals of *Luidia clathrata* collected haphazardly from a 9-m trawl towed in 30 m depth at Station A during the period January through June 1990. By using the parameters R and r as estimates of the size of individuals, we found no significant differences ($p > 0.05$) during the months collected. Since we could find no evidence for seasonal grouping, we accept H_o^1 and combined all samples for further data analyses.

When we examined the r value for the sampled population of *A. articulatus* (X = 11.21 mm; N = 369), we found that this parameter was not significantly different from the value of this parameter in *L. clathrata* (X = 11.19 mm; N = 251). Consequently we accept H_o^2.

We found, however, that the R value for sampled populations of *A. articulatus* (X = 55.12 mm; N = 369) was significantly smaller ($p = <0.05$) than the population sample of *L. clathrata* (X = 70.60 mm; N = 251). As a result, we reject H_o^3 and conclude that mean arm size is longer in the population sample of *L. clathrata*.

Figures 15.2 and 15.3 display the percent arms regenerating per size class of little r in the combined sample. Remember, this parameter was not found to be significantly different in the population samples compared. We tested these data using a Spearman Rank Correlation Test of little r and percent arms regenerating; we found a significant value of rs = 0.83 and $p = <0.05$. Consequently, we conclude that we can reject the null for H_o^4.

In Figure 15.4 we see the data comparing the number of regenerating arms (1-5) in both species. We found that a significantly higher number of regenerating arms occurred in *L. clathrata* when compared to *A. articulatus* (X^2 = 18.63; DF = 1; $p = <0.001$). Using a Mann-Whitney U Test to determine the relationship of the numbers of individuals for each species having 1-5 arms regenerating, we conclude that the difference is significant (U = 35; N1 = 5; N2 = 4; C>V = 19; $p = <0.05$). We can also use Figure 15.4 to look for patterns of regeneration. Whereas *A. articulatus* had significantly higher rates of single arm regeneration (X^2 = 38.71, DF = 1, $p = <0.0001$), *L. clathrata* had significantly higher numbers of multiple regenerations (X^2 = 5.73, DF = 1, $p = <0.025$). As a result, we feel comfortable rejecting H_o^5.

We have also examined stomach contents of three potential predators: (1) sand perch, *Diplectrum* spp. (N=15); pearly razorfish, *Hemipteronotus novacula* (N=40); and gray triggerfish, *Balistes capriscus* (N=15). We were unable to identify any distinctly stellaroid remains.

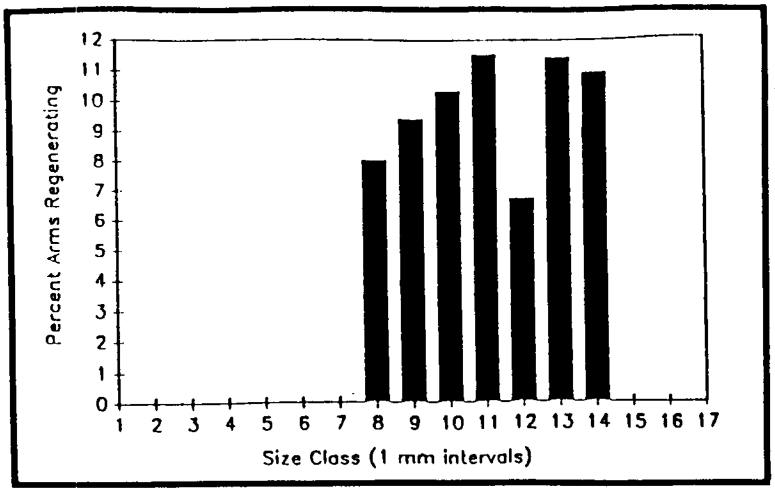

Figure 15.2.

A. articulatus: percent arms regenerating per size class (radius of oral disk).

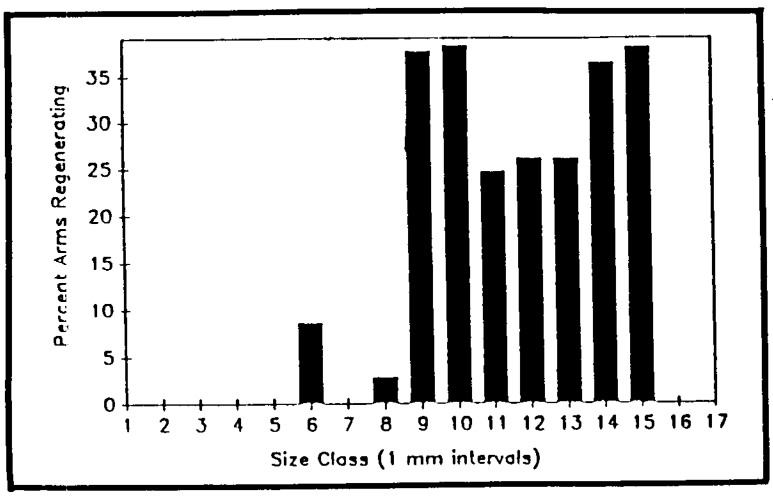

Figure 15.3.

L. clathrata: percent arms regenerating per size class (radius of oral disk).

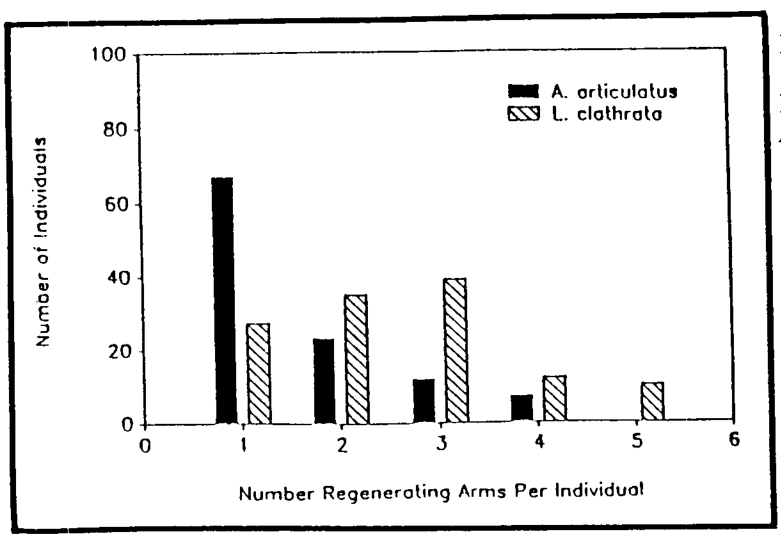

Figure 15.4.

Number regenerating arms in individuals of *L. clathrata* and *A. articulatus*.

In summary, it appears that arm loss and subsequent regeneration in these two co-occurring species puts *Luidia clathrata* in a disadvantageous position in the community. McClintock *et al.* (1990) have shown that the body wall tissue energy level is 3.51 kJ/g dry wt. in *Astropecten articulatus* and 6.74 kJ/g dry wt. in *L. clathrata*. As a result of the foregoing, we hypothesize that *L. clathrata* (1) may be more intensively preyed upon (arm loss data), (2) may likely have to invest considerably more energy into body wall and organ growth (energetic data), and (3) may contribute significantly more nutrient material (biomass from arm loss) and energy to higher trophic levels in the community being studied.

FUTURE STUDIES

The foregoing is only a progress report. At the present time we are doing the following:

1. Examining inside Mobile Bay and nearshore (1-2 km) populations of *Luidia clathrata* to assess the population parameters of R, r, and secondary growth in arms of sampled individuals. We are also measuring the percent of regenerative growth and the incidence of tertiary growth; e.g., multiple regeneration of the same arm, in these populations. We aspire to use these data to quantify the energetic loss of somatic and gonadal tissue of the population sampled, and its potential contribution to community energetics.

2. Continuing our field food habit studies at the three *Luidia clathrata* sites (a) listed in the first part of this work; e.g., its co-existence with *A. articulatus*, (b) nearshore where it co-exists with *L. alternata*, and (c) Mobile Bay where it has no stellaroid with which it has to partition resources.

3. Continuing our experimental food studies of *A. articulatus* and *L. clathrata* using both natural and prepared food sources in both laboratory microcosm and wet lab macrocosm set-ups to determine the comparative energetic value of these foods to these species allopatrically.

4. Developing experimental *in vivo* food studies of these two species living sympatrically in a macrocosm set up.

5. Continuing our search for a predator *in vitro* at Station A and conducting controlled macrocosm experiments with allopatric and potential sympatric predators in a wet lab set-up.

6. Conducting reciprocal transplant experiments by moving Station A *L. clathrata* to an inshore or Mobile Bay site and inshore or Mobile Bay *L. clathrata* to Station A to determine if differential arm loss occurs under these conditions.

7. Developing bioassays to determine the presence and concentrations of chemical defense compounds in the gonadal and somatic tissues of these species and the potential role these compounds may play in allopatric and sympatric predation experiments. These studies may provide insight into an explanation of higher arm loss rate in *L. clathrata* living sympatrically with *A. articulatus*.

SIGNIFICANCE TO COMMUNITY THEORY

We believe that the integrated synthesis of these and the other kinds of information we are developing will provide significant insight into the mechanisms and processes involved in structuring the biomass flux in the benthic invertebrate communities we are studying. Furthermore, we believe that this study will be of "global" application to other studies of open bottom areas of the inner continental shelf.

APPLICATION OF INFORMATION TRANSFER TO MMS AND GAS/OIL INTERESTS

1. *Astropecten articulatus* and *Luidia clathrata* are dominant macroinvertebrates of muddy sand and sandy shell hash in the near shore zone of the Gulf of Mexico Coast. *Luidia clathrata* invades estuarine settings where salinity remains relatively high.

2. Both of these animals are good bioassay animals for determining other fauna in the area; they are non-selective feeders.

3. *Luidia clathrata* exhibits a high propensity for arm loss/regeneration in natural environments. *Astropecten articulatus* does also but not to the same degree.

4. These data should help managers who are monitoring an area and wish to know the baseline difference in natural versus anthropogenic effects of oil and gas activities.

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HYDROACOUSTIC ASSESSMENT OF ABUNDANCE AND BEHAVIOR PATTERNS OF FISH ASSOCIATED WITH AN OIL AND GAS PLATFORM OFF THE LOUISIANA COAST

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Over 4,000 oil and gas platforms are currently operating in the northern Gulf of Mexico and constitute over 28% of the hard substrate found in this otherwise soft bottom environment (Gallaway 1984). Since there is a limited amount of hard bottom substrate in offshore waters from Mississippi to Texas, the expansion of the oil and gas industry has provided a significant portion of the habitat for organisms dependent on hard substrate (Carlisle *et al.* 1964; Shinn 1974; Sonnier *et al.* 1976; Gallaway and Lewbel 1982). Consequently, the gradual increase in the number of offshore platforms has likely played an important role in the development of a diverse aquatic ecosystem in the northern Gulf. The presence and abundance of many reef associated species, particularly fish, are correlated to the development of Outer Continental Shelf (OCS) oil and gas.

Artificial reefs are reported to function ecologically in a variety of ways that range from concentrating scattered fishes to elevating secondary production by increasing the growth and survival of new individuals. Although the exact mechanisms are not understood, the paradigm of attraction of fish to an artificial reef or increased production of biomass should not be viewed as an either/or situation, but as a continuum with few species falling at either extreme and most species operating between the delineations (Seaman *et al.* 1989). Since there are few studies examining the trophodynamics of artificial reefs, the ecological relationships between organisms and artificial habitats are not well understood (Bohnsak and Sutherland 1985).

Many species of fish found near oil and gas platforms are trophically independent of the structure but are thought to utilize the platform for other purposes (e.g., protection from predation, spawning habitat, shelter and orientation). For example, the association of pelagic fishes with artificial reefs has been attributed to visual attraction, increased food resources and protection from predation (Klima and Wickham 1971; Wickham *et al.* 1973). It has been hypothesized that large pelagic predators are often transient residents of artificial reefs as they lose visual orientation with structure at night or in low light conditions and/or because the availability of food resources around a single artificial reef may not be sufficient for survival.

Other species spend part or all of their life cycles within the same structure. They depend on the fouling community for food and habitat. Many of these fishes are coral reef species whose populations are usually habitat limited. Other commercially important species (e.g., red snapper, grouper, spadefish, and triggerfish) may have specific life stages that depend on the hard substrate for growth and survival.

The mechanisms and processes that lead to an increased abundance of fish near artificial reefs relative to adjacent environments are poorly understood (Grove and Sonu 1983). Some of the theories on factors influencing the abundance of fish at artificial reefs include

- current shadow or wake,
- shape and complexity,
- size of an artificial reef, and
- age and seasonality.

Due to the difficulty in sampling oil and gas platforms with standard fisheries methods (e.g., trawls and gill nets), new techniques must be developed in order to sample fish populations associated with these structures adequately. The use of hydroacoustic gear for the estimation of the biomass of various fish populations has the potential to replace the standard sampling methods. A stationary deployment of hydroacoustic gear can be used to detect fish near boundaries (i.e., the bottom, surface or near a platform) and enable researchers to obtain behavioral information such as diel movements and swimming speeds (Thorne 1983). With the advent of dual beam hydroacoustic equipment, measurements of *in situ* target strengths of free swimming fish can be measured and used to calculate the number, size and location of the fish detected. An estimate of abundance can be extrapolated once the volume sampled is determined (Burczynski and Dawson 1987).

To date, hydroacoustic gear has not been used to monitor fish populations near oil and gas platforms, but it has been used successfully in somewhat similar situations including the quantification of fish passage rates in lotic environments and near hydroelectric dams (Mesiar *et al.* 1987; Thorne and Kuehl 1987; Harte and Johnson 1989) and the observation of fish population patterns near artificial reefs (Arimoto and Inoue 1987; Thorne *et al.* 1989). Therefore, the application of hydroacoustic techniques to inventory fish populations near oil and gas platforms should prove to be successful with proper experimental design.

Hydroacoustics is particularly valuable in the Gulf because determination of the abundance and composition of fish stocks near oil and gas platforms has been inadequate. Most studies have been qualitative or were fisheries dependent studies and therefore not able to detect changes in species diversity and abundance accurately. New methods of assessment are necessary to determine the effects of OCS oil and gas development on fish populations. Similarly, meaningful management of the fishes in the OCS will in part depend upon the ability to assess quantitatively fish populations associated with oil and gas platforms.

The ability to determine the zone of influence on the ecological and behavioral patterns of the fish community near oil and gas platforms will help to determine the significance of the fisheries habitat provided by oil and gas platforms. Some innovative studies using remotely operated vehicles (ROVs), stationary cameras and diver surveys have been applied to surveying fish populations near oil and gas platforms and artificial reefs in the northern Gulf of Mexico (Continental Shelf Associates 1982; Putt 1982; Sanders 1983), but the results were only qualitative.

A research project applying state of the art hydroacoustics is currently underway to provide information on the factors that affect abundances of selected fish species associated with oil and gas platforms in the northern Gulf of Mexico. Specific objectives of the study are to

1. define the area of influence of a typical oil and gas platform on the behavior and abundance of various fish species,

2. provide biomass estimates of various species of fish associated with an oil and gas platform and determine if differences due to season and other factors occur, and

3. document the behavioral patterns of selected fish species in relation to oil and gas platforms in the northern Gulf of Mexico.

Louisiana State University's Coastal Fisheries Institute has established a joint project with Mobil Corporation USA to conduct this research project on an 8-pile oil and gas structure in 100 ft. of water off of Cameron, Louisiana. Dual beam hydroacoustic gear (120 and 420 kHz) has been deployed to assess the abundance of selected species of fish, define the area of influence of the structure, and document behavioral patterns of the fish associated with a typical oil and gas platform in the northern Gulf of Mexico. Based on hook-and-line capture species verification, data have been collected on red snapper, gray triggerfish, blue runner and Atlantic spadefish. These have been documented as the most abundant species typically found near platforms in water depths of approximately 30 m (Continental Shelf Associates 1982; Putt 1982). Future verification will be conducted with an ROV.

Two separate sampling regimes are being performed using hydroacoustic equipment. Four dual beam transducers oriented parallel to the surface (Figure 15.5) have been employed to determine the zone of influence of the structure. Deployment of the transducers is within the confines of the structure to sample adequately both the volume of water enclosed by the platform as well as that surrounding it. Sampling is conducted over a 24-hour period, (stratified by time) and will continue monthly over the next year. In addition, four transducers are being used to obtain behavioral patterns and biomass estimates of fish associated with the structure. Two dual beam transducers are placed on the sea floor oriented upwards and two suspended at the surface facing downwards (Figure 15.6). This orientation maximizes detection of fish at the boundaries of the water surface and at the sea floor. Sampling will occur over a 24-hour period following the 24-hour sampling outlined above. Other data collected during each sampling period will include current speed and direction.

Preliminary field excursions were dedicated to adapting the hydroacoustic gear to Mobil's platform. Following several adjustments, sampling techniques have been established such that the sonic fields are free of obstruction.

Data analyses are in progress, but preliminary patterns are evident. Fish biomass appears to fluctuate as a function of current direction, diel periodicity, and incident light. Target sizes have been highly variable and range from several grams to over 100 kilograms.

Although data analyses are far from complete, we have determined that hydroacoustics is a valid way to sample fish and other free swimming organisms associated with an oil and gas structure.

Results of this study should not only improve several parts of Louisiana's artificial reef program, but also lead to an improved understanding of the impacts of OCS activity on marine populations. Determination of the area of influence that platforms have as artificial reefs and insight into the behavior of species found near the structures will help to ascertain the number, proximity and configuration of platforms to be sited as artificial reefs to maximize their benefits. A better understanding of factors affecting the abundances of fishes and relationships between the de facto artificial reefs and associated fish populations will enable the Louisiana Artificial Reef Program to optimize and possibly justify the future additional siting of oil and gas platforms as artificial reefs.

Further, with the increasing demand placed on offshore fisheries by recreational and commercial users and concern over the impact of OCS activities on fish populations, knowledge of abundances and species composition of fishes associated with oil and gas structures with routine hydroacoustic assessment could provide necessary information to guide management and the fate of OCS fisheries better.

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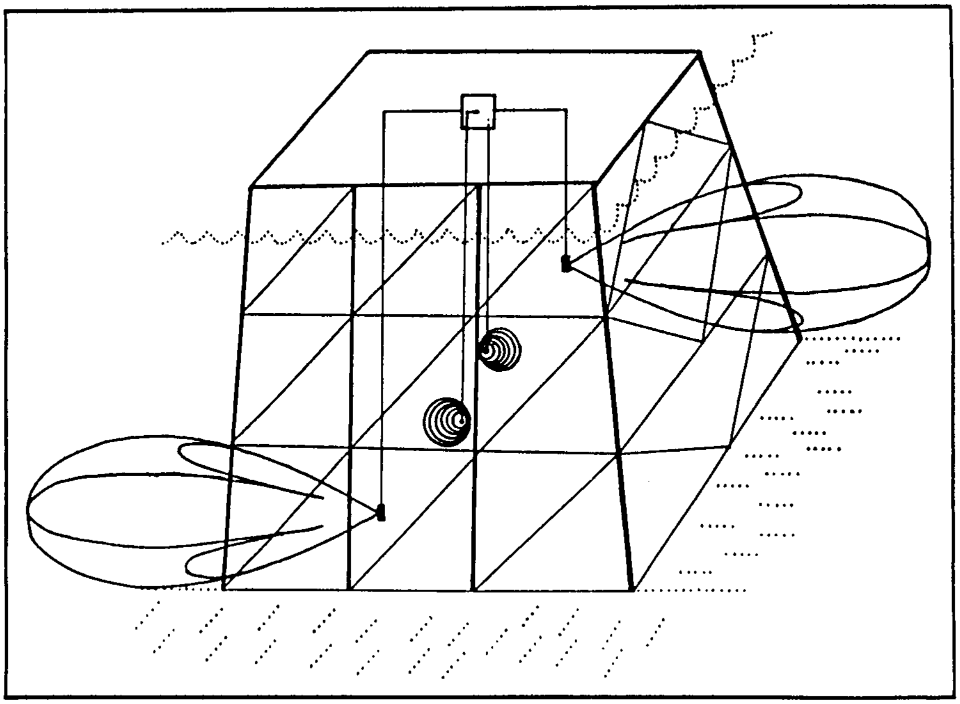

Figure 15.5. Deployment of four stationary dual beam transducers to sample the fish community horizontally from an oil and gas platform in the northern Gulf of Mexico.

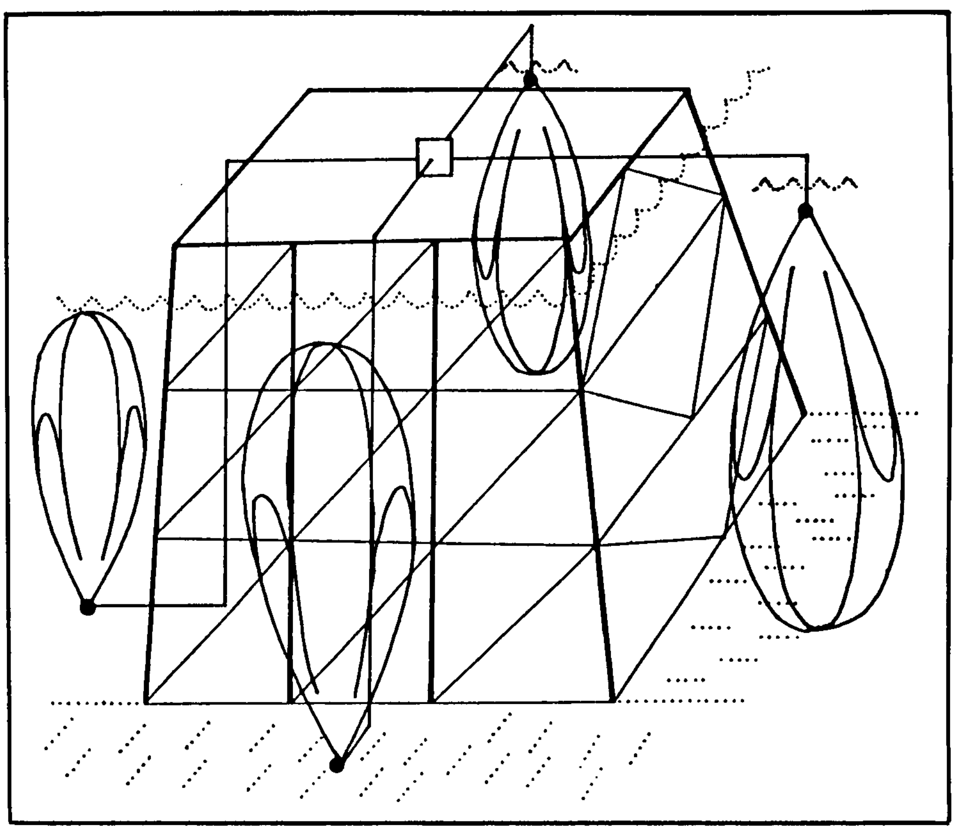

Figure 15.6. Deployment of four stationary dual beam transducers to census the fish populations near an oil and gas platform in the northern Gulf of Mexico.

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Mr. Curtis Cain is a Gas Control Coordinator for Mobile USA Inc. in Lake Charles, Louisiana. Mr. Cain has worked in the offshore oil and gas industry for over 35 years.

ESTIMATION AND MINIMIZATION OF UNDERWATER BLASTING EFFECTS ON FISH AND WILDLIFE ASSEMBLAGES

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SUMMARY

Underwater blasting is practiced throughout the world as a cost effective method for the maintenance and construction of waterways and harbors and the removal of subsurface structures. The shock waves that are created by underwater explosions may cause severe injury and death to nearby fish and wildlife. Historically, theoretical models have been developed to predict the lethal range of such underwater shock waves. Lethal range estimates are used by management to minimize and estimate the effects of blasting on fish and wildlife assemblages.

Unfortunately, the specific site geology and the temporal-spatial dynamics of fish and wildlife assemblages at blast sites are often too variable for accurately predicting the effects of underwater blasts. Our experience indicates that having information on the geological and biological variability at specific sites may offer, in part, a solution to minimizing the effects of underwater blasting. Using acoustical and optical measurement methods, we have developed procedures that provide rapid, real-time assessments of fish assemblages at blast sites. The baseline, real-time pre-blast and post-blast assessments of the abundance and distribution of fish have helped us to minimize and estimate the effects of underwater blasting at lacustrine, riverine, estuarine, and marine blast sites in Washington State.

The values of this research to industry are (1) the expansion and choice of work windows that are environmentally safe for underwater blasting operations, (2) the use of the best technology available to minimize deleterious environmental impacts, (3) the determination of specific environmental impacts of underwater blasting, and (4) the availability of novel measurement approaches for experimental evaluation of various engineering alternatives to mitigate the damage caused by underwater blasts. The wide range in site and operational conditions that this methodology has served suggests that the extent of its general applicability has not yet been determined.

Dr. Gary L. Thomas has been on research faculty at the University of Washington since 1979. He has 12 years' experience in fisheries acoustics. Dr. Thomas received his B.S. in biology from California Western, M.S. in zoology from San Diego State, and Ph.D. in fisheries from the University of Washington. Dr. Thomas has recently accepted the position of Director at the Prince William Sound Science Center in Cordova, Alaska.

Dr. Percy Washington has been president of GAIA Northwest, Inc., Seattle, for the past 8 years. Dr. Washington has 25 years of experience working on problems concerning marine, estuarine, and freshwater organisms. Dr. Washington received his B.S., M.S., and Ph.D. degrees in fisheries at the University of Washington.

THE OCCURRENCE OF HEAVY METALS IN SELECTED TISSUES OF THE ATLANTIC BOTTLENOSE DOLPHIN (TURSIOPS TRUNCATUS) STRANDED ALONG THE TEXAS COAST: A PRELIMINARY ANALYSIS

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INTRODUCTION

Increasing environmental awareness has fostered greater concern for marine ecosystems and their possible degradation by a variety of pollutants. Three broad categories of chemical contaminants that potentially impact marine mammals are recognized within the marine environment:

1. Petroleum Hydrocarbons--Oil.

2. Organochlorines--Polychlorinated biphenyls and pesticides such as DDT and its derivative compounds.

3. Heavy Metals--Naturally occurring elements such as lead, iron, mercury, and cadmium, which are also introduced into the environment by anthropogenic sources. Heavy metal concentrations are the focus of our study.

Several incidences of mass mortalities involving marine mammals worldwide have raised questions about contaminant levels in marine mammals. Reijnders (1988) reports that monitoring marine mammals is important ecologically, and one aspect of monitoring is the collection of baseline data on contaminant occurrence.

Because dolphins occupy a high trophic level in the food chain, analysis of their tissues may lead to a better understanding of bioaccumulation in the marine ecosystem. In Texas, no baseline levels have been established for heavy metals in local populations of bottlenose dolphins. The high number of strandings in Texas during the first quarter of this year (147 as compared to 55 in 1989 and 70 in 1988) created greater interest in monitoring the local cetacean fauna.

Monitoring these animals may help in identifying problems in the health of dolphin populations. Researchers (Stoneburner 1978) have speculated that high concentrations of heavy metals may be involved with some whale and dolphin strandings; substantial levels of heavy metals can be found in tissues of these animals.

Assembly of such data may provide a baseline in support of future conservation strategies with regard to marine contaminants and their impact on a marine mammal population.

MATERIALS AND METHODS

The Texas Marine Mammal Stranding Network (TMMSN) began collecting and storing tissues for monitoring in 1983. In Texas there is great potential for monitoring cetaceans due to an average of more than 110 strandings (89% Atlantic bottlenose dolphin, *Tursiops truncatus*) every year. The TMMSN is set up to collect information about each animal that strands. Since the first tissues were collected, a protocol has been established that considers variables related to contaminant concentration within tissues. This includes recording morphometric data as well as collecting stomachs for content analysis, teeth for aging, gonads for determination of sexual maturity and five tissues for toxicologic analysis. Sections of left caudal kidney and liver, muscle and blubber from just behind and to the left of the dorsal fin, and bone from left mid-thoracic ribs are collected and wrapped in aluminum foil, labeled and then placed in a plastic bag. All tissues are stored in freezers until analyzed.

Laboratory processing

A one-gram subsample was dissected from the center of the tissue in order to avoid contamination that may have occurred during field collection. The subsample was placed into a teflon bomb for digestion and 3 ml of Ultrex nitric acid was added to begin tissue digestion. After standing at room temperature overnight, the bombs were tightly closed and then placed in a 130°C oven for 10 hours.

Once the sample was digested, it was diluted with 20 ml deionized distilled water and then analyzed for heavy metals by atomic absorption spectrophotometry (AAS). Mercury was analyzed by the cold vapor technique (Hatch and Ott 1968), iron and zinc were determined by flame AAS, and selenium and cadmium concentrations were determined by graphite furnace AAS. Standard reference materials (National Research Council of Canada, Dorm-1 and Dolt-1) were also run with the dolphin samples in order to confirm accuracy of results.

RESULTS

In preliminary analyses the following trends previously documented in other dolphin species (Honda *et al.* 1983; Gaskin *et al.* 1972, 1979; Falconer *et al.* 1983; Thompson 1990) have been found. Liver generally concentrates the highest metal levels with the exception of cadmium in kidney. The kidney is the next highest concentrator of heavy metals. Muscle, which is considered to be a long-term storage organ, has lower concentrations of most metals.

Table 15.2 indicates that mean concentrations of iron and zinc, elements necessary for metabolism, are similar among different species of dolphins and different regions. Other metals tend to vary greatly. The highest concentrations of iron and zinc are found in the liver followed by kidney and then muscle. Cadmium, as mentioned earlier, is highest in kidney tissue followed by liver and muscle. It appears to be much lower than in the western Pacific populations of *Stenella coeruleoalba* (Honda *et al.* 1983). Within species, mercury in the liver shows a considerable range of values whereas kidney and muscle values appear to be more constant. Selenium, thought to be a protective agent against mercury poisoning, seems to be highly correlated (R^2 = 0.97) with mercury.

CONCLUSIONS

Preliminary analyses reveal trends similar to those reported in other odontocete species and other regions. Actual tissue metal levels in each region and species may reflect contaminant load in the specific region or the physiological capabilities of the species to eliminate heavy metals. Upon completion of preliminary analyses, a statistical study has been planned that will investigate the effects of age, sex and geographical region on concentrations of metals in tissues of dolphins stranded along the Texas coast. Because these animals are usually found dead, the comparison can only make a statement about the stranded animals and cannot be extrapolated to the general live healthy populations.

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Table 15.2. Metal Concentrations (ug/g tissue wet weight) in Liver (L), Kidney (K), and Muscle (M) of *Tursiops* from Texas, *Stenella* from East Coast of Japan (Honda *et al.* 1983) and *Phocoena* from East Coast of Scotland (Falconer *et al.* 1983) and Deer Island*, East Canada (Gaskin *et al.* 1979).

		N	*Tursiops*	N	*Stenella*	N	*Phocoena*
Cd	L	7	0.1006	57	6.3	17	0.2
	K	18	0.4167	54	24.8	17	1.1
	M	5	0.0034	58	0.1		
Zn	L	7	42.74	57	44.5	17	43.2
	K	16	30.02	30	30.1	17	23.8
	M	6	20.63	59	11.4		
Fe	L	7	287.4	57	215.0		
	K	18	185.3	30	143.0		
	M	6	92.8	59	159.0		
Hg	L	5	37.98	45	205.0	41	11.2*
	K	18	1.75	20	8.7	23	1.8*
	M	5	0.68	51	7.0	60	0.9*
Se	L	6	9.2	15	48.6		
	K	18	2.6	14	5.6		
	M	26	0.31	26	2.8		

is maintaining the database and archival of toxicology tissues from stranded marine mammals in Texas. Ms. Haubold received her B.S. in wildlife and fisheries science from Texas A&M University.

Dr. B. J. Presley is a full professor in the oceanography department of Texas A&M University where he has been a faculty member since 1970. He is the author of more than 60 publications on the behavior of trace elements in the marine environment, the chemistry of pore water in marine sediments and marine pollution. Dr. Presley received his B.S. in geology from Oklahoma State University, his M.S. in geology from West Virginia University, and PhD. in geology from UCLA.

Dr. Raymond J. Tarpley is an Assistant Professor in the Department of Veterinary Anatomy and Public Health at Texas A&M University. He has served as coordinator of the Texas Marine Mammal Stranding Network, which provides a mechanism for collecting and assembling specimens for toxicologic analysis. Dr. Tarpley received his D.V.M., M.S., and Ph.D. from Texas A&M University.

AN INVESTIGATION OF DOLPHIN (TURSIOPS TRUNCATUS) DEATHS IN EAST MATAGORDA BAY, TEXAS IN JANUARY 1990

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Acute mortality in localized dolphin pods of 10 to 40 animals has likely occurred but at present there are no comprehensive documented reports of such events. In January 1990, the U.S. Coast Guard Station at Freeport, Texas, was notified by a helicopter pilot that he had sighted a total of 23 dead bottlenose dolphins (*Tursiops truncatus*) on the shore or in the tidal flats of East Matagorda Bay (EMB), Texas, and another 3 dead dolphins (*Tursiops truncatus*) on the shore of East Matagorda Peninsula.

Each dead dolphin was identified with an ID number and its exact location noted as the animals were lifted from the beach. The carcasses were transported to Galveston, Texas, for necropsy analysis at facilities provided by Texas A&M University for the Texas Marine Mammal Stranding Network. Major necropsy findings included an average of 39% reduction in blubber thickness compared to similar-aged dolphins stranded during winter months during the previous 8 years and a predominant lack of food material in the stomachs of dead dolphins.

Data were collected on the physical characteristics of EMB. The effect of weather on bay temperature, tidal changes, and resident animal populations was examined. The major food source for the dolphins, the Striped mullet (*Mugil cephalus*), was devastated during the severe cold weather system that moved through the area in late December 1989. The mullet kill (2.75 million) in this small bay amounted to 42% of the total fish kill along the entire Texas coast for this time period. Average monthly temperatures of bay waters vary from about 12°C to 33°C; however, the water temperatures did drop to near 0°C for short periods during severe winter storms that hit the Texas coast as often as several times in a winter. The December 1989 water temperatures in this bay dropped to -1.36°C and stayed near 0°C for about 48 hours, causing the bay to freeze over. The major reduction in blubber thickness suggests that decimation of the food resource, in addition to any direct effects of the extreme cold, contributed to this acute dolphin mortality event.

Dr. W. George Miller has earned both a Ph.D. and D.V.M. from Texas A&M University. At present, he is working on marine mammals at the Naval Ocean Systems Center in San Diego, California. His interests include the documentation of the recent die-off of the bottlenose dolphin in East Matagorda Bay, Texas.

BOTTLENOSE DOLPHIN REACTIONS TO THE MEGA BORG OIL SPILL

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Little is known about the reaction of wild bottlenose dolphins, *Tursiops truncatus,* to oil, although studies of captive bottlenose dolphins exposed to controlled oil spills indicated that animals could detect and avoid thick, dark oil (Geraci *et al.* 1983; Smith *et al.* 1983). Several species of mysticetes and odontocetes have been opportunistically observed feeding or traveling through oil slicks with no apparent change in behavior (Goodale *et al.* 1979; Geraci 1990). Gray whales, *Eschrichtius robustus*, responded to natural oil seeps by changes in respiration and surfacing patterns (Kent *et al.* 1981). To determine the behavioral response of wild, offshore bottlenose dolphins to the *Mega Borg* oilspill in June 1990 off Galveston, Texas, an investigation was made jointly by the Marine Mammal Research Program at Texas A&M University and the National Marine Fisheries Service, Southeast Fisheries Center, Miami, Florida.

METHODS AND RESULTS

Behavioral descriptions of bottlenose dolphins in and near the *Mega Borg* oil spill were made from a DeHavilland Twin Otter aircraft circling at an altitude of 457 m on four days between 15 and 18 June 1990. Verbal descriptions by three observers were recorded onto an FMD430 Marantz tape recorder while one observer video recorded dolphins and observer voices with a high resolution 8 mm Sony CCDV97 video camera. The following information was recorded: (1) orientation and estimated distance of dolphins to oil; (2) general behavior and synchrony of dolphins based on the following categories: travel, mill, aerial, and social (body contact between dolphins); (3) surfacing respirations; (4) speed of movement (slow, medium, fast); (5) interanimal spacing; (6) group size; (7) visibility of dolphins to observers (time at or below surface, any visibility impediments such as sea state or glare); and (8) any boat or other activity occurring near dolphins. Three oil types were considered: sheen (a light luminescent oil); slick (a thick; iridescent oil which dolphins displaced while surfacing); and mousse (a dark-brown, frothy thicker oil).

A total of 5.9 hours of behavioral observations was collected from nine groups of bottlenose dolphins. Group size ranged from 3 to an estimated 50 individuals, with observation sessions ranging in duration from 20 to 51 minutes. Preliminary results indicate that bottlenose dolphins can detect but do not avoid most oil. Dolphins did not appear to detect or be affected by sheen oil. Dolphins were once observed to enter sheen oil from apparently oil-free water, with no apparent change in behavior or orientation. They were observed within sheen on four occasions, engaging in what seemed to be "normal" behavior, including socializing and aerial activity. Data indicate that dolphins were able to detect slick oil, although reactions varied. On one occasion, a group of dolphins was observed traveling in sheen directly toward an oil slick for a period of 25 minutes, when the group abruptly began milling and consequently turned to parallel the oil for 10 minutes when within approximately 400 m; the dolphins were last sighted swimming directly away from the slick. Upon 7 encounters with narrow (approximately 3 to 5 m wide) strips of slick oil, dolphins surfaced within the slick strip 4 times and dove under the slick strip 3 times. Dolphins were observed to hesitate or swim parallel to oil before entering an extensive slick area on two of two occasions. Preliminary analysis suggests that while swimming in extensive slick areas, dolphins respond behaviorally by decreasing interanimal spacing and social behavior and increasing dive time, depth of dive, and swim speed. However, on one occasion, two dolphins deviated from course while in a large slick to bow ride a vessel. Almost invariably (9 of 10 instances) dolphin groups dove under (7 times) or swam around (2 times) mousse oil. The exception was an opportunistically observed group of two dolphins that surfaced within a patch of mousse.

SUMMARY

Studies of bottlenose dolphins exposed to oil slicks in captivity indicated that the animals could not detect light oil sheen, but could detect thick, dark oil (Geraci *et al.* 1983; Smith *et al.* 1983). These observations are consistent with field observations in this study. However, captive studies showed that dolphins completely avoided surfacing in or swimming beyond slick oil after a few brief, initial tactile encounters. This did not appear to be the case with field observations near the *Mega Borg* oil spill: dolphins did not avoid slick oil in most circumstances, but rather continued swimming through extensive oil areas despite what appeared to be "cleaner" water near-by. This is similar to field observations of bottlenose dolphins in slicks reported by other investigators (Shane and Schmidly 1978; Gruber 1981; Henningsen pers. comm.). There is some evidence, however, that bottlenose dolphins may change general behavior in response to slick oil. Gray whales responded to the presence of natural oil seep slicks by modifying swim speed, decreasing respirations and time at the surface, and increasing dive time (Kent *et al.* 1981). Bottlenose dolphins appeared to avoid contact with mousse, although mousse did not impede movement. It is possible that bottlenose dolphins have become accustomed to oil due to the extent of related activity in the Gulf of Mexico, or that some overriding behavioral motivation, such as feeding, induced dolphins to swim through oil. It is also possible that dolphins in extensive slick areas did not know how to avoid oil.

These observations represent preliminary interpretations of the response of bottlenose dolphins to oil. Statistical analyses of data are in progress. Initial observations suggest that bottlenose dolphins may be vulnerable to volatile oil spills characterized by a light sheen on the water surface, which they appear unable to detect or to which they are indifferent. Few data are available on the potential physiological effects of oil on bottlenose dolphins or cetaceans in general. More studies on opportunistic behavioral observations of cetaceans near oilspills compared to baseline studies in oil-free water will help to interpret potential responses and vulnerability to oil.

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Dr. Bernd Würsig is Professor of Marine Mammalogy and Director of the Marine Mammal Research Program at Texas A&M University at Galveston. He is a specialist in marine mammal behavior and has studied right, bowhead and humpback whales and various balaenopterid species, as well as the behavioral ecology of dolphins in Argentina, Hawaii, New Zealand, Mexico, and China. He has been a principal investigator in Minerals Management Service's studies of the behavior and disturbance responses of bowhead and gray whales to seismic exploration. Dr. Würsig received his B.S. in zoology at Ohio State University, his Ph.D. in neurobiology and behavior, and ecology and evolution, at State University of New York-Stony Brook, and conducted his postdoctoral work through the University of California at Santa Cruz.

Ms. Mari A. Smultea has been involved in marine mammal behavioral studies since 1983 including ones on humpback, bowhead, beluga, and killer whales and harbor porpoises in Hawaii, Australia, Greenland, Alaska, the Arctic, and the Pacific Northwest. Her special interest lies in assessing the impact of human activities on cetaceans and the environment. She received her B.A. in human ecology at Connecticut College and is finishing her M.S. in wildlife and fisheries sciences at Texas A&M University, advised by Dr. Bernd Würsig, and is affiliated with the Marine Mammal Research Program at Texas A&M University at Galveston.

AGENDA

Minerals Management Service, Gulf of Mexico OCS Region
Information Transfer Meeting

Session I

Tuesday, November 13, 1990

International Ballroom (16th Floor)

Opening Plenary Session: The OCS Oil & Gas Program - Current Issues, Past Benefits, Legislative Outlook

Chairs: Dr. Richard Defenbaugh and Mr. Ruben Garza

9:30 a.m. **Welcome, Opening Remarks**

Dr. Richard Defenbaugh,
MMS, Gulf of Mexico OCS Region
and
Mr. Ruben Garza, Geo-Marine, Inc.

Agency Welcome

Mr. J. Rogers Pearcy, Regional Director,
MMS, Gulf of Mexico OCS Region

9:45 a.m. **MMS: Current Issues**

Mr. Barry Williamson, Director (invited)
MMS, Headquarters Office

10:15 a.m. **Financial Accounting for the OCS Leasing Program**

Dr. Scott Farrow,
Council on Environmental Quality

11:00 a.m. **MMS/OCS Program Legislative Outlook**

Ms. Jill Martin
MMS, Headquarters Office of Congressional and Legislative Affairs

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Session II.A

Tuesday, November 13, 1990

Crescent "A" Room (16th Floor)

MMS Environmental Studies for the Gulf of Mexico: Active Studies Progress Reports

Chairs: Dr. Robert Rogers and Ms. Bonnie LaBorde Johnson

1:30 p.m. **Welcome, Opening Remarks**

Dr. Robert Rogers
MMS, Gulf of Mexico OCS Region

1:45 p.m. **Long-Term Monitoring at the Flower Garden Banks**

Dr. Steve Gittings
Texas A&M University

2:15 p.m. **Mississippi-Alabama Pinnacle Trend Mapping**

Mr. Richard Shaul
Continental Shelf Associates, Inc.

2:45 p.m. **Refreshment Break**

3:00 p.m. **Sea Turtles and Marine Mammals Overflights Projects**

Dr. Keith Mullin
National Marine Fisheries Service, Pascagoula Laboratory

3:30 p.m. **Applications of an Archaeological Resource Study to Refine the MMS Historic Shipwreck Model**

Dr. Rik Anuskiewicz
MMS, Gulf of Mexico OCS Region

4:00 p.m. **Wetland Mitigation: A Study of Marsh Management**

Dr. Don Cahoon
Louisiana Geological Survey

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Session II.B

Tuesday, November 13, 1990

Crescent "B" Room (16th Floor)

Recent Seafloor Clearance Activities at Abandoned Oil and Gas Structure Sites

Chairs: Mr. Felix Dyhrkopp and Mr. Arvind Shah

1:30 p.m. **Welcome, Opening Remarks**

Mr. Felix Dyhrkopp
MMS, Gulf of Mexico OCS Region

1:40 p.m. **Role of Survey/Sonar Contractor in Locating and Removing Seafloor Debris**

Mr. Bill Tink
WIMPOL, Inc.

2:10 p.m. **Impact of Recent OCS Site Clearance Activities on the Oil and Gas Industry**

Mr. Mike Parker
Offshore Operators Committee
Exxon Company, U.S.A.

2:40 p.m. **Refreshment Break**

3:00 p.m. **Summary of Site Clearance Information Gathered to Date Under the Site Clearance: Notice to Lessees 90-01/03**

Mr. Felix Dyhrkopp
MMS, Gulf of Mexico OCS Region

3:30 p.m. **Panel Discussion: A Case Study Summary of a Site Clearance Operation**

Mr. Jimmy Martin, Shrimper
Mr. Mike Parker, Offshore operator, Exxon Co. USA
Mr. Robert Suggs, Salvage company, American Oilfield Divers
Mr. Bill Tink, Sonar company, WIMPOL, Inc.

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Session II.C

Tuesday, November 13, 1990

Rosedown Room, (2nd Floor)

Risk & Reward: **Fueling America's Recreation, Conservation, and Preservation Programs Through OCS Leasing**

Chairs: Mr. Villere Reggio and Ms. Linda Castaño

1:30 p.m. **Welcome, Opening Remarks**

Mr. Villere Reggio
MMS, Gulf of Mexico OCS Region

1:45 p.m. **Land & Water Conservation Fund - Impact on State Outdoor Recreation Programs**

Mr. Samuel Hall
Chief, Recreation Grants Division
National Park Service

2:15 p.m. **Land & Water Conservation Fund - Impact on America's National Parks and Seashores**

Mr. Willis Kriz
Chief, Land Resources Division
National Park Service

2:45 p.m. **Land & Water Conservation Fund - Impact on National Wildlife Refuges and Endangered Species**

U.S. Fish and Wildlife Service

3:15 p.m. **Refreshment Break**

3:30 p.m. **Land & Water Conservation Fund - Impact on National Forests**

Mr. Lawrence W. Braddock
Director of Recreation
U.S. Forest Service

4:00 p.m. **Historic Preservation Fund - Impact on Historic and Cultural Resources**

Mr. Stephen Newman
Grants Administrator (Historic Preservation Fund)
National Park Service

4:30 p.m. **Private Perspective: How a Private Conservation Group Can Help Generate More Acres Per Dollar from the Land & Water Conservation Fund**

Mr. Philip Ellender
Director of Development
The Nature Conservancy of Louisiana

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Session II.D

Tuesday, November 13, 1990

Shadows Room (2nd Floor)

Contributed Papers: Offshore Mapping and Deepwater Operations

Chairs: Mr. G. Ed Richardson and Ms. Susan Gaudry

1:30 p.m. **Welcome, Opening Remarks**

Mr. G. Ed Richardson
MMS, Gulf of Mexico OCS Region

1:40 p.m. **Overview of Current NOAA/NOS Bathymetric Mapping of Gulf of Mexico Outer Shelf and Slope**

Captain Skip Theberg
NOAA, National Ocean Service

2:00 p.m. **NAD 83: A Progress Report**

Mr. Lee Thormahlen
MMS, OCS Survey Group
Denver, Colorado

2:20 p.m. **Deep-Water Geohazards and Engineering Geology, Northern Gulf of Mexico**

Mr. Kerry J. Campbell
Fugro-McClelland Marine Geosciences, Inc.

2:40 p.m. **Refreshment Break**

2:55 p.m. **Deep-Water Pipeline Safety and Risk Assessment**

Mr. Howard S. Wright
J. P. Kenny, Inc.

3:15 p.m. **Extended Well Testing**

Mr. Bruce Crager
Ocean Systems Engineering, Inc.

3:30 p.m. **Offshore Technology Research in Support of Deepwater Operations**

Mr. John E. Flipse
Offshore Technology Research Center
Texas A&M University

4:00 p.m. **Open Discussion**

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Session III.A

Wednesday, November 14, 1990

Crescent "A" Room (16th Floor)

Mississippi/Alabama Shelf Marine Ecosystems Study, I

Chairs: Dr. Jim Brooks and Dr. Robert Rogers

8:30 a.m. **Welcome, Opening Remarks and Overview of the Mississippi-Alabama Marine Ecosystem Study**

Dr. Robert Rogers
MMS, Gulf of Mexico OCS Region
and
Dr. Jim Brooks
Texas A&M University

8:45 a.m. **Sediment Hydrocarbon, Bulk Organic Matter, and Trace Metal Distributions**

Dr. Chuck Kennicutt
Texas A&M University

9:15 a.m. **Physical Oceanography/Water Mass Characterization**

Mr. Frank Kelly
Texas A&M University

10:00 a.m. **Refreshment Break**

10:15 a.m. **Satellite Oceanography**

Dr. Drew Vastano
Texas A&M University

10:45 a.m. **Macroinfauna and Macroepifauna**

Dr. Don Harper
Texas A&M University

11:15 a.m. **Demersal Fish Taxonomy**

Dr. John McEachran
Texas A&M University

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Session III.B

Wednesday, November 14, 1990

Crescent "B" Room (16th Floor)

"Produced Waters:" Findings of Recent Studies in the Coastal Waters of Louisiana

Chairs: Dr. James Kendall and Ms. Gail Rainey

8:30 a.m.	**Welcome, Opening Remarks**	
		Dr. James J. Kendall MMS, Gulf of Mexico Region
8:40 a.m.	**Introduction to the MMS-Funded Study on Produced Waters and Study Site Descriptions**	
		Dr. Denise J. Reed Louisiana Universities Marine Consortium
9:00 a.m.	**Findings of the MMS-Funded Study on Produced Waters: Chemical Contaminants**	
		Dr. Jay C. Means Louisiana State University
9:20 a.m.	**Findings of the MMS-Funded Study on Produced Waters: Biological Assessment**	
		Dr. Nancy N. Rabalais Louisiana Universities Marine Consortium
9:40 a.m.	**Refreshment Break**	
10:00 a.m.	**Review: Findings of the API Study on Produced Waters**	
		Dr. Jerry Neff Arthur D. Little, Inc.
10:20 a.m.	**An Assessment of Produced Waters Impacts in Louisiana**	
		Mr. Kerry St. Pé Louisiana Department of Environmental Quality
10:40 a.m.	**Overview of Current Environmental Regulations Regarding Produced Waters**	
		Dr. Lee B. Gibson Environmental Protection Agency
11:00 a.m.	**Open Discussion**	
		Dr. James Kendall and Ms. Gail Rainey MMS, Gulf of Mexico Region

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Session III.C

Wednesday, November 14, 1990

Rosedown Room, (2nd Floor)

MMS Offshore Technology Assessment and Research Program

Chairs: Dr. Maurice Stewart, P.E., and Mr. Robert Lanza, P.E.

8:30 a.m.	**Welcome, Opening Remarks**	
		Dr. Maurice Stewart, P.E. MMS, Gulf of Mexico OCS Region
8:40 a.m.	**Overview of MMS Technology Assessment and Research Program**	
		Mr. Charles Smith, P.E. MMS, Headquarters Office
9:05 a.m.	**Verification Technology for Deepwater and Aging Structure**	
		Mr. Charles Smith, P.E. MMS, Headquarters Office
9:30 a.m.	**Blowout Prevention in Deepwater Drilling**	
		Dr. A. T. Bourgoyne, P.E. Louisiana State University
9:55 a.m.	**Refreshment Break**	
10:15 am.	**Blowout Fire Suppression**	
		Dr. David Evans National Institute of Standards and Technology
10:40 a.m.	**Engine Exhaust Emission Control Technology**	
		Mr. John Peirson Arthur D. Little, Inc.
11:05 a.m.	**Safety of Operations**	
		Mr. Elmer P. Dannenberger MMS, Headquarters Office

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Session III.D

Wednesday, November 14, 1990

Shadows Room (2nd Floor)

Advances in Telemetry, Tagging, and Tracking of Endangered Species, I

Chairs: Dr. Robert Avent and Mr. Patrick Mangan

8:30 a.m. **Welcome, Opening Remarks, and Discussion of Information Needs and Concerns for the Gulf of Mexico**

Dr. Robert Avent
Mr. Patrick Mangan
MMS, Gulf of Mexico OCS Region

8:45 a.m. **The Application of Sonic, Radio, and Satellite Telemetry for Studying the Ecology of Juvenile Kemp's Ridley Sea Turtles**

Dr. Edward Standora
State University College, Buffalo, NY
and
Mr. Stephen J. Morreale
Okeanos Ocean Research Foundation

9:15 a.m. **State of the Art Sea Turtle Tracking**

Mr. John Keinath
Virginia Institute of Marine Science

9:45 a.m. **Refreshment Break**

10:15 a.m. **Assessing Critical Habitats of Whales by Satellite Tracking**

Dr. Bruce Mate
Oregon State University, Hatfield Marine Science Center

10:45 a.m. **Telemetry of Large Whales**

Mr. Jeffrey D. Goodyear
University of Guelph

11:00 a.m. **Passive and Active Acoustic Detection of Biological Targets**

Dr. Coleman Levenson
National Oceanographic and Atmospheric Research Laboratory

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Session IV.A

Wednesday, November 14, 1990

Crescent "A" Room (16th Floor)

Mississippi/Alabama Shelf Marine Ecosystems Study, II

Chairs: Dr. Jim Brooks and Dr. Robert Rogers

1:30 p.m. **Welcome, Opening Remarks**

Dr. Jim Brooks
Texas A&M University

1:35 p.m. **Demersal Fish Food Habit Analysis**

Dr. Rez Darnell
Texas A&M University

1:55 p.m. **Geological Characterization of Topographic Features and Relationships to Sea Level**

Dr. Will Sager
Texas A&M University

2:45 p.m. **Topographic Feature Summit/Base Depth Relationships**

Dr. Will Schroeder
Dauphin Island Sea Lab

3:05 p.m. **Refreshment Break**

3:20 p.m. **Biological Characterization of Communities on Topographic Features**

Dr. Steve Gittings
Texas A&M University

4:00 p.m. **Summary and Synthesis**

Dr. Rez Darnell
Texas A&M University

4:30 p.m. **Utility and Application of Study Information for State Resource-Management Decision-making**

Mr. Steve Parker
State of Alabama

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Session IV.B

Wednesday, November 14, 1990

Crescent "B" Room (16th Floor)

Naturally Occurring Radioactive Materials

Chairs: Mr. Lars Herbst and Mr. Gary Rutherford

1:30 p.m. **Welcome, Opening Remarks**

Mr. Lars Herbst
MMS, Gulf of Mexico OCS Region

1:35 p.m. **Industry Perspective on Naturally Occurring Radioactive Materials (NORM)**

Mr. Buck Steingraber
American Petroleum Institute, NORM Subcommittee Chairman

2:05 p.m. **State of Louisiana Perspective on Naturally Occurring Radioactive Materials**

Mr. Hall Bohlinger
Louisiana Department of Environmental Quality

2:35 p.m. **State of Texas Perspective on Naturally Occcurring Radioactive Materials**

Mr. Ralph Heyer
Texas Department of Health

3:05 p.m. **Refreshment Break**

3:25 p.m. **The Applicability of Envirocares Disposal Site in Utah for Naturally Occurring Radioactive Materials**

Mr. Khosrow B. Semnani
Envirocare of Utah, Inc.

3:55 p.m. **Cleaning of Naturally Occurring Radioactive Materials and North Sea Procedures**

Mr. Rupert Macnamee
Hydrocut/Macnamee Services

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Session IV.C

Wednesday, November 14, 1990

Rosedown Room (2nd Floor)

Impact of Offshore Oil Exploration and Production on the Social Institutions of Coastal Louisiana

Chairs: Dr. Shirley Laska and Ms. Vicki Zatarain

1:30 p.m. **Welcome, Opening Remarks, and Project Introduction**

Dr. Shirley Laska
Environmental Social Science Research Institute
University of New Orleans

1:45 p.m. **Effects of Offshore Employment on Family**

Dr. Craig Forsyth
Department of Sociology and Anthropology
University of Southwestern Louisiana

2:00 p.m. **Poverty During Boom/Bust Cycles and Social Service Response**

Dr. Sarah Brabant
Department of Sociology and Anthropology
University of Southwestern Louisiana

2:15 p.m. **Changing Social and Demographic Characteristics of Oil-Involved Communities**

Dr. Ruth Seydlitz
Department of Sociology, University of New Orleans

2:30 p.m. **Governmental Adjustments to Fluctuating Oil Revenues**

Dr. Ralph Thayer
College of Urban and Public Affairs, University of New Orleans

2:45 p.m. **Offshore Leasing Activity as Corporate Strategy**

Mr. Charles Lambert
Department of Sociology, University of New Orleans

3:00 p.m. **Common Themes of Social Institution Impact and Response**

Dr. Vern Baxter
Department of Sociology, University of New Orleans

3:15 p.m. **Refreshment Break**

3:30 p.m. **Project Discussion**
Dr. William Freudenburg
Dept. of Sociology, University of Wisconsin
Dr. Robert Gramling
Department of Sociology and Anthropology
University of Southwestern Louisiana
Dr. Harvey Molotch
Department of Sociology
University of California at Santa Barbara

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Session IV.D

Wednesday, November 14, 1990

Shadows Room (2nd Floor)

Advances in Telemetry, Tagging, and Tracking of Endangered Species, II

Chairs: Dr. Robert Avent and Mr. Patrick G. Mangan

1:30 p.m. **Welcome, Opening Remarks**

Mr. Patrick Mangan and Dr. Robert Avent
MMS, Gulf of Mexico OCS Region

1:35 p.m. **Remote Sensing-Data Acquisition and Communication**

Mr. Bill Whelan
Ocean Communications Systems

2:00 p.m. **Acoustic Tracking Technology**

Mr. Don Brumbaugh
Sonotronics, Inc.

2:30 p.m. **Advances in Satellite and Radio Location Technology**

Mr. Stan Tomkiewicz
Telonics, Inc.

3:00 p.m. **Refreshment Break**

3:15 p.m. **Argos System Capabilities**

Mr. Christopher Estes
Service Argos, U.S.

3:45 p.m. **Open Discussion of Sea Turtle & Marine Mammal Study Designs for the Gulf of Mexico**

Dr. Warren Stuntz: MMS/NMFS Sea Turtle Study
Dr. Robert Avent and Mr. Patrick Mangan: MMS Marine Mammal Studies

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Session V.A

Thursday, November 15, 1990

Crescent "A" Room (16th Floor)

New Developments in Oil Spill Response and Response Planning, I

Chairs: Ms. Darice Breeding and Mr. Dennis Chew

8:30 a.m. **Welcome, Opening Remarks**

Ms. Darice Breeding
MMS, Gulf of Mexico OCS Region

8:35 a.m. **Update of Clean Gulf Associates Spill Response Planning**

Ms. Belinda Breaux
Chairperson, Clean Gulf Associates, Inc., Technical Committee

9:00 a.m. **Provisions of the Oil Pollution Act of 1990: USCG Perspective**

Capt. John E. Lindak
USCG, New Orleans, LA

9:25 a.m. **Refreshment Break**

9:45 a.m. **Panel Discussion - Update Results of Federal and Industry-Sponsored Oil Spill Research Programs**

Mr. Ed Tennyson, MMS, Technology Assessment and Research Branch
Mr. David Evans, National Institute of Standards & Technology
Capt. Don Jensen, USCG, Research and Development
Mr. Kurt Jakobson, Environmental Protection Agency

11:45 a.m. **Closing Remarks**

Ms. Darice Breeding
MMS, Gulf of Mexico OCS Region

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Session V.B

Thursday, November 15, 1990

Crescent "B" Room (16th Floor)

Physical Oceanography, I

Chairs: Dr. Murray L. Brown and Dr. Alexis Lugo-Fernández

8:30 a.m. **Welcome, Opening Remarks**

Dr. Murray Brown
MMS, Gulf of Mexico OCS Region

8:35 a.m. **Presentation of Award**

Mr. J. Kenneth Adams
MMS, Gulf of Mexico OCS Region

8:40 a.m. **A Short History of and Representative Current Measurements for Nelson Eddy**

Mr. Stephen P. Koch
Exxon Production Research Company

9:05 a.m. **A Digital Archive of Ocean Analyses During the "Eddy Nelson" Episode, Using the GULFPLOT Format**

Mr. Jeff Cox
Evans-Hamilton, Inc.

9:35 a.m. **U.S. Navy Tests of Sonobuoy-Size Oceanographic Buoys in Gulf of Mexico Eddies Episode, Using the GULFPLOT Format**

Dr. Robert Pickett
Naval Oceanographic and Atmospheric Research Laboratories

10:05 a.m. **"Quiet Eddy" Survey Results, Summer 1990**

Mr. Ken Schaudt
Eddy Joint Industry Project
Marathon Oil Company

10:35 a.m. **Refreshment Break**

10:50 a.m. **Benefits of NOAA-11 Channel #3 in Detection of Meso-Scale Eddies in the Gulf of Mexico During Summer**

Mr. Jeff Hawkins
Naval Oceanographic and Atmospheric Research Laboratories

11:20 a.m. **Eddy Monitoring in the Gulf of Mexico Using GEOSAT Altimetry**

Dr. Donald R. Johnson
Naval Oceanographic and Atmospheric Research Laboratories

11:50 a.m. **Gulf of Mexico High Resolution Marine Geoid Determined from Satellite Altimetry**

Dr. C. K. Shum
University of Texas

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Session V.C

Thursday, November 15, 1990

Rosedown Room (2nd Floor)

Gulf of Mexico Marine Laboratories:
An Overview of Current Research, I

Chairs: Dr. Richard Defenbaugh and Dr. James Kendall

8:30 a.m. **Welcome, Opening Remarks**

Dr. Richard Defenbaugh,
MMS, Gulf of Mexico OCS Region

8:40 a.m. **Overview of Southeastern Association of Marine Laboratories**

Dr. Tom McIllwain
Gulf Coast Research Lab, Ocean Springs, Mississippi

8:50 a.m. **Research Overview for Mote Marine Laboratory, Sarasota, Florida**

Mr. Jim Culter

9:10 a.m. **Research Overview for Florida Institute of Oceanography, St. Petersburg, Florida**

Dr. Sandra Vargo

9:30 a.m. **Research Overview for Florida Department of Natural Resources, Marine Research Institute, St. Petersburg, Florida**

Mr. Brad Weigle

9:50 a.m. **Refreshment Break**

10:10 a.m. **Research Overview for Florida State University Marine Laboratory, Tallahassee, Florida**

Dr. Nancy Marcus

10:30 a.m. **Research Overview for Dauphin Island Sea Lab, Marine Environmental Sciences Consortium, Dauphin Island, Alabama**

Dr. Ken Heck

10:50 a.m. **Research Overview for University of Southern Mississippi, Center for Marine Science, Stennis Space Center, Mississippi**

Dr. George A. Knauer

11:10 a.m. **Research Overview for Gulf Coast Research Laboratory, Oceans Springs, Mississippi**

Dr. Tom McIlwain

Note: Research Overview for University of South Florida, Department of Marine Sciences, St. Petersburg, FL will be provided as a handout.

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Session V.D

Thursday, November 15, 1990

Madewood A (2nd Floor)

Contributed Papers: Marine Biology

Chairs: Mr. Gary Goeke and Mr. Patrick Mangan

8:30 a.m. **Welcome, Opening Remarks**

Mr. Gary Goeke
MMS, Gulf of Mexico OCS Region

8:35 a.m. **Community Patterns in Echinoderms Associated With Substrate and Depth in the Northern Gulf of Mexico**

Dr. Thomas S. Hopkins
University of Alabama, Marine Science Program

8:55 a.m. **Variation in Reproductive Patterns in Echinoderms from the Northern Gulf of Mexico**

Dr. Thomas S. Hopkins
University of Alabama, Marine Science Program

9:15 a.m. **Secondary Production: Differential Arm Loss in Two Sympatric Species of Sand Stars**

Dr. Thomas S. Hopkins
University of Alabama, Marine Science Program

9:35 a.m. **The Application of Dual-Beam Hydroacoustics in Determining the Abundance and Behavior of Fishes Associated with Oil and Gas Platforms**

Mr. David R. Stanley and Dr. Charles A. Wilson
Louisiana State University, Coastal Fisheries Institute

9:55 a.m. **Refreshment Break**

10:15 a.m. **Estimation and Minimization of Underwater Blasting Effects on Fish and Wildlife Assemblages**

Dr. G. L. Thomas
University of Washington, School of Fisheries

10:35 a.m. **The Occurrence of Heavy Metals in Selected Tissues of the Atlantic Bottlenose Dolphin Stranded Along the Texas Coast**

Dr. Elsa M. Haubold
Texas A&M University, College of Veterinary Medicine

10:55 a.m. **An Investigation of Dolphin Deaths in East Matagorda Bay, Texas in January 1990**

Dr. George Miller
Naval Ocean Systems

11:15 a.m. **Bottlenose Dolphin Reactions to the Mega Borg Oil Spill**

Ms. Mari A. Smultea
Texas A&M University, Marine Mammal Research Program

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Session VI.A

Thursday, November 15, 1990

Crescent "A" Room (16th Floor)

New Developments in Oil Spill Response and Response Planning, II

Chairs: Ms. Darice Breeding and Mr. Dennis Chew

1:30: p.m. **Welcome, Opening Remarks**

Ms. Darice Breeding
MMS, Gulf of Mexico OCS Region

1:35 p.m. **Oil Transportation in the Gulf of Mexico**

Ms. Gail Rainey
MMS, Gulf of Mexico OCS Region

1:55 p.m. **Logistics of Mega Borg and Galveston Bay Spill Responses**

CDR. Philip Wieczynski
USCG, New Orleans, LA

2:20 p.m. **Logistics of the American Trader Oil Spill**

Lt. John Meehan
USCG (MSO, Los Angeles-Long Beach)

2:45 p.m. **Dispersant Use Logistics in the Gulf of Mexico**

Dr. Gordon Lindblom, Consultant

3:10 p.m. **Refreshment Break**

3:25 p.m. **MMS Unannounced Oil Spill Drill Program**

Mr. Joe Hennessey
MMS, Gulf of Mexico OCS Region

3:50 p.m. **Panel Presentation: Update of the Gulf of Mexico States' Oil Spill Contingency Planning**

Mr. John Holmead III, Florida Marine Patrol

Mr. John Carlton, Alabama Department of Environmental Management

Mr. Bruce Hammatt, Louisiana Department of Environmental Quality

Mr. David Barker, Texas Water Commission

5:05 p.m. **Closing Remarks**

Ms. Darice Breeding
MMS, Gulf of Mexico OCS Region

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Session VI.B

Thursday, November 15, 1990

Crescent "B" Room (16th Floor)

Physical Oceanography, II

Chairs: Dr. Murray L. Brown and Dr. Alexis Lugo-Fernández

1:30 p.m. **Welcome, Opening Remarks**

Dr. Alexis Lugo-Fernández
MMS, Gulf of Mexico OCS Region

1:35 p.m. **A United States-Mexico Cooperative Study of Cold-Core Eddies in the Western Gulf of Mexico**

Dr. Doug Biggs
Texas A&M University

2:05 p.m. **Nutrient-Enhanced Coastal Ocean Productivity Program**

Dr. Don Atwood
Atlantic Oceanographic and Meteorological Laboratory

2:35 p.m. **Formation, Movement, and Thermal Structure of Double Vortex Eddies in the Northeastern Gulf of Mexico**

Dr. Charles Eleuterius
Gulf Coast Research Laboratory

3:05 p.m. **Refreshment Break**

3:20 p.m. **Modernization and Restructuring of the National Weather Service**

Mr. Billy Crouch
National Weather Service, Slidell Forecast Office

3:50 p.m. **Overview of the GULFMEX Project: A Study of Return Flow in the Gulf of Mexico**

Mr. G. Alan Johnson
National Weather Service, Slidell Forecast Office

4:20 p.m. **Application of the "SOMS" Model to Studies of the Gulf of Mexico: Loop Current and Eddy Simulation**

Dr. David Dietrich
Ecodynamics Research Associates, Inc.

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Session VI.C

Thursday, November 15, 1990

Rosedown Room (2nd Floor)

**Gulf of Mexico Marine Laboratories:
An Overview of Current Research, II**

Chairs: Dr. Richard Defenbaugh and Dr. Jim Kendall

1:30 p.m. **Welcome, Opening Remarks**

Dr. Richard Defenbaugh,
MMS, Gulf of Mexico OCS Region

1:35 p.m. **Research Overview for Louisiana Universities Marine Consortium Laboratory, Chauvin, Louisiana**

Dr. Michael Dagg

1:55 p.m. **Research Overview for Louisiana State University, Department of Oceanography and Coastal Studies, Baton Rouge, Louisiana**

Dr. R. Eugene Turner

2:15 p.m. **Research Overview for Texas A&M University at Galveston, Texas**

Dr. Andre M. Landry

2:35 p.m. **Refreshment Break**

2:55 p.m. **Research Overview for Texas Parks & Wildlife Department, Marine Fisheries Research Station, Palacios, Texas**

Mr. Paul C. Hammerschmidt

3:15 p.m. **Research Overview for University of Texas-Austin, Marine Science Institute, Port Aransas, Texas**

Dr. Paul Montagna

3:35 p.m. **Research Overview for Corpus Christi State University, Center for Coastal Studies, Corpus Christi, Texas**

Dr. Jennifer Prouty

3:55 p.m. **Research Overview for University of Texas-Pan American, Coastal Studies Laboratory, South Padre Island, Texas**

Dr. Frank W. Judd

Note: Research Overview for Lamar University, Center for Coastal & Marine Studies, Beaumont, Texas will be provided as a handout.

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As the Nation's principal conservation agency, the Department of the Interior has responsibility for most of our nationally owned public lands and natural resources. The includes fostering the wisest use of our land and water resources, protecting our fish and wildlife, preserving the environmental and cultural values of our national parks and historical places, and providing for the enjoyment of life through outdoor recreation. The Department assesses our energy and mineral resources and works to assure that their development is in the best interest of all our people. The Department also has a major responsibility for American Indian reservation communities and for people who live in Island Territories under U.S. Administration.